PLENARY ADDRESSES

ROLE OF SOCIO-ECONOMIC FACTORS IN CORAL REEF PROTECTION AND MANAGEMENT.

Alcala, Angel C.* *Silliman University–Angelo King Center for Research and Environmental Management, Marine Laboratory, Bantayan, 6200 Dumaguete City, Philippines. Email: suakcrem@fil.net

Coral reefs are now under severe stress from both natural and human-induced environmental changes causing considerable damage. Many of the human activities directly or indirectly impacting coral reefs are driven by socio-economic factors. Foremost among these factors is poverty. In developing countries the need for sources of subsistence living, of livelihood, and of income through tourism and exploitation of economically important species is great. As a result, coral reefs have been mined, blasted, poisoned, overfished or otherwise subjected to misuse and abuse. There must be a way to utilize socio-economic values of and benefits from coral reefs as incentive for their protection and sustainable management. To do this, successful approaches to conservation such as establishment of marine protected areas, community-based coastal resource management and integrated coastal zone management as well as other useful management tools should be applied to current efforts at coral reef conservation. Indeed, experience has shown that such approaches may be our last option to stop the degradation of coral reefs and coral reef resources heavily impacted by man.

ECOMORPHOLOGY OF REEF FISHES: TRANSCENDING BARRIERS IN SPACE AND TIME

Bellwood, David R.*. *Dept Of Marine Biology, James Cook University, Townsville, Qld. 4811, Australia. Email: david.bellwood@jcu.edu.au

Coral reefs support a staggering diversity of species and forms. This grabs our attention but challenges our attempts to describe the system or the biology of the component species. We now have a workable taxonomic description for most reef fishes and corals. Quantitative and experimental studies have added to this knowledge to provide a picture of the factors shaping local populations. The challenge now is to look beyond individual species and reefs to patterns and processes operating at larger scales. Recent descriptions of congruent global biogeographic patterns in reef fishes and corals point to processes that operate beyond species and population levels, and highlight the need to consider reefs systems in a global context. Furthermore, observations of the abilities of individuals emphasises the critical importance of understanding the function or role of individuals in reef systems. Ecomorphology provides a basis for evaluating individual abilities which transcends space and time, a method based on a description of abilities alone. I will provide examples from reef fishes which describe how this approach may help us to understand the significance of abilities in shaping assemblages and in describing the roles of reef fish among habitats, between oceans and back through time to the reef fish assemblages of the Eocene, Jurassic and Triassic. This approach offers a common language as relevant to marine parks managers as to palaeontologists where abilities, not names or numbers, are important.

CORAL REEF CONSERVATION IN PALAU: A SUCCESS STORY

Idechong, Noah* Palau

No abstract

HOMAGE TO *STYLOPHORA PISTILLATA*: AN IMPORTANT CORAL IN CORAL REEF RESEARCH.

Loya Y., Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel. Email: yosiloya@post.tau.ac.il

Stylophora pistillata (Esper 1797), one of the most important hermatypic species on a global scale, has been used for many years as a key species for coral research in many fields, including Coral Biology, Ecology, Physiology, Biochemistry, Geochemistry, Immunology, Evolution, Paleoecology, Biogeography and others. This paper highlights some of the major contributions made in coral reef research using *S. pistillata* as a model species, from the community level to the cellular and molecular levels. Studies concerning regional variations at the population level include population structure and dynamics, life history strategy, growth and regulation of populations, regeneration, competitive networks and reproductive strategy. The accumulated information has served studies contributing to coral reef conservation and restoration strategies. Major contributions have been made to our knowledge of the physiology of corals, especially in advancing our understanding of the symbiotic relationship between the coral host and its symbiotic algae (zooxanthellae), such as environmental effects (biotic and/or abiotic factors) on photosynthesis, respiration and calcification mechanisms, energy budgets (autotrophy vs. heterotrophy), carbon partitioning and utilization, adaptive mechanisms of algal regulation and causes and effects of coral bleaching. Other studies concerning symbiotic relationships between the coral host and animals associated with it (sponges, other cnidarians, molluscs, crustaceans, worms echinoderms and fish) discuss obligatory, mutualistic or parasitic relationships affecting the life history of the coral and its symbiotic organisms. Seminal studies have been performed on marine pollution effects (crude oil, sewage and phosphates) at the

CORAL REEFS OF INDONESIA: PAST, PRESENT AND FUTURE

Nontji, Anugerah., Indonesian Institute of Science, Jakarta. Email:aanontji@indosat.net.id

The geographic setting of Indonesia, situated in the tropics between Asia and Australia, and between the Pacific and the Indian Ocean, has made this archipelago an ideal place for coral reefs to grow. Coral reefs are found along the coast of many of the islands in various formations e.g. fringing reefs, barrier reefs, and atolls. Coral reefs have been long known to provide various uses for the coastal community, such as for food, building materials, trades, etc. Recent development has confronted the reefs to an increasing threat because of the detrimental impact of human activities, such as from destructive fishing techniques (dynamiting, poisoning, etc), over exploitation of resources, pollution, etc. The total area of coral reefs in Indonesia is estimated roughly about 85,700 km^2. Recent surveys indicated that only about 6 % of the Indonesian reefs is still in excellent condition, and the rest are in various stages of destruction. There is a strong need to rehabilitate and manage the coral reefs in proper way so as to maintain their sustainability. A Coral Reef Rehabilitation and Management Program (COREMAP) was launched in 1998, to respond to this issue. This multi-sectoral program is planned for 15 years (until 2013) and will be executed in ten provinces in Indonesia. The first phase (1998-2001) however, will be executed in four provinces (Riau, South Sulawesi, Papua, and Nusa Tenggara Timur) and financially supported by the World Bank, Asia Development Bank, and AusAID.

CORAL REEFS AND CORAL REEF STUDIES IN JAPAN

Omori M.*. *Department of Aquatic Biosciences, Tokyo University of Fisheries, 4-5-7 Konan, Minato-ku, Tokyo 108-8477, Japan Email: makomori@tokyo-u-fish.ac.jp

Japan has a long history of coral reef research. Japan was even a leading nation in the world in this research at one time. In June 1934, the Japanese Society for the Promotion of Scientific Research established the Palao Tropical Biological Station in Koror Island, Palau, which was then governed by the Japanese Mandate of the League of Nations. The war unfortunately stopped all studies there in 1943. In spite of the short life span of the station, the research activities by Prof. S. Hatai and 29 young Japanese scientists contributed significantly to studies on coral reefs. The return of the Ryukyu Archipelago to Japan in 1972 allowed researchers access to coral reefs once again. The University of Ryukyus began research at the Sesoko Marine Science Center. The Akajima Marine Science Laboratory, which is a small non-governmental research station, was established at Akajima Island in 1988. Scientific research on coral reefs is being conducted at various institutions in Japan today. Japanese Coral Reef Society was established in 1997, and is actively promoting exchange of information and public awareness through research, training, and publications. The coral reefs in the Ryukyu Archipelago will be shown by video.

AGENDA 21, INTERNATIONAL CORAL REEF INITIATIVE AND THE NEW MILLENIUM: PROGRESS AND PROSPECTS FOR CORAL REEFS

Salvat, B.* *EPHE, ESA CNRS 8046, Université de Perpignan, France. Email : bsalvat@univ-perp.fr

1929 (Sir Maurice Yonge), the first International Coral Reef Symposium - ICRS - in India, 1969 , and the launching of the International Society for Reef Studies- ISRS - in 1980 (David Stoddart) and the International Coral Reef Initiative - ICRI - in 1995 (USA)… these are landmarks of the increasing interest in, and concern for, coral reefs. An analysis of what has been done and why is presented in the general context of political, economic and social evolution over these last decades : research for improved knowledge and management of resources; activities at local, national, regional and global levels; and creation and activities of international organisations (governmental and nongovernmental) and large international conferences. Several decades ago, the major concern focussed on the question of what are coral reefs and how they function. The main concern today is how to manage human activities affecting coral reef ecosystems. The present situation -global view of the reef ecosystem and the effects of global economic expansion - raises the challenge of what action must be undertaken at the beginning of the new millenium. Can we predict what will happen and how to react at different levels and in different fields of activities with the willingness to preserve coral reefs for the benefit of mankind ?

RETICULATE EVOLUTION: THE ALTERNATIVE PARADIGM.

Veron J.E.N.*. *AIMS, PMB 3, Townsville MC 4810, Australia. Email:

For most marine organisms, ocean currents are the vehicles of larval dispersal and are therefore the pathways of genetic connectivity. These paths repeatedly and continuously change over time, creating changes to the distribution ranges and genetic compositions of species. Geographic space and evolutionary time interact: species break apart, then re-form into different units. For corals, this creates 'reticulate' patterns in both geographic space and evolutionary time. In geographic space, species are typically distinct in any single region but loose their identity as definable units over very great distances. When these patterns are envisaged in evolutionary time, species have no time or place of origin and there are no distinctions between geographic (sympatric) and non-geographic (allopatric) concepts of origination. Differences between species and subspecies taxonomic levels and between species and 'hybrids' are arbitrary and/or unrecognisable. Importantly, reticulate evolution is driven by environmental parameters, not biological competition. Rates of evolution and extinction (which occurs through fusions as well as terminations of lineages) are similar over long geological intervals. Reticulate evolution gives the overall impression of punctuated equilibria, as is frequently observed in fossil records.

JOURNEY TO CENTRE OF THE CENTRE: ORIGINS OF HIGH MARINE FAUNAL DIVERSITY IN CENTRAL INDONESIA FROM THE PERSPECTIVE OF AN ACROPOROLOGIST.

Wallace, Carden C. Museum of Tropical Queensland, Townsville, Australia 4810. Email: carden@mtq.qld.gov.au

The reef coral mega-genus *Acropora* has been shown to have had its likely origins in Africa or Europe, far from the current "centre of diversity" of marine life, and its own location of greatest diversity, in the Wallacea region of Indonesia. How did this genus come to reach its current diversity focus? The most likely explanation involves historical tectonic and eustatic events, including partitioning of the old Tethys Seaway during the events of the Miocene period, as well as extinctions of a broader Pacific fauna during the more recent eustatic periods of the Plio-Pleistocene. The continuous presence of an open passageway through Wallacea, even during eustatic periods, through to the present day, has ensured that this area has retained its deepwater fauna as well as being open to settlement by shallow water Pacific species. The relevance of these events is collaborated by a morphological phylogeny of the genus: a revision of these ideas, using genetic characters, is not far behind

Session A1: Large Scale Ecology of Coral Reefs: Linking Biogeography, Meta Communities and Local Ecological Dynamics

SCALING THE CONTRIBUTION OF THE CORALLINE ALGAE *HYDROLITHON ONKODES* TO THE CALCIFICATION OF TWO REEFS USING IN SITU AND REMOTE SENSING DATA.

Andréfouët Serge*, Claude Payri, J.R.M Chisholm, J. Jaubert, H. Ripley. *University of South Florida, Dept. of Marine Science, 140 7th Ave. South, Saint Petersburg, Fl. 33701, USA. Email: serge@carbon.marine.usf.edu

Hydrolithon onkodes is the dominant coralline algae on the reef flats of atoll rims in the Tuamotu archipelago and can occupy as much as 80% of the reef surface. Conversely, on barrier reefs in the Society islands, *H. onkodes* is scarce, accounting for less than 3% percent of the total cover. Calcification on the reef flats of Rangiroa Atoll (Tuamotu) and Moorea Island (Society) is estimated to average 7 kg $CaCO_3.m^{-2}.y^{-1}$. Acquisition of multispectral (10 bands between 425-785 nm) remote sensing data using a Compact Airborne Spectrometer Imager in 1998, enabled the distribution of *H. onkodes* on these reefs to be mapped on scales of several km^2 at a spatial resolution of 1 m^2. The oceanic margins of the atoll reef flats were dominated by *H. onkodes*, interspersed with patchy communities of encrusting corals and turfs. At Moorea, it was necessary to combine airborne data with ground surveys in order to map the density of algae, as this could not be determined directly from airborne data. Considering that *H. onkodes* produces 8.5-11 g $CaCO_3.m^{-2}.d^{-1}$, its contribution to reef flat calcification on both reefs can be compared. However, some precautions are necessary when comparing these contributions to the total calcification measured along entire reefs. We discuss the hypotheses necessary to perform such comparisons and the limits of this multi-scale exercise.

THE LENGTH OF THE LARVAL PHASE IN CORALS: NEW INSIGHTS INTO PATTERNS OF CONNECTIVITY.

Baird A.*. *School of Marine Biology & Aquaculture, James Cook University, Townsville Q. 4811, Australia. Email: andrewbaird@ozemail.com.au

One of the major goals in marine ecology is to establish the degree of connectivity between local populations. To test the likelihood of localised recruitment and whether or not the geographical range of corals is influenced by dispersal ability I compared the larval longevity of five species of acroporid corals of contrasting distributions. Pronounced differences were apparent among species in the capacity to delay metamorphosis. The larvae of *Acropora valida* remained competent for 90 days, compared to 60 days for *A. millepora* & *A. gemmifera* and 14 days for *A. pulchra.* Furthermore, the larvae of wide spread species settled more rapidly with peak settlement in *A. valida* & *A. humilis* occurring on day 4 compared to day 7 for *A. millepora* & *A. gemmifera* and day 10 for *A. pulchra*. Successful colonization of remote locations seems therefore to depend on both larval longevity and on rapid settlement to enable populations to become established.

GENETIC POPULATION STRUCTURE OF A SOFT CORAL WITH SEXUAL AND ASEXUAL MODE OF REPRODUCTION.

Bastidas* C., Uthicke S., Fabricius K., Benzie J.A.H. *Australian Institute of Marine Science PMB No. 3 Townsville QLD 4810 and James Cook University Townsville QLD 4811, AUSTRALIA. Email: c.bastidas@aims.gov.au

Many anthozoans combine sexual and asexual reproductive modes, with dispersal between reefs being achieved by sexual propagules, whereas asexual division of colonies is suggested as an important mechanism to gain space in the reef. This study aimed to investigate the relative importance of sexual and asexual reproduction, and gene flow, between 12 reef populations of *Sinularia flexibilis* (Octocorallia, Alcyoniidae) along the Great Barrier Reef (maximum of 1300 km apart). This widely distributed Indo-Pacific species is a gamete broadcaster that can achieve large aggregations in near shore reefs in the GBR. The results of electrophoretic analyses of 9 polymorphic allozymes indicated that genotypic frequencies for each population did not differ significantly from those expected from Hardy-Weinberg predictions. This demonstrates a dominant role of sexual reproduction in these populations, i.e. clones do not extend considerably beyond the minimum spatial sampling scale in the study (5 m). However, significant genetic differentiation between some populations (F_{ST}), indicates that gene flow is restricted between some reefs and even sites within a reef. Nevertheless, there was no relationship between geographic separation and genetic differentiation. Analysis comparing groups of populations showed no significant differentiation on a north-south gradient or across the shelf (in relation to distance to the coast) in the GBR.

LARVAL COMPETENCE PERIODS INFLUENCE IN CORAL CONNECTIVITY AND SETTLEMENT: A MODELLING APPROACH.

Blanco-Martín, Bernardo*. *School of Marine Biology and Aquaculture, James Cook University, Townsville QLD. 4811, Australia. Email: Bernardo.Blanco-Martin@jcu.edu.au

Coral ecology, recovery from disturbance, biogeography and evolution are to a certain extent determined by the dispersive larval phase connecting their populations on different reefs. Various factors have been identified as driving dispersal, including the spatial properties of reefs, hydrodynamics and larval biology. Larval competence curves describe the relative amount of larvae available for settling at different times from release. A study of their influence in the connectivity and settlement in coral populations using a spatially realistic model is presented presented. A G.I.S. coverage of the Great Barrier Reef was employed to create an spatial representation of the Capricorn Bunker Group in a Cellular Automata Model. The models were run using five different larval competence curves (three brooders *Stylophora pistillata*, *Pocillorpora damicornis* and *Seriatopora hystrix* and two spawners *Acropora valida* and *Acropora millepora*) and two different current sets (random and south trend). The larval outputs and inputs for the whole system and six selected reefs were investigated. The earlier peak in the curves presented by the brooders is translated in a larger number of larvae settling per larvae produced in all current conditions. The longer tail in the curves for spawners allows them to have a higher connectivity under random currents but not under southern flow in this reef system. Individual reefs and coral species present very different behaviors, particularly in their connectivity.

RARITY IN COMMUNITIES OF CORAL REEF FISHES.

Caley J.R.*, Geoffrey P. Jones, and Philip L. Munday. *School of Marine Biology and Aquaculture, James Cook University, Townsville, Queensland 4811, Australia.

Patterns of rarity in biological communities reflect the interactions of processes operating on local ecological scales and regional and biogeographic scales. A species may be rare either in terms of its numerical abundance or its geographic range. Its status as rare or common has important implications for local ecological interactions and for conservation and management issues. The study of rarity in terrestrial species has developed rapidly in the past two decades. In comparison, issues of rarity for marine species are poorly understood. Here we report on analyses of rarity in coral reef fish communities. Our analyses confirm that some patterns of rarity in these communities are consistent with patterns previously identified for terrestrial species while inconsistent with others. These analyses have also highlighted the generally poor availability of data for marine organisms with which to do such analyses.

TURBIDITY AND SEDIMENTATION EFFECTS ON LARGE-SCALE PATTERNS OF OCTOCORAL BIODIVERSITY.

Fabricius K.* and Glenn De'ath. *CRC for the Great Barrier Reef World Heritage Area, Australian Institute of Marine Science, PMB No. 3, Townsville MC, Qld 4810, Australia. Email: k.fabricius@aims.gov.au

Patterns of octocoral biodiversity were determined from extensive reef surveys along and across the whole GBR. Species inventories and estimates of octocoral abundances were assessed on 361 sites (161 reefs), each covering 1000 to 4000 m^2 between 0 and 18 m depth. Mid-shelf reefs north of Latitude 16_ are the centre of octocoral biodiversity on the GBR. Overlapping distribution ranges of near-shore and off-shore taxa maximise richness on mid-shelf reefs. Taxonomic richness decreases with increasing latitude, and is low and relatively even across the shelf south of 21__lat. Richness is strongly affected by water clarity, and to some extent by sediment deposits: at any given position across and along the shelf, the generic richness is greatest in areas of low turbidity and high sediment deposits. Percent cover of hard corals and octocorals are poorly explained by physical and spatial variables. There are two major management implications of these findings: (1) Turbidity and sedimentation, which increase with run-off from disturbed soils, affect the generic richness of octocorals. The reefs with highest octocoral richness are < 20 km off the coasts, and thus well within the range of terrestrial run-off, indicating potential loss of diversity through expanding land use. (2) Taxonomic composition is more strongly related to environmental conditions than are total hard and soft coral cover; taxonomic inventories are thus better indicators of human impacts than is assessment of total cover.

THE ROLE OF ENDEMISM IN CORAL SPECIES DIVERSITY.

Douglas Fenner.* *Australian Institute of Marine Science, Townsville, Australia. Email: d.fenner@aims.gov.au

Endemic species have been proposed to contribute to high-diversity coral communities. Endemic species are those with restricted biogeographic distributions. However, in lists of endemic corals in areas such as Indonesia, most of the endemic species listed were described quite recently. A list of all *Acropora* species described in the past 30 years shows that most were known from one area when first described, but are now known from several areas. In this report, new records of coral species are given for the Philippines, Indonesia, and Australia, some of which were previously considered endemic to another country. Additional newly published records indicate very low numbers of endemic species, such as only two endemic corals now known from the Philippines, representing only about 0.5% of the coral species known there. A comparison of different areas around the globe indicates that the number of endemic coral species in most areas is about 0-6 species, and that the number of endemic species does not vary with the total species diversity in an area, over a range of two orders of magnitude of total species diversity. Thus, endemism does not contribute to the high coral species diversity seen on some coral reefs.

SOURCE/SINK POPULATION STRUCTURE OF CORAL REEF FISH: THE IMPORTANCE OF PATCH QUALITY VERSUS PATCH LOCATION AND IMPLICATIONS FOR MANAGEMENT.

Figueira W.F.*. *Duke University Marine Lab, 135 Duke Marine Lab Rd., Beaufort, NC 28516. Email: wff@duke.edu

Populations of fish on individual patches of coral reef are typically thought of as open sub-populations, dynamically coupled via larval dispersal to a larger network of patches. In such systems, successful management using spatial closures requires identification of areas that contribute disproportionately to the overall metapopulation. The coral reef literature generally considers the spatial location of a patch to be most important, with the term "source" applied to upstream patches due to their ability to seed downstream ("sink") patches with larval recruits. There is, however, considerable evidence that factors of habitat quality within a patch can significantly impact the demographic rates of resident fish. In this study I use a spatially explicit computer simulation model of a generalized reef fish to evaluate how patch contribution to the metapopulation is affected by these two patch characteristics: 1) relative location; and, 2) demographic rates. Previous modeling suggests that understanding the relative contribution of both factors can be central to designing successful reserves, and that uninformed placement of reserves has the potential to negatively affect the population by displacing fishing effort onto source areas. Conditions such as the magnitude and direction of currents, spatial geometry of the metapopulation, and relative differences in demography that may cause one or the other patch characteristic to dominate are discussed with special attention paid to the extent of local recruitment.

POPULATION DYNAMICS OF REEF FISHES AT LARGE SCALES: USING COMPUTER SIMULATIONS TO MAKE LARGE-SCALE INFERENCES FROM SMALL-SCALE DATA.

Forrester G.E.*, Richard R. Vance and Mark A. Steele. *Dept. of Biological Sciences, University of Rhode Island, Kingston, RI 02881-0816, USA. Email address: gforrester@uri.edu

Field demographic data collected from fish occupying small patch reefs (a few m^2 in area) were used to parameterize a model that describes fish abundance on a collection of several hundred such patches of reef (which we call a mesopopulation). Small-scale spatial density dependence causes the relationship between settlement and mesopopulation abundance to become nonlinear. Under many conditions simulated, however, the nonlinearity is very slight, suggesting that abundance measured at large scales in the field will often be strongly correlated with settlement rates. Overall, though, the model establishes that density dependent interactions on small patches of reef strongly influence population dynamics at larger spatial scales. In all cases considered, demographic rates that are density dependent on individual reefs also prove density dependent on the scale of the entire reef array, and demographic rates that are independent of density at small scales remain so at large scales. Furthermore, observed mesopopulation-level demographic rate functions strongly resemble approximations generated by "scaling up" the rate functions that apply to individual reefs. Changes in between-reef migration rate alter the magnitude but not the qualitative nature of these mesopopulation properties.

SPATIAL PATTERNS IN THE AGE STRUCTURE, DEMOGRAPHY AND ABUNDANCE OF A CORAL REEF FISH, *Acanthurus triostegus*.

Halford, A. R.* and Meekan, M. G. *The Australian Institute of Marine Science, P.O. Box 264, Dampier, WA, 6713, Australia. Email: a.halford@aims.gov.au

Few studies have examined spatial patterns in the demography of coral reef fishes at scales from 10's to 100's of km. Information that is currently available is either derived from a single locality or from localities spread across large spatial scales (>100km). In the latter case, such studies focus on species that are the targets of fisheries and as a result, demographic parameters are confounded by differences in fishing effort among localities. Here, we examine variation in the demography, age structure and abundance of a common surgeonfish at localities spread 200km along the length of Ningaloo Reef, WA. As this species is not fished, demographic patterns can be compared without confounding effects of fishing effort. Abundances were estimated using underwater visual census while collections of adult fish provided otoliths for age analysis. Abundances, age structures and growth and mortality rates were compared among localities. In addition, we attempted to identify peaks in age structures corresponding to successful year-classes and examined the spatial coherency of these events.

LOCAL AND REGIONAL PATTERNS IN THE COMMUNITY STRUCTURE OF CORALS.

Hughes, T.P*., H.V. Cornell, M.J. Caley, R.H. Karlson, C.C. Wallace, J. Wolstenholme. *Department of Marine Biology, James Cook University, Townsville, QLD 4811, Australia. Email: terry.hughes@jcu.edu.au

Community ecologists now recognize that to understand patterns of biodiversity, there is an urgent need to synthesize large-scale phenomena with local processes. This demands a multi-scale or hierarchical approach. We have begun a multi-scale study of the composition and relative abundances of corals along the pacific diversity gradient, from indonesia to french polynesia. Our goals are to examine how local diversity responds to variation in the size of the regional species pool, and to quantify the relative variation in community composition at different scales (ie. Among adjaSchleyer cent zones, sites, islands and regions). So far, we have sampled 52 sites on 14 islands within four regions (png, the solomon islands, samoa, and french polynesia), a total of 1,560 x 10m transects. Most variation in diversity and community structure occurs at the smallest and largest scales - among depth zones (the reef flat, crest and slope) and among geographic regions - compared to adjacent sites and islands that are much more homogeneous. Surveys of juvenile corals reveal major differences in the underlying dynamics of different regions. For example, over half of the coral recruits in png and the solomon islands belong to genera that are absent entirely in samoa and french polynesia. Widespread species typically vary in abundance among regions by an order of magnitude or more, highlighting the need to quantify biogeographical patterns using ecological as well as taxonomic data.

BENTHIC HABITAT ASSOCIATIONS OF REEF FISHES IN THE FLORIDA KEYS: COUPLING OF HABITATS AND FISH DISTRIBUTIONS VIA GIS TECHNOLOGY.

Jeffrey, C.F.G.*, C. Pattengill-Semmens, K. Buja, J.D. Christensen, M. Coyne, M. E. Monaco, and S. Gittings. *National Oceanic and Atmospheric Administration, National Ocean Service, 1305 East-West Highway, SSMC-IV, N/SCI-1 Room 9222, Silver Spring MD, 20910. Email: chris.jeffrey@noaa.gov

The spatial trends in the distribution of fish assemblages within the Florida Keys National Marine Sanctuary were examined as part of a collaboration between the Biogeography Program and Marine Sanctuaries Division of the National Ocean Service and the Reef Environmental Education Foundation (REEF). The objectives were to map and model the abundance and large-scale distribution patterns of reef fishes among benthic habitats, examine correlations between habitat diversity and fish community structure, and test hypotheses of non-uniform fish distribution patterns among benthic habitats. The Shannon-Weaver Diversity function, $\_p_i \ ln \ p_i$, where p_i is the proportion of each benthic habitat, was calculated from digitized (Arc View GIS) habitat data. GIS maps showing the distribution patterns and benthic habitat associations of fishes were developed from presence-absence fish data. Fish species richness was non-uniform among benthic habitats. Fish distribution and abundance varied among benthic habitats, and fish-habitat associations differed among several reef fish taxa. Probability maps and spatially-explicit GIS prediction models of fish-habitat associations across large spatial scales show that benthic habitat may determine reef fish assemblage structure and large-scale patterns of reef fish distribution.

CHANGES IN FISH AND CORAL COMMUNITIES ACROSS AN OCEANOGRAPHIC BOUNDARY IN THE GULF OF ADEN.

Kemp, Jeremy*. *Department of Biology, University of York, York YO1 5DD, UK. Email: jmk100@york.ac.uk

The seas of the Arabian peninsula are characterised by high levels of endemism in coral reef associated taxa such as shorefishes, and by highly varied ecological communities in the shallow sublittoral. These patterns have been attributed in part to the presence of one of the worlds five great coastal upwellings, occurring seasonally along the Arabian Sea coast of the peninsula. A study of fish and coral communities on the Gulf of Aden coast of the Republic of Yemen, at the western boundary of the upwelling, reveals that this boundary coincides with changes in fish assemblages and coral communities, and with a hybrid zone in angelfish. This supports the hypothesis that the upwelling is of central importance to the marine biogeography of Arabia.

CONCEPTUAL CHALLENGES OF HURRICANE ECOLOGY.

Kerr, Alexander M.*. *Osborn Memorial Laboratories, Yale University, PO Box 208106, New Haven CT 06520-8106 USA. Email: alexander.kerr@yale.edu

Cyclones, typhoons, and hurricanes are ecologically instantaneous terawatt events and the most acute form of disturbance to coral reefs likely to be observed in a human lifetime. Still, they can occur over twice a year on some western pacific reefs. Early empirical studies of cyclone effects assisted in shifting the focus from equilibrium-based models of community structure to those incorporating stochastic events. Conclusions from most later studies, though, have been speculative or, when qualitatively robust, rather obvious. This history has had two results: 1) continued ignorance about how cyclones affect variation in community structure at all but the smallest spatial and temporal scales and 2) a widely held belief that cyclones are unimportant ecologically because they are infrequently observed and their effects are locally unpredictable. The latter impression is based on a surprisingly limited sample of opportunistic and geographically biased studies. Still, the few large-scale observations to date suggest increasing predictability with increasing scale. Moreover, a considerable body of theory from fluid mechanics exists to guide hypothesis testing. Here, i demonstrate a mean-field approach based on linear wave theory for studying the ecological effects of cyclone waves at local to global scales. Shallow-water significant wave characteristics are produced for any given reef, incorporating the effects of shoaling and refraction on deepwater waves estimated from archived meteorological data. I find an unanticipated wave climate that may be useful for isolating the long-term effects of cyclones on coral-reef community structure.

MULTI-SCALE VARIATION IN THE SIZE STRUCTURE OF CORALS IN THE WESTERN-CENTRAL PACIFIC.

Kospartov, Marie C. * and Terence P. Hughes. *Dept. Marine Biology, James Cook University, Townsville, Queensland 4811, Australia. Email: Marie.Kospartov@jcu.edu.au

The size structure of a population is a product of its rates of recruitment, growth, mortality, and in the case of modular organisms, partial mortality, fission and fusion. Spatial variation in the size structure of populations of a taxon can therefore indicate the spatial scales at which the rates of these demographic processes differ. We examined spatial variation in the size structure of five coral taxa, at scales ranging from tens of metres to thousands of kilometres. For each taxon (*Galaxea fascicularis*, *Montastrea curta*, *Pocillopora meandrina*, *P. verrucosa* and massive *Porites* spp.), variation was greatest between depths, with populations on reef crests having a greater proportion of small colonies and smaller maximum sizes than reef slope populations. Regional-scale differences (between Papua New Guinea, east Australia and French Polynesia) also accounted for substantial amounts of variation in size structure, whilst there was very little variation among neighbouring sites or reefs nested within regions. Demographic modelling indicates that these patterns are created by modest differences in rates of recruitment and survival. The results of this study suggest that small-scale variation in demographic processes often exceed differences among regions, but both can have an important influence on population dynamics.

COLONY SIZE FREQUENCIES, MORTALITY, AND RECRUITMENT OF *ACROPORA PALMATA* AND *MONTASTRAEA ANNULARIS*, ANDROS ISLAND, BAHAMAS.

Kramer, Patricia R.*, Kramer, P.A., Ginsburg, R.N. *Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL, 33149. Email: pkramer@rsmas.miami.edu

The population dynamics of two reef building corals, *Acropora palmata* (n=2052) and *Montastraea annularis* complex (n=1445) were investigated at 60 sites along the semi-isolated, extensive (>150km) reef system of Andros Island, Bahamas. Aerial photographs and Landsat TM imagery were used to stratify and map reef distribution and select appropriate spatial scales (150km and <10km) to compare the variability of population parameters. Population data analyzed included colony size frequencies, the amount of partial mortality (recent and old), and the number of coral recruits. On shallow reefs *Acropora palmata* comprised 65% of the adult population, 9% of the recruits, and averaged 120-140 cm in diameter. On deep fore reefs, *M. annularis* complex comprised 70% of adults, 6% of recruits and averaged 40-50 cm. Average old mortality for *A. palmata* was 38%, 27% for *M. annularis* and for both species, mortality increased with size up to the mode of the population. The variation of these parameters between local populations is influenced by local and large-scale processes such as wave energy, presence of coastal creeks, grazing pressure, habitat availability and macroalgal competition. Consequences of two recent disturbance events (bleaching and disease) that resulted in significantly depressed local populations are discussed. We hypothesize the Andros system is fairly isolated from other large populations, but is well connected between local populations.

SPATIAL VARIATION IN ADULT DEMOGRAPHY AND REEF FISH POPULATION DYNAMICS: A SIMULATION STUDY.

Kritzer J.P.*, C.R. Davies. *CRC Reef Research Centre, James Cook University, Townsville, QLD 4811, Australia. Email: Jacob.Kritzer@jcu.edu.au

An important debate in the history of reef fish ecology has focused on the relative importance of recruitment intensity and its modification by post-settlement events in structuring populations. The role of adult populations in generating recruitment events, and therefore in structuring future states, has been largely overlooked. This study explored the implications of spatial variation in adult demography for population dynamics by simulation of hypothetical reef fish metapopulations. We considered the baseline case of a metapopulation with homogeneous demographic traits, then introduced progressively larger subpopulations with lower mortality or higher asymptotic sizes based upon empirical data for a tropical lutjanid. Exact results varied with underlying assumptions, but in general relatively small areas with lower mortality or larger body sizes had a pronounced effect on the stability of the system. However, the magnitude of the effect was strongly reliant upon the degree of stochasticity in the reproduction function, R. For example, the frequency with which the overall population collapsed was negligible under more static conditions (C.V. of R = 0.5) irrespective of spatial structure. Yet, under greater stochasticity (C.V. of R = 0.8), the baseline population collapsed in, on average, 44% of simulation years in contrast with 19% when 25% of reefs enabled fish to grow 10% larger.

THE PERCEPTION OF TROPHIC STRUCTURE OF REEF FISH ASSEMBLAGES AT DIFFERENT SCALES.

Kulbicki, Michel*, Ferraris, Jocelyne. *IRD - BP. A5 - Noumea - New Caledonia. Email: kulbicki@noumea.ird.nc

The trophic structure of reef fish assemblages is dependant of local and large scale factors. Among local factors one may cite reef type, substrate, coral or algae cover and among large scale factors are island type, island size and biogeographical region. The question is to know what dictates similarities or differences among reef fish assemblages. In the present study the species composition and the trophic structure of several reef types submitted to a range of factors were analysed. Reefs were selected from a very large data set (FISHEYE data bank). As a first step different reef types (fringing and inner barrier reefs) were selected within the same area (New Caledonia) and their fish assemblages considered for similarities in species composition and trophic structure. Then fish assemblages of inner barrier reefs from different island types (high island and atolls), island sizes (small, medium and large) and biogeographical regions (West and Central Pacific) were considered. Linear analyses (nested MANOVAs) were performed to test if trophic structure changed within reef type, within island or within region. Multiple factorial analysis were then made to compare simultaneously the grouping of these fish assemblages according to species composition and trophic structure. The aim was to detect which factors were the most significant in structuring these assemblages. In particular, we wanted to test if there was a convergence in the factors determining species composition and trophic structure. For each reef the same number of transects was selected, based on the relationship between species number and sampling effort.

LINKING BIOTIC AND ENVIRONMENTAL INFLUENCES ON REEF COMMUNITIES AT DIFFERENT SPATIAL SCALES IN BELIZE.

McField, Melanie D.* *Department of Marine Science, Univ. of South Florida, 140 Seventh Ave South, St. Petersburg, FL, 33701, USA, Email: melanie@marine.usf.edu

A stratified, random (haphazard) video-based monitoring scheme has been established at 17 windward fore-reef sites throughout Belize's 250 km barrier reef and three off-shelf atolls. The sites were chosen to provide the greatest geographical coverage and to represent the widest possible assortment of ranked environmental influences on community structure on various spatial scales. Sites were classified by five different environmental and management-linked influences (fishing pressure, scuba diving pressure, proximate coastal development, fluvial influence and wave exposure). Multivariate analysis techniques, including non-metric multi-dimensional scaling (MDS) plots, were then used to discern the relative importance of various environmental influences on reef community structure by determining the optimal set of environmental influences which “best explain” the biotic community structure. These comparisons can be made on sub-sets of sites with varying spatial resolution, determining which spatial scale is most relevant to particular environmental influences. Understanding the interaction of different environmental and biotic influences on varying spatial and temporal scales represents a challenge to reef managers with limited jurisdictional authority and illustrates the need for more regional coordination of management efforts.

MODELING THE RECOVERY PROCESS AFTER MASS BLEACHING.

Muko, Soyoka*, Kazuhiko Sakai, and Yoh Iwasa. *Department of Biology, Kyushu University, JAPAN. Email: muko@bio-math10. biology.kyushu-u.ac.jp

In coral communities, the composition of morphological types is very different in each habitat. In Okinawa, Japan, "branching *Acropora* sp*p*." dominated the protected site, whilst "tabular *Acropora* sp*p*." were abundant at the exposed site before mass bleaching occurred in 1998. The study of recovery process provides us an opportunity to understand the demographic processes, i.e., larval settlement, growth, and death, which form the observed patterns. We formulate a simple model incorporated the space-limited recruitment and growth for the dynamics of coverage of the two morphotypes. The result shows that recovery process after catastrophic event has three phases. [1] In the beginning, the relative abundance of the two types is controlled by the ratio of larval settlement. [2] When vacant space becomes occupied, both settlement of larvae and growth of settled colonies affect the dynamics of coverage. [3] After free space is depleted, both larval settlement and growth become very small. Now the slow process of colony death comes to have an influence and causes the final convergence to the equilibrium composition. The dominance of table-like corals at the exposed site is often regarded as the morphological adaptation for the severe wave action. However the same pattern can be explained by larger recruitment rate of table-like corals, if the total amount of recruitment is large. In order to distinguish the two hypothesis, we are investigating the demographic processes of the two morphotypes at three different sites in Sesoko Island, Okinawa.

SPATIAL AND TEMPORAL SCALING OF PROCESSES ON CORAL REEFS.

Mumby, Peter J* *Centre for Tropical Coastal Management Studies, Ridley Building, The University, Newcastle upon Tyne, NE1 7RU, UK. Email: p.j.mumby@ncl.ac.uk

Coral reefs are hugely complex environments governed by physical and biological processes which act over a wide range of spatial and temporal scales. Attempts to model reef processes, such as productivity or larval connectivity, are hindered by this complexity because the scales at which many processes occur are poorly understood, and it is neither computationally tractable nor biologically realistic to simulate many processes, acting at different scales, in the same model. Consider, for example, the problem of modelling metapopulation dynamics of corals among reefs. A spatial model of larval transport may need to represent mesoscale oceanic circulation of 100s km whereas the processes determining larval settlement space (e.g. herbivory, exposure) may act at scales of 0.001 km - 1 km. Clearly, metre-scale processes cannot be incorporated easily into a model that represents millions of metres. However, a better understanding of the scale-dependency of physical and biological processes will not only improve the modelling of such processes, but it may provide a hierarchical framework in which multiple models can be nested according to scale. Here, I discuss how geostatistics, cartographic models, field survey, and remote sensing might be integrated to create a hierarchical model of reef structure and associated physical environments.

A FUNCTIONAL-GROUP APPROACH TO THE DIVERSITY OF CORALS ON MULTIPLE SCALES.

Murdoch, Thaddeus J. T.* and Richard B. Aronson. *Dauphin Island Sea Lab, 101 Bienville Blvd., Dauphin Island, AL 36528, USA. Email: tmurdoch@disl.org

Phylogenetic classifications do not reflect the ecological functions of benthic marine organisms. An alternative is to classify benthic organisms by adaptive strategy. This approach has been successfully used by plant ecologists in addressing issues of biodiversity and ecosystem function. Coral reefs are exposed to environmental processes that covary over a wide range of spatial and temporal scales. Coral taxa that share morphologies and reproductive strategies should respond to the physical and biotic environment in similar, predictable ways. Two studies in the Western Atlantic demonstrate how functional groups of corals differ in distribution and adaptive strategy. First, in a survey of the Florida reef tract, we detected high variability in coral cover from reef to reef, but very low variability between sites within each reef. Only one functional group was responsible for this pattern. The differences in distribution were a direct result of differences in morphology and reproductive mode. Second, the recent demise of *Acropora cervicornis* in Belize from white-band disease indicates that not all corals respond to environmental change in the same manner. When *A. cervicornis* was eliminated, only one functional group increased opportunistically in abundance in response to the relaxation of competition. These results can be used to predict what coral reefs of the Caribbean will look like in the next millenium.

THE INTEGRATED GROWTH RESPONSE OF CORAL REEFS TO MONSOON FORCING: MORPHOMETRIC ANALYSIS OF REEFS IN MALDIVES.

Naseer, Abdulla* and Bruce G Hatcher, *Dept of Biology, Dalhousie University, Halifax, Nova Scotia, B3H 4J1, Canada, Email: anaseer@is2.dal.ca

Reefs of Maldives display asymmetric geomorphologies in their arrangement on the atoll rims and within atoll lagoons. In this study we seek empirical relationships among patterns of coral reef growth, morphology and environmental forcing in Maldives. Reefs on the oceanward rims of atolls have wider and more continuous reef flats than those lining the rims facing the sea between lines of atolls. These characteristics reflect broad-scale spatial variation in time-averaged, physical-biological control of reef growth, but have not been quantified. We hypothesize that monsoon forcing interacts with antecedent reef platform arrangements to produce characteristic growth configurations and predictable reef morphologies. The hypothesis is tested by the classification of LANDSAT-7 ETM+ imagery to measure hundreds of reefs along the N-S and E-W axis of the archipelago, and to calculate morphometric indices (e.g. ratio of reef flat to lagoon area). Well-defined gradients in monsoon forcing (i.e. swell and wind wave fields, surface currents, upwelling and precipitation) and antecedent platform structure are quantified along the same dimensions, and related to the morphometrics with multivariate techniques. Preliminary results determine the scales of similarity between asymmetries in reef geomorphology and monsoon forcing. The relationships can be used to infer patterns of reef development during the Quaternary, and to predict reef growth responses to global climate change in a sensitive atoll nation.

THE BENTHIC COMMUNITIES OF THE GREAT BARRIER REEF: A LANSCAPE ECOLOGY APPROACH.

Ninio R. * *Australian Institute Of Marine Science, Pmb 3, Townsville, Qld 4810 Australia. R.NINIO@AIMS.GOV.AU

At a large spatial scale, the Great Barrier Reef is a mosaic of patches formed by clusters of reefs with comparable histories of disturbance. Within each patch, reefs display similar temporal trends in cover of hard coral, soft coral and algae. The overall dynamics of this 'patchwork mosaic' will depend on the size and frequency of disturbance and resultant rates of recovery. We use data collected by the Australian Institute of Marine Science as part of the Long Term Monitoring Program to examine the effects of three different types of disturbance (cyclones and storms, Crown of Thorns Starfish and bleaching of hard corals) and the composition of benthic communities on the dynamics of this mosaic. We investigate the spatial scales at which each of these disturbances operates and how community composition influences the outcomes of these disturbance events.

PERSISTENCE IN CARIBBEAN CORAL COMMUNITIES OVER BROAD SPATIAL AND TEMPORAL SCALES.

Pandolfi, John M.*. *Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington D.C. 20560-0121, USA. Email: pandolfi.john@nmnh.si.edu

The degree to which coral reef communities are largely open, with com-position depending upon the regional species pool, or are partially closed, with limited species membership, is a key component in understanding their ecological dynamics. I examined the structure of Pleistocene Caribbean coral communities using a hierarchical sampling design at broad spatial and temporal scales. Significant differences in the composition of coral communities from the leeward reef crest among three islands (San Andrés, Curaçao, and Barbados) during the last interglacial, 125 ka (thousand years) ago, were driven by variability in the relative abundance of the same 4 or 5 abundant taxa. At Barbados, coral composition remained constant from 220-125 ka, but differed during the 104 ka reef-building episode. However, the 104-ka community was closer in composition to older coral communities from Barbados than it was to communities from San Andrés or Curaçao. Remarkably, separate analyses on the composition of the rare taxa (data compiled using 1 hr searches) and those of the common taxa (data compiled using 40-m transects) gave highly concordant results, suggesting the composition of the rare taxa is correlated with that of the common, structurally dominant corals. These Pleistocene data point to a high degree of order in coral communities over broad spatial and temporal scales and support the importance of local influences in determining reef coral community structure.

ECOLOGICAL VERSUS EVOLUTIONARY LIMITS TO DIVERSITY: SPECIES PACKING ON CORAL REEFS.

Roberts, Callum M.* *Environment Department, University of York, York, YO10 5DD, UK. Email: cr10@york.ac.uk

Studies of coral reef diversity in the 1970s and 1980s focussed on mechanisms promoting co-existence of species within habitats. Much of this research examined ecological constraints on species packing, such as the degree to which species were specialized in resource use. While such studies were conducted in many parts of the world, one interesting pattern that most overlooked was the considerable regional variation in species richness throughout the tropics. Some regions have much larger species pools than others, offering fertile material with which to explore constraints to species' coexistence. I explore differences in species-packing (within-habitat, or alpha diversity) among reefs in the Caribbean (Saba, Bonaire, Belize), Red Sea (Egypt) and Pacific Ocean (Palau). These reefs differed widely in the size of their species' pools (gamma diversity). At each site, fish were censused from the same habitat (outer slope at 15m deep), by the same observer using the same method (stationary point counts). Alpha diversity increased linearly with the size of the species pool suggesting that, on outer slope habitats, levels of species packing increase directly with the number of species present. Evolution and biogeography trump local ecological effects. These results contrast markedly with findings in the literature that similar-sized patch reefs in the Caribbean and on the Great Barrier Reef had similar levels of species packing despite widely different species' pools. Possible reasons for these differences will be explored.

LARGE SCALE ECOLOGY AND IMPROVED REEF MANAGEMENT

Sale, Peter F.* *Great Lakes Institute for Environmental Research & Dept. of Biological Sciences, University of Windsor, Windsor ON Canada N9B3P4. Email: sale@uwindsor.ca

There is growing awareness that coral reef communities may be interconnected at quite large spatial scales, and that their management should take account of this fact. Their inter-connection arises both from transport of nutrients and pollutants, and from that of propagules, however, the propagules of many taxa are proving to be far more than passive particles and this complicates the story. Current ecological research onrecruitment dynamics of fish, and to a lesser extent, corals, is beginning to provide evidence of the correct spatial scale at which to view coral reefs as inter-connected by larval dispersal. New techniques are being proposed that may facilitate estimates of the extent of this inter-connection. I will briefly review what is known about the large scale ecology of coral reef community dynamics, and then outline an approach to bring studies of recruitment dynamics into the baseline-building process when implementing sustainable management at regional scales. Examples from the Caribbean and from the Great Barrier Reef will be considered.

SPATIAL VARIATION AND PATTERNS IN BENTHIC COMMUNITY STRUCTURE IN THE FLORIDA KEYS

Swanson, D.W. M. Chiappone and S.L. Miller*. *The National Undersea Research Center, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, Florida, 33037, USA. Email: dwswanson@hotmail.com

To better understand how communities are structured at multiple spatial scales in the Florida Keys National Marine Sanctuary (FKNMS), a two-stage stratified, random sampling design was initiated in 1999. Design features include sampling multiple sites within no-take zones or reserves and reference areas, and comparison of sites within and among benthic habitat types, and among regions. One-hundred and four sites were surveyed, spanning over 200 km. The number of sites sampled within each habitat type was optimized based the existing benthic habitat map of the FKNMS, and pilot studies that used sample design statistics to assess spatial variation in measured parameters. Rapid assessment surveys included measurements of cover and species richness of sessile marine organisms, stony coral (adult and juvenile) and octocoral abundance, and stony coral size and condition. Significant regional, habitat, and reef differences were apparent. For example, scleractinian coral and octocoral abundance, species richness of cnidarians and sponges, and the frequency of algal overgrowth of live coral tissue causing lesions varied significantly among regional sectors within the 8-12 m habitat type. Juvenile coral density and coral cover, however, were similar among regions. Many reserves differed significantly from reference areas, due mostly to bias in original siting of the reserves. Data from the program establish a baseline to monitor community structure at multiple spatial scales.

SPATIAL VARIATION IN CORAL BIODIVERSITY AT INTERMEDIATE SCALES: EXAMPLES FROM OCEANIC ISLANDS.

Spalding, Mark D.*. *Cambridge Coastal Research Unit, Department of Geography, Downing St, Cambridge, UK Email: mark.spalding@wcmc.org.uk

Patterns of biodiversity on coral reefs are increasingly well understood at the fine resolution of the reef profile. At the other extreme, increasing amounts of information are becoming available describing biodiversity patterns, at global and regional levels. Between these two extremes, an understanding of patterns in reef diversity is more limited. In this paper the existing knowledge of spatial variation over scales of 1 to 100km is examined in more detail. New data are presented for coralline and high-island reef systems in the central Indian Ocean which show considerable variation in spatial patterns of reef fish communities between different reef systems. Communities in the Chagos Archipelago show considerable homogeneity between locations and between atolls, by contrast the low island reefs of the southern Seychelles show considerable variation both across and between atolls and other reef structures. Fringing reefs in the high islands of the northern Seychelles reveal event greater spatial variation in reef fish community structures. A theoretical framework to explain these patterns is presented. Finally the implications of these patterns for the design of protected areas systems are considered

THE CORAL REEFS OF BALI, BEFORE THE 1998-BLEACHING EVENT: A PHASE SHIFT CAUSED BY EUTROPHICATION OR REGIONAL UPWELLING.

van Woesik, Robert*. *Department of Chemistry, Biology and Marine Science, The University of the Ryukyus, Senbaru 1, Nishihara, Okinawa 903-0213, Japan. Email: b984138@sci.u-ryukyu.ac.jp

There was a major change to the coral reefs of southeastern Bali, Indonesia, between September 1992 and September 1997. The coral reefs changed from being dominated by corals to being dominated by macroalgae, sponges and other filter feeders. In 1992, the upper reef slopes of Sanur and Nusa Dua supported >30% coral cover and a high coral diversity. The average diameter of *Acropora* spp. and *Seriatopora* spp. colonies, the dominant corals in terms of abundance, was 17 to 42 cm. The same reefs in 1997 supported 2-3 cm colonies and approximately 15% coral cover, dominated largely by encrusting *Montipora, Porites spp.*, faviids, macroalgae, sponges and zoanthids. Such a change immediately evokes a response of 'local eutrophication'. Although local eutrophication is not discounted as a contributing factor, a regional upwelling may have exacerbated the effect through the provision of nutrients. Evidence of a regional upwelling was found along the southeast coast of Bali at the time of the survey using SEAWIFS satellite imagery and proxy cues in *Porites* samples (i.e., elevated Ba/Ca ratios). This upwelling and regional phase shift occurred one year prior to, and possibly not independent of, the 1998 ENSO.

THE EFFECT OF EL NINO ON THE DISTRIBUTION OF REEF-ASSOCIATED LABRID FISHES IN THE EASTERN PACIFIC OCEAN.

Victor, Benjamin* Gerard Wellington, D. Ross Robertson. *GSM, University of California, Irvine, CA 92604 Email: ben@coralreeffish.com

We surveyed the labrid reef fishes at multiple sites in the eastern Pacific Ocean before, during, and after the recent El Nino-Southern Oscillation event (ENSO). The only prominent changes in labrid biogeography noted were the extension of two tropical eastern Pacific species into Baja California (*Thalassoma virens* and *Stethojulis bandanensis*) and a massive ENSO-associated settlement of *S. bandanensis* onto the Galapagos Islands where the species was previously rare. Analysis of daily otolith increments revealed that the pelagic larval duration of the new arrivals of *S. bandanensis* was relatively short (about one month) and no different from the pelagic larval duration for the species recorded at other locations in the eastern Pacific Ocean before and during ENSO as well as from the western Pacific Ocean at Palau and the Cook Islands. The results suggest that a one month pelagic larval duration was sufficient for spread among isolated island groups in this region. Adults of this species were present at some of their new locations during the subsequent cold La Nina period.

REJUVENATION OR RUN-DOWN? THE LONG-TERM RESPONSE TO DISTURBANCE OF FIVE CORAL COMMUNITIES AT LIZARD ISLAND, GBR.

Wakeford, M. * and T.J. Done. *Australian Institute of Marine Science, PMB 3, Townsville MC, Townsville, Queensland, 4810, Australia. Email: m.wakeford@aims.gov.au

Following disturbance to corals (eg crown-of-thorns starfish outbreaks, coral bleaching and cyclones) there is potential for fundamental changes in the benthic community, such as phase shifts and alternate states. Large-scale and long-term shifts from reef building to non-reef building communities are of particular concern. We investigated a long-term photographic record (1981 – 1999) of coral communities at Lizard Island for evidence of such changes. Stereo-photographs taken of five permanent sites were analysed to gauge fine-scale community dynamics over time. During the study period, Lizard Island was affected by a cyclone, coral bleaching and two outbreaks of crown-of-thorns starfish. Diversity, species composition and age/size frequency distribution were monitored at each site and used to assess changes in the structural extent and complexity of the reef. The trajectories of the coral communities were characterised by varying degrees of rejuvenation and run-down following disturbance. At one extreme, there was no tendency for changes in the coral composition and cover. However, a reduction in the maximum colony size reached by *Acropora* plates reflected a decrease in the interval between disturbances. This suggests that colony size of plate *Acropora* may be a useful indicator of site resilience. At the other extreme, one site had been transformed into bare pavement supporting very little coral due to poor recruitment and survival.

EARLY LIFE HISTORY TRAITS, ADULT BODY SIZE, AND EXTENT OF GEOGRAPHIC RANGE IN GULF OF CALIFORNIA REEF FISHES.

Zapata, Fernando A.*. *Department of Biology, Universidad del Valle, Apartado Aéreo 25360, Cali, Colombia. Email: fazr@biologia.univalle.edu.co

Because adult reef fishes are sedentary and reef environments are patchily distributed, reef fishes are dispersed mostly by currents during their early life history (ELH). ELH traits are thus considered to be determinants of dispersal capability and extent of geographic distribution. This view, however, has not been adequately demonstrated. To examine whether egg type (P = pelagic, NP = non-pelagic) and presence/absence of a pelagic prejuvenile stage (PPS) affect extent of geographic distribution, I classified Gulf of California reef fishes (N = 196) into four categories with combinations of the above traits. Species endemic to the Mexican Pacific had a greater proportion of species with NP eggs than non-endemic species. Whereas 50% of the species with NP eggs and no PPS were endemic, < 1% of the remaining species were geographically restricted. On average, fishes with NP eggs and no PPS also had smaller geographic ranges than other species. Because species with NP eggs and no PPS are smaller than other species, the effects of ELH traits are confounded with those of adult body size. Large species should have greater dispersal potential because fecundity is positively correlated with adult body size. In fact, size of geographic range was positively correlated with maximum adult length, but only in species with NP eggs and no PPS. Partitioning of the confounding effects of ELH traits and adult body size by a two-way ANOVA confirmed that species with NP eggs and no PPS were the most geographically restricted, and that there was neither a significant effect of body size nor a significant interaction between the two factors. This study thus provides evidence that ELH traits influence extent of geographic distribution in marine reef fishes.

Session A2: Planktonic Food Webs in Coral Reef Waters: trophic Structure, Functioning and Interactions with Benthic and Pelagic Communities

PARTICULATE ORGANIC CARBON BUDGET AND POC FLUX IN A FRINGING CORAL REEF AT MIYAKO ISLAND, JAPAN.

Casareto B.E.* K. Yoshida and Y. Suzuki. *Laboratory of Aquatic Science Consultant Co., LTD, Meishin BLDG., Kamiikedai 1-14-1, Ota-ku, Tokyo 145-0064, Japan. Email: CASARETOBE@aol.com

The composition and the concentration of particulate organic matter were comprehensively investigated on a fringing coral reef area at Bora Bay of Miyako Island, Japan. Particulate organic carbon and nitrogen (POC, PON), plankton abundance, specific composition and its daily variation were studied for seven size classes (0.8 to 8 µm, 8 to 22 µm, 22 to 53µm, 53 µm to 0.106 mm, 0.106 mm to 0.5 mm, 0.5 to 1 mm and > 1mm) within the bay and in an outer influenced area. Based on the species composition, plankton was classified as "reef-lagoon" and "open ocean" plankton with the purpose to evaluate POC fluxes towards the open ocean. Main POC contribution within the bay was due to larval stages of benthic fauna (120 $\mu gC.l^{-1}$), nanoplankton composed by epiphytic microalgae (pseudoplankton) and filamentous cyanobacteria (124 $\mu gC.l^{-1}$), and picoplankton flagellates (65 $\mu gC.l^{-1}$). Faecal pellets and detritus were also very abundant reaching 82 $\mu gC.l^{-1}$. The organic carbon budget within Bora bay (477 $\mu gC.l^{-1}$) was slightly higher than that of the outer influenced area (437 $\mu gC.l^{-1}$). Plankton originating from the bay influenced the outer area, being also significantly transported to deep layers. All these features showed that there is a net flux of organic matter from bay towards the open ocean. The amount of this flux as net organic carbon was estimated to be 8 to 17 kgC day^{-1}. A degradation experiment carried out during 150 days indicated that 1 to 5 kgC day^{-1} of the exported amount of organic carbon are of refractory nature.

IMPORTANCE OF PICOCYANOBACTERIA IN CORAL REEF AREAS: A REVIEW

Charpy Loïc*, Blanchot Jean IRD, COM, rue de Batterie des Lions 13007 Marseille, France Email: lcharpy@com.univ-mrs.fr

Picocyanobacteria contribution to phytoplankton biomass and production was studied during the last decade in Pacific coral reef areas. Compiled data from literature show that *Synechococcus* were mostly dominant in coral reef waters, even when nitrogen is totally depleted like in Tuamotu atoll lagoons. The switch in dominance from *Prochlorococcus* in open ocean to *Synechococcus* in coral reef lagoons does not seem to be related to N availability. Interpretation of such results relies probably on differences in top-down control by benthic and planktonic grazers and/or on the ability of some strains of *Synechococcus* to fix N_2.

THE NEED FOR TAXONOMIC EXPERTISE IN FUNCTIONAL ECOLOGY OF CORAL REEF PHYTOPLANKTON

Delesalle B*. EPHE - ESA CNRS 8046, 52 Av. de Villeneuve, F-66860 Perpignan Cedex. Email: bd@univ-perp.fr

It is a cliché to state that taxonomy was not favoured during the past 20 years. This situation especially applies to phytoplankton ecology in coral reef waters. In fact, taxonomy requires an extensive background knowledge and is often deterrently time consuming. Consequently, phytoplankton studies were often restricted to the 'easy' and rapid measurement of the chlorophyll *a* concentration, roughly considered as a good estimate of the phytoplankton biomass. A better insight in the phytoplankton composition was gained with the development of advanced techniques such as size fractionation, epifluorescence microscopy or flow cytometry. However, these techniques were mainly applied to picophytoplankton whereas the nanophytoflagellates remained understudied. Several recent studies conducted in French Polynesian atolls has proven the functional importance of this compartment. Firtsly, the selective feeding of the pearl oyster *Pinctada margaritifera* was demonstrated using an elegant approach combining optical microscopy and HPLC pigment analysis. Secondly, taxonomic surveys undertaken within the frame of studies on harmful algal blooms showed the presence of several unknown species, some of them belonging to potentially toxic genera, e.g. the Haptophyte *Chrysochromulina* or the diatom *Pseudonitzschia*. Obviously, the identification of the phytoplankton species will be needed in future ecological studies of the planktonic foodwebs in coral reefs, using advanced techniques such as SEM, TEM and molecular biology.

LINKAGE BETWEEN BACTERIOPLANKTON AND CORAL REEF BENTHOS: SMALL SCALE SPATIAL VARIATION IN DOC, INORGANIC NUTRIENTS AND BACTERIOPLANKTON GROWTH.

van Duyl F.C.*, G.J. Gast. *Netherlands Institute for Sea Research, P.O. Box 59, 1790 AB Den Burg, The Netherlands. Email: duyl@nioz.nl

This study focuses on the links between coral reef contact water characteristics with respect to dissolved organic carbon (DOC) and inorganic nutrients (DIN, DIP) and bacterioplankton growth. At 5 reef stations along the SW coast of Curaçao (Netherlands Antilles) 6 different water types were sampled and analyzed for DOC, DIN, DIP, bacterial production and abundance: 4 reef water types (live coral surface contact water (CS), reef crevice water (RC), reef bottom water (RB), reef overlying water (RO)) and 2 reference water types collected offshore from each station at 2 and 8 m depth. Within stations consistent patterns in the different variables were found. DOC distribution suggests that live stony corals are the major source for the enhanced DOC concentrations over reefs. DIN was highest in RC water suggesting that crevices and not the sandy sediments between corals are the major net N regenerating spaces. Enhanced DIP concentrations suggest net P regeneration in RC and CS water. Highest specific growth rates of bacterioplankton were established in the CS water. Growth in crevices was also significantly enhanced compared to growth in reference water. Significant coupling between bacterioplankton growth and DIN suggests N-limitation of bacterial growth in CS and RO water. In RC and RB water, available DOC might be the growth limiting factor.

IMPORT AND EXPORT OF NET-ZOOPLANKTON TO AND FROM CORAL REEFS.

Hamner, William M.* and Colin, Patrick L. *University of California Los Angeles, Dept. Organismal Biology, Ecology & Evolution, Box 951606, Los Angeles, CA 90095-1606, USA, E-mail: hamner@biology.ucla.edu

The so-called "coral reef paradox" contrasts coral reefs as oases of high biomass and diversity surrounded by oceanic waters supposedly devoid of nutrients and plankton. We review the literature on zooplankton near the windward reef face and conclude that there is probably sufficient input across the windward reef from net-zooplankton alone, irrespective of net input from micro-zooplankton, phytoplankton and bacteria, to account for the high biomass and diversity of coral reefs. We then present new data from Palau where enormous quantities of fish eggs and invertebrate larvae are exported seaward from windward reefs on falling tides. Surprisingly, although exported larvae are advected rapidly seaward, many exported larvae do not disperse into oceanic currents but instead they are retained in an island boundary layer separated from oceanic currents by coastal shelf fronts. On rising tides, boundary layer water and previously exported larvae return to and reenter the reef complex. Flux between oceanic, boundary layer and lagoon waters near coral reefs must be reevaluated.

ORGANIC INPUTS TO REEF ECOSYSTEMS CONTRIBUTE TO NEW PRODUCTION. – HOW MUCH? – SO WHAT?.

Hatcher B.G.* *Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada, B3N 1G8. Email: Bhatcher@is.dal.ca

The new production of an ecosystem is that proportion of its net primary production during an ecological cycle that utilizes allochthonous nutrients in the synthesis of organic material. The remainder is recycled production that utilizes autochthonous nutrients. The ratio of new to recycled production (i.e. the *f*-ratio) reflects the relative importance of nutrient inputs from outside the ecosystem, and is a function of the degree of system closure. Large discrepancies between the theoretical and operational definitions of new production challenge the application of the theory to coral reef ecosystems. The conceptual model of production for coral reefs portrays them as relatively closed ecosystems with efficient recycling, and low levels of dependence on external nutrient inputs for primary production. Net ecosystem (i.e. excess) production as defined by inorganic carbon and nutrient fluxes has been estimated to approximate zero, suggesting that reefs have little capacity for sustained export of organics. This model is compromised if new nutrients supplied through the capture and remineralization *in situ* of advected particulates are recognized as contributing to new production. Calculations based on a growing body of measurements of organic inputs to reefs indicate that the new production of reef ecosystems in hydrodynamically open and nearshore environments exceeds excess production by 100% to 1000% (corresponding *f*-ratios may exceed 0.2). The high export production implied by these parameter values can reconcile large losses of detrital material from reefs, but do not necessarily inform the estimation of extractable yields from reef fisheries.

PLANKTON-BENTHOS COUPLING ON A CARIBBEAN FRINGING REEF.

Land L.S.*, R.A. Eustice, J.C. Lang and S.A. Macko. *P.O. Box 539, Ophelia, VA 22530, USA. Email: JandL@rivnet.net

Trophodynamic processes on coral reefs are complex and poorly understood in detail. Near Discovery Bay, Jamaica, particulate organic matter (POM–a mixture of phytoplankton and other suspended organic particles), net zooplankton, some planktivorous benthic invertebrates, and most benthic algae, are more depleted in ^{13}C than most zooxanthellate cnidarians (*Millepora*, octocorals, scleractinians, corallimorphs, zoanthids), other reef animals, cyanobacteria and the seagrass *Thalassia* ($\sum$ N = 290 $\partial^{13}C$ analyses). Organic matter released by the zooxanthellate cnidarians, probably as mucus and dissolved organic exudates, may constitute a significant source of carbon for many (especially non-planktivorous) reef animals. In contrast, POM and net zooplankton, along with most reef invertebrates and reef-associated fishes, are generally more enriched in ^{15}N than benthic photosynthesizers, such as cyanobacteria, algae, *Thalassia*, and the zooxanthellate cnidarians ($\sum$ N = 190 $\partial^{15}N$ analyses). Hence, much of the nitrogen present in the tissues of zooxanthellate cnidarians on this reef system probably originates as dissolved inorganic nitrogen that is initially utilized by their symbiotic microaglae, and which overwhelms the nitrogen derived from POM and zooplankton ingested by the animal hosts.

PICOPHYTOPLANKTON AND HETEROTROPHIC PROTISTS CONTRIBUTION TO THE DIET OF THE PEARL OYSTER *PINCTADA MARGARITIFERA* IN THE TAKAPOTO ATOLL (TUAMOTU ARCHIPELAGO, FRENCH POLYNESIA).

Loret, P. Blanchot L.P.* J, Delesalle B, Le Gall S, Jonquières G, Pastoureaud A, Dupuy C, Caisey X. Antenne *IRD Station Biologique de Roscoff, BP 74, F-29682 Roscoff, France Email: blanchot@sb-roscoff.fr

The pearl oyster *Pinctada margaritifera* is principally reared in atoll lagoons where picophytoplanktonic biomass and production is dominant. It was shown that under *in situ* conditions, *P. margaritifera* do not efficiently retain these picoparticles. The retention efficiency was negligible for *Prochlorococcus* and *Synechococcus* and only 30%. Pico/nanoeukaryotes were retained. Grazing experiments showed that pearl oyster retain efficiently ciliates (>90%) and dinoflagellates (99%). The ciliate *Protocruzia* was isolated from the lagoon. The maximal growth was obtained with the *Synechococcus* isolated from the lagoon. This ciliate was used as a picoplantonivorous model. The hypothesis of a trophic link between picoplanktonic communities and bivalves was tested. After being biolabelled with the autofluorescent *Synechococcus* isolated from the lagoon, the ciliate *Protocruzia* was offered as a prey to the pearl oyster. The high densities of ciliates observed in the stomach contents demonstrated that it was ingested by the bivalve. As a consequence, heterotrophic protists significantly contribute to the diet of the pearl oyster whereas picocyanobacteria play a minor role in the diet of this bivalve. From our experiments we concluded that heterotrophic protists play a significant role in the diet of the pearl oysters and can be considered as a valuable trophic link between picophytoplankton and the bivalves.

FEEDING AND MOVEMENT IN NOCTURNAL PLANKTIVORES:
IMPLICATIONS FOR THE TROPHO-DYNAMICS OF CORAL REEFS.

Marnane M.J.* Department of Marine Biology, James Cook University, Townsville, Qld. 4811. Australia. Email: Michael.Marnane@jcu.edu.au

Cardinalfishes (Family Apogonidae) form the major component of nocturnal planktivore assemblages on Indo-Pacific reefs. Their high abundances coupled with fast population turnover rates suggest that cardinalfishes are likely to play an important role in reef tropho-dynamics. To investigate this role, feeding and foraging movements were quantified in seven common species of cardinalfishes from the One Tree Reef lagoon, Great Barrier Reef, Australia. Of fish collected at dusk, 5% to 36% had identifiable material in their stomachs compared with 64% to 93% of fish collected at dawn, suggesting predominantly nocturnal feeding in all species. Stomach content analysis revealed generalised, overlapping diets in most species, consisting largely of benthic prey and emergent plankton. At night cardinalfishes moved into a range of habitats to feed and displayed a striking degree of spatial segregation between species. During the day species shared restricted resting sites on the reef. Fish displayed a strong fidelity to diurnal resting sites, with tagged individuals returning to within an average of 35 to 67 cm of resting positions daily over periods of up to 18 months. These results suggest that cardinalfishes play a functionally different role to that of diurnal planktivores, concentrating energy and nutrients from a range of reef habitats into restricted sites on the reef. This accrual of resources, in the form of fish biomass and faeces is likely to have important consequences for predator and detritivore communities.

PHYTOPLANKTON PRODUCTIVITY AND HYDROLOGY OF ROCAS ATOLL (BRAZIL).

Nascimento Feitosa, Fernando Antônio do, de Oliveira Passavante J.Z.* *Departament of Oceanography UFPE Recife, Pernambuco, Brazil. Email: zanon@npd.ufpe.br

The Rocas Atoll a Biological Brazilian Reserve is located at the South Atlantic Ocean at 3º51'30''S and 33º49'29''W, around 265km offshore from Natal City Rio Grande do Norte State. This Atoll ocupies a $3km^2$ area being an arid and of calcareous formation free of anthropic influence. This study was carried out in order know the area hydrology and the phytoplankton community production. In January/99 diurnal sampling were made at surface at low tide in three natural pools inside the Atoll(Tartarugas, Âncoras and Barretão) and one collection out side to measure the *in situ* productivity by the ^{14}C method and the biomass by the spectrophotometric method. Concurrent hydrological data(salinity, temperature, pH, dissolved oxygen, nitrite, nitrate, phosphate and silicate) were obtaind for comparation with the phytoplankton. The results showed that the area is free of pollution with oxygen saturation over 100%, the pH is alcaline and salinity of 35,29‰, the silicate varied from 8,91 to 16,51$\mu mol.l^{-1}$, nitrate from 0,66 to 1,34$\mu mol.l^{-1}$, nitrito from 0,04 to 0,06$\mu mol.l^{-1}$ e phosphate from 0,01 to 0,02$\mu mol.l^{-1}$ and the chlorophyll *a* concentration varied from 0,64 to 1,10$mg.m^{-3}$.

FIELD AND NUMERICAL STUDY OF THE PLANKTONIC FOOD WEB IN TAKAPOTO ATOLL LAGOON (FRENCH POLYNESIA): IMPLICATIONS FOR THE FARMING OF PEARL OYSTERS.

Niquil N.*, Stéphane Pouvreau, Asma Sakka, Louis Legendre, Bruno Delesalle. *Univ. La Rochelle, F-17042 La Rochelle Cedex 1. & EPHE-ESA CNRS 8046, F-66860 Perpignan Cedex. Email: nniquil@univ-lr.fr

The structure and functioning of the planktonic food web of the lagoon of Takapoto Atoll (French Polynesia) is described in order to assess the impact of farmed pearl oysters. Field data provided a quantification of the plankton carbon stocks and of some of the flows: net particulate primary production, DOC exudation, bacterial production, grazing by protozoa on different compartments, sinking rate of particles. The grazing of farmed pearl oysters on the different size classes of plankton was also quantified. All these data were combined in a carbon food-web model. The missing flows were estimated by inverse analysis. This combination of field and numerical approaches highlighted several characteristics of the functioning of the plankton community in the lagoon. As expected, primary production which is the single entry of carbon in the food-web, is mainly achieved by picophytoplankton. The overall flows were dominated by a high production of non-living matter, especially as dissolved organic carbon, and the trophic flows were dominated by protozoa. The plankton consumption of farmed bivalves was very low compared to the plankton flows and the effects of bivalves on the planktonic food-web can be considered as insignificant, at the scale of the whole lagoon.

PEARL-OYSTER GROWTH RATE IN OLIGOTROPHIC WATERS. PRELIMINARY RESULTS.

Pagès J.* & V. Prasil . *Centre I.R.D. de Tahiti. B.P. 529. Papeete (French Pölynesia). Email: pages@ird.pf

Pearl oysters (*Pinctada margaritifera*) are being farmed in increasing numbers in several lagoons of French Polynesia. The location of a farm in a given lagoon could determine growth performances through water renewal rate and trophic level. To explore this, we installed a number of oysters in 32 sites among 13 lagoons. On two successive years, we monitored gross shell weight (P) and shell height (H) during 12-15 months. In parallel, we monitored dissolved organic matter (as assessed by U.-V. light absorption, A_{254}) and planktonic chlorophyll (B_{tot}). We find that A_{254} (site average; n = 32) is negatively correlated with growth rate, either in shell weight (Y_P ; r_ = 0.42) or in shell height (Y_H ; r_ = 0.54). The scarcer B_{tot} data (n = 17) exhibit the same negative trend against Y_P (r_ = 0.51) and Y_H (r_ = 0.54). This counter-intuitive result can be interpreted on the basis of previous data gathered in comparable atoll lagoons. We had found that oligotrophic, well flushed environments showed a higher proportion of *i)* particulate organic phosphorus in "large" (10 - 60 µm), chlorophyll-less particles, *ii)* meso-zooplankton (>35 µm), and *iii)* heterotrophic flagellates. It would then appear that confined waters offer a qualitatively poorer diet despite high total particulate (phytoplanktonic) content. Further data are still being gathered. If the present results are confirmed, they mean that oyster growth, at least for pearl production, is not limited by carrying capacity as determined by bulk parameters. The qualitative (*i.e.* taxonomic) set-up of the whole trophic web should be considered.

ADVECTION AND CONSUMPTION OF ZOOPLANKTON IN A RED SEA CORAL REEF.

Richter, Claudio *, Mohammad I. Badran, Alexander E. Voigt and Riyad Manasreh. *Center for Tropical Marine Ecology, Fahrenheitstrasse 1, D-28359 Bremen, Germany. Email: crichter@uni-bremen.de

A six-week investigation was carried out to assess the lateral influx and consumption of zooplankton into a fringing coral reef in the Jordanian sector of the Gulf of Aqaba (Red Sea). A current meter deployed near the coral reef at 10 m depth over 70 m bottom, revealed a net shoreward transport of water, with a stronger onshore component during the cold than during the warm hours of the day (1.16±0.08 versus 0.54±0.08cm s^{-1}, respectively; mean±SE). Shoreward advection was driven mainly by the cross-shore component of the wind, and by the added effect of nearshore cooling during the night. Zooplankton collected every second day near the reef showed high densities (1389±171 ind m^{-3}) and biomass (266±37 mg wet mass m^{-3}) during periods of onshore flow. Offshore flowing water, by contrast, was depleted by 34% in terms of zooplankton abundance and by 61% in terms of biomass, indicating selective feeding on large-sized zooplankton by the reef biota. We calculate a net zooplankton uptake by the reef community of ~1 g C m^{-2} d^{-1}, equivalent to 25% of the gross community metabolism of the fringing reef system.

LINKS BETWEEN PHYSICAL AND BIOLOGICAL COMPONENTS IN SMALL CAVITIES ON A CORAL REEF SLOPE.

Scheffers S.R.*, F.C. van Duyl, R.P.M. Bak, J. de Goeij. *Carmabi Ecological Institute, P.O. Box 2090, Willemstad, Curaçao, Netherlands Antilles. Email: corals@cura.net

Hard substratum surface of crevices and cavities constitutes a major habitat in coral reefs (up to 90% of the total surface area), but there are few studies on their biological and physical characteristics. We studied these cryptic habitats on the reef slope (12-15 m) in Curaçao. Spatial characteristics of cavities were explored with a new method, "the cave–explorer". Cavities (n=12) had a volume of 100-200 l, were approximately 1 m wide, 0.5 m high, 1 m deep. They have a sandy bottom, a highly irregular inner structure with small openings in the side and back of the cavity. We used a cave-cam (video) to study the macrofauna distribution in the front, middle, and back compartments of cavities related to light-intensity and water movement. Approx. 80% of total surface area was covered: demosponges 39-53%, bryozoans 10-12%, ascidians 7%, polychaetes 2-8%, coralline algae 17-27%. Demosponge cover and species increased towards the back, while ascidians only shifted in species composition. Highest bryozoan cover occurred in the front and highest polychaete cover in the middle compartment. This highly heterogenic macrofauna composition is also reflected in a-biotic parameters. Light intensity decreased with a factor 10 from front to back. Water motion is highest in front of the cavity, decreasing towards the middle, slightly increasing in the back again. Video-tracking of suspended particles showed water to enter the cavity via the "back-openings", leaving through the front opening of the cavity. Links between the distribution of biological components and physical characteristics are studied.

A COMPARISON OF THE ROLE OF APPENDICULARIANS AND SMALL COPEPODS IN THE CYCLING OF CARBON THROUGH A COASTAL SUBTROPICAL FOOD WEB.

Scheinberg R.D.*, Albert Calbet and Michael R. Landry. University of Hawaii at Manoa, 1000 Pope Road, Honolulu, HI 96822, USA, Email: rebeccas@soest.hawaii.edu

The role of appendicularians and small copepods in the cycling of carbon through a coastal food web was investigated in Kaneohe Bay, an oligotrophic subtropical embayment located on the northeastern coast of O'ahu. The appendicularians *Oikopleura fusiformis* and *O. longicauda* and the small copepods *Acrocalanus inermis*, *Parvocalanus crassirostris*, *Oithona nana* and *O. simplex* are associated with patch reefs in Kaneohe Bay and potentially serve as a direct link between the dominant bacteria-sized primary producers and higher trophic levels in these waters. To evaluate the role of these organisms in the cycling of carbon, grazing rates were measured *in situ* using flow cytometric and epifluorescence microscopic analysis of cell decline during feeding. Weekly net tows and water collection were performed in the bay to distinguish the temporal and spatial variability of the plankton community. Results indicated that the mean transfer of carbon through both food webs was relatively inefficient (3-13%). However, the inefficiency of the appendicularian-mediated food web was due in large part to the loss of carbon to the environment in the form of particulates (82%). Therefore, the most significant impact of appendicularians or copepods in this system appears to be the contribution of appendicularians to particulate carbon flux rather than the ability to efficiently transfer carbon through the food web.

^{210}Po AND ^{210}Po BALANCE ASSOCIATED WITH PARTICULATE MATTER BEHAVIOR IN CORAL REEFS.

Tateda Y.* K. Kurosawa, Y. Suzuki, K. Iwao, M. Ouya. K. Shimoike, H. Taniguchi, and K. Yamada. *Abiko Laboratory CRIEPI, 1646 Abiko Chiba 270-1194 Japan. Email: tateda@criepi.denken.or.jp

^{210}Po concentrations in oligotrophic water are controlled by zooplankton density, which has high ^{210}Po affinity and removal from surface water by downward transport of ^{210}Po rich fecal pellet originated to zooplankton defecation. Contrary, the ^{210}Po is released from organic matter under decomposition process of biogenic debris in mid water. Therefore the ^{210}Po concentration in water column can be proxy of organic matter removal from surface water and degradation in deeper layer of ocean. In coral reefs, ^{210}Po is expected to be removed from water column by suspended organic matter consumption and released from degradation of organic matter by reef heterotrophic community. Thus imbalance between residence times of ^{210}Po in reef water and surrounding coastal waters are expected to be good information of organic particle inflow to reef from open water and consumption by reef habitat. We analyzed the ^{210}Po and POC/N concentrations in coral reef waters at Bora Bay in Miyako Island and Akajima in Kerama Islands. By box model calculation we estimate the ^{210}Po residence times in the water column in and around the coral reef, and calculate the balance of ^{210}Po to evaluate the POC and PON behavior in coral reefs. The result suggested that ^{210}Po in water is positively correlated with particle matter in reef water, however it also increased during degradation phase of organic matter in reef.

ROLE OF BACTERIOPLANKTON IN REEF ENVIRONMENTS.

Torréton, Jean-Pascal. IRD-Université Montpellier II, UMR-CNRS 5556, Case 093, Montpellier Cedex 05, France. Email: torreton@mpl.ird.fr

Detrital fluxes are known to be important in reef ecosystems and the heterotrophic bacterial production is a key process integrating the various pathways of detritus decomposition. This literature based review investigates the importance of bacterioplankton biomass, production and carbon demand, the coupling between possible sources and bacterial growth, and the fate of bacterial production. Bacterioplankton represents the dominant C, N and P biomass in reef waters as in other oligotrophic marine waters. Hence bacterioplankton represents an important standing stock capable to reduce the nutrient limitation of benthic organisms in these nutrient-poor environments. This trophic potential is supported by *in situ* studies. Indeed, over the reefs, bacterioplankton turnover rates, and exoenzymatic activities are higher than in lagoon and oceanic waters. Bacterioplankton production can reach values in the range of planktonic primary production. These characteristics suggest that bacterioplankton growth is fuelled by organic matter released by benthic communities. On the other hand, bacterioplankton abundance is lower over the reefs than in surrounding waters. This latter phenomenon, the elevated bacterioplankton turnover rates, and the short resident time of waters show that bacterioplankton is very actively consumed by benthic organisms. This trophic coupling has been actually repeatedly assessed in laboratory experiments. Establishing more quantitatively the trophic coupling between bacterioplankton and other – either planktonic or benthic – communities, using the study of temporal and spatial variations of bacterioplankton parameters, in conjunction with hydrodynamics, will require the use of new tools with high acquisition rates in order to reach an acceptable resolution.

TROPHIC SUBSIDIES IN THE TWILIGHT ZONE: ZOOPLANKTON COMMUNITY PATTERNS AND FOOD WEB STRUCTURE OF DEEP REEF FISHES IN THE NORTHEASTERN GULF OF MEXICO.

Weaver D.C.* U.S. Geological Survey, Biological Resources Division, Gainesville, FL, USA. Email: doug_weaver@usgs.gov

The food web structure of deep (50-110m) reef fishes in the northeastern Gulf of Mexico was examined. Fish communities on high-profile topographic features are numerically dominated by two species of streamer basses (Serranidae: Anthiinae): the roughtongue bass, *Pronotogrammus martinicensis*, and the red barbier, *Hemanthias vivanus*. Stomach content analysis revealed that calanoid copepods, pteropods, pelagic tunicates, and invertebrate larvae dominate the diets of both species, and that these small planktivores serve as primary prey for many larger reef predators. To compare diets of reef fishes with prey availability and encounter rates, stationary plankton tows (0.5m, 335_ nets) were made in the water column at surface (2m), midwater (35m) and near-reef (60-70m) depths. Preliminary results indicate high flow rates (3-24cm/sec) and high prey availability (0.2 to 3.0 zooplankters/m^3) in the vicinity of deep reef features. Estimates of the relative abundance indicate that 99% by number and 90% of the biomass of resident reef fishes are small, planktivorous taxa, and 65-90% of their diets are comprised of calanoid copepods, forming the main link to water column productivity and the primary source of prey for the reef fish community.

Session A3: Molecular Phylogeny and Population Genetics in Coral Reefs

GENETIC MARKERS AS ESSENTIAL TOOLS IN THE REGIONAL MANAGEMENT OF CORAL REEFS: AN INITIATIVE IN THE SOUTH CHINA SEA.

Ablan, M.C.A.*, McManus, J.W., Tsao, K.S., Chen, C.A.,Bell, J.D., Cabanban, A.S.,Tuan, V.S., and Arthana, I.W. *ICLARM, No.10 LL6 Equatorial Hotel Office Block 1 Jalan Bukit Jambul Penang, Malaysia 11900. Email: m.ablan@cgiar.org

Coastal water systems depend on a fluid medium to transport recruits for replenishment of populations. In coral reefs, currents may carry propagules of many species over large distances. The resulting connectivity among reef systems leads to situations where different groups harvest the same stock. Thus, management regimes in one area may be ineffective if there are no restrictions on harvests, or safeguarding of habitats, elsewhere. We report the use of genetic markers to evaluate connectivity among populations from selected coral reefs in Malaysia, Indonesia, Taiwan, the Philippines, Vietnam and Solomon Islands. This initiative, also known as Population Interdependencies in the South China Sea (PISCES), aims to determine the extent of unit stocks in the South China Sea region, to indicate the need for joint management of reef fisheries. The project uses a model based on 15-24 polymorphic loci in 13-15 isozyme markers of four coral reef species. Data were interpreted with information from current patterns, life-history characteristics and some macroecological correlates. Concordant results were obtained between this study and another on VNTR in the mtDNA and isozymes of the same *D. trimaculatus* individuals. The project is the result of collaboration between ICLARM and several national research institutions and is expected to facilitate the formulation of recommendations for the regional management of coral reef fisheries.

LEARNING FROM THE PAST: PERSISTANCE OF HISTORICAL GENETIC BOUNDARIES INDICATE LIMITS OF CONTEMPORARY LARVAL DISPERSAL.

Barber, P.H.* and Palumbi, Stephen R. *Dept. Organismic and Evolutionary Biology, Harvard University, Cambridge MA 02138, Email: pbarber@oeb.harvard.edu

Many coral reef organisms have pelagic larval phases that are believed to facilitate dispersal. It is commonly assumed that duration of larval period is an important predictor of dispersal potential and that realized dispersal can be estimated through combining larval period duration with ocean current data. To examine the relationship between larval period, ocean currents, and realized dispersal, we examined patterns of population genetic structure for three species of mantis shrimp with 4-6 week larval periods from populations throughout Indonesia. Although strong oceanographic currents predict extensive dispersal, striking patterns of regional genetic differentiation were observed in all taxa. Phylogeographic patterns among taxa were largely concordant and mirrored ocean basins that were more isolated during periods of lowered sea levels. Although the observed patterns likely have Pleistocene origins, the failure of dispersal to disrupt these historical associations during 10,000 years of modern oceanographic conditions forces us to conclude that contemporary dispersal is much more limited that predicted. The recovery of concordant regional patterns of genetic structure suggests that our understanding of larval dispersal behaviors and/or ocean currents may be over simplistic and highlights the need for fine scale population genetic studies in marine systems.

THE GENETIC STRUCTURE OF THREE WIDELY SEPARATED POPULATIONS OF *Chlorurus sordidus*.

Bay L.*, Christine Dudgeon and Prof. J Howard Choat, *School Marine Biology and Aquaculture, James Cook University Townsville Qld. 4811, Australia. Email: line.bay@jcu.edu.au

The effective management of coral reef fisheries depends on the identification of local populations and levels of connectivity amongst these. Recent advances in molecular techniques have provided reef fish biologists with the tools to examine the genetic structure of geographically separated populations and levels of gene flow amongst these. The majority of reef fishes have a bipartite life history where larvae spend some time in the pelagic environment before returning to the reef environment. During this phase larvae may disperse away or return to the natal reef. Recent studies have failed to find conclusive evidence of a relationship between genetic subdivision of geographically separated populations and length of larval life. It is possible that not only the duration of the larval phase but also behavioural capability of larvae may affect the dispersal ability and hence the level of genetic subdivision amongst geographically separated adult populations. We examine the genetic structure of the common reef fish *Chlorurus sordidus. C. sordidus* larvae spend ~30 days in the pelagic zone but are undeveloped compared to larvae of other reef fish species. We compare mitochondrial DNA sequence data amongst three widely separated geographic populations. Samples from the northern Great Barrier Reef are compared with samples taken ~ 3000 km to the west (Abrolhos Islands, WA) and those sampled ~1000 km to the north (Kavieng, PNG). Results are interpreted with respect to larval attributes and the geological history of the region.

CORALLIMORPHARIA (CNIDARIA, ANTHOZOA): AN ORDER, A CORAL, OR A SEA ANEMONE?

Cappola V.A. and D.G. Fautin*. *University of Kansas, Division of Biological Sciences, Haworth Hall, Lawrence, KS 66047. Email: fautin@ukans.edu

The anthozoan order Corallimorpharia is currently considered equivalent in rank to the Scleractinia (hard corals) and Actiniaria (sea anemones). Does Corallimorpharia merit ordinal status and, if not, does it belong in the scleractinians or actiniarians? This study is the first cladistic analysis of these anthozoan orders based on both morphology and molecules. Morphological and anatomical evidence (nematocysts, structure of mesenterial filaments, structure of the mesoglea, absence of siphonoglyphs, sphincter muscle feeble or absent, acrospheres) support the Corallimorpharia and Scleractinia being closely related, but the form of this relationship is unresolved. The corallimorpharians have variously been hypothesized to be corals without skeletons, representatives of the ancestral anemones from which skeleton-producing polyps diverged, the sister group to Scleractinia, and a suborder of Scleractinia. Published molecular data of 16S mitochondrial DNA and 18S ribosomal DNA support the corallimorpharians within the scleractinian clade, but data from 28S ribosomal DNA support corallimorpharians being more closely related to actiniarians. Monophyly of the corallimopharians has not been established by these molecular studies. We use morphological and molecular evidence both independently and combined to present a complete picture of the phylogenetic status of Corallimorpharia.

EVIDENCES FOR HIGHER RATE OF CYTOCHROME *B* EVOLUTION IN THE SCLERACTINIAN CORAL GENUS *ACROPORA* IN THE FAMILY ACROPORIDAE.

Chen C.A.* and Carden C. Wallace. *Institute of Zoology, Academia Sinica, Nankang, Taipei 115, Taiwan. Email: cac@gate.sinica.edu.tw

The fundamental discipline of molecular evolution is to estimate the divergence rates of molecules (DNA sequences or proteins), and apply the rate to infer absolute divergence times between species. The latter relies on well-preserved fossil records and evolutionary rate of the molecules which are approximately constant over time in all evolutionary lineages (i. e., molecular clock hypothesis). Recent advances in characterizing the mitochondrial genome of *Acropora* and phylogenetic relationships in the family provide an opportunity to examine the molecular evolution of mitochondrial genome in scleractinian corals. In this study, we apply the likelihood ratio test (LRT) and relative rate test (RRT) to examine the patterns of rate heterogeneity in the family Acroporidae at two mitochondrial genes, cytochrome b (cyt b) and ATPase 6. Based on both LRT and RRT, we find significant evidence of rate heterogeneity among evolutionary lineages of the family Acroporidae at cyt b gene, but not at ATPase 6. The effects of rate heterogeneity at *Acropora* cyt b gene in inferring the divergence time and phylogenetic relationships of the family Acroporidae are discussed.

DEMOGRAPHIC AND LIFE-HISTORY DIFFERENCES IN REEF FISHES IN THE GREAT BARRIER REEF LACK A GENETIC BASIS.

Dudgeon C.*, Nicholas Gust and David Blair. *James Cook University, Dept. of Zoology, Townsville, QLD, Australia, 4811. Email: Christine.Dudgeon@jcu.edu.au

Two species of parrot fish, *Chlorurus sordidus* and *Scarus frenatus* are known to exhibit demographic and life history differences across the continental shelf of the northern Great Barrier Reef (GBR). Mitochondrial control region sequences were analysed to test whether there was a genetic basis to the observed ecological differences. Analysis of molecular variance (AMOVA) revealed high levels of gene exchange for both species at a local scale between reefs on mid and outer continental shelf positions (20 km apart) and at a broader scale along the length of the GBR province (>1000 km apart), indicating that local differences in life history characteristics on the northern GBR do not have a genetic basis. Rather it appears more likely that phenotypically plastic responses to prevailing social and environmental conditions explain differences in the life history characteristics of both taxa. However, analysis of genetic variability and historical demography revealed striking differences between the two species suggesting *S. frenatus* has undergone a population expansion between 20 000 to 80 000 years ago whilst *C. sordidus* has maintained equilibrium over this time. These patterns could also reflect differences in the metapopulation sizes or generation times between taxa. This study illustrates contrasting ecological and genetic information which may have implications for fisheries management.

REEF CONNECTIVITY IN THE SOUTH CHINA SEA AND SULU SEA, PHILIPPINES, INFERRED FROM ALLOZYME ANALYSIS OF TWO REEF FISH SPECIES.

Endriga M.A.* Mamauag S.S, Menez M.A.J., Alino P.M. . *Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, Philippines. Email: marla@upmsi.ph

Allelic variation in 4 populations of *Pterocaesio tile* and 12 populations of *Chromis margaritifer* at 12 to 14 polymorphic loci was analyzed to compare levels of genetic structuring and determine the extent of gene flow in the South China Sea (SCS) and Sulu Sea. Fish were collected from the Kalayaan Island Group (KIG) and Western Luzon (WL) coast in the SCS and reefs in the Sulu Sea. Average heterozygosity was highest in *P. tile* (H = 0.421) compared with 1998 (H = 0.391) and 1999 (H = 0.362) populations of *chromis*. It was highest in Sulu Sea populations of both species, lowest at the NE Investigator Shoal of the KIG among *chromis*, and lowest in WL among caesionids. Overall F_{st} was significant in both species (F_{st} = 0.1473 for *P. tile;* 0.1732 for *C. margaritifer*), suggesting that these are highly structured populations. Effective number of migrants per generation (N_em) are 1.4 for *P. tile* and 1.2 for *chromis*. Genetic affinities were closest between KIG and Sulu Sea populations of *P. tile* (D = 0.112) which differed significantly from the WL population (D = 0.158). Cluster analysis on *chromis* populations yielded two major clusters: the KIG and WL-Sulu Sea clades. Pair-wise comparisons showed that each *chromis* population was significantly different from the rest (D = 0.069-0.127) included in the study. In general, proximate sites had higher affinities with one another, with some exceptions.

GENETIC STRUCTURE OF *LINCKIA LAEVIGATA* AND *TRIDACNA CROCEA* POPULATIONS IN THE PALAWAN SHELF AND SHOAL REEFS.

Juinio-Meñez, Marie Antonette*, Richard Magsino, Eizadora T. Yu. *Marine Science Institute, College of Science University of the Philippines, Diliman, Quezon City 1101 Philippines. Email: meneza@msi01.cs.upd.edu.ph

Allozyme variation of 10 populations of *Linckia laevigata* at 8 polymorphic loci, and 12 populations of *Tridacna crocea* at 6 polymorphic loci were analyzed to compare genetic variability and determine genetic affinities among shoal and shelf reefs of Palawan, Philippines. Heterozygosity was highest in populations from the shelf of Palawan and lowest in the shoal reefs of KIG in the South China Sea for both species. There were highly significant variations between populations in 3 loci of *L. laevigata* and 5 loci of *T. crocea*. Overall F_{st} for both species (*L. laevigata*, 0.049 and *T. crocea*, 0.1403) were significant indicating genetic structuring among shelf and shoal reef populations in Palawan. The estimated average number of effective migrants per generation (N_{em}) between the reef populations was 1.5 individuals for *T. crocea* and 5 migrants for *L. laevigata*. Nei's unbiased distance for *L. laevigata* was smaller than that for *T. crocea*. Cluster analysis based on genetic distance generally showed groupings of reefs that were geographically close to each other with a few exceptions. Highly significant pairwise comparisons (F_{st}) of the different reef groups indicate genetic substructuring of these reef invertebrates between and within the four geographic areas in Palawan.

PCR AMPLIFICATION OF 16S MITOCHONDRIAL GENE OF *ZOANTHUS SOCIATUS* (ZOANTHIDEA, ANTHOZOA) USING HETEROLOGOUS PRIMERS

Longo, L. L.*; M. C. Arias & E. Schlenz *Departamento de Zoologia Instituto de Biociências Universidade de São Paulo São Paulo, SP, Brazil Caixa Postal 11461 CEP: 05422-970 Email – lllongo@ib.usp.br

The Zoanthidea order (class Anthozoa) is comprised mainly of colonial cnidarians that do not secrete a skeleton, but some of them have an assimilation mechanism of sediments within their tissues. Most of the species have zooxanthellae endosymbionts. The morphological identification of Zoanthidea species has been very difficult due to the plasticity of polipo and colony morphology. Although this group of Cnidaria is very abundant, studies involving its biology and taxonomy are rare. Histological sectioning has been used in an attempt to determine characters that can be useful for taxonomic purpose. Allozime analysis has been the only molecular tool applied so far to Zoanthidea taxonomy. Mitochondrial DNA (mtDNA) analysis has been used successfully in taxonomic and evolutionary studies of several organisms. The main goal of our study is to test primers for mtDNA regions derived from different organisms in *Zoanthus sociatus*. As this species presents zooxanthellae endosymbionts, it is crucial to have DNA extractions free of this contaminant and also primers showing high specificity to Cnidarians. Primers for the 16S mtDNA gene, described for *Hydra vulgaris*, were inittially tested. The PCR product obtained was a unique fragment of 1022 pb. This fragment was cloned and sequenced.

GENETIC RELATIONSHIP OF COLOR ECOMORPHS OF THE REEF STARFISH *LINCKIA LAEVIGATA* (LINNEAUS) IN THE KALAYAAN ISLANDS GROUP (KIG), WEST PALAWAN, PHILIPPINES.

Magsino, Richard M. *, Rachel G. Ravago, Marie Antonette J. Meñez. *Marine Science Institute University of the Philippines, Diliman, Quezon City 1101 Philippines. Email: rickym@msi01.cs.upd.edu.ph

The coral reef starfish *Linckia laevigata* is an organism with a high potential for dispersal due to its 28d planktonic larvae. In the Kalayaan Island Group (KIG), Philippines, color morphs of blue, orange and combinations of both colors exist sympatrically. Genetic variation at 8 polymorphic loci for 3 reef populations in the KIG based on allozyme markers was examined. Data for 163 individuals (85 blue and 78 orange) showed highly significant genetic grouping for all populations (F_{st}=0.086) of *L. laevigata*. Pairwise comparisons between blue and orange ecomorphs of the species (F_{st}=0.079) revealed lower but significant genetic variation. In two reefs where both blue and orange *L. laevigata* occurred, significant F_{st} suggests genetic differentiation of color ecomorphs within sites. Cluster analysis revealed two genetically different groups of blue and orange populations. Comparison of DNA sequences of the COI segment of the mitochondrial DNA of the different color morphs show considerable variation among individuals. Results obtained were consistent with a previous allozyme study on the population genetics of *L. laevigata* color morphs in Pacific and Indian Ocean populations. Phenotypic and genetic structuring of color variants of *L. laevigata* within the KIG may reflect effects of the very variable and complex hydrographic regimes and habitats in the shoal reefs that affects recruitment dynamics of *Linckia* populations.

POPULATION GENETICS OF THE SEA URCHIN *TRIPNEUSTES GRATILLA* ALONG THE WESTERN COAST OF LUZON ISLAND, THE PHILIPPINES.

Malay, Maria Celia D. *, Marie Antonette Juinio-Meñez, and Cesar Villanoy. Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101 Philippines. Email: machel@msi01.cs.upd.edu.ph

The sea urchin *Tripneustes gratilla* is a fishery resource of high commercial value and is intensively harvested throughout much of Northwestern Luzon. However, the fishery is primarily unregulated, which has led to the steep decline of spawning stocks in many areas, notably in Bolinao, Pangasinan. Preliminary hydrographic larval dispersal models indicate that larval exchange within this region is influenced by monsoonal shifts in circulation patterns. The genetic structure of *T. gratilla* in Western Luzon, the Philippines is being investigated using allozyme electrophoresis to provide the basis for the formulation of coherent management plans for regional sea urchin resources. Samples of *T. gratilla* intestines were obtained from one batch of cultured sea urchins from the UP-MSI Bolinao Marine Laboratory and 4 "wild" populations in Western Luzon: Sta. Maria, Ilocos Sur; Bolinao, Pangasinan; Masinloc, Zambales; and Lian, Batangas. Seven polymorphic enzyme loci (MDH-1, MDH-2, SOD, GPI, MPI, PGM, and LT) and 2 monomorphic loci (IDHP and LP) are being screened to determine genetic variations between populations and estimate larval dispersal and gene flow between the different localities sampled. Baseline information on population genetic structure will also be useful in monitoring the impacts of enhancement efforts using cultured sea urchins on the genetic structure of natural populations of *T. gratilla.*

RETICULATE EVOLUTION IN THE ACROPORA HYACINTHUS GROUP: RESULTS FROM MITOCHONDRIAL AND NUCLEAR MARKERS.

Marquez L.M.*, M.J.H. van Oppen, B.L. Willis and D.J.Miller. Biochemistry and Molecular Biology, *James Cook University, Townsville 4811, Australia. Email: Luis.Marquez@jcu.edu.au

Two species in the *Acropora hyacinthus* group, *A. hyacinthus* and *A. cytherea*, hybridise *in vitro* with up to 100% fertilisation success, however, it is unclear whether this potential for hybridisation has led to introgression and reticulate evolution. Here, we present DNA sequence data for three independent markers: rDNA ITS and 5.8S, the *Pax-C* 46/47 intron and the putative mtDNA control region for these two species and for *A. tenuis*. The latter species was used as an outgroup in phylogenetic analyses, as it appears to be reproductively isolated from the former two through a difference in spawning time. We found high levels of variability in rDNA regions, with up to 55% variability for ITS1. ITS sequences were shared between the two species in the *A. hyacinthus* group suggesting that introgression occurs. No ITS sequences were shared with *A. tenuis*. Phylogenetic analyses of molecular data for samples of *A. cytherea* and *A. hyacinthus* from sites along the length of the Great Barrier Reef and from the Ningaloo Reefs in Western Australia indicate that these two species do not constitute monophyletic groupings. Moreover, phylogenies showed no clear biogeographic patterns. Comparisons of phylogenies based on the three different markers will be discussed.

ECOLOGICAL AND GENETIC DIFFERENCES BETWEEN EASTERN PACIFIC PANAMANIAN CORALS. AGARICIIDAE (*Pavona varians, P. frondifera* AND *Pavona* sp. *a*)

Maté JL*. University of Miami, RSMAS-MBF, 4600 Rickenbacker Causeway, Miami, FL 33149, USA; and Smithsonian Tropical Research Institute, Unit 0948, APO AA 34002, USA. Email: matej@naos.si.edu

Pavona is a common and conspicuous coral genus with a distribution that ranges from the Red Sea and western Indian Ocean to the far eastern Pacific. Three of six species reported for the Panamanian Pacific (*Pavona varians*, *P. frondifera* and *Pavona* sp. *a*) show strong development of colines that set them apart from the others. I studied the ecological and genetical differences among these three species to determine their boundaries. Ecological information consisted on species distribution, habitat preferences, tissue coloration, reproductive ecology, and tolerance to bleaching. Genetical information consisted on the analysis of the 10 allozyme loci. *Pavona varians* and *Pavona* sp. *a* are sibbling species. *Pavona varians* is the most widely distributed of the three species, found in both reef and non-reef environments in the Gulf of Chiriquí and the Gulf of Panamá.

COMPARING MITOCHONDRIAL AND NUCLEAR GENE SEQUENCES : CRITICAL TOOLS TO DETECT NATURAL SELECTION, CRYPTIC SPECIES BOUNDARIES, AND RETICULATE EVOLUTION IN REEF SPECIES.

Palumbi, Stephen R. *, Paul Barber, Laura Geyer, Shane Lavery, and Steve Vollmer, *Dept. Organismic and Evolutionary Biology, Harvard University, Cambridge MA 02138, Email: spalumbi@oeb.harvard.edu

Collection of gene sequence data to measure population structure can now make use of information from multiple independent loci to test hypotheses about the origin and maintenance of genetic variation within closely related species. The signature of selection on gene frequencies, typically ignored in studies of single loci, can be tested by comparing genetic structure of several loci. In the Indo-West Pacific sea urchins in the genus *Echinometra*, allele frequencies of at the locus responsible for egg-sperm recognition, the gene bindin, differ strongly among localities even though neutral intron variation does not. These patterns suggest selection driven by mate recognition acts within populations. In addition, comparison of phylogenetic patterns from multiple loci can 1) test for genetic barriers between sympatric, cryptic species, such as in comparisons of Indonesian stomatopods, 2) show the history of population exchanges, such as in Indo-West Pacific Penaeid shrimp, 3) and provide a robust framework for evaluation of patterns of reticulate evolution in corals.

(GACA)n SIMPLE SEQUENCE REPEATS IN THE NUCLEAR GENOME OF SEA ANEMONES (CNIDARIA: ACTINIARIA AND CORALLIMORPHARIA): ANALYSIS OF POPULATION STRUCTURE AND SPECIES DIVERSITY

Pinto, S.M.*, F.M.C. Fernandes-Matioli and E. Schlenz. *Depto. de Zoologia, IB, Universidade de São Paulo, CP 11461, 05422-970. São Paulo, SP, Brazil. Email: suzanamp@ib.usp.br.

DNA microsatellites molecular markers could be useful for addressing evolutionary questions in sea anemones, and may clarify the phylogenetic relationships among genera and species, which do not differ throughout the morphological characters. In this study, we show that PCR (polymerase Chain Reaction) amplification using primers based on microsatellite sequences are effective to address the genetic variability in 12 species of sea anemones. A total of 150 individuals belonging to 11 species of sea anemones, *Aiptasia pallida*, *Anthothoe chilensis*, *Anthopleura krebsi*, *Bellactis ilkalyseae*, *Carcinactis dolosa*, *Calliactis tricolor*, *Diadumene* sp, *Haliplanella lineata*, *Paratelmatactis roseni*, *Telmatactis rufa*, *Tricnidactis errans*, and one species of corallimorpharian, *Discosoma carlgreni* were examined. All species were collected from the Brazilian coast. Specimens were collected during low tide periods and SCUBA diving at depths bet ween 1 and 16 m . Total genomic DNA was extracted from living, and 100% ethanol-preserved sea anemones. DNA extracted from samples was used as a template in PCR amplifications with the SPAR technique using (GACA)4 as primers.

PHYLLOGEOGRAPHY OF CORAL REEF FISHES THROUGHOUT THE PACIFIC OCEAN INFERRED FROM GENETIC SURVEYS

Planes S.* *EPHE - ESA CNRS 8046 University of Perpignan, 66860 Perpignan cedex - France. Email : planes@univ-perp.fr

The geographic range of a species is mostly determined by a succession of historical accidents. Althrough the idea is simple, the combination can be infinite because species are formed at different times, barriers to migration appear and disappear through time. The Indo-Pacific area has been recognised as the most diverse biogeographic area among marine ecosystems. This diversity shows gradient with higher diversity in the Indonesia-Philippines area and decrease of species richness going East in the Pacific islands. Three major theories (center of origins, center of accumulation, and center of overlap) have proposed mechanisms that lead to higher diversity in the Indonesian-Philippines area. We investigate genetic approach as a new tool that could give evolutionary perspective in biogeography. The rationale of such an approach is that genetic diversity has been found to be correlated to species richness. Three species (Acanthurus triostegus, Forcipiger flavissimus and Zanclus cornuttus) that are found althrough the Indo-Pacific area from Baja California to South Africa were surveyed.

ASSESSMENT OF CRYPTIC REEF FISH SPECIES IN BRAZIL USING MOLECULAR MARKERS

Rocha, Luiz A. and Brian W. Bowen. *University of Florida, Department of Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, FL 32653 USA. Email: rocha@gnv.ifas.ufl.edu

In the last few years the growth of interest in reef fish systematics among Brazilian ichthyologists has generated a growing number of faunal surveys and, consequently, species descriptions. Many of the unknown species being found can be described based solely on morphology, but others seem to differ from Caribbean sister taxa in just a few characters such as color or size, what usually is not enough for establishing a species identity. Examples of those so called "cryptic" species are several grunts (Haemulidae), wrasses (Labridae) and damselfishes (Pomacentridae). One of the first species accessed during this study is the puddingwife *Halichoeres radiatus*. It has a green-yellow body with four white spots along the dorsum in the Caribbean, and a blue-orange body without white spots in Brazil, but no significant difference was found when comparing their morphology. In an attempt to solve long debated questions about the identity of such Brazilian taxa we are now applying molecular genetic techniques and testing hypothesis of gene flow and population structure between Brazilian and Caribbean reefs, which are separated by freshwater discharges of big rivers such as the Amazon and Orinoco in northeastern South America. Preliminary data on sequences of *Halichoeres radiatus* mitochondrial DNA indicate deep separations between locations on the Brazilian coastline, offshore islands, and the Caribbean.

MOLECULAR TOOLS FOR ASSESSING GENETIC VARIATION WITHIN SCLERACTINIAN CORAL SPECIES.

Romano, S.L.* and R.H. Richmond. *Marine Laboratory, Univ. of Guam, UOG Station, Mangilao, Guam 96923 USA. Email: sromano@uog9.uog.edu

Developments in molecular techniques have made it feasible to use genotypic characters for analyses of relationships among coral species, genera, and families. However, gene regions that are useful for detecting genetic differences within and among closely related species of many different organisms do not demonstrate genetic differentiation on a similar scale for coral species. Recent work has shown those molecular methods that sample throughout the genome, such as RAPDs, AFLPs and ISSRs, may provide the necessary resolution for analyzing intraspecific variation in corals. Randomly amplified polymorphic DNA (RAPD) markers have been used as a means of relatively easily, rapidly, efficiently and inexpensively assaying genetic variation, from the level of the individual to the species, in a wide variety of plants and animals. While RAPD markers successfully differentiate species within the genus *Acropora*, preliminary data indicate that they may not be useful for assessing genetic variation within scleractinian coral species. DNA extracted from azooxanthellate coral sperm from 45 colonies of *Acropora surculosa* was amplified with four different RAPD primers. Analysis of 27 loci generated from these primers demonstrates no population differentiation among four populations separated by as much as 50 km. Mean genetic distances within populations are 25-32% and between populations are 26-31%. Continuing research is being conducted to determine whether this result is due to lack of genetic variation within *A. surculosa* or to lack of variability in coral RAPD markers.

LOW LEVELS OF MITOCHONDRIAL SEQUENCE VARIATION IN SCLERACTINIAN CORALS.

Snell, Tonya L.*. *University at Buffalo, Dept. of Biological Sciences, Buffalo, NY 14260 USA, Email: tlsnell@buffalo.edu.

Mitochondrial 16S ribosomal RNA and cytochrome b gene sequences often exhibit unexpectedly low sequence divergence among some scleractinian corals. In this study, sequence variation of another mitochondrial gene, cytochrome *c* oxidase subunit 1 (COI), was investigated to determine whether this trend was exhibited throughout this region of the mitochondrial DNA (mtDNA). Approximately 700 base pairs of the COI gene from Caribbean coral species in several scleractinian families were sequenced and analyzed for intra- and interspecific nucleotide and amino acid variability. Levels of variability were extremely small (or zero) among colonies within a species, even when samples were collected from distant geographic locations (>3000 km). Among some species, nucleotide divergence and amino acid divergence were also very low. Phylogenetic relationships based on this COI region support the placement of genera within families, and the relationships among families were generally concordant with those hypothesized using 16S mitochondrial sequence data. Although mtDNA sequences are commonly used to assess population structure and estimate divergence of closely related species, low levels of mitochondrial nucleotide substitution rates in scleractinian corals inhibit the use of these markers for such purposes.

THE SCLERACTINIAN CORAL *PAVONA CACTUS* EXHIBITS HIGH LEVELS OF GENETIC POLYMORPHISM: A NEW GENETIC MARKER FOR CLONAL POPULATION STUDIES.

Smith,C.R.*, Willis, B.L., Miller, D.J. and Chen, C.A. *Australian Institute of Marine Science PMB No. 3 Townsville MC QLD 4810 Australia. Email: c.smith@aims.gov.au

The prevalence of asexual reproduction in the life history of scleractinian corals highlights the need for good genetic markers to assess clonal population structure. In order for genetic markers to be useful they must be easily assayed and exhibit sufficient polymorphism to address the question at hand. The ribosomal intergenic spacer region (IGS) is a region with considerable potential for use as a genetic marker in population level studies of scleractinian corals. A rapid, cost effective method of assaying variation within the ribosomal IGS region was developed for the agariciid coral *Pavona cactus*. Possible contamination from symbiotic zooxanthellae was avoided by the development of an assay which preferentially amplifies host coral DNA rather than zooxanthellae DNA through the use of the polymerase chain reaction (PCR). This PCR based technique was able to rapidly distinguish 17 distinct genotypes within a clonal population of *P.cactus* at Eclipse Island, Great Barrier Reef, Australia. Allozyme electrophoresis, the more traditional genetic assay for hard corals, resolved only 12 genotypes within the same sample set. The high level of polymorphism observed within the IGS region of *P.cactus* (as compared with that observed in a clonal marine gorgonian, *Junceella fragilis*) may be explained by the presence of internally repeated DNA elements (subrepeats) in the *P.cactus* genome.

REPRODUCTIVE AND MORPHOMETRIC CHARACTERS OF CARIBBEAN CORALS IN THE GENUS *ACROPORA* ARE CONSISTENT WITH A HYBRID ORIGIN FOR *A. PROLIFERA*

Stockwell, B., B. Willis.* and A. Morse. *Department of Marine Biology, James Cook University, Townsville, Qld.4811, Australia. Email: Bette.Willis@jcu.edu.au

Caribbean species in the coral genus, *Acropora*, comprise two common species, *A. palmata* and *A. cervicornis*, and a rarer species, *A. prolifera*, whose intermediate colony morphology and lack of genetic distinctness have lead to speculation that it may be of hybrid origin. We present evidence that, in addition to colony morphology, both corallite morphology and reproductive characters of *A. prolifera* are intermediate between those of the other two species. Mean egg volume and polyp fecundity are both distinct and intermediate for *A. prolifera*, with *A. cervicornis* being significantly more fecund and *A. palmata* having significantly larger eggs. Multivariate analyses of corallite characteristics (maximum calice diameter, calice roundness, corallite length, and corallite wall thickness) clearly separated all three species and indicated that corallite dimensions of *A. prolifera* are intermediate between those of *A. palmata* and *A. cervicornis*. Evidence that *A. palmata* and *A. cervicornis* may spawn concurrently, coupled with congruence in the intermediacy of *A. prolifera* for both reproductive and morphometric characters is consistent with suggestions that *A. prolifera* may have originated as a hybrid between *A. palmata* and *A. cervicornis.*

GENETIC CONNECTIVITY OF CORALS AMONG WESTERN PACIFIC REEFS.

Takabayashi, M.*, Carter, D.A., Hoegh-Guldberg, O. *Centre for Marine Studies, The University of Queensland QLD 4072 Australia. Email: misaki@bio.usyd.edu.au

Genetic connectivity over large distances (thousands of kilometres) is poorly described despite the widespread distributions of Scleractinian corals and the importance of the information for areas like conservation biology. Molecular methods offer powerful opportunities to investigate this area of coral reef biology. Variability in the DNA sequence of the internal transcribed spacer-1 (ITS-1) of ribosomal genes was investigated to analyse intra-specific genetic diversity of a common coral, *Stylophora pistillata*, across the western Pacific Ocean. Populations from Japan, Malaysia, northern and southern Great Barrier Reef (GBR) were studied. The resulting consensus dendrograms (maximum likelihood and neighbour joining analyses) revealed that the genetic and geographic distances were clearly correlated in these coral populations. Despite this, statistical analyses (AMOVA) of genetic distances revealed that ITS-1 sequence variability was greater within populations (78.37%) than among populations (12.06%). These results suggest significant connectivity among reef systems that may be separated by as much as several thousand miles. These results have important implications for the local and global management of coral reefs throughout the tropical Pacific.

EXAMINATION OF SPECIES BOUNDARIES IN THE *ACROPORA CERVICORNIS* GROUP (SCLERACTINIA, CNIDARIA) USING NUCLEAR DNA SEQUENCE ANALYSES.

van Oppen, MJH*, BL Willis, HWJA van Vugt, DJ Miller. *Biochemistry and Molecular Biology, James Cook University, Townsville 4811, Australia. Email: Madeleine.vanOppen@jcu.edu.au

While *Acropora* is the most species rich genus of the scleractinian corals, only three species occur in the Caribbean: *Acropora cervicornis*, *A. palmata* and *A. prolifera*. Based on overall coral morphology, abundance and distribution patterns, it has been suggested that *A. prolifera* may be a hybrid between *A. cervicornis* and *A. palmata.* We have examined species boundaries among these three morphospecies using DNA sequence analyses of the nuclear *Pax-C* 46/47 intron and the ribosomal DNA ITS1-5.8S-ITS2 regions. Up to 5.2 % overall sequence divergence was observed in the ITS and 5.8S sequences, but variability within species was as large as between species and all three species carried similar sequences. Since this is unlikely to represent a shared ancestral polymorphism, the data suggest that introgressive hybridisation occurs among the three species. For the *Pax-C* intron, *A. cervicornis* and *A. palmata* had very distinct allele frequencies and *A. cervicornis* carried a unique allele at a frequency of 0.769. All *A. prolifera* colonies examined were heterozygous for the *Pax-C* intron, while heterozygosity was only 0.286 and 0.333 for *A. cervicornis* and *A. palmata*, respectively. This suggest that *A. prolifera* is the product of hybridisation between two species that have a different allelic composition for the *Pax-C* intron, i.e. *A. cervicornis* and *A. palmata*. We therefore suggest that *A. prolifera* is a hybrid between *A. cervicornis* and *A. palmata*, which backcrosses with the parental species at low frequency.

POPULATION GENETIC ANALYSES OF THE RIBOSOMAL INTERNAL TRANSCRIBED SPACER 2 IN *ACROPORA* (CNIDARIA; SCLERACTINIA): EFFECT OF ANCESTRAL POLYMORPHISM IN EVOLUTIONARY HISTORY OF *ACROPORA.*

Wei, Nuwei Vivian*, Wallace, Carden C. Chang-Feng Dai, Shan-In Vanson Liu, Chaolun Allen Chen. *Institute of Oceanography, National Taiwan University, Taiwan. Email: teresa@gate.sinica.edu.tw

Reticulate evolutionary history enforced by synchronous spawning of *Acropora* has recently been suggested based on fertilization trials and molecular markers. Under this scenario, success of natural hybridization among morphologically distinct *Acropora* may reinforce the exchange of genetic background of species which spawn simultaneously in the populations, but create genetic difference among species with variations in spawning times, or of the same species at geographically-distant populations. In this study, population parameters were estimated for the ribosomal internal transcribed spacer 2 (ITS2) of several *Acropora* species obtained from diverse geographic localities. The ITS2 of *A. humilis*, containing a set of microsatellites, showed the highest genetic divergence (> 30%) in comparison to three dominant species, *A. muricata*, *A. hyacinthus*, *A. valida*, in the Penghu (Taiwan) population.

USING A MULTI-LOCUS APPROACH TO EXAMINE SPECIES-LEVEL RELATIONSHIPS IN THE SCLERACTINIAN CORALS.

Vollmer, Steven V.* and Stephen R. Palumbi. *Dept. of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, Email: svollmer@oeb.harvard.edu

Efforts to construct molecular phylogenies within the scleractinian corals have been hampered by surprisingly low levels of genetic variability at loci commonly used in other taxa. While there has been limited success with the higher-level systematics of the corals, few loci have been identified that are capable of resolving species-level relationships, and those loci with sufficient variation often lack fixed differences between species. As a result, the ability to address questions about species relationships in corals, including whether reticulate evolution may be common to some mass-spawning species, have been limited by a lack of appropriate markers. We examined patterns of genetic variability in *Acropora palmata* and *A. cervicornis* from the Caribbean using mitochondrial and nuclear loci. Sequence data from the putative control region and cytochrome oxidase III of the mitochondrion and nuclear intron data from 3 independent loci show that these 2 species are genetically distinct. Levels of genetic variability at these loci are suitable for inter- and intra-specific phylogenetic comparisons, and the comparison of mitochondrial versus nuclear loci may be useful for detecting introgression.

POPULATION PHYLOGENETICS OF THE COMMON CORAL REEF SPONGES *LEUCETTA* SPP. AND *PERICHARAX* SPP. (PORIFERA: CALCAREA) FROM THE GREAT BARRIER REEF AND VANUATU.

Woerheide, G.*; Degnan, B. M.; Hooper, J.N.A.. *Queensland Museum, P.O. Box 3300, South Brisbane, Q 4101, Australia & Molecular Zoology Lab., Dept. of Zoology and Entomology, University of Queensland, St. Lucia, Q 4072, Australia. Email: GertW@qm.qld.gov.au

Molecular data show that calcareous sponges (Porifera: Calcarea) might be the link between sponges and Ctenophora/Cnidaria. However, present knowledge of this group of sponges from Indo-Pacific coral reefs is deficient - this class of sponges remains fundamentally problematic at all levels. The aim of the present study is to investigate for the first time the phylogenetic relationships of populations of the common (and allegedly 'cosmopolitan') calcareous sponges *Leucetta* spp. and *Pericharax* spp. from the Great Barrier Reef and Vanuatu, using mitochondrial (COII) and nuclear (ITS) gene sequence analysis. Species of *Leucetta* and *Pericharax* are particularly well-suited for this study as they are found on nearly every Indo-Pacific coral reef; identification at species level is difficult using traditional morphological characters; and nothing is known about gene flow and larval dispersal capabilities between Indo-Pacific populations. We test the hypothesis that 'widely distributed' species of these taxa occur in the western Indo-Pacific (H_0), against the possibility that the populations of these allegedly 'widely distributed' species represent distinct cryptic sibling species (H_1). We will also compare different rates of evolution of investigated mitochondrial and nuclear genes in Porifera and indicate patterns of gene flow between populations – of high significance also to other marine invertebrate groups.

SPECIES BOUNDARIES IN SCLERACTINIAN CORALS.

Wolstenholme, Jackie*. *Dept of Marine Biology and Aquaculture, James Cook University, Townsville Qld 4811 Australia. Email: jackie.wolstenholme@jcu.edu.au

Accurate definition of species and species boundaries is critical for correctly interpreting evolutionary processes. However, definition of boundaries between many species of scleractinian corals remains unresolved because of merging or overlapping skeletal characters between morphologically similar species. Molecular evidence suggests that this apparent morphological continuum between some species of corals is due to hybridisation, and may be indicative of a reticulate rather than divergent evolutionary history. Detailed morphological analysis, using both descriptive and morphometric characters of all morphs of the *Acropora humilis* species complex, indicates that the five species present in American Samoa correspond with seven field-recognisable morphs. Three of the morphs have overlapping morphological boundaries while the other four morphs have distinct boundaries. Two of the distinct morphs are from a single species, *A. monticulosa*. One morph with indistinct boundaries and one morph with distinct boundaries are from the species *A. gemmifera*. Molecular data, for the same colonies used in the morphological analysis, compare the occurrence and frequency of interbreeding between morphs with overlapping and distinct morphological boundaries. Techniques established in this project will be used to analyse samples collected from the same species complex from six other Pacific locations to assess biogeographic variation. The combined results will be used to reconstruct the phylogenetic history, including zones of hybridisation, of this species complex.

Session A4: Zooxanthellae in Animal Hosts: Honoring Len Muscatine and Bob Trench

USE OF $\delta^{13}C$ TO STUDY THE CORAL SYMBIOSIS SYNERGY.

Amat A*, Juillet-Leclerc , Ruiz-Pino. LSCE, Domaine du CNRS, Gif-sur-Yvette, FRANCE. Email: amat@ccr.jussieu.fr

Zooxanthellate Scleractinian corals have not to be regarded as separate mineral and organic units. In order to investigate interactions between photosynthesis and calcification, it is therefore necessary to study simultaneously organic and inorganic parts. Stable isotopic carbon ratio ($^{13}C/^{12}C$) has been chosen here to allow this concomittant study. This proxy has been measured in zooxanthellae, coral tissues and skeletons from 4 species corresponding to 3 genus of Scleractinian corals, adapted successively to different pCO_2 and light conditions. Stable isotopic composition ($\delta^{13}C$) variations versus light and CO_2 are similar for animal and zooxanthellae organic matter. The animal metabolism is therefore highly coupled to the photosynthetic activity of its symbionts. Organic matter and skeleton $\delta^{13}C$ variations are not correlated. This result suggests that carbon sources for photosynthesis and calcification have different origins and not a common one as previously supposed by the common carbon pool hypothesis. Whatever the genus considered, a light decrease implies an organic matter $\delta^{13}C$ depletion; the CO_2 influence is less obvious. The impact of calcification on the aragonite$\delta\delta^{13}C$ is highly species dependent. The light influence as well as the pCO_2 impact through photosynthesis and calcification on $^{13}C/^{12}C$ ratio is not straightforward.

THE EFFECT OF SYMBIOSIS ON SKELETAL CHEMISTRY OF HERMATYPIC CORALS: IMPLICATIONS FOR INTERPRETING CORAL CLIMATE RECORDS

Cohen A.L.*, Gladfelter, Elizabeth H. and Layne, Graham D.; Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA; Email: acohen@whoi.edu

The skeletal chemistry of massive hermatypic corals correlates with sea temperature and other environmental variables and is an important tool for reconstructing past climate change. However, our confidence in interpreting coral proxy data purely as a climate signal is limited by lack of knowledge of how biological processes, specifically algal photosynthesis, influence skeletal chemistry. We examined the link between photosynthesis and skeletal Sr/Ca (a temperature proxy) in a *Porites lutea* colony stained *in-situ* for age-control and for which we have contemporaneous, logged hourly SSTs. Examination of skeletal ultra-structure with SEM and in thin-section yielded two different crystal morphologies whose existence is likely connected with symbiont-induced diurnal changes in pH of the extra-cellular calcifying fluid, encouraging equant crystals to form at night and acicular crystals during the day. We constructed Sr/Ca time-series separately for each crystal type at daily resolution over a growth period of one year using SIMS[1] ion microprobe. Biweekly Sr/Ca cycles track tidally-induced, biweekly SST cycles but the sensitivity of Sr/Ca to SST is five times greater during the day than it is at night. Furthermore, the temperature-dependence of daytime Sr/Ca is non-linear over the annual cycle, changing between the winter and summer seasons. We propose that algal symbiosis exerts a significant influence on this important temperature proxy by enhancing skeletal calcification rate. However, since the relationship appears neither simple nor non-linear, accurate interpretation of coral-based climate records will depend on our recognition and understanding of this complex interaction.

DIFFERENT FORMS OF CELL DEATH ACTIVITY DURING BLEACHING OF THE SYMBIOTIC SEA ANEMONE *AIPTASIA* SP.

, Simon*, Dr.J.C.Bythell, Dr.M.D.A.Le Tissier and Dr.J.C.Thomason. *Department of Marine Sciences and Coastal management, University of Newcastle upon Tyne, UK. Email: S.R.DUNN@NCL.AC.UK

The mechanisms of cell death, degradation and loss of host tissues and symbionts during bleaching in symbiotic cnidarians has remained equivocal. There is little evidence to indicate whether host or symbiont is the first to show the affects of an environmental stress. A critical issue that remains is whether bleaching is the outcome of an adaptive stress response or simply the degenerative effects of environmental perturbation. In this study, cell death pathways were investigated in response to hyperthermic treatment which induced bleaching in the sea anemone *Aiptasia* sp.. Using a suite of techniques, different forms of cell death activity were indicated. After a treatment period of 3-4 days the host gastrodermis tissues underwent necrotic cell death releasing zooxanthellae with a normal, healthy appearance into the coelenteron. Longer periods of hyperthermic treatment (7 days) were correlated with the in-situ degradation of zooxanthellae remaining within the degenerated host gastrodermis. Zooxanthellae degradation was characterised by cell shrinkage, condensation of the cytoplasm, formation of accumulation bodies at the periphery of the cell wall and DNA fragmentation, which was indicative of a form of programmed cell death. The existence of a programmed cell death pathway within zooxanthellae is important to the understanding of bleaching events and raises interesting questions regarding the evolution of this process which has previously been linked mainly with multicellular organisms.

NOVEL STABLE ISOTOPE APPROACH TO STUDY CARBON AND OXYGEN CYCLING BETWEEN CORALS AND THEIR SYMBIOTIC ALGAE.

Erez, J.*, Schneider, K. and Luz, B.. *Institute of Earth Sciences, Hebrew University of Jerusalem, Israel, 91904. Email: Erez@vms.huji.ac.il

The metabolic fractionations of $^{13}C/^{12}C$ and $^{17}O/^{16}O$, and $^{18}O/^{16}O$ in dissolved inorganic carbon (C_T) and oxygen (O_2), respectively, were used to study their cycling in *Acropora sp.* from Eilat, Red Sea. The $\delta^{13}C$ of C_T taken-up during photosynthesis was very low (Av.= -8 ‰), and negatively correlated with $CO_{2(aq)}$. These very low fractionations correlate well with high calcification rates, suggesting that at low $CO_{2(aq)}$ and high pH, photosynthesis may be supported by ^{13}C enriched $CO_{2(aq)}$ produced from HCO_3^- which combines with protons generated by calcification. During respiration the $\delta^{13}C$ released is more negative (-16 to -18 ‰) indicating that roughly 50% of the respiratory carbon is of planktonic origin. $\delta^{13}C$ of isolated symbionts show average values of –14‰ suggesting that up to 60% of the CO_2 utilized by the symbionts may be of host respiratory origin. Oxygen produced during photosynthesis is depleted in ^{18}O relative to atmospheric dissolved O_2. This depletion (corrected for respiration based on ^{17}O) allows for direct estimate of gross photosynthesis (GP). GP of the symbiotic algae determined by this method, suggest that light respiration was roughly twice the dark respiration. In addition these data showed that during photosynthesis, significant amount of oxygen (and probably also carbon) must be cycled internally in accord with the carbon isotope data. Excess light respiration and $CO_{2(aq)}$ production rates from calcification match the internal recycling needed to explain the observed oxygen isotopic data.

ZOOXANTHELLAL RESPONSE OF *TRIDACNA GIGAS* MANTLE TO ELEVATED TEMPERATURES

Estacion, J. S. *, J. S. Lucas and J. H. Norton. *Silliman University Marine Laboratory, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

The response of zooxanthellae within the giant clam (*Tridacna gigas*) mantle to elevated temperatures (30-31°C) was investigated under the laboratory conditions using zooxanthellae density, chlorophyll a content per zooxanthella and histological appearance of the mantle. Results showed that mean zooxanthellae density increased with prolonged exposure to elevated water temperatures. After 21 days, density of clams in elevated water temperatures (1.41×10^7 cells/g fresh mantle) was almost ten times lower than the control clams (13.4×10^7 cells/g fresh mantle) but chrolophyll a per cell was significantly higher ($p < 0.05$) in the former. Histological examination confirmed the decrease in zooxanthellae density in the mantle. Compared to the controls, there was also an increase in the number of zooxanthellae that were transparent. These zooxanthellae seem to degenerating and losing their cytoplasm.

COMPARISONS OF TISSUE BIOMASS AND ZOOXANTHELLAE POPULATIONS OF FIVE REEF-BUILDING CORALS LIVING IN THE BAHAMAS AND ON THE FLORIDA REEF TRACT AND RELATIONSHIP TO BLEACHING.

Fitt*,W.K., M.E. Warner, G.C. Chilcoat. University of Georgia, Athens GA 30602 Email: fitt@sparrow.ecology.uga.edu

Tissue biomass and zooxanthellae densities of five species of Caribbean reef corals tend to decrease with depth and vary with season, with highest values occurring during the coolest season and the lowest at the end of the warmest season. Same species, same depth comparisons between sites in the Bahamas with those in the Florida Keys show that corals at the latter site exhibit physiological parameters indicative of corals that would normally live deeper on reefs compared to their Bahamian counterparts. We suggest that the data illustrate the importance of light penetration and influence of water quality on the physiology and health of reef corals.

HOST-MEDIATED CO_2 SUPPLY FOR ENDOSYMBIONT PHOTOSYNTHESIS IN SEA ANEMONE

Furla, Paola* & Denis Allemand *Observatoire Océanologique Européen, Centre Scientifique de Monaco, Avenue Saint-Martin, MC-98000 MONACO (Principality of Monaco) Email:: Denis.Allemand@unice.fr

Within symbiotic Cnidarians, respiratory CO_2 is not enough to supply photosynthesis of intracellular dinoflagellates, *Symbiodinium* sp. Furthermore it has been shown recently that the Rubisco of these Dinoflagellates is a form II which has previously been reported to have a relatively low discrimination ratio between CO_2 and O_2, raising the question of how zooxanthellae fix inorganic carbon so efficiently?

To determine the mechanism of inorganic carbon supply, we used isolated tentacles of the Mediterranean sea anemone, *Anemonia viridis*. We demonstrated that the major source of inorganic carbon is the HCO_3^- present in the external medium surrounding the animal. The absorption of HCO_3^- from the external seawater induces a polarization of the oral epithelium, revealed by the generation of a pH gradient between sea water and the coelenteric cavity of about 0.8 pH units. To further study this mechanism, we used plasma membrane vesicles of ectodermal cells from tentacles. We found that HCO_3^- uptake results from a H^+ secretion by an H^+-ATPase which, in addition to a membrane-bound carbonic anhydrase, induces the dehydration of HCO_3^- into CO_2.

THE GROWTH AND SURVIVORSHIP OF REEF-BUILDING CORALS EXPOSED TO ELEVATED NUTRIENTS IN A LONG-TERM MANIPULATIVE FIELD STUDY.

Hoegh-Guldberg Ove*, *Centre For Marine Studies, University Of Queensland, StLucia, 4072. Qld, Australia. Email: oveh@uq.edu.au <mailto:oveh@uq.edu.au>

Two species of reef-building corals (pocillopora damicornis and acropora longicyathus) were exposed to increased concentrations of inorganic n (ammonium, nh4cl) and p (phosphate, nah2po4) in naturally ponding micro-atolls for 9 months as part of the encore (enrichment of nutrient on coral reefs) project at one tree island reef (southern great barrier reef). Growth rates were reduced to 57.7% and 71.1% of control rates in two morphotypes ("pink" and "brown" respectively) of p. Damicornis ($p < 0.05$) when exposed to elevated ammonium concentrations for 9 months. Adding phosphate resulted in similar yet not statistically significant ($p > 0.05$) trends and treatment with both ammonium and phosphate resulted in the lowest growth rates (59.4% and 75.7% of control growth rates) for the brown and pink morphotypes respectively. Rates of mortality in ammonium treated microatolls were 271% and 211% of control rates for pink and brown morphotypes respectively ($p = 0.0077$) and were highest in microatolls receiving both ammonium and phosphate. Similar though not statistically significant trends ($p > 0.05$) were seen with a. Longicyathus. The differences between the two species seen in the present study highlight the importance of multi-species studies. The results of this study also demonstrate experimentally (and for the first time) that increased concentrations of ammonium and phosphate under field conditions over ecologically relevant time scales can specifically decrease the growth and survivorship of reef-building coral associations.

EARLY DEVELOPMENT OF ZOOXANTHELLA-CONTAINING EGGS OF SCLERACTINIAN CORALS: DOES THE PRESENCE OF ZOOXANTHELLAE AFFECT THE DEVELOPMENT?

Hirose, M.* and M. Hidaka. Dept. of Chemistry, Biology and Marine Science, Univ. of the Ryukyus, Nishihara, Okinawa, 903-0213 Japan. Email: k988551@sci.u-ryukyu.ac.jp

Early development of zooxanthella-containing eggs of scleractinian corals was studied to understand how the presence of zooxanthellae influences early development of corals and how zooxanthellae become restricted to the gastrodermis of planulae during the course of development. Zooxanthellae distributed mainly in a hemisphere of spawned eggs of *Pocillopora verrucosa* and *P. eydouxi*. The first cleavage furrow started at the hemisphere that was rich in zooxanthellae, dividing the zooxanthellae almost equally into two blastomeres. The second cleavage divided the blastomere into a zooxanthella-rich blastomere and a blastomere with few zooxanthellae. The uneven distribution of zooxanthellae persisted until the zygotes developed into gastrulae. If blastomeres were isolated by pipetting at two- or four-cell stages, the next cleavage started at the zooxanthella-rich hemisphere as in the first normal cleavage, dividing the zooxanthellae almost equally. Blastomeres isolated even at 8-cell stage could develop into planulae suggesting that eggs of the corals underwent indeterminate cleavage.

THE FUTURE OF CORAL REEFS: INTEGRATING CLIMATE MODEL PROJECTIONS AND THE RECENT BEHAVIOUR OF CORALS AND THEIR DINOFLAGELLATES.

Hoegh-Guldberg, Ove*, *Centre for Marine Studies, University of Queensland, St Lucia, 4072. QLD, Australia. Email: oveh@uq.edu.au

Concern is increasing as to how coral reefs will fare under climate change. All major climate models concur that current rates of temperature change in the world's oceans (1-2°C per century) will continue over the next 100 years if atmospheric greenhouse gases increase. This scenario, together with the explicit link between coral bleaching, mortality and sea temperature, leads to the prediction that coral bleaching is likely to become an annual feature of coral reef environments in the 21st century. This paper reviews the rationale behind these predictions and explores how coral reefs might respond to an increased frequency and intensity of coral bleaching. While some workers suggest that corals-dinoflagellates will adapt fast enough to the changes in sea temperature, the data to support these opinions is scant or non-existent. Most evidence suggests that corals and their symbiotic dinoflagellates will not change fast enough to prevent major changes in coral reef ecosystem distribution and function. Simple ecological surveys done after a bleaching event reveal little about the long-term decadal trends and may even serve to confuse managers and policy makers who seek guidance in this important debate. Two issues are central to a better understanding of how reefs will respond to climate change. These are: (a) the rates of genetic change (adaptation) under extreme selection regimes and (b) the source of genetic variability on coral reefs. The latter also suggests that a greater knowledge of gene flow and connectivity between reefs is crucial. Work on these issues is surprisingly limited and must be a priority over the next few years.

PHOSPHORUS UPTAKE & ALLOCATION IN *AIPTASIA PALLIDA*.

Kelty, R.*, Lipschultz. National Oceanographic & Atmospheric Administration, National Centers for Coastal Ocean Science, 1305 East-West Highway SSMC4, Rm. 9224, Silver Spring, MD 20910. Email: ruth.kelty@noaa.gov

The physiology of phosphorus uptake and incorporation by the anemone *Aiptasia pallida* was investigated by using radiolabeled orthophosphate to trace the movement of phosphate from seawater into the symbiotic associate and then its redistribution within the anemone. The animal host is capable of both actively transporting and assimilating phosphate. In symbiotic anemones and corals, zooxanthellae typically provide the energy for phosphate transport, and uptake by symbiotic anemones is light enhanced. Regardless of its source, the oxidation of carbon and concurrent phosphorylation of ADP provide the ATP to drive active phosphate uptake by the animal. Once phosphate is transported across the plasma membrane, it is immediately incorporated into ATP and other metabolic intermediates, then slowly assimilated into macromolecular compounds. The algae compete with the animal for phosphate in the host cytoplasm and can also assimilate organic phosphorus compounds, including phosphorus released by the host. No evidence was found for phosphate recycling between the host and algae, but there is a unidirectional flow of phosphate from the animal to the algae. Furthermore, release of newly incorporated phosphate into the incubation water suggests that phosphorus is not tightly recycled.

THE MORPHOLOGY, BIOCHEMISTRY, PHYSIOLOGY AND GENETICS OF *SYMBIODINIUM*: A REVIEW AND SYNTHESIS OF CHARACTERIZATIONS MADE ON CULTURED SYMBIOTIC DINOFLAGELLATES.

LaJeunesse, Todd C.* and Robert K. Trench. Department of Ecology, Evolution and Marine Biology University of California Santa Barbara, CA 93106 Email: lajeunes@lifesci.ucsb.edu

The symbiosis between dinoflagellates of the genus *Symbiodinium* and numerous carbonate-producing invertebrates is unarguably the most important ecological interaction on present day coral reefs. Our knowledge of these endosymbiotic algae has improved remarkably since culturing techniques were developed to permit the isolation and manipulation of symbionts outside the host and to conduct comparative studies to distinguish attributes that are inherently genetic and those which are affected by growth under different environmental conditions. Over the last 25 years, examinations of morphology, biochemistry, physiology and genetics have identified high diversity among cultured isolates. However, most of these studies were conducted without knowledge of phylogenetic relatedness and thus prevented genealogical comparisons. The genetic analysis on those same isolates is now complete. We present a review of the various biological attributes measured and arrange this information in a phylogenetic context to determine how distinct lineages correlate with function. For certain attributes, genetic differences correlate with differences in morphology, physiology and biochemistry, while for other characters they do not.

SOURCES OF CAROTENOIDS IN THE ANEMONE, *Aiptasia pallida*, AND THEIR ROLE IN ULTRAVIOLET RADIATION PHOTOPROTECTION.

Mobley, K.B.* and D.F. Gleason. Georgia Southern University, Department of Biology, Statesboro, GA 30460-8042, USA. Email: kenyon_b_mobley@gasou.edu.

Using the common Caribbean anemone, *Aiptasia pallida*, as a model for coral/algal symbiosis, laboratory experiments were conducted to investigate the following: 1) the effects of enhanced ultraviolet radiation (UVR), zooxanthellae density and heterotrophic feeding (*Artemia* sp.) on carotenoid composition and concentration and 2) the role of carotenoid pigmentation in UVR photoprotection. Fed and unfed, zooxanthellate and apozooxanthellate *A. pallida* were exposed to the following light treatments: UVR (290 - 400nm) and PAR (Photosynthetically Active Radiation 400-700nm); PAR only; and no light. Chlorophyll *a* and *c*, as well as the carotenoids β-carotene, peridinin, diatoxanthin and diadinoxanthin, were analyzed by HPLC from anemone tissue collected during the course of the 40-day experiment. After a 14 day exposure to UVR, significant decreases in chlorophyll *a*, *c* and peridinin were observed in the UVR/ zooxanthellate/ unfed treatment. However there was no significant decrease in the diadinoxanthin/ diatoxanthin pool indicating the presence of the photoprotective xanthophyll cycle. This cycle is hypothesized to protect the light harvesting photosynthetic apparatus from excess excitation energy via non-photochemical quenching suggesting a primary role for carotenoids in UVR photoprotection in this species.

COMPARISON OF THE PHOTOSYNTHETIC FEATURES OF ZOOXANTHELLAE EXPELLED AND RETAINED BY STRESSED CORALS.

Muller-Parker, Gisele *. *Dept. of Biology & Shannon Point Marine Center, Western Washington University, Bellingham, WA 98225-9160, USA. Email: gisele@biol.wwu.edu

The SEARUN project team compared the photosynthetic parameters of expelled zooxanthellae with those retained by the host coral *Montastraea faveolata* after exposure to elevated (+2°C) temperature and enhanced PAR and UV-B irradiance. Zooxanthellae were obtained from coral plugs collected near Lee Stocking Island in the Bahamas (15 m depth; July 1998 and 1999) and subjected to different experimental treatments, including seawater ammonium enrichment (2 or 10 uM). Photosynthesis-irradiance curves were used to derive photosynthetic capacity (Pmax) and photosynthetic efficiency (alpha) of zooxanthellae. Photosynthetic parameters indicate that zooxanthellae in the host are protected from moderate UV-B stress and do not respond to increased seawater ammonium availability. In contrast, expelled zooxanthellae are damaged by UV-B exposure and utilize ammonium enrichments to increase both alpha and Pmax. Increased temperature decreases Pmax and alpha of both populations of zooxanthellae; detrimental effects are more pronounced under high PAR and UV-B. Our results show that the host provides adequate photoprotection for resident zooxanthellae under normal seawater temperatures. Although expelled zooxanthellae lose this advantage, they gain the ability to utilize seawater nutrient enrichments. However, there is no escape from high temperature; Pmax and alpha of both populations of zooxanthellae are reduced upon exposure to +2°C.

LIGHT UTILIZATION AND PHOTOSYNTHESIS IN *PORITES BRANERII.*

Pérez-Vivar, T.L., S, Enríquez, R Iglesias-Prieto*. Unidad Académica Puerto Morelos ICML-UNAM Apartado Postal 1152, Cancún Q.R. 77500 México. Email: iglesias@mar.icmyl.unam.mx

The spectroscopic characteristics and photosynthetic responses of the Caribbean stony coral *Porites branerii* were analyzed. Comparison of the absorption spectra of small fragments of *P. branerii* with those obtained from the freshly isolated symbiotic algae allowed us to quantify the effect of multiple scattering by the coral skeleton on the chlorophyll *a* specific absorption coefficient. Absorption spectra of colonies obtained during a natural bleaching event indicate the presence of a non-linear behavior of the coral absorptance (percentage of light absorbed) as a function of chlorophyll content. At high pigment concentrations, a two fold reduction in chlorophyll resulted in minor variations in absorptance, whereas at low pigment concentrations similar reductions in chlorophyll content resulted in dramatic reductions in the absorptance of the coral. Simultaneous determinations of photosynthetic activity by polarographic and pulse amplitude chlorophyll *a* fluorescence techniques indicate that oxygen evolution and electron transport rates measurements show a linear behavior at sub-saturating irradiances, but at high irradiances there is disproportional increase in the electron transport rate relative to oxygen evolution. Employing the spectroscopic data in conjunction with *in situ* modulated pulse amplitude fluorescence determinations we followed, the diurnal variations in the photosynthetic activity of a naturally occurring colony of *P. branerii*.

SYMBIOSIS GENES IN CNIDARIAN-ALGAL ASSOCIATIONS: A HOST GENE, SYM32, ENCODES A CELL ADHESION PROTEIN THAT IS UPREGULATED AS A FUNCTION OF SYMBIOSIS

Schwarz, J.A. * and Weis, V.M.. *Department of Zoology, Oregon State University, Corvallis, OR, 97331, USA. schwarzj@bcc.orst.edu

The symbiotic association between cnidarians and dinoflagellates is ultimately regulated by the interacting genomes of the partners. By identifying cnidarian genes that are expressed as a function of symbiotic state, we are beginning to gain insights into how these partnerships are regulated. Comparative protein profiles of the sea anemone *Anthopleura elegantissima* reveal that symbiotic individuals produce a variety of proteins that are absent, or nearly so, in individuals that lack symbiotic algae (=aposymbiotic). The most abundantly produced of these symbiosis proteins is a 32kD protein, sym32. Characterization of the cDNA sequence suggests that this protein is a member of the Fas I family of cell adhesion proteins, and possibly plays a role in cell signaling. This gene is not specific to *A. elegantissima*; it also exists in other symbiotic cnidarians that we have examined, a scleractinian coral, an octocoral, and a jellyfish. Immunolocalization studies in *A. elegantissima* have revealed 1) that the sym32 protein is not restricted to host cells which contain algae (ie., both endoderm and ectoderm contain sym32) and 2) that symbiotic individuals upregulate sym32 synthesis in both alga-containing and alga-free tissues. Sym32 levels are related to symbiont abundance; as the population of algae increases, so do levels of sym32 in host tissues. In the coral *Fungia scutaria*, the sym32 gene begins to be expressed during embryonic development, prior to the host acquiring algae, suggesting that this protein functions in early development as well as in the symbiosis with algae.

THE ROLE OF CARBON IN RELATIONSHIP BETWEEN ZOOXANTHELLAE AND CORALS ,

Stambler, Noga*, *Faculty of Life Sciences, Bar-Ilan University. Ramat Gan 52900, Israel. Email: Stambln@mail.biu.ac.il

The population density of zooxanthellae is controlled by nitrogen and carbon limitation. The coral host keeps the algal growth rates far below their potential maximum. Under increasing densities of algae, like those obtained as a result of nutrient enrichment, the algae may become CO_2 limited, and may even compete with the animal for carbon for calcification. Photosynthetic rates, on a per cell basis, were inversely correlated with algal densities, indicating possible competition among the algae for CO_2. The relation between CO_2 and Ca^{2+} exchange and photosynthesis by corals was studied with microelectrodes for Ca^{2+}, O_2, pH and CO_2. It seems that Ca^{2+} uptake is directly regulated by photosynthesis.

HOMOGENIZED TISSUE FROM APOSYMBIOTIC *Plesiastrea versipora* STIMULATES THE RELEASE OF ALGAL PHOTOSYNTHATE.

Starke-Peterkovic, T.*, A.J. Grant and R. Hinde. *School of Biological Sciences, University of Sydney, Sydney, Australia, 2006 Email: tomo77@hotmail.com

Stimulation of photosynthate release from isolated symbiotic algae (zooxanthellae) is believed to be due to the activity of a compound present in host homogenate referred to as host release factor (HRF). It has been proposed that HRF is only present in tissues from symbiotic animals. However, we observed HRF activity in two rare, naturally aposymbiotic samples of the temperate coral *Plesiastrea versipora* collected in 1992 and in 1994. To confirm these findings, aposymbiotic corals were produced by chilling at 4°C for 4 h in the dark then maintaining them in seawater in the dark at 20°C. After twelve weeks all algae had been expelled and corals were then fed fortnightly with fish food (Liquifry, diluted 2 x 10^{-7}) and used in experiments 8-11 weeks later. Homogenized tissue from aposymbiotic corals was incubated with freshly isolated algae from symbiotic corals for 2 h in the light. In three experiments, release of algal photosynthate was stimulated up to four fold by incubation in host homogenate (from symbiotic corals) and up to three fold by incubation in aposymbiotic homogenate when compared with algae incubated in seawater. Range expressed as nmol carbon released/10^5cells: 1.15 $\pm$ 0.09 to 1.6 $\pm$ 0.16 in seawater; 2.91 $\pm$ 0.14 to 6.19 $\pm$ 0.048 in host homogenate; 2.48 $\pm$ 0.16 to 5.29 $\pm$ 0.57 in aposymbiotic homogenate (mean $\pm$ SD, n = 3 or 4). These results using aposymbiotic corals suggest that HRF is constitutively produced by *P. versipora*.

CARBON ISOTOPIC RECORDS IN CORAL SKELETONS: WHAT DO THEY MEAN?

Swart*, P.K., *Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami Fl 33149 Email: Pswart@srmas.miami.edu

There have been numerous attempts to understand the meaning of carbon isotopic variation in zooxanthellate and non-zooxanthellate coral skeletons. The model that is currently acclaimed is that the carbon isotopic composition is a function of the amount of insolation, with more positive _^{13}C values occurring during periods of higher light intensity. We present data on temporal and spatial variation in the carbon isotopic composition of the zooxanthellae and coral tissue, which casts further information on the cycling of carbon in zooxanthellate corals. Our data, collected from *Montastraea faveolata* growing on the Florida reef tract over a period of two years, indicates a cycling in the carbon isotopic composition of the coral tissue over approximately 2 per mille and a variation of the difference between the carbon isotopic composition of the zooxanthellae and the coral tissue. Although these difference can be explained in a number of different ways, but one possible explanation is that during the summer (periods of high light intensity and long photoperiod), the corals are CO_2 limited causing a reduction in the amount of fractionation between the CO_2 and the photosynthethate. Other explanations involve seasonal change in the amount of heterotrophy and autotrophy, changes in the isotopic composition of the DIC, changes in the isotopic composition of the food source, or changes in amount of lipids in the organism.

VISUALIZATION AND ISOLATION OF THE CNIDARIAN SYMBIOSOME.

Trautman, Donelle* and Hinde, Rosalind. *School of Biological Sciences, University of Sydney, NSW 2006, Australia Email: rhinde@bio.usyd.edu.au

In cnidarian-algal symbioses, the alga is surrounded by a host-derived membrane which forms a symbiosome. This symbiosome membrane may have important roles in the physiology of the symbiosis, but until now its roles have not been investigated because it could only be seen using electron microscopy. We have developed a simple method to extract intact gastrodermal cells containing symbiotic algae, from the anthozoan *Zoanthus robustus*, and to visualize the symbiosome membrane using fluorescence microscopy. Large numbers of motile gastrodermal cells were squeezed out through a small slit made in the side of the zoanthid. The fluorescent probe MDY-64 (yeast vacuole membrane marker) was used to visualize the symbiosome membrane, and amino-chloromethyl-coumarin was used to stain the cytoplasm of the host cell. Intact symbiosomes, containing algae, were obtained by 'shearing' off the host plasma membrane and cytoplasm by dragging a suspension of the host cells through a needle and syringe. Clean algal cells were obtained by further use of the same method. Neither cleaned algae nor cultured algae showed any trace of staining by MDY-64. These fluorescent probes were also used successfully on host cells and symbionts from the coral *Plesiastrea versipora* and the anemone *Aiptasia pulchella*.

FISHING FOR SYMBIOSIS GENES IN CNIDARIAN-ALGAL MUTUALISMS.

Weis, Virginia M.*. *Department of Zoology, Oregon State University, Corvallis, OR, 97333, USA. Email: weisv@bcc.orst.edu

Mutualistic symbioses between cnidarians and their dinoflagellate symbionts form both the trophic and structural foundation of coral reef ecosystems. Despite the profound ecological significance of these symbioses, there have been few studies that examine the underlying genetic interactions between the animal host and algal symbiont. Genes and gene products governing the onset, regulation, and maintenance of these symbioses remain largely undescribed. We have been investigating the molecular interactions that drive cnidarian-algal symbioses in two associations; the temperate sea anemone *Anthopleura elegantissima* and its dinoflagellate *Symbiodinium californium*, and the tropical scleractinian *Fungia scutaria* and its symbiont *Symbiodinium* spp. We have identified several genes in *A. elegantissima* that are expressed specifically as a function of the symbiotic state. These include 1) carbonic anhydrase, known to be important in inorganic carbon transport, 2) sym32, a member of the fasciclin I family of cell adhesion proteins, 3) glyceraldehyde-3-phosphate dehydrogenase, a glycolytic and Calvin cycle enzyme and 4) a homologue to a calmodulin-binding protein. In addition to investigating the roles of these "symbiosis genes" in the regulation of the symbiosis, we are examining when these genes are first expressed during symbiosis onset in the larval stage of *F. scutaria*. In this way, we seek to identify the initial cascade of events surrounding symbiosis onset in cnidarians and their symbiotic algae.

PHOTOINHIBITION IN CORALS: IN THE EYE OF THE BEHOLDER?

Winters, G.*, Y. Loya and S. Beer. *Department of Plant Sciences and Tel Aviv University, Tel Aviv 69978, Israel. Email: gidw@post.tau.ac.il

The methods used to investigate light responses of zooxanthellae, and the different definitions of photoinhibition, make it unclear whether this phenomenon is common in shallow water corals. We used an underwater pulse amplitude modulated (PAM) fluorometer (Diving-PAM) to investigate the occurrence of photoinhibition in two Red Sea corals. *In situ* photosynthesis rates were measured under ambient light at half hourly intervals during 24hrs for *Stylophora pistillata* (2.15m) and *Favia favus* (1.9m) using PAM fluorescence point measurements. Measurements show diurnal variations in the relative electron transport rates (ETRs), but no decreases in ETRs as a result of high ambient irradiances were found. Optimal quantum yields of PSII (variable fluorescence, Fv, divided by maximal fluorescence, Fm) were measured for *S. pistillata* using *in situ* dark-adaptation, at different times of the day. After 30-60 min dark-adaptation, optimal yields did not change throughout the day. Thus, neither a decrease in Fv/Fm, nor in photosynthetic ETRs was detected during maximal natural mid-day irradiances on cloudless days and in clear shallow waters. "Photoinhibition" (defined as a decrease in photosynthetic rates at high irradiances) could be detected only under unnaturally high irradiances caused by the Diving-PAM's halogen light source during the generation of "rapid light curves". These results do not support the notion of photoinhibition in corals under natural high light conditions. Because of the variety of definitions of photoinhibition, we conclude that the presence of this phenomenon in corals is largely "in the eye of the beholder".

ALGAL ACQUISITION BY SEXUAL OFFSPRING OF A SOFT CORAL: DYNAMICS AND TEMPORAL ASPECTS.

Yacobovitch T.* Benayahu Y. and Weis V. *Department of Zoology, Tel-Aviv University, Tel-Aviv, Israel; Department of Zoology, Oregon State University, OR 97331, USA. Email: taliya@post.tau.ac.il

Acquisition of symbiotic algae (zooxanthellae) from the ambient environment by cnidarian sexual offspring occurs in both scleractinians and octocorals, and is far more common than maternal inheritance. We have been examining symbiosis onset in the soft coral *Heteroxenia fuscescens* which acquires its symbionts from the seawater as an aposymbiotic primary polyps. Freshly isolated algae, added to laboratory grown primary polyps, were seen swimming toward the polyp mouth opening and after 4-12 hours, symbionts were present in the primary polyps. Seven-day-old polyps contained an average of 45±18 algal cells (n=10), increasing in 60-day-old animals to 2128±713 cells (n=10). The location of the symbionts changed with time. Whereas in three-day-old polyps, symbionts were limited to the tentacle gastrodermis, in 7-day-old animals, symbionts were also present in the upper portions of the stalk, and in 30-day-old polyps, symbionts were present throughout the host gastrodermis. Our findings indicate that primary polyps are capable of acquiring symbiotic algae over a 2-3 month period. Finally, in the laboratory, algal swarmers had a diurnal rhythmic motility induced by light. This activity peaked once a day during the morning for 2-3 hours, when the swarmers aggregated in large numbers around the polyp mouth.

THE ACQUISITION AND FIXATION OF INORGANIC CARBON BY THE *TRIDACNA GIGAS* - *SYMBIODINIUM* SP. SYMBIOSIS.

Yellowlees, D.*, Leggat, W.. *Biochemistry and Molecular Biology, James Cook University, Townsville, Queensland, Australia 4811. Email: david.yellowlees@jcu.edu.au

The supply of inorganic carbon (C_i) to zooxanthellae is an essential component in the symbiotic relationship of *Tridacna gigas*. It is required for photosynthetic CO_2-fixation by the dinoflagellates, a process which is intimately coupled to light harvesting in all photosynthetic organisms. In symbioses such as the giant clam and corals, the C_i is sourced from both host respiration and sea water. The host supply system must meet zooxanthellae demands otherwise the algae will be carbon-limited and photosynthesis cannot operate at peak efficiency. To source C_i from sea water, uptake into the haemolymph of giant clams must occur through the gills before being made available to the zooxanthellae in the Z-tubules of the host mantle. This C_i gradient is contrary to most other marine organisms where C_i is removed through the gills. The C_i supply system in clams involves at least two carbonic anhydrase isoforms which occur in both the gills and mantle. These facilitate the movement of CO_2 through the host tissue. The zooxanthellae in turn possess an external carbonic anhydrase and possibly a bicarbonate transporter to aid uptake into the algae. However the kinetic properties of the Form II Rubisco found in zooxanthellae requires the presence of a CO_2-concentrating mechanism in the chloroplast to ensure productive carbon fixation and the resulting export of photosynthate (glucose) to the host for respiratory purposes.

UV-RESISTANCE MECHANISMS OF A SOFT CORAL AND THE INVOLVEMENT OF THEIR SYMBIOTIC ZOOXANTHELLAE.

Zeevi Ben-Yosef D.*, Y. Kashman, Y. Benayahu. *Department of Zoology, Goerge S. Wise, Faculty of Life Sciences, Tel Aviv University, Tel-Aviv 69978, Israel. Email: dafnaz@post.tau.ac.il

Along with photosynthetically active radiation that zooxanthellate corals require for photosynthesis, they are also exposed to damaging ultraviolet radiation (UVR). UV absorbing compounds (MAAs) provides the most important resistance mechanism against UVR in the marine environment. We studied the resistance of the Red Sea soft coral *Heteroxenia fuscescens* to UVR in course of its life cycle. The dominant MAA compound was found to be palythine, whose concentration declined with depth. Batches of azooxanthellate planulae obtained from 2-3 and 18-20 m were exposed to controlled radiation levels, corresponding to the ambient ones. Planulae derived from both depths had LD_{50} values of 41-60 cumulative hours of UVR exposure. Azooxanthellate primary polyps from the same depths showed LD_{50} values of 30-94 hrs. Zooxanthellate primary polyps derived from shallow and deep colonies had LD_{50} in the range of 136-210 hrs. Yet, it seems that the LD_{50} values depend on seawater temperature. Zooxanthellate polyps that were incubated with glyphosate, an inhibitor of MAAs biosynthesis, yield LD_{50} of 76 hrs, a value 2.5 times lowers than without its presence. Survivorship rates of planulae, azoo- and zooxanthellate primary polyps, and polyps incubated with or without glyphosate corresponded with their respective MAAs levels. Our findings indicate that the resistance to UVR is already acquired during early onthogenesis of a coral through MAAs, whose presence is related to the symbiotic state.

Session A5: Biodiversity and Biogeography of Zooxanthellae in Coral-Algal Symbiosis

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THE RELATIONSHIP BETWEEN MORPHOLOGY AND MOLECULAR VARIATION OF ZOOXANTHELLAE FROM TEMPERATE AUSTRALIAN REEFS.

Aisyah E.N *, Hoegh-Guldberg, O.; Hinde, R.; and Loh, W. *School of Biological Sciences, Zoology Building AO8, The University of Sydney, NSW 2006, Australia. Email: eaisyah@mail.bio.usyd.edu.au

Until recently, the majority of zooxanthellae have been ascribed to a single species, Symbiodinium microadriaticum. Genetic analysis of zooxanthellae from a diversity of host species has revealed that these symbionts potentially belong to hundreds of host specific species. This study investigated the morphological correlates of zooxanthellae from marine invertebrates growing on temperate reefs at the southern end of the Great Barrier Reef and Sydney Harbour. The results indicate that the molecular differences (18S, 28S rDNA, RFLP and sequence analysis) between zooxanthel-lae track differences in morphology (TEM and confocal mi-croscopy). Our results show that the soft coral Capnella gaboensis from Sydney contain clade C. Zooxanthellae from other marine invertebrates (clam Tridacna maxima; corals Acropora longicyathus, Heliofungia actiniformis and Stylophora pistillata; and zoanthid Palythoa caesia) taken from The Great Barrier Reef belong to clade C. Zooxanthellae from zoanthid Zoanthus robustus do not belong to either clade A, B nor C. The significance of these results to the diversity of zooxanthellae in the Pacific will be discussed.

ECOLOGICAL, BIOGEOGRAPHIC AND HOST-SYSTEMATIC PATTERNS OF SYMBIONT DIVERSITY AMONG REEF-BUILDING CORALS.

Baker A.C.*. *Wildlife Conservation Society, Osborn Laboratories of Marine Science, New York Aquarium, Boardwalk at West 8th St., Brooklyn, New York 11224, USA. Email: abaker@wcs.org

The diversity of symbiotic dinoflagellates ("zooxanthellae") in reef corals was surveyed using Restriction Fragment Length Polymorphisms (RFLPs) in large subunit ribosomal rRNA genes. In total >800 samples from >110 species of reef coral from the western Atlantic (Bahamas, Panamá), eastern Pacific (Panamá, Galápagos, Mexico) and Indo-west Pacific (Australia) were surveyed. These methods, combined with molecular sequencing of large subunit rDNA, distinguished 17-19 symbiont genotypes in four clades of *Symbiodinium* (*A, B, C* and *D*). The distribution of these genotypes showed strong ecological, biogeographic and host-systematic patterns. Many (>35%) of the >100 scleractinian coral species surveyed contained multiple symbiont genotypes (sometimes in single coral colonies) which often showed light-related patterns of zonation, both among colonies at different depths and within colonies across sunlit and shaded surfaces. Given the extremely conservative nature of: (1) the molecular methods, (2) the per-species number of samples, and (3) the number of sites visited, it is clear that inter- and intraspecific symbiont diversity is a common feature of reef-building coral biology with strong ecological and biogeographic implications. This conclusion argues for an explicit recognition of symbiont diversity in future studies of reef-building corals.

BLEACHING OF REEF CORALS PROMOTES RAPID RESPONSE TO ENVIRONMENTAL CHANGE.

Baker A.C.*. *Wildlife Conservation Society, Osborn Laboratories of Marine Science, New York Aquarium, Boardwalk at West 8th St., Brooklyn, New York 11224, USA. Email: abaker@wcs.org

The loss of zooxanthellae during bleaching is conventionally viewed as a pathological stress response of universal detriment to reef-building corals. However, because scleractinian corals are known to host multiple taxa of algal symbionts (whose distributions within host species often show strong patterns of ecological zonation), it has been suggested that bleaching may provide an opportunity for invertebrate hosts to recombine with different symbiont taxa that are better suited to the (changed) environment. This hypothesis was tested in eight species of Caribbean scleractinian coral using controlled reciprocal depth transplantation experiments. Results demonstrated that severe bleaching caused by transplanting corals from deep (20-23m) to shallow (2-5m) sites facilitated rapid adaptive change in symbiont communities by first removing existing symbionts. In contrast, transplants from shallow to deep sites, resulted in little or no bleaching, and did not lead to symbiont community change. The persistence of suboptimal host-symbiont combinations ("shallow" symbionts in the transplanted corals at the deep site) resulted in higher coral mortality after a one-year period. These data represent the first empirical findings supporting the "adaptive bleaching" hypothesis. They challenge the view that bleaching is universally detrimental, and demonstrate that bleaching may allow reef coral symbioses to respond more rapidly to environmental change.

SEASONAL POPULATION DYNAMICS OF ALGAL SYMBIONTS OF ACROPORIDS AND TRIDACNIDS IN AN OKINAWA REEF.

Belda-Baillie C.A*, Baillie, B.K.; Shimoike, K.; Maruyama, T. *Marine Biotechnology Institute Co., Ltd., Kamaishi Laboratories, Heita, Kamaishi City, Iwate 026-0001, Japan. Email: carmen.baillie@kamaishi.mbio.co.jp

Acroporids and tridacnids are common components of Akajima reef in Okinawa, Japan, where extensive bleaching and death of corals were recorded in 1998 in association with anomalously-high summer temperatures. To evaluate the dynamics and possible role of symbiotic dinoflagellates in the susceptibility of symbiotic reef organisms to bleaching, the dinoflagellate symbionts of the stony coral *Acropora digitifera* and the tridacnid clam *Tridacna* in Akajima reef were monitored over four seasons of 1999. *A. digitifera* and *Tridacna* were found to host at least 2 genetically-diverse populations of the dinoflagellate *Symbiodinium*, based on denaturing-gradient gel electrophoresis and sequence comparison of the hypervariable region of the algae's 18S rRNA gene. Measurement of the symbionts' Chl *a* content and density from replicate coral colonies and clams in replicate plots and weeks of sampling showed no significant seasonal bleaching and differences in algal growth. Initial assessment of the mixed algal populations of *A. digitifera* and *Tridacna* showed general consistency over the different seasons. The year 1999 was a typical year with no anomalous temperature changes on the reef, based on the daily temperature record of the Akajima Marine Science Laboratory. These findings suggest that no significant seasonal bleaching and algal population shifts occur in some acroporids and tridacnids during a typical year with respect to temperature. This constitutes important baseline information on algal population dynamics in reef invertebrates.

DIVERSITY OF ZOOXANTHELLAE IN A HOST INDIVIDUAL.

Carlos A.A.*, Baillie, Brett K. and Maruyama, Tadashi. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines. Email: binoy@msi01.cs.upd.edu.ph

The traditional view of zooxanthella-invertebrate symbioses suggests that individual hosts harbor taxonomically homogeneous symbiont populations. To assess the diversity of the zooxanthella assemblage inhabiting an individual host, zooxanthellae from 6 species of clam (*Tridacna gigas*, *T. squamosa*, *T. crocea*, *Hippopus hippopus*, *H. porcellanus*, and *Corculum cardissa*) and 1 species of sea anemone (*Aiptasia* sp.) were studied using temperature-gradient gel electrophoresis (TGGE), coupled with polymerase chain reaction (PCR) using zooxanthella-specific primers that were designed to target hypervariable regions of the small subunit ribosomal RNA (ssrRNA) gene. Results revealed that a clam may harbor 2 or more genotypically-distinct zooxanthellae, with 1 to 2 dominant taxa occurring at a time. The clams studied associated with at least 4 zooxanthella taxa. Nucleotide sequencing of the TGGE bands and phylogenetic reconstruction revealed that the zooxanthella taxa in clams were *Symbiodinium* spp.; 1 was identical to previously-cultured clam symbiont isolates, 1 appeared identical to a previously-studied unculturable clam symbiont, and the other 2 represented novel strains of *Symbiodinium*. Individual *Aiptasia* sp. harbored only 1 zooxanthella taxon, which had a ssrRNA sequence identical to that of *S. pulchrorum*, previously isolated from *Aiptasia pulchella*. This study has shown that individual tridacnid and cardiid clams can harbor heterogeneous zooxanthellae.

IS ZOOXANTHELLA DIVERSITY IN NEWLY SETTLED OCTOCORALS HABITAT SPECIFIC?

Coffroth M.A.*. *University at Buffalo, Department of Biological Sciences, Buffalo NY 14260, USA. Email: coffroth@acsu.buffalo.edu

The growing awareness of the diversity of zooxanthellae and the increasing incidence of coral bleaching events has focused attention on the nature and variability of naturally occurring host-symbiont dynamics. In octocorals such as *Briareum polyanthes* and *Plexaura kuna*, planulae initially lack zooxanthellae and acquire algae upon metamorphosis. Adults of these species harbor zooxanthellae belonging to *Symbiodinium* clade *B* over a range of habitats and depth, suggesting a stable symbiosis. Initial acquisition in new recruits involves zooxanthellae belonging to multiple clades that vary with habitat. Newly settled polyps placed at inshore sites initially acquired zooxanthellae in *Symbiodinium* clade *A*, while polyps from the same cohort acquired zooxanthellae principally in *Symbiodinium* clade *B* when place at offshore and forereef sites. The cladal composition within the newly settled polyp changed over time and after 3-6 months the majority of polyps harbored zooxanthellae of the same clade as those found in adult hosts, regardless of site. In early ontogeny the host-symbiont interaction appears to be more plastic than in the adults, which harbor zooxanthellae in *Symbiodinium* clade *B* throughout the species range. This flexibility may be driven by either local algal abundance or selection for the zooxanthella taxon best adapted for that environment. Why the initial colonists are eventually replaced remains to be determined.

ZOOXANTHELLAE DIVERSITY WITHIN THE CORAL GENUS *MADRACIS*.

Diekmann O.E.*, Tonk, Linda; Bak, Rolf P. M.; Olsen, Jeanine L. *University of Groningen, PObox 14, 9750 AA Haren, Email o.diekmann@biol.rug.nl

The diversity of zooxanthellae within five morphospecies of the coral genus *Madracis* was investigated. Individuals of the different morphospecies were sampled at one site on Curaçao, Netherlands Antilles, over a depth range from 2-50 meter. Restriction fragment length polymorphism and sequence analysis of large subunit rDNA showed that, although there is some variation, *Madracis* only harbours one type of zooxanthellae. Comparison with known sequences showed that all *Madracis* zooxanthellae belong to the type B clade and that there is no relation of zooxanthellae variation with morphospecies or with depth. The general idea that hosting more than one type of zooxanthellae, as has been found in *Montastraea annularis* complex, facilitates adaptation to a varying environment does not apply to *Madracis*. However preliminary data analysis of the faster evolving ITS region does show differentiation between the predominantly shallow *M. mirabilis* and the other morphospecies. This result suggests that not only different types of zooxanthellae but also variation within a zooxanthellae type may play an important role in adaptation to different environments.

SYMBIONTS (*"SYMBIODINIUM BERMUDENSE"*) OF *AIPTASIA PALLIDA* FROM BERMUDA AND FLORIDA RESPOND DIFFERENTLY TO TEMPERATURE AND IRRADIANCE.

Goulet T.L.* and Cook, Clayton B. *Harbor Branch Oceanographic Institution, 5600 U. S. 1 North, Fort Pierce, Florida USA 34946. Email: tgoulet@hboi.edu

One major correlate of temperature-related bleaching events is reduced photosynthesis by zooxanthellae of bleaching corals. We examined the effects of short-term elevated temperatures (32 and 34°C.) on the photosynthesis-irradiance responses of zooxanthellae from populations of the subtropical sea anemone *Aiptasia pallida* in Bermuda and the Florida Keys. Zooxanthellae from both locations have been identified as *Symbiodinium bermudense*. Using PCR to amplify the DNA encoding for ss-*r*RNA, we determined that the zooxanthellae of Bermuda *A. pallida* fell in Clade 'B' while those from Florida *A. pallida* fell in Clade 'A'. The zooxanthellae from the two locations differed in photosynthesis-irradiance responses. Zooxanthellae from Bermuda anemones had a typical P-I response at 25° with no photoinhibition up to 530 µmol m^{-2} sec^{-1}. At 32° these algae exhibited photoinhibition at I > 250, with net O_2 fluxes < 0 at I > 500. At 34° O_2 fluxes were always negative, increasingly so at higher irradiances. In contrast, zooxanthellae from Florida *A. pallida* never exhibited photoinhibition at these temperatures. P-I patterns were similar at 25 and 32°; P_{max} was reduced at 34°, although the cells were still net producers at I > I_c The zooxanthellae found in *A. pallida* from the two geographic locations clearly differed physiologically. We are currently determining whether these differences can be attributed to the zooxanthella cladal identity.

A PHYLOGENETIC COMPARISON OF ZOOXANTHELLAE FROM REEF CORALS WITH DIFFERENT MODES OF SYMBIONT ACQUISITION.

Hidaka, M* and Hirose, Mamiko. *Dept. of Chemistry, Biology and Marine Science, Univ. of the Ryukyus, Nishihara, Okinawa, 903-0213 Japan. Email: hidaka@sci.u-ryukyu.ac.jp

The purpose of this study is to test the hypothesis that corals that vertically transmit symbionts from their mother colonies contain species-specific zooxanthellae, while corals that acquire symbionts from the environment contain locality-dependent zooxanthellae. We analyzed the internal transcribed spacer 1 (ITS1) region of algal nuclear ribosomal DNA to study the phylogenetic relationships of zooxanthellae contained in shallow reef corals from Okinawa, Thailand and Hawaii that show different modes of symbiont acquisition. Algal ITS1 regions were amplified by PCR using zooxanthella-specific primers, and PCR products were directly sequenced after purification. In each case, one (presumably dominant) symbiont genotype was analyzed for each colony. When *Symbiodinium* from *Porites astreoides* in Florida was used as an outgroup, the zooxanthellae from corals in Okinawa were monophyletic while those from Thailand and Hawaii formed a large unresolved cluster. Symbiont identity appeared to depend on the locality where host corals were collected rather than the specific identity of the coral host or its mode of symbiont acquisition. This suggests that corals which receive zooxanthellae from their mother colonies may also acquire symbionts from the environment.

TESTING THE ADAPTIVE BLEACHING HYPOTHESIS: THE MECHANISM AND CONSEQUENCES OF ZOOXANTHELLA EXCHANGE.

Jacobs J. Rebecca*. *Biology Department, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, USA. Email: jacobs@biology.ucsc.edu

The "adaptive bleaching hypothesis" posits that loss of zooxanthellae by invertebrate hosts under stressful conditions provides the opportunity for acquisition of a genetically different type of zooxanthella potentially leading to a more fit symbiosis. It has also been suggested that acute bleaching may represent only the most extreme case of zooxanthella exchange and that new symbiotic combinations may form continually without acute bleaching and in the absence of perceptible stress. Here, the facultatively symbiotic sea anemone *Aiptasia pulchella* was used as a laboratory system for testing the adaptive bleaching hypothesis in three kinds of experiments. In *flexibility* experiments, different zooxanthella types were fed to aposymbiotic anemones to document the probability of successful symbiotic establishment and the subsequent fitness of symbiotic combinations (*e.g.*, survival, growth rate, susceptibility to bleaching) under several standard and altered (stressful) conditions. In *exchange* experiments, heterologous zooxanthellae were fed to symbiotic anemones to determine whether: (1) the introduced zooxanthella establishes a symbiosis; (2) the resident zooxanthella maintains a symbiosis; or (3) both zooxanthella types co-exist under standard or altered conditions. In *preference* experiments, various combinations of zooxanthellae were fed to symbiotic and aposymbiotic anemones to determine which symbiotic combinations were favored under what conditions. Zooxanthella genotypes were differentiated by denaturing gradient gel electrophoresis (DGGE).

CORAL ZOOXANTHELLAE DIVERSITY IN BLEACHED REEFS.

Loh William*, Sakai, Kazuhiko; and Hoegh-Guldberg, Ove.
Tropical Biosphere Research Center. The University of the Ryukyus. Okinawa, Japan. Email: w.loh@mailbox.uq.edu.au

Studies using ribosomal DNA sequences show that a diverse array of symbiotic dinoflagellate strains or species live within the tissues of reef-building corals which may affect the sensitivity of their host taxa to bleaching. Extensive coral bleaching occurred in shallow reefs off the Ryukyu Islands of Japan in 1998 and many coral genera in this region suffered local extinction. We have explored the question of whether the genotype of symbiotic dinoflagellate determines the sensitivity of corals by studying the molecular diversity of symbiotic dinoflagellates from 8 intertidal coral species on reefs off several Ryukyu Islands that were affected by bleaching. Five of the coral species (*Goniastrea aspera*, *G. edwardsi*, *Favites chinensis*, *Platygyra ryukyuensis* and *Pavona frondifera*) showed very little visible bleaching. The remaining species, *Acropora digitifera*, *Stylophora pistillata* and *Seriatopora hystrix* bleached extensively. Genetic diversity was investigated using the D1 and D2 domains of symbiotic dinoflagellates 28S rDNA and single stranded conformational polymorphism (SSCP). Up to 18 SSCP profiles were obtained which inferred a high level of diversity and also the presence of multiple genotypes within single hosts. Phylogenetic analyses were done using the 28S rDNA sequences. Interestingly, lower numbers of genotypes were detected from bleach-susceptible coral species, suggesting that low zooxanthellae diversity may contribute to host bleaching sensitivity.

SPECIFICITY OF HOST-ALGAL SYMBIOSIS FROM THE SCLERACTINIAN CORAL *PLESIASTREA VERSIPORA* ALONG A LATITUDINAL GRADIENT: ECOLOGICAL IMPLICATIONS OF SYMBIONT DIVERSITY.

Rodriguez-Lanetty, Mauricio*, Loh, William and Hoegh-Guldberg, Ove. *Centre for Marine Studies, University of Queensland, St Lucia QLD 4072, Australia. Email: m.Rodriguez@mailbox.uq.edu.au

Plesiastrea versipora is one of the most widely distributed hermatypic corals in the Indo-Pacific area and is recorded continuously from the cooler waters of South Australia through the tropics and subtropics to South Japan. This broad distribution stands in contrast to most other hermatypic corals that are restricted to the warm, sunlit and relatively stable conditions of tropical seas. Since the ability of this coral to live in such diverse habitats may be related to the identity of the symbiotic dinoflagellates it contains, we examined genetic diversity in the symbiotic dinoflagellates (*Symbiodinium sp*.) in *P. versipora* from southern Japan to Australia. Using Restriction Fragment Length Polymorphisms (RFLPs) in 18S ribosomal DNA (rDNA), together with sequence analysis of 28S rDNA, we found two geographically distinct clades of symbiotic dinoflagellates living within *Plesiastrea versipora*. In sub-tropical and tropical waters, *P. versipora* hosts symbionts belonging to *Symbiodinium* clade *C*, while at high-latitude sites it contains members of clade *B*. The presence of different symbionts at different latitudes in this hermatypic coral may account for its spread in evolutionary time to the cooler and more physiologically challenging environments of high latitude reefs.

DIVERSITY AND BIOGEOGRAPHY OF SYMBIOTIC DINOFLAGELLATES ASSOCIATED TO ANTHOZOANS FROM KOREAN WATERS.

Rodriguez-Lanetty, Mauricio *, Cha, Harim; and Song, Jun-Im. *Department of Biology, Ewha Womens University, Seoul 120-750, South Korea. Email: m.rodriguez@mailbox.uq.edu.au

Anthozoans are important components of the intertidal marine fauna along the coastlines of South Korea. Although the systematics of this group has been studied extensively within Korean waters, the diversity of the symbiotic dinoflagellates associated with these cnidarians is still unexplored. In this preliminary study, we examined the genetic diversity of symbiotic dinoflagellates associated with anthozoans from three locations within Korean waters. Partial nucleotide sequences of 28S ribosomal DNA gene were used to compare the symbionts extracted from three actinarians (*Anthopleura kurogane*, *Anthopleura japonica* and *Paracicyonis actinostolides*), two stony corals (*Alveopora japonica* and *Dendrophyllia* sp.), and one gorgonian (*Muricella muricata*). We found the same type of symbiont (*Symbiodinium* clade *A*) living within the actinarians occurring on the south and east coast of Korea. In the southernmost location (Cheju Island), which is under the influence of warm water currents from subtropical areas, different symbionts were found in association with several anthozoans. Most of the actinarians and one of the two stony corals *(Dendrophyllia* sp.) contained members of *Symbiodinium* clade *A*. The other coral (*Alveopora japonica*) and the actinarian *Paracicyonis actinostolides* contained members of *Symbiodinium* clade C. The gorgonian *Muricella muricata* contained symbionts that were unlike those reported so far. The biogeographical significance of these results will be discussed.

MOLECULAR AND PHYSIOLOGICAL DIVERSITY OF ZOOXANTHELLAE IN BERMUDIAN CORALS.

Savage, A. M.* and Douglas, A. E. *University of York, Department of Biology, P.O. Box 373, York, YO10 5YW, UK. Email: ams114@york.ac.uk

Bermuda is a high latitude reef site with an impoverished scleractinian coral fauna. The molecular diversity of the zooxanthellae in reef organisms was analysed using sequences of the 24S rDNA. All zooxanthellae isolated could be assigned to one of the three main ribotypes (A, B and C) known from lower latitudes, and none differed substantially in sequence from previously described zooxanthellae. The photosynthesis-irradiance characteristics of different zooxanthellae genotypes was investigated, using zooxanthellae freshly isolated from a variety of Bermudian host invertebrates (corals, sea anemones and jellyfish) which had photoacclimated to a common irradiance level. Significant differences in quantum yield (α), photosynthetic maxima (P_{max}) and saturating light intensity (I_k) were observed between 24S genotypes of zooxanthellae. Those of ribotype A were characterised by high values of α and P_{max}. Zooxanthellae of ribotype B had lower values of P_{max}, but were clearly subdivided into two physiological groups with significantly different α and I_k values.

A SURVEY OF THE GENOTYPES OF ZOOXANTHELLAE SYMBIOTIC WITH PHILIPPINE GIANT CLAMS.

Silvestre, Vivian A.*; Monje, Virginia D.; Sison, Marilou P.; Carlos, Alvin A.; Lluisma, Arturo, O..*Marine Science Institute, University of the Philippines,Diliman, Quezon City 1101 Philippines. Email: vivian@msi01.cs.upd.edu.ph

Recent studies in algal-invertebrate symbiosis suggest that different genotypes of zooxanthellae may have varying effects on the growth and survival of their hosts. In giant clams in particular, studies have been initiated to understand the ecological significance of these genotypes. In this study, a number of wild clams were sampled from selected parts of the country to assess the frequency and distribution of the different zooxanthellae genotypes. PCR-RFLP analysis of the 18srRNA gene segment using Taq I restriction enzyme revealed two genotypes , A and C, to be dominant in Philippine giant clams. Giant clams in Bolinao, Tubbataha reef and Investigator reef generally harbor C zooxanthellae (regardless of species of clams), while those in Cebu, Bohol and certain islands at KIG harbor A. Apparently, giant clams have a tendency to associate with only one genotype of zooxanthellae; co-occurrence of the two genotypes in the same host was rarely observed.

SHORT TERM RESPONSES OF ZOOXANTHELLAE FROM SYMBIODINIUM CLADES A AND C TO SUBOPTIMAL LEVELS OF TEMPERATURE, LIGHT AND SALINITY.

Sison, Marilou P.*, Licuanan, Suzanne M.; and Gomez, Edgardo D.;. *The Marine Science Institute, University of the Philippines, Diliman Quezon City, 1101, Philippines. Email: msison@msi01.cs.upd.edu.ph

Different zooxanthella genotypes respond to various physical factors in different ways. Some show resistance to suboptimal environmental conditions that may directly and indirectly be related to the host-symbiont association. To determine how zooxanthellae from *Symbiodinium* clades *A* and *C* differ in their response to suboptimal environmental factors, symbionts from four species of giant clams (*Tridacna gigas, T. derasa, T. squamosa* and *Hippopus hippopus*) were exposed to varying levels of temperature, light and salinity. The following basic physiological measures were determined: growth rate, pigment content, production and respiration. The physiological characteristics of each clade are discussed in relation to their possible use in enhancing the resistance of cultured giant clams to various stressful conditions that normally trigger symbiotic dissociation (bleaching).

VARIATION AMONG *CASSIOPEIA*-ALGAL SYMBIOSES.

Sloan, Adrienne J.*. *Department of Biology and Biochemistry, University of Houston, Houston, Texas 77204-5513, USA. Email: asloan@uh.edu

Theoretical and empirical investigations regarding the evolution and ecology of endosymbiotic associations are widespread. However, few studies address intraspecific symbiont variation among the same host species. Variation in cooperation among *Cassiopeia xamachana* and *Symbiodinium microadriaticum* was investigated using a series of cross-infection experiments. It was hypothesized that algal symbionts are not equally benevolent across *Cassiopeia* hosts. *Cassiopeia* larvae and their maternal algal symbionts were collected from ten sites across 160-km in the Florida Keys. Nine hundred larvae were collected from one medusa per site and were divided among flasks once they settled as polyps (30 animals per vessel). Polyps were infected with maternal algae and nine non-maternal algal types (10 combinations per host type; three replicates per combination). For each combination, host size, mortality, algal mitotic index and density *in hospite* were measured at 3, 13, and 28 days after infection. Analysis has revealed significant differences among the combinations for mortality and growth. Some combinations experienced 100% mortality while others experienced little or no mortality. Host size either increased, stayed the same, or decreased depending upon the combination type. On average, maternal combinations experienced more growth and less mortality than non-maternal combinations. There is also evidence of significant host-symbiont interaction effects.

SYMBIONT ZOOXANTHELLAE DIVERSITY OF ALCYONACEAN CORALS FROM THE KEPPEL ISLANDS, GREAT BARRIER REEF, AUSTRALIA: HOW DOES IT COMPARE WITH SCLERACTINIAN CORALS?

Strychar K.B*., Scott, P.T.; Coates, M.L.; and Sammarco, P.W. *School of Environmental and Biological Sciences, Central Queensland University, Rockhampton, QLD 4702, Australia,. Email: k.strychar@cqu.edu.au

While scleractinian corals are the principle reef forming organisms worldwide, alcyonacean corals are a primary constituent of Indo-Pacific reefs as well. Within reef environments, observations during bleaching events suggest that alcyonacean corals may bleach at different times, bleach less, or resist the effects of bleaching, when compared to scleractinian corals. To examine potential differences between these coral types, the small subunit ribosomal gene (18S rDNA) of symbiotic zooxanthellae from three dominant alcyonacean corals and two scleractinian corals was examined by restriction fragment length polymorphism (RFLP) and DNA sequence analysis following PCR amplification and cloning of the 18S rRNA gene using specific algae-related primers. The restriction enzymes *Taq* I, *Hha* I, and *Alw* 261 were used to digest 18S rDNA clones to produce RFLPs. Preliminary analysis of the RFLPs suggest soft coral zooxanthellae cannot be categorised into the paradigm established for scleractinian coral (i.e. clades A, B, and C). Detailed phylogenetic tree and DNA sequence analysis of clones from representative scleractinian and alcyonacean corals confirms the RFLP data. This study has provided strong evidence that soft coral symbiont zooxanthellae are different to scleractinian symbiont zooxanthellae, and may be more bleach-resistant.

THE PHOTOSYNTHETIC RESPONSE TO STRESS IN DIFFERENT TAXA OF SYMBIOTIC DINOFLAGELLATES.

Warner, Mark E.*, LaJeunesse, Todd; Schmidt, Gregory W.; and Fitt. *Department of Botany, University of Georgia, Athens, Georgia, 30602, USA. Email: mwarner@dogwood.botany.uga.edu

Previous studies have shown or suggested that different types of symbiotic dinoflagellates of the genus *Symbiodinium* show variable levels of stress tolerance to perturbations in temperature or light, or a combination thereof. While strong correlations exist between some taxa of dinoflagellates and their ecological distribution, the potential physiological mechanisms that may be driving such correlations have remained largely unexplored. Furthermore, it remains unclear if related symbiont taxa have similar physiological constraints that correspond to phylogenetic groupings. Multiple taxa of symbiotic dinoflagellates originally isolated from a broad range of host species and maintained in culture were subjected to brief periods of elevated temperature and light stress, and patterns of chronic photoinhibition, rates of photodamage to photosystem II (PS II), and the potential for photosynthetic recovery were assessed. Similar field experiments were also conducted on a smaller scale using one primary Caribbean reef building coral, *Montastrea annularis*, which is historically known to show a high degree of symbiont "polymorphism". These data were combined with genetic characterizations using the internal transcribed spacer region (ITS) to assess phylogenetic affiliation. The extent to which this species level marker may be used for inferring physiological responses to stress will be discussed.

EVOLUTIONARY RESPONSES OF ALGAL SYMBIONTS TO CORAL BLEACHING EVENTS.

Wilcox, Thomas P.* *University of Texas, Austin, TX 78712 USA. Email: tpwilcox@mail.utexas.edu

The ecology and physiology of coral bleaching has been extensively examined over the last 20 years. However, the evolutionary implications of bleaching are largely unexplored. Here I examine potential evolutionary responses of algal symbionts during bleaching events. Using multi-level selection theory, evolution of virulence theory, and simple population genetic models, I consider the following two points: 1) evolutionary implications of the 'adaptive bleaching' hypothesis, and 2) the evolution of resident algal populations in response to a bleaching stress. Results indicate that frequent sampling of environmental pools of symbiotic dinoflagellates, postulated by the adaptive bleaching hypothesis, favor algal symbionts that 'cheat'. This results in the eventual extinction of both hosts and symbionts. Evolution of resident (or remanent) symbiont populations during bleaching and recovery can be very complex. If the stress resulting in bleaching is prolonged, the resident symbiont population can recover through the accumulation of beneficial mutations that ameliorate the stress *for the symbiont*. However, the effect of this 'recovery' on the host depends upon the relationship between traits that help symbionts grow under stressful conditions and symbiont traits that help the host. In general, the models considered demonstrate that great care should be taken in interpreting field evidence for changes in resident symbiont genotypes during or after a bleaching event. A detectable change in symbiont composition does not mean that change is adaptive.

SEASONAL VARIATION IN SYMBIONT COMMUNITY COMPOSITION WITHIN SINGLE COLONIES OF *ACROPORA PALIFERA*.

Yang Y. Avon*, Soong, Keryea; and Chen, Chaolun Allen. *Institute of Marine Biology, National Sun Yat-sen University, Kaohsiung, 424, Taiwan. Email: yawen@mail.nsysu.edu.tw

Within-colony symbiont diversity has recently been documented in scleractinian corals, and the distribution of this diversity has been correlated with the ambient irradiance (depth) experienced by the coral host colony. In this study, the distribution of symbionts in the scleractinian coral *Acropora palifera* was investigated by line transect survey at Nanwang Bay (southern Taiwan), where the depth distribution of this species is restricted to 1–2m. Symbiont diversity within and among coral colonies was investigated using Restriction Fragment Length Polymorphisms (RFLPs) in 18S ribosomal DNA (rDNA). RFLP surveys revealed two distinct symbiont genotypes belonging to *Symbiodinium* clades *C* and *D*, with some samples containing composite RFLPs (*C*+*D*), indicating that *A. palifera* can harbor mixed symbiont genotypes. Surveys of within-colony symbiont diversity revealed that in August 1999 the distribution of *C : D : C*+*D* was 0 : 8 : 0 (N=8 colonies), while in January 2000 it was 4 : 10 : 4 (N=18) and in March 2000 it was 7 : 11 : 3 (N=21). These data suggest that seasonal variation in symbiont community composition may occur in colonies of *Acropora palifera*.

Session A6: Ecology of the Pelagic and Settlement Stages of Coral Reef Fishes

COMPARATIVE EGG DISPERSAL FROM INSHORE AND OFFSHORE SITES IN A CARIBBEAN CORAL REEF FISH, *Thalassoma bifasciatum*.

Appeldoorn, R.S.*, Hensley, D.A., Shapiro, D.Y., Kioroglou, S.. *Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico 00681-9013 USA. Email: r_appeldoorn@rumac.uprm.edu

Pelagically-spawning coral reef fishes are hypothesized to select sites for spawning that result in eggs being rapidly transported away from reef areas. Experiments at an inshore reef and shelf-edge site were conducted to test the hypothesis that shelf-edge spawning offers an advantage in rapidly transporting eggs away from reef areas, with the bluehead wrasse as the model species. Using drogues, spawning events were simulated at known spawning sites (N = 4/site) and water masses tracked for 24 hours. Simulated releases were paired sequentially offshore/inshore. Experiments were run only during the autumn season. There was no tendency for the dispersal paths from inshore and shelf-edge sites to merge over time: those from the inshore site stayed inshore, those from the shelf-edge site stayed within 4 km of the shelf edge. However, only one shelf-edge experiment resulted in dispersal off the shelf platform. Dispersal from the shelf-edge site was much more variable compared to the inshore site. Results indicate that differences in dispersal due to site selection are scale dependent: greater differences are observed when comparing sites at greater distances apart. Thus, shelf-edge spawning would facilitate the dispersal of eggs into an offshore environment merely by being located closer to that environment. Autumn spawning additionally favors retention of eggs in the near shelf-edge environment.

RECRUITMENT OF CORAL REEF FISHES AT LIMESTONE REEF, SOUTH AFRICA.

Beckley L.E.* *Oceanographic Research Institute, PO Box 10712, Marine Parade 4056, Durban, South Africa. Email: seaworld@dbn.lia.net

Limestone Reef, a shallow inshore reef off Durban on the east coast South Africa, is located about 300 km south of the coral reefs of northern KwaZulu-Natal. Despite this, numerous fish species commonly associated with western Indian Ocean coral reefs have been recorded at this site. A study of the recruitment of these fishes was made by deploying light traps to ascertain the occurrence of settlement stage larvae of these species in the water column on the seaward side of the reef. Replicate traps were deployed on one evening each month over a period of two years. Larvae of some 40 families of fishes were recorded with Clupeidae and Tripterygiidae numerically dominant. Larvae of coral reef fishes belonging to families such as Scorpaenidae, Lutjanidae, Apogonidae, Lethrinidae, Chaetodontidae, Synodontidae, Acanthuridae, Balistidae and Tetraodontidae were collected. Their seasonal abundance is discussed relative to known reproductive biology of the adults as well as local oceanographic events and variability in the Agulhas current.

OCCURRENCE AND DISTRIBUTION OF FISH LARVAE IN THE TAKLONG IS. NATIONAL MARINE RESERVE, CENTRAL PHILIPPINES.

Campos, Wilfredo L. * and. Delola, Alfredo P. Division of Biological Sciences, College of Arts and Sciences, University of the Philippines in the Visayas, Miagao, Iloilo 5023 Philippines. Email: oceanbio@miagao.i-next.net

The ichthyoplankton of the shallow reef flat portion of a marine reserve located in Central Philippines was investigated from August 1998 to May 1999. Of the twenty (20) species groups of fish larvae identified, thirteen (13) were epibenthic and seven (7) were pelagic. Overall mean density of all fish larvae was 39.6 ind.100 m^{-3}, while fish eggs showed a mean density of 840 per 100 m^3. Atherinids comprised about 75 % of the larvae in the samples. Species composition of the larvae was found to be consistent with fisheries catch composition. Larval densities in the reserve are well within the range reported for reef areas. Seasonal abundance was highest towards and during the southwest monsoon. Geographically, abundance was found to be highest around channels, and decreased towards the inner shallow portion of the reserve. Future investigations shall include comparisons with adjacent areas so to derive insights into the spatial scale of transport, as well as larval flux rates.

PROCESSES AFFECTING DISTRIBUTION OF PLANKTONIC EGGS OF PAIR AND GROUP SPAWNING REEF FISHES OF PALAU.

Colin, Patrick L.* and Hamner, William M.. *Coral Reef Research Foundation, P.O. Box 1765, Koror, Palau 96940. Email: crrf@palaunet.com.

Studies were designed to test the hypothesis that many reef fishes producing planktonic eggs spawn at times and places which promote the offshore dispersal of eggs. Many species of reef fishes, principally acanthurids, scarids and labrids, pair and group spawn daily just after high tide in a narrow band-like zone on the eastern and western fringing and barrier reefs of Palau, Western Caroline Islands. Many of these fishes migrate short distances daily to reach these spawning sites. Current-following drogues were released at spawning sites during times of intense spawning ("spawning drogues") and also some time after spawning had ceased ("post-spawning drogues"). The tracks of these drogues were determined for 8-24 hours after spawning and are presumed to reflect the movement of fertile eggs. No difference was found in the offshore transport component of the movement of spawning and non-spawning drogues. Many drogues launched in water containing newly spawned eggs came back over the reef, often near their spawning sites, on the next rising tide. Eggs were found to be concentrated on occasion after spawning by langmuir cell effects and spawning and post-spawning drogues often ended up very close to one another, centered in langmuir slicks.

THE ROLE OF LONG DISTANCE DISPERSAL VERSUS LOCAL RETENTION IN REPLENISHING MARINE POPULATIONS.

Cowen R.K.*, Claire B. Paris, Donald B. Olson. *Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149, Email: rcowen@rsmas.miami.edu

Early models and evidence from genetics suggested that long distance dispersal of larvae is likely a common event leading to considerable population connectivity among distant populations. However, recent evidence strongly suggests that local retention is more the rule, and that long distance transport is likely insufficient to sustain ecologically marine populations. We build on earlier model results to examine the probability of larval dispersal to downstream islands within different regions of the Caribbean at varying distances from source populations. Through repeated runs of an 3-D ocean circulation model (MICOM), coupled with a random flight model estimating larval subgrid turbulent motion, we estimate the likelihood of particular circulation events transporting large numbers of larvae to within a 5 and 10 km radii of downstream populations, as well as account for total accumulations of larvae over each year. Further, we incorporate realistic larval behavior and mortality estimates into our models. Our results are consistent with the hypothesis that marine populations must rely on mechanisms enhancing self-recruitment rather than depend on distant 'source' populations. We briefly discuss field efforts that will test the predictions of these model runs.

DEVELOPMENTAL PATTERNS AND THE ONTOGENY OF SWIMMING IN DEMERSAL SPAWNING CORAL REEF FISHES.

Fisher R.* & David R Bellwood. Department of Marine Biology, James Cook University, Townsville, Australia. Email: rebecca.fisher@jcu.edu.au

In recent years it has been demonstrated that late stage larval reef fishes have excellent swimming abilities. However, in order to assess the potential impact of active behaviour on dispersal we need to know how these abilities develop throughout the pelagic phase. Using larval rearing and current flume techniques we examined swimming abilities and gross morphological development in five reef fish species. Developmental patterns differed between species, but were similar within sub-families. At hatching, anemonefishes are large (4-5mm) and well developed. They develop swimming abilities quickly and have a short larval duration (8-11d). Damselfishes hatch small (~3mm) and undeveloped but have a longer larval duration (20-22d). The species examined gained excellent swimming abilities towards the end of the pelagic phase (~15d). Apogonids hatch at 3-4mm, are poorly developed and have a long larval duration (~24d). They are poor swimmers throughout their larval phase. While larval reef fish cannot be considered a single group in terms of their dispersal abilities, they may be classed into "functional" groups that could be used for modelling purposes. Larvae that have poor swimming abilities throughout their larval phase are unlikely to influence their dispersal via horizontal swimming. Larvae that develop swimming abilities early, or show good swimming towards the end of their pelagic phase may have the potential to exert considerable influence over their dispersal, and have a high potential for self-seeding.

RECRUITMENT OF LARVAL FISHES TO THE SOUTHERN MOST CORAL REEFS ON THE EAST COAST OF AFRICA, SODWANA BAY, SOUTH AFRICA.

Harris, Dr Shael*. Coastal Research Unit Zululand, University of Zululand, Private Bag X1001, Kwa Dlangezwa, 3886, KwaZulu-Natal, South Africa. Email: shaelh@worldonline.co.za.

As part of the coral ecosystem research on the Maputaland coast, a study on the early life history stages of coral reef fish was undertaken from July 1998 to May 1999. The main objective of the study was to examine whether the local coral reef fish populations are self-recruiting or being replenished from spawning areas further north i.e. have open populations. Quarterly samples were collected from four sites approximately 1 km offshore, and at three depths. Preliminary analysis of the samples from two-mile reef has indicated that over 30% of the fish larval species are reef-associated species which were found at all three depths sampled. Small numbers of larval priacanthids, apogonids, gobiids, pempherids, trichonotids and lutjanids at all developmental stages have been identified from these samples. However, the most abundant species were shore-associated species, *Bregmaceros atlanticus* and *Engyprosopon grandisquama*, and oceanic-associated species such as *Cyclothone pseudopallida* and myctophids. This indicates that the larval fish populations in the Sodwana area are being influenced by the south-flowing Agulhas Current which is probably an important source of eggs and larvae to the Maputaland reef fish populations.

TRACKING BENTHIC RECRUITMENT DYNAMICS OF THE WHITE GRUNT: A COMMERCIALLY IMPORTANT CORAL REEF FISH WITH CHOOSY – YET, NOT SO CHOOSY - HABITAT SELECTIONS.

Hill R.L.*. U.S. Dept. of Commerce, NOAA/National Marine Fisheries Service, 4700 Ave U, Galveston, Texas, USA 77551. Email: ron.hill@noaa.gov

The white grunt, *Haemulon plumieri* , is an important component of the reef-based fisheries of the Caribbean and Southeastern United States. Indications are that many populations, particularly in Puerto Rico and the US Virgin Islands, are currently on the decline. The benthic recruitment of this and other grunt species was assessed in a shallow backreef lagoon in La Parguera, Puerto Rico over a 10-month period to investigate fine scale temporal variation in settlement dynamics. Settlement strength varied throughout the experiment roughly in correlation to the documented spawning of grunts in this area of Puerto Rico suggesting some degree of self-recruitment. Social facilitation in settlement, density-dependent habitat selection, and hurricane-induced variations in habitat availability and selection are presented. Implications for local management through habitat protection and establishment of marine reserves are discussed.

DELIVERY MECHANISMS LIMIT LARVAL SUPPLY IN CORAL REEF FISHES.

Hixon M.A.*, V. Dufour, T.W. Anderson, and P.J. Doherty. MAH: Department of Zoology, Oregon State University, Corvallis, OR 97331-2914 USA. EMail: hixonm@bcc.orst.edu

We show that nearshore oceanographic features, particularly waves and tidal currents, can limit the rate at which fish larvae are delivered to coral reefs in both the Pacific and the Atlantic. In Moorea, French Polynesia, larvae are delivered to the lagoon by waves that break over a reef crest that is slightly above sea level. At times when settlement-stage larvae are present just offshore, larval delivery to the lagoon occurs only when waves are sufficiently high to break over the reef crest. Therefore, variation in wave height increases variability in larval delivery. High mortality within the lagoon due to predation substantially reduces this variability so that actual settlement is uniformly low. Near Lee Stocking Island in the central Bahamas, tidal currents deliver larvae from the deep Exuma Sound to shallow reefs on the Great Bahama Bank. Reefs further from the Sound receive fewer larvae, as evidenced by recruitment patterns. Here, larval delivery appears to be limited by variation in the range of tidal excursions and prevailing winds, such that isolated reefs far from the Exuma Sound receive settling larvae very infrequently and appear to be extremely recruitment limited.

OCEANOGRAPHIC SIGNALS AND THE REPONSES OF PRESETTLEMENT REEF FISHES

Kingsford, Michael J. *, Jelle Atema , *School of Biological Sciences, University of Sydney, NSW 2006, Australia. Email: mikek@bio.usyd.edu.au

Reefs have the potential to provide conspicuous signals to the pelagic forms of reef fishes and invertebrates that are seeking a suitable settlement site. In this study we describe conspicuous turbidity plumes at One Tree Island, Great Barrier Reef, water choice experiments were also done using presettlement fishes. Plumes may provide cues to presettlement forms, generate retention areas and cause significant changes to the predicted direction of tidal currents. On the flood and ebb tides, while the crest was broached, distinctive plumes were generated. When the tide flooded early in the morning, cool waters were exported from the lagoon. If the tide flooded late, CTD drops and temperature loggers indicated waters up to 3C^{o} higher were advected from the lagoon. Plumes were about 5-9 m deep near the reef crest and shallowed with distance from the reef. The turbidity of plumes was visible at distances of 1-4 kilometres from the reef crest, hence these plumes constitute significant intrusions into mainstream currents. Tide and wind determined the size and direction of movement of plumes. Presettlement fishes (especially Apogonidae) responded to different water masses in tank experiments. Some taxa, that settle in lagoons, showed a positive response to lagoonal waters. The ability of presettlement fish to distinguish between water masses may have a great influence on their ability to detect reefs.

SENSORY DEVELOPMENT IN THE SETTLEMENT STAGES OF CARIBBEAN LABROIDS WITH IMPLICATIONS FOR SETTLEMENT CUE DETECTION.

Lara Monica R.. NOAA/NMFS 75 Virginia Beach Dr. Miami, FL 33149 USA. Email: mlara@rsmas.miami.edu

In order to help explain the role that behavior plays in larval settlement it is necessary to investigate the sensory capabilities of settlement-stage larvae. If fish larvae are capable of exercising control over their movements then they must also possess the ability to assess their environment and alter their behavior according to cues detected in their environment. Sensory ability cannot be measured directly from morphology; rather by using a comparative method relative abilities can be inferred by comparing observed morphological development with that of conspecific adults or larvae of other species. A comparative study of the morphology of the olfactory, visual and lateral line systems using histological methods and scanning electron microscopy was conducted to assess the level of morphological development of these systems in some coral reef fishes at the time of settlement onto a reef. Thirteen species of Labridae and two genera of Scaride from the Caribbean were examined. The level of development of each of these systems was similar across taxa and may represent a minimum competency level required for settlement. These stages appear to have highly developed sensory structures when compared to adults and their morphology suggests that settlement-stage labroids may be capable of using all three of these sensory systems in the detection of reefs and selection of microhabitats within a reef. It is probable that a combination of sensory stimuli are used by settling fishes and these are discussed.

SUBSURFACE MOORINGS AS A RESEARCH TOOL FOR SETTLEMENT BEHAVIOUR IN REEF-FISH LARVAE.

Leis Jeffrey M. * and Brooke M. Carson-Ewart. Centre for Biodiversity and Conservation Research and Division of Vertebrate Zoology, Australian Museum, 6 College St, Sydney, NSW, 2010, Australia. Email: jeffl@austmus.gov.au

Artificial-reef units attached to subsurface mooring floats offer interesting research possibilities for the study of settlement behaviour in larvae of reef fishes. The artificial-reef units (loose rolls of plastic garden mesh) were located at depths between 8 and 15 m in water 20 m deep in the Great Barrier Reef Lagoon greater than 1 km from natural reefs. Ignoring one-offs, larvae of 23 genera of 13 families settled on these units. The most abundant taxa were pomacentrids, apogonids, blenniids, monacanthids, balistids, gobiids and tetraodontids. Experiments using these moorings evaluated visual, olfactory and auditory cues that reef-fish larvae may use to locate and settle onto reefs. Visual cues (large white panels) did not enhance settlement. Experiments on olfactory cues (corals in vented containers) and auditory cues (broadcast recordings of 'the nocturnal chorus' of tropical reefs) were compromised by low settlement levels, but show the potential of the approach. Design of the moorings allowed examination of depth selection at settlement. This revealed that there are clear depth preferences among species. The advantages and disadvantages of the method are discussed.

USING OTOLITHS TO STUDY CORAL REEF FISH LARVAE IN FRENCH POLYNESIA.

Lo-Yat*. EPHE-ESA CNRS 8046, Av. de Villeneuve, 66860 Perpignan, France & SRM, BP. 20 Papeete, Tahiti, French Polynesia. Email : loyat@univ-perp.fr

Coral reef fish larvae were studied in French Polynesia. In Rangiroa atoll (Tuamotu Archipelago), we collected larvae when they ended their pelagic phase by passing over the reef crest (colonization stage). The incoming larvae were trapped with a crest net (1.5m wide x 0.75m high, 1mm mesh size) erected in a shallow channel that connects the ocean to the lagoon. From 332 sampling nights evenly distributed over 2 years (from January 1996 to December 1997), at least 154 lagoonal species belonging to 46 families were identified. The mean larval fluxes were 132 larvae m^{-1}. j^{-1} for larvae with body depth>5mm and 16 055 larvae m^{-1}. j^{-1} for smaller larvae. A typology of otoliths using Fourier elliptic shape analysis was made in order to help in larvae identification and description. Otoliths daily growth increments were counted to determine pelagic larval durations (PLD). Among 60 species, observed PLD ranged between 18 and 80 days. PLD was relatively stable within species except for some species (e.g. *Aulostomus chinensis*, *Fistularia commersonii*). Then spawning period of the adults could be estimated by linking PLD and results from temporal monitoring of larval colonization. Finally we also tried to estimate the growth of some larvae during their pelagic phase. That was realised by associating PLD and age data from larvae caught during mesopelagic trawlings made in French Polynesia's EEZ between 1996 and 1998.

LUNAR AND TIDAL CYCLES IN SETTLEMENT OF REEF FISHES AT GORGONA ISLAND (TEP).

Lozano, S* and Zapata, F.A. Universidad del Valle, A.A. 25360 Cali, Colombia. Email: sachaloz@mafalda.univalle.edu.co

Larval settlement is an important life history event that may determine adult population dynamics in marine reef fishes. During one peak recruitment season (May-August 1998), we monitored fish larval settlement of 40 species in Gorgona Island, Tropical Eastern Pacific. Every other day we removed and counted all newly settled fishes on 15 semi-natural sampling units located nearshore on the eastern coast of the island. Time series analysis and circular statistical tests indicated that there were two temporally consistent patterns in settlement and that they were synchronized with the lunar and tidal cycles. Additionally, means and variances of settlement size, measured every sampling day, exhibited temporal patterns in some species that suggested the occurrence of size selection during certain dates. The first was a lunar pattern with settlement pulses in the days around the new moon (coincident with the widest spring tides) and it was exhibited by *Lutjanus guttatus*, *Pomacanthus zonipectus* and a non-identified Haemulid. This pattern was related to variation in moonlight intensity during the lunar cycle. The second was a semilunar pattern with settlement pulses around the first and third moon quarters, coincident with neap tides and it was exhibited by three combined species of Antennariidae (*Antennarius sanguineus*, *Antennarius coccineus* and *Antennatus strigatus*). This pattern seemed to be more related to the tidal cycle than to variation in moonlight intensity during the lunar cycle. Other eight species analyzed exhibited cyclical tendencies in settlement with partial or no temporal consistency.

THE ROLE OF PHYSICAL PROCESSES IN SHAPING PATTERNS IN LARVAL SUPPLY TO NINGALOO REEF, WESTERN AUSTRALIA.

McIlwain, J.L.* *Australian Institute of Marine Science (WA), PO Box 264 Dampier, WA 6713, Australia. Email: j.mcilwain@aims.gov.au

Ningaloo Reef is Australia's largest fringing coral reef, running parallel to the mainland for 280 km, from North West Cape to Cape Cuvier, Western Australia. The shallow nature of the reef crest and the unidirectional flow of water into the reef lagoon meant crest nets were an ideal tool for monitoring the abundance of larval fish during the transitional phase as they leave the plankton and swim into the adult habitat. During the summer months of 1994/95 and 1995/96 I deployed two and four nets respectively. These nets were emptied every day for up to four months at a time. A total of 89 598 larval fish from 65 families/groupings were captured, with twice as many fish caught in the first compared to the second summer. Primary peaks in larval supply occurred during the months of November and December, a comparative result to replenishment studies on the east coast of Australia (the Great Barrier Reef). Large inter-annual variability in the abundance of most taxa and families were attributed to variations in the strength of the El Niño Southern Oscillation (ENSO) during this time. This result is similar to the catch rates of commercially fished invertebrates along the Western Australian coast which varied with the strength of the Leeuwin Current and ENSO events operating in the region. At a smaller time scale, daily abundance of 28 different taxa were compared with nightly wind strength and direction. Although peaks in supply sometimes coincided with strong cross-shore winds, there were a number of days when under the same conditions catch in the nets remained low.

TEMPERATURE, FOOD AVAILABILITY, PLANKTONIC GROWTH RATES AND THE MAGNITUDE OF LARVAL SUPPLY IN A CORAL REEF FISH.

Meekan M. G.* and Flynn K. *The Australian Institute of Marine Science, P.O. Box 264, Dampier, WA, 6713, Australia. Email: l.vigliola@aims.gov.au

Evidence from temperate environments suggests that under conditions favourable to growth, survivorship of larvae in the plankton is high and results in strong year classes. We examined this hypothesis on the NW Shelf of Western Australia during two summers when coastal waters were characterised by very different conditions. During the first summer, upwelling occurred on the shelf and resulted in relatively cool water temperatures and high primary and secondary production. During the second, coastal waters were stratified and primary production was relatively low. Given these differences in food availability for fish larvae between summers, we predicted that growth rates and survivorship would be greater in the first summer than the second. In order to test this hypothesis, we used otolith analysis to examine the planktonic growth of a common reef fish (*Pomacentrus coelestis*) between summers. Growth rates were compared to the magnitude of catches of this species in light traps deployed on a transect across the shelf during the two summers.

LARVAL BEHAVIOR AS A MECHANISM FOR POPULATION SELF-RECRUITMENT IN A TROPICAL CORAL REEF FISH.

Ochavillo, Domingo G.* Bakus, Gerald J. and Aliño, Porfirio M.. *Department of Biological Sciences University of Southern California Los Angeles, CA 90089-0371, U.S.A. *(ochavill@scf.usc.edu**)**

It is not presently known how larval behavior of coral reef fishes influences their eventual settlement. The traditional paradigm is that coral reef fish larvae behave as passive particles under the mercy of physical elements such as currents and waves. Rare *in situ* observations in the swimming speeds and directions of larval reef fishes, however, indicated ability to maintain position in the water column, orientational swimming and ability to navigate (Leis et al. 1996). Planes (1993) hypothesized that larval behavior may be a mechanism for limited gene flow and larval dispersal in the convict surgeonfish despite a pelagic egg and high planktonic larval duration. In this study we tested this hypothesis of larval behavior as a mechanism for population self-recruitment. Previously, our analyses of the genetic structure of adult and recruit *Siganus fuscescens* among contiguous reefs indicated population self-recruitment. We released late pelagic presettlement *S. fuscescens* offshore from the reef and the results indicated active larval behavior, highly directional swimming, predator avoidance and orientation towards the reef.

EVIDENCES FOR SELF-RECRUITMENT IN A TROPICAL CORAL REEF FISH POPULATION.

Ochavillo, Domingo G.*, Gerald J. Bakus and Porfirio M. Aliño. *Department of Biological Sciences University of Southern California Los Angeles, CA 90089-0371, U.S.A. Email: ochavill@scf.usc.edu

The majority of tropical coral reef fishes have a bipartite life cycle which consists of a pelagic early life history stage and a reef-associated benthic adult stage (Ehrlich 1975). This possession of a planktonic stage has led to an assumption that reef fishes exist as spatially subdivided metapopulations largely interconnected by larval exchanges (Mapstone and Fowler 1988). In this paper we tested this hypothesis using a combination of the analyses of the genetic structures of both the spawning adults and the local recruits of the rabbitfish *Siganus fuscescens* to infer fish larval dispersal among contiguous reefs (< 450 km linear distance) using the highly polymorphic mtDNA control region. The results of the analyses showed a significant genetic heterogeneity among *Siganus fuscescens* in the neighboring reefs based on the sequence variation of the mitochondrial DNA control region. The mtDNA control region sequence of juveniles also indicated significantly high affinity to the local adults. These results indicate population self-recruitment and that larval dispersal may not be as widespread as usually assumed among fishes with an early planktonic phase. The implications of self-seeding reef fish populations are very important. It implies that patchy tropical coral reefs can exist in relative isolation and that management can be local in scale. Surprisingly, independent and very recent studies have also indicated self-recruitment on some coral reef fishes.

NEAR-FIELD TRANSPORT DYNAMICS OF LARVAL COHORTS OF CORAL REEF FISH IN THE VICINITY OF BARBADOS, W. INDIES.

Paris, Claire B.* and Robert K. Cowen, and Kamazima M.M. Lwiza. Marine Sciences Research Center, State University of New York at Stony Brook, NY 11794-5000, USA. Email: cparis@rsmas.miami.edu

Most coral reef fishes undergo a pelagic phase and it has been generally assumed that their offspring are widely dispersed and have little influence on the outcome of their transport. Alternatively, coral reef fish larvae could be retained in the vicinity of their natal reef, potentially limiting their dispersal. To test this latter hypothesis, high-resolution biological and physical surveys of the pelagic processes affecting the larval phase of Pomacentridae were conducted on the western shore of Barbados. The study region was limited to an array extending approximately 15 km from shore and 25 km along-shore. Sampling involved repeated quasi-synoptic physical and biological measurements following larval cohorts throughout their pelagic duration. An integrated view of the 3-D flow field is given by multivariate objective analysis of CTD and ADCP *in situ* data, in which virtual larvae are released using a 'random flight' scheme. Here we describe the formation, maintenance, and advection of larval patches by comparing, for different degrees of behavior, predicted and observed distributions of larval cohorts. Larval behavior was found to be critical to accurately model larval transport. Most importantly, by computing larval fluxes and the percentage of larvae retained in the Barbados near-field, we demonstrate that they largely explain observed variability in recruitment strength.

POPULATION STRUCTURE IN REEF FISHES: HOW OPEN IS REALLY OPEN AND HOW CLOSED IS CLOSED?

Sale, Peter F.* *Great Lakes Institute for Environmental Research & Dept. of Biological Sciences, University of Windsor, Windsor ON Canada N9B3P4. Email: sale@uwindsor.ca

Thirty years ago ecologists and managers treated reef fish populations as if they were closed on very local scales. Then we "discovered" that dispersive larvae permitted them to be open. Recently, ecologists have been documenting the openness, but arguing that this is limited to the local scale. Self-recruitment is seen as increasingly important. I review published, and limited unpublished data to address the question: "At what spatial scales can reef fish assemblages be considered open, and at what scales closed?". I also explore metapopulation theory to see whether the spatial scale at which openness is manifested is critical to the dynamics of such systems. While it is clear that we need new data, and new techniques to establish scales of interaction among local populations, it is also clear that we must resist the temptation to continue swinging the pendulum from one extreme view to the other.

SMALL CHANGES IN TROPICAL OCEAN TEMPERATURE CAN SIGNIFICANTLY INFLUENCE REEF FISH EARLY LIFE HISTORY.

Shafer, David J.*. *School of Ocean and Earth Science and Technology, University of Hawai'i, Honolulu, Hawai'i 96822, USA. Email: shafer@hawaii.edu

Declining populations of tropical reef fishes worldwide has focused attention on factors which may regulate their recruitment, growth, and survival. Variation in ocean temperature has traditionally been linked to fluctuation in the population dynamics of temperate marine fishes; however, little is known about its importance to tropical fishes. Here I reconstruct the effects of small changes in sea surface temperature (SST) on larval growth rate, larval duration, and size at settlement of a common Hawaiian reef fish, *Bathygobius coalitus*, by retrospective otolith analysis. Results show that small temperature changes can significantly influence early life history. Specifically, larval growth rate was directly related to SST, and larval duration and size at settlement were inversely related to SST. Frequency distributions of larval duration suggest a competency-based threshold to settlement during warm SST, but not during cool SST. Shorter larval durations during warmer SST may result from optimum conditions for growth and development, combined with physical conditions that result in nearshore retention. Because growth rates, larval duration, and size at settlement have implications for survivorship, competition, and recruitment success, variation in ocean temperature may have profound consequences for the population dynamics of tropical reef fishes.

JOINT ROLES OF LARVAL SETTLEMENT, REEF RESOURCES, AND POST-SETTLEMENT LOSSES IN THE RECRUITMENT OF A CORAL REEF FISH.

Shima, Jeffrey S.*. *Dept. of Ecology, Evolution, and Marine Biology and the Marine Science Institute, University of California, Santa Barbara, CA 93106, USA. Email: shima@lifesci.ucsb.edu

I evaluate the consequences of considering, separately and jointly, the effects of three factors (larval settlement, reef resources, and post-settlement losses) on spatial patterns of abundance of a coral reef fish, the six bar wrasse (*Thalassoma hardwicke*). Using commonly employed correlational methods, I show that local patterns of abundance of juvenile wrasse could be attributed entirely to either (1) patterns of abundance of settlement habitat, or (2) patterns of larval settlement. This occurred because habitat and presumed larval delivery co-varied positively with one another in space. I manipulated abundance of settlement habitat in a field experiment to uncouple this co-variation, and found subsequent settlement to be simultaneously influenced by both factors. However, joint effects of habitat and larval settlement failed to account for patterns of abundance of juvenile wrasses without also considering a third factor—post-settlement losses, which were density-dependent and qualitatively modified patterns of settlement. These results illustrate (1) how multifactorial explanations of ecological patterns may be falsely refuted when incomplete sets of multiple factors are considered, and (2) how single-factor studies may misrepresent underlying multifactorial causation of ecological patterns. Uncovering the interactive role of multiple factors in determining ecological patterns may require a shift from single-factor approaches to more pluralistic perspectives.

VARIABLE LARVAL GROWTH IN A CORAL REEF FISH AND IMPLICATIONS FOR POPULATION CONNECTIVITY.

Sponaugle S.*, Steven Searcy, and John Fortuna. *Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Cswy., Miami, FL 33149. Email: ssponaugle@rsmas.miami.edu

Recent results from otolith-based field efforts in Barbados and the Florida Keys suggest that certain reef fishes (*Thalassoma bifasciatum*) exhibit a high degree of variation in larval growth. New recruits settling after variable larval periods in the plankton exhibited strikingly different otolith growth trajectories. In the Florida Keys, cohorts of *T. bifasciatum* settling in the spring had grown more slowly in the plankton than those settling later in the summer. These differences are most likely the result of seasonal changes in water temperature. However, for fishes settling to Barbados, contrasting otolith growth trajectories likely result from variable pelagic food availability. Residency in water masses with reduced food content may lower overall larval growth rates. In order to attain a minimum condition necessary to undergo settlement and metamorphosis, slower-growing fishes therefore must remain in the plankton for longer periods. Thus, rather than delaying metamorphosis, those fishes with longer pelagic larval durations instead may be accumulating energy prior to settlement. The capacity of organisms to tolerate low growth for long periods of time (i.e. in oligotrophic open ocean waters) is a critical consideration in understanding and predicting population connectivity for benthic marine animals.

EVIDENCE AND MECHANISMS FOR SELF-RECRUITMENT IN AN ISLAND POPULATION OF A CORAL REEF FISH.

Swearer, S.*. *Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, California, USA. Email: swearer@lifesci.lscf.ucsb

Most populations of benthic marine organisms are considered to be open (when recruitment results from dispersal of larvae from other source populations). In truth we know little about the degree of connectivity among populations. For localities such as coral reef islands, relative isolation from other island populations may increase the importance of self-recruitment to population persistence. In order to test this hypothesis, we used otolith elemental signatures and nearshore seawater trace element concentrations to classify locally and non-locally produced populations of coral reef fish larvae. Using this approach in a study of reef fish recruitment to St. Croix, US Virgin Islands, we found that periods of high recruitment in the lee of the island were coincident with characteristics of locally-retained larvae. Physical measurements of the circulation dynamics of the island wake region using a high frequency radar indicate that high recruitment events occur during time periods favorable for physical retention of larvae. These results suggest that local processes operating in the nearshore regions of islands are important factors influencing the recruitment dynamics of island populations of reef fishes.

SIZE-SELECTIVE MORTALITY LINKS PRE- AND POST-SETTLEMENT PHASES OF THE LIFE HISTORY OF A CORAL REEF FISH.

Vigliola, L.* and Meekan, M. G. *The Australian Institute of Marine Science, P.O. Box 264, Dampier, WA, 6713, Australia. Email: l.vigliola@aims.gov.au

Newly settled coral reef fishes undergo very high rates of mortality. At present, the extent to which this mortality is determined by the condition, growth or size of fish is unknown. In this study, we repeatedly sampled a cohort of a damselfish (*Neopomacentrus filamentosus*) immediaetly prior to, at, and then at monthly intervals after settlement. Otoliths from these individuals were used to determine the growth characteristics of fish that survived up to three months after settlement. We found that one month after settlement, this species underwent an intense period of size-selective mortality where smaller, slow-growing fish had higher rates of mortality than larger fast-growing individuals. As fish that were fast-growing after settlement also tended to be fast-growing at earlier life history stages, the variation on which the size-selective mortality acted was present during the planktonic phase and potentially at hatching.

THE NATURE OF THE EVIDENCE FOR LOCAL RETENTION IN MARINE POPULATIONS WITH PELAGIC LARVAE.

Warner, Robert R.* and Stephen E. Swearer, *Dept. of Ecology, Evolution, and Marine Biology and the Marine Science Institute, University of California, Santa Barbara, CA 93106, USA. Email: warner@lifesci.ucsb.edu

The major unanswered question in marine ecology is the degree of connectedness between local populations. Put another way, what proportion of young arriving into a local population are products of local production? Since most marine animals have a pelagic larval stage, the paradigm thus far has been to assume extensive dispersal and massive export. In contrast, a working group convened at the National Center for Ecological Analysis and Synthesis suggests that evidence is accumulating in a variety of fields that indicates a surprising amount of local retention, even in species with long larval durations. The evidence arises from empirical studies of recruitment and endemic species, geographic genetic structure, spread of introduced species, larval distributions, proximal effects of marine reserves, and paleoecology. If retention turns out to be a common feature of local marine population dynamics, this will require major reassessment of marine metapopulation models, fishery management schemes, marine reserve designs, and ideas about the mechanisms of marine speciation. It also underscores the need for more intensive studies of larval ecology and behavior.

SPATIAL AND TEMPORAL PATTERNS OF CORAL REEF FISH SETTLEMENT TO NEIGHBOURING SMALL ISLAND STATES IN THE EASTERN CARIBBEAN.

Watson, Maggie * and Richard S. Nemeth. *ICLARM CEPO, 158 Inland Messenger, Road Town, Tortola, British Virgin Islands. Email iclarm@candwbvi.net

We investigated spatio-temporal patterns in the settlement of coral reef fish both between reefs and between neighbouring island states in the Eastern Caribbean. During the new moon periods of July August and September 1999, three light traps were set near each of three fringing reefs in the British Virgin Islands (BVI) and three in the United States Virgin Islands (USVI). Approximate separation was 2-5 km and 50-60 km within and between countries respectively. Catches varied substantially among traps, months and sites. Hierarchical cluster analyses of total catches showed sites within countries grouped together each month (except one site in July). BVI and USVI were clearly distinct. In BVI, the largest numbers of almost all species were caught consistently at one site. This site, a proposed Marine Protected Area, may be a local 'hotspot' for settlement. Peak abundance of each family generally coincided at BVI sites. By contrast, in USVI no one site consistently produced more fish, and abundances of several families peaked at different sites in different months. In September, 36.6, 2.4 and 4.3 snappers per trap were caught at the three sites in BVI, while USVI yielded only 0.1, zero and 0.4. For surgeonfish the pattern reversed, with 0.1, 0.9 and 0.8 fish from BVI and 27.6, 11.5 and 10.5 from USVI. Thus settlement was not uniform in space or time at these scales. We discuss the results in the light of the current debate over widespread dispersal versus local retention of postlarval fish.

THE INFLUENCE OF LIGHT TRAP OPERATION AND DEPLOYMENT ON CATCHES OF PRE-SETTLEMENT FISHES AROUND CORAL REEFS IN THE SAN BLAS ARCHIPELAGO, CARIBBEAN PANAMA.

Wilson. DT*. *James Cook University, Dept. Marine Biology, Townsville, QLD, Australia. Email: david.wilson@jcu.edu.au

Light traps are a popular technique for sampling patterns of larval supply to populations of coral reef fishes. However, relatively few studies have examined the biases of this sampling technique. This study examined the influence of tidal patterns, time of night factors and depth of deployment on catches in light traps. Tidal and time of night influences on catch rates were examined by sampling traps at 2 hr intervals for 13 d centred around the new moon in each of 3 lunar months. Larval catches were generally correlated to ebb tidal flows, although the pattern was weak and variable. This probably reflects the relatively small tidal range in the Archipelago. There were no significant changes in catch rates during the night, although a gradual trend of increasing catches towards dawn was identified. The effect of trap deployment depth on catches was examined by anchoring traps at the surface and just above the bottom in two habitats for 3 lunar months. All families of reef fishes collected in high numbers displayed clear patterns of depth preference. The larvae of gerrids, pomacentrids and lutjanids were predominantly captured in shallow traps, while acanthurids, gobies, labrids, apogonids, synodontids and blennies were usually collected in deep traps. These results suggest that the composition and abundance of catches will be strongly affected by the depth at which traps are deployed.

Session A7: The East Indies Triangle of Maximum Marine-Biodiversity: Definition and Origins

SPECIES COMPOSITION OF SOFT CORALS (OCTOCORALLIA) ON THE CORAL REEFS OF THE RYUKYU ARCHIPELAGO, JAPAN.

Benayahu Y.* Department of Zoology, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, Israel. Email: denlit@post.tau.ac.il

The history of studies on the octocoral fauna of Japan is over 120 years old. The latest taxonomic revisions of some major alcyonacean genera and the progress made to date in studying them on various Indo-Pacific reefs encouraged the initiation of an extensive collection of soft corals on the Ryukyu Archipelago. Species composition of the families Clavulariidae, Tubiporidae and Alcyoniidae was studied on 20 reef sites, from Sesoko Island in the north, to Yonaguni Island in the south. The collection, comprising over 325 specimens, yielded 56 species. The study established 4 new species and in addition over 30 new zoogeographical records. Many of the new records have already been described in the past from the reefs of the Bay of Nha-Trang, Vietnam and recently from Taiwan, indicating the close resemblance among these soft coral faunas. Therefore, it is clear that the soft corals of the Ryukyu Archipelago share many similarities with the fauna of the East China Sea reefs. Most of the species obtained in the present study are representatives of the family Alcyoniidae. Low number of genera characterizes this family in the surveyed sites, yet some are with remarkably high species richness. The alcyoniids of the genera *Alcyonium*, *Cladiella*, *Lobophytum*, *Sarcophyton* and *Sinularia* form large assemblages, which dominate shallow reef areas. Members of the families Nephtheidae, Xeniidae and Nidaliidae were also collected and are still being examined. They contribute to the diversity in habitats where Alcyoniidae species are rare. Further studies on other islands of Japan will enable an appropriate evaluation of the spatial and latitudinal patterns of octocoral biodiversity in the region.

VARIATION IN CORAL SPECIES DIVERSITY AND OCCURRENCE WITHIN INDONESIA: INFLUENCES OF BIOGEOGRAPHY, GEOMORPHOLOGY, AND LAND-BASED POLLUTION.

Edinger E.*, Jurek Kolasa, Michael Risk. Dept. of Earth Sciences, Laurentian University, Ramsey Lake Road, Sudbury, Ontario, Canada, P3E 2C6. Email: eedinger@nickel.laurentian.ca.

We assess local and regional variation in coral species diversity and species occurrence within the Indonesian archipelago, and the influence of regional species pools, geomorphology, and anthropogenic pollution on coral species diversity and occurrence. We measured line-intercept transects from 33 sites on 14 reefs in three regions of Indonesia: Ambon (Moluccas), South Sulawesi, and the Java Sea. Unpolluted reference sites in eastern Indonesia were approximately 20% more diverse than Java Sea reference sites. Rare species formed a higher proportion of the coral fauna on eastern Indonesian sites. Approximately 25% of the species recorded in Ambon and South Sulawesi did not occur in the Java Sea. Between-site variation in species occurrence was lower on Java Sea reefs than on eastern Indonesian reefs. Pollution from land-based sources was the primary determinant of coral species diversity and species occurrence on reefs. A larger species pool in eastern Indonesia than in the Java Sea probably accounted for most of the difference in within-site species diversity between eastern Indonesian and Java Sea reference sites. High fishing intensity in the Java Sea, including destructive fishing practices, may have also reduced within-site species diversity on Java Sea reference reefs.

GEOLOGICAL INFLUENCES ON INDO-WEST PACIFIC BIOGEOGRAPHY DURING THE CENOZOIC.

Hall, Robert*. *SE Asia Research Group, Royal Holloway London, Egham, Surrey TW20 0EX, UK; Email: robert.hall@gl.rhbnc.ac.uk

The distribution of land and sea and changing depths of seas, essentially the result of geological processes, have played an important part in the evolution of life and the development of biogeographic patterns in SE Asia and the West Pacific. Cenozoic geological events have also influenced climate and oceanic circulation in the region. Major plate reorganisations took place at about 45 and 25 Ma. Long term subduction maintained discontinuously emergent volcanic island chains. Early Cenozoic collision of India with Eurasia enlarged land areas. Later, Eurasia-Australia and New Guinea arc-continent collisions led to connections between Australia, Asia, and the Pacific. These changes will be examined with the aid of computer-animated tectonic models. Wallacea is a critical area between the Sunda and Sahul shelves where, since the early Miocene, an old deep-water barrier has been eliminated, but as mountains rose, new deep basins developed. There have been very rapid changes in geology, topography and land/sea distribution, with multiple opportunities for dispersal and vicariance. More subtle geologically-related forces have also modified biogeographic patterns, such as links between tectonics, mountain rise, sea level, climate, seaway closure and ocean circulation. Changes occurred within a framework of long-term cooling and sea level fall, with extreme variations during Quaternary glacial and interglacial periods. The complex links between geology, climate and ocean circulation are still to be understood but are likely to have significant biogeographic impact.

THE REEF CORAL FAUNA OF BALI AND NEARBY AREAS.

Hoeksema, Bert W.* & Ketut Sarjana Putra. *Nationaal Natuurhistorisch Museum / Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. Email: Hoeksema@naturalis.nnm.nl

Although Bali is well known for its diving tourism, surprisingly little is known of its underwater fauna. Three areas of Bali have been quickly monitored with regard to their reef coral fauna: (1) Bali Barat national marine park, west Bali, (2) the Tulamben - Amed area, northwest of Bali's easternmost point, and (3) Nusa Lembongan en Nusa Penida, two islands in the Lombok Strait between Bali and Lombok. Mushroom corals (Fungiidae) and scleractinian genera were selected as target taxa. Bali Barat, mainly consisting of uplifted limestone, appeared to be the least rich, a possible effect of bleaching. The Tulamben - Amed area, predominantly consisting of volcanic sediments with limestone outcrops, appeared to be the richest. The neighbouring islands Nusa Lembongan and Nusa Penida, also characterised by uplifted limestone, appeared to have very special fauna elements due to cold upwelling and strong currents. Compared to nearby areas in western and eastern Indonesia, the coral fauna of Bali, on the boundary between west and east, resembles most the fauna of eastern areas.

THE EAST INDIES TRIANGLE OF MARINE BIODIVERSITY.

Hoeksema, Bert W. *. *Nationaal Natuurhistorisch Museum / Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. Email: Hoeksema@naturalis.nnm.nl

Most tropical benthic animal species occur on coral reefs in the Indo-Malayan Triangle, which includes Malaysia, Indonesia, the Philippines and Papua New Guinea. Many species show an Indo-West Pacific range from the western Indian Ocean and the Red Sea toward the central Pacific, while others occur predominantly in the Indo-Pacific convergence. Cumulatively, these ranges form a centre of maximum marine biodiversity, which is located at the East Indies triangle. The boundaries of this triangle do not appear to have any biogeographic significance. Depending on the taxa and material studied, various triangles have been distinguished in the past. Consequently, we do not know yet where exactly the real centre of diversity is located. Species distributions presented in systematic revisions are usually incomplete. Nevertheless, well-defined boundaries are important for explaining the centre of diversity, since they may relate to the area's climatic and geological past or to dispersal by currents and its ecological barriers. The fossil record and data on molecular variation between and within species may also help herein. Taxonomists should design sampling programmes that focus on target taxa, which would enable them not only to look for occurrence data but also to obtain reliable information on species absence. Eventually, the patterns of many marine benthic taxa need to be compared in order to find their real diversity centre.

MOLECULAR PHYLOGEOGRAPHY OF THE *PATELLOIDA PROFUNDA* GROUP (GASTROPODA: LOTTIDAE).

Kirkendale, L.*. *Marine Lab, University of Guam & Florida Museum of Natural History, University of Florida, Gainesville FL 32611 USA, Email: kirkendale@flmnh.ufl.edu

Studies on the origin and diversification of Indo-West Pacific (IWP) biota are hampered by the frequently sympatric distribution of related species. Limpets of the *Patelloida profunda* group are exceptional in retaining largely allopatric ranges, which together with their predominant restriction to calcareous shores make them a promising group to address questions of IWP diversification. In the Pacific the group is basically confined to tectonically uplifted islands where emergent fossil reefs provide suitable substrata. Both tectonism and sea level fluctuations alter the distribution and connectedness of these habitats, and provide opportunities for speciation. Using 16S and COI mtDNA sequence data from most *P. profunda* group members and several other *Patelloida* and other limpet species, I explore the relationships and test hypotheses about the origins, of these limpet species. Results show a deep split between Pacific and Indian Ocean clades that may date from the Miocene tectonic restriction of circulation between the ocean basins. Differentiation within the Pacific is more shallow and consistent with Plio-Pleistocene sea level fluctuations as a driving mechanism. Indian Ocean taxa show deeper differentiation among themselves than Pacific taxa, consistent with the more fragmented nature of habitats in the former, and also with data from other groups. Results raise questions about the boundaries of the *P. profunda* group, the genus *Patelloida*, as well as of patellogastropod families in general.

INDO-WEST PACIFIC DIVERSITY: PHYLOGENETIC EVIDENCE FROM COWRIES FOR A MOSAIC OF CAUSES

Meyer Christopher *, Gustav Paulay. *Marine Laboratory, University of Guam & Florida Museum of Natural History, University of Florida, Gainesville, FL 32611 USA. Email: cmeyer@flmnh.ufl.edu

Cowrie snails (*Cypraea*) are diverse, well-known members of coral reef communities whose diversity peaks in the Indo-West Pacific triangle. As their overall diversity is comparable to other reef-associated taxa, we use the group as a model system to understand mechanisms that generate diversity in the region. A comprehensive phylogeny for the group based on 190 species from two mtDNA genes is used to test the relative roles of Center of Origin, Center of Overlap, and Center of Accumulation explanations. The phylogenetic hypothesis indicates the following patterns: (1) For center of origin, taxa endemic to the region are either a.) young (<3 MY) and often nested within a more widespread paraphyletic taxon or b.) older (>5 MY), deeper water species restricted to marginal areas of the triangle. (2) Evidence for center of overlap is evident in taxa where sampling has been more extensive (*C. mappa*, *C. arabica*, *C. tigris*). (3) There is little evidence for center of accumulation or refugia hypotheses playing a role in cowries as older peripheral taxa maintain their peripheral status (Cribrarula clade). However, the center of accumulation hypothesis is difficult to falsify without a good fossil record. For cowries, the diversity peak of the Indo-West Pacific triangle is clearly a mosaic of mechanisms operating at different time periods and within different arenas.

REGIONS OF MAXIMUM BIODIVERSITY AND RATES OF SPECIES TURNOVER IN STOMATOPOD CRUSTACEANS.

Reaka-Kudla, Marjorie*. *Department of Biology, University of Maryland, College Park, Md. 20742, USA. Email: mr9@umail.umd.edu

Within lineages of coral-dwelling mantis shrimps, species of smaller body size produce fewer larvae with lower dispersal potential, inhabit smaller geographic ranges, and show higher rates of speciation and extinction than species of larger body size. Among lineages that span the Central Pacific (CP), West Pacific (WP), Indo-West Pacific (IWP), and Indian Ocean (IO), populations reach larger body sizes along the margin of Africa and western Asia than on offshore islands of the IO; the largest range of body sizes occurs in the IWP continental region; and body sizes decrease toward the CP, with populations from atolls dwarfed relative to those from high islands. Endemism is high in the western IO, high in the IWP, low in the WP, and high in the CP. The Center of Origin (CO), Center of Accumulation (CA), and Center of Survival (CS) hypotheses all appear to operate, but the rate of species turnover (extinction/speciation) likely is critical for species richness among regions. Origination occurs in the IWP (predicted by CO) but also in peripheral areas (predicted by CA). Low dispersal of the small endemics, the diversity gradient, and the low endemism adjacent to the continental region, however, suggest that small peripheral species do not migrate and accumulate in the IWP (as predicted by CA). The ratio of extinction/speciation, however, likely is lower in the IWP continental area because of larger body sizes (high dispersal, low extinction) of some lineages there (predicted by CS).

LARGER FORAMINIFERA FROM THE SPERMONDE ARCHIPELAGO (INDONESIA) AND BOHOL (PHILIPPINES)

Renema, Willem* Nationaal Natuurhistorischmuseum PO Box 9517
2300 RA Leiden Email: Renema@naturalis.nnm.nl

Symbiont bearing larger foraminifera live in (sub)tropical seas. Previous studies have been shown that substrate type, light intensity (depth) and hydrodynamic energy are the most important parameters influencing larger foraminifera distribution patterns. In this study larger foraminifera of two carbonate seas have been studied, in order to find whether the same parameters affect larger foraminiferal distribution in mesotrophic conditions. At the sand cay type reefs in the Spermonde Arhipelago, depth and exposure related parameters were important parameters in determining the foram population. Highest densities were found in samples taken at the reef base. Hardly any larger foraminifera were observed shallower than 2m depth. The reefs around Cabilao constitute of steep walls and a shallow reef flat (<2m depth). The highest densities were observed on the reef flat, some meters from the reef edge. From 2m down to about 8m little foraminifera were found, while similar densities as in the Spermonde Archipelago were observed from 8m to 30m. Most species found at the reefbase in the Spermonde were not present around Cabilao. This shows that next to previously known parameters, also reef geometry is an important parameter in determining the fauna composition and density of larger foraminifera.

CENOZOIC HISTORY OF CORAL DIVERSITY IN THE INDO-WEST PACIFIC: GEOLOGICAL CONTROL OF AVAILABLE HABITATS.

Rosen B.* & Moyra Wilson. Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD, Great Britain. Email: b.rosen@nhm.ac.uk

The Indo-West Pacific is the most taxonomically rich region for numerous shallow-water marine organisms including zooxanthellate corals, but notwithstanding considerable research effort, this pattern continues to be enigmatic. The most popular explanation is that the region is a Centre of Origin (C-of-O) though other authors question this on cladistic grounds. An implicit prediction of the C-of-O model is that such regions should have a long history of species richness. For groups with high preservation potential like corals, one might expect this history to be reflected in their fossil record, yet such evidence has been largely neglected. We have quantified area of shallow-water carbonates of SE Asia through the Cenozoic as a proxy for availability of coral habitats, and compared this to the changing richness pattern of z-corals. Although suitable habitats were present throughout the Cenozoic, they increased dramatically early in the Neogene (c 25 Ma), coincident with the collision of Australia and SE Asia. Z-coral richness parallels this pattern, increasing four-fold around the same time. This and other evidence suggests that (1) the high biodiversity of the modern region is a surprisingly young feature, (2) the influence of geotectonics on biodiversity, particularly in controlling availability of suitable habitats, has been widely overlooked, and (3) these factors have been more important than the intrinsic evolutionary processes invoked by C-of-O advocates.

CORAL BARNACLES— DECLINE AND EXTINCTION IN THE ATLANTO-MEDITERRANEAN/EAST PACIFIC, DIVERSIFICATION IN THE INDO-PACIFIC DURING THE LATE CENOZOIC.

Ross, Arnold* & William A. Newman. *Scripps Institution of Oceanography, La Jolla, California 92093-0202 USA, Email: arross@att.net

The coral barnacles, first appearing in the Late Oligocene of the Caribbean, underwent diversification unparalleled by any other group of shallow-water sessile barnacles. An archaeobalanid ancestor, with a shell of six wall and four opercular plates, proceeded from an unspecialized, facultative, setose-feeding planktotroph to variously modified obligate commensals largely of corals. This not only led to a diversity of shell forms but to feeding on host coral tissues and ultimately to nutritional parasitism. Fragmentation of the Tethyan seaway, concomitant with polar cooling and wholesale extinctions of host corals, especially in Europe, the Mediterranean basin and eastern Pacific during the Tertiary, resulted in relict distributions and regional endemism. These events included Neogene and Quaternary extinctions of barnacle and coral genera in the western Atlantic/Caribbean which have not been replaced by originations. On the other hand, the development of the exceptional diversity of coral barnacles now evident in the Indo-Pacific was apparently tied to the survival and radiation largely of zooxanthellate corals there.

NATURE AND ORIGINS OF UNIQUE HIGH DIVERSITY REEF FAUNAS IN THE BAY OF TOMINI, CENTRAL SULAWESI: THE ULTIMATE "CENTRE OF DIVERSITY"?

Wallace, C.C*., Paulay, G., Hoeksema, B.W.H., Bellwood, D.R., Hutchings, P., Barber, P. H., Erdmann, M. and Wolstenholme, J. *Museum of tropical Queensland, Townsville, Australia 4810. Email: carden@mtq.qld.gov.au

The staghorn corals (*Acropora spp.*) of the Bay of Tomini in eastern Central Sulawesi may typify the maximal marine biodiversity associated with the idea of a "centre of diversity" in the central Indo-Pacific: other faunal groups have variable diversity, but unexpected species composition. Faunal assemblages from several phyla in this bay were assessed against phylogenetic and biogeographic data and biotic and environmental parameters in order to compare several hypotheses about the origins of the unusual species composition. It was found that the Togian Islands within the bay support a fauna with strong affinities to sites in the western equatorial Pacific, in all the studied groups except Stomatopoda. Both species composition and distribution of ecological functional groups is influenced by unusually calm and oligotrophic conditions in the islands and populations within the islands have various levels of genetic connectively to populations in other parts of Sulawesi, including complete isolation of some populations. It is proposed that these islands represent lagoonal refugia from Pleistocene lowstands, with affinities to similar refugia in the western Pacific. Additionally, the bay is possibly influenced by larval distributions from the Pacific through-flow current and there is little or no influence from the Indian Ocean.

ASPECTS OF BIODIVERSITY AND ENDEMISM IN THE OCTOCORALLIAN FAUNA OF THE TROPICAL WESTERN PACIFIC.

Williams, Gary C.*. *California Academy of Sciences, San Francisco, California, U.S.A. 94118 Email: gwilliams@calacademy.org

Recently acquired data from the southeast Asian region has allowed for a preliminary assessment of species diversity on coral reefs of the western Pacific. Regarding octocorallian coelenterates, the northern and eastern points of the high diversity triangle are estimated to be in the regions of southern Luzon (Philippines) and the Milne Bay area (Papua New Guinea). The western point has not yet been clearly defined, other than central Indonesia. A single dive site in the Philippines is shown to approximate the shallow-water (<30 meters depth) octocoral diversity (species richness) of the entire Caribbean region - exceeding one hundred species. Zooxanthellate octocorals of two of the world's largest coral reef regions, the western Pacific and the Tropical Western Atlantic, are compared. It is shown that the western Pacific is approximately nine times more diverse than the tropical western Atlantic. The tropical western Atlantic octocorallian fauna of shallow-water coral reefs (<15 m depth) is composed almost entirely of gorgonians, while these corals comprise only approximately 6% of the western Pacific fauna within a similar depth range. Two families make up 96% of the tropical western Atlantic fauna, while 92% of the western Pacific fauna is comprised of three soft coral families: Alcyoniidae, Neptheidae, and Xeniidae. The remaining western Pacific elements include helioporacean, stoloniferan, and pennatulacean taxa.

Session A8: Lessons from the Past: Reef Palaeoecology and Its Applications

FATES OF SKELETAL CARBONATE IN TROPICAL SEDIMENTS: HARSHEST TAPHONOMIC FILTER IN REEF ENVIRONMENTS?

Best, M.M.R*. *Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Ave., Chicago, IL60637, U.S.A., Email: mmrbest@midway.uchicago.edu

Environmental assessments in coastal environments rarely include baseline surveys before the onset of change. We can turn to sediments and skeletal death and fossil assemblages to investigate the past and develop longer time series on community composition and environmental conditions. In order to use this historical information, potential biases arising from the processes of fossilization need to be identified across environments. Study of both carbonate and siliciclastic settings in Caribbean Panama has provided insight into processes of skeletal preservation along environmental axes including sediment grain size, chemistry (carbonate, organic carbon, iron), and accumulation rates. Post-mortem condition of experimental and naturally occurring bivalve death assemblages is compared to coordinated environmental datasets. Sediment texture and chemistry show a strong relationship with post-mortem condition, with destruction being highest in reefal carbonate settings and shell persistence highest in iron-rich siliciclastics. These results imply that reef skeletal deposits are more highly filtered than adjacent habitats, though deceleration of damage accrual over time suggests information loss is not complete. Furthermore, when environments shift, siliciclastic sedimentation in some reefal areas may result in a greater fidelity of the reef skeletal fossil assemblage.

ARE THERE PROXIES FOR ENVIRONMENTAL STRESS IN LIVING AND FOSSIL REEF-BUILDING CORALS?

Burr,*S.A. Department of Geological Sciences, Snee Hall, Cornell University, Ithaca NY, 14853 . sab45@cornell.edu

Corals can be stressed by fluctuations in the parameters that control their growth and limit their environment. Solar irradiance, varying symbiont photosynthetic rates, volcanism, sedimentation, elevated nutrient levels, ENSO events, storms, ship groundings, disease, outbreaks of predators, and die-offs of herbivorous organisms that control the proliferation of algae are stressors must have existed in the Pleistocene and Holocene eras, but what should we look for as indicators in the fossil record? Stress does not always result in an obvious marker such as a community phase shift. The stable isotope fraction content of Holocene scleractinian coral skeletons has been used as a proxy for past climate, salinity, and average and seasonal temperature, and as such may act as a proxy for a bleaching event. Coral skeletal density can be a proxy for water temperature, light intensity, and nutrient supply. $^{13}C/^{12}C$ ratios can be indicators of ocean nutrient levels. The trace metal contents of Holocene scleractinian coral skeletons have been used as proxies for paleo ocean circulation and chemistry. Can these chemical proxies also record stress, disturbance, and/or disease in the fossil record? If proxies for coral stress exist, the Pleistocene and Holocene fossil record could become a source of information about the permanence of the damage done to coral reef communities by pathogens and other factors, the effect on the biodiversity of the reef community, and the prognosis for recovery of today's reef systems.

THE "PARADOX" OF GLOBAL MID-PALEOZOIC REEF EXPANSION DURING SUPER GREENHOUSE EPISODES.

Copper P.*, *Dept. Earth Sciences, Laurentian University,Sudbury, Ontario, P3E 2C6, Canada, Email: pcopper@nickel.laurentian.ca

Giant coral-sponge reef tracts of the silurian (wenlock) and devonian (eifel-givet) were common during greenhouse climate maxima, with average ssts at 24c-26c, and atmospheric pco2 16x to 24x today's. Epicontinental seas flooded equatorial cratons during sl highstands: reefs ranged to latitudes 50s, and c.60n. Reef builders were calcitic tabulate-rugose corals, aragonitic stromatoporoid sponges, aragonitic chloro- and calcitic rhodophytes, and diverse calcitic calcimicrobes. This paradox of optimal reef cum maximal greenhouse suggests: (1) warm, supersaturated calcite oceans enhanced precipitation, sequestering co2 otherwise suppressing caco3 production, (2) zooxanthellae were more abundant and efficient at removing co2 and buffering tropical mid-paleozoic oceans, (3) reef builders spread to higher latitudes during global warming episodes, (4) stratified, sluggish deep ocean waters were effective sinks for surplus co2 and p, except during las niñas events at mass extinction boundaries.

BRYOZOAN REEFS AND BRYOZOAN-RICH LIMESTONES IN THE MIDDLE ORDOVICIAN OF SOUTHWESTERN VIRGINA.

Cuffey R.J.* Cawley, J.C.; Lane, J.A.; Bernarsky-Remington, S.M.; Ansari, S.L.; McClain, M.D.; Ross, T.L.; & Savill, A.C. *Dept. Geosciences (Deike Bldg.), Pennsylvania State Univ., University Park, PA 16802, USA. Email: cuffey@ems.psu.edu

Bryozoan-built reef mounds are rare, small, exotic compared with coral reefs, but started early in their phylum's history. Several are preserved in thick gray fossiliferous limestones (upper Chazyan and lower Blackriveran) across southwestern Virginia, and were examined to understand critical aspects of such structures at that time. The bryozoan reefs are small (meter-sized) crust-mounds built largely by the sheet-like to massive trepostome *Batostoma chazyensis*; the resulting rock averages cruststone (with packstone to wackestone matrix). Much larger (km-scale) regional calcarenite shoals and banks contain considerable skeletal sediment derived from break-up of scattered branching bryozoan colonies; these rocks are most commonly floatstone (with packstone to grainstone matrix). Shallow shoals host trepostomes (*Nicholsonella acanthobscura*) and bifoliates (*Pachydictya sheldonesis, Stictopora fenestrata*), deeper banks the trepostomes *Anaphragma hermitagensis* and *Nicholsonella inflecta*. Locally, the branching trepostome-like fistuliporoid *Constellaria islensis* forms dense but non-reefal thickets (packed rudstones with micstone to mud-stone matrix). Overall, 51 bryozoan species have been identified here, some in frame-building and others in sediment-forming constructional ecologic roles.

MID-HOLOCENE FOSSIL REEF AT JEPARA, CENTRAL JAVA, INDONESIA: A BENCHMARK OF NEARSHORE REEF DIVERSITY AND COMPOSITION BEFORE HUMAN DISTURBANCE?

Edinger E.N., Joyce Lundberg, Michael Risk.* *Dept. of Earth Sciences, Laurentian University, Ramsey Lake Road, Sudbury, Ontario, Canada, P3E 2C6. Email: eedinger@nickel.laurentian.ca

Modern nearshore reefs of the Java Sea, Indonesia, have been subjected to high levels of anthropogenic sedimentation, sewage, agricultural and aquacultural runoff for the past century or longer. Comparison with fossil reefs may show the nature and degree of change in reef ecology associated with long-term pollution. Fossil reef exposures in the Jepara region, Central Java, include reef flat facies from siliciclastic dominated nearshore environments which grew approximately 7000 ybp during the Holocene hypsithermal sea level highstand. Species richness of the fossil reef was not significantly different from that of the degraded shallow modern nearshore reefs, nor from unpolluted reefs growing among mangroves. Microatolls, massive corals, and branching corals dominated the fossil reefs. Multilobate submassive corals were much more abundant on the modern degraded reefs than in the fossil reefs. While fossil reefs were dominated by typical reef flat corals, polluted modern reefs were dominated by taxa tolerant of turbid or polluted water, especially *Goniopora djiboutiensis*, *Galaxea fascicularis*, *Alveopora* spp., and *Lobophyllia hemprichii*, and taxa typical of reef flats and shallow reef fronts. *Acropora* corals were rare on both fossil reefs and degraded modern reefs. Pleistocene and Holocene fossil reefs can provide a useful pre-pollution benchmark of nearshore reef coral species composition.

MIRRORS, PRISMS, OR SNAPSHOTS: HOW CLOSELY DO FOSSIL REEFS RESEMBLE SOURCE LIFE AND DEATH ASSEMBLAGES?

Edinger E.*, John Pandolfi, Russell Kelley. *Dept. of Earth Sciences, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada. Email: eedinger@nickel.laurentian.ca

The diversity and taxonomic composition of Holocene raised fossil reefs was compared with those of modern reef coral life and death assemblages in adjacent moderate and low-energy shallow reef habitats of Madang Lagoon, Papua New Guinea. Species richness per sample area and Shannon-Weiner diversity (H') were highest in the fossil reefs, intermediate in the life assemblages, and lowest in the death assemblages. The taxonomic composition of the fossil reefs was most similar to the combined composition of the life and death assemblages from the modern reefs adjacent to the two fossil reefs. The Madang fossil reefs represent depth-specific snapshots of the combined life and death assemblages as they existed at the time the reef was uplifted. Lagoonal facies of fossil reefs are dominated by the dominant sediment producing taxa, which are usually, but not necessarily, the most abundant in the life assemblage. Rare or slow-growing taxa accumulate more slowly than the encasing sediments, and are under-represented in fossil reefs. Nevertheless, Holocene and Pleistocene fossil reefs provide a time-integrated historical record of community composition, and may be used as long-term benchmarks for comparison with modern, degraded, nearshore reefs. Comparisons between fossil reefs and degraded modern reefs display gross changes in community structure more effectively than they demonstrate local extinction of rare taxa.

MOLLUSK ASSEMBLAGES WITHIN PLEISTOCENE AND MODERN REEFS RECORD THE ECOLOGICAL VARIABILITY OF BACKREEF AREAS.

Gardiner, L.* University of Georgia, Department of Geology, Athens GA 30605, USA. Email: gardiner@gly.uga.edu

Previous interpretations of paleoenvironmental conditions from Pleistocene reef deposits have relied upon the predicable zonation of coral species identified in modern reef settings. However, mollusks from different Pleistocene and modern backreef locations with similar coral assemblages do not have such constancy in different locations. Mollusk assemblages from two different geographic locations of Pleistocene reef building within the Bahamas were investigated through identification of over 4000 mollusk specimens. The two mollusk assemblages were significantly different (MANOVA, $p<0.001$) despite similar coral assemblages. Investigation of over 6000 mollusk specimens from modern Bahamian backreefs also revealed high variability of mollusk death assemblages associated with variable habitats. Thus, differences in the Pleistocene mollusk assemblages may be attributed to variability of paleohabitats within Pleistocene backreef areas. The mollusk assemblages within backreef coral deposits will differ if adjacent habitats are unlike, regardless of the similarity of corals. While corals have been cited as demonstrating the constancy of Neogene reefs, mollusks from different fossil reef localities demonstrate the ecological patchiness and habitat variability within shallow platform environments. Therefore, investigation of mollusks from ancient reef deposits provides important paleoecological information about reefs and adjacent near-reef habitats that is not typically obtained from analysis of coral zonation pattern.

TAPHONOMY OF REEF BUILDING CORALS AT INTRA- AND INTER-PROVINCIAL SPATIAL SCALES: IMPLICATIONS FOR PALAEOECOLOGICAL STUDIES.

Greenstein, Benjamin J. *, John M. Pandolfi. Department of Geology, Cornell College, 600 First St. West, Mt. Vernon, IA 52314 U. S. A.; Email: bgreenstein@cornell-iowa.edu

In order to interpret more accurately the results of palaeoecological studies of Pleistocene and Holocene fossil reef coral assemblages, we have investigated the taphonomic processes affecting coral death assemblages on a variety of spatial scales. We have made comparisons between shallow (reef tract and patch reef) and deep (20 and 30 m) reef environments of the Florida Keys, between shallow reef environments of the Florida Keys and Bahamas, and between shallow reef environments of the tropical western Atlantic and Indo-Pacific Provinces. Dead corals were examined to determine the extent of coverage of a variety of physical, chemical and biological agents of degradation. The results of this multi-year study of taphonomic processes affecting the common reef-building corals of these regions reveal complex patterns of degradation between and within reef environments and coral colony growth forms. The influence of both wave energy regime and coral colony growth form on the amount of degradation suffered by dead corals is evident from our inter-provincial comparisons. However, within-province differences in preservation potential exist, and are related to background sedimentation rate and light availability. Differences observed between and within reef provinces suggest that the fossil record of reef corals can best be understood if studies of reef coral palaeoecology are coupled with taphonomic studies in closely analogous modern environments.

REEFFORMING POTENTIAL OF RECENT AND FOSSIL CORALS.

Gudo, Michael*. *Forschungsinstitut Senckenberg, Department for Comparative Anatomy, Senckenberganlage 25, 60325 Frankfurt am Main, Germany, Email: m.gudo@em.uni-frankfurt.de

Due to the abilities of Rugosa and Scleractinia to build reefs, two processes have to be distinguished: 'reef-building' and 'reef-forming'. Reef-building is determined by the environment, the climate, and life assemblages, and reef-forming is detemined by the bauplan of the soft bodies and the individual growth potential. Reef-forming depends on the ability to build an organism with an endless number of polyp-modules that share the volume of their gastric cavities. Due to the bauplans of polyps four types of reef-forming will be presented: solitary corals, colonial corals, stock-corals and autositary corals. Solitary corals are single polyps excreting a carbonate substrate, colonial corals are assemblages of individuals, in stock-corals the polyps share their carbonate substrate but they are individuals, and in autositary corals the polyps share their gastric cavities, which means that the polyps are functional units (modules) in one large organism. The solitary, colonial and the stock-corals only have a low reef-forming potential, but the autositary corals have a high potential of reef-forming. Due to their bauplan the Rugosa had a limited number of growth sectors so that they build solitary, colonial or stock-corals. But the Scleractinia have an unlimited (exponentially increasing) number of growth sectors and consequently they were able to build autositary corals and they have an high reef-forming potential.

RELATIONS BETWEEN BIO-COENOCLINES AND TAPHO-COENOCLINES OF LARGER FORAMINIFERA IN FRONT OF CORAL REEFS.

Hohenegger, Johann * and Elza Yordanova. Institut für Paläontologie, Universität Wien, A-1090 Wien, Austria. Email: johann.hohenegger@univie.ac.at

Larger Foraminifera living on coral reef slopes show strong habitat differences. Since all house symbiotic algae, light attenuation and water energy are the most important limiting factor that must be dealt with test structures. The local topography influences the hydrodynamic regime leading to various substrates. Since all factors correspond to depth, species are restricted to small intervals along the depth gradient. A sequence of assemblages correlated to an environmental factor is called a coenocline. Comparisons between living and death assemblages of larger foraminifera are carried out at a NW-Pacific island slope. Transport is estimated by comparing relative frequencies between living individuals and empty tests. The complex slope topography leads to allochthonous specimens that additionally hamper the relation between coenoclines of living individuals (bio-coenoclines) and empty tests (tapho-coenoclines) based on depth displacement. On the one hand, specimens living in backreef regions are transported into the fore reef areas during waning tropical cyclones, while elements of relict sediments, on the other, are reworked in the deeper slope during these episodic events. Both factors, in combination with down-slope transport and slope inclination, disguise the clear depth dependence of living larger foraminifers as manifested in bio-coenoclines.

BIOLOGICAL VERSUS GEOLOGICAL REEF COMMUNITIES AT BUCK ISLAND, U.S. VIRGIN ISLANDS.

Hubbard, D.K.*, Bythell, J., Gladfelter, E. Dept of Geology-Oberlin College, Oberlin, OH, USA, 44074. Email: dennishubbard@oberlin.edu

Both distribution and abundance of corals in seven cores from Buck Island National Reef Monument are similar to the patterns quantified by over two decades of repeated surveys. In addition, differences in accretionary styles in the northern versus southern reefs over the past 7000 years mimic differences in present coral-community structure. Along the northern reef, protected from most major storms, the zonation pattern is well-delineated with few corals from one zone being found in others. Along the more frequently disturbed southern reef, coral zonation was mixed in the cores, as it is on the reef today. The distribution of *Acropora palmata* in cores compares best with the 1976 survey conducted before the devastation of the *A. palmata* community by White Band Disease. This may suggest that such afflictions are relatively new to Caribbean coral reefs. The core data largely agree with averaged patterns seen over the duration of the survey; they often are at odds with individual surveys. This points out both the short-term plasticity of the reef community and the importance of a well-constrained and longer-term data base when addressing questions about either long-term reef stability or the importance of recent changes seen on reefs throughout the Caribbean, and probably elsewhere.

TAPHONOMIC COMPARISON OF MIDDLE EOCENE-EARLY OLIGOCENE CARBONATES.

Nebelsick J.*, Bassi, Rasser. *Inst. Geology & Palaeontology, Univ. Tübingen. Sigwartstr. 10, D-72076 Tübingen. Email: nebelsick@uni-tuebingen.de

The middle Eocene to Early Oligocene time period is generally recognized for its paucity of coral reefs and rapid change-over of major carbonate facies types. We have analyzed different taphonomic aspects of the major facies types recognized in circum-alpine, middle Eocene to Early Oligocene carbonates. These carbonates are characterized by a wide variety of facies types dominated not only by larger foraminifera, but also coralline algae, corals and bryozoans. Important changes of facies composition and distribution are caused by extinction events of larger foraminiferal taxa (alveolinids, large *Nummulites*, *Orbitolites* and orthophragminids) and the development of other facies types. Reefs as such do not constitute a major facies type and carbonate build-ups seem to be restricted to coral patches and thicket as well as larger foraminiferal banks. We use a microtaphofacies approach, analyzing such factors as disarticulation, fragmentation, abrasion, bioerosion and encrustation which are readily recognizable in thin section analysis. This comparison shows important differences in taphonomic signatures which can be related to variations in the skeletal morphology of the constituent components as well as general depositional environment. These differences of preservation should help in the general ecological interpretation of different facies types. This approach can also contribute to answering questions concerning the paucity of reef formation and rapid change-over of facies types formed during this important transitional time in the general development of carbonate facies and reefs.

PREDICTING REEF AND SURROUNDING ENVIRONMENTS FROM THE TAPHONOMIC CONDITION OF MOLLUSK REMAINS.

Parsons-Hubbard, K.M., *Oberlin College, Oberlin, OH 44074, Email: karla.hubbard@oberlin.edu

Reef-related zonation patterns are difficult to decipher in the record of fossil reefs. Much of the argument over the classification of ancient reefs has centered around the determination of reef core vs. flank beds and surrounding environments. As the "framework" in the reef core is increasingly composed of in-situ but disturbed colonies and debris, it becomes more difficult to differentiate the core from flank deposits and surrounding associated environments. What would help is a biomarker that is sensitive to subtle environmental differences between the reef and these surrounding areas. Hundreds of mollusk remains were collected from the open shelf, reef proper, back reef, sandy lagoon, sea-grass bed, mud-bottom, and beach on the north coast of St. Croix, U.S. Virgin Islands. Each shell was characterized according to breakage, color loss, surface condition, and epibiont encrustation. Taphonomic data for each shell sample were run through a discriminant analysis to establish a predictive model for each of the reef-associated environments. When "unknown" bivalve remains were analyzed based on the model, the model predicted the correct depositional environment more than 75% of the time for all environments except for the grassbed (which was correctly identified 60% of the time). Results were much more sensitive than taxonomically-based cluster analyses for the same shells. Because mollusks have been a common reef-associated group throughout much of the Phanerozoic, the utility of taphofacies analysis to interpretations of ancient reef deposits may prove to be very useful, especially given the fact that taxonomic identity changes, while taphonomic signatures are more constant through time.

STORM HORIZONS WITHIN PLEISTOCENE SHALLOW WATER REEF FACIES: LONG-TERM RECORDS OF STORM DEPOSITION AND COMMUNITY RESPONSE.

Perry, C.T.*. Dept. of Environmental & Geographical Sciences, Manchester Metropolitan University, Manchester M1 5GD, U.K. Email: c.t.perry@mmu.ac.uk

Changes in community composition, coral fragmentation, and mobilisation of coral rubble and sediment, are well documented following hurricane impacts on reef systems. Whilst a number of modern studies have indicated the potential for relatively rapid recovery of coral communities following such natural disturbance events (especially via regeneration of fragmented corals), combined anthropogenic (e.g., over-fishing, pollution) and disease (e.g., white band disease, *Diadema* die-off) events often result in both delayed recovery and subsequent major community shifts. These may, however, give an unbalanced (and perhaps negative) view of community response to storm events under undisturbed post-storm conditions. Uplifted, shallow water (*Acropora palmata* dominated) facies in the Pleistocene reef terraces of Barbados record evidence of multiple storm deposition events over timescales (10^2-10^4 years) that are beyond the scope of modern studies. Storm horizons are identified using high resolution field mapping and analysis of epilithic community successions preserved on *A. palmata* rubble

HYDRODYNAMIC SELF-RIGHTING IN *MANICINA AREOLATA*, A STRATEGY WITH PALAEOECOLOGICAL SIGNIFICANCE.

Piller, Werner E.*, B. Hubmann, B. Riegl. *Institut für Geologie und Paläontologie, Karl-Franzens-Universität Graz, Heinrichstraße 26, A-8010 Graz, Austria. Email: werner.piller@kfunigraz.ac.at

The scleractinian *Manicina areolata* is a common coral on Caribbean hard and soft substrata and was studied at Lee Stocking Island (Exuma Cays, Bahamas). It is not only found on reefs but also on bioclastic sand with seagrasses. Investigated coralla ranged in size from 2 to 10 cm, growth form varied from conical with round to oval cross-section to turbinate forms with few meanders and flat oval cross-section. The conical morphotype was usually attached to hard substratum, while the turbinate morphotype was usually unattached and upright, in soft substratum. In infratidal areas, both attached and unattached turbinate forms were found in close vicinity, however, conical attached forms were rare. Habitats with sandy softgrounds, where free-living turbinate morphotypes were common, were influenced by strong tidal currents with concurrent danger of burial or "disorientation" of the coralla. Investigations in a flume channel showed that the colony shape itself led to passive cleaning and self-righting, which was achieved by the flat-turbinate morphology, with a concave side and a flat to slightly convex opposite side, under high current speeds. The concave side, and particularly the median lobes formed by many meandroid coralla, were the critical morphological factors. Grooves formed in between the lobes channelled currents in a way that scour underneath the coral and drag produced by the lobes allowed passive self-righting. This could be used to explain ecological strategies in similar-shaped fossil solitary corals.

LATE EOCENE CRUSTOSE ALGAL BUILDUPS OF THE ALPINE FORELAND - A NEW TYPE OF CORALLINE ALGAL REEFS?

Piller, Werner E. * and Michael W. Rasser. Institute of Geology and Paleontology, University of Graz, Heinrichstrasse 26, A-8010 Graz, Austria. Email: werner.piller@kfunigraz.ac.at

Late Eocene sediments of the Upper Austrian Molasse Zone contain up to 80 m thick red algal limestones, which are underlain by up to 40 m thick siliciclastic series. Red algal limestone facies are dominated by Maërl sediments (i. e., coralline algal branches, rhodoliths, and their detritus). Up to 7 m thick crustose algal buildups develop from rhodolith accumulations. The buildups consist of up to 0.5 - 10 mm thick consecutive coralline algal crusts, mainly formed by *Neogoniolithon* sp., as well as crustose corals; other biota, such as peyssonneliacean algae, benthic foraminifera, bryozoans and serpulids, are rare. Small laminar rhodoliths can occur within the framework. Growthforms of *Neogoniolithon* sp. cause considerable constructional cavities, which are filled by finegrained bioclasts and micrite. Modern crustose algal buildups are known from tropical to temperate environments. Tropical and subtropical buildups are restricted to the intertidal/shallow subtidal and usually develop from coral reefs. Temperate buildups are known from the Northern Atlantic and the Mediterranean. They lack corals and either occur in the rocky intertidal or on Maërl sediments from 30 to 150 m water depth. The studied coralline algal buildups are unique in earth history due to the combination of framework building crustose corallines and corals within a Maërl-dominated sediment.

DECIPHERING CHANGE IN HOLOCENE REEF COMMUNITIES

Precht, William F.*, Richard B. Aronson and Ian G. Macintyre. PBS&J, 2001 NW 107th Ave., Miami, FL 33172, Email: bprecht@pbsj.com

Coral reefs of the Caribbean have been in flux for the past few decades. Among the changes has been the near elimination of the dominant coral species at intermediate depths, *Acropora cervicornis* (staghorn coral). Whether the transition is natural or the result of human disturbances is a topic of strenuous debate. To address this issue, we must ask the question, "Did episodes of reef degradation occur in the past, before the era of human interference, or is the current state of coral reefs unique to our time?" Because coral reefs are both geologic and biologic entities, it should be possible to observe the effects of various disturbances in ecological time, detect historical changes in the fossil record, and deduce the multi-scale processes behind those patterns. We have undertaken a multidisciplinary approach of this sort to decipher the Holocene history of lagoonal reef complexes in Belize. Catastrophic mortality of staghorn coral populations during the 1980's was documented using standard ecological reef-monitoring techniques. Subsurface investigation of these reefs showed that the recent collapse of staghorn coral populations in the Belizean lagoon is without precedent in at least the last few millennia. The novelty of recent events suggest that the current state of the Belizean reefs was produced by a combination of factors unique to our times. If these Belizean reefs are representative of the Caribbean as a whole, the possibility of an anthropogenic role in their decline cannot be discounted and warrants further study.

MIOCENE BIOSTROMAL CORAL FACIES (LEITHA LIMESTONE, AUSTRIA) – LOW DIVERSITY CORAL CARPETS AND THEIR ACTUALISTIC INTERPRETATION.

Riegl, Bernhard*, Werner E. Piller. Institut für Geologie und Paläontologie, Karl-Franzens-Universität Graz, Heinrichstrasse 26, 8010 Graz, Austria. Email: bernhard.riegl@kfunigraz.ac.at

The Leitha Limestone of Badenian age (Middle Miocene) at the type-locality in Grosshoeflein (Burgenland, Austria) is characterized by biostromal coral-rich strata which were re-interpreted from an actualistic viewpoint in comparison with Recent Caribbean and Arabian Gulf coral communities. The investigated outcrop (quarry "Fenk") is interpreted as a sequence of biostromal framebuilding coral carpets and non-framebuilding coral communities, which alternate with bryozoan and corallinacean calcarenites as well as bivalve beds. A sequence of 10 coral intervals was observed, which can be grouped into 2 coral carpet types (high carpet framework, low bushy framework), four non-framework communities and one bivalve/coral community. All coral communities were dominated by Porites species. Within this sequence, no unequivocal indication for sea-level changes at the time of deposition was apparent. In comparison with Recent coral systems in the Caribbean (Bahamas, Florida, Cayman Islands) and the Arabian Gulf (Dubai, UAE), we interpreted the different coral facies as having been deposited in similar water depths. We assume that the facies represent different lateral positions within the same spatially highly complex environment which is illustrated by a distribution map of benthic biota in the Arabian Gulf, a structurally comparable system that illustrates what the likely lateral distribution of the Miocene facies could have looked like.

THE CLOSURE OF THE TETHYAN SEAWAY AND ITS INFLUENCE ON CORAL FAUNAS.

Schuster, Frithjof*. *Research Institute Senckenberg, Senckenberganlage 25, D-60325 Frankfurt, Germany. Email: fschuste@sngkw.uni-frankfurt.de

The closure of seaways has a profound influence on the distribution of benthic organisms as it forms invincible barriers. Additionally, oceanic circulation systems already change previously to such an event. The Tethyan Gateway which connected the Atlantic Ocean with the Tethyan Sea during the Mesozoic and Cenozoic was closed during the Early Miocene due to the collision of the African/Arabian plates with the Eurasian continent. Oligocene and Early Miocene coral faunas were investigated in the critical region now covering the central and eastern part of the Mediterranean, NE Africa, and the Middle East. Highly diverse Late Oligocene coral assemblages from central Iran show marked differences to coeval coral occurrences of the Mediterranean Tethys. Several new species and faunal elements known only from the Indopacific area are taken as evidence for a beginning faunal separation as early as the Late Oligocene, a time when the Tethyan Gateway still provided an open marine connection. A species level based comparison of the Iranian fauna with species known from the Mediterranean Tethys show a correspondence of 27 per cent. The main reason for this early faunal separation is seen in a change of the oceanic circulation system responsible for the larval distribution of corals. Fluctuating sea levels locally lead to evaporation phases during the Aquitanian but renewed marine conditions prevailed until the Burdigalian. Burdigalian coral faunas of northern Iran (Qom Basin), Turkey (Mut Basin), and Egypt (northern Gulf of Suez) are all very similar suggesting an open marine connection between these regions.

BIONTS ON MOLLUSCS IN MODERN AND FOSSIL REEFS AS USEFUL INDICATORS OF ENVIRONMENT AND REEF HEALTH.

Walker, S.* and Gardiner, L. Department of Geology, University of Georgia, Athens, GA 30602. Email: swalker@gly.uga.edu

Coral reef communities contain molluscs and bionts (bioeroders and encrusters) that can be used to interpret modern and fossil reef community diversity, associated environments, and relative reef health. Shells of molluscs and their associated bionts were examined along beach-to-reef transects from two Recent sites: a stressed reef (i.e., Lindsey Reef, LR: few living corals; algal cover dominant) and a less stressed reef (i.e., Telephone Pole Reef, TPR: lacking *Acropora cervicornis*) from San Salvador Island, Bahamas. Most (80%) of the TPR shells had bionts, whereas 30% of the LR shells had bionts. The TPR site had the highest biont and mollusc diversity. The LR site was dominated by a foraminiferan, *Homotrema*, and characterized by a bryozoan species, a vermetid (*Dendropoma*), and a general lack of coralline algae and bioeroders. Whereas, the TPR site was dominated by the foraminiferan (*Planorbulina*), five species of bryozoans, coralline algae, and bioeroders. We then compared our Recent findings to fossil molluscs from a Pleistocene reef on San Salvador Island: 80% of the fossils had remarkably preserved bionts: *Homotrema* and *Planorbulina* were rare; *Dendropoma* was relatively common; bryozoan diversity was higher than reported here for the TPR reef; bioeroders were relatively common.

NOVEL PALAEOECOLOGY OF A POST EXTINCTION REEF:FAMENNIAN (LATE DEVONIAN) OF THE CANNING BASIN, WESTERN AUSTRALIA

Wood, R.* *Dept. of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK. Email: rw43@esc.cam.ac.uk

Reefs are widely supposed to be particularly susceptible to mass extinction events, and to survive only as low-diversity, remnant communities dominated by holdover and disaster taxa. The Famennian (Late Devonian) reefs exposed in the Windjana Limestone, of the Canning Basin, Northwestern Australia demonstrate, however, that a quite novel reef ecology was established in the immediate aftermath of the Frasnian/Famennian mass extinction event. Here, diverse calcimicrobes (including Rothpletzella spp., Shuguria spp., Ortonella, and Girvanella) together with bryozoans, brachiopods, and stromatoporoid, sphinctozoan and lithistid sponges, grew as complex framework intergrowths in previously undocumented morphological forms, forming spectacular elevated laminar to platy structures up to 3 m in diameter and 0.35 m thick. At least fifteen morphospecies of lithistids are now identified, where only two were previously documented. These communities show no substantial reduction in biodiversity compared to Frasnian counterparts, nor any change in tiering or loss of complex ecological interactions. These observations suggest that where stable carbonate platforms persisted after mass extinction events, reef-building could continue. More importantly, they demonstrate that no protracted interval of time was necessarily required for either recovery to ecological stability, or for completely new reef ecologies to assemble. Such studies highlight the need to document ecosystem recovery after mass extinction and other catastrophic events using detailed palaeoecological analyses in addition to simple compilations of global biodiversity changes.

LIVING AND DEAD MOLLUSCS ON CORAL REEFS IN THE NORTHERN RED SEA – IMPLICATIONS FOR THE FOSSIL RECORD

Zuschin, Martin*, *Institute of Palaeontology, University of Vienna, Althahnstr. 14, A-1090 Vienna, Austria. Email: martin.zuschin@univie.ac.at

Reef-associated hard substrata (reef flats, reef slopes, coral carpets, coral patches, rock grounds), were studied in order to determine the agreement of assemblages of living and dead shell-bearing molluscs. A total area of 340.5 m_ was investigated and 2846 individuals were counted at 68 sample localities ranging from shallow subtidal to 40 m water depth. Most taxa found dead in the study area were also found live and *vice versa*. Strong differences exist in the proportion of living and dead fauna, dominant taxa, and molluscan distribution patterns. The ratio of live to dead molluscs is high. Living molluscs are strongly dominated by taxa with distinct relations to corals, mainly *Pedum*, *Coralliophila* and *Tridacna*, and the encrusting gastropod *Dendropoma*. Five distinct groups of living molluscs can be differentiated and related to specific hard-substrata. In contrast, the death assemblages are always strongly dominated by encrusting bivalves, mainly Chamoidea and Spondylidae, and cerithiid gastropods in varying dominances. The observed bias is due to the close relationship of molluscan life habits and post mortem history of shells. Molluscs that live permanently attached to or within living corals (mostly bivalves and encrusting *Dendropoma*) can easily be overgrown after death by the large amounts of living substrata available. Rapid transport of dead shells into surrounding sediments or into crevices within corals is typical of gastropods that feed on corals. Molluscs that colonize dead surfaces preferentially accumulate on rock grounds.

Session A9: Reef Response to Rapid Climate and Sea Level Change During the Late Quaternary

THE RESPONSE OF CORAL REEFS TO SEA SURFACE TEMPERATURE CHANGE: EVIDENCE FROM THE RAISED HOLOCENE REEFS OF KIKAI-JIMA.

Abram N.J.* J.M. Webster, P.J. Davies and W.-Chr. Dullo. School of Geosciences, Division of Geology and Geophysics, The University of Sydney, Australia 2006. Email Address: Nerilie.Abram@anu.edu.au

The Holocene reefs of Kikai-jima (central Ryukyu Islands, Japan) provide a rare opportunity to define both environmental and biological variations within a reef ecosystem over a geological time frame. This study documents the palaeoenvironmental records archived in the $\delta^{18}O$ and $\delta^{13}C$ isotopic composition of four Holocene *Porites* cores collected from the raised Holocene reef terraces of Kikai-jima. These coral samples record mean sea surface temperatures (SST) of 23.5ºC at 4220yBP, falling to 22.2ºC at 3790yBP and to a minimum of 21.4ºC at 3400yBP. After this time mean SST rose to 23.5ºC at 1860yBP before reaching modern day conditions of 24.9ºC. During the cool water period between 3790yBP and 3400yBP the coral isotope data indicate that SSTs were below the currently accepted 18ºC minimum temperature for reef development approximately 14% of the time. Ecological variations preserved in the raised Holocene reef terraces of Kikai-jima can be explained by these variations in Holocene sea surface temperature.

PARADOXICAL OCCURRENCE OF CORALGAL REEFS ON THE SOUTH TEXAS SHELF EDGE DURING LAST DEGLACIATION.

Belopolsky A.V.* and André W. Droxler Rice U., *Dept. of Geology & Geophysics, Houston, TX 77005. Email: andre@rice.edu

Southern Bank, a relict coralgal reef located 55 km offshore Corpus Christi on the edge of the South Texas Shelf, is one among twenty individual coralgal reefs that flourished during the first half of the last deglaciation within an embayment between the Rio Grande and Brazos/Colorado shelf margin lowstand deltas. The elevations of each individual reef crest fall between - 58 and - 62 m below sea level. Single channel seismic profiles across some of the reefs and a grid of 8 very high resolution 24 channel seismic profiles, acquired in the area of Southern Bank by IFREMER and Rice, demonstrate that the thickness of the lower part of the reefal edifice, buried in an Holocene siliciclastic mud blanket, is at least as thick as 15 to 20 m. Including the average 15 m thickness of their outcropping part, each individual reefal edifice is, therefore, 30-50 m thick. Once established on top of lowstand siliciclastic coastal deposits, the different coral reef edifices flourished and were paradoxically capable of keeping up with very fast rates of sea level rise during the first part of the deglaciation. Moreover these reef systems grew during a time when large volumes of fresh water were discharged into the Gulf of Mexico through the Mississippi River due to the melting of the Laurentide continental ice sheet. The reef demise during the Younger Dryas can be explained by the establishment of colder SST in the Gulf of Mexico and a contemporaneous significant sea level fall. The reef is expected to have drowned at the end of the Younger Dryas when sea level rose sharply (Melt-Water Pulse-1B?). Southern Bank is, therefore a rich source of information concerning sea-level fluctuations, climate change, and the environmental conditions associated with rapid reef growth in siliciclastic marginal seas.

SOME EFFECTS OF REEF ARCHITECTURE ON SEA LEVEL CURVES DERIVED FROM REEF CORES.

Blakeway,. D.* *Department of Geography, University of Western Australia, Nedlands, W.A. 6907 Australia, Email: blakeway@cyllene.uwa.edu.au

Three conditions must be met for reef growth curves derived from core to accurately represent sea level curves: reefs must colonise the substrate immediately it is submerged, reef growth must keep pace with sea level, and the core must penetrate the first-formed reef. In environments where reef colonisation occurs in patches, and/or the topography of the growing reef is irregular, the third condition may be difficult to achieve. In this paper I use computer simulations to determine the extent to which growth curves derived from such reefs may misrepresent the actual sea level curve. The approach I have used is to simulate reef growth under a predefined pattern of sea level rise, then examine how closely the growth curves derived from 'cores' through the reefs represent the actual sea level curve. The results indicate that cores generally underestimate the timing of reef colonisation and overestimate the reef growth rate. Proxy sea level curves derived from cores will tend to indicate a later and faster sea level rise than was actually the case. Alternatively, if an independent regional sea level curve already exists, reef growth will seem to lag sea level rise, then rapidly catch up to sea level. This potential for error should be taken into account in core-based studies of reef growth and sea level change.

DISCOVERY OF A SUBMERGED, EARLY HOLOCENE, RELICT REEF OFF GRAND CAYMAN: A CASUALTY OF THE 8.2 KA COLD EVENT?

Blanchon P.*. *Coral Reef Systems Lab, U.A. Puerto Morelos, ICMyL, National Autonomous University of Mexico, Email: blanchon@icmyl.unam.mx

Ten short cores drilled on the eastern shelf off Grand Cayman have revealed the presence of a relict, early Holocene, breakwater reef at a depth of 21 m below msl. Cores from the crest of the relict reef consist not of *in-situ* coral framework but of cobbles of *Acropora palmata* in a matrix of skeletal sand—a facies that is identical to the modern reef-crest deposit. The surface of the relict reef slopes seaward from -21 to -24 m and, in some areas, is overlain by up to 1 m of mixed-coral framework containing severely bioeroded stumps of *A palmata* and other corals. In other areas, this veneer is absent and marine abrasion has produced furrows that cut down into the relict reef surface. Dating the reef surface gives U-Th TIMS ages that range from 9878 ±97 to 8122 ±101 Cal. years, indicating that reef growth had stopped by ~8.1 Cal. ka. The depth of the relict breakwater reef around Grand Cayman is close or identical to the depth of relict reefs reported from other Caribbean islands. Radiocarbon dating of those reefs indicates that they ceased accreting in a narrow window between 7-8 ^{14}C ka and had re-initiated in new positions 5-10 m higher up slope by 6-7 ^{14}C ka. When the dates of reef demise on these islands are calibrated for secular variation in atmospheric ^{14}C production, the demise of relict reefs across the Caribbean clusters around 8 Cal. ka—closely matching the age of reef demise on Grand Cayman. The cause of this Caribbean-wide reef demise is uncertain, but has been previously attributed to a rapid sea-level jump caused by ice-sheet collapse (CRE-3).

GROWTH STRATEGY OF THE UPLIFTING POSTGLACIAL REEF OF URELAPA IN VANUATU (SOUTHWEST PACIFIC).

Cabioch G.*, Kirsten A. Banks-Cutler, Frederick W. Taylor, George S. Burr, Jacques Récy, Lawrence R. Edwards, Thierry Corrège, Warren J. Beck. * IRD, BP A5, 98.848 Nouméa cedex, Nouvelle-Calédonie. Email: cabioch@noumea.ird.nc

The cores recovered into the uplifting reef of Urélapa at Espiritu Santo in Vanuatu (Central Vanuatu island arc), reveals the most continuous postglacial growth record for the last 22 kyr. The reef settled during the last glacial maximum and, then, provide data on environmental changes during the deglacial period in Vanuatu. The ability of reefs to grow continuously during the last 22 kyr also provide additional informations on the initiation and development factors of the regional postglacial reefs. Although the plaoesea surface temperatures were 3 to 4°C colder than the modern ones during the former period of the sea level rise (Taylor *et al.*, 2000), the reef was able to settle and kept up the sea level. But at around 11-12 ka, a clear change of biofacies informs on a change of growth strategy, the reef catching up the sea level. In the west Pacific, the delay in the settlement and the development of postglacial reefs appears to depend on a lack of suitable substrate and accomodation space. These last factors could be dominating parameters of the postglacial reef growth accompanying temperatures cooler than present.

GEOLOGICAL EVOLUTION OF THE NINGALOO REEF SYSTEM DURING THE LATE QUATERNARY.

Collins, Lindsay B.* Zhong Rong Zhu, Karl- Heinz Wyrwoll, and Anton Eisenhauer. *School of Applied Geology, Curtin University of Technology, Perth, 6102, GPO Box U1987, Perth, WA, 6845. Email head@lithos.curtin.edu.au

The Ningaloo Reef, Australia's largest fringing reef system, is developed for over 200 km along the western margin of the Cape Range Anticline, an uplifted Tertiary structure. The peninsula and its bordering reef system are flanked by a narrow continental shelf on the west. A series of raised Pliocene-Quaternary terraces, including an extensive Last Interglacial reef terrace (the Tantabiddi Terrace) landward of the reef. The reef system extends from 21.5 to 24°S and is fully tropical. The Leeuwin Current is an important influence on the regional oceanography. Seismic profiles suggest a maximum Holocene reef thickness of <20 m. Most reef development is in depths <35m. An interpreted drowned reef crest is also evident to seaward of the present reef. Stratigraphic data are available for the northern part of the reef, from short cores and from a 26m core drilled in immediately seaward of the reef crest. The cored section showed 7m of Holocene reef (giving a projected Holocene thickness of 18m at the reef crest), underlain by 12 m of Last Interglacial reef, which was in turn underlain by coarse skeletal grainstone. These data indicate that Holocene reef growth (basal age of the cored Holocene reef is 7.57 ka U/Th) recolonised the Tantabiddi Terrace (Last Interglacial reef) near its submerged, seaward margin, and is relatively thin. The envelope of Last Interglacial U/Th reef ages (115-120 ka) in the cored section (at SL -18 to -36 m) postdates the Last Interglacial highstand reef deposits (125 ka at SL+ 2m), suggesting that this submerged, distal part of the Tantabiddi Terrace grew under post-highstand conditions of falling sea level.

FORWARD MODELLING OF THE GROWTH OF A POSTGLACIAL BARRIER REEF SYSTEM (TAHITI, FRENCH POLYNESIA)

Dalmasso, H.., L. Montaggioni *, G. Cabioch, G. Camoin, D. Bosence. *Centre de Sédimentologie et Paléontologie. UPRESA-CNRS 6019. Université de Provence. 3, Place Victor Hugo. 13331 Marseille Email : reef@newsup.univ-mrs.fr

A numerical model CARBONATE developed by Bosence and Waltham (1990), is used to investigate the reef growth patterns of a Tahitian barrier reef for the last 14 kyr. The dataset comes from previous chronostratigraphical and paleoecological works by Bard *et al*. (1996), Montaggioni *et al.* (1997), Cabioch *et al*. (1999). The main input parameters include (1) initial surface, (2) sea-level changes, (3) carbonate production rates. The basic predicted initial surface was purely speculative. Two variants of the sea-level curve were used (1) a regularly rising sea-level ; (2) a sea-level integrating the Meltwater Pulse 1B (11,5-10,5 ka B.P.). Rates of carbonate production ranges from 6 to 20.6 m kyr^{-1}. Carbonate production is assumed to be dependent only on depth and not to vary laterally. The facies distribution was output from four coralgal assemblages, diagnostic in terms of water depth range : 0-5 , 5-15 , 15-25 and deeper than 25 m. The predicted facies distribution is in good agreement with the natural depositional environnements.

WORLDWIDE MODERN BARRIER REEF ESTABLISHMENT, OPTIMUM NERITIC $CaCO_3$ PRODUCTION, AND DISSOLUTION OF PERIPLATFORM/PELAGIC $CaCO_3$ IN THE MID-BRUNHES.

Droxler, A.W.*, *Rice University, Dept. of Geology & Geophysics, Houston, TX 77005. Email: andre@rice.edu

Results of our research along the Belize margin point out that, as for other modern barrier reefs offshore Northeast Australia, South Florida, and Southeast Asia, the Belize Barrier Reef appears to represent young (late Pleistocene) and thin carbonate sedimentary deposits covering a series of prograding siliciclastic paleo coastlines (deltas and possibly beach ridges). The mid-Brunhes interval (interglacial marine isotope stage MIS 11 - 463-362 KA) is also characterized by optimum production of $CaCO_3$ banks (Bahamas, Maldives, and Queensland Plateau). These findings are explained by MIS 11 warmer climates and overall flooding of tropical paleo fluvial plains and tops of carbonate banks caused by the first exceptionally high amplitude (more than 100 m) late Pleistocene sea level transgressions since the onset of the main northern Hemisphere glaciations 2.8 Ma. In contrast, the late Pliocene and early Pleistocene were characterized by an overall lowering of the marine base level tied to the establishment and the expansion of the northern hemisphere major continental ice sheets. Massive accumulations of neritic $CaCO_3$ at low latitudes in a relatively short time are expected to have dramatically modified the oceanic carbonate mass balance, decreased the $[CO_3^{=}]$ in the water column, and can explain an interval, centered around MIS 11, marked by a clear global dissolution pulse from subthermocline to abyssal depths.

LATE HOLOCENE SEA-LEVEL VARIATIONS AND CONGLOMERATE PLATFORM FORMATION AT THE CHAGOS ISLANDS, INDIAN OCEAN

Dullo, Wolf-Christian .* Anton Eisenhauer *GEOMAR Research Center for Marine Geosciences, Wischhofstrasse 1-3, 24148 Kiel/Germany. Email: cdullo@geomar.de

Emerged conglomerate platforms extending up to 100 m and more seawards belong to the most interesting geological features of the Chagos and other Indian Ocean atolls. In order to constrain the formation and timing of their horizontal progradation we dated fossil corals from various platforms of the Chagos Islands applying the U/Th mass-spectrometry technique. Seven out of eleven coral ages cluster in a narrow time frame from about 2.8 to 3.8 ka B.P.. This chronological information is in accordance with independent observations from other Indian Ocean islands showing a similar age distribution. A qualitative model discusses the formation of these platforms in the light of the generally decreasing Indian Ocean sea level since about 6.5 ka. The prominent cluster of coral ages is then interpreted as to reflect a time of intense coral growth and horizontal reef progradation due to a relatively stable sea level above its present position, corresponding to a time of generally warmer climate from about 2.8 to 4.3 ka B.P.. Only a few and scattered coral ages fall along the period before (6.5 to 4.3 ka B.P.) and after (2.8 ka B.P. to present) the prominent time interval of enhanced platform formation. This scattered coral ages may reflect periods of rapid sea level oscillations or may be interpreted as fossil corals displaced from their original position.

CORAL GROWTH DURING RAPID SEA-LEVEL CHANGES.

Esat Tezer M*. Department of Geology, The Australian National University, Canberra ACT 0200. Email: tezer.esat@anu.edu.au

Rapid sea-level change over the last glacial period and during glacial to interglacial transitions has been established as a recurrent mode of climate variability. Because of this, at uplifting sites such as the Huon Peninsula, the previously held views of reef growth patterns have had to be revised. The most prominent Terrace at Huon represents the Last Interglacial (5e), often situated at elevations beyond 200 m above present sea-level, with other, lower elevation, major terraces representing stages 5a, 5c and stage 3. Recent dating of these terraces reveal that the structure of 5e extends below stages 5a and 5c, and possibly underlies a part of stage 3. Therefore, corals that grew during periods of rapid sea level oscillation through the stage 6 to 5 transition are now overlain by coral terraces of stages 5a and 5c. However, these corals can be accessed at many locations through caves and patchy cover of younger overlain reefs. Some corals collected and dated from terraces representing stages 5a and 5c have much older ages relating to an earlier sea-level history. In particular, we have located a number of well preserved corals in a large cave overlain by stage 5c corals. The cave appears to have corals that represent at least four sea-level transgressions through the same location, but at effectively different elevations due to rapid uplift, over a period from 145 ka to about 90 ka. This finding highlights the complexity of the coral record in an era dominated by rapid climate change but also the opportunity it presents for documenting rapid sea-level changes. I will discuss the sea-level curve we have derived from this record and compare it with sea levels during the stage 2 to 1 transition.

AGGRADATION OF THE OAHU CARBONATE SYSTEM IN THE LATE QUATERNARY.

Fletcher C.*, Clark Sherman, Eric Grossman, Jodi Harney, Colin Murray-Wallace, Ken Rubin. *University of Hawaii, Department of Geology and Geophysics, 1680 East West Rd., Honolulu, HI, USA 96822 Email: fletcher@soest.hawaii.edu

The Oahu insular shelf, Hawaiian Islands, is a gently-dipping terrace (depth 0 to ~20 m) ending in a seaward-facing vertical wall (depth ~20 to 30 m). Cored facies indicate it is a fossil reef complex. Th-U ages of *in situ* corals date to MIS 7 (223.3±1.4 to 202.7±1.9 kyrs: $\delta^{234}U_i$ 145 to 165‰). Named the Waianae Reef, it formed when paleosea-level was -14 to -18 m. Later accretion occurred along the seaward front of the Waianae Reef in late MIS 5 (110.1±7 to 82.8±5 kyrs: $\delta^{234}U_i$ 145 to 165‰). Stage 5 corals formed when sea level was below present. The terrace front displays a prominent fossil intertidal notch at –24 m, potentially marking the fall of late Stage 5 sea levels or a melt-water pulsed jump during the early Holocene. Holocene accretion is limited by accommodation space and flexural uplift. Where antecedent relief and wave energy shadowing provides for Holocene growth, accretion opportunistically infills the karstified basement beginning in the range 8 to 9 kyrs. Both "catch-up" and "keep-up" Holocene facies are observed. Carbonate eolian deposits correlate largely to late Stage 5 and Holocene time based on AAR analyses. Unconsolidated beach and shoreface sands are typically fossil, with ~70% dating 0.5 to 4.5 kyrs and ~12% of modern age.

AGE, STRUCTURE AND CORAL COMMUNITY OF AN OFFSHORE REEF PLATFORM, EGYPT, RED SEA

Fletcher C.*, Mathew Barbee, Christopher Conger, Dolan Eversole, Eric Grossman, Jodi Harney, John Rooney, Clark Sherman.
University of Hawaii, Department of Geology and Geophysics, 1680 East West Rd., Honolulu, HI, USA 96822 fletcher@soest.hawaii.edu

Located 7 km offshore the southern Egyptian mainland, Geziret Suyul is a carbonate reef platform of approximately 12 km^2, one in a chain characterizing this coast. A small parabolic cay of well-sorted fine to medium carbonate sand, oriented along strike of the dominate NW trade winds (300 – 320°), is the only emergent feature at high tide. The majority of the platform surface is characterized by presently intertidal fossil reef-framework facies (indicating a fall in relative sea level), carbonate sand shoals responding to tidal and wave-driven currents, beachrock, and coralgal flats with increasing coral cover toward leeward and windward margins. Platform slopes are characterized by sand chutes and fields, limestone outcrops, soft corals, algal turfs, and scleractinian corals. Shallow (0 to 10 m) coral communities are characterized by abundant (>10%) *Porites* sp. (*lobata, lutea, rus, solida*), *Acropora* sp. (*digitifera, hemprichii, nasuta, valenciennesi, valida*), *Pocillopora verrucosa*, and *Montipora informis*; deeper communities (10 to 40 m) have abundant *Porites* sp. (*lobata, lutea, rus, solida*), *Montipora* sp. (*danae, informis*), *Pocillopora verrucosa*, *Goniastrea edwardsi*, and *Acropora valida*. Wireline cores with a maximum penetration of 15 m provide the internal structure (largely algal-dominated with coral-rich facies of "catch-up" behavior) and age (prob. Early Middle Holocene: samples still under analysis) of the platform interior.

LATE QUATERNARY HISTORY OF REEF ACCRETION AND DIAGENESIS AT KWAJALEIN ATOLL, MARSHALL ISLANDS.

Gray, S.C.*, Lewis, S., and Hunt, C.D., Jr. *Marine and Environmental Studies, University of San Diego, 5998 Alcala Park, San Diego, CA, U.S.A. Email:sgray@acusd.edu

The relationship between reef growth, sea-level change, and diagenesis during the Holocene and late Pleistocene was investigated through a lithologic, petrographic, mineralogic and AMS ^{14}C dating study of two cores drilled into a rim islet of Kwajalein Atoll, Marshall Islands. XRD and petrographic analyses revealed that the Holocene reef is primarily aragonite with some high-magnesium calcite. Secondary low-magnesium calcite and primary aragonite (without low Mg calcite) characterize the mineralogy of the Pleistocene reef platform. Reservoir corrected AMS ^{14}C ages indicate that a Holocene reef was established at Kwajalein 7030 +/- 75 years B.P. on a Pleistocene reef platform, which is presently 25-27 m below sea level. Comparison of ^{14}C ages of the deepest corals to published sea-level curves suggests Holocene reefs colonized Pleistocene substrates relatively soon after flooding of the platform. Subsequently, reef growth lagged behind sea-level rise until the outer reef rims reached sea-level. The average rate of reef accretion over the past 7030 years was 3.3 +/- 0.3 m/1000 years. Average reef accretion rates were higher (5.8 m/1000 yrs.) between 7030 and 4795 yrs. B.P. when reef growth was "catching up" to rapidly rising sea level. The islet formed more recently than 1140 yrs. B.P. The depth of the Holocene/Pleistocene boundary at Kwajalein is deeper than the boundary reported for Enewetak or other Pacific atolls in "tectonically stable" environments (e.g., Cook Islands, Tarawa, Mururoa) where Holocene reefs colonized submerged Last Interglacial reefs.

SUBMERGED PLEISTOCENE COASTAL LAKES AND DROWNED REEFS IN HAWAII

Grigg, Richard W.* Earle, Sylvia A; Gittings, Stephen R; Evans, Kip; Lott, Dave; and McDonough, John. *Dept. of Oceanography, University of Hawaii, Honolulu, Hawaii. Email: rgrigg@iniki.soest.hawaii.edu

At the last glacial maximum (LGM), about 21,000 years ago, the Hawaiian Islands of Maui, Lanai and Molokai were inter-connected by two karstified limestone bridges creating a super-island that has been named, Maui-Nui. Approximately 120 meters of sea-level rise during the Holocene Transgression flooded and then drowned both bridges separating the islands by narrow channels. A new multibeam high resolution bathymetric survey of the channels between the islands, coupled with observations and video transects utilizing DeepWorker 2000 submersibles, have revealed the existence of numerous drowned reef features including irregular concentric basins, ribbon reefs, reticulate ramparts, patch reefs and reef pinnacles. The concentric basins contain flat lagoon-like bottoms and are rimmed by steep sided limestone walls. Many of the walls are incised by horizontally oriented notches, possibly eroded by former sea or lake levels. At one stage or another during the transgression, all of the basins appear to have been shallow shoreline lakes. Today, the undercut notches serve as habitat for two species of commercially harvested black coral (*Antipathes dichotoma* and *A. grandis*) and bottom fish.

CARIBBEAN-WIDE LOSS OF *A. PALMATA* 7,000 YR AGO: SEA-LEVEL CHANGE, STRESS, OR BUSINESS AS USUAL?

Hubbard, D.K.*, Gill, I.P., Burke, R.B. Dept of Geology-Oberlin College, Oberlin, OH, USA, 44074. Email: dennis.hubbard@oberlin.edu

Cores through shelf-edge reefs at 3 Caribbean sites (U.S. Virgin Islands, Puerto Rico, Florida) show similar depositional histories. *A. palmata* reefs developed at the shelf break shortly after flooding (ca. 10,000 ybp - cal ^{14}C age). Approximately 7,000 ypb, accretion stopped at all three sites and the locus of reef development shifted 4-10 km landward to head-coral reefs. These three examples closely match patterns of ancient "backstepped reefs". A survey of *A. palmata* dates from the Caribbean reef literature indicates a near or total disappearance of *A. palmata* from the Caribbean at this time. The synchronicity between sites with widely varying oceanographic/sedimentary settings argues for an extrinsic control. However, no evidence for a rapid rise in sea level exists. Closely spaced cores yield different stratigraphic sequences (i.e., local environmental controls dominate over any sea-level signal). Data to implicate disease, inimical waters, or other factors commonly equated with "give-up" reefs are equivocal. A computer model based on the average rate of sea-level rise at the time and calcification rates from these and nearby reefs closely matched the actual "start-up" and "give-up" times, measured rates of accretion (cores), and the ultimate reef thickness at all three sites without a sudden and rapid rise in sea level. Perhaps we should not be using such events in the geologic past as universal indicators of drastic environmental or climatic change.

SKIPPED REEF INITIATION AND DELAYED REEF-SLOPE FORMATION DURING RAPID SEA-LEVEL RISE AT HIGH-LATITUDE, KUME ISLAND, RYUKYUS.

Kan, H.*, Nakashima, Y., Takahashi, T., Koba, M., Adachi, H., Naito, G. Faculty of Education, Okayama University, Okayama 700-8530, JAPAN. Email: kan@cc.okayama-u.ac.jp

Seventeen drill cores from Kume Island located 26°20'N in the central Ryukyus exhibit a significant reef initiation and growth sequence during Holocene sea-level rise at high-latitude. Reef started to grow in 7470yBP at –15m and 7380yBP at –10m to form the present reef-flat where tabular *Acropora* assemblages accumulated at the average rate of 4m/ka. However, initiation occurred in 6250yBP at –20m beneath the reef-slope terrace where massive coral assemblage is accumulating at the rate of 1 to 2m/ka. Although –20m substratum had been provided at an appropriate depth before 7500yBP, reefs skipped it under the rapid sea-level rise and started to grow on the shallower landward substrate at 7500yBP. It contrasts to the early initiation and continuous or give-up reef growth sequences in tropical region. Our result implies the high-latitude reefs would not possibly respond to further rapid sea-level jump immediately.

THE ROLE OF SEA LEVEL ON THE EVOLUTION OF BRAZILIAN REEFS DURING LATE QUATERNARY.

Leão Zelinda M. A. N.* and Ruy K. P. Kikuchi. Laboratório de Estudos Costeiros, Universidade Federal da Bahia, Rua Caetano Moura 123, Salvador 40210-340, Bahia, Brazil. Email: zelinda@ufba.br

Holocene reef growth, in Brazil, began as early as 7220 cal yrs B.P. (calibrated years before present), a further evidence that reef initiation, after 8000 yrs B.P., was a global scale event. But the last post-glacial sea level oscillations that occurred along the coast of Brazil, left distinctive imprints on the development of the reefs. A drowned phase must have occurred during early Holocene, before the 5100 yrs B.P. maximum sea level (+5m above present position), which characterizes the "give-up" facies of coralline algae rhodoliths developed above submerged reefs found at the shelf edge. At the inner shelf initial reef growth follows the "catch-up" pattern of vertical accumulation of the reef structures, and this occurred when sea level was already at or above its present position. This reef growth phase is characterized by a vigorous and rapid upward accretion reflected by reef accumulation rates in the order of 7 mm/y. An ultimate stage started when the reef structures reached sea level and from then to the Present, during the regressive phase of sea level, the development of nearshore reefs is characterized by a passage from a phase of reef aggradation to their dominant lateral growth. This period responds for the sub-aerial exposure of the top of the reefs, which are now subject to heavy sedimentation, high levels of turbidity and the intertidal reef community to intense solar radiation.

LOCAL EXTINCTION OF *ACROPORA* CORAL SPECIES ON NIUE ISLAND (SOUTH PACIFIC) DURING A REGRESSION CAUSED BY TECTONIC UPLIFT.

Paulay, Gustav * and Carden C. Wallace. *Florida Museum of Natural History, University of Florida, Gainesville FL 32611-7800. Email: paulay@flmnh.ufl.edu

Like other remote islands of the south Pacific, Niue enjoyed a greater diversity of reef corals of the genus *Acropora* during the Plio-Pleistocene than is currently present on its reefs. This is demonstrated from a comparison of fossil assemblages from the fossil lagoon and fore reef of this uplifted atoll, with living assemblages that now inhabit its narrow fringing reef system. Several widespread Indo-Pacific species absent today occur as fossils. Several of the local extinctions may be attributed to loss of, and changes in, habitats accompanying the Pleistocene uplift of the island. The uplift transformed Niue from a large atoll with a shallow lagoon, to an emergent limestone island, with consequent loss of all lagoonal habitats. The local extinction shown by *Acropora* and other faunal elements provides a model for what happened to the faunas of central Pacific islands in general during each glacio-eustatic regression in the Pleistocene. The absence of some species may not be attributable to habitat loss, as suitable habitats remain, even if reduced in extent. Failed recolonization of these, in particular the larval-brooding, species, may be a result of the isolation of the island and the unstable nature of upstream distributional boundaries. A caution is taken against interpreting biogeographic events based on current surveys and models based on simple ecological processes.

PLEISTOCENE (5e) SEA LEVEL DECIPHERED FROM DETAILED STRATIGRAPHY OF CORAL REEF SEQUENCES:

Precht, William F. * PBS&J, 2001 NW 107th Ave., Miami, FL 33172, Email: bprecht@pbsj.com

Exposures of reefal limestones from the Pleistocene (Sangamon, Marine Isotope Stage 5e) of Jamaica present an opportunity to evaluate the stratigraphic history relative to high-order eustatic changes in sea level. Outcrops from localities on both the northern and western coast show similar relationships between relative sea level history, sedimentary sequences, internal facies mosaics, and subsequent overprinting by diagenetic processes. Evaluation of wholly preserved stratigraphic sections indicate that, vertically, the Sangamon is composed of three discrete shallowing-upward depositional stages, which can be correlated within and between complexes. This stratigraphic evidence strongly suggests the occurrence of a triple-high sea stand during the last major interglacial maximum. The three pronounced reefal sequences appear to be correlative with warm substages 5e5, 5e3 and 5e1 of the Greenland Ice-Core Project (GRIP), respectively. The lower two sequences are separated by a distinct stratigraphic discontinuity. This surface represents a drop in relative sea level in the middle of Stage 5e and is marked by indicators of subaerial exposure. This surface is correlative with cool substage 5e4 from the GRIP.

RESPONSE OF ALGAL REEFS TO SEA LEVEL CHANGES AND CLIMATE DURING THE LATE QUATERNARY ALONG THE WESTERN CONTINENTAL MARGIN OF INDIA.

Rao, Purnachandra V.*, L. Montaggioni, K.H. Vora and F. Almeida *National Institute of Oceanography, Dona Paula – 403 004, Goa, India. Email: esa6019@newsup.univ-mrs.fr

Bathymetric and shallow seismic studies on the outer continental shelf off western India, at depths between 75 and 110 m, indicate the presence of pinnacles and reef-like structures, 4 m to 14 m high. Carbonate nodules are the predominant samples recovered from these geomorphic features and range from 8,000 to 12,000 years B.P. in age. Three types of nodules occur (1) foraminifera - dominated with *Discogypsina*, *Gypsina plana*, *Rupertina stabilis*, *Homotrema ruber*. (2) coralline algae – dominated, with *Lithophyllum*, *Lithothamnium*, *Spirolithon*, *Mesophyllum*, *Porolithon*, *Hydrolithon*, *Lithoporella* (3) mixed, encrusting foraminifera and coralline algae. Ferruginized coral chunks, belonging to *Porites*, have been recovered from two pinnacles located at 105 and 110 m depth off Mangalore ; their ^{14}C ages are 12,180 and 13,270 years B.P. On the carbonate platform, mound-shaped structures, resembling bioherms, are common. The limestones recovered from the mound-shaped structures contain abundant *Halimeda* grains and faecal pellets. Faecal pellets corespond to *Palaxius* genus of *Thalassinidea tribe*, *Palaxius habanensis*, *P. decum lunulatus*, *Upogebia deltura*, *Favreina salevensis*. The age of the limestones ranges from 9,200 to 8,400 years B.P. The timing and growth conditions of the algal and foraminiferal nodules were correlated to climatic conditions and glacio-eustatic sea level positions during the late Quaternary. Ecological succession of different organisms implies changes in light and nutrient conditions during their formation.

GROWTH HISTORY OF THE HOLOCENE RAISED CORAL REEF AT KIKAI ISLAND OF THE CENTRAL RYUKYUS, SOUTHWESTERN JAPAN.

Sasaki K* and Omura, Akio. *LLRL, Kanazawa Univ., Ishikawa 923-1224, Japan. Email: sasak1@llrl.ku-unet.ocn.ne.jp

Holocene raised coral reefs are developed encircling the whole island of Kikai, central Ryukyus, southwestern Japan, which has been uplifted since the last interglacial maximum. It is thus possible to discuss a pattern of reef growth in response to relative sea level change. The well-developed raised reef at the northeastern coast was investigated by using five cores drilled throughout the Holocene sediments with high recovery (> 70%). The total of thirty-one corals was dated by the _-spectrometric $^{230}Th/^{234}U$ method. The Holocene reef, underlain directly by unconsolidated Plio-Pleistocene mudstone, is composed of two lithologic units with the maximum thickness of 25.8 m and age of 9.56±0.15 ka. The lower unit is consisted of a mixture of terrestrial grains derived from the basal mudstone and limestone with Holocene bioclastics in contrast to the upper reef limestone unit representing a typical reef zonation of coral community. A distinct time lag between the maximum transgression at 7.5 ka and facies change to the upper limestone at 6.6 ka indicates that a regression-induced reduction of terrigenous inputs has triggered the rapid growth of Holocene reef under the low-turbidity condition. After catching up with the sea level, the reef was emerged by episodic uplift events. During the stage of regression, spurs were prograded and grooves were buried and cemented to facilitate a characteristic process of physical erosion at the level of mean high-tide, which constructed continuous terrace surfaces carving into the main reef slope dominated by the spur-groove system.

LATE HOLOCENE SEA-LEVEL CHANGES AND TECTONIC UPLIFT AT KIKAI-JIMA, RYUKYU ISLANDS, JAPAN

Sugihara, K.*, T. Nakamori, Y. Iryu *Fukuoka Univ., Fukuoka, JAPAN, Email: sugihara@fukuoka-u.ac.jp

Kikai-jima (Kikai Island) is surrounded by four Holocene raised coral reef terraces, which are thought to be an offlapping sequence of reef deposits caused by combined effects of seismic uplifts and Holocene sea-level changes. Many studies have been conducted to discuss Holocene sea-level changes and reef growths, but there are relatively few references in which reliable paleobathymeters (sea-level indicators) were given. We have found that *Pocillopora verrucosa*, one of the most abundant coral species on the upper reef slope of fringing reefs in the Ryukyus, is overwhelmingly dominant in the shallowest part of reef slope (< 2 m deep) in Kikai-jima. Therefore, this species is considered to be available as a dipstick for the Holocene reef deposits in this island. Our results, combined with hitherto known and new radiometric dates (109 dates in total), clearly show that the four terraces were formed in response to 4 repeated tectonic uplifts (at approximately 7, 4, 3, and 1.5 ka) and that the sea-level was about 1.5 to 2 m higher at about 6-7 ka than the present.

RESPONSE OF SOUTHEAST FLORIDA AND BAHAMAS HOLOCENE RELICT REEFS TO DEGLACIAL SEA-LEVEL RISE.

Toscano, M. A.* Macintyre, I. G.. *NOAA/NESDIS/ORA/ORAD E/RA3, NOAA Science Center Rm 711, 5200 Auth Road, Camp Springs, MD 20746 USA. Email: mtoscano@nesdis.noaa.gov

One hundred sixteen (116) high-quality dates from samples collected off the southeast coast of Florida, Bahamas, USVI, Panama, and Belize (16 TIMS U-TH coral, 49 ^{14}C coral, and 51 ^{14}C peat dates) provide a detailed record of coral-reef accumulation in response to sea-level rise over the last 10.6 ka. South of Miami at Sand Key and Carysfort Outlier Reefs, Holocene framework dates from 9-5 ka, at depths of δ20 to δ7m. North of Miami, three shore-parallel ridges preserve Holocene reefs ranging in age from 10.6 to 8.0 Cal kaBP (lower ridge; δ27 to –16.5 m MSL) and 7.4 to 6.8 Cal kaBP (upper ridge; δ9.5 to –7.8 m MSL). Dated mangrove peats that closely tract sea-level positions record initial flooding of the Florida shelf at about 8.5 Cal kaBP, which immediately predates the demise of the lower outlier reef tract near Miami. The Sand Key profile stopped accreting at 6.9 ka. Only the Carysfort profile survived to 5 ka in a protected area. A shallower δ5.5 to –7.3 m) reef tract on the eastern edge of the northern Bahamas experienced a similar die-off around 3.9 Cal kaBP when the back-reef platform was flooded. Because post-10.6 ka sea-level rise rates are well within the range of *Acropora palmata* framework accumulation rates, any gaps specifically in the record of *A. palmata* must be accounted for by coincidence with platform flooding, local environmental/climatological constraints, or missing data, rather than by reef drowning related to sudden pulses of sea-level rise in the last 8000 years.

THE RESPONSE OF CORAL REEFS TO SEA-LEVEL CHANGE : EVIDENCE FROM THE RAISED HOLOCENE REEFS AT KIKAI-JIMA.

Webster J.M.*, and P. J. Davies. *School of Geosciences, Division of Geology and Geophysics, University of Sydney 2006. Australia. Email: jody@es.su.oz.au

Kikai-jima (central Ryukyu Islands, Japan) is fringed by exposed terraces of Holocene reefs, formed by periodic local tectonic uplift associated with regional subduction/collision. The terraces form four topographically distinct features (TI-IV) around the island and represent reefs that grew to sea-level at 9000-6065 y BP, 6065-3390 y BP, 3790-2630 y BP, and 2870 to 1550 y BP. The reef terraces were uplifted sequentially around 6050 y BP (4 m), 3390-3790 y BP (2.5 m), 2630-2870 y BP (1 m) and 1550 y BP (2.5 m). Five locations were studied to define reef development in response to rapid periodic relative sea-level fall and different stillstand recovery periods. Significant horizontal variations in total coral abundance, genera number, diversity, eveness and the coverage density of *Acropora* sp. and Faviids occur both within and between the terraces. Stratigraphically, drill core and outcrop data record shallowing upward sequences characterised by tabulate *Acropora* sp. overlying massive *Porites* sp. and Faviids. These biological variations represent growth strategies responding to initial colonisation, episodic perturbation (relative sea-level fall) and differing recovery times during stillstands, and indicate a reef ecosystem stable and strong enough to recover after substantial perturbations.

Session A10: Coral Reefs in Turbid Environments: Geological and Ecological Significance

ADAPTATION OF CORAL REEFS IN A MARGINAL ENVIRONMENT.

Bak, RPM *, Meesters, EH. *NIOZ, P.O. Box 59, 1790 AB Den Burg, The Netherlands. Email: rbak@nioz.nl

Coral reefs are known to flourish typically in clear oligotrophic waters but, contrary to this dogma, many reefs occur under marginal conditions such as high turbidity and/or high sedimentation environments. The question we pose is: how are reefs adapted to such marginal environments? As a model system we studied the reefs of the turbid Bay of Banten, NW Java, Indonesia. Reef surveys (transects) along a string of islands showed changes in community characteristics (inshore-offshore): Coral colony partial mortality decreased, coral cover and species richness increased. Asexual recruitment was dominant on all reefs, but sexual recruitment was still occurring (~10%). High turbidity (k' = 0.17-1.26) and sedimentation (2.5-63 mg $cm^{-2}day^{-1}$) did not correlate with reef development. Resuspension of bottom sediments, possibly preventing negative effects of sedimentation, paralleled patterns in reef development. Variation also occurred at the level of the coral organism. Chlorophyll *a* levels were high in coral colonies (*Porites* massive) in turbid conditions compared to less turbid conditions (depth < 4m, 36 versus 15 µg cm^{-2}). Most of the changes in community structure are probably the result of phenotypic adaptation at the organismic level. There are also indications of adaptation *sensu stricto*, representing genetically based variation. We found RNA/DNA ratios in coral tissue, which are presumed to reflect tissue growth characteristics, to be consistently higher in corals living in turbid environments. However, under the most extreme turbidity conditions RNA/DNA ratios were not higher. Apparently, corals are able to adapt to some degree to higher turbidity levels.

CARBONATE-CLASTIC INTERACTIONS AND THE IMPLICATIONS FOR CORAL REEF SURVIVAL; TERTIARY EXAMPLES FROM SPAIN.

Burton L.*, Moyra Wilson and Maurice Tucker. *Department of Geological Sciences, University of Durham, South Road, Durham, England. DH1 3LE. Email: l.m.burton@durham.ac.uk

The Vic Basin (NE Spain) and the Fortuna Basin (SE Spain) provide well-exposed examples of carbonate production and development within predominantly siliciclastic semi-arid shelf environments. The aim of this paper is to show the response of coral reefs and other important carbonate-producing organisms to terrigenous siliciclastic sedimentation in terms of species diversity, organism morphology and biotic zonation. This paper also aims to explain the evolution of the carbonate-clastic successions in response to changing sediment influx, climate and relative sea-level change. The methods employed were 1) the production of detailed sedimentary logs, 2) palaeoshoreline-normal transects across carbonate-clastic successions, 3) production of photomontages and 4) detailed sampling of lithofacies for petrological and geochemical analysis. This study has implications in understanding carbonate production and coral reef development and survival in modern turbid waters.

CORAL COMMUNITIES IN VARIOUS ECOLOGICAL CONDITIONS AT NORTHERN VIETNAMESE REEFS.

Dautova T.N.*, Yu.Ya.Latypov, S.Sh.Dautov. *Institute of Marine Biology, RAS, Vladivostok, Russia. Email: daut@mail.primorye.ru

The specifics of reefs of Bay Thy Long Archipelago (Gulf of Tonkin, South-China Sea) are determined by effect of monsoon climate, heavy terrigenous sediment flow and freshening water by rivers. The studied reefs, six of which was studied ecologically, differed significantly by coral populations and conditions. The reefs in the closed island bays had small average total water flow Qint, which was even less above coral settlements. This reefs were specified by low values of suspended load in water body SCOL (25-33 g/(m^2day)) and of bottom suspended load SBOT (16-60 g/(m^2day)), which was calculated with resuspension effect estimation, and by small values of resuspension intensity RI above coral settlements (0,2-0,5, arb. units). As a result almost all bottom layer suspended matter settled here. Oportunistic corals of *Porites, Pavona, Favia, Favites, Goniastrea* genera prevailed on this reefs. Well washed, open reefs was characterised by high load of SBOT (69-100 g/(m^2day)) and SCOL (45-61 g/(m^2day)), high Qint, increasing above coral settlements, and high RI (0,6-0,9 arb. units). This reefs was dominated by *Acropora, Gonyastrea, Goniopora* at the reef flat and slope. This relation of coral communities structure to the physical conditions is explained by various environment adaptations of this corals. *Porites* and *Pavona* colonies with good self cleaning system are dominant in the silting, poor water exchange conditions. Fast growing and more aggressive *Galaxea, Goniopora, Acropora* take advantage in favourable conditions.

PORITES CORALS RECORD HIGHER TRACE ELEMENT CONCENTRATIONS (ZN, PB, Y, LA, CE) DURING INCREASED SEDIMENTATION, MISIMA ISLAND, PNG.

Fallon, Stewart J., McCulloch, M.T. White, J.C., Barnes, D.J., Lough, J.M. *Research School of Earth Sciences, The Australian National University, Canberra, ACT. Australia. Email: Stewart.Fallon@anu.edu.au

In 1989 open pit gold mining commenced on the island of Misima in Papua New Guinea. Open pit mining by its nature causes a significant increase in sedimentation, both natural and mining-induced. This increased sedimentation affected the nearby fringing coral reef to varying degrees, causing coral mortality (complete suffocation) in some areas. This sediment consists of soft mine waste which is made up of quartz feldspar, greenstone and schist. These rocks have distinct chemical constituents (rare earth elements [REE], zinc and lead etc.), which are entering the near-shore environment in considerably higher than normal concentrations. Using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) we analyzed eight colonies (2 from high sedimentation, 2 transitional, 2 minor and 2 control sites) for Y, La, Ce, Zn and Pb. All sites show low steady "background" levels prior to the commencement of mining. After mine construction began in 1988, all sites aside from the control show dramatic increases of Y, La, and Ce associated with the increased sedimentation. Zn and Pb increase after 1989 when the ore processing began. The concentration of these elements in these corals decreases as the distance from the mine increases.

RESPONSE OF A REEF TO SEDIMENT OVERLOAD: MOLOKA'I, HAWAI'I

Field M.*, Michael Bothner, Paul Jokiel, and Andrea Ogston. *US Geological Survey, Pacific Science Center, University of California, Santa Cruz, CA, 95064. Email: mfield@usgs.gov

The coral reef off southern Moloka'i hosts some of the most continuous and densest live coral in the Hawaiian chain. The reef consists of a broad (1 km) and shallow (1-1.5 m) reef flat succeeded seaward by extensive spur and groove development to depths of 25 m. Erosion rates of the adjacent volcano terrain appear to have dramatically increased due to deforestation, agriculture, and overgrazing; terrigenous mud is now accumulating on the reef flat and along the shoreline, and corals in a number of locations are degraded and necrotic. Our study focuses on the processes of mud transport and accumulation on the reef, and their impact on coral viability. Excessive sedimentation from land run-off and past reef dredging events appear to have had a substantial impact on coral health that is superimposed on other stresses from natural processes (e.g. large waves) and anthropogenic activities (e.g. fishing, anchors). Corals are stressed and impoverished in several locations on the inner reef and fore reef (less than 50 % live coral coverage at 10 m depth, compared to ~90 % elsewhere). Their status reflects both excessively large sediment loads and also entrapment of fine sediment on the reef flat. The inner reef flat is typically mantled with 5-15 cm of mud, and no live coral is present. Sensors on an instrumented tripod show that mud may be resuspended by trade wind processes, and that net transport is to the west and offshore towards the zone of impoverished coral. Pb 210, Cs137, and trace metal analysis are being conducted on sediment cores from expected depositional sites in the reef platform to investigate changes in sediment input resulting from major storms, land use and coastal development.

MIXED SILICICLASTIC-CARBONATE SEDIMENTS FROM A HIGH VOLCANIC ISLAND LAGOON, FIJI.

Gussmann O.A.* and A.M. Smith. University of Otago, Department of Marine Science, PO Box 56, Dunedin, New Zealand. Email: GUSOL423@student.otago.ac.nz

Modern lagoonal sedimentation in the Navua-Suva Lagoon, Fiji, derives from both allochthonous siliciclastics and autochthonous marine carbonates. Sediments are characterized by a high insoluble load, small grain size, a wide range of textures, and a high degree of mixing. Sediment facies are controlled by the adjacent shallow-marine area and its carbonate sediment productivity, and by rate and distribution of siliciclastic sedimentation. Molluscs and *Halimeda* dominate the mostly lagoonal skeletal composition. Preliminary budget calculations indicate that 96% of the siliciclastic supply by-passes the lagoon; about 0.3 Mt/y is accumulating in the lagoon, which is not yet enough to inhibit potential carbonate production (0.1 Mt/y). Contemporary allochthonous siliciclastic and autochthonous skeletal carbonate sedimentation in the lagoon results in true syndepositional (*in situ*) mixing. We predict that tropical *in situ* mixing of carbonate and siliciclastic sediments is more common than previously appreciated (the *high volcanic island mass effect*), which makes them excellent testing grounds for the study of carbonate-siliciclastic interactions.

ADAPTATION TO LIFE ON TURBID REEFS: A CORAL ENERGY-NICHE MODEL WITH A WORKED EXAMPLE

Anthony, Kenneth R.N. Hoegh-Guldberg, Ove *, and Bette L. Willis *Department of Marine Biology, James Cook University, Townsville 4811 QLD and the *Centre for Marine Studies, University of Queensland, 4072 QLD Australia. Email: Kenneth.Anthony@jcu.edu.au

The conditions on inshore fringing reefs are often in strong contrast to those on offshore reefs. Periodically high sediment concentrations inshore can severely reduce light levels compromising coral photosynthesis, and high rates of sedimentation may smother coral tissues. Nevertheless, many inshore reefs display high coral cover, suggesting that inshore corals have become adapted or acclimated to periodically turbid conditions. Traditional models of coral energy budgets poorly account for the physiological mechanisms for acclimation in corals since these models use fixed parameters for the functional responses of energy acquisition to available resources, and ignore variation in energy losses among levels of resources or stressors. Here, we present a model that enables analysis of the effect of dynamic functional responses on the coral energy balance. Based on experimental physiological data and model predictions for two coral species we analyse the role of photo-acclimation and heterotrophic capacity in delimiting the resource niches of corals on turbid reefs. Sensitivity analyses of the model suggest that three factors are critical for maintaining a positive energy balance on turbid reefs: (1) a capacity to vary the parameters of the *P-I* curve within short time frames, (2) minimised respiratory and excretory losses under high turbidity, and (3) a high capacity to utilise heterotrophic sources of energy.

BOUNDARY CONDITIONS FOR CORAL REEF DEVELOPMENT IN TURBID WATERS IN BRAZIL.

Kikuchi, R. K. P.* and Leão, Z. M. A. N. *Universidade Estadual de Feira de Santana, Feira de Santana, Brazil. Email: rkpkikuchi@geocities.com

The Brazilian continental margin is characterized by a transition of siliciclastic to carbonate sediments. Our study focuses on turbidity and sedimentation rate on bank reefs of the northern coast of Bahia State, Brazil, between latitudes 12°33'S and 12°44'S and longitudes 37°55' W and 38°05' W, where a coral community of early successional stages develops in a high energy environment. The bank reefs are generally 3 to 5 m high, with their tops 5 to 15 m deep, within 2 km from the coast. A small river drains to the area affecting but the reefs closest to shore. Coralline algae cover up to 90% of reef surface. Coral community is composed by 9 species, the most important being endemic species such as *Mussismilia hispida*, *M. braziliensis*, *Siderastrea stellata*, *Favia gravida* and the cosmopolitan *Agaricia agaricites*. An average Secchi disk depth of 4,5 m characterizes water turbidity and mud fills many reef cavities and surface depressions. Summer (November-March, dry season) sedimentation rates, though, are relatively low, varying from 0.06 mg cm^{-2} d^{-1} up to 1.25 mg cm^{-2} d^{-1}. River plume in the summer has a small area of influence and sediment discharge in that season is small, around 50 kg d^{-1}. A higher sediment discharge, to be measured this winter (May-August, rainy season), may respond for a higher sedimentation rate during this season. The dispersal of the sediment during the remaining time of the year may be carried out by the constant waves with periods of 6-7 s that dominate the region.

TURBIDITY EXCEEDENCE CURVES AND INFERRED SEDIMENT ACCUMULATION RATES FROM FIELD DATA AT NEARSHORE CORAL REEFS OF THE CENTRAL GBR.

Larcombe Piers*. *Marine Geophysical Laboratory, School of Earth Sciences, James Cook University, Townsville 4811, Australia. Email: piers.larcombe@jcu.edu.au

Worldwide, many researchers work on coral reefs in turbid coastal and shelf environments, but few field studies have focused upon the links between the coral reefs and their dynamic sedimentary environment. In terms of coral physiology, durations of turbidity and sedimentary impacts of a few hours are particularly relevant, because longer exposure to high levels may induce stresses leading to coral death. Time-series oceanographic data taken at various nearshore and inner-shelf coral reefs near Townsville (central Great Barrier Reef shelf) allow high-quality delineation of exceedance curves for turbidity. For the nearshore reef of Paluma Shoals, most notable is a strong non-linearity of the exceedance curves. In particular interest is that relatively little time occurs at mid-range turbidity (15-50 NTU) compared to lower (0-15 NTU) or higher (50-200 NTU) levels. This relates to the energy characteristics of the sampled time-period, and the non-uniform nature of the available bed sediment. Both these factors are regional in scale. The field data can also be used to infer time-series of instantaneous rates of sediment accumulation onto the sea floor, which range up to 123 mg/cm 2/ day for periods of 2 hours. This rate is 3-4 orders of magnitude greater than the average rate of sediment accumulation over the last 6-7000 years in the area, and indicate the overwhelming dominance of sediment transport on the shelf, relative to net accumulation.

CORAL COMMUNITIES IN TURBID AND EUTROPHIC WATERS ON GULF OF TONKIN.

Latypov Yu. Ya. *, T. N. Dautova. Institute of Marine Biology FEB RAS, Vladivostok, 690041, Russia. Email: ltpv@online.marine.su

The originality coral reef of Gulf of Tonkin (South-China Sea) is defined by influence of a drain rivers bearing turbid and freshening of water. The salinity can be reduced up to $26^{o}/_{oo}$ and temperature of water can fall to winter time up to 16° C. The Red River have annual discharge of 137 billion m water and 116 million ton suspended sediments. Directly on a coral reef in usual time is besieged up to 70-100 g/m^2 of deposits, which quantity during typhoons is increased by the order. The distribution of corals is determined by intensity of a turbidity of a deposit, both in the certain sites, and on all reef. More 160 species of Scleractinia belonging to 45 genera were identified. Acroporidae create the high coral diversity (26% of species composition) as with the majority of Indo-Pacific reefs. The reefs of Gulf of Tonkin have from 59.4 to 71.7% species in common with reefs of South Vietnam. There was a reorganization in composition and structure of communities under influence constant turbidity and eutrophication of waters. The Poritidae and the Faviidae was dominate in coral community instead of branchy Acroporidae, characteristic for the majority is reef. Its form not only a framework of a reef, but also play an essential role in expansion of its area. A passive colonization of new sites of a bottom occurs by destruction massive colonies. The new organogenous substratum is formed on a slope reef, on which the corals and other representatives a phito - and zoobenthos can settle. These factors are very important for Gulf of Tonkin with its shallow water, abundance soft grounds and limitation of a firm substratum with removal from coast.

SEDIMENT IMPACTS ON LAGOON REEFS WITHIN DISCOVERY BAY, JAMAICA: CONSEQUENCES FOR CORAL COMMUNITIES AND CARBONATE PRODUCTION

Macdonald, I.A.* and Perry, C.T., *Department of Environmental & Geographical Sciences, Manchester Metropolitan University, Chester Street, Manchester, M1 5GD, U.K. Email: I.Macdonald@mmu.ac.uk

Sedimentation on reef corals is widely documented but detailed case studies relating directly to sediment stress on reef communities are limited. In addition, there is currently a paucity of data relating to coral preservation processes under such conditions, despite potential consequences for rates and styles of carbonate accumulation. This study examines the reef lagoon communities at Discovery Bay, Jamaica. In addition to naturally turbid conditions additional fine grained bauxite sediment accumulates in the south-west region of the Bay. This anthropogenic stress has been present for over thirty years and is not subject to large seasonal fluxes as reef systems in the proximity of fluvial sources may be. The paper documents initial studies into hermatypic coral communities (i.e. species diversity, live coral cover, colony size) within this bauxite impacted setting and comparisons are made with, 1) other less impacted, but naturally turbid areas of the lagoon, and 2) data from previous studies of sediment impacted systems. In addition, ongoing work on carbonate sediment production (carbonate content, sediment composition, grain size) and coral/sediment preservation processes (bioerosion, encrustation) will be discussed.

UPTAKE OF SUSPENDED AND DEPOSITED PARTICULATE MATER ASSOCIATED NITROGEN BY SCLERACTINIAN CORALS.

Mills, M.M.*, F. Lipschultz, and K.P. Sebens. *Department of Biology, University of Maryland, College Park, Maryland 20742, USA, Email: millsmatt46@hotmail.com

The uptake of suspended and deposited particulate associated nitrogen by four species of scleractinians, utilizing suspension or mucus feeding, was measured using stable isotopic tracer, ^{15}N. Particulate matter collected at a reef in Bermuda was split into < 63µm and > 105µm size fractions and living organisms labeled with $(^{15}N\text{-}NH_4^+)_2SO_4$. The corals were incubated in flow chambers with the labeled particulate matter in suspension (< 63µm), or layered onto the surfaces of the corals (> 105µm). The three mounding species, *S. radians*, *M. franksi*, and *D. strigosa*, all showed uptake of particulate matter nitrogen using both feeding modes, while the branching species *M. mirabilis* had no particulate matter nitrogen uptake. Only the coral host was enriched with ^{15}N with no tracer appearing in the symbiotic zooxanthellae. Specific uptake rates for the three corals ranged from $0.001h^{-1}$ to $0.015h^{-1}$. Corresponding particulate matter dry weight ingestion rates ranged from 80 - 720 $\mu gDW \cdot cm^{-2} \cdot h^{-1}$. These results are the first to quantify scleractinian nitrogen benefits from heterotrophic uptake of suspended particulate matter or particulate matter deposited onto coral surfaces. The present results suggest that differences in colony morphology allow some corals to take advantage of this potentially nutritious food source more than other corals.

REEF FLAT PHYSICAL PROCESSES AND SEDIMENT TRANSPORT OBSERVATIONS: MOLOKA'I, HAWAI'I.

Ogston, Andrea*, Michael Field, Curt Storlazzi School of Oceanography, Box 357940, University of Washington, Seattle, WA 98195-7940 Email: ogston@ocean.washington.edu

An instrumented tripod was deployed off south-central Moloka'i on the broad, shallow reef flat in approximately 1.3-m water depth. The instrumentation was designed to examine the physical processes and sediment transport regime as part of the U.S. Geological Survey's Coral Reef project. Hourly bursts of current, wave, suspended-sediment concentration, salinity and temperature data are presently being obtained for a year-long period. In the initial deployment, both tidal and wind-driven currents were observed to contribute to the circulation on this reef flat. During periods of stronger trade winds, near-bed currents were predominantly offshore and to the west. Near-bed orbital velocities due to both locally-generated waves and incoming swell were strongly modulated by tidal fluctuations of the water depth at the tripod location, and were, at times, of high enough magnitude to suspend fine-grained sediment. The near-bed flow and the presumed direction of sediment transport on the shallow reef flat appeared to be controlled by the interaction of tidal and wind-driven currents and sea-level elevation which varies according to tide height, and wind- and wave-generated set-up over the reef flat. In the initial two-month deployment of the proposed year-long record, the limited data suggests increased suspended-sediment concentrations occurred during periods of peak trade winds, due to resuspension, and at times of low tidal elevation, possibly due to advection from the inner reef flat.

EVOLUTION OF REEF-BUILDING SCLERACTINIA IN TURBID ENVIRONMENTS: A PALEO-ECOLOGICAL HYPOTHESIS.

Potts, D.C.*. Institute of Marine Sciences, University of California, Santa Cruz, CA 95064, USA. Email: potts@biology.ucsc.edu

Evidence is presented for radiations of reef-building corals during periods of poor reef development in habitats resembling those of modern, inshore shelves, rather than in more "typical" oceanic habitats. Indications of a history of adaptation to turbid environments include: 1.The Holocene is "atypical", having one of the longest and highest periods of stable sea-level since the mid-Pliocene; 2. Mean Plio-Pleistocene sea levels (45-50m below present) approximated the average depth of modern tropical shelves; 3. Hence, typical Plio-Pleistocene coral habitats probably were shallow shelves exposed to high frequency transgression-regression cycles; 4. Analogous inshore habitats today are often close to sea-grass and mangrove communities, and exposed to high terrigenous organic, nutrient and sediment inputs; 5. Corals in such habitats often have high growth rates, and assemblages may be diverse, despite unusual species compositions and growth forms; 7. Because they often grow on unconsolidated, anaerobic muds with limited carbonate accretion, such assemblages may not be recognized as "reefs" or studied by "reef" scientists. It is proposed that turbid shelf environments have always been common for corals, and more continuous in space and time than oceanic habitats; that several scleractinian radiations (e.g. Triassic, Paleocene, Oligocene) occurred during reef hiatuses; and that adaptations for success in turbid environments "pre-adapted" corals for success in oceanic settings.

TISSUE THICKNESS: A METHOD TO ASSESS THE PHYSIOLOGICAL RESPONSE OF MASSIVE CORALS TO SEDIMENT STRESS.

Rotmann, S.*. *Australian Institute of Marine Science, Townsville, Qld. 4810, Australia; Email: s.rotmann@aims.gov.au

Monitoring the health of living corals usually requires complex and expensive physiological measurements. The thickness of the tissue layer (TTL) in massive *Porites* alters along environmental gradients, including gradients in sediment stress. This paper presents preliminary results from an investigation of TTL response to elevated sedimentation at Lihir Island, PNG, where the third biggest gold mine in the world has been in operation since 1997. TTL was measured along an impact gradient due to disposal of large amounts of soft waste. It was also measured at different depths along the gradient and in different size classes of corals. TTL was measured by removing small cores from the summit of colonies. Results suggest that TTL of massive *Porites* represents a simple and reliable indicator of coral health.

TURBIDITY AND SEDIMENTATION AS STRESSORS TO FLORIDA REEF CORALS.

Szmant, A.M.* C. Yeung and K. Cohen. *Dept. of Biological Science, University of North Carolina at Wilmington, 1 Marvin K. Moss Rd., Wilmington NC 28403 USA; Email: szmanta@uncwil.edu

Recent Florida reef decline has been accompanied by claims of increasingly turbid and silty reef waters as a cause of the decline. Suggestions that the turbidity is related to nutrient enrichment prompted an investigation of levels of sedimentation stress and turbidity. Turbidity sensors and sediment traps were deployed in the upper Florida Keys, from Oct. '96 to March '98. Sedimentation rates of fine particles were higher inshore and near coastal passes, while those of coarser particles were higher offshore (more wave energy). Sedimentation rates averaged >100 g/m2/day, a level considered stressful to corals. N content of resuspended sediments were higher inshore, were greater than the N content of surrounding sediments, and were primarily associated with finer fractions; however, P content was higher offshore, as well as higher than surrounding sediments. These results suggest that inshore areas are accumulating finer nutrient rich particles, while offshore areas are being rid of such particles by storm resuspension. Sediment resuspension rates were high everywhere and likely a major stressor to Florida corals. Spectral analysis of turbidity records were compared with those of concurrent wind records, showing that most of the turbidity in the area is due to resuspension during 13-day cycle events. Florida coral reefs, at the northern limit of reef development in the Western Atlantic, are exposed to greater climate extremes than those in the Caribbean; it appears that most of the documented sedimentation and turbidity stress is climate related.

PARTICULAR MATERIALS IN THE LARGE CORAL REEF LAGOON OF MAYOTTE HIGH ISLAND (SW INDIAN OCEAN): NATURE AND SEDIMENTATION RATES

Thomassin, Bernard A*. *CNRS-UMR n° 6450 "Dimar", C.O.M., Univ. de la Méditerranée, 13007 Marseille, France & G.I.S. "Lag-May".Email: thomassi@com.univ-mrs.fr

Mayotte I. (N Mozambique Channel, 12-13°S) is an eroded volcanic island (with the lagoonal islets: 376km^2 of lands) showing a very jagged coastline (successions of caps and deep bays). It is surrounded by a very large and deep coral reef lagoon (surface near 1,500km^2, up to 15km large, average depth: near 40m, with 70-80m deep canyons) that belts a near continous ribbon barrier reef system. Seasonal winds, NW-N monsoon during the wet austral summer and SE-S dry tradewinds during the winter, and secondarily a high tidal range (up to 4m) are the main factors inducing water movements inside this lagoon, according to the coastal geomorphology and to the presence of functioning passages through the narrow modern barrier reefs (up to 2km large) and the drowned pleistocene fossil barrier reef platform (up to 7-10km large in some areas, at 35-30m deep today). Monsoon rainfalls above the lagoon vary between 500 up to 1500mm of water per year; but coastal rivers show important swellings few hours after storms, with huge sediment transport into the bays and the lagoon. Tropical storms and hurricanes are uncommon, but few were very catastrophic. Lagoonal waters can be subdivided in two categories: (a), those landwards in the inner areas which show neritic features, peculiarly in the bays with mangroves, with the highest contents of suspension materials, chlorophyll a and C, linked with the highest values of NH_4 and Si; (b) those seawards in the outer areas which show oceanic features, with lowest values of these parameters. Phytoplankton seems not very rich. To estimate the sedimentation rate and the features of this decanting materials on bottoms in a large bay and in front in the outer open lagoon an experiment was conducted during the 1989-90 year, using two kinds of traps, collected near every 12-14 days. So it was recorded that: in the bay, near 12 kg of dry material*m^{-2}*y^{-1} decants in a rainy year (about 2600 mm of water on the nearest land) while in the open outer lagoon near 6.8 kg of dry material*m^{-2}*y^{-1} settles down. In the bay, most of this fine materials (issued from lateritic alterites and detrital materials) showed highest values of the degraded chlorophylls in comparison to living chlorophyll a (average ratio chloro a / phaeopigments = 0.02 to 0.3), low N content (average: 0,3% in dry season up to 1,1% after rainfalls), highest values in lipids and proteins during the dry season in comparison to the values in rainy season. These results are analyzed with comparisons of data from the other similar environments (high island lagoons) opposed to different ones (low island or atoll lagoon).

CORAL COMMUNITIES OF NARIKEL JINJIRA, BANGLADESH.

Tomascik, T.* and Paiker, S.A. Parks Canada, 300-300 West Georgia St., Vancouver, BC, Canada V6B 6B4; Email: tomas_tomascik@pch.gc.ca

The present study was conducted on Narikel Jinjira, a small island located about 210-km south-southeast of the Ganges/Brahmaputra Delta. The objective of the study was to conduct an environmental assessment of the island's coral reefs, and to identify major environmental threats to the future sustainable use of coral reef resources. The weather and coastal oceanographic processes in the area are heavily influenced by a subtropical monsoonal climate that prevails over Bangladesh. Seawater salinity during the dry season (November/February 1997) fluctuated between 25.0‰ and 32.0‰, while SSTs ranged from 22°C to 29°C. The turbidity of inshore waters, as measured by the *Secchi disk*, ranged from 1.5 m to 8.0 m. The results of this study refute previous studies that documented an existence of coral reefs at Narikel Jinjira. However, the rocky subtidal that extended from the seaward margin of the intertidal to about 300 m offshore supported a relatively diverse veneering scleractinian coral community. A total of 66 scleractinian coral species, belonging to 22 genera, were collected and recorded during the study. The genera *Porites*, *Favites*, *Goniopora*, *Cyphastrea*, and *Goniastrea* were the most abundant. Corals accounted for only about 8% of substrate cover, while benthic macrophytes covered over 80% of the available rocky substrate. The coral community supported a diverse fish and invertebrate fauna characteristic of coral reef ecosystems. Based on visual counts, there were 34 reef-associated fish families represented by 86 species. The most abundant reef-associated fish herbivores were the Pomacentridae, Scaridae and Acanthuridae.

GROWTH OF *SIDERASTREA SIDEREA* AND *PORITES ASTREOIDES* IN CLEAR AND TURBID WATERS.

Torres, Juan L.*. *UPR, Dept. of Marine Sciences, PO Box 3210, Lajas, PR 00667 USA, Email: jltorres@caribe.net

The linear extension rates obtained from cores of the two reef-building Caribbean coral species *Siderastrea siderea* and *Porites astreoides* were measured and compared to sedimentation rates prevailing at the different study sites. Sedimentation rates as well as sediment composition were significantly different between control and stressed sites. Data revealed no significant differences in the linear extension rates of *S. siderea* between clear and turbid waters suggesting the high resistance of this species to sedimentation. In fact, the growth of neither growth band (high or low density bands) was statistically significant between sites. On the other hand, cores from *P. astreoides* revealed an average growth of 2.30 ± 0.36 mm/yr, and a predominance of high density bands over low density ones at all years. Considering the low growth rates of this species, it not surprising that the greater part of the skeleton is comprised to a high density level. Our results compare to those reported in the literature for both species even though this becomes the first study that takes into account the differences in growth between the different density bands, which seems to be a factor when considering different sediment regimes.

SEDIMENTATION RATE MEASUREMENTS: EFFECTS OF TRAP DESIGN AND IMMERSION TIME.

van der Wateren, Peter*; Nacorda, Hildie, Maria E.; Vermaat, Jan E. and Yap, Helen T. *The Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, The Philippines;. Email: peterwat@msi01.cs.upd.edu.ph

Sedimentation rates are generally compared regardless of trap design and trap immersion time. The aspect ratio of tubular traps is often seen as the most important parameter in describing the trap. For the present study two *in situ* experiments with different sediment traps were performed. Tubular traps with different diameters yielded significantly different sedimentation rates (g dry weight.dm^{-2}.day^{-1}). Smaller traps yielded higher sedimentation rates. Differences in aspect ratios (4, 5 and 6) had no effect on the amount of sediment trapped. Four tubes of 1" diameter inside a pipe of 3" diameter attached to a stake did not trap differently from 1" tubes that were individually mounted to a stake. The average catch of sediment (g dry weight.dm^{-2}.day^{-1}) over a period of 14 days differed significantly between traps that were emptied at different time intervals (every 1, 3, 7, 14 days). Shorter intervals resulted in higher catches. In addition, a coral surface simulating trap is introduced. It consists of an acrylic disk covered with a disk cut from a plastic doormat that features polyp-like structures. Preliminary results using the disk-traps are compared with the results from tubular traps.

SPECIAL HARDGROUNDS FOR THE INITIAL DEVELOPMENT OF CORAL REEFS IN NONCARBONATE ENVIRONMENTS.

Wang S.W.* and Dai C.F.. *Institute of Oceanography, National Taiwan University, Taipei, Taiwan, R.O.C. Email: wsw@nmns1.nmns.edu.tw

The Pleistocene coral reefs in SW Taiwan developed on several local structural highs, which are characterized by: (1) rapid facies change from underlying mudstones upward into fossiliferous sandstones, then into the basement of reef limestones, and (2) being located within a foreland basin and in close association with anticlines and faults. However, it is still uncertain that how these coral reefs built up in a noncarbonate environment dominated by fine-grained siliciclastics. Based on studies of 4 quarry outcrops and 21 drilling cores, we found localized lenticular dolomitic mudstones, tubular dolomitic structures, and muddy conglomerate which consists of dolomitic mudstone pebbles and cobbles near or at the tops of "soft" mudstones. Besides, we found abundant *in situ* lucinid bivalves in one of those lenticular dolomitic mudstones, in which the upper parts consist of encrusting coralline algae and scleractinian corals, then overlaid by bioclastic limestone. Base on the tectonic settings and special occurrences of those dolomitic mudstones and fossil lucinids, we suggested that they are the so-called "cold seep carbonates", which developed during the shallowing of structural highs in SW Taiwan and served as the hardgrounds for the initial development of coral reefs in noncarbonate environments.

CLASTIC INFLUENCE ON DELTA-FRONT REEFS, BORNEO

Wilson, Moyra E.J.* *Department of Geological Sciences, University of Durham, Durham, DH1 3LE, UK, Email: moyra.wilson@durham.ac.uk

Clastic sedimentation on shallow marine shelves is generally thought to inhibit carbonate production. However, modern and Neogene carbonates within the Mahakam Delta in Borneo were affected by high clastic input. Studies of these modern and ancient delta-front reefs shows that coral patch reefs developed in less than a few tens of metres water depth on delta-front mouthbars, whereas *Halimeda* dominates in deeper water reefs. In outcrop the coral reefs consist of lithologies dominated by platey, branching, head, branching and platey corals passing successively up section from base to top of the carbonate unit. These cycles represent apparent shallowing then deepening of the depositional environment, inferred to be related to amounts of clastic input. The development of these delta-front reefs was controlled by a complex array of factors, including climate, relative-sea level changes, oceanographic factors, sediment and nutrient input. Carbonates buildups are common along certain horizons and this study explores local and regional factors which may have influenced the initiation of carbonate production. This study has implications for the interactions between clastics and carbonates in tropical marine settings and shows that carbonate producers can thrive in areas of high clastic input.

CHANGES IN ZOOXANTHELLAE DENSITIES AND CHLOROPHYLL-A CONCENTRATIONS IN THREE CORAL SPECIES AFTER SHORT-TERM SEDIMENT BURIAL.

Wong, C.C.*, Yeung, K.P., P.O. Ang, Jr. *Department of Biology, The Chinese University of Hong Kong, Shatin, N.T., HKSAR, China. Email: put-ang@cuhk.edu.hk

Responses of three common coral species were monitored after full burial with sediment in two experiments at Tung Ping Chau, Hong Kong from Oct 1999 to Jan 2000. In the first experiment, colonies of *Porites lobata*, *Goniopora columna* and *Platygyra sinensis* were buried *in situ* for 0 (control), 2, 6, 17, 24 and 48 h. Their zooxanthellae densities and chlorophyll-a concentrations were assessed immediately after burial. In the second experiment, changes in these two parameters were monitored in colonies of *G. columna* before burial, immediately after 24 h burial, 4 and 40 days after burial. *Goniopora columna* has the highest mean density of zooxanthellae (1.7 x 10^{7} cells cm^{-2}) and chlorophyll-a density (95 μg cm^{-2}). *Platygyra sinensis* has only 1/3, and *Porites lobata* only 1/10 of these values. For all these corals, increasing burial time generally caused a decrease in both these values. However, statistically significant decrease was found only in 48 h treatment with a 50% drop in these values compared with those of the controls. All coral colonies survived the sediment burial except those buried for 48 h. For *G. columna*, 24 h burial did not change the zooxanthellae density and chlorophyll-a concentration significantly. These corals recovered within 4 days after being released from the burial stress.

REEF PRODUCTION IN A SHALLOW, TURBID ENVIRONMENT

Yates, K.K.* and Halley, R.B. U.S. Geological Survey, St. Petersburg, Florida, U.S.A. Email: kyates@usgs.gov

Agricultural practices on the island of Molokai in Hawaii have resulted in increased erosion and transport of sediment to reefs surrounding the island. Reef productivity (including calcification, photosynthesis, and respiration) was measured on representative substrate types of a shallow reef flat located on Molokai's southern coast. Measurements were made on coarse sand, coral rubble, and patch reef substrata over 24-hour time periods during increased turbidity using a large incubation chamber (Submersible Habitat for Analyzing Reef Quality, S.H.A.R.Q.) to isolate water over the substrate and measure changes in key geochemical parameters. In addition, air:sea CO_2 gas fluxes were measured along a transect across the reef flat, perpendicular to the shore. Preliminary results indicate that rates of calcification and photosynthesis range from 0.002 to 0.196 g $CaCO_3/m^2$/hour and 0.01 to 0.06 g carbon/m^2/hour, respectively, during light hours. Net dissolution of carbonate sediments was observed during dark hours with respiration rates ranging from 0.07 to 0.12 g carbon/m^2/hour. Productivity rates are similar to those measured on reef flats unaffected by increased turbidity in the western and southern Pacific. Gas flux measurements correspond to zonation of the reef flat with net uptake of CO_2 over algae-covered coral rubble near shore and net evolution of CO_2 associated with patch reefs offshore near the reef crest. These results suggest that light attenuation resulting from turbidity in shallow reef environments may be insufficient to reduce reef production.

Session A11: Reef Bioerosion

CORAL REEF BIOEROSION IN TIMES OF CRISES – THE LATE TRIASSIC/EARLY JURASSIC EXAMPLE.

Bertling.M* *Geologisch-Paläontologisches Institut und Museum, Pferdegasse 3, D-48143 Münster, Germany; Email: markus.bertling@uni-muenster.de

A study across a major reef crisis in Earth history was performed because data on the fate of borers after reef decline seem to be lacking. Scleractinian reefs flourished during the Late Triassic (Norian and Rhaetian) but corals suffered a major extinction phase soon afterwards. No reefs are known from the earliest Jurassic (Hettangian) but identical coral taxa reappeared later. Hence, similar substrate conditions prevailed for coral borers during these 5 million years of crisis, and samples could be evaluated for macroborings quantitatively. Norian reefs suffered almost no bioerosion (abundance of borings less than 0.01 /cm_) in the Alps but in northern Iran, they were moderately bored (0.14/ cm_) with ”worms’’ dominating over bivalves and cirripeds. Late Rhaetian reefs independently of the environment were only slightly bored (0.09-0.11/cm_) by the same borers. In the Pliensbachian, ”worms’’ still dominated over bivalves and cirripeds (0.08-0.12 borings/ cm_). The pattern of coral reef macroboring hence remained essentially unchanged across the major end-Triassic extinction phase of corals. This becomes obvious especially when viewed against the different situation prevailing from the Middle Jurassic onwards. This indicates that coral borers had evolved together with their substrate (co-adaptation?); they suffered the same fate during reef crisis and reappeared with the same corals during recovery. It was only the changing Middle Jurassic coral fauna which triggered a different suite of borers, not the extinction phase.

LAGOON SPONGES FROM THE BUNAKEN MARINE PARK (NORTH SULAWESI, INDONESIA): INTERACTIONS WITH SEDIMENTS

Cerrano Carlo*, Bavestrello, Giorgio Boyer, Massimo Calcinai, Barbara Lalamentik, Laurentius Th. X. & Pansini, Maurizio. *Dip.Te.Ris., Università di Genova, Corso Europa 26, I-16132 Genova. Email: cerrano@dipteris.unige.it

Sponges hold complex ecological roles in coral reefs. Our study take in account two populations of lagoon sponges from the island of Bunaken, that are charcterized by a unusual psammobiotic habitus, which support different ecological adaptations. The considered species are *Aka* sp., *Oceanapia amboinensis*, *Spirastrella solida*, *Biemna fortis* and *Acarnus tortilis.* The study by corrosion casts of the aquiferous system of these species shows different strategies of filtration among the different sponge groups. The simultaneous presence of boring (*Aka* sp.) and engulfing (*O. amboinensis; S. solida* and *B. fortis*) sponges leads to a reworking of the organic carbonates: i) boring sponges destroy the coral rocks contributing to the production of the overlaying sediments; ii) massive sponges incorporate sediments (more than 80% of the sponge dry weight) structuring a second hard substrata and modifing the interstitial pore water nearby the buried sponge body.

FORAGING BEHAVIOR OF TWO TRIGGERFISH (BALISTIDAE) AND ITS RELATION WITH CORAL REEF BIOEROSION AT GORGONA ISLAND, COLOMBIAN PACIFIC.

Francisco V.* and Fernando A. Zapata Departamento de Biología, Universidad del Valle, Apartado 25360, Cali, Colombia. Email: vafranci@biologia.univalle.edu.co

The feeding activity of several fishes influence the process of reef bioerosion. We studied the foraging behavior of *Sufflamen verres* and *Pseudobalistes naufragium* to examine their impact on reef bioerosion at Gorgona island, Colombian Pacific. Fish foraged mainly on coral substrates searching for invertebrates associated with coral. Coral rubble (mainly *Pocillopora* spp.) was the preferred foraging substrate in both species. Mean foraging rates were 0.91 bites per min. for *S. verres* and 0.78 bites per min. for *P. naufragium*. During their feeding activity, the fish fragmented coral into small pieces or turned it into sediment. Thus triggerfish facilitate the natural erosion of reefs, accelerating the transformation of coral debris into sediment. Triggerfish abundance at Gorgona is high compared to other reefs in the eastern Pacific. Therefore, the contribution of these fish to bioerosion is particularly important at Gorgona. We obtained preliminary estimates of bioerosion rates for these species in one reef based on estimates of the amount of substrate removed per bite, foraging rates and fish density (1.13 kg m^{-2} $year^{-1}$ for *S. verres* and 0.62 kg m^{-2} $year^{-1}$ for *P. naufragium*). Bioerosion caused by triggerfish at Gorgona is lower than that caused by parrotfish (1.6 kg m^{-2} $year^{-1}$) and higher than erosion caused by urchins (0.19 kg m^{-2} $year^{-1}$).

S*carus ghobban* BIOEROSION RATES IN A GORGONA ISLAND CORAL REEF – COLOMBIA (TROPICAL EASTERN PACIFIC).

Jiménez J. M. * and F. A. Zapata. *Universidad del Valle, A.A. 25360, Cali – Colombia, S.Am. Email : jumajime@mailcity.com

To estimate the bioerosion rates by *Scarus ghobban* in a Gorgona island fringing coral reef (Tropical Eastern Pacific) indirect and direct methods reported in literature were combined. Fish size, time of day and reef zone as well as the foraging substrates were considered. Bioerosion turned out to be greater at the backreef and diminished towards the slope, following the distribution and abundance pattern of the species within the reef. Small individuals showed the greater bioerosion rates in the reef as a whole (1.2 kg m^{-2} $Year^{-1}$) given their greater abundance. On the other hand, a large individual eroded more sediment than a small one (123.6 Vs. 8.2 kg $Ind.^{-1}$ $Year^{-1}$, respectively) showing that bioerosion rates per individual are proportionally inverse to fish size. High densities and large body sizes found for *S. ghobban* in this reef resulted in greater bioerosion rates (1.6 kg m^{-2} $Year^{-1}$) than the rates found for other scraping species, but lower than the bioerosion rates found for excavating species in other oceans.

BIOEROSION OF EXPERIMENTAL SUBSTRATES ON HIGH ISLANDS AND ATOLL LAGOONS (FRENCH POLYNESIA)- FIVE YEARS OF EXPOSURE.

Peyrot-Clausade,M.*, Hutchings, P.A., and Pari, N. *Centre D'océanologie De Marseille, Umr Cnrs 6540, Université De La Méditerranée, Station Marine D'endoume, Rue De La Batterie Des Lions, 13007-Marseille, France. Email: PEYROT@COM.UNIV-MRS.FR

Rates of losses of $CaCo_3$ from bioerosion (grazing and boring) and gains from accretion were determined from experimental coral substrates exposed for 5 years and laid in the lagoons of high islands and atolls in French Polynesia. Significant differences in rates of grazing and boring were found between sites. Maximum rates of grazing and boring were found in the atoll lagoons (9.53 kg $CaCO_3$ $m^{-2}.y^{-1}$ at Tikehau, 3.47 kg $CaCO_3$ $m^{-2}.y^{-1}$ at Takapoto). A positive correlation was found between the density of algal turf and the intensity of boring by clionid sponges which reachs 1.04 kg $caCO_3$ $m^{-2}.y^{-1}$. Rates of grazing by echinoids and scarids were also positively correlated with high biomass of microborers. These results were compared with those obtained after 6 and 24 months of exposure at the same site and rates measured experimentally elsewhere. These studies allow us to develop models as to the interaction between rates of grazing and boring and the protective role of accretion by coralline algae and the types of factors which influence the net rates of bioerosion on "healthy" and "disturbed" reefs.

BIOEROSION RATE OF THE SPONGE *CLIONA CELATA* (GRANT 1826) FROM THE CORAL REEFS OF NORTH BAHIA, BRAZIL.

Reis, Maria Alice* and Zelinda Margarida Leão. Universidade Santa Úrsula, Instituto de Ciências Biológicas e Ambientais, Rua Jornalista Orlando Dantas 59, Rio de Janeiro 22231-010, BRAZIL, Email aliceusubr@apc.org.br

The nearshore bank reefs along the north coast of Bahia, Brazil, are subjected to the influence of a continent derived highly siliciclastic sediment influx and a nutrient enrichment. In order to compare the degree of coral infestation by the sponge *Cliona celata* (Grant 1826) with reefs within a carbonate dominate province, massive colonies of the endemic coral *Siderastrea stellata* (Verrill 1868) were sampled from the intertidal shallow pools (0.2 to 0.6 m deep) of the emergent top of two isolated reefs, from the surface of a bank reef, 5m deep, and of a reef located at depths around 10 m. This coral species was chosen because it is amply distributed along the entire coast of Brazil, and is particularly abundant in shallow reefs. Five roughly hemispherical and partially living coral heads, with diameters ranging from about 10 to 20 cm, were haphazardly collected from each selected zone. X radiographs of sliced coral colonies were performed for estimating the percentage of skeleton removed, and the rate of coral growth. Traces of bioeroding animals were identified in the coral slabs according to track characteristics. The boring activity of sponges, in the studied area, coincides with that of worldwide investigated reefs. It is controlled either, by characteristics of coral host, i.e. coral growth rate and density, as well as by some local environment parameters, such as high levels of water turbidity and sedimentation.

EFFECT OF PREDATION ON LIVE CORAL BY *SPARISOMA VIRIDE* AT THE TAYRONA NATURAL PARK (COLOMBIAN CARIBBEAN).

Reyes-Nivia, M.C.*, J. Garzón-Ferreira & A. Rodríguez-Ramírez. *Instituto de Investigaciones. Marinas y Costeras, INVEMAR, A.A. 1016, Santa Marta, Colombia; Email: catarey@invemar.org.co

The effect of predation by the stoplight parrotfish (*Sparisoma viride*) as a coral mortality agent, was evaluated within SIMAC (National Monitoring System for the Corals Reefs of Colombia). The. Surface and volume of live coral removed by bite (measured with Vernier calliper) and change over time of the affected areas (using video-image analysis) were estimated for several species of hard corals. Bites were made principally by terminal and initial phase *S. viride* (sizes 20-40 cm fork length). The means of surface and volume by bite on the different species were: 38.7 cm^2 and 355.5 cm^3 in *Colpophyllia natans*, 22.5 cm^2 and 31.8 cm^3 in *Montastraea annularis*, 25.7 cm^2 and 97.9 cm^3 in *Montastraea faveolata*, 21.9 cm^2 and 25.9 cm^3 in *Porites astreoides*. At the beginning of study, 43 colonies showed a total recently grazed surface of 7336.7 cm^2 on 4000 m^2 of reef area (with live coral cover= 35%). During the next three months, 42% of these colonies were bitten repeatedly, being *C. natans* suffered the highest grazing rate (4.63 cm^2d^{-1}), followed by *M. faveolata* (0.13 cm^2d^{-1}), while *P astreoides* was the only that showed live tissue recuperation. After five months, the total affected area increased by 49%. These results show that *S. viride* is able to originate rapid and considerable damages on live coral surfaces of reefs especially on *C. natans*. This kind of tissue loss by depredation is uncommon and has been observed recently in the Caribbean Sea.

INTERNAL BIOEROSION OF *MUSSISMILIA* FROM EXPOSED AND SUBMERGED REEF FLATS, EASTERN BRAZIL

Santa-Isabel, L. M* . Z. M. A. N. Leão, M. C. Peso-Aguiar and R. C. F. Assis *Universidade Federal da Bahia, Instituto de Biologia, Departamento de Zoologia, Campus Universitário de Ondina, s/n. CEP 40170-290, Salvador, Bahia, Brazil. Email: ledama@ufba.br

The internal bioerosion of dead corals, belonging to the endemic genera *Mussismilia* (*M. braziliensis* and *M. hispida*), was analyzed in specimens collected from an exposed and a submerged reef flat at Guarajuba Beach (Bahia). Twenty coral colonies were sliced (80 replicates) and x-rayed to identify internal bioeroders and to estimate the degree of bioerosion produced by each group. The most representative borers are: the bivalves *Lithophaga bisulcata*, *Gastrochaena hians*, *Spengleria rostrata* and *Gregariella coralliophaga*, the sipunculids *Phascolosoma antillarum* and *Aspidosiphon elegans*, and polychaetes *Eunice wasinensis* and *Lysidice ninetta*. Total bioerosion is significantly lower at the exposed reef flat, where sipunculids is the most important group. Boring bivalves dominate in the submerged reef. The polychaete exhibit low level of bioerosion in both studied reefs. The lowest level of internal bioerosion registered for the exposed reef is reflected by the diversity, abundance and population density of bioeroders, which may be controlled by the sub-aerial exposure of the reef organisms, the characteristics of the coral species, as well as the periodic migration of sand on the exposed reef flat.

CHANGING ENVIRONMENTS AND SPONGE BIOEROSION - IS THERE A CONNECTION?

Schönberg*. Carl von Ossietzky *Australian Institute of Marine Science, PMB 3, Townsville MC, QLD 4810, Australia. Email: christine.schoenberg@mail.uni-oldenburg.de

Worldwide, reefs are suffering from destruction. Bioerosion is a natural form of carbonate degradation, with sponges being major agents of tropical reef bioerosion. However, little is known about natural levels of sponge bioerosion and the factors influencing them. It is unknown what factors may increase natural sponge bioerosion to levels that disrupt natural reef growth rates. Occasional field observations of increased sponge bioerosion associated with elevated nutrient levels have been reported, however, this has not been experimentally tested. The Australian sponge *Cliona orientalis* is very common on the inshore Great Barrier Reef and has been used in several experiments to study growth and erosion capabilities. Influences of nutrient levels, water movement and substrate porosity were investigated. Results indicate that *C. orientalis* growth is enhanced by increased water movement, whereas high nutrient levels are detrimental. However, bioerosion is enhanced by both factors. Porosity of natural substrate, which in turn is influenced by nutrient levels and water movement, is indirectly proportional to erosion by the sponge. Varying levels of substrate porosity have little influence on sponge growth itself, unless the substrate is very dense, i. e. *C. orientalis* grew better in *Tridacna* shells than in coral substrates. Results imply complicated interactions between factors influencing growth of and erosion by *C. orientalis*. Therefore it is very difficulty to predict how sponge bioerosion will behave with changing environments.

ROLE OF THE BORING MICROFLORA AND MEIOFAUNA COMMUNITIES IN THE DESTRUCTION PROCESSES OF CORAL REEFS. VARIABILITY OF BIOEROSION IN EXPERIMENTAL CORAL SUBSTRATES ON THE GBR, AUSTRALIA.

Tribollet A. *, Decherf G., Hutchings P. and Peyrot-Clausade M. *Centre d'Océanologie de Marseille, Station Marine d'Endoume. Rue de la batterie des Lions, 13007 Marseille (France). Email: tribollet@com.univ-mrs.fr

Increasingly coral reefs world-wide are under considerable stress and are experiencing damage. Dead corals are available for colonisation by boring organisms and subsequently for grazers, which both participate in reef destruction. Several studies on bioerosion of coral substrates by macroborers and grazers have been undertaken on the GBR. In contrast, very little is known about the development of the microboring communities through time and their bioerosion rate spatial variability. Boring communities were studied after one year of colonizing experimental coral substrates *Porites lobata* at six different stations along a cross shelf transect from the coast out into the Coral Sea, in far North Queensland. Dominant species of microborers and subfamilies of boring meiofauna and macrofauna were identified and counted. Their biomass and bioerosion rates as well as bioerosion of grazers and accretion rates were quantified in order to establish the calcium carbonate balance sheet of the experimental substrate. External erosion of these blocks varied considerably from 0.28 ± 0.12kg of $CaCO_3$ $m^{-2}.y^{-1}$ on Snapper Island (coastal site) to 3.5 ± 0.5 kg of $CaCO_3$ $m^{-2}.y^{-1}$ on Ribbon Reef and Lizard Island. Such significant between sites differences reveal the impact of terrigenous inputs on the coastal sites and the influence of the grazers on the microboring communities.

LONG TERM DISTRIBUTION PATTERNS OF *ECHINOMETRA MATHAEI* ON SUVA BARRIER REEF, FIJI.

Vuki, V.C* and Zann,L.P* *Marine Studies Programme, University of the South Pacific, P.O. Box 1168, Suva, Fiji. Email: Vuki_V@usp.ac.fj

Suva Barrier Reef lies between one and five kilometers off the coast of Suva. It is one of the most polluted and overfished reefs in the South Pacific. A narrow lagoon of about 10m deep separates the reef from the city of Suva. Suva Barrier Reef has experienced an almost continuous presence of *E.mathaei* since 1979. Large numbers of *E.mathaei* were observed at six sites from 1979 to 1999. They are major bio-eroders on the reef flat and contribute to changing the structure of the reef framework from hard coral rock substratum to rubble and sand. The occurrence of large numbers of *E.mathaei* is associated with *Acanthaster planci* predation and high fishing pressure on Suva Barrier Reef. It is possible that anthropogenic factors contribute to the high densities of *E.mathaei* on Suva Barrier Reef. Adults and juveniles are consistently more frequent here than in any other Fijian reefs studied. The removal through fishing and gleaning of predators must affect the high densities of *E.mathaei*.

Session A12: Hyrdodynamics of Reefs and Modelling of Circulation in Lagoons

EFFECTS OF WAVES ON NUTRIENT UPTAKE INTO THE BIOSPHERE 2 MESOCOSM.

Atkinson, M*, *Department Of Oceanography, University Of Hawaii, Honolulu, Hi 96822, Usa. Email: marlinatkinson@aol.com

…Waves increase nutrient uptake to an experimental coral reef community. Biosphere 2 ocean is a self-contained, 850 m^2, 3.1 m-deep coral reef mesocosm, maintaining a mixed community of macro-algae, corals, fish, and associated invertebrate crytofauna. Water motion in the mesocosm is controlled by a vacuum-driven wave machine, producing waves 10 cm to 130 cm high . Waves propagate onto a reef-flat, break and create back-reef currents. Nutrient uptake rates were measured over a two year period by raising water concentrations to 10 µM NH_4 and 1 µM PO_4 and then measuring a decay in nutrient concentration to ambient nutrient concentrations (NH_4 ~ 0.2 µM, PO_4 ~ 0.05 µM). Nutrient uptake rates were first-order (Uptake=S[Concentration], with rate constants, S, similar in magnitude (4.7 to 10.8 m d^{-1}) to published rates for flumes and for field measurements during Encore experiment). Wave heights were varied and currents measured 10 cm above the bottom at 20 locations within the mesocosm during a summer and winter period. Rate constants, S, for NH_4 and PO_4 (4.7 –10.8 m d^{-1}) were positively correlated to water velocities (from 2.3-8.3 cm s^{-1}) and consistent with mass transfer relationships. These results are the first measurements of increasing nutrient uptake from water motion created by waves, supporting the contention that reef communities residing in higher wave environments experience increased metabolic exchange with the environment.

A 3D COUPLED PHYSICAL-BIOGEOCHEMICAL MODEL TO SIMULATE INFLUENCES OF MAJOR HYDRODYNAMIC FORCING ON THE EVOLUTION OF PELAGIC ECOSYSTEM IN THE SOUTH-WEST LAGOON OF NEW CALEDONIA.

Bujan S.*, Pinazo, C., Douillet, P., Grenz, C., Fichez, R.. *National Institute of Water and Atmospheric Research (NIWA) PO Box 8602 Christchurch New Zealand. Email: s.bujan@niwa.cri.nz

Evolution of knowledge on physical processes and biogeochemical cycling of the south-west lagoon of New Caledonia bring enough material today to allow their integration for the development of a determinist modelling for this ecosystem. A 3D hydrodynamic model with 21 vertical sigma levels and a spatial grid of 500 m was coupled with biogeochemical equations. The resulting model was used to calculate phytoplanktonic biomass and nutrient concentrations in the 2000 km^2 wide south-west lagoon of New Caledonia. Simulations were achieved for several wind driven hydrodynamic conditions and as a function of : the light and nutrient effects on pelagic primary production, the effect of temperature on the biological processes, and the impact of freshwater inputs during the rainy season. Several realistic scenarios are established and results compared with field data from the Ecotrope Program for the validation. Simulations showed that the biological flows are very sensitive to the wind with a general influence of south boundary conditions, in concordance with the dominant trade wind. Even during the summer rainy season, impact of terrigeneous nutrients on pelagic ecosystem is reduced to shallow, wind protected bay directly influenced by the main river (Dumbéa). The vertical resolution of the model provide useful information to explain seasonal variations in lagoon phytoplankton.

PHOSPHORUS SUPPLY FOR ATOLL BIOLOGICAL PRODUCTIVITY

Charpy, Loïc* *IRD, COM, rue de Batterie des Lions 13007 Marseille, France lcharpy@com.univ-mrs.fr

Origin of phosphorus for whole atoll productivity is discussed using biogeochemical data from Tikehau atoll (French Polynesia), new concept on coral reef fractal dimension and recent advances in modeling groundwater flow in an atoll platform. The conclusion is that horizontal flow of oceanic waters, in spite of low P concentration is largely enough to sustain atoll productivity.

DETERMINATION OF THE HYDRODYNAMIC CIRCULATION OF THE LAGOON OF SUVA (FIJI) USING MODELISATION AND MEASUREMENTS.

Douillet P*, Kumar. *Centre IRD, BP A5, Nouméa, New Caledonia. Email: douillet@noumea.ird.nc

The lagoon of Suva, Fiji, is subject to significant anthropogenic and terrigenous inputs and a precisely determining water circulation is a perquisite to a better knowledge of the fate of such inputs. In coastal circulation and environmental studies a high level of resolution is generally needed and numerical modelling is the only satisfactory method. 2-D and 3D modelling where used to calculate instantaneous current in space and time. As tide, wind and freshwater inputs represented the three major driving forces, numerical modelling was associated to data collection of current speed and direction, water levels, wind, river discharge. Validation of the models, realised by the comparison of computations and measurements, showed a good agreement. From the instantaneous bi-dimensional model used to determine tidal currents it was possible to calculate the long term trajectories of water that represent the effective displacement of the water masses resulting from several complete tidal cycles. Wind driven currents calculated by the three-dimensional model showed how circulation generate specific vertical structure in the lagoon. The influence of freshwater inputs by the Rewa river on the circulation is presented and discussed.

BOUNDARY CURRENTS AND BARRIER REEFS.

Furnas, Miles *. *Australian Institute of Marine Science, Townsville, Queensland 4810, Australia. Email: mfurnas@aims.gov.au

Well organized boundary currents flow along the seaward margins of the Great Barrier Reef (GBR: East Australian Current), Ningaloo Reef (Leeuwin Current) and the Papuan Barrier Reef (PBR: Kiri Current). Wind-stress along the Ningaloo Reef system and the western PBR is strongly favorable to Ekman upwelling. While upwelling can bring large quantities of nutrients to the surface, stimulating productivity, cold water from the thermocline would retard coral growth. A dynamic balance between wind stress and geostrophic pressure gradients in the Leeuwin and Kiri Currents inhibits large-scale or continuous upwelling. Along southern GBR, the geostrophic structure of the EAC favors large-scale intrusive upwelling which is counter-balanced by a cross-shelf pressure gradient set up by wind stress from the SE trade winds. Intermittent upwelling has also been recorded along southern Java and the Gulf of Panama. Barrier reef development appears to be favored in settings which receive episodic nutrient inputs from upwelling processes, but are not continuously subject to low-temperature upwelled waters.

MODELLING GENE CURRENTS BETWEEN CORAL REEF ISLANDS.

Hearn, C*, Black, R, Johnson, M, and Hatcher B, Oceanography, University College, University of New South Wales, ADFA, Canberra, Act 2600, Australia. Email: C.Hearn@adfa.edu.au

This paper presents a model of the transport of larvae between coral reef islands in the Easter Group of the Abrolhos Islands off Western Australia. It investigates the relationship between model inter-island hydrodynamic connectivity and observed genetic connectivity. Its outcome provides new information on the role of ocean dispersal in gene flow. This basic question of the spatial scales over which ocean currents can carry genetic information is critical to our knowledge of the interdependence of marine systems, and the management of biodiversity. The study involves two species of inter-tidal snail, one a direct developer *Bembicium vittatum* and the other a planktonic disperser, and spans spatial scales of hundreds of metres to tens of kms. The numerical model SPECIES was run for a period of one year using combined wind, wave, tidal, and Leeuwin Current forcing with all of these forcing factors varied seasonally. At first sight, *B. vittatum*, which has no planktonic stage, might be thought to have no means of moving between islands but the genetic variances point strongly to the existence of such hydrodynamic connectivity and this is presumably due to rafting of the egg masses. A comparison is made between the observed genetic variance G_{st} of *B. vittatum*, between various inter-island sites, and the SPECIES model hydrodynamic connectivities based on the dispersal of surface water between the same sites.

OBTAINING INFORMATION ON CORAL REEF FRICTION AND SOME IMPLICATIONS FOR NUTRIENT UPTAKE.

Hearn, C* and Atkinson, M. *Oceanography, University College, University of New South Wales, ADFA, Canberra, ACT 2600, Australia. Email: c.hearn@adfa.edu.au

Changing sealevel over a coral reef affects the strength of wave-driven currents. This effect has the potential to provide considerable information on the nature of friction and turbulent energy dissipation on reefs. Current-depth (c-d) coefficients are introduced that describe the fractional change of across-reef, and lagoonal, current with change in depth of water over the reef flat. The c-d coefficients can be easily measured by tidal analysis of reef, or lagoonal, currents and have the potential to provide information on some of the most poorly understood aspects of reef hydrodynamics. This paper derives c-d coefficients theoretically using both an analytical hydrodynamic model, and the three-dimensional numerical model SPECIES. Comparisons are then made with data from two reefs. The first is Ningaloo Reef in northwest Australia, which is a typical barrier reef with a narrow coastal lagoon, and the second is Kaneohe Bay in Oahu, Hawaii, where the reef is unusually wide. The analysis uses mixing length theory based on various roughness lengths for different types of coral. The modelled turbulent energy dissipation is used to determine both the Stanton number (which measures the ratio of the uptake of phosphorus to its net flux over the reef flat), and its variation with the depth of water over the reef; comparisons are made with Atkinson-Bilger roughness theory.

SEASONAL VARIATIONS IN DENSITY DISTRIBUTIONS AND CIRCULATION PATTERNS AT MAJURO ATOLL, THE REPUBLIC OF THE MARSHALL ISLANDS.

Kraines, Steven*, Masahiko Isobe, Hiroshi Komiyama. *Dept. Chemical System Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656 Japan. Email: steven@prosys.t.u-tokyo.ac.jp

As a part of an ongoing project to study the negative effects of human activities on coastal margin ecosystems and how they might be mitigated, we have been investigating the circulation patterns at Majuro Atoll. Majuro Atoll is characterized by the nearly complete closure of the southern atoll rim by US army engineers in the 1950's. This closure of exchange channels between the lagoon and the open ocean may have altered the circulation and residence time of water in the atoll lagoon. In order to clarify the mechanisms that determine the circulation in the lagoon, we measured vertical and horizontal distributions of temperature and salinity every three months from April 1998 to June 1999, characterizing density distributions for each season. We used a robust diagnostic three dimensional residual currents circulation model to simulate the circulation patterns for each of the measured density distributions. The circulation patterns within the lagoon, which have been shown to be driven primarily by a combination of wind stress, wave induced radiation stress, and density variations, varied significantly. Water exchange times between the lagoon and the ocean ranged from 11.5 to 14.2 days. In conclusion, seasonal variations in wind, density and wave height have non-negligible effects on the circulation patterns at Majuro Atoll.

BOUNDARY LAYER MIXING AND CIRCULATION OVER ROUGH TOPOGRAPHY: FLOW OVER CORAL REEFS.

Monismith, S.G.*, M.A. Reidenbach, J.R. Koseff, A. Genin, G. Yahel. Environmental Fluid Mechanics Laboratory, Stanford University, Stanford, CA 94305-4020 USA. Email: monismith@ce.stanford.edu

A field study was conducted in Eilat, Israel, the Red Sea to study the role that bottom roughness plays on mixing and turbulence in the overlying water column. The motivation for this work is the fundamental role that turbulence plays in coral reef ecology. Fluid flow acts to transport nutrients, larvae, wastes and numerous other constituents to and from a reef. The structure of the flow near the reef, within the turbulent bottom boundary layer, is related to the complex structure of the topography of a reef. This turbulent flow controls exchanges of both mass and momentum between the corals and the overlying water. In this study, flow measurements were made using Accoustic Doppler Current Profilers (ADCP), Accoustic Doppler Velocimeters (ADV), and Conductivity, Temperature, Depth (CTD) probes. A detailed bathymetric study was also conducted to capture the roughness of the reef. Three different sites were measured, two over the reef system and, as a control experiment, one site over a sandy bottom. To test the relationship between form drag and skin friction, nylon sheeting was also placed over one test section whithin the reef to study the relative contributions of form drag and skin friction. Detailed measurements of near-bottom turbulence give a measure of Reynold's stresses and bottom shear stresses. Mixing coefficients were measured using calculations of turbulence dissipation and shear. Combining these measurements with velocity profiles throughout the water column give us a complete picture of circulation in and above the reef.

FIELD-OBSERVATION ANALYSIS OF PHYSICAL ENVIRONMENTS OF A FRINGING REEF AT ISHIGAKI ISLAND UNDER INFLUENCES FROM INLAND AND OFFSHORE.

Nadaoka K.*, Y. Nihei, R. Kumano, T. Yokobori, T. Oomija. Graduate School of Information Science and Engineering, Tokyo Institute of Technology, 2-12-1 O-okayakma, Meguro-ku, Tokyo 152-8552, Japan. Email: nadaoka@mei.titech.ac.jp

To investigate the physical environments of a fringing coral reef, especially possible influences both from inland and offshore, we have conducted a field survey at Shiraho coast in the Ishigaki Is., Okinawa, Japan, by deploying 16 moored buoys in and around the reef, on which various sensors for continuous measurements of water temperature, salinity, turbidity and chlorophyll.a concentration were installed. Several bottom-mounted current meters and wave gauges were also. The results show, e.g., the abrupt decrease and increase of the water temperature during the attack of a typhoon, resultant temperature being about 1 degree lower than before. The main cause of this abrupt change and the difference between inside and outside the reef in the thermal response to the atmospheric agitation are investigated. For normal atmospheric conditions, the overall characteristics of currents in the coral reef is found to be governed by the dynamic balance among tide, waves and wind effects. Thermal environments in the reef are also examined by a heat budget analysis, indicating that it is influenced both by the atmospheric conditions and the temperature difference between in and outside the reef. The salinity and turbidity variations near the river mouth and their cause are also investigated.

NEARSHORE WAVE MODELLING FOR BEACH WITH CORAL REEFS ALONG THE RED SEA.

Rakha K.A. and Abul-Azm A.G.*. *Irrigation and Hydraulics Dept., Faculty of Engrg., Cairo University, Giza, Egypt. Email: ecma@access.com.eg

The Sahl Hasheesh development is located about 20 km south of Hurghada City along the Red Sea coast in Egypt. The shorefront is almost 12 km with a large sandy bay situated in the middle of the development. A small island is located about 2.5 km east of the shoreline with a coral shoal (water depth of 6.0m) surrounding the island. This paper provides the nearshore wave conditions calculated using the RCPWAVE and the REF/DIF models. Both models are based on the Mild Slope Equations (MSE) valid for bed slope up to 1:3. The simulations performed showed that the RCPWAVE model is not suitable for this specific site due to the complexity of the bathymetry involved. The model produced spurious results at areas with the waves propagating parallel to steep coral edges. These spurious results increased for the cases with larger angles between the direction of propagation and the wave direction. Results obtained using the REF/DIF model showed to be more realistic compared to those obtained by RCPWAVE model. This paper shows that for areas with complex coral reef formation -as in the Red Sea- more research is needed to develop models capable of incorporating all the relevant physical processes.

A LABORATORY STUDY OF FINE-SCALE MIXING AND MASS TRANSPORT ABOVE A CORAL REEF.

Reidenbach*, M.A., J.R. Koseff, and M.A.R. Koehl. *Environmental Fluid Mechanics Laboratory, Stanford University, Stanford, California 94305-4020, USA. Email: mar10@stanford.edu

Dissolved chemical cues have been shown in the laboratory to induce settlement by the larvae of various benthic invertebrates. One such species is the nudibranch, *Phestilla siboga*, whose larvae metamorphose in response to a species specific metabolite from its prey, the coral *Porites compressa*. To determine how such chemical cues affect larval settlement in nature, a detailed understanding of how dissolved cues disperse in ambient water flow is needed. In this study, a constructed reef made of *P. compressa* skeletons was placed in a water flume capable of producing both a mean current and surface waves. The flow environment in the flume was driven to mimic the turbulent flow measured in the reef dominated by *P. compressa* in Kaneohe Bay, Hawaii. Using laser-Doppler anemometry (LDA), detailed flow fields above the constructed reef were measured. The structure of the odorant field leaching off the corals was studied using a planar-laser induced fluorescence (PLIF) technique. In this technique, rhodamine dye was spread over the surfaces of the coral and leached into the water column. The dye was fluoresced with the laser, then digitally photographed, and the resulting images were interrogated to quantify the structure and mass transport of the dissolved constituent. The fine scale spatial structure of chemical filaments from the reef not only reveals the spatial and temporal patterns of concentrations encountered by larvae, but also sheds light on how rough reef topography affects mixing processes.

EFFECTS OF ACROSS-SHELF HEAT TRANSPORT ON SUMMERTIME REEF TEMPERATURES.

Smith, Ned P.* *Harbor Branch Oceanographic Institution, 5600 Highway 1 North, Fort Pierce, Florida 34946 U.S.A. Email: nsmith@hboi.edu

A finite-difference computer model is used to simulate across-shelf heat transport and the resulting temperature fluctuations under upwelling and downwelling conditions. Bottom topography and summertime weather conditions are based on historical data from Lee Stocking Island, Exuma Cays, Bahamas. Results suggest that advective heat transport is highly sensitive to wind direction, and that temperature changes occur over time periods of 1-2 days. In contrast, local heating and cooling, primarily in response to incoming solar radiation, net outgoing longwave radiation and evaporation, occurs over time periods on the order of one week and longer. Under normal midsummer weather conditions, advective warming and cooling dominates local warming and cooling. Heating under clear skies is significantly reduced if wind directions are upwelling favorable and produce advective cooling. Even for relatively cloudy conditions, near-bottom heating at the reef can be significant if wind directions are downwelling favorable and warm water floods onto the inner shelf.

ALONG-REEF CURRENTS FORCED BY OBLIQUELY INCIDENT WAVES

Symonds, G*. *School of Geography and Oceanography, University College, ADFA, University of New South Wales, Canberra, Australia.
Email g.symonds@adfa.edu.au

As normally incident waves break on the seaward facing reef slope cross-reef gradients in cross-shore wave momentum produce wave setup of order 0.1 to 0.5m and cross reef currents of order 0.1 to 1m/s. The magnitude of the setup and cross-reef currents depends on factors such as the incident wave height, the depth over the reef, the width of the reef flat and bottom friction. In addition to setup and cross-reef currents, obliquely incident waves will also force along-reef currents due to cross-reef gradients in the along-reef wave momentum flux. The situation is similar to alongshore currents on beaches forced by obliquely incident waves for which numerous theoretical and observational studies have been reported in the literature. In this paper some of these models are applied to an idealised reef which differs from a beach in that the bottom slope through the surf zone is typically an order of magnitude larger and there is not necessarily a shoreline. The steeper bottom slope produces narrower surf zones and hence stronger along-reef currents than the equivalent, less steep beach with the same incident wave height. However, high friction coefficients on the reef will reduce current speeds. The absence of a shoreline allows strong cross-reef flows which, through non-linear interaction with the along-reef flows, may provide an efficient mechanism for lateral mixing of along-reef momentum. Analytic and numerical results using both uniform and randomly distributed incident wave fields will be discussed.

Session A13: Dust and Caribbean-wide Coral Reef Decline: an Hypothesis and Geosceintific Contributions to the Understanding of Coral Reefs

BALI AS A REEF HABITAT.

Borel Best M.* & Boekschoten, G.J. *National Museum Natural History, Naturalis P.O.Box 9517, 2300 RA Leiden The Netherlands. Email: Best@naturalis.nnm.nl

Geological and biological data on balinese reefs are presented. The oldest reefs developed on top of neogene pillow lava flows. From these, only travertine remains as redeposited karstic infillings. Sections of early and late pleistocene reefs are preserved in the bukit peninsula. Post glacial reef originated in several submarine settings: along limestone cliffs and denuded volcanic hardnecks, on lava outflows and on residual boulder coasts washed by oceanic surfs from lahar deposits. Because of a varied topography and the presence of active volcanoes, reefs developed under a multitude of different environmental stresses. Living reefs are discussed, and compared to other reefs in indonesia in respect to coral composition and biodiversity.

PLEISTOCENE REEFS IN THE SOUTHERN RED SEA AS FORAGING HABITAT FOR HOMINIDS.

Bruggemann J.H.*, M.M. Guillaume, R. von Cosel, R.T. Buffler, B. Negassi, S.M. Berhe, Y. Libsekal, R.C. Walter. *Experimental Zoology Group, Wageningen University, P.O. Box 338, 6700 AH Wageningen, The Netherlands. Email: henrich.bruggemann@morf.edc.wag-ur.nl

The discovery of early Middle Stone Age tools in primary context within a raised Pleistocene reef terrace on the Red Sea coast of Eritrea, dated to 125 +/-7 ka, suggests that early humans were harvesting food from marine habitats during the last interglacial (Walter et al. 2000). Sediment characteristics and faunal compositions of these marine deposits are currently under investigation to reconstruct potential resources for these hominids in time and space. Vertical changes in sediment facies represent a depositional cycle from the onset of the last interglacial marine highstand to still stand. This transgressive cycle begins with an oyster-bearing cobble lag deposit, followed by a biostrome with molluscs, echinoids and scattered corals, and concludes with the development of a fringing coral reef. Lateral facies changes, especially in coral growth form and position, suggest the remains of a complete fringing reef sequence. Comparison with modern coral fauna in the area indicates that it developed in an open-marine, shallow and calm embayment. In the course of the transgression cycle, food sources changed from oysters attached to rocks to free-living, diversified molluscs and crustaceans, related to the development of a coral reef ecosystem. This change in potential food sources provides clues to interpret the pattern of distribution of bifaces and obsidian flakes and blades in the terrace, and to the adaptation of early humans to marine habitats. Walter et al. (2000). *Nature* 405: 65-69

CARBONATE DYNAMICS ON HIGH ENERGY REEF FRONTS.

Chisholm J.R.M.*. *Observatoire Océanologique Européen, Centre Scientifique de Monaco, Avenue Saint-Martin, MC98000, Monaco; email: j.chisholm@aims.gov.au

Reefs in high energy environments grow to sea level because their shallow windward margins are dominated by coralline algae, not by corals. Coralline algae have been likened to the cement that binds together the bricks from which reefs are built, inferring that their contribution to carbonate deposition is substantially less than that of corals. Measurements of crustose coralline calcification on the windward reef at lizard island, northern gbr, indicate that low rates of vertical accretion are a product of high rates of erosion, not of low rates of carbonate deposition. Calcification was measured *in situ* by isolating samples within an incubation chamber and then following changes in the o_2 concentration and ph of the surrounding seawater induced by their metabolism using sensors connected to a submersible respirometer. Removal of water samples during certain experiments enabled determination of changes in seawater total alkalinity (a_t). Incorporating the measured changes in chemical parameters into equations describing the seawater carbonate equilibrium enabled calculation first of the metabolic quotients of samples and second of their rates of carbonate deposition. Concomitant measurement of light enabled calcification to be regressed against irradiance and whole day net calcification to be estimated by integrating the resulting equations with half sine curve models of the diurnal change in solar irradiance. These calculations indicate that coralline calcification can contribute up to 10.3 kg $caco_3$ m^{-2} y^{-1} on reef crests that have a surface relief factor of 3.1 when they cover 100% of the reef.

CORAL REEFS OF THE AMERICAS.

Cortés.J.* *Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Ciudad de la Investigación, Universidad de Costa Rica, San Pedro, San José 2060, Costa Rica. Email: jcortes@cariari.ucr.ac.cr

The American continent has three main coral reef areas: Brazil, Caribbean and eastern Pacific. Brazilian reefs are peculiar in their structure and coral composition. Caribbean reefs are the best studied, most diverse, largest, and extensive. Eastern Pacific reefs are small, isolated and built by a few corals. The present day reef building coral species composition is the result of tectonic events and ocean currents. The opening of the south Atlantic and the uplift of the Andes resulted in the separation of the Brazilian and the Caribbean faunas, which is reaffirmed by the ocean currents. The Caribbean and eastern Pacific were separated by the rise of the Central American isthmus, and the present day fauna of the eastern Pacific is the result of ocean circulation. The corals and structure of these three areas are very different but the impact of natural and anthropogenic disturbances are similar. International cooperation is needed to study, protect and used the coral reefs of the Americas.

CORAL MICROATOLL SEISMOCHEMISTRY AND THE GREAT TAMBORA ERUPTION OF 1815 AD.

Gagan, M.K.*, Sieh, K., Hantoro, W.S., Lynch, H.S., Edwards, R.L. and Zachariasen, J. Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia. Email: Michael.Gagan@anu.edu.au

We present a new method for reconstructing seismic uplift associated with palaeo-earthquakes and volcanic aerosol-induced reductions in solar irradiance using carbon isotope ratios $\delta^{13}C$) in *Porites* spp. microatolls. We tested the hypothesis that $\delta^{13}C$ in *Porites* skeletons is sensitive to light intensity by sampling a slab cut horizontally into a large, dead *Porites* spp. microatoll from southwest Sumatra, Indonesia. High temporal resolution measurements (bi-weekly) of $\delta^{13}C$ in the coral skeleton show an abrupt increase in ^{13}C in response to the 0.7 m co-seismic uplift of the coral during a magnitude 8 earthquake that rocked southwest Sumatra on 10 February 1797. The increase in coral $\delta^{13}C$ immediately following uplift is a response to higher light intensity in the shallow water where the coral continued to grow. We then established an annual chronology using the clear annual cycle in the coral $\delta^{13}C$ to see if we could detect any volcanic aerosol-induced reduction in solar irradiance following the great 1815 AD eruption of Mt Tambora in Sumbawa, Indonesia. The coral $\delta^{13}C$ record shows sharply lower values for ~16 months immediately following the eruption that equate to solar irradiance levels lower than those during a typical cloudy monsoon season. Microatolls appear to be extraordinary natural instruments for extending the record of earthquakes and volcanic eruptions into the pre-instrumental past.

NUTRIENT INFLUX FROM AFRICAN DUST AT VIRGIN ISLANDS NATIONAL PARK.

Garrison, V.*, J. D. Ray, L. Ashbaugh and T. Cahill. Biological Resources Division, U.S. Geological Survey, P.O. Box 710, St. John, U.S. Virgin Islands 00831. Email: ginger_garrison@usgs.gov

The Saharan Air Layer transports approximately one billion tons of African dust annually to the Caribbean and Americas to the west and the Mediterranean to the north. Originating in an area stretching from Chad to Mauritania, the dust is composed primarily of clay soil minerals and transports nutrients and biological organisms to the oligotrophic waters of the Caribbean. At Virgin Islands National Park (VINP) in the northeastern Caribbean, mean aerosol (<2.5 _m) concentrations are among the highest nationwide and reported to exceed 21 _g/m^3 during dust events. In this study, we estimate the annual influx of nutrients (ammonia, nitrate, nitrite, and phosphorous) and trace metals (Fe, Hg, Pb) from African dust to Virgin Islands waters and coral reefs, using PRIMENET data from VINP.

NATURAL HYDROCARBON SEEPAGE: A CONTROL ON THE DISTRIBUTION OF CARBONATE REEFS AND BUILD-UPS IN AND AROUND THE MARINE RESERVES OF CARTIER ISLET AND ASHMORE REEF, NORTH-WEST SHELF, AUSTRALIA.

Glenn, Kriton & Geoffrey O'Brien Australian Geological Survey Organisation, GPO Box 378, Canberra, 2601 Email: Kriton.Glenn@agso.gov.au

The newly declared Cartier Marine reserve and Ashmore Reef (a Category '1' marine park) are shelf edge coral reefs located on Australia's North-West Shelf, a prolific hydrocarbon province. The reefs are situated at a major geologic and oceanographic boundary, with the conjunction of the Indonesian Through Flow (ITF) and the Indian Ocean providing diverse genetic opportunities fed by significant nutrient upwelling. Ashmore Reef (~150 km^2), and Cartier Islet (36.3 km^2) rise from depths of >400m, harbour a wide range of habitats, and are considered a vital regional genetic 'bank'. Remote sensing studies (synthetic aperture radar, geochemical sniffer, airborne laser fluorosensor and seismic data) and sediment sampling have demonstrated that the majority of reefs and build-ups in the area are associated spatially with active and palaeo-hydrocarbon seeps. These seeps are localised over either fault systems which tap the reservoir, along migration fairways, or at the pinch-out of the regional Cretaceous top seal. The data suggest that the reefs and the build-ups formed via a sequential process. Firstly, hydrocarbon seepage localised seafloor biological communities, which formed topographically positive features.

DUST TO DUST: IRON AS THE FUNCTIONAL LINK BETWEEN EOLIAN DUST AND MARINE INFECTIOUS DISEASES.

Hayes M.L.*, E.A. Shinn and R.T.Barber. *Duke University Marine Laboratory, 135 Duke Marine Lab Rd., Beaufort, NC USA. Email: mhayes@duke.edu

Recent variability in climate (NAO and Sahelian precipitation) and eolian dust transport have been well-documented in the scientific literature. Observations of recent increases in the outbreak rate of marine infectious diseases have also been widely documented. Analysis of climate, dust and disease time series suggests that significant changes occurred in the early to mid-1970s, particularly between 1972 to 1976. We propose that the mid-1970s climate shift increased the amount of iron supplied to the oceans via atmospheric deposition of dust, thereby altering the micronutrient (iron) supply that under normal climatic conditions limits growth and virulence of pathogenic microbes. In order to test this iron/virulence hypothesis, we developed a mesocosm infectious disease model based on the temperate scleractinian (stony) coral *Oculina arbuscula* and confirmed bacterial pathogens. This model allows controlled inoculation experiments with pathogens grown under varying micronutrient conditions. These experiments specifically test whether iron-replete growing conditions can increase virulence enough to alter the dose/response curve of the pathogen-coral mesocosm. We have mechanically generated pseudo-eolian dust from sediments collected in the Lake Chad Basin of the African Sahel (N'Djamena, Chad). The geochemical similarity of this pseudo-eolian dust to Caribbean eolian dust samples confirms the connection between Lake Chad supply source sediments and the material actually deposited in the Caribbean Basin.

COMPOSITION AND DISTRIBUTION OF RELATIVELY FINE-GRAINED SEDIMENTS OFF MIYAKO-JIMA, RYUKYU ISLANDS, JAPAN.

Iryu, Yasufumi* Takayuki Ogoshi, and Yoshihiro Tsuji. *Institute of Geology and Paleontology, Graduate School of Science, Tohoku Univ., Sendai 980-8578, Japan. Email: iryu@dges.tohoku.ac.jp

Examined were composition and distribution of relatively fine-grained (< 4 mm in diameter) sediments in reef to shelf areas off Miyako-jima, Ryukyu Islands, Japan. The sediments from selected 50 sites were embedded in an epoxy resin and then made into thin sections. Composition of organic skeletons (benthic foraminifera, planktonic foraminifera, corals, bryozoans, molluscs, coralline algae, *Halimeda*, and other bioclasts) and intra-/extraclasts were determined by point counting method. Eight sedimentary facies were discriminated by Q-mode cluster analysis. They are: coralline algal-molluscan facies (no particular environment), coral facies (reef), intra-/extraclast facies (shelf edge to upper shelf slope), benthic foraminiferal gravelly facies (outer shelf), benthic foraminiferal sandy facies (reef to inner shelf), planktonic foraminiferal facies (shelf slope), fine bioclast facies (shallow (< 50 m) restricted environment and deep (> 200 m) shelf slope), and coarse bioclast facies (shelf to upper shelf slope).

SUPRATIDAL AND INTERTIDAL LITHIFICATION ON RAINE ISLAND, NORTHERN GREAT BARRIER REEF, AUSTRALIA.

Jell J.S.*. *Department of Earth Sciences, The University of Queensland, St Lucia 4072, Australia. Email: j.jell@earth.uq.edu.au

Raine island lies 620 km north-northwest of cairns on a detached reef of the northern great barrier reef. Raine island has a suite of geomorphic features which, in combination, are not reported from reef islands elsewhere on the great barrier reef. The dominant geomorphic feature is a phosphate rock platform which forms the island core. The phosphate rock is a classical example of a recent insular phosphate deposit that has formed by cementation and replacement of holocene carbonate sands by phosphate leached from a superficial blanket of avian guano. The main phosphate mineral is dahllite, which occurs as microlaminated grain coatings and as bioclast replacement. Whitlockite occurs as minor pore-fillings. The platform is surrounded by a scarp which is indicative of a period of significant island erosion. Surrounding the phosphate platform is a broad swale zone, which is underlain at shallow depth by lithified beach sediments with carbonate cements mainly as thin fringes of aragonite loosely coating the grains.

A CLASSIC CARIBBEAN ALGAL RIDGE, HOLANDES CAYS, PANAMA: AN ALGAL COATED STORM DEPOSIT.

Macintyre Ian G., Peter W. Glynn, and Robert S. Steneck. National Museum of Natural History, Smithsonian Institution, Washington, DC 20560 USA. Email: Macintyre.Ian@NMNH.SI.EDU

Holandes Cays, Panama, long considered a classic Caribbean algal ridge, can no longer be classified as such because crustose coralline algae have played a very minor role in the formation of its relief. Six core holes drilled across the outer ridge of Holandes Cays indicate that the relief was formed by storm deposits. In addition, the crustose coralline flora is more characteristic of coral reefs than that associated with algal ridges. Twenty-seven radiocarbon dates reveal that these deposits accumulated 2,000 to 3,000 years ago. The present-day surface of this ridge is extensively bioeroded and is dominated by a thin cover of crustose coralline algae, but little substrate accumulation has occurred over the past 2,000 years.

HOLOCENE SEDIMENTS OF THE HERON-WISTARI REEF PLATFORM: A NEW MODEL FOR PLATFORM REEF EVOLUTION.

Opdyke, Bradley N.* David A. Ryan, & John S. Jell, *The Australian National University, Department of Geology, Canberra ACT 0200. Email: Bradley.Opdyke@anu.edu.au

The combination of core and seismic data from the Heron-Wistari reef platforms have allowed the development of a new conceptual model for the evolution of carbonate facies on the antecedent platforms during the Holocene. Rather than the fore-reef, reef, back-reef and lagoon facies growing straight up to sea level, as is illustrated in most text books, these facies on the Heron and Wistari platforms change dramatically. During the post-flooding "catch-up" phase of reef growth most of the surface of both platforms was covered with coral growth. Only after the windward side of the reef caught up with sea level, at approximately 4000 ybp did the modern facies distribution get established.

METEORIC SOLUTION TEMPLATE FOR ATOLL MORPHOLOGY.

Edward G. Purdy* and Edward L. Winterer. *PetroQuest International Inc. "Foxbourne", Hamm Court, Weybridge, Surrey, KT13 8YA, UK, EGPurdy@compuserve.com

A data base of 301 atolls from the Pacific, Indian and Atlantic oceans has been analyzed with respect to factors governing maximum atoll lagoon depth. Statistically significant correlations between maximum atoll lagoon depth and both atoll area and present day rainfall are viewed as the combined effect of paleo-rainfall with catchment area in contributing to lagoon depth. The reality of solution predicated atoll morphology is documented by the gross saucer-shaped morphology of several of the Lau, Fiji islands and the subsurface Cretaceous Golden Lane Atoll of Mexico, where evidence of reef rim construction is lacking but evidence for significant solution relief is compelling. Anewetak drill data demonstrate the preservation of only about 8 m of lagoonal sediment for the past 400 kyrs, compared to a Holocene lagoonal sedimentation rate of about1m ka^{-1} that would fill the lagoon in about 60 kyrs. The implication is that most lagoonal sediment has been removed by erosion during sealevel lowstands. Additionally the role of reefs in contributing to modern atoll rim construction appears generally limited to approximately 10 m, leaving more than 20 m of relief to be explained at most atolls. Subsidence rates of even 5 cm ka^{-1} do not suffice to explain the subsea depth of this unconformity. Calculations of solution rates relative to the residence time of sea level below given depths during the past 700 ka suggests that the observed atoll relief is in part inherited from more than one Pleistocene glacial stage or perhaps even before then.

SMALL-SCALE UPWELLING AS A CONTROL FOR REEF HEALTH AND FRAMEWORKS. PRELIMINARY FINDINGS FROM THE BAHAMAS AND THE ARABIAN SEA.

Riegl, Bernhard*, Werner E. Piller. Institut für Geologie und Paläontologie, Karl-Franzens-Universität Graz, Heinrichstrasse 26, 8010 Graz, Austria. Email:bernhard.riegl@kfunigraz.ac.at

Coral health and framework development was investigated in Eleuthera, Cat Island (Bahamas) and Khor Fakkan (Arabian Sea, United Arab Emirates) in 1999. In the Bahamas, coral cover and reef framework development was found to be better in Eleuthera than in Cat Island. However, coral mortality, bleaching and disease frequency was much higher in Eleuthera than in Cat Island. Repeated small-scale upwelling of water about 2 degrees colder than surface waters was observed on Cat Island and the shelf-edge reefs were covered by this water. It is assumed that in bleaching years, when sea-surface temperatures are elevated and corals bleach, such moderate upwelling can protect the Cat Island corals from bleaching. The coral's price for this protection is the disadvantage of having to live in a colder environment with ensuing lower calcification and framebuilding rates. In the Arabian Sea, Shark Island experiences frequent small-scale upwelling events which lead to a temperature stratified water column. *Pocillopora* frameworks were found to be dead above 5m but completely alive underneath. The geometry of the reef and the mortality signs allow speculation that this mortality in shallow water was also caused by surface waters heated above bleaching threshold, while corals growing in water deeper than 5m were protected by cool, upwelled water.

CORAL REEFS AND THE THREAT OF SOIL DUST

Shinn, E. A.* and Charles W. Holmes. U.S. Geological Survey, St. Petersburg, Fl 33701 Email: eshinn@usgs.gov

Whereas dredging, boat groundings, deforestation, sewage, storms, overfishing, and related anthropogenic actives threaten coral reefs locally, most researchers agree that diseases, possibly associated with El Nino-warming events, are the major threats faced by coral reefs today. The mechanisms for coral pathogen distribution therefore should be of major concern. Water currents are inferred to be the most common pathogen transport mechanism. However, atmospheric distribution appears to be an emerging, viable alternative. Increasing African soil-dust transport into the Caribbean and Florida (hundreds of millions of tons per year) has been shown to deliver high levels of iron and phosphorus as well as fungal and possibly bacterial pathogens. African soil dust also contains elevated levels of mercury and pesticides. Other studies have also shown that soil dust is ingested by corals and becomes part of the sclerochronological record. Here we report that African soil dust is unusually radiogenic. African soil dust contains elevated levels of ^{7}Be (half-life 53 days) and ^{210}Pb (half-life 23 years). Gamma radiation levels of dust landing in the Caribbean exceed acceptable breathable levels for humans as defined in NCPR report No. 32. We speculate that radiation from ingested particles may affect corals directly and/or enhance susceptibility to anthropogenic stresses. For example, the period of maximum dust flux in the Caribbean and Florida is June through August when waters are the warmest and coral expulsion of symbiotic algae is most likely.

MICROBIAL ACTIVITY AND SEDIMENT INTERACTIONS IN MODERN MICROBIALITES FROM A LAGOONAL ENVIRONMENT (TIKEHAU ATOLL, FRENCH POLYNESIA)

Sprachta, S.*, G. Camoin, S.Golubic, P. Gautret & Th. Lecampion *CEREGE, B.P. 80, UMR 6635 CNRS, Europôle Méditerranéen de l'Arbois, F-13545 Aix-en-Provence cedex 4, France. Email: sprachta@cerege.fr

Tikehau atoll (french polynesia) provides the opportunity to document the development of microbialites (stromatolitic structures, gelatinous masses and mats) in a lagoonal environment apparently in pristine conditions. Their distribution in time and space is clearly governed by short-term environmental and/or climatic changes. Dome-shaped stromatolitic structures are produced by three distinctive *phormidium* species (*phormidium* spp.1 and 2 and *p. Hendersonii*) and a possibly new species of *schizothrix* which exhibit a clear depth zonation between 3 and 25 m. Greenish and shapeless gelatinous masses hanging from the ceiling of caverns in coral reefs are produced by the sheathed filamentous cyanobacterium *phormidium laysanense* at depths between 5 and 7 m. Microbial mats are well developed at all depths on the flanks of pinnacles where they form coatings over various substrates. Biosedimentological and biochemical data indicate various sources of carbonates within the microbialites involving several processes dominated by organomineralization processes that occur on, or at the expense of, decaying microbial fabrics and interstitial mucilage (microbial extracellular polymer secretions) released by microbial organisms in the pores of the organic network.

CORAL REEF COMMUNITIES ON THE PACIFIC COAST OF COLOMBIA: GEOLOGIAL ASPECTS.

Vargas-Angel, Bernardo. *University of Miami, RSMAS-MBF, 4600 Rickenbacker Causeway, Miami, FL 33149, USA. Email: bvargas@rsmas.miami.edu

Well-preserved Holocene reef framework deposits provide a historical window to compare coral reef community composition in the recent past. Eight sediment cores were studied from each of two coral reefs of the Pacific coast of Colombia; La Azufrada and La Chola. Composition analyses revealed that reefs are mainly built by fast growing *Pocillopora damicornis* with minor contributions of *Psammocora*. Evidence indicated that La Azufrada experienced a temporal change in coral community composition. *Pocillopora damicornis* was replaced by *Psammocora* as the dominant species for near a century between ca. 200-300 YBP. _^{18}O thermometry suggested that changes may be possibly linked to the Little Ice Age (LIA). Cores extracted from La Chola reef did not present clear evidence of LIA-related community changes. Secondary evidence is used to draw inferences on the magnitude and severity of the LIA on a local scale. Additional findings indicated that framework deposits at Chola reef were richer in fine (<62µm) sediments, and terrigenous clasts than La Azufrada reef. These results are interpreted as evidence of increased terrigenous influx in this region. The development of relatively vitally calcifying communities in environmentally "poor" conditions is an example of the co-occurrence of carbonate and siliciclastic sedimentation.

THE RELATIONSHIP BETWEEN GORGONIAN CORAL (CNIDARIA: GORGONACEA) DISEASES AND AFRICAN DUST STORMS.

Weir, JR*, V Garrison, E Shinn, and GW Smith. *University of South Carolina, Dept of Marine Science, EWS Bldg., Columbia, SC 29208 Email: julianna@mail.biol.sc.edu

Recently, the number of reports of diseases affecting gorgonian corals in the Caribbean has increased due, at least in part, to increased sea surface temperatures and/or anthropogenic factors. There are many types of microorganisms that can cause these diseases. For example, *Aspergillus sydowii*, a common terrestrial fungus causes aspergillosis in two species of sea fans, *Gorgonia ventalina* and *G. flabellum*. Until recently, the source of this and other pathogens remained unknown. One hypothesis is that dust storms originating over African deserts transport various microorganisms, including several types of fungi, into the Caribbean. Once deposited, these organisms may cause disease among gorgonian corals. We isolated and compared fungal strains during dust events and non-dust events in the Caribbean. *A. sydowii* was among the isolates collected during the dust events. Subcultures were used to inoculate healthy *G. ventalina* from the Bahamas. In addition, known pathogenic and non-pathogenic strains were tested as positive and negative controls. Dust isolates of *A. sydowii* showed pathogenic activity on *G. ventalina*. These results show that pathogens can be carried in African dust. We are investigating the possibility that other pathogens may also be carried in these dust storms.

CALIBRATION OF THE RADIOCARBON TIME-SCALE

Yokoyama Y., T.M. Esat*, K. Lambeck and K. Fifield. The Australian National University, Canberra ACT 0200. Email: tezer.esat@anu.edu.au

Uranium series and radiocarbon ages were measured in corals from the uplifted coral terraces of Huon Peninsula (HP), Papua New Guinea, to provide a calibration for the radiocarbon time-scale over the past 30,000 years to 50,000 years. Improved analytical procedures, and quantitative criteria for sample selection, helped screen diagenetically altered samples. The base-line of the calibration curve follows the trend of increasing divergence from calendar ages, as established by previous measurements. In addition, four well defined peaks of excess atmospheric radiocarbon concentration (>200% relative to current levels) were observed correlated with the timing of specific reef growth at HP. These peaks appear to be synchronous with Heinrich events and concentrations of ice-rafted debris found in North Atlantic deep sea cores. The time sequence of events are as follows: An initial abrupt sea-level high is followed by a large increase in atmospheric radiocarbon as the sea-level subsides. Over 2000 years the atmospheric radiocarbon drops to below present ambient levels. Each of these four periods bears a close resemblance to ice-calving episodes of Dansgaard-Oeschger and Bond cycles and the slow-down or complete interruption of the North Atlantic thermohaline circulation. We attribute the pulses of increased atmospheric radiocarbon to the cessation of the North Atlantic circulation.

Session A14: Caribbean Reefs 17 Years After Mass Mortality of *Diadema antillarum*

Diadema antillarum: A FACILITATOR OF RECOVERY ON THE REEFS OF DISCOVERY BAY, JAMAICA.

Cho, Leandra*, Woodley, J. *Centre for Marine Sciences, University of the West Indies, Mona, Kingston 7, Jamaica. Email: leancho@uwimona.edu.jm.

The reefs of Discovery Bay have suffered from large-scale degradations since 1980, which resulted in a decline of coral diversity and abundance. The status of the reefs near Discovery Bay was assessed in 1997 to investigate the extent of degradation on Jamaican reefs. Was the excessive abundance of macroalga due to nutrient pollution or to a lack of herbivores? Data was collected from 27 reef sites, and three depths based on percentage cover. Coral cover was lowest at 15m, 10.7 ±3.3% but was approximately the same for 5 and 10m, 15.8 ±7.2%. Macroalgae cover increased with depth from 34.3 ±12.1% at 5m to 61.8 ±8.0% at 15m. The abundance of *Diadema* was 1.54 ±1.5 m^2 at 5m, 0.1 ±0.3 m^2 at 10m, and they were absent at 15m. This was an increase in density in shallow waters since the last 5 years. Coral cover has increased significantly at all three depths (from <5% to 13.8 ±5.7%) since 1989, due partly to recruitment by opportunistic colonizers such as *Porites astreoides*, and *Agaricia agaricites* and at 5m, due to grazing by *Diadema antillarum*. Cover by macroalgae has decreased (from 79% to 50.6 ±11.5%), especially at 5m, where the abundance of *Diadema* and other urchins has increased in recent years. The nutrient levels on the fore reef were very low, with infrequent surface pulses of 1.0-1.5 δM of DIN and 0.1-0.2 δM of DIP, related to rainfall.

POPULATION FLUCTUATIONS OF THE RED URCHIN *ECHINOMETRA VIRIDIS* SINCE 1989 IN SOUTHWEST PUERTO RICO.

Sean P. Griffin*, Angie McGehee and Ernesto Weil. *University of Puerto Rico, Dept. of Marine Science, P.O. Box 908, Lajas, Puerto Rico, 00603, USA. Email:griffin@caribe.net.

In coral reefs, sea urchins may function as key species controlling community structure, biomass of macroalgal communities and structural dynamics of the invertebrate community. Mass mortality events of urchin populations can then produce drastic changes in the structure and dynamics of these communities, as was the case of the black sea urchin *Diadema antillarum* in the Caribbean in 1983. When a better competitor species disappears, the niche void could become occupied by another, formerly subdued, species. This seems to be the case for some populations of the Caribbean red sea urchin *Echinometra viridis.* Recent population densities of *E. viridis* were estimated for three patch reefs in La Parguera, southwest Puerto Rico and compared with densities recorded in 1989 and 1995 in the same reefs. Similar methods were used in all surveys. A transect line was laid along different depth intervals (0–1, 1–2, 2–3, 3–4, and 5–6 m). Mean densities were estimated using 1 m^2 quadrats placed every other meter along the transect line (n=8/depth interval). Results indicate high variability in urchin densities through time with significant lower densities in 1995 and significant higher densities in 2000. Shallow areas (1–4 m) had significantly higher mean densities in all reefs and throughout the years. Two of the patch reefs, Las Palmas and Ahogado, had significantly higher peak mean densities (41 urchins/m^2) than the other, Cayo Lopez (23 urchins/ m^2). The significant increase in densities of *E. viridis* through time in these Caribbean reefs could be a result of the prolonged absence of *D. antillarum*, an aggressive competitor.

CARICOMP MONITORING INDICATES CHANGES IN TRENDS ON EASTERN REEF, TOBAGO DUE TO 1997/1998 EL NINO EVENT.

Guppy, Reia *. *Institute of Marine Affairs, P.O. Box 3160, Carenage Post Office, Trinidad and Tobago. Email: rguppy@ima.gov.tt

Eastern Reef is part of the fringing Buccoo Reef, Tobago that has been monitored by the Institute of Marine Affairs for five years through the regional CARICOMP program. The reef was monitored once a year, and parameters included coral, algal and sponge growth, fish and sea urchin abundance, nutrients and temperature. During the first three years of monitoring, coral, algal and sponge growth showed an upward trend in the mean % cover, whereas in 2000, there was a marked decrease except in the mean algal cover. Fish and sea urchin abundance also appeared to follow similar trends in 2000 as their numbers were noticeably reduced from in 1998. Although the cause has not yet been determined, additional data suggests that the cause may be associated with the 1997/1998 El Niño event. Temperature recordings were higher than normal during that year, and visual observations in March 1998 on Eastern Reef indicated a severe bleaching event, from which the corals may not have recovered.

WHEN DID CARIBBEAN *DIADEMA ANTILLARUM* EXPAND ITS POPULATIONS? AN ANSWER FROM GENETICS.

Lessios, H.A.* M. Garrido, B.D. Kessing. *Smithsonian Tropical Research Institute, Box 2072, Balboa, Panama. Email: lessiosh@naos.si.edu

Diadema antillarum is a sea urchin which until 1983, when mass mortality removed 97 % of the individuals, was the most abundant herbivore and most important bioeroder of Caribbean reefs, affecting every aspect of benthic ecology in the area. There is disagreement as to whether its high population densities were "natural" or due to overfishing of its predators and competitors. The populations have not recovered in the intervening 17 years. Isozyme data collected before and after the mass mortality had showed no evidence of a genetic bottleneck. Subsequent to the mortality, we gathered data from the ATPase 6 and 8 region of mitochondrial DNA from hundreds of individuals from the Caribbean and from the eastern Atlantic (which was not affected by the mass mortality), as well as from the eastern Pacific *D. mexicanum*. These data indicate that the Caribbean populations are characterized by a star-like phylogeny, a unimodal mismatch distribution of haplotype differences, and excess variability relative to eastern Pacific and eastern Atlantic populations. Thus, rather than having undergone a genetic bottleneck, Caribbean *D. antillarum* shows the signs of population expansion. By estimating mutation rates from divergence between *D. antillarum* and *D. mexicanum*, separated at a known time by the Isthmus of Panama, we date the expansion as having occurred in the Pleistocene, 200,000 ya. Thus, the view that high abundance before 1983 was due to anthropogenic effects and that the mass mortality represented a "natural correction" is not supported by genetic data.

PROLONGED HERBIVORE DEFICIENCIES SUPPRESS RECOVERY OF AN ALGAE-DOMINATED "CORAL" REEF.

Murray, R. A.* *Discovery Bay Marine Laboratory, University of the West Indies, Discovery Bay, Jamaica. Email: rmurray@dbml.org

As a result of prolonged multiple stresses, initially natural and now mainly anthropogenic, north coast jamaican reefs still have low coral cover and are generally macroalgal dominated. These reefs have been in decline since hurricane allen (1980), and show little sign of recovery 20 years on. Many studies have recognised the regional importance of the echinoid herbivore *diadema antillarum*, but more work is required to identify other important herbivorous components in the system to provide a more complete understanding of the trophic imbalance that persists between producers and consumers. Investigation of the relative and potential impacts of some of the principal herbivorous fish species at discovery bay (*sparisoma chrysopterum*, *scarus iserti*, and *acanthurus bahianus*) suggests that at least one local species is capable of having a significant grazing impact, especially in terms of macroalgal displacement (often not achieved by other herbivores). Observations have been made on reef substrate composition, algal productivity, herbivore distribution and grazing potential. Profound differences in grazing potential between subjects were found, along with a high degree of consistency in algal preferences. Rates of algal productivity and consumption recently observed at discovery bay indicate that whilst current levels of grazing may provide some stability to the system's standing crop, they remain inadequate to effect a shift back from algal to coral dominance. It is suggested however that a selective increase in the abundance of at least one principal herbivorous fish may contribute positively towards this aim.

STATUS AND TEMPORAL TRENDS AT *CARICOMP* CORAL REEF SITES.

CARICOMP, Warner, G.F.*, *Centre for Marine Sciences, University of the West Indies, Mona, Kingston 7, Jamaica, W.I. Email: gfwarner@uwimona.edu.jm

Twenty-one forereef (10m deep) sites in the Caribbean region, with a wide variety of relief and morphology, have been monitored by the CARICOMP protocol since 1993. Mean percent hard coral covers at 20 sites have shown only slight changes. Of sites reporting data spanning at least three years, five sites showed slight upward trends, six downward and four no change. High coral mortality occurred at Moroccoy, Venezuela, in 1996. Recent mean coral cover varied from 44.79% at La Parguera, Puerto Rico, to 5.77% at Cayo Coco, Cuba, and only 1.12% at the hardground site of Puerto Morelos, Mexico. With few exceptions, sites with relatively high coral cover (>20%) lie east of a line from Panama through the Windward Passage and south of latitude 15° N. Sites differed in coral community composition, but overall the five most abundant species (mean % cover) were *Montastraea annularis* sensu lato (8.23%), *Agaricia agaricites* (1.38%), *Porites astreoides* (1.25%), *Colpophyllia natans* (1.24%) and *Diploria strigosa* (1.23%). Using all stations and years, within-station coral cover showed no relationship with either algal cover or numbers of urchins (all species), and algae were not correlated with urchins. However, at stations with >2 *Diadema* m^{-2}, fleshy algae were virtually absent. Nine sites reported the presence of *Diadema*, compared with three in 1995, but many sites are still dominated by algae rather than by corals. No widespread reductions in coral cover have occurred during the 1990s even though it has been a period of intense hurricane activity and bleaching events.

LAGOONAL GRASS-BED SEA-URCHIN APPEARS ON WEEDY REEFS

Woodley, Jeremy*, Peter Gayle, Kenneth Fedorka, Loureene Jones, Nancy Judd, Courtney Washburn. *Centre for Marine Sciences, University of the West Indies (Mona), Kingston 7, Jamaica. Email: woodley@uwimona.edu.jm

Jamaican north coast coral reefs have suffered, in the last 17 years, a phase shift to dominance by macroalgae. Contributory factors include the mass mortality of the herbivorous sea-urchin, *Diadema antillarum*, in 1983. The recovery of *Diadema* has been slow and restricted to depths shallower than about 10 m. Prior to 1983, the browsing sea urchin, *Tripneustes esculentus*, was abundant in turtle-grass beds in the back-reef at Discovery Bay, but was never seen on the fore-reef. Since the mid-1980s, small numbers of this urchin have recruited to the dense beds of algae on the shallow fore-reef. In 1991, and again in 1996-98, it became locally abundant at sites on the West Fore-reef (1.9 ± 0.76 m^{-2} in April 1998 at 8 m on Monitor Reef, a site monitored for CARICOMP). On neither occasion did the high *Tripneustes* populations survive: by April 1999, its abundance had fallen to 0.3 ± 0.29 m^{-2} , and dead tests were frequently seen. *Tripneustes* is a browser, reducing fleshy algae to a low turf, while ignoring calcareous algae. The abundance of fleshy algae at that site decreased from 0.96 kg wet weight per m^{2} in October 1997 to 0.27 kgm^{-2} in April 1998. The temporary clearance of algae may have facilitated the migration of *Diadema* populations into deeper water: their abundance at the 8 m site rose from 0.04 ± 0.9 m^{-2} in September 1996 to 0.2 ± 0.2 m^{-2} in April 1999.

Session A15: Functional Roles of Sponges on Coral Reefs

MORTALITY OF SPONGES IN NEW BRITAIN (PAPUA NEW GUINEA).

Cervino J.M.*, G. W. Smith, & K. Winiarski. *Marine Science Dept., University of South Carolina, Columbia, SC Dept. of Marine Sciences 29208 Email: cnidaria@earthlink.net

Ianthella basta sponges in New Britain (Papua New Guinea) showed progressive mortality during 1996-2000. Sponge fans are mottled with brown lesions, rotted tissue, and large holes surrounded by brown tissue with mucus smothering the ostia evident under light microscopy. *Ianthella* showed 90% mortality at six sites within 2 km from the shore, but no mortality was observed at 10 sites 20 km away from shore, suggesting a terrestrial source of stress. Infected tissues show fungal filaments and increased density of gram negative bacteria compared to controls. Tissue necrosis was also seen on the undersides and bases of *Jaspis sp.*, *Xestospongia sp.* & *X. testudinaria (Haplosclerida)* at all locations. Although upper portions appeared normal, their bases were rotted away, causing colonies to fall over when touched. Further investigations and microbial analyses are needed to identify pathogens and determine their origins.

DOES ALGAL-INVERTEBRATE SYMBIOSIS PROMOTE THE ECOLOGICAL SUCCESS OF SPONGES ON CORAL REEFS?

Davy S.K., A.J. Grant, D. Trautman, M.A. Borowitzka And R. Hinde* *School Of Biological Sciences, University Of Sydney, Nsw 2006, Australia. Email: rhinde@bio.usyd.edu.au

The symbiosis between corals and zooxanthellae has long been cited as the predominant reason for the ecological success of coral reefs. This is because these symbioses are phototrophic and can recycle and conserve essential elements such as nitrogen. Both these factors promote survival in oligotrophic tropical seas. However, corals are not the only ecologically important organisms on reefs, with sponges in particular making a significant contribution to reef biomass and function. As with corals, many reef sponges harbour microalgal symbionts, and some sponges also form intercellular symbioses with macroalgae. It has long been known that, like corals, symbiotic sponges have the potential to be phototrophic. However, the nutritional interactions in sponge-algal symbioses are only now becoming clear. Here we discuss findings from our biochemical, physiological and ecological studies on the intercellular symbiosis between the Indo-Pacific reef sponge *Haliclona cymiformis* and the red macroalga *Ceratodictyon spongiosum.* We suggest that the nutritional interactions in sponge-algal symbioses are comparable to those in coral-zooxanthella symbioses, as similarities exist with respect to carbon fixation and translocation, and the recycling and conservation of nitrogen. We propose that, as for corals, symbiosis with algae is a significant factor in the ecological success of sponges on tropical reefs.

ALLELOPATHIC ACTIVITIES OF CARIBBEAN SPONGE EXTRACTS.

Engel, Sebastian and Joseph R. Pawlik.* *Center for Marine Science, UNC-Wilmington, 5001 Masonboro Loop Rd, Wilmington, North Carolina, 28409, USA. Email: PawlikJ@UNCWil.edu

Although there is anecdotal evidence for allelopathic interactions between coral reef invertebrates engaged in spatial competition, only a few studies have established the involvement of chemical agents in field experiments. We have developed a technique in which crude organic extracts of marine sponges were incorporated into hard, stable gels that serve as a substratum for overgrowth by invertebrates in the field. Extracts of 20 species of Caribbean sponges were assayed in the Florida Keys using three overgrowth sponges: *Tedania ignis*, *Lissodendoryx isodictialis*, and *Haliclona hogarthi*. The allelopathic effects varied between extracts of different sponge species, but were consistent across overgrowth organisms. Of the extracts tested, 30% inhibited sponge growth (*Amphimedon compressa*, *Aplysilla longispina*, *Aplysina cauliformis*, *Dysidea etheria*, *Ectyoplasia ferox*, and *Phorbas amaranthus*), while 15% promoted overgrowth (*Agelas wiedenmeyeri*, *Geodia gibberosa*, and *Halichondria* sp.). The remaining 55% of extracts had no effect on sponge growth. Our technique represents a more ecologically relevant method for assaying the allelopathic properties of extracts of marine organisms. Moreover, it provides evidence that sponge metabolites may act as allomones by preventing overgrowth of some sponge species, and as both allomones and kairomones by enhancing overgrowth of others.

SMALL TO LARGE SCALE PATTERNS IN BIODIVERSITY OF TROPICAL AUSTRALASIAN SPONGES – HETEROGENEITY AND PREDICTABILITY OF CORAL REEF PORIFERA.

Hooper, J.N.A * & Kennedy, J.A. *Queensland Museum, P.O. Box 3300, South Brisbane, Q 4101, Australia. Email: JohnH@qm.qld.gov.au

Biodiversity of marine sponges (species distributions, richness and application of predictive numerical models) was examined at small (local), medium (regional) and larger (provincial) scales throughout tropical Australasia. Species richness varies considerably between study sites, at all scales; does not necessarily follow latitudinal gradients; and numerical modeling is ineffective in predicting species richness without *a priori* knowledge of the diversity of habitats contained within study sites. Species distributions are even more heterogeneous, with few ubiquitous and many rare species producing relatively low patterns of similarity between faunas, at all scales. High species endemism does not generally correlate with high diversity. Biodiversity modeling increases in accuracy at larger scales, but perhaps becomes less relevant to resource management and assessment at these scales. At the small-scale high heterogeneity in species distributions enables only major community patterns to be discerned (e.g. near-shore vs. off-shore). Predictive models are ineffective at this scale. At the medium-scale biogeographic trends are more easily discerned between sites, although levels of similarity have a median value of only about 33%, with endemism mainly a function of connectivity vs. isolation, whereas at the larger-scale biogeographic influences produce relatively homogeneous provincial faunas and lead to more accurate predictive numerical models. Alternate hierarchical-based classifications are explored as potential tools for marine conservation planning and assessment.

THE NATURAL DIET OF OBLIGATE AND FACULTATIVE COELOBITE (CAVITY-DWELLING) SPONGES IN A CARIBBEAN CORAL REEF.

Kötter Iris * and Jakob Pernthaler. *Center for Tropical Marine Ecology, Fahrenheitstr. 1, 28359 Bremen, Germany. Email: Ikoetter@uni-bremen.de

An *in situ* enclosure experiment was carried out in Curaçao to determine the diet and feeding rates of seven species of coelobite (cavity-dwelling) sponges in a Caribbean coral reef. The objective of the study was to test whether food-scarcity in coral reef cavities favours filter-efficiency in coelobite filter feeders. We found that obligate coelobites, occurring exclusively in cavities, had lower clearance rates than facultative coelobite sponges occuring both, inside crevices and on the outer reef surface. Filtering efficiencies in the facultatively cryptic *Chondrilla nucula*, *Clathria raraechelae*, *Halisarca caerula*, *Merlia normani* and *Ulosa ruetzleri* averaged 1.0 µg C phytoplankton (cm^3 sponge)$^{-1}$ h^{-1}, 0.9 million cyanobacteria (cm^3 sponge)$^{-1}$ h^{-1} and 77 million bacteria (cm^3 sponge)$^{-1}$ h^{-1}. The two obligate coelobite species suitable for experiments, *Desmanthus incrustans* and *Diplastrella megastellata*, removed only 0.4 µg C phytoplankton (cm^3 sponge)$^{-1}$ h^{-1}, 0.2 million cyanobacteria (cm^3 sponge)$^{-1}$ h^{-1} and 22 million bacteria (cm^3 sponge)$^{-1}$ h^{-1}. The low diversity and filtering performance of obligate coelobite sponges in Curaçao indicates that in spite of the low ambient food concentrations, food limitation is not a selective factor in the framework cavities of this Caribbean reef.

ENVIRONMENTALLY INFLUENCED VARIABILITY IN MORPHOLOGY OF *CINACHYRA AUSTRALIENSIS*

McDonald Justin I. *, John N.A. Hooper & Keith A. McGuinness.
***Northern Territory University, Darwin, N.T. 0909 Email:** j_mcdonald@site.ntu.edu.au

This study examined how environmental variability within Darwin Harbour influenced form and tissue structure of *Cinachyra australiensis* (Sollas 1886). External morphology varied from the typical spherical shape of this species at Channel Island (CI) and East Point (EP), to a flattened form at Fannie Bay (FB). Across all sites a large proportion of dry weight was inorganic matter, *ie.* structural spicule skeleton, ranging from 62.9 to 78.2%. CI individuals, which experienced highest water velocities and largest sediment size, had greatest structural spicule content (78.2% ± 1.3 SE) and lowest organic content (21.8% ±1.3 SD), followed by EP (structural 73.6% ± 3.3 SE; organic 26.4% ± 3.3 SE). Conversely FB, with lower water velocity and smaller sediment size, had higher organic content (37.1% ± 2.7 SE) and lower structural content (62.9% ± 2.7 SE). Sponges in high velocity and large sediment environments may devote more energy to spicule re-enforcement relative to organic content. The low organic content of *C. australiensis* may indicate that, despite the high abundance and relatively large size of this species, it may be regarded as a more structural than dynamic organism in the coral reef habitat.

EXAMINING THE POTENTIAL OF SPONGES AS INDICATORS OF POLLUTION

McQuillan, Lea*. *Centre For Ecosystem Management, Edith Cowan University, 100 Joondalup Drive, Joondalup, WA. 6027

Sponge diversity in area affected by sewage and an area unaffected were compared. The objective was to determine if sponges could be used as indicator taxa to detect impacts on temperate reef communities from marine pollution, specifically that arising from sewage. Sampling took place in June 2000, comparing three sites affected by sewage with three reference sites. Quantifying the variation in sponge community composition was determined by digital video, recording 10 replicate quadrats with an area of $0.25m^2$ with three replicate sites at each of the two sites (impacted and reference). The results so far indicate that diversity of sponges is extremely immense, over 60 species were collected in area of approximately $20m^2$. Additionally variability between sites is high, with the six reefs sampled at each of the two sites hosting different sponge communities.

CHEMICAL DEFENSES OF CARIBBEAN *APLYSINA* SPONGES. I. ROLES OF SECONDARY METABOLITES IN MEDIATING SPONGE-MICROBIAL INTERACTIONS.

Monica Puyana*, William Fenical and J. R. Pawlik. *Scripps Institution of Oceanography. University of California, San Diego. 9500 Gilman Drive La Jolla, California 92093-0204. Email: mpuyana@ucsd.edu

The genus *Aplysina* can be considered a model in understanding ecological interactions mediated by chemistry in reef communities. The genus is well defined morphologically and chemically. Most species are fairly common and usually have a wide distribution. The chemistry of *Aplysina* is unique. These sponges lack terpenes and possess a high percentage of sterols, but most important, they contain an elaborate series of brominated metabolites derived from tyrosine. These metabolites exhibit a wide spectrum of biological activity in *in-vitro* assays. It has been suggested that these metabolites convey protection against potential pathogens or could prevent the establishment of a microbial layer that would favor subsequent fouling. We have detected several unhealthy sponges by the observation of lesions and necrotic tissue. However, there are very few isolated reports of disease or microbial invasion in aplysinids, and usually these events follow major anthropogenic or environmental disturbances.. Elucidating the causes of disease is as important as determining what are the mechanisms by which organisms overcome microbial threat. This is the purpose of our study, using as model organisms diverse *Aplysina* species. We are investigating the mechanisms by which chemical protection against microbial invasion is achieved using a liquid culture assay and surface associated bacteria isolated from healthy and decaying sponges. Assessment of antibacterial activity is highly dependent on the test strain(s) used. Not all the brominated compounds from *Aplysina* exhibit antibacterial activity against cooccuring marine bacteria. We have found highly resistant strains isolated from lesions or necrotic tissues of *Aplysina*. Strains isolated from decaying unrelated sponges (not *Aplysina* spp.) are sensitive to these metabolites, providing an indication that agents of disease and degradation in sponges may be species-specific and in some instances may circumvent or resist the chemical defenses of sponges.

CHEMICAL DEFENSES OF CARIBBEAN *APLYSINA* SPONGES. II. HOW MANY SPECIES EXIST? ADRESSING CHEMICAL VARIABILITY.

Monica Puyana* and William Fenical. Scripps Institution of Oceanography. University of California, San Diego. 9500 Gilman Drive La Jolla, California 92093-0204. Email: mpuyana@ucsd.edu

Sponges of the genus *Aplysina* are among the most conspicuous and diverse sponges on Caribbean reefs. In the Caribbean Sea, eight species of *Aplysina* are generally recognized. Most species are widely distributed and may be very important elements of the reef fauna in open and cryptic environments. The genus is well-defined, fairly distinct in terms of morphology and chemistry. However, there is still some degree of confusion in recognizing certain species. Chemically, aplysinid sponges are extremely distinct. They lack terpenes, many possess a high percentage of sterols, generally with the modified aplystane skeleton, and most important, they contain an elaborate series of brominated metabolites derived from tyrosine. Also, most species, upon damage or death, exhibit a striking color change. This is due to the presence of a guanidine pigment that becomes rapidly oxidized to blue-purple, almost black. Chemical variability is high even within conspecifics. However, the causes of variability remain unknown and could be related to environmental and/or biotic parameters. This is the first comprehensive study aimed at clarifying the status of the genus *Aplysina* in the Caribbean Sea using traditional morphological and a chemotaxonomic approach. We are investigating the chemical composition and variability of the following species: *Aplysina archeri*, *A. fistularis*, *A. insularis*, *A. fulva*, *A. cauliformis* and *A. lacunosa*. Crude extract fingerprints correlate very well with the different species.

BIODIVERSITY OF BACTERIA LIVING IN ASSOCIATION WITH THE SPONGE *CHONDRILLA NUCULA*.

Ritter J E, Zengler K, Trapido-Rosenthal H G*. *BBSR, Ferry Reach, St George's, GEO1, Bermuda. Email: hank@bbsr.edu

Marine sponges have been the subjects of natural products chemists' investigations for a number of years, and these chemists have had a record of successfully isolating novel chemicals with interesting biomedical potentials. More recently, it has been noted that many marine sponges harbor large populations of symbiotic bacteria, a finding which has led to the thought that these bacteria may be the organisms responsible for many of the interesting chemicals that have been found in sponge homogenates. However, attempts to culture these symbionts prior to further taxonomic and chemical studies have not always been successful. We have begun to investigate the biodiversity of bacterial populations that live in association with the sponges found in Bermuda's marine environment using techniques that allow us to bypass the culturing step. In one experiment, the sponge *Chondrilla nucula* Schmidt was collected from shallow depths, homogenized and lysed. The 16S ribosomal RNA genes present in the lysate were amplified by means of PCR. The results of these experiments suggest that a considerably larger number of prokaryotic species are present in the sponge than is indicated by the small number that have been identified in other studies by culturing or microscopic techniques. Molecular methods thus have the potential to enhance our understanding of the sponge-bacteria relationship at the chemical, physiological, and ecological levels.

MULTIDISCIPLINARY GEOBIOLOGICAL APPROACH TO A FUNDAMENTALLY PROBLEMATIC GROUP OF CORAL REEF SPONGES: CALCAREOUS SPONGES (PORIFERA: CALCAREA) FROM THE GREAT BARRIER REEF.

Woerheide, G.*, Hooper, J.N.A, Gagan, M., Degnan, B. M., Thiel, V. & Reitner, J.. *Queensland Museum, P.O. Box 3300, South Brisbane, Q 4101, Australia Email: GertW@qm.qld.gov.au

Calcareous sponges (Porifera: Calcarea) are an important class of sponges. 18S rDNA data suggests that they might be the link between Porifera and Ctenophora/Cnidaria. However, our present knowledge of this group of sponges from Indo-Pacific coral reefs is deficient – they remain a fundamentally problematic class of lower metazoan at all levels. Prior to our current investigations no one has worked on this class in Australasia for the last 50 years. In this paper we will firstly provide an overview of the current state of knowledge and on problematic issues concerning this group, and then present new data from multidisciplinary geobiological approaches to shed new light on 'old issues'. Our studies range from (1) the population level scale, where we used molecular approaches (analyses of mitochondrial and nuclear DNA sequences) to investigate the population structure of selected allegedly 'cosmopolitan' taxa from the GBR to (2) species level (alpha)taxonomy, using mainly morphological and cytological characters to newly describe the GBR biodiversity, to (3) the subclass and class level scale, where we used stable isotope analysis ($\delta^{13}C/\delta^{18}O$) of calcareous spicules to test the biological basis for the two subclass distinction in calcareous sponges and biogeochemical approaches (analysis of lipid-biomarkers) to investigate phylogenetic relationships.

SPONGE ASSOCIATIONS AS ENVIRONMENTAL INDICATORS?

Wulff, J.L.*. *Biology Department, Middlebury College, Middlebury, VT 05753, USA. Email: wulff@jaguar.middlebury.edu

Distinctive sponge assemblages that are typical of particular habitats on coral reefs and adjacent linked habitats, such as seagrass meadows and mangrove roots, suggest that some sponge species have quite specific requirements. Understanding which environmental factors exert firm constraints on distribution of common sponge species could allow us to evaluate at least some important aspects of these environments by observing the resident sponge species. In San Blas, Panama, distribution and abundance patterns were quantified for all 64 sponge species living in 5 defined habitats (seagrass meadow hard substrata, islet mangroves, coastal mangroves, shallow patch reefs, continuous shallow reef) at similar depths and within 180 m of each other. Limitations on habitat distribution of each sponge species were determined using reciprocal transplants, feeding choice experiments, and evaluations of water and substratum qualities. With respect to environmental assessment, absence of sponge species was difficult to interpret, due to vagaries of sponge recruitment. However, at least in this case, presence of sponge species provided reliable indications of environmental variables, especially fish and starfish predators, turbidity, exposure, and substratum size, continuity, and stability.

RAPID, PATHOGEN-CAUSED SHIFTS IN CORAL REEF SPONGE COMMUNITY COMPOSITION

Wulff, J.L.*. *Biology Department, Middlebury College, Middlebury, VT 05753, USA. Email: wulff@jaguar.middlebury.edu

Influence of pathogens on population and community dynamics of coral reef sponges may be underestimated because pathogens can kill sponges rapidly, after which denuded skeletons deteriorate, leaving no trace. Rapid healing and regeneration of sponges after partial mortality further decrease chances of accurate estimation of losses due to pathogens. Documentation of sponge losses therefore requires frequent censuses, with every sponge and its size (volume) recorded at each census. On a shallow reef in the Panamanian Caribbean, rates of infection, rates of progression (and occassional cessation) of infections within individual sponges, and population and community consequences of pathogen-caused partial and entire mortality were monitored over a 14 yr period. More than half of the original 39 sponge species were lost during this period. The combination of differential susceptibility to pathogens among species and the great speed at which pathogens are able to devastate susceptible sponges, resulted in rapid shifts in community composition. Sponges of massive growth form and in keratose orders were disproportionately represented among the species lost, resulting in abrupt alteration of relative abundances of sponges that serve different functional roles (e.g., carbonate eroders, carbonate binders, harborers of primary producers, and food for fish or starfish) in the coral reef community.

Session A16: Environment and General Papers

AN EXPERIMENTAL EVALUATION OF SHADING ON COLOR CHANGE IN A CORAL AND CRUSTOSE CORALLINE ALGA ON A FRINGING REEF, ABROLHOS ARCHIPELAGO, BRAZIL.

Creed J.C.*, Marcia A. de O. Figueiredo, Debora O. Pires and Clovis B. Castro. *Setor de Ecologia, IBRAG-DBAV, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, PHLC Sala 220, CEP 20559-900, Rio de Janeiro, RJ, Brazil. Email jcreed@openlink.com.br

In December 1997 an experiment was set up on a reef of the Abrolhos archipelago to monitor color change in the crustose coralline alga *Porolithon pachydermum* and the coral *Mussismilia braziliensis* during the summer increase in sea temperature and light intensity. An experimental approach was used to investigate the effect of reduced light (shading by acrylic plates) on color change in these species in order to separate changes due to irradiance from temperature. Color was measured weekly along with environmental variables during three months. Observer bias in color perception was corrected *a posteriori*. There was a reduction in the red, blue and yellow components of the color of the alga during the experimental period. The coral also showed changes in color over time. In both organisms, units shaded by opaque acrylic plates had more color (red and blue) than controls (steel screw or steel screw and clear acrylic plate). Differences developed in red and blue after 2 (algae) or 4 (coral) weeks. These results demonstrate that color changes occur in two key benthic reef forming organisms and that color change was due to the activity of visible light rather than UV or water temperature. In the coralline alga, growth rates did not differ between treatments and color change seemed to have no harmful effect, contrary to that reported for "true" "bleaching" events.

STRUCTURE AND DISTRIBUTION OF ZOOPLANCTON AT THE BAI THU LONG ARCHIPELAGO.

Dautov S.Sh.* *Institute of Marine Biology, RAS, Vladivostok, Russia. Email: daut@mail.primorye.ru

The Ba i Th u Long Archipelago (Gulf of Tonkin, South China Sea) is close to the mouths of several large rivers, which carry out a lot of silt and fresh water which lower the salinity of sea water (to 29-30‰) in this area. The plancton at the Bai Thy Long Archipelago was characterized by an abundance of phytoplancton and diversity of protozoans. By the number of taxa distinguished, the plancton was the most diverse at Bo Hon (Station 10), Cong Tay, Bo Hom, and Cong Do Islands, which at the open seaside extremities of islands situated. The least number of species was recorded in plancton at the closed bay of Bo Hon Island and at a isolated lake with sea water at Bu Xam Island. The density of zoo- and phytoplancton was much lower in the lake, neverthelesss, the plancton community consisted of copepods, pteropods, chaetognaths, appendicularians, jelly fishes, larvae of gastropod, and bivalve molluscs and of ascidians.Most often copepods, chaetognaths, pteropods, and siphonophores in holoplancton, and larvae of polychaetes, crustaceans, bivalves, and ophiurs in meroplancton occurred at the Bai Thy Long Archipelago. Actinotrochae, tornariae, and sea urchins plutei were recorded at stations with the most divers plancton. The presence of these larvae could indicate of the quality of sea water at seaside island coasts with water is more often exchanged during the tide.

TEMPORAL FLUCTUATIONS IN TROPICAL LAGOONS: RELATIONSHIPS BETWEEN BENTHIC COMMUNITIES AND ENVIRONMENTAL PARAMETERS IN NEW CALEDONIA.

Frouin, Patrick *, Clavier, Jacques. *Laboratoire d'écologie marine, Université de la Réunion, 15 avenue René Cassin, 97715 Saint Denis Messag Cedex 9, France. Email: Patrick.Frouin@univ-reunion.fr

Environmental factors rarely exhibit seasonal trends in the tropics. However, in New-Caledonia, temperature, light and rainfall show seasonal fluctuations. Particular organic carbon and primary benthic production, which supply the macrobenthos with energy, are clearly influenced by these parameters. These variables regulate the general metabolic response (respiration) of the benthic biota, which is mainly the result of the activity of small organisms. However, few data are currently available about macrobenthic responses to the temporal variability of environmental factors and putative food paths. We studied three macrobenthic communities in the South-West lagoon of New-Caledonia, on a monthly basis over one year, to identify the seasonal response of the macrobenthic assemblages. Seasonal variability was not significant. That result at the community level actually conceals several population strategies for recruitment. The diversity of the recruitment tactics is common in the tropics and corresponds to an optimal use of environmental resources.

ANTHROPOMORPHY AND THE NANNOS. A QUASI-HISTORICAL PERSPECTIVE.

Hubbard J.* KCL WC2R 2LS Email: julia.hubbard@kcl.ac.uk

Anthropomorphy is not the stuff of science but of journalism. But it can sometimes provide a useful reminder of the sorts of problems that occur in nature. As such simple behavioural observations on coral polyps can provide information on their welfare and act as sources of preventative mareculture. We may not know the preferred diet but we have evidence that corals are isotonic with seawater and as such must be intimately affected by its contents whether in solution or nannoscopic form. We know that the ancient mariners depended on submarine freshwater springs amongst coral reefs therefore it comes as little surprise to find *Montastrea* thriving alongside one of these springs. We know of marine yeasts that are a form of fungi as well as their terrestrial counterparts that are fine enough to infiltrate freshwater lenses during times of heavy flooding. Advances in technology since corals and coral reefs attained popular interest in the early nineteenth century have given way to an increasingly technical literature. This is replete with useful factual matter. Much is known of soil fungi. But it seems that we are in danger of overlooking simple observational details that can be sensitive indicators of behavioural responses to stress that would have been noticed previously. Since medical doctors accompanied the earlier expeditions, physiology played a major influence on the resultant works. These lack the necessary calibration required of understanding causal relationships that one would expect to result from medical and veterinarian observations prior to treatment. Thus our findings are out of line with the capabilities available.

A CASE OF *RED TIDE* IN THE WATER OR WEST SUMATRA

Indrawadi and Efendi, Yempita. *Fakultas Perikanan Universitas Bung Hatta Padang, Indonesia. Email : Incune@indosat.net.id

The phenomenon of the Red Tide in West Sumatra Waters has happened since December 1997-January 1998. This case has been watched and observed by Fishery Faculty of Bung Hatta University together with a Study Club- "Terumbu Karang Indonesia" (POSTERI) in Sumatra Region I. From the field monitoring result, it was clearly seen that the color of sea water changed into brown to reddish. There were many dead fishes floating found on the surface of the sea. The ecosystem of coral reef in the observed location broke up for almost 100 %. As the Red Tide happened until May 1998, there were no *teri* fishes (Stolephorus sp) trapped by fishermen. It could be said that almost all of West Sumatra Waters faced the Red Tide. Even, according to the information given by Nias waters, in North Sumatra also faced the same case. Based on the analysis result of sea-water samples in the laboratories, it was found that there were various types of plankton that caused Red Tide. The various types found are *Gonyaulax spinifera, Pseudonitzshia punges, Trichodesmium thiebautii, Asterinella japanica, Graminatophora marina, Navicula membranaceus, Nitzschia longissima, Ditoma hyalina, Navicula concellata, Biddulphia mobiliensis, Ceratinum forca, Odontella sinensis, Ceratinum tripos* and *Protoperidium conicum.* As a result of the Red Tide, the ecosystem of coral reef is threatened, there are many fishes die, *Teri* fishes (Stolephorus spp) are rarely found, even there is no any fisherman who catch that fish.

ENVIRONMENT CONDITIONS IN THE GULF OF TONKIN.

Khristoforova, N.K. *, Zhuravel, E.V. *Far East State University, Vladivostok, 690600, Russia. Email: nadezhda@tigdvo.marine.su

The northern part of the Gulf of Tonkin, named Ha Long Bay, is declared by UNESCO as a World Natural Heritage site. This bay is a shallow marine water basin with many vertical limestone islands, surrounded by coral reefs. This unusual place is visited by many tourists. The growing tourism press, accompanied with wastes from hotels, located along the beach, is the reason for the government and environmental societies to worry. Moreover, for many years coastal industrialization, shipping, coal-mining and coal-processing were and are active near the coast. Two years ago an extensive coral bleaching was observed here. It is obvious, that anthropogenic press is one of the primary components of the ecological stress of this area. Therefore, the aim of this work is to estimate the environmental conditions in Ha Long Bay. The water quality control parameters included: temperature, salinity, dissolved oxygen, mineral and total phosphorus, detergents and phenols. According to the results of sample analyses none of the determined parameters exceeded the background level and all data obtained have had typical values for tropical shallow waters. Thus, it was concluded, that the bay has a high ability for self-cleaning. The main reason of this phenomena is suspended matter. Shallowness, closeness of the bottom provide for precipitation of adsorbed on the suspended particles organic and mineral chemicals and microbes into the sediments. High water temperature promote destructive processes. Turbidity complicate life of the reef inhabitants and decrease the permissible biodiversity. On the other hand, this is the ultimate source of the self-cleaning process.

PHOTOPRODUCTION OF REDUCED OXYGEN AND IRON SPECIES IN TROPICAL MARINE ENVIRONMENTS.

Szymczak, Ron*. *ANSTO Environment Division, PMB 1, Menai, NSW 2234 Australia, Email: rsx@ansto.gov.au

Over-reduction of photosynthetic electron transport components during photosynthesis under high irradiances leads to elevated concentrations of oxygen and hydroxide radicals which are damaging to corals' cellular defence mechanisms. However, formation of significant concentrations of reactive oxygen species also occurs in seawater. One of the major mechanisms involves the photoionization of naturally occurring organic matter with concomitant reduction of oxygen to superoxide, which subsequently disproportionates to hydrogen peroxide. Recent studies have identified that deil variations in the photogeneration of transient chemical species play a significant role in the geochemistry, hence bioavailability of the elements iron and manganese which are required for production of oxygen scavenging cellular defence mechanisms (SODs). Photochemical processes in marine surface waters may also potentially impact on photosynthetic processes and contribute to photoinhibition and bleaching.

OCCURRENCE OF STAGHORN CORAL (*ACROPORA CERVICORNIS*) OUTCROPS AT HIGH LATITUDES IN NEARSHORE WATERS OF FT. LAUDERDALE, FL, USA.

Thomas*, J. D., Dodge, R. E., Gilliam, D.S. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania, FL 33004, USA. Email: thomasjd@ocean.nova.edu**.**

Investigations by the National Coral Reef Institute (NCRI) in May, 1998 revealed the occurrence of a number of robust populations, or "thickets", of *A. cervicornis* in shallow nearshore waters off Broward County, Florida. These colonies not only flourish at northern marginal temperature limits, they are situated in the midst of significant anthropogenic stresssors including coastal pollution, periodic ship groundings, and extensive urbanization of the coastal zone. Investigations into the ecology of these populations can provide a scientific counterpoint to understanding the continuing collateral demise of *A. cervicornis* Caribbean-wide. The Ft. Lauderdale populations apparently persist in spite of being "upstream" of Florida Keys' populations of *A. cervicornis* which have been decimated by waterborne disease agents. The fact that these high latitude colonies have shown no significant signs of disease or other infectious agents poses an important contrast to past and current Caribbean occurrences. A number of research projects involving these populations have been initiated including population genetics, mapping and distribution, classification and census, trophic and food web dynamics, and essential fish habitat prey characteristics. Continued detailed studies and mapping of such high-latitude *A. cervicornis* reefs are of importance to provide greater understanding of these apparently unique biological resources.

NUTRIENTS AND ORGANIC MATTER IN THE SEDIMENTS OF CORAL REEF AND SEA-GRASS BED OF GULF OF MANNAR MARINE BIOSPHERE RESERVE, INDIA.

Vinith-kumar, N.V., and Balasubramanian, T.. *Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai – 608502, Tamil Nadu, India.

Investigations were made to collect information on sediment nutrients and organic matter in the coral rich Gulf of Mannar (GOM) endowed with seagrass beds and mangroves, during July 1994 to June 1996. Samples were essentially collected arou-nd two islands *viz*. Manoli and Hare. The sediments were mostly sandy (95-99 %), carbonate mixed and with calcium content of 8.8-40 %. The total organic carbon (TOC), total nitrogen (TN) and total phosph-orus (TP) concentrations varied between 0.69-5.73 mg/g, 163.43–487.21 μM and 7.14–33.45 μM respectively with significant variations between stations and seasons. The C:N, C:P and N:P ratios calculated were 0.88-0.30:1, 0.29-3.75:1 and 2.92-18.73:1 respectively. Higher nutrients, organic matt-er concentrations and C:P ratios in the seagrass beds than coral reef sediments reveled the influence of organic matter production and subsequent release and absorption in sediments. It seems, seagrass bed sediments act as reservoir for nutrients and organic matter, whereas coral reef acts as user and sink.

Session A17: Proxy Records of Climate in Coral Skeletons

OXYGEN ISOTOPE AND STRONTIUM/CALCIUM RECORDS FROM CORALS OF MID-HOLOCENE CLIMATES AT OKINAWA ISLAND

Abe, Osamu* Eiji Matsumoto, Takehiro Mitsuguchi and Toshio Kawana *Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya, 464-8601, Japan. Email: oabe@ihas.nagoya-u.ac.jp

Oxygen isotope ratios ($^{18}O/^{16}O$) in bio genic carbonates are mainly controlled by the temperature and $^{18}O/^{16}O$ ratio in water when the carbonates were formed. Based on the composite analysis using the Sr/Ca and $^{18}O/^{16}O$ ratios in coral skeletons, information on changes of past SSTs and surface seawater $^{18}O/^{16}O$ ratios can be obtained. The Sr/Ca and $^{18}O/^{16}O$ ratios of two fossil coral specimens (5.8 ka and 6.4 ka) from Okinawa Island, Japan, provide evidence for the prevalence of a stronger evaporative regime in the northwestern Pacific results of during the mid-Holocene as compared to today. Our findings differ from results of general circulation models which indicate wetter condition for the mid-Holocene tropical region. These results suggest a possible intensification of the atmospheric meridian circulation had increased in the mid-Holocene.

CORAL GROWTH RECORDS ACQUISITION BY LUMINESCENCE IMAGING PLATES AND ANALYTICAL TREATMENT : A TOOL FOR APPREHENDING CLIMATE RECORDS

Bessat, F.* *Department of Physical Geography - Sorbonne University, Paris, France. Email: Frederic.Bessat@paris4.sorbonne.fr

Reef corals have proven to be sensitive monitors of the marine environment. Their calcium carbonate skeletal material preserves a detailed record of past environmental conditions which can be used to reconstruct the history of climate variability and understand its impact on the marine environment. However, there were apparently conflicting reports about aspects of density bands, especially their appearance. Thus, it is no surprising that there emerged no definite link between annual density bands in corals and environmental factors. Conventional X-radiography has been a widely used technique in the study of coral skeletons for nearly thirty years. Measurements of coral skeletal densities have been made by photodensimetry of X-radiographs (Buddemeier), by gamma densitometry (Chalker and Barnes) or more recently by computerized tomography (Logan, Heiss, Bessat).The present work describes the use of to enhance the density banding and develop a new method to obtain density measurement directly on the X-radiograph. First, an experience with luminescence imaging plates in marine biology radiography is tested. Second, a methodological approach to pretreatment of X-rayed skeleton slices of the massive coral *Porites sp*. is described. Its allows the reconstruction of images cleared of the signal characterizing coral individual skeletal elements and noise.

A HISTORY OF NORTH ATLANTIC CLIMATE IN BERMUDA BRAIN CORAL

Cohen A.L.*, Michael M. McCartney, Jackie van Etten and Struan R. Smith *Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA. Email: acohen@whoi.edu

The North Atlantic Oscillation (NAO) is an atmospheric phenomenon which impacts the climate of Europe and North America. In recent decades, the NAO has exhibited decadal variability and a lower frequency trend which leads us to enquire after its natural long-term behaviour and the possible impacts of anthropogenic forcing. Instrumental data analysis reveal an especially strong correlation between ocean temperatures at Bermuda and the NAO since 1957. Large colonies of the brain coral *Diploria labyrinthiformis* are common on the Bermuda reefs, their size and low growth rate indicates that individual colonies may live more than 500 years. We examined chemical and structural variations in the skeletons of two small brain corals collected on the southern reefs of Bermuda to assess the fidelity of this species as a climate archive. Both $\delta^{18}O$ and skeletal density are strongly correlated with North Atlantic climate over the past 40 years. Winter-time $\delta^{18}O$ anomalies are well-correlated with the NAO index but lag the instrumental dataset by three years. This lag is unlikely to be climate-induced but rather caused by the mixing of aragonite prisms with younger blocky crystals deposited in the porous spaces of the excotheca as the coral grows. The timing of backfilling is estimated from the number of open pore spaces at the top of the colony and is used to explain the apparent lag between coral SSTs at Bermuda and the atmospheric circulation. Our data show that Bermuda braincorals record a history of the NAO as chemical and structural changes in their aragonite skeletons. However, accurate interpretation of climate from the proxy record requires that mechanisms of skeletal growth be well-understood.

OCEAN-ATMOSPHERE VARIABILITY IN THE WESTERN INDIAN OCEAN SINCE 1696 A.D.: $\delta^{18}O$ AND BA/CA IN A KENYA REEF CORAL.

Dunbar, R.B.*, Cole J.E., McClanahan T.R, Muthiga N. *Geological & Environmental Sciences, Stanford Univ., Stanford CA 94305-2115 USA. Email: dunbarro@lmg.polar.org

Instrumental records of climate variability from the equatorial Indian Ocean are scarce and short. Here we present stable isotopic and trace element records of climatic change acquired from large *Porites* heads from Malindi, Kenya (3°S, 40°E) that extend from 1696 to 1996 A.D. The record exhibits a long-term warming trend of about 1.5°C that accelerates in the latest 20th century, superimposed on interannual-decadal variability that persists throughout the record. Although dramatic temperature excursions occurred during several intervals of the 1700's and 1800's, the 1990's are the warmest decade of the past 300 years. Interannual SST variations reconstructed from the Malindi coral are coherent with ENSO indices and other ENSO-sensitive coral records. In addition, Ba/Ca levels in the coral skeleton exhibit a strong correlation with ENSO indices, the result of ENSO-related rainfall anomalies in East Africa. Recent work by Webster et al. and Saji et al. suggest the existence of a climatic dipole internal to the Indian Ocean, with periodic cooling off Sumatra and warming off east Africa. The uppermost part of our coral record is broadly consistent with dipole forcing but the extent to which ENSO versus internal Indian Ocean phenomena modulate interannual SST variability is not yet clear.

MID-HOLOCENE MONSOON DYNAMICS AND THE SEASONAL EXPRESSION OF EL NINO IN THE WESTERN PACIFIC

Gagan, M.K.*, Ayliffe, L.K., Hopley, D., Hantoro, W.S., McCulloch, M.T., Lynch, H.S. and Mortimer, G.E. Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia. Email: Michael.Gagan@anu.edu.au

We present high temporal resolution measurements of skeletal Sr/Ca, $\delta^{18}O$, and $\delta^{13}C$ for modern and mid-Holocene (6.2 to 4.8 ka) corals from the Australian Great Barrier Reef and the island of Sumba, eastern Indonesia. Our aim was to investigate potential changes in the Asian-Australian monsoon and the El Niño-Southern Oscillation (ENSO). The modern coral records show a 3-part sequence of environmental change within the annual cycle that is diagnostic of El Niño in the western Pacific, including: (i) relatively cool sea-surface temperature (SST) in the austral winter indicated by both the coral Sr/Ca and $\delta^{18}O$; (ii) reduced cloudiness in spring-summer indicated by the coral $\delta^{13}C$ values; and (iii) lower than average monsoon rainfall in summer shown by the $\delta^{18}O$. Results for the mid-Holocene corals indicate that this time-slice may be characterised by weak El Niños with a frequency of 6-9 years, in contrast to the relatively strong, high frequency El Niños (2-5 years) of the 1970s-1990s. In addition, the fossil coral records show that rapid warming of SST in spring coincided with strong evaporation and that the maximum in monsoon rainfall was delayed by about two months. These changes in the annual cycle of SST, evaporation, and rainfall support the hypothesis that differences in the seasonal cycle of insolation ~5-6 ka ago altered the stability of the coupled ocean-atmosphere system, including the dynamics of the Asian-Australian monsoon and El Niño.

EXPANDING THE SCALES OF CORAL PROXY RECORDS

Gill, IP*, Dickson, JAD and Hubbard, DK. Dept. of Geology, University of Puerto Rico, present address: Department of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148. email: igill@uno.edu

This study addresses two constraints of coral records: 1) the length of record, normally limited to the coral life span, and 2) the high apparent temporal resolution of the chemical record, which is being continuously improved by new analytical techniques. Regarding length of record, reef drilling allows the construction of a composite coral record spanning the last six millennia. Three fossil *Montastrea annularis* pieces from two island-shelf study sites, Lang Bank, St. Croix, and La Parguera, Puerto Rico were analyzed for stable isotope variation (398±80, 1768±70 (La Parguera) and 5958±90 ybp (Lang Bank)). The samples show no statistical difference in annual average oxygen isotopic values, suggesting average sea-surface temperatures did not change from 3960BC (Holocene Temperature Maximum) to AD1600 (Little Ice Age). With regard to increasing temporal resolution, SEM and electron microprobe analysis of modern *Montastrea annularis* skeletons reveals ornate radial 5-10 µm micro-banding oriented transversely to annual banding. The micro-banding displays density or solubility variation correlated to trace-element compositional changes (notably Sr) and may not be controlled extrinsically. This should suggest caution in interpreting high-resolution proxy records until more is known about the mechanisms and timing of coral skeletonization.

IDENTIFICATION OF SEASONAL TO DECADAL TIMESCALE VARIATIONS IN THE ZONAL CURRENTS OF THE CENTRAL EQUATORIAL PACIFIC PRIOR TO 1955 USING $\delta^{14}C$ IN CORAL.

Grottoli*, A. G., E. R. M. Druffel, S. T. Gille and R. B. Dunbar. *Department of Earth System Science, University of California, Irvine, CA 92697-3100. Email: grottoli@uci.edu

Oceanographers have a limited record of the natural variation of the width of the eastward flowing North Equatorial Counter Current (NECC) and its relationship to El Niño Southern Oscillations (ENSO). Here, we reconstructed the seasonal-to-decadal variation in the zonal currents of the central equatorial Pacific for the period of 1923-1955 using radiocarbon measurements $\delta^{14}C$) in a *Porites* coral skeleton from Fanning Island ($3^0$54'N, $159^0$19'W). Fanning lies in the path of the South Equatorial Current (SEC) during most of the year. During the warm phase of ENSO, the SEC weakens and the eastward flowing NECC broadens extending south of 4^0N, laving Fanning Island. This southward expansion of the NECC is more pronounced and lasts longer during El Niño events. Since radiocarbon levels in the NECC are higher than in the SEC, we were able to reconstruct the natural variation in the placement of these two zonal currents associated with ENSO from 1923-1955 from a Fanning coral. Initial results indicate that prior to 1955, $\delta^{14}C$ averages -54l and maximum $\delta^{14}C$ values seem to correspond with warm phases of ENSO. The large range in $\delta^{14}C$ indicates a strong contrast between warm and cool phases of ENSO in this region.

MULTISITE, MULTITRACER RECORD OF CLIMATE CHANGE FROM INDIAN OCEAN CORALS.

Grumet Nancy *, Robert Dunbar, Julia Cole Stanford University, Stanford Ca Usa. . Email: NGRUMET@LELAND.STANFORD.EDU

Recent discoveries by climate dynamicists suggest that the Indian Ocean exhibits an internal mode of variability similar to the Pacific's ENSO phenomenon. However, a longer perspective is required to document the presence/persistence of an Indian dipole through time, and to assess Indian Ocean SST interactions with ENSO events, the Afro-Asian monsoon, and global climate change. High-resolution coral records from coastal Kenya spanning 1° to 4°S (Lamu, Malindi, Watamu, Mombasa and Kisite) demonstrate that chemical and isotopic tracers within coral aragonite accurately record seasonal and annual changes in environmental parameters (e.g., SST, river input, and salinity/precipitation). Results from calibration studies indicate that the $\delta^{18}0$ of a Watamu *Porites lutea* reflects primarily SST. Linear regression of coral $\delta^{18}0$ versus SST yields a slope of –0.22 per mil ($^0/_{00}$) per 1 ^{0}C. In comparison, a Malindi coral $\delta^{18}0$ yields a slope of –0.26. Variability between the two calibration studies may reflect greater seasonality in seawater $\delta^{18}0$ at Malindi due to runoff from the Sabaki River. The highest correlations between SST and coral $\delta^{18}0$ (r^2 = 0.6 to 0.8) are achieved at quarterly timescales. We present the first multisite analysis of oceanographic variability along the East African coast deduced from isotopic and chemical (Sr, Mg, Ba) measurements in corals.

SURFACE WATER RADIOCARBON HISTORY IN THE SOLOMON SEA A RECORD OF WATER MASS MIXING.

Guilderson T*, Schrag, Cane, Kashgarian, and Southon. *Center for Accelerator Mass Spectrometry, LLNL L-397, Livermore CA, 94551, USA. Email: guilderson1@popeye.llnl.gov

The western tropical Pacific plays in important role in the localization of deep atmospheric convective activity and is a major exporter of latent and sensible heat to both hemispheres. On interannual and longer timescales the transport of warm surface water into and out of the western equatorial Pacific is thought to play an important role not only in regulating the development and termination of warm ENSO events, but also in global climate through atmospheric teleconnections. The relative paucity of observational data requires broadscale or coarse synoptic averaging and does not allow for more detailed questions regarding interannual to decadal scale variability, and in general is relegated to the last 10-20yrs. Such a time-history is insuffiencient to look at longer time-scale variability or to address such questions as anthropogenic influences on climate variability. Sub-annual radiocarbon measurements of coral skeletal material which accurately records the $\delta^{14}C$ of δCO_2 have added important information to water sampling programs like GEOSECS and WOCE. $\delta^{14}C$ is a quasi-conservative, passive advective tracer, and time-series such as those derived from archives such as hermatypic corals can augment historical, conventional observations especially in times and regions where observations are sparse. Corals act like strip-recorders continuously recording the radiocarbon content of the waters in which they live and thus it is possible to use records derived from these biogenic archives to study ocean mixing.

SKELETAL ARCHITECTURE AND DENSITY BAND ANALYSIS IN *DIPLORIA STRIGOSA* BY X-RAY COMPUTED TOMOGRAPHY.

Helmle, K.P., and Dodge, R.E. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania, Florida 33004 USA. Email: kevinh@ocean.nova.edu

Due to variability across coral taxa, the specific architectural variations responsible for density banding are not fully understood. Variations in the accretion of skeletal structures within long-lived reef corals produce annual density bands. The chemical composition of the skeletal material and the chronological reliability of the density bands has previously provided accurate and useful records for reconstruction of long-term climatic and ecological conditions. The western Atlantic/Caribbean reef coral, *Diploria strigosa*, is the first meandroid (brain) coral analyzed for skeletal variations relative to density band formation. Skeletal architecture was analyzed by X-radiography, optical densitometry, X-ray computed tomography (CT), and computer image analysis. High resolution X-ray CT images were used to reconstruct the density band pattern, to create three-dimensional models of the skeletal structure, and to create movies essentially traveling back in time through the coral skeleton. Further, computer image analysis was used to quantify the observed skeletal variations associated with density banding. Results indicated that high-density bands were the product of thickened septa and tightly organized and thickened columella.

A MULTI-CENTURY COMPARISON OF CORAL FRESHWATER-PROXY RECORDS.

Hendy, Erica *, Malcolm McCulloch, Michael Gagan, and Janice Lough. *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia Email: Erica.Hendy@anu.edu.au

Four centuries of coral freshwater-proxy records are presented for eight *Porites* cores collected from the central Great Barrier Reef (GBR), Australia. Fluorescence, $\delta^{18}O$ and δBa/Ca have been measured at low resolution, 5-year increments, from 1565 to 1985. These records are used to assess proxy reconstructions of freshwater flux in the GBR, and to test the level of reproducibility between coral colonies. Inshore and midshelf sites (within 17.5-18.5°S and 146-147°E) allow the separation of coastal influences on proxy behaviour. The $\delta^{18}O$ records are strikingly consistent between inshore and midshelf sites on both the decadal and century time scale. A dramatic 0.4 permil shift in inshore coral $\delta^{18}O$ records occurs from the late 1850s to lighter modern values in the 1870s marking the end of the Little Ice Age. Inshore Ba/Ca ratios track inshore $\delta^{18}O$ records, including the offset in the 1870s, which is coincidental with the start of European settlement and dramatic land-use changes. Decadal oscillations are faithfully replicated in all three proxies. The composite approach to coral proxy records, presented in this study, tests the reliability of reconstructions over multi-century time-scales and allows spatially significant environmental signals to be identified.

SR/CA THERMOMETRY IN CORALS – THE EFFECT OF EARLY DIAGENESIS.

Lazar Boaz * Rivka Enmar, Mira Bar-Matthews, Amitai Katz, Eytan Sass And Mordechai Stein. Institute Of Earth Sciences, The Hebrew Univ. Of Jerusalem, Jerusalem, Israel 91904. Email: BOAZL@VMS.HUJI.AC.IL

The effect of early diagenesis on sr thermometry in coral skeleton was studied in live coral heads (*porites*) from the nature reserve reef, elat, northern red sea. Petrography of the corals shows diagenetic features of dissolution, recrystallization and secondary aragonite precipitation (pore filling), which are most extensive in the oldest part of the coral. The secondary (chemical) aragonite is characterized by a significantly higher sr/ca ratio than the primary aragonite reflecting significantly higher sr distribution coefficient in the chemical precipitate. Total alkalinity and sr concentration in pore and reef water is consistent with precipitation of secondary aragonite and recrystallization of the primary skeleton. The present filling rate was measured to be 1.5±0.3 kg aragonite per year. The corals show clear annual fluctuations in sr/ca ratios that are interpreted as reflecting changes in sst. Yet, parts of the coral, which contain both pristine and secondary aragonite, may produce erroneous (about 1.5 °c lower) sst estimates by the sr/ca thermometers due to the high sr content of the chemical aragonite. The sr distribution coefficient converges to unity in the biogenic aragonite, which probably indicates that the polyps precipitate aragonite in an approximately close system. We have indications that similar behavior may be relevant to other important paleotracers such as u, and mg.

A CORAL $\delta^{18}O$ RECORD OF ENSO DRIVEN SEA SURFACE SALINITY VARIABILITY IN FIJI (SOUTH-WESTERN TROPICAL PACIFIC OCEAN).

Le Bec N*, Juillet-Leclerc, Corrège, Delcroix, Blamart, Le Cornec. Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CNRS-CEA, Avenue de la Terrasse, 91198 Gif sur Yvette, France. Email: Nolwenn.Le-bec@lsce.cnrs-gif.fr

We studied a coral core from Fiji Islands (South-Eastern edge of the Western Pacific warm and freshpool). This region is believed to play a major role in the coupled ocean-atmosphere system and especially in the onset of the ENSO (El Niño-Southern Oscillation) phenomenom. We analysed oxygen isotopes of the coral skeleton $\delta^{18}O_{coral}$) which depend on both SST and seawater $\delta^{18}O$, thus SSS (Sea Surface Salinity). The comparison of the coral $\delta^{18}O$ record against the instrumental SST and SSS data (1961-1998) shows that the seasonal $\delta^{18}O_{coral}$ is driven by seasonal SST changes whereas the inter-annual $\delta^{18}O_{coral}$ variability reflects the inter-annual SSS variations. In Fiji, SSS variations reflect the migrations of the South Pacific Convergence Zone (SPCZ) and associated freshpool during ENSO events. Because the ENSO-related SST fluctuations are very small, the inter-annual $\delta^{18}O_{coral}$ is a "direct" tracer of paleo-salinity. We used this tool to reconstruct SSS in the past century and show that variations of the SSS — estimated from the $\delta^{18}O_{coral}$ — are in good agreement with the SOI (Southern Oscillation Index). This paleosalinity record should contribute to a better understanding of ENSO events since salinity have a significant impact on the dynamics of the warm pool through density effect.

DECADAL TIME SCALE CHANGES AS REVEALED BY THE Sr/Ca THERMOMETER IN *PORITES LOBATA* ACROSS THE HAWAIIAN ARCHIPELAGO.

Liebeler J.K. *, R. W. Grigg, E. H. DeCarlo. University of Hawaii, Department of Oceanography, 1000 Pope Rd. Honolulu, HI, 96822, USA. Email: Liebeler@soest.hawaii.edu

A long-term record of sea surface temperature is necessary to differentiate current global climate change from natural variability in the climate system. Analysis of the ratio of Strontium to Calcium (Sr/Ca) in coral skeletons reveals the water temperature at the time of skeletal deposition. In this study, *Porites lobata* were collected over a range of 1900 km in the Hawaiian Archipelago, from Oahu (22^0N) to Midway Atoll (28^0N) and analyzed for Sr/Ca using an ICP-OES. Temperature records retrieved from corals reveal decreasing temperature with increasing latitude, with the exception of corals from lagoonal environments (inside Midway Atoll). Corals analyzed from French Frigate Shoals reveal temperature records 1.2-3.1^{0}C warmer from 1988-1997 than 1977-1987, with the maximum shift seen in corals from areas most exposed to open ocean water. This increase may be reflecting a shift in the North Pacific Oscillation, which shifted in 1988 to a warmer background state, with a shallower mixed layer depth. Corals analyzed from the inside of Midway atoll show a significantly higher temperature (1.0-1.2^{0}C) than corals growing on the outside of the lagoon, this difference is greatest during the summer months.

THE GEOCHEMICAL RECORD OF CHANGING LAND/SEA INTERACTIONS FROM COASTAL CORAL SKELETONS IN THE GREAT BARRIER REEF, AUSTRALIA.

McCulloch Malcolm*, Stewart Fallon, Chantal Alibert, Daniel Sinclair, and Janice Lough. Research School of Earth Sciences, Australian National University, Canberra, Australia 0200, Email: Malcolm.McCulloch@anu.edu.au

The worlds coral reef systems are in decline. The reasons are complex and incompletely understood, but it is clear that enhanced sediment and nutrients loads from terrestrial erosion, acting together with climatic stresses is proving to be a lethal combination. It is shown here how inshore corals from the Great Barrier Reef of Australia provide a quantitative record of river discharge volume, as well as suspended sediment load. *Porites* corals from Pandora and Havannah Reefs, located north of Townsville, experience episodic discharge of freshwater flood plumes from Australia's second largest river, the Burdekin. The salinity change at these sites is generally proportional to the maximum river flow (from zero to >25 million megalitres) and is preserved in the coral skeleton as a combination of Sr/Ca, $\delta^{18}O$ and fluorescent flood-band proxy records. In contrast, Ba/Ca ratios in corals provide a long-term proxy of suspended sediment loads and it is shown, for example, that following the drought of 1968/69, the suspended sediment load increased dramatically due to enhanced erosion. Barium acts as a monitor for suspended sediment as it is desorbed from particles as flood plumes experience increasing salinity, and thereafter Ba acts as an essentially conservative dissolved tracer. Ba/Ca ratios in corals therefore provide a means to determine long-term changes in suspended sediment loads and thus nutrients (P) that are entering inshore coral reefs since more intensive land-use following European settlement.

CORAL RECORDS OF MID-HOLOCENE CLIMATE VARIABILITY IN THE WESTERN PACIFIC WARM POOL.

Mcgregor H.V. *, M.K. Gagan, M.T. Mcculloch And J. Chappell. *Research School Of Earth Sciences, Australian National University, Canberra, Act 0200 Australia. Email: Helen.McGregor@anu.edu.au

The Western Pacific Warm Pool (WPWP) plays an essential role in modulating tropical climate and in the initiation of El Niño - Southern Oscillation (ENSO) events. This study aims to examine the nature of ENSO when SSTs appear to have been slightly warmer than present, using mid-Holocene coral proxy climate records, from within the path of the Sepik River flood plume, Papua New Guinea, central WPWP. Reduced SST and rainfall, experienced in this area during modern El Niño events, are reflected in coral skeletal oxygen isotope ($\delta^{18}O$) and Sr/Ca ratios. $\delta^{18}O$ results for two modern corals agree to within 0.06‰ (equivalent to 0.3°C) for the years 1981-1997. Fossil coral $\delta^{18}O$ values from 7100 to 5000 yrs BP show drier conditions compared to present. At the same time coral Sr/Ca ratios indicate a warm SST peak ~1°C higher than present. $\delta^{18}O$ values and Sr/Ca ratios suggest cooler and wetter conditions between 5000 and 4700 yrs BP. By 1900 yrs BP, present conditions prevail. A reduction in interannual range in $\delta^{18}O$ values persists until 1900 yrs BP and suggests that the ENSO cycles may have been weaker from 7100 to 1900 yrs BP. The timing and nature of major, rapid climate shifts identified in this study coincide with mid-Holocene changes in the Asian monsoon, which may have implications for ENSO dynamics during the mid-Holocene.

INTER/INTRA COLONY VARIATION AND BETWEEN SPECIES VARIABILITY in the stable oxygen isotope of *Porites*

Maier, C*; Paetzold, J; Bak, RPM. *NIOZ, P.O.Box. 59; 1797AB Den Burg, The Netherlands; Email: maier@nioz.nl

The $\delta^{18}O$ stable isotope record of coral skeletons is used as proxy to reconstruct temperature (and salinity) changes of tropical marine environments on a high resolution temporal scale. We investigated variations in skeletal $\delta^{18}O$ within one coral genus, looking at inter/intra-colony variability and variation between species. Coral skeletons of *Porites lutea, P. australiensis* and *P. murrayensis* were subsampled along their main growth trajectories, resulting in comparable profiles that cover at least 5 years of coral growth. All specimens originate from one Indonesian reef site (121°13'E; 6°32'S) and were sampled at the same time (October 1984). Consequently, the colonies have grown under the same environmental conditions with respect to SST and salinity, and the profiles should be expected to be alike in their seasonal $\delta^{18}O$ amplitudes. However, comparing the minima and maxima of each seasonal cycle, the $\delta^{18}O$ values show an average variation of 0.43 ‰ ± 0.13 SD between profiles. There is no consistent shift to either higher or lower $\delta^{18}O$ signals between the isotope lines of the various profiles. The variation between profiles within a single coral colony is as high as between profiles of different colonies or species. This indicates that other sources of variation are more prominent than specific colony or species characteristics. Changes in calcification rate and temporal precision of "bulk-sampling" are taken into consideration to explain the observed variation of 0.4 ‰ in the oxygen stable isotope signal.

EVIDENCE OF MID-HOLOCENE COOLING OF THE TROPICAL WESTERN PACIFIC FROM SR/CA RATIOS OF CORALS FROM THE CENTRAL GREAT BARRIER REEF, AUSTRALIA.

Marshall J.F.*, D.P. Burrows, and M.T. McCulloch. Research School of Earth Sciences, Australian National University, Canberra, ACT, Australia. Email: John.Marshall@anu.edu.au

Sr/Ca ratios have been measured by ID-TIMS on both modern and fossil *Porites* sp. from Myrmidon and Stanley Reefs in the central Great Barrier Reef. Four *Porites* sp. from Myrmidon Reef give U/Th ages of 7.6-8.0 kyr, while two from Stanley Reef give U/Th ages of 6.2-6.3 kyr. The Sr/Ca ratios have been converted to sea surface temperature (SST) by calibrating the modern corals with instrumental records. The fossil corals from Myrmidon Reef show SSTs that are within the same range as modern values, but there is a variation of some 2ºC between all four corals, similar to the variability observed in the modern coral. Both Ba/Ca and fluorescence records suggest increased upwelling along the shelf edge during this period. The 6.2-6.3 kyr corals from Stanley Reef show summer SSTs that are 2ºC cooler than modern summer SSTs, but, significantly, winter SSTs that are 4ºC cooler than modern. Comparison with other coral proxy SST records from the tropical SW Pacific confirms that by 8 kyr SSTs were as warm as present day, but that between 7.5-6.0 kyr there was a distinct cooling of some 3ºC , with temperatures returning to present values by about 5 kyr. While there is a general perception that the mid-Holocene was slightly warmer than present, it is possible that SSTs in the region of the West Pacific Warm Pool were depressed as a result of relaxation or even reversal of the Trade winds at this time.

A GROWTH DEPRESSION MODEL FOR CORAL DENSITY BANDING IN *MONTASTRÆA ANNULARIS*.

Mendes Judith M.* & Jeremy D. Woodley. Centre for Marine Science, University of the West Indies, Mona, Kingston 7, Jamaica. Email: jmendes@uwimona.edu.jm

The potential of coral skeletal density bands as recorders of environmental conditions has not been realised because the biological basis for their formation is poorly understood. This study, in Jamaica, examined banding in *Montastræa annularis* in relation to growth rate (measured as skeletal extension), while monitoring reproductive state and environmental factors. Growth rate was not constant throughout the year. Two periods of reduced growth were found. One, between August and October, corresponded to the time of annual dense band formation. The other, in February, marked the formation of an additional sub-annual dense band. Dense band formation was negatively correlated with growth rate ($r=-0.68$, $p<0.05$). It is proposed that dense banding in *M. annularis* is the result of reduced growth rate; any factor that reduces growth will thus promote dense band formation. Factors significantly correlated with dense band formation, and reduced growth rate, were gonad development ($r=0.84$, $p<0.05$) and deviations in water temperature from the annual mean ($r=-0.67$, $p<0.05$). The marked annual dense band in *M. annularis* is the result of these growth disrupting factors (i.e., gonad development and high water temperatures) coinciding. The sub-annual band is the result of only one of these growth reducing factors (temperature deviation) being present.

VARIATIONS IN Mg/Ca, Na/Ca, AND Sr/Ca RATIOS OF CORAL SKELETONS WITH CHEMICAL TREATMENTS.

Mitsuguchi Takehiro *, Uchida, Tetsuo and Matsumoto, Eiji. *Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya, 464-8601, JAPAN. Email: mituguti@ihas.nagoya-u.ac.jp

Minor and trace elements in coral skeletons are useful for retrieval of palaeoceanic environments. Especially, the Sr/Ca, Mg/Ca, and U/Ca ratios are important proxies for sea surface temperature. However, the method of sample pretreatment has not been standardized yet among the researchers. If the elemental concentrations are altered with any treatment, the retrieved environments will also be altered. We evaluated the effects of chemical treatments on Mg/Ca, Na/Ca, and Sr/Ca ratios of *Porites* coral skeletons. Four modern and one fossil samples were powdered, then 40 replicate subsamples were taken from each sample. The 40 replicates were split into 4 groups each consisting of 10. One group was left untreated as the control group, while the other three groups were treated stepwise with (I) distilled water, (II) unbuffered 30 % H_2O_2, and (III) weak HNO_3. The control group and stepwise-treated groups were dissolved in 0.5 M HNO_3 and measured by ICP-AES for Mg, Ca, and Sr and by Flame-AES for Na. In result, the Mg/Ca and Na/Ca ratios varied significantly with all treatment steps, while the Sr/Ca ratio showed little variation. Moreover, the Mg/Ca variation was closely parallel with the Na/Ca variation. We ascribe these results to the elemental distribution in the skeletal micro-structure: Mg and Na are concentrated both on the skeletal surface as adsorptive phase and at the skeletal innermost as unknown phase, while Sr is distributed almost homogeneously. Thus, the chemical pretreatment of coral skeletons should be standardized, especially if the Mg/Ca and Na/Ca ratios are used for palaeoenvironmental analysis.

EARLY HOLOCENE SEA SURFACE TEMPERATURE IN THE RYUKYUS RETRIEVED FROM CORAL Mg/Ca AND Sr/Ca RATIOS.

Mitsuguchi Takehiro *, Eiji Matsumoto, Tetsuo Uchida, Peter J. Isdale, Toshio Kawana, and Hironobu Kan. *Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya, 464-8601, JAPAN. Email: mituguti@ihas.nagoya-u.ac.jp

The Sr/Ca ratio and oxygen isotope ratio of hermatypic coral skeletons are the most reliable proxies for sea surface temperature (SST) in palaeoceanography. Although the Mg/Ca, U/Ca, B/Ca, and F/Ca ratios are also proposed as palaeo-SST proxies, some of these appear to be more affected by other effects (e.g., vital effects). We determined Mg/Ca and Sr/Ca ratios along the growth axes of modern and fossil coral skeletons (*Porites* spp.) collected from the Great Barrier Reef (GBR) and the Ryukyus. The fossil corals have calibrated ^{14}C ages of 7200 ~ 7800 cal yr BP. The elemental analysis was performed by ICP-AES. All of the specimens showed synchronous seasonal variations in the Mg/Ca and Sr/Ca ratios, which can be ascribed to SST variation. We calibrated the Mg/Ca-SST and Sr/Ca-SST relationships for a modern specimen from the GBR, and applied them to the Mg/Ca and Sr/Ca results of the Ryukyu fossil specimens for SST retrieval. In result, the Mg/Ca-derived SSTs are in excellent agreement with the Sr/Ca-derived SSTs in both average and amplitude. In the Ryukyus, the SSTs at 7.2 ka ~ 7.8 ka were probably the same as seen today.

SEA SURFACE TEMPERATURE AROUND 6000 YEARS AGO FROM CORAL RECORDS OF KIKAI ISLAND IN THE SUBTROPICAL NORTHWESTERN PACIFIC.

Morimoto M. *, H. Kayanne, O. Abe, E. Matsumoto and C.-H. Chiu. Department of Earth and Planetary Science, the University of Tokyo, Hongo, Tokyo 113-0033 Japan. E-mail Address: morimoto@sys.eps.s.u-tokyo.ac.jp

Middle Holocene is thought to be a warmer period, based mainly on terrestrial pollen and ice core data at middle to high latitudes. On the other hand, little paleoclimatic data have been obtained from the ocean at low latitudes. So the sea surface temperature (SST) and the ocean circulation mode were not well known. In this study, we reconstructed the SST and sea water $d^{18}O$ near 6000 yr B.P. for Kikai Island, Ryukyu in the subtropical Northwestern Pacific from skeletal Sr/Ca and $d^{18}O$ in *Porites* corals. From those data, we examined the difference and variability in SST and water circulation of the Asian summer monsoon region between modern and 6000 years ago. Several fossil corals were collected at Kikai Island, Ryukyu with ^{14}C dates ranging from 4900 to 6300 yrB.P. Sr/Ca and $d^{18}O$ in fossil corals indicate that the SST in this region was lower than the present by as much as 2 degrees. Moreover, the sea water then was enriched in ^{18}O by 0.4 per mil relative to the modern isotope ratio. These results seem to suggest that thermal contrast between land and sea might be enhanced during that period. We speculate that this larger contrast could induce a stronger summer monsoon hence an accelerated hydrological cycle in the East Asia 6000 years ago.

HIGH RESOLUTION ANALYSIS OF TRACE ELEMENTS IN CORALS BY LASER ABLATION ICP-MS TO ASSESS THE IMPACT OF ANTHROPOGENIC POLLUTION AND ENVIRONMENTAL CHANGE IN BARBADOS, W.I.

Runnalls, Lesley A.* *Postgraduate Research Institute for Sedimentology, University of Reading, Whiteknights, Reading RG6 6AB, UK. Email: L.A.Runnalls@reading.ac.uk

Coral reefs and their associated communities are affected by environmental parameters such as water temperature, depth and light intensity. The reef environment is also disturbed by human influences such as anthropogenic pollutants which in Barbados are released close to the reefs. Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICP-MS) has been used to assess the effects of pollution on the corals and their associated communities. It offers the possibility of evaluating the relative impact of both anthropogenic pollutants and natural stresses. Sclerochronolgy is also being employed primarily to document the framework and skeletal growth of a suite of *Montastrea annularis* coral cores. X-radiography has shown the annual growth band patterns of the corals which extend back over several decades. Preliminary results using LA-ICP-MS have shown a contrast in the concentration of the trace elements (Mn, Zn, and Pb) within the corals at different locations. Thus this method is shown to be a powerful tool for extracting high resolution environmental records from corals and, in combination with sclerochronolgy, of showing the relationship between growth rate and environmental pollution.

U–TH DATING OF REEF CORALS - THE EFFECT OF EARLY DIAGENESIS.

Stein, Mordechai*, Rivka Enmar, Mira Bar-Matthews, Ludvik Halicz and Boaz Lazar. *Institute Of Earth Sciences, The Hebrew Univ. Of Jerusalem, Jerusalem, Israel 91904. Email: MOTIS@VMS.HUJI.AC.IL

U-series dating of scleractinian corals provides the most precise ages of late Pleistocene and Holocene marine reef terraces, yet the introduction of TIMS methods to the analysis of U and Th isotopes reveals small changes in the calculated initial U isotopic composition of many corals. We investigated the effect of secondary aragonite precipitation within live coral skeleton on the U-isotopic system. We analyzed the U concentration and isotopic composition in the aragonitic skeleton, porewater and open seawater from the Nature Reserve Reef, Elat (northern Red Sea). The U isotopic composition of primary (biogenic) and secondary (chemical) aragonite is the same and indistinguishable from seawater or porewater. The secondary aragonite shows significantly higher U concentration than primary aragonite. The porewater is lower in U compared to contemporaneous seawater, which probably reflects selective removal of U by organic matter. A uranium uptake model indicates that after several kyr of submergence, secondary aragonite precipitation can cause a 5-10% shift in the age calculation, but would induce only a negligible effect on the initial U isotopic composition. Pristine Holocene corals (~ 5,000 y) from Elat yielded, however, initial $\delta^{234}U$ values of ~170. The elevated $\delta^{234}U$ values may reflect local variation in the seawater composition due to enhanced input of runoff water with elevated $\delta^{234}U$ values from the Pan-African crystalline basement.

INTER-ANNUAL TO CENTURY-SCALE CLIMATE RECORDS FROM THE ATLANTIC: CORAL BASED RECONSTRUCTIONS

Swart, Peter K.*, Richard E. Dodge and David Enfield Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami Fl 33149 Email: Pswart@srmas.miami.edu

There is a demonstrated correlation between land-climate variations and sea surface temperature (SST) distributions in recent decades of good instrumental records. This has generally been characterized as the result of large-scale interactions between the ocean and atmosphere, the most notable of, which is the El Nino/Southern Oscillation (ENSO), known to produce teleconnections, to land climate anomalies around the globe. We have examined associations between variations Atlantic Dipole and the oxygen isotopic record of corals in two areas of the Atlantic (Gulf of Guinea and Cape Verde) which have particularly strong association with temperature variations in the north and south sub-tropical Atlantic. At both these locations massive corals are present which have density records in excess of 100 years. At the Gulf of Guinea location, oxygen isotopic composition is positively correlated to salinity as a result of the input of water from the many rivers, which drain the western portion of Africa. Hence during the period of extreme drought in the Sahel portion of Africa, the oxygen isotopic values of the corals were isotopically enriched compared to periods of high rainfall in the region. In contrast in the Cape Verde region the oxygen isotopic composition of the corals respond principally to temperature variations as there is little annual variation in the salinity in this region

LONG-TERM VARIABILITY IN ENSO: EVIDENCE FROM LIVING AND FOSSIL CORALS IN PAPUA NEW GUINEA.

Tudhope, Sandy*; Chilcott, Colin; McCulloch, Malcolm; Shimmield, Graham; & Ellam, Rob. *Department of Geology & Geophysics, Edinburgh University, West Mains Road, Edinburgh EH9 3JW, Scotland, U.K.. Email: sandy.tudhope@ed.ac.uk

Despite its global significance, there is still a poor understanding of variability in the strength and frequency of the El Niño Southern Oscillation (ENSO) climatic phenomenon. For example, there is a vigorous debate as to whether recent severe ENSO events are a result of global warming, or merely a manifestation of natural variations in the system. To help reveal the range and likely causes of variability in ENSO, we have obtained proxy records of ENSO from geochemical (stable O isotope, Sr/Ca and U-series dating) analysis of the skeletons of living and sub-fossil annually-banded massive *Porites* corals in Papua New Guinea. Specifically, we investigated the range of natural variability in ENSO during periods of similar global climatic boundary conditions to those of today (e.g., over the past 3,000 years), as well as investigating sensitivities of ENSO to changes in climatic boundary conditions (e.g., during 'ice ages'). Our results indicate that ENSO is a remarkably persistent component of the climate system, operating even during some major changes in global and regional climate. However, ENSO amplitude does appear to have varied through time, with Modern ENSO being relatively strong. These changes in amplitude are not simply related to changes in global or regional temperature, but may possibly be related to subtle changes in seasonality due to precessional orbital forcing (c.f., Clement et al., 1999).

INTERANNUAL AND DECADAL VARIABILITY IN SST IN THE SUBTROPICAL SOUTH PACIFIC GYRE BACK TO 1726 A.D.

Wellington, G.M.*, Linsley B.K., and Schrag D.P. *Department of Biology and Biochemistry, University of Houston, Houston 77204 USA, Email: wellington@uh.edu.

The past variation in surface ocean properties in the Pacific gyres remains poorly constrained over the last several centuries, particularly in the western subtropical South Pacific (WSSP) which, in addition to being the identified dominant source region for water transport to the equatorial thermocline, has also been identified as an important source region for interannual sea surface temperature (SST) anomalies propagating into higher latitudes of the southern Hemisphere. Here we present a time-history with near-monthly resolution of variations in skeletal Sr/Ca in a 275 year-long core from a colony of Porites lutea at 18m depth off the island of Rarotonga (21.5°S, 159.5°W) in the WSSP. Singular Spectrum Analysis (SSA) indicates that after the annual cycle and a long-term trend, decadal-scale variance is greater than interannual variance in this time-series. The trend and decadal modes are highly coherent with SST behavior in the central North Pacific Gyre as summarized in the PDO index indicating that the WSSP has responded generally in phase with the North Pacific Gyre. The most striking feature of the record is an observed step-function shift in SST of 2°C warming since 1760.

EARLY HOLOCENE δ^{18}O-BASED SSTS MODULATED BY "VITAL EFFECTS" OF HERMATYOIC CORALS (*PORITES*).

Yamada, Tsutomu*, Kiyama, Osamu; Iryu, Yasufumi; and Nakamori, Toru. *Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Sendai, 980-8578, Japan. Email: yamada@dges.tohoku. ac.jp

Examined are δ^{18}O records from two Holocene (7.0 and 9.2 kyrs BP) and two modern corals, both of which were collected at Shitooke, Kikai-jima, Ryukyu Islands. δ^{18}O values in modern corals show distinct annual cycles. Based on temperature-dependency of δ^{18}O values, a δ^{18}O-based thermometer is established for the modern corals. This thermometer is modified so that it can be applied for Holocene corals by taking account of ^{18}O-enrichment of seawater caused by increased polar ice volumes and that by the degree of isotopic disequilibrium resulting from the "kinetic isotope effects". No diagenetic alternations (marine cementation and terrestrial diagenesis) are detected in the fossil samples by X-ray diffraction analysis and thin-section observations. The calculated SSTs at 7.0 and 9.2 kyrs BP by using the modified thermometer indicate that annual mean SSTs were about 2.8 °C lower and 1.0 °C higher than the present, respectively. Our estimates are inconsistent with those of other workers. It is highly probable that these anomalous temperatures are ascribed mainly to incomplete evaluation of the "kinetic isotope effects" and biotic modifications of annual mean isotopic ratios caused by coral growth processes.

Session A18: Reproduction, Recruitment and Effects of Stress on Reproductive Success of Corals and Other Reef Invertebrates

REPRODUCTIVE MODES AND GENE FLOW IN THE SCLERACTINIAN CORAL *POCILLOPORA DAMICORNIS*.

Adjeroud, Mehdi. Ecole Pratique des Hautes Etudes, ESA CNRS 8046, Universit_ de Perpignan, 66860 Perpignan. Email: adjeroud@univ-perp.fr

The variation in the relative contribution of sexual and asexual reproduction and in the level of gene flow between populations of the scleractinian coral *Pocillopora damicornis* was examined. Reproductive modes and gene flow were estimated from the genetic structure of populations revealed by allozyme electrophoresis. Populations were collected from 3 regions that represent 2 distinct coral reef systems: an insular coral reef system (Ryukyu Archipelago), and a continental system (Great Barrier Reef, and Southwestern Australia). Two spatial scales were examined: the local scale (populations from the same reef/island), and the regional scale (populations from different reefs/islands separated by up to 1200 km). The relative contribution of sexual and asexual reproduction varied considerably between the 3 regions. The results support the assumption that asexual reproduction has a higher importance at the margin of the geographical range of the species. The level of gene flow also varies considerably with the geographic location. Populations were highly differentiated in Southwestern Australia, whereas populations from the GBR were connected by a considerable gene flow, both at the local and regional scales. The situation in the Ryukyu Archipelago was intermediate (moderate gene flow). This important variation in life-history traits may explain why this species is so common throughout Indo-Pacific reefs.

PROMOTING RECRUITMENT OF SCLERACTINIAN CORALS USING ARTIFICIAL SUBSTRAT IN GILI INDAH, LOMBOK BARAT.

Bachtiar, Imam*. *Universitas Mataram, NTB, Indonesia. Email: ibachtiar@hotmail.com

The effectiveness of promoting abundance of coral recruitment by providing small concrete blocks was investigated in Lombok waters. The study was carried out 10 months in the marine tourism park Gili Indah consisting of three small islands: Gili Air (GA), Gili Meno (GM) and Gili Trawangan (GT), in the district of Lombok Barat. Result of this study show that introducing small concrete blocks (30x15x20 cm^3, LWH) does not increase the abundance of coral recruits. It is likely that the study period is too short that many new recruits might be too small to be counted *in situ* by a diver. It is also found that the abundance of recruits in GM is lower than those in GA and GT, beside the fact that GM has higher coral cover and lower rate of sedimentation. The abundance of recruits is not different between exposed (north) and sheltered (south) reefs. Interaction effect between treatment and island is not significant, neither is interaction between depth and island; while interaction effect between location and island is significant. The results suggest that coral reef of Gili Indah, which suffered mass coral mortality due to El-Nino 1998, still receive larvae supply from source reefs somewhere. The ineffectiveness of concrete block placement on the reef is unlikely to be justified at this stage, as recruits needs longer time (>10 months) to be visible to a scuba diver.

MASS SPAWNING OF *ACROPORA* IN THE CORAL SEA.

Baird A.*, Marshall, Paul; Wolstenholme, Jackie. *School Of Marine Biology & Aquaculture James Cook University, Townsville Q. 4811, Australia. Email: ANDREWBAIRD@OZEMAIL.COM.AU

The annual synchronous spawning of numerous species of scleractinian corals is one of the most spectacular of natural phenomena. Comparisons available suggest that mass spawning is restricted to regions with large variations in environmental cycles with a progressive breakdown in seasonality and synchrony of reproduction towards the equator. To test this hypothesis we compared the spawning patterns of *Acropora* at 4 locations in the Coral Sea with contrasting environmental cycles. In the Solomon Islands (8° 06 S) mature eggs were found in 28 of the 41 *Acropora* species sampled. Overall 36 % of colonies (n=403) had mature eggs, 6 % had immature eggs and no eggs were visible in the remaining colonies. At Lizard Island (14° 39 S) 15 of 26 species had mature eggs or 62 % of the colonies sampled, while 10 % contained immature eggs. On Orpheus Island (18° 40 S) 19 of 21 species had mature eggs or 72 % of the colonies sampled, and less than 2 % of colonies had immature eggs. In the few widespread species abundant at each of location the proportion of the population fecund declined from Lady Elliot (23° 45) towards the equator, suggesting that degree of synchrony may be less and the reproductive season longer. However, the high proportion of colonies without eggs even in locations where the reproductive season is restricted to the mass spawning period suggests that not all colonies spawn every year. Furthermore, the proportion of fecund colonies in some morphologies is consistently low (e.g. arborescent = 35 %), suggesting that many *Acropora* have more a complicated life history than implied by the paradigm of the mass spawn.

MOLECULAR CONTROL OF DEVELOPMENT IN *ACROPORA MILLEPORA*. I. MORPHOLOGICAL DEVELOPMENT AND HOX-RELATED GENES.

Ball E.E.*, Hayward, David C.; Catmull, Julian; Reece-Hoyes, John S; Hislop, Nikki; Harrison, Peter J.; Miller, David J. *Research School of Biological Sciences, Australian National University, P.O. Box 475, Canberra, ACT 2601, Australia. Email: ball@rsbs.anu.edu.au

We are studying the genes controlling coral development with several questions in mind. First, what genes are present? Corals have many fewer cell types than higher metazoans, but we have found representatives of every major class of genes that we have searched for: structural genes, housekeeping genes, nuclear receptors, *Hox*-like genes, and *Pax* genes. Second, since the Phylum Cnidaria is widely accepted to be an ancient group of organisms, what can we learn about gene evolution by comparing coral genes with those of higher metazoans? Thus far, although most gene families are represented in corals, all coral gene families seem to have fewer members. Third, what roles do the genes that we have discovered play in development and how does this compare to their roles in higher organisms? To obtain a detailed description of the various developmental stages of *Acropora* we have used scanning electron microscopy, and have developed a trichrome stain for plastic sections which helps us to determine the time of appearance of specific cell types. This morphological information, plus the distribution of messenger RNA from specific genes, as determined by in situ hybridization, often allows us to infer gene function. The *Hox*-like genes are discussed as an example of this approach.

TEMPORAL ENVIRONMENTAL FEATURES AND REPRODUCTIVE PROCESSES OF THE SOFT CORAL *HETEROXENIA FUSCESCENS*.

Ben-David-Zaslow, R.* **and Benayahu, Y. *Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel, Email:** revitbd@post.tau.ac.il

In the Red Sea, during its year round planulation period the zooxanthellate soft coral *Heteroxenia fuscescens* is subjected to a seasonal environmental regime that alternates between stratified warm summer waters and upwelling of low temperature winter waters. It was therefore hypothesized that variation in the abiotic conditions affects the coral reproductive and biochemical processes. During summer and fall the average percentage of planulating colonies was significantly higher than in winter and spring. Since the coral gains nutritional benefit from uptake of DOM as well as from carbon fixation by zooxanthellae, it is suggested that this seasonal pattern is related to changes in nutrient and light levels. Seasonal and year to year fluctuations were also found in the biochemical and energetic content of *H. fuscescens* colonies. These patterns correspond to temporal changes in the coral fecundity, suggesting that the increase in energy content during the summer is due to the increasing number of developing planulae in the colonies. The results show for the first time that planulae of *H. fuscescens* can take up dissolved free amino acids. Absorption of amino acids by the planulae may contribute to their energy, and thus extend their longevity and competence periods. This uptake may also have a significant impact on their nitrogen budget. Based on these results, we suggest a model that illustrates the relationship between the environmental parameters and the processes examined in the study.

INTRASPECIFIC VARIABILITY IN THE TIMING AND OUTPUT OF CORAL GAMETES AFTER LONG-TERM EXPOSURE TO ELEVATED TEMPERATURES.

Beretta, Giglia A.* ***The University of Queensland, Centre for Marine Studies, Brisbane, QLD 4072, Australia. Email:** gberetta@biousyd.edu.au

The effects of long-term exposure to elevated temperatures on the timing of spawning and output of gametes was studied in two species of corals (*Acropora millepora* and *Montipora digitata*) over a two year period at Heron Island Reef and Research Station on the southern GBR. A large-scale manipulative experiment was run from Jul. 1998 to Feb. 1999 and again from Jul. 1999 to Feb. 2000, where 5 replicate colonies of each species were maintained in each of six 2000L aquaria for the duration of each study. Three of the aquaria were kept at ambient reef flat temperatures while 3 were heated to 2^0C above ambient temperatures. Gamete development was followed through polyp dissections. Analysis of spawning dates and egg-sperm bundles collected from spawned colonies shows that heated colonies for both species spawned up to 1 lunar month earlier then field controls. Spawning timing was variable within species and among years. Egg number and size varied between the two species but appear to not be affected by temperature treatment. Concurrent studies by S. Ward have shown reduced fertilization of gametes and settlement of larvae due to these temperature elevations. These experiments show that relatively small increases in ambient temperatures can alter the timing and output of gametes and in some instances be detrimental to coral fitness.

REPRODUCTIVE ECOLOGY OF *DIASERIS DISTORTA* (MICHELIN) (FUNGIIDAE) IN THE GALÁPAGOS ISLANDS.

Colley S.B.*, Feingold, Joshua S.; Peña, Juan; and Glynn, Peter W. *Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149. Email: stheodosiou@rsmas.miami.edu

The sexual reproduction of *Diaseris distorta* is described from a population at Corona del Diablo (Devil's Crown) off Floreana Island in the Galápagos Islands, Ecuador. Gametogenesis is classified in four developmental stages for each gender. Individuals are gonochoric and most likely broadcast spawners. Gametogenesis was favored during the warm, wet season from at least March to June, peaking at the end of April. Ripe female gametes occurred around full moon with some incidence around new moon. Synapticular pouches are repleat with eggs or spermaries in all stages of development. Hence, it is likely that this coral develops gametes continuously during the breeding season(s). Fecundity of female individuals yielded preliminary estimates of 25,000-31,000 mature eggs/cm^2 live surface tissue/cycle. However, the sex ratio of the study population was highly skewed toward the male gender (approximately 5:1). Individuals as small as 240 mm^2 surface tissue were found to be sexually active. The relative ecological importance of asexual vs. sexual reproduction is addressed.

THE EFFECT OF ELEVATED AMMONIA ON REPRODUCTION IN TWO HAWAIIAN SCLERACTIANS WITH DIFFERENT LIFE HISTORY PATTERNS.

Cox E.F.* **and Ward, Selina. *Hawaii Institute of Marine Biology, P.O. Box 1346 Kaneohe HI 96744 USA. Email:** fcox@hawaii.edu

Colonies of a broadcast spawning coral, *Montipora verrucosa,* and a planulating coral, *Pocillopora damicornis,* were collected in March 1997 and randomly distributed among 6 microcosm tanks. Beginning in April 1997, ammonium sulfate was dripped into 3 experimental tanks to elevate ammonium concentrations to approximately 20 µM. Spawning of *M. verrucosa* was monitored during June, July and August. There were only small differences in reproductive parameters measured (n=the number of colonies for which each parameter was measured): # eggs $bundle^{-1}$ (control 11.1 ± 2.13 SD, n=13; experimental 11.1 ± 1.49, n=11), egg size (control 430 µm ± 16, n=11; experimental 408 µm ± 14, n=8), or fecundity (control 1.21 mg ml^{-1}± 1.2, n=15; experimental 0.71mg ml^{-1} ± 0.97, n=14). There were no differences in fertilization success (control 61%, n=6 trials, experimental 71%, n=3 trials). Experimental colonies of *P. damicornis* did not release planulae in July. Planulae collected from control colonies showed no differences in settlement rates (control 50% ± 13, n=4; experimental 54% ± 6.5, n=4) or short term survivorship (control 33% ± 5.8, n=2; experimental 52% ± 7.8, n=2) in both ambient and ammonium enriched seawater. Although ammonium enrichment in the microcosms ended mid November 1997, experimental colonies did not release planulae until the full moon of March 1998.

THE EFFECT OF TEMPERATURE ON CORAL REPRODUCTION ON BERMUDA'S REEFS.

de Putron, Samantha * and Smith, S.R.. *Bermuda Biological Station for Research, St. Georges, Bermuda. Email: sputron@bbsr.edu

The study of the reproductive biology of corals in Bermuda is of particular interest because of the northerly location of this pseudoatoll in the Atlantic (32N 65W). The low winter seawater temperatures and geographical isolation make it an extreme of distribution for many of the species there. This study examined temporal and spatial variability of sexual reproduction of the broadcasting gorgonian, *Pseudoplexaura porosa*, and the brooding scleractinian, *Porites astreoides*. The Bermuda platform is comprised of different reef zones that experience diverse environmental conditions due to gradients of temperature, turbidity and wave intensity from inshore to offshore. Seawater temperature in the lagoon falls to 15.5 °C during winter and rises to 30.5 °C in the summer. The outer rim reefs are buffered by oceanic waters, moderating the temperature range from between 19 ° to 29 °C. Inshore water temperatures rise earlier in the year creating a temperature gradient over the 18km of lagoon. Variation in the timing, duration and intensity of reproduction of *P. porosa* and *P. astreoides* has been observed in different zones across the Bermuda platform. Populations from the deeper outer lagoon spawn progressively later in the summer compared to inshore reefs in conjunction with the slower rise in offshore seawater temperature. Interannual variability in the reproductive patterns of these species can also be related to changes in seawater temperature. Finally, the reproductive cycles are offset by one or two months later in Bermuda relative to the Caribbean.

RECRUITMENT OF *Agaricia* AND *Porites* TO ALUMINUM SUBSTATA, CONCH REEF, KEY LARGO, FLORIDA

Feingold J.S.* and Reaka-Kudla., M. *Nova Southeastern University Oceanographic Center, 8000 N. Ocean Dr., Dania, FL 33004 USA. Email: joshua@polaris.nova.edu

Six aluminum frames were deployed at 14m depth for 27 months at Conch Reef, Key Largo, Florida. Three of these were dosed monthly with nutrients and 3 were controls. Two species of scleractinian corals (*Agaricia* sp. and *Porites* sp.) recruited to the upper and side surfaces of all 6 frames. While only one colony of *Porites* recruited on natural substrata within the frames, 115 colonies of *Agaricia* and 46 colonies of *Porites* were present on the aluminum frames at the end of the experiment. Colony size ranged from 6 to 628mm^2 (*Agaricia*) and 29 to 469mm^2 (*Porites*) and mean colony size was 154 ± 129mm^2 and 121 ± 96mm^2 respectively. However, there was no significant difference (t-test, n=3, p=0.35) in the numbers of colonies observed on treatment (32.0 ± 36.9) vs. control (21.7 ± 25.5) frames. Nor was there a significant difference (t-test, n=96,65, p=0.33) between the mean surface area of the coral recruits on treatment (142 ± 120mm^2) v.s control frames (149 ± 124mm^2). These data suggest that *Agaricia* and *Porites* effectively recruit to aluminum substrata and pulsed nutrification does not affect their recruitment and subsequent early growth.

CORAL SETTLEMENT AND RECRUITMENT IN SHARM EL-SHEIKH.

Field, S. and Glassom, D.* *Dept Marine Sciences and Coastal Management, University of Newcastle. Ridley Building, Newcastle Upon Tyne, UK. NE1 7RU. Email : s.n.field@ncl.ac.uk.

Recruitment studies on coral reefs utilise a variety of artificial substrates as settlement surfaces ranging from ceramic tiles to dead coral rock. A count of the coral settlers on these surfaces is used as a relative index of settlement rates within and between reefs. Frequently, data from such studies are converted to and cited as numbers of corals/m^2 often with no mention of the area of the substrates used. However, if recorded settlement rates are affected by the size of the plates used this information is needed to standardise results between studies. Preliminary observations have shown that corals are significantly more likely to settle close to the edge of ceramic tiles used as settlement substrates than near the centre. This implies that use of smaller tiles with proportionately higher edge-to-area ratios should result in higher settlement rates /m^2. This hypothesis was tested by deploying 20 tiles of each of three different sizes at five meters on the reef slope at Sharm el Sheikh, northern Red Sea. Tiles remained underwater for 3 months, checked for settlement and replaced with new tiles for a further 3 months. Spat were counted and identified to family where possible. Numbers of spat were compared to determine the effect of tile size on recorded settlement rate. Results from preliminary experiments have shown that 70% of settlers counted were discovered on the sides of tiles and to within 10mm of the under surface edge. The dispersion of settlers on artificial tiles is discussed in terms of standardization of results from settlement studies.

REPRODUCTION OF ZOOXANTHELLATE, A ZOOXANTHELLATE AND BLEACHED COLONIES OF THE CORAL *Oculina patagonica*.

Fine, M.* and Loya, Yossi. *Department of Zoology Tel Aviv University, Tel Aviv Israel 69978. Email: mfine@post.tau.ac.il

The reproduction of the Mediterranean scleractinian coral *Oculina patagonica* was studied along the Israeli coast at a depth range of 0.5-10 m. Zooxanthellate, azooxanthellate (inhabiting dark caves) and bleached colonies were sampled monthly. Using standard histological techniques, *O. patagonica* was found to be a gonochoric species. Colonies exceeding 2 cm in diameter (10-25 polyps), estimated to be 1-2 years old were already found to be fertile during the reproduction season. Female gonads first appear in May, following a rise in the sea water temperature. Maturation of gonads reach a peak in late August and early September, when the oocytes mean size is ca.100µm. Male gonads first appear in July at the bases of the polyp. Simultaneous spawning of male and female colonies was observed in 1995-1998, during the full moon of September, on two consecutive nights only. Azooxanthellate colonies of *O. patagonica* were found to develop gonads normally and simultaneously spawn with nearby zooxanthellate colonies exposed to light. However, in *O. patagonica* colonies undergoing bleaching no gonads were found during the reproduction season. Fragments obtained from tagged zooxanthellate colonies which were transplanted to dark caves in January and lost their zooxanthellae by March showed normal gametogenesis starting in May. However 60% of the control (exposed to light) tagged zooxanthellate colonies, which underwent bleaching, did not complete gametogenesis.

CORAL DISPERSAL AND SETTLEMENT AT EILAT, NORTHERN RED SEA.

Glassom D. and N.E. Chadwick-Furman, N.E.. *Interuniversity Institute for Marine Science. P.O. Box 469, Eilat, Israel. Email: dglassom@popeye.cc.biu.ac.il

Information on recruitment of stony corals to reefs is important to issues of reef ecology and management. In the northern Red Sea, the proximity of reefs of several adjoining countries means that dispersal of planulae between them is probable. Nonetheless, there is a paucity of information on patterns of coral dispersal and settlement in the area. In this study, coral settlement was monitored at 18 stations along the coast of Eilat, Israel over a period of 2 years. Settlement plates were ceramic tiles mounted on metal racks anchored to the substrate at 6m depth. Since coral species in Eilat spawn asynchronously, tiles were changed at intervals of 3 months to detect seasonal settlement patterns. Additional tiles on each rack were left in place for a period of 15 months before being removed. All coral spat were counted and their size, number of polyps and state (dead or alive) noted. Spat were identified as pocilloporid, acroporid or other corals. The former 2 groups accounted for over 85% of all corals found on the plates. Numbers of spat varied according to season, peaking in mid to late summer, but were generally low compared to similar studies in areas where mass spawning occurs. Geographically, settlement varied according to distance from reefs and to coral family. Patterns of settlement suggest that pocilloporids are recruiting from local reefs but a substantial number of acroporids are likely to be recruited from reefs outside Israeli waters. This highlights the need for regional cooperation on reef management.

REPRODUCTION OF SCLERACTINIAN CORAL IN SINGAPORE.

Guest J.R*, Goh B.P.L., Chou L.M. *Reef Ecology Laboratory, Department of Biological Sciences, National University of Singapore, 10 Kent Ridge Crescent, 119260 Singapore. Email: scip9051@nus.edu.sg

To date, very few studies exist regarding coral reproductive biology and ecology in South East Asia. Singapore's coral reefs are adjacent to one of the world's busiest ports and land reclamation has introduced large amounts of sediment in to the coastal waters. Singapore's coral reefs offer an opportunity to study reproductive biology and ecology in an unusual and adverse environment. For this study a number of common coral species were sampled monthly between September 1999 and September 2000. The coral species sampled included *Goniopora djiboutsiensis*, *Fungia scutaria*, *Galaxea fascicularis* and *Diploastrea heliopora*. Samples were taken from three different reef sites around Singapore's southern islands. All samples were examined in the laboratory to establish the presence and state of gonads. This was done either by direct dissection of coral polyps or by histological sectioning. Preliminary observations suggest that coral spawning may occur around September or October for some species. Some observations of Singapore's coral reproductive cycles and the timing and synchrony of spawning will be presented. In addition the implications of heavy sedimentation on reproductive success on Singapore's reefs will be discussed.

LARVAL BEHAVIOR IN RESPONSE TO A DISSOLVED SETTLE-MENT CUE AIDS RECRUITMENT ON CORAL REEFS.

Hadfield M.G.*, Koehl, M. A. R. and Unabia, C.. *Kewalo Marine Laboratory, University of Hawaii, 41 Ahui, St., Honolulu, HI 96813; Email: hadfield@hawaii.edu.

Many marine-invertebrate larvae, including species on coral reefs, settle in response to dissolved chemical cues produced by conspecific individuals, prey, or associated plants, animals or micro-organisms. We used larvae of a common Indo-Pacific coral predator, the nudibranch *Phestilla sibogae,* to examine responses to a settlement cue from their requisite prey species. Analyses of video recordings of metamorphically competent larvae swimming in seawater revealed that the larvae take all possible trajectories, many of them nearly horizontal or upward. When seawater conditioned by *Porites compressa* is added to the chamber, all of the larvae immediately sink in tight spiral paths. Microscopic observation of competent larvae after the addition of "coral water" revealed that the locomotory cilia on their velar lobes immediately ceased beating, but that the paired velar lobes and the larval foot remained extended, explaining the spiral trajectories of settling larvae. Having the foot extended during the cue-elicited descent allows the larva to attach by its sticky surface the instant contact is made with the substratum. These responses are not observed when larvae are exposed to water rich in the metabolites of other coral species. We are analyzing the speed and duration of responses of tethered larvae in a small flume when exposed to filaments of coral cue likely to be encountered when a larva is transported through mixing water at different levels above the reef.

ADULT DISTRIBUTION AND LARVAL DISPERSAL OF BLUE CORAL *HELIOPORA COERULEA* IN SHIRAHO REEF, JAPAN

Harii, Saki * and Kayanne, Hajime. *Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan. Email: harii@sys.eps.s.u-tokyo.ac.jp

It has been reported that planulae of brooding corals have relatively low potential for dispersal and they recruit within a natal reef. However, few studies have been conducted on relationship between adult distribution and recruitment. We studied adult distribution pattern, larval behavior, settlement and recruitment of brooding coral *Heliopora coerulea* in Shiraho Reef, Ishigaki Island, southwest of Japan. *Heliopora coerulea* is a gonochoric brooding species and planulae cleave on the surface of female colonies before releasing. Reproductive seasons in June and/or July 1998 and 1999. Planulae came out from mucus and were released form the colonies. Planulae 3.7 mm long did not swim actively. They lacked zooxanthellae and their color was white. When planulae grounded on a substratum, they crawled on it for settlement behavior. In the settlement experiment, 74% (SD=14.7) of planulae settled within 24 hours after releasing, however 3% (SD=4.5) settled 20 days after releasing. In Shiraho Reef, recruitment was observed between the branches of *H. coerulea* (0.3 spat per 10^2cm experimental tile). These results show that planulae of this species can settle down immediately after releasing and recruit in the reef, suggesting that *H. coerulea* maintains its population within the reef by sexual reproduction. Shiraho Reef was experienced severe bleaching in July and August 1998, yet adult of *H. coerulea* was least susceptible to that event and their planulae could recruit in the following years.

MORE SEX ON THE REEF: RECENT ADVANCES AND NEW HORIZONS FOR RESEARCH ON SEXUAL REPRODUCTION IN SCLERACTINIAN CORALS.

Harrison P.L.* *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

The recent renaissance in research on sexual reproduction in scleractinian corals has continued to strengthen our understanding of this fundamentally important aspect of coral reef ecology. Significant new data on the reproductive biology and ecology of scleractinian corals have become available in the last decade. This paper reviews current knowledge of sexual reproductive patterns in scleractinians, and highlights the results of recent research. The majority of scleractinian species studied to date are simultaneous hermaphroditic broadcast spawners, while gonochoric broadcast spawners are moderately common. Comparatively few coral species are known brood planulae, and these species are either hermaphroditic or gonochoric. A few coral species have mixed sexual patterns or modes of development. Information on patterns and timing of coral spawning and planulae release has steadily increased during the past decade, and the geographic and taxonomic range of reproductive studies throughout the Indo-Pacific and Caribbean regions continues to expand. Other recent themes in coral reproduction studies include hybridization among mass spawning species, fertilization biology and embryogenesis, larval competency and dispersal potential, larval settlement cues and recruitment patterns, effects of natural and pollution stressors on reproductive success, molecular studies on reproductive biology and population genetics, and reproduction in subtropical corals. Despite these important recent advances, sexual reproductive patterns have not been studied in the vast majority of scleractinian species or in many important coral reef regions, hence further detailed studies are needed in future.

POST- BLEACHING CHANGES IN CORAL SETTLEMENT AT THE HIKKADUWA MARINE RESERVE IN SRI LANKA.

Jinenendradasa, S. S. and Ekaratne, S.U.K..* *Department of Zoology, University of Colombo, Colombo 3, Sri Lanka. Email: suki@eureka.lk

Increased temperatures were associated with coral bleaching and mortality in April 1998. Settlement panels were deployed-recovered at monthly intervals in triplicate at 3 locations of the Hikkaduwa Marine Reserve over the 3-year study period which coincided with a 1-year pre-bleaching period, followed by 2 years of post- bleach. The study of corals settling on recovered settlement panels revealed a marked reduction in post-bleaching coral settlement at the reef lagoon site. Settlement (as settled numbers m^{-2} $month^{-1}$) was high (369±67) in the pre-bleaching year and was followed by a zero settlement period over the first 4 months of the post-bleaching study period. In the first year after bleaching, settlement was depressed by 82% (to 68±26) while the second year settlement was reduced by 71% (to 106±98), though without a significant difference ($p<0.05$) between these first and second years. Five types of settling corals were recorded at this site before bleaching. Only 1 of these types settled in the 2 years that followed bleaching, with their settlement numbers not showing a significant difference between pre and post-bleaching years. In the first and second post-bleaching years, a hitherto unrecorded coral form settled in low numbers (10±7 and 5±5, respectively).

A NON-DESTRUCTIVE CORAL GAMETE TRAP.

Kline, David I. * . *Marine Biology Research Division-0202; Scripps Institution of Oceanography; University of California San Diego; La Jolla, CA 92037-0202, U.S.A. Email: dkline@ucsd.edu

Collection of coral gametes is important for genetic studies, reproductive studies, and coral systematics. Traditionally, coral gametes are collected by removing coral colonies from the reef and keeping the corals alive in buckets or a seawater system, until spawning. A non-destructive coral gamete trap was designed and tested in two mass-spawning events in Bocas del Toro, Panama. These traps were designed to permit collection of coral gametes from a large number of coral colonies, with a limited amount of underwater assistance; as well as allowing accurate in-situ determination of setting and spawning times. Using the coral gamete traps it was possible to collect large quantities (a mean of 15.62±3.97 mg/ trap) of pure, high molecular weight coral DNA, suitable for molecular studies. The traps can be used in reserves and other protected areas where it was not previously possible to collect gametes, expanding the scope of reproductive and systematic studies.

CAN LARVAE OF BENTHIC ANIMALS USE DISSOLVED CHEMICAL CUES IN WAVE-DRIVEN FLOW ON A CORAL REEF?

Koehl*, M.A.R., Hadfield, Michael; Cooper, Tim; and Unabia, Catherine. *Department of Integrative Biology, University of California, Berkeley, CA, 94720-3140, USA. Email: cnidaria@socrates.berkeley.edu

Can chemical cues in the water affect the settlement of larvae on coral reefs subjected to wave-driven water flow? We addressed this question using the sea slug, *Phestilla sibogae*, whose larvae metamorphose in response to a species-specific chemical cue from its prey, the coral *Porites compressa*. *P. compressa* are abundant corals that form reefs in shallow, wave-dominated habitats in Hawaii. We used dye releases and acoustic doppler velocimetry to characterize the water flow and mixing above and within *P. compressa* reefs in Kaneohe Bay, HI. We collected water in the field from a variety of positions within and above the reefs and used bioassays of larval behavior and of metamorphosis to assess the strength of *P. compressa* cue in these samples. Coupling our field flow measurements with the bioassays of cue strength elucidated patterns in the locations on a reef where water-borne chemical cues are concentrated enough to induce *P. sibogae* larvae to stop swimming and sink, and to undergo metamorphosis when on a substratum. After quantifying the sinking rates of induced *P. sibogae* larvae, we conducted a series of field experiments monitoring the transport of larval mimics that showed that *P. sibogae* larvae sink rapidly enough to be retained on the reef when wave-driven flow moves across it.

FUNGIA GRANULOSA: REGENERATION, REPRODUCTION AND EVERYTHING IN-BETWEEN.

Kramarsky-Winter, E. and Loya, Y. *Dept of Zoology, George S. Wise Faculty of Life Sciences Tel Aviv University, Tel Aviv, Israel. Email wintere@post.tau.ac.il

. Understanding the relationship between regeneration and reproduction may provide an insight into how these processes influence a coral's ability to survive in disturbed habitats. In the Northern Red Sea the solitary coral, *Fungia granulosa* is common in areas susceptible to stress and provides a good model system for studying this relationship. Using conventional histological techniques the coral's normal reproductive cycle was followed monthly for two years. Gametogenesis began in early March and spawned in July-August. Only in individuals over 5.0 cm in diameter were reproductive. To study the relationship between damage and reproduction, tissue lesions were inflicted using an air pick, in mature and immature individuals, during gametogenic and post reproductive months. Corals were monitored using photography and computerized image analysis. Reproductive effort was investigated two months following lesion infliction. Morphological and cellular changes occurring during regeneration, reproduction and bud formation were investigated microscopically. During post reproductive months, lesions were repaired in mature corals within 8 weeks. Lesion repair in immature corals did not undergo repair regardless of season. During the gametogenic months, none of the corals underwent complete repair. In damaged corals fecundity was reduced though gametogenesis continued indicating a competition for stem cells. Fungiids that underwent damage involving mouth tissue survived by forming buds. A model illustrating the relationship between regeneration, reproduction and environmental disturbance is proposed.

EFFECTS OF ULTRAVIOLET RADIATION ON LARVAL RECRUITMENT OF THE REEF CORAL *Pocillopora damicornis*.

Kuffner Ilsa B. *. University of Guam Marine Laboratory, UOG Station, Mangilao, GU 96923. Email: ilsak@uog9.uog.edu

Sedimentation, predation and visible light are cited as causal factors to explain the preferential recruitment of coral larvae to shaded undersides of recruitment substrates. Here I examine the effects of ultraviolet radiation (UVR, 280-400 nm) on recruitment of *Pocillopora damicornis* larvae and the role of UV-absorbing compounds, mycosporine-like amino acids (MAAs). Larvae were obtained from adults of four origins: shallow, deep, incubated under UV-transparent (UVT), and under UV-opaque (UVO) filters. Larvae were then exposed to UVT or UVO conditions in specially designed larval recruitment chambers in the field. UVR had a negative effect on total recruitment. UVR did not significantly increase mortality. Larval origin did not have an effect on survival or recruitment. Lack of an 'origin' effect suggests either MAAs may not be important to the larval ecology of this species or the deep and UVO larvae had the minimum amount of MAAs required for UVR protection. The negative effect of UVR on recruitment indicates that *P. damicornis* larvae exhibit an avoidance response to UVR that could account for the observation that coral larvae recruit to shaded microhabitats.

REPRODUCTIVE NEIGHBORHOODS IN CORALS?

MacKenzie, Jason. *Department of Marine Biology, James Cook University, Townsville, Qld 4811 Australia. Email: jason.mackenzie@jcu.edu.au.

The extent of coral mass spawning events is largely determined by the number of species participating and the level of synchrony within species. Pooling observations of spawning by species across multiple sites within reefs, as has been done traditionally, can overlook potentially significant geographic subdivisions in spawning behaviour. Observations of six dominant *Acropora* species (n=162 colonies) from two sites separated by less than 2 km in Coral Bay, Western Australia indicate that adjacent neighbourhoods, consisting of similar species assemblages, sometimes breed *en masse* on different nights. These findings are supported by data from the Central GBR (Eastern Australia), which also indicate the occurrence of fine-scale reproductive subdivisions, or neighbourhoods, within reefs of similar species composition. Despite the potential for localised breeding units, several factors would prevent detection of such boundaries in population genetic studies of broadcast spawning corals. Even under assumptions of self-seeding scenarios (high retention of locally generated coral larvae) sufficient levels of migration between nearby populations can prevent substantial genetic subdivision within reefs. Thus, the reported pattern of reproductive isolation in broadcast spawning corals is unlikely to be detected in population genetic surveys, and ultimately reveals only part of a complex process of sexual reproduction in corals.

NEW REPORTS ON THE TIMING AND MODE OF REPRODUCTION OF HAWAIIAN CORALS.

Maté JL*. *University of Miami, RSMAS-MBF, 4600 Rickenbacker Causeway, Miami, FL 33149 and University of Hawaii at Manoa, Hawaii Institute of Marine Biology, P.O. Box 1346, Kaneohe, Hawaii 9674. Email: matej@naos.si.edu

Seven Hawaiian reef coral species were monitored in the laboratory for direct observations of spawning from June to September, 1997. Four species were observed to spawn: *Pavona varians* and *Montipora studeri* which represent new reports for Hawaii, *Porites lobata*, observed to spawn for the first time around the full moon of June and thus extending the known reproductive season from June to September, and *M. verrucosa*, a species with a well known reproductive cycle and a predictable spawner. Neither *P. evermanni* nor *Psammocora stellata* spawned during the monitoring. *Pavona varians*, a gonochoristic spawner, spawned before sunset at 1905-2015 from the 16th-18th lunar days of June. *Porites lobata*, a gonochoristic spawner, released eggs and sperm at 0120-0314 between the 16th-18th lunar days of June, July, and August. *Montipora studeri*, a simultaneous hermaphroditic spawner, released egg/sperm bundles between 2130-2300 on the 3rd-6th lunar days of July, August, and September. *Montipora studeri* began to spawn after *M. verrucosa* had stopped spawning (2030). The timing of spawning between *M. studeri* and *M. verrucosa* typically differed in 1 to 2h, providing evidence of reproductive isolation. These findings may have taxonomic implications since *Montipora studeri* has recently been synonymized with *M. verrucosa*.

SETTLEMENT ON EXPERIMENTAL SUBSTRATE OF *PORITES* LARVAE IN MEXICAN PACIFIC DAMAGED CORAL REEFS AFTER EL NIÑO 1997-98.

Medina-Rosas, Pedro*, Carriquiry, J and Cupul, AL. *Universidad Autónoma de Baja California and Universidad de Guadalajara. Carretera Tijuana-Ensenada, km 103, CP 22800, Ensenada, Baja California, México. Email: pmedina@faro.ens.uabc.mx

Coral reefs of Mexican Pacific suffered severe damages by warming in sea surface water caused by El Niño 1997-98. Coral mortality was high as 96% in some localities. The objective was check the effects of sublethal temperature on reproduction capability of survival corals and reefs recovery, by observing coral recruits settled on artificial substrata at nine reefs of Jalisco and Nayarit, in Mexican Pacific, since December 1998 to July 1999. The results was nine *Porites* recruits settled on terracotta tiles at two localities. This find represent the first report of *Porites* recruits and the highest sexual coral recruitment settled on artificial substrata in Eastern Tropical Pacific. Also proves that the reefs of this region has no complete need of larval supply from reefs at other localities, like Central or Indo Pacific. Moreover, survival colonies of *Porites* species has sexual reproduction with successful larvae. The recovery of reefs after El Niño disturbance at this area could be not slower than in other regions, like Central America, where estimates of recovery time range from one to two hundred years before reefs will assume pre El Niño levels of development. More biological and ecological studies are required for improve the chances for reefs recovery and protection.

EVIDENCE OF MODULAR AND COLONY LEVEL REPRODUCTIVE SENESCENCE IN THE BROODING CORAL, *ACROPORA PALIFERA*.

Merritt, MA* & Willis, BL. *Dept Marine Biology, James Cook University, Townsville, Australia. Email: Melissa.Merritt@jcu.edu.au

Evolutionary theory suggests that modular organisms should not senesce because germ and somatic cell lineages are not distinct and senescence is an evolved characteristic of the soma, however very little is known about senescence in reef corals. We present evidence of reproductive senescence in the brooding coral, *Acropora palifera*, at both the modular (polyp) and colony level, where the latter refers to synchronous deterioration of the whole colony. We assumed that polyps at the tips of branches were younger than those at the bases and that small colonies showing no evidence of fragmentation or partial mortality were younger than large ones. We found that mean (±SE) reproductive output was significantly lower in old compared to young polyps, as measured by volume of either eggs ($1.85\pm0.58 \times 10^{-3} mm^3$ *vs* $12.49\pm1.11 \times 10^{-3} mm^3$) or testes ($0.15\pm0.03$ mm^3 *vs* 0.40 ± 0.03 mm^3). It is also noteworthy that mean testes volume per polyp was 50X greater than mean egg volume, suggesting that greater investment in testes may be required to accomplish internal fertilisation in brooding corals. At the colony level, polyps assumed to be the same age (i.e. same distance from branch tips) had lower mean (±SE) testes volumes in old compared to young colonies (0.40 ± 0.03 mm^3 *vs* 0.65 ± 0.05 mm^3). A greater understanding of patterns of senescence in corals will allow more accurate predictions about the lifetime reproductive contributions of coral colonies and the natural lifespan of coral species.

MOLECULAR CONTROL OF DEVELOPMENT IN *ACROPORA MILLEPORA* II. *PAX* GENES

Miller David J.* Hayward, David C. Reece-Hoyes, John Scholten, Ingo Catmull, Julian Larsen, Jill E. and Ball, Eldon E.. *Biochemistry and Molecular Biology, James Cook University, Townsville, Queensland 4811, Australia. Email: david.miller@jcu.edu.au

Pax genes are involved in many aspects of development and pattern formation in higher animals. The functions of some *Pax* genes have been established in *Drosophila*, and genes that may correspond to these are known to be responsible for developmental abnormalities in mammals. However, perhaps predictably, the identification of common (conserved) functions and ancestral roles of these fly and mammalian genes has not been simple. As part of a multi-disciplinary study of coral development, we are studying the *Pax* genes of *Acropora*, and this is providing novel perspectives on many aspects of the evolution of this complex gene family. So far, we have identified four *Pax* genes in *Acropora*. Two of the coral genes are particularly interesting to us: *Pax-A* may represent a precursor of the entire *Pax* family, and *Pax-C* we view as corresponding to an ancestor of the *Pax-6* genes, which in higher animals are thought to play 'master control' roles in eye specification. In situ hybridization has shown that during *Acropora* development *Pax-A* is expressed in what are likely to be interstitial cells, and *Pax-C* in a subset of neurons. This latter pattern suggests that *Pax-C* may be involved in differentiation of sensory neurons, playing a role analogous to that of *Pax-6* in the photoreceptors of higher animals.

A HYDRODYNAMIC EXPLANATION FOR THE PRESENCE OF MULTIPLE EGGS IN CORAL GAMETE BUNDLES.

Moore S.W. *, Best, B.A. Koehl, M.A.R. and Merz, R.A.. *CA State Univ. Monterey, Seaside, CA 39355-8001, USA. Email: Steve_Moore@monterey.edu

Many coral species release their gametes in bundles during mass spawning events. The bundles contain lipid-rich eggs, and sometimes sperm, and float to the surface before breaking apart. This surface concentration presumably augments fertilization success. The buoyancy of the eggs clearly contributes to the effectiveness of this gamete-concentrating mechanism, but what, if any, is the role of bundling? A simple hydrodynamic model for non-neutrally-buoyant particles reveals that, for particles of a given mass density in a fluid with a given turbulence intensity, particle size does not significantly influence the vertical distribution of those particles except when the size of those particles is within a limited range of values. Within that limited range, small size changes can have a dramatic effect on the tendency of those particles to concentrate in a surface or bottom layer. We measured bundle rising rates for two species of *Acropora* and used dye-tracking to measure turbulence above the colonies during a mass spawning event at Lizard Island, GBR, Australia. We combined these data with literature values for bundle size, egg size, and egg mass density to show that these coral eggs are in the limited parameter space where size strongly affects their surface concentrations. We propose that bundling may have evolved in corals, at least in part, because it creates the hydrodynamic equivalent of a bigger, more buoyant egg (and therefore enhances gamete concentrations and fertilization success) without incurring the costs (in reduced egg number) of actually creating bigger eggs nor the costs (in additional energy expenditure) of higher lipid-content per egg.

FACTORS THAT INFLUENCE SUCCESSFUL RECRUITMENT OF *ACROPORA PALMATA* ON BONAIRE REEFS.

Morse, Aileen N. C.* Readdie, Mark D. Martin, Dan and Raimondi, Peter T. *Marine Science Institute, University of California Santa Barbara, Santa Barbara, CA 93111. Email: a_morse@lifesci.ucsb.edu.

Our studies of the major Caribbean shallow-water reef-building coral, *Acropora palmata*, on the reefs of Bonaire reveal that there are a number of factors that can influence the outcome of successful recruitment of this species. The first of these is reproductive success. Fecundity, as measured by the number of colonies releasing egg bundles and the number of bundles released/colony, appears to be directly correlated with combined fertilization success and rate. Additionally, we found that the number of sperm and their viability influenced these same factors. Reduction in fertilization success, but not rate, resulted in the die-off of large numbers of developing larvae during the first 24-48h of culture, with additional significant losses throughout the culture period. Surviving larvae were found to have significantly retarded larval development to competence, becoming fully competent for metamorphosis 16 days post-fertilization compared to 7 days for larvae in successful cultures. In both the field and the lab, larvae exhibited a stringent requirement, for ≤ 60 days, for detection of a specific chemical cue, previously demonstrated by us to be a sulfated polysaccharide associated with the cell wall of crustose red algae,. Larval behavior in the plankton was found to influence recruitment site selection. Post-metamorphic differential survivorship and growth were found to be influenced by various factors associated with recruitment sites.

EFFECT OF PLANULA SIZE AND ZOOXANTHELLAE ON THE LIFETIME OF PLANULAE IN THREE POCILLOPORID CORALS

Naoko, Isomura ,* and Nishihira, Moritaka. *Biological Institute, Graduate Schools of Science, Tohoku University,Sendai 980-8578, Japan Email: iso@mail.cc.tohoku.ac.jp

Dispersal of propagules plays an important role in ecology, distribution and genetic diversity, particularly for marine benthic and sessile organisms including corals. Three pocilloporid corals, Pocillopora damicornis, Seriatopora hystrix and Stylophora pistillata, are brooders and release planulae having symbiotic zooxanthellae. In these 3 corals, planulae showed a great size variation especially at peaks of planulation, and there were negative correlations between zooxanthella density and planula size. Studies of the lifetime of planulae cultured under both light (100?E?m-2s-1) and dark conditions revealed that larger planulae had longer lifetime. In addition, when the same-sized planulae were compared, they had longer lifetime under light condition than under dark condition. These findings suggest that planulae utilize energy from photosynthetic products of zooxanthellae and that these corals enjoy long-dispersal by producing larger planulae with greater dispersal potential at the peak of planulation. It is conceivable that variation in dispersal potential of planulae seem adaptive in widening the chance to settle on the suitable habitat.

SETTLEMENT PATTERNS AND POTENTIAL FOR DISPERSAL OF LARVAE OF THE REEF CORAL *PLATYGYRA DAEDALEA* FROM THE GREAT BARRIER REEF.

Nozawa, Yoko * and Harrison, Peter L.. *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

The extent to which larvae from broadcast spawning reef corals settle on their natal reefs or disperse between reefs, and their potential for long distance dispersal are controversial issues. Very little information is available on settlement rates and competency periods of reef coral larvae. Accordingly, this study examined the larval pre-competency and settlement competency periods, and the effects of temperature on settlement rates of larvae from the broadcast spawning brain coral *Platygyra daedalea* from the Great Barrier Reef. Approximately 20% of larvae in replicated experimental settlement cages attached to substrata 3-4 days after spawning (DAS), which would enhance the potential for some of these larvae to remain near their natal reef and may result in some degree of self-seeding. Larval settlement began 4-6 DAS, with peak mean settlement of 23% recorded from 36-42 DAS. The maximum settlement competency period recorded for *P. daedalea* larvae was 93-105 DAS, and maximum larval longevity was 124 DAS. The delayed peak settlement response and extended settlement competency periods recorded in this study indicate that there is considerable potential for long distance larval dispersal and settlement on geographically distant reefs for some *P. daedalea* larvae. Experiments on the effects of altered temperature on larval settlement patterns showed that slightly elevated temperatures of 29ºC enhanced mean settlement rates of *P. daedalea* larvae, compared with settlement at 25ºC and 27ºC.

IMPACT OF THE 1998 BLEACHING EVENT ON THE POTENTIAL FOR REPRODUCTIVE SUCCESS OF *Acropora millepora* AND OTHER CORALS OF THE PALM ISLANDS, CENTRAL GREAT BARRIER REEF.

Page, Cathie *, and Willis, Bette. *Australian Institute of Marine Science. PMB 3, Townsville, 4810. Australia. Email: c.page@aims.gov.au

Corals within the Palm Island group experienced severe bleaching and high mortality levels following the 1998 bleaching event. The reproductive output of *Acropora millepora* was examined to determine the sub-lethal impact of this disturbance. In the first reproductive season following the 1998 bleaching event, the reproductive output of *A.millepora* was found to have declined in two ways relative to the previous reproductive season. Firstly, the size of the population of *A.millepora* on these reefs was substantially reduced through whole colony mortality. Secondly, the reproductive output of the surviving population was reduced in three ways. The proportion of colonies reproducing was reduced by 50%, while second and thirdly, the number of eggs per polyp and the average size of eggs produced were reduced, each by approximately a third. Declines in reproductive output are also likely to have occurred in other *Acropora* and non-*Acropora* species in this area. The potential for reproductive success was further hindered in some species of *Acropora*, by different colonies spawning in one of up to a maximum of five months.

CHEMICAL STUDIES OF A NATURAL INDUCER OF SETTLEMENT AND METAMORPHOSIS IN THE CORAL-EATING NUDIBRANCH *PHESTILLA SIBOGAE*.

Paul, Valerie J. *; Hadfield, Michael G. *University of Guam Marine Laboratory, UOG Station, Mangilao, Guam, Email: vpaul@uog9.uog.edu

The waterborne inducer for settlement and metamorphosis in *Phestilla sibogae*, released from its preferred food *Porites compressa*, has been studied extensively. This small molecule (molecular weight 300-500) has defied attempts at isolation and structural characterization for over two decades. It is a very minor component of a complex mixture of metabolites released by the coral into seawater; therefore, obtaining enough material for structural elucidation has been difficult. We have recently developed some different and rapid isolation techniques and obtained NMR spectral data at each step of the isolation process. The active inducer can be extracted into ethyl acetate from seawater acidified to pH 3-4 by liquid-liquid partitioning. However, at the pH of seawater, very little activity extracts into ethyl acetate. This suggests that the active molecule is acidic. After extraction, the extract can be separated in one or two steps by reverse phase HPLC with a reverse phase column designed for working with polar compounds and acetonitrile:water (2:8) mixtures for a mobile phase. We also found that *Phestilla sibogae* would respond to soluble cues from some species and genera of corals besides *Porites compressa* but not others, but always at lower frequencies than for *P. compressa*. Extraction and HPLC separations of extracts of these different corals suggest that the compounds that induce metamorphosis have the same polarity and may all be structurally similar.

CORAL REPRODUCTION AND RECRUITMENT AS PREDICTIVE ECOLOGICAL INDICATORS OF STRESS ON REEFS.

Richmond, R.H.. *Marine Laboratory, Univ. of Guam, UOG Station, Mangilao, Guam 96923 USA. Email: Richmond@uog9.uog.edu

Reproduction and recruitment are the dual processes responsible for the persistence of reefs over time. Most reef-building scleractinian corals sexually reproduce via the release of gametes into the water column, with subsequent fertilization and development to the planula larval stage. Five chemically-mediated links have been identified which include synchronization among conspecifics, egg-sperm interactions, embryological development, metamorphic induction, and in most cases, subsequent acquisition of zooxanthellae. Different life history stages have differential sensitivities to environmental parameters including water and substratum quality, with reductions in either leading to reproduction and/or recruitment failure, and hence, population decreases and instability. Runoff and sedimentation associated with poor land use practices in watersheds adjacent to reefs prevent successful reproduction and recruitment in corals and other reef organisms. Stress and decreases in adult populations can also result in reduced reproductive output and success by negatively affecting fecundity and opportunities for gamete interactions when outcrossing is necessary (allee effect). Measurements of reproductive and recruitment success provide a critical set of data to determine sublethal effects of actions and activities, and also serve to determine if management initiatives are effective. Developing water and substratum criteria that are biologically relevant to reproduction and recruitment is a critical step towards addressing the decline of coastal reefs.

OXYGEN CONSUMPTION RATE OF JUVENILE STAGES OF THE SOFT CORAL *HETEROXENIA FUSCESCENS.*

Riechert-Lavy, T.* Ar, A.; & Benayahu, Y. *Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel. Email: Riechtal@post.tau.ac.il

Heteroxenia fuscescens is a common zooxanthellate soft coral on the shallow reefs of the Gulf of Eilat (Red Sea). Its azooxanthellate planulae were considered as lecitotrophic larvae. We hypothesized that the oxygen consumption rate (Vo_2) changes with development from a planula through a primary polyp stage and with ambient temperature during development. The Vo_2 averages of two-day old planula at 21, 26 and 28°C, were 1.152±0.045, 0.845±0.051 and 0.458±0.047 µl/h [STPD] respectively (±sd, 6 replications, 5 planulae each). It decreased to 0.311±0.047, 0.259±0.018 and 0.188±0.05 respectively as the planula changed to a polynula (an intermediate developmental stage) and remained low until the primary polyp opened its mouth. Then, the Vo_2 increased rapidly to 0.611±0.067, 0.51±0.044 and 0.582±0.05 respectively, both in their ecological temperature range (21 and 26°C) and above it (28°C). Although the developmental rate of the planulae was temperature dependent, there were no significant differences between the lowest Vo_2 values that were recorded at time when their mouth was opened. This pattern may suggest that energy shortage, rather than temperature, triggers the mouth formation. The Vo_2 of polyps at a given age increased with temperature. However, the Vo_2 of two-day old planulae was highest in the low temperature and vise versa, which means that the Q_{10} for Vo_2 was negative. This is the first evidence of such a phenomenon among corals.

EFFECTS OF HUMAN-INDUCED SEDIMENTATION ON JUVENILE CORAL ASSEMBLAGES.

Schelten, Christiane K.*. *Environment Department, University of York, York YO10 5DD, U.K. Email: cks102@york.ac.uk

The persistence of coral reefs depends on the balance between coral mortality and carbonate deposition (coral growth and recruitment). Reef framework degradation arises when carbonate erosion exceeds carbonate deposition. Degradation may be compounded by the effects of sedimentation, mainly caused from river run off. Several studies show that sedimentation inhibits settlement of coral larvae. In contrast, little is known about its impacts on juvenile coral assemblages. In this paper I describe the density and diversity of juvenile corals along four nearshore to offshore gradients on the west coast of St. Lucia, West Indies, two exposed to river discharge (sediment gradients) and two not exposed (control gradients). The density of juvenile corals was reduced nearshore, but did not differ between sediment and control gradients. However, the number of juvenile coral species was significantly lower on the sediment gradients compared to the control. This was linked to an altered juvenile coral composition, probably towards more sediment tolerant species in areas of high sedimentation. *Agaricia agaricites* and *Porites astreoides* were the most abundant juvenile coral species along both sediment gradients. In general, recruitment of massive corals (e.g. *Colpophylia natans*, *Meandrina meandrites* and *Diploria spp.*) was very low in all areas. The percentage of damaged juvenile corals (e.g. from overgrowth or disease) increased, while average size decreased with increasing sedimentation. Thus sedimentation detrimentally affects coral recruitment, intensifying reef degradation.

SMALL INCREASES IN TEMPERATURE REDUCE SETTLEMENT OF CORAL LARVAE.

Ward, Selina* Harrison, Peter and Hoegh-Guldberg, Ove *Centre for Marine Studies, University of Queensland, QLD 4072 Australia. Email: selinaward@bigpond.com

The effects of small increases in temperature on the settlement of broadcast spawning and brooding coral larvae were examined at Heron Island, Great Barrier Reef, Australia. Six 2000L flow-through tanks were set up with a heat control system that kept the temperature in three tanks 2°C above the temperature of three control tanks. Temperatures in the experimental system fluctuated in a normal daily and seasonal pattern. Fewer larvae settled on tiles in the heated tanks when previously untreated larvae from broadcast-spawning corals were placed into settlement cages within the tanks. Settlement rates of unheated larvae were also lower on tiles that were conditioned in heated tanks, and settlement rates were lower for larvae that were reared in the heated tanks. Settlement experiments were also run in aquaria at a maximum of room temperature and two degree increments to 34°C. In 1998, settlement was reduced at 30°C for both the brooding and broadcast-spawning species compared to room temperature with almost no settlement at all at 32 and 34°C. In 1999, when room temperature was two degrees lower, settlement rates were reduced at 28°C and at 26°C for some species. The size of both larvae and settled spat was also reduced at the higher temperatures relative to room temperature. These data indicate that small changes in temperature, even over every short periods of time can have dramatic and negative effects on coral reproduction.

ECOLOGICAL CHARACTERISTICS OF A NOVEL MECHANISM OF ASEXUAL REPRODUCTION IN MASSIVE CORALS.

Weil, E*, A.L. Ortiz, H. Ruiz & M. Schärer. *Dep. of Marine Sciences, U. of Puerto Rico. BOX 908, Lajas PR 00667, USA. Email: eweil@caribe.net

Corals can reproduce asexually by at least five described strategies. Fragmentation and asexual larvae were the only two reported/observed in the Caribbean. In this study we describe some ecological characteristics of a novel strategy of asexual reproduction in massive colonies of the genus *Diploria* in the Caribbean. Pigmented tissue buds develop on the sides or top of the ridges and deposit a well organized hard skeleton that is not connected to the parent colony. We have termed these buds gemma (pl. gemmae). Gemmae stay attached to parental colonies until they get large and/or surge conditions are strong. Detached gemmae form "rolling stones" or re-attach to the substrate. Surveys indicate that; (a) gemmae were common across the wider Caribbean, and were restricted to shallow habitats (< 5 m); (b) in Puerto Rico, *D.clivosa* had a higher abundance of colonies with gemmae (25.5 %) compared to *D.strigosa* (11.7 %) and *D.labyrinthiformis* (8.7 %), and *D.strigosa* and *D.clivosa* had significantly higher average number of gemmae/colony (14.9 and 6.8) compared to *D.labyrinthiformis* (1.2); (c) the number and size of gemmae was not related to parent colony size; (d) the average size of gemmae was similar between the three species in Puerto Rico. Survivorship (tested with a two-way factorial design with three replicates in two localities) was significantly higher in caged experiments but low overall. Further research is needed in many aspects of this strategy and its possible consequences on the genetic compositions of shallow water populations of massive species.

PLANULATION OF *POCILLOPORA DAMICORNIS* IN SUBTROPICAL WINTER.

Yamazato, K.*, T. Ushioda, M. Sato and E. Suwardi. *Meio University, Nago, Okinawa, Japan 905. Email: ris-yama@ii-okinawa.ne.jp

Planulation of *Pocillopora damicornis* has been known to take place monthly throughout a year in tropical areas, but it was not known if this is the same at higher latitudes when we initiated this study in 1982. The purpose of this study is to elucidate the reproductive cycle of this species at hiher latitude as in Okinawa. It was made clear that this species does not planulate during winter and that this is due to low sea water temperature. Histological studies showed that the species stops gametogenesis, embyogenesis, and planulation during four months in winter (Jan. to Apr.). When corals were kept at a constant temperature of 26C in winter, they planulated but they did not planulate in autumn when kept at the constant temperatures of 22 and 20C, respectively.

Session A19: Ecology of Local-scale Environment Perturbations on Reefs

MORPHOLOGICAL VARIATIONS IN CORALS FROM THE SUAPE INDUSTRIAL-HARBOR COMPLEX, NE BRAZIL

Banja M.*, C. Oliveira, E. Mayal, V. Ferreira, A. Sial, A. Coccentino, A. Silva, P. Santos, V. Manso, B. Pinheiro, E. Lima.
***Univ. of Pernambuco, Brazil; mucio@ netpe.com.br. Support: Suape Industrial-Harbor Complex. Email:** valderez@npd.ufpe.br

The Suape estuary-lagoon complex, in which an industrial-harbor complex is located, NE Brazil, presents a beachrock line parallel to the coast, most of it used as natural barrier for the harbor. Corals have been collected in this barrier (*Siderastrea stellata* and *Favia gravida*) along 5 sampling points, starting from the harbor main entrance. Coralite diameters and distance among them, number of septa, columella width, and meander lengths measurements have been made in the collected samples. Both specimens are smaller in points 1 through 3 than those from point 5, which are well developed, and taller coral walls in the *F. gravida* are more common in the points 1, 2, and 3. As a whole, the specimens show larger morphological variations in the points closer to the harbor entrance, than far from it.

IS THE GROWTH RESPONSE OF *ACROPORA* CORALS TO ELEVATED NUTRIENTS DIFFERENT TO THAT OF OTHER CORAL TAXA?

Bucher, Daniel J.* and Harrison, Peter L.. *School of Resource Science and Management, Southern Cross University, P.O. Box 159, Lismore, NSW, Australia. Email: dbucher@scu.edu.au

The rates of linear extension, buoyant weight and displacement volume increments were measured in *Acropora longicyathus* exposed to elevated concentrations of ammonium and/or phosphate in the ENCORE experiment at One Tree Island, southern Great Barrier Reef. Linear extension was accelerated in phosphate treatments and depressed by elevated ammonium. Ammonium also reduced the ability of corals to repair lesions, a result which has implications for the recovery of polluted reefs following physical damage. Buoyant weight growth was accelerated by elevated ammonium on an annual basis, but significant reductions occurred in some seasons. Phosphate increased buoyant weight growth in some seasons but had no significant effect on an annual basis. Caution is therefore advised when extrapolating short-term growth data to represent annual trends. Phosphate-treated corals with high zooxanthellae densities showed no evidence of inorganic carbon limitation of calcification. Consecutive buoyant weight and displacement volume measurements demonstrated seasonal changes in the balance between the processes of skeletal extension and infilling and indicate that elevated nutrients may have the potential to alter the timing of density band formation in massive coral species. When the results from this study are compared with other studies, it is evident that growth of *Acropora* corals may be less sensitive to clean elevated inorganic nutrient concentrations than growth of other coral taxa used in nutrient enrichment studies to date.

EXPRESSION OF HSP60 BY THE SEA ANEMONE *ANEMONIA SULCATA*: A POTENTIAL EARLY WARNING SYSTEM FOR MONITORING ENVIRONMENTAL CHANGES.

Choresh O*, Ron, Eliora; Loya, Yossi. *Faculty of Life Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, ISREAL. Email: omerch@post.tau.ac.il

Recently, great concern has been expressed to the fate of coral reefs, in view of their accelerated degradation due to global warming. The development of early warning systems concerning the condition of coral reefs, and as an indication of global warming, is of great importance. Marine invertebrates respond to stress, which causes damage to cellular proteins, by inducing the synthesis of Heat Shock Proteins (HSPs), which is correlated with the adaptation to environmental stressors. This work examines the role of HSPs in adaptation to thermal stress through a study of the influence of changes in seawater temperature (SWT) on the expression of these proteins in the sea anemone *Anemonia sulcata*. Results reveal for the first time the HSP60 in sea anemones, and show by laboratory and field experiments that its expression is varied with changes in SWT. *A. sulcata* displayed high levels of HSP60 when extreme temperature conditions prevailed in stressful habitats such as tide pools. Specimens removed from different temperature layers in the same tide pool differed in the level of HSP60. Furthermore, specimens from subtidal zones exhibited a seasonal pattern of expression of this protein, according to the seasonal changes in SWT. This study may offer a useful tool for detecting HSP60 in marine invertebrates, and contributes to the understanding of HSPs role in the adaptation of organisms to stressful environments.

THE ROLE OF INTRODUCED MACROALGAE IN PHASE SHIFTS ON CORAL REEFS IN KANEOHE BAY, HAWAII USA.

Conklin, Eric J.* *Department of Zoology, University of Hawaii, Honolulu, HI 96822 USA. Email: econklin@hawaii.edu

The overgrowth of reef-building corals by macroalgae is an increasingly common phenomenon on many coral reefs, contributing to widespread reef degradation. It is generally held that these overgrowths (termed "phase shifts") result from a reduction in grazing pressure by herbivorous fishes on the invasive macroalgae. In the case of the phase shift that has occurred on reef crests and slopes in Kaneohe Bay, Hawaii, this reduced grazing pressure may be partly due to the introduction of several alien macroalgal species to the bay. I have been testing components of the hypothesis that the introduction and establishment of palatable macroalgae on reef flats in Kaneohe Bay has reduced grazing pressure on reef crest algal species by providing an abundant, preferred food source, and thereby contributed to the phase shift. Preference tests show that the two most abundant introduced species are more preferred than the algal species competing with corals for space. Field studies indicated that grazing intensity generally decreased from the reef crest, the habitat of greatest shelter availability and greatest herbivore biomass, onto the reef flat, where shelter and herbivore biomass are less abundant. However, preferred algal species were restricted by intense grazing pressure to areas far from the shelter of the reef crest while less preferred species were able to sustain positive growth at the reef crest. This study concludes that herbivorous fishes forage far from shelter onto reef flats to feed on the preferred algal species that have been introduced to the bay, ignoring less preferred species that are more easily obtainable and potentially allowing these species to overgrow corals.

PARTICIPATORY MAPPING OF THE IMPACTS OF INDUSTRIALIZATION ON THE CORAL REEF ECOSYSTEM OF CALUMPAN PENINSULA IN BATANGAS BAY, PHILIPPINES – LESSONS LEARNED FOR THE MARINE BIODIVERSITY CONSERVATION PROGRAM IN ADJACENT BALAYAN BAY.

Dumaup J.N.B.*. *World Wildlife Fund-Philippines, 23-A Maalindog St., U.P. Village, Diliman, Quezon City 1101, Philippines. Email: ndumaup@wwf-phil.org.ph

World Wildlife Fund-Philippines currently implements a marine biodiversity conservation program in the coastal municipalities of Mabini and Tingloy, Batangas, Philippines. Two bays – Batangas Bay on the east and Balayan Bay on the west – are found in these municipalities. Batangas Bay is a highly industrialized area supported by an alternate international seaport. The industrial zone is limited to the northern third portion of Calumpan Peninsula but there is a plan to extend it to cover the entire eastern coast of the peninsula. Balayan Bay, on the other hand, is devoted to fisheries and tourism. Its coral reef ecosystem shows a low abundance of reef associated fishes but the benthic community remains rich with some areas showing 70% live coral cover. Growing industrialization and weak law enforcement threaten the coral reef ecosystem along the eastern coast of Calumpan Peninsula, which are the source of food and livelihood of the local populace. Participatory mapping and validation of the condition of the coral reef ecosystem before and after expansion of industrialization will provide valuable learning that must be considered in future development of an integrated coastal management plan for the municipalities of Mabini and Tingloy and Balayan Bay in general.

STRESS IN CORALS FROM THE SUAPE INDUSTRIAL-HARBOR COMPLEX, NE BRAZIL

Ferreira V., E. Maÿal, A. Sial, M. Banja, A. Coccentino, A. Silva, P. Santos, B. Pinheiro, E. Lima, C. Oliveira *Federal Univ. Pernambuco, Brazil.. ufpe.br. Support: Suape Industrial Harbor Complex Email: valderez@npd

The Suape Industrial Harbor Complex, NE Brazil, is in a region where a lagoon complex occurs, separated from the open sea by beachrock line. In 1988, 5 *Siderastrea stellata* specimens, and in 1999, 6 specimens, were collected. Morphological studies indicate rather low zooxantella activity, which resulted in smaller skeletal growth. $\delta^{13}C$ and $\delta^{18}O$ compositions suggest that this low activity is correlated with increasing temperature, implying that corals were under thermal stress. This, associated with large amount of suspended, very fine-grained material, contributed for the rather low photosynthetic activity. Corals growth bands suggest they were rather young (12 year-old), one of them was only 3 year-old, indicating it was fixed and grew after the harbor complex set up, in spite of the unfavorable conditions.

TEMPORAL ABUNDANCE AND EFFECTS OF NO3, PO4 AND Fe ON CYANOBACTERIA AND ALGAE IN GUAM.

Kuffner, Ilsa B. *, Thacker, Robert, Paul, Valerie. *University of Guam Marine Laboratory, UOG Station, Mangilao, GU 96923. Email: ilsak@uog9.uog.edu

The abundance of cyanobacteria and macroalgae on Guam's reefs varies greatly on a temporal scale. The causes of this variance are not well understood. In this study, monitoring data were collected for two years, estimating percent cover of all major species of cyanobacteria and macroalgae on three transects in Cocos Lagoon. *Dictyota bartayresii*, *Halimeda* spp., and *Padina tenuis* accounted for the bulk of the macroalgal community. *Tolypothrix* sp., *Schizothrix* sp. and *Lyngbya majuscula* were major components of the cyanobacterial assemblage. Six representative species were tested for phosphate, nitrate and iron limitation in an outdoor laboratory experiment. Results indicated that *Dictyota bartayresii* and *Halimeda incrassata* may be nitrate-limited, while *Lyngbya majuscula* may be limited by phosphate availability. *Tolypothrix* sp. released a substantial number of hormogonia during the experiment. *Tolypothrix* filaments covered the bottoms of the containers and thalli of *P. tenuis* while not attaching to the other organisms, suggesting important interactions among these species in the Cocos Lagoon community.

SIMULATION OF CORAL REEF COMMUNITY DYNAMICS AND DISTURBANCE.

Langmead, O.* and Sheppard, CRC. *Department of Biological Sciences, University of Warwick, Coventry, CV4 7AL, UK. Email: fsla@dna.bio.warwick.ac.uk**.**

Disturbance is a key process in coral reef community dynamics. Understanding the capacity of reefs to recover after disturbance and the causal mechanisms is fundamental to the prediction of the stability properties of reef systems. This is particularly relevant now, following the global decline of reefs during the last decade. A discrete, spatially explicit model (cellular automaton), was developed to simulate a $9m^2$ plot on a Caribbean fore reef slope between 10 and 20m. The model represents recruitment, growth and interspecific competition of coral colonies at the modular level (coral colonies being composed of many identical polyps). Parameters used were based on real data. Results in terms of quantitative and qualitative changes in coral community structure were assessed under different disturbance regimes. Findings indicate that the modelled community is stable (resilient and persistent) except when proportions of the total area exceed particular thresholds, whose values equate with several recent disturbances, or when the spatial scale of disturbed patches is large. In such cases the community structure adapts to an alternate state. This constitutes a phase shift, and will be discussed in relation to real reefs. The structure of the modelled community appears to be resilient to temporal variability in larval supply over a wide range. Rates of change and recovery following simulated impacts to reflect what is increasingly occurring on coral reefs will also be demonstrated. We conclude that the model does reflect this complex natural system.

EFFECTS OF A PESTICIDE ON LARVAL RECRUITMENT OF THE SCLERACTINIAN CORAL *GONIASTREA RETIFORMIS*.

Leota S. T.*, S. Mckenna, And R. H. Richmond. *Marine Laboratory, Univ. of Guam, UOG Station, Mangilao, Guam USA 96923. stleota@guamcell.net

Successful recruitment of coral larvae enables them to become permanent members of the benthic reef community. Larvae of several corals use chemical cues in their selection of substratum as a settlement site. The recruitment process may be a sensitive indicator of the effects of pollutants on coral reefs because larval settlement and metamorphosis is susceptible to changes in ambient water or substratum quality. We investigated the effects of the organophosphate pesticide, chlorpyrifos, on larval recruitment of *Goniastrea retiformis*. Static recruitment bioassays were conducted to determine whether *G. retiformis* planulae would recruit onto natural, crustose coralline algae-covered substrata conditioned with three different concentrations of chlorpyrifos. Results of two recruitment bioassays were inconsistent. In 1998, there was a statistically significant difference between the control and two treatments (5 and 50 ppb, ANOVA, $p<0.05$). There was no significant difference in larval recruitment between the control and the 0.5 ppb treatment. In 1999, however, there was no significant difference between controls and all experimental treatments (ANOVA, $p>0.05$). Several possible factors that could have contributed to the disparity in results include: 1) reduced fitness of larvae in 1999, 2) reduced chemical activity of coralline algae on substrata in 1999, and 3) unrecognized differences between bioassays. Results suggest that recruitment bioassays may be a useful method to determine the effects of certain pollutants on coral larvae. However, additional tests will be necessary to validate this method.

POINT SOURCE AND NON-POINT SOURCE POLLUTION ON CORAL REEFS OF GUAM.

McKenna S.A. * and R.H. Richmond. *University of Guam Marine Lab, Mangilao, GU 96923 U.S.A. Email: sheilamckenna@yahoo.com

Point source and non-point source pollution have impacted the reefs of Guam. Finding a sensitive parameter to detect the effect of various pollutants on the reef is a challenge. We investigated the use of physiological and community level parameters on reefs subject to varying types of pollution. The sites included a reef subject to point source pollution (PS), a reef subject to non-point source pollution (NPS), and two reference reefs (REF1 and REF2). Laboratory cultivated colonies of *Pocillopora damicornis* of five known parental lines were transplanted to one of three sites (PS, REF1, and REF2). After five months, the corals were collected and survivorship and growth were determined. Survivorship and growth of corals was significantly different among site x parental line (two-way ANOVA $p< 0.001$). This suggests a genetic component to the survivorship and growth of coral in response to the environment. Dry biomass accumulation was measured at all sites using settlement plates. NPS had significantly less dry biomass than PS and REF1 sites ($p<0.01$). At PS and NPS sites, percent cover of reef substrata/biota were determined by 50m belt transects. ANOSIM comparisons were used to detect differences between shallow and deep surveys within and among PS and NPS sites. The NPS site had lower coral coverage, more fleshy algae and silt in comparison to the PS site ($p<0.001$). Community level parameters may provide a better estimate of reef viability than physiological indicators due to the genetic variability among corals.

PHASE SHIFT AND RECRUITMENT STATEGIES OF FISHES ON STRESSED CORAL REEF

Manthachitra, Vipoosit.* Sudara, Suraphol. *Dept. of Aquatic Science, Burapha University, Chonburi 20131, Thailand. Email: vipoosit@bucc.buu.ac.th

Fish assemblages on coral reefs at khangkao island, the inner gulf of thailand, are subjected to low salinity but high sediment environment and also limited connection to other reefs. Results from the monitoring of reef fish assemblages at khangkao island during october 1997 to november 1998 found 83 species from 28 families. Pomacentridae solely dominated the area (20 species, 76.9% abundance) while labridae and apogonidae were the next abundance families (8 species, 5.6% abundance and 6 species 4.2% abundance respectively). According to trophic categories, small water column feeders (15 species, 39.6% abundance) and small herbivores (4 species, 38.5% abundance) dominated in the assemblages while predatory fish had moderate number of species but very low abundance (16 species, 0.9% abundance). There was a considerable shift on community structure when compare with previous study as the stresses from human activities had increased during the last 15 years. Recruitment of fish were detected for 33 species which the most dominant recruit species are the most abundance species. The different on recruitment strategies among reef fishes might explain how community structure had shifted after extensively disturbed from any sources.

COMPARISON OF CORAL REEF FISH ASSEMBLAGES ON PHYSICALLY DAMAGED AND ADJACENT UNDAMAGED SITES: SIGNIFICANCE FOR REEF COMMUNITY STRUCTURE.

Michael, CA*, S Clark, MA Le Tissier, S Field, A Edwards and NVC Polunin. *Department of Marine Sciences and Coastal Management, University of Newcastle, Newcastle upon Tyne, NE1 7RU, UK. Email: c.a.michael@ncl.ac.uk

Coral reef fish assemblages at four ship grounding sites in the Gulf of Aqaba, northern Red Sea were studied using a stationary visual point count method during summer 1999 and winter 2000. Ship groundings affect the structure and function of reefs and provide discrete disturbances on a small spatial scale. A comparison of fish assemblages on damaged and adjacent undamaged sites was made to determine the effect of localised physical disturbance on community structure. Mean species richness and total fish abundance were higher on adjacent undamaged than damaged areas of reef for all sites studied. Herbivorous fish (Scarids and Acanthurids) however were more dominant on damaged than adjacent undamaged areas of reef. Correlations between fish density, species richness and diversity on the one hand, and rugosity and benthic cover on the other are discussed. The significance of differences in fish assemblages are discussed in the context of the role which functional groups play in structuring coral reef communities and consequent recovery from local-scale perturbations.

COMMUNITY METABOLISM ON THE REEF FLATS AT REUNION (INDIAN OCEAN) : NATURAL VERSUS ANTHROPOGENIC DISTURBANCE.

Mioche, D.* and P. Cuet. *Laboratoire d'Ecologie Marine, Université de la Réunion, BP 7151, 97487 Saint-Denis messag. Cedex 9, France. Email: domi@univ-reunion.fr

This paper documents community metabolism on (1) two undisturbed reef flats, (2) a reef flat damaged by the combined effects of nutrient loading and undergrazing (Planch'Alizés), and (3) a reef flat destroyed in 1989 by a hurricane (Saint-Leu). The undisturbed sites display similar excess productions (E), slightly positive in summer (56 - 57 mmol $O_2.m^{-2}.d^{-1}$, gross primary production to respiration ratio (P_g/R) = 1.11 - 1.13), and nil in winter. Whatever the season, E is higher than 0 at Saint-Leu (177 - 325 mmol $O_2.m^{-2}.d^{-1}$; P_g/R = 1.18 - 1.22), and lower than 0 at Planch'Alizés (–125 to –71 mmol $O_2.m^{-2}.d^{-1}$; P_g/R = 0.87 - 0.94) ; E is higher at Saint-Leu, and the P_g/R ratio lower at Planch'Alizés, than at the other sites. Planch'Alizés displays lower mean calcification rates (mmol $CaCO_3.m^{-2}.h^{-1}$) than the other sites, during the day in winter (respectively 1.7 and 10.7 - 14.3), and at night in summer (respectively –15.1 and –1.6 to 5.4). Therefore, net productivity and calcification allow the characterization of the disturbed areas. At Saint-Leu, they reflect the shift in community structure which occurred after the hurricane. The dominance of massive corals may affect the carbonate budget at Planch'Alizés. However, the E value and the $CaCO_3$ dissolution observed at night in summer at this site presumably result from an input of exogenous organic matter, and, therefore, mainly reflect anthropogenic disturbance.

CHANGES IN THE COMMUNITY STRUCTURE OF THE ENSENADA DE CHICHIRIVICHE DE LA COSTA, VENEZUELA, AS A CONSEQUENCE OF AN INTENSE PERIOD OF RAIN.

Ortiz, J. C.*, M. del C. Gomez and S. M. Pauls *BIOSUB, Coord. de Extension, Fac. De Ciencias, Universidad Central de Venezuela, A.P. 20513 CCS 1020-A, Venezuela. Email: coralin@telcel.net.ve

In December 1999 abnormal precipitations affected Venezuela, caused rivers to flood and landslides on the Coastal Range. Ensenada de Chichiriviche de la Costa, have a stony coral community recently characterized in April 1999 that was affected. We found in 1999 that this community was relatively rich in coral species (22), but presents low values of coverage (6.6%) and a patchy distribution. Along this shore three major landslides occurred in December 1999. In 2000 we repeated the sampling performed in 1999. From 22 species, we found only 17. Total coverage of stony coral decreases 42.4%. Total coverage of living coral per transect reached maximum declines close to the landslides. The greatest loss (30%) in number of species occurs in the intermediate stratum (4.1 to 10m). The total coverage of living coral showed the greatest decreases (62.8%) in the upper stratum (0 to 4m). Despite that 42.4% of the total living coverage in 1999 was dead in 2000, only 21.8% of the living coral remaining were partially damaged. This and the increase in the rocky substrate suggest that the principal cause of coral coverage decrease was crushing during the landslides and little death occurred as a consequence of low salinity and high sedimentation. Providing us with a probable explanation for the presence of a relatively high number of species, but low values of coverage, and also the patchy distribution of these in the cove.

SURVIVAL AND TISSUE REDUCTION OVER HURRICANE-GENERATED FRAGMENTS OF ACROPORA PALMATA.

Ortiz-Prosper, Antonio L.* and Ruiz, Hector. *University of Puerto Rico, Mayagüez Campus, Department of Marine Science, P.O. Box 908, Lajas, P.R. 00667-0908. alortiz9@hotmail.com

Acropora palmata (Elkhorn coral), a Caribbean branching coral which usually forms densely aggregate patches in shallow, high energy zones of the reef are very prone to dislodgment and fragmentation after a hurricane. Because hurricane generated fragments usually survive this process, they have been considered to play an important role in the persistence of local populations. One of the suggested attributes of this type of asexual propagation is increased genet fitness by stimulating genet growth rates and indirectly increasing genet fecundity. However, this depends in the survivorship of the fragments and in the persistence of live tissue cover. Hurricane George passed over Puerto Rico in Sept. 22, 1998, severely affecting shallow reef areas of the southern coast. Following the hurricane we established two belt transects (2 m by 30 m) in the A. palmata zone at four reefs on the La Parguera platform in southwestern Puerto Rico to examine the fate of fragments. Within these transects, each standing colony and detached fragment of A. palmata was counted, identified, tagged, measured (max. length and width), and its position was recorded. Additionally, the cover of live tissue of each fragment was measured (max. length and width). Significant differences ($p< 0.001$, N= 433 fragments) between reefs were observed in terms of fragment length (40.5 ± 20.1 cm), max. length of live tissue of the fragments (20.8 ± 15.1 cm), and tissue reduction (area) of the fragment (79.7 ± 15.1). No relationship has been observed between the reduction in live tissue cover and the initial fragment length (R_=0.003, N=433) or initial live tissue cover (R_=0.007). Results are discussed in terms of fragmentation as a means of asexual reproduction, and the role of genet survival and fitness.

USE OF HYPERSPECTRAL SENSING TO OBTAIN MICRO-SCALE ECOLOGICAL DATA ON MESO- TO MACRO- SCALES.

Potts, D.C.*, D. Siciliano, B.A. Martini, W.L. Pickles, E.A. Silver. *Institute of Marine Sciences, University of California, Santa Cruz, CA 95064, USA. Email: potts@biology.ucsc.edu

Most coral reefs exist at land-sea-air interfaces surrounding tropical land masses, where they are vulnerable to changes in all three habitat components. These land masses also support many of the world's densest and most rapidly growing human populations that are creating accelerating impacts on local (e.g. overfishing, construction, sewage), regional (e.g. land-use, runoff) and global (e.g. climate change, ocean alkalinity) scales. Adding human impacts to "natural" processes of environmental change ensures that coral reefs and associated habitats (mangroves, seagrasses) are changing more rapidly than any other global ecosystem, and more rapidly than traditional ecological methods can document either "baseline" states or the changes themselves. Aerial hyperspectral sensing allows environmental data (biological, geological, physical, chemical) can be gathered on ecological spatial scales ($\leq$ 1-3m) over entire regions (10^2 - 10^3 km^2) in a single flight. Hyperspectral sensors record high-resolution spectra from independent measurements of many ($\geq$100), narrow ($\leq$15nm), contiguous spectral bands (UV-visible-IR). Spatial resolution (pixel size) depends on aircraft altitude.

THE METABOLIC RESPONSE TO EUTROPHICATION OF A CORAL COMMUNITY AND *MONTIPORA CIRCUMVALLATA* NUBBINS.

Rard M.*, Mioche, D. ; Seychelles, L. ; and Cuet, P. *Laboratoire d'Ecologie Marine, Université de la Réunion, BP 7151, 97487 Saint-Denis messag. Cedex 9, France.: Email: mrard@univ-reunion.fr

The reef flat at Planch'Alizés (Saint-Gilles/LaSaline fringing reef, Reunion) is dominated by macroalgae as a result of nutrient loading and undergrazing. In order to document the impact of eutrophication on coral reef metabolism, we compared, at Planch'Alizés and in control conditions: (1) the O_2 and $CaCO_3$ budgets of two coral communities enclosed *in situ* (each one comprised of a *Montipora circumvallata* colony with its associated fauna and flora, and surrounded by sand), and (2) the growth and the O_2 budget of *M. circumvallata* nubbins. In summer, the community enclosed at Planch'Alizés had higher daily gross primary production (P_g) and respiration (R) than the control one. Differences between sites disappeared in winter, and may have resulted from intraspecific variations or differences in community structure. However, in winter, the nubbins left at Planch'Alizés also displayed higher P_g and R than nubbins originating from the same parent colony, but allowed to stay for a few weeks in control conditions before measurements. The data at Planch'Alizés remind of the observations made with artificially elevated levels of N, and may therefore reflect the increase in N availability previously reported at this site. However, the growth of the nubbins was not affected. The community enclosed at Planch'Alizés had a lower daily calcification than the control one. However, this was due to some $CaCO_3$ dissolution occurring at night, and presumably reflected an input of organic matter at this site.

WHY MARINE RESERVES ARE NEEDED IN THE US VIRGIN ISLANDS.

Rogers, Caroline S. *, Beets, James P.. *US Geological Survey, P.O. Box 710, St. John, USVI 00830. Email: caroline_rogers@usgs.gov

Marine resources in the US Virgin Islands, including those within Buck Island Reef National Monument (St. Croix) and Virgin Islands National Park (St. John), have been seriously degraded from natural and human stresses. In the last two decades, eight hurricanes have passed near or over St. John and St. Croix, some causing extensive damage to reefs and seagrass beds. Coral diseases (notably white band disease and plague type II) have caused extensive mortality. In general, reefs now have less live coral and more algae. Reef fish assemblages have also changed significantly. The effects of natural disturbances have been severe, and recovery of fishes and benthic habitats is unlikely unless the concomitant stresses imposed by humans are reduced or eliminated. The effects of degradation of coral reefs, mangroves, and seagrass beds on reef fishes are difficult to separate from the effects of overfishing. However, some changes in fish assemblages became apparent well before the dramatic habitat changes of the last two decades. The loss of spawning aggregations and decreases in average size and abundance of groupers and other commercially important species also point to fishing as a major contributing factor. The existing, limited regulations (e.g., on fishing and anchoring) in these marine "protected" areas have not prevented serious deterioration. Marine reserves, within which trap fishing and other detrimental human activities would be prohibited, should be established as soon as possible to allow recovery of fish assemblages and benthic habitats.

EFFECTS OF CONTINENTAL INFLUENCE IN CORAL COMMUNITIES OF THE SANTA MARTA AREA, COLOMBIAN CARIBBEAN.

Rojas-Ruiz, Jaime A.*, Jaime Garzón-Ferreira, Alberto Rodríguez-Ramírez, Diego L. Gil-Agudelo, Nazira Mejía-Niño and Bienvenido Marín Zambrana. Instituto de Investigaciones Marinas y Costeras, Santa Marta, Colombia, A.A. 1016. Email: jrojas@invemar.org.co

The status of coral communities as well as sedimentation rates (including calcium carbonate content), nutrients, transparency, temperature, suspended solids, chlorophyll *a* in surface waters and heavy metal content (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) of sediments, were assessed at two nearby reef sites (Santa Marta and Chengue bays) of the Colombian Caribbean between October 1998 and July 1999. Santa Marta Bay, the site with a higher influence of continental runoff and anthropogenic activities, showed in general higher levels of nutrients, temperature, suspended solids and chlorophyll *a*, sedimentation rates and heavy metals. Nevertheless, those levels were not within ranges considered harmful to the coral community. However, it was found much lower coral cover in Santa Marta (13%) than in Chengue (35%), and in contrast a higher algae abundance in Santa Marta (32-53%) than in Chengue (24-35%). These differences in community structure between both sites, together with some observations of a strong coral decline during the last 30 years in Santa Marta Bay, suggest that the evaluated parameters have originated a negative impact. As the measured levels were no lethal, their impact could have been produced in a chronic slow way or by a synergic action between them.

UPTAKE OF ESTROGENS BY REEF-BUILDING CORALS.

Tarrant, Ann M.*, M.J. Atkinson, and Shannon Atkinson. *University of Hawaii, Department of Oceanography, 1000 Pope Road, Honolulu, HI 96822, USA, Email: atarrant@soest.hawaii.edu

Estrogens and other steroids are present in coral tissues, but it is unknown whether corals synthesize estrogens, or concentrate them from food particles or from the overlying seawater. Dissolved estrogens have been detected in rivers, lakes and coastal seawater; sewage outfalls and runoff from livestock enclosures may expose nearby corals to unusually high doses of estrogens. If estrogens help to regulate reproductive processes in corals, then water column sources of estrogens or "estrogen mimics" will influence coral reproduction. To determine whether corals can remove estrogens from the water column, we measured the uptake of dissolved estrone in a 24-m flume filled 2 m^2 of scleractinian corals. In each experiment, the flume was spiked with estrone (starting concentrations 1.0 - 2.5 ng l^{-1}) and water samples were collected intermittently for 1-7 days. The assemblage of coral removed estrone from the water column at a rate proportional to concentration. The rate constants (85 x 10^{-6} m s^{-1}) are close to maximal uptake rates, based on mass transfer theory applied to nutrient uptake by corals. Given concentrations of dissolved estrone are 50 to 500 pg l^{-1} over coral reefs, uptake rates of dissolved estrone into corals range from 0.1 to 1 g estrone m^{-2} day^{-1}. This implies a turnover time on the order of 10-100 days.

PHENOTYPIC PLASTICITY IN TWO SCLERACTINIAN CORALS AROUND SINGAPORE.

Todd, P.A.*, Sanderson, P.G., Chou, L.M. *Department of Geography, National University of Singapore, 1 Arts Link, Kent Ridge, Singapore, 117576. Email: artp8501@nus.edu.sg

Fragments of two scleractinian corals, *Diploastrea heliopora* and *Montastrea curta*, were reciprocally transplanted across three of Singapore's southern reefs, located 4km, 11.5km and 15km off the mainland shore. These reefs represent a sediment gradient – the nearest being the most heavily affected by sedimentation. At each reef two stations were established, a shallow site (3m) and a deep site (10m), i.e. high and low light environments (due to high sediment levels there are no reefs below 10m off Singapore). Four colonies of each of the two species were sampled from the three reefs (a total of 12 colonies for each species). From each colony, six fragments (clone-mates) were removed and spread over the six stations, thus there were 12 fragments (one per colony) of each species at each station. All fragments were photographed immediately after transplantation. After four months the fragments were photographed once more before being collected for treatment and analysis. During this time a suite of physical environmental measurements were regularly taken at each station. Polyp and corallite morphometric traits were measured from photographs and cleaned skeletons. Comparisons of traits across colonies and stations were made using multivariate statistical techniques.

THE MAINTENANCE OF CORAL ASSEMBLAGES ALONG THE SOUTH SHORE OF ST. JOHN, U.S. VIRGIN ISLANDS.

Treml, EA* and Colgan, MW. *Technology Planning and Management Corporation, NOAA Coastal Services Center, 2234 South Hobson Avenue, Charleston, SC 29405-2413, USA. Email: Eric.Treml@noaa.gov

Coral reef communities have been studied extensively throughout the past five decades, although with little emphasis on the importance of history and scale. Until recently, cross scale, multivariate studies have not been completed on coral reefs. Now, utilizing geographic information systems (GIS), enables one to study coral reefs, while controlling the many spatial and temporal scales. This study applies a broad-scale approach, spanning multiple watersheds and bays containing many patch reef communities along the undeveloped south shore of St. John, USVI. The line transect method was used to quantify reef communities and GIS was used to create maps of individual reef patches, delineate and map watersheds, locate stream beds, and find the location of stream outlets. The GIS was also used to summarize the storm history of St. John, visualize the ecological data results, and explore spatial relationships between the reef patch communities. This study reveals the widespread lack of recovery from Hurricane Hugo (category IV, 1989), which is seen at all community levels. In addition, the variability in coral community structure is significant at the bay-to-bay level and may best be explained by the degree to which patch reefs are exposed to waves.

TERRESTRIAL NITROGEN IMPACT TO CORAL REEFS EVALUATED BY STABLE NITROGEN ISOTOPE OF MACROALGAE.

Umezawa, Y.*, Miyajima, T. Yamamuro, M. Kayanne, H. and Koike, I. *Marine Biogeochemistry Lab., Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai Nakano-ku Tokyo 164-8639, Japan. Email: umezawa@ori.u-tokyo.ac.jp

In fringing reefs, supply of terrestrial nitrogen through groundwater or river is spatially and temporally variable, and quantitative evaluation of terrestrial nitrogen impact on reef vegetation is difficult from water column nutrient data. Application of δ^{15}N-values in brown algae as an indicator of integrated nutrient regime in their habits was tested in the reefs surrounding Ishigaki Island, southwest of Japan. The δ^{15}N values in two brown macroalgae, *Padina* spp. and *Dictyota* sp., distributed widely in the reefs, decreased logarithmically from +8‰ to +2‰ with increasing distance from shoreline, indicating clear difference of δ^{15}N between those affected by terrestrial nitrogen source inflow through groundwater and those by other sources. At the area >400m distant from shoreline where corals are mainly distributed, the values fell down to +3‰ or +2‰. These results suggested that impact of anthropogenic nitrogen on corals was minor in the study area, although the impact of nitrogen inflow was considerable for macroalgae distributed near the shoreline. The availability of terrestrial nitrogen for coral reef macroalgae is primarily controlled by residence time of reef seawater and the fluxes of terrestrial nitrogen. Using δ^{15}N-value of brown algae as an indicator, we successfully evaluated fine spatial scale distribution of terrestrial nitrogen impact on subtropical coral reefs, which had been missed by conventional sampling of the water column nutrients.

Session A20: Fish Ecology I: Life History and Reproduction

THE RELATIONSHIP BETWEEN BODY SIZE AND HOME RANGE SIZE FOR NASSAU GROUPER (*Epinephelus striatus*).

Bolden, S.K.*. *NOAA/NMFS 75 Virginia Beach Drive, Miami, Florida 33149 USA Email: stephania.bolden@noaa.gov

Most life history traits of an animal species are strongly correlated with their body size; ecological relationships tend to be weaker. Individual size and a host of other variables have been shown to correlate or interact with, or otherwise influence home range size. Home range is simply the area in which an animal normally lives, exclusive of migrations, emigrations, dispersal movements, or unusual wanderings. Most home range theory is derived from studies principally on terrestrial mammals and birds; information from the marine environment is scant. Recent advances in telemetry provides opportunity to investigate larger numbers of marine fishes over longer periods of time to reveal accurate information about home range. Twenty two Nassau grouper (*Epinephelus striatus*) ranging from 39.1 to 72.1 cm TL were tracked for 16 - 24 days (_ = 20.1) with positions recorded every two minutes. These data were classified into four size classes and analyzed to investigate the relationship between body size and home range area.

RECRUIT CONDITION INFLUENCES THE LINK BETWEEN SETTLEMENT AND ESTABLISHMENT OF CORAL REEF FISHES

Booth, David J.* *Dept. of Environmental Sciences University of Technology, Sydney Westbourne St. Gore Hill 2065 AUSTRALIA. Email: David.Booth@uts.edu.au

Settlement of marine organisms varies greatly in space and time, and it is currently recognised that settlement variation is a major determinant of patterns of juvenile and adult abundance of coral reef fishes. However, such relationships can be dampened by variable mortality rates of recruits between settlement and recruitment. Predation is likely to be the predominant mechanism causing early mortality of recruits, and predator patchiness has therefore been proposed as a mechanism generating variable mortaility. In this study, I demonstrate that the physiological state (condition) at settlement can also affect subsequent mortality patters for two species of damselfishes (*Stegastes partitus* [Bahamas], *Pomacentrus moluccensis* [GBR]). This link is likely to be due to higher predation risk for settlers in lower condition, but may also be indirectly due to lower competitive ability. Based on data for *P. moluccensis* at 3 locations on the Great Barrier Reef, I show that the poor relationship between settlement and establishment can be improved by including data on recruit condition into the model. The results from this study suggest that caution should be adopted in the use of settlement or larval supply as predictors of subsequent population dynamics of reef fishes, and in the use of recruitment surveys to hindcast settlement patterns.

ABOUT REPRODUCTIVE STRATEGIES SELECTED BY WILD SPECIES.

Chauvet, Claude.*, *Univ. of New Caledonia - BP 4477 Noumea, Email: chauvet@univ-nc.nc

I would like to focus interest on the first parts of marine species development phases - i.e. : spawning *s.l.* (fry behaviour, spawn *s.s.*, eggs fertilisation) rarely well known, pelagic phase, and settlement. The last two phases are classically describe as a very critical on physiological point of view and drastic mortality period. Our studies and observations on 3 lagoon mollusc *Pectinidae*, 10 fish species (*Epinephelidae*, *Plectropomidae*, *Siganidae*, *Lethrinidae)* and 2 species of spiny lobsters (*Palinuridae)* show that the number of annual recruit has no quantitative link with spawning effort (i.e. number of spawners, spawning duration). Moreover, in stable adult stocks sexual activity, spawning behaviour and spawning capability change from year to year (Fishes, Spiny Lobsters) or not (Molluscs). Estimations on recruitment level show considerable inter-annual fluctuations (Fishes, Spiny Lobsters) or intra-annual fluctuations (Molluscs) without link with the spawning effort. Sometime, it can be related to the climate but sometime not. Most of reproduction models seem to show that species haven't selected to maximise eggs number strategy. Some (Molluscs) present an opportunistic pelagic phase and seem to be under regulation mechanisms only after settlement, other (Fishes, Spiny Lobsters) are shaky and seem to be totally under regulation mechanisms. Although, spawn and recruitment are not totally disconnect on a quantitative point of view, but, be that as it may, all of these models converge to show that the best way to maximised the recruitment is mostly to protect juveniles than spawners. In concrete terms, it means protecting against predators as much as possible and keep nurseries healthy and with sufficient food supply.

TEMPORAL AND SPATIAL RECRUITMENT PATTERNS OF THE ARC-EYE HAWKFISH, *PARA-CIRRHITES ARCATUS*, IN HAWAII.

DeMartini E.D.*. *National Marine Fisheries Service (NMFS, NOAA), 2570 Dole Street, Honolulu, Hawaii 96822, USA. Email: Edward.DeMartini@noaa.gov

As part of an ongoing study of the species= morph dynamics, the relative abundances of young-of-year (yoy) and older arc-eye hawk-fish (F. Cirrhitidae) were monitored during 1989-99 along a 30-km leeward stretch of Hawaii Island, in order to describe local-scale recruitment patterns. Delimited areas within seven sites on the fringing reef at 1- to 5-m depths, differing in wave exposure, were surveyed by snorkeling at quarterly intervals. Patterns were evaluated using factorial ANOVAs evaluating site, season, and year effects. Overall, yoy abundance varied among years; differences among sites in relative recruitment (ratio of yoy to older fish) persisted for multiple years or the entire decade, depending on site. Temporal persistence of different relative recruitments may reflect site differences in either replenishment by planktonic settlers or post-settlement growth and mortality. Descriptive studies such as this unique 10-yr time series identify the basic patterns necessary for designing experimental evaluations of processes producing pattern.

SPATIAL PATTERNS IN FISH RECRUITMENT TO MEXICAN CARIBBEAN REEFS.

González-Salas C*. and J.E. Arias-González. *Centro de Investigación y de Estudios avanzados del I.P.N. Unidad-Mérida. Ant. Carr. a Progreso Km 6. Cordemex A.P. 73. C.P. 97210 Mérida, Yucatán, México. Email: carlosgs@mda.cinvestav.mx

Spatial patterns of recruitment of juvenile reef fishes were analysed during summer season of 1999, on the reef slope of six reefs in the Mexican Caribbean. Three inside Sian Ka'an Biosphere Reserve: Boca Paila (20° 08" N; 87° 28" W), Punta Yuyum (19°58"N; 87°27" W), Punta Allen (19° 50"N; 87° 26" W), and three unprotected areas outside the Reserve: Mahahual (18° 43" N; 87° 41" W), Xahuayxol (18° 30" N; 87° 45" W) and Xcalak (18° 13" N; 87° 49" W). The highest species richness was recorded on Boca Paila reef with 39 species, followed by Xahuayxol reef with 36 species of juveniles of coral reef fishes. The lowest species richness was recorded at Punta Allen and Mahahual reefs with 28 and 29 species respectively. In terms of abundance, expressed in this work as density of juveniles (fish/m^2). Atotal of 6327 recruits of 18 fish families were censused on the transects

CHEATING IN FISH CLEANING INTERACTIONS

Grutter, Alexandra*; Bshary, Redouan; Bansemer, Carley; Poulin, Robert. *Department of Zoology and Entomology, University of Queensland, Brisbane, Qld. 4072, Australia, Email: a.grutter@mailbox.uq.edu.au

Cooperation theory largely focuses on how cooperation between unrelated individuals is maintained despite the option of profitable cheating. Recent studies show that fish cleaning behaviour is mutualistic, yet cleaner fish diet analyses suggest some cheating occurs. As the rewards of cheating are likely to vary with client ectoparasite load, we compared the frequency of cheating in the cleaner fish *Labroides dimidiatus* and all its client species between two sites on the Great Barrier Reef that differ in ectoparasite abundance. In the laboratory, we tested the effect of parasites and hunger levels on cleaner cheating behaviour. As most clients cannot cheat and eat a cleaner, while the cleaner can still cheat, we examined how the grazer *Ctenochaetus striatus* controls cheating cleaners. At Heron Island, where clients harbour fewer parasites, fish were inspected longer on average by cleaners than conspecifics at Lizard Island, and they incurred more bites and swipes at their sides per unit time from cleaners. These and other differences between the two sites suggest that the local availability of ectoparasites as a food source for cleaners can determine whether cleaners will be honest and feed on parasites, or cheat and feed on client tissues. In laboratory experiments, parasites and hunger levels also affected cleaner cheating behaviour. The main control mechanism used by *C. striatus* was immediate 'punishment' of cheating cleaners by aggressive chasing. This study shows that when honesty in fish cleaning behaviour does not pay, cheating is favoured.

LIFE HISTORY CHARACTERISTICS OF FIVE SPECIES OF TROPICAL MARINE GOBY (TELEOSTEI: GOBIIDAE).

Hernaman VJ *, PL Munday and PK Probert. *Department of Marine Science, University of Otago, PO Box 56, Dunedin, New Zealand. Email: crava594@student.otago.ac.nz

Life history theories predict that small-sized organisms often exhibit certain characteristics such as early maturation, enhanced reproductive effort, fast growth and a short life span. Whilst many small-bodied species of fish are short-lived, there is increasing evidence that this is not always the case, especially for coral reef fish. In this study, the extent to which five species of tropical marine goby conform to these life history theory predictions was investigated. Gobies (family Gobiidae) are an abundant and diverse group of marine and freshwater fishes found in a wide range of habitats in both temperate and tropical regions. Gobies are present in high numbers on coral reefs where they are found in association with a variety of substrata including live branching corals, dead coral rubble, sea whips and sand/rubble burrows. This high abundance and diversity, combined with a small body size, make gobies an ideal group of fish to test life history theory predictions. The study species (*Asterropteryx semipunctatus*, *Amblygobius phalaena*, *Amblygobius bynoensis*, *Istigobius goldmanni* and *Valenciennea muralis*) were collected from the leeward fringing reefs of Orpheus Island, Australia (18° 36'S, 146° 30'E). Estimates of growth rates and longevity were obtained from counts of otolith growth increments (having first validated the periodicity of increment formation). The size and age of fish at maturity was determined and fecundity estimates obtained. The extent to which these five goby species conform to life history theory predictions are discussed.

PELAGIC LARVAL DURATION AND EARLY POST-SETTLEMENT GROWTH OF SOME REEF SNAPPERS (PISCES: LUTJANIDAE) FROM THE TROPICAL EASTERN PACIFIC.

Herrón, P.* and F. A. Zapata. Department of Biology, Universidad del Valle, Apartado Aéreo 25360, Cali, Colombia. Email: piherron@biologia.univalle.edu.co

The early life history traits of marine organisms may have profound ecological, biogeographic and evolutionary implications. Analysis of otolith microstructure of juveniles has proved very valuable in the study of the early life history of coral reef fishes. By counting the number of pre-settlement increments in otoliths and by examining the relationship between size and otolith-estimated age, we estimated the pelagic larval duration and quantitatively described the early post-settlement growth of five species of reef snappers of the Tropical Eastern Pacific: *Lutjanus guttatus*, *L. argentiventris*, *L viridis*, *L. novemfasciatus* and *Hoplopagrus guntheri.* We found the frequency of increment formation to be daily in the otoliths of *L. guttatus* and *H. guntheri*. Assuming that the formation of otolith microincrements begins at the time of hatching, we estimated that the pelagic larval phase lasts from 21 to 38 days in these snappers. Pelagic larval duration also showed low intraspecific and interspecific variability. *L. viridis*, the most widely distributed lutjanid in the Tropical Eastern Pacific, had the longest and most variable larval duration. Early post-settlement growth was exponential with absolute growth rates from 0.66 to 1.10 mm/day at the time of settlement, which are higher than growth rates reported for other reef fish families. It seems that diet and other ecological characteristics are responsible for rapid post-settlement growth rates in these species.

DIET COMPOSITION AND FEEDING RHYTHM IN SIX PLANKTIVOURUS FISHES FROM THE JORDANIAN GULF OF AQABA.

Khalaf Maroof *, Mohammd Zibdeh, Sayeeda Mir and Nemeh Kanan. *Marine Science Station, PO. Box 195, Aqaba-Jordan. Email: maroof@ju.edu.jo

Qualitative and quantitative aspects of the diet as well as its feeding rhythm were investigated in six planktivourus species from the Gulf of Aqaba-Red Sea. The study was conducted over one annual cycle (March 97-March 98) on the following fishes; *Priacanthus hamrur*, *Apogon aureus*, *Sargocentron diadema*, *Dascyllus timaculatus*, *Chromis pelloura* and *Teixeirichthys jordani*. Food varied according to fish species and to the composition of zooplanktonic fauna within fish habitat. Based on the index of relative importance (RI), Crustaceans were the major dietary components of all fish examined. Values of RI showed that food item descents observed in the digestive duct of *P. hamrur* are molluscs, polychaets and fish larvae. In A. *aureus*, polychaets, fish eggs and larvae. In S. *diadem, molluscs, polychaets and fish egg.* In *D. trimaculatus*, and *C. pelloura*, fish eggs and larvae, respectively. In *T. jordani*, fish larvae and molluscs. Nematodes, chaetognaths in the diet of *P. hamrur* and echinoderms in food of *S. diadema* occupied last ranks in importance. Based on % occurrence and % biomass of the ingested food, composition, consumption and occurrence of food varied with season. Moreover, the rhythm of feeding was strongly influenced by the state of maturity to the extent that all fishes might even fast completely during the spawning period..

TROPHIC FLUXES, EUTROPHICATION AND THE HERBIVORE PATHWAY : CASE STUDY OF A FISH AND A SEA URCHIN REEF RESIDENT AT LA RÉUNION (INDIAN OCEAN).

Lison de Loma, T.*, Conand, C. and Harmelin-Vivien, M.L.. *Laboratory of Marine Ecology, University of La Réunion, Av. René Cassin, 97715 St Denis Messag. cedex 9, La Réunion. Email: lison@univ-reunion.fr

Fish and sea urchins are among the most conspicuous herbivores on coral reefs and have important and diverse roles in coral reef ecology. Trophic fluxes have been investigated for a while in corals or microbial communities, but few studies have quantified the herbivore pathway. Fewer of them compared the respective role of fish and sea urchin. Nutrient-enrichment of reef waters can enhance, under certain conditions, primary production and algal biomass. Is the yield to grazers enhanced, and what consequences can eutrophication imply for the following trophic levels? In order to answer these questions, a damselfish, Stegastes nigricans, and a sea urchin, Tripneustes gratilla, were studied in two sites of a coral reef at La Réunion, in summer and winter. One site is oligotrophic (site O), while the other is nutrient-enriched (site E). Organic matter, organic carbon, nitrogen, carbohydrates, lipids and proteins were measured in the food and faeces of both organims. Consumption, defecation and excretion rates of both organisms were estimated. Similar between-site differences were observed for the fish and the urchin. Both foods and faeces were richer, in terms of organic nutrients, in site E than in site O. Trophic fluxes were more intense in site E than in site O for both organisms. More algal matter and nutrients were consumed, absorbed and reinjected into the reef system in site E than in site O, suggesting a positive feed-back of herbivores on nutrient-enrichment, through subsequent microbial recycling.

REPRODUCTIVE BEHAVIOR OF A CORAL REEF FISH UNDER THREAT OF PREDATION.

Lyman, Sean J.* and Figueira, William F.. *Duke University Nicholas School of the Environment Marine Laboratory. 135 Duke Marine Lab Road, Beaufort, NC 28516 USA Email: sean.lyman@duke.edu

The ideal free distribution is rarely perfectly met in nature, but nevertheless serves as the basis for useful models predicting animal behavior in environments in which behaviors can incur costs due to risk of predation. Most of these models focus on foraging behavior, using growth as a measure of fitness, though relatively few studies have used more direct measures of fitness such as reproductive success. In this study, the risks and rewards of courting behavior in the male bicolor damselfish (*Stegastes partitus*) are measured *in situ* by quantifying reproductive effort, subsequent reproductive success, and predation hazard in the Florida Keys, USA. Focal males are presented with females in the presence and absence of a model grouper predator, and the results utilized to determine which of three behavioral models males follow: minimizing predation, maximizing reproduction, or minimizing the ratio of predation to reproduction. Males are also presented with multiple sizes of females to determine whether the threshold courting size changes when faced with increased predation risk. Our hypotheses are that males will act to minimize the ratio of predation to reproduction, and that the size threshold for courting will increase when a predator is present. This work has potential management implications as marine protected areas tend to increase the size and number of predators in the system, thereby altering behavior and potentially population dynamics of small reef fishes.

REVIEW OF MULTI-SPECIES FISH FORAGING ASSOCIATIONS, AND THEIR IMPLICATIONS FOR A TROPICAL BENTHIC CARNIVORE, *PARUPENEUS BARBERINUS* (FAMILY MULLIDAE)-

Lukoschek, Vimoksalehi and McCormick, Mark I. *-*Marine Biology Dept., James Cook University, Townsville, 4811, Email: vimoksalehi.lukoschek@jcu.edu.au

Multi-species fish foraging associations occur whenever a nuclear species and one or more associate species forage together. Although common, the theoretical background regarding foraging benefits and predator avoidance for multi-species fish foraging associations is sparse and poorly developed. However they are thought to increase food availability to associate fishes, compared with foraging alone, and may reduce the risk of predation for nuclear and associate fishes. In this study we investigated the foraging associations formed with an important tropical benthic carnivorous fish, *Parupeneus barberinus*, on Lizard Island, GBR, using scan sampling and focal animal behavioural observations. Altogether 31 associate species, comprising 14 genera and 7 families, were involved in foraging associations with *P. barberinus.* The most important associate species were from the families Labridae, Nemipteridae and Mullidae. Typically foraging associations comprised between 2 to 6 individuals (max 18), representing 2 to 4 species (max 6). Associate fishes foraged with *P. barberinus* in 65 % of foraging observations. *Parupeneus barberinus* foraged in single species groups in 6% of cases and alone in 29 % of cases. On average foraging associations lasted longer (21 ± 0.6SE secs) than solitary foraging episodes (16 ± 0.4SE secs). Detailed behavioural observations indicate that associate species gained access to prey items liberated during vigorous foraging by *P. barberinus* and due to enhanced prey detection.

MONITORING FISH RECRUITMENT ON FOUR REEFS IN ST. JOHN, U.S. VIRGIN ISLANDS.

Miller Jeff*, Beets, Jim. *U.S. Geological Survey, Biological Resources Division, P.O. Box 710, St. John, VI 00830. Email: j_miller@usgs.gov

Juvenile reef fishes were surveyed during July of 1997, 1998, 1999 at four reefs with similar coral and physical structure located around the island of St. John, U.S. Virgin Islands. Yawzi, Tektite, and Haulover reefs occur in Virgin Islands National Park, while Newfound reef lies outside the park. Belt transects were conducted in the forereef zones of each site at a depth range of 8.5-15.2 meters. The objective of this study is to evaluate temporal and spatial recruitment patterns and to compare juvenile fish with adult fish assemblage data. Mean number of recruits per transect varied greatly among reefs, however the species composition was relatively consistent with adult composition. The masked goby, *Coryphopterus personatus*, was the dominant recruit at each site. The second most abundant recruit on Yawzi and Tektite, the bluehead wrasse (*Thalassoma bifasciatum*), was both less numerous and had a lower abundance ranking on the other two reefs. The striped parrotfish, *Scarus croicensis*, was the most abundant parrotfish at all sites, with consistently high abundance ranking. The planktivorous, blue damselfish, *Chromis cyanea*, was the most abundant damselfish followed by the bicolor damselfish (*Stegastes partitus*) and threespot damselfish (*Stegastes planifrons*). Relatively large pulses of tomtates (*Haemulon aurolineatum*) were observed at three of the reefs, while none were observed at Haulover reef.

WHY IS FALSE-CLOWN ANEMONEFISH (*Amphiprion ocellaris*) GROUP SIZE CORRELATED WITH HOST ANEMONE (*Stichodactyla gigantea*) SIZE?

Mitchell, J. S.* *Behavioural Ecology Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, Canada, V5A 1S6. Email: jmitchel@sfu.ca

In false-clown anemonefish (*Amphiprion ocellaris*), the number of members in a dominance-structured social group is positively correlated with the size of a host sea anemone. This correlation could arise in a number of ways: 1) Mortality rates of all group members might lower be on larger anemones, leading to, on average, larger groups on larger hosts. 2) Anemone size might affect the maximum size of the dominant group member. There would then be more 'social space' for subordinate fish behind a larger dominant. 3) Would-be settlers might more readily detect larger anemones. 4) Settlers might prefer larger anemones. Such a preference would be expected if reproductive success were affected by host size or if lower mortality rates on large hosts increased the likelihood that a settler survived to maturity. The fourth possibility treats false-clown social hierarchies as queues and group size, or queue length, as a reflection of terminal reward value (reproduction) and the likelihood of realizing that reward (mortality). I discuss implications of these alternatives and distinguish between them using data from a nearshore false-clown population at Bunaken Island, North Sulawesi, Indonesia.

LONG DISTANCE DISPERSAL OF REEF FISHES ASSOCIATED WITH FLOATING OBJECTS.

Mora C*, Francisco V, and Zapata, F. *Departamento de Biologia, Universidad del Valle, Cali, Colombia. A.A. 25360. Email: moracamilo@hotmail.com

Regarding the ecology and biogeography of reef fishes, it is widely accepted that dispersion occurs mainly during the larval phase. In this paper we report the dispersal of juvenile and adult reef fishes associated with floating objects, in a dispersal event that exceeded the larval dispersion capacity. In May1999, at Gorgona island (tropical eastern Pacific) we observed a marine current carrying several floating objects. Associated with the floating objects we found juvenile and adult fishes of 12 species, 6 of which were reef species. The surface current patterns in this area of the Pacific and the labels of many man-made objects found in the current provided strong support for the idea that the floating objects came from Ecuador and Peru. We support the idea that these fishes settled as larvae on the substrate provided by the larger floating objects and remained associated with them until reaching adulthood. If the reef fishes had been associated with the floating objects at Ecuador or Peru localities, they would have traveled 300 or 600 km to Gorgona. Such distances could hardly have been covered during the larval phase of these species. Furthermore, the age of many of the reef fishes associated with the floating objects was 20 times greater than their larval duration, which indicates that these fishes were dispersing during a longer time that that possible during their larval phase.

THE EXTENDED LONGEVITY OF A SMALL CORAL REEF SERRANID; *Cephalopholis cyanostigma* (BLUE SPOT ROCK COD) FROM THE CENTRAL GREAT BARIER REEF.

Mosse, Jacobus W., * and Davies, Campbell R. *Department of Marine Biology, James Cook University, Townsville, Queensland 4811, Australia. Email.: Jacobus.mosse@jcu.edu.au

The blue spot rock cod, *Cephalopholis cyanostigma*, is a small common coral reef rock cod, which forms a significant proportion of the discarded by-catch in Queensland reef Line Fishery. A total of 262 fish were sampled from Orpheus and Pelorus Islands on central GBR using hook and line and spear over a thirteen-month period. We used sagittal otoliths to obtain age-based parameters of the populations for each island. Analysis of marginal increments indicated that a single opaque band was deposited annually in November-December. Recaptures of three fish, five years after injection with oxytetracycline, further corroborated our conclusion that band formation is annual. The maximum age in our sample (31 years) suggests that the blue spotted rock cod is one of the longest living serranid documented to date. The von Bertalanffy growth function provide the best description of the pattern of growth for both populations (R^2 = 0.86 and 0.82 for Orpheus and Pelorus Islands, respectively). Growth was relatively slow (K = 0.22 and 0.25), not reaching asymptotic size until 7-10 yrs. $L\infty$ was significantly larger at Orpheus Island ($L\infty$ = 258mm) relative to Pelorus Is ($L\infty$ = 244mm). Instantaneous total mortality was low (0.13 and 0.16) and did not differ significantly between populations. Such population parameter estimates demonstrate that *C.cyanostigma* is considerably longer lived than expected for a coral reef serranid of it's diminutive size and further demonstrate the utility of age-based methods in studies of the demography of tropical reef fish.

INTERSPECIFIC COMPETITION AMONG CORAL-DWELLING FISH.

Munday, Philip L. *School of Marine Biology and Aquaculture, James Cook University, Townsville, QLD, 4811, Australia. Email: Philip.Munday@jcu.edu.au

The role of competition in structuring communities of reef fishes remains controversial. I investigated the effects of interspecific competition on habitat use and abundance of six species of obligate coral-dwelling fish (genus *Gobiodon*) that inhabit a range of acroporid coral species at Lizard Island, Great Barrier Reef. In laboratory experiments, species of *Gobiodon* differed in their ability to compete for preferred corals. Body size and prior residency of coral colonies also had a significant effect on competitive ability. In the field, the abundances of two species, *G. axillaris* and *G. brochus*, increased significantly following the removal of one of the competitively dominant species, *G. histrio*, from replicate patches of reef. Moreover, there was a very close relationship between the change in abundance of *G. histrio* and the change in abundance of *G. axillaris* and *G. brochus* combined. This demonstrates that competition for space limits the abundance of these species on reefs at Lizard Island. Three other species of *Gobiodon* did not compete for space with *G. histrio*, either because they preferred different species of coral or were able to co-habit coral colonies with *G. histrio*. Competition among species of *Gobiodon* also influences demographic rates because dominant species limit access of subordinate species to high quality habitats. A transplant experiment revealed significant differences in survival and/or growth for individuals of both *G. histrio* and *G. brochus* inhabiting different species of coral.

TESTING A NEW SIZE-ADVANTAGE MODEL FOR SEX CHANGE WITH THE BUCKTOOTH PARROTFISH, *SPARISOMA RADIANS*: NOVEL PREDICTIONS FROM SPERM COMPETITION.

Muñoz, Roldan C.*, and Warner, Robert R.. *Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, California 93106-9610 U.S.A. Email: munoz@lifesci.lscf.ucsb.edu

Sequential hermaphroditism is common in marine fishes, with protogyny (sex change from female to male) predominating. The size-advantage model has been highly successful in explaining the adaptive significance of sequential hermaphroditism in fishes and predicts protogyny where large males monopolize matings to the detriment of small ones. In many protogynous fishes with haremic social systems, upon removal of the dominant male it is always the largest remaining female that changes sex and takes over the harem. In several protogynous fishes, however, females may change sex even in the presence of the dominant male, and it is not always the largest females that change sex, suggesting that the simplest form of the size-advantage hypothesis needs some modification. By incorporating the effects of sperm competition and exponential increases of female fecundity with length, we have developed a more realistic model that provides explanations for seemingly "early" sex change. Most notably, the model predicts a variety of circumstances when the largest female remaining in a harem should not change sex in the absence of the dominant male. Removal experiments in 22 harems resulted in six females changing sex, and every changer was smaller than the largest female remaining in the harem. The local environmental effects of sperm competition and female size/fecundity-skew may substantially lower the benefit of changing sex for large females.

IDENTIFICATION OF TROPICAL CORAL REEF FISH LARVAE: MTDNA MARKERS, MORPHOMETRICS AND MULTIVARIATE ANALYSIS.

Ochavillo, Domingo G.*; Bakus, Gerald J.; and Aliño, Porfirio M. *Department of Biological Sciences University of Southern California Los Angeles, CA 90089-0371, U.S.A. Email: ochavill@scf.usc.edu

The planktonic stage among fishes associated with coral reefs has been recognized as important in structuring their communities (Cowen 1985, Victor 1986), their biogeography and conservation (Roberts 1999) and as tracers of physical transport processes (Leis 1982, Mountain et al. 1989, Hare and Cowen 1991). Most of these early stages, however, are morphologically distinct larval and juvenile forms (Leis 1991) and the inability to distinguish these forms is a long standing problem (Fahay 1983, Leis and Rennis 1984, Leis and Trnski 1989, Matarese et al. 1989). The problem is magnified in tropical coral reef systems which are characterized by very high species diversity and the occurrence of morphologically similar species. In this paper, we used mitochondrial DNA cytochrome *b* sequences and morphometrics to identify three morphotypes of the late pelagic presettlement fish larvae of the family Siganidae. The phylogenetic analysis indicated that the larval morphotypes were from three different species (*Siganus fuscescens*, *Siganus argenteus* and *Siganus virgatus*) and the standard discriminant function analyses of morphometric variables indicated high and significant discrimination.

EFFECTS OF REEF SIZE AND ISOLATION ON THE DEMOGRAPHY OF BAHAMIAN REEF FISHES.

Overholtzer, Karen L.* *Department of Zoology, Oregon State University, Corvallis OR, USA 97331-2914. Email: overholk@bcc.orst.edu

The contribution of post-settlement movement to the local population dynamics of coral-reef fishes is poorly understood. I examined the effects of reef size (small vs. large) and reef isolation (5 vs. 50 m apart) on the demography of the bluehead wrasse *Thalassoma bifasciatum* and the territorial beaugregory damselfish *Stegastes leucostictus* on 24 artificial reefs in the Bahamas. Recruitment was patchy in time and space. Six months after construction, total fish densities were greater on small than large reefs. Tagging studies showed that immigration and emigration were more frequent between reefs separated by 5 m than those separated by 50 m, and were greater for *T. bifasciatum* than *S. leucostictus*. The highest emigration rates for both species were from small (higher-density) reefs that were less isolated (5 m apart). Preliminary results suggest that per capita mortality rates were density-dependent for both species and tended to be higher on more isolated reefs in which successful post-settlement movement was negligible. Results of this study emphasize the importance of differentiating between mortality and emigration as sources of loss in field studies with respect to the degree of reef isolation.

RECRUITMENT PATTERNS OF JUVENILE REEF FISHES ACROSS THE BERMUDA PLATFORM – COMPARISONS WITH RECRUITMENT IN THE CARIBBEAN REGION.

Pitt, Joanna M*. *Bermuda Biological Station for Research, 17 Biological Station Lane, Ferry Reach, St. George's GE 01, Bermuda. Email: jopitt@bbsr.edu

Visual surveys of juvenile reef fishes were conducted in a variety of reef habitats around the Bermuda platform during the summer / autumn periods of 1999 and 2000. Three pairs of sites formed a transect across the lagoon to the north of the island. There was also a pair of sites off the south shore, and a pair of inshore sites in the semi-enclosed Castle Harbour. Distinct distribution patterns at both the family and species level emerged. The Labridae and the Scaridae were the most ubiquitous families, and were dominant on the north and south rim reefs. There was a transition in the within-family species dominance of labrids across the lagoon. The mid-lagoon, north shore and inshore sites generally exhibited greater species diversity than the rim reefs. Juvenile acanthuridae were most abundant on the mid-lagoon reefs, followed by the north shore reefs and the inshore reefs. Juvenile pomacanthidae were most abundant at the north shore and inshore sites. Juvenile haemulidae were common on mid-lagoon and inshore reefs, and their tendency to aggregate in large shoals greatly influenced the data from these sites. When haemulids are removed from consideration, total relative abundance at the rim reef sites was between 30 and 50 individuals per 60 m^2, while the other sites had total relative abundances ranging from 10 to 30 individuals per 60 m^2. The details of these observed distribution patterns are presented, and compared with the literature on recruitment patterns in the Caribbean.

REGULATION IN POPULATIONS OF CORAL REEF FISH: AN EXPLORATION OF VARIANCE IN MODELS AND DATA.

Sandin, Stuart A.* and Pacala, Stephen W. *Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544-1003 USA. Email: sasandin@princeton.edu

Coral reef fish populations vary greatly through space and time. Data collected through long-term censuses and from biological responses to experimental manipulations reveal that the variability of reef fish communities has definite pattern and structure. Therefore, to elucidate ecological patterns structuring reef fish populations, it is imperative for the researcher to use variance as a source of information and not simply as a source of error. We have developed a series of models describing the propagation of recruitment variability into adult fish populations. Variance propagation is estimated by linearizing a set of coupled population equations and decomposing the spectrum of the output variance. Patterns of mortality, predation, and foraging each affect the characteristics of the resultant demographic variability in qualitatively different ways. We compared predictions derived from the model with data from our field studies and from the literature. This comparison suggests a prevalence of predator-mediated regulation among reef fish populations. We find predators to be most important in regulating population numbers while density dependent growth and other intraspecific interactions are dominant in regulating population biomass. Such decoupling of variability in population numbers and biomass highlights the importance of selecting the appropriate response variable when searching for evidence of specific ecological processes.

EFFECTS OF *STEGASTES PLANIFRONS* TERRITORIES ON SOME CORAL SPECIES AT TAYRONA NATURAL PARK (COLOMBIAN CARIBBEAN)

Santodomingo-Aguilar, N.*, A. Rodríguez-Ramírez and J. Garzón-Ferreira, Instituto de Investigaciones Marinas y Costeras INVEMAR, A.A. 1016, Santa Marta, Colombia; Email: *nadiaks@invemar.org.co.

Throughout the development of SIMAC (the National Monitoring System for the Coral Reefs of Colombia) the effect of threespot damselfish *Stegastes planifrons* territoriality was assessed on nine species of hard corals at four reef habitat types. These habitats were: multispecific coral assemblages dominated by (1) *Colpophyllia natans* or (2) *Montastraea* spp; and monospecific coral stands of (3) *Acropora palmata* or (4) *A. cervicornis*. Changes over time of the affected areas within marked colonies were evaluated directly by estimating live coral cover surface or indirectly by measuring the extension rate of the algal turf surface, using video-image analysis. The majority (92%) monitored colonies showed decrease of living tissue or increase of algal turfs. In general, the highest rates of tissue loss were found on monospecific habitats: *A. palmata* (1.78 cm^2d^{-1}) and *A. cervicornis* (1.65 cm^2d^{-1}). Within *C. natans* habitat the most affected specie was *Diploria strigosa* (0.95 cm^2d^{-1}), while *M. faveolata* (0.43 cm^2d^{-1}) was the most affected on *Montastraea* spp. habitat. There were significant differences (one-way ANOVA, $p<0.05$) between tissue loss rates of the different coral species that could be related with differences in the morphology and size of the polyps. This research gives new information about the role of *S. planifrons* over the structure and composition of coral reef communities.

SPATIAL AND TEMPORAL VARIABILITY IN THE FLATFISH COMMUNITY AT A CARRIBIAN REEF SYSTEM (CURAÇAO, NETHERLANDS ANTILLES).

van der Veer, H.W.*, J.IJ. Witte. *Netherlands Institute for Sea Research, P.O. Box 59, 1790 AB Den Burg, The Netherlands. Email: veer@nioz.nl

This study describes the spatial and temporal variability in the flatfish community at the reefs at Curaçao, Netherlands Antilles. Flatfish were collected year round at a number of transects from shallow waters until about 30 m in depth along the slope. A total of three species were found, al in low densities and belonging to the family Bothidae (*Bothus ocellatus, B. maculiferus* and *B. lunatus*). The three Bothidae showed clear differences in distribution pattern: *B. ocellatus* was found primarily in the shallow zone on sandy beaches; *B. maculiferus* was found also in deeper water and *B. lunatus* was distributed at the edge of the reef and along the slope. Stomach content analysis revealed that the main prey items of all species consisted of epibenthic prey and this could explain the observed large temporal variability in abundance over the year. Juveniles and adults of the same species were distributed in the same areas, suggesting that the complete demersal life cycle of these species is restricted to these areas. In all three species both males and females became mature in their second year of life and reproduction occurred almost year round, except for the winter period. The von Bertalanffy growth curves of the various species showed that the maximum size and age differed between species from about 15 cm at a maximum age of 4 years in *B. ocellatus* ; 35 cm at an age of 5 years in *B. maculiferus* to 45 cm at an age of 6 years in *B. lunatus* .

RECRUITMENT, POST-SETTLEMENT MORTALITY AND GROWTH OF THE DAMSELFISH *CHROMIS FUMEA* (TANAKA 1917) (PISCES: POMACENTRIDAE) ON TWO ARTIFICIAL REEFS NEAR NOUMEA (NEW CALEDONIA).

Wantiez, L.*, Lervem, Thollot P. *University of New Caledonia, BP 4477, 98847 Noumea, New Caledonia. Email: wantiez@univ-nc.nc

Density and size of *Chromis fumea* were regularly censused during 13 months, on two artificial reefs: one ship wreck (CT2) just after scuttling, and an assemblage of iron boxes (Caissons) sunk more than 50 years ago. The recruitment of *C. fumea* was first observed 20 August 1996 and lasted 20 days. At the beginning the recruits were 1-cm class fish and at the end 2-cm class. This major recruitment phase was again observed one year later (September 1997). A second minor recruitment phase occurred in summer (December 1996) uniquely on the CT2. Significant immigrations of adults were also observed between November 1996 (6-cm) and April 1997 (7-cm), indicating that this species is capable of medium range migrations (> 50 m). Population size decreases by 87.8% between the recruitment of juveniles and the first immigration phase of adults. The final density of the 1996 cohort was 10.5% of the initial of input of juveniles on the CT2 and 19.3% on the Caissons. Density was 3.4 times more important on the CT2 than on the *Caissons* after the recruitment. Densities were similar at the end of the survey, indicating that the magnitude of post-recruitment mortality was greater on the CT2. *C. fumea* von Bertalanffy growth models were similar on the CT2 and the Caissons. This short-lived species is characterized by an initial rapid growth ($K > 3.36$ year^{-1}), with the fish reaching 68.5% of $L\infty$ in 3 months, and a slow second growth phase (1-cm in 10 months).

DIET SELECTION BY SMALL HERBIVOROUS REEF FISHES, AN APPRAISAL OF TROPHIC STATUS.

Wilson Shaun*. *Dept. Marine Biology, James Cook University, Townsville, Queensland, Australia. Email: shaun.wilson@jcu.edu.au

Small "herbivorous" fish provide a major link between primary production and secondary consumers on coral reefs. However, analysis of gut contents from nine species of salariin blennies and three species of territorial pomacentrids revealed that the major item ingested by all of these fish is detritus. Comparisons of gut contents with dietary items in the territory of the three pomacentrid species and a representative blenny species indicates that these fish select fine detrital particles <125µm, avoiding the larger particles and filamentous algae. Fine detrital particles are the major source of organic material in the territories of these species, accounting for more than 50% of all organic matter available. C:N ratios of the fine detritus are very similar to ratios for filamentous algae collected from the same territory. The consistent patterns of detrital selection, abundance and quality for these ubiquitous and ecologically significant reef fish suggest that detritus plays a much more important role in coral reef tropho-dynamics than previously thought.

REPRODUCTIVE BIOLOGY AND GROWTH OF SIX PALNKTIVOURUS FISHES FROM THE GULF OF AQABA-JORDAN.

Zibdeh, Mohammd*; Mir, Sayeeda; Kanan, Nemeh; and Khalaf, Maroof. Marine Science Station, PO. Box 195, Aqaba-Jordan. Email: zibdeh@ju.edu.jo

During a period of one annual cycle (March 97 until April 98) aspects of growth and reproduction were studied in six planktivourus fishes from the Jordanian Gulf of Aqaba. Investigations were conducted on the following species; *Priacanthus hamrur), Apogon aureus, Sargocentron diadema, Dascyllus timaculatus, Chromis pelloura* and *Teixeirichthys jordani* The length-weight relationship (LWr) was found to be of an allometric exponential form ($W=aL^b$), and the slope of Length weight regression was less than 3 in all examined species. The condition factor (K) was relatively high, while corresponding prominent correlation between total length and weight (r^2 ranged from 0.967 to 0.71) in both sexes of all species except for *Teixeirichthys jordani* ($r^2=0.42$). This may indicate a well being of the examined fishes amongst other fish populations in Aqaba Gulf. All fishes showed seasonal periodicity of maturation and spawning. However, periods of spawning commencement were different based on gonadosomatic index (GSI) of each fish. It occurred for *A. aureus, S. diadema, T. jordani* and *D. trimaculatus* during Summer and that for *C. pelloura* and *P. hamrur* occurred during Winter. When these species ceased sexual activity and entered a resting period, active feeding conceived with increased growth was distinctly obvious. The lengths at first maturity were exhibited almost similar values in both sexes within each species.

Session A21: Fish Ecology II: Assemblages and Structure and Disturbances

COMPARATIVE EFFICIENCY OF CLOVE OIL VS ROTENONE FOR SAMPLING REEF FISH ASSEMBLAGES.

Ackerman, John L*& Bellwood, David R. *Department of Marine Biology, James Cook University, QLD 4811, Australia. Email: John.Ackerman@jcu.edu.au

The reef fish assemblage at Orpheus Island, Great Barrier Reef, was examined using the ichthyocide rotenone and the anaesthetic clove oil. Small 3.5 m^2 areas were enclosed using a fine mesh net (1.5 mm mesh) and an impermeable cloak (to minimise by-catch), then sampled using clove oil or rotenone. On average, *Neopomacentrus bankieri* (f. Pomacentridae) and *Eviota queenslandica* (f. Gobiidae) were the dominant components of the samples collected using either technique. Whilst the samples initially appear to be comparable, only 31 species (45 %) in 8 families were common to both techniques. Furthermore, of these common species, total abundance estimates from rotenone samples were on average 45 % higher than those based on clove oil samples (i.e. 98.6 individuals/3.5m^2 ± 32.9 SE vs. 68.0 ± 18.5 SE). When using clove oil fish often recovered before collection and were not driven out of the reef during anaesthesia. Clove oil samples approximate the results obtained using rotenone, although enclosed rotenone stations remain the only method for providing complete quantitative samples.

CORAL REEF FISH ASSEMBLAGE STRUCTURE AND TERRITORIAL DAMSELFISH (POMACENTRIDAE) BEHAVIOR.

Basurto-Lozano D.* & Macias-Ordonez, Rogelio. *Departamento de Ecologia y Comportamiento Animal Instituto de Ecologia, A.C. Xalapa, Veracruz, Mexico. Email: dorinabl@hotmail.com

The back reef fish assemblage structure of Ixlache Reef, Isla Contoy, Mexico, was assessed by means of visual transects. Relative abundance of 71 species was obtained. Five species of territorial damselfishes ranked among the top ten most abundant ones, representing 39% of all individuals recorded. Habitat (substrate) use for territorial behavior by all individuals of these five species in a 20x25 m area was mapped. A non-random use of available substrate suggested species-specific habitat preference and interspecific competition among damselfishes. Focal behavioral records of territorial defense (chases) and feeding (substrate nips) on the two most abundant species of damselfishes suggested differences in potential costs of territorial defense and food availability of the substrates preferred by these species: rubble by *S. leucostictus*, and elkhorn coral (*Acropora palmata*) by *S. planifrons*. The data obtained at the community (assemblage), population (substrate use) and individual (behavior) levels on the same area enable us to propose behavioral mechanisms behind population and community dynamics.

CHAETODONTID-FISH ASSOCIATION WITH CORAL LIFEFORM AT LEMON ISLAND, MANOKWARI-IRIAN JAYA.

Bawole, Roni & Boli P.*. *Fishery & Marine Science Department, Cenderawasih University, Manokwari-Irian Jaya, Indonesia (98314). E-mail: incune@manokwari.wasantara.net.id

A quantitative study of chaetodotid-fish association with coral lifeforms was carried out along a 100 m-length transect, at a depth of 3 m on the coral reefs in Lemon Island, Manokwari-Irian Jaya from November 1998 to April 1999. Twenty species of Chaetodontidae were observed, and they represented three genera: *Chaetodon* (16 species), *Forcipyger* (2 species) and *Heniochus* (2 species). Correspondence Analysis (CA) was applied to determine chaetodotid-fish association with coral lifeforms among the locations. The results showed that the chaetodontid assemblages of Lemon Island were distributed along the first and the second axes. Sixteen of chaetodontid fishes (*C. raflesi, C. ornatissimus, H. varius, C. citrinellus*, *C. lunula*, *C. vagabundus, C auriga*, *C. melanotus, C. punctatofasciatus, Forcipiger longirostris, F. flavisimus, C. unimaculatus*, *C. lineolotus, C. reticulatus, C. ulietensis, C. meyeri*) were closely associated with massive coral. However, *C. baronessa*, *C. trifasciatus* and *C. trifascialis* were highly related to the branching acropora and an-acropora coral. This study also indicated that the abundance of two species of chaetodontid (*C. trifasciatus* and *C. trifascialis*) in Lemon Island showed its healthy condition of coral reefs.

DIET AND CONDITION OF BUTTERFLYFISH IN HABITATS WITH VARYING CORAL COVER AND COMPOSITION.

Berumen M.* and Pratchett, Morgan. *Honours Dept., Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, Arkansas 72701. Email: mberume@comp.uark.edu

Given the highly stochastic nature of larval supply, coral reef fish may often settle in sub-optimal habitats with limited prey. This study examines the dietary habits and physiological condition of a coral feeding butterflyfish, *Chaetodon baronessa* living in two contrasting habitats with markedly different coral prey. In exposed front reef habitats, where coral prey was highly abundant, *C. baronessa* was highly selective in its choice of prey and aggressively maintained small territories. In contrast, in back-reef habitats where coral prey was scarcer, *C. baronessa* was far more generalist in its choice of prey, and had larger territories that were only weakly defended. The contrasting habits of *C. baronessa* in different reef habitats are consistent with predictions of optimal foraging theory, in that dietary specialisation and territoriality are reduced to maximise food intake where prey is less abundant. Despite differences in their feeding habits, the physiological condition of *C. baronessa* in back-reef habitats was far lower compared to *C. baronessa* from exposed habitats.

LIFE-CYCLE MIGRATIONS AND HABITAT PREFERENCE OF EIGHT CORAL REEF FISH SPECIES THAT USE SEAGRASS BEDS AND MANGROVES AS NURSERY HABITATS IN A CARIBBEAN BAY.

Cocheret de la Morinière E.*. *Department of Ecology, Laboratory of Aquatic Ecology, University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands. Email: elroycm@sci.kun.nl

Biotopes that harbour reef fish species, of which most individuals are in their juvenile phase, are recognised as nurseries. Especially mangroves and seagrass beds have received considerable attention, but comparisons were often made with different methodologies. Thus, relative importance of different biotopes to specific size-classes of reef fish remains unclear. In this study, 35 transects in 13 sites of mangroves, seagrass beds and coral reef were surveyed daily, in as well as in front of a non-estuarine bay on the island of Curaçao. The density and size-frequency of eight reef fish species (including herbivores, piscivores and zoobenthivores) was determined during a five-month period using a single methodology (underwater visual census). All selected species depended on bay habitats, *i.e.* mangroves or seagrass beds, for a large part of their life. Only the largest individuals of these species were found on the reefs, at sizes that correspond to their average size at sexual maturity. Some species were dominant in mangroves, other species were observed in high densities in seagrass meadows. Size-frequency distributions of some species showed a spatial pattern, in which small juveniles occurred in the mouth of the bay, the larger ones in the bay habitats, and the largest individuals were found on the reefs. From this we argue that juveniles of *Scarus iserti*, *Ocyurus chrysurus* and *Haemulon flavolineatum* perform Stepwise Life-Cycle Migrations. This type of migration, combined with habitat preference, shows that reef fish using in-bay habitats in post-settlement life stages may do so by actual choice, and underline the necessity of these habitats to Caribbean coral reef systems.

SPECIES DIVERSITY, ABUNDANCE AND BIOMASS OF THE FISH ASSEMBLAGES INHABITING NON-REEFAL CORAL COMMUNITIES IN SUB-TROPICAL HONG KONG, CHINA.

Cornish A.S.*. *Department of Ecology and Biodiversity, The University of Hong Kong, Pokfulam Rd., Hong Kong, China. Email: ascornis@hkusua.hku.hk

The fish assemblages associated with 3 non-reefal coral communities in sub-tropical Hong Kong, China are described in terms of species diversity, abundance and biomass. Fish assemblages were quantified over two years using an Underwater Visual Census (UVC) methodology tested for accuracy and precision. One hundred and ninety-five species were noted in total from the 3 sites and 58 of these were recorded by UVC. Nine species from 8 families dominated both abundance and biomass of the non-cryptic fish fauna. Biomass from UVC estimates averaged only 15.5 $g.m^{-2}$ in the shallows where the coral community was most developed. Low biomass was believed to be at least partly due to the low density of larger fish (> 20 cm). Comparisons of fish biomass are made with other Indo-Pacific localities and potential explanations for the low biomass are discussed.

THE DISJUNCT DISTRIBUTION PATTERNS ON THE SOUTHWESTERN ATLANTIC REEF FISHES.

Floeter S.R.*, J-C. Joyeux, C. E. L. Ferreira & J. L. Gasparini. Universidade Estadual Do Norte Fluminense - Lca. Campos Dos Goytacazes, Rj, 28015-620, Brazil. Email: floeter.vix@zaz.com.br

While the reef ichthyofauna of the western North Atlantic has been subject to substantial study, the South Atlantic has remained poorly known. In this work we documented disjunct patterns of distribution and investigate ecological and oceanographical factors, extinctions and dispersal abilities that possibly determined the observed patterns. The study was based on the recorded occurrences of conspicuous characteristic reef-associated fishes in the SW Atlantic continental shelf and oceanic islands. Some intriguing distribution patterns were found, especially in oceanic islands. We documented what seems to be a short-term extinction of a fish species, various records of vagrant species “too far” from original populations, as well as the absence of wide-ranging species (that theoretically do not have larval dispersal restrictions) from certain sites. Thus, we infer that: 1) long distance dispersal processes and subsequent colonization are more common than generally predicted, 2) local extinction processes of apparently established populations are probably more frequently than usually expected, and 3) ecological factors such as food or habitat availability, competitive exclusion, or requirements for proper larval development are also important in determine the long-term success of colonists. The disjunct patterns of distribution found in the sw atlantic reef fishes are therefore the outcome of the interaction of long distance dispersal and ecological processes that may led to species extinction, more often than generally expected.

BRAZILIAN REEF FISHES: HIGHLY ENDEMIC.

Guimarães R.Z.P.*. *Laboratório de Biodiversidade de Recursos Pesqueiros, NIGP/UFRJ, Depto Biologia Marinha, Cidade Universitária, 21941-569, Rio de Janeiro, Brazil. Email: ricardo@biologia.ufrj.br

Since the earlier biogeography text books by Sven Ekman and John Briggs indicated the existence of an endemic component of the Brazilian shore fauna, it has been shown that such component is much more significant and several subsets can be recognized. Many new species of reef-associated fishes have been identified, some restricted to different segments of the Brazilian coastline, some endemic to each of the three insular complexes within Brazilian territorial waters: Martin-Vaz - Trindade, Atol das Rocas - Fernando de Noronha and São Pedro - São Paulo, and some distributed in a combination of two or more of these areas. From large conspicuous dasiatid rays to small secretive scaled-blennies, the list of Brazilian shallow-reef endemics is rapidly growing, reaching a rate of about 20 %. In the last decade of the century, one chaetodontid, two syngnathids, two opistognathids, three pomacentrids, four blenniids, six gobiids and eight labrisomids have added to the list. Among described TECO events that could be related to the existence of such a major area of endemism and its subsets are the late Pleistocene sea-level changes.

ECOSTRUCTURE AND SPATIAL DISTRIBUTIONOF CORAL REEF FISHES (FAMILY LABRIDAE) IN THE WATERS OF AMBON BAY

Hukom, Frensly D* *Departemen of Marine Resources, CRD-Oceanology, Indonesian Institute of Science,Jakarta, Indonesia

The research was conducted at Ambon bay, in May 1997. The objectives of this research is to study the community structure and spatial distribution of Labridae. For this purpose, six stations were chosen purposively. It was found around 50 species of Labridae in Ambon Bay. Diversity index value was 0.92 – 3.02, Evenes index value was 0.91 – 0.99 and Dominance value was 0.01 – 0.866. The quantitative spatial distribution of Labridae assosiated with coral growth lifeforms, evaluated by matching correspondence analysis and hierachical cluster analysis. The result showed that the species of Labridae- *Halichoeres melanurus* were assosiated with types of coral lifeform Macro algae, similarly, the Labridae *Pseudocheilinus hexataenia* were corelated with Coraline Algae coral life form, whereas *Cirrhilabrus cyanopleura* were assosiated with branching corals.

DISTRIBUTION AND ABUNDANCE OF BLUECHIN AND BICOLOR PARROTFISH IN TWO GORGONA ISLAND CORAL REEFS (TROPICAL EASTERN PACIFIC).

Jiménez, J. M.* and Zapata, F. A.. *Universidad del Valle, A.A. 25360, Cali – Colombia, S.Am. Email: jumajime@biologia.univalle.edu.co

To document patterns of spatial and temporal variation in the distribution and abundance of *Scarus ghobban* and *Scarus rubroviolaceus* population at La Azufrada and Playa Blanca reef, Gorgona Island (Tropical Eastern Pacific), visual censuses were done on quadrates and belt transects between November 1992 and December 1993 and September and October 1997, respectively. At Playa Blanca abundance for *S. ghobban* (the only parrotfish species present at the reef) considerably decreased from the Backreef trough the reef Slope and small individuals were by far more abundant than medium and large individuals. Those differences seem to be related to the distribution of foraging substrates, shelter abundance, intra and interspecific competition and ability to escape from predators. In contrast, at La Azufrada, no differences in the abundance of *S. ghobban* or *S. rubroviolaceus* among zones or sampling months were detected. Those results are intriguing due to similarity and proximity of both reefs. Only differences in the abundance were detected between the two species over the year of study. *S. ghobban* reached it's maximum in April – May and *S. rubroviolaceus* in August. Overall densities and maximum sizes of *S. ghobban* at Gorgona island, were greater than those reported by other studies for many Caribbean and Indopacific parrotfish species. These higher densities and maximum body sizes may be supported by a greater food supply in the T.E.P. due the greater nutrient concentration on the water.

BUTTERFLYFISH POPULATION DIVERSITY IN YANBU CORAL

Joseph, P.S.*, & Sy, Jaime C. *Former Project Manager, GSTE-4032, Royal Commission for Jubail & Yanbu, Yanbu, Saudi Arabia. Email: dilu@eth.net

A species diversity and population evenness of reef fishes- namely, butterflyfish (Family Chaetodontidae) at locations subjected to sedimentation loading (Gap & SE End stations) on Yanbu Port Barrier reef and at Control station were assessed for the indirect effect of coral reef health on the butterfly fish population. All the ten fish species studied were present at Control station, with six at Gap station and seven at SE End station, with five species present at all stations. The most common and abundant species was Chaetodon auriga. C. melanotus and C. paucifasciatus were recorded only at Control. No significant difference in species diversity was evident between Gap and SE End stations. A significant difference was evident between the pooled data of two locations and the Control. No significant difference in population evenness among the stations was evident. The number of individuals was significantly less in the Port barrier reef, as was the number of species. The low coral cover and high algal growth in the Port Barrier reef clearly indicated that the removal of live coral was not the only negative effect of man made stresses but also had reduced the number of associated species proportionately. One of the first fish populations affected by the environmental stress is the coral reef feeder and for this reason butterflyfish stands as a candidate for environmental quality indicator.

FISH COMMUNITIES ON JORDANIAN CORAL REEFS AND ADJACENT HABITATS IN THE GULF OF AQABA, RED SEA.

Khalaf M.* & Kochzius. Marine Science Station (MSS), University of Jordan, P.O. Box 195, Aqaba, Jordan. Email: maroof@ju.edu.jo

This study investigates for the first time the fish communities of shallow water habitats along the Jordanian coast. For the establishment of the joint Jordanian-Israeli "Red Sea Marine Peace Park" it is important to collect baseline data for a proper management of the marine reserve. At each site permanent transects were marked, three at a depth of 5 m and three of a depth of 10 m. The main focus is on Al Mamlah Bay, because this bay is considered to be one of the most productive parts of the Jordanian coast. It is characterized by the presence of well developed coral reefs at the south and northern part of the bay, and seagrass beds in the sandy bottom in the middle. 194 species belonging to 122 genera and 43 families were identified. Most individuals belong to the families Serranidae, subfamily Anthininae (38.8%), Pomacentridae (20.2%) and Labridae (7.9%). Shannon-Wiener-index indicate a significant lower diversity in shallow (1.49) than in deep transects (2.00) (ANOVA, $p = 0.001$). Cluster analysis by species shows two main cluster, one representing fishes of the coral habitat, the other fishes of the seagrass beds. Cluster analysis by samples indicates that the shallow water fish communities of Al-Mamlah Bay share the lowest similarity to all other transects. On the other hand deep transects of Al-Mamlah Bay were grouped with all other sites outside the bay. This indicates that Al-Mamlah Bay provides different habitats with distinct fish communities in a relatively small area. Therefore it is a very important part of the "Red Sea Marine Peace Park".

MONITORING OF CORAL REEF FISHES POPULATION IN THE BAY OF BUYAT AND RATATOTOK, NORTH SULAWESI.

Lalamentik L.Th.X.*; Dj.W. Emor, A.B. Rondonuwu, U.N.W.J. Rembet; D. Sompie, J. Kojansow *Koordinator CRITC-4 Propinsi Sulawesi Utara; Staf Pengajar Pada Laboratorium Bio-Ekologi Laut Tropis, Program Studi Manajemen Sumberdaya Perairan Fakultas Perikanan dan Ilmu Kelautan Universitas Sam Ratulangi, Manado. Email: jkoj0638@corp.newmont.com

The aim of this research is to inform the reef fish population in coral reef area at the Bay of Buyat and Ratatotok, North Sulawesi. The method used is a 'Visual Census' on along 50 m line transect in 3 m and 10 m depth. The finding result, based on species total variable, individual abudant, and species diversity, showed that species population and target-predator population of reef fish, still categorized as good enough.

SPECIES RICHNESS AND ENDEMISM LEVELS OF THE SOUTHWESTERN ATLANTIC REEF FISH FAUNA,

Moura, Rodrigo L.*, and Sazima, Ivan *Museu de Zoologia, CP 42694 Universidade de Sao Paulo, 04299-970 Sao Paulo SP Brazil, Email: rlmoura@usp.br

We present a qualitative synopsis of the Southwestern Atlantic (Brazilian) reef-fish fauna, based on extensive recent collections, literature records and survey of museum specimens. Southwestern Atlantic reef-fish species richness is higher than previously reported, but considerable lower than that of the Caribbean region. The current idea that the tropical West Atlantic has a relatively homogeneous reef-fish fauna is questioned and we suggest that it is biased by the lack of Brazilian specimens in taxonomic revisions of several groups. Levels of endemism within reef fish families show a strong negative correlation to dispersion capabilities, with a few exceptions. The wide taxonomic spectrum of fishes bearing Brazilian-endemic species, from elasmobranchs to tetraodontiforms, indicates that major cladogenetic events effectively isolated some groups in the Southwestern Atlantic. Plio-Pleistocene sea-level fluctuations may account for breaking gene-flow between the Caribbean and the Southwestern Atlantic during regressive periods, allowing allopatric speciation. A species/area relationship may explain the low species richness of the Southwestern Atlantic, besides other historical and ecological factors.

REEF FISH COMMUNITIES OF MEXICAN CARIBBEAN: A MULTI-SPATIAL AND MULTIVARIATE ANALYSIS.

Núñez-Lara, E.* and Arias-González, Ernesto. *Centro de Investigación y de Estudios Avanzados IPN, Carretera Antigua a Progreso Km 6, AP 73, CP 97310, "Coordemex" Mérida, Yucatán, México. Email: enunez@mda.cinvestav.mx

An analysis based on a spatial hierarchical design was made of reef-fish community structure on eight reefs in the Mexican Caribbean. Comparisons at different spatial scales were established to detect statistically significant differences in the ecological descriptors of fish communities. The selected reefs were distributed in three regions according to their latitudinal position, with a distance of 20-30 km between each other. Four reefs are included in a human protected area (Sian Ka'an Biosphere Reserve) and the remaining four in an unprotected area, subject mainly to fishing pressure. Two habitats (lagoon and reef slope), and 18 transects by habitat (replicates) were sampled. Fish and habitat data were obtained using, in the first case, visual census technique, and in the second, detail measures and substratum video. One hundred and twenty eighth fish species belonging to 40 families were identified. A one-way ANOVA did show statistically significant differences ($P>0.05$) in the species richness and in the abundance values of reef fishes among regions. At reef scale did was not significant difference ($P<0.05$) in the fish species richness and in the abundance, among reefs belonging to the same region, but did was between reefs of different regions. The results suggest that the difference observed among regions (hundreds of kilometres) could be attributed to a combination of natural and anthropogenic effects. Geomorphologic similarities among reefs of the same region (tens of kilometres) to seem to have greater influence than the effects of the human activities to defined spatial patterns of fish communities.

PERSISTENCE IN A REEF FISH ASSEMBLAGE MEASURED ON A LARGE SPATIAL SCALE.

Pattengill-Semmens, Christy V.*. *Reef Environmental Education Foundation, P.O. Box 246, Key Largo, FL, 33037, USA, Email: Pattengill@mailexcite.com

Documenting the natural variability inherent in a system is vital to understanding change. The variability in the presence and abundance of reef fishes remains poorly understood. Recruitment dynamics can influence the stability of a coral reef fish assemblage due to the pelagic nature of most species, and several studies have found that an assumption of stable and organized systems may not apply to reef fish assemblages. A three-year monitoring study was conducted in the Flower Garden Banks National Marine Sanctuary, three banks in the northwest Gulf of Mexico. These banks have large, continuous reefs and support coral reef fish assemblages. Fishes were visually censused semi-annually using a point-census method and the persistence in species presence and abundance was measured. Results suggest levels of stability higher than those reported from patch reefs. In addition, greater stability was evident at the feeding guild level, suggesting underlying organization. The size of the banks, their predictable physical environment, and their reduced species richness all likely affect the variability of these assemblages. The data collected in this study provide persistence information that can serve as a baseline for future monitoring in the Sanctuary. By studying natural variability, resource managers and scientists will be able to make reasonable and accurate assessments of community health in the face of natural and anthropogenic change.

DISTURBANCE ALTERS HABITAT ASSOCIATIONS AND FEEDING PREFERENCES OF SYMPATRIC BUTTERFLYFISH.

Pratchett, Morgan.*, *School of Marine Biology and Aquaculture, James Cook University, Townsville Q4811, Australia. Email: morgan.pratchett@jcu.edu.au

Recent outbreaks of the crown-of-thorns starfish, *Acanthaster planci* (L.), have greatly modified the composition and structure of benthic reef assemblages at Lizard Island, on the northern Great Barrier Reef. Such disturbances are likely to have major repercussions for fish communities, particularly butterflyfish (Family Chaetodontidae) which are dependent on benthic assemblages for both food and shelter. This study examined the distribution, abundance, and feeding preferences of 16 species of *Chaetodon* butterflyfish over five years from 1995 to 2000. Individual *Chaetodon* species responded very differently to disturbances caused by *A. planci*. The most notable responses were those of specialist corallivores, *Chaetodon trifascialis* and *C. baronessa*. *Chaetodon trifascialis* underwent rapid population declines and became virtually extinct on reefs affected by *A. planci*. Whereas, the apparent feeding specialist *C. baronessa* responded to the disturbance by expanding both the range of prey it consumed and also its depth distribution. Consequently there was only a limited decline in the abundance of *C. baronessa*. Annual monitoring is continuing to assess the changes in the distribution, abundance, and feeding preferences *Chaetodon* populations, as the reef recovers from *A. planci* outbreaks.

MULTI-LEVEL COMPARISON OF SCALES OF FISH-BENTHOS CORRELATIONS

Rañola, Maria Catalina G.* and Porfirio M. Aliño. The Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines. Email: catski@msi01.cs.upd.edu.ph

The correlation between the distribution of reef-associated fish assemblage and benthic cover is usually evident at the various scales considered in most reef studies. However, little is known about such correlation when small-scale patch distribution is considered. The study attempts to determine emergent patterns of correlation between small-scale patch patterns in reef fish distribution and benthic cover. Fish visual census and benthic lifeform surveys were undertaken in two offshore reef complexes, the Kalayaan Islands Group, South China Sea and the Tubbataha atolls. Twenty 150 m x 10 m belt transects representing as many sites were surveyed. Fish species were recorded every 5 m segment. Coral cover was determined using the line intercept technique in three 30 m segments along the transect. Patch distribution was obtained using a combination of divisive clustering, species-area curve, occurrence and abundance analyses. Analyses of lifeform benthos and fish correlations were made at various scales. The complementary information derived from small-scale insights in relation to overall transect information further refines the understanding of the dynamics in reef complexes.

REEF FISH STRUCTURE AND THEIR FEEDING ECOLOGY ON SEAGRASS MEADOWS IN HURUN BAY, SUMATRA, INDONESIA.

Supratomo, Raden Tomi*. Wisma Asri, Jln. Gugahsari no.6, Gg. Sd Insan Kamil, Marga Jaya, Darmaga, Bogor. Email: toimboy@yahoo.com

Observation of community structure and feeding ecology of fish on seagrass beds were conducted from September to November 1999 in Hurun Bay, Sumatra. This research aims to investigate community structure, feeding ecology and food habit of reef fish on seagrass beds. This information is useful in the study of the functional of seagrass ecosystem. Tha data could make us better understand the seagrass role and contribution to coastal habitat, especially coral reef, supporting the formulation of coastal managament policy, and the restoration and conservation of natural resources. Sampling was undertaken at five station (station 1 - 5). Trammel net, mesh size 25 mm (1 piece) and 60 mm (2 pieces), was used to collect fish and operated on seagrass-reef border, day (2 hour) and night (2 hour). Species diversity (*H*) and evennes (*E*) indices based on numbers of each species were calculated using the Shannon-Wiener function and the evennes equation: $E = H/H_{max.}$ Environmental parameter analized with Principal Component Analysis (PCA). Correspondence Factorial Analysis (CA) were used to asses correlation between seagrass-study site and fish-seagrass. The stomach contents were indentified and counted under a binoculare microscope and food habit measured with Index of Preponderance.

CORRELATION BETWEEN THE ABUNDANCE OF BUTTERFLYFISHES AND CORAL COMMUNITIES OF THE SOUTHERN RED SEA.

Zekeria Z. A.* and Videler, J. J. *University of Asmara Marine Sciences Field Station P. O. Box 324 Massawa ERITREA Email shark@eol.com.er

Relationships between percentage coral cover and the abundance of butterflyfishes were investigated across 15 reefs around Massawa in the Southern Red Sea. The surveyed reefs had different proportions of live coral cover. Visual census of butterflyfishes were conducted along 100 meters line transects and the nature of the substrate was investigated using quadrat method. Five Chaetodontid species and fourteen genera of scleractinian corals were recorded from the study site. Among the butterflyfishes, the abundance of *Chaetodon larvatus*, *C. semilarvatus* and *C. mesoleucos* showed significant positive correlation with the live coral cover (p=0.000, 0.012 and 0.040 respectively). On the other hand, the relationships between coral cover and the abundance of the remaining two species (*C. fasciatus* and *Heniochus intermedius)* were not significant. The first two-butterflyfish species are corallivores while the last three species feed mainly on turf algae and/or invertebrates. This result suggests the existence of strong link between corallivorous chaetodontids and the cover of live scleractinian corals.

Session A22: Coral-algal Interactions, Marine Plant Dynamics and Roles and Phase Shifts of Reefs

THE DISTRIBUTION AND SOME VEGETATIONAL ASPECTS OF ECONOMIC SEAWEEDS (MACRO ALGAE) ON THE CORAL REEF OF INDONESIA,

Atmadja, Wanda S. *Research and Development Centre for Oceanology, Indonesian Institute of Sciences, Jl. Pasir Putih I, Ancol Timur, Jakarta Utara. Email: procoremap@attglobal.net

Seaweeds of Indonesia have long been of interest to people, especially in their relationships within commercial uses for domestic consumption and for export. *Eucheuma* spp., *Gelidium* spp., *Gracilaria* spp., *Hypnea* spp., and *Caulerpa* spp., are recognized as economic seaweeds of Indonesia. These seaweeds are commonly grow on any hard substrates under suitable sites on the coral reefs which are extensively found in the Indonesian waters. The distribution of these seaweeds on the coral reefs are characterized by the extends of water movements including water tides, topographical preferences and also subject to the competition and predators. From these viewpoints, there are some data and information to be described in this paper based on the results of research activities conducted in Indonesia.

FLORISTIC AND ECOLOGICAL STUDIES OF CRUSTOSE CORALLINE ALGAE ON BRAZIL'S ABROLHOS REEFS.

Figueiredo, M.A de O..* and Steneck, Robert S.. *Instituto de Pesquisas Jardim Botanico do Rio de Janeiro, Rua Pacheco Leao 915, Rio de Janeiro, RJ, 22460-030 Brazil. Email: mfigueir@openlink.com.br, steneck@Maine.EDU

Brazil's Abrolhos reef National Park biota is isolated from the Caribbean by the Amazon River. Its reefs are unique; dominated by an endemic genus of coral. We systematically collected and identified the crustose coralline algae relative to herbivory and overgrowth from filamentous algal turfs and fleshy macroalgae. The coralline flora has relatively low species diversity. Zonal dominance at the coralline subfamily and functional group levels was similar to that observed throughout the the tropics. That is, shallow zones were dominated by thick, adherent Mastophoroidea crust and the complexly branched Lithophylloidea crust. In contrast, deeper zones or in shallow zones under macroalgae were often dominated by relatively thin, leafy corallines such as some Melobesioidea. There was a strong inverse relationship between filamentous turf and coralline algal abundance. Corallines thrived under conditions of little or abundant foliose algae but were rare under conditions of intermediate foliose algal biomass. This complex relationship reflects the functional differences between subcryptic (melobesioid) algae that thrive under macroalgal canopies and the massive and complexly branched *Lithophyllum* corallines that dominates in habitats with low macroalgal biomass. Rates of herbivory were low at all sites and comprised primarily of acanthurid grazing (with little scarid grazing). Coralline abundance varied inversely with our measured fish bite-rates. With depth, fish bite rates declined and coralline abundance increased.

VARIABLE EFFECTS OF MACROALGAE ON HARD CORALS.

Jompa, Jamaluddin*, and McCook, Laurence J. . *Marine Biology Dept. James Cook University, Australia & Marine Science Dept. Hasanuddin University, Indonesia. Email: Jamaluddin.Jompa@jcu.edu.au.

Interactions between macroalgae and scleractinian corals are important to the structure of coral reefs, especially during reef degradation. However, their competitive outcomes are not uniform. We here report several studies demonstrating a range of effects of macroalgae on corals, from negative, neutral, to positive. The filamentous red alga *Corallophila huysmansii*, for example, can invade and kill live tissue of *Porites cylindrica*, apparently by allelochemical effects. Another filamentous red alga, *Anotrichium tenue*, can encroach on healthy coral *Porites lobata*, but coral death appears to result from trapped sediments. Both these algae also act as pioneer species allowing other 'common' turf algae to settle on dead coral skeleton after the infection. The foliose brown alga *Lobophora variegata* can overgrow and kill *P. cylindrica*, especially under conditions of reduced herbivory. However, we also found that this coral also inhibits the growth of *Lobophora*, indicating an active and reciprocal competitive interaction. Observations of *Chlorodesmis fastigiata* ("Turtle Weed") and *Hypnea pannosa* growing on live corals suggest that those macroalgae had relatively neutral or minor effects on the corals. Finally, in the 1998 bleaching event we recorded that hard coral bleaching increased in plots from which the normally abundant canopy of *Sargassum* had been removed, suggesting that the algal canopy actually protected the corals. In summary, we argue that the effect of macroalgae on corals varies among algae and corals, and with circumstances, so that generalisations about coral-algal interactions should be treated with caution.

SPATIAL AND SEASONAL VARIATION IN PRIMARY PRODUCTIVITY OF SEAGRASS COMMUNITIES IN BON ACCORD LAGOON, TOBAGO.

Juman, Rahanna.* *Institute of Marine Affairs, Hilltop Lane, Chaguaramas, Trinidad and Tobago. Email: Rjuman@Trinidad.net

The seagrass community in Bon Accord Lagoon covers an area of about 53.6 ha and is one of the largest communities found in Trinidad and Tobago, and the best example of contiguous coral reef, seagrass bed and mangrove swamp. Turtle Grass (*Thalassia testudinum*) is the dominant species and the focus of this study. Standing crop biomass, areal productivity and percentage turnover rates for *Thalassia* showed seasonal and spatial variations. These parameters were higher in the dry season (January-May) than in the wet season (June- December). Standing crop was 35.9 g dry wt m^{-2} in the dry season and 13.8 g dry wt m^{-2} in the wet season while areal productivity was 4.9 and 3.9 g dry wt m^{-2} d^{-1} respectively and percentage turnover rate per green biomass of plant per day was 5.6 and 4.7. Standing crop biomass, areal productivity and percentage turnover rates were higher in the back reef area than in the mangrove-fringed Lagoon and lowest at sites subjected to nutrient enrichment. The major factors influencing seagrass productivity in the Bon Accord Lagoon were turbidity and nutrient effect, which varied seasonally, while annual areal production was estimated at 249 metric tonnes of dry weight.

TOP-DOWN VS. BOTTOM-UP CONTROLS OF CORAL REEF COMMUNITY STRUCTURE.

Littler, M.M. & Littler, D.S. *Smithsonian Institution, Washington, D.C., USA. Email: Littler.Diane@MNNH.SI.EDU

This study used bioassays and manipulative experiments of herbivory (i.e., top-down control) and nutrients (i.e., bottom-up control) to assess the interactive mechanisms controlling phase shifts among the major space-occupying primary producers on coral reefs. Low nutrients alone did not preclude fleshy algal growth when herbivory was reduced. Coral cover decreased concomitant with algal increases under elevated nutrients relative to low nutrients; such consistent changes in abundances led to profound long-term effects.

MARINE PLANT IDENTIFICATION FOR CORAL REEF RESEARCH.

Littler, D.S. & Littler, M.M.. Smithsonian Institution, Washington, D.C., USA. Email: Littler.Diane@NMNH.SI.EDU

Because of the rapid deg radation of tropical reefs, it is imperative that they be studied from all aspects in a timely, efficient and scientifically verifiable manner. Marine plants, in conjunction with coelenterate corals, are the major primary producers and builders of many reef systems, impacting most fields of sciences whether it be the study of fisheries resources, invertebrates, marine chemistry, ecology, geology or any of the associated biological disciplines. It is essential that marine scientists, regardless of discipline, have a usable means of accurately identifying the principal marine plants which form the basis of the food web and play major roles in building and maintaining living reef structures. Our goal is to make algal identification possible for ecologists, physiologists, chemists, geologists, coastal-zone managers or any other scientists, including both amateur and professional biologists. We have just completed a "user-friendly" identification guide to the reef plants of the Caribbean region, relying where possible on vegetative rather than on technical reproductive characteristics for determinations.

ALGAE-CORAL INTERACTIONS: MEDIATION OF CORAL SETTLEMENT, EARLY SURVIVAL AND GROWTH BY MACROALGAE IN THE CENTRAL PHILIPPINES.

Maypa, A. P. * Raymundo, L.J.H. Calumpong, H.P. and de Leon, R.O.. Silliman University Marine Laboratory, Dumaguete City 6200, Philippines. Email: ai@fil.net

Degraded Philippine reefs are often colonized by macroalgae which can impact coral recovery. This study examined morphological and chemical effects of four macroalgal species on early life history of the coral *Pocillopora damicornis.* Morphologies of *Sargassum polycystum* and *Laurencia papillosa* significantly inhibited larval settlement, juvenile survival and growth, while their exudates enhanced settlement (*S. polycystum:* 67%±6; *L. papillosa:* 71%±4; control: 20%±4). Neither morphology nor exudates of *Halimeda opuntia* and *Peyssonnelia rubra* significantly affected larval settlement, but juveniles survived less in aquaria containing *H. opuntia*. Survival was facilitated in aquaria with *P. rubra*. Colonies growing with *L. papillosa* (5±0.8) and *S. polycystum* (4±0.1) were significantly smaller at three months than those with *H. opuntia* (6±0.9) and *P. rubra* (6±0.6). Our findings show that these common macroalgae can impact coral settlement and early life history, and these impacts vary between species.

EFFECTS OF ERECT ALGAL REDUCTION MANIPULATIONS ON FISHES IN KENYAN AND BELIZEAN CORAL REEFS

McClanahan, Tim R.* *The Wildlife Conservation Society, Coral Reef Conservation Project, P.O. Box 99470, Mombasa, Kenya Email: crcp@africaonline.co.ke

Reports of fleshy erect algae overgrowing corals and changing coral reef ecology has increased during the past 20 years, but most studies have focused on coral-algal rather than algal-fish interactions. Experimental methods to reduce macroalgal abundance were explored in areas > 100 m^2 in a coral reef park in Watamu, Kenya and Glovers Reef, Belize to determine the effects of these manipulation on the fishes. One experiment added ~2000 sea urchins from the Diademidae family to four experimental plots in Watamu to achieve a population density of 3 individuals per m^2. This manipulation attracted a large number of fishes and two species of sea urchin, *Diadema savignyi* and *D. setosum*, which were quickly eaten by two triggerfish predators, *Balistapus undulatus* and *Balistoides viridescens*. After the sea urchins were reduced other fish populations dropped. The second experiment physically reduced erect fleshy and calcareous algae with shears and wire brushes and was completed in both the Watamu and Glovers Reef, Belize. In Watamu, increased numbers of individuals and species were found for herbivorous surgeonfish and excavating and scraping parrotfish, but also for invertebrate-eating fishes including angelfish, butterflyfish, snappers, triggerfish, and wrasses.

COMPETITION BETWEEN CORALS AND BENTHIC ALGAE ON INSHORE CORAL REEFS OF THE GREAT BARRIER REEF.

McCook Laurence J.*, J. Jompa, G. Diaz-Pulido, R. Cumming, C. Mundy, I. Price. *Australian Institute of Marine Science & CRC: Reef Research, PMB #3, Townsville, Australia. Email: L.McCook@AIMS.Gov.Au

Competition between corals and benthic algae is critical to reef ecology and degradation, yet there is surprisingly little evidence rigorously demonstrating or examining this interaction and its variability. On inshore fringing reef flats of the Great Barrier Reef, it is argued that macroalgae are abundant because high nutrient and sediment inputs allow macroalgae to outcompete corals. We report here several studies which test this hypothesis. Extensive areas of healthy coral persist on these reef flats, even after recent severe bleaching events, even under luxuriant algal canopies. Previous work found that macroalgae are abundant because herbivores are scarce. However, this abundance may not cause exclusion of corals. Exclusion of herbivores from coral patches for 1_ years did not cause large increases in macroalgae, nor declines in corals. Removal of macroalgal canopy from large plots indicated that the canopy actually protected established corals from bleaching. However, coral recruitment was reduced by the algal canopy. Small-scale competitive interactions between algal turfs and massive *Porites* along a water quality gradient suggested that corals were the superior competitor, and were in fact most successful on the reef most exposed to terrestrial runoff. Together these results suggest that i. competition between corals and algae is neither uniform nor simply predicted by nutrient supply; and ii. competition between established corals and algae may be less critical to reef degradation than the effects of algae on coral recruitment and recovery from disturbance.

EFFECTS OF SEDIMENTATION AND HERBIVORY ON MACROALGAL ABUNDANCE AND COMPETITION WITH CORALS ON A CARIBBEAN CORAL REEF.

Nugues, M.M.*, C.M. Roberts, J.P. Hawkins. *Environment Department, University of York, York YO10 5DD, UK. Email: mmn100@york.ac.uk

Many disturbances presently affect coral reefs. In numerous areas, these combine to promote shifts from coral to macroalgal dominance. However, their interaction and relative importance are often unclear. We examined spatial and temporal variation in macroalgae and parrotfish abundance along four nearshore-to-offshore gradients in St. Lucia, two exposed to river sediment discharge and two serving as low sediment controls, to try to partition the role of sedimentation and herbivory on macroalgal abundance. Macroalgal cover was lower both in areas exposed to river sediments and in areas having the highest parrotfish biomass. Where macroalgae were abundant, their competition with corals, as measured by the amount of live or bleached coral surface area covered by macroalgae, was also high. Surprisingly, while parrotfish biomass increased three fold throughout the study area, macroalgal cover remained steady. We conclude that both sedimentation and herbivory are important factors determining the distribution and cover of macroalgae. However, the potential to reverse large-scale phase shifts from coral to macroalgal communities by restoring herbivore populations may be limited by the existence of a size-response by grazers to algae (large macroalgae are less palatable that small) and by sedimentation.

CHEMICAL ECOLOGY OF BENTHIC MARINE CYANOBACTERIA.

Paul, Valerie J. *, Thacker, Robert W. Manglona, Jesse B. *University of Guam Marine Laboratory, UOG Station, Mangilao, Guam. Email: vpaul@uog9.uog.edu

Cyanobacteria are abundant in coral reef habitats around Guam. They sometimes form thick mats covering large areas of the reef which we call cyanobacterial blooms. They produce many different nitrogenous secondary metabolites. We hypothesized that cyanobacteria are unpalatable to a variety of reef herbivores because they are chemically defended. In laboratory experiments, we tested the palatability of 27 different collections of cyanobacteria to three herbivores common to reef habitats on Guam: the parrotfish *Scarus schlegeli*, the sea urchin *Echinometra mathaei* and the sea hare *Stylocheilus longicauda*. We compared the consumption of freeze-dried, powdered cyanobacteria to freeze-dried powdered *Enteromorpha clathrata*, a palatable green alga. We also compared the consumption of *E. clathrata* coated with crude organic extracts of cyanobacteria to uncoated *E. clathrata*. All strains, when freeze-dried and powdered, were deterrent to all three herbivores; however, it is unclear whether this deterrence is due to secondary metabolite content, low nutritional value, or other factors. Most organic extracts tested deterred feeding by the parrotfish and sea urchin but stimulated feeding by the sea hare, a more specialized consumer of cyanobacteria. We propose that the production of deterrent secondary metabolites by many benthic cyanobacteria provides protection from grazing by generalist herbivores and can facilitate the formation of cyanobacterial blooms in coral reef habitats.

SHIFTS IN MICROHABITAT UTILIZATION BY THE THREESPOT DAMSELFISH *STEGASTES PLANIFRONS*: IMPLICATIONS FOR ALGAL DYNAMICS ON CARIBBEAN CORAL REEFS.

Precht, William F. * , Kaufman, Leslie S. and Aronson, Richard B.. *PBS&J, 2001 NW 107th Ave., Miami, FL 33172, Email: Bprecht@pbsj.com

The threespot damselfish, *Stegastes planifrons* (Cuvier), is important in mediating coral-algal, herbivore-algal, and herbivore-herbivore interactions on Caribbean coral reefs. Throughout the region, the primary microhabitat of the threespot damselfish was thickets of the branching staghorn coral *Acropora cervicornis*. Within the past few decades, mass mortality of *A. cervicornis* due to white-band disease and other factors, has nearly eliminated this coral throughout its range. The loss of the threespots' primary microhabitat has caused a shift in the distribution and recruitment of these damselfish onto remaining high-structured corals, especially the *Montastrea annularis* species complex. The consequence of this microhabitat shift has been an increase in coral predation caused by the biting of living tissue and the tending of algal gardens on the *Montastrea* species complex resulting in significant coral mortality and overgrowth by fleshy and filamentous macroalgae. Evidence from Jamaica (heavily fished), Florida (moderately fished) and Belize (lightly fished) indicates that threespot distribution patterns are positively correlated with live coral cover and topographic complexity. These data suggest that species specific microhabitat preference and/or availability of topographic complexity is more important than abundance of predatory fish in controlling their distribution and abundance.

THE EFFECT OF ALGAL TURFS ON POST-RECRUITMENT PROCESSES IN JUVENILE CORALS IN THE CARRIBEAN.

Prude, Traci M.* And Edmunds, Peter J.. *Department Of Biology, California State University, 18111 Nordhoff St., Northridge, California, Usa 91330-8303. Email: traci.m.prude@csun.edu

Post-recruitment events affecting scleractinian corals cannot be described fully without considering the interaction between corals and other taxa. This study examined whether the growth, morphology, and oxygen microenvironment of juvenile and small adult corals were affected by interactions with algal turfs on the forereef of Discovery Bay, Jamaica. In situ growth rates of *Siderastrea siderea* and *Agaricia agaracites* were significantly lower for colonies located inside algal turfs than for colonies that occurred alone. Mensurative experiments demonstrated that there was a significant difference in the morphology (i.e., colony shape) of*S. siderea* and *A. agaracites* colonies located inside versus outside of algal turf habitats. In the laboratory, under high versus low flow and day versus nighttime conditions, O_2 levels adjacent to coral tissues differed significantly between turf and non-turf treatments. For juvenile and small adult corals found within algal turfs, the physical microenvironment may influence survivorship by indirectly affecting the growth and morphology of coral colonies.

CORAL REEF ASSOCIATED MACROPHYTES OF THE KALAYAAN ISLANDS GROUP, SOUTH CHINA SEA.

Roleda, Michael Y.* and Maria Gregoria Joanne P. Tiquio. *The Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines. Email: maikee@msi01.cs.upd.edu.ph

Subtidal seaweeds associated with corals from 6 islands of the Kalayaan Islands Group (KIG), South China Sea were collected within the 150 m transect line concomitant for the coral and fish survey. Intertidal seaweeds were collected haphazardly within the tide flat. Seaweeds were identified *in situ* and voucher specimen was processed for confirmation of the field identification. A total of 32 seaweed species was recorded in this study. Initial field identification of marine macrophyte showed Lawak Island with the most diverse subtidal species while Pagasa Island accounts for the most diverse intertidal species composition. The most diverse group of seaweed found in KIG belongs to the Genus *Halimeda*, where 4 out of nine species remain to be fully identified. These calcareous seaweeds are found to be abundant in the subtidal region, which provides one of the rare floristic reports for the area despite its recognized as predominant contributors to the bulk and frame structures of the majority of reef limestone deposits. This contributes to a total of 65 species reported by the Marine Science Institute expedition and biodiversity study in the area.

HERBIVORY AND NUTRIENT ENRICHMENT ON TROPICAL REEFS: AN EXPERIMENTAL ANALYSIS OF BENTHIC COMMUNTIY STRUCTURE IN HAWAII.

Smith, Jennifer E.*, Dr. Celia Smith & Dr. Cynthia Hunter. *Department of Botany, University of Hawaii, Manoa, 3190 Maile Way, Honolulu HI, 96822, USA. Email: jesmith@hawaii.edu

Phase shifts from coral to algal dominance on tropical reefs have become increasingly common over the last few decades, driving a need to identify potential causes leading to these shifts. Both "top down" (herbivory) and "bottom up" (nutrients) factors have been independently implicated as the primary mechanism affecting the abundance of algae on reefs. Studies of these factors have tended to be exclusive and have not considered the interactive relationships between the very different processes involved. Littler and Littler (1984) proposed the Relative Dominance Model (RDM) whereby, the dominant benthic photosynthetic organism is predicted as a function of long term exposure to both herbivory and nutrients. A randomized factorial block design was used to simultaneously test the effects of nutrient enrichment and herbivory on benthic communities. Total algal biomass was greatest on experimental surfaces that were exposed to both nutrient enrichment and herbivore exclusion simultaneously. Fleshy algal biomass was highest on surfaces removed from herbivory while, calcified algal biomass dominated surfaces exposed to elevated nutrients. Species diversity estimates, successional patterns, microinvertebrate abundance and sediment accumulation also exhibited significant treatment effects. This research shows that nutrient enrichment and herbivore exclusion can separately and synergistically support shifts in benthic algal community structure on tropical reefs in Hawaii.

STUDIES ON THE EFFECT OF NITROGEN SOURCES ON THE GROWTH RATE, AGAR QUANTITY AND QUALITY OF THE RHODOPHYTA *GRACILARIA MARAMAE* .

Sulu, Reuben John*, *Institute of Marine Resources, University of the South Pacific P.O.Box 460, Honiara, Solomon Islands Email: rjsulu@welkam.solomon.com.sb

Studies on the effect of nutrients were conducted on the growth rate, agar quantity and quality of the Rhodophyta *Gracilaria maramae.* Nutrients investigated were the nitrogen sources ammonium (NH_4^+) and nitrate (NO_3^-). Ammonium produced better growth than nitrate as nitrogen source. Increases in ammonium concentration resulted in an increase in growth up to a concentration of 300 µm. Ammonium concentration above 300 µm resulted in a decline in growth. For the nitrate fast growth rates were obtained at a concentration of 100 µm. Further increase up to 300 µm does not result in an improvement in growth. Nitrate concentration of 500 µm resulted in a decline in growth rate. Native agar yield was higher in plants grown under nitrate as a nitrogen source, agar yield ranged from 21.78-27.155 %. Native agar yield from plants grown under ammonium sources as nitrogen source ranged from 18.13-26.75. Agar yield for ammonium was higher at the extreme high and lower concentrations and was lowest at 200 µm, with a yield of 13.25 %. The yields are not significantly different between sources and concentrations.

IS HERBIVORY THE PRIMARY STRUCTURING FORCE OF CORAL REEF ALGAL COMMUNTIES?

Wilder, R.M.*. *Dept. of Ecology, Evolution, and Marine Biology, University of CA, Santa Barbara, CA, 93106, USA. Email: wilder@lifesci.ucsb.edu

Coral reefs are among the most productive ecosystems on earth. However, their primary producers, algae, are often overlooked due to their short vertical profile and low standing stock. A major factor preventing macroalgal dominance on such reefs is intense herbivory by fish and sea urchins. However, it has been suggested that dissolved nutrient levels and water flow rates are also important. Using comprehensive surveys and experimental manipulations around the island of Moorea, French Polynesia, I determined the relative importance of these 3 factors (herbivory, nutrient concentration, and flow rate) on the distribution and abundance of algae. The biomass of algae protected from herbivores was positively correlated with dissolved $PO4^{3-}$ levels across 14 locations. No such relationship was observed when herbivores were present. Sites with high flow rate had high algal biomass. At all 14 sites, algal biomass was significantly higher on substrates protected from herbivores. I also performed a 3-way factorial experiment manipulating herbivore density, nutrient concentration, and flow rate. The change in algal biomass over 28 d was 130% greater where herbivores were excluded, 69% greater where nutrients were added, and 16% greater where flow rate was increased. When herbivores were absent, the effect of nutrient enrichment was 3X greater than when herbivores were present, revealing that, although nutrient levels are important to algal biomass, their effect is not realized unless herbivores are absent. These data suggest that all 3 factors structure the algal community -- herbivory being most important, followed by nutrient concentrations, then flow rate.

THE IMPACTS OF SEAWEED FARMING ON CORAL REEFS.

Zemke-White, W. Lindsey* *School of Biological Sciences, University of Auckland, Private Bag 92019, Auckland, New Zealand. Email: l.zemke-white@auckland.ac.nz

Worldwide, seaweed utilization generates in excess of US$6 billion per annum. Approximately half of this seaweed is harvested from the wild while the other half is produced on farms. In the tropics, seaweed farms are found primarily on coral reefs or reef flats and cover many thousands of hectares. The species farmed in this manner, *Eucheuma* spp. and *Kappaphycus* spp., are used to produce carrageenan. The supply of carrageenan is currently unable to meet the global demand and consequently seaweed farming is likely to expand throughout the tropics. Given a) this likely expansion and b) that seaweed farming in the tropics is carried out in close association with coral reefs, it is vital that we seek to understand the impacts that this farming might have. This paper reviews the literature on the environmental impacts of seaweed farming on coral reefs, discusses farming techniques which may ameliorate negative impacts and outlines areas which are in need of further research. Impacts are placed into 3 categories: 1) the effects of introducing seaweed species to a new location for the purposes of aquaculture, 2) the effects of farming operations, and 3) the effects of related human activities. Surprisingly few studies have investigated the impacts of seaweed farming on coral reefs. Given the spread of seaweed farming in the tropics and the possible impacts of this activity on coral reefs, it is suggested that a comprehensive study should be undertaken in a number of locations to monitor and fully assess the impacts.

Session A23: Coral Reef Symbioses and Interactions

CORAL REEF BENTHIC CYANOBACTERIA AS FOOD AND REFUGE: DIVERSITY, CHEMISTRY, AND COMPLEX INTER-ACTIONS.

Cruz-Rivera, E.* and Paul, Valerie J.. *University of Guam Marine Laboratory, UOG Station, Mangilao, Guam. Email: ecruzriv@uog.edu

Large filamentous cyanobacteria are important primary producers and conspicuous components of Pacific coral reef communities. These cyanobacteria produce a variety of secondary metabolites that serve as defenses against large grazers such as fish and urchins, but do not deter smaller, more specialized, consumers such as certain amphipods, sea hares, cephalaspideans, crabs and shrimp. The biodiversity of coral reef cyanobacteria and their associated fauna is largely unexplored, and our studies suggest that intraspecific variation among populations of both algae and consumers could be an important component of this biotic complexity. For example, different strains of the same cyanobacterial species may be differentially palatable to specialist consumers, but this in turn, is modified by the consumers' experience with a particular strain and population of origin. Our research demonstrates interesting parallels between the ecology and evolution of cyanobacterial-grazer interactions and those of better known algal-herbivore interactions.

MAJOR COLOUR PATTERNS OF REEF-BUILDING CORALS ARE DUE TO A FAMILY OF GFP-LIKE PROTEINS.

Dove, Sophie G.* & Hoegh-Guldberg, Ove. *Centre for Marine Studies, University of Queensland, QLD 4072 Australia Email: sophie@mailbox.uq.edu.au

Reef-building corals are renown for their brilliant colours yet the biochemical basis for the pigmentation of corals is unknown. Here we show that these colours are due to a family of GFP-like proteins that fluoresce under ultraviolet (UV) or visible light. Pigments from a broad spectrum of coral species were similar to previously isolated Pocilloporin (Dove *et al*. 1995) being dimers or trimers with approximately 28 kD subunits. Degenerative primers made to one of the common N-terminal amino acid sequence yielded a complete sequence from reef-building coral cDNA that had 19.6% amino acid identity with Green Fluorescent Protein (GFP). Molecular modeling revealed a '_-can' structure like GFP with 11 _-strands and a completely solvent-inaccessible fluorophore composed of the modified residues Gln-61, Tyr-62 and Gly-63. The molecular properties of these proteins indicate a range of functions from the conversion of high intensity UV radiation into photosynthetically active radiation (PAR) that can be regulated by the dinoflagellate peridinin-chlorophyll-protein (PCP) complex, to the shielding of the Soret and Q_x bands of chlorophyll a and c from scattered high intensity light. By changing the balance of these pigments within tissue, corals therefore have the ability to employ them either to protect the photosynthetic machinery of the symbiotic dinoflagellates of corals under high light conditions or enhance the availability of photosynthetic light under shade conditions.

MASS MORTALITY OF TRAPEZIAN CRABS IN CORAL REEFS OF GULF OF MANNAR (SOUTHEAST COAST OF INDIA)

Jeyabaskaran R.* and Venkataraman, K. *Marine Biological Station, Zoological Survey of India, 100 - Santhome High Road, Chennai - 600 028, INDIA. Email: jeybas@usa.net

Coral reef ecosystems are well known for their species richness, and also complexity. It is quite remarkable that an environment with so small area, has so much life and so many species and thus diversity. Coral reefs around the world are deteriorating rapidly. Some sources estimated that 10% of all reefs has been degraded beyond recovery and another 20 to 30% may be lost by 2010. The Indian part of Gulf of Mannar contains about 21 islands covering an area of 625 hectares and coral reefs of fringing and pach types extending from Rameswaram to Tuticorin (Lat. 8°50' - 9°10" N and Long. 78°10'-79°10" E covering a distance of 140 km). Brachyuran crabs constitute one of the most diverse components of coral reef communities and the brachyuran crabs associated with scleractinian corals have generated much interest. In this backdrop, extensive coral reef survey was done in the year 1997 and March to May 1998. The previous studies in the year 1997 showed only three species of Corallicolous symbionts namely *Trapezia cymodoce*, *T. areolata* and *T. ferruginea* crabs were found in the colonies of coral *Pocillopora damicornis*. The recent study results showed, all the coral colonies of *P. damicornis* in the coral reefs of Gulf of Mannar were died due to bleaching. These colonies were invaded by the boring sponges and covered by the turf algae. All the Trapezian crabs found in these colonies were died and these crabs were not found. The reason for the mass mortality of these corals and crabs are discussed in the paper in detail.

CHEMICAL ECOLOGICAL ASPECTS OF ANTIMICROBIAL ACTIVITY OF RED SEA CORALS AND SPONGES.

Kelman, Dovi*, Kashman, Y., Rosenberg, E., Ilan, M., Kushmaro, A. and Loya, Y. *National Center for High Throughput Screening (HTS) of Novel Bioactive Compounds, Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, ISRAEL. Email: kelmand@post.tau.ac.il

Living corals and sponges are frequently colonised by bacteria that may be pathogenic to them. One of the means by which they are able to combat microbial attack is by chemical defence. Organic extracts of several species of stony corals, soft corals and reef sponges from the coral reef of the northern Gulf of Eilat, Red Sea were tested for their antimicrobial activity against a panel of marine bacterial isolates. These bacteria were isolated from the natural environment of the corals and sponges being tested. None of the stony corals exhibited any significant activity against the test bacteria. On the other hand, three of the six soft corals tested exhibited appreciable activity against more than 50 % of the test bacteria. The soft coral *Xenia macrospiculata* exhibited the highest activity. The antimicrobial activity was due to the presence of a range of compounds of different polarities. One of these antibiotic compounds, 11,19-desoxyhavannahine, was successfully isolated and crystallised. Among the 11 sponges tested, *Amphimedon viridis* (Keller) exhibited the highest activity. Bioassay-directed fractionation of this sponge' extract resulted in the isolation of halitoxin. The antimicrobial assays suggest that the antibiotics of the studied reef corals and sponges possess specific antimicrobial activities rather than broad-spectrum activities.

FUNGI ASSOCIATED WITH GORGONIANS IN SINGAPORE: A PRELIMINARY STUDY.

Koh, Li Ling*; Koon, Tan Teck; Goh, Nigel;, Chou, Loke Ming. *Department of Biological Sciences, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260. Email: scip9543@nus.edu.sg

This preliminary study aims to establish the biodiversity of fungi associated with gorgonians as well as to investigate the differences in the type of fungi and the number of isolates found on healthy and unhealthy gorgonians. Gorgonian species chosen for this study were from 3 families: Ellisellidae, Plexauridae and Subergorgiidae to facilitate inter-family and inter-genera comparison of gorgonian-fungal association. Results obtained so far shows that there is no significant trend of unhealthy gorgonian possessing more fungal isolates that healthy gorgonians. Fungi isolated from both healthy and unhealthy gorgonians were also of similar genera. Fungi isolated were all Deuteromycetes (imperfect fungi) except for 1 ascomycete. The very common genera of fungi isolated include sterile fungi, *Aspergillus*, *Penicillium*, *Trichoderma* and *Cladosporium*. The less common genera include *Tritirachium*, *Gliomastix*, *Scolecobasidium* and *Acremonium*. This study seems to suggest that fungi are not the causative agent of gorgonian diseases on the reefs in Singapore. They may simply be the natural flora associated with gorgonians or saprophytes utilizing the dead tissues found on unhealthy gorgonians. A continuation of this study may give new insights into the implications of such fungal associations with gorgonians and the role they play in gorgonian diseases.

TENTACLE EXPANSION BEHAVIOR OF STONY CORALS SUGGESTS A LINK TO PHOTOSYNTHESIS OF ITS SYMBIONTS WITH RELATION TO ZOOXANTHELLAE DENSITIES.

Levy O.*, L. Mizrahi, D. Iluz, Z. Dubinsky, N. Chadwick-Furman and Y. Achituv *Faculty of Life Sciences, Bar-Ilan University, Ramat Gan 52900, Israel Email - levysher@netvision.net.il

Three species of corals with different patterns of tentacle expansion and contraction were investigated. *Favia favus* and *Plerogyra sinuosa* expand their tentacles nocturnally, while *Goniopora lobata* remains expanded constantly also during daytime. When colonies of *Favia favus* and *Plerogyra sinuosa* were exposed to weak (10 and 30 δE m^{-2} s^{-1}) monochromatic light (400-700 nm, at 20 nm intervals), it was found that wavelengths of 400-520 nm were the most effective in eliciting full tentacle contraction within a few minutes. Contraction also occurred at wavelengths of 660-680 nm, but only at a higher irradiance level (30 δE m^{-2} s^{-1}). Measurements of zooxanthellae densities within the tentacles, by confocal microscopy and flow cytometry (FCM), showed that nocturnally-active corals have significantly lower densities of zooxanthellae in their tentacles tissue compared to *G. lobata* tentacles. The expansion contraction behavior of stony corals may be at least partly mediated by the number of zooxanthellae in the tentacle tissues.We suggest that daytime expansion of corals with low densities of algae in their tentacles can lead to a self-shadow on the rest of the coral tissue which contain denser algae, leading to a decrease in overall photosynthetic ability.

THE SYMBIOTIC INTERRELATIONS OF CORALOBIONTS AND CORALS WITH AN EXAMPLE DECAPODA.

Marin Ivan N.*. Altai State University, Barnaul, Russia.: Email: ic771inm@ic.dcn-asu.ru.

Classic Crustacea is one of the more diverse components of ecosystem of coral reef. Total number of crustacea's species on Indo Pacific reefs exceed 1200, including 800 Decapods. Different representatives of Decapoda occupy in different ecological niches. Being a one of main fodder resources for filtering and predatoring fauna of fauna, Crustacea composite 20% of zooplankton, macro- and meiobenthos's species. Some Decapoda are predators, which occupy a top of food pyramid of coral reef. Most interesting field of studying Decapoda is symbiotic interrelations with corals and coral-dwelling animals. Looked over the spatial localization of ecological groups of Decapoda to different vital forms of corals, types of nourishment and ways of getting food, intensity and intimacy of connections coralobionts and host-coral. Almost all Decapoda possess adaptations (structural (morphological) and behavioral) to the life on the coral reef, which allow them to move inside coral colony, ability to escape from predators and hunting. Considering more closely interrelations Decapoda and other animals in ecosystem of reef allow to study ecosystem of coral reef more completely.

DISTRIBUTION OF THE *SPIROBRANCHUS CORNICULATUS* SPECIES COMPLEX IN PHILIPPINE CORAL REEFS.

Montebon, A. Rex F.*; and Yap, Helen T.. *The Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, Philippines. Email: arfmontebon@msi01.cs.upd.edu.ph

The distribution of the *Spirobranchus corniculatus* species complex was studied in 7 reefs over 2 provinces (>300km). Less than 10 species of corals, which comprised ~20% of the total encountered, were colonized by the Christmas tree worms. The massive ones were chiefly preferred over the other growth forms. This growth form also harbored the most number of large worms (~adults) in most sites. The degree of preference, from highest to lowest, is *Porites cf. lobata* (massive), *Porites cylindrica* (branching), *Porites rus* (submassive) and *Montipora* spp. (all massive). Number of worms seems to be higher in shallower depths but is clearly associated with the abundance of massive *Porites*. Orifice diameter of worm tubes and colony diameter of their coral hosts was positively correlated ($p<0.01$). Presence on dead corals was mostly limited to the larger worms. Apparently, longevity of coral hosts improves survival of the worms into adults (~fitness) and that smaller corals appear to be the preferred recruitment sites. Data also suggest that the obligate nature of the symbiosis, i.e., Christmas tree worms must associate with living corals, is temporary and important mostly in the initial stages of the association.

SYSTEMATICS AND ECOLOGY OF PREDATOR/PREY INTERACTIONS BETWEEN FACELINID NUDIBRANCH *PHYLLODESMIUM* AND OCTOCORAL COELENTERATES ON INDO-PACIFIC CORAL REEFS.

Ortiz, Delisse M.* *San Francisco State University. Email: delmar22@juno.com

The genus *Phyllodesmium* is among a unique group of aeolid nudibranchs that feed on a diverse array of octocorals throughout Indo-Pacific coral reefs. Previous studies have traced the evolution and the possible phylogenetic relationships between the species through adaptations from symbiosis with zooxanthellae (Rudman, 1981,1991). A preliminary phylogeny of the genus *Phyllodesmium* showed a close relationship among the species when taking into consideration the structure and arrangement of the cerata, branching of the digestive gland, position of anus and denticles on jaw plates. Most of the morphological characters show a high degree of variability among the species. Characters like the branching of the digestive gland, size and structure of the cerata display modifications for the storage of zooxanthellae. Of the fifteen species described to date, the majority are known to feed upon and store zooxanthellae in the cerata. They generally have been found preying upon alcyonacean octocorals. Among some of the corals they feed upon are *Xenia* spp., *Briareum* spp., *Sinularia* spp., *Stereonepthea* spp., *Acabaria* spp., and *Sarcophyton* spp. The predator/prey relationship between the *Phyllodesmium* species and octocorals is of significant importance in terms of understanding the ecological interactions and dynamics of biotic and abiotic aspects of these organisms regarding evolution. A diversity of nudibranchs store zooxanthellae for nutrition, and others store zooxanthellae without nutritive need, but rather to camouflage themselves with the octocoral they are foraging on (Rudman, 1987).

FATE OF INGESTED NITROGEN IN ANTHOZOAN SYMBIOSES.

Piniak, Gregory A.*; Lipschultz, Fredric; and Kirby-Smith, William W. *Duke University Marine Laboratory and Bermuda Biological Station for Research. 135 Duke Marine Lab Road, Beaufort, NC 28516 USA. Email: gap1@duke.edu

For nutrient recycling to occur in reef corals, zooxanthellae should utilize nutrients from host feeding, synthesize them into new products such as amino acids, and return these products to the animal host. Researchers have begun to examine nitrogen partitioning and amino acid synthesis in corals, but the use of nitrogen from host feeding has not been addressed. This study follows the metabolic fate of zooplankton nitrogen ingested by the sea anemone *Aiptasia pallida* and the temperate coral *Oculina arbuscula* under a variety of nutritional conditions using the stable isotope tracer ^{15}N. In all experiments both the host and zooxanthellae were highly labeled within 4 hours. Fed anemones retained less label than those that had been starved, and starved anemones with an inorganic nutrient supplement did completely compensate for a lack of ingested food. In *O. arbuscula*, these differences are seen in the zooxanthellae but not the host or the homogenate. For both species, there were no differences between treatments in the relative distribution of label among biochemical pools. The ethanol-soluble (low molecular weight) pool is the most highly labeled after 4 hours, but all biochemical pools are at approximate equilibrium by 24 hours. This study provides direct experimental evidence that zooxanthellae can rapidly acquire nitrogen obtained from host zooplanktivory.

CHARACTERIZATION AND EVOLUTION OF PCP GENES IN SYMBIOTIC DINOFLAGELLATES.

Reichman, Jay*, Vize, Peter; and Wilcox, Tom. *School of Biological Sciences, University of Texas at Austin, Austin, Texas, USA 78712. Email: j.reichman@mail.utexas.edu

Most symbiotic and free-living photosynthetic dinoflagellates photo-acclimate through light-regulated transcription of peridinin chlorophyll-a binding protein (PCP) genes. PCPs increase the efficiency with which blue-green solar energy is made available for photosynthesis. Laboratory examples of distinctive photo-acclimation patterns of *Symbiodinium* species and naturally occurring ecological zonation of *Symbiodinium* suggest that various specialized traits have evolved for different light regimes. PCP genes of symbiotic dinoflagellates may be selected for as a function of the light intensity and spectral properties of their habitats, or PCP gene diversity may be a reflection of neutral substitutions that occurred in each lineage. In this paper, characterization PCP genes of *Symbiodinium* from *Hippopus hippopus* is presented, and derived amino acid sequence is compared to *Symbiodinium* from *Acropora formosa*, *Amphidinium carterae* and *Gonyaulax polyedra*. Amino acid substitutions found in *Symbiodinium* from *H. hippopus* PCP are mapped into the computer rendering of the *A. carterae* PCP. Comparisons will be extended to other *Symbiodinium* cultures with unique PCP spectroscopic and fluorescence properties and to field samples collected from the same coral host species through a range of depths. Evolution of PCP genes in *Symbiodinium* will be discussed in relation to symbiont ecology and phylogeny.

DNA EVIDENCE SUGGESTS THAT MORE THAN ONE SPECIES OF SIPUNCULAN WORMS IS ASSOCIATED WITH TWO FREE-LIVING CORALS.

Rotmann, S.* and C. Dudgeon. *Australian Institute of Marine Science, Townsville, Q-4810, Australia; Email: s.rotmann@aims.gov.au

Two genera of free-living corals, *Heteropsammia* and *Heterocyathus*, have evolved a symbiotic relationship with a sipunculan worm, allegedly *Aspidosiphon muelleri*, which provides them with transport in exchange for shelter. This association is well documented but poorly understood, with many controversies relating to the identity of the partners involved. The most recent review lumped all previously described sipunculan species into one (*A. muelleri*). Because of differences in the behavioural ecology of the animals a preliminary DNA analysis of the partial CO1 sequences of the sipunculan commensalists was conducted. The results show large differences in DNA sequences from different sipunculans. However, the differences do not seem to be coral species-specific. That is, sipunculans from *Heterocyathus* are not necessarily different to sipunculans from *Heteropsammia*. It is assumed that more than one species, and probably two genera (*Aspidosiphon* and *Phascolion*) of sipunculans are involved in the symbiotic relationship with free-living corals. It is also suggested that the two species of corals may not be specific as to which sipunculan species they settle on as planulae during the initiation of the partnership.

FACTORS INFLUENCING DISTRIBUTION AND ABUNDANCE PATTERNS OF MUTUALISTIC GOBIES AND SHRIMPS.

Thompson, Andrew R.*. *Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106. Email: andrew2112@yahoo.com

I utilized a geospatial approach to examine relationships between habitat parameters and distribution patterns of the fierce prawn goby (*Ctenogobiops feroculus*) and its obligate symbiotic shrimp partner (*Alpheus sp.*) at two spatial scales within sandy lagoons in Moorea, French Polynesia. At the large scale, I recorded habitat variables and goby abundance within a 3x3 m grid at 200 m intervals throughout the north shore of Moorea. At the small scale, I quantified the same factors at 10 m intervals within four 100x100 m plots separated by >0.5 km. Krige-generated image maps of habitat variables and goby abundance at the large scale indicated that gobies and shrimps were found in locations comprised primarily of sand. Image plots at the small scale provided increased resolution and showed that gobies and shrimps avoided areas comprised entirely of sand but were found in microhabitats with a mixture of sand and hard substrate (e.g., coral rubble or coral). To elucidate experimentally whether shrimps/gobies were actively choosing a particular microhabitat, I introduced one shrimp and one goby to an aquarium in which the substrate on one half was pure sand and the other was sand mixed with coral rubble. In 16 out of 16 trials, shrimps established burrows within the coral rubble/sand substrate. Taken together, results from the field and laboratory indicate that along the north shore of Moorea fierce prawn goby distribution and abundance patterns are governed by the ability of their shrimp partners to excavate burrows.

HABITAT SPECIALISATION IN TRAPEZIID CRABS: CONSEQUENCES FOR RARITY AT LOCAL SCALES.

Sin, Tsai M. *; and Lee, Ai-Chin. *School of Marine Biology and Aquaculture, James Cook University, QLD 4811, Australia. Email: tsai_sin@hotmail.com

The distribution and abundance of organisms may be limited by habitat requirements at a variety of spatial scales. The local distribution and abundance of the strongly habitat-associated organisms will be positively related to the amount of habitat available. This relationship is highly dependent of the extent of specialisation to particular habitats. We examined the consequences of habitat specialisation in crabs of the genus *Trapezia* at Kimbe Bay, New Guinea. In particular, we examined predictions that species with wider niche breadths would a) be more abundant, and b) have a wider local distribution. The results indicate that habitat specialisation is consequential in determining patterns of local abundance. *Trapezia* species that used a wider range of pocilloporid (Pocilloporidae) species occurred in greatest abundances. This pattern was disrupted when crab species specialised on highly abundant corals. Similarly, generalised crabs were more common, being found at more reefs than crabs which only used one or two coral species. These results suggest that highly habitat specialised organisms may naturally occur in low numbers in reef communities. This greatly increases their susceptibility to disturbances that result in habitat destruction. Furthermore, the loss of these organisms may not be detected by sampling methods conducted using coarse taxonomic groupings. The relationship between habitat specialisation and rarity should therefore be an important consideration in reef monitoring studies.

Session A24: Coral Growth

STRETCHING: A CORAL GROWTH RESPONSE TO ADVERSE ENVIRONMENTAL CONDITIONS.

Carricart-Ganivet, J.P. *; Merino, M.. *Depto. de Ecología Acuática, ECOSUR. Apdo. Postal 424, Chetumal, Q. Roo. 77000. MEXICO. E-mail address: jpcarri@ecosur-qroo.mx

In order to identify common coral skeletal growth patterns, we analyzed published data on coral growth from four species of reef-building corals growing at different environmental conditions: *Montastraea annularis sensu stricto* (from the Mexican Caribbean, Southern Gulf of Mexico and St. Croix, U.S., Virgin Islands), *Porites lobata* (Great Barrier Reef, Australia), *P. lutea* (Thailand), and *Siderastrea siderea* (Costa Rica). Data suggest that corals can modulate the way they use available calcium carbonate to extend their skeletons in response to environmental conditions. This process can be quantitatively described as the efficiency in which the calcification process produces coral skeleton (*i.e.* skeletal extension rate / calcification rate). We suggest that as corals experience a harsher environment they respond by extending their skeletons to a greater extent, using the same or less amount of calcium carbonate, with a concomitant reduction in skeletal density. We have named this "stretching". In all cases, the stretching response by corals increased with increases in environmental disturbance as measured in terms of decreasing calcification rate and coral diversity, and increases in continental influence and wave intensity. More extensive field and experimental research is needed to corroborate this hypothesis, however, stretching is in agreement with current knowledge concerning factors and mechanisms that are involved in coral growth.

GROWTH DIFFERENCES IN *PORITES CYLINDRICA* NUBBINS TRANSPLANTED TO MONOSPECIFIC AND MULTISPECIFIC PLOTS.

Dizon, Romeo M.*; and Yap, Helen T.. *The Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, Philippines. Email: dizonr@msi01.cs.upd.edu.ph

The effects of lower versus higher diversity on coral survival and growth are being investigated in a northwestern Philippine reef. Nubbins of the branching coral *P. cylindrica* were transplanted to twelve 1 m^2 wire mesh grids that were set up within a marine sanctuary. Six grids contained 30 *P. cylindrica* nubbins while the other 6 contained 10 transplants each of *P. cylindrica*, *P. rus* and *Pavona decussata*. Weight measurements taken every 2 months indicate significantly higher growth rates in the *P. cylindrica* nubbins that were transplanted to the multispecific grids than those in the monospecific grids ($p<0.05$). Results indicate that *P. cylindrica* either responds favorably when in proximity to other coral species by means of rapid growth or is growth-limited by intraspecific competition when occurring in single species patches.

GROWTH OF *ACROPORA FORMOSA* (DANA) AT SELECTED REEF LOCATIONS IN SRI LANKA.

Jinendradasa, S.S. and Ekaratne, S.U.K.*. *Department of Zoology, University of Colombo, Colombo 3, Sri Lanka. Email:suki@eureka.lk

The lack of any growth studies on Sri Lankan corals and the ecological importance of *A. formosa* prompted the study of this dominant coral in the shallow reefs (0.5 to 1.5m) at Hikkaduwa Marine Reserve (HMR) and Roomassala. Growth was monitored at each location over 1-year using the linear extension method. Growth increments of 12 individually tagged coral colonies were measured repeatedly each month, *in situ*, yielding growth values of the same colonies. Rough monsoon seas prevented access to Roomassala colonies over some monsoon months. Growth of *A. formosa a*t HMR was 0.306!0.0131 (mean!s.e.m, in mm day^{-1}) in 1997/1998 and was not significantly different (t-test, $p<0.05$) between monsoonal (0.292!0.0162) and non-monsoonal (0.521!0.1151) months. Growth at Roomassala (0.330!0.0272) was not significantly different from that at HMR. At Roomassala also, monsoonal (0.357!0.0635) and non-monsoonal (0.323!0.0663) growth were not significantly different. Absence of a significant difference in growth between HMR and Roomassala (t-test, $p<0.05$) and among their monthly growth (Kruskal-Wallis Test, $p<0.05$) indicate that *A. formosa* grew uniformly over the year at both sites. *A. formosa* colonies experienced zero and 3.7% mortality at HMR and Roomassala, respectively, and similar cropping pressure. These growth data are now unique in that bleaching in April 1998 has killed all *A. formosa* colonies in these and other surrounding locations. MacArthur Foundation and Biodiversity Support Program assistance is acknowledged.

MODELLING AND ANALYSIS OF GROWTH AND FORM OF STONY CORALS AND THE INFLUENCE OF THE PHYSICAL ENVIRONMENT

Kaandorp Jaap*, *Section Computational Science, Faculty of Mathematics, Computer Science, Physics & Astronomy, University of Amsterdam, The Netherlands, Email jaapk@wins.uva.nl

In many stony corals a combination of light and filter-feeding by trapping suspended material from the environment is being used as an energy source. In the case filter-feeding represents a significant part of the energy input, the growth process is influenced by the local concentration of (organic) suspended material. The distribution of suspended material is determined by a combina-tion of flow and diffusion. A method, the lattice Boltzmann method, for modelling nutrient distributions in complex three dimensional geometries, caused by a combination of diffusion and flow, will be discussed. From the nutrient distributions it is possible to model different types of growth processes, which are driven by the local amount of available nutrients. The influence of light can be represented in a growth model by a three dimensional model of underwater light intensities. In stony corals growth proceeds in an accretive growth process, where new layers of material are being deposited on top of the previous growth layers. A model for growth by accretion will be discussed. In the accretive growth models examples will be shown of growth processes driven by the local available amount of (simulated) food particles and of growth processes driven by the local light intensities.

MECHANICAL PROPERTIES AND STRUCTURAL DESIGN OF SCLERACTINIAN CORALS.

Madin, J. S.* and Hughes, T. P. *James Cook University, Townsville Queensland, 4811, Australia. Email: joshua.madin@jcu.edu.au

A biomechanical approach to sessile organisms in hydrodynamic environments is imperative for a fuller understanding of behavioural, ecological and evolutionary patterns. This study explores the mechanical properties of reef corals by comparing the strength (compressive and tensile) and density of skeletal core samples from one branching and three massive coral species. The staghorn *acropora intermedia* had an average compressive strength (δ_{mean}=91.78 mnm^{-2}) almost 9 times greater than the three massive species (*goniastrea favulus, favia favus* and *porites lobata*). Tensile strength was significantly less than compressive strength in all four taxa, with *a. Intermedia* again being significantly stronger than the massive species. Significant correlation was found between skeletal density and strength. Axial and radial density gradients were detected in the branches of *a. Intermedia* but did not occur within hemispherical colonies of the massive species. Gradients in density are clearly adaptive, allowing for the efficient use of skeletal resources by strengthening basal regions of the colony where stress concentrations are highest. However, in the case of peripheral strengthening (optimising bending strength), the necessity of polyp interaction with ambient surroundings reduces the peripheral density, and therefore colony strength. A better knowledge of coral biomechanics will be valuable for explaining ecological patterns in different hydrodynamic habitats and for predicting colony response to destructive events such as cyclones.

REGULATION OF CA^{2+} BY cAMP DURING SKELETOGENESIS IN HERMATYPIC CORALS.

Mueller, Erich; Allemand, Denis; and Jaubert, Jean. *Mote Marine Laboratory, Center for Tropical Research, 24244 Overseas Highway, Summerland Key, FL 33042 USA. Email: emueller@mote.org

Several mechanisms are involved in the movement of Ca^{2+} from seawater to the skeletogenesis site in reef-building corals. We have found that channels lie along this pathway, possibly facilitating entry of Ca^{2+} into calicoblastic epithelial cells. Active transport also occurs along the Ca^{2+} pathway, possibly moving Ca^{2+} from these cells into the sub-calicoblastic space to create $CaCO_3$ supersaturation conditions for skeletogenesis. Dibutyryl cAMP, forskolin (increases tissue cAMP by stimulating adenylate cyclase) or D600 (a Ca^{2+} channel inhibitor) reduced intracellular Ca^{+} levels and inhibited calcification in micro-colonies of *Stylophora pistillata*. The evidence suggests that elevated intracellular cAMP acts to deactivate Ca^{2+} channels involved in coral skeletogenesis, presumably via protein kinase phosphorylation.

GROWTH RATES OF SECONDARY BASAL DISC (SBD) OF TWO CORAL SPECIES, *Acropora grandis* AND *A. valenciennesi* IN HORIZONTAL AND VERTICAL POSITION ON ARTIFICIAL SUBSTRATE.

Panares, K.*; Pacifico K.; Heeger, T.; Sotto, F.; and Gatus, J. *University of San Carlos -Marine Biology Section-Cebu City 6000, Cebu, Philippines. Email: fili@mangga.usc.edu.ph

The Secondary Basal Disc (SBD) growth rates of two acroporid species: A. grandis and A.valenciennesi, in horizontal and vertical mount positions on artificial substrate were determined. For each species 20 set-ups were made, ten in horizontal and ten in vertical mount position in the 2-hectare coral farm at Barangay Caw-oy (10°16'24"N; 124°4'10"E), Olango Island, Cebu, Philippines over a period of ten weeks. Results showed that Secondary Basal Disc (SBD) growth followed a trend of minimal growth for the first two weeks, increased exponentially in the third up to the fifth week and fluctuated on the last three to four weeks. The species, the mount position of the fragments and the type of growth as single or multiple SBD attachments had no effect whatsoever, on the SBD growth. However, the survival rate was affected by these three variables. A. valenciennesi, in horizontal mount and multiple attachments showed higher mortality rate ( ) than A. grandis ( ). In propagating both species, care is needed for A. grandis during the last weeks while for A. valenciennesi, for the first two weeks when mortality was high.

PRELIMINARY RESULTS ON THE EFFECT OF INDUCED MINERAL ACCRETION ON GROWTH AND SURVIVAL OF *PORITES CYLINDRICA*.

Sabater, Marlowe G.* and Yap, Helen T.. *The Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, Philippines. Email: maloy@msi01.cs.upd.edu.ph

The mineral accretion technique introduced by hilbertz (1992) is being tested experimentally for the first time in the philippines. After four months, results show no significant differences in growth among control colonies, corals with induced mineral accretion, and corals without. However, there is a significant difference in survival. There is higher mortality in the grids with mineral accretion due to the abundance of fleshy algae that recruited on the grids during periods of electrical interruption. This is not the case so far with the untreated grids. Thus grids with induced mineral accretion apparently provide a favourable substrate for algal settlement.

Session A25: Response to Disturbances and Impacts

IMPACT OF TROPICAL CYCLONE 'TESSI' ON FRINGING REEFS OF MAGNETIC ISLAND, AUSTRALIA.

Ayling, Tony * and Neale, Stephen. *Sea Research. PO Box 810, Mossman, Australia, 4873. Email: ayling@internetnorth.com.au

On April 3 2000 Cyclone 'Tessi' passed within 50 km of Magnetic Island, Australia. Sustained wind speeds of 103kph and gusts up to a maximum of 143kph were recorded at an Australian Institute of Marine Science weather station located adjacent to Magnetic Island. Reef flats and slopes of fringing reefs in four bays of Magnetic Island were intensively surveyed using fixed position line transects in the week prior to the cyclone. These sites were resurveyed two weeks after the passage of 'Tessi'. Grand mean coral cover over all reef slopes was reduced by 38% by the cyclone. Other benthic groups also suffered significantly. There was a 49% reduction in total algal cover, a 50% reduction in sponge cover and a 40% reduction in soft coral cover. All four bays have a similar aspect and similar depth ranges. The extent of damage to benthic communities and reef structure at each bay varied. Florence Bay was worst effected with a 60% reduction in hard coral cover while Geoffrey Bay had only an 18% reduction. Arthur Bay and Nelly Bay sustained intermediate damage with coral cover reductions of 31% and 45% respectively. Less damage was recorded at reef flat sites due to the passage of the cyclone occurring at low tide. All sites were surveyed in February 1998 immediately prior to a major bleaching event. Coral cover measured in March 2000 revealed bleaching related mortality was highest in Florence Bay and Geoffrey Bay, with Arthur Bay and Nelly Bay having little or no reduction in coral cover. Reduction in coral cover due to bleaching was considerably less than that caused by cyclone 'Tessi'. Re-surveys of all sites will occur in June/July 2000.

RESPONSES OF CORAL AND FISH ASSEMBLAGES TO A SEVERE BUT SHORT-LIVED TROPICAL CYCLONE.

Cheal, A.*; Coleman, Greg; Miller, Ian; Neale, Stephen; Osborne, Kate and Sweatman, Hugh. *Australian Institute of Marine Science. PMB 3, Townsville, 4810. Australia. a.cheal@aims.gov.au

Manta tows of reef perimeters and intensive surveys of specific sites were used to assess changes in assemblages of corals and fishes on a number of reefs following the passage of a tropical cyclone in northern Australia. Only one reef experienced an obvious and immediate decline in coral cover due to the cyclone. Here, mean reef-wide coral cover fell from 24 to 7% while abundance and species richness of adult damselfish assemblages on intensive survey sites were not affected despite the removal of 50% of hard coral habitat. Adult fish assemblages showed a similar lack of response at three other reefs where no significant habitat changes had occurred. Ten months later, total abundance of damselfishes had decreased substantially at 8 out of the 10 reefs while abundance of larger mobile fishes remained stable. We infer that the observed effects on coral assemblages were strongly influenced by the short duration and orientation of the cyclone, the history of exposure to wave energy (influencing life-form structure and therefore degree of fragility) and the relative consolidation of the reef matrix. The lack of short-term responses of adult fishes to a considerable reduction of hard coral (on one reef) implies that this resource was not limiting at the recorded fish densities, and these fishes can endure periods of intense underwater turbulence. The reasons for general decreases in damselfish numbers 10 months after the cyclone remain enigmatic.

A NEW THREAT TO THE CORAL REEFS OF THE HIKKADUWA NATURE RESERVE, SRI LANKA

De Silva,.R.M.W.N.*; and Rajasuriya, Arjan. *Borneo Marine Research Unit, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia Email: arjan@nara.ac.lk.

The Hikkaduwa Marine Sanctuary recently upgraded to a Nature Reserve could be taken as an after thought as critical irreversible changes had already taken place to the area and the coral reefs before it was declared a sanctuary. Anchoring of mechanised fishing boats, spillage and discharge of diesel, kerosene and petrol from boats, irresponsible operations of and unsustainable number of glass bottom boats, increasing tourist pressure, pollution, removal of marine organisms including corals were among the primary causes of reef degradation in the area. The paper describes a new threat posed to the living corals of the Nature Reserve by an overgrowth of the calcareous alga *Halimeda*. The initial steps taken to contain the alga in areas of good live coral cover through physical removal with the assistance of the local community and possible short and long term strategies to meet this new threat are discussed.

DO WE NEED NEW PARAMETERS TO ASSESS THE STATUS OF CORAL REEF COMMUNITIES UNDER CHRONIC AND HEAVY SEDIMENT STRESS?

Dikou A*., Koh M., Chou L.M. *Department of Biological Sciences, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260. Email: scip7318@nus.edu.sg

Coral reefs in singapore have been subjected to chronic sediment stress mainly due to land reclamation and dredging for the last thirty years. Community parameters of hard corals such as species diversity, percent live coral cover, mean colony density, partial colony mortality, and mean density of recruits have been assessed in a number of sites with differential exposure to sediment impact. We evaluated the relative merits and limitations of each one of the aforementioned community parameters in assessing the status or health of coral communities under heavy sediment stress. In an effort to improve our assessment of one of the most widespread impacts on coral reef communities worldwide, i.e. Increase in sediment load, the description of the partition of space by all main components of the community is essential. Which component of coral reef communities replaces which under heavy sediment stress is of paramount importance. For example, the percent cover by sediments and its change in sites with differential impact by sediments may be particularly informative and relevant because it relates both to utilization of space (pattern) and recruitment (process) in coral communities in both spatial and temporal assessments. It may also prove to have meaningful predictive value of the status of coral reef communities.

VARIATIONS OF ECOLOGICAL PARAMETERS AT EASTERN REEF, TOBAGO.

Guppy, Reia *. Institute of Marine Affairs, P.O. Box 3160, Carenage Post Office, Trinidad and Tobago. Email: rguppy@ima.gov.tt

Eastern Reef is part of the fringing Buccoo Reef, Tobago that has been monitored by the Institute of Marine Affairs for five years through the regional CARICOMP program. The reef was monitored once a year, and parameters included coral, algal and sponge growth, fish and sea urchin abundance, nutrients and temperature. During the first three years of monitoring, coral, algal and sponge growth showed an upward trend in the mean % cover, whereas in 2000, there was a marked decrease except in the mean algal cover. Fish and sea urchin abundance also appeared to follow similar trends in 2000 as their numbers were noticeably reduced from in 1998. Although the cause has not yet been determined, additional data suggests that the cause may be associated with the 1997/1998 El Niño event combined with chronic nutrient-enrichment stress. Temperature recordings were higher than normal during 1998, and visual observations in September 1998 on Eastern Reef indicated a severe bleaching event, from which the corals may not have recovered. Further, nutrient analysis indicated persistent levels of nutrients that exceed accepted standards.

ASSESSING CORAL STRESS RESPONSES AT THE LEVEL OF GENE EXPRESSION.

Morgan, Michael B.*, Snell, Terry W. *Georgia Institute of Technology, School of Biology, 310 Ferst Drive, Atlanta, GA, 30332, USA. Email: gt3099b@prism.gatech,edu

Using established molecular techniques, researchers now have the ability to evaluate coral stress gene response at the level of transcription providing an opportunity for earlier diagnosis of a stressed condition. Differential display PCR was used to identify gene fragments that could serve as inducible biomarkers of stress from exposure to copper or the insecticides permethrin and dibrom. Ten-centimeter branches of Staghorn coral *Acropora cervicornis* were exposed for 4 hours to Cu^{2+} 25ug/L, 1ug permethrin/L, or 0.5ug dibrom/L. Several differentially expressed mRNAs produced in response to copper, permethrin and dibrom exposure have been isolated. The differentially expressed genes were reversed transcribed to produce cDNAs fragments that were subsequently isolated, amplified, and developed into probes. Chemiluminescent detection was used to identify when a probe annealed to its corresponding target mRNA. Verification of probe specificity and the elimination of "false positives" were performed by Northern dot blot analysis. Probe specificity was further demonstrated by its hybridization to a target transcript within a matrix of 15 different total RNA samples. Selected probes were sequenced and 5' RACE performed to generate additional sequence information. These sequences were compared to genes of known function by performing blast searches in several databases. Differential display PCR can be used to identify toxicant-induced genes that can serve as molecular biomarkers for rapid toxicity assessment in scleractinian corals.

RESISTANCE TO DAMAGE OF REEF CORALS EXPOSED TO PHYSICAL DISTURBANCE.

Marshall, Paul A*. *CRC Reef Research Centre & Department of Tropical Environment Studies, James Cook University, Townsville, Queensland 4811, Australia. Email: p.marshall@gbrmpa.gov.au

Physical disturbance is one of the most important influences on the structure of coral populations and communities, yet our understanding of the factors that determine the response of individual colonies to physical stress remain relatively poor. In this study, I examine the factors that determine the ability of corals to resist physical damage. I tested the resistance of twelve species of corals by experimental exposure to mechanical stress, and then related resistance to biomechanical properties of colonies. Resistance ranged from very high for species such as *Leptoria phrygia*, *Porites cylindrica* and *Porites spp.* (0% damage) to low in species such as *Pocillopora damicornis*, *Seriatopora hystrix* and *Montipora sp.* (>60% damage). Regression tree analysis indicated a strong relationship between resistance and colony morphology, based on only four morphological variables: colony height, branch thickness, branch spacing and colony area. Contrary to expectations, skeletal density was relatively unimportant in determining susceptibility to breakage. This has important implications for interpretations of the ecological significance of reduced calcification rates in corals under global warming scenarios.

METAL TOXICITY IN CNIDARIAN-ALGAL SYMBIOSES.

Mitchelmore, C. L. * and V. M. Weis. *Oregon State University, Department of Zoology, 3029 Cordley Hall, Corvallis, OR 97331. Email: mitchec@bcc.orst.edu

Coral reef ecosystems are being stressed, compromised or even changed as a consequence of various anthropogenic inputs, such as heavy metals. Heavy metal toxicity is a complex process and the interplay between zooxanthellae and their animal hosts makes assessment of toxicity even more challenging. Our research is focused on the cellular and molecular events that prevail before the onset of bleaching, ultimately to identify specific bioindicators to predict symbiosis breakdown. The anemone *Anthopleura elegantissima* is used as a model for our investigations to address 1) metal accumulation, partitioning and toxicity to both the animal and their zooxanthellae and 2) changes in the gene expression of known "symbiosis" genes present in the host. A high level of metal accumulation was seen in both symbiotic and aposymbiotic (symbiont free) animals with metals seen in both algae and host coupled with partitioning into "metal rich granules". Several other measures of metal toxicity and stress were investigated, including bleaching, mucus production, levels of the antioxidant glutathione, and activity of carbonic anhydrase (CA) coupled with changes in the gene expression (quantitative RT-PCR) of heat shock protein (70) and known symbiosis-specific genes e.g. CA and sym32.

BENTHIC COMMUNITY STRUCTURE VERSUS NITRATE INPUT AT REUNION (SW INDIAN OCEAN).

Naim, O*. and Cuet, P. *Laboratoire d'Ecologie Marine, Université de la Réunion, 97487 Saint-Denis messag. Cedex 9, France. Email: naim@univ-reunion.fr

This study documents the impact of submarine groundwater discharge (SGD), which is considered to be the main source of anthropogenic nutrients to the reef, on the Saint-Gilles/La Saline coral reef. A "Principal Component Analysis" (PCA) made on substrate categories and echinoderm densities analysed in 17 areas of the reef opposed 2 types of benthic communities: (1) a first one (ACR) dominated by a living and diverse *Acropora* community (mainly *A. formosa*), with a very low fleshy algae coverage and high densities of sea-urchins on the reef flat (*Echinometra mathaei* and Diadematidae), and (2) a second one (MAS) consisting of a massive coral community (mainly *Montipora circumvallata* and *Porites (Synaraea) rus*) in competition with abundant fleshy algae and Cyanophytes, with few sea-urchins on the reef flat and high densities of Holothuroids (*Holothuria atra*) in the back reef. The corresponding areas clearly separated on a nitrate-silicate curve plotted from samples taken at low tide in the back reef at the end of the rainy season. ACR disappeared when NO_3^- was higher than 1.3 µM, and MAS appeared when NO_3^- was higher than 3.5 µM. Regular back reef water sampling showed that nitrate was lower ($p < 0.0001$) at one of the sites dominated by ACR (0.73 ± 0.62 µM) than at one of the sites dominated by MAS (3.23 ± 1.93 µM). Therefore, at Reunion, ACR appears to turn gradually into MAS when NO_3^- concentration increases from 1 to 3 µM in the back reef.

REGENERATION OF A REEF FLAT TEN YEARS AFTER THE IMPACT OF THE CYCLONE FIRINGA (REUNION, SW INDIAN OCEAN)

Naim, Odile; Chabanet, Pascale; Done, Terence; Tourrand, Catherine; Letourneur, Yves. *Lab. d'Ecologie marine, Univ. Réunion, 97715 Saint Denis messag Cedex 9, France. Email: naim@univ-reunion.fr

In 1989, high coral reef mortality (more than 99% of coral coverage) due to hypersedimentation was generated by the cyclone Firinga on the fringing reef flat of Saint-Leu. Regeneration of coral, urchin and fish communities was censused in 1993, 1997 and 2000 (through coral coverage CV, urchin and fish densities, diversity), on two sites : one under terrigeneous influence (SLT), and one under oceanical influence (SLO). Corals were censused along linear transects, urchins in quadrats and fish along 100 m2 belt-transects. Following results concern the bioconstructed part of the reef flat. On SLT, CV increased from 2% in 93, to 11% in 97 and to 23% in 00, while on SLO, CV increased from 24% in 97 to 53% in 00. Likely, the relative abundance of *Acropora formosa* (the dominant species of Reunion reef flats) increased, on SLT, from 0% in 93, to 23% in 97, and to 61% in 00 while, on SLO, from 68% in 97, to 78% in 00. Data are still in process for estimating the evolution of the coral diversity, urchin densities and diversity during time. The fish density vs time decreased in SLT (360 in 93, 300 in 97, 260 in 00) and increased in SLO (910 in 97, 756 in 00). From 97 to 00, fish diversity increased in SLT (2,77 to 4,35) and decreased in SLO (3,21 to 2,34). Fish patterns are essentially due to the variable distribution of the territorial damselfish *Stegastes nigricans*. The first results appear to confirm that diversity is higher on SLT than on SLO, suggesting that this site corresponds to an "intermediate level of disturbance" sensu Connell.

SIMULTANEOUS AND SEQUENTIAL STRESS FROM HEAT AND COPPER EXPOSURE ON THE METABOLISM OF *PORITES CYLINDRICA*

Nyström, M.* and Nordemar, I. *Department of Systems Ecology, Stockholm University, Sweden. Email: magnusn@system.ecology.su.se

This study investigates the physiological response of the scleractinian coral *Porites cylindrica* to copper and increased temperature, when these stressors occur separately and simultaneously. Relative changes in production (Pg/chlorophyll *a*) and respiration (R/cm^2) rates, measured as dissolved oxygen, were used as indicators of stress. The respiration rate was significantly affected by all treatments, whereas production was unaffected when corals were exposed to copper alone. In order to investigate the effects from stressors arriving sequentially, corals were pre exposed to increased temperature for 24 hours. After heat exposure, the corals were allowed to recover for three days before exposed to copper. In contrast to corals exposed to copper only, both production and respiration were significantly influenced (a decrease and an increase respectively) by copper in the pre heated corals. The results from this study show that several stressors, arriving simultaneously or sequentially, may have a greater negative impact on coral's physiology than the same stressors occurring separately.

STUDIES ON A MARGINAL REEF IN A WOOD-PULP EFFLUENT PLUME.

Schleyer, Michael H.*, Risk, Michael J. and Heikoop, Jeffrey M.. *Oceanographic Research Institute, P.O. Box 10712, Marine Parade, Durban 4056, South Africa. seaworld@dbn.lia.net

Aliwal Shoal, a large reef south of Durban in South Africa, consists of dune rock partially colonised by corals. It is heavily used by fishermen and recreational divers, and lies within a plume of effluent discharged from the marine outfall of a large wood-pulp factory. User-conflict and environmental degradation on Aliwal Shoal are presently receiving attention. Bathymetric and biological surveys were thus undertaken to provide decision support in developing a management plan for the reef. During the biological survey, it emerged that encrusting sponges were most abundant close to the outfall. Stable isotope analyses were thus undertaken on POM, an encrusting sponge (*Suberites kelleri*) and hard coral (*Stylophora pistillata*). Stable isotope ratios in the POM were variable, reflecting their transience and instability. The $\delta^{13}C$ of the POM (~ -25 ‰) was slightly higher than that of the effluent (-27 ‰, cf. bulk wood) and quite different to that of typical reef POM (-18 to -20 ‰). The $\delta^{13}C$ in the sponge and coral samples was closer to that of reef POM, reflecting the sponge's dependence on this food source and mixed autotrophy and heterotrophy by the coral. There was a gradient in $\delta^{15}N$ in both the coral and sponge, manifesting a reduction in terrigenous eutrophication along the reef for which effluent dilution provided the only reasonable explanation. The results are discussed relative to the location of Aliwal Shoal, the effects of the effluent and the suitability of the technique for further monitoring of biotic responses to changes in its discharge.

PHOTOADAPTATION AND PHOTOACLIMATION OF THE MUSHROOM CORAL *FUNGIA* SP. IN A TURBID ENVIRONMENT.

Tun, Karenne P. P.*, Cheshire, A. C. and Chou, L. M.. *Tropical Marine Science Institute, 14 Kent Ridge Road, Singapore 119223. Email: karenne@nus.edu.sg

The photoadaptive and photoaclimative capabilities of the mushroom coral *Fungia* sp. in turbid water conditions were investigated *in situ* using an underwater fluorometer (Walz Diving PAM). Corals along the reef crest and 6m below the reef crest were studied, and complimentary transplantation of corals from both depths were conducted. Fluorometric measurements were made at 3 hr intervals over a 24 hr period on day 1, 3, 5 and 10 of the experiment. Dark adaptation experiments were conducted during 2 of the sampling times on each sampling day. In addition, turbidity measurements using 2 LICOR light meters were made to characterise the water quality (in terms of light attenuation) at the time of the experiment. The photoadaptive and photoaclimative responses of the corals were determined from their fluorometric parameters (F, Fo, Fm, Fm' and Yield), and correlated to water quality.

IMPACTS OF INTENSIVE RECREATIONAL SCUBA DIVING ON REEF CORALS AT EILAT, NORTHERN RED SEA.

Zakai, D.* and Chadwick-Furman, N. E. *Israel Nature & National Parks Protection Authority, P.O. Box 667, Eilat, Israel. Email: dudu.zakai@nature-parks.org.il

Frequencies of recreational scuba diving on coral reefs at Eilat, northern Red Sea, are among the highest in the world, with >200,000 scuba dives per year within 3.5 km of protected coral reef zone. Reefs at Eilat have become degraded in recent years due in part to the impacts of intensive tourism, but little data exists on the extent of the damage and connection to scuba diving. We collected information on rates of scuba diving at 13 coral reef sites in Eilat during 1996, which show that some sites receive up to 25,000 dives per year, mostly by inexperienced divers in training courses or on one-time introductory dives. Levels of damage to both massive and branching stony corals are highest at sites with many dives and lowest at a restricted site where dives are limited. Observations of diver behavior underwater revealed that they contact corals approximately 15x per 40-min dive, mostly by stirring up sediment and fin contact, resulting in several hundred thousand corals broken by divers each year at Eilat. Some corals, when fragmented experimentally, significantly reduced their sexual reproductive output. We conclude that frequencies of recreational scuba diving are above carrying capacity for reef sites at Eilat, leading to substantial physical and reproductive damage to resident reef corals. Management recommendations to reduce coral impacts to sustainable levels include the diversion of trained divers to artificial reefs, removal of scuba training courses from delicate reef areas, and improvement of environmental awareness levels among recreational divers at Eilat.

Session A26: Reef Metabolism and Nutrient Cycling

COMMUNITY METABOLISM OF CORAL REEFS IN THE RED-SEA.

Erez Jonathan*, Silverman Jacob, and Lazar Boaz. *Institute of Earth Sciences, Hebrew University Jerusalem, Israel 91904. Email: Erez@vms.huji.ac.il

Community metabolism studies were conducted on 4 Red-Sea reefs using diurnal changes in oxygen and pH, inorganic carbon and total alkalinity for 2-3 day periods. Metabolic rates measured at Bullisar Is. (Dahlak), Ras Abu-Galum (Sinai), and Eilat (1 and 2) were as follows: (all in mmoles $C*m^{-2}*day^{-1}$). Pn: -666, -302, -15, 110; Pg: 900, 453, 739, 403; R: 1566, 756, 750, 293; and G: 180, 262, 121, and 41, respectively. Where, Pn-Net Production R-Respiration, Pg-Gross Productivity, and G-calcification. These reefs operated in a heterotrophic mode, *i.e.* Pg:R<1 (except Eilat2). Plankton depletions from the open sea towards the reef indicated that excess R over Pg is maintained by consumption of open-sea plankton. In Bullisar Island a massive *Trichodesmium* bloom in the open-waters was completely consumed by the reef community. High respiration is accompanied by high calcification rates indicating the well being of framework builders (mainly corals). In contrast Eilat2 displays a Pg:R>1 and reduced calcification. This was caused by an increase in nutrient supply due to vertical winter mixing at the Gulf of Eilat. Fringing reefs of the Red-Sea and probably other nutrient-poor waters are often heterotrophic, deriving their nutrients from digestion of open sea plankton. When nutrient enrichment occurs (naturally or man-made) these reefs become autotrophic (Pg:R>1) displaying massive algal growth and reduced calcification. By continuous monitoring of community metabolism in such reefs, it should be possible to assess their well being before actual coral mortality occurs. Preventive management measures may thus be taken to reduce nutrient inputs and encourage coral calcification.

PRODUCTION AND RESPIRATION IN THE BIOSPHERE 2 REEF MESOCOSM.

Falter, J.L.*; Atkinson, Marlin J.; Langdon, Chris. *Dept. of Oceanography, Univ. of Hawaii, 1000 Pope Rd., Honolulu, Hawaii, 96822 USA. Email: jfalter@soest.hawaii.edu

Nearly continuous measurements of dissolved oxygen in the Biosphere 2 ocean (Southern Arizona, USA) have allowed us to monitor changes in the organic metabolism of this reef mesocosm for the past four years. Rates of Gross Community Production (GCP) and Community Respiration (CR) vary between 100-400 mmolC m^{-2} day^{-1} and are similar to values found for other high-latitude reef environments. Mean values of GCP and CR during the fall and winter are ~30% lower than spring and summer values. There is a good correlation between CR and GCP over the length of the time-series ($r^2 = 0.6$) after correcting for statistical artifacts. Net Community Production (NCP) is typically 10-20% of Gross Community Metabolism (GCM = GCP/2 + CR/2) for all years and all seasons, however, daily values can be in excess of 100% of GCM. Furthermore, daily changes in GCP are only weakly correlated with daily changes in CR ($r^2 = 0.3$) indicating that production and respiration are only weakly coupled on a day-to-day basis. In addition, daily changes in GCP are typically much greater than daily changes in CR suggesting that Community Respiration responds slowly to changes in Gross Community Production. None the less, CR and GCP appear to be well balanced on seasonal and yearly time scales.

SYMBIOSIS CORAL-ZOOXANTHELLAE AND PRIMARY PRODUCTION IN THE ROCAS ATOLL, BRAZIL*

Maÿal, E.*; Feitosa, F.; Ferreira, V.; Sial, A.; Pinheiro, B.; and Lima, E. *Federal Univ. of Pernambuco, Brazil. Email: emm@npd.ufpe.br

The Rocas Atoll, NE Brazil, is located in the 3º45' e 3º56' S and 33º37' e 33º56' W. Studied species from this atoll are *Siderastrea stellata*, *Montastrea cavernosa*, and *Porites astreoides*, from which zooxantella have been quantified. $\delta^{13}C$ and $\delta^{18}O$ analyses from coral skeletons indicate they have been suffered strong thermal stress, which resulted in decreasing in the zooxantella activity. Productivity data indicate this is a productive environment, whose biomass is greater than $1 mmg/m^3$, probably associated to the local avifauna richness. Oxygen saturation index suggests it is an environment free of anthropic action. Silicates have higher concentrations than nitrate, phosphate and nitrite, although contents vary in the different sampled points. Nitrate values indicate influence of the avifauna.

FATE OF HMW-DOC AND LMW-DOC IN CORAL REEF AT MIYAKO ISLAND, OKINAWA: EXPORT FLUX, DEGRADATION, AND TURNOVER TIME.

Suzuki, Y.*; Casareto, B.E.; Yoshida, K.; Kurosawa, K. *Dept. Of Biology And Geosciences, Shizuoka University, Japan. EMAIL: SEYSUZU@SCI.SHIZUOKA.AC.JP

The organic matter and nutrient cycles among the different organisms support the maintenance of coral reef ecosystem. Knowing the fate of organic matter within coral reef is a key point in order to understand the interaction between organisms and material cycling. DOC, DON and nutrients were measured in a coral reef at Miyako Island, Okinawa, Japan. Organic matters are produced by primary production and released by metabolism or breakdown of living organisms. According to a biodegradation experiment, DOC and DON were divided into two categories: labile and refractory fractions. Our results showed that fresh and labile organic matter concentrations in coral reef are greater than in open ocean. Dissolved organic matter (DOM) was divided using ultrafiltration into three different molecular weight fractions: < 1, 1-10, and > 10 kDa. The difference of concentrations between day and night was 15 to 22 µM for DOC and 3 to 4 µM for DON. High molecular weight (HMW, > 1 kDa) DOC and DON increased from 22 µM DOC and 2.8µM DON in daytime to 37 µM DOC and 6.1µM DON in nighttime. These results indicate that HMW-DOM has been produced during night time throughout metabolism by coral reef and low molecular weight DOM (< 1 kDa) was almost constant over the day. The C/N ratio of HMW-DOM increase from day to night was about 4.5, suggesting that the contribution of coral metabolism to the increase of DOM in water during nighttime is important.

Session A26: Reef Metabolism and Nutrient Cycling

NITROGEN FIXATION AND NITROGEN BUDGET IN CORAL REEF AT MIYAKO ISLAND (BORA BAY), JAPAN

Yamada, Koichi*; Suzuki, Yoshimi; *Department of Fine materials Engineering , Shinshu University, 3-15-1, Tokida, Ueda, Nagano Pre. 386-8567, Japan Email : yamada@giptc.shinshu-u.ac.jp

Nitrogen fixation is a key feature in the nitrogen cycle of most coral reefs. Here, we determined the nitrogen fixation in coral reef at Miyako Island (Bora Bay), Japan using cyanobacteria (Phormidium) collected from flat reef rocks and then the ethylene method. Our results show that the ethylene concentrations increased after 8 hours of incubation. Our results also confirm that nitrogen fixation is related to photosynthesis; assuming that nitrogen fixation occurred 12 hours/day, we estimated the total amount of nitrogen fixation at Miyako Island at about 7 mol-N day-1, or 2.5 Kmol-N year-1. Nitrogen fixation is most active in periphyton, which covers the rubble, dead coral, and flat rocks, as well as in the layer of coarse Halimeda sand. This relatively small nitrogen fixation compared with 40~98 mol-N day-1 (Hanson and Gundersen, 1976) is due to the distribution and composition of biocommunities in the coral reef and to the large amount of nutrients supplied as nitrate by stream water into Bora Bay. Contribution of nitrogen fixation is small for a coral reef enriched by nutrients, such as for a fringing coral reef.

Session A27: Tridacna and Other Molluscs and Gastropods

CONDITION OF GIANT CLAM NATURAL POPULATION IN INDONESIA.

Ambariyanto*. *Marine Science Dept., Diponegoro University, Kampus Tembalang, Semarang, Indonesia. Email: ambari@indosat.net.id

Giant clams (Tridacnidae) natural populations in many part of Indonesian coral reef ecosystems have been decreasing sharply. Although, the government of Indonesia have banned giant clams exploitation, the people from coastal area around the country, such as in Irian, Jepara, and Makasar, still use them as a source of food. building materials, household equipment and souvenir. The target species is not only large species, such as *Tridacna gigas*, *T. derasa*, *T. squamosa*, and *Hippopus* sp., bust since they are getting harder to be found, the small species such as *T. maximai* and *T. crocea* have become the target as well. Considering this condition, restocking project need to be done in order to restoring giant clam natural populations and the Indonesian coral reef ecosystems.

POPULATION REGULATION OF THE CORALLIVOROUS GASTROPOD *CORALLIOPHILA ABBREVIATA* LAMARCK (CORALLIOPHILIDAE) IN THE CARIBBEAN.

Baums, I.B.*; Miller, Margaret W.; Szmant, Alina M.* RSMAS-MBF, University of Miami, 4600 Rickenbacker Causeway, Miami, Fl 33149, USA. Email: ibaums@rsmas.miami.edu

C. abbreviata is commonly found throughout the Caribbean preying upon 14 species of scleractinian corals. The two major frame building corals, *Acropora palmata* (Ap) and *Montastraea* spp (M) are some of the preferred prey. Snail populations show distinct differences on *A. palmata* compared to *Montastraea* hosts including a lower infestation rate, larger mean individual size of snails but fewer snails per colony, higher growth rates of snails (Ap snails: 0.1g/3 months, M snails: -0.01g/3months) but possibly higher predation pressure on snails, and more visible tissue eaten. The differences in snail populations can be at least in part attributed to host effects: snails transplanted from Ap to M show a decrease in growth rates whereas snails transplanted from *Montastraea* to *A. palmata* show equally high growth rates as the native snails. Since *Montastraea* tissue provides more carbon per area (981±189 μmol cm^{-2}) than *A. palmata* (343±91 μmol cm^{-2}) the nature of the host effect remains unclear. Ap snails of the same length as M snails have heavier shells (Ap snails: 0.13±0.04 g/mm, M snails: 0.11±0.01 g/mm), an adaptation widely attributed to higher predation pressure. Across the Caribbean snail populations show comparable host specific population characteristics. It is concluded that a mixture of top-down, bottom-up and snail population intrinsic effects regulate *C. abbreviata* populations.

WATER TEMPERATURE INFLUENCES ON PHYSIOLOGICAL BEHAVIOUR IN THREE SPECIES OF GIANT CLAMS (TRIDACNIDAE).

Blidberg, E. and Tedengren, M. *. *Department of Systems Ecology, University of Stockholm, Sweden. Email: michaelt@system.ecology.su.se

Global warming and coral bleaching have been widely discussed in recent years. An increase in water temperature could negatively affect giant clam species that also depend on symbiotic zooxanthellae. These clams are locally endangered throughout the Indo-Pacific region and therefore cultured in several Asian countries. The aim of this study was to investigate physiological behaviour in three species of giant clams, *Tridacna gigas*, *T. derasa* and *Hippopus hippopus*, exposed to an increased temperature (ambient+3°C for 24 hours). The experiments were performed at Bolinao Marine Laboratory, University of the Philippines and the parameters analysed were oxygen net production and respiration, and calculated GP/R ratios on 24-hr basis. *Tridacna gigas* had the highest metabolic rate per mg wwt (including shell) compared to the other species, also demonstrated as higher production vs irradiance (P-I curves). Both *T. gigas* and *T. derasa* showed a negative trend in all parameters when exposed to heat, reducing their total metabolism. Despite this *T. derasa* increases its GP/R ratio because of a decreased respiration. *H. hippopus* showed a large increase in respiration when exposed to increased water temperature resulting in a decreased GP/R ratio. General ecological knowledge is important when restocking giant clams and the implication of the results from this study is discussed from a mariculture perspective.

THE GENUS *HALGERDA* (MOLLUSCA: OPISTHOBRANCHIA). THE EVOLUTION OF A COLORFUL INHABITANT OF CORAL REEFS.

Fahey, S.J.* *Department of Zoology, University of Queensland. Brisbane, Australia 4072. Email: sfahey@calacademy.org

The opisthobranch genus *Halgerda* is found only on the highly diverse coral reefs of the tropical Indo-Pacific. This monophyletic group of nudibranchs is found from intertidal to moderately deep waters. While the animals have been found associated with a complex assortment of invertebrate life on the reefs, their primary food source is sponges. This taxon is important in the study of biochemical compounds, ecological and evolutionary studies. Recent workers have increased the described number of *Halgerda* species from fourteen (prior to 1998) to thirty-two at present. Studies of external, reproductive and radular morphology have been used to develop parsimony-based analyses of the relationships of the described species. The evolutionary hypothesis developed by Fahey & Gosliner (2000) indicates that the genus is closely related to another tropical Pacific genus *Asteronotus*. A highly derived clade is also found in moderately deep water near the Philippines and New Caledonia. This indicates that the genus evolved from shallow water into deeper waters. There is evidence of vicariant events that have separated species of the genus in the past. Certain sister taxa are found exclusively in either the Indian or Pacific Ocean. No members of this genus are found in the Atlantic or eastern Pacific Oceans. Since the basal members of the genus are found in the Indo-Pacific, it is likely that the group was never present in the Atlantic or eastern Pacific, rather than having gone extinct.

REGULATION OF THE ZOOXANTHELLAE-TRIDACNA SYMBIOSIS BY LIGHT INTENSITY AND NITROGEN AVAILABILITY.

Grice, A.M.*, & D. Yellowlees. *Queensland Environmental Protection Agency, 80 Meiers Road, Indooroopilly, Queensland 4068. Angela.Grice@env.qld.gov.au

Light intensity and nitrogen availability are two of the most important environmental factors affecting the symbiotic relationship between zooxanthellae and their host animals. A 30-d outdoor experiment was conducted on the giant clam, *Tridacna maxima*, and its zooxanthellae to investigate the effects of light intensity (100%, 30% and 10% full sunlight) and nitrogen availability (50 δM and <1 δM N) on the metabolism and physiology of the symbionts. Results of this study showed that zooxanthellae were able to photoadapt sufficiently in low light conditions to satisfy their own nutritional requirements for metabolism and growth. The composition of the zooxanthellae community was regulated by light rather than nitrogen conditions. Under all light conditions, overall zooxanthellae populations increased significantly in response to nitrogen enrichment. In contrast to the zooxanthellae, the growth of the host clams under low light conditions was negligible, primarily due to reduced translocation of photosynthates from the zooxanthellae. Extremely low glucose and elevated amino acid levels in the clam haemolymph at low light intensity indicated catabolism of the host tissues was occurring. Nitrogen enrichment at low light intensity was detrimental to clam growth as the zooxanthellae retained their photosynthate for growth. A generalised conceptual model of the regulation of the host animal-zooxanthellae symbiosis by light intensity and nitrogen availability is presented.

EFFECTS OF SHELL MARKERS ON CALCIFICATION IN TRIDACNIDS.

Mingoa-Licuanan, S. Suzanne* And Bella Sheila L. Albasin. *The Marine Science Institute, P.O. Box 1, University Of The Philippines, Diliman, Quezon City, Philippines. E-Mail Address: SUZANNE@MSI01.CS.UPD.EDU.PH

The effects of external physical tags (Floy tag and monofilament-dymo tag) and an internal shell marker (alizarin red-S) to permanently mark *Tridacna gigas* were determined from short- and long-term studies on survival and growth in tagged juvenile clams, and from analyses of shell and tissue for alizarin-stained clams. The physical tag was inserted by drilling the clam shell and plugging with dental curing mixture. Alizarin was applied by exposing clams to 0, 5, 10, 20 and 30 ppm alizarin either with daily solution changes or continuous drip for up to 3 weeks. The amount of alizarin in stained shells was determined by colorimetry. Clam tissues were preserved in formalin for sectioning. Linear shell growth was not detrimentally affected by the presence of the physical tags. Shell growth rates from the drilled hole to the shell edge were similar for the Floy and monofilament-dymo tags. Alizarin could be used in short-term growth studies as an internal shell marker at 10 ppm concentration, with exposure for about 3 weeks. Alizarin could be used to measure shell deposition under defined experimental conditions, and more importantly, to measure total shell deposition, which is not completely determined using linear shell growth measurements. The effects of alizarin on clam tissues are also discussed.

REPRODUCTIVE CONDITIONING OF THE REEF-DWELLING SYMBIOTIC CLAM *Tridacna crocea* (Tridacnidae) USING ALGAE AND DISSOLVED INORGANIC NITROGEN.

Roa-Quiaoit, H.F.*, Belda-Baillie, C.A. & Gomez, E.D. *Marine Science Institute, University of the Philippines, Diliman, 1100 Philippines. Email: rhamq@cdo.philcom.com.ph

To evaluate whether reproductive conditioning of *Tridacna crocea* can be facilitated using nutritional supplements to the animal host and the algal symbionts (Dinophyceae), adult-size clams were exposed to one of the following treatments: (1) mixed algal diet of live *Isochrysis galbana* and *Tetraselmis tetrathele*, (2) dissolved inorganic nitrogen (DIN), (3) algae+DIN, and (4) control (no conditioning). After three months, DIN- and algae-supplemented clams had significantly increased concentrations of protein and carbohydrate in the gonads, respectively. Lipid significantly increased only in the algae-supplemented clams. Although there were significant changes among treatments in the reproductive stages of the ovary and testis, these were not associated with the changes in the biochemical composition of the gonads. The duration of the study and sampling frequency were not sufficient in assessing the effect of different conditioning on the reproductive development of the clams.

ECOLOGY OF THE FAMILY VERMETIDAE RAFINESQUE, 1815 (MOLLUSCA: CAENOGASTROPODA): DEPTH TRANSECTS IN THE BUNAKEN MARINE PARK, NORTH SULAWESI (INDONESIA).

Schiaparelli, Stefano*; Giada Franci, Silvester Benny Pratasik & Lalamentik, Laurentius Th. X. *DIP.TE.RIS. Università di Genova, Corso Europa 26, I-16132 Genova Italy. Email: isamge1@unige.it

The family Vermetidae Rafinesque, 1815 is a group of caenogastropods whose taxonomy, biology, ecology are still far to be adequately understood. Their particular shell is cemented to the substratum becoming hardly detectable in the field. Vermetids feed on particulate organic matter and/or living plancton which are collected either filtering water or spreading mucous sticking nets on the substratum. In the framework of the *Bio*diver*sity Program* some density estimates along depth transepts (up to 30 metres), mucus samples collections and vermetid biodiversity assessments were achieved for some sites in the Bunaken Marine Park (North Sulawesi, Indonesia). This lead to understand the possible ecological ranges of five vermetid species (two belonging to the genus *Dendropoma* and tree to the genus *Vermetus*) and to define their feeding behaviour.

ENDEMISM AND DISPERSAL IN MARINE MOLLUSKS: EVIDENCE FOR SPECIES SELECTION AND CLOSED POPULATIONS?

Selkoe, Kimberly A.* *Dept. of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106 USA Email: selkoe@lifesci.ucsb.edu

Many believe that dispersal strategy has a strong impact on the behavior of species in space and time. I examined the relationship of dispersal ability to 3 species-level traits: species diversity, endemism and population structure. I catalogued the developmental mode of 1000 benthic, marine mollusks in 184 families and assigned each family a dispersal ranking based on the fraction of species in the family with pelagic dispersal capability. I found that families with both pelagic and non-pelagic species are 3-4 times more speciose than families with only pelagic or only non-pelagic species. This finding supports the idea that shifts in development may be a common, rapid mode of speciation. Selection for local adaptation may lead planktonic dispersers to give rise to low dispersal forms with the cost of increased extinction rate. Next I examined the effect of dispersal on endemism. I used faunal lists from Easter Island, tropical Australia, and the Hawaiian, Kermadec and Galapagos Archipelagoes to assess endemism in 135 families with dispersal rankings. Endemism is significantly higher in families with only non-pelagic species than in families with mostly or totally pelagic species, indicating that dispersal impacts species range. Finally, I investigated the potential for high dispersal mollusks to have closed populations. Over 200 endemics in the 5 locations likely have planktonic larvae, evidence that populations with planktonic larvae can be closed and self-seeded, perhaps with significant frequency.

POPULATION DYNAMICS OF THE SPIDER SHELL, *Lambis lambis* (L.) (GASTROPOD:STROMBIDAE) IN THE RYUKYU ISLANDS, JAPAN.

Ueno, S.*, Mouri, S. and Hamaguchi, K. *School of Marine Science and Technology, Tokai Univ. 3-20-1 Orido, Shimizu, Shizuoka Prefecture 424-8610 Japan. Email: 9jofm005@scc.u-tokai.ac.jp

The spider shell, *Lambis lambis* is one of the most common species on coral reefs. Though the number of the snail is not few and the snail is important for marine products, the dynamics of the species are unclear. Surveys were carried out from June 1998 to August 1999 at the sea grass bed in Amitori Bay on Iriomote Island in the Ryukyu Islands of Japan. The research site (100_100m) consisted of 100 quadrates (10_10m). All the snails in the area were marked with a tag and painted. The snail were concentrated in the sea grass bed. Though the number of adult snails was stable two hundred every month, the number of immature and the juvenile snails varied monthly and increased from September to November. This population increase was the result of snail births during the spawning season (March to October). Snail population depletion was mainly attributed to predation by another animals, e.g.. *Conus marmoratus marmoratus*, *Conus textile*_and *Calappa gallus* . The number of dead snails was balanced in the year by births, enabling the area to maintain the snail population in status quo.

Session A28: Taxonomy

SKELETAL MORPHOLOGY OF *Millepora* SPECIES FROM BRAZIL, INCLUDING A PREVIOUSLY UNIDENTIFIED SPECIES.

Amaral, F.D*; Broadhurst , M.K.; Cairns, S.D.; and Schlenz, E. *UFRPE, Brazil. Email: famaral@nelore.npde.ufrpe.br,

The aim of this study was to identify the species of *Millepora* occurring in Brazil and also to compare the skeletal morphology of *M. braziliensis* from Brazil and *M. squarrosa* from the Caribbean. Over 100 colonies of *Millepora* were collected from various sites along the Brazilian coast. In an attempt to facilitate delineation between species, diameters of the gastropores and dactylopores were compared in addition to other less specific morphological characters. We proposed that the colonies collected from Brazil comprised four species: *M. alcicornis* (33 colonies), *M. braziliensis* (45), *M. nitida* (13) and one previously undescribed species (9). Analyses of variance of the diameters of gastropores and dactylopores among the various species showed considerable intra-specific variability and some inter-specific spatial variation. At the Abrolhos Islands, significant differences were detected between *M. alcicornis*, *M. braziliensis* and *M. nitida* for the mean diameter of the dactylopores, but not the gastropores. In contrast, significant differences in mean diameter of the gastropores were detected between *M. braziliensis* and *M. alcicornis* across three other locations. We hypothesized that *M. squarrosa* is a species distinct from *M. braziliensis*, although the use of molecular systematics may be required to eliminate doubts about their synonymy.

A PRELIMINARY APPROACH OF THE PHYLOGENETIC RELATIONSHIPS OF CARIBBEAN *PORITES* (ANTHOZOA, SCLERACTINIA).

Beltrán-Torres, A.U.*, Monks, S. *Depto. de Ecología Acuática, ECOSUR. Apdo. Postal 424, Chetumal, Q. Roo. 77000. MÉXICO. Email: abeltran@ecosur-qroo.mx.

The phylogenetic relationships and the monophyly of the six species of *Porites* present in Caribbean waters were evaluated based on 41 binary and multistate characters derived from previous morphometric analyses of Central American Poritidae. The outgroup consisted of six extant species from the eastern pacific. A Branch-and-Bound analysis of the data set produced nine equally parsimonious tree topologies, all 145 steps long with a consistency index=0.938, homoplasy index=0.062, and retention index=0.816. Two clades were defined by the strict consensus of the nine trees. One contained all of the Caribbean species except *P. astreoides. Porites astreoides*, found in the Caribbean, was placed in an unresolved clade along with two Pacific species, *P. panamensis* and *P. sverdrupi*. These two clades were supported in all of the nine trees. The relationships of the other four Pacific species were unresolved. Interpretation of the strict concensus tree suggests that Caribbean species do not form a monophyletic group and that two separate colonization events occurred. As well, the occurrence of both ramose and massive colony types in each of the two clades suggests that either ramose or massive colonies (or both) evolved more than once. The ability of the analysis to resolve relationships among members of the ingroup supports the conclusion that morphological data are a valuable source of information useful for phylogenetic analyses.

A DISSIMILARITY MEASURE FOR STRUCTURED DESCRIPTIONS IN NATURAL SCIENCES: APPLIED TO SPONGE AND CORAL SYSTEMATICS

Conruyt, N. *; Grosser, D.; Le Renard, J. *IREMIA, University of La Réunion, B.P. 7151, 97715 Saint-Denis, France. Email: conruyt@univ-reunion.fr

In the natural sciences, the structuring, depiction and treatment of knowledge can be of great complexity. For example, in biosystematics, the scientific discipline that investigates biodiversity, the descriptions of specimens are often highly structured (composite or specialized objects), noisy (erroneous or unknown data) and polymorphous (variable or imprecise data). Consequently, the design of new symbolic/numeric methods of data analysis which master this complexity is a challenge for computer science in inductive learning and case-based reasoning. We present here a dissimilarity measure well adapted to the purposes of phenetic classification and identification. The presentation is divided into three parts: (1) the explanation of our motivation for designing this new criterion based on the semantic of the domain emphasizing the importance of acquiring high quality descriptions through a well designed descriptive model. (2) the explanation that the measure is founded on the two structural and local dimensions of descriptions. We put the emphasis on the structural dissimilarity, with different treatments depending on the nature of the dependencies between the objects of the descriptions (i.e. composition versus specialisation relations). (3) our application of the dissimilarity measure to the *IKBS* system to structured descriptions of : 1/ sponge specimens of the genus *Hyalonema* and 2/ coral specimens of the family *Pocilloporidæ* for different comparison tests dealing with *monothetic* (based on a single criterion in decision trees) and *polythetic* (based on multiple criteria in comparisons) approaches. The results show that our dissimilarity measure is better adapted to the classification and identification in computer aided systematics, than classical dissimilarity measures which fail to take into account relations between objects of the descriptions.

Session A29: Biology and Ecology of Non-Scleractinian Cnidarians

THE ROLE OF FISSION AND FRAGMENTATION IN POPULATION DYNAMICS OF *Palythoa caribaeorum*.

Acosta, A*. Sammarco, P. *Pontificia Universidad Javeriana Carrera 7 # 43-82. Depto. de Biología, Bogotá, Colombia. Email: laacosta55@hotmail.com

Three variants of fission and two modes of fragmentation were quantified for one year on Brazilian populations of *P. caribaeorum* to assess 1) the impact of ramet production on population growth, and 2) differences in the frequency of these modes between two contrasting sites (varying in levels of turbidity, light, and sedimentation); between two depths (contrasting in light levels); and between seasons (varying in temperature). 55% of the monitored colonies (n_t = 579) exhibited at least one variant of fission, yielding 1,304 ramets / year. Fragmentation occurred in only 7.2% of the population, yielding 64 new ramets. Fission played a critical role in ramet production and most likely functions to increase population growth. There was no significant difference in ramet production *via* fission between sites, depths, or seasons. There was no difference in total ramet production *via* fragmentation between sites. Ramet production did vary, however, with respect to depth and season, with a higher number of fragments being produced in shallow waters, and in the fall, respectively.

MODES OF ASEXUAL REPRODUCTION IN THE ZOANTHID *Palythoa caribaeorum*.

Acosta A*. & Sammarco, P. *Pontificia Univ. Javeriana. Kra. 7#43-82. Depto. Biología, Bogotá, Colombia. Email: laacosta55@hotmail.com

P. caribaeorum populations were followed in Brazil for two years in order to study their asexual reproductive modes. This species was found to use four variants of fission (Teardrop Formation -TF, Polyp Ball Production -PBP, Edge Fission -EF, and Pseudo-Colony Lift-Off -PCLO) as well as two variants of fragmentation -*via* partial colony mortality (*i.e*. disease), and *via* physical disturbance. All modes described here for this species are reported for the first time (PBP is also new for the Zoanthidea). In TF, tissue grew into teardrop formations, hanging beyond the edge of the colony and then autotomizing. In PBP, a small group of polyps (< 9) grew upward and outward from the upper surface of the colony; after the coenenchyme connecting neighboring polyps had degenerated, the new ramet was dispersed. EF and PCLO required the formation of basal coenenchyme, and then the production and severing of polyp-groups. EF occurred at the colony edge, while PCLO occurred at the center of larger colonies. In the latter, a polyp-group would separate itself from neighboring groups and the substratum, then lift off and drift away.

GORGONACEA (OCTOCORALLIA: COELENTERATA) IN THE GULF OF AQABA (JORDAN) WITH DESCRIPTION OF TWO NEW SPECIES AND ONE NEW RECORD.

Al-Zereini, Wael*; Al-Moghrabi, Salim M. *Marine Science Station, Aqaba, 77110 Jordan. P.O. Box 195. Email: w_zereini@usa.net

The Gulf of Aqaba is one of two appendages at the north tip of the Red Sea. It embraces highly diverse reef structures of the fringing type, which represent the most northern latitudinal distribution of coral reefs worldwide. Nevertheless, scarce studies have been done on Octocorallia in general and on Gorgonians in particular. This is the first study that deals with the identification of Gorgonians from the Gulf. Samples were collected from five sites along the northern coast of the Gulf of Aqaba (Jordan). All samples were found in surge-protected locations, but in zones of some current due to tidal flow. Morphological characteristics, including color, shape, dimensions, etc… of each colony were done in situ and in the laboratory on preserved samples. Furthermore, several underwater photographs have been made for each sample. At a later stage, the specimen itself or a piece of it, was used for detailed study using scaning electron microscopy. Taxonomic descriptions of these species are based on such closer investigation of axial structures and sclerite forms. Collected samples were found to represent seventeen species of Gorgonacea that belong to eight genera and four families. Out of these, two new species were identified and described. In addition, one sample was reported for the first time to flourish in the Gulf of Aqaba.

EFFECTS OF AXIAL FLEXIBILITY AND STRENGTH ON *PLEXAURA KUNA* FRAGMENTATION.

Boller, M. L.*; Swain, T. D.; and Lasker, H. R. *University at Buffalo, Buffalo, NY 14260, USA. Email: boller@buffalo.edu

For many colonial marine organisms, opposing selective forces will influence the flexibility and strength of the organism's supportive structures. The ability to form asexual propagules via fragmentation will be enhanced by stiff skeletons that are unable to shed drag load and by weak skeletons. Alternatively, flexing and shedding of drag load may prevent holdfast failure and strength of the skeleton is needed for support of the colony in the water column. Aggregations of the gorgonian coral *Plexaura kuna* found in the San Blas Islands of Panama are formed via failure at constriction points in the axial skeleton and variation in the size of clones suggests that skeletal properties may vary among clones. We looked at the flexibility and strength of the axial skeleton of several genotypes of *P. kuna* to predict if there was great enough variation in those traits to cause variation in the rate of fragmentation . Flexibility, measured with Young's modulus, significantly varied among clones suggesting that stiff clones would shed less drag load, be subjected to higher forces, and have increased rates of fragmentation. The modulus of rupture, which measured the strength of the skeleton, also significantly varied. Variation among clones in flexibility and strength of the axial skeleton, in concert with axis constrictions, may provide a mechanism through which selection can act to favor asexual reproduction and clonal growth.

CONTRIBUTION OF STUDIES ON LIVE TO ESTIMATE HYDROID BIODIVERSITY IN CORAL REEFS.

Gravier-Bonnet, N*; & Bonnet, Bernard. *Ecomar, Université de La Réunion, 15 Av. René Cassin, BP 7151, 97715 Saint-Denis Messag Cedex 9, FRANCE. Email: Nicole.Gravier-Bonnet@univ-reunion.fr

Hydroids represent an important part of coral reefs biodiversity regarding to species number, large distribution within biotopes and depth, and varied adaptations and life-cycles. In litterature, hydroid biodiversity is usually and mainly viewed through taxonomy based on the study of preserved specimens and, for the thecates (75 % of hydroids) on the diagnosis of the single skeleton. Through examples, we are illustrating here how the observation of living specimens can modify and greatly improve the knowledge of species and even contribute to reconsider both diagnosis and classification. Including the characteristics of the soft bodies (polyps, tissues, cells) to the description of specimens conduced to question the synonymy of two species and their possible belonging to the genus *Sertularella*; to discover a new type of specialized polyps, a new nematocyst type for sertularids and jointed tentacles at base, i.e. three important characters for their relationship with other families; and to describe a sphincter structure, new for hydroids, at the polyp base. *In situ* and laboratory studies of living colonies of three species of the genera *Rhizogeton*, *Sarsia* and *Nemalecium* cohabiting into shrimp crevices, provided new data about the numerous adaptations shown by these species inside the microhabitat, either functional or ecological (varied reproductive modes, diets and microdistributions). Moreover, adhesive tentacles on the *Sarsia* medusae, a so far unknown characteristic within the family, was discovered.

DETERMINATE GROWTH IN OCTOCORALS: WHY IT AFFECTS CONSERVATION, MANAGEMENT AND REMEDIATION.

Lasker, Howard R. *Dept. of Biological Sciences, University at Buffalo, Buffalo, NY, 14260, USA. Email: hlasker@buffalo.edu

The Caribbean gorgonian *Pseudopterogorgia elisabethae* is harvested for the extraction of commercially valuable pseudopterosins. Therefore, data on colony growth are important in developing harvest and mariculture strategies. Colonies develop through the iterative replication of polyps to generate branches and the iterative replication of branches to generate overall colony form. This pattern of modular growth is generally characterized as indeterminate, i.e., colonies continue growing after reaching maturity. Analyses of the growth patterns of 261 colonies on San Salvador, Bahamas over 2 y indicates many aspects of *P. elisabethae* growth are determinate in nature. Tributary branches grow to a characteristic length and then stop growing. Growth of source branches, measured as either branching rates or branch extension, decreases as colonies grow/age and varies with position. The presumption of indeterminate growth among modular taxa such as corals and octocorals, suggests that colonies readily recover from disturbance or harvesting and that colonies can be indiscriminately partitioned to generate "brood stock" for mariculture. Determinate colony growth does not preclude either harvesting or mariculture, but it indicates that assumptions about the resilience of colonies are probably inaccurate and that species-specific analyses will usually be required in developing management plans and mariculture techniques.

DISTRIBUTION AND SEXUAL REPRODUCTION OF THE TROPICAL ACTINIARIAN, *PHYMANTHUS STRANDESI* (CNIDARIA; ANTHOZOA; ACTINIARIA; PHYMANTHIADE) IN SOUTHERN TAIWAN.

Lin, M.-D.*; Chen, C. A.; Fang, L.-S. *Institute of Zoology, Academia Sinica, Taipei, 115, Taiwan. Email: mingdoun@ms32.hinet.net

Distribution and sexual reproduction of the tropical actiniarian, *Phymanthus strandesi*, was investigated in the Hsiaoliuchiu Island, southern Taiwan from June 1997 to May 1998. *P. strandesi* was distributed in the intertidal zone of reef flat with a mean density (±SD) of 775.9 ± 462.4 m^{-2}. The distribution pattern of *P. strandesi* was contagious, and significantly correlated to the presence of seagrasses, *Thalassia hemprichii* and *Halodule uninervis*. *P. strandesi* was a dioecious actinarian with the mean pedal disc diameter of 0.32 ± 0.11 cm. Most of the anemones examined in this study were reproductively inactive, and their sizes were significantly smaller than those of males and females. The mean fecundity and gonad index were 294 and 14.1%, respectively. The released eggs were 500 to 560 δm in diameter. Gametogensis examined by paraffin section did not show seasonal variation among the monthly samples, suggesting that *P. strandesi* might reproduce continuously throughout the year. Although small body size confined the fecundity, large eggs, continual gametogensis, and contagious aggregation might ensure the success of sexual reproduction and recruitment of *P. strandes* in the seagrass bed of reef flat.

THE RELATIONSHIP BETWEEN GORGONIAN ASAMBLAGE ABUNDANCE AND BODY SIZE IN CARIBBEAN CORAL REEFS.

Rodriguez-Lanetty Mauricio, Mauricio*, Freddy Losada. *Centre for Marine Studies. University of Queensland. St. Lucia QLD 4072. Australia. Email: m.Rodriguez@mailbox.uq.edu.au

Studies of the relationship between body size and animal population density has been an issue of active research in the last two decades, especially for terrestrial and non-sessile animals. All these studies have found a negative linear relationship between abundance and body size. Several interpretations of the power value that population density scales with body size are being based on the energy flow within animal assemblages. In this study, we examined and compared the relationship between population density and body size in assemblages of gorgonians (Octocorallia) in two coral reefs located on the central coast of Venezuela, to answer two questions: (1) What form does the relationship between body size and abundance within gorgonian assemblages usually take? (2) Is body size a good predictor of gorgonian abundance? A negative relationship between log body size and log population abundance was found for both assemblages and sites studied. Moreover the same amount of variance (40%) in abundance for both sites is explained by the body size. The regression slopes were similar for both sites (scaling at – 0.23), which were different and much lower to those reported so far for non-sessile animals. This difference could be associated to the well-known ecological differences between marine sessile animals and non-sessile terrestrial animals. The explanation for the relationship found in this study is uncertain at this early stage. Future work is required to corroborate this finding. However, we state some possible hypothesis and explanation based on the ecological properties of coral systems.

Session A30: Coral Reef Community Structure

FACTORS CONTROLLING CORAL REEF COMMUNITY STRUCTURE IN THE SHALLOW RED SEA REEFS OF MASSAWA (ERITREA).

Ateweberhan, M.*; Bruggemann, J.H.; and Breeman, A.M. *Department of Marine Biology and Fisheries, University of Asmara, P.O. Box 1220, Asmara, Eritrea. Email: mebrahtu@marine.uoa.edu.er

Hard coral and reef algal distribution were investigated for 18 months for four stations in two sites in the shallow reefs of Massawa (Eritrea). Corals are limited to lower zones and their distribution in shallow areas is controlled by extreme environmental conditions in the hot season (south-western monsoon) and competition by reef algae in the cold season (north-eastern monsoon). Upper zones are dominated by different algal functional groups and the community structure reflects inter-group competition for un-partitioned resources in temporal and spatial scales.

THE NEW HARD CORAL RESOURCES OF ORISSA COAST

Bapuji, M.*, Sree, A., Vimala, A. and Choudhury, S. *Regional Research laboratory, Bhubaneswar, PIN 751 013, India Email: mbapuji@email.com

About one hundred years back, twenty sponges were collected by dredge from Orissa (Bay of Bengal) coast. Thereafter, there was no report on the occurrence of any sedentary fauna in this coast. During the past ten years, following certain tell-tale signals, systematic geophysical scanning of the sea bottom, SCUBA diving, under water video documentation and collection of the live specimens was carried out. The study revealed for the first time the distribution of nine species of scleractinian hard corals. Two of them occur in considerable quantities : the foliaceous Mycedium elephantotus, is spread over 2 X 0.2 km area in the southern end of Orissa coast. Video-documentation of this species shows probable active, biogenic reef build up. The encrusting coral, Cladangia exusta, which was so far reported only from Cochin on the west coast of India, is now found to occur extensively near Dhamra mouth, in the Northern Orissa coast. Except these two, the rest of the corals are found to be widely distributed all along the newly found lineations at 30m depth. These findings are important in view of (1) the occurrence of other, non-sedentary, unique, endangered marine resources of this coast like Olive Ridley turtles and the Blue crab (2) the increasing industrial activity and the Human needs.

DISTRIBUTION AND DIVERSITY OF CORAL COMMUNITIES IN THE ABROLHOS REEF COMPLEX, BRAZIL.

Castro, C.B*; Segal, Bárbara; and Pires., Débora O. *Museu Nacional/Universidade Federal do Rio de Janeiro, Departamento de Invertebrados, Quinta da Boa Vista, s/n, São Cristóvão, 20940-040, Rio de Janeiro, RJ, Brasil. E-mail: cbcastro@pobox.com

The Abrolhos Reefs Complex is located on a broadened area of the Brazilian continental shelf. The most complete description of these reefs was undertaken in the 60s by Jacques Laborel. Based on descriptive data, he suggested that the diversity of reef communities in the Abrolhos Reef Complex rose with increasing distance from the mainland. This assumption was tested using quantitative and semi-quantitative data to describe the diversity of communities and the distribution of key species. Five point intercept transects (10 m long; 250 data points each) were laid over three reef pinnacles (tower-like patches) in each of three reef areas located with increasingly greater disce from the mainland. Shannon's diversity and Heip's evenness indices increased for reefs with increasing distance from shore, in accordance to Laborel's general assumption. This occurred mostly because of the overwhelming dominance of *Palythoa caribaeorum* coverage in areas closer to shore. Non-metric MDS plot showed transects of the two reef areas closer to the mainland clustered together, while those of the furthest reefs were scattered aside from this cluster. Visual estimates and a grading system (ra sparse, common, 1-5% bottom coverage, 5-25%, 25-50%, >50%) were used to evaluate a larger number of areas distributed all over the Complex. Most species are widespread throughout the Complex. However, mapping of the grades of each species at each site wed that reefs areas varied in species abundance and/or occurrence.

POPULATION STRUCTURE OF MUSHROOM CORALS (FUNGIIDAE) IN THE NORTHERN RED SEA.

Goffredo, S.*; and Chadwick-Furman, N. E. *Dipartimento di Biologia Evoluzionistica Sperimentale, Università degli Studi di Bologna, Via F. Selmi 3, I-40126 Bologna, Italy. Email: sgoff@tin.it

Population dynamics of scleractinian corals are difficult to model due to complex processes that alter the correlation between size and age (i.e. fragmentation and fusion of individuals or colonies). In certain solitary forms, for example in mushroom corals, these processes are rare and if they occur, are clearly recognizable. In these corals, age and size may be correlated, and it is possible to apply classic population dynamic models. The demography of *Ctenactis echinata, Fungia scutaria, F. fungites* and *F. (Danafungia)* spp. was analyzed on a coral reef at Eilat (Israel). Through identification of the cohort sizes, we estimated growth parameters and mortality rates of the coral populations. The four taxa show different demographic traits, which relate to their relative depth distributions. Species with individuals that occur mainly in shallow waters (*F. scutaria* and *Ctenactis echinata*) show the highest mortality and growth rate. In particular, members of the species that is limited mostly to the reef flat (*Fungia scutaria*) have a population structure characterized by a great quantity of young individuals, in part asexually generated. This high rate of recruitment could be fundamental to the survival of *F. scutaria* polyps in this frequently disturbed reef habitat. In conclusion, our results indicate a relationship between the type of reef habitat occupied and the demographic characteristics of mushroom corals on a fringing reef in the northern Red Sea.

CORAL POPULATION DYNAMICS IN THE SOLITARY ISLANDS MARINE PARK.

Harriott, Vicki J.*; Smith, Stephen D.A. *School of Resource Science and Management, Southern Cross University, Lismore, NSW (Present address: CRC Reef Research Centre, James Cook University, Townsville, 4811. Email: vicki.harriott@jcu.edu.au

The population dynamics of coral communities have rarely been studied in subtropical coral communities, despite hypotheses that such communities may be subject to more variable mortality and recruitment rates than tropical coral reefs. In the Solitary Islands Marine Park (30° S), changes in cover of coral and other biota in mapped fixed quadrats were recorded at three island sites at approximately annual intervals between 1993 and 1998. At two of the sites, coral cover was relatively stable over time and ranged between 30% and 35% cover over the five years. At the third and most inshore site on the coastline at Coffs Harbour, coral cover approximately doubled during the study period, from 10% to 20% cover. For all times pooled, coral recruitment rates averaged 1.3 to 2.0 recruits /m^2 /year, while mortality rate was 1.2 corals recruits /m^2 /year. Recruitment rate was strongly correlated with mortality rate for different taxa. *Pocillopora damicornis* contributed about 50% of the population turnover, but only 23% of the coral cover at the three sites. Principle causes of coral mortality during the period were localised storm damage and overgrowth with worm tubes.

RECRUITMENT AND SURVIVAL RATE IN YANBU CORAL REEF.

Joseph, P.S.*; & Sy, Jaime C. *Former Project Manager, Environment Monitoring Project, Royal Commission for Jubail & Yanbu, Saudi Arabia. Email: dilu@eth.net

A coral recruitment study in Yanbu coral reef (Red Sea) aimed at measuring the standing crop or biomass accumulation was conducted at three monitoring sites to ascertain the factors affecting coral survival. The percentage cover of bare space, sediment, fleshy algae and crustose coralline algae and the number of other settling organisms on settling plates were recorded. The Shannon diversity indices for the inner protected surfaces of the plates at the less stressed Control station appeared to be more diverse. The species diversity on the unprotected plate surfaces at SE End was greater than of the other stations. Coralline algae were more abundant on the unprotected plate surfaces at all depths and stations. About 42 –50% of the plates exposed at Control and SE End stations were recruited by corals, with 25 –30% at Gap station. The SE End had more coral recruits, with 99 individuals at 5m and 127 at 10m depth, Gap station with the least number of 10 at 5m and 23 at 10m depth, Control station with 61 at 5m and 36 at 10m. The protected plate surfaces at 5-m depth had more coral recruits at all stations. The majority of coral recruits at SE End were over grown by fleshy algae and had a very low survival rate. The chances of survival were even less at Gap station. The critical factors on larval attachment and metamorphosis and the local environment that influenced the coral recruitment were discussed.

NEIGHBORHOOD EFFECTS ON GROWTH AND SURVIVAL OF PATCH-FORMING STONY CORALS IN LOOSE SEDIMENT COMMUNITIES.

Licuanan, Wilfredo Y.*. *Biology Department, De La Salle University, 2401 Taft Avenue, Manila 1004 Philippines. Email: licuanan@edsmail.com.ph

Reciprocal cross transplantation experiments were performed to assess the role of interspecific competition and local environmental effects on the formation and maintenance of monospecific stands of stony corals, *Anacropora puertogalerae* and *Acropora subglabra*, found on unconsolidated reef substrates. *Acropora subglabra* appeared superior to *A. puertogalerae* in terms of digestive interactions. Despite this, *A. subglabra* experienced higher mortality rates when transplanted into *A. puertogalerae* patches (the cross transplant treatment for the former). However, branch extension rates of *A. subglabra* did not differ among the control, transplant (handling) control, cross transplant, and release (colonies moved into areas naturally devoid of coral) treatments. *Anacropora puertogalerae* cross transplants and release colonies, on the other hand, had significantly lower branch extension (growth) rates when compared to controls but spread rapidly. These results may be due to the reduced water flow and sedimentation regimes found in the *A. puertogalerae* patches, which allowed the latter species to overcome the digestively superior *A. subglabra*. Thus, within-zone distributions of these corals may be determined by interactions among neighboring colonies, but the outcomes of these interactions depend on changes in the physical environment brought about by the presence of the corals themselves.

CNIDARIAN COMMUNITY STRUCTURE ON BEACH ROCK IN SANTA CRUZ, ARACRUZ, ESPÍRITO SANTO, BRAZIL

Longo, L.L.*; Rosso, S.; & Schlenz, E. *Depto de Zoologia, IB/USP, São Paulo, SP, Brazil, CP:11461, CEP: 05422-970. Email: lllongo@ib.usp.br

Most studies on benthic communities take into account faunistic composition and taxonomy. Nowadays there is a trend towards working with a wider methodology, that supplies more information on community structure. The present work aimed at finding out the composition, abundance and space-time dispersion of a beach rock cnidarian community at the "Estação de Biologia Marinha de Santa Cruz", Aracruz, ES (20^0S $40^0$10'W). The pools were called erosion pools and constituted the sampling units. Randomly located 30 sampling units were studied, using the point quadrat method to measure substratum coverage, every 2 months during the period from May-94 to Feb-95. This resulted in a space-time matrix with 35 species and sediment covers, and 180 sampling units. An environmental factors matrix was also constructed. According to sand bottom coverage the classification and ordination analysis pointed to two homogeneous strata. The most abundant species were the zoanthids *Palythoa caribaeorum* (mean coverage between 86,5% and 50,8%) and *Zoanthus sociatus* (mean coverage between 21,63% and 4,62%). They occurred on both strata however, *Palythoa caribaeorum* was more abundant on hard bottoms, and *Zoanthus sociatus* more so on sandy bottoms. Other Cnidaria species were registered, but less abundant, and with restricted dispersion. Composition, abundance and dispersion of organisms did not show any seasonal variation during all the study period. These data provided reliable informations for further studies on environmental impact on beach rocks.

THE BIODIVERSITY OF THE BENTHIC FAUNA OF THE SUVA AND NADI LAGOONS (FIJI).

Mohammed, Shirley*. *Marine Science Programme,University Of The South Pacific. P.O.Box 1168, SUVA.FIJI.
Email: S95007500@USP.AC.FJ.

Fiji Islands are amongst tropical ecosystems subject to increasing anthropisation. Although of cultural and economical importance to human populations, the reef complex is quite poorly known, especially when dealing with soft bottom substrata. This research identifies taxa of benthic communities in lagoon sediments and describes community structure, and highlights functioning patterns, including effects due to anthropic disturbances. Comparison with environmental variables of sediment (grain size, organic composition) and variables related to benthos (taxonomic richness, abundance, biomass) lead to identification of the nature and intensity of disturbances. Research work involved the collection of grab samples (Smith McIntyre) from stations located in Suva and Nadi lagoons (FIJI), using global positioning system (GPS). A preliminary study carried out on 10 stations from the Suva lagoon showed that abundance and taxonomic variables were influenced by increasing anthropic disturbances. The dominance of deposit feeder populations was apparent in impacted areas. Polychaetes and, mollusc, to a lesser extent are good indicators for disturbance in the coastal system. The polychaetes *capitella sp.* (Polychaete: Capitellidae) and *cossura sp.* (Polychaete: Cossurridae) are used as indicator species for disturbed areas.

PATTERNS OF RARITY IN HERMATYPIC CORALS OF THE EASTERN PACIFIC.

Reyes Bonilla, Héctor*. *University of Miami. Rosenstiel School of Marine and Atmospheric Science. Division of Marine Biology and Fisheries. 4600 Rickenbacker Causeway. Miami, FL 33149. U.S.A. Email: hreyes@rsmas.miami.edu

Rarity is a concept applied to taxa that have a restricted distribution range and are prone to local extinction. It is important from the conservation point of view but it has been rarely investigated in marine communities. The objective of this work was to look for patterns of rarity in the hermatypic coral fauna of the eastern Pacific region. The research was supported by a database including all coral species known and the localities where they were observed. A total of 44 species of reef corals have been reported for the western coast of the Americas and of these, 7% are regionally extinct and 11% have disappeared from specific localities. Taken in account the extinct species and those that have been observed only in one or two sites, 19 coral species from the region can be considered as rare. They are prevalent in the families Acroporidae, Faviidae and Poritidae and scarce in Siderastreidae and Agariciidae. In relation to geographic location, 74% of the rare species are restricted to oceanic islands, espacially the Revillagigedos, Clipperton and Easter. Rarity is also linked to characters correlated with a predominantly asexual mode of reproduction like hermaphroditism, and ramose, free-living and foliose morphologies. The eastern Pacific region have a high percentage of coral taxa with propensity to be extinct due to their rareness, and its faunal composition should be considered as unstable. It is presumable that populations of these uncommon species have a limited ecological role in this region, but some of them may actually be suffering speciation.

SPATIAL ANALYSIS OF JUVENILE CORALS IN THE MEXICAN CARIBBEAN.

Ruiz-Zárate, M.A.*; Hernández-Landa, R.C.; Arias-González, E. *CINVESTAV, km 6 antigua carretera a Progreso, A.P. 73 Cordemex 97310, Mérida, Yuc., México.
Email: mruiz@kin.cieamer.conacyt.mx

During the 1999 AGRRA surveys of 8 reefs in southern Quintana Roo, México, small (<2 cm max. diameter), naturally-occurring, stony corals, presumed to be juveniles, were counted in 0.0625 m^2 quadrats (N = 1,747) at ~10 m on 3 sites/reef. 21 taxa were identified (10 scleractinians each to species and genus and 10 scleractinians each to just genus, 1 milleporine species). The richness and density of juvenile taxa were significantly different at the Sector (75-80 km) and reef (20-30 km) scales; only density differences were significant at the Site (0.9-1 km) scale. In three-levels nested ANOVAS**,** the Site level contributed the greatest proportion (51.87 %) of the variance for the richness of juvenile taxa, whereas the variance among taxa (89.76%) overwhelmed any geographic differences in their density. Three coral genera (*Agaricia* > *Siderastrea* > *Porites*) were the most important (Sanders' biological index) in terms of relative abundance and the highest frequencies of occurrence (at 88%, 88%, 79% of the sites, respectively) at 10 m depth. However, the significant differences among spatial scales found in taxon richness and density suggest that regulatory mechanisms differentially modify the composition and survival of coral recruits on these reefs**.**

THE FLOWER GARDEN BANKS – THRIVING REEF SYSTEMS IN THE NORTHWESTERN GULF OF MEXICO.

Schmahl, George P.*; Hickerson, Emma L. *Flower Garden Banks NMS, 216 W. 26th Street, Ste. 104, Bryan, Texas, USA. Email: george.schmahl@noaa.gov

The Flower Garden Banks National Marine Sanctuary encompasses the northernmost coral reefs on the North American continental shelf. Located 107 miles south of the Louisiana/Texas border in the northwest Gulf of Mexico, the reefs thrive despite being nestled in the middle of one of the world's most productive oil and gas producing fields. The healthy reefs survive precariously at the fringe of coral's biological and physiological requirements. The low diversity and high coverage of the corals make for an impressive show of mass spawning, as well as provide habitat for resident and seasonal populations of reef fish, invertebrates, elasmobranchs, and sea turtles. Since the early 1970's researchers have been travelling far offshore to study this unique area, as well as to initiate the long term monitoring efforts, which continue today. During the 1990's scientists have looked to the Flower Gardens as a healthy coral reef system to help answer questions pointing to the decline of coral reefs around the world. Sanctuary personnel use modern techniques to manage and protect the site. Projects supported by the Sanctuary office include: satellite tracking of threatened loggerhead sea turtles; genetic studies of reef fishes, corals, and algae; identification and habitat use assessment of manta rays; population age structure of two species of reef fishes; and several mass coral spawning investigations. This site continues to provide scientists opportunities for discovery.

DYNAMICS OF JUVENILE CORAL POPULATIONS IN THE NO-TAKE ZONES OF THE FLORIDA KEYS.

Smith, S.R.*; Webster G.; Grayston L.; Stanley A.M.; Hellin D.C. *Bermuda Biological Station for Research, 17 Biological Station Lane, Ferry Reach, St. George's GE 01, Bermuda. Email: robbie@sargasso.bbsr.edu

Juvenile coral populations in large permanent photo-quadrats at six shallow and six deep reef sites in No-take Specially Protected Areas (SPA) and reference areas in the Upper and Lower Keys were surveyed visually and photographed in June 1998 and June 1999. Hurricanes Mitch and Georges affected the sites in fall 1998. Five of the six shallow sites displayed unusually high rates of juvenile mortality (35-60%), compared to historical data (15-25%) from the Keys and may be an effect of the 1998 hurricanes. Deep sites in the Upper Keys had higher juvenile coral mortality rates (40%) than deep sites in the Lower Keys (25%). The Lower Keys deep sites exhibited the highest levels of juvenile coral recruitment (8-10 m^{-2}) compared to the Upper Keys deep sites (2-3 m^{-2}). The recruitment rates were low and fairly consistent at all shallow sites (2-3 m^{-2}). No consistent differences in recruitment and juvenile coral mortality rates were noted between the No-take and reference sites.

WHICH FACTORS STRUCTURE CORAL POPULATIONS OVER REEF SLOPES?

Vermeij, M.; and Bak, R.P.M.*. *Netherlands Inst. for Sea Research (NIOZ), P.O.Box 59, 1790 AB Den Burg, The Netherlands, Email: rbak@nioz.nl

The distributional patterns of six species of the coral genus *Madracis*, over a reef slope (5-60m), shows: Firstly that all size frequencies are species specific and, secondly, that species specific size frequencies do not change with depth. While species size frequencies remain identical there are significant changes in abundance of colonies with changes in environmental factors (light, temperature and sedimentation) over the reef slope. These changes are not linearly related with depth. Light is an important environmental factor structuring coral populations. There are structural and positional adaptations. At 30m (xx % surface light) positional adaptation is no longer possible for 3 species, 2 species reach peak abundance and 2 species only occur beyond this depth.

The similarity of size frequency distribution for each species over depth shows that life histories respond similarly to a broad range of interacting environmental factors. However, at the outer limits of a species' distribution populations show characteristic changes. Descriptors of size-frequency data showed that in these marginal habitats populations are characterised by relatively large and equally sized colonies. Size frequencies of these populations are skewed to the left after log-transformation and gini-coefficients are low (0.2-0.3). The average colony size, after range-standardising the original size data, is a new size-independent determinant to see whether populations occur in marginal habitats. This technique may be useful to assess other coral populations for their fitness to local circumstances.

TEMPORAL SHIFTS IN COMMUNITY STRUCTURE OF LITTLE AFRICA PATCH REEF, DRY TORTUGAS, FLORIDA: INFLUENCE OF *ACROPORA* MASS MORTALITY.

Weaver, D.C.* and Funicelli, Nicholas. *U.S. Geological Survey, Biological Resources Division, Gainesville, FL, USA. Email: doug_weaver@usgs.gov

Trends in benthic invertebrate and fish community structure of the *Acropora* zone of Little Africa Patch Reef, Dry Tortugas, FL were surveyed from 1995 to 1999. Shifts in live coral coverage and fish communities in the *A. cervicornis* zone were pronounced after an episode of mass mortality between the 1995 and 1997 surveys. Percent cover of live corals in the staghorn zone declined from 13% in 1995 to 1% in 1997, 0.4% in 1998, and 0.1% in the 1999 survey, while live coral cover on a nearby *Montastrea* zone remained relatively high from 1995 to 1998 (15 to 24%). During this period, a shift in reef fish community structure and overall increase in reef fish abundance was observed, becoming numerically dominated by parrotfishes (Scaridae) and grunts (Haemulidae). A decline in territorial behavior by damselfish and subsequent increase in reef visitation by grazing parrotfishes is likely to exacerbate the low recolonization rates of *A cervicornis*. The increase in abundance of grazing fishes on the *A. cervicornis* reef at Little Africa may be a contributor (in addition to low temperature mortality and coral disease) to the cycles of *Acropora* abundance throughout the Dry Tortugas that has been observed during the past century.

COMMUNITIES OF CORAL REEF CAVITIES IN JORDAN, GULF OF AQABA (RED SEA).

Wunsch, Mark *; Al-Moghrabi, Salim M.; and Kötter, Iris. *Center for Tropical Marine Ecology, Fahrenheitstr. 1, 28359 Bremen. Email: mwunsch@uni-bremen.de

Cavities are a ubiquitous feature of coral reefs offering a large substrate to benthic organisms. Due to their small size very little is known about the communities lining their walls. Using the video-endoscopic CaveCam we investigated the community composition of coral reef cavities in a Red Sea fringing reef. Cavities measuring 0.2-0.6 m in diameter and 1.25-1.75m in length were studied at a depth between 2-20 m. From 1400 close-up images a total of 274 macrobenthic taxa were distinguished covering 57.7 % of the substrate. Algae constituted 52.4% of the living cover. The fauna cover consisted mainly of sponges (15.9 %), polychaete crusts (5.6 %), scleractinian corals (2.2 %) and ascidians (1.8%). Algal cover decreased from 60 % at the cavity entrance to below 20 % at 0.75 m distance from the entrance. Conversely faunal cover increased from less than 20 % near the entrance to up to 40 % within the cavities. Light and water flow were the main factors governing the zonation within cavities, whereas water depth and water flow determined the community differences between cavities.

Session B1: Designing Effective Coral Reef MPAs: Lessons Learned from Across the Sciences Around the World

SITE SELECTION CRITERIA AND CONSTRAINTS FOR MPAS.

Agardy, Tundi *. *Conservation International, 2501 M St. NW Washington, DC 20037 USA. Email t.agardy@conservation.org

Marine protected area design and implementation has entered a new phase of sophistication as more rigorous approaches to protected area planning have emerged, and as experiential learning across several decades has increased. Certain scientifically-rigorous criteria now guide the selection of marine protected area sites as well as the subsequent size, shape, and management regime of individual protected areas. These criteria relate directly to the specific objectives that the protected area or protected area system are established to achieve. Such objectives include, inter alia, habitat protection for overall biodivesity conservation, fisheries management and stock enhancement, nature-based tourism development, protection of traditional use and tenure, and scientific research. Coral reef marine protected areas are classified according to these objectives with objectives-specific subsets of criteria for selection and design. Specific examples are given for each subset, spanning the spectrum from small-scale community-based marine protected areas to large scale protected areas and networks of protected areas administered by centralized government authorities. Finally, we must recognize that though serious advances have been made in marine protected area planning, the "science" of marine protected area site selection and design is still something of an art, and neither hard and fast rules for optimizing design nor a model marine protected area can be said to exist.

CHALLENGES AND OPPORTUNITIES FOR COMMUNITY PARTICIPATION FOR THE MANAGEMENT OF MARINE PROTECTED AREAS (MPAs) IN THE PHILIPPINES.

Aliño, Porfirio M.*, Hazel O. Arceo, Nadia Palomar and Andre Uychiaoco. *The Marine Science Institute, University of the Philippines at Diliman, Quezon City 1101, PHILIPPINES. Email: pmalino@msi01.cs.upd.edu.ph

The Philippines provides a broad range of experiences in conservation initiatives at the community based levels, in national integrated protected areas planning and the establishment of transboundary MPAs. Despite the paucity of a consistent objective and clear framework statement for representative network of MPAs, community participation has been espoused as inherent feature in the formulation of a conceptual approach for designing these networks of marine protected areas. Lessons drawn from the evaluation of various criteria in the planning and operational implementation of MPAs in the Philippines show various challenges and opportunities to achieve greater impacts and sustainability. For most of the community based MPAs, the expectation for sustaining fisheries has been consistently apparent. While larger biogeographic regions primarily aim to conserve and protect biodiversity these management objectives are linked to a perceived paradoxical utility to the community. The challenge presented by this seeming contradictions can be overcome by looking at opportunities for cooperative areas and processes as seen in the sample cases of good practices. These sample cases show participatory adaptive management at the local community level, mechanisms for harmonizing national and regional legislation, and moving towards joint activities to enhance confidence and goodwill in working together towards common goals or at least identifying complementary roles and contributions.

CORAL REEF CONSERVATION IN HONG KONG: DEVELOPMENT OF A NEW MARINE PARK IN TUNG PING CHAU - MANAGEMENT ISSUES AND STRATEGIES.

Ang, P.O. Jr*. *Department of Biology, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China. Email: put-ang@cuhk.edu.hk

Tung Ping Chau, an island in the NE part of Hong Kong, has one of the most extensive coral reefs and seaweed beds within the Hong Kong territorial water. Its conservation value is one of the best in Hong Kong. It is being proposed as the fourth marine park by the Hong Kong SAR government. The island is located close to the border with the Shenzhen Special Economic Zone in mainland China. Management issues facing this new proposed marine park are therefore more complicated than those of the other existing marine parks in Hong Kong. Many of these issues, including trans-border illegal fishing activities, potential siltation problem arising from urban and industrial development on the mainland side of the border, risk management associated with increase in container boat traffic in the adjacent waters and disposal of marine debris, require a higher degree of collaboration between governments from the two sides of the border to ensure effective implementation of marine parks regulations. The island itself is becoming a popular weekend destination for Hong Kong people. Control of further develop-ment in the island and other activities associated with this increase in human pressure, are the main issues that should be faced by Hong Kong government. Some management strategies to address these issues are proposed.

WHAT MOLECULAR GENETICS CAN CONTRIBUTE TO THE DESIGN OF SUSTAINABLE MARINE PROTECTED AREAS.

Barber P.H.* and Stephen R. Palumbi. *Dept. Organismic and Evolutionary Biology, Harvard University, Cambridge MA 02138, Email: pbarber@oeb.harvard.edu

Although Marine Protected Areas can enhance local productivity and biomass, individual MPA's may be too small to retain locally produced pelagic larvae. Because most coral reef organisms have a pelagic larval phase, it is believed that sustainable MPA's should consist of networks of reserves interconnected through larval dispersal. Pelagic larval phases may last weeks or months leading to the assumption that dispersal between distant populations is high and surface current patterns between reserves have been proposed as a crucial predictor of the ecological and genetic connections among reserve populations. To test such predictions, patterns of genetic structure were examined in several species of mantis shrimp from reefs throughout Indonesia. Although current patterns predict high connectivity between populations, results showed striking patterns of genetic differentiation, showing that ecological connections are rare across distances as low as 300 – 400 km. Patterns of genetic differentiation mirror the separation of ocean basins during periods of low sea level indicating that biogeographic history can be an essential consideration when predicting contemporary connectivity and that current mediated larval dispersal cannot naively be assumed to provide ecological connectivity among distant marine populations. Genetics offers an indispensable tool for determining realized connections between distant reserve populations and should be incorporated into the design of marine reserve networks.

DANJUGAN ISLAND: A UNIQUE INTEGRATED APPROACH TO ESTABLISH A COMMUNITY-BASED MARINE PROTECTED AREA IN THE PHILIPPINES.

Beger M.*, A.R. Harborne, G. Ledesma, A.W.M. Page and P.S. Raines. *Coral Cay Conservation, 154 Clapham Park Road, London, SW4 7DE, UK. Email: science@coralcay.org

The Danjugan Island Marine Reserve and Sanctuary (Negros Occidental, Philippines) was established via a collaborative project that aimed to pioneer a unique approach to marine resource management. The project combined reef assessment using international 'volunteer' divers, expert knowledge of a local NGO and continuous involvement and training of the local community. Lessons learnt include (a) the importance of addressing needs locally but with legislation up to provincial level; (b) the use of a habitat map and associated data in both reserve design and to describe the ecosystem to local stakeholders; (c) the cost-efficiency of using a volunteer programme for data collection; (d) that acquiring island ownership rights facilitates long-term stability; (e) the presence of a continuous research programme leads to steady alternative local income generation and highly effective community skills development and involvement; (f) that successful small-scale projects can act as an impetus for larger regional initiatives; (g) collaboration between Filipino and international organisations is crucial and (h) the provision of alternative livelihoods is vital for long-term sustainability of the reserve. This project would be further assisted by initiatives at a regional or national level which could include: a database of information on other programmes and their outputs, an expert network, an accreditation scheme for trained local people, regional scale research programmes, reserve design workshops and facilitating access to funding.

A RATIONALE FOR MINIMUM 20% NO-TAKE REEF PROTECTION.

Bohnsack, J.*, Billy Causey, Michael Crosby, Roger Griffis, Mark Hixon, Tom Hourigan, Karen Koltes, James Maragos, Ashley Simons, and James Tilmant. *Southeast Fisheries Science Center, NOAA Fisheries, 75 Virginia Beach Dr., Miami, FL 33149 USA. Email: Jim.Bohnsack@noaa.gov

In response to worldwide coral reef declines, several countries and conservation organizations have adopted a goal of protecting a minimum of 20% area of all representative reef habitats with no-take reserves (NTRs), areas protected from all fishing and other extractive activities. Fishing disturbs coral reefs by removing organisms for food, sport, commerce and bait, but also damages habitat and kills unwanted organisms as bycatch with mostly unknown long-term impacts. Quantitative support for 20% NTRs comes from reproductive theory, past fishery failures, empirical data from existing NTRs, and knowledge about life history and vulnerability of reef species to exploitation. Additional support comes from the need to apply precautionary and adaptive management and to have minimally disturbed areas with ecological integrity for scientific reference purposes. NTRs should be viewed as an ecosystem and habitat based protection measure to be used in addition to other traditional resource management measures. 20% NTR protection should be considered a minimum for protecting biodiversity and ecosystem structure and function, but will not be sufficient to protect all species. Optimal fishery production will require other protective measures and possibly larger total closed areas applied to all species or individual fisheries. Management must focus on protecting the integrity, health and beauty of the coral reef ecosystem.

DESIGNING MARINE PROTECTED AREAS: THE NEED TO INTEGRATE THE SCIENTIFIC AND PRACTICAL APPROACHES.

Causey, Billy D. Superintendent. *Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, USA 33050. Email: Billy.Causey@noaa.gov

The greatest achievements in the design and management of marine protected areas are yet to come. They will occur when theorists and practitioners learn how to effectively collaborate. The new wave of theory in designing marine reserves has the potential to assist in planning and placing these areas in ways we never thought possible. Researchers have developed computer models that, given the critical physical and biological data, can forecast the benefits of locating an ecological reserve (marine reserve) in one site over another. Using oceanographic data such as water circulation patterns, the location, velocity and duration of local currents, reproductive patterns and mechanisms for fish and other marine life, scientists soon will be able to recommend precise locations for reserves. While this is a tremendous advancement, this is not the sole answer to establishing MPAs and more precisely, "no take" ecological reserves (marine reserves). Herein lies the void between the science of MPAs and their field application. Practitioners, or managers of MPAs, have abundant "lessons learned" to integrate into the process of designing and locating MPAs. Excellent MPA science and models are becoming available to field managers. However, the long-term acceptance of these areas by the waterfront community must be considered if they are to be successful. This acceptance is best gained through a process that includes local stakeholders who provide their years of experience in a collaborative process. This paper describes one such process.

OBJECTIVES, DESIGN AND EVALUATION OF CARIBBEAN MARINE RESERVES: WHAT HAVE WE LEARNED?

Chiappone M.*, S.L. Miller and D.W. Swanson. *The National Undersea Research Center, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, Florida, 33037, USA. Email: mark@benthos.cox.miami.edu

Marine reserves, areas of the ocean protected from extractive activities, are important mechanisms to advance conservation and fisheries management. This is especially true in the Caribbean, where conventional approaches to reef fisheries management are problematic because of the lack of data, diversity of species targeted, complex species interactions, and diverse fisheries objectives. Ecological theory and mounting empirical evidence provide strong arguments on the potential benefits of marine reserves for fisheries, maintenance of ecosystem structure and integrity, and enhancement of non-consumptive opportunities. Factors driving the creation of most reserves, and marine protected areas in general have centered on "hot spot" criteria, and biological performance evaluations are often problematic because of this biased site-selection. The majority of marine reserve studies show predictable effects on target species, but spillover effects from movement patterns and larval export have not been unequivocally demonstrated. Evaluations of fisheries benefits have often been undertaken in an *ad hoc* fashion, and as a result, several recent reviews advocate the use of design principles from a few, well-studied areas to guide the implementation of marine reserve networks.

MANAGING MARINE PROTECTED AREAS OF SOUTHEAST ASIA TO IMPROVE THEIR CONTRIBUTION TO SUSTAINABLE FISHERIES.

Chou L.M*. *Department of Biological Sciences, Faculty of Science, National University of Singapore, Blk. S2, 14 Science Drive 4, Singapore 117543. Email: dbsclm@nus.edu.sg

A growing variety of reef conservation measures is present throughout Southeast Asia in direct response to increased awareness of the benefits of reefs and their continuing widespread degradation. Many protected areas were selected based on biological diversity of the reef systems while some were former fisheries protected zones. Reefs contribute to fisheries production and their use as spawning and nursery grounds are well documented. Reef fisheries contribute as high as 30% of total fish catch in the region and effective reef management to enhance sustainable fisheries has been demonstrated. The selection of protected areas should focus not only on reef areas but also on non-reef sites that are used by spawning aggregations. The inclusion and effective management of such sites will enhance the contribution of protected areas to fisheries production. To further facilitate the fisheries-production function of protected areas, a systematic approach should be adopted in identifying target areas serving as larval sources and sinks, or along main migratory routes. This should be considered in connection with hydrodynamic patters for the region rather than within national boundaries. Emerging from this is a regional system of strategically located protected areas that remain connected rather than isolated.

COMMUNITY-BASED MARINE SANCTUARIES IN NORTH SULAWESI, INDONESIA.

Crawford B.R.* and Johnnes Tulungen. Coastal Resources Center, University of Rhode Island, Narragansett RI 02882, USA Email: crawford@gso.uri.edu

Community-based marine sanctuaries are an increasingly popular element of integrated coastal management programs in many parts of the world. In the Philippines, these no-take zones have proven effective in conserving coral reef ecosystems, increasing fish biomass, increasing fish production in adjacent areas, as well as benefiting nearby coastal communities. In nations where governance regimes are moving towards increased decentralization and local autonomy this can be an appropriate, simple and cost effective coastal management approach. Efforts have been underway in North Sulawesi since 1997 to adapt community-based marine sanctuary approaches that have been developed over a twenty-year period in the Philippines to the Indonesian context. This paper summarizes North Sulawesi experience in establishing community-based marine sanctuaries as part of participatory, village-level, integrated coastal resources management plans. It includes current efforts to scale-up from pilot sites to a regency-wide community-based marine sanctuary extension program. Analysis of lessons learned concerning the challenges of widespread scaling-up in the Philippines and how they can be applied in the North Sulawesi case are also explained.

THE BONAIRE STORY: IMPLICATIONS FOR THE MANAGEMENT OF SMALL SCALE CORAL REEFS MARINE PROTECTED AREAS.

De Meyer.K.* *CORAL (The Coral Reef Alliance). 2014 Shattuck Ave. Berkeley. CA 94704. USA. Email: kdemeyer@coral.org

Like many small islands around the world, the mainstay of the economy on Bonaire for the past several decades has been tourism. Tourism development and exploitation have also become the source, directly and indirectly, of the major threats to the island's marine resources, particularly its fringing coral reefs. The management objective of the Bonaire Marine Park is to protect and preserve the island's coral reefs, seagrass beds and mangroves whilst maximizing returns from recreation and commerce. The challenge has therefore been to make tourism work for the island. The proactive role of the Marine Park and its innovative work over the past decade have resulted in an unprecedented level of protection for the island's fringing coral reefs. It has also lead to the Marine Park fast becoming a role model to other aspiring protected areas and has set the pace for the management of small scale coral protected areas throughout the region. The Bonaire Marine Park has had some notable successes particularly in terms of developing a mechanism for sustainable funding and in benefiting from close and productive working relationships with the local community, tourism industry and visiting tourists. This paper examines the implications of the work which has been done on Bonaire for the management of small scale coral protected areas around the world with particular reference to sustainable financing mechanisms and the pivotal role of stakeholders in protected areas management.

MANAGEMENT AND POLICY DYNAMICS IN SUPPORT OF A SYSTEM OF MARINE PROTECTED AREAS IN INDONESIA

Djohani, Rili*, Dahuri, Rokhmin *The Nature Conservancy, Director, Coastal and Marine Conservation, Jl. Pengembak no.2, Sanur, Bali

Within the dynamic political and socio-economic context of Indonesia marine protected areas or other forms of closed areas may be the only option to protect coral reef resources from excessive fishing pressure. Apart from their importance for the coastal fishery, most of the marine parks are great assets for nature based tourism which can lead to the financial self sufficiency of marine reserves. With the establishment of the new Department of Sea Exploration and Fisheries, Indonesia has the opportunity to focus and put together a concerted and coherent effort to coordinate and implement the policy and implementation context for marine protected areas. At present, there are 34 MPAs, which cover more than 4,600,000 ha in Indonesia. A combination of enforcement, awareness and training programs, monitoring and alternative livelihood programs has proved to be a successful strategy for the abatement of destructive fishing practices in Komodo National Park. Essential for the feasibility of MPAs and no take reserves is the ability to not only deal with the status quo but also with the dynamics in the field, i.e. emerging threats, new stakeholders, and long term financing mechanisms. This paper will review and recommend the local and regional policy context, key elements for design and management tools for MPAs and no take reserves that would allow: I) adaptive management, II) collaborative management, and III) self-financing mechanisms.

SEX, FOOD, AND SHELTER: THE STORY BEHIND A PROPOSED MARINE PROTECTED AREA IN THE U.S. VIRGIN ISLANDS.

Garrison, V.*, J. Bohnsack, R. Boulon, G. E. Davis, and J. Tilmant. Biological Resources Division, U.S. Geological Survey, P.O. Box 710, St. John, U.S. Virgin Islands 00831. Email: ginger_garrison@usgs.gov

In their present configurations, virgin islands national park and buck island reef national monument lack essential habitats and sufficient areas of habitats necessary to sustain their coral reef system, making preservation and protection of the marine resources over time nearly impossible. At the request of the u. S. Secretary of the interior, boundaries were proposed for a u.s. virgin islands marine protected area, created to preserve and protect a functional coral reef ecosystem. Primary factors in boundary selection included: current national park boundaries, location of protected watersheds, location of essential habitats, unique habitats, habitats and species not currently represented in existing parks, spawning sites, and the life histories of key species (nassau grouper, spiny lobster, and queen conch). Simply changing the boundaries would provide little benefit, as current fishing pressure is unsustainable, with populations of some harvested species near collapse. Prohibition of extractive activities is the most effective method of habitat and ecosystem management, is ideally suited to the ecology of marine organisms, and will allow the system to restore itself. Three "no-take" areas constitute the central core of the proposed marine protected area and incorporate upland watersheds, mangroves, shelf habitats (including coral reefs, seagrass beds, sand flats, gorgonian hardbottom and algal plain communities, unique bank and barrier reefs, shelf edge), abyssal, and oceanic habitats.

A HIGHLY ADAPTABLE METHOD FOR DEALING WITH THE MESSY BUSINESS OF DESIGNING MARINE PROTECTED AREAS.

Grober-Dunsmore, Rikki *, Ridgley, Mark. *University of Hawaii, Dept. of Geography, 2424 Maile Way, Honolulu 96822. Email: rikki@akule.soest. hawaii.edu

For all their merits, the design, siting and implementation of marine protected areas (MPAs) often founder on the shoals of conflict, uncertainty, and vastly different forms of knowledge and communication. A conceptual and linguistic chasm separates those reasoning through experiential knowledge (e.g., fishermen) and those employing the practices of Western science, making the decision process difficult. A general multi-disciplinary methodology to circumvent these problems is discussed and we will demonstrate how it can be adapted to quite disparate and contentious situations. In all variations of the method, objectives are formulated, alternative MPAs are designed and then evaluated. Three quite different ways of designing options are presented-- a "low-tech" (LEGOLAND) approach, a "medium-tech" GIS approach and a "high-tech" procedure employing multiobjective optimization. While the sophistication of the approaches varies considerably, several features make it easy to apply. Multicriterion methods are used to measure intangibles, assess the importance of uncertainty, accommodate subjective judgement and local knowledge, and integrate these with conventional scientific data. Candidate MPAs are then generated and evaluated. A case study of the methodology will focus on our experience in Kaneohe Bay, Oahu during a Hawaii Coral Reef Initiative project.

THE IMPACT OF MARINE RESERVES: A REVIEW OF KEY IDEAS

Halpern B.*. *Dep't. of Ecol., Evol., and Mar. Biol., UCSB, Santa Barbara, CA, 93106, USA. Email: halpern@lifesci.ucsb.edu

Marine reserves are quickly gaining popularity as a management option for marine conservation, fisheries, and other human uses of the oceans. However, few appear to have been designed with biological considerations in mind and little is known about general patterns of how reserves affect species within them. I reviewed the literature that empirically assessed the impacts of marine reserves on the density, biomass, size, and diversity of organisms, paying particular attention to the role reserve size plays in determining those impacts and the rapidity of occurrence and duration of any impacts following reserve creation. Results from 89 separate studies show that, on average, overall density doubles, biomass triples, and size and diversity increase by 20-30% inside reserves compared to reference sites, and results are similar for each functional group (carnivorous, herbivorous, and planktivorous fishes, and invertebrates), with few exceptions. Surprisingly, results also show that the effects of marine reserves increase linearly in proportion to reserve size. Therefore, small reserves can function well but larger reserves will provide greater absolute differences in biological measures. Consequently, larger reserves may be necessary to meet the goals set for marine reserves. Finally, biological measures increase in value inside reserves shortly after reserve creation, and these higher values do not change or become more variable as reserves age. These results suggest that nearly any marine habitat can benefit from the implementation of a reserve, and that reserves may offer a quick and lasting solution for conservation and management goals.

THE DEVELOPMENT AND ESTABLISHMENT OF CRMPAs.

Kelleher, Graeme*. Email: graeme_kelleher@gbrmpa.gov.au

Particularly in developing tropical countries, many local communities depend on coral reefs for food. These reefs are subject to many stresses, both from direct use and from the effects of land-based human activities. The progressive degradation of these resources has been documented in many publications. Setting up MPAs in these circumstances is difficult. Strong support from local users is essential. This paper describes the approaches that have been successfully applied in developing and establishing coral reef MPAs. Lessons learned globally are outlined.

SOLOMON ISLANDS COMMUNITY PARTICIPATION IN MARINE CONSERVATION AREAS: INTEGRATING SCIENCE AND CUSTOM.

Kile, Nelson *, John E. Parks, A. Meriwether Wilson, and Michelle_Lam. *Honiara PO, Solomon Islands. Email: lamkile@welkam.solomon.com.sb

The solomon islands archipelago comprises over 900 islands and is reputedly one of the largest areas of intact coral reef ecosystems throughout the pacific islands. However, increasing dependency on nearshore marine resource extraction to support even basic subsistence livelihoods threatens to degrade the functioning of these reefs. Community-based management of coastal resources in the solomons is the *de facto* inshore management regime as village communities have ancestral-based customary tenure rights for 86% of nearshore waters. In order to proactively address increasing food scarcity and cash income needs, reef owners and landowners, resource managers, and researchers are forming management alliances to minimize coastal-marine ecosystem degradation through exploring ways of integrating science and customary practices. As part of a global environment facility project preparation exercise, field-based economic, ecological and socio-cultural reviews were conducted to examine offshore and nearshore resources management issues and consider models for establishing marine conservation areas which could enhance fishery productivity through linking traditional wisdom with conservation science monitoring protocols.

EVALUATING PRIVATE SECTOR INVOLVEMENT IN THE MANAGEMENT OF MARINE PROTECTED AREAS.

Kramer Randall A.*. *Nicholas School of the Environment, Duke University, Durham, NC 27708 USA. Email: kramer@duke.edu

Concerns about coral reef destruction and loss of marine biodiversity have led to the establishment of marine national parks and other protected areas by the public sector in many tropical areas around the world. In addition to these expanding public efforts, there is a small but growing set of examples of the private sector engaging in marine biodiversity conservation efforts, especially when tourism presents significant revenue potential. This paper examines the role of the private sector in establishing and managing marine protected areas. In this context, private sector means anything not purely governmental. Hence, private sector involvement could refer to activities by stakeholder organizations, not for profit organizations, and for-profit firms. The activities of the private sector organizations might include a wide range of possibilities including raising revenues from users and donors, provision of tourism services, implementation of conservation programs, monitoring and enforcement and outright ownership. This paper provides a framework for assessing the relative strengths and weaknesses of private sector organizations as compared to state agencies in implementing and managing marine protected areas. Several case studies are presented including the Chumbe Island Coral Park Project in Zamzibar, (an example of a privately owned park), the Bunaken Marine Park in Indonesia (an example of a private-public partnership), and the Komodo National Park in Indonesia (an example of a proposed tourism concession involving a for profit firm). Lessons learned about the advantages and disadvantages of private sector involvement will be presented, and a research program will be proposed for more systematic hypothesis testing about the effectiveness of different organizational types.

THE ARNAVON ISLANDS MARINE CONSERVATION AREA: LESSONS IN MONITORING AND MANAGEMENT.

Lincoln Smith, M. P*., Bell, J. D., Pitt, K. A., Thomas, P. and Ramohia, P. The Ecology Lab Pty Ltd, 4 Green Street, Brookvale, NSW, 2100, Australia. Email: projects@theecologylab.com.au

The Arnavon Islands Marine Conservation Area (MCA) was declared in August 1995 as a refuge for marine invertebrates. Protection from harvesting was done with agreement from, and active participation by, local communities. Protection was also facilitated by appointment of a local management committee and conservation officers. Variation in abundance of species at the MCA and at three fished "reference" areas was established before declaration, and monitored over the next four years. Regular visits to communities by the management committee, conservation officers and monitoring team maintained local commitment to the MCA. However, some illegal harvesting indicated that a regulatory component was also important for management. Increases in invertebrates within the MCA occurred slowly, and at small spatial scales. Despite the illegal harvesting, significant increases in abundance occurred within the MCA relative to the reference areas, particularly for trochus. The main lessons from the MCA so far are that recovery of most invertebrates has been slow and patchy, and would not have been detected without the monitoring program. It has also proved difficult to provide complete protection to the MCA, even with the commitment and participation of local communities. Mechanisms that allow communities to benefit from species that have recovered, while continuing to protect the other species, may be needed to maintain total commitment of local communities to management plans.

DESIGNING EFFECTIVE CORAL REEF MARINE PROTECTED AREAS: INSIGHTS FROM POLITICAL SCIENCE THEORY.

Mascia Michael B.. Duke University. 135 Duke Marine Lab Rd., Beaufort, NC 28516, USA. Email: michael.mascia@duke.edu

Coral reef marine protected areas (CRMPAs) are a critical component of local, national, and international biodiversity conservation and sustainable development policies, but our ability to design CRMPAs that meet these policy objectives remains limited. In order to inform the policymaking process, I tested political science theories of sustainable resource governance at three study sites in the Wider Caribbean region (Hol Chan Marine Reserve, Belize; Exuma Cays Land and Sea Park, Bahamas; and Barbados Marine Reserve, Barbados), using quantitative and qualitative measures of political, social, and biological variables derived from formal and informal interviews, document analysis, direct and participant observation, focus groups, and participatory mapping exercises. Study results are consistent with theoretical predictions. CRMPA governance regimes with clear resource boundaries, well-defined resource use rights, accountable monitoring and enforcement systems, graduated sanctions, accessible conflict resolution mechanisms, and state recognition of user-designed management strategies led to positive social and biological outcomes. CRMPAs without these traits were characterized by negative social impacts and sub-optimal biological performance. Though this research needs to be replicated, these results strongly suggest that coral reef management could be significantly improved by designing CRMPAs consistent with the theoretically based, empirically grounded framework presented here.

DESIGNING EFFECTIVE CORAL REEF MPAS? A CASE STUDY OF THE CORAL REEF ECOSYSTEM FISHERY MANAGEMENT PLAN PROCESS.

Miller Katharine B.*, Nancy Daschbach, James E. Maragos, David A. Gulko, Alan M. Friedlander, Cynthia L. Hunter, , Todd J. Pitlik
***Coral Reef Ecosystem Plan Team, PMB 72 P.O. Box 10003, Saipan, MP 96950 U.S.A. Email: kb_miller@itecnmi.com**

Under the Magnuson-Stevens Fisheries Conservation and Management Act (M-S Act), the fisheries management councils have been given the authority to develop fishery management plans (FMPs) for fisheries occurring in the U.S. exclusive economic zone (EEZ). All of the existing FMPs have focused on species or species complexes as the basis for management. The vast majority of these plans have also been developed to primarily address fishing for food resources, as opposed to fisheries for aquaculture, ornamentals or other uses. In 1998, the Western Pacific Regional Fisheries Management Council convened a group of Pacific coral reef scientists and managers to develop a Coral Reef Ecosystem FMP that addresses fisheries as diverse as marine ornamental collection and bioprospecting. This is the first attempt to apply the M-S ActÕs species-specific fisheries management scheme to an entire ecosystem. One of the principle management tools that the Coral Reef Ecosystem Plan Team (CREPT) recommended in draft versions of the FMP was the establishment of several no-take Marine Protected Areas in the EEZ surrounding the NW Hawaiian Islands.

SUSTAINABLE ARTISANAL FISHING WITHIN A MULTIPLE USE ZONE OF A RED SEA MARINE NATIONAL PARK.

Ormond R.F.G.* & Galal N. *University Marine Biological Station Millport, Isle of Cumbrae, Scotland, UK. Email: rupert.ormond@millport.gla.ac.uk**.**

Since its establishment the Ras Mohammed National Park (Egyptian Red Sea) has been extended to include the whole of the Sinai coast of the Gulf of Aqaba, although artisanal fishing by local bedouin is permitted in this northern section. We investigated methods of securing the sustainable use of reef fish resources within the 20 km long Nabq sector of the Park. Here trammel and gill nets are used to obtain a catch dominated by parrotfishes, surgeonfishes, rabbitfishes, emperors and groupers. Total yield at different sites was found to range from 1.9 to 6.2 ton km^{-2} yr^{-1}. Total yield increased with effort to a maximum at 100-150 unit gear km^{-2} yr^{-1} beyond which yield decreased. Catch per unit effort (CPUE) declined sharply from 1.3 – 2.7 kg $net.ha^{-1}$ at lightly fished sites to 0.6 – 1.8 kg $net.ha^{-1}$ at those which were most heavily exploited. With the support of the local bedouin, obtained after extensive consultation, 5 no-take reserves were established occupying nearly half of the Nabq sector, so that fisheries activities were concentrated in the intervening area. After 2 years a significant increase in both abundance and mean size of some fish species had occurred within some no-take areas, while mean CPUE in the fished areas had increased from 0.84 to 1.01 kg $net.ha^{-1}$. The combination of regulated total effort and no-take reserves may secure maximum sustainable yield, while leaving ample fish on the reef for the benefit of the SCUBA-diving based tourist industry.

HOW TO AVOID "PAPER PARKS" – EXPERIENCES FROM SE ASIA.

Pet-Soede Lida *. *Wageningen Agricultural Univ. Netherlands. Email: lidapet@attglobal.net

Coastal fisheries in South-East Asia are difficult to manage due to their multi-gear and multi-species character, the open access nature of the resource, the vastness of coastal waters, and the small-scale nature of the operations. The concept of Marine Protected Areas (MPAs) is sold to managers as an option to facilitate monitoring and control and it is explained to fishers as an option to improve catches. Although these are indeed major advantages in theory, in practice it takes more than declaring an area officially protected. Careless site selection, little understanding of socio-economic and other factors that influence fishers attitudes, and a lack of funds and local presence of authority, are three major reasons causing MPAs not to live up to expectations. Disregard of the status of reefs and fish stocks at a proposed site, of patterns in oceanography, of the presence of spawning populations or sites and of characteristics of the fishing communities living off it, blocks the outcome from the beginning. Lack of a community strategy that incorporates measures to sustain the existing socio-economic environment, reduces community acceptance and involvement. This in turn, puts a greater pressure on the budget (funds and manpower) available for monitoring and control. This paper draws upon experiences, mainly in Indonesia, to illustrate each of these issues and to conclude with recommendations on how to improve the effectiveness of existing MPAs and on what to consider when selecting new areas. A well designed and implemented MPA can then serve as a showcase to both managers and fishers of the causal relation between fishing pressure and the status of fish stocks.

ARE MARINE PROTECTED AREAS EFFECTIVE IN THE RESTORATION AND THE MANAGEMENT OF MULTI-SPECIES INVERTEBRATE FISHERIES: A CASE STUDY IN SOLOMON ISLANDS.

Ramohia, Peter C.* *Fisheries Division, Ministry of Lands, Agriculture and Fisheries, P. O. Box G13, Honiara, Solomon Islands. Email: sbfish@ffa.int

Marine reserves or marine protected areas (MPAs) are created for many purposes including the management of marine resources. Although numerous studies have been undertaken on the effectiveness of MPAs both in temperate and tropical countries, appropriate ways of evaluating MPAs are lacking as a result of (a) lack of baseline information before establishment of MPAs and (b) no spatial controls to measure natural variation compared to the reserve. To evaluate the effectiveness of an MPA, data on abundance and average body size of trochus (*Trochus niloticus*), sea cucumbers (Holothuridae) and giant clams (Tridacnidae) were collected prior to and after the declaration of the Arnavon Marine Conservation area (AMCA) in Solomon Islands between 1995 and early 1999 using a sampling program which provides a sound basis for detecting the effects of AMCA on the abundance and size structure of studied species. Data from three surveys prior to and three surveys after the declaration of the AMCA were interpreted graphically for selected study invertebrate species. The implication for Solomon Islands in terms of MPAs as a tool for management of multi-species invertebrate fisheries is discussed. The broader implication of the results is also presented.

BIO-PHYSICAL DESIGN OF MARINE PROTECTED AREAS.

Roberts, Callum M.*. *Environment Department, University of York, York, YO10 5DD, UK. Email: cr10@york.ac.uk

A key constraint on the success of marine protected areas (MPAs) is the extent to which they are able to encompass the life cycles of the organisms we hope they will protect. People often assert that only very large MPAs will be sufficient to protect highly mobile or migratory species. However, even sedentary and sessile species, those that might seem well-served by small MPAs, may be highly mobile during some life stages (e.g. larval dispersal). Other species may require a series of habitats as they develop, migrating from one to another throughout life, and some authors suggest all such habitats should be included for MPAs to successfully protect them. MPAs are also subject to large-scale physical oceanographic influences that both shape the ecology of the habitats they protect, but could also harm them through the transport of pollutants, for example. While such processes and life cycles argue for very large MPAs, there are few opportunities to establish them. Most will have to be far smaller than the scales of either species' life cycles or physical oceanographic influences. However, to be successful, MPAs must protect sufficiently-large areas of habitat to be viable over the long-term, placing constraints on their minimum effective size. In this paper I discuss design approaches for realistically-sized MPAs that will help secure essential large-scale linkages without the necessity of physically encompassing them. I will also explore ways of designing reserves to help assure habitat viability.

PUERTO MORELOS REEF NATIONAL PARK: HAVE 5 YEARS OF COMMUNITY WORK BEEN WORTH IT?

Rodríguez-Martínez, R.E.*, E. Jordán-Dahlgren. Instituto de Ciencias del Mar y Limnología, UNAM. Ap. Postal 1152, 77500 Cancún, Q. Roo, México. Email: rosaer@mar.icmyl.unam.mx

Puerto Morelos Reef National Park, created in 1998, runs 21km along the eastern side of the Yucatán Peninsula, México and has an area of 9,066 hectares. This Park is a community-based project that started in 1995 to prevent unsustainable use. In 1998, a management program was devised by Puerto Morelos town stake holders with the participation of two research Institutes, and is expected to be published by June 2000. Government agencies support the creation of the park but declined to provide funds for its operation so stake holders have taken several actions to implement the management program. Fishermen and tourist operators pay the salary to an enforcement agency employee, and for the maintenance and operation of a boat. Tourist operators have installed buoys and agreed to respect regulations. Fishermen have agreed to stop fishing in some reef sectors. Environmental education has been given by local scientists and NGOs. Unfortunately a new law, published in December 1999, requires that the money collected in the NPA has to go to the Internal Revenue Service with no mention of how the money will be used. High level negotiations are presently being made in an attempt to modify the law so that the money is used for management in the areas where it is obtained. Unless this happens the implementation of the management program will not be possible. Causes of conflicts and how they were resolved are discussed.

EXPERIENCE FROM IMPROVING MANAGEMENT OF AN "URBAN" MARINE PROTECTED AREA: GILUTONGAN MARINE SANCTUARY, PHILIPPINES

Ross, Michael A.*, Arleigh C. Sitoy, Maria Fe Portigo, Dolores A. Diamante-Fabunan *Tetra Tech EM, Inc., Coastal Resource Management Project 5th Floor, CIFC Tower, North Reclamation Area Cebu City, Cebu, Philippines 6000 Email: crmhot@oneocean.com

Since the first so-called municipal marine protected area (MPA) was officially established in the Philippines in 1974, the establishment of such MPAs has been widely promoted as a practical yet important means of managing coastal resources, particularly coral reefs and their associated fisheries, within the country. In general, most of these MPAs have been declared or established in relatively remote areas. Numerous reports and studies have documented the experienced gained in planning and managing these types of MPAs. In contrast, Gilutongan Marine Sanctuary (Municipality of Cordova, Cebu) is located near a major urban and tourist resort center, with an estimated population of some 2 million within a 20 kilometer radius. A process for improving the planning and management of an "urban" MPA is presented, involving multi-sectoral stakeholder collaboration and initiation of user fees, to strengthen and support community-based management and monitoring activities. Initial monitoring results and cost and benefit analyses show that there is a very strong justification on the part of the Gilutongan community, local government and the private sector to further strengthen sanctuary management. A proposed action plan is presented to support these future activities building upon the experiences gained to date.

COMMUNITY-BASED STRATEGIES FOR THE SUSTAINABLE MANAGEMENT OF MARINE PROTECTED AREA.

Salmo S.G. III*, Ma. Antonette R. Juinio-Meñez and Porfirio M. Aliño. *Marine Fisheries Resources Management Project, Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101 Philippines. Email: jon@msi01.cs.upd.edu.ph

The community-based strategies in the implementation of a marine protected area (MPA) in Bolinao, Pangasinan (northwestern Luzon, Philippines) is presented. The factors necessary to sustain the successful implementation of a community-managed MPA involved heightening of environmental awareness, training, information campaigns and legal/institutional and financial assistance. The empowerment of a people's organization (PO) played an important role in sustaining the management of the MPA. Among the activities conducted by the PO are sponsoring information campaigns, forging multi-sectoral collaboration, lobbying and networking to advocate institutional assistance and patrolling of the MPA. The PO are also conducting regular monitoring of the MPA (e.g. benthic lifeform, fish visual census, fish catch). Results of recent monitoring compared to the baseline data reveal improved % coral cover and increased fish biomass. Overall, the community-based strategies in the management of the MPA has proven to be very resilient indicating a high possibility of sustaining its successes despite some obstacles and shortcomings. Thus, this case study will draw on the lessons from the experience of a community-managed MPA.

EFFECTIVE MARINE PROTECTED AREA MANAGEMENT IN PENINSULAR MALAYSIA: MAKING THE MYTH A REALITY

Samarasekara, Vidhisha N.*, Sukumaran, Jeet. *WWF Malaysia - 49 Jalan SS23/15 Taman Sea, 47301 Petaling Jaya MALAYSIA. Email: svidhisha@wwfnet.org

Well-managed MPA's should contribute directly to the conservation of marine ecosystems, while at the same time supporting the sustainable use of their natural resources. In Southeast Asia however, the reality is often far from this ideal, and Malaysia is no exception. Conflicting uses of MPA's seriously challenge management efforts, while at the same time, activities taking place outside the protected areas may render management useless altogether. This paper will present an overview of the current challenges confronting the management of MPA's in Malaysia. It will outline positive management actions that can be taken to address these challenges—such as zoning Marine Parks; gazetting park islands as State Parks; implementing comprehensive education and awareness programmes; enforcing Marine Park regulations; limiting visitor use; training Marine Park Managers, tour and dive operators; as well as establishing monitoring and evaluation programmes. These proposed solutions may find applicability in marine protected areas throughout the Southeast Asia region, given the commonality of issues.

INCREASE OF FISHES IN CORAL REEF FISHERY RESERVES: A COMBINED ANALYSIS.

Uychiaoco, A.J.*. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines. Email: auychiaoco@yahoo.com

Most of the past reported attempts to investigate the effects of marine reserves on reef fishes do not properly test the effectiveness of reserves in general to cause changes: some do not simultaneously monitor comparable control sites, others report on "snap-shot" differences at one point in time while the handful that do both of these only report of 1 protection treatment each (no replication). Four recently-established coral reef fishery reserves (Sibulan, Cabacongan, Minombonan & Lomboy-Cahayag in the Philippines) and adjacent control areas were monitored for 3 years. Responses of major carnivorous (Epinephelinae, Lutjanidae and Lethrinidae), Chaetodontidae, Scaridae and Acanthuridae to protection were observed. These data were combined with data of 5 other coral reef reserves taken from the literature (Saba Marine Park, Kisite and Mombasa Marine National Parks, South Lagoon Marine Park and Apo Islands Reserve). Non-parametric Wilcoxon paired rank tests were used to see if carnivorous reef fishes, butterflyfishes and herbivorous reef fishes increase faster in unfished sites than in fished sites. Carnivorous and herbivorous reef fishes in the fished areas did not change significantly with time whereas those in the unfished areas increased significantly with time. Butterflyfishes did not change significantly with time in either the fished or unfished areas.

EXPERIENCE WITH MARINE PROTECTED AREA AND FISH SANCTUARY PLANNING AND MANAGEMENT, PHILIPPINES.

White, Alan T.*, Albert Salamanca and Catherine A. Courtney *Tetra Tech EM Inc., Coastal Resource Management Project 5th Floor, CIFC Tower, North Reclamation Area Cebu City, Cebu, Philippines 6000 Email: awhite@mozcom.com

Coastal management has been practiced in the Philippines over the last two decades to try to stem the increasing tide of destruction to coastal habitats and the decline of fisheries. Yet, coastal resources continue to decline and deteriorate at alarming rates. Selected experiences and two case studies in coastal management that involve marine protected areas and fish sanctuaries are presented. Important lessons and approaches that can be used for marine protected area management in the context of sustainable coastal management are highlighted such as: the role of donor-assisted non-government organization and government projects in establishing marine protected areas; the effect of devolution of authority from central to local governments (municipal, city, and provincial); and the role of other institutions, including research institutions, employing different strategies and approaches. Other key findings include the importance of defining marine protected areas in the Philippine context, the value of truly participatory processes, various localized options for financing protected areas and the need to establish integrated coastal management programs to provide planning, institutional and financial support.

CHANGES AND LESSONS (1985-2000) FROM TWO MARINE PROTECTED AREAS IN CENTRAL PHILIPPINES.

White Alan T. *, Christie, Patrick and Deguit Evelyn. *Tetra Tech EM Inc., Coastal Resource Management Project 5th Floor, CIFC Tower, North Reclamation Area, Cebu City, Cebu, Philippines 6000. Email: awhite@mozcom.com

A May 1999 survey team collected baseline data on the condition of the coral reefs inside and adjacent to marine sanctuaries in southwest Bohol Island and updated surveys conducted at two sites in 1986 and 1992. The study sites all show signs of fairly healthy coral growth except for corals affected by bleaching of 1998 and physical damage from boat anchors and other causes. On those reefs with survey data from 1986 and 1992, the coral condition is stable and not significantly different than in years past. Fish abundance and diversity, in contrast, are very low at all sites except where sanctuaries are being actively implemented on Balicasag and Pamilacan Islands. Particular problems include: 1) location and maintenance of anchor buoys at all sites because of increasing numbers of recreation boats; 2) increasing over-exploitation of fish for food and the aquarium trade and other useable marine organisms outside of the sanctuaries; 3) sporadic incidents of destructive fishing; and 4) a lack of implemented use zones for popular dive sites, in and outside of sanctuary areas. A growing awareness about the importance of conserving reefs was noticed through interactions with local villagers and boatmen. Lessons learned from 15 years of management focus on participation, localized benefits, clear authority and responsibility and the need for broad support from government.

DEVELOPMENT OF A LOCALLY-MANAGED FISH SANCTUARY AT DISCOVERY BAY, JAMAICA.

Woodley, Jeremy*, *Centre for Marine Sciences, University of the West Indies (Mona), Kingston 7, Jamaica.
Email: woodley@uwimona.edu.jm

Coral reef fish populations of the narrow submarine shelf off the north coast of Jamaica have been severely over-exploited. In 1976 I proposed the creation of a Scientific Reserve, within which fishing would be prohibited, to limit degradation of the benthic community, and to benefit adjacent fisheries. It would also be an opportunity to work with a single fishing community, helping them to introduce management measures. Such work needed more staff, and awaited a funding opportunity: the Fisheries Improvement Programme (FIP) of the University of the West Indies was established in 1988, and has worked with the fishing communities around Discovery Bay ever since. Products of this collaboration include the formation of fisher's organizations; support for gear changes; and creation of the Discovery Bay Fishery Reserve, a fish sanctuary rather than a scientific preserve. Together, we have learned many lessons. Biologists wishing to manage natural resources, found that they had to manage people: a task for which they had no training. They found that education is a two-way process. They learned that changes in knowledge, attitudes and behaviour take much longer than they had suspected. The fishers learned the value of group solidarity, saw some benefits to their catches, and began to restrain their rivalries. The transfer of operational funding to the Fishermen's Association, increased its sense of ownership. But local action still requires government support in a co-management framework: legal status of the Reserve is essential. Finally, we all learned the value of continual communication .

Session B2: Large-scale Spatial Frameworks for Tropical Marine Conservation

USING INTERNATIONAL ENVIRONMENTAL LAW TO ENHANCE CONSERVATION OF CORAL REEFS THROUGH MARINE PROTECTED AREAS.

de Fontaubert A.C.*, *Marine Specialist, 1428 Foxhall Road, NW, Washington, DC, 20007, USA. Email: fontaubert@att.net

As States and other stakeholders strive to enhance the conservation of threatened coral reefs, they sometimes ignore the opportunities provided by the evolving international legal regime. Starting with the Law of the Sea Convention adopted in 1982, the community of nations has developed a strong legal regime to manage marine living resources sustainably. Whilst coral reefs have not been the subject of a particular legal regime, their protection has been tremendously enhanced by the negotiation and adoption of a growing body of agreements and programmes of action, particularly those that call for the designation of marine protected areas. Among the most significant are the Convention on Biological Diversity and the Barbados Programme of Action on the Sustainable Development of Small Island Developing States. In addition, States have recognized that existing political boundaries do not reflect a biological reality and transnational cooperation has been enhanced by a series of regional agreements and the evolving work of UNEP's Regional Seas Programme. At the national and regional levels, governments can and should make full use of these international legal instruments to give stakeholders better control over this important resource.

THE CORALWEB: A WWF GLOBAL PROGRAM TO ENHANCE THE CONSERVATION OF CORAL REEF ECOSYSTEMS.

Jorge, Miguel *; Atkinson, S.; Cripps, S.; Drijver, C.; Golder, B.; Kamau, I.; Llewellyn, G.; Mangubhai, S.; Marin, S.; Millstein, E.; Nias, R.; Putra, K.; Ratsimbazafy, R.; Romero, M.; Samarasekara, V.; Tupacz, J..
***WWF, 1250 24th Street, Washington D.C. 20037 Email jorge@wwfus.org**

Coral reefs throughout the world are under intense pressure from anthropogenic threats, including destructive fishing, over-harvesting of key species, pollution, sedimentation, coastal development, and many others. Recent bleaching events have highlighted both the vulnerability of coral reef ecosystems to natural perturbations and the possible relationship between bleaching and climate change. Recognizing these persistent threats, the World Wide Fund for Nature (WWF) has launched the CoralWeb initiative, which provides a framework of action by which WWF will redouble its efforts to enhance the conservation of coral reefs globally. The mission of CoralWeb is to mobilise action at all levels to overcome the most critical threats to the long-term health of coral reef ecosystems. CoralWeb will pursue this mission by working to increase the conservation capacity and skills of WWF and our partners, facilitating opportunities to learn how to improve conservation practices, and engaging the public and major actors in a global campaign to conserve coral reefs. CoralWeb will enhance, refine, and build upon ongoing conservation activities in priority ecoregions to magnify collective conservation action and help secure the long-term ecological integrity of coral reef systems. This paper provides a synopsis of the CoralWeb initiative, including the rationale for its development and the framework by which it will strive to enhance the conservation of coral reefs.

THE APPLICATION OF GIS-BASED ANALYSIS FOR SELECTING CONSERVATION PRIORITY AREAS IN THE MESOAMERICAN REEF SYSTEM.

Kramer, Philip A.,* Vierros, M., Kramer, P.R. *Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL, 33149. Email: pkramer@rsmas.miami.edu

The Mesoamerican Reef System (MRS) is the second largest barrier reef in the world supporting extensive marine biodiversity. A standardized, systematic Geographical Information System (GIS) was developed and used to synthesize existing data and create new data layers in order to provide a spatial framework for conservation planning in the region. The multiple layers in the GIS incorporated benthic habitats, species distribution, oceanic currents, marine protected areas, watersheds and socioeconomic data. A cross-shelf habitat approach was used to develop a common classification scheme and conduct a representation analysis. For the analysis, benthic communities were subdivided into cross-shelf zones, ecounits, conservation priority areas and the amount of a particular substrate and cover type in each area was determined and compared. Key ecological processes, threats, and habitat and species distribution were incorporated in the final analysis. The use of GIS-based spatial analysis of large systems provides a powerful tool for assessing the distribution of natural resources, the interconnectedness of these resources, and ultimately for determining where to focus efforts and resources for management, conservation and research.

ECOREGION BASED CONSERVATION (ERBC) AS A PLANNING FRAMEWORK FOR TROPICAL MARINE CONSERVATION

Llewellyn G.*, M. Jorge, S. Atkinson, D. Olsen, E., Dinerstein *WWF Indonesia, Wallacea Bioregion, 179 Jl. Hayam Wuruk, Denpasar 80235 Bali, Indonesia mcmast@idola.net.id

Ecoregion Based Conservation (ERBC) is the planning framework being advocated and implemented by the World Wide Fund for Nature (WWF) at priority sites for conservation throughout the globe. Working within a framework of large spatial units termed Ecoregions, the foundations of successful conservation interventions over large spatial and temporal scales are considered to be I) a biological vision that provides inspiration and sets priorities II) an Ecoregion Conservation plan that provides guidance for interventions. Involving a wide range of stakeholders is considered fundamental to the process of formulating both these strategic documents, preferably through workshops where priorities can be identified and consensus can be built. What sets ERBC apart from previous planning frameworks is that both the time-scale and spatial scales are much larger than typically used, and the use of large participary workshops both to set biodiversity priorities and design interventions. Experiences from the Sulu-Sulawesi Sea and Meso-American reef have been strongly supported by both scientists and local resource managers and provide many lessons for achieving ambitious conservation goals when working with tropical marine ecosystems.

LARGE-SCALE SPATIAL CLASSIFICATION SYSTEMS FOR MARINE CONSERVATION PLANNING

Llewellyn G., K. Putra, N. Dwisasanti *WWF Indonesia, Wallacea Bioregion, 179 Jl. Hayam Wuruk, Denpasar 80235 Bali, Indonesia Email: mcmast@idola.net.id

Relative to the terrestrial realm, the marine realm has proven difficult to sub-divide into smaller spatial units. Coastal oriented classification schemes favor geomorphological criteria, oceanic oriented classifications tend to favor productivity or some other biophysical parameter, while general schemes tend to integrate both physical and biogeographic criteria. Over the last decade, several new theoretical schemes have been published, including a range of global marine conservation planning systems such as the wwf-us ecoregions, large marine ecosystems (lmes), conservation international's hotspot approach, the iucn commission on national parks and protected areas' (cnppa) map-based description of 'world marine regions', bailey's marine ecoregions, and longhurst's biogeochemical provinces. A comparison of these schemes is useful as it reveals the orientation of the various authors and institutions with respect to setting priorities, and points to general trends in marine conservation science. For example, the large marine ecosystems (lmes) approach focuses on 'trophically linked' areas of ocean space, whereas wwf ecoregions place greater emphasis on spatial arrays of habitats rather than on biogeography. However both focus on relatively large units for conservation or marine resource management planning and point to a general adoption of 'systems' or seascape based approachs. If adopted broadly, these schemes have the scope to totally reorient marine conservation strategic planning if adopted broadly across the globe.

A MULTIOBJECTIVE APPROACH FOR IDENTIFYING NO-TAKE ZONES IN LARGE-SCALE CORAL REEF ECOSYSTEMS.

Parrish, Frank Ridgley, Mark *. *Dept. of Geography, University of Hawaii; 2424 Maile Way; Honolulu, HI 96822; USA. Email: Ridgley@hawaii.edu

"No-take" (no-fishing) marine protected areas (MPAs) are becoming a core element in the management of coral reefs. A recent Federal decision has mandated that 20% of all US reefs, by area, are to be so designated by the year 2010, with the figure of 30% currently (May 2000) being discussed for uninhabited coral-reef areas such as the Northwest Hawaiian Islands (NWHI). The criteria on which such designation should be based, while still being formulated, include: maximizing biological value (e.g., biogeographic representativeness, biodiversity, ecosystem integrity, ecological significance); minimizing socioeconomic impacts of closure; maximizing support by nearby communities; and maximizing compatibility with existing no-take zones. Such criteria clearly conflict, and tradeoffs among those objectives will generally be unavoidable. The task is thus one of selecting an adequately sized subset of the total area that reflects the most preferred tradeoffs. Uncertainty (*e.g.*, due to poor data or expert disagreement) and conflicting preferences across interest groups exacerbate the problem. We formulate this task as a multiobjective optimization problem and, using the case of the NWHI for illustration, demonstrate how the model can be used.

MARINE PROTECTED AREAS, STATUS AND MANAGEMENT IN THE EASTERN AFRICAN REGION.

Waruinge, Dixon*; Nilsson, Agneta; Njunguna, Stephen. *FAO Project Coordinator, P.O. Box 30552 Nairobi, Kenya Email Dixon.Waruinge@unep.org.

This paper provides a comprehensive overview of the status of the Marine Protected Areas (MPAs) and policies governing the management of the coral reefs in protected areas in the Eastern African Region. The overview was prepared as part of a study undertaken in the implementation of a UNEP project entitled " International Coral Reef Action Network (ICRAN) in the Eastern African Region. Management plans and objectives of key MPAs in Comoros, Kenya, Madagascar, Mozambique, Seychelles, and Tanzania, are analysed. In an attempt to protect the integrity of the marine ecosystems, Governments of the region have created protected areas referred to as Marine parks, reserves, or sanctuaries. Ordinances, acts of parliament or administrative regulations are in place at the national level, however, at the local level, besides private sanctuaries, none of the protected areas has effective management structures. Inadequate and unpredictable funding, untrained personnel, management plans that are inimical to local communities, are some of the reasons for failed management regimes. A series of participatory workshops with frontline stakeholders have provided action strategies and indicators for effective management required to reduce the effects of human related activities that threaten the health of marine ecosystems in the Region

Session B3: Conservation Biology of Coral Reef Fishes

ABUNDANCE PATTERNS AND DYNAMICS OF LARGE CORAL REEF TELEOSTS.

Choat, J.H.*, *School of Marine Biology, James Cook University, Queensland Australia 4811 Email john.choat@jcu.edu.au

The harvesting of coral reef fishes in the Indo-West-Pacific region has three main features. Most species targeted have wide geographic distributions. They are generally large fishes. Of 95 species targeted in the Asia-Pacific live fish trade 70% have a maximum size > 0.5 m. Most are uncommon relative to numerous smaller fishes on coral reefs. Management of large, widely distributed and uncommon species requires two sorts of biological information. 1) estimates of abundance and size structures; 2) estimates of age specific demographic events, growth, reproductive maturity and mortality. Abundance estimates of large reef fishes require methods that take into account relative rarity, clumped distributions and distinctive patterns such as mobile schooling or cryptic behaviours. Visual census methods for large fishes will require extensive swims within defined habitat features. Numerous counts over small areas are unlikely to yield useful results. Estimates of age specific demographic rates are necessary as in many species age and size are decoupled. Moreover reef fishes may show marked demographic changes along latitudinal gradients. Examples used to illustrate these points will be drawn from a variety of taxa. Large labroid fishes (*Bolbometopon* and *Cheilinus*) may be mobile and display diver oriented behaviours. Serranids (especially *Epinephalus*) are usually cryptic. The relationship between size and age will differ substantially between different lineages of reef fishes, especially labroids and acanthurids, and among different localities for similar taxa. Estimates of the effects fishing pressure over wide areas of a species geographic range must take such variation into account.

CHANGE IN FISH BIODIVERSITY FOLLOWING A CORAL BLEACHING EVENT AT HELEN REEF, SOUTHWEST PALAU ISLANDS.

Donaldson, T.J.* and Myers, R.F.. *International Marinelife Alliance, University of Guam Marine Laboratory, UOG Station, Mangilao, Guam 96923 USA. Email:

Helen Reef (Hotsarihie Atoll) is a large (61.7 km $^{-2}$ reef slope perimeter), relatively remote, and biologically diverse atoll in the Southwest Palau Islands of Micronesia. Biogeographic affinities are more closely aligned with neighboring Indonesia. This atoll experienced a coral bleaching event between July-September, 1998. The effects of this event upon biological resources were assessed in April-May, 2000. The assessment included measures of fish biodiversity which could be compared against those made during a previous expedition (1992). The results of this comparison indicate a shift in species richness and diversity of fishes at Helen Reef. We attribute this shift to losses of habitat and food as a consequence of coral bleaching. The pattern of species presence-absence observed resembles that of another large, recently surveyed atoll in the Solomon Islands that also experienced a significant bleaching event in 1998. Both atolls are currently at risk from illicit harvests that threaten recovery of their respective fish communities from this bleaching event.

RARITY OF HUMPHEAD MAORI WRASSE AND BUMPHEAD PARROTFISH IN FIJIAN SUBSISTENCE REEF FISHERIES.

Dulvy, N.K.* and Polunin, N.V.C. *Department of Marine Sciences and Coastal Management, University of Newcastle-upon-Tyne, Newcastle-upon-Tyne, NE1 7RU, UK. Email: N.K.Dulvy@ncl.ac.uk

Larger species are theoretically more vulnerable to exploitation than smaller species, due to lower rates of population increase. On coral reefs this assumption has scarcely been explored. We determined the abundance of the both the world's largest wrasse (*Cheilinus undulatus*), and parrotfish (*Bolbometapon muricatum*), down a fishing gradient. Questionnaire surveys indicated spearfishers target both species and that fishing pressure was relatively light, <50 people per km^{-1} of reef front island^{-1}. *B. muricatum* had not been caught at 8 islands for at least 10 years, although it had been caught recently at 3 islands. Numbers and lengths of each species were visually censused on the leeward outer fringing reefs, <10m deep, by a single observer. A single reef section ~130-150m long was examined at each of 3-8 sites per island and repeated for two seasons. Abundance was calculated as numbers or biomass hour^{-1} island^{-1}. Forty-five *C. undulatus* were observed and their abundance was weakly log-linearly, negatively related to fishing pressure. Only 11 individuals, comprising one shoal, of *B. muricatum* were sighted in 130 hours of survey time. This suggests studies of fishing effects have little statistical power to detect rarity or extinction of large species, and this may in turn help explain the paucity of documented marine extinctions. We present data from nine additional Pacific locations to suggest that *B. muricatum* is rare or absent at exploited locations, but common at unexploited locations.

IDENTIFICATION AND MONITORING OF GROUPER AGGREGATIONS IN SOUTHERN FLORIDA, U.S.A.

Eklund A.*, Coleman, Felicia C.; Harper, Douglas E.; Koenig, Christopher C.; and McClellan, David B. *Southeast Fisheries Science Center, NOAA Fisheries, 75 Virginia Beach Dr., Miami, FL 33149 USA. Email: anne.marie.eklund@noaa.gov

Jewfish, *Epinephelus itajara*, aggregate on isolated wrecks in the eastern Gulf of Mexico in 30-50 m of water during their spawning season from July-September. Up to 100 individuals were observed on these aggregations when they were first discovered. Within a couple of years after discovery, the abundance of jewfish at the aggregation sites declined precipitously to less than 10 individuals. After ten years of protection, these numbers have increased to 20-40 fish per site. In 1998, we also documented an aggregation of 100 black grouper, *Mycteroperca bonaci*, in the Florida Keys, during their spawning season in January and February. This observation is the only documented siting of black grouper in numbers greater than a dozen individuals. The black grouper are not afforded the same protection as the jewfish, however future marine protected areas may encompass the vulnerable aggregation.

REEF FISHES AND FISHERIES IN BRAZIL´S CORAL COAST MPA: MANAGEMENT PERSPECTIVES.

Ferreira, B.P.* and M. Maida. *Dep. Oceanografia, Universidade Federal de Pernambuco, Recife, PE, Brazil. Email: beatrice@free.elogica.com.br

Reef fisheries is an important activity in the Coral Coast MPA, Northeast Brazil. Since 1998 fish and fisheries assessment through fishermen interviews, collection of fisheries catch statistics and underwater visual census have been conducted along the MPA. Local fishermen were trained to collect and report fisheries data and participated of the UVC surveys. Initial phase Scarids were the most caught fish by line and spear fishing in the inshore, shallow reefs. Top predators as Serranids and Lutjanids, which dominate the catches of the offshore bottom line fisheries, were less abundant, and represented mainly by juveniles or smaller, faster growing species. In 1999, a reef area of four square kilometers was closed to all fishing and tourism activities. A rapid initial recovery was observed, probably the result of reduced mortality, fish migration and behavioural changes. Fishing avoidance may have played an important role in the recovery. Due to weather conditions, fishing intensity varied seasonally. Catches decreased during summer, as fishing pressure was intensified and increased again after the winter recess. Deeper reefs may be for some species, a spatial refugia that has been maintaining fisheries despite the intense pressure over the shallower habitats.

EFFECT OF OVER-EXPLOITATION BY CYANIDE FISHING ON THE POPULATION STRUCTURE OF *PLECTROPOMUS LEOPARDUS* (SERRANIDAE: EPINEPHELINAE) IN THE PHILIPPINES.

Mamauag, Samuel S.*; Pratt, Vaughan R.; Donaldson, Terry J.; and McCullogh, Bryan. *International Marinelife Alliance, 83 West Capitol Drive, Bo. Kapitolyo, Pasig City 1601 Philippines. Email: sam@imamarinelife.org.

Cyanide has been reportedly used in the live fish food trade (LFFT) in the Philippines. Present levels of harvest in the LFFT may indicate that over-exploitation is likely. One of the highly targeted fish species in the LFFT is the coral trout *Plectropomus leopardus* (Serranidae: Epinephelinae). To determine the effects of over-exploitation by cyanide fishing on the population structure of *P. leopardus*, fishery data between 1997-1999 were assessed in Coron and Guiuan. Landings of live *P. leopardus* in the two sites showed increased catches. Population parameters of *P. leopardus* were estimated using FISAT analysis of age estimates which, however, await validation. Initial results from age estimates inferred from validated age estimates of *P. leopardus* in a previous study, indicated that *P. leopardus* was slow-growing and long-lived. Recruitment of *P. leopardus* peaked in summer while total mortality (Z) and exploitation (E) rates seemed to be high. Since cyanide-fishing targets a wide range of sizes (and ages) and is biased towards sexually mature moderate-sized fish that bring high prices, this harvest method could therefore result in recruitment overfishing. As such, cyanide fishing will possibly cause limited recruitment of *P. leopardus* and, consequently, may lead to the decline and/or depletion of the population.

THE LIVE FISH TRADE: IMPACTS ON THE SUSTAINABILITY OF REEF FISH STOCKS AND THE FISHING COMMUNITY.

Muldoon, Geoffrey *; Fernandes, L.; Davies, C. *CRC for the Great Barrier Reef World Heritage Area, James Cook University, Townsville QLD 4811 AUSTRALIA. Email: geoffrey.muldoon@jcu.edu.au

The growing demand for live reef food fish has seen an increasing number of countries participating in the live fish trade. This has raised concern over the effects targeting this 'high value-added' product may have on the sustainability of fish stocks. Live product, predominantly Common Coral trout (*Plectropomus leopardus*), was first marketed from the Great Barrier Reef (GBR) reef-line fishery in 1993 and has coincided with an increase in fishing effort and catch. This research examined implications of the shift to live fishing in terms of individual vessel productivity and found significant differences in productivity of vessels that fished solely for frozen product versus those that targeted live product. The implications of the shift to marketing live fish within the GBR region may be both positive and negative with respect to the fishery's sustainability. In the short term, the premium paid for live reef fish provides considerable incentive for fishers to augment effort to increase profits. In the longer term, increased revenue per unit of product allows for smaller catches with income remaining stable or increasing. The net effect of these will be contingent on effective management of both effort and fishing practices. In South-east Asia and the Indo-Pacific, higher prices for live fish have led to the use of destructive fishing practices that threaten the long-term sustainability of biological and human systems. Evidence from this research suggests that with passive and non-destructive fishing techniques (ie hook and line) and effective controls on fishing effort, the live fish trade could have long term ecological and economic benefits for fish stocks and the community

ARE MANGROVES AND SEAGRASS BEDS OBLIGATE NURSERIES FOR CARIBBEAN REEF FISHES?

Nagelkerken, I.; S. Kleijnen, T. Klop, R. van den Brand, C.M. Roberts, G. van der Velde, M. Dorenbosch, M.C. van Riel, E. Cocheret de la Morinière, and P.H. Nienhuis. Aquatic Ecology, University of Nijmegen, 6525 ED Nijmegen, The Netherlands. Email: inagelk@cura.net

Mangroves and seagrass beds are considered important nursery habitats for coral reef fishes, but it is not known if these habitats are obligate or facultative nurseries. The abundance of 17 fish species, known to utilise mangroves and seagrass beds as nurseries, was compared among 11 different bays with/without mangroves/seagrass beds in Curaçao. Also , the densities of these fish species on the coral reef were compared between islands with bays containing mangroves/seagrass beds and islands lacking these nursery habitats. Most fish species were absent or showed highly reduced densities in bays without mangroves/seagrass beds and on islands lacking these nursery habitats.

CHALLENGES AND FRUSTRATIONS IN AN OVERFISHED MULTI-SPECIES REEF FISHERIES.

Pastor, Davelyn S.*; Castrence, Fernando I.; Aliño, Porfirio M.; and Juinio-Meñez, Marie Antonette. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, PHILIPPINES. dabe@msi01.cs.upd.edu.ph

Over the years declining fishery resources have been documented in Bolinao, Pangasinan, Philippines. Changes in the state of coastal resources were determined from habitat and resource monitoring, landed catch, underwater fish visual census, gear maps and harvest techniques. The decline is in terms of species diversity and composition, catch volume, catch-per-unit of effort (CPUE). Moreover, commercially important fin fishes and invertebrates were significantly reduced – reaffirming the overfished status of the Bolinao reef. The rabbitfish *Siganus fuscescens* is one of the most important fishery resource of Bolinao. The traditional harvesting of *S. fuscescens* recruits (*padas*) for fish paste and spawners (*barangen*) before it can successfully spawn are classic examples of the combined effect of growth and recruitment overfishing. Added to this issue are the conflicts on gear use (i.e. mesh sizes), ineffective implementation of open and close season and the lack of support for the establishment of a marine protected area around the Malilnep Channel, a major siganid spawning route in Bolinao. Thus, the regular monitoring of the fisheries indicate challenges as well as opportunities to address overfishing in Bolinao. Some interventions that in place are the establishment of a marine protected area (reserve), policy reforms on concession, resource enhancement and engendering stakeholder participation.

REHABILITATION OF CORAL REEF FISH COMMUNITIES: ARE HIGH-RELIEF ARTIFICIAL STRUCTURES BETTER RECRUITES THAN LOW-RELIEF ONES?

Rilov, Gil;* and Benayahu, Yehuda. *Institute for Nature Conservation Research, George S. Wise Faculty of Life Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel. Email: shaishir@hotmail.com

Artificial reefs have been suggested as a potential tool for the restoration of coral reef systems. Size, relief, surface area, complexity and location were all demonstrated to be important factors in influencing the success of an artificial reef. In the present study, conducted in eilat, red sea, we tested the hypothesis that high relief structures are a most useful design for artificial reefs in coral reef areas. First, we demonstrated that both species richness and fish abundance were significantly higher around the pillars of the eilat oil jetties (vertical structures) than at all three natural sites investigated (located on a moderated slope), with the lowest values at the site closest to the city (most exposed to anthropogenic effects). Secondly, we compared the initial recruitment of coral reef fishes to vertical high-relief versus near-bottom low-relief experimental installations, and showed that recruitment was about two orders of magnitude higher to the former design. Planktivores formed the initial stage of the fish-assemblage on the vertical installations, and most settled at the installations' upper sections. Regarding conservation, this study demonstrates that in order to achieve rapid recruitment and maximum biodiversity of coral reef fish in a denuded coral reef environment, the construction of complex vertical structures is preferable over low-relief ones, where applicable.

THE QUESTION OF SPECIES ENDANGERMENT IN REEF FISHES.

Sadovy, Yvonne*. *The Department of Ecology & Biodiversity, The University of Hong Kong, Pok Fu Lam Road, Hong Kong. Email: yjsadovy@hkusua.hku.hk

The question of whether or not marine fishes can or have become endangered by human activities has only received serious consideration within the last decade. Prior to this, and even among many biologists today, it has been assumed that the widespread geographic distribution, high fecundities and dispersive capabilities of the eggs and/or larvae of most marine fishes, especially those of commercial importance, render them immune to reductions in population numbers at a scale that could threaten the long-term persistence of the species. Data on several species of reef fishes, however, strongly suggest potentially serious population-level declines. Examples are to be found particularly among the groupers (Serranidae) and the wrasses (Labridae) with these two groups representing 10% of all fishes, fully 50% of all the commercial species, included in the 1996 IUCN Red List of marine fishes. Species in these families exhibit life history characteristics that make them particularly vulnerable. These include long lives, and, for many species, reproductive activities that are highly concentrated in time and space. Moreover, for many, their market value increases with rarity whereby fishing pressure persists even under severely reduced catch rates per unit of effort. The life history traits and our ability to assess these meaningfully in the context of species endangerment, and the fishing pressures encountered by these two families of reef fishes are examined and evaluated.

IMPACTS OF THE 1998 CORAL MORTALITY ON REEF FISH COMMUNITIES IN THE SEYCHELLES.

Spalding, Mark D.*. *Cambridge Coastal Research Unit, Department of Geography, Downing St, Cambridge, UK Email: mark.spalding@wcmc.org.uk

Coral reef fish communities in the Seychelles are highly diverse and remain less affected by the direct impacts of human activities than many other reefs in the Indian Ocean. These factors make them highly suitable for a detailed survey of the impacts of the 1998 mass coral mortality which devastated the coral faunas of the region. Using underwater visual census (UVC) techniques, fish communities were sampled from three localities in the southern Seychelles and one locality in the northern (granitic) Seychelles. Initial counts were undertaken from one site in 1997, counts were taken at all sites during the coral bleaching episode in 1998 prior to any major changes in the reef fish communities. Repeat counts were undertaken in 1999 one year after the coral mortality. Over 250 fish species were sampled from 35 families. Results suggest changes in the overall fish community structures and biomass have been minimal, despite massive changes in the benthic cover. There have been minor changes in the abundance of particular species, notably those most heavily dependant on live coral cover for shelter or sustenance. Future potential changes are discussed, and potential management interventions are considered.

ASSESSING THE STATUS OF ORNAMENTAL FISH AND INVERTEBRATES IN SRI LANKA: A DUAL APPROACH USING UNDERWATER SURVEYS AND COLLECTOR'S KNOWLEDGE

Wood, Elizabeth*; and Rajasuriya, Arjan. *Marine Conservation Society, 9 Gloucester Road, Ross-on-Wye, Herefordshire HR9 5BU. UK. E-mail: ewood@globalnet.co.uk

For many years the marine ornamental export trade in Sri Lanka was not monitored or regulated, and there were concerns about possible impacts of the fishery. This led to the development of a collaborative programme involving resource managers and the ornamental industry, the aim of which was to produce a conservation management plan for the fishery. Underwater censuses were carried out by researchers to provide data on the distribution and abundance of a range of species of interest to the ornamental trade. These findings were reviewed by collectors and exporters and their collective input sought so that a more comprehensive assessment of conservation status could be made. Those who work daily with the resource hold a huge store of knowledge which goes largely unrecorded. Whilst information from collectors is not quantitative, and so may be rejected as being ‘unscientific’, its usefulness in providing an assessment of the availability of species is beyond doubt. Population censuses and user assessments of the resource have made it possible to produce a plan for the conservation and management of marine ornamental resources that is acceptable to all sectors and so more likely to succeed.

Session B4: Global Priorities for Coelacanth Research and Conservation in the 21st Century

ON-GOING CONSERVATION EFFORTS FOR THE PRESERVATION OF *LATIMERIA CHALUMNAE* IN THE COMORO ARCHIPELAGO

Ahamada, Said *. Association for Gombessa Preservation B.P. 1545 MORONI Comoros. Email: s.ahamada@caramail.com

Until the recent discovery of an Indonesian coelacanth, the Western Indian Ocean islands of Grand Comoro and Anjouan were the only known biotope in the world of coelacanth populations. Recent estimates by Drs. Hans Fricke and Raphael Plante reported this population to be between 200 to 300 individuals. However, since the discovery of the Comoros Islands population in 1952, more than 200 coelacanths specimens have been captured as accidental by-catch of an established artisanal fishery. There is therefore a risk of extinction of the population in the next few decades. In previous years the high demand for specimens from museums and other scientific institutions was met, in part, by an increase in near-shore fishing activity. This may directly or indirectly have resulted in a serious depletion of the Comoros coelacanth population. This situation has led to conservation actions undertaken by local communities and political authorities, assisted by international and regional scientists and sponsors. Those efforts include Public Awareness and Environmental education; Research and Monitoring ; Law Enforcement; Alternative fishing techniques; Establishment of the regional marine coelacanth park; Establishment of the coelacanth Resuscitation unit and deep-water release techniques. In each programme we discuss aspects of the diagnosis of the situation, specific aims and activities. For the establishment of the regional coelacanth marine park an emphasise is given to steps of the process especially the feasibility study.

The above programmes need to be consolidated through a holistic plan to be conceived and executed from a local level with the co-operation and participation of all interested parties.

NEUROANTOMY OF COELACANTHS: UNIQUE INSIGHTS INTO NATURAL HISTORY AND ECOLOGY

Albert James S.*. Florida Museum of Natural History, University of Florida, Gainesville, FL, 32611, USA, Email: albert@flmnh.ufl.edu

The morpholgy of all vertebrate species is a mosaic of specialized and primitive features. Coelacanths provide a celebrated illustration if this principle, being the only surviving members of an ancient vertebrate lineage while simultaneously possessing certain features highly specialized for life in deep, dark, poorly oxygenated tropical waters. Neurological studies of *Latimeria menadoensis* will provide unique insights into natural history and ecology. In particular, detailed knowledge of the connections in olfactory, visual, electrosensory, and gustatory pathways provides otherwise inaccessible information on the nature of meaningful life history cues. Using fluorescent tracers we can study neural connections in formalin preserved specimens. Neural networks are now being resolved for members of all major vertebrate taxa. Yet the organization of the brain of *Latimeria* remains among the most poorly understood of all vertebrates. R. Nieuwenhuys reports "our present knowledge of the CNS... of *Latimeria chalumnae* is exclusively based on non-experimental histological materials, most of which is at best of mediocre quality (Nieuwenhuys, 1998:1038)." Establishing a protocol for preserving incidentally captured coelacanths is indispensable to advancing knowledge of their biology, and for making informed conservation decisions.

THE SENSORY CANAL SYSTEMS IN THE LIVING COELACANTH.

Balon E.K.* & Karol Hensel. *Axelrod Institute of Ichthyology, University of Guelph, Guelph, Ontario N1G 2W1, Canada. Email: ebalon@uoguelph.ca

The entire sensory canal system of the late term fetuses of coelacanth, *Latimeria chalumnae*, is described: not only the course of principal canals with their primary and secondary collaterals, but also the course and branches of the pit-line and reticular canals. The number of pores on one side of the head were found to be 296 in an early (yolksac) embryo, 321 in a late term fetus, 485 in a juvenile, and 2974 in adults. This means that in *Latimeria* most of the lateral-line canal system develops after parturition. Pit lines of the living coelacanth are not rows of superficial neuromasts but canals covered by thin epidermis similar to other sensory canals of the lateral line. These pit-line canals, however, have a very specific structure and branching pattern: the medial dorsal pit-line canals are connected by fine branches on top of the head. The infradental pit-line canal connects via these branches with canals deep inside the bones. Several fine and richly branched canaliculi of unknown function radiate from each quadratojugal pit-line canal. The gular plate pit-line canal has superficially branching arms as well as connections to numerous deeper canals inside the bone. These canals consist of fine branches that in turn open on the ventral surface of the gular plates as small pores. The system is reminiscent of the reticular (pore) canal system known only from some fossil agnathans and fishes. Thus *Latimeria* combines the reticular system of ancient vertebrates with the lateral-line system of modern fishes.

LATIMERIA MENADOENSIS: A CONSERVATION SUCCESS STORY.

Erdmann M.V.,* MK Moosa and RL Caldwell. Univ. California, Berkeley, CA 94720 USA. Email: flotsam@manado.wasantara.net.id

The discovery of the heretofore unknown coelacanth *Latimeria menadoensis* provided a unique opportunity to formulate a conservation plan for a species not yet intentionally exploited by humans. Before the discovery was publicly announced, we initiated an awareness campaign among Indonesian government officials to begin the process of enacting conservation measures to prevent overexploitation of *L. menadoensis* by local and international museums, aquariums, and rare animal collectors. Shortly after the public announcement, a series of meetings with Indonesian scientists, environmentalists and policy makers resulted in a national law protecting the species and an international proposal to expand CITES Appendix 1 protection to the Indonesian coelacanth. An intensive coelacanth conservation awareness campaign by the Indonesian Institute of Sciences and the Japanese agency JICA produced posters, information brochures, tshirts, hats, calendars and a children's book, all with a coelacanth conservation message. This campaign, aided by frequent and widespread media exposure of the coelacanth and its conservation status, has resulted in a strong sense of local and even national pride over the Indonesian coelacanth. A recent program funded by WWF has created a team of youth volunteers in the park to monitor coelacanth catches, and has promoted the development of several cottage industries producing coelacanth handicrafts for sale to tourists.

CONFESSIONS OF A COELACANTH CATCHER: THE EVOLUTION OF THE COELACANTH RESCUE MISSION AND EXPERIENCES WITH RESUSCITATION ATTEMPTS ON CAPTIVE SPECIMENS OF *LATIMERIA CHALUMNAE*.

Hamlin J.* . Coelacanth Rescue Mission, Greenwich CT 06831 U.S.A. Email: dinofish@cloud9.net

In the 1980's the author led a series of expeditions to the Comoro Islands with the goal of capturing a living coelacanth for eventual display in a public aquarium. These attempts were met with a mixture of support and international outcry, and eventually led to the development of the present Coelacanth Rescue Mission Conservation Project which focuses instead on public education and coelacanth conservation strategies in the Comoros. The author will present an historical overview of the evolution of the Coelacanth Rescue Mission, with a focus on recent initiatives including the www.dinofish.com website, deep release kits for use by Comoran handliner fishermen, and especially the "life boat" resuscitation pool strategy for accidental coelacanth bycatch specimens. Failures of resuscitation attempts in the past are examined critically and a new strategy for accidental catch resuscitations using a unique cooling system is presented. The use of this resuscitation method in combination with fishermen deep release kits should help greatly reduce fatalities of bycatch coelacanth specimens in the Comoros.

THE COELACANTH PARADIGM : A COGNITIVE ECOLOGY FOR THE ENVIRONMENT.

Henon C*. CRRM-University of Aix-Marseille III, France (and CRC-University of Canberra). Postal Address: 15 rue Mme Curie, 08000 Charleville-Mézières, France. Email: christinehenon@hotmail.com

The coelacanth has survived relatively unchanged throughout ~ 400 million years, today comprising 2 species surviving at 2 widely separated localities (latimeria chalumnae in comoros island, latimeria menadoensis in sulawesi). This paper discusses the circumstances and characteristics of the coelacanth which may lead to an understanding that "development" doesn't always mean "evolution" toward increased complexity. The history of the coelacanth and of the human view on the exceptional particularities of this fish, from the old socio-economics dominated paradigm to the new paradigm (one of environmental knowledge and awareness), can help us to understand the different approach to knowledge, the different values, and the values of such knowledge. The coelacanth may thus symbolize and benefit the diversity and complexity of life and cognition, and the natural environment, in both space and time. The paper develops the concept of a cognitive ecology for the environment, aimed to a new environmental philosophy of "evolutionary everlastingness". A pragmatic proposition follows with a project centered on the iconic coelacanth. This project begins with a complementary, cooperative and adaptive organization and management of a cluster of «complexity reserves» (displaying environmental, sociologic, economic, and cognitive complexity), through sustainable tourism (as a transitional tool from the old paradigm to the new paradigm).

COELACANTH PRESERVATION AND UTILIZATION.

Jewett, Susan L.* Division of Fishes, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0159, USA. Email: jewett.susan@nmnh.si.edu.

The large size of coelacanths and the unpredictable timing of their capture has resulted in many specimens being preserved by the most convenient method available. This often entails freezing the specimen initially. Formalin fixation followed by alcohol preservation is the time-honored method of preserving fish specimens for scientific collections and is ideal for the study of gross anatomy. Tissue sampling for DNA analysis must be conducted prior to formalin fixation. Freezing specimens before fixing them hinders the study of microanatomy because the resulting ice crystals severely damage tissues for use in histology. The various needs of scientific study also must balanced with those of public exhibition and education. A protocol for the preservation of incidentally captured coelacanths is proposed, based on maximizing the potential use for scientific study and public exhibition. A summary of the preservation methods used for existing museum specimens is presented, along with (where determinable) each museum's policy on allowing examination and destructive sampling of the specimens. The establishment of an international coelacanth advisory committee to make recommendations pertaining to coelacanth preservation, appropriate international repositories for newly obtained specimens, and policies relating to international transport and the sharing of resources is suggested.

CHARACTERIZING DEEPWATER HABITATS IN HAWAII USING MULTIBEAM SONAR AND SUBMERSIBLE TECHNOLOGIES.

Kelley, Christopher*. *Hawaii Undersea Research Laboratory, University of Hawaii at Manoa, Honolulu, HI, 96822, USA.

The ehu, *Etelis carbunculus*, is a commercially valuable deepwater snapper whose population in the main Hawaiian Islands has been severely depleted. These fish inhabit areas of hard substrate between the depths of 200-350 m. Since very little else is known about their ecology, research is presently being conducted to gain a better understanding of their habitat requirements. Four habitat sites around the island of Oahu were recently studied in an attempt to identify their common geological and biological features. High-resolution bathymetry and backscatter data were obtained using a Simrad 300 multibeam sonar system and imported into Arcview GIS to generate 2-D and 3-D seafloor images. Direct observations of the substrate, invertebrates, and fish on the sites were obtained with the use of the Pisces V submersible and the RCV-150 ROV. The submersible and ROV tracking data were subsequently imported into Arcview and superimposed on the multibeam images. At the megahabitat scale, the multibeam data showed distinct topographic differences between these sites. However, at the meso- and macro-habitat scales, data from the submersible and ROV dives indicated that the four sites had several important similarities with respect to availability of cavities and densities of small fish and invertebrates. The results of this study indicate that a substrate with numerous cavities, where ehu and their potential prey organisms can find shelter, is an important characteristic of the habitats for this deepwater snapper. The potential applicability of these technologies to the study of coelacanths is discussed.

THE 1975 CAS COELACANTH EXPEDITION, WITH COMMENTS ON ATTEMPTS BY AQUARIUMS TO CAPTURE AND DISPLAY *LATIMERIA*.

McCosker J. *. California Academy of Sciences, San Francisco, California, USA. Email: jmccosker@calacademy.org

The history of the 1975 American-Franco Coelacanth Expedition to Grande Comore will be reviewed. No specimens were captured during the six-week expedition, probably as a result of the east African drought; however, two previously-captured frozen specimens were returned to American museums and intensely investigated. Many deep-water scuba dives were made in the vicinity of Iconi and at other locations, an ichthyological inventory was accomplished, and coelacanth fishermen were interviewed. The history of attempts by various aquariums to capture coelacanths for research and display will be reviewed

DEMOGRAPHICS AND EXTINCTION RISK IN THE COELACANTH, *LATIMERIA CHALUMNAE*.

Musick, John A.*, Milani Chaloupka, and David H. Secor. Virginia Institute of Marine Science, PO Box 1346, Gloucester Point, VA 23062 USA. Email: jmusick@vims.edu

Examination of the otoliths of a female specimen of *Latimeria chalumnae* (CCC no. 141) suggest that previous estimates of age and growth of this species based on scales have grossly overestimated these parameters. In addition, the relationship between growth rate, size, and ambient water temperature recorded for other fishes suggests that growth in *L. chalumnae* should be much slower than that estimated from scales. The reliability of scales as an aging tool has been questioned for many species of fishes, particularly those that are long-lived. A Von Bertalanffy growth curve based on back-calculation of presumed annuli found on the otoliths suggests that *L. chalumnae* has very slow growth, (k=0.04), matures at about 27 years, and may attain 60 years of age. Based on these parameters and the average of two published accounts of litter size (x=16) we have used stochastic demographic modeling techniques to simulate the population trajectory of *L. chalumnae* off Grand Comoro. We examine published estimates of fishing mortality and submersible observations of recent population decline as part of this simulation study.

A COELACANTH PARK IN GRANDE COMORE ? REQUISITES AND PROJECTS.

Plante, R. *, H. Fricke, C. Chaboud, G. David, C. Hénon, Y. Hénocque. *C.O.M. Univ. Méditerranée, rue Batterie des Lions 13007F Marseille France. Email: Plante@com.univ-mrs.fr

Because the source population of *Latimeria menadoensis* in Indonesian waters has probably not yet been found, the Comorian population of coelacanths remains sofar the only known well established coelacanth population on earth. From *in situ* observations and studies on traditional fishing activities, the Comorian population appears to be endangered, primarily by the bottom-line fishing method of local fishermen. For several years, ecological investigations and socio-economic feasibility studies for a Marine Coelacanth Park have been performed at Grande Comore. Because of the behavioural and ecological habits of the coelacanths, the Park should be established more in terms of a new fisheries management than of restrictions of rural fishing activities. We propose the use of Fish Aggregating Devices (FAD's) to target pelagic fisheries, thus diverting the fishing effort from the bottom. The socio-economical context of the project (fishermen are among the poorest groups in comorian society) leads to the idea of an integrated management policy: conservation of coelacanths should go together with the social development of fishermen and coastal human populations. Such prerequisites are similar to those which are used under the Man and Biosphere regulations, *i. e.* ensuring a simultaneous and harmonious development of environment and human society. In the past, political instability prevented the enforcement of a rigid environmental program. Therefore the establishment of a Marine Coelacanth Park should rely upon the traditional organisation of the Comoran society, i.e. the village´s civilian and religious authorities, but at the same time it should be ruled by an International Association.

Session B5: Worldwide Examples of Coral Reef Resource Management

PROACTIVE MANAGEMENT FOR CONSERVATION OF *ACROPORA PALMATA* AND *ACROPORA CERVICORNIS*: APPLICATION OF THE U.S. ENDANGERED SPECIES ACT.

Bruckner, A.W.* **and Hourigan, T.F. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email:** andy.bruckner@noaa.gov

Acropora palmata and *A. cervicornis* are important framework-building corals that provide a critical structuring role on shallow Caribbean reefs. In recent decades both species have declined from white-band disease and other factors. To increase awareness about their decline, the National Marine Fisheries Service in June 1999 identified *A. palmata* and *A. cervicornis* as candidate species for the United States Endangered Species Act (ESA). Candidate status does not add legal protection, but is designed to promote efforts to obtain reliable information on the species and to encourage voluntary conservation strategies for the protection of remaining populations. Application of the ESA to marine invertebrates presents several challenges. While distinct vertebrate populations can be listed, a marine invertebrate must be threatened throughout its range. Both *Acropora* spp. are widespread, however a survey of available information revealed gaps that prevent a synoptic overview of their status. Furthermore, measures of rarity have been developed for individuals, and may not be applicable to clonal organisms that rely on asexual fragmentation as a primary mode of propagation. An ESA listing requires implementation of a recovery plan and action by Federal agencies to conduct conservation programs, and to promote research, restoration and protection for these species, thereby benefitting associated coral reef organisms and the ecosystems upon which they depend.

MANAGING CONSERVATION PLAYERS: SOCIOECONOMIC ASPECT OF SSME PLANNING.

Cola.R* ***WWF-Philippines, 23 Maalindog St. UP Village, Diliman 1101 Quezon City. Email:** rcola@skyinet.net

Gearing individual and group behavior for conservation is prerequisite to its success. This is the reason behind the conduct of two main activities in ecoregional planning: profiling the conditions and activities of resource users along Sulu-Sulawesi Marine Ecoregion (SSME) and conduct of nation-wide stakeholders' planning meetings. The profile presents the population dynamics, cultural processes and resource use of people directly using the SSME's resources. The profile attained many purposes including identification of key players and emphasizing the urgency of SSME. The players range from government bodies making sweeping national policies to subsistence fisherfolks who fish everyday just to eat. The multi-player planing process anticipates a multi-player implementation process required by the enormity and complexity of SSME conservation. The stakeholders attain common understanding of SSME condition in six regional and one national meetings. The national meeting wrapped-up the result of regional meetings into national agenda. The result is a multi-activity and multi-phase plan. In the national meeting, the stakeholders committed their participation in implementation in consideration of their mandate and resources. The actions developed into Philippine SSME Management Framework Plan that merged with those of Indonesia and Malaysia to become SSME Management Framework Plan.

PROBLEMS ENCOUNTERED AND REMEDIAL MEASURES NEEDED IN THE GULF OF MANNAR BIOSPHERE RESERVE.

Dhandapani P.*, *Chief of Marine Biological Station, ZSI, Ministry of Environment and Forests, Govt. Of India, C-9/113, Kendriya Vihar, Thiruverkadu. P.O., Chennai-600 077. Email : telflow@vsnl.com

The Gulf of Mannar Biosphere Reserve is known to have a rich marine biodiversity comprising of coral reefs, pearl oysters, sacred chunks, marine algae, seagrass, innumerable species of invertebrates, Hemichordates, Protochordates , ornamental and edible fish, turtles, the migrating Cetaceans and the domicile Sirenian, the *Dugong* dugon . Unfortunately, improper management and unethical methodology adopted to harvest the marine products with absolutely no respect for environmental ethics is gradually depleting its biodiversity. The trade in seahorses, sea cucumbers, sea fans, sea ferns and algae has almost tilted the process of natural recuperation of these biotic components to the extent of possible extirpation from this coral reef ecosystem. Shore based industrial activities, coral mining, use of dynamite for fishing have added to the misery of this biosphere reserve. It is high time to take a serious view of this situation and with the involvement of local communities, take up remedial measures through regulated trade of marine products backed by community based marine resource management.

CORAL REEFS OF THE ABROLHOS BANK, BRAZIL: MANAGEMENT AND CONSERVATION STATUS.

Dutra, Guilherme F.* & Werner, Timothy B.. *Conservation International do Brasil, Av. Antônio Abrahão Caram, 820/302 – 31275 000 – Belo Horizonte, MG, Brazil. Email: g.dutra@conservation.org.br

The Abrolhos Bank, located off the Southeast coast of the state of Bahia in Brazil, supports the most biologically diverse coral reefs in the Southern Atlantic, and has the largest concentration of Brazilian reef endemics. The biodiversity of the Abrolhos Bank is currently threatened by overfishing from coastal communities, by an apparent increase in sedimentation from logging of the once extensive coastal Atlantic Forest, and by unmanaged growth in tourism. Since 1983, three marine protected areas have been established on the Abrolhos Bank, and a fourth will soon be established for a total coverage of 532,000 hectares. Although all of these areas together will put over 90% of the Bank's coral reefs under protected status, only 15% of this area can be considered effectively managed. A recent rapid marine biodiversity survey of the Abrolhos Bank also identified that a number of biologically rich and distinct areas were not yet captured within existing protected areas. Management of existing conservation units falls under different government departments at the national, state, and municipal levels. The protected areas of the Abrolhos Bank form the core of a multiple-use area that falls under a regional conservation strategy developed by Conservation International together with these government agencies, local fishermen, scientists, tour operators, and other non-governmental organizations. In our paper, we present some progress to date including the creation of a mangrove forest reserve and an extractive fishing reserve, as well as plans for integrating coral reef protection into a broader coastal zone management strategy.

PROTECTION OF THE CORAL REEFS OF GUAM.

Gawel M.*. 120 Bengbing St., Yigo, GU 96929, USA. Email: mgawel@ite.net

Guam consists of a single main island surrounded by shallow fringing coral reefs. The marine species and ecology of Guam's coral reefs have been studied extensively, especially through programs of the University of Guam's Marine Laboratory. In addition to overfishing and destructive fishing practices, the coral reef communities of Guam have been damaged by destruction from major storm waves; loss of corals to crown of thorns starfish predation; damage by recreational swimmers, divers and watercraft operators; grounding of ships and pollutant discharges of sewage and of stormwater. However, the most serious damage is due to accelerated siltation, sedimentation and turbidity due to erosion related to land use practices. Steps are taken to protect Guam's coral reefs and coastal waters through legislation, regulations, permit systems and policies. Environmental impact assessments, Guam's Coral Reef Initiative, fisheries regulations, water quality standards and controls by the Guam Seashore Protection Commission play a major role in the protection of Guam's coral reefs, while research and plans for new legislation to protect coral reefs and their resources are underway.

MANAGEMENT OF MARINE SANCTUARIES IN BOHOL, CENTRAL PHILIPPINES.

Gulayan S*, Ancog, Isidore; Pajaro, Marivic; and Brunio, Erwin. *Haribon Foundation for the Conservation of Natural Resources, 9 Malingap St. Teachers Village, Diliman, Quezon City, Philippines. Email: gulayan@mozcom.com

Bohol has 58 marine protected areas more (commonly known as marine or fish sanctuaries) scattered all over its mainland and islets. These are mostly no fishing zones with only 28 of them strictly enforced and the other 15 with moderate and weak enforcement. The rest (15 MPAs) have only a legal basis but is not enforced. Bohol has a tradition of managing coastal areas called *sona* which may be part of the reason for the ready acceptance of MPAs in many villages. There is support from several local government units, i.e. the provincial, municipal and village levels which help enforce the sanctuaries although management is mostly at the village level. One of the very few MPAs that operate with a management plan is that of Batasan village which formulated this in a participatory manner. The community became involved in assessment of the coastal resources and in the analysis which was carried on to management planning. This process of designing management plans is also being done in other MPAs whose management is being shared by more than one village. However, absence of a formal management plan does not preclude effective management of MPAs in Bohol. Several other mechanisms of managing its MPAs either through people's organizations, management councils and the local government units has been evolved. The management scheme that works and does not work for this island province can serve as guide to other areas wanting to establish or improve the management of their MPAs.

BEYOND DATA: THE EXPANDED ROLE OF A VOLUNTEER PROGRAMME ASSISTING RESOURCE ASSESSMENT AND MANAGEMENT IN THE BAY ISLANDS, HONDURAS.

Harborne, A.R.*, Afzal, D.; , M.J.; Ridley, J.M.; and Rodriguez, M.C.. *Coral Cay Conservation, 154 Clapham Park Road, London, SW4 7DE, UK. Email: arh@coralcay.org

The use of non-professional researchers is an efficient means of generating data within marine science, providing self-financing manpower to undertake large-scale temporal and spatial surveys, particularly in remote locations. In addition, 'volunteer' programmes can significantly expand their role when located within coastal communities and can add value to internationally funded interventions. For example, work by Coral Cay Conservation (CCC) in the Bay Islands, Honduras, is benefiting local communities by providing immediate technical assistance on sustainable use and protection of coastal resources and expanding the scope of the Government of Honduras' Environmental Management Project of the Bay Islands (EMPBI). CCC achieves this by (a) establishing a constant fieldwork programme which rapidly provides 'no cost' habitat descriptions for resource mapping along with reef health and monitoring data; (b) the continual presence of qualified staff to provide objective opinions on reef management; (c) an ability to implement studies to address new community concerns such as dredging or bleaching and (d) providing logistical support to visiting researchers. In addition, CCC's training and environmental education to host country counterparts complements that of the EMPBI and with tangible benefits to the local community. Finally, CCC's long-term commitment provides a conduit for additional funding to develop local capacity for sustainable coastal management.

THE TORTUGAS ECOLOGICAL RESERVE: PROTECTING CRITICAL CORAL REEF HABITAT IN THE FLORIDA KEYS NATIONAL MARINE SANCTUARY.

Haskell B.*, Delaney, Joanne. *Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, USA 33050. Email: ben.haskell@noaa.gov

The remote Tortugas region of the Florida Keys, located over 225 km from the continental U.S., is an area of high stony coral density and soft coral diversity, excellent water quality, and productive reef fisheries. Due to its location at the juncture of several major ocean currents, the Tortugas has the potential to serve as both a source and sink for marine larvae. The Florida Keys National Marine Sanctuary is designating a no-take ecological reserve in the Tortugas to conserve the unique marine resources of this region. The reserve will preserve biodiversity, maintain ecosystem integrity, and act as a reference site to help scientists discriminate between natural and anthropogenic changes to the Keys' ecosystem. Planning for the reserve has emphasized community input and consensus-based decision-making. Critical to the success of the process has been a diverse working group comprised of stakeholders and government agency representatives. The Tortugas Ecological Reserve will complement the Sanctuary's existing network of 23 no-take zones, instituted in 1997 to protect marine resources from overuse, conserve biodiversity, and separate conflicting uses. Reserve implementation is scheduled for late 2000.

A REGIONAL PROGRAM FOR THE CONSERVATION AND SUSTAINABLE USE OF THE MESOAMERICAN BARRIER REEF.

Hatziolos M.*. *The World Bank. 1818 H St., N.W., Washington, D.C. 20043, U.S.A. Email: Mhatziolos@worldbank.org

The Mesoamerican Barrier Reef System (MBRS), extending from the Yucatan Peninsula in Mexico to the Bay Islands of Honduras, includes the second longest barrier reef in the world. It is unique in the Western hemisphere due to its length, composition of reef types, and diversity of habitat. Despite its designation as a World Heritage Site, the MBRS is increasingly at risk to a number of threats. These include: (i) coastal/island development and unsustainable tourism; (b) inappropriate land use in upland watersheds; (iii) overfishing of high value stocks such as lobster, conch, and grouper, and poaching of sea turtles and manatee, (iv) increased shipping and maritime pollution; (v) natural disturbances linked to climate change. Recognition of these threats to the ecological integrity and economic productivity of the MBRS has led to a commitment by the governments of Mexico, Belize, Guatemala and Honduras, to a regional plan of action for the conservation and sustainable use of this transboundary system. Implementation of the plan is being supported by the Global Environment Facility, the World Bank and several partners. Regional coordination is required to: (i) harmonize national policies and regulations governing use of shared resources; (ii) establish marine protected areas in transboundary locations; (iii) develop and implement a regional coral reef ecosystem monitoring and information system; (iv) promote sustainable development of the fisheries and marine tourism sectors; (v) increase capacity for environmental management through education and training.

ESSENTIAL FISH HABITAT (EFH) LEGISLATION PROMISES CONSERVATION, ENHANCEMENT AND RESEARCH BENEFITS FOR U.S. CORAL REEFS.

Hill R.L.*, Leathery, Stephen L.; and Bigford, Thomas E. *U.S. Department of Commerce, NOAA/National Marine Fisheries Service, 4700 Ave U, Galveston, Texas, USA 77551. Email: ron.hill@noaa.gov

In 1996, the United States Congress unanimously passed the Sustainable Fisheries Act (SFA), increasing the conservation mandate for U.S. managers of marine fisheries, including those dependent on coral reefs. The SFA bolstered existing habitat protections in the Magnuson-Stevens Fishery Conservation and Management Act, the primary legislation governing US marine fishery resources, by requiring that regional fishery management councils describe and identify essential fish habitats (EFH), minimize to the extent practicable adverse effects on EFH caused by fishing, and identify other actions for the conservation and enhancement of such habitat. Councils throughout the USA have identified coral and coral reef habitats as essential. This paper provides an overview the description and identification of coral habitats as EFH, a discussion of the steps taken to reduce adverse effects to these key habitats, and explores research topics needed to improve our conservation and management of coral reefs and coralline fish habitats.

MANAGEMENT AND MONITORING PROPOSAL OF THE MEXICAN MESO-AMERICAN BARRIER REEF SYSTEM (MBRS).

Lara M,* Loreto R.M, Padilla C, Gutiérrez D, Bezaury, J. *SEMARNAP, km.4.8 Z.H, Cancún77500, Q.Roo, México. Email: pncontoy@prodigy.net.mx

Located in the state of Quintana Roo, Mexico's fringing reef constitutes the northern extent of the MBRS, extending approximately 645 Km. These reefs represent an important regional resource base for fisheries, tourism, and marine conservation areas. The recently developed MBRS action plan promotes a consistent management regime to support conservation and sustainable development in the reef system at a regional level, and incorporates reef characterization, monitoring, and marine protected areas. Since 1990, scientists and local NGO have collaborated to develop a detailed survey of these reefs. The belt-quadrant methodology was used to analyse macroalgae, scleractinian, gorgonian, sponges and fishes communities; as well as aerial and bathymetry surveys were made. The reef assessment utilized the following classification criteria: a) reef zonation patterns, b) scleractinian species assemblages; and c) reef framework development. This resulted in the classification of 6 coastal areas and 3 insular areas, divided in to 60 subareas according the criterions used. This information identifies exceptional reef traits, conservation areas and disturbance areas, as well as the existing use by humans. Within mexican MBRS developed a management proposal which incorporates 7 new MPAs (in addition to the existing 5). The team has also proposed the development of a sustained monitoring network with 15 stations. This network would incorporate monitoring of both existing and proposed MPAs, and would gather data at three resolution levels.

CENTRAL SULAWESI – A "FORGOTTEN PROVINCE"?

Moore, Abigail*; Sofyan, Andi SP; *Yayasan Adi Citra Lestari, Jl Setia Budi No 14D, Palu Timur 94111, Sulteng, Indonesia, Email: rosontapura@palu.wasantara.net.id

Central Sulawesi is the largest Province, with arguably the longest coastline, in Sulawesi. At the heart of the Wallacea maximum biodiversity region, blest with rich and diverse natural resources, it has to date largely escaped the attention which has been foccused on the other three provinces with their Marine National Parks (Bunaken, Taka Bone Rate and more recently Wakatobi). The state of knowledge regarding marine resources is particularly poor, with the exception of some sterling work in the Togean Islands and to a lesser extent in the Banggai Islands. Available data, anecdotal information, and personal observation lead the authors to believe that nearly all of the coastline is fringed by reefs, which although mainly of the fringing type, include all forms, and are a vital source of livelihood for many coastal communities. It also paints a picture of an area heavily impacted by anthropogenic activities, including destructive fishing, overfishing, coral mining, sedimentation, pollution, etc, and with severe and increasing poverty in many coastal communities. Firstly, the extent of current data related to these reefs and associated eco-systems, including socio-economic factors is evaluated. Various implications are then presented, including examples, gaps in our knowledge, and some likely outcomes if no action is taken. Finally, various options and ideas for the future will be put forward, including integrated survey and monitoring programmes, and processes which it is felt could lead to a more hopeful future for the people and reefs of this beautiful and diverse region.

THE SURVIVAL CRISIS FACED BY COASTAL ECOSYSTEMS IN TROPICAL AND SUBTROPICAL AREAS

Nakaza, Eizo *; Tsukayama, Seiko; Makino, Tosiaki; Kitamura, Koji; Takeuchi, Rika; Eto, Shunsuke. *University of the Ryukyus, Shenbaru-1, Nishihara, Okinwa, Japan. Email: enakaza@tec.u-ryukyu.ac.jp

In tropical and subtropical coastal areas, there are unique ecosystems in which the land hermit crab plays an important roll. Recent land developments have forced them into a survival crisis, particularly around the Okinawan islands in southern Japan. The Okinawan islands consist of several dozen small islands that lie on the path of Kurosio, a warm ocean current th atoriginates along the equator, nears the Philippines, then travels northward toward Japan. The islands of Okinawa used to be surrounded by cobalt color reef seas and abundant ecosystems, of which the land hermit crabs were at the heart. While still dominant, most of them are now being destroyed by the construction of artificial barriers such as sea walls for roads, and land development. Land hermit crabs usually live among vegetation on land near the seashore. At spawning time, they make their way to the sea where they release their spawn. They cannot easily survive in an environment that contains artificial eco-barriers. Field surveys have revealed that coastal ecosystems in subtropical seas are facing a survival crisis.

STATUS OF MARINE PROTECTED AREAS IN THE PHILIPPINES: BETTER MANAGEMENT OF CORAL REEFS AND THE COASTAL AREAS IN THE TROPICS.

Pajaro, M.G.*, Nozawa, C.M.; Lavides, M.; and Gutierrez, S. *Haribon Foundation for the Conservation of Natural Resources, 9 Malingap St. Teachers Village, Diliman, Quezon City, Philippines. Email: science@haribon.org.ph

The Philippines has a rich experience in the establishment and management of marine protected areas. This is proving to be a popular management technique for both local communities and local governments specially with the recent enactment of Republic Act 8550 requiring every coastal municipality to allocate an area for a fish sanctuary. Thus, a total of 558 MPAs are recorded with over 150 areas being proposed in the Philippines. These are of various purpose, design, sizes, management and enforcement. The size of one protected area can range from 1 to 2,000 hectares and may have strictly no fishing zones, regulated zones or a combination of both. Fisheries enhancement appear to be the major objective for most of these MPAs. Their management may entirely be by the local government, by the people's organization, by an NGO or a composite of the two or three groups. Less than half of the total number of MPAs are functional, mostly managed by the communities and usually with core zones of below 50 hectares in size. Issues and problems before, during and after the establishment of MPAs were encountered. Most problems included lack of facilities and/or financial support and politics. The communities appeared to persevere due to encouragement from catalysts and the perceived benefits such as increase in biodiversity and biomass particularly among fish populations. The number of MPAs is expected to increase over the next few years and the formation of a national alliance of community managers of MPAs to assist communities in sustaining their efforts in managing functional MPAs was seen as a necessary intervention.

EVALUATING TOURISM TRAINING AND INTERPRETIVE STRATEGIES IN THE GREAT BARRIER REEF MARINE PARK: A COMPARATIVE APPROACH.

Potter, Elizabeth* and Dinesen, Zena. *School of Tropical Environment Studies and Geography, James Cook University, Townsville 4811, Australia. Email: Elizabeth.Potter@jcu.edu.au

Performance indicators are currently being developed to assess management of the Great Barrier Reef (GBR) through the use of case studies. Within the reef-based marine tourism industry, visitor interpretation is seen as one of the key means by which tourist impacts on reef ecosystems can be minimized. This study focuses on evaluation of tourist operator education programs within the Whitsundays (central section of the GBR Marine Park). Two key sectors of the Whitsunday marine tourism industry, bareboat and day reef trip operations, will serve as the focal point of this research. An accreditation program involving tourist operator staff training and visitor interpretation has recently been introduced in the Whitsunday bareboat sector, however the program's effectiveness has not been evaluated. Within the day-trip sector of reef tourism, no standardization of staff training or visitor interpretation efforts has been introduced, thus emphasis placed upon these areas varies widely. Descriptive and comparative surveys of operator staff and visitors will be used in order to draw comparisons between groups within each of these sectors. Such differences will serve to highlight strengths and weaknesses of various training and interpretive strategies currently employed, as well as provide a tool for future evaluation in other geographic areas. Initial results of this work will be presented, and challenges of developing performance indicators for the marine tourism industry will be discussed.

SUSTAINABILITY – ATTAINABLE GOAL OR WILD DREAM?
AN ASSESSMENT OF THE PROSPECTS OF ACHIEVING SUSTAINABLE MANAGEMENT OF CORAL REEF RESOURCES IN THE MAFIA ISLAND MARINE PARK, TANZANIA

Rubens, Jason.* and Msumi" George D *Worldwide Fund for Nature (WWF), PO Box 23, Mafia Island, Tanzania. Email: wwfmafia@raha.com

The Mafia Island Marine Park was established in 1995 as Tanzania's first national marine park. Despite initial success in eliminating dynamite fishing and beach-seine nets, sustainable management remains a far off goal. Fish catch-per-unit-effort continues to deteriorate as a result of increasing fishing pressure and habitat damage. Marine resources such as sea cucumber, shells and lobster, once economically important, have virtually disappeared. In an increasingly urgent attempt to reverse the corresponding decline in livelihoods, fishermen are switching to more destructive, less sustainable fishing gears. Adding to this the coral bleaching in 1998, the condition of reef habitats has deteriorated significantly even since the establishment of the park, causing serious concern to tourism investors. Financially, far from being self-financing, the marine park still depends heavily on donors and the Tanzanian central government. Under a new 5-year programme, the marine park is developing a strategic plan aimed at resolving short-term livelihood demands with long-term conservation and sustainability goals. A zoning plan, gear regulations and a resource-use permit system provide the legislative core around which to build a sustainable pattern of resource-use and alternative income sources within the park.

PRESENT STATUS OF REEF FAUNA OF GULF OF MANNAR, A BIOSPHERE RESERVE ON THE SOUTHEAST COAST OF INDIA AND STRATEGIES FOR ITS CONSERVATION.

Satyanarayana*,Ch; and Venkataraman, K. *Zoological Survey of India, Marine Biological Station, 100 Santhome High Road, Chennai-600 028, INDIA. Email:dugong@md2.vsnl.net.in

Gulf of Mannar the biologically rich biosphere reserve situated on the southeastern board of India is composed of a chain of 21 islands of coral origin along the coast line for a distance of 140 kms and has a reef area of 6.49 sq.kms. It has nearly 3,600 recorded biological species to its credit. The fauna of Gulf of Mannar is subjected to ever increasing anthropogenic pressure. An inventory of fauna of an ecosystem depicts the health of the ecosystem and status of individual organisms in that ecosystem. Nine faunistic surveys (1988 to 1996). A total of 1097 species of fauna belonging to 254 families and 567 genera are reported on this account and the results clearly show a decline in the abundance and disappearance of some species. The GIS based underwater biophysical ground truthing surveys between October 1988 to February 2000 revealed the presence of only 25% of live coral represented by a half of live corals reported earlier from this reserve. The ramose form *Montipora digitata* and the massive forms dominante over one time dominants *Acropora* sps. An incidence of coral bleaching due to raise in temperatures is also noticed during the GIS survey.

CONSORTIUM TOGEAN'S CONTRIBUTION TO MARINE AND COASTAL RESOURCE MANAGEMENT IN THE TOGEAN ISLANDS, CENTRAL SULAWESI

Uno, Jana Halida;*, Togean, Sekber; *Jl. Sisingamangaraja 10C, Palu, Central Sulawesi, Indonesia; Email: togean@palu.wasantara.net.id

Consortium togean is a joint project by conservation international and local non-governmental organization yabshi (indonesian foundation for the advancement of biological sciences). In field, all the program is accomplished by sekber togean, the implementing agency of consortium togean. The togean islands is an archipelago of some 50 small islands in tomini bay with a total land area of 60,000 hectares and a marine area of 100,000 hectares. The togean islands are rich in both marine and terrestrial biodiversity. In 1996, consortium togean began working directly in villages to develop sustainable development alternatives. Consortium togean's program is designed to handle human and nature threat to biodiversity, pressure from outside interest, and the needs of the local community. Consortium togean's program is divided into 3 main activites : (1) collection of baseline data on ecology, social, and economy. Specific to ecological aspects overall studies should be carried out employing both rapid assessment techniques and detailed research covering soils, and topography, climate, geology, hydrology, vegetation structure and composition, inventory of terrestrial and marine flora and fauna ; (2) empowering communities and local institutions, through an integrated program that combines community enterprise development and community self-confidence improvement through participatory activities and local information gathering ; (3) policy influence is achieved through formal and informal communication with decision makers at kecamatan, kabupaten, and provincial level, such as : workshops, dialogs, negotiations with involve local people and decision makers

AN ASSESSMENT OF COASTAL RESOURCES IN THE NORTHERN SIERRA MADRE NATURAL PARK AND AN APPROACH FOR MANAGEMENT.

Van Lavieren, Hanneke*. *Plan International Philippines; Northern Sierra Madre Natural Park Conservation Project. Project Management Office In Eic Buildings, Isu Campus, Garita Heights, Cabagan, Isabela, The Philippines. Email: HANNEKE@CAG.PWORLD.NET.PH

The Northern Sierra Madre Natural Park located in North-Eastern Luzon, Philippines, covers 287,861 hectares of forest and 71,629 hectares of marine habitats and is one of the ten priority sites for biodiversity selected under the National Integrated Protected Area System Act, 1996. Since it's declaration as a park, several rapid marine resource appraisals were conducted, but more detailed assessment studies on the coastal resources, habitats and management issues were not conducted until 1999. Detailed studies endangered species, shellfish status and uses, fisheries and resource utilization patterns, coral reefs and the associated fish communities, seagrass beds and mangroves were conducted. An over view is given of the results of these studies and constraints to community based conservation and management of this protected area are discussed together with suggestions for sustainable management. The socio-cultural attitudes of the indigenous people or "Agta's" and the lowlanders or "Philipino's" within the park influence the acceptability and effectiveness of coastal resource management schemes. Involvement of coastal community members in the protection of marine resources has been achieved through their participation in a bio-diversity monitoring system and their participation in the formulation of development plans for the coastal areas. A management plan has been formulated for the NSMNP and zonation is designed and enforced as defined by the Department of Environment and Natural Resources (DENR).

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BETTER PRACTICE MARINE IMPACT ASSESSMENT: A CASE STUDY OF THE GREAT BARRIER REEF MARINE PARK AUTHORITY.

Abdulla A* *School Of Tropical Environment Studies And Geography, James Cook University Of North Queensland, Townsville, Qld 4811, Australia. Email: AMEER.ABDULLA@JCU.EDU.AU

Environmental impact assessment (EIA) is widely recognised as an integral part of natural resource and protected area management. Post-decision EIA however is underdeveloped in theory and less emphasised in practice. Furthermore, increasing the quality of scientific information and effectively incorporating it within EIA are current challenges. Environmental impact monitoring is a crucial scientific component of the post-decision audit of potential impacts caused by coastal development activities within protected areas. One such region, the Great Barrier Reef, has been designated as a multiple-use Marine Park and World Heritage Area due to its outstanding value, large size, and varied range of users. A "better practice" model for marine impact assessment incorporating distinct environmental monitoring and post-decision management has been developed by the Great Barrier Reef Marine Park Authority in an effort to balance conservation and reasonable use of the Marine Park. The process in use is characterised by rigorous ecological sampling, a technical foundation for decision-making, independence between consultants and developers, and external review to ensure quality control. Suggestions to further refine the process are presented as an adaptive cycle of policy development, technical review, and information dissemination.

CHOOSING THE APPROPRIATE SPATIAL RESOLUTION FOR REMOTE SENSING OF CORAL BLEACHING EVENTS.

Andréfouët, Serge*, Ray Berkelmans, Terry J. Done, Jamie K. Oliver, Lucia Odriozola, Frank E. Muller-Karger. *University of South Florida, Dept. of Marine Science, 140 7th Ave. South, Saint Petersburg, Fl. 33701, USA. Email: serge@carbon.marine.usf.edu

Bleached corals provide a strong optical signal that suggest that remote sensing investigations of bleaching events is feasible using airborne or satellite sensors. However, the patchy patterns, the local coral cover and the variations in depth limit the potential of remote sensing. Today, multispectral high resolution satellite sensors provide images from 4 meters to 30 meters resolution but the adequacy of these sensors for monitoring bleaching events remains unclear. To clarify this issue, scanned aerial photographs acquired during a significant bleaching event in 1998 around Magnetic Island (Australia), were analyzed at various spatial resolution, from 10cm to 5 meters. Results show that the resolution necessary to capture the maximum of local variance of a bleached reef is around 50cm. The most common supervised image classification algorithms accurately recognized bleached surfaces because of the high contrast with the background. The 10 cm resolution images show that the maximum of bleached surface was about 10% of the total surface (considering 160x160m quadrats). This maximum drops to 5% using 1 meter resolution data, and 2% using 5 meter resolution data. The main spatial patterns are still visible at 1 meter but not at lower resolution. Therefore, to investigate accurately bleaching events with similar intensities than in Magnetic Isl., it appears that 1 meter resolution is a minimum requirement.

REEFS, WORLD HERITAGE, DEVELOPMENT AND POLITICS - CAN THEY CO-EXIST?

Bugler, Michael*. Southern Pacific Petroleum (Development) PO Box 7101, Riverside Centre, Brisbane, Qld. 4001. Australia.

The greatest reef in the world, the Great Barrier Reef, is a World Heritage Area and lies off north Australia's east coast. Near and on this coast there are a large number of current and potential developments, many of them world class in processing, manufacturing and infrastructure resources. But it is difficult to obtain objective and rational assessment of proposals to develop these resources. Several new industries, thousands of long-term jobs and billions of dollars of income are potentially at risk due to a decision-making system that currently struggles to balance competing demands. This paper outlines the issues, and examines an alternative approach to decision-making being developed by proponents, with scientists, regulators and other key stakeholders, in which a balance is sought between environmental, social and economic factors.

KEEPING THE WOLF FROM THE DOOR: MANAGING LAND-BASED THREATS TO THE GREAT BARRIER REEF.

Brodie, Jon*. *Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld 4810. Australia. Email: j.brodie@gbrmpa.gov.au

Pollution of the GBR is dominated by runoff from the adjacent catchment. Catchment land-use is dominated by grazing & cropping with relatively minor urban development. Runoff of sediment, nutrients & pesticides is increasing & for nitrogen is now four times the natural amount discharged 150 years ago. Significant effects & potential threats are now evident on inshore reefs, seagrasses & marine animals. There is no effective legislation or processes in place to manage agricultural pollution. The Great Barrier Reef Marine Park Act does not provide effective jurisdiction on the catchment. Queensland legislation relies on voluntary codes & there is no assessment of the effectiveness of the codes. Integrated catchment management strategies, also voluntary, provide some positive outcomes but are of limited success. Pollutant loads are predicted to continue to increase & it is unlikely that current management regimes will prevent this. The Great Barrier Reef Marine Park Authority is investigating mechanisms which may improve this situation.

ACHIEVING ECOLOGICALLY SUSTAINABLE FISHERIES IN THE GREAT BARRIER REEF WORLD HERITAGE AREA

Cadwallader, Phil. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld 4810. Australia. Email: phil@gbrmpa.gov.au

The Great Barrier Reef Marine Park is a multiple-use park in which commercial, recreational, charter and indigenous fishing activities occur. Commercial fishing includes trawling, line fishing, netting, crabbing and several "collection fisheries". The Park is zoned to regulate the various kinds of fishing activities. Achieving the balance between conservation and sustainable fisheries requires on-going consultation between marine park managers, fisheries managers, scientists, industry and other stakeholders. The ecological sustainability of fishery resources and the ecosystems on which they depend is required under legislation. The State of Queensland is responsible for day-to-day fisheries management under a Federal/State agreement. A key political question is the extent to which the GBRMPA (a Federal agency) can achieve its objectives through cooperation and negotiation with State agencies, rather than use its legislative mandate in areas that are traditionally the responsibility of fisheries management agencies.

MANAGING THE GREAT BARRIER REEF MARINE PARK AND WORLD HERITAGE AREA THROUGH CRITICAL ISSUES MANAGEMENT.

Chadwick, Virginia *. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld. 4810. Australia.

The Great Barrier Reef Marine Park (GBRMP) and World Heritage Area (WHA) is the largest Marine Protected Area in the world. Unlike most large coral reef ecosystems, the GBRMP is under one system of management through the Commonwealth Government's Great Barrier Reef Marine Park Authority (GBRMPA). GBRMPA has taken a critical issues approach to managing the GBRMP and WHA by clearly identifying the issues that present the greatest threat to this important area. They are: maintaining the conservation, biodiversity and world heritage values of the site; ensuring ecologically sustainable uses (especially fisheries, tourism and recreation); and reducing land based impacts on water quality through active participation in coastal zone management. In order to address these more effectively, the Authority is structured around critical issues groups which provide a strategic, policy-based approach to these issues. Policies are implemented through planning and environmental impact management. Compliance surveillance and enforcement programs are implemented through a Day to Day Management unit jointly funded by the GBRMPA and the State Government of Queensland. Other sections provide support for these initiatives, including providing a scientific basis for management, educational programs (through the aquarium), technical support (eg GIS unit), and parliamentary and ministerial liaison.

REGIONAL VARIATION IN THE EFFECTIVENESS OF MARINE PROTECTED AREAS ON THE GREAT BARRIER REEF: EVIDENCE FROM CPUE AND SIZE STRUCTURE OF PLECTROPOMUS LEOPARDUS.

Davies, C. R. * and B.D. Mapstone. CRC Reef/School of TESAG, James Cook University Queenland 4811 Australia. campbell.davies1@jcu.edu.au

Coral reef fisheries are generally complex, multi-species fisheries for which assessment and management resources are often scarce. Marine Protected Areas (MPAs) have received considerable attention as an alternative for management of coral reef fisheries. There have been, however, few empirical tests of the effectiveness of MPA as a management tool. We examine the effectiveness of MPA in relation to relative abundance (CPUE) and size structure of the common coral trout, *Plectropomus leaopardus*, the primary target species of the reef line fishery on the Great Barrier Reef. Twenty-four reefs were surveyed in spring 1995-1996 by research line fishing surveys, as part of baseline surveys for a large-scale manipulative experiment (Effects of Line Fishing Experiment). The reefs were located in four clusters of six reefs spread over a 7° latitudinal gradient. Each cluster included four reefs that were closed to fishing and two reefs that were open to fishing. Analyses of CPUE and size structure data for *P.leopardus* indicated that the effect of management zone (open/closed to fishing) differed among regions of the GBR. Furthermore, the magnitude of the regional trends in abundance was substantially greater than the contrast between management zones in any one region. We conclude that MPA cannot be assumed to be uniformly effective, and emphasise the need to incorporate large-scale spatial variation in the structure and exploitation of reef fish populations into the design of MPAs and assessment of their effectiveness.

THE REPRESENTATIVES AREAS PROGRAM – PROTECTING THE BIODIVERSITY OF THE GREAT BARRIER REEF WORLD HERITAGE AREA.

Day, J*, L Fernandes, B Barnett, S Slegers, B Kerrigan, D Breen, G De'ath, A Lewis, J Innes & J Oliver. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld 4810. Australia. Email: j.day@gbrmpa.gov.au

One of the most exciting but challenging tasks currently being undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA) is the Representative Areas Program (RAP). Current zoning does not adequately protect the range of biodiversity that is known to exist within the Great Barrier Reef World Heritage Area (GBRWHA). Presently, highly protected areas (ie 'no-take' zones) within the Great Barrier Reef Marine Park reflect a historical focus on coral reefs and remote areas. The aim of the RAP is to enhance protection of the region's biodiversity by developing a network of highly protected areas typical of all the different habitats and communities within the GBRWHA. Biophysical data combined with expert consensus has now enabled the classification of 65 reef and non-reef bioregions within the GBRWHA. Current phases of RAP aim to identify and protect adequate and representative examples of each bioregion. GBRMPA is identifying options for networks of highly protected areas using a combination of expert opinion, stakeholder involvement and analytical approaches (including a computer-aided reserve selection process developed in conjunction with some of Australia's top analytical experts). Minimising economic, cultural and social costs (where 'costs' do not refer just to monetary value) will be critical in the selecting the final network of highly protected areas.

LONG TERM CHLOROPHYLL MONITORING IN THE GREAT BARRIER REEF. CONCERNS FOR THE EUTROPHICATION OF THE INSHORE LAGOON.

Devlin Michelle* and Jon Brodie Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville. Q. Australia.

…The Great Barrier Reef Marine Park Authority long term water quality program was established in 1992 to provide long-term data on trends and regional differences in the nutrient status of GBR waters. Chlorophyll concentrations are used as a surrogate measure of water column nutrient status. Samples are collected at fixed sites at monthly intervals along transects in the GBR. Chlorophyll *a*, salinity, secchi depth and sea conditions are measured. Data collected from seven years of the monitoring program demonstrates persistent cross-shelf and regional differences in chlorophyll concentrations. Chlorophyll a concentrations (an indicator of eutrophication) were higher and more variable in nearshore waters than in samples collected further from the shore. Latitudinal trends were significant with inshore concentrations of chlorophyll *a* up to three fold higher in the coastal waters adjacent to the catchments with high human use than of inshore waters adjacent to the 'pristine' catchments. Chlorophyll *a* time series over seven years demonstrate seasonal and local variability

PERFORMANCE INDICATORS TO EVALUATE MANAGEMENT OF THE GREAT BARRIER REEF – HOW CAN WE TELL IF MANAGEMENT IS EFFECTIVE?.

Dinesen, Zena.*, *CRC Reef Research Centre and Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville 4810, Australia. Email: Zena.Dinesen@jcu.edu.au

This research seeks to develop performance indicators and benchmarks to evaluate management of the Great Barrier Reef World Heritage Area. The aim is to develop practical performance indicators, to assess how key ecological, social, economic, cultural and management objectives are being achieved in different regions of the Great Barrier Reef. Given the scale of this marine protected area, this major task is focusing initially on some critical issues for management of the Great Barrier Reef, namely biodiversity conservation and tourism management. In this paper, performance indicators relevant to ecological, social and management concerns are discussed in the context of a case study, the Representative Areas biodiversity conservation program. The "Rep. Areas" program aims to provide a comprehensive, adequate and respresentative network of highly protected areas within the Great Barrier Reef ecosystem, whilst minimising impacts on existing users. This case study addresses some interesting challenges in identifying appropriate indicators to assess the effectiveness of marine biodiversity conservation strategies. It also highlights the need to have clear management objectives and targets, acceptable to resource managers and stakeholders, against which to measure progress.

SELECTING INDICATORS TO ASSESS STRATEGIES TO CONTROL ANCHOR DAMAGE ON FRINGING REEFS IN THE WHITSUNDAY REGION, GREAT BARRIER REEF.

Dinsdale E.* and Zena Dinesen. *School of Tropical Environment Studies and Geography, James Cook University, Townsville, 4811 Australia. Email: Elizabeth.dinsdale@jcu.edu.au

Performance indicators are being developed to evaluate the effectiveness of management of the Great Barrier Reef World Heritage Area. This particular project evaluates a reef protection strategy, where moorings and reef protection markers have been installed to protect some sensitive fringing reefs from anchor damage while still allowing people to access the areas. The reef protection markers identify the reef edge and anchoring is not allowed landward of the markers. Indicators to evaluate the reef protection strategy were selected using the following process: 1) A wide range of parameters of coral condition were quantified on heavily and lightly visited reefs, including numbers of injuries, fragments, overturned corals, and diseased colonies. 2) Parameters found to differ significantly between compared reefs were identified as potential indicators and evaluated against a set of feasibility criteria. 3) Potential indicators that met the criteria were checked to ensure their ecological relevancy and ease of interpretation. Indicators that fulfilled all these requirements will be used to evaluate the effectiveness of the reef protection strategy to reduce coral damage.

REACTIVE MONITORING OF SEAGRASS MEADOWS.

Hall, Vicki*, Graeme Inglis, & Michelle Boyle. CRC Reef Research Centre, James Cook University, Townsville Qld 4811, Australia. Email: vivki.hall@jcu.edu.au

Reactive monitoring studies are now a standard requirement in the environmental management of developments within the Great Barrier Reef Marine Park. To be useful, reactive monitoring programs must provide information on changes in the condition of the resource in a timely manner, so that subsequent remediatory actions can be taken before irreversible damage is done. In this study, we describe the development of rapid assessment techniques using Near-Infrared Reflectance Spectroscopy (NIRS) for monitoring the condition of submerged aquatic vegetation during periods of light stress. Marine angiosperms ("seagrasses") have a comparatively high requirement for light and are adversely affected by reduced light availability caused by human activities and natural disturbances. Survival during periods of light stress is facilitated by mobilisation and transport of carbohydrate reserves within the plant to support anaerobic respiration of the roots. We investigated the utility of NIRS for monitoring changes in storage carbohydrates of seagrasses under light stress by (1) measuring concentrations of storage carbohydrates in both clear and turbid water for seagrasses in three regional areas of the Great Barrier Reef, and (2) monitoring changes in the concentrations of storage carbohydrates under ambient and low light regimes for two commonly occurring species, *Halophila ovalis* and *Halodule uninervis.* An assessment of variability in these stored reserves under different ambient conditions and their utilisation by plants under stress will provide a means of assessing the susceptibility of individual seagrass meadows to changes in light availability caused by coastal construction works.

RESEARCH AND EDUCATION FOR CORAL REEF MANAGEMENT: AUSTRALIA'S COOPERATIVE RESEARCH CENTRE FOR THE GREAT BARRIER REEF WORLD HERITAGE AREA.

Harriott, Vicki J.* Vicki R. Hall, David McB. Williams CRC Reef Research Centre, James Cook University, Townsville, Australia. 4811. Email: vicki.harriott@jcu.edu.au

The functions of the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef) are to enhance the viability of reef-based industries and to provide an improved basis for reef management and regulatory decision making. To fulfil this function, the CRC Reef facilitates an integrated program of applied research, development, education and extension. The formation of the CRC Reef is consistent with the Australian government's policy to encourage applied research and close co-operation between researchers and industry, and to provide postgraduate training that meets industry needs. The CRC is funded by contributions from industry partners and research and educational institutions, as well as by a government grant, with an aim to produce significant research and educational training that would not otherwise have been possible within the member organisations. In its second seven-year funding cycle, the CRC supports four major research programs: Management for Sustainability; Sustainable Industries; Maintaining Ecosystem Quality; Information Systems and Synthesis, and a fifth program in Education and Communication. In this paper, the success of the CRC Reef program in achieving its aims will be evaluated, and the CRC model will be discussed with respect to its capacity to integrate science, management, industry and education.

MANAGEMENT ISSUES FOR SUBTROPICAL CORAL REEFS AT LORD HOWE ISLAND, EASTERN AUSTRALIA.

Harrison, Peter L. *. *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW 2480. Australia. Email: pharriso@scu.edu.au

Lord Howe Island is a World Heritage List site located 630 km east of the subtropical East Coast of Australia (31º33'S). Although it is located more than 1,000 km south of the Great Barrier Reef, the island is surrounded by the southernmost coral reefs in the Pacific Ocean. These coral reefs are characterised by luxuriant reef communities and clear water, and support unique assemblages of tropical, subtropical and temperate species of corals, algae, fish and other reef biota. Most of the tropical species are at, or near, their southernmost distribution limits, and it is likely that many of these tropical species have recruited from northern reefs including the Great Barrier Reef through larval dispersal via the East Australian Current. Some endemic subtropical marine species also occur at Lord Howe Island. The coral reef communities around Lord Howe Island are mostly in a pristine condition. The Lord Howe Island Marine Park was declared in February 1999. Major management issues for the coral reefs at Lord Howe Island include predation on corals by Crown of Thorns starfish, intermittent disturbance from coral bleaching, severe storms, exposure by unusually low tides, and landslides and low salinity stress associated with occasional severe rain depressions. Potentially important human impacts on these reefs include the inflow of eutrophic ground water and runoff from urban areas, overfishing, fish feeding, and anchor damage. Monitoring the status of water quality and reef communities is essential for managing these unique subtropical coral reef ecosystems in perpetuity.

MANAGING TOURISM SUSTAINABLY - LESSONS LEARNED ON THE GREAT BARRIER REEF, AUSTRALIA.

Ilett, Annie *. *Great Barrier Reef Marine Park Authority, GPO Box 1379, Townsville Qld 4810. Australia. Email: anniei@gbrmpa.gov.au

The Great Barrier Reef World Heritage Area is a phenomenal collection of reefs and islands located adjacent to the north-eastern coast of Australia which attracts visitors from all over the world. Growth in tourism to the Great Barrier Reef has been dramatic in the past ten years. Unmanaged tourism could not continue without bringing about degradation of the very environment that tourists come to experience. Yet it is through the assistance of the tourism industry that most people are able to experience the Reef. A range of management "tools" has been established by the Australian Government's Great Barrier Reef Marine Park Authority in conjunction with the Queensland State's Parks and Wildlife Service to manage tourism in the Great Barrier Reef World Heritage Area. These include regulatory Zoning Plans, Area Plans of Management and site specific plans as well as a standardised permit system and monitoring and enforcement strategies. Industry "best practice" is also encouraged and an education and training program is in place. This paper reviews this range of management "tools", identifies the lessons learnt by the managing agencies and the industry in the Great Barrier Reef and proposes a way forward to a less prescriptive and self-regulatory approach by governments and the industry in partnership.

COMPLIANCE IN THE GREAT BARRIER REEF MARINE PARK - A STRATEGIC APPROACH.

McGinnity, Peter * & Bob Nankivell. *Great Barrier Reef Marine Park Authority, PO Box 1379 Townsville, Qld 4810. Australia. Email: peter.mcginnity@env.qld.gov.au

Education and enforcement activities aimed at ensuring compliance have been undertaken in the Great Barrier Reef Marine Park since the mid 1980s. Initial emphasis was given to extensive public information programs supported by vessel patrols in high use locations. By the early 1990s, managers began placing more emphasis on enforcement and with the purchase of two larger sea going vessels and formal training for inspectors the number of prosecutions rose from less than 5 per year, to between 50 and 70 per year since that time. Despite the immediate results of the stronger emphasis on enforcement, in the late 1990s management was receiving concerning reports of significant illegal activity, culminating in a research report estimating that up to 40 commercial vessels were illegally operating in one of the more remote parts of Park. In response the Government has provided an additional $3.4 million dollars over three years to implement an enhanced surveillance and enforcement program. This paper outlines how a strategic approach has been adopted for the enhanced Great Barrier Reef Marine Park Compliance Program, resulting in a combination of: short term increase in targeted surveillance and enforcement activities; and the introduction of strategies for the future, including investment in new surveillance technology, the upgrading of intelligence driven planning systems, and the development of improved public education strategies.

EVALUATIONS OF MANAGEMENT STRATEGIES IN THE TROPICAL REEF SYSTEMS: INSTITUTIONAL AND OBJECTIVE UNCERTAINTIES FOR THE IMPLEMENTATION OF ACTIVE ADAPTIVE MANAGEMENT.

Mapstone B. D.* C. R. Davies & A. D. M. Smith. Effects of Line Fishing Project, CRC Reef Research Centre, James Cook University, Townsville Qld. 4811. Australia. Email: bruce.mapstone@jcu.edu.au

Management of marine living resources generally has been reactive, with strategies being developed in reaction to evidence of problems with resources under exploitation. Management of the Great Barrier Reef (GBR) began as an exception in this respect, with the GBR Marine Park declared largely because of threats of exploitation rather than evidence of over-exploitation. The early establishment of a system of spatially replicated management zones in a marine protected area provided a unique opportunity to explore alternative management strategies experimentally and pro-actively. Thus, the GBR Marine Park provided perhaps the world's greatest opportunity for active adaptive management. Instability in the institutional arrangements, uncertainty about specific management objectives and inappropriately focused research, however, may mean the opportunities from an innovative history are lost. The (pro) active evaluation of management strategies will require clarity about objectives, acknowledgment of key uncertainties in existing knowledge, institutional certainty and political independence, and a shift in research focus from the components of the system to the response of the system to use. We discuss the importance of these implementation conditions and the prospects for their achievement in the light of recent work on management of reef fisheries and new initiatives in the management of the GBR Marine Park.

USING IMPACT MONITORING PROGRAMS TO MINIMISE ENVIRONMENTAL RISK DURING MAJOR DEVELOPMENTS.

Marshall, Paul*, Alison Green & Jamie Oliver. *Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld. 4811. Australia. Email: p.marshal@gbrmpa.gov.au

Major developments within the Great Barrier Reef Marine Park require the permission of the Great Barrier Reef Marine Park Authority. Permits, if granted, are subject to strict conditions including a requirement for an Impact Monitoring Program (IMP). An important component of the IMP is the Reactive Monitoring Program (RMP), which is designed to enable impacts to be predicted or detected as they occur, and thus facilitate reactive management of development activities. RMP results are compared to predefined thresholds designed to indicate when the level of risk and likely damage has become unacceptable. Breaches of thresholds trigger well-defined management responses which may include an order to stop work until the problem is rectified. Where there is incomplete knowledge of the risk relationship between threatening activities and environmental consequences, the RMP can be designed as a cascading set of sub-programs that trigger more intense monitoring as the level of risk increases. This design can also incorporate an adaptive approach, whereby the monitoring strategy and trigger levels are refined in response to information obtained during the program. We present a case study illustrating a cascading, adaptive approach to RMP design and implementation. An important benefit of our approach has been that the cost and magnitude of the monitoring program are commensurate with the environmental performance of the development.

ARE ACANTHASTER PLANCI LARVAE FOOD LIMITED IN THE GREAT BARRIER REEF WATERS?

Okaji, K *. T Ayukai. J Lucas. IMG Inc. Sanno 1-2-25, Nishinari, Osaka, 557-0001 JAPAN, Email: ken_okaji@pop06.odn.ne.jp

Evaluating factors affecting survivorship during early life stages of the crown-of-thorns starfish, *Acanthaster planci* (L.), is essential to understand the mechanisms of population outbreaks. The objective of this study was to determine whether food availability is a crucial factor controlling the growth, development and survival of the larvae of *A. planci* in the Great Barrier Reef Waters. This was undertaken by rearing larvae in freshly collected seawater that was coarse filtered, and in the same seawater treated by further filtration or food enrichment. Larvae were also reared in nutrient-enriched seawater (NES), where the concentration of natural phytoplankton was elevated by adding nutrient solution and incubating for a few days. Larval development rate and survival were nil or significantly lower in 2 µm filtered and the coarse-filtered seawater than in the same seawater enriched with cultured microalgae, dissolved free amino acids (DFAA), or in NES. When larvae were reared in NES having different fixed concentrations of phytoplankton (chlorophyll *a*), a change from low larval survival to optimal survival through rapid development occurred between 0.5 and 0.8 µg L^{-1}. This range is slightly higher than typical chlorophyll *a* levels found in the field, suggesting that larvae are usually food limited in the Great Barrier Reef waters.

PROVIDING A SCIENTIFIC BASIS FOR MANAGING THE GREAT BARRIER REEF MARINE PARK AND WORLD HERITAGE AREA.

Oliver, Jamie* & Alison Green. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville. Qld 4810. Australia. Email: jamieo@gbrmpa.gov.au

Having the best information available for decision-makers is essential to high quality scientifically based management of coral reefs. The Great Barrier Reef Marine Park Authority has a system to ensure that this is the case by clearly identifying research priorities, coordinating high priority research, and developing processes for ensuring that the results are presented in a manner that can be used effectively by managers. Recently, GBRMPA underwent a process in which its research priorities were identified. The results are now being used to coordinate relevant research with research providers. The Representative Areas Program provides an excellent example of how scientific information can be used effectively by managers. Scientists have participated in a bioregionalisation process, and are currently providing information on the social, cultural and economic values of the area. This information is being processed using GIS technology, which will provide the basis for designing a new system for protecting representative areas in the Marine Park and World Heritage Area.

FISH SPAWNING AGGREGATION PROTECTION IN THE GREAT BARRIER REEF MARINE PARK.

Russell, Martin *. *Great Barrier Reef Marine Park Authority, PO Box 1379 Townsville, Qld 4810. Australia. Email: russell@gbrmpa.gov.au

The increased abundance of spawning coral reef fish in localised areas at predictable times makes fish spawning aggregation sites (FSAS) particularly vulnerable to overexploitation and disturbance by fishing, tourism and research activities. Fishing on FSAS has resulted in severe stock depletion of fish around the world, and there is concern that commercial and recreational fishers are targeting FSAS in the Great Barrier Reef Marine Park (GBRMP). Tourism activities in the GBRMP occur in areas where several FSAS are known to occur, and there is concern that physical damage to corals caused by anchoring and divers, and fish feeding and the presence of divers can affect the formation of aggregations and the normal spawning behaviour of fish at these sites. Some research activities also have the potential for impacts similar to those caused by fishing and tourism. The Great Barrier Reef Marine Park Authority (GBRMPA) is attempting to mitigate the impacts of these activities, to ensure the maintenance of FSAS and the aggregating fish that depend on them. The GBRMPA is working with Queensland fisheries managers to minimise target fishing on spawning aggregations of reef fish through proposed seasonal closures; GBRMPA officers and field staff are being trained to identify and assess FSAS; a reef-wide re-zoning exercise is considering FSAS; the locations of mooring, pontoon and anchoring sites are being considered to protect FSAS from tourist activities; and research permit assessments consider the potential impacts of research on FSAS.

MAKING IT HAPPEN – PLANNING AND ENVIRONMENTAL IMPACT MANAGEMENT ON THE GREAT BARRIER REEF.

Skeat, Andrew *, John Baldwin, Martin Robinson & Adam Smith. Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Qld 4810. Australia. Email: a.skeat@gbrmpa.gov.au

The Great Barrier Reef Marine Park is a multiple use reserve of some 350,000km^2. Activity is controlled by legislation, plans and permits. Plans are of three types. Zoning Plans cover the entire Marine Park and are the primary control on use. Management Plans apply to smaller areas or to species requiring special protection. Management plans not only provide additional protection for the environment, but also separate conflicting use. Site plans are prepared for areas of only several hectares when natural and cultural values need to be protected at a fine scale. Environmental impact assessment is generally carried out before permits are issued. Major projects, involving significant infrastructure or disturbance to the environment, undergo rigorous assessment and associated monitoring. Routine permits such as tourism activities are assessed more quickly against criteria defined in legislation. This management system is applauded for its rigour. It also attracts criticism because of its complexity and high cost. Changes are being made to reduce the time taken to make permit decisions.

MONITORING THE REGIONAL STATUS OF CORAL REEFS IN THE GREAT BARRIER REEF WORLD HERITAGE AREA.

Sweatman, Hugh*. Australian Institute of Marine Science, PMB 3 Townsville MC, Qld 4810, Australia. Email: h.sweatman@aims.gov.au

The Australian Institute of Marine Science's (AIMS) Long-term Monitoring Program (LTMP) provides information on the status of coral reef areas across most of the length and breadth of the Great Barrier Reef (GBR). This provides significant material for the "State of the GBR World Heritage Area" reports and hence contributes to statutory reporting obligations to the World Heritage Committee. Forty-eight "core" reefs are surveyed annually. Reef fishes and benthic organisms are both surveyed in permanently marked sites in one habitat of these reefs: the NE reef slopes. Manta tow surveys of the perimeters of core survey reefs and a number of other reefs assess the numbers of crown-of-thorns starfish and estimate reef-wide cover of live coral. The program is working to automate analysis and reporting so as to publish findings rapidly via the internet. As well as reporting trends in the abundance of reef organisms on individual reefs and by region, surveys of assemblages on so broad a geographic scale have contributed to the identification of representative areas within the marine park. The scale of the sampling program gave a quantitative basis for assessing the impact of the coral bleaching in 1998, countering perceptions that the GBR had been devastated. Website: www.aims.gov.au/reef-monitoring

MEASURING HOW GREAT IS GREAT: STATE OF THE ENVIRONMENT REPORTING FOR THE GREAT BARRIER REEF WORLD HERITAGE AREA.

Wachenfeld, David* & Jamie Oliver. *GBRMPA, PO Box 1379, Townsville, Qld 4810, Australia. Email: davidwa@gbrmpa.gov.au

In 1998 the report 'State of the Great Barrier Reef World Heritage Area 1998' was released. This is the first ever synthesis of information on the state of the environment, human pressures on the environment and management responses to those pressures for the whole of the Great Barrier Reef World Heritage Area. The report feeds into Australia's process for reporting to UNESCO on World Heritage Areas. The overall picture is that, while some elements of the GBR are subject to intensive human pressures, the ecosystem as a whole is in good health. Out of the 12 categories used for reporting, all have had extensive surveys conducted for at least part of the environmental attribute on at least one occasion. However, significant areas of uncertainty regarding basic distribution and abundance remain for many groups of organisms, including macroalgae, inter-reefal and lagoonal benthos, sea snakes and inshore dolphins. Currently, the GBRMPA is developing a set of environmental indicators to be used in future State of the Reef reporting.

SELECTING REPRESENTATIVE AREAS OF THE GREAT BARRIER REEF WORLD HERITAGE AREA (GBRWHA).

Ward, Trevor*, Hugh Possingham, Adam Lewis and Suzanne Slegers

***University of Western Australia, and Great Barrier Reef Marine Park Authority (GBRMPA), PO Box 1379 Townsville Mail Centre, Qld, 4810, Australia. Email: tward@geog.uwa.edu.au**

The Great Barrier Reef Marine Park Authority is developing procedures and software to identify representative biological features of the GBRWHA, and assemble these into a set of candidate areas (CAs) for high protection. Scientists involved in this collaborative work are from the GBRMPA, University of Adelaide, University of Western Australia, James Cook University, the Reefs CRC, CSIRO Division of Marine Research, Environment Australia and the Queensland Department of Environment and Heritage. Biological data on reef fish, hard corals, soft corals, seagrasses, and invertebrates have been spatially modelled to define reefal and inter-reefal bioregions as surrogates for biological diversity. The WHA is divided into a set of 50,568 hexagonal 10 km^2 planning units (PUs) for assembly into CAs. MarXan, an optimising program, selects PUs for CAs according to specific rules including: (a) a minimum size; (b) replication and spatial distribution within a bioregion; (c) selection of whole reefs; (d) include specified number/areas of each biological feature type; (f) include special places; and (g) take into account adjacent land/sea uses and existing zoning. MarXan uses an objective function to assemble groups of PUs that meet the selection rules with minimal 'cost' (e.g., long boundary length or value for competing uses). The project is the first use of detailed spatial criteria in advanced optimisation procedures to identify representative areas for marine conservation purposes.

Session B7: The Interface of Science, Management and Policy

DEMYSTIFYING THE SCIENCE POLICY PROCESS: HOW CAN SCIENTISTS CONTRIBUTE TO THE PROCESS?

Best, B.A.* *U.S. Agency for International Development, Global Environment Center, 1300 Pennsylvania Ave. NW, Washington, D.C. 20523-3800, USA. Email: Bbest@USAID.gov

Coral reefs are threatened by a range of human activities. To address these threats, sound science-based decisions are often needed at the local, national, regional and international levels. How can scientists and professional societies contribute to the policy process at these various levels, and in what capacities? How is science applied in the development of policy frameworks? To be most useful for managers and decision-makers, scientific information should be made available in a timely manner and be appropriately presented so as to be easily understood by the general public. Such information can help shape priorities and direct actions and funding. Drawing upon several issues, I will discuss how scientists and professional societies can contribute to the policy process as related to coral reef policy development and implementation. The discussion will also target specific areas where more scientific and socio-economic information is needed to assist the policy process.

MARINE PROTECTED AREAS AUSTRALIA – A NATIONAL AND LOCAL PERSPECTIVE

Beech, Graeme* – *Environment Australia, Email: graeme.beech@ea.gov.au

Australia's Oceans policy commits the Federal Government to developing Australia's oceans sustainably through regional marine planning. As part of the Oceans policy, Australian government departments are also working together to develop a national representative system of marine protected areas (NRSMPA) throughout the entire marine estate (16 million km^2). Environment Australia has responded to the NRSMPA with the identification and declaration of 5 new MPAs over the last 3 years. These MPAs will have performance assessment programs supporting the plans of management. Cartier Island Marine Reserve, one of the most recently declared Reserves, in combination with nearby Ashmore Reef National Nature Reserve, protects a biologically rich area. The primary purpose of the Cartier and Ashmore Reserves is to protect their unique and vulnerable coral reef and island communities including CHAMBA / JAMBA birds, endemic coral and reptile species, and turtle and dugong populations. Cartier and Ashmore are located in the Indian Ocean on Australia's North West Shelf where traditional Indonesian fishers have visited and harvested the reefs of the region for many years. Subsequent depletion of the target species and their dependents is one of the major pressures that impacts on the biodiversity values of these strategic Reserves. The Plan of Management determines strategies necessary to protect the values of the Reserves and are subject to Performance Assessment criteria. These strategies are being developed in close consultation with interested stakeholders, in particular the Indonesian interest groups due to their longstanding association with the area. With limited resources, effective management in the long term is dependent on the productive involvement and support of stakeholders.

IMPLICATIONS OF CATCHMENT MANAGEMENT FOR CORAL REEFS IN A PERIOD OF GLOBAL CLIMATE CHANGE

Done, TJ.*, King, B, McAllister, F. *Australian Institute of Marine Science, PMB #3, Townsville MC. Qld., Australia. Email Address: t.done@aims.gov.au

Improved management of land and water to reverse deleterious effects of land runoff on coral reefs will come at a cost that will have to be justified to those asked to pay for the improvements. It will take place during a period in which rainfall and other climate variable are projected to change. In terms of improved coral reefs, over what area would the change in catchment management be effective, and would they be enhanced or negated by changes in rainfall? What are the indicators of success? Here, we focus only on water quantity, not quality. We applied a computer simulation model and a risk assessment approach to better quantify the extent and nature of influence of river plumes on marine habitats in the Great Barrier Reef under present climate and catchment management and water allocation regimes. Maps of return periods based on analysis of simulations of all floods of the Burdekin River (Queensland's largest) for the period 1966-1995 - (see AIMS website) show the return period for exposure to Burdekin River water at a range of dilutions and durations for any point in the central Great Barrier Reef waters ranged from < 1 to > 30 years. Catchment management and climate change would both tend change both these return periods and the annual probabilities of exposure. From the perspective of the coral reef ecosystem, too frequent exposure to runoff precludes reefs, less frequent exposure to runoff allows longer intervals for recovery and development of functional, scenic and biodiverse reefscapes.

CORDIO: A COLLABORATIVE RESEARCH PROGRAM INVESTIGATING THE EFFECTS OF CORAL REEF DEGRADATION IN THE INDIAN OCEAN.

Lindén, Olof* *CORDIO, Dept. Marine Sciences, Kalmar University, 391 29 Kalmar, Sweden. Email: olof.linden@cordio.org

CORDIO is a research program created to respond to the degradation of coral reefs throughout the Indian Ocean, particularly the extensive bleaching and mortality of corals that occurred in 1998. Projects funded through CORDIO focus on determining a) the bio-physical impacts of coral reef degradation as a result of bleaching and other disturbances, and the long term prospects for recovery, b) the socio-economic impacts of coral mortality and options for mitigating these through management and development of alternative livelihoods, and c) the prospects for restoration and rehabilitation of reefs to accelerate ecological and socio-economic recovery. Results from the CORDIO Program is presented in several other reports at this symposium. CORDIO is implemented in 12 countries around the western and central Indian Ocean by scientists from 15 national institutions. Some activities are co-ordinated and implemented as regional projects, e.g. the socio-economic studies and the investigations of coral larval distribution and settlement, while others are conducted as national projects. All research is co-ordinated through regional centres in Mombasa, Reunion and Colombo.

CREATION OF A NEW INTERNATIONAL MEASURE TO PROHIBIT ANCHORING ON CORAL REEFS BY LARGE SHIPS.

Johnson, Lindy S.* and Schmahl, George P.. *Office of International Law, NOAA, Room 7837, 14th and Constitution Avenues, NW, Washington D.C. 20230 USA. Email: Lindy.S.Johnson@NOAA.GOV

An international measure has been proposed to protect coral reefs from impacts of anchoring by large vessels within the Flower Garden Banks National Marine Sanctuary (NMS), a marine protected area in the northwest Gulf of Mexico. Anchoring by large ships on coral reefs can destroy and degrade significant portions of these fragile and valuable habitats by crushing or dislodging coral heads and destabilizing the reef substrate. The United States has submitted two proposals to the International Maritime Organization (IMO), a Specialized Agency of the United Nations that addresses international shipping issues, to address this problem. The first proposal would create a new measure under international law for "no anchoring" areas, by amending an instrument called the General Provisions on Ships' Routeing. The second proposal would establish three such no anchoring areas for the unique coral reefs of the Flower Garden Banks NMS. These proposals will be considered in July 2000 by the IMO Sub-committee on Safety of Navigation (NAV) and then, if approved by NAV, will be forwarded for final adoption by the IMO Maritime Safety Committee in December. If adopted, these U.S. proposals will establish a tool that other countries can use to protect valuable coral ecosystems from anchor impacts, as well as protecting the coral resources of the Flower Garden Banks NMS.

THE INTERNATIONAL TROPICAL MARINE ECOSYSTEMS MANAGEMENT SYMPOSIUM (ITMEMS): MANAGEMENT QUESTIONS FOR SCIENCE.

Kenchington, Richard *, Baldwin, John. *RAC Marine Pty Ltd, PO Box 588, JAMISON, ACT 2614, Australia. Email: kenchington@yahoo.com

This paper presents an analysis of the information needs identified by The International Tropical Marine Ecosystems Management Symposium (ITMEMS) participants in Townsville in November 1998. ITMEMS was held as part of the International Coral Reef Initiative to consider the priorities of managers for the maintenance and restoration of coral reefs. The underlying requests of science are those of understanding of how reefs and related ecosystems function and interact and how human uses and impacts affect the natural resilience of reef communities. The most immediate needs are for studies which help to explain phenomena which occur over large areas and long time scales. The other information needs of managers relate to the linkages of social, economic and environmental considerations. Some of the practicalities of managing multidisciplinary reef programs are discussed.

PARTNERSHIPS IN MANAGING ECOLOGICALLY SENSITIVE AND TECHNICALLY DEMANDING PROGRAMS.

McCloskey, Gary W.*. *U.S. Army Program Manager for Chemical Demilitarization. JACADS-PMCSD, ATTN: SFAE-CD-CO-J(JI), P.O. Box 156, APO, AP 96558-0008. Email: gary.mccloskey@pmcsd.johnston.af.mil

Johnston Atoll, located approximately 800 miles southwest of Hawaii, is home to many seabird, shorebird and marine species, including an extensive coral reef, and is a designated national wildlife refuge. It is also home to the Johnston Atoll Chemical Agent Disposal System (JACADS) — a U.S. Army incineration facility built to dispose of chemical weapons. Operation of JACADS in an ecologically-sensitive environment has drawn scrutiny by citizens' groups and the general public. Management of JACADS with environmental sensitivity includes use of the best available technology and establishment and maintenance of baselines for land and reef species surrounding Johnston Atoll through partnerships with environmental scientists and related government agencies. Initial efforts failed, however, to recognize animosity due to past nuclear testing and establish community partnerships in decisions surrounding chemical weapons disposal operations in the region. For the last three years, the Army's chemical weapons disposal program has been managed as a true partnership among all of its diverse constituents. A highest priority, management has met with success in preserving its relationships to safeguard and invest in the environment throughout the life cycle of the project, and building relationships that in addition to fostering public support for the program, provide a positive cost benefit to industry and resource trustees.

THE INADEQUACY OF CURRENT LEGISLATION TO PROTECT SCLERACTINIAN CORAL COMMUNITIES IN HONG KONG, CHINA.

McCorry, Denise*. *The Swire Institute of Marine Science and Department of Ecology and Biodiversity, The University of Hong Kong, Cape d'Aguilar, Shek O, Hong Kong. Email: dmmccorr@hkusua.hku.hk

Hong Kong's mainland and surrounding islands support high-latitude, shallow, fringing coral communities. These communities are considered to be depauperate, non-reef forming assemblages composed of widespread, common Indo-Pacific faviid species in association with a small number of species with a more restricted high-latitudinal range, e.g., *Acropora solitaryensis.* These communities receive intense anthropogenic impacts due to dense urban populations and massive associated development. High levels of domestic and industrial effluent, reclamation and dredging and destructive fishing practices have contributed to the extirpation and demise of local corals and communities. Results from a recently completed baseline study of 31 sites indicated that 26 % of coral communities surveyed were dead or severely degraded. The ability of current legislation to protect the remaining well-established coral communities is examined with particular reference to Hoi Ha Wan Marine Park, established in 1996. Recommendations for amendments to the existing legislation are made with the aim of increasing the long-term survival of local scleractinian coral communities.

IFRECOR : A FRENCH GOVERNMENT INITIATIVE FOR THE PROTECTION AND MANAGEMENT OF ITS CORAL REEFS.

Pichon, M.*; Gabrié, C. *E.P.H.E., Université de Perpignan, 66860 Perpignan, France. Email: pichon@univ-perp.fr

Through its overseas territories, France has coral reefs in the three major oceans : Martinique and Guadeloupe in the Atlantic Ocean, Mayotte, La Réunion and Scattered Islands in the Indian Ocean, New Caledonia, Wallis and Futuna, and French Polynesia in the Pacific Ocean. The total surface area covered by these reefs and associated lagoons is close to 55,000 km^2 representing approximately 10% of the surface area covered by coral reefs worldwide In March 1999, the French government launched the "French Initiative on Coral Reefs" (IFRECOR). This national scheme covers all measures and actions taken for a better management and protection of what is now regarded as a piece of the French natural heritage. To implement this Initiative, the government has set up a National Committee, operating under the umbrella of the Minister for the Environment and the Minister for Overseas Territories. The committee includes members of the different categories interested and/or involved in the management and protection of coral reefs. The National Committee is supported by 7 local committees (one for each of the overseas territories concerned) which bring together the local players in the field of reef management. A National Strategy for coral reef protection and management was adopted in December 1999. The National Strategy specifically addresses the following issues : (1) planning, (2) protection against pollution and disturbances, (3) research and monitoring, (4) information, education and training, (5) improvement of the legal and regulatory framework and (6) strengthening of inter-territory, regional and international cooperation. The National Strategy is implemented through a 5-year action plan.

ARE WE TACKLING THE MAIN ISSUES CONSTRAINING INTEGRATED COASTAL MANAGEMENT IN CORAL REEF AREAS?

Westmacott, Susie* *University of Newcastle upon Tyne. Address: 33 Old Priory Close, Hamble, SO31 4QP, UK. Email: s.westmacott@ncl.ac.uk

Coral reefs are a fragile but valuable resource attracting a high level of use and attention. The increasing pressure put on our coastal zones, particularly in these tropical areas means that increasingly integrated coastal management (ICM) is being called upon. ICM is defined as the “ideal” situation where institutions, defined as agencies, stakeholders and organisations involved or affected by the management of the coastal zone, work in an integrated manner to manage the multiple uses. The goal of ICM is to achieve the conservation and sustained multiple use of the coastal zone. ICM is an ambitious task requiring institutional stability, institutional capacity, legislative capacity, political and public will and participation as well as involvement of scientists in the management process. A recent survey of tropical coastal areas has identified the main impediments affecting the ability to implement ICM in these areas. The results show the main impediments are not the lack of finance and trained personnel but the lack of grass roots involvement in decision making, sufficient legislation and the political will to be involved in sustainable development initiatives and balance decisions between economic and environmental objectives. The challenge now is how to overcome these impediments and prioritise the order in which we approach them. Continuing research explores the development of various management tools to help overcome these impediments.

Session C1: Bringing Social Sciences and Economic Issues into Coral Reef Management

WHALE WATCHING IN BAIS CITY, NEGROS ORIENTAL, PHILIPPINES: AN ECOTOURISM ENTERPRISE.

Abrenica B.T.*and Calumpong, H.P. *Silliman University Marine Laboratory, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

Whale watching is part of the ecotourism industry that creates revenue and jobs by satisfying the demands of tourists to experience and observe marine mammals in the wild. It is considered a valuable non-consumptive and sustainable alternative source of income to fishers who are directly or indirectly taking them. Bais City in Negros Oriental, Philippines through its Local Government Unit, has pioneered and popularized dolphin and whale watching since 1993, after which the city got its famous trade name, "City of Whales and Dolphins". A one year monitoring study was conducted from April 1999-March 2000 to obtain information on marine mammal population, revenue from tourism and peak tourist season. The peak months for tourists were April to June, associated with the summer season and calm weather conditions. Highest number of visitors & trips were in May (1,126 visitors and 57 trips), with Filipinos comprising the majority (3,541 or 89%) who mainly go for recreational purposes (81%). Of the seven cetacean species sighted by tourists, spinners (*Stenella longirostris*) were the most common being sighted in all months, with highest sightings in May (19±2.2 ind/hr) and lowest in December (4±1.9 ind/hr). Dwarf-sperm whales and bottlenose dolphins were least seen. A total net income of PhP 504, 000 (US$ 12,600) for one year was generated, of which 53.4 % or (PhP 269, 151) went to the government and the rest went to the private sector.

DIVERS' WILLINGNESS TO PAY TO VISIT MARINE SANCTUARIES: AN EXPLORATORY STUDY.

Arin, Tijen *; Kramer, Randall A. *World Bank, H5-341, 1818 H Street, N.W., Washington, DC 20433, USA. Email: tarin@worldbank.org

User fees that divers would pay to enter marine sanctuaries constitute a significant potential revenue source to finance coral reef conservation. An exploratory contingent valuation study was carried out among foreign and local tourists in three major dive destinations in the Philippines to examine diver demand for visits to protected coral reef areas. Results indicate most divers would be willing to pay an entrance fee to marine sanctuaries where fishing, one of the major threats to coral reefs, is prohibited. An econometric model was estimated analyzing the socioeconomic and travel related factors that affect divers' willingness to pay. Results indicate that substantial amounts of revenues may be collected to support coral reef conservation. Most tourists interviewed preferred NGOs as the most trustworthy organizations to collect and manage entrance fees.

BALANCING PERCEPTION INFORMATION WITH SCIENCE-BASED PARTICIPATORY MONITORING, EVALUATION AND RESPONSE-FEEDBACK SYSTEM (MERFS).

Bacudo I.V. *, Ma. Maida S. Aguinaldo, Porfirio M. Aliño, Miledel Christine C. Quibilan and Hazel O. Arceo. *DENR-National Integrated Protected Areas Programme, Ninoy Aquino Parks and Wildlife Nature Center, North Ave. Diliman, Quezon City 1156, PHILIPPINES, 1101, Email: saryaya@yahoo.com

Broad surveys based on anecdotal reports obtained from the Coral Reef Information Network of the Philippines (PhilReefs) partners provided a synoptic picture of the nationwide extent of coral bleaching. Fishers, local communities and tourists commonly attributed the bleaching impact to human activities such as destructive fishing methods and to non-scientific probable causes. Nonetheless, stakeholders felt the impact of the phenomena through the decrease in fish catch and tourist entries, or low visitor satisfaction. It is important to measure communities' and tourists' level of perception to coral bleaching, and enhance their consciousness with scientific knowledge, in order to deliver more appropriate community-based intervention strategies. Through focused group discussions, and workshop consultations with affected stakeholders, perceptions on coral bleaching were measured. This ensured that the establishment of participatory Monitoring, Evaluation, and Response-Feedback System (MERFS) as a resource management tool in partnership with affected stakeholders.

LISTENING TO COMMUNITIES: A COMPARATIVE SURVEY OF COASTAL RESOURCE MANAGEMENT IN THE PACIFIC ISLANDS.

Bettencourt, S.*; Gillett, Robert; and Muller, Jeffrey. *The World Bank Group, 1818 H Street, NW, Washington, D.C. 20433, U.S.A., Email: Sbettencourt@worldbank.org

In 1998/99, the World Bank sponsored a survey of 31 coastal communities in Fiji, Palau, Samoa, Solomon Islands, and Tonga. The survey found an overwhelming perception among community groups that coastal resources were declining. Coral reefs and lagoons were the ecosystems perceived to have declined the most over the past decade. Communities perceived pollution as the fastest rising threat to coastal resources, while destructive practices were perceived as having declined the most. National management rules that were perceived as relevant and that were subsequently adopted as local rules were perceived to have significantly better compliance than either purely national or purely community rules. Finally, the communities perceived that alternative income generation programs which relied on aquaculture, tuna fisheries or deep slope fisheries had generally not succeeded in alleviating fishing pressure on coastal resources. The findings of this study can be used to formulate better systems of co-management between coastal communities and their external partners."

CORAL CONSERVATION IN PEARL CULTURE ZONES.

Black, M*. *CRMP/Proyek Pesisir, Jakarta, Indonesia. Email: Guava@cbn.net.id

In Lampung Bay, Sumatra, pearl culture, shrimp culture and capture fisheries exist concurrently, and their synergistic influence affects the entire ecology of the coastal zone. Investigation quantifying the environmental impact of pearl culture on surrounding coral reefs has previously never been undertaken in SE Asia. Research in Lampung Bay included a benthic coral cover survey (86 line intercept transects) done over a three month period during 1999. The survey was conducted at near-shore pearl culture facilities, comparing the condition of the coral reefs. The main pattern observed was that reefs inside and adjacent to (within 0.5 km of the boundary) the pearl culture farms have healthier corals than those located outside of the pearl farm areas. Reefs inside and adjacent to the pearl farms had 18% more live hard coral cover than reefs outside these areas. Additionally, reefs inside the pearl farms had about 12% less dead coral cover and 10% less coral rubble. These findings suggests that the pearl culture farms, and the presence of their guarded perimeter, protect the nearby reefs from direct degradation from common factors such as blast fishing, anchor damage, and coral mining. The findings of the study indicate that pearl farms have dual functions: as pearl oyster culture production areas and as *de facto* coral reef conservation zones. Coastal management strategies seldom seek partnerships between governing institutions and private business. Possible co-management arrangements between aquaculture business and government agencies are discussed in the context of Indonesia.

COMMUNITY PERCEPTION OF COASTAL RESOURCES IN LAMPUNG, SUMATRA.

Black, Mark*. *CRMP/Proyek Pesisir, Jakarta, Indonesia. Email: *Guava@cbn.net.id*

The impact of human activity on coastal resources is a well-known issue for coastal resource management programs. In indonesia these issues are of particular importance. The 17,000 islands of the archipelago contain a significant portion of the world's coral reef that directly provides food for about 40 million coastal dwellers. A socioeconomic survey was conducted from march-april 1999, among 338 residents from four coastal villages in lampung bay, sumatra. The survey focused on villagers' attitudes about coastal resource use, blast-fishing and their perceptions of pearl culture facilities. Results from the survey suggest that people from the villages view coral reefs as a vast resource. The respondents tend to value coral for building material, rather than fish habitat. Their attitude about blast-fishing is paradoxical: they know that bombs hurt coral reefs and that it is illegal; however, they feel that it is a socially acceptable method of fishing. Tradition, short-term gain and, perhaps declining fish catches using other fishing methods, appear to be important factors in the decision to practice blast-fishing. With the current need for effective coastal management strategies for coral reef conservation, partnerships between governing institutions and private business and other stakeholder demand more attention. Co-management arrangements between aquaculture business and government are discussed in the context of indonesia.

TRADE-OFF ANALYSIS FOR CORAL REEF MANAGEMENT.

Brown, Katrina*, Neil Adger, Emma Tompkins, Peter Bacon, David Shim, and Kathy Young. School of Development Studies, University of East Anglia, Norwich, NR4 7TJ, U.K. Email address: k.brown@uea.ac.uk

This paper outlines an approach to coral reef management that incorporates multiple objectives for coral reef resources within a decision-making framework. The approach uses a framework based on multi-criteria analysis but involves stakeholders at all stages to enhance decision-making processes. We call this approach trade-off analysis. This holistic approach is appropriate for multiple use, complex systems such as coral reef ecosystems, where many different users are apparently in conflict and where linkages and feedbacks between different aspects of the ecosystem and economy exist. The paper applies trade-off analysis to the case of Buccoo Reef Marine Park in Tobago. Stakeholder analysis is undertaken, and social, economic and ecological criteria are identified. The impacts of four different development scenarios are evaluated for these criteria. using: economic analysis, contingent valuation method surveys, qualitative analysis of semi-structured interviews and key informant interviews, and rapid ecological survey assessments. Stakeholders are asked to weight different criteria and then the outcomes of different stakeholder weightings in the multi-criteria analysis are used to explore different management options. The case study offers an empirical application of participatory integrated assessment, and provides wider lessons for coastal resource management, namely that participation of heterogeneous stakeholders in the governance of natural resources requires inclusiveness, information sharing and the validation of local knowledge and experience.

REGULATING ECOTOURISM IN APO ISLAND, NEGROS ORIENTAL, PHILIPPINES

Cadiz, P.L.* and Calumpong, H.P. *Marine Laboratory, Silliman University, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

Apo Island Marine Reserve in Central Philippines was established in 1986 as a fisheries intervention using a community-based approach. Its success resulted not only in increased fish standing biomass and harvest but also in the preservation of its coral reefs making it a major success. However, the unregulated number of tourists diving and snorkeling in the sanctuary has raised concerns among members of the community and the PAMB (Protected Area Management Board) of the damage it has caused to the corals. Hence, this study was conducted to monitor tourism in Apo Island with the objective of aiding the PAMB in regulating it. April was the peak month for tourism (2,301 visitors) and September the low month (737 visitors). Average number of visitors daily ranged from 28 to 59. Majority of visitors were Filipinos (39.68%) followed by Japanese (26.67%), Germans (11.74%), Americans (5.25%) and others (16.66%). Revenues as user fees from visitors before PAMB implementation was only PhP 4,633 monthly (US$ 116) whereas, monthly revenue after the PAMB implementation was PhP 149,635 (US$ 3,741). Twenty-five per cent went to the National Integrated Protected Area Fund (IPAF) and 75% went to the local IPAF. Results of coral damage monitored during this period are presented in a separate paper.

THE ECONOMIC VALUE OF THE INVALUABLE INDONESIAN CORAL REEFS

Cesar H.S.J.* *Institute of Environmental Studies, Free University Amsterdam, Boelelaan 1115, 1081 HV Amsterdam,The Netherlands. Email: hcesar@ivm.vu.nl

Coral reef ecosystems provide many services and goods to coastal populations, especially in developing countries like Indonesia. A variety of anthropogenic practices threatens reef health and therefore jeopardizes the benefits flowing from these services and goods. These threats range from local pollution, sedimentation, destructive fishing practices and coral mining to global issues like coral bleaching. Economic valuation can help to shed light to the importance of the services and goods by 'getting some of the numbers on the table'. This paper presents estimates of the economic value of Indonesian coral reefs, based on original work as well as a literature review of past studies. Also, the paper presents a cost benefit analysis for marine parks in Indonesia focusing on Taka Bone Rate and the Spice Islands and the net economic costs of destructive fishing practices. For instance, the costs of blast fishing appears to be four times higher than the net profits of such fishermen. For Indonesia as a whole, the cost of inaction with respect to enforcing the existing blast fishing regulations alone over the last decades is estimated at a hefty US$ 3.8 billion. Finally, the paper presents a stakeholder analysis for unsustainable reef practices, followed by a discussion of management strategies of how to cope with these threats.

AN EVALUATION OF THE SHORT-TERM SOCIO-ECONOMIC IMPACTS OF MARINE RESERVES ON USER GROUPS IN KEY WEST, FL.

Dobrzynski, T. and Nicholson, Betsy *. *Duke University Marine Lab, 135 Duke Marine Lab Road, Beaufort, NC 28516 USA. Email: een@duke.edu

Traditional marine resource management has failed; evidenced by resource overexploitation, water quality declines, and habitat degradation. Marine reserves, well-defined marine areas where consumptive uses are prohibited, have the potential to reverse current declines in the marine ecosystems, however the lack of understanding for their social and economic impacts has impeded their establishment in U.S. waters. We conducted a survey research project using relatively open-ended interview guides to assess the short-term social and economic impacts of recently established marine reserves on dive/snorkel operators, commercial fishers, and charter fishing operators in the Key West region of the Florida Keys National Marine Sanctuary (FKNMS). Our findings indicate that reserves have had low economic impact and high social / behavioral impact on marine user groups surveyed. Additionally, while user groups reported minimal ecological changes outside reserves, they reported definite ecological benefits inside reserves. Finally, while all user groups exhibit support for the concept of reserves, they all exhibit lower levels of support for the process used by the FKNMS to develop and implement marine reserves. Recommendations for resources managers include better communication of reserve objectives to user groups, further investigation of user group impacts on habitat, and a balance of scientific, political, and socioeconomic factors in marine reserve design, implementation, and monitoring to ensure their success.

A SOCIAL ASSESSMENT OF QUEENSLAND'S COMMERCIAL FISHING INDUSTRY.

Fenton, M.* and Marshall, Nadine. *Cooperative Research Centre for Reef Research, James Cook University, Townsville 4811, Australia. Email : ebcmark@ozemail.com.au

There are currently approximately 5,500 commercial fishers living and working in coastal communities in Queensland, Australia. It is important that Reef Managers understand the direct and indirect socio-economic impacts of changes in fisheries management regimes at specific locations within the marine park. A baseline social assessment of Queensland's commercial fishing industry has been undertaken, including the harvest fishery and tourism charter fishery. One of the objectives of this research was to predict the socio-economic impacts of implementing the Great Barrier Reef Marine Park Authority's (GBRMPA) Representative Areas Program on the communities that are dependent on fishing resources in Queensland. Town Resource Cluster (TRC) Analysis was used to develop quantitative spatial models that define clusters of communities as consisting of mutually interdependent towns. Spatial linkages were established between the marine resource and the TRCs in which fishing businesses were located. Spatial linkages were also established between the fishing town and other towns and communities within the region. Through TRC analysis the location and type of social impacts associated with changes in fisheries management regimes could be identified, allowing the inclusion of social data and information in the determination of representative areas.

RELATIONSHIP BETWEEN ARTISANAL FISHERIES AND TOURISM IN BRAZILIAN COASTAL REEFS.

Ferreira, B.P.* and Maida. M. *Dep. Oceanografia, Universidade Federal de Pernambuco, Recife, PE, Brazil. Email: beatrice@free.elogica.com.br

Along the Northeastern Brazilian coast, the economy of small rural towns is based on subsistence fisheries on reefs and mangroves, small scale offshore commercial fishing and seasonal work during the peak tourism season, when population of small towns can increase five times fold. In 1998, the Coastal Reef Project started to assess fisheries and follow tourism flux through the nearshore waters and reefs of the Coral Coast MPA. Artisanal fisheries in this region is intense, targeting a large variety of reef fish, crustaceans and other species. A cost/benefit analise of the artisanal and commercial fleets indicated that the commercial fisheries had a larger annual production, employed less people but earned less money per fisherman than the artisanal fisheries. Ownership structure, sharing system, poorly dimensioned loans, overfishing and marketing system explained the observed pattern. Declining fisheries make tourism development the most promising alternative employment opportunity. Results from seasonal variation of effort and CPUE show a tendency to a transition from a fisheries-based to a tourism-based economy. However, because tourism flux is highly seasonal, fishing still represents a fundamental source of food and income.

MULTICRITERIA ANALYSIS FOR DECISION SUPPORT AS AN USEFUL TOOL TO IMPROVE THE MANAGEMENT OF THE NATIONAL PARK CORALES DEL ROSARIO AND SAN BERNARDO, COLOMBIA.

Galvis N.H.*, *Corporación Propuesta Ambiental, Santafé de Bogotá, Colombia. Email: galvis@itc.nl

The National Park Corales del Rosario and San Bernardo has focused its management in a mainly ecological marine approach. The park was created in 1978 and in 1996, the protected area was increased to include the coral reefs of the Archipielago of San Bernardo. Despite of the declaration of protected area, ecological monitoring has shown an increasing degradation trend in the coral reefs. Participatory decision making is an alternative to diminish the anthropogenic impact. Weighting techniques allow us to evaluate the effectiveness of management based on the measurement of ecological and socioeconomic indicators. Sustainable management emphasises in the cumulative values given by the different stakeholders.

CAPTURING CORAL REEF BENEFIT VALUES – FINANCING MARINE ENVIRONMENT CONSERVATION IN MONTEGO BAY, JAMAICA.

Gustavson, Kent * and Huber, Richard M. *Gustavson Ecological Resource Consulting, PO Box 115, Gabriola, BC, V0R 1X0, Canada. Email: gustecol@netcom.ca

By capturing a portion of the economic value of the benefits derived from the local marine environment, the Montego Bay Marine Park (Montego Bay, Jamaica) will be able to finance management activities to protect and restore its coral reefs. Given the current inadequate investment in the resource, rent capture can be effective in aligning social costs with private costs to improve economic decision-making and provide sustained revenues for management authorities. Rent capture and market based instruments (MBIs) are reviewed as they apply to the socio-economic and institutional context of Montego Bay, with specific attention paid to the distribution of the costs among users, the change in incentives that may result, and the anticipated size of the revenues. The results of separate local use and contingent valuation studies provide guidance regarding the extent of producer and consumer surplus. The recommended instrument is an earmarked hotel room fee of US$1 per bed-night, to lead to an annual revenue of approximately US$1.5 million. Key in the recommendations is the provision of information to hotel guests regarding management activities and the benefits of the coral reefs. An independent administration of the program by the Montego Bay Marine Park, in cooperation with the hoteliers, is necessary to ensure accessible and sustained funding.

HUMAN MIGRATION AND RESOURCE USE IN SULAWESI FISHING COMMUNITIES.

Kramer, Randall A.*; and Simanjuntak, Sahat M.H. *Nicholas School of the Environment, Duke University, Durham, NC 27708 USA. Email: kramer@duke.edu

This study examines the relationship between human population changes and the use of coastal resources in several communities in North Sulawesi, Indonesia. This area has some of Indonesia's richest marine biodiversity and a number of important coastal resources that support the likelihood of a large number of fishing communities. Property rights for these resources are generally non-existent, so there is open access for harvesters. Direct interview surveys were conducted in July 1999 with 601 households whose primary occupation was fishing. Results indicate that fishing remains an importance economic activity in the area and there are some important differences between migrants and those of local origin. The economic importance of fishing is indicated by the fact that 60% of the fishermen made daily fishing trips. One quarter of the fishermen were migrants. Migrants were more dependent on fishing income than locals, and migrants were less likely to own their own boats. Both groups reported noticeable declines in catches over the past five years, with a higher percentage of migrants reporting such declines. Relatively few fishermen reported conflicts with other villages' fishermen, but many reported encounters with dynamite fishing.

SOCIO-ECONOMIC ASSESSMENT FOR CORAL REEF MANAGEMENT: DOES IT MATTER WHO YOU ASK?

O'Brien, Michael L.*, *NOAA Damage Assessment Center, Station 10220, SSMC4,1305 East-West Highway, Silver Spring, Maryland, USA, 20910. Tel.: (301)-713-3038 ext. 183, Email: Michael.O'Brien@NOAA.gov

As coral reef management programs around the world become more sophisticated, emphasis is shifting from exclusive consideration of biophysical processes alone towards broader perspectives. There is a move to integrate the values of people who live near, work with, and come to enjoy these resources. Numerous socio-economic studies have been conducted to study the consumptive and non-consumptive activities which link particular users to specific resources. Frequently, these studies target easily-defined groups of people, such as local residents, subsistence or commercial fishermen, dive tourists, etc.. The choice as to whose values should be included in such studies is not, however, always straight-forward. Often it may appear as if the more easily-defined the chosen study population, the greater the number of individuals whose values go unaddressed and therefore unaccounted for. Conversely, the more encompassing the study population definition, the more general the study must become and the greater the validity concerns. When defining whose values are to be considered, socio-economic assessments for natural resources must follow the thin line between being too specific about the user groups (and thereby not counting valid "holders of value") and being too global (and thereby running the risk of an invalid, overly-general result.) The purpose of this paper is to discuss issues related to the choice of the relevant user groups for socio-economic assessments of coral reefs. Special emphasis will be placed on the role of "respondent familiarity" with coral reefs as a central limiting factor for their valid integration in contingent valuation and conjoint analysis studies of recreational use. Both practical and theoretical issues will be highlighted in a case-study approach.

ASSESSMENT OF SOCIOECONOMIC FACTORS INFLUENCING THE SUCCESS OF MARINE SANCTUARIES IN THE PHILIPPINES.

Pollnac, Richard B.*; Crawford, Brian R.; and Gorospe, Maharlina L.G. *Coastal Resources Center, University of Rhode Island, Narragansett, RI 02882-1197, U.S.A. Email: rpo4903u@postoffice.uri.edu

Numerous papers have been written describing the establishment and sustainability of community based marine sanctuaries (CBMS) for coral reefs. A review of this literature and results of focus group meetings with individuals responsible for establishing CBMS in the Philippines resulted in identification of variables allegedly impacting CBMS success. These factors include sociocultural, economic and political aspects of the involved communities, methods used to establish the sanctuary, types and extent of community education programs, as well as aspects of support provided by external groups (NGOs, government agencies, universities, etc.). The assessment involved collecting data from a sample of 45 marine sanctuaries in the Visayas on this wide range of variables, as well as measures indicating the level of success of the sanctuaries. The paper discusses methods used for collecting the socioeconomic data and presents a multivariate analysis identifying variables responsible for success of marine sanctuaries in the Philippines. The results will be of use to marine sanctuary managers as they identify key factors for success of existing and proposed marine sanctuary projects and particularly for developing successful monitoring programs.

SOCIO-ECONOMIC ASSESSMENT FOR THE HONDA BAY, PHILIPPINES, COASTAL RESOURCES CO-MANAGEMENT PROJECT

Pomeroy, Robert S.* *World Resources Institute, 10 G Street NE, Washington, DC 20002, USA. Email: rpomeroy@wri.org

Honda Bay is located on the eastern side of mainland Palawan within Puerto Princessa City. Honda Bay is large, approximately 280 square kilometers, with 12 charted islands. The islands are generally small and are emergent portions of reef flats. These give substrate to the growth of its critical ecosystems, coral reef, mangrove and seagrass, upon which Honda Bay's fisheries are dependent. There are 19 villages surrounding Honda Bay with approximately 2500 households. Eighty-five percent of the households are engaged in fishing as a primary or secondary income source. In 1997, participatory research was undertaken to collect and analyze baseline data on the people, communities and natural resources of the Bay to provide a technical and scientific basis for establishing a Bay-wide co-management project. The research included a socio-economic assessment of two villages, a legal and institutional assessment for the whole Bay, and a resource and ecological assessment of the whole Bay. The purpose of this paper is to present the results of these baseline analyses and a discussion of the methods used to collect the data. In addition, the baseline data served as the foundation for a participatory project design workshop involving the active participation of local stakeholders. The paper will discuss the results of this workshop which produced a current reality synthesis based on the findings of the research, a vision for Honda Bay, and an initial project proposal for a five-year fisheries co-management project. The paper will conclude with a discussion of the importance of conducting socio-economic assessments of coral reef resources and their use in management and conservation.

A BIOECONOMIC MODEL OF A CORAL REEF MARINE RESERVE – MOMBASA MARINE NATIONAL PARK.

Rodwell, Lynda D.*; Barbier, Edward B.; Roberts, Callum M.; and McClanahan, Tim R.. *Environment Department, University of York, York, YO10 5DD, U.K. Email: ldr102@york.ac.uk

The excessive and unsustainable exploitation of our coral reefs has led to the promotion of marine reserves as a fisheries management tool. Marine reserves – areas in which fishing is restricted or prohibited - can offer opportunities for the recovery of exploited stock and fishery enhancement. This paper focuses on the contribution of tropical marine reserves to fishery enhancement through the development of a bioeconomic model of marine reserve-fishery linkages. The consequences of reserve establishment on equilibrium biomass and fishery catch levels in an open access coral reef fishery are evaluated. In contrast to earlier models, this study highlights the roles of both adult (and juvenile) migration and larval dispersal between the reserve and fishing grounds by employing a spawner-recruit model. Uniform larval dispersal, uniform larval retention and complete larval retention combined with zero, moderate and high adult migration scenarios are analysed in turn. The numerical simulation is based on Mombasa Marine National Park, Kenya – a fully-protected coral reef marine reserve. The establishment of a fully-protected marine reserve leads to an increase in total biomass. In a moderate to heavily exploited fishery with at least a moderate degree of either adult or larval movement total fishery catch will also increase.

BLUE PRICING OF UNDERSEA TREASURES – USE OF ENVIRONMENTAL ECONOMICS RESEARCH FOR CORAL REEF MANAGEMENT IN SOUTH EAST ASIA.

Ruitenbeek, Jack*; and Cartier, Cynthia. *HJ Ruitenbeek Resource Consulting Limited, RR2 – Site 52 – C21, Gabriola Island, BC, Canada, V0R1X0. Email: hjruiten@web.net

Coral reefs in SE Asia represent about 30% of the world's reefs, and they are currently undergoing unprecedented levels of degradation. Institutional capacity to manage reefs through appropriate policy measures is pervasively weak. Economic valuation of the damages wrought by institutional failures and various direct stresses is of substantial policy interest. A comprehensive literature survey of marine economic valuation studies is used to inform research needs and opportunities in the developing countries of SE Asia. We specifically outline conditions and policy priorities in Cambodia, China (including Taiwan), Indonesia, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand, and Vietnam. We employ benefit transfer methods of conventional environmental economics to calculate a present value of US$1.5 trillion for SE Asia's coral reefs. The value encompasses direct tourism, recreation and fisheries uses, as well as potential benefits from various functions and indirect uses such as erosion control and pharmaceutical development. The methodological and empirical shortcomings inherent in such an analysis, however, underline a greater need for original site-specific empirical studies that reflect local system complexities and local policy needs. Environmental economic analysis can assist in addressing local priorities through: (i) increasing awareness of absolute and relative economic values; and, (ii) providing valuation estimates that can assist in coral reef management.

MODELING FINANCIAL LOSSES RESULTING FROM CORAL REEF DEGRADATION.

Schuttenberg, Heidi*; and French, Deborah. *Coastal Resources Center, URI, Narragansett, RI 02882, USA. hzs@gso.uri.edu

Methods to link coral reef degradation with its consequent financial losses are useful for coastal management activities such as planning, public education, and assessment of damages. The Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) was developed by Applied Science Associates under contract to the U.S. National Oceanic and Atmospheric Administration to estimate monetary damages from oil and chemical spills. The model was used to investigate the impacts of cyanide fishing and chronic and acute oil pollution on coral reefs. Physical and biological models calculate the mortality of fish and coral from exposure to varying concentrations of these pollutants using published toxicity data. Resulting financial losses are calculated using criteria established by the U.S. Oil Pollution Act (1990), and are based on 1) the cost of restoration, and 2) the value of losses of natural resources and the services they provide until restoration is complete. These interim losses are based on commercial and recreational values for damaged species and their lost progeny. Results of the study illustrate different approaches for valuing financial losses from reef destruction; highlight strengths, gaps, and issues with existing coral reef valuation data sets; and demonstrate the usefulness of this publicly available model as a framework to integrate economics, science, law, and management of coral reefs.

AN ECONOMIC ANALYSIS OF CORAL REEFS IN THE ANDAMAN SEA OF THAILAND.

Seenprachawong, Udomsak*. *School of Economics, Sukhothai Thammathirat Open University, Thailand. Email: ecassudo@stou.ac.th

Powerful economic forces are driving the observed destructive patterns of coral reef use, often rendering short-term economic profits, sometimes very large to selected individuals. Some of the most important values of coral reefs, such as those of to future generations and intrinsic values, cannot be quantified. The omission of these benefits in conventional economic analysis means that coral reefs are undervalued. This can result in unsustainable use of coral reefs. This is of particular concern for coral reefs in areas such as the Southern Seaboard Development Project area. The area is well favored with pristine coral reefs. Because local communities in the Anadman Sea are totally dependent on the coral reefs, sustainable coral reefs management options urgently need to be identified for the area. An economic valuation of the benefits of coral reefs can provide information in the design of coastal area management plans. In this study, no attempt is made to calculate the total economic value of the coral reefs. Phi Phi Islands will be selected to assess their recreational values using the Individual Travel Cost Model (ITCM). Data will be collected from a sample of 600 visitors through on-site face to face interviews. Once the most suitable demand curve functional form has been estimated, the individual consumer surplus can be calculated. The individual WTP resulting from the analysis will be multiplied by the total number of visitors to Phi Phi Islands during the year. The obtained results will be explained, interpreted, and compared with those of other similar studies.

VALUING RECREATION AT MENJANGAN ISLAND, WEST BALI NATIONAL PARK

Setiasih, Naneng*; and Tinch, Robert. *School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ. Email: R.Tinch@UEA.ac.uk

Menjangan Island lies on West Bali National Park. It has beautiful snorkelling and diving sites to be visited. However, coral quality fell due to the Acanthaster plancii outbreak in 1996, and during 1993-1997, visitor numbers increased from 1768 per month in 1993 to 2056 in 1997. This could lead to a further environmental degradation and disturb the recovery rate of the reef. Thus, there is a need to consider an environmental view in the managerial process. During 1997-1999, ecological data of the reef was collected by using line intersect transects at various depths from 3 to 25 metres, and park managers were interviewed. Average living cover percentage was 26.75%, classified as the poor condition. The highest degradation was found at the northwestern edge of the island. A SWOT analysis was run to set up a management recommendation based on a location's aesthetic weighting as a diving and snorkelling area. However aesthetic characteristics are unpriced and their value can often be neglected in the decision making process. Research is now underway to address this problem using a combination of contingent valuation and conjoint analysis. The study will measure tourists' willingness to pay for mitigating tourism impacts by valuing their preferences on the possible changes of certain recreational attributes. The conjoint analysis involves three attributes: tourist congestion, living cover percentage, and an additional conservation fee.

ECONOMIC VALUE OF THE IRANIAN CORAL REEFS IN THE PERSIAN GULF

Shokri, Mohammad Reza* and Mohammad, Seyed; Fatemi, Reza. *Iranian National Center for Oceanography, #51, Bozorgmehr Ave, 14168, Tehran, Iran, Email: mrshok@hotmail.com

Reef-related economical benefits in Iran stem mainly from commercial fisheries of shellfish, ornamental fishes and recreational activities. The annual landing of reef fishery is estimated at 18000 tones of fish from the waters surrounding the 18 coral reef islands, creating food, revenue and considerable occupation for the local people living in these areas or are dependent on these resources. Ornamental fishery shows a significant reduction in number of catch in islands such as Kish Island, where the destruction of habitats of these fish has occurred, causing a financial loss of about US$ 40000 annually. The world famous pearl oyster fishery in the Persian Gulf today, shows a sharp reduction today, because of the habitat destruction and the overfishing, dropping from 4.5 million oysters in 1990 to 970000 in 1995. Reef-related recreational activities are a major potential source of job and income and are expanding rapidly in islands such as Kish and Qeshm. This would definitely affects the coral health and therefore needs an urgent attention regarding the Sustainable Development of Reef Areas. This paper aims to provide an overview on the economic values of the Iranian coral reefs based on the existing data and also reviews and evaluates the financial losses caused by reef destruction, as well as indicating the hot spots which need immediate preventive and reconstruction measures.

MAXIMISING OPPORTUNITIES FOR SUSTAINABLE FINANCING OF CORAL REEFS BASED ON A TOTAL ECONOMIC VALUE APPROACH.

Spurgeon, James* *GIBB Ltd, London Road, Reading, RG6 1BL, UK. Email: jspurgeo@gibb.co.uk

Despite the potential for coral reefs to provide substantial long-term economic and social benefits, their degradation continues worldwide. Key to their sustainable utilization and future survival are appropriate means of management and protection both on and off-site. In recent years, a wide range of financing mechanisms have been identified and implemented to help fund the management of coral reef systems. These include user fees, concessions, permits, environmental taxes, trust funds, donations, privatization, damage compensation, Government support and international assistance. This paper explores how the concept of the "Total Economic Value" of coral reefs could help maximize opportunities for the sustainable financing of reef management. Central to this approach are both comprehensive stakeholder analysis and environmental valuation. Such techniques enable the identification of all reef beneficiaries and the quantification of benefits accruing from direct, indirect and passive uses of coral resources. With this information at hand, there is considerable scope for seeking new and enhanced sources of funds from both direct beneficiaries and also from those organizations with responsibilities towards the beneficiaries. In particular, the encouraging global trend in "corporate social responsibility" could yield significant additional finances. This systematic and strategic approach to financing is discussed using case studies from Florida, Mexico, Egypt and Tanzania.

PARTICIPATORY SOCIO-ECONOMIC ASSESSMENTS AND THE REEF MANAGEMENT PROCESS.

Townsley, Philip.* *NOAA/GCRMN Consultant, Via Annio 12, 01100 Viterbo, Italy. e-mail : ptownsley@libero.it

A socio-economic assessment has commonly been regarded as a means of collecting additional information to assist reef managers in formulating more appropriate plans for reef management. However, the improvement of reef managers' understanding of socio-economic issues is only one of the potential uses of an assessment. The use of participatory approaches during an assessment can help reef managers to both collect the socio-economic information they need and establish productive and pro-active relationships with reef stakeholders. These can be extremely beneficial to the reef management process in general, helping to build a common understanding of management issues among stakeholders and to identify commonly agreed management objectives. This in turn can help greater commitment to reef management plans that reflect these common objectives. But building a "participatory management process" is complex and time-consuming. The socio-economic assessment is only a first step in this process and, before committing themselves to the adoption of a participatory approach during the assessment, reef managers need to carefully assess the social, economic, political and institutional context in which they are operating and the extent to which it can accommodate participatory management. Some of the factors that can influence the appropriateness of more participatory assessment approaches are considered.

REEFVALUE - AN ECONOMICALLY ORIENTATED GLOBAL CORAL REEF DATABASE FOR DECISION MAKERS

Vogt, Helge Peter *; Kunzmann, Andreas; Richter, Claudio. *Zentrum für Marine Tropenökologie (ZMT), Fahrenheitstr. 1, D 28359 Bremen, Germany, Email: HP_Vogt@compuserve.com

In many developing countries and small island nations, coral reefs provide the main livelihood of coastal communities. Healthy coral reefs may also attract tourists and international reefs tourism already contributes considerably to many states' budgets. However, the benefits of reefs for society are being diminished due to human activities. In 1992, the European Union identified a coral reef management strategy in developing countries and subsequently funded reef related programmes. Building on these previous achievements, the ReefValue-project aims to add a key component which is missing at present. The destruction of coral reefs is driven by economic forces. However, the essential economic data required for successful reef management are scarce and not easily accessible in developing countries. The ReefValue-project addresses this need, and provides reef managers and decision makers with a globally available and user friendly database, which covers quantitative economic values as a prerequisite for sustainable reef management. The key features of the database including data entry and retrieval using the ReefValue website will be presented. An overview of the global network of partner organisations, regional workshops on reef economics and local reef valuations-projects will be provided.

BENEFITS AND COSTS OF CORAL REEF AND WETLAND MANAGEMENT, OLANGO ISLAND, PHILIPPINES.

White, Alan T.*; Ross, Michael; Flores, Monette. *Tetra Tech EM Inc., Coastal Resource Management Project 5th Floor, CIFC Tower, North Reclamation Area Cebu City, Cebu, Philippines 6000. Email: awhite@mozcom.com

The Philippines has an estimated 27,000 km^2 of coral reef with only about 5 percent of this area still in excellent condition. Recent valuation studies indicate that reefs in the whole country are contributing a conservative US$1.35 billion to the national economy and that one km^2 of healthy Philippine reef with some tourism potential produces annual net revenues ranging from US$29,400 to US$113,000. A case study of Olango Island, Cebu with 40 km^2 of poor quality coral reef is analyzed together with its wetland habitat and mangrove contribution. The current annual net revenue range from the Olango Island reef is US$38,300 to 63,400 per km^2 or US$1.53 to 2.54 million for the entire 40 km^2 reef area. Another US$389,000 is added when wetlands are considered. The revenues accrue primarily from on and off site expenditures of diving tourists. Costs of managing Olango Island coral reefs and wetland habitats for improved net revenues (benefits) and conservation would amount to less than US$100,000 per year. Cost and benefit analyses show that there is a very strong justification on the part of local and national government and private sector groups to invest in the management of reefs such as Olango Island. Improved reef quality and wetland stewardship on Olango could easily mean a 60 percent (US$1.4 million) increase in annual net revenues from reef and mangrove fisheries and tourism expenditures.

Session C2: Building Capacity for Tropical Marine Biodiversity Conservation:

STRENGTHENING MARINE CONSERVATION CAPACITY IN THE WESTERN PACIFIC.

Atkinson, Scott R.*; Salm, Rod; Agardy, Tundi; Barber, Charles; Colwell, Stephen; Hale, Lynne; Lauck, Liz; Pratt, Vaughan; Linggi, Sylvia; Vergara, Sheila. *World Wildlife Fund, 1250 24th Street, Washington, D.C. 20010 ATKINSON@WWFUS.ORG

Throughout the western pacific, limitations in the number of trained conservation practitioners have long confounded efforts to effectively manage and conserve marine ecosystems. While the character of capacity limitations and needs differs from country to country, there is virtually unanimous agreement within the conservation community that support for building individual and institutional capacity is the region's single greatest need for marine conservation. Nine international non-governmental organizations have come together in an effort to better understand and address marine conservation capacity issues in the western pacific including: indonesia, the philippines, malaysia, papua new guinea, solomon islands, palau, and the federated states of micronesia. Recognizing the enormity of the task, the group designed a collaborative strategic planning process which focuses on understanding and addressing capacity needs of conservation practitioners within a limited set of projects and programs. Additionally, the group identified two focal countries, indonesia and papua new guinea, where it is striving to understand the full range of marine conservation capacity experiences and needs. The strategic planning process will culminate in august of 2000 with the development of framework for cooperation that is intended to provide guidance to participating ngos and partners on ways to enhance the capacity of target projects and countries. This paper summarizes key elements of this framework and the process by which it was developed.

MARINE CONSERVATION IN ASIA AND THE PACIFIC: EXPERIENCES AND LESSONS FROM THE WORLD WIDE FUND FOR NATURE (WWF).

Atkinson, Scott R.*; Jessup, Timothy; Llewellyn, Ghislaine; Mangubhai, Sangeeta; Mejia, Manuel; Putra, Ketut; Romero, Mon; Samarasekara, Vidhisha; Trono, Romeo. *WWF 1250 24th Street Washington, D.C. 20037 Email: atkinson@wwfus.org

The World Wide Fund For Nature (WWF) is implementing numerous marine conservation efforts throughout the nations of Asia and the Pacific, including the Philippines, Indonesia, Malaysia, Thailand, Papua New Guinea, Solomon Islands, Fiji, and the Cook Islands. Projects run the gamut from strengthening marine protected areas to establishing finance mechanisms to support the recurring costs of conservation. While the nature of our projects are varied, a common agenda throughout is a commitment to work with stakeholders to reverse the decline of marine systems while facilitating conservation in the long-term. This commitment has led to many innovative programs. For example, in the Philippines, WWF has partnered with government agencies to launch an enforcement campaign to immediately halt destruction of critical marine systems. While such efforts may secure an area in the short term, other more fundamental efforts are needed to ensure that conservation will persist. These include capacity strengthening of resource managers, education and outreach, alternative livelihood schemes, policy intervention, and sustainable finance schemes. Through pursuing these and numerous other approaches, WWF has learned many lessons in marine conservation.

IMPEDIMENTS TO COMMUNITY MANAGEMENT OF CORAL REEFS: SANDY BAY-WEST END MARINE RESERVE, BAY ISLANDS, HONDURAS.

Badilla Forest, Nelia*. *Dept. of Geography, University of California-Berkeley 94720 USA , nforest@igc.org, nelia@socrates.berkeley.edu

Sandy Bay-West End, located on the north coast of Roatán, on the Bay Islands of Honduras, is the site of a spectacular and biologically diverse coral reef ecosystem. This case study describes the development of a management plan for the Sandy Bay-West End Marine Reserve which is under the management of a local NGO, the Bay Islands Conservation Association (BICA). Unfortunately, most of the poor and middle-income islanders feel estranged from BICA's goals and objectives. BICA has not made the effort to address the socio-economic concerns of the Bay Islanders regarding the allocation and use of coastal and marine resources. Also, the fact that the families of the two highest officers are major stakeholders in Roatán's tourism industry is an immediate conflict of interest, allowing one stakeholder group to dominate through financial patronage and whose interests are allowed to prevail. A review of a survey conducted by Wildlife Conservation Society, indicates that BICA must begin to make fundamental changes in its governance style and arrangements (Forest 2000). Considering the mistrust of the management entity, unilateral decision-making and poor communications, it will take several years for BICA to gain the trust of local residents and fully engage the stakeholders.

COMMUNITY-BASED COASTAL RESOURCE MANAGEMENT IN THE PHILIPPINES.

Broad, G.* and Quiring, M. *Tambuyog Development Center, 1164 Molave Street, Sorsogon, Philippines. Email: tdc@k-net.edu

The Philippine archipelago comprises over 7,100 islands and has a vast coastline of 18,000 km. Thus, the small-scale municipal fisheries are responsible for supplying basic food requirements to a large proportion of the population. A rapid population increase over the past 30 years, combined with a lack of alternative livelihoods, has led to intensive over-fishing and destruction of inshore coral reef habitats. The outcome has been increased poverty in coastal communities and a steady decline in biodiversity. Tambuyog's long-term program in Bicol aims to encourage the development of empowered communities with the capability and skills to manage their marine resources sustainably. The program works through People's Organizations, combining local knowledge with technical training and involving stakeholders at all stages of the project. The result has been the establishment of two community-managed marine reserves, training for community SCUBA divers to monitor the reserves and a number of alternative livelihood options. One community has proposed the exciting concept of a seagrass sanctuary. These results confirm that coastal communities possess the capability and the will to manage their marine resources responsibly and sustainably. We conclude that co-management can be a powerful force for social development and the conservation of biodiversity.

COMMUNITY-BASED GIANT CLAM RESTOCKING - HOPES FOR BIODIVERSITY CONSERVATION

Calumpong H.P.*, A.B. Apao, J.R. Lucañas and J.S. Estacion. Silliman University Marine Laboratory, Dumaguete City 6200, Philippines.
email: nida_hpc@mozcom.com.

Efforts at restocking coral reefs with giant clam juveniles have been done by the Silliman University Marine Laboratory since 1997 using community -based approach. Only reefs protected by local communities were restocked. So far, six reefs have been restocked with 1,337 individuals of five species: *Tridacna gigas*, *T. squamosa*, *T. derasa*, *T. crocea* and *Hippopus hippopus*. Survival and growth in three reefs were monitored during this period. Survival for *T. gigas* is 24.24% and for *H. hippopus* is 2.5%. Growth rate for *T. gigas* is 0.75 ± 0.16 cm mo^{-1} and for *H. hippopus* is 0.21 ± 0.07cm mo^{-1}. *Tridacna squamosa*, *T. crocea* and *T. derasa* clams did not survive in these three sites.

THE BIOLOGICAL AND SOCIAL EFFECTS INFLUENCING THE SUSTAINABILITY OF THE SAN SALVADOR ISLAND (PHILIPPINES) MARINE PROTECTED AREA.

Christie P.*. *School of Marine Affairs University of Washington 3707 Brooklyn Ave NE Seattle, WA 98105-6715 USA Email: patrickc@u.washington.edu

The San Salvador Island 127-hectare marine protect area off of the west coast of Luzon, the Philippines, has been in existence since 1989. The marine protected area was established through a community-based project in the late 1980s that has evolved into a co-management effort mainly involving the local community and government. Rationale for these strategies and the sequential move from community-based to co-management in this context will be offered. This paper also documents these efforts and the recovery of the fish populations and coral within the sanctuary. Visual surveys document that fish density has increased from an average of 373 individuals per 500 m2 in 1989-91 to 1041 individuals per 500 m2 in 1998-99. Species richness has increased from 126 species belonging to 19 families in 1988 to 138 species belonging to 28 families in 1998. Similarly, coral cover has also recovered substantially, despite recent bleaching events, from 23% living hard coral cover in 1988 to 57% in 1998. Despite these positive results, internal divisions within the community, threats from illegal fishers, and lack of diverse community leadership threaten the continued management of this valuable protected area that has served as an important example of effective coral reef management. Potential solutions will be highlighted.

BUILDING PHILIPPINE GOVERNMENT CAPACITY FOR COASTAL RESOURCE MANAGEMENT: METHODS, PROGRESS AND TRENDS.

Courtney, Catherine A.* and Alan T. White *Tetra Tech EM Inc. Coastal Resource Management Project 5th Floor, CIFC Tower, North Reclamation Area Cebu City, Cebu 6000, Philippines Email: Courtney@mozcom.com

Over the last 10 years, the Philippine government has been experimenting with new systems of governance based on decentralization, local autonomy and large-scale participation of communities and civil society in democratic processes. The responsibility for managing coral reefs and other coastal resources was largely devolved to the over 830 coastal municipalities and cities in the Philippines in 1991 under the Local Government Code. Local government capacity to carry out this mandate; however, has only recently begun to mature as municipalities and cities have become aware of the importance of coastal resources to communities and economic development. This paper describes trends in local governance and coastal resource management in the Philippines over the last 10 years. Processes and methods to increase local government capacity for coastal resource management are described based on the experiences of the Coastal Resource Management Project of the United States Agency for International Development. Qualitative and quantitative surveys were used to evaluate the current capacity of local government to undertake coastal resource management. Emerging co-management arrangements between local government, national government and other sectors are described in terms of supporting mechanisms, reinforcing systems, and derailing forces.

SOCIAL AND LEGAL CONTEXTS OF ESTABLISHING AND MONITORING COMMUNITY-BASED MARINE RESERVES IN WESTERN SOLOMON ISLANDS.

Foale S.*, Casper Rebi and Seri Hite.*World Wide Fund for Nature – South Pacific Programme, P.O. Box 21, Gizo, Solomon Islands. wwf@solomon.com.sb

This paper illustrates some of the range and complexity of social and legal contexts within which marine protected areas are being developed in western solomon islands, by outlining wwf's, and others' experiences with efforts to establish marine protected areas in specific localities in this area. In the solomon islands, around 87% of land is controlled by clan groups under customary rules, which are generally upheld by the constitution. The government owns most of the remainder. While the seabed is traditionally regarded as an extension of coastal land, legal support for customary marine tenure (cmt) is not as clear-cut as for land. Wwf is attempting to facilitate establishment of marine reserves in areas under three tenure categories: government-owned, customary, and customary but uninhabited. Opportunities and constraints in each case are very different, but each case illustrates the importance of adequately addressing the complex legal and socioeconomic issues surrounding proposals for spatial and temporal closures, strategies for enforcement, and monitoring resource abundance, in each area. The primary challenge for all areas is enforcement, while tenure disputes also often retard progress in areas under customary control. Opportunities include using tourism levees (for enforcement), and obtaining informed compliance through awareness campaigns that combine local and scientific knowledge.

"BUILDING CORAL REEF MANAGEMENT CAPACITY: EXISTING LITERATURE, LESSONS FROM THE CARIBBEAN, AND PROSPECTS FOR INDONESIA"

Fougeres, Dorian* *Marine & Coastal Policy Fellow IUCN – The World Conservation Union Washington Office 1630 Connecticut Ave., N.W. Third Floor Washington, D.C. 20009-1053 U.S.A.
Email: fougeres@iucnus.org

In recent years the term "capacity-building" has gained popularity among international aid organizations (IAOs) seeking to help countries manage their natural resources. In particular, IAOs have advocated the term with regard to nations and regions which cannot presently address their environmental challenges, whether due to a lack of management personnel or conflicting political jurisdictions or other causes. Yet the term holds multiple connotations, from gathering scientific information to training planners to providing programmatic funding. Unless practitioners take care, these various meanings can impede organizational efforts to create and integrate capacity-building projects. In this paper the existing literature is first surveyed to review and systematize prevalent concepts of capacity-building. From here the author moves on to focus specifically on the dynamics of building coral reef management capacity in decentralized contexts. He begins by exploring a series of capacity-building projects in the Caribbean, a region with numerous national jurisdictions and a significant history of reef management. In examining successful and unsuccessful efforts here, he aims to identify both challenges to, and opportunities for, improving reef management in this area. Afterwards he considers Indonesia's present political shift toward decentralization, and draws out the parallels and contrasts between this context and the Caribbean. In closing, based on the lessons from the Caribbean region, he recommends the next steps IAOs can take to help Indonesia build its capacity for balancing the conservation value and the economic importance of its reefs.

APPLICATION OF HAWAIIAN TRADITIONS TO COMMUNITY-BASED FISHERY MANAGEMENT.

Friedlander, A.*, Poepoe, K., Helm, K., Kaai, J., Bartram, P. Maragos, J. and Ili, S. *The Oceanic Institute, Makapuʻu Point, Waimanalo, Hawaiʻi 96795. Afriedlander@oceanicinstitute.org.

Despite the opinion of many fishers that over-harvesting is one of the major reasons for a long-term decline in inshore marine resources in Hawaiʻi, there is poor compliance with state fishing laws and regulations. The community (Hui Malama o Moʻomomi) in the Hoʻolehua Hawaiian Homesteads on the island of Molokaʻi is currently attempting to strengthen community influence and accountability for the health and long-term sustainability of their marine resources. The traditional system in Hawaiʻi emphasized social and cultural controls on fishing with a code of conduct that was strictly enforced. Harvest management was not based on a specific amount of fish but on identifying the specific times and places that fishing could occur so it would not disrupt basic processes and habitats of important food resources. Local resource monitors, in conjunction with visiting scientists, are creating a predictive management tool based loosely on the Hawaiian moon calendar (a traditional tool for organizing fishing and planting).

ESTABLISHMENT OF NO-TAKE MARINE RESERVES THROUGH COMMUNITY BASED MANAGEMENT IN NABQ, SOUTH SINAI, AND INVESTIGATION OF EFFECTS UPON COMMERCIALLY TARGETED CORAL REEF FISH STOCKS AND CPUE.

Galal, N*, Afifi, A. & Ormond, R. F. G. *Nature Conservation Sector, EEAA, Cairo, Egypt Gulf of Aqaba Protectorates. South Sinai. Egypt. Email: ngalal@datum.com.eg

Underwater Visual Census was used to compare the abundance of piscivorous fish species within the Nabq Protected Area before and after the establishment of five no-take fisheries reserves in 1995. A comparison of mean abundance of groupers (Serranidae), emperors (Lethrinidae) and snappers (Lutjanidae) between 1995 and 1997 showed a significant overall increase in fish abundance in two of the no-take reserves, those at Ras Atantour and South Ghargana. There was also a statistically significant increase in mean length of the serranids, *E. fasciatus* and *C. argus*, and the lethrinids, *L. nebulosus and M. grandoculus* across the no take reserves. In 2000, these effects were also detected in four of the no-take reserves. In line with this mean catch per unit effort within the fished area was observed to increase over the two years from 0.84 +/-0.19 S.E to 1.01 +/-0.24 S.E., though the difference was not statistically significant. However, two years later, in 2000, CPUE increased significantly. Nevertheless, the establishment of no-take fisheries reserves appear to date have benefited the fishery. The benefits of no-take reserves are discussed, and social aspects of involving local fishermen in the co-management of fisheries resources are described.

COMMUNITY-BASED MANAGEMENT AND CORAL REEF MONITORING OF HELEN ATOLL, PALAU.

Guilbeaux M.*; Atkinson, Scott; Ridgley, Mark. *Community Conservation Network; 2440 Campus Rd., #561; Honolulu, HI 96822, USA. Email: guilbeau@hawaii.edu.

An atoll in Palau's Southwest Islands, Helen Reef is the epitome both of challenges to implementing effective coral reef management and of potential losses if not succeeding. In the region with the world's highest levels of marine biological diversity, and having one of the most diverse and intact reef systems in the tropical Western Pacific, Helen's integrity is being jeopardized by resource over-exploitation and a management system hamstrung by scant resources, no permanent settlement on its single, tiny island, limited formal educational, erosion of traditional marine-resource knowledge, divergent views on the need for and ways to achieve conservation, cultural conflicts, and a location on the periphery of Palau and two days' voyage from its capital. While such conditions ensure that centralized governance will remain deficient in the best of cases, it is far from certain that the much-heralded alternative of community-based management can succeed in this context either. This paper describes an ongoing initiative to assist local communities to design and develop a long-term community-based management (CBM) system for Helen Reef. A major goal of the endeavor is to integrate natural science and management science with CBM to mitigate the impediments to effective resource management. One example of such integration was a major 10-day monitoring expedition conducted in April-May 2000, an activity guided heavily by CBM concerns.

INTEGRATED COASTAL MANAGEMENT AND CORAL REEF CONSERVATION.

Hale, L.Z.*, B. Crawford, H. Schuttenberg, Ian Dutton, M. Amaral, P. Rubinoff. *Coastal Resources Center, University of Rhode Island. Narragansett, RI, USA. Email: lzhale@gso.uri.edu

Integrated coastal management (ICM) is one of four pillars of the International Coral Reef Initiative's Plan of Action. ICM programs around the world have attempted to address issues related to coral reef use and conservation in a number of ways, including community-based coral reef sanctuaries, community ICM plans, special area management plans, different types of marine protected areas, and national policy initiatives. In North Sulawesi, Indonesia, and Xcalak, Mexico, community-based sanctuaries are helping both to conserve areas of reef as well as to catalyze ICM plans that address the fuller suite of land-based and marine activities and uses that ultimately determine coral reef condition. In Tanzania, a newly adopted national coastal management policy provides a facilitative framework and resources, as well as high level political support to both local level ICM action plan development and the creation of a marine protected areas system. These cases are illustrative of coastal management efforts occurring in many nations. They demonstrate how to link local and national management, how to make participation and co-management a reality in nations that lack democratic traditions, and how to build capacity and promote learning and replication both within and across nations.

CORAL REEF MONITORING FOR COMMUNITY-BASED ECOTOURISM DEVELOPMENT IN TOGEAN ISLANDS, CENTRAL SULAWESI, INDONESIA

Hutabarat, C.*; Supriatna, dan Jatna; *Yayasan Bina Sains Hayati Indonesia. Email: jatna@cbn.net.id

The Togean Islands, a Marine Tourism Park, occupy a land area of approximately 70,000 ha and nearly 200,000 ha of sea in Sulawesi's Gulf of Tomini. The remote archipelago is globally significant for being part of the "coral triangle", the area of highest coral diversity, roughly bordered by the Philippines, Indonesia and Oceania/Melanesia. The marine environments include seagrass beds, mangroves, and a large diversity of coral reef habitats (atoll, fringing, barrier, and patch) in relatively close proximity. Approximately 30,000 people representing diverse ethnic backgrounds and livelihood patterns inhabit 37 villages on the 7 major islands of the Togeans Island. The revenue from ecotourism activities has been recognized as importance roles in communities in the islands and contributed to Central Sulawesi's economy growth. Ecotourism program involving community has been started for approximately 5 years and starting from 400 (1995) and more than 4000 tourists (1999). Coral reef monitoring at diving sites by community and Earthwatch volunteers have been started since 1997. Feed back mechanism from monitoring results was used to maintenance and improve the monitoring techniques and sites. Community meeting was created regularly and action plans to deter coral reef encroachers were suggested by community and home stay owners.

TARGETING ROOT CAUSES OF ENVIRONMENTAL DEGREDATION AND PLANNING FOR SUSTAINABILITY: WWF'S ACTION NETWORK APPROACHES APPLIED TO CORAL REEF CONSERVATION

Llewellyn G., Putra, K.; Dwisasanti, N. *WWF Indonesia, Wallacea Bioregion, 179 Jl. Hayam Wuruk, Denpasar 80235 Bali, Indonesia Email: mcmast@idola.net.id

Over the past two decades, conservation organizations have not succeeded in reversing the general trend of global environmental degradation. The range of threats and the vast areas at risk are causing many conservation groups to rethink their strategic approaches in order to become more effective. WWF's Action Network advocates selecting interventions that maximise conservation gains over a large region and which focus on actors or institutions who represent the root cause of environmental problems. Both communities and habitats often emerge as the victims of decisions made by governments, banks and the private sector, and facilitating more conservation-friendly activities by the latter is now seen as being key for better practices in natural resource management. Equal emphasis is placed on forming partnerships, where long-term benefits, whether economic, social or image-wise, provide incentives for others to adopt the model. This combination of voluntary adoption and involvement of key players is seen as the crucial means of ensuring sustainability beyond the funding cycle of the project. WWF Indonesia's Wallacea bioregion is piloting such an approach in its "Partners for Parks" coral reefs campaign, in an attempt to ensure enforcement and better management in National Marine Parks. The initial pilot sites are Bali Barat and Bunaken with partnerships and advocacy efforts initially targeting private sector and government partners.

ESTABLISHING COMMUNITY-BASED MARINE RESERVES IN THE FIJI ISLANDS – LESSONS FROM THE FIELD.

Mangubhai, Sangeeta * and Rupeni, Etika. *World Wide Fund for Nature – South Pacific Program, Private Mail Bag, GPO, Suva, Fiji Islands. smangubhai@wwfpacific.org.fj

The fiji islands, like many other south pacific countries, have their coastal and foreshore waters and resources shared under dual ownership, where the state owns the land beneath the sea and the indigenous fijian communities own the right to fish in customary marine grounds for subsistence. The failure of conventional and nationally legislated marine reserves to protect the intrinsic cultural, economic and biological value of marine ecosystems in fiji has heightened efforts to actively involve resource owner communities in the management of marine reserves. This has led to a renewed surge of discussions and scattered efforts to strengthen and incorporate traditional management regimes, particularly in isolated islands where under-funded and under-staffed sectoral authorities cannot adequately police marine-based activities. Wwf has been working with waisomo villagers, other interested communities, educational institutions, government and non-government organisations, in the island group of kadavu, to establish fiji's first community-based marine reserve within the great astrolabe reef ecosystem. This paper provides an overview of the process involved, the challenges faced and the lessons learned by wwf in designing and establishing marine reserves within resident landowners customary marine areas, and provide insight on the key elements to promote replicability and long-term sustainability of these reserves in fiji.

COMMUNITY BASED CORAL REEF MANAGEMENT IN THE PADAIDO ISLANDS, WEST PAPUA, INDONESIA.

Marien, Jeffrey, Ismuranty, Christien; Marlesy, Cliff; Henning, Jan Steffen*. *KEHATI-The Indonesian Biodiversity Foundation, Jakarta, Indonesia. Email: jsteffen@cbn.net.id

The padaido islands in the province of west papua, indonesia, consist of about 30 islands of which 10 are permanently inhabited. Based on several marine resource surveys, a 183.000 ha area including most of the padaido islands was declared a marine tourism park in 1997. Following up on a community based eco-tourism development project in three selected villages by the biodiversity conservation network (bcn), the indonesian biodiversity foundation kehati supports since 1998 local communities and the local ngo rumsram in their attempts to develop a community based marine resource management approach. To overcome imminent threats by blast fishing and over exploitation of reef resources, most of the 18 villages formed conservation groups and participated in resource and traditional law inventories and in the mapping of local reef condition, finally aiming on the development of village based sanctuaries. Experiences regarding strengths and weaknesses of the cbm approach in the 18 villages, as well as external problems and threats are analyzed and conclusions are drawn regarding the applicability of the chosen approach in other areas.

PAYING FOR MARINE CONSERVATION THROUGH SUSTAINABLE FINANCING: THE TUBBATAHA EXPERIENCE.

Mejia, Manuel N.*, Subade, Rodelio., Scott Atkinson, Barry Spergel. WWF Philippines. 23-A Maalindog St. UP Village, Diliman, Quezon City, Philippines. Email: mmejia@mozcom.com

In the middle of the Sulu Sea lies Tubbataha Reef National Marine Park. Because of its globally significant biodiversity, UNESCO declared Tubbataha a World Natural Heritage Site in 1993. Due to lack of staff and financial support, however, enforcement capacity was low and areas of Tubbataha were ravaged by illegal activities. To address and eliminate these threats, Tubbataha is now under year-round patrols and a comprehensive management plan. However, once donor funding ends, how will conservation be paid for? One sustainable financing option that is being pursued by the Tubbataha Protected Area Management Board is the levying of a conservation fee to visitors. Experience from other marine protected areas shows that divers are willing to pay relatively high fees, provided that the fees are used solely for the conservation of marine life. Results from a willingness to pay survey conducted in 1999 supported the idea of a conservation fee in Tubbataha. The park fees raised will be used to cover park operating and maintenance costs, while a portion will be put into a fishing community's trust fund and a Park trust fund, which will later be used to attract donor funding. This paper would like to share the caveats, pitfalls and lessons learned in the implementation of the Tubbataha conservation fee. Conservation projects worldwide invariably collapse once donor funding stops. Sustainable financing through a park user fee or conservation fee is one way to add value to protected areas. These park revenues fees will also help ensure that conservation is lasting.

ECOREGION-BASED APPROACH TO THE CONSERVATION OF A LARGE MARINE ECOSYSTEM: THE SULU-SULAWESI SEAS

Miclat, Evangeline F.B.*; Llewellyn, Ghislaine; Samarasekara Vidisha, and Atkinson, Scott. *World Wildlife Fund-Philippines, 23-A Maalindog St., U.P. Village, Diliman, Quezon City 1101, Philippines. Email: emiclat@wwf-phil.org.ph

The Sulu-Sulawesi Marine Ecoregion (SSME) is located in the global center of marine biodiversity and bordered by Indonesia, Malaysia, and the Philippines. Numerous forces including destructive fishing, over exploitation, and coastal development threaten the marine resources of the ecoregion. Overlapping boundaries; shared ecosystem dynamics and resources; and transboundary environmental issues warrant an ecoregion wide approach to conservation and management in this important area. The WWF and partners have launched an Ecoregion-based conservation (ERBC) initiative in the SSME. The ultimate goal of the marine ERBC approach is the maintenance and restoration of marine systems such that ecological integrity, biodiversity, and natural ecosystem dynamics persist in the long-term. A targeted ERBC planning process is currently assessing biological, socioeconomic, political, and institutional factors. An SSME Biodiveristy Conservation Action Plan is under development through collaboration with stakeholders. The SSME is still at an early stage in the ERBC planning process. However, there are experiences and lessons worth sharing and WWF would value feedback on this approach. This paper presents initiatives and strategies being undertaken through the collaboration of WWF offices and partners, which either support ERBC planning or contribute to the biodiversity conservation in the SSME.

DIVERS' WILLINGNESS TO PARTICIPATE IN THE CROWN-OF- THORNS STARFISH CONTROL IN CORAL REEFS OF OKINAWA.

Nakaya, S*. and Yamazato, S. *Research Institute for Subtropics, 1, Asahi-machi, Naha, Okinawa, Japan. Email: seijin@ii-okinawa.ne.jp

Outbreaks of crown-of-thorns starfish have repeatedly occurred on coral reefs of Okinawa, Japan, since the 1960s. Although more than 10 million starfish have been hand-collected, the control efforts were unsuccessful in saving the corals from predation. We found dense populations of starfish (800 starfish/ha) on a few reefs, where corals survived the 1998 severe bleaching and which are, therefore, of great importance as sources of coral larvae and as major attracting diving sites. Former experiences suggest that only a small area of coral reef could be preserved by skilled divers through careful repeated control efforts. We administered a questionnaire to 333 diving shops, marine leisure outlets and fishing cooperatives to identify the characteristics of professional divers who are willing to participate in control programs. Questions including the year of diving experience, frequency of diving, former participation and willingness to participate in control and/or monitoring of the starfish were asked to test a hypothesis suggested by the specialization concept: the more experienced a diver is, the more the diver becomes concerned about conservation of reefs. Results of a logistic regression showed that the hypothesis was not supported and that divers from tourism sector were more willing to participate in control/monitoring programs than those from the fisheries sector. Involving of willing divers may help organize effective system to control and monitor the starfish.

A NETWORK OF COMMUNITY-MANAGED MARINE RESERVES: AN ALTERNATIVE TO PERMANENT NO-TAKE ZONES?

Parks, John E. *, Pomeroy, Robert S. and Salafsky, Nick. *World Resources Institute, 10 G Street NE, Washington DC, 20002 USA. Email: jparks@wri.org**.**

It is estimated that over 70% of coral reefs in the western pacific are at risk of degradation from human activities including destructive fishing, overexploitation, and coastal development. To address such threats, the use of large, permanent no-take zones within coastal ecosystems is increasingly being cited by conservation practitioners as a panacea. At the same time, there is recognition that the assumed sustainability utility behind such measures has yet to be adequately documented, and that these zones often require a degree of managerial and financial resources that may not be available or appropriate everywhere coastal habitats are at risk. As a result, there is increased interest in the exploration of low-cost, low-technology alternatives to supplement more formal, permanent no-take areas. One such potential alternative is the use of networks of smaller reserves that can be temporarily designated and community-managed. An evaluative study of a few western pacific case examples suggests that while such networks may not provide the assumed protective benefits arising from larger, permanent areas, in some instances they can provide short-term benefits in regard to fisheries replenishment and biodiversity maintenance value. A conclusion arising from this evaluation is that the underlying assumptions behind such alternatives need to be more systematically tested across a larger portfolio of western pacific sites. As a consequence, a learning portfolio methodology is proposed that uses science to determine the conditions under which such alternatives operate most effectively.

VOLUNTEER MONITORING IN HAWAII, A SUCCESS STORY

Peck, Sara.* *University of Hawaii Sea Grant Extension Service PO Box 489 Kailua- Kona Hawaii USA 95745. Email: peck@hawaii.edu

Successful volunteer programs result when management biologists, university researchers and educators, in collaboration with volunteers, develop protocols laypersons are willing to master. The goal of this project was to develop a coral reef monitoring program for West Hawaii using volunteers to gather data for human impact and fish population studies, and to record changes over time. Essential requirements were that data collected be useful to managers, the program be cost-effective, and cause minimal impact to the resource. Volunteer protocol formats were developed which can be adapted to other geographic regions: A Human Impact (SCUBA and Snorkel) Survey, a Tide Pool Survey, plus random and reef belt transect survey techniques. Impelling advantages to volunteer participation lie in the potential for long term, frequent observation and strong community support for conservation management. This project was launched in tandem with the establishment of a regional fishery management area unique to Hawaii. State resource managers and university researchers designed an ongoing monitoring program to which volunteer data may provide a supplement. Preliminary survey results show trends that conform to similar surveys undertaken by scientific researchers. Lessons learned with this project will provide insights for both volunteer project managers and resource trustees.

THE MARINE CONSERVATION PROJECT FOR SAN SALVADOR ISLAND: A CASE STUDY OF FISHERIES CO-MANAGEMENT IN THE PHILIPPINES

Pomeroy, Robert S. * and Brenda M. Katon. World Resources Institute, 10 G Street NE, Washington, DC 20002 USA. Email: rpomeroy@wri.org

The case of San Salvador Island, Philippines illustrates how community based coastal resource management can serve as a route to sustainable, equitable and efficient coastal resource and coral reef management and as a route to co-management. The purpose of this paper is to generate insights into responsibility sharing for management over time and the mutually supportive roles of resource users and stakeholders, external agents, and government at various stages in the management process. The paper will present results of one of the few quantitative analyses of the biological, social and economic performance of a coastal resource co-management and coral reef conservation project. The Marine Conservation Project for San Salvador, which was implemented from 1989 to 1993, highlights how the fisher community and the local government jointly regenerated fishery and coral reef resources through a marine reserve and sanctuary. The redefinition of property rights and rules in 1989, along with vigorous law enforcement activities, complemented resource management efforts. Several conclusions are presented which provide insights on the characteristics of successful fisheries co-management arrangements, along with the underlying explanatory variables. These include recognition of resource management problems, specification and enforcement of user rights, provision of legal and policy support, participation of partners and sense of ownership of co-management arrangements, and clarity of objectives.

CONFLICT OF COASTAL MANAGEMENT IN NORTH SULAWESI.

Sapta Putra* and Cottrell, Alison. *Ditjen Bangda – MOHA, School of Tropical Environment Studies and Geography – James Cook University, Townsville Australia. Email: Sapta.Putra@jcu.edu.au

The rapid development of agriculture, reclamation, urban expansion, tourism resorts and the special economic development zone (*Kapet*) in the North Sulawesi, which has mostly occurred on the coast, was achieved primarily at the expense of the environment. Several gold mining and other mineral mining operation over the last four years have contributed tailing mud and sedimentation to the marine water. The degradation of the coastal resources are partly caused by the ambiguity of property rights, and associated problem such as competing resource use, overlapping of planning and conflict of management between interest groups. Despite the ambiguity of property rights and the nature of commons, the ambiguity of the jurisdiction has resulted in coastal resource management becoming a gray area of management. Jurisdiction is subject to the interpretation of the stakeholders. Every concerned agency will claim that the coastal resource is under its jurisdiction, once it becomes important to the agency and a significant amount of money is involved in the coastal resource business, such as license fee, tax and commission. But the agency will deny any association once the resource has been degraded and is no longer important. Coastal resource is neither common nor public property. This poorly defines property regime leads to conflict of coastal management, and jeopardize the sustainable of coastal resources in North Sulawesi Province.

PUTTING THE "ACTION" INTO THE U.S. NATIONAL ACTION PLAN TO CONSERVE CORAL REEFS – THE ROLE OF NON-GOVERNMENTAL ORGANIZATIONS (NGOS)

Raney, Dave,* *Pacific NGO Representative to the U.S. Coral Reef Task Force, 1621 Mikahala Way, Honolulu, Hawaii 96816, USA. Email: d_raney@aloha.net

On March 2, 2000, the U.S. Coral Reef Task Force adopted the National Action Plan (the Plan) to Conserve Coral Reefs, setting a goal of protecting twenty percent of U.S. reefs as no-take marine protected areas by the year 2010. Effective implementation of the Plan will depend on adequate funding by Congress, the will of federal agencies to comply with policies prohibiting adverse impacts on coral reef ecosystems, the cooperation of state and territorial resource management agencies, and the support of the general public. This paper discusses implementation of the National Action Plan to Conserve Coral Reefs as a case study exploring the roles of NGOs in the political processes controlling successful implementation of the Plan. Little resistance to the Plan's mapping, assessment, and monitoring projects is expected, but opposition has emerged to plans for establishing new no-take marine protected areas and other proposed actions threatening to change the status quo. Jurisdictional disputes over the powers of the two lead agencies of the Task Force to regulate fishing resources stalled key legislation needed to fund implementation of the Plan. The strategy, tactics and experiences of NGOs in responding to these and other challenges will be presented and discussed.

INTEGRATING VOLUNTEER MONITORING WITH CORAL REEF RESOURCE MANAGEMENT IN HAWAI`I.

Raney, Dave * and Gulko, David A. *Sierra Club, 1621 Mikahala Way, Honolulu, Hawaii 96816, USA. Email: d_raney@aloha.net

To be of ultimate value, coral reef monitoring must be linked to management actions. Volunteers can play an important role in augmenting available resources of management agencies. This paper documents cooperative efforts underway between volunteer groups and the Hawai`i Division of Aquatic Resources to integrate efforts for coral reef ecosystem management. Expected products of these efforts include a manual for use by volunteer groups seeking to implement coral reef assessment or monitoring programs such as Reef Check. The manual will include protocols to be followed for diver safety and protection of the marine resources potentially impacted by volunteer activities. It will also provide guidance for selection of sites to be assessed or monitored, identification of site-specific stressors and relevant parameters for monitoring, and a suite of monitoring protocols appropriate for volunteers. Linkages between volunteer monitoring activities and management actions, such as procedures for identification, documentation, and reporting of illegal mooring activities by a third party, also will be developed. Depending upon the nature of potential stressors, data gathered by volunteers may include more than the customary measurements obtained from reef transects, such as data on the number of recreational divers using a site within a specified time. Successful integration of volunteer monitoring activities with management agency actions in Hawai`i appears possible and mutually beneficial.

HOW MUCH DAMAGE DO DIVERS/SNORKELERS DO TO CORALS?

Reboton, C.* and H.P. Calumpong. *Marine Laboratory, Silliman University, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

Monthly monitoring of corals in Apo I. Protected Landscape and Seascape was conducted since April 1999 to determine the amount of damage caused by divers/snorkelers. This is to aid the Apo Island Protected Area Management Board in determining the number of divers/snorkelers that the 11-hectare marine sanctuary can support. Accumulated fin damage to living hard coral from April 1999 to January 2000 was 10.73%. Total number of divers/snorkelers in the sanctuary during the same period was 7,312.

PROSPECTS OF COMMUNITY BASED CERTIFICATION OF BLUE CRAB FISHERY IN NEGROS OCCIDENTAL, PHILIPPINES.

Romero, Filemon G. *, Katrina Jayme , Ria Apostol and Julia Novy.WWF-Philippines, 23 Maalindog St. U.P. Village Diliman Q.C. Philippines. Email: mromero@wwf-phil.org.ph

Certification using market forces as an instrument to promote sustainable fishing for blue crabs (mainly *Portunus pelagicus*) is being tested in three selected coastal communities in Negros Occidental, central Philippines. Assessment and survey studies were conducted to determine the community and fisheries profile, existing management, pricing and market structures. An in-depth assessment on the health of the blue crab fishery and its environmental impacts served as input to the development of a management plan. This process helped determine the potential of this fishery to be certified based on the principles and criteria of the Marine Stewardship Council. Identified problems and issues were the following: insufficient information on the size of blue crab population, conflicts on resource use, destructive fishing practices, weak fishermen's organizations, insufficient local legislation, and ineffective law enforcement. However, some enabling factors like the willingness of the fisherfolk and local government officials to buy into the process, environment friendly gears used by fishers, support of processors, and the presence of legal institutions and management structures provide encouraging prospects for certification.

COMMUNITY-BASED STRATEGIES FOR THE SUSTAINABLE MANAGEMENT OF MARINE PROTECTED AREA.

Salmo, S.G. III*, Juinio-Meñez, Ma. Antonette R.; and Aliño, Porfirio M. *Marine Fisheries Resources Management Project, Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101 Philippines. Email: jon@msi01.cs.upd.edu.ph

The community-based strategies in the implementation of a marine protected area (MPA) in Bolinao, Pangasinan (northwestern Luzon, Philippines) is presented. The factors necessary to sustain the successful implementation of a community-managed MPA involved heightening of environmental awareness, training, information campaigns and legal/institutional and financial assistance. The empowerment of a people's organization (PO) played an important role in sustaining the management of the MPA. Among the activities conducted by the PO are sponsoring information campaigns, forging multi-sectoral collaboration, lobbying and networking to advocate institutional assistance and patrolling of the MPA. The PO are also conducting regular monitoring of the MPA (e.g. benthic lifeform, fish visual census, fish catch). Results of recent monitoring compared to the baseline data reveal improved % coral cover and increased fish biomass. Overall, the community-based strategies in the management of the MPA has proven to be very resilient indicating a high possibility of sustaining its successes despite some obstacles and shortcomings. Thus, this case study will draw on the lessons from the experience of a community-managed MPA.

THE GROUP DISCUSSION AS A FRAMEWORK FOR INCORPORATING STAKEHOLDER PARTICPATION IN MARINE RESOURCE MANAGEMENT: THE CASE OF PULAU TIOMAN, MALAYSIA

Samarasekara, Vidhisha N*. *Head Marine Unit WWF Malaysia - 49 Jalan SS23/15 Taman Sea, 47301 Petaling Jaya MALAYSIA. Email: svidhisha@wwfnet.org

This paper describes the use of the group discussion as a methodology designed to enhance decision making in marine and coastal resources management. This approach aims to develop a decision-making tool which enables different stakeholder perspectives and values to be incorporated in marine resources management. This approach has been used in Pulau Tioman Marine Park a very popular tourist destination located off the southern tip of Peninsular Malaysia, on the southeast state of Pahang. The main attraction of the Marine Park to tourists is it coral reefs, which cater mostly for snorkellers, although some diving activity does occur in the area. The Marine Park has seen a tremendous increase in visitor numbers over the years. As such the reefs are under increasing pressure from tourism development and related activities. The resources in this marine park are crucial in terms of their economic and recreational linkages and pre-liminary use of this methodology has revealed that different perceptions and values of different actors creates an opportunity for decision making and management based on consensus rather than conflict. The paper argues that such an approach is likely to lead to sustainable resource management in a variety of contexts.

EFFORTS OF ISLAND WOMEN IN REEF MANAGEMENT: THE CASE OF CABACONGAN WOMEN'S ASSOCIATION, CABILAO ISLAND, BOHOL AND CAW-OY WOMEN'S ORGANIZATION, OLANGO ISLAND, CEBU, PHILIPPINES

Sotto, F.*, Laron, C. and T.Heeger. *University of San Carlos -Marine Biology Section- Cebu City 6000, Cebu, Philippines

In the island communities of the Philippines, women performed a range of activities related to fishing. Traditionally, they have been caring for and harvesting resources in coral reefs such as molluscs, crustaceans and seaweeds. Activities of the two women's organizations in the islands of Cabilao and Olango, Philippines related to protection and management of reef resources have been documented. Conscious of the fact that their reef resources are dwindling largely due to illegal fishing and overharvesting, the Cabacongan Women's Organization with 35 members took action in guarding their 12-ha marine sanctuary in support of their fisher husbands. While the Caw-oy Women's Organization of 40 members are involved in coral farming activities specifically the tying of coral fragments on the limestone substrates two times a week With this efforts and consciousness, women are major players and active participants in managing and developing the reef and its resources.

USING SERVICE LEARNING TO CREATE PARTNERSHIPS BETWEEN EDUCATION AND CONSERVATION.

Stanton, Frank G.*. *Leeward Community College, 96-045 Ala Ike, Pearl City, Hawaii, 96782, Usa. Email: fstanton@hawaii.edu

Service Learning is a program that promotes community service as part of the educational process with the intent of building stronger ties between campuses and community groups. When incorporated into biology courses, it provides an excellent way to reinforce biological concepts with practical experience that benefits the community. Theoretical discussions about biodiversity conservation in the classroom are made real by having students participate in conservation projects that reinforce learning and promote student participation the community. I have used Service Learning as part of lecture courses to reinforce learning and to promote participation in a local coastal restoration program. This has resulted in students returning with family and friends to continue involvement after the course is over. A related laboratory course has become a long term monitoring program that has allowed the students access to facilities normally not open to the public. In return the cooperating community and government organizations that are responsible for managing biodiversity receive the help of trained "volunteers" that are supervised while the data is collected and analyzed. The laboratory course provides the training and the continuity in the monitoring program benefiting both the students and the conservation efforts. Service Learning is a very flexible program that can be used in many creative ways to promote cooperation between schools, government and civic organizations, and to promote awareness of biodiversity issues through education and participation.

COMMUNITY-BASED MANAGEMENT, HAWAIIAN STYLE.

Stepath, Carl M.*, *James Cook University, Tropical Environmental Studies and Geography, Townsville, Qld 4811, Australia. Email: Carl.Stepath@jcu.edu.au

Many island people depend on the ocean for subsistence, and marine protected areas are an integral part of maintaining local fisheries for future generations. The Hui o Maka'ainana and Save Our Seas organizations have facilitated this program to provide a model for the protection, management, and stewardship of Hawaiian Watersheds. In Hawaii, the Ahupua'a is a unique catchment concept, as it includes the coral reef. This traditional Hawaiian management technique was adopted in this project. The aim is to use modified traditional Hawaiian beliefs and community input, in a contemporary management setting. This allows communities, government agencies, scientists and academics to empower people to manage marine resources at a community level. Education about ecological systems, monitoring, working with scientists and assisting governmental resource agencies accomplishes this goal. The idea was to establish a community group to conserve and manage the coral reef area, and transfer knowledge and skills to locals through training about marine resources. Another significant result is the creation of fish breeding areas, reserve areas for ecologically sound fishing, an increase in fish diversity, and documentation about the current fisheries situation for the future. This Ahupua'a program is providing communities the opportunity to manage their marine resource through ideas of their own in conjunction with the Hawaii State park system.

AWARENESS AND COMMUNITY CORAL REEF MONITORING.

Stepath, Carl M.* *James Cook University, Tropical Environmental Studies & Geography, Townsville, Qld 4811, Australia. Email: Carl.Stepath@jcu.edu.au

Coral reef monitoring is critical for resource management; and increasingly volunteers are participating in data collection. Many questions have been raised about the advantages and reliability of using volunteers. Save Our Seas, an NGO, conducted a community monitoring program, on the island of Kauai, which provided valuable information about the contribution of volunteer programs in educating and raising awareness about coral reef issues. Collecting coral reef monitoring data actually increased local awareness, improved students' attitudes towards coral resources and educated them in science and coral reef ecology. If these advantages of working with volunteers are utilized, it will help in monitoring fieldwork, data could concurrently be improved, community based resource management promoted, while providing much needed assistance on the local reefs for information. At this time, no other studies that measure the amount of awareness generated by monitoring could be identified, so this is an important baseline. Recommendations included increasing communication between scientific, managerial, and local communities, and promoting community based monitoring.

THE CONSENSUS AMONG STAKEHOLDERS ON MARINE RESOURCES MANAGEMENT IN TOGEAN ISLANDS, CENTRAL SULAWESI, INDONESIA.

Sundjaya*, Conservation International Indonesia Program, Jl. Taman Margasatwa No. 61, Jakarta Selatan, Indonesia. Email: sunjaya@conservation.or.id

Togean Islands on Gulf of Tomini, Central Sulawesi, has the high unique biodiversity, both in terrestrial and marine area. Local people depend on nature resources use in reaching their needs through the traditional farming and fishing. They have less accessibility to nature resource in order to increase their quality of life, while some outside investors, with vary interests, are exploiting nature resource in Togean. Therefor, conflict of interests on use are occurred, mainly between local people and private sectors that backed up by local government. The destructive fishing is the shortcut way in marginalization on marine resource use. The Consortium of the Integrated Development of Togean Islands, that established by Yabshi and Conservation International, has been working to develop the multi-purpose nature resource management that built by consensus between local community and other stakeholders based on equality and conservation principals. The equity is the impossible thing as long as local people have no equal position in bargaining process with other stakeholders. Forum Masyarakat Togean (Forum of the People of Togeans) is the one of component, that facilitated by Consortium, where the local people able to voice their aspiration to desicion making process on nature resource management. Forum is directed to become the conservation infrastructure that merge the power of all social groups at village level, such as: Lembaga Adat, fihers, peasants, women, local enterpreneurs, etc. At the future, Forum will strengthen local community to face decentralization isue and prepare people to participate in nature resource management sustainably.

COMMUNITY REFUGIA MANAGEMENT IN FIJI.

Tawake Alifereti* and Bill Aalbersberg. *The University of the South Pacific, Suva, Fiji. Email: Aalbersberg@usp.ac.fj.

Marine biodiversity is increasingly under threat in the South Pacific. Through a Biodiversity Conservation Network (BCN) project people from the Verata district in Fiji have developed skills to help address these threats. Using participatory techniques communities determined threats and developed an integrated marine resource management plan. Overharvesting was identified as a key threat and the designation of “tabu” or refuge areas as the management technique to counter the threat. Community members were also trained to perform participatory aquatic resource transects (PART) to judge the effectiveness of the use of “tabu” sites. Two keystone species, mud lobsters (*Thallasia anomala*) and “kaikoso” clams (*Anadara sp.*) were monitored. In the longest time series to date (18 months) there has been a 600% increase in “kaikoso” population in the refuge area and a 200% increase in the harvested areas indicating the success of these interventions. Consequently, new refuge areas have been set up in other Verata villages and monitored by the community. Efforts are also underway to replicate the “Verata model” in other areas in Fiji. This will help determine conditions under which the declaration and monitoring of community-managed fishery refugia can be an effective tool in marine biodiversity conservation.

SOLOMON ISLANDS DEVELOPMENT TRUST – COMMUNITY RUN TAMBU SITE AND CORAL GARDENS IN MALAITA PROVINCE, SOLOMON ISLANDS.

Waleani, Donald, Hora, Lucy.* *Solomon Islands Development Trust P.O. Box 147 Honiara, Solomon Islands Email: sidtcid@solomon.com.sb

Mala'afe Coral Project is a family managed project. The owner of the island has announced the project during the Christmas period, 1999. The tambu site, which means an area that is out of bounds for a period of time, will last for about one year. The reason for the study is to plant the corals and preserve the area so that it will be the home for different types of fish species. This is a change from how it was before, demonstrating the fact that the customary practice of tambu sites, or protected areas, can be a useful tool in conservation efforts today. As for conclusion, the owner of the island which has been made tambu just wants to show an example for others in the community to see the result of preserving the natural resources and encourage them to do the same.

INTERPRETIVE EDUCATION AS A CORAL REEF CONSERVATION TOOL AT HANAUMA BAY NATURE PRESERVE, HAWAII, USA.

Wanger, Jolie R.* *University of Hawaii at Manoa, Department of Geography, SSB 445, 2424 Maile Way, Honolulu, HI 96822, USA, Email: wanger@hawaii.edu

As visitation of marine protected areas, specifically of coral reefs, increases throughout the world resource managers are seeking ways of managing the behavior of people within these areas as one aspect of conservation. One of the techniques widely utilized is interpretive education such as visitor centers, signs, and interpretive talks by trained educators. However, it is unclear to what degree such programs are effective as management and conservation tools. In addition, many believe that what is learned through such educational exposure may be absorbed and taken home, contributing to a more global understanding of the coral reef environment. This study evaluates the degree of effectiveness of the Hanauma Bay Education Program at Hanauma Bay Nature Preserve, Oahu, Hawaii in increasing awareness of the coral reef environment and appropriate behavior while visiting Hanauma Bay and coral reefs throughout the world. Visitor surveys, staff and volunteer surveys and interviews were conducted, supplemented by direct observation and quantification of visitor behavior (walking on reef, feeding fish, etc.) Results were analyzed to assess the level of awareness among visitors regarding park rules, appropriate behavior, and safety, and, to assess the level of general knowledge relating to the coral reef environment. Preliminary conclusions indicate that education efforts appear to contribute to increased awareness of rules and appropriate behavior within the preserve.

ESTABLISHING A STRATEGIC FRAMEWORK FOR CORAL REEF MANAGEMENT IN LAMPUNG, INDONESIA.

Wiryawan, Budy*, Bengen, Dietrich G. and Dutton, Ian M.. *Center for Coastal and Marine Resources Studies, IPB, Proyek Pesisir, Jl. Sutan Syahrir No. 4, Bandar Lampung, Indonesia, 35231. Email crmp-lpg@indo.net.id

Lampung province, contains a diverse range of coastal and marine ecosystems, including extensive fringing reefs. When Proyek Pesisir, part of the USAID-BAPPENAS Indonesian Natural Resources Management program, first commenced work in the Lampung in early 1998, very little was known about the coastal resources of the Province. Equally significantly, given the large number of marine resource-dependent industries along Lampung's 1,100-kilometer coastline, no formal management system was in place. As a consequence, there is widespread resource degradation, mounting conflict between resource users and no framework in place to coordinate coastal development activities. Working closely with local government and non-government organizations, including the University of Lampung, the first step in the integrated coastal management process involved development of an Atlas of coastal resources of Lampung and the second step development of a provincial level Coastal Strategic Plan. This paper describes the process for development of the Coastal Atlas and Strategic Plan and outlines the roles both play in coral reef management. By linking the Atlas and Strategic Plan, a comprehensive planning process has been initiated which will ultimately enable provincial stakeholders to address key local issues.

"DE-MYSTIFYING THE GLOBAL ENVIRONMENT FACILITY": A REVIEW OF LESSONS LEARNED IN PROJECT DESIGN AND IMPLMENTATION FOR G.E.F. CORAL REEF BIODIVERSITY CONSERVATION PROJECTS IN ERITREA, EGYPT, SAMOA, SOLOMON ISLANDS, TANZANIA AND VIETNAM.

Wilson, A. Meriwether* and Kelleher, Graeme. *Department of Geology, Edinburgh University, West Mains Road, Edinburgh EH9 3JW, United Kingdom. Email: Meriwether.Wilson@ed.ac.uk

The global environment facility (gef), established in the early 1990s, is now the world's largest single funding source for biodiversity conservation and is at present the funding instrument for implementing the convention on biological diversity (cbd). Both the gef and the cbd increasingly support measures to monitor, conserve and restore coral reef ecosystems in 'developing countries', with a strong emphasis on in-situ conservation of reef-associated habitats and species through the establishment of marine protected areas (mpas). While gef funding is grant-based it is also a fundamental leverage tool for additional funding through both government and private sector sources to support coral reef related research and conservation. Gef is therefore highly competitive and rigorous in its application of acceptable project criteria and requires ongoing review of effectiveness. This paper summarises the findings from an initial review of six gef supported projects which illustrate various stages of implementation during the past 10 years, and collectively address a spectrum of coral reef conservation and marine protected area challenges across the pacific, asia, east africa and the middle east.

BREAKING THE CYCLE OF RESOURCE OVER-USE AND REEF DEGRADATION: A CASE STUDY FROM SABAH, MALAYSIA.

Wood, Elizabeth*, Mahmud Mansor, Saini Suliansa and Ajirin Angkaji
***Marine Conservation Society, 9 Gloucester Road, Ross-on-Wye, Herefordshire HR9 5BU. UK. Email:** ewood@globalnet.co.uk

The importance of the Bodgaya group of islands off Semporna on the east coast of Sabah, Malaysia has been recognised for decades. So too has the need for measures to conserve biodiversity, manage the over-exploited resources and prevent further degradation of the reefs as a result of fish blasting and other disturbances. The first proposal to establish a marine park was made in 1977 and a second in 1992, but these were rejected mainly because local people feared a loss of fishing rights, lands and livelihoods. In 1998 a new programme was launched, involving a strong alliance between NGOs (Marine Conservation Society and World Wide Fund for Nature Malaysia) and Sabah Parks, and involving many other institutions within Sabah, together with local communities. The goal of the Semporna Islands Project is to promote the concept and potential benefits of establishing a marine protected area at the site, and to produce a management plan. This paper explains the strategies adopted to turn a 'no' vote into a 'yes' vote, to establish a shift from over-use to sustainable use, to promote reef recovery and to ensure conservation of biodiversity.

INTEGRATED COASTAL MANAGEMENT IN THE PHILIPPINES: THE PLANNING PROCESS FOR BAIS BAY, NEGROS ORIENTAL

Yambao, Alexis C.* and Bayer, Thomas G. *Coastal Resource Management Project, 5th Floor CIFC Towers, J. Luna Corner Humabon Streets, Cebu City 6000, Philippines, Email: crmhot@mozcom.com

The philippines consists of over 7,000 islands, most of which have extensive coral reefs or coral-related communities. This paper documents the on-going integrated coastal management process occurring in three adjacent municipalities along the bais bay in the province of negros oriental. A summary of environmental and socioeconomic impacts along the bay will be presented, as well as the resulting issues and prioritized issues. Community participation and cooperation of all institutions involved in coastal resource management are regarded as the key elements of planned sustainable integrated coastal management in this area. This paper outlines the strategic planning process within the overall framework of coastal management as a government service. The objectives, programs and achievements, in addition to the fruitful networking of the participating institutions, will be presented. The lessons learned from this experience will be summarized, including: integrated forms of management involving various stakeholders, and addressing numerous intertwined issues, will save the philippine coral reefs and other coastal resources.

Session C3: Communicating Reef Science

COMMUNITY EDUCATION: JOINING FORCES TO PRESERVE CORAL REEFS AND A WAY OF LIFE.

Anspacher, G. *, S. McCafferty, G. Davis and R. Richmond. University of Guam Marine Lab, UOG Station, Mangilao, GU 96923 USA Email: gila@efn.org

The conservation of the world's coral reefs depends upon direct involvement of all players, from scientists to the general public. In order for conservation to be actualized, tropical island communities need to be informed and concerned. To accomplish this, scientific information needs to be made available in these communities in a usable and accessible form. One approach being taken in the Mariana Islands is a collaborative effort among educational institutions, resource managers, the tourism industry and the stakeholders to provide information for the general public, with a focus on young people, on the biology, ecology and conservation of coral reefs. This effort has spawned a variety of projects that center upon direct community participation in meeting the goals of coral reef education and preservation. These projects include an educational video and a CD-ROM aimed at high school students, as well as an educational outreach and restoration project aimed at both the local community and tourists, focusing on a new marine preserve that is an economically valuable resource. The process of developing these projects with direct community participation is the focus. While specific components may not be completely successful, the participation and associated education ensures the process will be a success. The collaboration and participation of scientists, educators, resource managers and the general public in community education projects will make it possible to achieve conservation goals.

SCIENTISTS ARE FROM VENUS, JOURNALISTS ARE FROM MARS

Baron N.* Nancy Baron, c/o Jessica Brown SeaWeb 1731 Connecticut Ave., NW, Suite 400 Washington, DC 20009 Telephone: (202) 483-9570 Email: c/o Jessica Brown, jbrown@seaweb.org

Drawing on her previous experience as a journalist specializing in marine issues, award winning science writer Nancy Baron (SeaWeb's Ocean Science Director) will share perspectives "from the other side," and provide tips on how to bridge the gap. This session will arm you with some simple tools for your next interview by covering the following: What do media want? How to prepare for an interview. Do's and don'ts. "Managing " your message, and " what you can and can't expect from the media."

INFORMATION AND COMMUNICATIONS TECHNOLOGIES, A VEHICLE IN MANAGING SOUTH EAST ASIA'S OCEANS AND COASTS

Bonto, J.M.A.* *World Wildlife Fund-Philippines, 23 Maalindog St., U.P. Village, Diliman, Quezon City 1101, Philippines. Email: jbonto@wwf-phil.org.ph

The absence of relevant, timely, and easily accessible marine resources information prompted the World Wildlife Fund Philippines to develop a computer-based system that could be used for policy analysis and information base to support the planning and management of the South East Asia's oceans and coasts. Better known as the South East Asia Marine Resources Information System, SEAMARIS uses state-of-the-art computer geographic and modeling systems to create an interactive, user-friendly means by which decision makers can gain an understanding of the potential impacts of specific policies on marine resources. It is also aimed at improving the current system of collection and delivery of marine resources information and correlating this information to assist in evaluating the constraints and opportunities in the management of coastal and marine areas. This is made possible by dramatic developments in information technology, geographic information system software, multimedia technology, and the Internet. Initial work of SEAMARIS focused on the Sulu and Sulawesi Seas covering the areas of Southern Philippines, Malaysia, and Indonesia. Upon completion, SEAMARIS will provide: 1) A cost efficient method of processing large quantities of marine and coastal information in an interactive mode and Geographic Information System format. 2) Large scale map overlays for a clearer understanding among policy makers of the transnational, interdependent character of the sea environment and the resources and activities it harbors and supports. 3) Marine awareness and education enhancement and support program.

REPORTING MONITORING RESULTS WHILE THEY ARE STILL NEWS.

Coleman.G.* *Australian Institute of Marine Science. PMB 3, Townsville, 4810. Australia. Email: g.coleman@aims.gov.au

Collecting data is just one step in the operation of an effective monitoring program. The results of monitoring are most useful, and sometimes only useful, if they are analysed and presented to users quickly. Monitoring programs usually collect the same types of information repeatedly which allows reports to follow a standard format. This presentation uses the Australian Institute of Marine Science Long Term Monitoring Program on the Great Barrier Reef as an example. The structure of reports is evolving, but there is as much continuity as possible. At the same time, we are flexible enough that we can say something which does not fit our structure. First, data entry routines include automatic error traps and statistical routines that check for improbable values. Then simple plots based on raw data are combined with observers' initial impression and published on the internet within one week of a field trip. More complete analyses of results are produced annually. Batch processes use standard queries to select data from the database, run standard analyses and produce summary plots. The content of much of our reporting, including text, is stored in a database so that it can be reformatted automatically for printing, for presentation on the Web or other formats as needs arise.

THE INTERNATIONAL CORAL REEF INFORMATION NETWORK (ICRIN): NEW METHODS AND OPPORTUNITIES FOR CORAL REEF SCIENTISTS TO REACH IMPORTANT SEGMENTS OF THE PUBLIC.

Colwell S.* *Executive Director, The Coral Reef Alliance (CORAL), 2014 Shattuck Avenue, Berkeley, California, 94704 USA,
Email: scolwell@coral.org

Many significant studies and reports on coral reefs do not reach an audience beyond the scientific community. A primary goal of International Coral Reef Information Network (ICRIN) is to find new ways to reach government and industry leaders, conservation groups, funding organizations and other influential segments of the public with important scientific information about coral reefs. ICRIN's public awareness activities will reach hundreds of millions of people in the next four years by using a wide array of communications methods including television and radio broadcasts, press briefings, websites, and multi-lingual brochures, videos and educational materials for schools and communities. ICRIN will provide coral reef scientists with an unprecedented opportunity to reach significant audiences – including conservation organizations, government agencies, foundations and other potential sources of funding. ICRIN is sponsored by the International Coral Reef Initiative (ICRI) – which is composed of member nations from around the world, multilateral organizations such as the United Nations Environmental Programme and the World Bank, the International Society for Reef Studies (ISRS) and other non-governmental organizations. ICRIN will work in concert with the outreach and education programs of the United States Coral Reef Task Force and the International Coral Reef Action Network (ICRAN).

WHAT THE PUBLIC KNOWS, WHAT WE THOUGHT THEY KNEW, AND WHAT NEXT ON CORALS.

Heckman M.B.* *Waikiki Aquarium/ University Of Hawai'i - Manoa
2777 Kalakaua Avenue Honolulu, HI 96815 USA Email: mheckman@hawaii.edu

The Waikiki Aquarium is a small conservation-oriented aquarium with a strong history of coral research. Recently, a new exhibit entitled "Corals Are Alive" was created to help educate the public about coral biology. The exhibit included hands on, video and live coral components. A formal evaluation of the exhibit examined visitor knowledge of coral biology before and after the exhibit, impacts of a regular visit versus a visit with a live interpretive show, and a video evaluation of flow pattern, wait time and element preference. Results showed statistically significant improvement in understanding of coral biology from a visit to the exhibit, supported the use of a live interpreter, and gave useful information on areas of public familiarity (and unfamiliarity) with coral biology. Research on the exhibit continues. Although small and limited in funds, the Waikiki Aquarium has found that simple research methods can help in the accurate and effective communication of reef science.

THE CORAL COROLLARY: THE LIMITS OF SCIENCE-BASED GOVERNANCE IN CORAL REEF MANAGEMENT.

Hempel, Lamont C.. University of Redlands, California, 92373-0999, USA. Email: hempel@uor.edu

The world's coral reef ecosystems are experiencing increased stress from a combination of rising CO_2 levels at the ocean's surface, temperature increases, sea level rise, coastal development, associated human population pressures, and rising per capita consumption of reef-related organisms and materials. The increasing rate and magnitude of coral bleaching events has triggered alarm among some marine scientists and resource managers. The predictable response has been to develop or expand coral monitoring programs, policy initiatives, scientific task forces, and public outreach and education programs. Although science-driven policy and management response strategies are clearly called for, insufficient attention has been directed at the social, political, and cultural barriers to science-led responses. This paper draws lessons about target group behavior from the literature on international environmental policy and resource management. These lessons that can be applied in the design and implementation of coral reef protection strategies. In particular, the author examines the social construction of target groups, the political conversion of marine science into policy aimed at those groups, and the role of the arts and electronic media in assisting marine policy makers in changing target group behavior through the use of visual symbols and novel techniques of cross-cultural communication.

BUILDING FOR THE FUTURE – PROMOTING ACTIVE INVOLVEMENT OF YOUTH IN CORAL REEF ECOSYSTEM PROTECTION.

Zicus Sandra A.. Dept. of Geography, University of Hawaii at Manoa, Honolulu, Hawaii, USA. E-mail address: zicus@hawaii.edu

Coral reefs around the world are in danger. According to data compiled by the World Resources Institute, 58% of the world's coral reefs are potentially threatened by human activities. In Southeast Asia, center of world marine biodiversity, more than 80% are at risk. Experience in many countries has shown that community-based coastal resource management projects, and the establishment of marine protected areas, can be effective tools to use for coral reef ecosystem protection. However, there is often little emphasis on the role of youth in these community development and resource management efforts. Social science research and experiences from around the world indicate that active youth participation in community projects fosters a long-term sense of responsibility towards the natural environment. To date, little analysis has been done of the actual effectiveness of existing youth curricula and programs. Ongoing research into youth-oriented coral reef projects in Hawaii, the Philippines, and Indonesia is investigating the key socio-cultural, political, economic, and pedagogical factors crucial to the long-term success of these youth initiatives.

Session C4: A Sustainable Trade in Marine Ornamentals: Linking Reef Science Conservation and Use

INTERNATIONAL TRADE IN CITES-LISTED CORALS AND LIVE ROCK.

Bruckner, A.W.*and Daves, N.K. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: andy.bruckner@noaa.gov

Stony corals and reef substrate (live rock) enter the international trade as aquarium organisms, curios, jewelry, and for medical purposes. All stony corals and live rock are listed on Appendix II of the CITES and can be traded commercially provided that the exporting country finds that the take does not constitute a significant risk to the species, or its role in the ecosystem. Although the total trade in coral reef fishes and most other ornamental organisms is unknown, CITES provides a means to monitor the trade in stony corals through annual reports submitted by exporting and importing countries. The volume of coral skeletons in trade has remained fairly constant since 1993, while the trade in live coral and live rock has increased annually at a rate of 12-30%. In 1997 over 775,000 kilograms and 1.6 million items of coral were traded, with most from Indonesia and Fiji and over 80% imported by the United States. The most common genera of live coral in trade are *Euphyllia*, *Goniopora*, *Catalaphyllia*, *Acropora*, *Trachyphyllia* and *Plerogyra* respectively; with the exception of *Acropora*, these taxa are slow-growing, and may be locally uncommon or are vulnerable to overexploitation due to their life history. Branching corals such as *Acropora* and *Pocillopora* are predominantly traded as curios; although these species are abundant, and exhibit faster rates of growth and greater recruitment success, they are traded at a larger size, and are more susceptible to mortality from physical damage, predation and bleaching.

ADDRESSING INFORMATION NEEDS IN THE MARINE AQUARIUM INDUSTRY.

Green, E.P*. and Holthus, P. *World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, United Kingdom. Email: ed.green@wcmc.org.uk

Economic exploitation of ornamental marine resources by the countries of North America, Europe and the Far East has had serious impacts on coral reefs. This has fuelled some sensational journalism, and driven the trade in coral reef organisms far up the political agenda. However the aquarium trade also provides employment for very many people in the source countries, people who live in communities with few alternative sources of income. Some simple estimates of the magnitude and taxonomic composition of the trade exist (15-20 million fish per year may be traded over approximately 1000 species) but the future management of the marine ornamental industry should be based on sound quantitative data. The Marine Ornamentals Information System meets this need through an industry-wide self-monitoring system closely linked to product certification: wholesale importers and exporters of marine ornamental species have contributed their sales records to a central database. This has permitted a preliminary survey of the species in trade and will form the basis of the first quantitative analyses of the trade in the organisms not listed under the Convention on International Trade in Endangered Species of Flora and Fauna (CITES). It will eventually possible to assess the wider impacts of the trade by combining sales data and biological information (the life stage at which individual species are traded, known life cycle parameters, longevity in aquariums, biogeographical range, collection methods and conservation status, *etc*.).

CAPTURE AND CULTURE OF POSTLARVAL CORAL REEF FISHES IN SOLOMON ISLANDS

Hair, C.A.*; Bell, J.D.; Doherty, P.J.; Lam, M. ICLARM Coastal Aquaculture Centre. PO Box 438 Honiara, Solomon Islands. Email: chair@iclarm.org.sb

Coral reef fishes are caught and sold live for the aquarium and live reef fish food (LRFT) trades. Both fisheries have contributed to overfishing in some areas (especially with respect to the LRFT) and to habitat degradation due to destructive fishing techniques such as cyanide fishing. An ICLARM project in Solomon Islands is examining the feasibility of supplying these markets by harvesting postlarval coral reef fishes and rearing them in captivity, thus developing a new artisanal fishery. Light traps and crest nets have been used to capture fish for culture. We present six months of data, from November 1999 to April 2000, comparing the two methods for harvesting species of value. At least 35 families were taken by both collection techniques but several other families were caught predominantly by only one method and a greater species diversity was sampled by light traps. Both light traps and crest nets produced juveniles fit for culture; more than 60 species belonging to 20 families were grown out successfully after capture. Most of the cultured fish were of value to the aquarium trade and only low numbers were suitable for the LRFT. The cultured fish were well received by local aquarium fish exporters.

CORAL PROPAGATION IN SOUTH AFRICA.

Jordan I.E. * and M. H. Schleyer. *Oceanographic Research Institute, P.O. Box 10712, Marine Parade, Durban 4056, South Africa. Email: seaworld@dbn.lia.net

The marine aquarium industry has expanded greatly during the past decade. A major disadvantage in this industry is that most animals in aquaria are collected in the wild. Live corals are prized by aquarists and are commonly chiseled off reefs that are already degraded by pollution or excessive tourism. Poaching is fairly common, even though restrictions are becoming more stringent. In addition, many specimens die from transport stress or placement in unsuitable aquaria. We believe that the future of a sustainable supply of corals for the aquarium trade lies in their artificial propagation with the provision of information on their maintenance when they are sold. This project was initiated to supply the market with a reliable source of suitable aquarium species, focusing on the culture of South African corals. An open seawater tank system consisting of thirteen 800 l, free-standing, semi-transparent tanks was constructed for this purpose. Coral specimens were collected at Sodwana Bay and transported to the holding facility. The corals were left for a period of two months to allow them to acclimatise. Several cutting and attachment experiments were conducted. The twelve most suitable hard corals were selected for culture from the 36 species tested. Current flow, feeding and light were manipulated to obtain the optimum growth conditions. Results will be presented on various attachment techniques, including electrolysis; the most suitable current regimes; the best artificial feeds; and the most appropriate light regime for each species. These will be discussed in terms of subculture growth rates monitored using the buoyant weight technique.

A REVIEW OF THE TROPICAL LIVE FISH INDUSTRY OF THE MALDIVES.

Saleem, Mariyam R.* and Ibrahim Naeem *Marine Research Centre, Ministry of Fisheries Agriculture and Marine Resources, Male, Republic of Maldives. Email: marine@fishagri.gov.mv

The aquarium fishery of the Maldives started around 1979 and is predominantly export oriented. Previously the fishery was concentrated around Malé atoll but recently has spread to atolls further out such as the northern most atoll of Haa Alifu. Aquarium fish collection is allowed in all areas except the "housereefs" of tourist resorts and the protected dive sites. About 114 species of live tropical fish are exported of which 20 species makes up about 75% of the export. At present there are 4 licensed exporters compared with 17 in 1996. However, two of the four companies dominate the trade. The largest market is in Sri Lanka followed closely by the European market (mainly U.K and Germany). In 1999, more than 160,000 fish were exported earning about 3.5 million Rufiya (~ US$300,000). There was a sharp decline in the export of live tropical fish in 1998 and 1999 exporting about half the quantity of that of 1996 and 1997. This trend is presumably due to the lower number of licensed exporters involved in the trade after 1997. The Ministry of Fisheries set a blanket quota of 100,000 fish for 1988 and 1989 but it this was not properly implemented. These quotas were revised in 1996 and appear to be working more effectively. The live tropical fish trade includes species that are very rare in the Maldives as well as some quasi-endemic species and this collection is depleting many favored species in the country. This is a concern for the biodiversity of the Maldives and hence is an important issue to be investigated. This study reviews the status of the tropical live fish industry of the Maldives and discusses the management and monitoring issues of the fishery.

CHALLENGES AND OPPORTUNITIES THAT EXIST IN THE PACIFIC ISLANDS WITHIN THE MARINE AQUARIUM INDUSTRY.

Walt Smith*, *Walt Smith International Ltd. P.O. Box 4466 Lautoka, Fiji Islands. Email: wsi@is.com.fj

Opportunities exist for Fiji and other small developing South Pacific countries to participate in the advanced marine aquarium markets around the world. This situation presents benefits for all parties involved, at a minimum, measurable impact on the collection sites. In all recent studies that focused on our industry it has been pointed out that careful and systematic collection of aquarium fish, live coral and live rock has left minute negative impact on the environment. The studies also pointed out that this industry provided far better than average income for those who lived in remote areas where there is little chance of gainful employment. The country can benefit in many ways from an industry such as this if basic environmental guidelines are strictly followed. The challenge we must face as responsible exporters is to educate our collectors in sustainable reef management. Sustainable harvest is a reality when you consider the extensive geological areas available for collection. While the conscientious and increasingly sophisticated end-user continues to insist on sustainably collected marine organisms, the exporting countries in the South Pacific have an opportunity to maximize their potential in this market. In addition to selective and manageable harvest there is huge parallel potential for developing countries to become involved in setting up and training locals to grow and harvest certain species of hard and soft coral thus enabling them to sell their products to the existing market through the established exporters.

A COMPARATIVE ANALYSIS OF THE GLOBAL TRADE IN MARINE ORNAMENTAL SPECIES AND IN FISHERY MANAGEMENT STRATEGIES

Wood, Elizabeth* *Marine Conservation Society, 9 Gloucester Road, Ross-on-Wye, Herefordshire HR9 5BU. UK. Email: ewood@globalnet.co.uk

Over forty countries have a marine aquarium fishery based on coral reef species, and at least 20 million fish are captured annually to supply the market. As many as 1,000 species of fish from 50 families are used in the trade worldwide, but generally each supplying country has fewer than 10 species that form the bulk of exports. Invertebrates are an important component of the trade, being worth about 20% of the total export value. This paper summarises the results of an investigation in which the following were compared on a country-by-country and/or regional basis a) size of fisheries and volume of trade, b) research and monitoring programmes c) conservation issues, d) management schemes and e) regulations. The discussion considers which methods are proving most effective in ensuring sustainable use of resources and highlights the importance of the Marine Aquarium Council Certification Scheme which promotes best practice within the industry.

A SYNOPSIS OF THE LIVE REEF FISH TRADE IN THE PACIFIC.

Yeeting B*and Labrosse. Secretariat of the Pacific Community (SPC), B.P.D5, 98848 Noumea, New Caledonia. Email: BeingY@spc.int

The live reef fish trade for food fish and aquarium fish is increasingly becoming important in the pacific as live reef fish operators extend their operations into the insular Pacific. The two parts of the trade although quite different in terms of target species and markets, still have a lot of common features in their development and management. Both are seen as important value adding activities to the marine resources with potential for increasing cash benefits to local Pacific Island fishing communities. The live reef fish trade however if not managed and regulated appropriately can be destructive to the marine resources as was experienced in Indonesia and the Philippines as well as in some of the Pacific countries who started their live reef fish trade without seeking advice. The Secretariat of the Pacific Community and various other organizations are collectively trying to stop this. The present paper is a synopsis of the work conducted so far in the pacific countries aimed at developing a sustainable live reef fish trade. The situations in the different countries in terms of species, stocks and biomass are described and compared. The current problems in the development and management of the industry are identified and appropriate guidelines and recommendations to address them are given.

Session C5: Coral Reef Fisheries

CATCH, EFFORT, AND YIELD FOR A CORAL REEF FISHERY AT KANEOHE BAY, HAWAII.

Everson, Alan R.* National Marine Fisheries Service, Pacific Islands Area Office, 1601 Kapiolani Blvd., Suite 1110, Honolulu, HI 96814. Email Alan.Everson@NOAA.Gov

Combinations of two standard creel survey techniques were used to estimate seasonal and annual catch and effort for Kaneohe Bay. In addition, yield per unit area was estimated based upon the survey data. A secondary goal of the study was to chronicle user perceptions of the resource. Effort and catch data were collected bi-weekly (weekend and weekday) on alternate weeks using a combination of roving creel (for effort) and access (catch) survey techniques. Data were collected from December 1990 through February 1993. The study was part of the Main Hawaiian Islands Marine Resources Investigation. Expanded catch and effort estimates were calculated for all major fishing methods observed in Kaneohe Bay. Pole and line fishing accounted for the most active (measured in angler-hours) seasonal and annual effort. Spear-fishers had the highest active CPUEs, while pole and line CPUEs were among the lowest. Spear fishers also accounted for the highest seasonal and annual expanded catch estimates of active methods. Up to 89% of the seasonal spear catch consisted of octopus. Passive (nets, traps) catch and effort was calculated as a daily average. Total (all active and passive methods combined) catches for 1991 and 1992 were 52.2 and 79.8 t respectively. Total production ranged from 0.92 - 1.4 t km^{-2} yr^{-1} during the study period. The sampling program enabled comparison of changes in seasonal and annual catch and effort for most of the fishing methods observed in Kaneohe Bay. Accurate catch and yield estimates are lacking for Hawaiian coral reef fisheries.

ABUNDANCE AND SIZE OF FISHES AS INDICATIVE OF FISHING IMPACT AT THE ABROLHOS REEF COMPLEX - BRAZIL

Ferreira, C.E.L.* & Gonçalves, J.E.A. *Instituto de Estudos do Mar Almirante Paulo Moreira (IEAPM), Dept. de Oceanografia, Rua Kioto 253, Arraial do Cabo, RJ, Cep:28930 000. Email: kadu@ax.apc.org

The Abrolhos reef complex (60,000 Km^2) includes the southernmost coral reefs in the Atlantic Ocean. They exhibit several different morphologies, besides the whole region is economically viable for fisheries and ecotourism. Parts of the region including offshore and coastal reefs have been protected since 1983 as national park. A monitoring program including two coastal, impacted reefs and two offshore, protected reefs, were initiated in 1997. Replicated visual census (strip transects) were used to compare abundance and size of herbivorous (scarids, acanthurids and damselfishes) and top predator (serranids, lutjanids and carangids) fishes. Among top predators, only carangids showed density values not significantly higher at protected reefs. Among herbivorous fishes, scarids and acanthurids were more abundant at protected reefs, despite values were not significantly different, while damselfishes showed significant higher densities ($p < 0.001$) at protected reefs. Size of top predator fishes, except lutjanids, were significantly higher ($p < 0.01$) at protected reefs. Scarids and acanthurids were also larger in protected than impacted reefs, while for damselfishes the size was not considered. In a broad analysis, protected reefs seems to sustain higher abundance and larger fishes than impacted reefs. These data consists in the first approach to understand the actual conservation status of different reefs from Abrolhos region.

REEFS OF AN UNINHABITED CARIBBEAN ISLAND: I. FISH COMMUNITIES AND MANAGEMENT.

Gerstner C.L..*. *John G. Shedd Aquarium, Chicago, IL USA. Email: cgerstner@sheddaquarium.org

Navassa is an uninhabited island in the Jamaica Passage, 40 miles west of Haiti and 70 miles northeast of Jamaica. The 1.9 square mile US protectorate has recently been designated as part of the Caribbean Island National Wildlife Refuge. Visual surveys of reef fishes were conducted using replicated 30x2m belt transects in five sites around the northwestern and southwestern areas of the island, with depths ranging from 11-23m. Navassa reefs possess a remarkably high mean density of fishes for the Caribbean, with sites ranging from 96.7 (9.4) to 139.8 (16.5) fishes/$60m^2$ [Mean (SE)]. Grouper and parrotfishes were relatively abundant, exhibiting overall mean densities of 1.6 (0.2) and 6.5 (0.5) fishes/$60m^2$, respectively. Snapper mean density was comparatively lower (0.9 (0.3)), however 92.1% of snapper sampled possessed lengths greater than 40cm. Grouper and parrotfish sizes were also comparatively larger with 14.7% of grouper and 22.5% of parrotfish sampled greater than 40 cm. Rough estimates of fishing effort by artesanal fishers from Haiti consisted of 1-4 small boats per day, with 3-5 men per boat. Fishers primarily used handlines over the reef, but placed traps further offshore in deeper water. They also appeared to be non-selective with either the species or the size of their catch. Thus given the non-selectivity and minimal level of fishing effort, plus the high level of fish density and size, reef fish communities of Navassa appear relatively "unexploited". Therefore Navassa reefs may provide a unique baseline for Caribbean reef fish populations, and may document the sole impact of fishing in the absence of other anthropogenic stressors. However, preventing an escalation in the level of effort may be challenging, given the international-level management that will be required.

UNCERTAINTY, CONFLICT, AND THE DESIGN OF FISHERY MANAGEMENT AREAS: MEASURING CPUE AND FISHING PREFERENCES.

Grober-Dunsmore, Rikki *, Frederick J., Ridgley, Mark. *University of Hawaii, Dept. of Geography, 2424 Maile Way, Honolulu, HI 96822. Email: rikki@akule.soest.hawaii.edu

Catch per unit effort is frequently used as a proxy for fish abundance and to assess the state of a fishery and fisheries research typically provides this crucial information. Too many times the process of designing and implementing reserves is thwarted because people feel they need to collect "more" information before they can make a decision. In reality, decisions may need to occur sooner than ecological data can be collected. Using the Analytic Hierarchy Process (AHP), a method for assessing catch per unit effort is presented that incorporates gear selectivity, fishing intensity, and habitat characteristics. The approach shows how scientific data (complete or incomplete data sets), local knowledge of the fishery, and/or other expert judgement can complement one another to improve predictions of CPUE, and how this in turn can be integrated into the optimization model described in a companion paper. Multicriterion assessment methods are used to measure intangibles, such as the behavior of different gear types, habitat quality, and preferred fishing locations. In a similar manner, we use the AHP with fishermen, organized into groups by their preferred gear type, to assess their fishing preferences by habitat and zone (location). Results from the two methods can be combined to predict the efficacy of different no-take zones.

SUSTAINABLE DEVELOPMENT OF CORAL REEF FISHERIES? – THE CASE OF ERITREA.

Hatcher B.G.* Canadian Fishery Consultants Ltd. 1489 Hollis Street, Halifax, Nova Scotia, Canada, B3J 2R7. Email: Bhatcher@canfish.com

Few reef fisheries may be deemed to be in need of development in the common use of the term "Fisheries Development" (i.e. increased fishing power and effort efficiency). Many reef fisheries are in need of developmental change towards exploitation practices and management policies which foster ecologically sustainable use of marine resources. In the case of Eritrea: thirty years of war destroyed the human capacity and physical infrastructure for fishing the extensive reefs of the nation's 1200km of coast and 600km^2 of the Dehalak Archipelago. A result is that the reefs of this hotspot of marine biodiversity and endemism in the SW Red Sea have been virtually unexploited for four decades. Reestablishment of viable fisheries is an economic and social necessity for the reconstruction of the young African nation. Over $25.M has been lent and given by International Financial Institutions to fund the rebuilding of the fishery, essentially from scratch. Recently, almost $5.M has been allocated from the GEF for the conservation management of Eritrea's coastal, marine and island biodiversity. This nexus of development and conservation represents a rare opportunity for Eritreans to develop their fisheries using ecosystem and precautionary principles. The emphasis for reef resources is to foster the artisanal fishery and limit the growth of the industrial sector. Infrastructure is being dispersed widely in small centres, and the level of investment is being pre-determined on the basis of multiple social and natural science criteria rather than simply on estimates of maximum sustainable yields.

CORAL REEF FISHERIES MANAGEMENT IN THE UNITED STATES: FIRST STEPS TOWARD AN ECOSYSTEM APPROACH.

Hourigan, Thomas F*. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: Tom.Hourigan@noaa.gov

The United States includes an exceptional diversity of coral reef habitats, as well as great cultural diversity and wide range of commercial, recreational and artisanal fisheries activities. U.S. reefs are home to over half of all federally managed fisheries species for all or part of their life-cycle. The health of the ecosystems and the value of these fisheries is threatened by overfishing; habitat impacts of fishing operations; bycatch; and other indirect impacts associated with fisheries, such as anchor damage and grounding of fishing vessels on reefs. The U.S. Coral Reef Task Force has identified a number of steps to address these fisheries impacts. These range from traditional approaches such as enhanced enforcement and stricter limits on allowable fishing gear, to addressing the collection of aquarium species and fisheries impacts on deeper reefs and banks. Most promising, however, is the commitment to map reef habitats and prioritize areas for protection in networks of no-take marine reserves. The Task Force has set a goal of protecting a balanced suite of representative coral reefs and associated habitats comprising at least 20% of all U.S. reefs and associated habitat types by 2010. The expansion of no-take marine reserves has begun at both the Federal and state/territorial level. Together, these steps hold the promise of maintaining the integrity of ecological processes within communities and the ecological links among habitats – a prerequisite to an ecosystem approach to fisheries management.

TRADITIONAL FISHING TECHNIQUES OF BAJAU PEOPLE , TOGEAN ISLANDS, CENTRAL SULAWESI (INDONESIA)

Hutabarat, Christoverius* *Yayasan Bina Sains Hayati Indonesia (YABSHI), Depok, Indonesia. Email: tropbiod@pacific.net.id

Togean Islands, lies in Tomini Bay is an archipelago with more less 35 small and big islands comprises several ethnic groups, of which the Bajau mostly depends on marine resources. They usually live on barren coral but distantly far from freshwater sources. Since the reefs are often far from Bajau village they usually erect resting huts (*sabua*) on the coral (*sappa*). They use their traditional boat (*leppa*) for travelling as well as seeking various marine biota for their subsistence and selling. Regularly they run activities called *bapongka* where they are in groups make a travel out of the *desa* (village) in weeks for collecting marine resources especially sea cucumber. In *desa* Kabalutan, while looking for marine biota, they use some traditional techniques or methods : line hook (*missi, bapatape, ngarinta, etu, nonda*); fishing net (ngarua); spear fishing (*nyingke, mana/bapanah*); using light; fish traps (bubu); as well as using hands. This study aimed for documenting the Bajau the traditional techniques as well as traditional knowledge of marine resources using. While, at the other side conservation efforts as well as sustainable use of marine resources in Togean Islands could be simultaneously encouraged since so called modern techniques (i.e. bombing and poisoning) that obviously giving bad impact to the reefs are becoming widely used.

STRUCTURE AND SOCIOECONOMY OF ARTISANAL CORAL REEF FISHERY IN A PHILIPPINE COASTAL COMMUNITY.

Kochzius, M.*. *Centre for Tropical Marine Ecology (ZMT), University of Bremen, Fahrenheitstrasse 1, 28359 Bremen, Germany. Email: kochzius@uni-bremen.de

In Southeast Asia many small scale fishermen depend on shallow water habitats like coral reefs and seagrass meadows as their fishing grounds. A field study in the small coastal community of Malatapay, southern tip of Negros Oriental, Philippines, was conducted to evaluate the structure and socio-economic importance of artisanal fishery and different fishing gears in this area. The annual yield from the Bay of Malatapay is estimated at 13.0 – 24.6 t/ha (7.5–14.4 t/ha without pelagic species). This seems to be a good yield for Philippine coral reefs, with a range of 1.0–37.0 t/ha/year, but this yield is only possible with a very high fishing effort (time and manpower). The most important fishing gears by catch were beach seine (31.0%), bamboo trap (24.5%), hook & line (23.0%), spear (8.6%), set gillnet (5.0%), fish pot (4.3%) and encircling gillnet (3.6%). Respectively the most important fishing gears by CPUE were fish pot (5.0 kg/trip), beach seine (4.7 kg/trip), encircling gillnet (4.5kg/trip), set gillnet (2.9 kg/trip), bamboo trap (1,8 kg/trip), hook & line (1,2 kg/trip) and harpoon (1.0 kg/trip). The mean annual income of families (n = 15) in 1995 was 40,000 Pesos (poverty line: 30,000 Pesos = 1,200 US $). Only one third of the income comes from fishery, because most of the fish is used for personal needs. The subsistance nature of this fishery is also reflected by the low proportion of fish which is sold from the catch (37%). These results demonstrate the importance of coastal marine resources for the livelihood of small-scale fishermen and their families.

PROTECTION OF GROUPER SPAWNING AGGREGATION SITES - BERMUDA'S EXPERIENCE WITH THE RED HIND *EPINEPHELUS GUTTATUS*.

Luckhurst, Brian E.*. *Division of Fisheries, P.O. Box CR52, Crawl CRBX, Bermuda. Email: bluckhurst@ bdagov.bm

Two spawning aggregation sites of the red hind *Epinephelus guttatus* , at the opposite ends (SouthWest , NorthEast) of the Bermuda reef platform, were afforded protection from fishing through the seasonal summer closure of these two defined areas in 1974. Periodic monitoring of these sites by hook and line sampling indicated that the modal size of fish from these sites increased significantly during the 1980s. A third identified spawning aggregation site was included in the seasonal closure regulations in 1989. Following the fish pot ban of 1990, the reported landings of red hind declined significantly from levels in the 1980s mainly as a result of a decrease in catchability. A long term research tagging program commenced in 1993 to assess site fidelity and longevity as well as to monitor the dynamics of these two aggregations. The results to date have demonstrated high levels of site fidelity and well-developed navigational ability by displaced fish. Modal sizes have not changed significantly over the past seven years but abundance at the NE site has declined. These results indicate that the geographical location of both spawning aggregation sites has not changed over a period of 25 years and that the seasonal closure of these sites has probably contributed to the maintenance of the red hind population in Bermuda.

MANAGEMENT PERFORMANCE FOR THE SUSTAINABILITY OF FISHERIES RESOURCES THROUGH SYSTEMS BASED ON CUSTOMARY MARINE TENURE IN MELANESIA.

Mees, Christopher *, Anderson, James and Polunin, Nicholas. *MRAG Ltd, 47 Prince's Gate, London, SW7 2QA. Email: c.mees@ic.ac.uk

There has been considerable interest in the potential of community-state partnerships as a means of attaining a more effective management of widely dispersed, small-scale artisanal fisheries. One approach may be to combine the best components of a traditional, or customary, marine tenure (CMT) system, with appropriate intervention and advice from the state. It has been assumed that customary management activities are beneficial, both to the community and in terms of the sustainability of natural resources. This paper examines the ecological sustainability achieved by of a number of extant CMT regimes in Fiji and Vanuatu. The success of customary management actions for fin-fish resources across a range of fishing pressures at different sites was examined. In addressing the question, 'Has customary management been successful', the criteria used related to western notions of fisheries management success. Little evidence for the success of customary management against western objectives of the long term benefits of resource sustainability could be demonstrated from this study. Short term benefits, which meet specific community objectives such as 'ear-marking' resources for social events were, however, apparent. However, forms of human-resource organisation ('management') exist which are appropriate to western notions of resource management (e.g. closed areas, effort and gear controls), and institutional arrangements exist within fishing communities to implement them. Thus, within a co-management framework with advice from government fishery departments, it was considered that customary 'management' activities could be adapted for the purpose of achieving long term ecological benefits and sustainability.

REEFS OF AN UNINHABITED CARIBBEAN ISLAND: II. OPPORTUNITIES TO DISCERN FISHING IMPACT ON BENTHIC COMMUNITIES

Miller, Margaret W.*. *NOAA-Fisheries, Southeast Science Center, 75 Virginia Beach Dr. Miami, FL USA. Email: margaret.w.miller@noaa.gov

Navassa Island is a tiny, uninhabited US protectorate located between Jamaica and Haiti. The reefs of Navassa, though not conforming to the classical Caribbean reef zonation paradigm, have high live coral cover (at least in the examined depth range of 11-23m) and a high degree of architectural complexity. High abundance of small, newly recruiting corals and low incidence of coral disease suggest that these reef communities are "healthy". Mean percent cover of live coral ranged from 20 (2.5) to 26.1 (7.2) [mean (SE)] for four sites surveyed along the west coast. Other major community components (in terms of space occupation) were sponges (range of 7-27% cover), fleshy brown algae (range 10-24% cover), and crustose coralline algae (range 5-16% cover). Lastly, the keystone grazing urchin, *Diadema antillarum*, was moderately abundant in all sites (2.9 (0.9) *Diadema* per $30m^2$ belt transect). The only human impact on Navassa reefs is a small artesanal fishery by Haitians, but their impact on the reef community seems, so far, minimal. It will be a great management challenge to maintain fishing impacts at current levels. If fishing pressures increase, it may be possible to resolve "threshold" levels of artesanal fishing intensity at which adverse impacts on the reef community become evident, information that would be of utmost value to reef management and conservation.

RELATIONSHIPS BETWEEN FISHING EFFORT AND SEA URCHIN ABUNDANCE IN TRADITIONAL FIJIAN FISHING GROUNDS.

Mitchell, R.E. *, Dulvy, N.K. Polunin, N.V.C. *Marine Studies Programme, University of the South Pacific, P.O. Box 1168, Suva, Fiji. Email: mitchell_r@student.usp.ac.fj

The increase in abundance of sea urchins is a suggested indirect effect of fishing, thought to be due to the removal of predatory fishes. However, the hypothesis remains untested across a range of fishing pressures in the absence of other confounding factors. We tested this hypothesis at the pristine Lau islands of Fiji. This region provides discrete fishing grounds where effort can easily be quantified without additional factors such as pollution or destructive fishing. At each island the abundance of reef associated sea urchins were censused within 50-70 randomly positioned $1m^2$ quadrats along a 50m outer reef section, at 3-8 replicate sites <7m deep. As a measure of predator abundance, numbers and lengths of fish species reported to consume urchins were visually censused at the same sites within 6 circular areas of 7m radius. The study focused upon low levels of fishing pressure (0 - 50 people per km reef front), as this is where greatest changes in fish communities have previously been recorded. The abundance of sea urchins initially declined with increasing fishing intensity. However the highest abundance of sea urchins occurred at the most heavily fished island, suggesting a non-linear relationship.

SPATIAL DISTRIBUTION PATTERNS IN RESOURCE USE BY THE FISHING COMMUNITIES IN AND AROUND KOMODO NATIONAL PARK, A MARINE PROTECTED AREA IN CENTRAL INDONESIA.

Mous, Peter J. *, Muljadi, & Pet, Jos S.. *Indonesia Coastal & Marine Program, The Nature Conservancy. Jakarta Office, Jln Hang Tuah Raya 42, Jakarta 12120, Indonesia Email: pmous@attglobal.net

Komodo National Park (1,800 km ^{2}) is situated in Central Indonesia, between Flores to the East and Sumbawa to the West. The Park was established in 1980 to protect the Komodo dragon *Varanus komodoensis*, but it also encompasses 1,200 km^2 of highly diverse marine habitats. The fishing communities in and around the Park, numbering ca. 20,000 people, use a variety of fishing methods to exploit pelagic resources such as squid, small clupeids, and demersal resources such as lobster, groupers (*Plectropomus* spp. and *Epinephelus* spp.), sea cucumber and abalone. Especially if destructive fishing methods are used, the exploitation of demersal resources threatens the marine biodiversity of the Park. During 1997, 1998 and 1999, creel surveys were conducted in the Park to study resource use by the fishing communities to support the management of the Park. The creel surveys revealed distinct spatial patterns in resource use, which vary between fishing communities and between years. Based on resource use patterns, and on the spatial distribution of marine habitats in the Park, a zoning plan was proposed and endorsed by the Indonesian Park authorities.

ARE LENGTH-BASED METHODS OF GROWTH ASSESSMENT APPROPRIATE WHEN MANAGING LONG-LIVED, SLOW GROWING SPECIES?

Pilling, Graham*; Kirkwood, Geoffrey; Mees, Christopher; Barry, Catherine; Nicholson, Simon; Branch, Trevor. *MRAG Ltd, 47 Prince's Gate, London, SW7 2QA. Email: gpilling@ic.ac.uk

Length-based methods are commonly used by developing country fisheries institutions to assess growth in tropical reef fish species. However, the life history of many fish species renders the outputs of such methods uncertain. Age-based growth assessments are considered to be more robust for long-lived, slow growing species, and they have been used for an increasing number of fish species. Using Monte-Carlo simulations, this study examines the accuracy of both length- and age-based growth parameter estimates for the emperor *Lethrinus mahsena*, an important commercial demersal fish species in the Indian Ocean. The 'knock-on' effect of using these respective growth parameter estimates in subsequent length-based stock assessment methods is examined. Finally, the impact on management actions based on these stock assessments is evaluated though management strategy simulations. Overall, age-based methods resulted in the most accurate and precise growth parameter estimates. Management performance was better when age-based rather than length-based growth parameter estimates were used, but in neither case was it particularly good. This may have resulted from the use of length-based methods in the later stages of the stock assessment process. Further improvements in management performance may be gained by increasing the age-based component of tropical fish stock assessments.

UNCERTAINTY, CONFLICT, AND THE DESIGN OF FISHERY MANAGEMENT AREAS: AN OPTIMIZATION MODEL.

Ridgley Mark* Frederick J., and Rikki Grober-Dunsmore, *Department of Geography, University of Hawaii, 2424 Maile Way, Honolulu, HI 96822, USA; Email: ridgley@hawaii.edu**.**

The design, siting, and selection of fishing management areas (FMAs) is bedeviled by conflict (e.g., between fishers and conservationists) and uncertainty (e.g., stock assessment, CPUE, preferred fishing grounds and practices). Two other papers in this three-paper sequence describe and illustrate ways to quantify CPUE, fisher preferences, and fish movement and its uncertainty. Here we present a multiperiod, multiobjective optimization model the solution of which specifies fishing activities, by gear type and intensity level, to allow or disallow in any of a set of preestablished spatial zones. The core of the model is a zone-specific mass-balance equation that relates the stock in zone *i* at the start of time period *t* to the stock in the same zone at the start of the next period by accounting for natural mortality, recruitment, fish harvest, and stochastic fish movement between zones. The model can accommodate any number of conflicting objectives the concern of which are apt to address fishing (e.g., preferred locations, gear types, intensity and catch levels) and stock sustainability (total, by zone, and/or by time period). Uncertainty is addressed though stochastic programming, the inputs for which are determined through Markov and Monte Carlo analyses (described in the first paper), with model outputs specifying stock levels in probabilistic terms. An example is presented for illustration.

SPATIAL STRUCTURE OF COMMERCIAL REEF FISH COMMUNITIES IN THE SOUTHWEST LAGOON OF NEW CALEDONIA

Sarramegna S. LERVEM, *University of New Caledonia, B.P. 4477, 98847 Nouméa New Caledonia. Email: sarrameg@univ-nc.nc

The spatial distribution of commercial reef fishes from five reefs of the southwest lagoon of New Caledonia was studied following a distance to coast gradient. The survey was performed using underwater point coint visual census. Firstly, three reef fish communities were identified using correspondance analysis. The first assemblage occured on reef flats (11.9 specie point^{-1}, 0.61 fish m^{-2}, 138.5 g m^{-2}). This assemblage was caracterised by *Lethrinus harak*, *Acanthurus triostegus* and *Siganus spinus*. The second fish assemblage occured on reef slopes (23.0 species point^{-1}, 0.96 fish m^{-2}, 468.8 g m^{-2}). Piscivores (Epinephelidae), carnivores (Lutjanidae) and corallivores (Scaridae) dominated this community. The third assemblage was found on lagoon soft bottoms (11.7 species point^{-1}, 0.70 fish m^{-2}, 174.1 g m^{-2}). This community was dominated by benthic carnivores (Haemulidae, Lethrinidae, Mullidae) and herbivores (Siganidae). The reef slope and the lagoon soft bottom assemblages were distributed along a coast to barrier reef gadient of density. At least, marine reserves had impacts on species richness and biomass of main fished species. In New Caledonia the major factor structuring the commuties is the caracteristics of the biotope (percentage of coral cover, habitat complexity). Secondly, the distance to the coast modify these assemblages and at least the status of protection had effects on target species.

THE SEA CUCUMBER FISHERY OF SAIPAN, NORTHERN MARIANA ISLANDS.

Trianni. M* *Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife. Email mstdfw@itecnmi.com

A sea cucumber fishery targeting the surf redfish, *Actinopyga mauritiana* and the blackteatfish, *Holothuria nobilis*, occurred on the island of Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) during 1996 and 1997. A pre-harvest stock assessment was not conducted and the fishery was managed based on catch-effort statistics. The fishery was temporarily halted in early 1997 due to declining CPUE. A subsequent analysis of catch-effort statistics was conducted using three depletion models; the Leslie, DeLury, and an unbiased likelihood estimator derived from the Leslie, termed the Akamine model. These models indicated that the remaining population numbers in the fishery management units were considerably harvested, with 78 % to 90 % of the initial population sizes taken. The fishery was subsequently shut down and a post-harvest survey conducted by the CNMI Division of Fish and Wildlife supported the depletion model analysis results. Results from the depletion models varied, with the Leslie and DeLury failing to produce valid results for all management units. The Akamine model was preferred for any future depletion estimation analyses, although a pre-harvest stock assessment along with the collection of harvest statistics was concluded essential for coherent management.

OVER FISHING OF HOLOTHURIANS ON THE GBR: THE EFFECTS ON POPULATION STRUCTURE OF *HOLOTHURIA NOBILIS*, AND LIKELY SOURCES OF NEW RECRUITMENT

Uthicke, Sven* and John A. H. Benzie *Australian Institute of Marine Science, PMB No. 3, Townsville MC, Qld. 4810, Australia. Email: S.Uthicke@aims.gov.au

Decreasing catch rates for *H. nobilis* on the GBR prompted management agencies to close the fishery on this species in October 1999. We surveyed densities and size structure of *H. nobilis* at 20 reefs and investigated the genetic connectivity between reefs using allozyme and mitochondrial DNA (mtDNA) analyses. Densities of *H. nobilis* on four reefs protected from fishing were about 4 times higher compared to 16 reefs open to fishing and the average weight of the animals was significantly smaller on fished reefs. The study of 7 polymorphic enzymes revealed no significant population differentiation between reefs separated by distances up to 1300 km. This may indicate a high potential for larval dispersal and that larvae from populations or regions which were not fished could re-colonise overfished reefs. However, conclusions based on the allozyme data may be flawed because the allozymes may not be in evolutionary equilibrium due to the relatively young age of the reef. Preliminary studies using higher resolution genetic markers (mtDNA sequences) have indicated that population differentiation may exist even on small geographic scales. Therefore, a recommendation on the scale on which the beche-de-mer fishery on the GBR should be managed can only be made after final analyses of the mitochondrial markers.

A MULTI-DISCIPLINARY EVALUATION OF ALTERNATIVE MANAGEMENT STRATEGIES FOR THE SEYCHELLES ARTISANAL FISHERY.

Wakeford, Robert C.*, Kirkwood, Geoffrey P. *RRAG, Imperial College, London, SW7 1NA. U.K. Email: r.wakeford@ic.ac.uk

The Seychelles artisanal fishery has two sectors: a large number of small boats exploit the inshore fish resources, and a smaller number of larger vessels target relatively lightly exploited offshore resources. Continued high levels of fishing effort inshore have given rise to concern over the status of the fish resources there and the socio-economic welfare of inshore fishers. Previous fiscal incentives in the form of soft loans were intended to help fishers purchase larger vessels and relocate fishing pressure further offshore, but to date these have met with limited success. In this study, the status of the inshore fish resources was re-evaluated, and constraints on relocating fishing effort faced by different socio-economic groups of fishers were examined. Field sampling, rapid rural appraisal and formal socio-economic surveys were used to collect quantitative biological, technical and economic information for each fishery sector, as well as information on the decision-making arrangements of different socio-economic groups. This was used to develop a bio-socio-economic simulation model of the artisanal fishery, which allowed the likely outcomes of alternative management strategies to be evaluated. Continuation of existing policy was predicted to put further pressure on inshore resources. Access restrictions, involving both vessel and fisher licence schemes, were found to provide the greatest opportunity for sustainable biological and economic recovery.

PREHISTORIC FISHERIES IN THE CARIBBEAN.

Wing SR* and ES Wing. Department of Marine Science, PO Box 56, University of Otago, Dunedin, New Zealand. Email: steve.wing@stonebow.otago.ac.nz

We studied faunal remains from archaeological sites on five caribbean islands, each with an early (1300-1800 ybp) and late (1300-500 ybp) occupation. On each of these islands; puerto rico, st thomas, st. Martin, saba, and nevis the mean size of reef fishes in the faunal remains declines from the early to the late occupation. The large samples from sites on st. Thomas and nevis allowed examination of the size distribution of individual taxa. Samples of obligate reef fishes; scaridae, acanthuridae, lutjanidae, and serranidae show large reductions in size between the early and late occupations. Samples of facultative reef fishes such as carangidae and clupeidae show little change in size distribution. The percentage of estimated reef fish biomass in the total faunal record sharply declines in the samples from four of the islands, while on nevis there is a slight increase. The mean trophic level of reef fishes declines from the early to the late occupations on each island. Together these patterns suggest that populations of reef fishes adjacent to occupation sites on these islands were heavily exploited in prehistoric times. Such exploitation resulted in shifts in size structure and species composition among the reef fish fauna. On some islands the decline in reef fish resources corresponds with a shift towards greater exploitation of pelagic species.

LONG-RANGE RECRUITMENT OF THE SPINY LOBSTER (*PANULIRUS ARGUS*) POPULATION IN THE CORAL REEFS OF SOUTH FLORIDA, USA.

Yeung, Cynthia*. *Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149, USA. Email: cyeung@rsmas.miami.edu

Marine species inhabiting coral reefs that possess an extended planktonic larval stage may have the advantages of colonizing a wider geographic range and insuring against local population extinction. Few species could rival the phyllosoma larvae of the spiny lobsters (Palinuridae) in their potential for teleplanic dispersal, as their planktonic larval duration is estimated to be between six months to one year. The spiny lobster *Panulirus argus* is a major fishery species throughout the Central Western Atlantic, including South Florida near the downstream limit of its range. The offshore reef zone in South Florida in which the adult population spawns is impinged by the strong Florida Current. Faced with a mean downstream flow speed of 100 cm^{-1}, it seems unlikely that the phyllosoma larvae could remain within their approximately 200 km stretch of natal habitat for the many months until they are ready to settle. The South Florida population would then rely on a supply of larvae from remote upstream populations, transported via large-scale boundary currents, meso-scale gyres and meanders, and local winds and tides. The implications are that transport variability is a major control factor in recruitment, and management of this key fishery species requires coordination on a wide geo-political scale.

Session D1: Global Coral Reef Monitoring Network & ReefCheck.

CORAL REEF MONITORING IN REUNION ISLAND USING IOC METHOD (WESTERN INDIAN OCEAN ISLANDS STATES PROGRAM)

Chabanet, P.* ; Bigot, Lionel; Naim, Odile; Garnier, Rémi; Tessier, Emmanuel ; Moyne-Picard, Marylène. *Laboratoire d'écologie marine, Université de la Réunion, 97715 Saint Denis Messag Cedex 9, France. Email: chabanet@univ-reunion.fr

Since 1998, part of reef assessment in Reunion follows a standardised methodology applied in 4 others islands states : Comoros, Madagascar, Mauritius and Seychelles. This monitoring fits into a regional (Regional Environment Program of Indian Ocean Commission) and an international (Global Coral Reef Monitoring Network) strategies. The overall objectives of IOC/GCRMN network are to improve the management and sustainable uses of coral reefs, and provide individuals, organisations and governments with the capacity to assess their coral reef resources, and collaborate within a global network. In Reunion, the IOC/GCRMN network is operating at the research level, that is a high resolution assessment and monitoring over small scales. Scientists and institutes currently participate to the monitoring reefs and pool data into ARMDES database. In 1998, assessment of reef using IOC/GCRMN method started with 2 sites (St-Gilles and La Saline reefs). In 1999, 2 others sites were added (St-Leu reef) and 3 others in 2000 (Etang-Salé and St-Pierre reefs). On each site, 2 stations are assessed, one on the reef flat and the other on the outer slope (around 10 m depth). Results of reef assessment constitute an evolutionary and comparative data base which is an important tool for the management of the coastal zone.

SOUTHEAST ASIAN REEFS – STATUS UPDATE.

Chou L.M.*. *Department of Biological Sciences, Faculty of Science, National University of Singapore, Blk. S2, 14 Science Drive 4, Singapore 117543. Email: dbsclm@nus.edu.sg

Southeast Asian reefs continue to face development and exploitation pressures in spite of greater awareness of their ecological and economic importance. Reefs that were once considered remote have not escaped the destructive aftermath of poison or blast fishing. Common threats from human activities are spreading throughout the region and there is no apparent sign of reversal or reduction in the trend of increasing reef degradation. There is evidence of expanding monitoring efforts on reef health status in tandem with increasing numbers of rehabilitation projects. Line-Intercept Transect data are available for more reefs of which little was previously known. Established reef-monitoring programmes now exist in many countries. Reef Check surveys have increased steadily in the region and monitoring by volunteers indicate little difference in reef condition between marine parks and non-protected reefs. This confirms earlier observations that few marine protected areas are meeting management objectives. Countering the pattern of reef-integrity loss are isolated instances of management by local communities and coastal resorts. Apart from the impact of human activities, many Southeast Asian reefs were affected by severe bleaching events in 1998 with recovery ranging widely from marginal to almost complete. Stronger, more effective and perhaps innovative management measures are necessary to facilitate the survival of Southeast Asian reefs in the new millenia.

MONITORING AND STATUS OF CORAL REEFS IN SOUTHERN TROPICAL AMERICA.

Garzón-Ferreira, J. *, Cortés, J. Croquer, A. Guzmán, H. Leão, Z. & Rodríguez-Ramírez, A. *Instituto de Invest. Marinas y Costeras (INVEMAR), A.A. 1016, Santa Marta, Colombia; Email: jgarzon@invemar.org.co

Under the framework of the Global Coral Reef Monitoring Network (GCRMN), UNEP-CAR/RCU is supporting the creation of a sub-regional GCRMN node for southern tropical America, a region with common attributes, interests and problems. This task was commissioned to INVEMAR, a marine research institution which has participated within the CARICOMP program since its origin and has been developing a national reef monitoring system in Colombia (SIMAC) during the last two years. Since the end of 1999 we started to work on this project which has focussed on: (1) Analyzing experience, capacity and needs for reef monitoring at each country; (2) Undertaking coordinated reef monitoring activities during 2000 throughout the sub-region; (3) Preparing reports on current status of reefs in each country and in the sub-region. Experienced reef researchers from 5 countries (Costa Rica, Panamá, Colombia, Venezuela and Brazil) are now cooperating and assessing monitoring capacity via a questionnaire being completed by each participant. All countries (except Brazil, which started in 1999) have conducted permanent reef monitoring activities for at least the past five years, but concentrated in the Caribbean and with a small geographic coverage due principally to financial limitations. Most reefs in the sub-region have suffered from both anthropogenic and natural impacts. Detailed reports will be presented, focussing on a description of the status, threats and recent changes of coral communities from each country.

STATUS OF CARIBBEAN REEFS: INITIAL RESULTS FROM THE ATLANTIC AND GULF RAPID REEF ASSESSMENT (AGRRA) PROGRAM

Ginsburg, R.N*., Alcolado, P., Arias, E., Bruckner, A., Claro, R., Curran, A., Deschamps, A., Fonseca, A., Feingold, J., Garcia-Saez, C., Gilliam, D., Gittings, S., D., Glasspool, A., Horta-Puga, G., Klomp, K., Kramer, P.A., Kramer, P.R., A., Leao, Z., Lang, J., Manfrino, C., Nemeth, R., Pattengill-Semmens, C., Peckol, P., Posada, J., Riegl, B., Robinson, J., Sale, P., Steneck, R., Vargas, J., Villamizar, E.

***Rosenstiel School Of Marine And Atmospheric Science, University Of Miami, 4600 Rickenbacker Causeway, Miami, Fl, 33149. Email:** RGINSBURG@RSMAS.MIAMI.EDU

Since june, 1998, over twenty large-scale AGRRA assessments have been undertaken in the western atlantic covering approximately 300 reef sites. At each site, non-permanent 10-m line transects were used to measure a suite of standardized benthic parameters including coral cover, coral mortality (recent and old), coral size (diameter and height), coral condition, coral recruits, relative abundance of algae (turf, crustose coralline, and macro), macroalgal height, and *Diadema antillarum* abundances. In addition, the sizes and abundances of selected fish families were assessed using non-permanent 30x2 m belt transects and overall fish diversity was measured with a roving diver census. All data have been compiled into a single ACCESS database using standardized species codes and hierarchically defined location codes. These data establish a baseline scale of caribbean-wide reef condition and can be used to identify degraded, normal, or luxuriant areas.

THE STATUS OF CORAL REEFS IN THE HAWAIIAN ARCHIPELAGO.

Gulko, David A.*, Maragos, James E. Friedlander, Alan M. Hunter, Cynthia L. *Division of Aquatic Resources, Hawai'i Department of Land & Natural Resources, 1151 Punchbowl St. Rm. 330, Honolulu, HI 96813 U.S.A. Email: david_a_gulko@exec.state.hi.us

Approximately 85% of all U. S. coral reef area occurs within the Hawaiian Archipelago. The reefs that make up this region stretch over 2,000 km and contain a majority of the reef types seen throughout the Pacific. Coral reefs in Hawai'i are characterized by their isolation from other Pacific reefs and extremely high endemism across most phyla. The Archipelago consists of two distinct regions: the Main Hawaiian Islands (MHI), made up of populated, high, volcanic islands with non-structural reef communities and fringing reefs directly abutting the shorelines; and the Northwestern Hawaiian Islands (NWHI), consisting of uninhabited atolls and banks. The MHI are urbanized with extensive coastal development and associated runoff effects. Overfishing (for food organisms and marine ornamentals), alien species, marine tourism and pollution impacts are of increasing concern. The NWHI coral reefs are affected primarily by marine debris, and fishery impacts from lobster and bottomfish fisheries. Concerns exist over proposed ecotourism activities and new fisheries to be managed under the Western Pacific Regional Fisheries Management Council. Examples of recent management initiatives to address coral reefs impacts include new forms of MPAs related to marine ornamental collection and tourism impacts, and assessment and long-term monitoring programs involving active partnerships between academia, community groups and management agencies.

REEF CHECK 2000 IN PALAU.

Kitalong, A*. *The Environment, Inc. Box 1696 Koror Palau 96940. Email: kitalong@palaunet.com

Preliminary Reef Check data were collected from four sites: Ngerchelong and Koror at one depth and Angaur at two depths covering 320 m^2. One bumphead parrotfish was seen in Angaur. Grouper were counted in Ngerchelong and Angaur (n = 5, mean = 0.31, STD = 0.68). Sweetlips were seen at all sites (n = 7, mean = 0.43, STD =0.86). Butterfly fish were the most abundant fish (n = 85, mean = 5.31, STD = 4.35) with the highest counts in Angaur (n= 62). Giant clams (*Tridacna* spp.) were the most abundant invertebrates found at all site (n = 80, mean = 5.00, STD = 8.70). Three lobsters were found at two depths in Angaur. No *Diadema* urchins, Triton shells, edible sea cucumbers or crown of thorns starfish were seen at the four Reef Check sites. In Angaur, at the 12-meter depth, 50% of the coral population and 40% per colony of coral were bleached. Coral damage due to anchors was low and no impacts from dynamite, fish nets or other impacts were found. In Angaur, at a 5-meter depth, 50% of the coral population and 30% per colony of coral were bleached. Coral damage was due to bleaching but not to anchors, dynamite, trash or fish nets. In Ngerchelong, coral damage by anchor damage was low but coral damage due to bleaching was high. It was noted at the Ngerchelong site that in 1998 a severe bleaching event caused more than 95% mortality to the corals. In Koror, coral damage due to bleaching was high. The percent of substrate types for the Angaur, Ngerchelong and Koror sites were as follows: 29% hard coral, 4% soft coral, 23% dead coral, 0.1% fleshy seaweed, 2% sponge, 22% rock, 13% rubble and 6% sand. No silts or clays were observed at the four sites.

RECON (REEF ECOSYSTEM CONDITION): A PROGRAM FOR RAPID MONITORING OF THE REEF BENTHOS BY VOLUNTEERS.

Lang J.C.*, Monk, L.A. and Sheavly, S.B.. *P.O. Box 539, Ophelia, VA 22530, USA. Email: JandL@rivnet.net

Reefs that are in good condition are expected to have large, healthy, stony corals, an abundance of crustose coralline algae, and numerous fishes; however, their status at many sites is not well known. The Center for Marine Conservation (CMC), with support from the U.S. Environmental Protection Agency, is teaming up with dive shops, clubs, resorts, and with recreational SCUBA and snorkel divers, to help fill this data gap. The goals of RECON (Reef Ecosystem Condition) are to broaden the scope of available information on the condition of stony corals, to alert local reef researchers and managers about changing reef conditions, and to increase public understanding about the threats to coral reef ecosystems. Hence, the data will complement existing international (*e.g.*, REEF, Reef Check, Reef Keeper International) and regional (*e.g.*, AGRRA, CARICOMP, GCRMN) monitoring and assessment programs. Volunteers will take a short training course from a CMC-certified RECON instructor, who will also provide local oversight and information about current conditions (*e.g.*, mass bleaching events, outbreaks of disease, recent storm damage). Data will be sent to CMC for analysis and archiving (both in-house, and with other organizations); results will be posted at CMC's website, and freely-available for use by reef scientists and managers.

STATUS AND TRENDS OF THE CORAL REEFS OF MICRONESIA.

MAREPAC. C/O Marine Laboratory, Univ. of Guam, UOG Station, Mangilao, Guam 96923 USA. Richmond@uog9.uog.edu

Micronesia consists of a series of islands that span an area greater than that of the continental United States of America, and includes the Republic of Palau, Guam, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia (Yap, Chuuk, Pohnpei, and Kosrae), Nauru and a portion of Kiribati. The coral reef fauna of the region is rich, with over 350 species of scleractinian corals, 2,000 species of mollusks and 1,000 species of reef fishes. Reef access and tenure systems vary across the region, with some reefs open to the general populace, while others are owned and managed at the village level. Typhoons, El Niño-related warming events (coral bleaching) and *Acanthaster* outbreaks are among natural disturbances affecting Micronesian reefs. Sedimentation, pollution, eutrophication, over harvesting, destructive fishing practices and ship groundings are among the anthropogenic disturbances of greatest concern. The management expertise and traditional governance systems that exist within the region have the potential for reversing the decline in reef health being experienced by reefs. The dependence of the islands on coral reef related resources makes effective management initiatives critical to present and future generations of Micronesian residents.

ECOLOGICAL EFFECTS OF THE 1998 EL NIÑO ON CORAL REEFS OF EASTERN AFRICA.

Obura*, D.O., Mohammed, S, Motta, H, Schleyer, M. Coral Reef Degradation In The Indian Ocean (CORDIO), Box 10135, Mombasa, Kenya; dobura@africaonline.co.ke.

East Africa, comprising Kenya, Tanzania, Mozambique and South Africa, was greatly affected by coral bleaching and mortality as a result of the 1997-98 El Niño. Bleaching most probably started in late February to early March in the south, progressing northwards with the Inter-Tropical Convergence Zone to finish in May in the north. At any single location surface water temperatures were raised for up to 2 months, with +1-2°C anomalies recorded *in-situ*. Coral bleaching and mortality increased from high to low latitudes, from <1% at 26-27°S in South Africa to 50-80%, and in some locations approaching 95%, at 2-4°S in Kenya. In between, bleaching and mortality levels of 30-80% were documented from northern Mozambique and Tanzania. Mortality was least where local features reduced surface heating, influenced by depth, tidal exchange in reef channels and upwelling on continental shelves. Newly dead surfaces were colonized by a variety of algal groups, invertebrates, microbial mats and bioeroders, and are currently undergoing succession. Changes in consumer populations have been documented but vary greatly. Until the end of 1999 recovery of corals has been principally through regrowth of surviving colonies, however surveys in early 2000 have revealed significant recruitment at some reefs, dominated by *Pocillopora damicornis* and a mix of acroporids, siderastreids and faviids. Recovery also appears to be faster on reefs previously impacted by anthropogenic stressors, where opportunistic species predominated. Socioeconomic impacts of bleaching and loss of corals appears to have been minor, with other factors dominating resource use practises.

THE ROLE OF REEFCHECK: LESSONS LEARNED FROM INDONESIA.

Putra, Ketut Sarjana. *WWF Indonesia, Wallacea Bioregional Program, Bali, Indonesia. EMAIL: KPUTRA@WWFNET.ORG

WWF Indonesia has been primarily responsible for implementing Reef Check in Indonesia since its inception in 1997. From the outset, the focus has been on using Reef Check both as a tool for monitoring reefs and as a tool for raising awareness and building support for coral reef conservation among key government sectors and reef users. Reef Check activities included a training of trainers (TOT) for participants, a media launch by the minister of environment, and a media event to disseminate the results. Important lessons from the RC experience included the following; use of media and key government figures helps raise the profile of reef conservation nationally, care should be taken to ensure that there is good communication between the Reef Check coordinators and the government and academic monitoring programs so that good collaboration can be achieved. To maximize impact, 31 participants received training, who went on to leverage local funding sources for funds to implement Reef Check 1999. Priority in selection of trainers was given to Indonesian NGOs, university representatives and government officials, rather than the private sector, with a view of building capacity and creating an Indonesian network for coral reef conservation and monitoring. Reef Check was then conducted by the TOT participants at 33 sites in eight locations and involving a total of 134 divers. The major obstacle faced in Indonesia is to get sponsorship to implement the Reef Check.

PAPUA NEW GUINEA'S PARTICIPATION IN A GLOBAL ASSESSMENT OF HUMAN EFFECTS ON CORAL REEFS.

Quinn, N.J.*, B.L. Kojis & R. Sammuel. Biology, Dept., Uni. of Papua New Guinea, Port Moresby, Papua New Guinea. Email: quinnnj@upng.ac.pg

The transformation of PNG's economy has altered the use of coral reefs. Today reefs are increasingly fished commercially, visited by tourist divers, and impacted by resource exploitation. The impact of these activities on the reef ecosystem needs to be assessed. Using the Reef Check protocol, PNG university students have been conducting surveys on PNG coral reefs. To do this, students needed to be taught scuba skills and marine survey techniques. Preliminary results suggest that the main human impact on PNG's reefs is from coastal artisanal fisheries. Offshore reefs still retain high fish populations as exemplified by the large schools of Maori Wrasse within 15km of Port Moresby. Coral cover is generally high, with very few Crown-of-thorns starfish and no reported outbreaks.

STATUS OF CORAL REEFS IN SOUTH ASIA.

Rajasuriya A.*; Zahir, Hussein; Muley, E.V.; Subramanian, B.R.; Venkataraman, K.; Wafar, M.V.M.; and Whittingham, Emma. *National Aquatic Resources Research and Development Agency, Crow island, Colombo 15, Sri Lanka. Email: arjan@nara.ac.lk

Major coral reefs in South Asia surround the oceanic islands of Lakshadweep, Maldives, Chagos and the high islands of Andaman and Nicobar. Other extensive reefs are in the Gulf of Mannar region. There are also numerous fringing and patch reefs in India and Sri Lanka. In Bangladesh the only coral reef occurs around St. Martin's Island. Recent surveys indicate that recovery of corals bleached in 1998 is poor. Natural and human disturbances, such as the crown of thorns starfish, coral mining, destructive and unmanaged resource harvesting, sedimentation and pollution continue to cause much damage to coral reefs in South Asia and reduce their capacity to recover from the 1998 bleaching event. Capacity for monitoring coral reefs has been improved with donor assistance, however there is limited application of monitoring data due to a lack of management mechanisms. Due to the absence of proper management the condition of marine protected areas in South Asia has degraded. Several new protected reef areas have been recently declared in the Maldives. This report highlights the increasing population pressures on reef resources, lack of awareness and inadequate capacity for management and discusses the need to improve management capacity for the conservation and sustainable use of coral reefs in South Asia.

ADAPTING REEF CHECK TO CORAL REEF RESOURCE MANAGEMENT IN HAWAI`I.

Raney, Dave*, *Sierra Club Coral Reef Working Group, 1621 Mikahala Way, Honolulu, Hawaii 96816, USA. Email: d_raney@aloha.net

Although Reef Check was initially designed as a one-time assessment of coral reef health on a global basis, it has evolved into an ongoing program, has been adopted widely for community-based coral reef monitoring programs, and in 1998 was chosen by the Global Coral Reef Monitoring Network (GCRMN) for the community-based tier of monitoring within GCRMN. This paper discusses the use of Reef Check by community volunteers in Hawai`i, and its integration with state and local resource management programs so the work of the volunteers is credible, linked to resource management actions, and of value to local communities. One of the challenges encountered was the need to adapt and extend the core Reef Check methodology to fit local requirements while retaining consistency with Reef Check's global monitoring protocol and data structure. Other challenges include (1) the need to address state agency concerns over diver safety and potential impacts of volunteer monitoring activities on the resources being monitored; (2) identification of which findings by volunteers might trigger responses by resource management agencies if reported; (3) the need for funding or donated goods and services to cover costs of ongoing monitoring programs; and (4) the need to effectively involve community members so as to build an informed constituency in support of coral reef protection.

STATUS OF SOUTH EAST PACIFIC CORAL REEFS. POLYNESIA MANA NODE : COOK IDS, FRENCH POLYNESIA, NIUE, KIRIBATI, TOKELAU, TONGA, WALLIS AND FUTUNA.

Salvat, B., *EPHE, ESA CNRS 8046, Université de Perpignan, France, and CRIOBE, B.P. 1013 Moorea, Polynésie française. Email: bsalvat@univ-perp.fr

Cook Ids, French Polynesia (F.P.), Niue, Kiribati, Tokalau, Tonga and Wallis and Futuna are 7 independent or autonomous countries or territories with 347 islands with coral reefs and an EEZ more than 12 millions sq.km. The total population is about 450.000 living on less than half the number of islands, with about 80% concentrated in 6 islands with urban centres. Coral reef habitat and biodiversity are reduced along a west to east gradient in the Pacific. Cyclones do impact on the reefs but only at about decadal scales. Crown-of-thorns starfish have appeared with varying levels of intensity, but the only major outbreak was in the 70's in F.P. Bleaching events with high mortality were reported in F.P. in 1991 and in some localities all over the region in 1999 and 2000. Pollution (mainly eutrophication and sedimentation) only occurs near urban centres. Documented information on reef stocks and exploitation of resources is poor except in F.P., but coral reef resources are very important for subsistence economies, with local commercial exploitation developing. Tourism - about tourists per year - is still in early stages of development except in F.P. Black pearl oyster culture is only important in the Cooks and F.P. Nacreous gastropods have been introduced and now constitute income for local communities. Threatened species include giant clams with plans for reintroduction and commercial exploitation. Regular monitoring programmes only exist in F.P. with only occasional or starting programmes elsewhere. Even where conservation laws and legislation exist, enforcement is very weak

GLOBAL CORAL REEF MONITORING NETWORK – REGIONAL REPORT: IOI-PACIFIC ISLANDS.

South, G. Robin* & Skelton, Posa A.. *IOI-Pacific Islands, Marine Studies Programme, USP. PO Box 1168, Suva, FIJI. Email: south_r@usp.ac.fj

The IOI-Pacific Islands GCRMN Node covers six independent nations (Fiji, Kiribati, Nauru, Samoa, Tonga and Tuvalu), consisting of over 1000 islands and islets and spanning from 32°S to 4°N and 166°E to 168°W. The countries comprise high and low lying islands and atolls, containing fringing, barrier, submerged, platform, oceanic ribbon and drowned reefs, atolls and near atolls. The diversity of marine species declines eastwards from the Indo-Pacific centre of origin. The fin fishes decline from 1900 species in Fiji to 991 in Samoa and just over 400 in Tuvalu. Marine benthic algae decrease from 422 in Fiji to 287 in Samoa and 40 in Nauru. Extinct species include the giant clams: *Tridacna maxima* and *Hippopus hippopus* from Nauru and Samoa, respectively. Endangered species include marine turtles, giant clams, giant tritons, mangrove crabs, bêche-de-mer, trochus and turban shells, and highly targeted reef fishes. Coral reefs are in good condition in most countries, although significantly degraded in urban areas. The reefs are becoming increasingly vulnerable from over-fishing, pollution, sedimentation, environmentally unsound development, crown-of-thorns starfish outbreaks and habitat loss. Climatic factors such as cyclones, sea level rise, coral bleaching (such as the early 2000 bleaching event in Fiji and Tonga) are real or potential threats. Long-term monitoring of biotic reef systems is not in place, although the development of marine protected areas has been implemented in Samoa and Tuvalu or identified in Fiji and Nauru. There is a need for integrated coral reef management. Technical knowledge exists in most government departments, but there is a lack of trained biologists, taxonomists, ecologists and managers.

ADAPTIVE COMMUNITY-BASED MANAGEMENT OF A MARINE RESERVE NETWORK IN HAWAI'I.

Tissot, Brian*; Walsh, William; Hallacher, Leon. *Program in Environmental Science and Regional Planning, Washington State University, 14204 NE Salmon Creek Ave., Vancouver, WA 98686 USA Email: tissot@vancouver.wsu.edu

Monitoring programs often suffer from weak links to effective management strategies. In Hawai'i, aquarium collecting on reef fish populations has caused multiple-use conflicts between collectors and other ocean users. Using a control-impact design we determined that 8 species targeted by collectors were significantly less abundance at impact relative to control areas. In response to widespread perceptions of declines in reef fishes and community pressure the state legislature passed a bill in 1998 to establish Fish Replenishment Areas (FRAs), reserves closed to aquarium collecting along 30% of the west Hawai'i coastline. Based on scientific input, a network of 9 FRAs was proposed by a community-based group, the West Hawai'i Fishery Council. In 1998 we began monitoring 23 study sites to evaluate changes in abundance and community structure as the reserve system is implemented. After 5 years, our goal is to maximize fishery production by modifying the design of the network based upon community input and our findings.

THE CORALS AT CON DAO ARCHIPELAGO (SOUTH VIETNAM) –BEFORE, DURING AND AFTER THE BLEACHING EVENT IN 1998

Tuan, Vo Si* *Institute of Oceanography Nha Trang Vietnam. Email: thuysinh@dng.vnn.vn

Reef Check with more detail records was used to monitor variation of coral community Con Dao archipelago. By April 1998, exposed reefs showed major hard coral cover loss (up to 100%) due to the typhoon, while repeated surveys of 6 sites not hit by the typhoon revealed that high coral cover was still present. Follow-up surveys in October 1998 coincided with the world-wide bleaching event. The frequency of coral colonies suffering bleaching ranged from 0 to 74.2% (n=11 sites) with a mean value of 37% including 10.8% considered as mortality up to this time. The soft coral *Sinularia* was most affected by bleaching with almost 100% colonies bleached and then the fire coral *Millepora* (83%). The hard corals belonging to strong impact group included *Porites* (57%), *Symphyllia* (42%), *Leptastrea* (40%), …and also *Acropora*. Contrarily, there was no bleaching among 45 *Galaxea* colonies observed. In July 1999, most reefs showed recovery with some new recruits evident, but coral abundance was less than that before bleaching. The long-term influence was significant for massive corals, especially big *Porites* colonies.

SCIENTIFIC IMPLICATIONS OF MONITORING CORAL REEFS FOR SUSTAINABLE LIVELIHOOD DEVELOPMENT IN POOR COUNTRIES; EXPERIENCES IN SOUTH ASIA.

Whittingham, Emma* & Rubens, Jason. *Global Coral Reef Monitoring Network South Asia, 48 Vajira Road, Colombo 5, Sri Lanka. Email: reefmonitor@eureka.lk

Coral reef monitoring protocols have generally been designed by scientists from developed countries where academic perspectives govern research and monitoring, funding is relatively plentiful, and subsistence livelihoods are not a priority concern. However in developing countries where most coral reefs occur, funds and staff resources for coral reef assessment and monitoring are often very scarce, and are strongly tied to sustainable livelihood development objectives. Therefore changes may be required to match scientific monitoring designs to the needs and capacity of developing countries. The problem is acute in South Asia where over two and a quarter million, mostly poor, people live in direct proximity to coral reefs and depend wholly or partly on direct use of coral reef resources. Development priorities and the shortage of resources both support a case for de-centralising research activities to community level officers, NGOs and community groups. This serves both to reduce costs and to promote awareness amongst resource users. However, in doing so there is likely to be a compromise in the reliability and resolution of data collected. Since quality scientific information is still at a premium amongst donors and governments, such community approaches must still be balanced with orthodox specialist research. With the above perspective to the fore, this paper will present the experiences of the past 3 years in developing a coral reef monitoring network in India, Sri Lanka and the Maldives.

CORDIO: REPORTS OF CORAL REEF DEGRADATION IN SOUTH ASIA

Wilhelmsson Dan*, *SACEP, 10 Anderson Road, Colombo 5. Email: dan.wilhelmsson@cordio.org

The reefs of South Asia were severely degraded by the bleaching event of 1998, with subsequent mortality of corals ranging between 50% and 100%. In early 1999, the CORDIO program was launched to determine the ecological and socio-economic effects of coral reef degradation in the Indian Ocean. The South Asian component of CORDIO includes activities in India, Sri Lanka and Maldives and is co-ordinated from a regional office (SACEP) in Colombo. Biophysical monitoring of the reefs is combined with research focussed on recruitment patterns of corals, rate of erosion of the reef framework and changes in community structure of coral reefs. Also, socio-economic studies were conducted to determine the impacts of coral reef degradation on fisheries and tourism. In addition, projects investigating alternative livelihoods for people dependant on coral reefs, such as fishermen and ornamental fish collectors, are being conducted. Already, research has identified ecological and economic effects resulting from coral reef degradation in South Asia. Reef surveys conducted during 1999 and early in 2000 recorded some coral recruitment, but many areas still show no signs of recovery. Changes in fish communities have also been reported in some areas, such as in Sri Lanka where a dramatic decrease in the number of butterfly fish has been recorded. Declines in tourism are likely to be most pronounced in the Maldives, where dive tourism contributes approximately 20% to the GNP. Surveys have already indicated economic losses attributable to reef degradation. This paper presents the activities and results obtained during the first year of the CORDIO program in South Asia.

THE QUIKSILVER CROSSING AND CORPORATE SPONSORSHIP FOR REEF CHECK

Willcox, K.* *Quiksilver International Pty. Ltd., 303 Barrenjoey Road, Newport Beach, NSW, 2106, Australia. Email: kirk.willcox@quiksilver.com.au

"The quiksilver crossing" is a unique surfing, scientific and cultural expedition to remote coral reefs sponsored and managed by quiksilver international, a boardriding company. The crossing, which started in march 1999, involves a series of voyages of the motor vessel indies trader within 21 degrees of the equator, with the primary purpose of finding new surfing locations. As an environmentally responsible corporation with an ocean focus, quiksilver also seeks to educate surfers and the public about the value of conservation of the marine environment, especially coral reefs. Quiksilver thus sponsors reef check scientists to travel on the ship to carry out surveys on the health of remote reefs. Data from such locations isolated from most human influences are critical to determining baseline conditions at reefs elsewhere. The scientists also train surfers and local island residents in basic reef ecology and reef check methods. A website (www.quiksilver.com), films (including a 13-part national geographic/southern star entertainment television series) and videos document the expedition and disseminate what is learned throughout the world. When seeking corporate sponsorship, it is helpful to contact companies with an overlapping interest such as the ocean, the environment, sports or education. The corporate sponsor should also be able to generate some positive public relations from the sponsored activity. Innovative sponsorship methods such as granting permission to use the reef check logo can help the corporation see a direct benefit of sponsorship.

THE STATUS OF CORAL REEFS IN THE NORTHERN CARIBBEAN & WESTERN ATLANTIC.

Woodley, Jeremy*, Pedro M. Alcolado, Timothy Austin, Rodolfo Claro-Madruga, Gina Ebanks-Petrie, Reynaldo Estrada, Francisco X. Geraldes, Floyd Homer, Eleanor Phillips, David Shim, Kathleen Sullivan, Monica B. Vega, Jean Wiener. Centre for Marine Sciences, University of the West Indies (Mona), Kingston 7, Jamaica W.I. <woodley@uwimona.edu.jm>

Deterioration of reef resources is reported from all countries. The most extensive direct human impact is over-fishing; acute in Jamaica, Haiti and the Dominican Republic, where narrow fringing reefs are easily accessible. Reef fish stocks dispersed over broad shelves are less depleted, as in Cuba and, especially, in the Bahamas and the Turks & Caicos Islands. Higher standards of living in the Cayman Islands and Bermuda result in less fishing pressure. Mass mortality of the sea-urchin *Diadema antillarum*, throughout the region in 1983, resulted in excessive growth of macroalgae, especially where over-fishing had already depleted herbivores. This, and white-band disease in the *Acropora* spp, led to catastrophic declines in coral cover; notably in Jamaica, but there has been some recovery in recent years. In 1998, coral bleaching was severe in Cayman and Cuba, but mortality seems to have been low. Sediment run-off and nutrient pollution are especially prevalent in the three high islands. Careless coastal development for tourism has impacted reefs in most countries, while increasing pressures of diving tourism are apparent in Cayman and the Turks & Caicos Islands. There is increasing local awareness of the need for coastal conservation, and all countries, except Haiti, have declared Marine Protected Areas. There is generally little enforcement of conservation laws, and most agencies need more resources, trained personnel and political support.

REPORT ON ICRI/GCRMN ACTIVITIES IN JAPAN.

Yoshinaka, Atsuhiro*. *Nature Conservation Bureau, The Environment Agency of JAPAN, 1-2-2, Kasumigaseki, Chiyoda-ku, Tokyo, Japan. Email: NAOKO_NAKAJIMA@eanet.go.jp

Japan has been continuously committing the International Coral Reef Initiative(ICRI) activities since the beginning of the Initiative. Especially, in order to promote ICRI activities in East Asian Sea Region, we organized and/or co-organized workshops, training courses, conferences etc. such as follows, with co-operation with other Countries, international organizations, NGOs, and etc.

1995-: JICA Training Courses for Coral Reef Conservation

1996-:Development of Management Plan of Tubbataha Reef

1997: The 2nd Regional Workshop for the East Asian Seas(Okinawa) GCRMN Socio-Economic Workshop (Bolinao, Philippine)

1999: Training Course in Global Coral Reef Monitoring Techniques (Vietnam)

In order to promote Global Coral Reef Monitoring Network(GCRMN), which is recognized as one of the primary activities of ICRI, we established "International Coral Reef Research and Monitoring Centre" in Okinawa Prefecture, so that it may work as a "node" in East Asian Sea Region. Based on the Centre, we have started Coral Reef Monitoring Surveys (CRMS) to know the present situation around coral reefs in Japan with Government-level, Public-level and Researcher-level Monitoring Surveys. The Centre also has started collecting references, reports, monographs, and documents on Coral Reefs especially in the Region and plans to send the information on them as well as the results of CRMS globally through Internet and publications.

Session D2: Central Questions, Experimental Design and Methods of Long Term Monitoring Programs

IDENTIFICATION OF CHANGE IN MULTI-SPECIES ASSEMBLAGES OF CORAL REEF FISHES.

Anderson, Marti J. and Angus A. Thompson* Australian Institute of Marine Science, PMB # 3 Townsville MC. Queensland, Australia 4810. a.thompson@aims.gov.au

Coral reef fish communities typically have many species, most of which are locally rare. This presents considerable problems for univariate statistical analysis of both spatial and temporal dynamics. A common solution is to group species into a higher taxonomic or functional level to reduce the prevalence of zeros in the data matrix. Such groupings will likely desensitise the analysis by obscuring species level response to factors of interest. By nature large-scale ecological monitoring studies require a broad taxonomic coverage as impacts are often unpredictable in origin and effect. In the context of monitoring for change, we present examples of a multivariate approach that tests the observed location of a community in multivariate space against that expected under the hypothesis of no change. We expect that this novel approach will have general application to any multi-species environmental monitoring program.

ADVANCES IN REEF FISH MONITORING AND ASSESSMENT IN THE FLORID KEYS.

Bohnsack, J.A.*, Ault, Jerry S. and Smith, Steven G. *Southeast Fisheries Science Center, NOAA Fisheries, 75 Virginia Beach Dr., Miami, FL 33149 USA. Email: Jim.Bohnsack@noaa.gov

Reef fish monitoring of species presence, abundance, and sizes has been conducted in the Florida Keys, USA for over 20 years using the circular plot sample technique with a centrally located stationary diver described by Bohnsack and Bannerot in 1986. Statistical power has been significantly improved by using a habitat-based stratified random sample design in which effort is allocated based on sample variance. Other improvements involve sampling more sites with fewer samples per site, combining data for buddy pairs for analysis, and using nitrox for divers. These changes have significantly increased the sample size, geographical coverage, and habitat types that can be monitored. Further technological developments could potentially increase the accuracy of size estimates and biomass projections. This monitoring is being used to evaluate habitat importance to individual species, changes in reef fish communities due to no-take protection, and regional changes in management and water quality. In addition, the fishery-independent data generated can be used to do traditional fishery stock assessments with several advantages over using only fishery-dependent data.

CENTRAL QUESTIONS IN CORAL REEF MONITORING: A SYNTHESIS OF ECOLOGICAL CONCEPTS AND INTEGRATION WITH MANAGEMENT NEEDS.

Brosnan D.M.* Sustainable Ecosystems Institute, 0605 SW Taylors Ferry Road, Portland Oregon 97219 USA. e-mail brosnan@sei.org

Over the past decade, the status and fate of coral reefs has emerged as a critical issue in conservation science. As a result, reefs are being monitored at an unprecedented scale by academic scientists, policy makers, and conservation groups. How each group views monitoring is a reflection of their training, profession, and goals. All share a common aim, an understanding of the factors affecting coral reefs and a framework for their conservation. Monitoring is both a scientific endeavor and a tool to inform management decisions. This dual nature has frequently led to intense debate over which methods and designs to use. This in turn has often obscured the central questions surrounding monitoring. Our goal is to focus on the relationship between the questions (scientific and management) and the methods used, in order to move towards a more predictive and question-driven approach. Bringing together the results from the simple volunteer approaches to sophisticated scientific programs, we can now focus on a more synthetic approach. Our aim is a review and synthesis that addresses: 1. What are the main scientific and management questions? 2. Is current experimental design sufficient to address the proposed questions? 3. Can we develop a question-driven decision tree that provides guidance on methodologies and experimental design? 4. How do we develop a synthesis of ecological concepts and monitoring goals?

CHANGES OF CORAL COMMUNTIES ON THE FRINGING REEFS IN SOUTHERN TAIWAN: 1987-1999

Dai, C.-F.*. *Institute of Oceanography, National Taiwan University, Taipei 106, Taiwan, R. O. C. Email: corallab@ccms.ntu.edu.tw

Coral communities at six sites (Wanlitung, Hongchai, Maobitou, Houbihu, Tiaoshi, and Hsiang-chiaowan) in southern Taiwan were resurveyed in 1999 and comparisons with the data obtained in 1987 were made to illustrate the changes of coral communities. The results show that significant changes of coral communities have occurred at three sites (Wanlitung, Hongchai and Tiaoshi). These changes include decreases in species richness, number of coral colonies, living coral cover, and species diversity. Species composition of the communities has also changed with the relative abundance of branching corals (such as *Acropora* spp.) decreased and those of massive corals increased. Possible factors responsible for the changes of coral communities are sedimentation pollution, mass production of macroalgae, and extensive growth of sea anemones. Minor changes were found in coral communities at the other three sites. These results indicate that coral communities in southern Taiwan are under severe stresses and protective measures must be taken to prevent the degradation of the coral communities.

BRIDGING SCIENCE, POLICY, AND MANAGEMENT OF CORAL REEFS: THE KEY ROLE OF MONITORING PROGRAMS

Griffis, Roger* and Turgeon, Donna. *National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 14th and Constitution Ave. N.W., Washington, D.C. 20230 USA, Email: roger.b.griffis@noaa.gov

Monitoring programs can play key roles in linking scientists, policy makers, and managers involved in the conservation and sustainable use of coral reef ecosystems. In 1998, the United States embarked on an ambitious new effort to increase protection, conservation, and sustainable use of coral reef ecosystems for current and future generations. A critical part of this effort is to develop and implement a comprehensive national program to assess and monitor US coral reefs. Development of this national monitoring program faces a variety of challenges and opportunities. At present, there are numerous monitoring activities being operated by various governmental and private entities at local and regional levels, but these generally lack consistent designs, purpose, and comparable data sets, and leave wide gaps in coverage. This program seeks to integrate existing Federal, State, Commonwealth, Territorial, and non-governmental efforts into a national monitoring network. The goal is to fill critical gaps in the ability to determine and track the condition of US coral reef ecosystems by expanding existing monitoring programs and sponsoring activities that will lead to the establishment of new long-term monitoring sites. This presentation will highlight the challenges, opportunties, strategies, and current status of this effort to develop a national coral reef monitoring system that effectively links science, policy, and management.

THE X-FILES: THE USE (OR NON-USE) OF SCIENTIFIC MONITORING DATA FOR CORAL REEF MANAGEMENT.

Gulko, David A. Division of Aquatic Resources, Hawai'i Department of Land & Natural Resources, 1151 Punchbowl St. Rm. 330, Honolulu, HI 96813 U.S.A. david_a_gulko@exec.state.hi.us

A number of long-term coral reef monitoring programs are currently on-going in the State of Hawai'i. Frequently, as part of the grant review process, claims are made as to the benefits of such monitoring to active management of coral reef resources. Often the results of such efforts never live up to these claims, in part due to a disconnect between management and academic needs, and in part due to a system that encourages the creation of technical reports which end-up amongst hundreds of other technical reports filed away on shelves somewhere. This talk will focus on the major disconnect between a scientist's view of what and how monitoring should be accomplished and a manager's need for information that can be actively used to manage the resource. It will look at the end products produced and their practicality for use in active management of coral reefs. Focus will be on topics such as the value of various levels of measuring change (i.e. detecting change at a precision level far above the level at which the resource is actively managed), the difference between watching an event and determining its cause (i.e. should one also monitor users and inputs?), and finally, the cost-to-benefit ratio of such programs when weighed against the need to manage resources with severely limited dollars in the socio-political environment that currently exists. Suggestions will be made as to how the current system might be improved in order for scientific monitoring programs to better support active management of coral reef resources.

CLASSIFYING CORAL REEFS FOR DIAGNOSTIC MONITORING.

Jameson, SC*, Erdmann, MV, Potts, KW. *Coral Seas Inc - Integrated Coastal Zone Management, 4254 Hungry Run Road, The Plains, VA 20198-1715. Email: sjameson@coralseas.com

The first step in developing a diagnostic monitoring program using the biocriteria process is to design a classification system for coral reefs that will determine regional ecological expectations and reference sites representative of classification categories. A classification system for coral reefs under United States jurisdiction that includes ecoregions and classes of sites is proposed. The classification system groups coral reefs by physical and biological community characteristics such that biotic responses are similar both in the absence of human disturbance and after human disturbance. This system creates only as many classes as are needed to represent the range of relevant biological variation in a region and for detecting and describing the biological effects of human activity in that place. It is hoped that these groupings will give reliable metrics and accurate criteria for scoring metrics to represent biological condition and evaluate sites over time and place. The proposed coral reef classification system is different than traditional classification systems designed for identifying conservation areas. Classification based on ecological dogma, on strictly chemical or physical criteria, or even on the logical biogeographical factors used to define ecoregions is not necessarily sufficient for biological monitoring. One must use the best natural history, biogeographic, and analytical resources available to choose a classification system. Higher level taxonomic and ecological structure usually provide better guidelines for classification than focusing primarily on species.

THE CARIBBEAN COASTAL MARINE PRODUCTIVITY PROGRAM (CARICOMP) DATABASE.

CARICOMP, Linton Dulcie*. *Centre for Marine Sciences, University of the West Indies, Mona, Kingston 7, Jamaica. Email: dmlinton@uwimona.edu.jm

The Caribbean Coastal Marine Productivity Program (CARICOMP) is a regional, cooperative project monitoring attributes of the three main ecosystems, coral reefs, seagrass beds and mangrove forests. Since 1993 twenty-two marine laboratories, parks and reserves in 14 islands and 8 mainland countries have collected data according to the protocols outlined in CARICOMP Level 1 Methods Manual (1994, 1998). The data are stored in a relational database allowing correlation between data parameters to be explored through the use of queries. Example query outputs include the effect of the presence of one benthic organism on the abundance of another, e.g the density of urchins on fleshy algae or hard coral % cover. CARICOMP data showed generally that high urchin density was not correlated with low % cover by fleshy algae or high % cover by hard corals, though at the Discovery Bay site (Jamaica) there was some correlation between high urchin density and low % cover by fleshy algae. Physical data queries can highlight coral reef stations with high seawater temperatures allowing prediction of future bleaching events. Other queries can explore possible relationships between particular coral species and high seawater turbidity, indicating tolerance of species to high sediment load. Extracting data by coral species gives information on the relative abundance and regional distribution, dominant and rare species and temporal patterns of change in species abundance, suggesting possible tolerance to anthropogenic stresses by species. This database is an invaluable regional marine resource.

SAMPLING STRATEGIES FOR MONITORING BENTHOS ON CORAL REEFS: SIMULATION STUDIES.

McManus John W.*. *National Center for Atlantic and Caribbean Reef Research (NCORE) RSMAS, 4600 Rickenbacker Causeway, Miami, Florida 33149 Email: jmcmanus@rsmas.miami.edu

Monitoring can be viewed as area sampling in which the characteristic of interest is the change in benthos over time. The development of sufficient sample designs for monitoring programs must account for variability in both space and time. As the time scales of interest are often annual or longer, it is difficult to develop guidelines for such sampling based solely on field observations. In this study, I test a variety of sampling designs using an automaton model. The model simulates the growth and perturbation of corals and other benthic components across grids of square centimeters over substrates of tens of square meters. A range of simulated sample units, deployment patterns and sampling frequencies are being investigated. The results of these trials are summarized in support of suggested guidelines for the design of benthic monitoring programs.

MULTIPLE SPATIAL SCALE ASSESSMENT AND MONITORING OF MARINE RESERVES IN THE FLORIDA KEYS.

Miller S.L. *, D.W. Swanson and M. Chiappone. The National Undersea Research Center, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, Florida, 33037, USA. Email: smiller@gate.net

The Florida Keys National Marine Sanctuary (FKNMS) management plan features 23 relatively small (0.2-30 km^2) no-take zones or reserves that were designed to evaluate human impacts such as fishing, minimize user group conflicts, and preserve many of the well-developed reefs in the Sanctuary. The reserves provide a unique opportunity to monitor ecosystem structure and function in the absence of fishing and other extractive activities. We implemented a large-scale (over 100 sites from south of Miami to the Dry Tortugas), stratified random sampling design (multiple habitat types in reserves and fished areas) in 1999. The design includes a large and spatially dispersed sampling scheme instead of paired site measurements. Using the benthic habitat map for the FKNMS, site locations were randomly assigned. Rapid assessment surveys measured stony coral, octocoral and sponge species richness; abundance measurements for stony corals (juvenile and adult) and octocorals; percent cover estimates for sessile benthic organisms and abiotic reef components (sand, rock, rubble); coral size and condition measurements; rugosity; and reef fish abundance and size. Unique features of the program include the diversity of benthic taxa sampled, the suite of static and process variables measured, and the linkage of essential fishery habitat data with concurrent fishery-independent surveys of reef fishes. Sample design statistics provide the power to detect spatial variation within reef, among reefs, between specific reserves and reference areas, and among regional sectors that differ in physical setting. Large-scale ecological patterns, and the potential changes in community structure and function that result in reserves, link compelling scientific questions with important management issues in the Sanctuary.

MEASURE OF MESOBENTHIC REEF DIVERSITY: A PILOT STUDY USING 3-DIMENSIONAL ARTIFICIAL SUBSTRATES AS A SURROGATE FOR NATURAL SUBSTRATA.

Robinson, J.L.* and Thomas, J.D. National Coral Reef Institute, Dania, FL. 33004. Email: robinj@nova.edu.

While coral reefs harbor an extremely rich diversity of organisms, the species diversity, in most taxa of reef-associated organisms, is poorly understood and strongly underrepresented in many ecological studies and monitoring programs. Historically, biodiversity analyses in reef systems has been coral, fish, and molluscs. This focus on spatially obvious components in reefs creates a biological bias for using organisms that may not be as informative as other groups such as motile mesobenthic invertebrates, which may provide a higher degree of information in monitoring coral reef biodiversity. However, the lack of suitable non-destructive techniques to collect data hampers estimations at these lower trophic levels. We conducted a study of mesobenthic assemblages in shallow-water reef systems incorporating 3-dimensional artificial substrate units (ASUs). These units were placed in two representative reef habitats (live hardbottom and rubble) and collected at two-week intervals for one year. Collateral measures of *in-situ* natural substrata were also performed. Results are presented describing population dynamics of mesobenthic invertebrates colonizing 3-dimensional ASUs. The potential use of ASUs in assessing this ecologically important, but little studied component of reef systems will also be discussed.

AN EVOLUTION IN OUR APPROACH TO CORAL REEF MONITORING.

Rogers, Caroline S.*. US Geological Survey, P.O. Box 710, USVI 00830 Email: caroline_rogers@usgs.gov

The effort required to collect, analyze, and interpret high quality long-term data from coral reefs has been seriously underestimated. In general, monitoring has been less valued than experimental research. There is now acknowledgement that monitoring is a professional research activity that provides the context for experimental research, and that some information can only be obtained through long-term monitoring or interpreted in light of long-term data. Initially, my research team's objective was to try to differentiate natural variation from change due to human activities on presumably more "protected" reefs in Virgin Islands National Park. This perspective changed after eight hurricanes, massive bleaching, and widespread disease epidemics! Our monitoring program has evolved to become more comprehensive, with a larger spatial scale and more statistical rigor, as a response to an unprecedented combination of stresses affecting reef resources. We feel an obligation to provide information useful for park managers. I believe that the overall goal of managers and scientists is the same---a greater understanding of reef ecosystems---and that the scientist vs. manager dichotomy has been overstated. Many questions and challenges remain. For example, how statistically rigorous must we be to learn what we want to know? How can we conduct research over the appropriate temporal and spatial scales? Coral reef assessment is even more complex than people initially thought and is best accomplished through collaboration with other scientists and with clear objectives in mind.

ATLANTIC AND GULF RAPID REEF ASSESSMENT (AGRRA): A SPECIES AND SPATIALLY EXPLICIT REEF ASSESSMENT PROTOCOL.

Steneck, Robert S. Robert N. Ginsburg, Philip Kramer, Judith Lang and Peter Sale. University of Maine, School of Marine Sciences, Darling Marine Center, Walpole, ME 04573. USA. Email: Steneck@Maine.EDU

Are coral reefs dying throughout the western Tropical Atlantic; if so, at what rate? Are patterns of mortality related to species, regions, population centers or specific human activities? What, if any, agents of mortality correspond with observed patterns? These are questions the Atlantic and Gulf Rapid Reef Assessment protocol (http://coral.aoml.noaa.gov/agra/), seeks to address. The primary bjectives are to determine species-specific and spatially-explicit patterns in distribution, abundance, mortality, and size of major reef-building corals. Specifically, we record percent cover, colony size, diversity, structural height, mortality rates (recent and past), bleaching, and coral diseases. High biomass macroalgae can smother reef corals, hence, their relative abundance, canopy height and biomass are estimated. Reef fish communities affect the structure and function of coral reef ecosystems, so population density, average body size, trophic structure, and species diversity of key species are censused. Biomass estimates and population densities of grazing fish and the sea urchin Diadema antillarum, respectively, indicate herbivory. Reef monitoring is accomplished by repeatedly applying the protocol on fixed reefs, as done for the impacts of Hurricane Mitch and bleaching in Mexico. Workshops and electronic data summaries give reef managers and researchers free access to the completed assessments.

CORAL REEF MONITORING PROGRAMS: WORKING TOWARDS A SYNTHESIS OF SCIENCE, MANAGEMENT AND POLICY.

Tissot, Brian*. *Environmental Science and Regional Planning, Washington State University, Vancouver, WA 98686 USA Email: tissot@vancouver.wsu.edu

Monitoring programs can be used to effectively manage human impacts. However, many monitoring programs suffer from weak links to effective management strategies and from gaps between state and federal policy. Problems with sustaining strong connections between science, management and policy include institutional barriers, traditional disciplinary boundaries, lack of funding and scientific perceptions of monitoring activities. The most important long-term driver of monitoring programs is likely to be changes in technology. Increases in the resolution of remote sensing combined with increasing scale of underwater survey work will provide large-scale data for ecosystem management. However, efficient management at the ecosystem level will require better integration of state and federal policy and cooperation and collaboration among a wide variety of stakeholders. Moreover, community-based councils are likely to play an increasing role in resource management and require better integration of community education with monitoring programs. In the US the Coral Reef Protection Act offers an unparalleled opportunity to mesh state and federal policy and establish a national coral reef monitoring program. However, in order to develop an efficient, effective and sustainable monitoring program we need to conduct a comprehensive review and synthesis of existing long-term programs, identify gaps in information, and develop a greater integration of ecological concepts into experimental design.

STATUS AND TRENDS IN CORAL REEF ECOSYSTEMS—A NEW US INITIATIVE

Turgeon, Donna D.*. *Center for Coastal Monitoring and Assessments, National Centers for Coastal Ocean Science, National Ocean Service, NOAA, 1305 East-West Highway, Silver Spring, MD 20910 USA, Email: donna.turgeon@noaa.gov

In 1998, the United States established new policies to conserve and protect US coral reef ecosystems that initiated a variety of significant activities to map, monitor, and manage US coral reefs. One of these activities is the development of a national program to assess, inventory, and monitor US coral reef ecosystems, and report to the nation biennially on the status and trends of US coral reef ecosystems. Beginning in 2000, this multi-disciplinary, multi-partner effort is implementing a monitoring network and assessment of coral reef resources nationwide. Assessment reports have been prepared on the condition of coral reef resources from nine US State, Commonwealth, and Territories (i.e., Hawai'i, Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, Florida, Texas, the US Virgin Islands, Puerto Rico, and Navassa). This and other information has been used to prepare an *Initial Report on the Status of US Coral Reef Ecosystems*. The first report on the condition of US coral reefs is now available and has been incorporated into the GCRMN World 2000 report. This presentation will highlight findings from the initial US report.

WHAP! THE WEST HAWAI`I AQUARIUM PROJECT.

Walsh, William J. *, Tissot, Brian N. Hallacher, Leon E.. *Hawai`i Division of Aquatic Resources, 88-1610 Mamalahoa Hwy. Captain Cook, HI 96704 USA. Email: DARkona@interpac.net

Commercial aquarium collecting has been controversial in West Hawai`i for over 20 years. In response to widespread perceptions of declines in reef fishes and to community pressure, the 1998 Hawai`i State Legislature created a 235km West Hawai`i Regional Fishery Management Area to sustainably manage and enhance nearshore resources and to reduce user conflicts. A prohibition on aquarium collecting was mandated for a minimum of 30% of the area (termed Fish Replenishment Areas or FRAs). A community-based fisheries council proposed nine FRAs, which, with existing protected areas, comprise 35% of the coast. WHAP is a collaborative effort between university scientists and resource managers to evaluate the effectiveness of the FRAs to sustainably manage the aquarium fishery. Additional objectives include estimating impacts of ongoing aquarium fish collecting, documenting temporal and geographic recruitment patterns of reef fishes to examine developmental dynamics and population-level outcomes of a Hawai`i marine reserve system, determining critical habitat characteristics for aquarium fishes in relation to nearshore bathymetry, developing stock assessment data of heavily exploited species, and baseline monitoring of associated corals and selected invertebrates. A total of 23 permanent study sites have been established in FRAs, open areas (impact), and existing MPAs (control). Visual surveys are conducted bimonthly on four belt transects at each site. Six complete baseline surveys were conducted prior to FRA implementation and on-going monitoring will continue for five additional years.

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BIODIVERSITY MAPPING AND CONSERVATION IN SULAWESI, INDONESIA.

Allard, Patrick J., *Collaborative Environmental Project in Indonesia (CEPI), BAPEDAL Wilayah, Jl. Letjen Hertasning No. 22, Makassar, 90222. Email: pallard@evsenvironment.com

Indonesia's archipelago is one of the world's most biologically diverse regions. However, with a rapidly increasing human population, the exploitation of its ecosystems and natural resources has been expanding and intensifying. As part of their Collaborative Environmental Project in Indonesia (CEPI), the Canadian government completed a geographical information system (GIS) assignment aimed at developing a biodiversity classification framework for Sulawesi and applying it to specific case-studies (the Bantimurung Karst Area, the Bunaken-Manado Tua National Marine Park, and the Togian Islands). The biodiversity classification framework was developed using representative areas concepts based on ecosystem (or habitat) diversity rather than species diversity information. This was done for two reasons: 1) species diversity is difficult to define accurately because it may involve different measurement endpoints (i.e., richness, endemism, rare/endangered species), and 2) species diversity information does not take into account the ecological function of different habitat types. Work on the representative areas of Sulawesi involved three steps: 1) the systematic classification of terrestrial and marine bioregions based on habitat types, biogeography, and uniqueness (e.g. spawning grounds, nesting sites); 2) a review of the anthropogenic threats and current levels of protection relevant to each bioregion; and, 3) the identification of a number of potential representative areas (PRAs) based on their capacity to represent the biodiversity of Sulawesi.

INDO-PACIFIC CORAL REEF FISHES AS INDICATORS OF CONSERVATION HOTSPOTS.

Allen, Gerald R *. Conservation International, 2501 M Street, NW, Suite 200, Washington, DC 20037, USA. Email: fish@multiline.com.au

The concept of "hotspots" or threatened areas of extraordinary endemism and/or biodiversity has been effectively used to target conservation priorities, although it has been applied mainly to terrestrial systems. In the present study coral reef fishes are used as general hotspot indicators in the Indo-Pacific region. A zoogeographic analysis involving 2051 species reveals 46 sites of local endemism, as well as elucidating regional trends. Locally, the highest number of endemics are found in the Hawaian Islands, southern Japan, Marquesas Islands, Oman, Lesser Sunda Islands, eastern Andaman Sea, Palawan Island, and northern Red Sea. The greatest percentage of endemic species in relation to overall faunal totals are found at Easter Island (31.8 %), Hawaiian Islands (26.2 %), Red Sea (12.1 %), Marquesas Islands (11.8 %), Galapagos Islands (11.1 %), and Clipperton Island (7.7 %). Additional analysis of published faunal checklists and personal survey data reveals a detailed pattern of reef fish diversity in the Indo-Pacific, centred on the Indonesia-Philippines region. This pattern is corroborated by the distribution of the 285 Indo-Pacific species of damselfishes (Pomacentridae), one of the largest families of coral reef fishes. The hotspots data suggest that Indonesia and the Philippines are worthy of the highest conservation priority due to their extraordinary diversity, significant endemism, and high degree of threat.

A JOINT NOAA/USFWS CORAL REEF ASSESSMENT OF THE U.S. LINE AND PHOENIX ISLANDS.

Brainard, R.* Maragos, J., DeMartini,V., Wass, R., Parrish, F., Boland,V., Newbold, R. *NOAA Fisheries - Honolulu Laboratory, 2570 Dole Street, Honolulu, HI, USA, 96822-2396. Email: Rusty.Brainard@noaa.gov

In April 2000, the NOAA ship *Townsend Cromwell* completed a joint NMFS-USFWS research cruise to conduct rapid ecological assessments of the remote coral reef ecosystems of Howland, Baker and Jarvis Islands and Palmyra and Kingman Atolls of the U.S. Line and Phoenix Islands. Two teams assessed the spatial distributions of reef resources and characterized habitat along >100 km of 5-20 m isobaths on upper reef slopes using diver-observers on towed sleds with mounted digital video cameras. Observers alternated between recording ecologically/economically important fish taxa (>30 cm TL) and recording only sharks and large (>50 cm TL) jacks, maori wrasse, bumphead parrotfish, and groupers. Seventy stationary fish censuses were conducted. Detailed reef fish surveys (roving diver and line transects) to document species composition and relative abundance at sites differing in wave exposure and coral habitat were conducted. Detailed surveys of stony and soft corals, macro-invertebrates, and algae also were conducted at most of the same sites. Observed shallow reef fish/coral species were: 145/53, 160/60, 160/31, 200/110 and 170/102 at Howland, Baker, Jarvis, Palmyra and Kingman, respectively. Algal vouchers were archived. One permanent coral monitoring transect (100 m) was established at each island/atoll. Oceanographic dynamics of these ecosystems were described using closely-spaced CTD casts and current profiles around the islands/atolls.

ECOLOGICAL AND BIODIVERSITY INDICATORS FOR MARINE PROTECTED AREAS PLANNING: CORAL COMMUNITIES OF THE SAUDI ARABIAN RED SEA.

DeVantier, L.M.*; Turak, E.; Al-Shaikh, K.A. *JICA-NCWCD Study, c/o National Commission for Wildlife Conservation and Development, P.O. Box 61681 – Riyadh 11575, Kingdom of Saudi Arabia. Email: coralfish@bigpond.com

Towards development of a system of large multiple-use Marine Protected Areas in Saudi Arabia and the greater Arabian region, coral communities of the central-northern Red Sea coast were assessed in terms of cover, species diversity, community structure, and representativeness – uniqueness in 1998-99. The communities were composed of ~ 260 scleractinian species forming four major community types developed in relation to differences in degee of exposure, depth and water clarity. Although coral communities on some reefs (< 10 %) had been badly affected by predation or coral bleaching, most reefs (~ 90 %) were in good condition, with a strong overall positive ratio of living : dead coral cover (~ 6 : 1) and little local human impact. Ecological and biodiversity indices incorporating attributes of cover, diversity, endemism and rarity identified individual reefs and larger reef tracts of special conservation value, with the Gulf of Aqaba, Tiran area and Al-Wajh Bank forming important reservoirs of biodiversity and replenishment. These are priority areas for development of Marine Protected Areas, augmenting those already developed in Saudi Arabia and neighbouring Red Sea and Gulf nations.

BIODIVERSITY, ENDEMISM AND EVOLUTION OF OPISTHOBRANCH GASTROPODS ON INDO-PACIFIC CORAL REEFS.

Gosliner T.M.* *California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118, U.S.A. email address: tgosline@calacademy.org

The Indo-Pacific tropics support more than three thousand species of opisthobranch gastropod molluscs. The greatest species richness is found within the reefs of the western Pacific from the Philippine Islands, Indonesia and Papua New Guinea. Areas of high diversity and endemism have been traditionally identified as regions of particular concern for assessment of conservation priorities and hotspots. With increased understanding of phylogenetic relationships of highly diverse taxa, other important data are available for consideration in determining conservation priorities: 1. Are endemic taxa representative of basal or highly derived lineages? 2. Are groups of endemic taxa the result of single instances of adaptive radiation or are endemic biotas composed of representatives of several different lineages within a monophyletic group? 3. Are sister species of endemic taxa found in relatively close geographic proximity to their sisters or in distantly separated portions of the Indo-Pacific? Phylogenetic studies of many clades of opisthobranchs strongly suggest that Indo-Pacific representatives generally form monophyletic lineages that the sister clades to Atlantic and eastern Pacific lineages. This fact suggests that the Indo-Pacific represents an historically significant evolutionary and biogeographical unit. Different taxa within the Indo-Pacific may exhibit radically different patterns of speciation, diversification and evolutionary history, thus adding to the challenge of developing unified conservation strategies for preserving the diversity of life that inhabit the world's riches coral reefs.

BIODIVERSITY AND HABITATS OF THE CENTRAL-NORTHERN SAUDI ARABIAN RED SEA: AN INTEGRATED ASSESSMENT FOR MARINE PROTECTED AREAS PLANNING.

Matsushima N. *, Khushaim, O. Suzuki, K. Tsubouchi, T. DeVantier, L. *National Commission for Wildlife Conservation and Development, P.O. Box 61681 – Riyadh 11575, Kingdom of Saudi Arabia. Email: nmatusima@jwrc.or.jp

The National Commission for Wildlife Conservation and Development, with support from the Japanese International Cooperation Agency, conducted a large multi-disciplinary assessment of the biodiversity and habitats of the central-northern Red Sea coast of Saudi Arabia in 1998-99, for future marine protected areas planning. The study included assessment of the biodiversity, present status and distributions of marine turtles and mammals, corals, fish, algae and sea-grasses, other benthos, birds, coastal vegetation and mangroves. The results were used to 'ground-truth' detailed habitat-maps (scale 1 : 50,000) prepared from higher resolution aerial photographs. Socio-economic status and trends of the region were also assessed and, with the above information, incorporated in a customized GIS package to facilitate future management. An index incorporating the biodiversity, habitat and socio-economic information identified three key areas for conservation, with high priority for development of Marine Protected Areas. These should provide the foundation for integrated coastal zone management cored by Marine Protected Area Network in the Red Sea. These also should augment MPAs already developed in other areas of the Red Sea by Saudi Arabia and neighbouring countries.

THE GALAPAGOS ARCHIPELAGO: STATUS OF ICHTHYOLOGICAL KNOWLEDGE AND FISHERY-RELATED PROBLEMS.

McCosker J*. *California Academy of Sciences, San Francisco, California, USA. Email: jmccosker@calacademy.org

The Galápagos Archipelago is a living laboratory for the study of marine organism dispersal, endemism, and evolution, and more recently, of human impacts on a limited near shore ecosystem. The Galápagos ichthyofauna is fairly well known to -60 m and endemism is approximately 14-16% (several species are shared with Malepelo and the Cocos islands). Recent surveys to -1000 m using submersibles have increased knowledge of the deep reef fauna and depth distribution of many shallow water species. The effects of recent El Niño events and expanding fisheries will be discussed.

BRAZILIAN REEFS AS PRIORITY AREAS FOR BIODIVERSITY CONSERVATION IN THE ATLANTIC OCEAN,

Moura, Rodrigo L., *Museu de Zoologia, CP 42694 Universidade de São Paulo, 04299-970 São Paulo SP Brazil, Email: rlmoura@usp.br

Considerable attention has been devoted to reef degradation in the Caribbean region, resulting in an increase in monitoring and research activities, besides a number of effective conservation actions. The southwestern Atlantic (Brazil), on the other hand, has received fewer local and international attention, in part due to the smaller size and lower relative species richness of its reefs. Nonetheless, these reefs have high percentages of endemism (33% in reef corals and 20% in reef fishes) concentrated in only 0.4% of global reef area, and therefore constitute a global conservation priority. Alarmingly, habitat destruction and coral reef degradation is occurring at extremely high levels in the Southwestern Atlantic. Coastal deforestation (less than 8% of Brazil's Atlantic Forest is now left) and urban pressure are dramatically increasing sedimentation rates on all major Brazilian coastal reefs. With a few exceptions, the existing Marine Protected Areas are not equipped and prepared for enforcing fisheries restrictions and monitoring programs. The small reef area of the Southwestern Atlantic, together with the high endemism levels, categorize this region as an Atlantic coral reef "hot spot", deserving immediate attention from scientists and conservationists.

ON THE STATUS OF GIANT CLAMS, RELICTS OF TETHYS (MOLLUSCA: BIVALVIA: TRIDACNIDAE).

Newman, William A. * and Gomez, Edgardo D. *Scripps Institution of Oceanography, La Jolla, CA 92993-0202, USA. Email: wnewman@ucsd.edu**.**

Giant clams, family Tridacnidae, have long stimulated the interest and imagination as well as the pallet of man. The family includes two extant genera, *Hippopus* and Tridacna, represented by two and seven extant species, and five and one extinct species, respectively. The extant species are presently restricted to the Indo-West Pacific, with the center of diversity in the western Pacific, but fossil evidence of the extinct species and four extinct genera not only shows the family once had a pan-tropical, Tethyan distribution, but a substantially greater generic diverse during the Tertiary than it does today. The reliction included total extinction in the tropical Atlantic (Europe and Caribbean), and some extinction and range reduction in the Indo-W. Pacific as recently as the Pleistocene. Due to increasing human populations and concomitant resource exploitation and environmental deterioration in the Indo-West Pacific, some species have become depleted or even locally extinct, so that current management practices include rearing and re-introductions as well as some regulatory measures.

BIODIVERSITY AND ENDEMISM IN THE INDO-WEST PACIFIC REEF FAUNA: HOW MUCH AND WHERE?

Paulay, G. *, Meyer,. *Marine Lab, University of Guam & Florida Museum of Natural History, University of Florida, Gainesville FL 32611 USA. Email: paulay@flmnh.ufl.edu

The Indo-West Pacific (IWP) has long been recognized for its species richness, yet the extent of its diversity remains poorly understood. Taxonomic compilations have led to estimates of reef-associated diversity of generally <100,000 species. Several centers of endemism have been recognized, especially at peripheral areas and the Indo-Malayan diversity center, but emerging data from field-based and molecular taxonomic approaches are changing our views of species boundaries and ranges. Results from an intensive survey of the marine fauna of Guam suggest that faunas of even well-studied areas remain poorly known, and that small islands can host several tens of thousands of species. Extrapolations via traditional taxonomy imply IWP-wide diversity in the hundreds of thousands. Emerging data from field-based taxonomy and molecular genetic scrutiny however are revealing an even higher provincial diversity of likely >1 million species. In a family-wide survey of the species-rich, reef-associated gastropod family Cypraeidae, most wide-ranging "species" are differentiable into numerous allopatric taxa under genetic scrutiny. Narrowly distributed endemics appear to be common virtually everywhere, and several groups are comprised largely of patchwork mosaics of allopatric taxa. Although hotspots of diversity and endemism remain, the assumption that most archipelagoes virtually lack marine endemics is not tenable. The endemism documented has major implications for marine speciation and reef conservation.

GLOBAL PRIORITY REGIONS FOR CORAL REEF CONSERVATION.

Roberts, Callum M.*, Hawkins, Julie P. McAllister, Don E. McClean, Colin J. and Werner, Tim. *Environment Department, University of York, York, YO10 5DD, UK. Email: cr10@york.ac.uk

Coral reefs worldwide are under threat from human activities and many are rapidly being degraded. The scale of the problem greatly outstrips the level of conservation funding available with which to tackle it. This means that scarce conservation resources must be carefully targeted to areas where they will have the greatest benefits. In this study we use information on the distributions of reef-associated fish, cone shells and lobsters, combined with data on the distribution of threats to reefs, to identify priority sites for conservation worldwide. We created maps showing the global distribution of species richness and endemism of fish, cone shells and lobsters, using an equal-area grid. This grid divides tropical seas into around 4500 cells of approximately 50,000km^2 (an edge length of 225km, equal to 2° latitude at the equator). The grid enabled us to compare patterns of species richness and endemism across taxa, and to link such patterns to levels of threat experienced by reefs in each cell. Threat scores were calculated from the 'Reefs at Risk' database developed at the World Resources Institute. The results show a high level of concordance between hotspots of species richness across all taxa, while hotspots of endemism show substantial overlap between fish and cone shells, but not lobsters. Conservation strategies focused on regions rich in restricted-range species could have much value in stemming loss of species. However, there is a dilemma between whether to target the most threatened hotspots or those currently in better condition and where long-term prospects of success may be greater.

A NEW MODEL FOR IDENTIFYING EVOLUTIONARY DIVERSITY IN CORAL REEFS USING MARINE INVERTEBRATES: A SYNTHESIS OF GEOLOGY AND BIODIVERSITY.

Thomas, J. D.*. *National Coral Reef Institute, 8000 N. Ocean Dr., Dania, FL 33004 USA. Email: thomasjd@ocean.nova.edu

While reports and evidence for large-scale change in coral reefs and associated reef communities continues, scientists and managers persist in viewing reef biodiversity through a narrow lens of coral, fish, and mollusks. This constrains accumulation of additional informative data from other highly diverse taxon groups, especially small cryptic marine invertebrates. While global networks of marine protected areas and similar conservation and management tools are intended to ensure long-term survival of coral reefs and associated habitats, current efforts in this regard lack testable hypotheses to affirm or measure the value of such actions once taken. Often, marine protected areas are situated by socio-political process rather scientifically testable predictions that attempt to "target" areas of critical biodiversity. A new approach is proposed using an overlay of plate tectonics and phylogenetic data from selected marine invertebrates to define critical areas of biodiversity. This model, based on identifying centers of evolutionary diversification, can be readily tested using selected groups of invertebrates. Initial emphasis should be directed at reef areas where geological history and biodiversity data together indicates specific location(s) and areas of reef systems and events that may explain unusual patterns in biodiversity not obvious from other methods. Such patterns include elucidation of widespread paleoendemic faunas, high levels of regional endemism, areas of composite biodiversity, and ex-*situ* versus *in-situ* evolutionary patterns and processes.

GLOBAL PATTERNS OF REEF CORAL BIODIVERSITY.

Veron, J.E.N.*. *AIMS, PMB 3, Townsville MC 4810, Australia. Email: j.veron@aims.gov.au

Patterns of diversity of zooxanthellate corals have been generated by combining the distribution ranges of all 793 recognised species. At the family level, there is no well-defined Indo-Pacific centre of diversity and the Caribbean is almost as diverse as the Indo-Pacific. At the generic level, there is a well-defined Indo-Pacific centre of diversity in the Indonesian-Philippines archipelago and the Caribbean has a substantially lower diversity than the Indo-Pacific. At species level, this centre attenuates progressively to the north and east but is mostly uniform in the tropical Indian Ocean. The Caribbean is no more diverse than a depauperate outlying location of the Indo-Pacific. These distribution patterns have largely separate explanations. At the family level, they are mostly explained by continental drift and mass extinctions. At the generic level, they are mostly explained by closure of the Tethys Sea and the Central American Seaway. At the species level, they are mostly explained by patterns of ocean currents and changing climates. This is a progression of level of detail from the family to the species and from the most distant times to the most recent. Like the taxonomic hierarchy itself, there is a progression of inheritance in explanations of distributions.

BIODIVERSITY OF MOLLUSCS IN THE INDO-WEST PACIFIC.

Wells, Fred E*. *Western Australian Museum, Perth 6000, Western Australia. Email: wellsf@museum.wa.gov.au

The distribution of 1268 species of molluscs in 10 geographical regions of the tropical Indo-West Pacific is examined. The greatest diversity (745 species) occurs in the "coral triangle". Diversity in the Coral Sea is nearly as great at 708 species. Intermediate diversity occurs in the western (532 species) and eastern (524 species) Indian Ocean and the western Pacific Ocean (503 species). The lowest diversity occurs in the region between Lord Howe Island and the Kermadec Islands (66 species), Hawaiian Islands (245 species), South Pacific Ocean (293 species), and the Red Sea-Persian Gulf area (336 species). A total of 321 species are endemic to one of the 10 regions. Similar numbers of endemic species occur in the Red Sea-Persian Gulf (51 species), "coral triangle" (49 species), and eastern Indian Ocean (44 species). The fewest endemic species were found between Lord Howe Island and the Kermadec Islands (4 species), and the central Pacific Ocean (14 species). The combination of diversity and endemism provides a powerful tool for determining where to direct survey efforts for studies aimed at protecting and conserving coral reefs in the Indo-West Pacific.

A COMPARISON OF CORAL REEF BIODIVERSITY BETWEEN THREE SITES IN THE INDO-PACIFIC'S "CORAL TRIANGLE."

Werner, Timothy B.* and Espinel, Alvaro. *Conservation International, 2501 M St., N.W., Washington, DC 20037 USA. Email: t.werner@conservation.org

The central Indo-Pacific has long been known as the region with the biologically richest coral reefs, especially the "coral triangle" which includes Indonesia, Philippines, Malaysia, and PNG. Between sites within the coral triangle, there is little information indicating how species diversity and assemblages vary. Between 1997 and 1999, a team of marine scientists organized by CI inventoried zooxanthellate coral (Order Scleractinia), fish and mollusc diversity in three different areas of the coral triangle. Each survey lasted approximately two weeks with an average of 43 sites inventoried across a mean geographic area of 8000 km^2. Sites within each area were pre-selected to maximize habitat heterogeneity. Rapid assessments at each site involved recording all species observed between the surface and approximately 35m depth during 75 minutes bottom time using scuba. Unknown species were collected for later determination in the lab. The PNG location had the richest diversity of fishes (869 species) while the area selected in the Philippines had the highest species diversity for corals (386) and molluscs (657). Mean richness by site for molluscs (70 species) was highest in PNG, whereas mean richness in fishes was greatest in Indonesia (175). Fish and mollusc diversities showed a positive correlation with all sites pooled, but when analyzed separately only in the Philippine location was the correlation significant. Our results suggest ways to improve rapid biological assessment methodologies and recommend how conservation resources can be targeted to capture priority areas for coral reef biodiversity.

Session D4: Coral Reef Restoration in the Next Milennium

CORAL COLONIZATION (SCELERACTINIAN) ON ARTIFICIAL SUBSTRATE AT SIKUAI ISLAND BUNGUS TELUK KABUNG PADANG WEST SUMATERA (A CONSERVATION PLANNING FOR DAMAGED CORAL REEF)

Abrar, Muhammad S.Si* : *Indonesia Association Coral Reef Study (IACRS) Region I Sumatera. Email: sanari@padang_id@yahoo.com

The study about coral colonization on different substrates and temporal variation was conducted from June to November 1996 at Pulau Sikuai Bungus Teluk Kabung Padang West Sumatera. Artificial substrates in the form of cement, tile and iron size 12 x 12 cm was deployed at 5 metre deep at four stations. Station I, was a sandy area, Station II, a sandy area with the poor coral cover, Station III, live coral area with the rubble of dead coral, Station IV, dominated live coral. The result of this study founded six genera from three families tehere being Acropora and Genus X (Family Acropoidae), Pocillopora, Seriatopora and Stylophora (Family Pocilloporidae) and Porites (Family Poritidae). The taxa of coral settlement was dominated by Pocilloporidae, consist of genera Pocillopora, Seritopora and Stylophora. There were a total of 108 colonies on srtificial substrates within a five month periods that is 59 colonies on cement, 29 colonies on tile and 20 colonies on iron. The cement plate could be consistant and its can't damaged on the water volume. The period with the highest abundace of coral settlement as September with a total of 63 colonies. During September the weather conditions in Indonesia change from the West Moonson to the East Moonson called "Pancaroba Akhir Tahun". The highest density of coral colonization was 0,41 colony/m^2/month by Pocillopora at September. The highest relative frequency was 64,28 % by Pocillopora at August. Diameter of these settled corals were 0.7 mm to 3.1 mm. All genera were found on the lower surface of substrate. The distribution pattern of coral colonization was generally clustering and several genera were not counted. Analysis of waters condition at Sikuai Island were normaly and optimal for coral communities. This result to be very important on aquaculture development project, especially in the Coral Farming

CAGING STRATEGIES FOR REEF BASED GROW-OUT OF TROCHUS NILOTICUS (GASTROPODA) IN VANUATU.

Amos, Moses * and Purcell, Steven W. *ACIAR Trochus Research Project, PO Box 71, Broome WA 6725, Australia Email: spurcell@fish.wa.gov.au

Trochus niloticus ('trochus') has been overfished throughout the Indo-Pacific. Intermediate grow-out in cages may be an effective approach for restocking. In Vanuatu, 15-30 mm tagged juveniles were grown over a 9-month period at varied stocking densities inside steel benthic, plastic benthic and plastic floating cages. Growth rates were highest during the first 3 months, >4 mm $month^{-1}$ in some cages. Benthic cages on the reef were more problematic but generally yielded faster growth than floating cages. The caging methods produced different growth rates, which dif-fered over time. Stocking density related negatively to growth rate. The findings show that reef based grow-out is effective at producing sub-adult trochus for restocking.

SOFT CORAL TRANSPLANTATION AS A MEANS FOR REEF REHABILITATION.

Barneah O.* and Benayahu Y. *Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, 69978 Tel Aviv, Israel. Email: oritbar@post.tau.ac.il

Transplants of the soft corals *Dendronephthya hemprichi* and *Litophyton arboreum* (family: Nephtheidae), taken from artificial reefs, were used as a means for reef rehabilitation in Eilat (Red Sea). Natural attachment of the transplants of both species to hard substrate, rather than using glue, was found to be ideal. The overall survival rates obtained after 200 days in *D. hemprichi* and *L. arboreum* were 20 and 14% respectively, the first ever presented results for soft coral transplants. The highest survival of *D. hemprichi* transplants (35%) coincided with seasonal availability of phytoplankton (January-March), which comprises its major food source. Therefore, it is suggested that timing of transplantation is a crucial factor. The advantage of using *D. hemprichi* transplants is due to their fast attachment by rhizoids developing at their basal part. Rhizoids appeared 4 days after removal from the parent colony and reached maximum number 4 days later. Firm attachment was accomplished within 10 days and the number of rhizoids decreased thereafter. Light and electron microscopy elucidated the cellular cascade of events during the attachment process of *D. hemprichi* transplants and desmocytes were discovered to be the main cellular component involved in it. This is the first record of desmocytes mediating attachment to substrate in an octocoral. Using soft corals, flourishing on artificial reefs, as a source of transplants for recovery of denuded natural reefs is thus a recommended practice for coral reef rehabilitation.

REEVALUATING THE FIELD OF CORAL REEF RESTORATION.

Bowden-Kerby, Austin*. *Foundation for the Peoples of the South Pacific P.O. Box 14447, Suva, Fiji Islands Email: bowdenkerby@is.com.fj

The long-term conservation value of prevailing approaches to coral reef restoration has recently been questioned. Coral transplanting and substrate stabilization methods are generally quite expensive and are thus of limited applicability on a global scale. Coral reefs are complex ecosystems, however an ecosystem approach appears to be largely missing from much of the current work. As no adequate or generally accepted definition of "coral reef restoration" can be found in the literature, i define coral reef restoration as: *any manipulation of biotic or abiotic factors that leads to a recovery of coral cover, biotic diversity, or ecological functionality in the overall coral reef ecosystem.* In addition to direct manipulations such as transplanting corals, this broad definition encompasses the management of fish, invertebrate, and algal communities to correct for ecological imbalances that have lead to coral reef decline or that prevent recovery. The current state of the field of coral reef restoration is reviewed in this light, attempting to more directly connect the field to that of fisheries management, and modeling methods more closely after natural fragment-based coral reef recovery and development processes. Gaps in ecological understanding needing more research are discussed in the paper. The potential of low-tech methods to restore fisheries habitat within marine protected areas or to restore coral cover to former blast fishing areas is discussed as well, accelerating resource recovery and amplifying the effectiveness of community-based conservation measures.

SURVIVORSHIP OF RESTORED *ACROPORA PALMATA* FRAGMENTS SECURED USING WIRE AFTER A SHIP GROUNDING IN PUERTO RICO.

Bruckner, R.J.* and Bruckner, A.W. NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: robin.bruckner@noaa.gov

On July 23, 1997 the M/V *Fortuna Reefer* ran aground on a coral reef off the southeast coast of Mona Island, Puerto Rico, fracturing and dislodging colonies of *Acropora palmata*; the grounding and vessel removal impacted over 6 acres of coral reef. A primary, emergency restoration took place within two months, during which 1857 *A. palmata* coral fragments were attached to the reef substrate or to dead, standing *A. palmata* skeletons using stainless steel wire. Fragment survivorship and condition were assessed after 23 months and again after 31 months. During August 1999, 17% of the fragments were identified as missing and 26% had died. Mortality was attributed to sponge overgrowth, predation, disease, and damselfish algal lawns, respectively. Living fragments (57% of the total surveyed) had tissue covering 52% of the branch surface; 23% experienced little or no tissue loss and 27% exhibited signs of new growth (protobranches). Eight months later few additional fragments were lost (<1%) or had died (<1%) and 36% of the live fragments had protobranches. Limitations of the wire included breakage and a low ability (16%) of coral tissue to overgrow it. Low rates of natural fusion to the substrate (14%), continued wire corrosion and breakage, and additional periods of high wave surge may hinder long-term recovery; these concerns have prompted mid-course corrective actions to ensure that surviving fragments remain stabilized on the site.

EFFECTS OF SEASON AND CORAL SIZE ON THE GROWTH RATE AND SURVIVAL OF TRANSPLANTED ACROPORA CERVICORNIS IN THE CARIBBEAN.

Chilcoat, G.C.* Brazeau, D. and Fitt, W.K. *University of Georgia, rm 711 Biosciences, Athens GA, 30602 Email: gcc7314@arches.uga.edu

Pieces of *Acropora cervicornis* were transplanted in the Florida Keys and in the Bahamas during four different seasons in order to determine the relationship between size of the transplant and seasonal growth rates and survival. Fragments 2-20 cm in length were mounted to PVC such that buoyant weight and linear extension could be monitored seasonally. The following questions were addressed: (1) Will the time of year of transplant influence survival and growth rate? (2) Does survival or growth vary with size of transplants during any season? (3) What is the relationship between linear growth and buoyant weight increase for each season transplants were conducted? The answers to these questions are discussed in terms of potential restoration of damaged or diseased reef corals.

A TEST OF POST-BLEACHING RECOVERY USING CORAL FRAGMENTS AS SEEDLINGS

Eakin C.M.*. *NOAA/National Geophysical Data Center, 325 Broadway, E/GC, Boulder, CO 80303. Email: mark.eakin@noaa.gov

In a study designed to look at the use of fragments as a recovery tool on a reef severely affected by bleaching, 8 1m x 1m plots were seeded with 25 loose fragments each of *Pocillopora damicornis* and *Pocillopora elegans*. These plots, located in two different parts of the reef at Uva Island (Pacific Panama), were tracked for changes over 11 years. Similar to other experiments using coral fragments, a large percentage were lost in the first year. Survival rates over the initial 7 months ranged from 2-12%. However, subsequent losses were low, and surviving colonies grew larger while suffering mortality and changes in colony size throughout the experiment. Losses of colonies well after they had become established provides some indication of mortality rates that can be expected in attempts to seed reefs after mass mortalities. In regions with low sexual recruitment like the eastern Pacific, such seeding efforts can be effective means of encouraging recovery. However, without ongoing attention to replace lost colonies, such efforts may have little influence on reef coral cover. Results from this experiment will be compared with other plots that have been tracked for community changes at Uva Island and elsewhere.

CORAL REEF RESTORATION AFTER BLAST FISHING IN INDONESIA

Fox, H.E., Pet, Jos S.; Dahuri, Rokhmin; Caldwell, Roy L. *Department of Integrative Biology, U.C. Berkeley, Berkeley CA 94720 3140 USA. Email: hfox@socrates.berkeley.edu

One of the most devastating threats to reefs in Southeast Asia comes from dynamite or "blast" fishing. Inexpensive homemade bombs not only kill fish, but also pulverize coral skeletons, leaving bare, shifting rubble fields. This study, conducted in blast-damaged areas of Komodo National Park and Bunaken Marine Park, Indonesia, tests methods to recreate the structural foundation of the reef with stable, complex substrate. Significantly greater recruitment occurs on the experimental treatments compared to the bare, untreated rubble. In shallower water (2-6 m deep), rubble is often overgrown by soft coral and corallimorpharians. The survival of hard corals in these soft coral fields is being quantified with tagged juveniles, transplanted *Acropora* nubbins, and soft coral removal quadrats. Although rubble is stabilized in the soft coral fields, hard coral mortality is high. In addition, blast sites of known age are being studied, with pre- and post-blast analysis of community composition. Despite the blast crater rubble becoming more stable over time, coral recruitment in the craters has been slow. An integral goal of this research is to develop a relatively inexpensive and effective method for enhancing coral reef rehabilitation.

TRANSPLANTING "AT-RISK" CORAL FRAGMENTS IN VIRGIN ISLANDS NATIONAL PARK.

Garrison G.*. *Biological Resources Division, U.S. Geological Survey, P.O. Box 710, St. John, U.S. Virgin Islands 00831. Email: ginger_garrison@usgs.gov

The coral reefs of Virgin Islands National Park (VINP) continue to sustain damage from a variety of natural disturbances and human activities, with little evidence of recovery of scleractinian corals. Transplanting corals to damaged sites may initiate or speed up recovery, but the source of colonies is problematic. Naturally occurring fragments of elkhorn (*Acropora palmata*), staghorn (*A. cervicornis*), and finger (*Porites porites*) corals, three of the fastest growing Caribbean species, were taken from marginal environments in the park and attached to stable substrate on VINP reefs. Survival rates, growth, and causes of mortality are being documented over a two year period for 60 transplanted fragments (30 *A. palmata*, 15 *A. cervicornis*, and 15 *P. porites* corals) and 75 control fragments or small colonies in naturally occurring communities (45 *A. palmata*, 15 *A. cervicornis*, and 15 *P. porites* corals). After one year, preliminary results show a highly dynamic shallow reef system, with similar survival rates for transplanted and natural community corals. Mortality was high in all groups due to unusually powerful storm swells in January 2000 and predation by corallivorous snails. Growth of transplanted *Acropora palmata* exceeded that of the other two species. Transplanting "at-risk" fragments of *A. palmata* and *A. cervicornis* appears to be a viable, low-tech method for accelerating reef recovery without degrading other reefs.

COMMUNITY-BASED CORAL FARMING: ECONOMICALLY VIABLE REEF REHABILI-TATION AND LIVELIHOOD OPTION FOR FISHERFOLK.

Heeger, T.; Sotto, F.; Gatus. J. and M. Langevoord. *Unversity of San Carlos -Marine Biology Section- P.del Rosario St., Cebu City, Cebu, Philippines Email: theeger@mangga.usc.edu.ph

The Philippine coral reefs are degrading at an alarming rate. Overexploitation using destructive techniques is the single most important factor in long-term habitat destruction causing decline of fish stocks and catches. More than 1 million artisanal fishermen in the Philippines compete daily for the decreasing production of coral reefs and remain under the poverty level. A new low-cost coral farming technology was developed in Olango Island, Cebu. At present 62 scleractinian coral species of various life forms have been farmed. Studies showed that the fragmentation process is not hampering further growth of donor corals. The fragments in the Coral Nursery Units (CNU) grew for less than 2 to 4 months and were sold by the fisherfolk for reef rehabilitation at an average density of 2 fragments per squaremeter (=12.5% cover). Coral species selection followed the natural community structure of adjacent reefs with good coral cover. The net rehabilitation cost of a one hectare reef with 12.5% cover is US$ 2,100,-. Considering the cash revenue of more than US$ 700,- annually for a hectare of healthy reef, rehabilitation through coral farming may be an option providing income for fisherfolk and enhancing coral biodiversity.

INTEGRATED COASTAL ZONE MANAGEMENT OF CORAL REEFS: DECISION SUPPORT MODELING.

Huber R.M.* *The World Bank, Environmentally and Socially Sustainable Development Sector Management Unit, Latin America and the Caribbean Region (LCSES), 1818 H Street NW, Washington DC 20433, USA. Email: rhuber1@worldbank.org

Ecological economic decision support models can play a critical role in the development of effective ICZM for the protection and restoration of coral reefs. In 1995, work commenced under World Bank Research Committee funding on two streams of research: i) cost-effectiveness modeling of management interventions (i.e., a question of the "supply" of biodiversity as an economic asset); and, ii) marine system valuation (i.e., a question of the "demand" for biodiversity). The results are reported for the primary case study site – Montego Bay, Jamaica. Total benefits from the Montego Bay reefs are US$401 million NPV, with an estimated additional potential benefit of US$70 million NPV through pharmaceutical bioprospecting. The price (marginal benefit) of the coral reefs is US$9.88 million/% abundance. Up to a 20% increase in coral abundance may be achievable through the use of appropriate policy measures with a present value cost of US$153 million over 25 years. If economic efficiency is the goal, both costs and benefits must be considered when dealing with complex systems such as coral reefs. Marginal cost function (least cost intervention study) in conjunction with the marginal benefit estimates (valuation studies), allows one to arrive at a global optimization. Optimization requires a 13% improvement in coral reef abundance, requiring net expenditures of US$27 million. Advice is offered regarding policy applications and priorities for further research.

INJURY ASSESSMENT AND RESTORATION OF THE R/V COLUMBUS ISELIN GROUNDING SITE: LOOE KEY REEF, FLORIDA KEYS NATIONAL MARINE SANCTUARY, FLORIDA.

Hudson J.H.* and Spadoni, Richard H. *Florida Keys National Marine Sanctuary, P. O. Box 1083, Key Largo, Florida, USA. Email: harold.hudson@noaa.gov

The purpose of this report is to document assessment methods used to quantify injury to Looe Key reef caused by M/V Columbus Iselin and to provide information on restoration techniques and materials used to rebuild four coral spurs excavated by the ship and a post-grounding hurricane. An accurate injury map was created from aerial photographs of the site, and excavation volume was determined by diver measurements and high-resolution depth-sounder. Coral spurs were reconstructed by using a barge, crane, and divers to place quarried limestone boulders, fiberglass reinforcing rods and a specially formulated tremie-pumped concrete. On upper finished surfaces, exposed fresh concrete between boulders was ornamented with randomly placed limestone rocks to increase surface area and create a more natural appearance. Both hard and soft corals will be transplanted onto repaired spurs. Donor specimens will be collected from nearby reef rubble areas and other sources as appropriate.

HISTORY AND USE OF QUICK-SETTING PORTLAND CEMENT TO TRANSPLANT CORALS: TWO DECADES OF PROOF THAT IT WORKS.

Hudson, J. Harold*. *Florida KeysNational Marine Sanctuary, P. O. Box 1083, Key Largo, Florida, USA. Email: harold.hudson@noaa.gov

The purpose of this report is twofold: to show that a quick-setting (hydraulic) Portland cement developed by the author has long-term efficacy as a coral transplant adhesive, and to describe its basic formulation, preparation, and application under various environmental conditions. The hydraulic cement described here was first used on a large scale in 1977 to transplant 32 hard corals onto precast hollow concrete "coral" domes. The cement was also used to grout the domes to underling bedrock. After 23 years and a major hurricane, all cemented corals and grouted concrete domes remain firmly attached. Basic formula is 4 parts Portland type 2 cement and 1 part moulding plaster**.** Cement is combined with water and mixed by hand to the consistency of firm putty, formed into a ball and quickly applied. Both materials are inexpensive and are available from large companies that supply cement and plaster products to building contractors. This product requires strict adherence to sound practices of storage, handling, prepration, and application.

REEF REHABILITATION THROUGH TRANSPLANTATION OF STAGHORN CORALS: ARTIFICIAL STABILISATION AND EFFECTS OF BREAKAGE AND ABRASION.

Lindahl, Ulf. *Göteborg University, Department of Marine Ecology, Kristineberg Marine Research Station, 450 34 Fiskebäckskil, Sweden. Email: u.lindahl@kmf.gu.se

The staghorn corals *Acropora formosa* and *A. vaughani* were used in experiments on reef rehabilitation. A newly developed low-cost method for transplantation of corals was tested in a shallow reef area with loose substrate and moderate exposure to waves. To avoid dislodgement and abrasion due to water movement the transplanted coral branches were tied to string sections, which were connected at the seabed to form a grid. This treatment created stability and improved the survival and growth of the transplanted corals. The average annual live weight increase was 56%, which was significantly more than the control treatment with loosely placed coral branches. Mortality was negatively related to the initial size among the loosely placed branches, whereas the trend was reversed among the branches tied to strings. Staghorn corals transplanted on sand suffered severe mortality through burial and smothering whereas corals transplanted to thickets of dead standing corals survived and grew well. Branches of *A. formosa* were experimentally damaged to simulate the effects of breakage and severe abrasion during and after transplantation. The growth rate was not affected by the damage, and the results also show that the growth rate may vary up to five-fold between different clones.

SEA URCHIN REDUCTION AS A RESTORATION TECHNIQUE IN A NEW MARINE PARK

McClanahan T.R.* *The Wildlife Conservation Society, Coral Reef Conservation Project, P.O. Box 99470, Mombasa, Kenya. Email: crcp@africaonline.co.ke

Coral reefs degraded from heavy fishing may require both fisheries management and habitat manipulation in order to promote desired species of fishes and corals. This study explores the effect of a large-scale (~100 m x 100 m studied for three years) sea urchin reduction experiment in a new marine park to determine the effectiveness of this method in promoting the recovery of hard corals and finfishes and I compare the outcome of this management experiment with a previous smaller scale (~ 50 m x 50 m for one year; McClanahan et al. 1996), but better replicated experiment. Both experiments found increases in fleshy algae, estimates of total finfish wet weights, and particularly parrotfish, wrasses and scavengers biomass after the manipulation. Changes in fish wet weights were smaller in the large compared to the small-scale study which suggests a dilution effect with the increasing scale of the manipulation. The small-scale manipulation produced a loss while the large-scale manipulation produced an increase in hard coral cover. In both cases this appeared to be caused by an initial rapid increase in fleshy algae during the first 200 days of the experiment. Afterwards, fleshy algae decreased and hard coral increased. The decrease in fleshy algae and increase in hard coral were probably attributable to increased herbivory and seasonal storms. The loss of algae combined with reduced sea urchin grazing promoted hard corals. Sea urchin reductions in new parks is a useful reef restoration technique but requires sufficient fisheries restrictions, to promote commercial herbivores like parrotfish, and time, to promote coral recovery.

THE IMPORTANCE OF EVALUATION, EXPERIMENTATION, AND ECOLOGICAL PROCESSES IN ADVANCING REEF RESTORATION SUCCESS.

Miller, Margaret W.*. *NOAA-Fisheries Southeast Science Center, 75 Virginia Beach Dr. Miami, FL USA. margaret.w.miller@noaa.gov

The practice of coral reef restoration in the past has been largely confined to replacement of habitat with artificial structures and the transplant of coral colonies or fragments, either borrowed from nearby populations or rescued from the disturbance. Despite lip-service paid to "monitoring" in most restoration plans, the rigorous evaluation of these efforts has been, often, lacking completely and the declaration of success is often based on the most rudimentary criteria (stability of artificial structures or survival of x% of coral transplants). In very few cases, restoration projects have been designed to test the effectiveness of different restoration approaches (e.g. structure designs) in enhancing the biological performance (e.g., recruitment, growth, disease susceptibility) of key organisms and, in even fewer cases, in enhancing community function. However, these studies demonstrate the power of an adaptive management approach to restoration; that is, rigorously evaluating the ecological performance of alternative restoration approaches in order to do better in the future. If coral reef restoration is to advance beyond its current "build it and they will come" paradigm, an experimental approach and the evaluation and implementation of ecological restoration measures built upon our understanding of reef community processes and function must be pursued.

ECOSYSTEM SERVICES IN THE TROPICAL SEASCAPE: ECOSYSTEM INTERACTIONS, SUBSTITUTING TECHNOLOGIES, AND ECOSYSTEM RESTORATION.

Moberg, F.* and Rönnbäck, P. Natural Resources Management, Department of Systems Ecology, Stockholm University, S-106 91, Stockholm, Sweden. Email: fredrikm@system.ecology.su.se

The tropical coastal "seascape" often includes a patchwork of mangroves, seagrass beds, and coral reefs that produces a variety of natural resources and ecosystem services. By looking into a number of attempts at substitution and restoration of ecosystem services (e.g. artificial reefs, aquaculture in mangroves, and artificial seawalls) we address the notably complex questions: (1) to what degree can technologies substitute for ecosystem services in the seascape? and (2) how can ecosystem restoration reestablish not only the functions of direct value to humans, but also the ability of the systems to absorb future perturbations? Substitutions often imply the replacement of a function provided free by a solar powered, self-repairing resilient ecosystem, with a fossil-powered, expensive, artificial substitute that needs to be maintained. Further, restoration usually do not focus on large-scale processes as the numerous physical, biological and biogeochemical interactions between mangroves, seagrass beds and coral reefs. Nonetheless, restoration might be the only way to facilitate recovery when the system is essentially locked into an undesired stability domain after a phase-shift. We conclude that ecosystem services cannot be readily replaced or restored without extensive knowledge of the dynamics, multifunctionality and interconnectedness of ecosystems.

COMPARISON BETWEEN ARTIFICIAL AND NATURAL REEFS.

Perkol S.* and Benayahu Y. *Department of Zoology, Tel-Aviv University, Tel-Aviv 69978, Israel, Email: sperkol@post.tau.ac.il

Coral reefs all around the world are experiencing substantial decline, partly due to anthropogenic perturbances. Despite increasing interest in alternative ecosystems, little is known about the relationship between artificial reefs and their surrounding natural environment. Initial surveys conducted in Eilat (northern Red Sea) have led us to the hypothesis that the species diversity and community structure on artificial reefs are different than those found on the nearby natural reefs. Community structure of stony and soft corals was characterized using line transects conducted on two artificial reefs and on adjacent natural reefs. Stony coral coverage on the natural reefs was three times higher than on the artificial reefs, while soft coral coverage was ten times lower. The older artificial reef had higher species diversity than the younger (30 and 12 years respectively), and resembled the values obtained for the natural reefs. Soft corals such as *Dendronephthya*, *Scleronephthya* and *Nephthea* dominated the artificial reefs, yet had a minor significance on the adjacent natural reefs. Highest soft coral species count was found on the artificial reefs, also contributing to their remarkable total living coverage. These results are consistent with our hypothesis and present the value of artificial reefs as a successful tool for ecosystem rehabilitation, demonstrated by rapid colonization and establishment of high species diversity. Consequently, artificial reefs are attractive sites which may divert man made pressure away from degraded reefs, by that helping to sustain natural habitats and prevent their loss.

THE HISTORY AND FUTURE OF CORAL REEF RESTORATION

Precht, William F. * and Dodge, Richard E. *PBS&J, 2001 NW 107th Ave., Miami, FL 33172, USA. Email: bprecht@pbsj.com

Coral reefs are in crisis. It seems evident that if we continue the present rate of destruction, reef ecosystems will likely suffer continued degradation, possibly to the point of irreversible decline. Accordingly, the most appropriate course of action is to replace damaged reefs with fully functional, restored reefs at a rate resulting in no-net loss of ecosystem value. To date, most coral reef restoration programs have been focused on the physical damage caused by humans. In fact, much of what we know about the rehabilitation of coral reef systems stems from our work in repairing reefs injured by vessels that have run aground. Although quantification of reef restoration projects has been increasing, our level of understanding varies greatly based on our personal experiences. Finding appropriate solutions to a particular damage scenario is hampered by a lack of quantitative descriptions of the ecological effects of anthropogenic disturbance on coral reefs and an even greater lack of data describing the direction and rate of natural recovery. Inasmuch, there is little basis for understanding what works, what does not, and why? Hypothesis driven, ecological studies are the only means of answering these critical questions. Formulating and testing hypotheses about the response of both corals and reefs to these disturbances, allows us to establish the scientific protocol necessary to design and implement restoration strategies (by setting definable scientific goals), develop a baseline for developing quantifiable success criteria, and determine the efficacy of the restoration effort. It is to be hoped that these lessons learned will help to develop successful restoration efforts into the next millennium.

SURVIVORSHIP, REGENERATION, AND GRAZING-ALGAE EFFECTS ON TRANSPLANTED COLONIES OF *MONTASTRAEA ANNULARIS*.

Sánchez, Juan A.*; Gil, Maria F.; Alvarado, Elvira M.; Arenas, Olga L.; & Chasqui, Luis H.. ***Dept. Biol. Sci., SUNY at Buffalo, NY 14260, USA. Email:** js15@buffalo.edu

Coral reef restoration techniques usually include transplantation of scleractinian corals. We conducted an experiment with colonies of *Montastraea annularis* to study survival of coral transplants. Following disturbance, Caribbean reefs often undergo algal blooms that may prevent coral growth. Therefore, corals were transplanted to an algae-dominated fore-reef terrace (dead *Acropora cervicornis* stands). In order to control for the effect of algae bordering the corals we included a treatment excluding surrounding algae. Grazing pressure was twice as great among colonies surrounded by algae. Annual grazing rates were lower than the rate of polyp origination. The time required to recover from grazing increased with the amount of area affected. Net size of the transplants oscillated over time but most colonies exhibited net growth after one year. The plastic capability to recover after grazing allows *M. annularis* to survive transplantation even at algae-dominated areas.

ANALYSIS OF THE CORAL REEF RESTORATION FOR THE GROUNDING OF THE *CONTSHIP HOUSTON*, FLORIDA KEYS.

Schmahl, George P.*, *NOAA, Flower Garden Banks National Marine Sanctuary, 216 W. 26th St., Suite 104, Bryan, Texas 77803 USA. Email: George.schmahl@noaa.gov

On February 2, 1997, the 187 meter container ship *Contship Houston* ran aground on the Florida reef tract near Maryland Shoal in the Florida Keys National Marine Sanctuary. This incident resulted in significant injury to coral reef resources over an area 650 meters in length. A major coral reef restoration effort followed the incident to repair and mitigate the injury. Three primary categories of injury were addressed: 1) corals that were crushed, broken or dislodged from the substrate as the ship approached the grounding site; 2) accumulations of coral rubble created by propeller action as the vessel tried to remove itself; and 3) reef substrate fracture and destabilization in the area which supported the weight of the grounded vessel. A partnership between NOAA and the responsible party enabled a rapid response and restoration effort. Over 3,000 broken and dislodged corals were reattached to the substrate utilizing hydraulic cement and epoxy. A "liquified" epoxy was developed and poured over the rubble berms for stabilization. A combination of flexible concrete mats and large limestone boulders were utilized to stabilize the fractured reef substrate. A natural "test" of the restoration came in August 1998, when the category 2 hurricane *Georges* made almost a direct pass over the study location. Performance of the restoration technologies used in this effort was mixed. Reattached corals fared well, but the stabilization effort required repair.

ENHANCED FORMATION OF PROTOREEFS BY ACCRETION TECHNOLOGY AND CORAL TRANSPLANTATION

Schuhmacher, Helmut; and van Treeck, Peter *Institute of Ecology, University of Essen, D-45117 Essen, Germany, Email: h.schuhmacher@uni-essen.de

Mechanical damages of reefs often result in and leveled gravel fields inhospitable for recolonisation by corals. However, a living reef nucleus can be formed within a few years by combining a) the creation of an artificial reef framework formed by electrodeposition of calcium minerals from the sea-water and b) the transplantation of living coral fragments (nubbins) onto this frame and cementation of these nubbins by the precipitating limestone substrate itself. Ideally the nubbins are taken from coral nurseries. The protoreef community is successively enriched by coral larvae thus serving at key locations as a stepping stone for further recolonisation of wide areas. After the feasibility of the technology has been proved first results of experiments run in Ras Muhamed National Park (Red Sea, Egypt) are presented. The combination of an ecologically unobjectionable technology to create reef structures from the sea-water with the option to transplant coral nubbins offers a huge variety of applications for conservation and beyond that - for coastal protection, recreational diving, and coral farming.

THE STUDY ON INTEGRATED CORAL REEF REHABILITATION AND MANAGEMENT IN NORTH SULAWESI PROVINCE IN THE REPUBLIC OF INDONESIA

Suzuki, K.* *Social Development Study Department, Japan International Cooperation Agency Shinjuku Maynds Tower Bldg. 7th Floor, Yoyogi, 2-chome, Tokyo, Japan. Email: ksuzuki@jica.go.jp

JICA is now conducting the study on the Integrated Coral Reef Rehabilitation and Management in North Sulawesi Province in response to the official request made by the government of the Republic of Indonesia. Needless to say, Indonesia is composed of around 17,000 islands and their coastlines are quite complicated. these coastlines are surrounded by several kinds of natural environments such as coral reef, sandy beach, mangrove, etc.Especially in the North Sulawesi, around 350 species of coral have been officially found. Unfortunately, coral reefs in North sulawesi have been damaged by inappropriate natural resources use and spatial use including illegal human activities such as dynamite fishing. Therefore, it is indispensable to avoid conflicts between natural preservation and economic utilization in the area of this Study and to get involved with local government, local communities including fisherman, local NGOs and others concerned in planning for coral reef management. Under this situation, this Study aims to formulate a integrated master plan for conversation of coral reef ecosystem through sustainable natural resource management from the perspective of biodiversity conservation in close cooperation with the Government of Indonesia.

CORAL RESTORATION PLANNING IN U.S. MARINE SANCTUARIES.

Symons, L.* Benson, K. *National Marine Sanctuaries Program, NOAA, 1305 East-West Hwy., Silver Spring, MD 20910 USA. Email: lisa.symons@noaa.gov

Lasting impacts of physical injuries to coral reef ecosystems are well documented. NOAA has the statutory responsibility, under the National Marine Sanctuaries Act (NMSA), to restore injured resources and habitats within the National Marine Sanctuaries. Under this mandate, NOAA has completed a number of coral restorations from vessel groundings in the Florida Keys National Marine Sanctuary (FKNMS). To facilitate future restoration work, NOAA has undertaken a comprehensive compilation and assessment of the available physical and biological coral restoration technologies to be approved for use in marine sanctuaries. The work will encompass three marine sanctuaries (Gray's Reef, Florida Keys and Flower Garden Banks), and a broad range of restoration activities. This document, along with appropriate funds from litigation, will serve to significantly shorten both response and restoration implementation times. In addition, the effort will stand as a definitive description of the types of coral restoration technologies and approaches NOAA can implement in National Marine Sanctuaries and will serve as guidance for other resource managers as well.

CORAL REHABILITATION STUDIES IN THE ANDAMAN COAST OF THAILAND.

Thongtham, Nalinee*, Panchaiyapum, Pitul; and Somlap, Som-ying. *Phuket Marine Biological Center, PO Box 60, Phuket 83000, Thailand. Email: pmbcnet@phuket.ksc.co.th

The studies on coral reef rehabilitation were started in 1995 in some degraded coral reef areas of Phuket, Thailand. Two studies were done, coral transplantation and providing artificial substrates of different complexity for natural coral recruitment. For coral transplantation study, effective methods for transplant fragments of staghorn coral (*Acropora formosa*, Dana, 1846) were evaluated, including handling, transplanting techniques, survival rate, growth and number of new branches were determined. Study on recovering of staghorn corals in donor reef and transplantation of massive coral (*Porites lutea*) were also done. For the study on providing artificial substrate for natural coral recruitment, three different complexities, but triangular in shape and 50*50*50 cm^3 in size of concrete modules were used as settlement substrate. After 25 months, the first monitoring found *Porites* sp. to be the most dominant of the corals that had settled on these modules. The second monitoring, made six months later, found that *Porites* sp. was still the most dominant, but the fire coral, *Millepora* sp. had the highest rate of survival. The number of colonies, percentage and diversity of surviving corals were significantly higher on high-complexity modules than on the less complex ones. The results indicate that artificial substrate provided a more suitable area for settlement and growth of coral larvae than natural substrate. In conclusion, for the area that natural substrates are no longer suitable for settlement of coral larvae, providing artificial substrates could be an answer to coral rehabilitation

Session D5: Remote Sensing and GIS in the Study of Coral Reefs

COMPARISON OF SPACE SENSORS FOR ESTIMATION OF CORAL REEF AREAS IN SOUTH PACIFIC ATOLLS.

Andréfouët, Serge *, Julie A. Robinson, Gene C. Feldman, Frank E. Muller-Karger, Chuanmin Hu, Bernard Salvat. *University of South Florida, Dept. of Marine Science, 140 7th Ave. South, Saint Petersburg, Fl. 33701, USA. Email: serge@carbon.marine.usf.edu

A variety of remote sensing data, including Landsat 7-ETM+, SPOT-HRV, SeaWiFS Local Area Coverage (LAC), Space Shuttle photography and High Definition Television (HDTV), were collected over various atolls of the Tuamotu archipelago (French Polynesia). The objective was to assess the accuracy of each data set in addressing: 1/ detection of an atoll and estimation of its area, 2/ detection and estimation of rim and lagoon areas, 3/ characterization of the structure of the rims (4 classes) and main geomorphological lagoon features, 4/ characterization of the structure of the rims (7 classes) and detection of hard and soft bottom in the shallow parts of the lagoons, 5/ characterization of the structure of the rims (11 classes) and habitat zones (4 classes) in the shallow parts of the lagoons, 6/ characterization of the structure of the rims (11 classes) and shallow habitats zones both in the lagoon and outer slope. SeaWIFS data meet the first goal, but lacked sufficient spatial resolution to provide better than 80% accuracy for the distinction between rim and lagoon areas (goal 2). Space Shuttle HDTV images and photographs were useful for simple characterization of the rims and lagoon features (goal 3) but could not accurately classify at more detailed levels (goal 4 and higher). SPOT-HRV or LANDSAT/ETM+ were useful to classify the rim structure and simple habitat zones (goal 5), but did not provide information on the steep outer or inner slopes (goal 6).

ESTIMATION OF CORAL REEF AREA FOR 82 FRENCH POLYNESIAN ATOLLS USING SPACE SENSORS: A PATHFINDER FOR GLOBAL SCALE ASSESSMENTS.

Andréfouët, Serge *, Bernard Salvat, Frank E. Muller-Karger. *University of South Florida, Dept. of Marine Science, 140 7th Ave. South, Saint Petersburg, Fl. 33701, USA. Email: serge@carbon.marine.usf.edu

Coral reef ecosystems worldwide are now consistently targeted by several space missions. This includes the EOS (Earth Observing System) LANDSAT mission, which has collected over 3500 images over coral reef areas in less than one year (1999-2000). The new data allows consistent quantification of the spatial extent of "units" that can be defined from an ecological, biogeochemical or economical point of view. They complete the old, inappropriate and sometimes inaccurate hydrographic maps traditionally used to assess the extent of coral reefs in remote regions. This study presents how estimates of coral reef area coverage can be updated using recent LANDSAT 7 ETM+ images acquired in 1999-2000 or older SPOT-HRV images acquired in the late 80's. As a pilot study, we focussed on a large sample (72 images covering 82 islands of various size) of one type of geomorphological formation (atolls), located in one biogeographic region (South Pacific), and associated to one political entity (French Polynesia). Principles of the methods of image interpretation, typology of coral reef formations and statistics on surface areas are presented, as well as the limitations of such an approach. This large-scale exercise provides lessons useful for other similar studies that may be attempted in other regions of the world.

ASSESSING THE EXTENT OF CORAL BLEACHING USING AERIAL PHOTOGRAPHY AND IMAGE PROCESSING TECHNIQUES, GREAT BARRIER REEF, AUSTRALIA.

Baxter, K*. *School Of Tropical Environment Studies And Geography, James Cook University, Townsville, Qld, Australia 4811. Email: KAT_MID@HOTMAIL.COM

Management authorities face difficulties when attempting to monitor large scale disturbances, primarily due to the extent and isolation of their jurisdictions. Remote sensing provides a potential means of cost effectively monitoring coral reefs across a variety of scales. Remote sensing techniques were applied to high-resolution aerial photographs of two sites on the Great Barrier Reef to detect coral reef bottom types and in particular, coral reef bleaching. 1:2000 and 1:500 scale photographs were classified to distinguish coral growth forms that were (1) more than 50% bleached (2) 10 to 50% bleached and (3) unbleached. Supervised remote sensing techniques, which require ground truth data to classify with, and unsupervised techniques, which do not, were applied. Both techniques were shown to provide an efficient and accurate means of distinguishing corals more than 50% bleached at both scales of observation. The success of the unsupervised technique illustrates the potential to rapidly assess severe bleaching events with minimal ground truthing. However, further research to improve the accuracy of the results is required. Partially bleached corals were often incorrectly classified as unbleached corals, at both scales using both techniques. Without an understanding of why misclassifications occur, the extent of bleaching can be over or under estimated. Determining at which scale reef types are best classified may improve accuracies and ensure the overall health of the reef system is not misinterpreted.

PRELIMINARY RESULTS FROM A NASA EXPERIMENTAL ADVANCED AIRBORNE RESEARCH LIDAR (EAARL) SURVEY OF PACIFIC REEF IN BISCAYNE NATIONAL PARK, FLORIDA, USA.

Brock, J.C.* And Wright, C. Wayne. *Usgs Center For Coastal Geology, 00 4th Street South, St. Petersburg, Florida 33701-4846 Usa. Email: JBROCK@USGS.GOV

Airborne hyperspectral passive sensors that offer distinct advantages over existing satellite and photographic methods have recently become available for mapping coral habitats. However, submerged reefs present fundamental difficulties for strictly passive remote sensing, which relies upon reflected sunlight that is greatly attenuated and spectrally contaminated during passage through the water column. Accordingly, aircraft LIDAR remote sensing techniques are of particular interest, as these techniques can acquire highly detailed bathymetry and bottom texture, and water depths for the correction of passive imagery, and can also stimulate and detect the fluorescence of coral heads, algae, and other benthic cover types. Following a successful test of a preliminary proof-of-concept instrument in the spring of 1999, NASA built the Experimental Advanced Airborne Research LIDAR (EAARL), which couples a small field-of-view receiver with a high repetition rate (5000 Hz), low power, short-pulse laser. The NASA EAARL, specifically designed for low cost coral reef investigations that require extremely high density bathymetry and hyperspectral scanning for scientifically useful benthic reef classification, was tested over Pacific Reef in Biscayne National Park, Florida, USA.

REEFS AT RISK IN SOUTHEAST ASIA – A SPATIAL ANALYSIS OF THREATS, PROTECTION AND CONNECTIVITY.

Burke, Lauretta*, Selig, Elizabeth. *World Resources Institute, Washington, DC, USA. Email: lauretta@wri.org

The global *Reefs at Risk* analysis, released by the World Resources Institute in 1998, concluded that over 80% of the coral reefs in Southeast Asia are threatened by human activity. Reefs at Risk in Southeast Asia is a more detailed follow-up to the global report, utilizing new research to more accurately predict threats to coral reefs. Implemented with many partner institutions in the region, this analysis is aimed at developing and making available an integrated base of information for exploring threats to coral reefs, including an examination of the link between human activities and reef condition. The analysis models and maps threats from coastal development, overfishing, destructive fishing, marine pollution, and sedimentation from inland activities. In addition, the study examines management factors and natural features, which influence human pressures on coral reef ecosystems. During the project, collaborators have improved data sets reflecting coral reef locations, marine protected area locations, management effectiveness, tourism pressure, and use of destructive fishing techniques. These data, modeling techniques, and results, as well as a written report will be available over the Internet.

USE OF DIGITIZED AERIAL PHOTOGRAPHS AND AIRBORNE LASER BATHYMETRY TO MAP AND MONITOR CORAL REEFS

Chavez P.S., Jr.* and Mike Field *United States Geological Survey. Email: pchavez@usgs.gov

The U. S. Geological Survey is using remotely sensed image data to help map and study coral reef environments. Digitized aerial photographs and airborne digital SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) laser bathymetry data covering portions of the island of Molokai, Hawaii are being used. Digital image maps with 1.0 and 0.3 m resolution were generated using aerial photographs, as well as a laser bathymetry image map with two m resolution and 15 cm vertical accuracy. The digital georeferenced image maps are being used as a guide for extensive field work that includes on-the-ground validation and interpretation of the information seen in the remotely sensed data. The laser bathymetry and aerial photography images show information to a depth of approximately 35 and 20 m, respectively. Both data sets were useful for defining geomorphologic features such as channels, spur-and-groove, and reef holes. Areas covered by sand or hardrock can be mapped in water depth less than about 15 m, but information such as sediment cover and thickness, presence/absence of live coral, and percentage of live coral cover can't be determined without field studies. The main advantages of the remotely sensed data have been to locate features on the reef, define the local geomorphology, and as a geographic base to plot results. A promising application deals with temporal monitoring of change. Using digitized aerial photographs collected in September 1993 and January 2000 we have detected changes in the amount of sea grass and sand cover.

REMOTE SENSING AND GIS: DEVELOPING A SPATIAL MODEL OF REEF-TOP HABITATS AND MARINE INVERTEBRATES ON RAROTONGA, COOK ISLANDS.

Drumm D.J.*. *Department of Marine Science, University of Otago, P.O. Box 56, Dunedin, New Zealand. Email: druda019@student.otago.ac.nz

Coral reef ecosystems are among the most complex, diverse and beautiful ecosystems on earth and they provide many commercial, recreational, aesthetic and environmental benefits to humans. It is widely acknowledged that coral reefs are subjected to numerous anthropogenic and natural stresses resulting in rapidly increasing global degradation. In the Pacific Island nations there is a priority for accurate mapping and data collection to provide baseline information for resource management decisions in the coastal zone. Classification and mapping of marine habitats and their associated communities is fundamental to management of the ecosystem, yet reliable maps and baseline data on global or regional reef ecosystems are rare. This study satisfies these priorities for the island of Rarotonga, Cook Islands by utilizing aerial photographs and a geographic information system (GIS) to develop a spatial database of the shallow-water reef habitats and invertebrate resources. The primary goal is to assess the spatial relationships between the reef-top habitats and associated macroinvertebrate species (i.e. sea cucumbers, giant clams, sea urchins and trochus) distribution and abundance patterns. The GIS provides the basic tool for the classification of the marine habitats, sample design, and spatial analysis of the species-habitat relationships. Aerial photographs and GIS provide a valuable, cost-effective method for small Island nations to develop high quality databases and long-term monitoring programmes for their marine environment.

AN UPDATE ON THE SYSTEMATIC LANDSAT 7/ETM+ ACQUISITIONS OVER CORAL REEFS WORLDWIDE.

Gasch J.*, Terry Arvidson, Samuel N Goward, Serge Andréfouët, Chuanmin Hu, Frank E. Muller-Karger. *Goddard Space Flight Center, Landsat 7 Mission Operations, Code 428.1, Bldg 32 Rm W210A, Greenbelt MD 20771. Email: john.gasch@gsfc.nasa.gov.

Landsat 7 (L7) satellite and the ETM+ sensor were launched in April 1999. Routine imaging operations started in July 1999. Although L7 was designed principally for land survey, the coral reef science objectives have justified periodic imaging of shallow coastal regions. Therefore, the Long Term Acquisition Plan (LTAP) of the L7 program is directing the acquisition of images worldwide as a support for research on coral reefs for which a poor or non-existent coverage existed. LTAP was created to acquire and periodically refresh an archive of sunlit, substantially cloud-free scenes. Of the roughly 14,000 distinct global scenes targeted by LTAP for routine acquisition, 878 of these have been now identified as containing coral reefs, including the ~9000 reefs in ReefBase V3.0. Many of these coral reef scenes reach a high rate of acquisition owing to their proximity to coastal land already planned for acquisition. As a result, 70% of the reefs have acquisition rates of twice per year or more, 65% have acquisition rate of 4 times per year, and 33% are acquired as often as possible (typically 5 or more times per year). This communication will present the state of the L7 archive as acquired in September 2000 (3500 coral reef images in April 2000). Statistics on acquisitions and cloud cover will be presented by geographic regions.

MEXHAB: A MODEL FOR PREDICTING CORAL REEF HABITAT IN THE TROPICAL WESTERN ATLANTIC AND EASTERN PACIFIC.

Guinotte J.*. *James Cook University, Tropical Environment Studies and Geography, Townsville, Australia. Email:john.guinotte@jcu.edu.au

This study identifies potential coral reef habitat by investigating the key physical and chemical controls that limit coral reef development and survival. MexHab is an extension of the ReefHab model developed by Dr. Joanie Kleypas is 1997. ReefHab used temperature, salinity, nutrients, and depth-attenuated level of photosynthetically active radiation (PAR) to predict the distribution of reef habitat at the global scale. Both models share similar methods but MexHab differs from ReefHab in two ways: (1) the scale of modelling, and (2) the selection of an additional environmental variable. MexHab models reef habitat at a spatial resolution of 2 × 2 minutes and incorporates topographic relief as the additional environmental variable that exerts a physical control on reef occurrence. MexHab model results show a strong quantitative and qualitative similarity to documented reefs depicted in two data sources that are thought to be representative of ecological reality: ReefBase and World Conservation Monitoring Center reef maps. It is possible that MexHab false positives may identify reefs that are uncharted and thus not included in ReefBase or WCMC reef maps. This research indicates that within limits defined by temperature, salinity, nutrients, depth-attenuated level of PAR, and topographic relief, MexHab can accurately predict coral reef habitat at the regional level. This study represents the first quantitative attempt to use topographic relief as a physical control on reef occurrence and demonstrates that this variable is useful as a predictor of potential reef habitat.

GIS - AN ESSENTIAL TOOL FOR EDITING AND VALIDATING MARINE DATABASES.

Hartcher M.G.*. *GIS Australasia Pty. Ltd., PO Box 1583, Townsville, QLD 4810, Australia. Email: michael.hartcher@jcu.edu.au

As research funds become increasingly limited, it is essential to validate and utilise existing digital databases, such as the Crown-of-thorns starfish (COTS) data managed by the Great Barrier Reef Marine Park Authority (GBRMPA). Accordingly, in October 1996, the COTS Program research staff at GBRMPA began verifying the existing COTS historical database by cross checking the digital data with paper records on file. It was apparent that the database was highly corrupt and most of the records had not been entered. Additionally, Mr Bob Pearson from DPI Fisheries contributed some 25 years of field diaries, which contain the original COTS field data, previously only published as broad-scale counts. A new database structure was then designed to accommodate spatial information as well as COTS sample data, coral data, size frequency data, oral history data, and world data. During the process of editing, the use of GIS software was essential - particularly for correct site identification using multiple data sources. Using ArcView to integrate topographic reef data layers with aerial photographs, satellite images, and scanned maps saved time and improved the accuracy of site identification. After editing, the COTS data was imported into ArcView from Excel and spatially linked to the reef data layer. Finally, custom query and zoom tools were set up to help managers quickly access information about COTS outbreaks. The final product, COTSbase Version 1.0, was completed in March 2000.

SPECTRAL REFLECTANCE CHARACTERISTICS OF CORAL REEF BENTHIC COMMUNITIES.

Hochberg, E. J. *, M. J. Atkinson. *University of Hawaii, Department of Oceanography, 1000 Pope Road, Honolulu, HI 96822 USA. Email: hochberg@soest.hawaii.edu

Successful remote sensing of coral reef benthos ultimately requires that different communities of interest have characteristic and distinct spectral reflecting properties. We use a portable fiber optic spectrometer to measure *in situ* spectral reflectance, *R*, for coral reef benthic communities. To date, our spectral library consists of ~10,000 individual *R*'s, representing reef benthos and substrates from Hawaii, French Polynesia, Fiji, Puerto Rico, and the Virgin Islands. We have measured *R* for ~50 coral species, ~20 algal community types (brown, green, red), and ~5 sedimentary community types (reef-derived, terrigenous). Our analysis indicates that these reef community types have characteristic *R*'s that are consistent across geographic locations. The distinctions of these communities, however, are subtle, and thus resolution of community types requires narrow wavebands. With this knowledge of *R* for reef benthos, it is straightforward to tailor remote sensing classification functions for particular applications and sensors. We present two examples of such algorithm tailoring: one with airborne hyperspectral imagery of Kaneohe Bay, Hawaii, and one with airborne multispectral imagery of Moorea, French Polynesia.

OPTICAL WATER COLUMN PROPERTIES OF A CORAL REEF ENVIRONMENT: TOWARDS CORRECTION OF REMOTELY SENSED.

Holden, Heather * and LeDrew, Ellsworth. *Department of Geography, National University of Singapore AS2 1 Arts Link Singapore 117 570, Email: geohmh@nus.edu.sg

The primary concern in using remote sensing data for applications such as identifying water quality, bathymetry, or benthic habitat, is that water depth variations are indistinguishable from bottom type variations. With relatively constant inherent water optical quality, 51 multispectral radiometric profiles were measured in environments with (1) common bottom types, but variable depths, and (2) common water depths, but variable bottom types. Cluster analysis and analysis of variance reveals that a significant amount of variability in both downwelling irradiance and upwelling radiance attenuation coefficients can be attributed to water depth when bottom type remains constant. Investigation of the downwelling irradiance and upwelling radiance profiles indicate that water column effects are not simply additive, but are more complex and involve variable contributions from bottom reflectance and water depth. The database also enabled calculation of spectra at the top and bottom of the water column to examine the potential effects of the water column on measured spectra. An unpredictable "crossover" effect was observed in these spectra over both living coral and rubble substrata in depths ranging from 2-27m: spectra measured at the bottom of the water column displayed increased magnitude of upwelling radiance at longer wavelengths. The anomalous cases correspond to the cases excluded from the dominant clusters in the cluster analysis. Both predictable and anomalous observations occurred in a common range of water depths and occurred independent of bottom type, suggesting complex radiative transfer in the water column that may not be adequately addressed given available models for water column correction at present.

INTEGRATION OF HYPERSPECTRAL AND PULSE AMPLITUDE MODULATED (PAM) FLUOROMETER TECHNIQUES FOR PHOTOSYNTHESIS AND PIGMENTATION ANALYSIS OF CORALS.

Joyce, K.E. and Phinn, S.R. *. *Biophysical Remote Sensing Group. Department of Geographical Sciences and Planning. The University of Queensland, Brisbane, Queensland, 4072, Australia. Email s.phinn@mailbox.uq.edu.au

Remotely sensed data sets are a "potentially" powerful tool for understanding spatial and temporal variations in the biological and physical processes of coral reefs. Reflectance curves of selected coral and algae features were obtained *in situ* on Heron Reef and used to draw correlations with photosynthetic capacity and pigment content within samples. The greatest spectral variance between features was found between 570 – 595nm, highlighting the ability to discriminate between targets based solely on their reflectance spectra. This is likely due to differences in pigment content, in addition to morphological or structural variations between species. All targets exhibited an absorption feature about 675nm, attributed to the presence of chlorophyll a. The degree of correlation between photosynthetic capacity and spectral reflectance varied between features. The generally weak relationships observed between spectral response and these biophysical properties were most likely due to more complicating factors influencing the absorption and reflection of incident light (eg. water depth, refraction of light at the air-sea interface, water column optical properties) not previously considered in similar terrestrial studies. This highlights the requirement for a changing approach to coral reef remote sensing, incorporating models that take into account air-water interfaces and specific scales of reef features and processes.

DISTRIBUTION AND BIOMASS OF PRIMARY PRODUCERS IN SHIRAHO REEF, JAPAN INTEGRATED IN GIS

Kayanne H.*, Y. Tanaka, S. Harii, H. Yamano, M.A. Haltuch, M. Yamamuro, Y. Ide, N. Miyamoto, F. Akimoto, N. Ito and T. Nakane. Department of Earth and Planetary Science, University of Tokyo, Hongo, Tokyo 113-0033 Japan. Email: kayanne@eps.s.u-tokyo.ac.jp

To monitor and estimate changes in distribution and relative abundance of primary producers in a coral reef, we made repeated surveys along five transects in the field from 1997 to 2000 in Shiraho Reef (ca 0.8 x 1.2 km), southwest of the Ryukyu Islands, Japan. The results were compared with remotely sensed images (aerial photos and satellite images) and integrated in a GIS framework together with some physical parameters (depths, currents, temperature etc). The dominant primary producers in this reef are *Sargassum*, corals and seagrass. They form a distinct zonation parallel to the shoreline: *Sargassum* on the reef crest, corals on a reef pavement behind the reef crest and seagrass along the shore separated by a sand flat. Biomasses of *Sargassum*, corals and seagrass were 0.6-56.1, 4.6 and 3.8-12.1 tons of carbon for the whole area, respectively. The biomass of *Sargassum* showed large seasonal variation: low in winter and high in summer. During our survey, Shiraho Reef experienced severe bleaching from July to September, 1998. Changes in living coral distribution just before and after the bleaching and recovery/demise process of corals were recorded and analyzed quantitatively in the GIS database. GIS together with ground surveys and remote sensing provide a useful and basic tool for modeling and management of coral reef ecosystems.

DECADAL-SCALE NUTRIENT ENRICHMENT CORRELATES WITH CHANGES IN THE OPTICAL PROPERTIES AND BIOTIC STRUCTURE OF CORAL REEF COMMUNITIES ON BANK REEFS OF THE LOWER FLORIDA KEYS, U.S.A.

Lapointe B.E.*, C.S. Yentsch, C.M. Yentsch, P. Barile, D. Phinney, J. Vanderbloemen, and S. Andrefouet. *HBOI, 5600 U. S. 1 North, Ft. Pierce, FL 34946. Email: lapointe@hboi.edu

We integrated a 15-year (1983-1998) low level nutrient database for the "core area" of Looe Key National Marine Sanctuary (LKNMS) with measurements of benthic community structure, optical properties of the water column (chl-a, Km^{-1}, spectral reflectance), and satellite imagery. From the 1980's to the 1990's, annual mean dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) concentrations increased significantly from ≈ 0.5 uM and 0.05 uM in the 1980's to ≈ 1.0 uM and 0.10 uM in the 1990's, respectively. The nutrient enrichment of the fore reef at LKNMS since 1992 was accompanied by parallel increases in water column chl-a, Km^{-1}, and benthic algal cover but also dramatic decreases in live coral cover. These marked changes in water quality and reef biota correlated temporally with increased freshwater flows from the Everglades, which resulted in decreased salinity and increased chl-a and turbidity in "upstream" waters of central and western Florida Bay. Outflows of degraded water from Florida Bay were evident in satellite images, which showed plumes of turbid water flowing through tidal passes of the middle and lower Florida Keys towards offshore bank reefs, including LKNMS.

CHANGE DETECTION OF SATELLITE IMAGERY FOR MAPPING AND MONITORING STRESSED CORALS.

Ledrew, Ellsworth F.*; Wulder, Mike; Holden, Heather. *Department of Geography, University of Waterloo, Waterloo, ON, N2L 3G1, Canada. Email ells@watleo.uwaterloo.ca

Considering the vast area of Coral Reefs, and the remote nature of many of them, an effective procedure to map and monitor ecosystem stress from satellite imagery is needed. The procedure must not be dependent upon *in situ* measurements that typically have been used to correct beam attenuation through the water column if it is to be a reconnaisance tool for remote and/or historical imagery. The stresses may be related to El Niño-induced temperature and radiation changes, pollution and siltation, or unsustainable fishing practices. For our trial study, we have selected Savusavu Bay of Fiji as a test region. A gold mine was recently recommissioned on the west side of the bay. During an anomalous winter storm, the retaining walls of some effluent storage facilities failed and a toxic spill was released through the adjacent river system and dispersed over a large coral reef. We have SPOT satellite imagery from before and after the event. Preliminary reconnaissance indicates severe damage to the corals with colonization by algae. In this paper we determine a procedure for change detection from the multidate SPOT data that is independent of spatial variations in water depth over the features of interest. The Getis statistic, which is based solely on image characteristics, is evaluated as a tool for change detection. Preliminary examination suggests that it meets the requirements for rapid assessment for environmental change without the need for individual image calibration based upon *in situ* information.

DETECTION OF A CORAL BLEACHING EVENT FROM HIGH RESOLUTION SATELLITE IMAGES.

Lindell L. Tommy *, Petra Ammenberg & PhilipKramer.*Centre for Image Analysis, Uppsala University, Sweden. Email: tommy@cb.uu.se

The dramatic bleaching events on the coral reefs of the world have once again put a focus on the environment and the necessity for resource monitoring. Sparse point observations from the field can not alone satisfy the need for large scale bleaching status, particularly in remote areas. This paper investigates the value of present high resolution satellites to detect coral bleaching. An image from the Indian Remote Sensing satellite (IRS) from the beginning of the bleaching event in Belize 1998 has been compared to Landsat TM images before the bleaching. The digital counts on the TM scenes have been normalized to the IRS and difference images created. Lighter pixels in areas interpreted as coral habitats were marked and then compared to field observations collected during and immediately after the bleaching event. Several of the lighter pixels in the 1998 image correspond to field observations of bleaching. The spectral characteristics of those pixels have been analysed and methods for an automated analysis suggested. Field observations from Belize suggest that recovery from the 98 bleaching was variable with both depth and location and that different coral species were differentially affected. The current spatial, spectral and temporal resolution of satellite images limit the ability to detect these finer scale bleaching patterns. Improved radiometry of the data associated with Landsat-7, MODIS, and EVISAT may allow for a more quantitative evaluation of coral bleaching.

STATUS OF THE REEFS IN THE TURKS, CAICOS, AND MOUCHOIR BANKS.

Manfrino, C. *, B. Riegl, K, Hoshino, and S.C.C. Steiner. Kean University, Department of Geology and Meteorology, 1000 Morris Avenue, Union, New Jersey, 08540. Email: ckievman@turbo.kean.edu

Coral reefs of the Turks, Caicos and Mouchoir Banks (TCI) were surveyed using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol in August 1999. Twenty-eight study sites on the rims of the banks were surveyed and a total of 3276 corals in 289 transects, 1421 algal quadrats and 279 fish transects were measured. The TCI expedition focused on the reefs of both remote and more popular areas, and reefs in marine protected and unprotected areas. The TCI area is at the far southern extent of the Bahamas Archipelago and may be an important source of larvae for reef dwellers and builders as ocean currents drift up from the south. Live coral cover and coral recruit occurrence was lowest, and the percent recent mortality, old mortality and total mortality and the incidence of white, black, and yellow band syndromes was the highest on the Mouchoir Bank, the most remote location. Coral cover averaged 17.8 % across the region, but was 13.8 % on the Mouchoir Bank. Bleaching was not observed at any of the study sites, whereas, the white plagues were found at every site. A*cropora palmata* stands occurred mainly on the eastern facing areas of the bank, and *A.cervivornis* was rare at all but one location. Fish size and abundance was lowest on the Mouchoir Bank. The reefs in the TCI are most at risk from under regulation in marine parks where tourism and development and from poaching and hazardous fishing practices (Dominican poachers and local fishers using gasoline mixtures) which is obvious in the Mouchoir and South Caicos regions.

REMOTE SENSING OF CORAL REEFS USING HIGH-RESOLUTION SATELLITE DATA

Maeder J. *, S. Narumalani, J. Schalles, D. Rundquist, and K. Hutchins
CALMIT, University of Nebraska, Lincoln, NE 68588-0517, USA. Email: jmaeder@calmit.unl.edu

Monitoring coral reefs, seagrasses and sand features with remotely sensed data can be a cost effective and time efficient means for reef management. Prior efforts at sub-surface feature discrimination with satellite remote sensing have been limited in accuracy because of the coarse spatial resolutions. This research utilizes imagery acquired by the newly launched IKONOS satellite, at a nominal spatial resolution of 4x4-m in the multispectral mode, for underwater feature identification and discrimination. The image was acquired on 10 March 2000 for the western coast of Roatan Island, Honduras, and two study areas including Half Moon Bay and Tabyana Bay were subset from the image. Spectral pattern recognition was performed on these subsets using the visible IKONOS bands, because of their water penetration capability. Sub-surface feature stratification included sand, coral reef, sparse seagrass, dense seagrass, and deep-water categories. Significant *in situ* work involving a Global Positioning System (GPS), close-range spectral information gathering, and simultaneous digital video capture had been performed at the site one day prior to the image acquisition. These data were used to determine the accuracy of the classification. Overall accuracy was 86%, which was higher than previous studies that have utilized coarser spatial resolution satellite data.

HOW GOOD IS *CASI* FOR RED SEA CORAL REEF SURVEY?

Minghelli-Roman, Audrey *, John R. M. Chisholm, Manuel Marchioretti, Herbert Ripley & Jean M. Jaubert. *Observatoire Océanologique Européen, Centre Scientifique de Monaco, Avenue Saint-Martin, MC98000, Monaco; Email: amingh@club-internet.fr

Spectral reflectance images of a species rich coral reef near gübal island, red sea, were obtained using a compact airborne spectrographic imager (*casi*) in combination with ground-level spectra and photographic records to determine the absolute reef-mapping capability of *casi*. The *casi* was flown at 4 altitudes to obtain images composed of pixels representing projected ground areas of 0.35×0.35, 0.5×0.5, 0.75×0.75 and 1.0×1.0 m. Identically orientated white targets (4×4 m), were secured to the seabed at depths of 1, 5, 10, 15 and 20 m to acquire images with pixels parallel and perpendicular to the sides of the targets. A 5×5 m pvc quadrat (with 1×1 m subdivisions) was positioned along the same edge of each target and the underlying reef communities were photographed using a camera mounted on an aluminium frame. Over 200 reflectance spectra were obtained of algae, sand, rock, corals and other invertebrates *in situ*, while diving on scuba, using a li-1800 spectroradiometer fitted with a fibre optic sensor. The sensor was maintained at a vertical distance of 30 cm from each subject to provide a circular capture area of 10 cm diameter, thus obtaining an average reflectance signature for subjects with variable surface topography and colouration. Comparison of *casi*-derived thematic maps (by decomposing the pixel reflectance signatures) with photographed reef areas indicated that *casi* has the potential to discern and map diverse reef communities to a depth of at least 15 m with good precision.

SPATIAL DISTRIBUTION PATTERNS IN RESOURCE USE BY THE FISHING COMMUNITIES IN AND AROUND KOMODO NATIONAL PARK, A MARINE PROTECTED AREA IN CENTRAL INDONESIA.

Mous Peter J. *, Andreas Muljadi & Jos S. Pet. *Indonesia Coastal & Marine Program, The Nature Conservancy. Jakarta Office, Jln Hang Tuah Raya 42, Jakarta 12120, Indonesia Email: pmous@attglobal.net

Komodo National Park (1,800 km ^{2}) is situated in Central Indonesia, between Flores to the East and Sumbawa to the West. The Park was established in 1980 to protect the Komodo dragon *Varanus komodoensis*, but it also encompasses 1,200 km^2 of highly diverse marine habitats. The fishing communities in and around the Park, numbering ca. 20,000 people, use a variety of fishing methods to exploit pelagic resources such as squid, small clupeids, and demersal resources such as lobster, groupers (*Plectropomus* spp. and *Epinephelus* spp.), sea cucumber and abalone. Especially if destructive fishing methods are used, the exploitation of demersal resources threatens the marine biodiversity of the Park. During 1997, 1998 and 1999, creel surveys were conducted in the Park to study resource use by the fishing communities to support the management of the Park. The creel surveys revealed distinct spatial patterns in resource use, which vary between fishing communities and between years. Based on resource use patterns, and on the spatial distribution of marine habitats in the Park, a zoning plan was proposed and endorsed by the Indonesian Park authorities.

SEA-SURFACE CURRENT INVESTIGATION CONCERNING LONG-DISTANCE TRANSPORT OF CORAL PLANULAE WITH HF RADAR, DRIFTING BUOYS AND NUMRICAL SIMULATIONS.

Nadaoka K.*, Y. Nihei, G. Hanada, S. Fujii, K. Sato, T. Ikema, S. Kakuma, K. Iwao. Graduate School of Information Science and Engineering, Tokyo Institute of Technology, 2-12-1 O-okayakma, Meguro-ku, Tokyo 152-8552, Japan. Email: nadaoka@mei.titech.ac.jp

Regarding the possible long-distance transport of coral planulae from the Kerama Islands and Chiibishi toward the southwest coast of the main Okinawa Island, a field observation using a set of HF radar and drifting buoys and numerical analyses were performed, as an activity of CREO (Coral Reef Environments in Okinawa) project, to clarify the Eulerian and Lagrangian characteristics of sea-surface current and thereby to examine possible trajectories and extent of the coral planulae transport. The HF-radar data in the area of the southwest of the main Okinawa Island shows the regional dependence of the current characteristics; i.e., in the shelf area including the Kerama Islands, the currents are exclusively governed by tide and winds, whereas in the area beyond the shelf boundary the contribution of the ocean currents becomes appreciable, providing unidirectional currents toward the west coast of the main Okinawa Island. In accordance with this, the drifting buoys released in the Kerama Islands were transported toward the main Okinawa Island, when they entered in the region beyond the shelf edge. These results are supported also by a numerical simulation of the 3-D currents for the region concerned and that of the Lagrangian tracking of neutral particles.

A TWENTY YEAR EVOLUTION IN REMOTE SENSING OF REEF MORPHOLOGY: EVALUATION OF 1979 VERSUS 1999 LANDSAT IMAGERY OF THE NORTHERN MALDIVES.

Naseer, Abdulla* and Bruce G Hatcher, *Dept. of Biology, Dalhousie University, Halifax, Nova Scotia, B3H 4J1, Canada. Email: anaseer@is2.dal.ca

Atolls of the Maldives exhibit distinctive, large-scale morphological characteristics, which can be depicted using digital satellite multispectral data. In an attempt to understand spatio-temporal changes in the gross morphology of atoll reefs in response to monsoon forcing, we quantify the zonation and distribution of shallow reefs of the northern Maldives at two spatial scales: 100's of metres within reefs and 1000's of metres among reefs within an atoll. A LANDSAT-MSS (80m pixel size) image of the large atolls of Miladhunmadulu and Maalhosmadulu acquired in 1979 was compared with a LANDSAT-7-ETM+ (30m pixel size) image of the same atolls acquired in 1999. Individual reefs and faros were classified into six, clearly defined morphological categories (reef top islands, shallow reef flats, shallow sand sheets, sandy lagoons, patch reefs, seagrass beds) that could be derived from a supervised classification of the MSS image using bands 1, 2 and 3, and bands 1, 2, 3 & 4 of the ETM+ image. The proportions of each category within each atoll were determined from the spatial and spectral properties of the images, and compared across time and sensors to measure reef growth and destruction. The accuracy and reliability of the classifications is compared between sensors by configuring the LANDSAT-7 image to MSS specifications and calculating confusion matrices and the 'kappa' statistic. The degree to which natural and anthropogenic changes can be inferred from LANDSAT multispectral data are considered.

A MULTI-NESTING APPROACH FOR NUMERICAL SIMULATION OF COASTAL CURRENTS WITH A NEW ASSIMILATION METHOD

Nihei, Yasuo *, Kazuo Nadaoka, and Ryoko Kumano. Civil Engineering, Science University of Tokyo, Japan. Email: nihei@ rs.noda.sut.ac.jp

For accurate computations of currents in near-shore regions facing open sea, like coral reefs of an island in an ocean, the conditions at the open boundaries of the computational domain must be properly specified. However no methods which are reliable theoretically and reasonable in cost have existed for this purpose. We employ a multi-nesting approach, in which the computational results in a larger-scale domain are taken into account successively in a smaller-scale computation. In the conventional nesting methods, the larger-scale computational results are used as the boundary conditions for the smaller-scale computation. However, the scattering waves, which may arise in the computational domain, cannot propagate through the open boundaries so the computational domain may be contaminated with the multi-reflected waves. In the present study, a new method is proposed in which the lager-scale computational results are incorporated as the values to be assimilated in the smaller-scale computation. all the dependant variables in the governing equations are separated into the assimilating components and their residues. For the residual components, simple radiation conditions may be applied. The currents at Shiraho reef in the Ishigaki Island are computed in which the large-, intermediate- and small-scale domains have the spatial resolution of 2000m, 250m and 90m,. Computational results of give good agreements with observed data, indicating the fundamental validity of the present method.

ALL STORMS ARE NOT CREATED EQUAL: PREDICTING REEF IMPACTS FROM CYCLONES IN THE GREAT BARRIER REEF REGION.

Puotinen, ML*. *School of Tropical Environment Studies and Geography, James Cook University, Townsville, QLD, Australia 4811. Email: gemlp@jcu.edu.au

Tropical cyclones can have major long-term impacts on coral reef communities, and have been suggested to 'set the stage' within which other reef disturbances operate. Thus, effective management of coral reef systems like those of the Great Barrier Reef Region (GBRR) requires a basic understanding of the long-term cyclone disturbance regime (which reefs are likely to be affected and how often). However, since both the distribution of cyclone energy and that of storm impacts on reefs are difficult and costly to measure, the history of cyclone impact even for a single reef across the GBRR is poorly known. In response to this lack of data, scientists worldwide have developed methods to reconstruct (hindcast) the likely magnitude and distribution of cyclone energy from the meteorological record. This hindcast energy can then be linked statistically to field observations of reef impact to predict the distribution of cyclone impacts on areas not surveyed. With today's improved computing power and advances in GIS technology, it is now possible to use these techniques to span longer time periods and cover larger areas than has typically been done. Such an effort is nearing completion for the entire GBRR over the last three decades. A logistic regression model has been developed linking hindcast cyclone energy with field data from several cyclones, and will be used to build a history of likely impacts across the region. A key finding of the study thus far is that unusually large and long-lived cyclones (Cyclone Justin 1997) produce significantly different patterns of impact than that generated by more typical cyclones (Cyclone Joy, 1990).

MAPPING OF TUBBATAHA REEF USING AERIAL VIDEOGRAPHY.

Ramos, Abigail Joy A.*, Jose Noel B. Dumaup, Emmanuel S. Bate. *World Wildlife Fund-Philippines, 23 Maalindog St., U.P. Village, Diliman, Quezon City 1101, Philippines. Email: aramos@wwf-phil.org.ph

Essential for the effective management and protection of a marine habitat is the availability of a detailed, accurate and current base map of the area. This would serve as an important tool in acquiring a complete resource assessment over time, as well as an efficient means of monitoring a particular region. The Tubbataha Reefs National Marine Park, consisting of 33,000 hectares of rich biodiversity and various forms of marine life, has long been declared a one of a kind marine park and in recognition of its uniqueness, was eventually included in UNESCO's list of World Heritage Parks. In recognition of the importance of having an accurate base map of the area, WWF-Philippines has adopted an effective and low cost means of mapping the reef. An aerial videography survey was carried out using the conventional techniques for aerial photography. Flying at an altitude of 3,000 feet and at 70 knots per hour, two video cameras were mounted and positioned at a near-vertical angle to the ground. From the resulting video footage, images were then captured to create a mosaic of the area. The mosaic was then interpreted for reef features and bottom cover using the interpretation technique for aerial colour photography that was developed by UNESCO in 1978. The final output is the first large-scale and accurate base map of the area showing significant features of the reefs as well as the classification of bottom cover.

BENTHIC MICROALGAL SPATIAL DISTRIBUTION AT A CORAL REEF, DETERMINED BY REMOTE SENSING

Roelfsema,C.M.*, Dennison, W. C., and Phinn, S. R. *Department of Botany, University of Queensland, Brisbane, Australia 4072 Email: C.Roelfsema@mailbox.uq.edu.au

Understanding the ecological role of algal communities in coral reef ecosystems, requires information on their spatial distribution. Benthic microalgae are single celled algae which are found in the top centimeters of the sediment and until now not much is known about these highly productivity algae. Benthic microalgal communities are often interspersed with coral and macroalgal communities and can occupy a large spatial area within a coral reef, creating challenges for measuring their distribution. The spatial extent of benthic microalgae on Heron Reef, a platform reef in the southern Great Barrier Reef, Australia was mapped using Thematic Mapper data synchronized with field measurements of benthic microalgal chlorophyll and sediment reflectance. Sediment chlorophyll concentrations, ranging from 23 to 1153 mg chl a m^{-2}, were classified into three classes using a K-means of clustering algorithm and combined with spectral measurements to produce spectral signatures for the chlorophyll a classes. The Thematic Mapper image data were then classified into three classes based on benthic microalgal chlorophyll a levels and reflectance measurements. The resulting map of sediment chlorophyll-a distribution levels revealed large-scale (>1 Km^2) patterns in benthic microalgal distribution on Heron Reef, with high values in the lagoon and on the windward side of the reef, and low values on the leeward side near Heron Island. Results from this study indicate that benthic microalgae constitute 20% of the total benthic chlorophyll-a on Heron Reef, and thus may potentially contribute significantly to total primary productivity on the reef.

HYPERSPECTRAL IMAGING SENSORS AND ASSESSMENT OF CORAL REEF HEALTH IN THE FLORIDA KEYS.

Richardson, Laurie L.* and Fred A. Kruse. *Department of Biological Sciences, Florida International University, Miami, Florida 33199, U.S.A. Email: richardl@fiu.edu

Hyperspectral imaging sensors provide data in which each pixel of an image contains an entire spectrum due to numerous narrow-width, spectrally contiguous bands. We are working with AVIRIS (the Airborne Visible-Infrared Imaging Spectrometer) data of reefs of the northern Florida Keys on which we have been studying coral health and coral microbial pathogens for a number of years. Each AVIRIS scene images an area 10 by 12 km, with 20 m spatial resolution, the result of flying the sensor in high altitude mode on NASA's ER-2 aircraft. Individual scenes were atmospherically corrected using ATREM, and then spectrally subset to yield images that contained pixel spectra from 395 to 930 nm (visible to near IR) with a spectral resolution of 10 nm. Image-derived endmember spectra were extracted from pixels that corresponded to our study reefs, and used to construct a spectral library based on coral reef health and benthic community structure. These spectra were then used to classify the AVIRIS image data using a spectral-based algorithm (the Spectral Angle Mapper) in which each pixel of the image was compared to each spectrum within the spectral library. Classification results yielded mapped images that both showed the distributions of different coral reef-associated benthic communities as well as general coral reef health.

GLOBAL AND REGIONAL CORAL REEF MAPPING USING SEAWIFS AND ASTRONAUT PHOTOGRAPHY.

Robinson, Julie A.*, Gene C. Feldman, Norman Kuring, Bryan Franz, Ed Green, Marco Noordeloos, Richard P. Stumpf. *Office of Earth Sciences, Johnson Space Center, Houston, Texas, U. S. A. Email: julie.a.robinson1@jsc.nasa.gov

To meet needs for global and regional coral reef mapping, scientists need to work simultaneously at multiple scales to produce maps quickly and then improve these maps over time. We describe an approach to reef mapping that uses a uniform 1-km dataset (SeaWiFS) as a backbone for global-scale reef mapping and for integrating other higher-resolution remote sensing data. SeaWiFS data were used to produce composite maps of shallow bathymetry. Global reef maps compiled by the World Conservation Monitoring Centre can be overlaid with SeaWiFS data to facilitate comparison and refinement of the maps. Data sets at moderate resolution (e.g. Landsat) and high resolution (e.g. aerial photography) were converted to the same projection. Astronaut photography of Earth is an additional source of moderate resolution (pixel sizes of 30 m or less) remote sensing data that makes a unique contribution to these datasets. Georeferenced astronaut photographs were incorporated as GIS base layers into a prototype for ReefBase: A Global Database on Coral Reefs, and linked to information on coral reef biology, status, exploitation, management and socioeconomics. Finally, the global maps and remote sensing data were made available for interactive searching on a prototype Coral Reef Remote Sensing Web site (http://seawifs.gsfc.nasa.gov/reefs).

SPECTRAL REFLECTANCE MEASUREMENTS OF CORALS AND OTHER REEF SUBSTRATES AT CLOSE RANGE AND NEAR THE SURFACE

Schalles, J.*, J. Maeder, D. Rundquist, J. Keck, And S. Narumalami. Creighton University, Omaha, Ne 68178, Usa, Email: Jfsaqua@Creighton.Edu

An Ocean Optics spectroradiometer and a 20 m fiber optic cable were used in the western Caribbean (Roatan, Honduras) and northern Red Sea (Eilat, Israel) to collect high spectral resolution reflectance data of corals, nonliving coral substrates with algal overgrowths, macroalgae, and other substrates. Data were primarily collected at close range (FOV's of about 4 – 8 cm) at depths of about 1 to 10 m. Additional measurements were made of emergent reflectance signals just below the water surface - representing mixed pixels at FOV's of 0.5 to 4 m. Instrument measurement biases were problematic at low signal strengths and we sometimes used underwater lamps to boost incident signals. The biophysics of coral reflectance can be treated as a two layer system with a living, pigmented outer layer and opaque, highly reflective aragonite layer. Corals and other algal colonized substrates have clear pigment absorption features, with a strong chlorophyll *a* band near 670 nm and related red edge near 700 nm. Strong absorption of blue light occurs from both chlorophyll and carotenoids. Corals and other carbonate substrates have strong NIR reflectance. Although water path attenuation renders the upper red and NIR signals undetectable at the surface, these spectral features may be useful in close range monitoring of coral physiology and photosynthetic state. Endosymbiot accessory pigment affects are readily apparent in the spectra and are relatable to apparent color and taxonomic patterns. Depth variation greatly complicates analysis of emergent, mixed pixel signals and good resolution bathymetry is probably required.

REMOTE SENSING OF CORAL REEF HEALTH.

Skirving, William*, Tiit Kutser, John Parslow, Terry Done, Mary Wakeford, Ian Miller and Lesley Clementson. *Australian Institute of Marine Science, PMB No. 3, Townsville M.C., Qld., Australia. 4810. Email: w.skirving@aims.gov.au

A new joint project between the CSIRO and AIMS is aiming to answer the question of the usefulness of remote sensing for mapping and monitoring the health of coral reefs. Unlike most previous projects this project has taken a fresh approach to this problem. It does not include the use of any air- or space-borne data. Instead, spectral measurements of radiometric reflectances were taken in such a way as to allow the development of models, which will help answer the main question of "how useful is remote sensing", as well as help determine the form of the most suitable instrument. This paper will describe the techniques used to collect spectral information from the water column and benthic habitat in and around three GBR coral reefs. The reefs were chosen to represent a range of water quality. Along with the description of the instrumentation and techniques, some preliminary results will be presented.

AN INTEGRATED STUDY USING AERIAL PHOTOGRAPHY, GEOGRAPHICAL INFORMATION SYSTEMS AND FIELD STUDIES, OF THE CORAL REEF COMMUNITIES AT NUKUBUCO REEF, SUVA, FIJI.

South Robin, Dr. Veikila Vuki, Dr. Robyn Cumming, Liza Koshy*. *Marine Studies Programme, University of the South Pacific, P.O. Box 1168, Suva, Fiji Islands. Email: S93005004@student.usp.ac.fj

The Nukubuco Reef forms part of the barrier reef system which protects the shoreline of the Suva Peninsula in the Fiji Islands. This study is being conducted to study the effectiveness of integrating colour aerial photography, Geographical Information Systems (GIS) and Global Positioning Systems (GPS) in the spatial analysis of the distribution and composition of the 5-6 seagrass species found on this reef: *Syringodium isoetifolium*, *Halophila spp.*, *Halodule pinifolia* and *Halodule uninervis.* The ground truth of the colour aerial photography for the backreef region of the reef indicates that the western, eastern and mid region of the backreef have different species compositions. Preliminary results show that patches with percentage cover between 0%-99% are recorded in interspresion with unvegetated sand. A GIS database will be created for interpolative spatial analysis of the data, using IDRISI software, to represent the spatial patterns extracted from the field sampling. Differential GPS coordinates are collected to create thematic maps. Photointerpretation to date, on the basis of field observation, reveals that there are 'mottled' patterns in the backreef with distinct colour contrast, tone and texture corresponding to distinct mono-specific and multi-specific seagrass stands. Further image analysis will be carried out using ENVI software to digitise and classify the scanned colour aerial photographs of 1998.

ANALYZING PIGMENT COMPOSITIONS AND REFLECTANCE SPECTRA OF CORALS IN HIGH NITRATE WATER.

Tomasetti, RJ* & MJ Atkinson. University of Hawaii at Manoa, 2525 Correa Rd. HIG#215 Honolulu, HI 96822 USA. Email: tomasett@hawaii.edu

High nutrients can affect pigment densities in zooxanthellae, in turn altering spectral reflectance properties in corals and impacting the ability of remote sensing to identify corals. We used HPLC to compare pigment compositions of corals in high nitrate water at the Waikiki Aquarium, Hawaii, USA to published data from corals in low nitrate conditions at Puako, Hawaii. Coral tissue pigments, normalized to peridinin, were 1.295±0.138 (90% confidence limit) for chlorophyll *a*, 0.477±0.039 for chlorophyll c_2, 0.054±0.005 for chlorophyllide *a*, 0.021±0.003 for _-carotene, 0.229±0.021 for diadinoxanthin, and 0.017±0.006 for diatoxanthin. Ratios of _-carotene and chlorophyll *a* for corals were lower than similar ratios from field corals (0.29±0.11 for _-carotene and 1.90±1.00 for chlorophyll *a*). This indicates higher peridinin and lower accessory pigment concentrations resulting from increased zooxanthellae densities in high nitrate corals. We used an underwater fiberoptic spectrometer to collect reflectance spectra at the Waikiki Aquarium (n=676) and in low nitrate water in Kaneohe Bay, Hawaii (n=193). We computed fourth derivatives to identify features in the spectra. Reflectance peaks do not vary with nitrate concentration, but higher nitrate causes greater variability in reflectance peaks between 500-590 nm. The effects of nitrate on coral reflectance spectra are small, so remote sensing algorithms will be able to detect corals regardless of nitrate concentrations.

SPECTRAL CHARACTERISTICS OF *ACROPORA CERVICORNIS* AND *PORITES PORITES* UNDER LABORATORY CONDITIONS.

Torres, Juan L.* and Roy A. Armstrong. *UPR-Dept. Marine Sciences, PO Box 3210, Lajas, PR 00667 USA. Email: jltorres@caribe.net

The spectral response of the Caribbean shallow-water coral species *Acropora cervicornis* and *Porites porites* was measured under laboratory conditions with the aid of a spectroradiometer GER-1500. Spectral curves for both species revealed absorption peaks in the blue and red regions of the visible spectrum and a high reflectance in the green region, both indicative of the presence of chlorophyll *a* in the zooxantellae. These peaks were absent in spectra taken from bleached colonies of both species. Also, a second derivative analysis revealed a peak at 500nm corresponding to the presence of peridin in the zooxantellae. The reflectance curves for both species were significantly different, at least, in the magnitude of the different peaks. This methodology is proposed as a possible tool for a later creation of a spectral library that could aid in the identification of these species in remotely sensed images.

UTILISING THE POWER OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) FOR CORAL REEF RESEARCH AND MANAGEMENT.

Treml, EA* and Puotinen, ML. *Technology Planning and Management Corporation, NOAA Coastal Services Center, 2234 South Hobson Avenue, Charleston, SC 29405-2413, USA. Email: Eric.Treml@noaa.gov

Over the last decade, ecological theory and geographic information science have advanced together to form a conceptual and technological framework suitable for the investigation of multi-scale, system-wide scientific issues. Consequently, the computer-based analysis tools provided by Geographic Information Systems (GIS) have become essential for land management, forestry, and terrestrial ecological studies over the last several decades. However, extending the use of these analysis tools to the marine environment has begun only very recently. Yet GIS, combined with a broad-scale, landscape ecology approach, is potentially of great use in both understanding and managing the world's coral reefs. This approach enables one to study the structure, function, and change in and between marine communities while managing the many spatial and temporal scales. This paper explores the key issues that have limited the use of GIS in the coral reef context in the past and what work has been done to overcome them. In addition, several case studies are used to illustrate the range of benefits of using GIS tools to research and manage coral reefs.

INTEGRATING MULTI-LEVEL REMOTE SENSING AND GIS FOR MONITORING BERMUDA'S BENTHIC RESOURCES.

Vierros, M. K.*, *Rosenstiel School of Marine and Atmospheric Science, Division of Marine Geology and Geophysics, 4600 Rickenbacker Causeway, Miami, Florida 33149-1098, USA. Email: mvierros@rsmas.miami.edu

A combination of SPOT data and aerial photography were used to map the benthic habitats of the Bermuda platform, and the map was incorporated as a base layer in a multi-level GIS designed to monitor changes in Bermuda's seagrass beds. A number of benthic habitat classes were mapped, including coral reef classes. The mapping was achieved with low-cost software and existing satellite imagery, providing an alternative for those looking for cost-effective methods. Bermuda's high population density contributes to intense human pressure, highlighting the need for monitoring key benthic habitats. Bermuda's seagrass meadows are known to have fluctuating coverage, with recent reports of disappearance of seagrass cover from some areas. The base map is the first step towards a more comprehensive understanding of seagrass dynamics and will be incorporated in a hierarchical seagrass monitoring program including quadrat-based sampling, digital underwater video and repeated aerial photography. The habitat map was also used as a basis for calculating feeding area available for the green turtle (*Chelonia mydas*) and the carrying capacity of the seagrass meadows as feeding grounds. GIS techniques will be used to assess the effect of fluctuations of seagrass coverage on green turtle distribution and carrying capacity.

USING AN ACOUSTIC GROUND DISCRIMINATION SYSTEM TO MAP CORAL REEF BENTHIC CLASSES.

White, W.H.*, A.R. Harborne, I.S. Sotheran, R. Walton and R.L. Foster-Smith. *SeaMap Research Group, Department of Marine Sciences and Coastal Management, Ridley Building, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK. Email: w.h.white@ncl.ac.uk

An Acoustic Ground Discrimination System (AGDS) can extract information on the nature of the seabed. Compared to satellite or airborne sensors, AGDS is rarely used in tropical environments but is easy to operate and produces a modest amount of digital data. This study aimed to assess acoustic surveys of coral reef benthic classes using a RoxAnn™ AGDS in the Philippines. Benthic classes were categorised into four levels of detail using hierarchical classification of field data. Using independent data, subsequent maps were shown to have overall accuracies of: 85% at coarse resolution (three classes), 61% and 54% at two intermediate levels (five and four classes) and 28% at fine resolution (10 classes). These accuracies are assumed to be conservative because of constraints during this study including semi-quantitative data for discriminating class types, benthic changes between AGDS and accuracy assessment surveys and lack of differential GPS. Despite these limitations, AGDS accuracy levels were comparable to those achieved by satellites and it has advantages including greater water penetration and independence from cloud cover. Acoustic data are, therefore, proposed +-as a useful tool for tropical habitat mapping and complimentary to satellite and airborne sensors.

APPLICATION OF REMOTE SENSING DATA FOR CORAL REEF MAPPING IN INDONESIA

Winarso, Gathot.* and Budhiman, Syarif, *Marine Application Division Remote Sensing Application Center National Institute of Aeronautics and Space (LAPAN) Email: dayat@bogor.net

Coral reef is a marine resource, which have a great value, ecologically for marine ecosystem or economically for the benefit of coastal communities. Indonesia is one of the countries, which has a large area for coral reef. On the other hand, coral reef is an ecosystem that is vulnerable to the environment changes. The government feels that Indonesia has to participate to save the coral reef, through activities including the conservation and management of coral reef conducted in the form of coral reef rehabilitation and management program (coremap). The first step of this activity is to provide the database of coral reef spreads in indonesia, using the remote sensing data. This method is the answer to provide the database, because it can map a large area in short times and cheap cost. At least it can be the early reference for management of coral reef. Remote sensing application for mapping has develop very fast until the scale of 1:50.000, even with the new technology it can get the scale of 1:5000. But the application is only for the land area. Remote sensing application for marine area especially for coral reef is not as develop as for the land. One big problem is that electromagnetic wave that is utilized to identify the coral reef has to go through the water bodies and it will get influence by many things. This paper examines the research result of the remote sensing application for coral reef mapping, the problems that occurred, the suggested method to solve the problem, the ability of remote sensing and the quality of the result. Landsat-tm data is use as main data and spot multi spectral data as comparison because of the availability of data in Indonesia

DEVELOPMENT OF AN OPTICAL MODEL FOR EXTRACTING CORAL REEF BLEACHING.

Yamano, H.* and M. Tamura. Social and Environmental Systems Division, National Institute for Environmental Studies, Onogawa, Tsukuba, Ibaraki, Japan. Email: hyamano@nies.go.jp

Coral bleaching is a major scientific and socio-economic issue on coral reefs. The bleaching may be related to the high sea surface temperature (SST) possibly induced by global warming. SST is monitored by the NOAA/AVHRR sensor on a global scale. However, till now, most studies on the effect of increased SST on coral bleaching are based on *in situ* data and of regional scale. Present situation demands monitoring the same on a global scale. For that purpose, satellite data should be quite useful as it has large spatial scale. However, satellite sensors measure not only the radiance reflected directly by the object of interest but also receive the radiance from scattering by aerosols and the radiance from reflection on the sea surface, etc. Moreover, the photons are absorbed or scattered as they travel through the air or in the water. Thus, it is a must to remove or to calibrate these effects to get the correct readings. Here, we develop an optical model on the transmittance through the air, the sea surface, and the seawater. The model contains three sub-models (1) transmittance in the air, (2) reflectance on the sea surface, and (3) transmittance in the seawater. Using this model, we will examine the spectral and spatial resolution needed for detecting the bleaching, and discuss the feasibility of satellite data for monitoring coral reef bleaching.

Session D6: Monitoring & Assessment of Coral Reefs: Examples

MONITORING REEF-BUILDING CORALS: HOW OFTEN TO CENSUS AND WHAT TO MEASURE?

Cumming, R.L. *. *Department of Biology, School of Pure and Applied Sciences, The University of the South Pacific, PO Box 1168, Suva, Fiji. Email: cumming_r@usp.ac.fj

The costs and time commitment of monitoring can be large, so optimizing the frequency of censuses is important when developing a monitoring strategy. I examined what might be missed in censuses of reef-building corals spaced one or two years apart compared with 3-5 monthly censuses. The study organisms were 1627 colonies of Indo-Pacific branching corals of the genus *Acropora* (25 taxa) and the family Pocilloporidae (5 taxa). Several variables were tested as predictors of demographic fate (growth, shrinkage, death) using log-linear models: growth form, size, presence of recent injury (inflicted within the few days prior to censusing), presence of old injury and presence of the predatory gastropods *Drupella* spp. Colony size was the least useful predictor of fate within 3-5 months, and was significantly related to demographic fate for only one group, the pocilloporids. This suggests that size-based population models for acroporids should incorporate a measure of colony condition. Recent injury, old injury and predators were highly significant predictors for corymbose acroporids (small, compact branches), whereas injury was not a significant predictor for staghorn acroporids (large, widely-spaced branches), even though recent injury was up to three times more common in staghorn colonies.

FISH-BENTHOS CORRELATIONS IN SOME OFFSHORE AND SHELF REEFS IN THE PHILIPPINES.

Dantis A.L.*; Quibilan, M.C.C.; Nañola, Cleto L.; and Aliño, Porfirio M. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, PHILIPPINES.. Email: arvinld@msi01.cs.upd.edu.ph

The differential effects of natural forcing factors (e.g. wave exposure and reef geomorphology) and disturbances (i.e. coral bleaching) in the community structure and recruitment dynamics of reef fishes in some offshore and shelf reefs of the Philippines were explored based on fish-benthos correlations using classification (TWINSPAN) and ordination (CANOCO) techniques. Coral reef surveys and monitoring in the Kalayaan Islands Group (KIG), South China Sea, Palawan Shelf and Tubbataha Atolls, Sulu Sea were undertaken from 1997-1999. A total of 87 fish transects were analyzed vis-à-vis benthos data generated from line transects and video information. Spatio-temporal variability in species richness, abundance and biomass estimates of adult and juvenile reef fishes were also determined. Initial results reveal that the predominant natural forcing factors such as high energy, wind and wave stress and the general reef morphology (i.e. offshore atoll reefs vs. shelf fringing reefs) were observed to influence the fish community structure. The widespread coral bleaching in 1998 caused a significant changes in the benthos (i.e. reduced live coral cover), thus this catastrophic event is implicated to have caused the subsequent decrease in reef fish abundance, biomass and diversity for that period.

MONITORING REEF FISH STOCKS IN THE NORTHWESTERN HAWAIIAN ISLANDS.

DeMartini, E.D.*; and Parrish, Frank A. *National Marine Fisheries Ser-vice (NMFS, NOAA), 2570 Dole Street, Honolulu, Hawaii 96822, USA. Email: Edward.DeMartini@noaa.gov

The status of coral reef fish stocks has been monitored at two sites (French Frigate Shoals, FFS; Midway Atoll, MA) in the Northwestern Hawaiian Islands (NWHI) in support of conservation of the endangered Hawaiian monk seal, *Monachus schauinslandi*, whose generalized prey base includes reef fishes. Initial baseline surveys conducted by the US Fish and Wildlife Service in 1980-83 were resumed by NMFS personnel in 1992 (at FFS) and 1994 (MA). Visual diver-surveys, conducted annually during 1995-99, have estimated the density, size-structure, and biomass of reef fishes in forereef, backreef, and lagoonal patch reef habitats. Sampling effort was initially chosen to provide 80% power to detect a 50% change in stocks of compound taxa comprising trophic levels and major foraging guilds. Results-to-date include fivefold (for lizardfishes) and fifteenfold (moray eels) greater densities at MA compared to FFS, where monk seal preda-tors of lizardfish and moray eel prey are ten times more abundant; and a fivefold less frequent encounter of large jacks such as *Caranx ignobilis* at MA compared to FFS, probably caused by recreational fishing by military personnel prior to wildlife refuge establishment in 1996.

NAUTILUS POMPILIUS POPULATION STUDIES AT OSPREY REEF

Dunstan, Andrew.*; Medway, Tracey; and Hutchison, Emma. *Undersea Explorer, Port Douglas, Qld, 4871, Australia. Email: adunstan@ozemail.com

Nautilus inhabit the tropical Indo Pacific region and have been studied in the field through mark recapture, in-situ photography, radio tracking and associated laboratory/aquarium experiments. Two species of *Nautilus*, *N. pompilius* and *N. stenomphalus*, have been found in waters of the Northern Great Barrier Reef. This study presents data on the presence of *Nautilus pompilius* at Osprey Reef, an isolated Coral Sea reef with vertical reef walls to 1000 metre depths. It appears that just one species of *Nautilus*, *N. pompilius*, inhabits the northwestern study sites of Osprey Reef. The isolated nature of this reef system and the natural impediments to dispersal of *Nautilus* suggest that this could be a genetically isolated population. Between July 1997 and April 2000, 395 *N. pompilius* have been captured, marked, measured and released with a 6.5% recapture rate. Recaptures occurred between one week and 29 months after the initial capture, giving confidence in the tagging method and viability of released animals. *N. pompilius* at Osprey Reef are smaller (mean diameter 130mm) than the same species at other Indo Pacific sampling locations (133mm to 220mm mean diameter). The population sampled is composed of mature and semi-mature individuals of which 16.1% are female, which equates with nautilus sampling programs elsewhere but leaves many questions to be answered. This study provides the base to investigate the unanswered questions of juvenile nautilus habitat, sexual dimorphism and habitat partitioning and geographical isolation and species drift.

UTILISING PUBLIC AQUARIUMS FOR RESEARCH TO INCREASE OUR DATABASE ON REEF SPECIES.

Gill A.B.*. *Jones Building, School of Biological Sciences University of Liverpool, L69 3BX. Email: abgill@liv.ac.uk

Although advances in our understanding of reef species ecology depend on target species research, one consequence is that we are left with large gaps in our knowledge of many other reef species. This can be problematical when we consider such important topics as species diversity, community dynamics and reef management. To address this lack of knowledge, we have been exploring the utility of research within the setting of a public aquarium, which represent huge investments into simulating the natural environment for display species. These facilities far exceed anything that could be contemplated in a research environment other than *in situ* field research. A major constraint of field based research is the lack of control of extraneous variables. In the context of a public aquarium we have an example of a more controlled environment that is more closely related to the real situation than a controlled research laboratory. Here I highlight the potential for research utilising current behavioural ecology techniques within a relatively controlled setting where standard, repeatable data can be obtained on a variety of species which are of sufficient validity to be analysed scientifically. I focus on a selection of behavioural based categories and discuss some specific results that we have obtained, relating them to the context of the environment that the species are in and how this links to the natural circumstances. This approach also provides for education about reef species to a wider audience.

THE IMPORTANCE OF COMBINING METHODS WHEN ASSESSING CORAL POPULATION DYNAMICS: CONTRASTING CONCLUSIONS FROM DESCRIPTIVE, TAGGING AND GENETIC DATA.

Gilmour, JP*. *Department of Zoology, University of Western Australia, Nedlands, W.A. 6907, Australia. Email: jgilmour@cyllene.uwa.edu.au

Three different methods were used to investigate a population of mushroom coral exposed to chronic sedimentation stress and acute cyclone disturbance. 1) Descriptive information for different life history stages of polyps was collected through time, in the form of size frequency distributions. These data provide information on population structure from which inferences were made about factors driving this structure. 2) Polyps at a variety of life history stages were tagged and recaptured to yield a suite of size specific life history traits relative to the period of investigation. These data provide specific information on individuals within a population and factors affecting them, from which inferences regarding population dynamics and structure were drawn. 3) Genetic analysis was performed to quantify the cumulative contribution of sexual and asexual recruitment to the population, also indicating levels of reproductive exchange within and outside the population. Descriptive, tagging and genetic analysis each provide specific, but limited, data from which population dynamics are routinely extrapolated. In this study population dynamics were inferred from each of the three methods alone, and similarities and differences in conclusions compared. A true indication of population dynamics was obtained only when all three methods were combined. Thus illustrating the importance of combining methods of investigation and the care required when extrapolating conclusions from limited types of data.

ESTIMATES OF THE SIZE AND COMPOSITION OF SEA SNAKE POPULATIONS AT ASHMORE REEF, EASTERN INDIAN OCEAN.

Guinea, M L*; and Whiting, S D. *Northern Territory University, Darwin 0909, Northern Territory, Australia. Email: m_guinea@site.ntu.edu.au

Population estimates and ecology of sea snakes (Hydrophiidae) inhabiting Ashmore Reef National Nature Reserve, Eastern Indian Ocean, were investigated from 1994 to 1999. Research was conducted in September and October each year. The surveys concentrated on the species that utilised the extensive reef flat. Of the 16 species of sea snake recorded from Ashmore Reef, the most prominent in this study were: *Emydocephalus annulatus*, *Aipysurus laevis*, *A. foliosquama*, *A. apraefrontalis* and *A. fuscus*. Opportunistic observations were made on other near shore species including *Acalyptophis peronii* and *Hydrophis coggeri* and *Astrotia stokesii*. Seven transects of variable length but known width, were used in estimating the population density of 228 snakes per square kilometre of reef flat at high water at that time of the year. Mark and recapture studies of *E. annulatus*, indicated that approximately 90 individuals utilised a coral patch approximately 15 m in diameter. An association between species and substrate appeared stronger than species and water depth for the inshore species. The sea snake assemblage at Ashore Reef is characterised by a large number of species, including three endemics, and large population sizes.

COMPOSITION AND MONTHLY VARIATION OF FAUNA INHABITING REEF-ASSOCIATED *HALIMEDA*.

Jinendradasa, S.S.; Abeysirigunawardana, M.D.; and Ekaratne, S.U.K..* *Department of Zoology, University of Colombo, Colombo 3, Sri Lanka. Email: suki@eureka.lk

Composition and monthly variation of fauna inhabiting *Halimeda*, a common calcareous reef alga, was studied in the reef lagoon of Hikkaduwa Marine Reserve (HMR) in Sri Lanka. The 1-year study was carried out using monthly triplicated 25x25cm quadrat samples. The fauna was made up of 18 classes distributed among Coelenterata, Platyhelminthes, Nemertinea, Nematoda, Annelida, Mollusca, Arthropoda, Echinodermata and Chordata. The major classes in these phyla were Crustacea (37.6%), Polychaeta (23.6%), Gastropoda (19.9%), Ophiuroidea (17%), Bivalvia (1.8%), Turbellaria (0.9%), Nemertinea (0.8%) and Pycnogonida (0.5%). Crustaceans were dominated by amphipods (43.7%) and crabs (29.0%). Other crustaceans included hermit crabs (10.5%), prawns and shrimps (11.1%), isopods (2.4%) and tanaids (2.7%). Polychaetes included the Terrebellidae (13.9%), Sabellidae (3.8%), Polynoidae (8.1%), Eunicidae (12.6%) and Syllidae (5.7%). Gastropods consisted of prosobranchs (78.9%) and opisthobranchs (21.1%). Dominant ophiuroids were the Amphiuridae (65.7%) and Ophiactidae (31.0%) followed by Ophionereidae (1.3%), Ophiocomidae (1.0%), Ophiodermatidae (0.3%), Ophiomyxidae (0.3%), Ophiuridae (0.3%) and Ophiotrichidae (0.2%). Juveniles inhabiting *Halimeda* included corals, echinoids, asteroids, holothuroids, ophiuroids, fish and squid. *Halimeda* of HMR had a diverse faunal composition serving as a refuge habitat and a nursery ground. Monthly faunal variations will be discussed. Support from MacArthur Foundation and Biodiversity Support Program is acknowledged.

MONITORING ANTHROPOGENIC EFFECTS ON CORAL REEFS WITH DEMERSAL FISH EMBRYOS.

Kerr, Lisa M.*. *University of Massachusetts, Biology Department, 100 Morrissey Blvd., Boston, Massachusetts 02125. Email lisa.lobel@umb.edu

The early life stages of fishes are particularly sensitive to anthropogenic perturbations and pollution assessment techniques in temperate regions include assessing abnormality levels in pelagic fish embryos. Since pelagic embryos are rapidly transported from the site they are spawned, it may be difficult to compare areas that are fairly close together. The use of demersal fish embryos may allow for finer spatial resolution in pollution studies. On coral reefs, nests of territorial, demersal spawners like damselfishes or triggerfishes are easily identified and synchronous development within clutches facilitates identification of abnormal embryos. Nests of individual fish can be identified for sampling or followed over time. As part of the U.S. Army coral reef monitoring program at Johnston Atoll, a study was conducted to address concerns about potential effects of contaminants in resident organisms. Damselfish (*Abudefduf sordidus*) and triggerfish (*Rhinecanthus aculeatus*) embryos were collected from a site with sediment PCB contamination and from uncontaminated reference sites. Although the PCB contamination was confined to a small area, some samples exceeded screening levels for sediment PCBs. The occurrence of abnormal embryos was significantly higher at the site contaminated with PCBs for both species. Examining embryos from demersal spawning fishes allowed specific comparisons between the occurrence of abnormalities in embryos from resident fishes at the PCB contaminated site and the reference sites approximately 1000m distant. Ultimately, observing demersal embryos from fishes with restricted spatial ambits may allow comparisons at the scale of the home range or territory.

VARIATION IN SETTLEMENT OF LOBSTER PUERULI AROUND ST. THOMAS, U.S. VIRGIN ISLANDS.

Kojis, B.L.*; Quinn, N.J.; and Caseau, S.M.. *Division of Fish and Wildlife, United States Virgin Islands. Email: bkojis@vitelcom.net

Settlement of pueruli of the western Atlantic spiny lobster, *Panuluris argus*, was monitored at five locations from December 1997 to March 1998 in waters off St. Thomas, U.S. Virgin Islands. The number of pueruli differed greatly between sites. The greatest number settled on collectors located over sand in Nazareth Bay. The mean catch per unit effort (CPUE) at this site was 5.6 pueruli per sampling time. Pueruli were recorded on 61% of the sampled dates. The CPUE at other sites varied from 0.8 pueruli in the Mangrove Lagoon to 0.3 pueruli at Lovango Cay and Shark Island. Pueruli were present on collectors at the three sites on 77%, 57% and 50% respectively of the dates sampled. The results will be compared to an earlier study in the U.S. Virgin Islands.

TEMPORAL CHANGE IN HARD SUBSTRATE COMMUNITIES, 10-250 M, THE BAHAMAS.

Liddell, W*; and Avery, WE. *Department of Geology, Utah State University, Logan, UT, USA 84322-4505. Email: davel@cc.usu.edu

Fine-scale change in hard-substrate community structure was determined through repeat photography of natural substrates and artificial settling panels over a three year period and along a depth gradient of 10-250 m off Lee Stocking Island, The Bahamas. Indices were developed to address temporal changes in substrate components, including percent areas occupied and addition and losses of individuals or colonies. Overall values for change were relatively low at 10 m depth, increased to a maximum between 30 and 50 m, and then declined with increasing depth to 250 m. Numbers of fish grazing scars counted on artificial settling panels were positively correlated with the loss index and negatively correlated with algal cover, suggesting that fish are a major contributor to the observed temporal changes in the sessile community between 10-50 m. Dominant substrate components shifted from algae to corals to sponges with increasing depth. Although correlations between change indices and hard-substrate community structure suggest an association between intermediate values of change and high species richness (S) and Shannon diversity (H'), a simple causal relationship between agents (wave action, fish grazing) of fine-scale change and community structure was not demonstrated. Instead, a complex interplay of abiotic and biotic disturbance forces, diminishing light levels, and changing phyletic dominance accompanied by shifting tradeoffs in competitive abilities occurs along the bathymetric gradient.

CHARACTERIZATION OF FORAGING AND INTER-NESTING HABITAT FOR THREE HAWKSBILL SEA TURTLES IN MAUI, HAWAI'I.

Ligon, Allan* and Bernard, Hannah J.. *Hawai'i Wildlife Fund, P.O. Box 637 Paia, HI 96779 Email: wild@aloha.net

In order to assist in the successful recovery of the endangered hawksbill sea turtle (*Eretmochelys imbricata*) in Hawai'i, efforts are underway to identify its foraging, nesting and inter-nesting habitats. Hawai'i Wildlife Fund (HWF) is beginning to address some of these critically important recovery actions for the hawksbill sea turtle in Hawai'i, including the characterization of the coral reef habitat they utilize during resting and foraging. In Fall of 1999 and Winter 2000, HWF staff performed a series of reef surveys using techniques compatible with the University of Hawaii's Coral Reef Assessment and Monitoring Program's (CRAMP) video transect methodology in order to characterize the reef habitat utilized by three radio and satellite tagged hawksbill turtles. The habitats varied dramatically for each of the turtles, ranging from sand and halimeda beds to rich and diverse coral fields. It appears, however, that most of the site locations occur across the edges of habitat boundaries, some defined by dramatic vertical relief. The boundary edges may incidentally occur at these same sites, or it could signify active selection by the turtles. This report identifies and characterizes the foraging and inter-nesting habitat for three hawksbill sea turtles that were tagged and instrumented after nesting events on the islands of Maui and Hawai'i from 1996-1998.

DIVERSITY OF FISH COURTSHIP AND SPAWNING SOUNDS AND THE APPLICATION OF ACOUSTIC TECHNOLOGY FOR MONITORING REPRODUCTION.

Lobel, Phillip S.. *Boston University, Marine Biological Laboratory, Woods Hole, MA 02543. Email: Plobel@mbl.edu

It has been known for a long time that many fishes produce sounds especially during reproduction. Recent studies using a new system for synchronous audio and video recordings reveal that several species produce species specific and behavior specific sounds associated with courtship and the mating act. Passive acoustic technology has been developed that utilizes these sounds to remotely monitor the breeding behavior of reef fishes. This application is being tested as an alternative or supplement to the traditional methods involving sampling fish gonads, plankton tows for ichthyoplankton and direct observation by scuba diving. One problem with these traditional methods is that they involve destructive sampling, manually intensive labor, are limited by time that can be spent by people in the field and the number of sites that can be sampled simultaneously. The presentation will show a video with sounds of fishes courting and spawning, will describe their acoustic characteristics and will describe the system developed for monitoring these sounds.

STATUS OF CONTAMINANTS IN SEDIMENTS AND BIOTA AT JOHNSTON ATOLL, AFTER 70 YEARS OF MILITARY OPERATIONS.

Lobel, Phillip S.*; and Kerr, Lisa M.. *Boston University, Marine Biological Laboratory, Woods Hole, MA 02543. Email: Plobel@mbl.edu

Johnston Atoll has been a military base since the 1930's. It is located about 800 miles SW of Honolulu and has never had an indigenous population. The US expanded the atoll's island landmass by dredging from about 50 acres to over 660 acres. The atoll has been used for nuclear testing, storage of herbicide (agent) orange (of which 250,000lbs. leaked), airfield operations, and it is currently the site for the US Army Chemical Weapon Demilitarization Program. The scientific challenge has been to define appropriate sampling and ecological studies which both define the relative impacts from the various military operations as well as to define the nature and extent of contamination in the atoll. The main contaminants of concern include plutonium, dioxins, furans, PCBs, PAHs, herbicide, and heavy metals. This paper will describe the concentrations and distribution of contaminants in sediments and biota as well as present a preliminary assessment of the ecological impact to the coral reef ecosysytem.

IN SITU CORAL RESPIRATION MONITORING BY USING AN UNDERWATER LABORATORY AQUARIUS.

Okamoto, M.*; Nojima, S.; and Yamaguchi, Hitoshi. *JAMSTEC, Yokosuka, Japan. Email: okamotom@jamstec.go.jp

NOAA's underwater laboratory AQUARIUS IS located at 18 m depth off Key Largo, Florida. We have developed a coral respirometer and evaluated its working during the AQUARIUS dive mission (July 1999). This respirometer consisted of acrylic resin housing, a DO sensor with stirrer, a 4π PAR sensor, a thruster for seawater exchange and three seawater driven magnetic stirrers. DO and PAR data of the surrounding water was logged into AQUARIUS at ten seconds interval. Two respirometers were fixes at the bottom, one with a settled *Siderastrea siderea* and the other without, as a control. Measurement were made for 24 hrs at 30 minutes interval and with 10 minutes water exchange cycle. Current, water temperature, salinity and DO were monitored at this locality. The results of these experiments showed, in situ measurement of coral respiration at a particular locality could provide valuable information on the primary production of that area where coral distribution is estimated precisely. In addition this experiments also provided technical information to develop new in situ coral respirometer.

PLOTTING OF NATURAL BUTTERFLYFISH DIVERSITY AND ABUNDANCE CLINES ACROSS THE RED SEA AND INDIAN OCEAN AS A TOOL FOR CORAL REEF MONITORING.

Ormond, R*; & Chen, T.C. *University Marine Biological Station, Millport, Isle of Cumbrae, Scotland. Email: rupert.ormond@millport.gla.ac.uk

Butterflyfishes (Chaetodontidae), because many of them are obligate corallivores, have often been proposed as convenient indicator species for monitoring the health of reefs. However the number of species and their abundance on unimpacted reefs varies widely between regions as a result of zoogeographic factors. We have now collated standardised Underwater Visual Census counts of butterflyfish along horizontal 200 x 10 m band transects on over 1000 relatively unimpacted reefs extending from the Northern Red Sea to the Great Barrier Reef. As a result we are able to plot contours of butterflyfish diversity and abundance. At 3-5 m depth for example, total number of species recorded ranges from 6 in the Gulf of Suez, via 12 in the central Red Sea, and 20 in East Africa, to 22 in Taiwan and on the Great Barrier Reef. However mean number of species per transect ranges from 2 - 3 in the Gulf of Suez to 9 - 10 in the central Red Sea, and mean total abundance per transect from 20-40 in the Gulf of Suez to about 200 in the central Red Sea. In most regions there is a correlation between mean abundance per species and number of species per transect. There is however no relationship between mean total abundance per transect in different regions and total number of species in those regions, suggesting that total number of butterflyfish per transect may be a particularly useful universal indicator of reef quality.

DEEPWATER CORAL BEDS AS FORAGING HABITAT FOR THE ENDANGERED HAWAIIAN MONK SEAL.

Parrish F.*; Craig, M.; Abernathy K.; Marshall G.; and Buhleier, B. *NOAA Fisheries, Honolulu Laboratory, 2570 Dole St., Honolulu, HI 96822 USA. Email: Frank.Parrish@noaa.gov

Recent plans to commercially harvest deepwater precious corals in the vicinity of islands populated with monks seals prompted concerns about impacts to the seals' forage grounds. A review of movement data from 33 seals fitted with satellite tags at French Frigate Shoals (FFS), Hawaii identified two areas where seals revisited subphotic depths (>300 m). Submarine surveys of the seafloor at each area revealed beds of deepwater coral including species of *Gerardia* and *Corallium*. Previous submarine surveys (n=12) conducted over the wider FFS region, at relevant depths, found no coral beds indicating the seals were targeting the few areas that supported deepwater corals as preferred forage habitat (Fishers exact P=0.01). In an attempt to document seals foraging in the coral beds five seals were instrumented with a back mounted video recorder (CRITTERCAM). None of seals visited subphotic depths. However, three seals were recorded to visit beds of filamentous black coral (*Cirrhipathes* sp.) at moderate depths (80-100 m) where they fed on resident fish. The vertical relief afforded by deepwater coral provides shelter superior to adjacent habitat and thus attracts and supports a fish community. Proposed is a hypothesis that seals frequent these coral beds to feed on the associated fish assemblages and improve their overall foraging success.

ECOLOGY OF OIL PRODUCTION PLATFORMS AND ADJACENT REEF AREAS IN THE GULF OF MEXICO.

Rodriguez, AA*; and Liddell, WD. *Artificial Reef Research Institute, 1802 Ennis Joslin #1232, Corpus Christi, TX, USA 78412. Email: albertor@cbi.tamucc.edu

The Gulf of Mexico is the primary source of offshore oil and gas production for Mexico and the United States with over five thousand production platforms currently located within its boundaries. These platforms create dynamic artificial reef ecosystems by providing hard substrate which is utilized by marine flora and fauna. The structures are quickly colonized by microorganisms, polychaetes, algae, and barnacles, creating a suitable habitat for secondary colonization by sponges, cnidarians, molluscs, and crustaceans. The man-made structures and biofouling community provide prey and shelter for mobile benthic and nektonic species, many with commercial value. As such, the platforms may support commercial and recreational fisheries and sport diving. Five PEMEX production platforms in the Southwestern Marine Zone of the Gulf of Mexico and reefs located off the islands of Arcas and Arenas were chosen to evaluate the effects of the platforms on the marine environment. For example, what is the linkage between the artificial and natural reef environments? What migration of species occurs between the two? Also, do platforms actually increase production of valuable fish species or do they simply serve as attractants and congregate existing fishes, subsequently making them more vulnerable to fishing pressures? What negative effects, if any, do the platforms have on the marine environment - chemical pollution, noise, increased fishing pressure, other? These questions will be addressed through quantitative assessment of the composition of sessile and mobile biota, including plankton, of the platforms and adjacent natural reef areas and through monitoring of chemical and physical environmental parameters.

TRACKING CHANGES ON A REEF IN THE US VIRGIN ISLANDS WITH VIDEOGRAPHY AND SONAR.

Rogers, Caroline S.*; Miller, Jeff; Waara, Robert J. U.S. Geological Survey, P.O. Box 710, St. John, USVI 00830. Email: caroline_rogers@usgs.gov

Living coral cover and cover by other organisms and substrate were monitored at Newfound Reef, St. John, in March 1999 and March 2000 using a digital video camera and an underwater position-locating system. Newfound Reef is associated with an undeveloped watershed and has little exposure to anthropogenic disturbance. The objective was to monitor the lower forereef in a statistically rigorous way, with the locations of samples (transects) selected without bias before the divers entered the water. Twenty, independent transects (10 m long) were selected randomly as a subset of the "population" of all possible transects based on superimposing a uniformly spaced 10 m x 10 m (virtual) grid over the study site. The positioning system uses SONAR signals from fixed reference units and a mobile unit carried by a diver. Transects were videotaped a set distance above the substrate. Benthic components were quantified using random dots applied to video images. Mean cover of live coral changed significantly, decreasing from 18.0 $\pm$ 6.3 (SD) in March 1999 to 13.9 $\pm$ 6.1 (SD) in March 2000. Mean cover of macroalgae, dead coral with algal turf, and sand did not change significantly. The decrease in coral cover may be the result of damage from two hurricanes in the fall of 1999, although dives on the study site following these storms suggested only limited, patchy damage. The decline of 4% coral cover seems small and would be difficult to detect visually but represents a loss of over 20% of the coral cover on this reef.

EARLY WARNING SYSTEMS IN CORAL REEFS: NOVEL BIOSENSORS FOR ON-LINE AND *IN-SITU* MONITORING OF ENVIRONMENTAL POLLUTANTS.

Ron, E.Z.; Choresh,O; Biran,I; Babai,R; Biran, D; and Rishpon, J.. *Department of Molecular Microbiology & Biotechnology, Tel-Aviv University, Israel, 69978. Email: eliora@post.tau.ac.il

Early warning systems (EWS) are essential for prevention of environmental damage. With the growing concern to the world-wide degradation of coral reefs due to human perturbations, the development of EWS for efficient assessment of the health of coral reefs is of great importance. Ideally, these systems should operate on line and *in situ* to report potential problems as they occur. We have developed a novel biosensing technology, based on electrochemical monitoring consisting of whole cell biosensors constructed by molecular fusion of promoters of interest to reporter genes encoding enzymes that can be assayed electrochemically. The electrochemical measurements are performed using disposable screen print electrodes, that allow the simultaneous on-line monitoring of several pollutants. Using bacterial promoters that respond to heavy metals or to organic pollutants we monitor *in situ* and on line the presence of pollutants such as cadmium and oil. The high sensitivity of the biosensors enables the detection of ppb concentrations of the pollutants in marine environments. We are currently searching for stress-responsive genes of marine invertebrates and have already identified such genes from sea anemones and scleractinian corals. These genes will serve for constructing additional electrochemical biosensors that will report on various types of stress to marine organisms. The electrochemical biosensing enables rapid, specific and quantitative real-time monitoring of pollutants and stressors in marine environments.

TRENDS IN CORAL REEF FISH POPULATIONS: PRIORITIZING SITES FOR MANAGEMENT BASED ON A LARGE VOLUNTEER-GENERATED DATA SET.

Semmens, B.X.*; Pattengill-Semmens, C.V.; and Ruesink, J.L. *University of Washington, Dept. of Zoology, Box 351800, Seattle, WA 98197-1800, Email: semmens@u.washington.edu

Information is a precious resource in the marine environment. Due to the high costs associated with fieldwork and the unpredictable nature of marine conditions, gathering more than rudimentary information on coral reefs is difficult. Several volunteer monitoring programs have recently been established to defray the costs and logistical challenges faced by scientists and resource managers wishing to gather data on coral reefs. In 1993, the non-profit organization REEF (Reef Environmental Education Foundation), began a coral reef fish monitoring program in the tropical western Atlantic based on volunteer data collection. Since that time, more than 5,000 volunteer surveys have been conducted in the Florida Keys National Marine Sanctuary (FKNMS). In this paper, we describe a technique for interpreting the REEF data in terms of trends in presence and abundance of coral reef fish species. Rather than relying on long-term trends in single species, we quantify short-term (6 yr) trends for several taxa at each site. The results of this analysis highlight a subset of survey sites throughout the FKNMS that have a proportionally higher number of species with significant population trends. This subset of sites is considered in light of past, current, and future resource use and management actions and options.

RAPID BROAD-SCALE SURVEY TECHNIQUES FOR MARINE RESOURCE ASSESSMENT AND SEABED MAPPING.

Skewes, T.D.; Gordon, S.R; Dennis, D.M.; Pitcher, C.R.; Long, B.G.; Smith, G.P.; McLeod, I.R.; Taranto, T.J.; Haywood, M.D.E.; Griffin, D.A. *CSIRO Marine Research. PO Box 120, Cleveland, Q 4163, Australia. Email: tim.skewes@marine.csiro.au

We demonstrate rapid broad-scale survey techniques for resource assessment and habitat mapping of shallow reefs (0–15 m deep) and shoal areas (15–50 m deep) in a 60,000 km^2 area off the Australian north western coast. The study area contained seven shallow reef systems, including Ashmore and Scott reefs, totaling 560 km^2, and 1226 km^2 of shoals (15 to 50 m deep). The fieldwork was done over a 6 week period during September and October 1998. On the shallow reefs, the technique used diver transect surveys and visual censuses (finfish and shark) to collect field data, and remote sensing to map shallow reef habitats. On the shoals, we used video camera transects, acoustics and sediment grabs. GIS was used for designing efficient stratified sample strategies, for data analysis and reporting. Using data from the survey, we were able to produce estimates of the marine resources of the shallow reefs and shoals, including commercial holothurians, trochus, finfish and shark, with sufficient precision to assess stock status. We were also able to describe the ecology and structure of the reefs and shoals, and map representative seabed types. The survey data was also used to measure the size and extent of a recent mortality of hard corals on some of the shallow reefs.

GROWTH RATES OF GREEN SEA TURTLES (*CHELONIA MYDAS*) FROM TWO REEF SYSTEMS IN THE INDIAN OCEAN.

Whiting, Scott D.* and Guinea, Michael. *Faculty of Science, Information, Technology and Education, Northern Territory University, Darwin, NT, Australia. Email: s_whiting@site.ntu.edu.au

Animal growth rates are essential to established realistic population models and to investigate ecological processes. Green turtles were captured and tagged from two reef systems in north-western Australia. These reef systems, separated by 800km, included Ashmore Reef, a shelf-edge platform reef on the edge of Australia's continental shelf, and an algal dominated inshore fringing reef in Fog Bay, near Darwin. Growths rates were obtained from green turtles that ranged between 40 and 60 cm curved carapace length (ccl). Green turtles at Ashmore Reef (mean=3.79 cm ccl, sd=1.34, n=16) grew 2.6 times faster than those from Fog Bay (mean=1.45cm ccl, sd=0.75, n=20). Ashmore Reef green turtles had a diet dominated by the seagrass *Thalassia hemprichii* while the Fog Bay green turtles had a diet dominated by the low biomass algae *Laurencia spp*, *Gracilaria spp* and *Gelidiella spp*. This difference in diet and the suspected differences in seasonal abundance of food resources were probably the major influences in determining growth rates. Genetic factors may also play a major role but this needs further investigation. The large difference in growth rates has a significant impact on the dynamics of each population. To move through the 40-60 cm size range it would take Fog Bay green turtles approximately 14 years while it would take Ashmore Reef green turtles 5 years. As green turtles from these areas reach maturity at approximately 100 cm ccl, the age at maturity for each population may differ by decades. Such differences in growths rates indicate that population and harvest models produced for some areas are not applicable to all populations.

VARIATIONS IN SEAGRASS PARAMETERS ACROSS THE CARIBBEAN: THE CARICOMP NETWORK STATIONS.

Zieman J.C. * and CARICOMP seagrass team. *Dept. of Environmental Sciences, Univ of Virginia, Charlottesville VA, USA. Email: jcz@virginia.edu

The CARICOMP program has been collecting seagrass data on biomass and productivity since 1993 at up to 19 institutions across the greater Caribbean using standardized protocols and methodologies. The stations monitored at each site were selected as representative of lush, well-developed *Thalassia testudinum* beds with minimal disturbance. The mean productivities across the region were 2.7 $g \cdot m^{-2} \cdot d$ and turnover rates averaged 3.9 $\% \cdot d^{-1}$. The high turnover rates are a function of the tropical latitudes of the stations. Shoot densities averaged 725 $sh \cdot m^2$, and total above and below ground biomass averaged 1507 $g \cdot m^2$. Average leaf length and width were 14.4 cm and 10.6 mm, respectively, and leaf area index averaged 3.4 $m^2 \cdot m^{-2}$. Maximal values were typically 2-3 times greater then the means, although maximal biomass was five times the mean. On a regional basis, seagrass biomass showed varying patterns in the interval 1993-1999 with some stations increasing by a factor of two (Jamaica), decreasing precipitously (Bermuda), maintaining a value with little variation (Mexico), and showing wide variation about a mean (Belize). C:N:P ratios of the *Thalassia* leaves were determined to determine localized nutrient excesses and deficiencies.

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RESPONSE OF CORAL GROWTH TO CLIMATIC CO_2 VARIATIONS.

Amat A*, Ruiz-Pino, Suzuki, Poisson, Juillet-Leclerc. LSCE, Domaine du CNRS, Gif-sur-Yvette, FRANCE. Email: amat@ccr.jussieu.fr

Atmospheric pCO_2 has been strongly fluctuating at different time scales. During the Last Glacial Maximum (LGM,18000 yr BP), pCO_2 was 80ppm lower than preindustrial atmospheric pCO_2 (280ppm). Human activities increase today the pCO_2 at a rate of 0.4 % yr^{-1}. According to the average emissions scenarios, a value of 700ppm is expected in 2100. This study investigates the response of Scleractinian corals to atmospheric pCO_2 variations. pCO_2 controlled aquarium experiments have been performed for three coral genus (*Acropora*, *Porites* and *Stylophora*). Seawater pCO_2 was modified by changing the pCO_2 of air used to bubble the aquarium. Three conditions of pCO_2 have been imposed, corresponding to glacial (200ppm), present-industrial (350ppm) and expected future (700ppm) concentrations. Simultaneous responses of organic and inorganic ($CaCO_3$) biomass and metabolic processes (photosynthesis and calcification) to pCO_2 variations were analysed. For the three coral genus, a non linear relationship between metabolism, biomass and pCO_2 which depends on pCO_2 levels has been obtained. For the LGM change and all genus, all biomass and metabolic processes increase as a function of increasing pCO_2. For the predicted doubled pCO_2 (year 2100) and all genus, inorganic biomass and calcification decrease even if organic biomass increase. The photosynthetic response is however genus dependent. Our experimental data support simultaneously both hypothesis : an increase of coral biomass and calcification during the LGM transition and a decrease for the next century.

SOLUTION OF REEF ROCK BUFFERS SEAWATER AGAINST RISING ATMOSPHERIC CO_2.

Barnes D.J.* and C. Cuff. *Australian Institute of Marine Science, PMB 3, Mail Centre, Townsville Qld 4810, Australia. Email: d.barnes@aims.gov.au

Rising levels of atmospheric CO_2 will increase the activity of dissolved CO_2 in surficial seawater and lower seawater pH. It has been shown that this will reduce calcification in corals and other reef organisms, and reduce the ability of reefs to maintain themselves. Although solution of reef rock by more acid seawater might return pH towards original values, it has been suggested that tropical seawater is so supersaturated with respect to calcium carbonate that such solution will not occur. We raised CO_2 in seawater to levels likely to be reached before 2100 and recorded the pH. We then added powdered minerals: laboratory grade calcite, coral skeleton (aragonite), magnesium carbonate and skeleton of the red alga, Lithothamnion (high magnesian calcite). Addition of calcite and aragonite did not alter the pH of the acidified seawater indicating no significant solution. However, high magnesian calcite and magnesium carbonate both returned the pH to values approaching or higher than its initial value. Interpretation of the results and consideration of the statistical and kinetic behaviour of high magnesian calcites leads to the proposition that rising CO_2 will not greatly impact reef systems since any reduction in pH will be rapidly compensated by dissolution of the high magnesian calcite components (up to 50%) of reefs rock. Dissolution of high magnesian calcite will cause the pH to be buffered between approximately 8.15 and 8.35 depending upon the overall high magnesian calcite composition. Moreover, increase in the total alkalinity of seawater due to solution of carbonates is likely to enhance calcification.

PHOTODEGRADATION OF MYCOSPORINE-LIKE AMINO ACIDS IN ACROPORA PALMATA AND PALYTHOA CARIBAEORUM.

García R* and Corredor J. Department of Marine Sciences, University of Puerto Rico, P.O Box 908, Lajas PR 00667. Email: rochy98@hotmail.com

Mycosporine-like amino acids (MAAs) are a group of water-soluble compounds abundant in benthic marine invertebrates exposed to high fluxes of UV. These compounds have maximum absorption in the range of 310-360nm, corresponding to biologically harmful wavelengths of UV and are consequently thought to provide protection from damaging ultraviolet (UV). The goal of this project was to quantify photodegradation rates of MAAs in two species of reef coelenterates (*Acropora cervicornis* and *Palythoa caribaeorum*) on San Cristobal reef at La Parguera, Puerto Rico. Samples were extracted in 20% tetrahydrofuran /methanol, evaporated and re-dissolved in seawater. These were placed in quartz tubes and exposed to direct sunlight during 13 days. Aliquots were sampled every three days. Absorption was recorded between 290 to 400nm using spectrophotometer. All extracts exhibited exponential loss of their capacity to absorb UV radiation over the period of exposure. Differential photodegradation of individual MAAs was documented by HPLC. MAA photodegradation may represent a significant metabolic cost to benthic marine organisms exposed to high UV fluxes. Our work demonstrates that MAAs are photolabile and indicates that organisms exposed to high fluxes must continuously renew their pool of photoprotective MAAs.

WILL REEF SEDIMENTS BUFFER CORALS FROM INCREASED GLOBAL CO_2?

Halley R. B.* and Yates, K. K. U.S. Geological Survey, St. Petersburg, Florida, USA. Email: rhalley@usgs.gov

Laboratory experiments suggest that increased atmospheric CO_2 will cause a reduction in coral calcification due to a decrease in aragonite saturation state of seawater. Field experiments in Hawaii suggest that larger, community scale experiments, including natural substrates, are needed to more accurately examine the effects of increased CO_2 on coral reefs. We have used an 11.3 m^3 incubation chamber (Submersible Habitat for Analyzing Reef Quality, S.H.A.R.Q.) to increase CO_2 and measure calcification, photosynthesis, and respiration of different benthic communities on the reef flat of south Molokai. Trapping CO_2 evolved by respiring organisms elevates carbon dioxide inside the S.H.A.R.Q. Preliminary results show that elevated CO_2 is accompanied by an increase in dissolution of associated, magnesian-calcite rich, carbonate sediments. Dissolution predominates in sand and coral rubble substrates. Further experimentation of elevated CO_2 in natural reef settings is warranted to examine the degree to which sediment dissolution may locally limit the lowering of saturation states as atmospheric CO_2 increases.

DECLINE IN CORAL CALCIFIATION RATE OVER THE LAST CENTURY: PRELIMINARY EVIDENCE.

Helmle, K.P.*, Wellington, G.M., Dodge, R.E., and Swart, P.K. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania, Florida 33004 USA. Email: kevinh@ocean.nova.edu

Recently reported calculations of changing ocean calcium carbonate ($CaCO_3$) saturation state based on increasing atmospheric carbon dioxide (pCO_2) levels indicated the potential that calcification rates of calcium carbonate producing organisms have experienced past declines which will accelerate in the future. Reef-building coral skeleton cores from the northern Caribbean, eastern Pacific, and western Pacific have been collected and analyzed to investigate this hypothesis. Annual density bands in these coral skeletons provide a physical record of growth variation over time. X-radiographs were used to expose density banding, and image processing densitometry was used to measure three parameters of coral growth (extension, density, and calcification) over the last century. Preliminary results indicate historical declines in annual calcification on the order of 10%. This is consistent with calculated decreases in calcification resulting from a reduction in the aragonite saturation state via increasing pCO_2. Further data collection and analysis is underway to assess the spatial and temporal variability of this trend. Other environmental variables (including sea-surface temperature) will be compared to identify possible confounding effects. This research is aimed at assessing the degree to which coral growth has been affected by recent atmospheric and ocean chemistry changes.

INTEGRATED MONITORING SYSTEM FOR CORAL REEF WATER *p*CO_2, CARBONATE SYSTEM AND PHYSICAL PARAMETERS.

Kayanne H.*, S. Kudo, H. Hata, H. Yamano, K. Nozaki, K. Kato, A. Negishi, H. Saito, F. Akimoto and H. Kimoto. Department of Earth and Planetary Science, University of Tokyo, Hongo, Tokyo 113-0033 Japan. Email: kayanne@eps.s.u-tokyo.ac.jp

To monitor changes in reef water carbonate system in response to community metabolism and global changes, an integrated monitoring system for *p*CO_2, total alkalinity (TA), total inorganic carbon (TIC) and related physical parameters was developed. The system was loaded on a small boat and run with minimum maintenance. It was set on a coral reef flat and continued automatic monitoring for one year from September 1998 to September 1999 except for TA and TIC. The continuous (on-line and flow-through) TA and TIC monitoring system was also loaded and operated by supplying standard solutions daily. The *p*CO_2 values between a flow-through type and a membrane type equilibrators matched within 6 µatm. The TA and TIC values by the continuous system matched with those by a precision analyzer with a deviation of 10 µmol kg^{-1}. The monitoring results showed that *p*CO_2, TA, TIC, temperature, dissolved oxygen (DO) and pH in coral reef water changed diurnally by photosynthesis and calcification during the day and respiration at night. The system succeeded in monitoring short-time TA and TIC spikes corresponding to the other physical parameters, which were difficult to observe by periodical manual water sampling. These synchronicities validate the performance of this integrated system. This system can be applied to coastal zone monitoring and buoy system in general.

OVERVIEW OF CO_2-INDUCED CHANGES IN SEAWATER CHEMISTRY

Kleypas, Joan* and Chris Langdon, National Center For Atmospheric Research, Po Box 3000 Boulder Co 80307-3000, Usa. Email: kleypas@ucar.edu

Anthropogenic increases in atmospheric co_2 are changing ocean chemistry, and particularly that of the surface mixed layer. Although total dissolved inorganic carbon (dic, or tco_2) is increasing in response to increases in the partial pressure of co_2, both ph and the carbonate ion concentration ($[co_3^{2-}]$) are decreasing. Several reef-building species and reef "mesocosms" demonstrate a marked decrease in calcification rate in response to decreased $[co_3^{2-}]$, and so it important to quantify future changes in ocean carbonate chemistry. Thermodynamic calculations of the co_2 system in shallow tropical water indicate that a doubling of preindustrial pco_2 will cause surface ocean ph in the tropics to decrease from preindustrial values of about 8.15–8.2 to less than 8.00; and $[co_3^{2-}]$ will decrease accordingly by more than 30%. This presentation will review how atmospheric co_2 affects carbonate chemistry in the surface ocean. It will then provide an overview of both modeled and measured changes in surface ocean chemistry, including results from global ocean carbon surveys conducted through the joint global ocean flux study (jgofs) and the world ocean circulation experiment (woce), as well as evidence from carbon isotopes. Finally, various strategies for examining the effects of changing seawater chemistry on marine calcification will be outlined.

OVERVIEW AND UPDATE ON EFFECTS OF CO_2 ON CALCIFICATION OF REEF BUILDERS
PART 2. THE EXPERIMENTAL EVIDENCE.

Langdon Chris. Lamont-Doherty Earth Observatory of Columbia Uni., Palisades, NY, 10964, USA. Email: langdon@ldeo.columbia.edu

An overview on the experimental evidence for the sensitivity of corals and coralline algae to elevated CO_2 will be presented. Studies range from a single organism in a small tank to simple assemblages of reef organisms in aquaria ranging from 150 to 2.65×10^6 L. All data sets show that calcification decreases with increasing pCO_2. Most data sets show a linear relationship between calcification and the carbonate ion concentration or saturation state, δ_{arag}, suggesting that saturation state is the actual controlling variable and that pCO_2 is acting on calcification indirectly through its effect on carbonate ion concentration. This is supported by the results of the Biosphere 2 study which varied $[Ca^{2+}]$ and $[CO_3^{2-}]$ and showed that calcification rate varied in response to changes in the concentration of either and was linearly related to the ion concentration product. The slopes of the calcification $\delta\delta_{arag}$ relationship from the various studies show considerable variability (3 -51% decrease by mid 21st century). It is not possible to say at this time whether this range reflects real differences between species and taxa in their sensitivity to change in δ_{arag} or if the range reflects the effect of varying degree of light limitation or nutrient limitation. Either way it is clear that δ_{arag} is an important environmental variable and that there is reason to be worried that coral growth and carbonate accretion on reefs may fall to critical levels in the next century.

ATMOSPHERIC CO_2 AND CORAL MESOCOSM METABOLISM

Leclercq Nicolas*, Jean-Pierre Gattuso & Jean Jaubert *Observatoire Océanologique Européen, Centre Scientifique de Monaco, Avenue Saint-Martin, MC98000 Monaco. Email: nleclercq@scientist.com

A coral mesocosm has been used to test the hypothesis that the anthropogenic increase in atmospheric CO_2 partial pressure (pCO_2) might affect the metabolism of coral reefs. We manipulated seawater pCO_2, in the mesocosm, to reproduce the predictions made by the Intergovernmental Panel on Climate Change and achieved short-term (1 day) and long-term (30 days) experiments. Both experiments showed that the rate of calcification of hard- and soft-bottom communities was reduced under elevated pCO_2 (and the associated reduced aragonite saturation state, δ_{arag}). A shift in the pCO_2 from 370 µatm (present day) to 700 µatm (year 2100) resulted in a drop of 10% of the present rate of calcification for a Scleractinian-dominated community. No change in net primary production was found after one month of exposure to elevated pCO_2, suggesting that the photosynthetic organisms inhabiting the mesocosm (mostly Scleractinian corals) are bicarbonate-users. Also, after its initial decline, the reduction of the rate of calcification remained constant over 4 weeks, suggesting that no community acclimation to elevated CO_2 occurs. On the basis of these results, we estimate that the global reef calcification will decrease by 36% and that the associated global flux of CO_2 will decrease by 20% during the next century.

CLIMATE CHANGE AND GROWTH OF *PORITES*.

Lough J.M. * and D.J. Barnes. Australian Institute of Marine Science, Townsville, Qld 4810, Australia. Email: j.lough@aims.gov.au

Growth characteristics (extension, density and calcification) were obtained from annual density banding patterns in >240 similar-sized colonies of massive *Porites* from 29 reefs along the length and breadth of the Great Barrier Reef, Australia. Combined with previously published growth characteristics from Hawaii and Thailand these data allow examination of the environmental controls on *Porites* growth through 20° of latitude and an annual average sea surface temperature (SST) range of 23-29°C. Calcification and extension are significantly and linearly related to annual average SST (84% variance explained) and provide for an increase of 0.33 $g.cm^{-2}.yr^{-1}$ and 3.1 $mm.yr^{-1}$ of calcification and extension, respectively, for each 1°C rise in SST. Calcification and extension are more closely related to annual minimum SST than annual maximum SST. The sensitivity of calcification rates in *Porites* to SST combined with observed 20th century increases in SSTs on the GBR suggests that calcification rates in some massive coral species may, at least initially, increase as a result of global warming due to the enhanced greenhouse effect. There is some evidence that the calcification rate of massive *Porites* on the GBR has already increased over the present century in association with observed warming of SSTs.

CORAL RESPONSE TO CHANGES IN ARAGONITE SATURATION STATE OF SEAWATER.

Marubini, Francesca*, Ferrier-Pagès, Christine and Jaubert, Jean. Observatoire Océanologique Européen, Centre Scientifique de Monaco Av. Saint-Martin. MC-98000 Monaco. Email: Francesca.Marubini@csm.monaco

It has been recently established that calcification rate in hermatypic corals is proportional to the saturation state of seawater (Ω_{arag}). The predicted decrease in Ω_{arag} over the next century as atmospheric pCO2 rises, is a potential cause of concern for coral growth and reef accretion globally. In order to improve our ability to predict how corals will cope with future changes we have to improve our understanding of the mechanisms of calcification and photosynthesis in relation to Ω_{arag}. A decrease in Ω_{arag} is due to a decrease in $[CO_3^=]$, brought about by a decrease in pH as pCO_2 increases. We set up a growth experiment to test 1) which parameter among $[CO_3^=]$, pH and pCO_2 is the key in the control over coral calcification rate and 2) if photosynthesis is also affected. Nubbins of *Stylophora pistillata* were grown for 4 weeks in laboratory chemostats (light = 300 µE m^{-2} s^{-1} for 12h, temperature = 26.5°C). By adding solutions of NaOH, HCl and $NaHCO_3$ to the incoming seawater we maintained 3 different pH levels (pH_{SW} = 7.6, 8.0, 8.2) at 2 different TCO_2 levels (normal seawater and with the addition of 2mM $NaHCO_3$) resulting in 6 different Ω_{arag} treatments (ranging from 1 to 12). Calcification rate was monitored by buoyant weighing at weekly intervals and by linear extension. Photosynthetic parameters (P_{max}, alpha, I_k), respiration rates and tissue characteristics (zooxanthellae population density and protein content) were measured at the end of the experiment. The results obtained could constitute the bases for a novel hypothesis of coral calcification.

REGIONAL VARIATION OF WATER TEMPERATURE AROUND OKINAWA COASTS AND ITS RELATIONSHIP TO OFFSHORE THERMAL ENVIRONMENTS

Nadaoka, K. ; Y. Nihei, K. Wakaki*, R. Kumano, S. Kakuma, S. Moromizato, T. Oomija, T. Ikema, K. Iwao, K. Shimoike, H. Taniguchi. Graduate School of Information Science and Engineering, Tokyo Institute of Technology, Email Address: nadaoka@mei.titech.ac.jp

As one of the possible causes of the spatially non-uniform appearance of the coral mass bleaching, the regional variability of the water temperature is investigated with the near-shore temperature monitoring network data taken around the okinawa islands in 1999 and noaa-sst image data in 1998 and 1999. The network data indicates appreciable regional difference in the temperature; e.g., At the kerama islands located in the southwest of the main okinawa island the temperature in june and july in 1999 is about two degrees lower than that at the west coast of the main okinawa island. Similar feature of the temperature difference is observed in noaa-sst images both in 1998 and 1999, and the degree of the coral bleaching is found to correlate approximately with this regional temperature variation. Comparison of the noaa-sst images with the bottom bathymetry and a numerical experiment suggests that the presence of a shelf around the kerama islands may cause the relatively lower temperature; i.e., The warm water mass from the kuroshio currents may be extended toward the okinawa island, but it may be blocked at the shelf edge, resulting in the relatively lower temperature at the kerama islands.

ANTHROPOGENIC CO_2 ADDITION AND FUTURE TROPICAL SURFACE WATER CHEMISTRY: A COMPARISON TO THE PAST 70 MILLION YEARS.

Opdyke, Bradley N. * & Robert W. Buddemeier. The Australian National University, Department of Geology, Canberra ACT 0200. Email: Bradley.Opdyke@anu.edu.au

It has recently become apparent that rising atmospheric CO_2 concentrations will reduce calcification rates within coral reef ecosystems around the world. This change will quite likely be detrimental to these neritic calcifying communities. Consideration of the probable reductions in the calcium carbonate saturation state (δ) of the tropical surface ocean during the next century raises the fundamental question: What were tropical saturation states like on Cenozoic time scales, over which modern coral reef ecosystems evolved? We construct a calcium carbonate saturation state envelope that represents the probable surface water chemistry in which coral reef communities evolved during the past 70 million years, and show that predicted near-future conditions may be without evolutionary precedent.

SEA SURFACE TEMPERATURE (SST) VARIABILITY AROUND OKINAWA ISLANDS.

Sartimbul, Aida* and Momoki KOGA. Fakultas Perikanan, Universitas Brawijaya, Malang, Indonesia. Email: aida@malang.wasantara.net.id

Okinawa Islands are the most Southern islands of Japan. They are an interesting area with their specific characteristics such as the warm Kuroshio Current and large typhoon intensity exists. Those characteristics are well known giving large impact to the SST variability. During 1998, when unusual climate (ENSO: El Nino-Southern Oscillation) occurred, the SST around Okinawa had shown the increasing of SST as well. As the result, most of coral reefs around Okinawa damaged. The continuous SST observations have been done by the Physical Oceanography Laboratory, University of the Ryukyus using 2 (two) ferries service (HIRYU 3 and 21) which cruises from Nagoya to Taiwan or oppositely. They have yielded a good tool for knowing the SST fluctuation in relation with the warm Kuroshio Current, typhoon, and ENSO. The long period of SST have shown the 1998's SST was the warmest SST (increased about 2°C) of the record. The presence of ENSO and absence of typhoon might cause this condition. Furthermore, using the correlation analysis has shown the positive correlation between short period of SST and meteorological elements. Finally, further study about the variability of SST around Okinawa Islands will be useful for studying coral reefs, fisheries, and other biology aspects.

SOUTH AFRICAN CORAL REEFS: A REVIEW OF THEIR STATUS AND IMPORTANCE IN FUTURE RESEARCH.

Schleyer Michael H.* and Louis Celliers. *Oceanographic Research Institute, P.O. Box 10712, Marine Parade, Durban 4056, South Africa. Email: seaworld@dbn.lia.net

South African coral communities represent the marginal, southernmost African distribution of this fauna. While soft coral cover comprising relatively few species exceeds that of scleractinians over much of the reefs, the coral communities attain a biodiversity peak at this latitude on the East African coast. Comparative data are provided in this regard. A long-term monitoring programme has revealed only small changes in community structure on the reefs in recent years, despite consistent increases in mean and maximum temperature. Insignificant bleaching was encountered during the 1998 ENSO event, unlike elsewhere in East Africa, but outbreaks of COTS have caused longer term changes in isolated areas. A study of coral larval dispersal and recruitment has been initiated to establish the capacity of the reefs to recover from the latter form of disturbance. The marginal nature of the reefs is further manifested by corals that generate aseasonal and atypical natural products and have a reproductive pattern which conforms with that found on marginal reefs in W Australia. Calcium deposition on the reefs is also low due to physico-chemical factors that are related to latitude. Published projections on the long-term effects of climate change indicate that more reefs will become marginal as a result of global warming.

PHOTOSYNTHESIS AND CALCIFICATION IN CORALS UNDER VARIABLE SEAWATER CARBONATE CHEMISTRY EXPECTED FROM ATMOSPHERIC CO_2 INCREASE.

Schneider, Kenneth and Erez, Jonathan*. Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem 91904 Israel. Email: Erez@vms.huji.ac.il

Colonies of the coral *Acropora sp* . collected off the Interuniversity Institute at Eilat, were incubated in a laboratory respirometer for 1-2 hours. Dissolved oxygen, total alkalinity, total inorganic carbon (C_T) and its $\delta^{13}C$ were measured during light and dark incubations. Seawaters were treated to keep either C_T, pH or $CO_{2(aq)}$ constant while changing all other parameters of the carbonate chemistry. Rates of calcification (light and dark) displayed positive linear slopes with pH of ~ 25 % increase for 0.1 pH unit, a value much higher then previously reported. Light enhanced calcification may be explained by an internal pH increase of ~ 0.35 units caused by photosynthesis. The carbonate ion (CO_3^{2-}) and not necessarily aragonite saturation level (δ), seems to control coral calcification rate. Atmospheric CO_2 increase may have reduced coral calcification by 25 % and future CO_2 doubling may reduce it by additional 35 %. Hence, the balance between growth and erosion of coral reefs may be shifted towards net erosion. Unlike calcification, photosynthesis did not show any trend with pH, $CO_{2(aq)}$ or C_T, however, the overall data set (including light and temperature experiments) showed a clear positive correlation between the two processes. $CO_{2(aq)}$ for photosynthesis may be provided internally from respiration and indirectly via calcification, which produces protons that combine with HCO_3^- to form $CO_{2(aq)}$. This latter source may become important at high pH values when $CO_{2(aq)}$ was low, but calcification rates increased. Independent support for such mechanisms comes from our observations on the isotopic fractionations during photosynthesis and respiration.

A COLLABORATIVE INVESTIGATION OF SETTLEMENT AND RECRUITMENT PATTERNS OF CORAL ON A REGION-WIDE SCALE IN THE INDIAN OCEAN

Souter David* and Turner, John. CORDIO, c/o SSPA Sweden, St: Eriksgatan 121a, 113 43 Stockholm, Sweden. E-mail: souter@pi.se

During 1998, extreme climatic conditions caused global increases in sea temperature. As a consequence, coral reefs throughout the world suffered a mass bleaching event that some consider the worst ever witnessed. The subsequent mortality of corals was unprecedented. In the Indian Ocean, mortality frequently exceeded 75% and sometimes attained 90%. In addition, bleaching occurred in colonies of coral at depths of 50 m and also in species thought previously to be tolerant of temperature fluctuations. The potential of a reef to recover from such a massive perturbation is dependent on a number of factors, of which, perhaps the most important is the influx, settlement and recruitment of coral larvae and subsequent survival of recruits. However, the timing of coral spawning and patterns of larval dispersal in the Indian Ocean are poorly known. The dynamic hydrology of the western Indian Ocean caused by the changing monsoons determines that patterns of larval dispersal and subsequent settlement and recruitment of corals are likely to be complex. These patterns are only likely to be understood by conducting a broad-scale investigation of coral settlement and recruitment over spatial scales that transcend country borders. Through collaboration between marine scientists at institutions from five countries in the central and western Indian Ocean and international experts, CORDIO will investigate the spatial, temporal and taxonomic patterns of coral settlement and recruitment thus, providing estimates of recovery times and potentially identifying important sources of coral larvae.

NEW ESTIMATE OF GLOBAL REEF CARBONATE PRODUCTION

Vecsei, A.*. *Geologisches Institut der Universität, Albertstr. 23B, 79104 Freiburg i. Br., Germany. Email: adam@perm.geologie.uni-freiburg.de

Reef al carbonate pr oduction is impor tant for global budgets and cl im ate change, but poor knowledge of the fore- reef CaCO3 flux has been a major problem. Extending to a regional scale the census- based method, I have calculated the aver age gross CaCO3 pr oduction of cor al-dominated reefs from coral cover and extensi on rates by growth form bef ore the most recent reef decl ine. The flux is est imated usi ng porosit ies of framewor k and bi odetr it al facies. The few known for e- reef dat a are fair ly well repr oduced. Caribbean fr amework reefs have G = 9 (kg CaCO3 m^{-2} yr^{-1}) in 0- 10 m depth, G = 6 in 10-20 m, and G = 2 in 20-40 m. T ypi cal bar rier reef transect s have tot al G = 3.4 (≤80 % fr om the for e- reef). The total flux in Car ibbean biodetri tal r eefs wi th low cor al cover is 1.1 G. The compari son wit h act ual accr et ion data (Hubbar d et al. 1998) suggest s ≥1/2 of the for e-r eef pr oduct ion is com monly export ed. T he Indopacifi c dat a are f rom fr am ework-domi nat ed reef s. The highest for e- reef flux (G = 11) i s fr om the Great Barr ier Reef in 5-10 m dept h. Data for other regi ons are rare. P aci fi c i sl and slopes have a si mil ar pr oduct ion as Cari bbean fore-reef s. Indian Ocean fore-reef s have G = 8 in 0- 10 m and G = 2 in 10-30 m. Typical Indopacifi c bar ri er reefs with acti ve reef- fl at have total G = 2.9 t o 3.1 (up to 30 % fr om the for e- reef). The t otal Caribbean and I ndopaci fic f luxes for transect s wi th fr am ework reef s (excludi ng lagoons) conver ge at G = 3 (30- 80 % fr om the for e- reef) . Usi ng this value and G = 1 f or tr ansects wi th bi odetr it al reefs, tentativel y equal ar eas f or both facies, and Spal ding & Grenfell 's (1997) global r eef area, the m odern global reef pr oduct ion i s ca. 0.5 x 10^9 t yr^{-1}.

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INTERSPECIFIC VARIATIONS IN THE PHYSIOLOGICAL RESPONSES OF CULTURED AND *IN HOSPITE* SYMBIOTIC DINOFLAGELLATES TO ELEVATED TEMPERATURES.

Ayala-Schiaffino, Natalia. T. LaJeunesse, R. K. Trench, R. Iglesias-Prieto*. Unidad Académica Puerto Morelos ICML-UNAM Apartado Postal 1152, Cancún Q.R. 77500 México. Email iglesias@mar.icmyl.unam.mx.

The physiological responses of 6 species of cultured symbiotic dinoflagellates and the algae inhabiting 14 species of reef-dwelling invertebrates including 12 scleractinians to brief exposures to elevated temperatures (60 min) were analyzed using two different chlorophyll *a* fluorescence techniques. Comparative analyses of the responses of cultured symbiotic dinoflagellates and the algae in the intact invertebrates, indicate the existence of species-specific sensitivities to elevated temperatures, with up to 4 ºC differences in the temperature required to inhibit 50% of the initial charge separation capacity of photosystem II (Tc_{50}). Analyses of the restriction fragment length polymorphism of the small subunit ribosomal RNA gene from cultured *Symbiodinium* and from the symbionts isolated from the same colonies use in this study, indicate that the species-specific Tc_{50} can not be correlated with the phylotype of the symbiont. Comparative studies of the induction of photoprotective mechanisms under thermally-induced impairment of photosystem II, indicate that different symbionts possess different capacities to elicit non-photochemical pathways to dissipate excess excitation energy.

THE RESPONSE OF *MILLEPORA ALCICORNIS* TO TWO BLEACHING EVENTS IN THE MEXICAN CARIBBEAN.

Banaszak A.T.*, N. Ayala-Schiaffino, A. Rodríguez-Román, S. Enríquez, R. Iglesias-Prieto. *Unidad Académica – Puerto Morelos, ICML-UNAM, Apartado Postal 1152, Cancún 77500 México. Email: banaszak@mar.icmyl.unam.mx

Two naturally-occurring colonies of *M. alcicornis* were monitored during 1997/98, both years in which this species bleached in the Mexican Caribbean. One colony (HL) was exposed to a high light environment in front of the pier at the marine station in Puerto Morelos, México. The other colony (LL) was exposed to lower light levels due to shadowing for most of the day by the same pier. During August 1997 sea water temperatures rose approximately 1ºC above monthly average. The HL colony bleached (i.e., loss of symbionts or pigments) following this increase in sea water temperature whereas the LL colony did not. The HL colony recovered within several weeks. The following year sea water temperatures rose approximately 4ºC above monthly average in August and both colonies bleached. Several experiments were conducted on these colonies before, during and after the bleaching events, using quantum yield (QY) of photosystem II charge separation of the symbiotic algae in intact colonies as an assay. Exclusion of ultraviolet (UV) radiation indicates that QY in HL and LL colonies is higher than in colonies exposed to UV. HL colonies are affected more by exposure to UV than LL colonies but recover quickly. Monitoring of QY indicates that HL colonies were affected more than LL colonies during both bleaching events suggesting that temperature is not the only factor affecting photosynthetic efficiency in this species. During 1998 the HL colony bleached earlier than the LL colony and neither colony recovered its symbionts or pigmentation.

EFFECT OF TEMPRATURE AND ULTRAVIOLET LIGHT ON *VIBRIO SHILOI* BLEACHING OF *OCULINA PATAGONICA*.

Banin E.*, T. Israely, M. Fine, Y. Loya and E. Rosenberg. *Faculty of Life Science, Tel Aviv University, Israel. Email: eueqene@ccsg.tau.ac.il

Coral bleaching and high seawater temperatures are corellated. This has led to the hypothesis that bleaching is stress related. Bleaching of *Oculina patagonica* in the Mediterranean Sea is the result of an infection by *Vibrio shiloi.* The correlation between elevated seawater temperatures and bleaching (70-90% of the colonies are bleached in the summer) is due to the fact that the bacterium becomes more virulent with increasing temperatures. Adhesion of *V. shiloi* to *O. patagonica* is temperature regulated. When the bacteria were grown at 16^0C there was no adhesion to corals maintained at either 25^0C or 16^0C. However, when the bacteria were grown at 25^0C, they adhered avidly to corals maintained at 16^0C and 25^0C. After adhesion the bacterium penetrates and multiplies in the coral tissue. The ability of the bacterium to multiply and maintain itself inside the coral tissue was also found to be temperature regulated. In addition, toxins which inhibit photosynthesis, bleach and lyse the zooxanthellae are produced at much higher levels when the bacterium is grown at elevated temperatures. Colonies in shallow-water show little (2-15%) bleaching, even though they are exposed to higher temperatures than the deeper water corals. When *O. patagonica* were infected with *V. shiloi* in laboratory aquaria and subsequently exposed to sunlight, the intracellular bacteria were rapidly killed, aborting the infection and preventing bleaching. When infected corals were protected from UV light, the intracellular *V. shiloi* multiplied and the coral bleached. Thus UV radiation can prevent bacterial bleaching.

DIFFERENCE IN STRESS SUSCEPTIBILITY AMONG ZOOXANTHELLAE ISOLATED FROM DIFFERENT CORAL HOSTS.

Bhagooli, R.*, Kanemoto, H. and. Hidaka, M. *Department of Chemistry, Biology and Marine Science, Univ. of the Ryukyus, Nishihara, Okinawa, 903-0213 Japan. Email: hidaka@sci.u-ryukyu.ac.jp

The purpose of the present study is to detect differences in susceptibility to environmental stress among zooxanthellae derived from different coral hosts. Coral tissue was removed with a WaterPik and zooxanthellae were isolated by centrifugation. Zooxanthellae in suspension or collected on Millipore filters were treated with a combination of high temperature and various intensities of light. Photosynthetic efficiency (Fv/Fm) of the zooxanthellae collected on Millipore filters was measured using a MINI-PAM after a dark adaptation of 20 min. In some experiments, rapid light curve and photochemical and non-photochemical quenching (qP and qN) were also measured. Light intensity during heat stress treatment affected the photosynthetic efficiency of isolated zooxanthellae: the photosynthetic efficiency decreased with increasing light intensity during the heat treatment. The decrease in photosynthetic efficiency was greater in zooxanthellae isolated from *Pachyseris rugosa* than those isolated from *Galaxea fascicularis.* Photosynthetic efficiency of zooxanthellae isolated from *Montipora* species was very low and became almost zero after stress treatment. The present results suggest that there are considerable differences in stress susceptibility among zooxanthellae isolated from different coral hosts.

"JELLYFISH LAKE", PALAU: DISTURBANCE BY AND EARLY STAGES OF RECOVERY FROM THE 1997/8 EL NIÑO-LA NIÑA.

Dawson, M.N*, L.K. Penland, E. Basilius, L.E. Martin, and L.J. Bell. Coral Reef Research Foundation, Koror, Box 1765, Palau. Email: mikend@ucla.edu

Palau is one of the most popular dive destinations in the Western Pacific because of its splendid coral reefs. A slightly more heterodox beauty is found in a perennial swarm of 1.5 million golden-medusae (*Mastigias* sp.) crowded into the land-locked, marine, "Jellyfish Lake". Both 'natural wonders' contributed to a 500% increase in tourism in Palau between 1986 and 1997. Both natural wonders also suffered considerably during the El Niño-La Niña of 1997-98. Here we describe the disappearance of 1.5 million medusae from Jellyfish Lake and document the early stages of the lake's recovery. Field measurements and laboratory-based experiments indicate the disappearance of golden-medusae was due to dramatic warming and stratification of Jellyfish Lake, which probably began during the 1998 El Niño-induced drought. Stratification was reinforced during early- to mid-1999 when water temperatures rose as high as 35ºC. Since then, stratification has weakened and the lake has cooled, but recovery is slow. In January, 2000, the first golden-medusae re-appeared. Since then, the medusae have grown and matured and there have been further strobilation events. However, as of April 2000, Jellyfish Lake still is warm, stratified, and depauperate in golden-medusae.

THE ROLE OF WATER TEMPERATURE AND UV RADIATION IN THE RECOVERY OF THE EXPERIMENTALLY BLEACHED CORAL *Pocillopora damicornis* FROM THE EASTERN PACIFIC OCEAN (PANAMA).

D'Croz L* and Maté JL. Smithsonian Tropical Research Institute, Box 2072 Balboa, Republic of Panamá. E-mail address: dcrozl@naos.si.edu

Field observations and experiments have amply demonstrated that elevated water temperature in the eastern Pacific Ocean induce to bleaching in the coral *Pocillopora damicornis*. However, the effect of UV radiation is not that clear, particularly during their recovery. To study the coral-zooxanthellae symbiosis during simulated post-ENSO scenarios, colonies of *P. damicornis* were exposed to elevated water temperature and natural UV radiation until they bleached. The significant decline of zooxanthellae and photosynthetic pigments occurred after 5 weeks of exposure. Bleached corals were then exposed to experimental conditions to test the effect of increased exposition to natural UV radiation and slightly elevated water temperature, and monitored for 7 weeks. Corals kept under ambient water temperature regained their density of zooxanthella and concentration of chlorophylls, regardless of the exposition to UV radiation. Corals under slightly elevated water temperature and reduced UV radiation remained pale. The condition of corals exposed to slightly elevated water temperature and increased UV radiation continue to decline in time. Results indicated that the time of exposure to slightly elevated water temperature, increased exposition to natural UV radiation, and their interactions hampered the recovery of experimentally bleached corals.

A COMPARISON OF PRODUCTION EFFECTS BETWEEN CORALS AND MACROALGAE AT INCREASED SEAWATER TEMPERATURE.

T., M. Tedengren*. *Department of Systems Ecology, University of Stockholm, Sweden. Email: michaelt@system.ecology.su.se

The last decade, there have been numerous reports on macroalgae overgrowing coral reefs, especially from the Caribbean region. Most phase shifts described to date involve dramatically increased mortality rates of scleractinian corals and subsequent overgrowth by macroalgae. In this study we investigate whether a temperature increase by 3°C may have different effects on the physiological performance (net-production, respiration and GP/R ratios) of coral and macroalgae. Four species of macroalgae (two brown algae *Turbinaria sp.* and *Sargassum sp*., one red algae *Laurencia sp*., and one green algae *Dichtyosphaeria sp*.) and one of the most abundant coral species *Porites porites* were collected at Glovers Reef Atoll, Belize. The general trend in our study was that GP/R ratios increased for the algae species and decreased for the coral, although the coral maintains a net producing state. Since the macroalgae seem to benefit from the temperature increase it can be hypothesized that the relative competitive abilities have been altered and that this might lead to an increased algal overgrowth although the coral component is still in a physiologically fit state. This could contribute to changes in ecosystem structure and function without dramatic bleaching events or increased coral mortality as warning signals.

TAPHONOMIC ALTERATION OF BRANCHING CORAL SKELETONS FOLLOWING A MASS MORTALITY EVENT IN THE ARABIAN GULF (DUBAI, UAE).

Greiss, Mourad*, Riegl Bernhard. *Institut für Geologie und Paläontologie, Karl- Franzens-Universität Graz, Heinrichstrasse 26, 8010 Graz, Austria, mourad.greiss@kfunigraz.ac.at

In the aftermath of a coral mass mortality in the southern Arabian Gulf (Dubai, UAE), taphonomic alteration in death assemblages of the coral genus *Acropora* were investigated. Between May and August 1996, sea-surface temperatures in the study area were elevated by 2 degrees above average which led to widespread coral death in an area previously covered in dense *Acropora* growth. In November 1999, samples of dead *Acropora* corals were taken and compared to samples of the same species collected in October 1995, when still alive. Early constructive (encrustation, cementation) and destructive (micro- and macroboring, grazing) diagenetic processes and their influence on framework formation were studied. A sequence of encrustation was found: after death, the skeletons were rapidly colonized by a layer of bivalves (*Chama* spp.) which were later replaced by coralline red algae and other bivalves, particularly *Spondylus* spp. This latter encrustation added significantly to the carbonate mass of the branches. The earliest destructive processes were associated with sea-urchin grazing, which led to erosion of external structures. Later, boring by clionid sponges and boring bivalves caused dissolution and ensuing mechanical weakening of the skeletons. Three years after the mass mortality, the constructive processes were volumetrically still more important than destructive processes. The latter, however, are expected to become increasingly important with time.

THE FUTURE OF CORAL REEFS: INTEGRATING CLIMATE MODEL PROJECTIONS AND THE RECENT BEHAVIOUR OF CORALS AND THEIR DINOFLAGELLATES.

Hoegh-Guldberg, Ove*, *Centre for Marine Studies, University of Queensland, St Lucia, 4072. QLD, Australia. Email: oveh@uq.edu.au

Concern is increasing as to how coral reefs will fare under climate change. All major climate models concur that current rates of temperature change in the world's oceans (1-2°C per century) will continue over the next 100 years if atmospheric greenhouse gases increase. This scenario, together with the explicit link between coral bleaching, mortality and sea temperature, leads to the prediction that coral bleaching is likely to become an annual feature of coral reef environments in the 21st century. This paper reviews the rationale behind these predictions and explores how coral reefs might respond to an increased frequency and intensity of coral bleaching. While some workers suggest that corals-dinoflagellates will adapt fast enough to the changes in sea temperature, the data to support these opinions is scant or non-existent. Most evidence suggests that corals and their symbiotic dinoflagellates will not change fast enough to prevent major changes in coral reef ecosystem distribution and function. Simple ecological surveys done after a bleaching event reveal little about the long-term decadal trends and may even serve to confuse managers and policy makers who seek guidance in this important debate. Two issues are central to a better understanding of how reefs will respond to climate change. These are: (a) the rates of genetic change (adaptation) under extreme selection regimes and (b) the source of genetic variability on coral reefs. The latter also suggests that a greater knowledge of gene flow and connectivity between reefs is crucial. Work on these issues is surprisingly limited and must be a priority over the next few years.

THE ROLE OF PLANKTIVORY IN THE BLEACHING OF 5 CORAL SPECIES FROM THE EASTERN PACIFIC, PANAMA

Hueerkamp C.* and D'Croz L. *Center for Tropical Marine Ecology ZMT, Bremen, Germany. Email: chrhueerkamp@hotmail.com

Reef-building corals contain endosymbiotic zooxanthellae, which account for a high percentage of the coral's nutrition. Corals have in addition a further source of energy and nutrients from the zooplankton captured by their tentacles. Under conditions of increased water temperature, such as during ENSO events, the corals show a decline in the density of their symbionts and in the concentration of photosynthetic pigments. When this occurs, the corals loose not only their color (bleach) but also their main nutritional source. The main 5 reef-building coral species of the eastern Pacific coast of Panama were experimentally exposed to elevated temperature to compare their responses under fed and unfed conditions. The corals fed with nauplii of *Artemia salina* generally bleached later than the unfed ones. The massive corals *Pavona clavus* and *P. gigantea* with larger tentacle sizes exhibited the smallest decrease in the density of zooxanthellae, and in the concentration of chlorophyll, when compared to the branched corals *Pocillopora damicornis* and *P. elegans* with smaller polyp sizes. This work provides further evidence to the hypothesis that corals with larger tentacles can quantitatively catch more prey and therefore can better compensate the loss of energy due to the decline of the zooxanthellae during sea warming episodes.

DARK METABOLIC DYSFUNCTION: TRACING THE ORIGINS OF STRESS IN REEF-BUILDING CORALS AND THEIR SYMBIONTS.

Jones Ross, and Hoegh-Guldberg Ove, *Centre for Marine Studies, University of Queensland, St Lucia, 4072. QLD, Australia. Email: oveh@uq.edu.au

Stress in reef-building corals and related symbioses can arise for a number of reasons yet the outcome can often appear identical (bleaching = loss of symbionts). In this paper, high temperature and high cyanide concentrations are compared. In both cases, damage to or over-loading of the dark reactions of symbiont photosynthesis leads to an increased sensitivity to photoinhibition, making the extent of damage during stress light sensitive. This matches field observations during thermal stressed related mass bleaching in which the top (most sunlit) sides of coral colonies are damaged the most. These laboratory and field observations suggest a physiological model for stress that begins with the failure of the dark metabolism of the symbiotic dinoflagellates. We have further extended these ideas by exploring how stress tolerant symbiotic dinoflagellates might operate. Two general observations fall out of the model. Clearly, as light stress increases, shading dinoflagellates using host-based pigments or tentacle retraction (deep tissues like *Porites*) will reduce the damage induced by these types of stresses. The second observation is that symbiotic dinoflagellates that are able to handle high light environments will have a greater tolerance of situations in which there is an over-supply of excitations stemming from the light reactions.

GLOW IN THE DARK: PHYSIOLOGICAL CONTROL AND BIOCHEMICAL CHARACTERISTICS OF FLUORESCENT PIGMENTS IN *Montipora digitata*.

Klüter A.* & Hoegh-Guldberg O., *Centre for Marine Studies, University of Queensland, St Lucia, QLD 4072. Email: a.klueter@mailbox.uq.edu.au

The often brilliant colours of reef-building corals are amongst the most conspicuous elements of a living coral reef. These animal based pigments fluoresce under irradiation with ultra-violet light, producing either blue or green light. At present, the structure and function have not been fully described. Preliminary studies suggest that the pigments are related to light stress and may have an important role in photoprotection and hence the survival of reef-building corals in conditions of high light and temperature that cause coral bleaching. Recent episodes of mass coral bleaching have sparked new found interest in these pigments, with the suggestion that they may function to reduce the influences of high temperature stress. We have been examining the biology of the reef-building coral *Montipora digitata* at Heron Island (Great Barrier Reef) which occurs as two morphs (differing spatially and physiologically) based on their ability to fluoresce. Interestingly, the fluorescent morph of this species lives in the extreme shallows where temperature exceed 36°C during the summer months, yet bleaching does not occur. We are currently investigating how *M. digitata* is able to resist these high temperature conditions and are exploring if the production of fluorescent pigments can impart greater bleaching tolerance.

EFFECTS OF TEMPERATURE, LIGHT, AND NUTRIENTS ON PIGMENTS OF ZOOXANTHELLAE FROM THE CORAL *MONTASTRAEA FAVEOLATA*.

Macri Erin*, Strom Suzanne, Bright Kelley, and Peterson Emily. *Western Washington University, Shannon Point Marine Center, 1900 Shannon Point Rd., Anacortes, WA 98221 USA Email: macrie@hotmail.com

In this study we compared pigment content and composition of zooxanthellae retained by the host (AZ) and expelled (EZ) after exposure to stress. Our goal was to determine pigment changes associated with temperature and light stress and to gain insight into the condition of cells being expelled. Plugs of *Montastraea faveolata* were collected from Lee Stocking Island, Bahamas from 15m (± 1m) in July of 1998 and 1999. Plugs were placed in an outdoor incubator covered with screen and Mylar to create the desired light treatments and exposed to either ambient reef or elevated (+2°C) temperature. In addition corals were exposed to various light regimes (including enhanced ultra-violet B) and inorganic nutrient additions (2, or 10 µM). Analysis by HPLC showed AZ pigments (chlorophylls and carotenoids) decreased (per cell) in corals exposed to elevated temperature alone but not in corals exposed to elevated light alone. The difference in overall pigment content between AZ and EZ was greatest at elevated temperatures and light. Pigment decreases at elevated temperature and light were sometimes alleviated by nutrient additions. In general, pigments changed proportionally, and large variations in pigment composition were not seen.

CHANGES IN PHOTOGRAPHIC R, G, AND B VALUES QUANTITATIVELY REFLECT DECREASE IN PIGMENTS AND OF ZOOXANTHELLAE DURING BLEACHING OF *PORITES ASTREOIDES*

Maguire Bassett, Jr., Gleason Daniel F., Mojica Raymond, and Mojica Elizabeth C. *Dept. Zoology, University Texas, Austin, Texas, USA. Email: b.maguire@mail.utexas.edu

Quantitative measures of coral bleaching are much needed; a description of a photographic method of obtaining such data noninvasively is provided. Portions of eight *Porites astreoides* colonies were transplanted from 17 to 2 m depth and the rapid and severe bleaching thereby induced was documented through both photographic/computer analysis and quantification of zooxanthella densities and concentrations of the chlorophylls and carotenoids. Time series data during bleaching showed a strong positive relationship between exponentially decreasing coral Red, Green, and Blue (RGB) reflectance densities, concentrations of algal pigments, and numbers of zooxanthellae. This shows that simple, noninvasive photographic/ computer methods can provide data which serve as good proxies for the more fundamental pigment concentrations and zooxanthella numbers of this scleractinian coral. This technique was used again later, but photographs were taken much more frequently, and approximately half of each colony was shaded in such a way that water currents could freely pass through the 2 to 4 cm "slot" between the shade and the colony. The shaded portions of the colonies did not bleach but the sunlit portions did, and they did so with an exponential decline which was surprisingly continuous regardless of whether it was dark (night) or light (day).

BIOLOGICAL EFFECTS OF THE 1995 -1996 BLEACHING EVENT ON *MONTASTREA ANNULARIS* IN JAMAICA.

Mendes Judith M.,* & Woodley Jeremy D.. *Centre for Marine Science, University of the West Indies, Mona, Kingston 7, Jamaica. Email: jmendes@uwimona.edu.jm

Fifteen colonies of *Montastrea annularis* were monitored for growth, gonad development, density band formation and polyp tissue depth for one year prior to the 1995 - 1996 bleaching event. Monitoring was continued for the duration of bleaching, and for two years following the bleaching event. During the bleaching event seven of the monitored colonies did not bleach, six were mildly bleached (two months or less) and two were severely bleached (more than four months). This natural experiment revealed the long-term effects of bleaching on the biological parameters mentioned above. The immediate effects were a reduction in polyp tissue depth and a cessation of growth (measured as skeletal extension) that was proportional to the length of time the colonies remained bleached. In the year following bleaching there was a reduction in the number and size of gonads in mildly bleached colonies, and a failure to complete gametogenesis and spawning in severely bleached colonies. With respect to density banding, the width of the 1995 annual dense band increased in both mild and severely bleached colonies, while no distinct annual density band formed in the year following bleaching in severely bleached colonies (i.e. those that did not complete gametogenesis). These effects support the newly proposed Growth Depression Model of density band formation.

THE EFFECTS OF HIGH IRRADIANCE AND TEMPERATURE ON TISSUE LEVELS OF UV-ABSORBING MAAS IN SOFT CORALS. NO EVIDENCE FOR THERMAL LABILITY OF MAAS.

Michalek-Wagner Kirsten*. *Departments of Marine Biology and Chemistry, Cooperative Research Centre Reef, James Cook University, Townsville, Qld, 4811, Australia, Email: kirstenm@gbrmpa.gov.au

Mycosporine-like amino acids (MAAs) are believed to be an important component of a coral's biochemical defence system against high irradiance, and thus could play a role in their protection against light stress during coral bleaching episodes. This study investigates the role of temperature and UV radiation (UVR) alone and in combination on levels of MAAs, using manipulative bleaching experiments and data collected during a natural bleaching episode. UVR and temperature were found to act synergistically in the bleaching process in soft corals. The long standing notion that MAAs are thermo-labile, and thus chemically degraded during a thermal bleaching event, however, could not be confirmed. To the contrary, MAA levels in-creased in response to simultaneous exposure to elevated temperature and UVR, in experimentally and naturally bleached colonies, suggesting in-creased resource allocation towards photo-protection in corals already experiencing thermal stress. Subsequent studies with high and low MAA-acclimatised soft corals, which examined whether increased investment into MAAs results in reduced bleaching, revealed that there was no ecological advantage in high MAA acclimatised colonies when bleaching was solely triggered by increased temperature. When solar radiation alone, or in combination with temperature, act as stress factors, however, increased MAA levels do translate into higher protection against bleaching in soft corals.

NITRIC OXIDE SYNTHASE ACTIVITY AND ANTIOXIDANT STATUS IN THE CNIDARIAN *AIPTASIA PALLIDA* DURING AN ARTIFICIALLY INDUCED THERMAL BLEACHING.

Morrall C E*, Depledge, M H, Galloway, T S, Trapido-Rosenthal H G. BBSR, Ferry Reach, St George's, GEO1, Bermuda.
Email: cmorrall@bbsr.edu

Cnidarian bleaching involves the breakdown of the intimate symbiotic relationship between cnidarian host and zooxanthellal symbiont, and oxidative stress has been implicated in bleaching events. Nitric oxide (NO), a multi-functional messenger implicated in the control of many fundamental cellular processes is formed by the action of nitric oxide synthase (NOS). NO may exhibit both pro- and anti-oxidant properties depending on the availability and concentration of potential reaction partners. Antioxidants serve to ameliorate or prevent damage posed by oxidative stress. We examined the effect of a stress that induces bleaching on the capacity of host organisms to both generate NO and to generate antioxidants. Responses of *Aiptasia pallida* to whole organism exposure to temperatures between 25-35°C were investigated. Anemones maintained at 35°C for 48 h had reduced levels of chlorophyll and reduced numbers of symbionts per host (respectively, 44% and 88% of control values). Host protein concentration was also dramatically lower (66% of control values). However, on a per animal basis, NOS activity and antioxidant capacity remained unchanged relative to control values, although when expressed on a per unit of protein basis, these parameters were significantly increased relative to controls. Thus, even under conditions of heat stress that lead to the expulsion of zooxanthellae, the host organism maintains its capacity to generate both NO and antioxidants.

SIGNIFICANT DROP OF FERTILIZATION OF *ACROPORA* CORALS IN 1999. AN AFTER-EFFECT OF THE HEAVY CORAL BLEACHING OUTBREAKS?

Omori, M.*, H. Fukami, M. Hatta, and H. Kobinata. *Department of Aquatic Biosciences, Tokyo University of Fisheries, Minato-ku, Tokyo 108-8477, Japan Email: makomori@tokyo-u-fish.ac.jp

In June l999 after devastating coral bleaching outbreaks in l998, laboratory fertilization of *Acropora nasuta*, one of the most abundant reef-building corals in Okinawa, Japan, decreased significantly from usual rates (>90%) to an average of 42% at a sperm concentration of $10^5 ml^{-1}$. Similar decreases were observed in 5 other mass-spawning acroporid corals. Sperm motility was reduced and, we consider that the low fertilization was an after-effect of coral bleaching. A series of laboratory experiments to determine the effects of gamete dilution on fertilization rates revealed that sperm concentration of $l0^7 ml^{-1}$ was needed to obtain a rate of more than 60%. Fertilization in the laboratory of *A. nasuta* and *A. tenuis* reached a maximum approximately 1 hr after spawning. Sperm concentration in surface seawater during mass spawning was highest within the first 1.5 hr after spawning but decreased sharply thereafter. These results suggest that gamete dilution plays an important role in limiting the fertilization of coral eggs in the sea. As successful fertilization appears to have been much lower in 1999, we suspect that production of new coral polyps was reduced greatly after bleaching. Coral reefs are severely threatened by current and future sea-temperature increases.

CO2 RISE IS A MAIN BLEACHING FACTOR.

Pêcheux, Martin*. Nice University, 15bis rue des Roses, 06100 Nice, FRANCE. Email : martinpecheux@minitel.net

Bleaching is the major threat to reefs. The Global Warming is generally invoked. Never examined, the CO2 rise from 280 to 360ppm is the only other possible global cause (www.essi.fr/~sander/article/Misc /Coral_Reef.html). Current works converge to indicate that it originates in symbiont photoinhibition. best measured by chlorophyll fluorescence. I used its fast kinetics with a PEA. First, seven long term bleaching experiments were conduced at four CO2 levels (85, 230, 560 and 1270ppm) on the coral *Stylophora pistillata* and the large foraminifers *Amphistegina*. Bleaching occured under the high CO2 conditions (not always in short term shock experiments) at Fv/Fm around 0.275. With 100 000 fluorescence data, the origin of bleaching is discussed at the PS II (Qa-Qb), the Rubisco, or the bicarbonate pumps. Secondly, tentacles of *Anemonia viridis* were incubated for 1 hour under 4 lights, 5 temperatures and the 4 CO2 levels. CO2 has a strong effect on photochemistry, and very similar to temperature. This allows to establish an equivalence between them. The actual CO2 rise corresponds to an warming of 0.4°C, more probably 1.2°C. The future CO2 level (500-700 ppm) will be equivalent to a tremendous stress of 2.8-4.5°C, in addition to Global Warming. I surmise that reefs as they are known today will disappear. Reef scientists must urgently call for a strong mitigation of anthropogenic CO2.

CORAL BLEACHING: WHAT CAN BE LEARNED FROM REEF CONNECTIVITY?

Ridgway, T.*, Hoegh-Guldberg, O. *Centre for Marine Studies, The University of Queensland, St Lucia, QLD 4072, Australia. Email: tyrone@mailbox.uq.edu.au

Coral bleaching has had a major influence on the state and health of coral reefs around the world. A great deal of effort has been given to the physiology and mechanisms behind the bleaching phenomenon, but as yet, the implications and management of these bleaching events are not fully understood. Rates of recovery of affected reefs are largely unknown. Differences in the connectivity of reef systems and the life histories of corals are crucial for determining patterns of recovery or decline. Recent work has shown that coral populations may be self-seeding despite the high levels of genetic connectivity and this therefore challenges the notion that reefs may be rapidly repopulated after the removal of adults following disturbance. Thus, there is an urgent need for information relating to the connectivity and relatedness of reef systems around the world's oceans. Connectivity studies using DNA sequence and RFLP analysis of mtDNA of populations of *Pocillopora damicornis* and *P. verrucosa* have been examined at different scales in an attempt to assess the relative connectivity and relatedness of corals from different ocean systems. Preliminary results, coupled with future directions and implications related to the management of reefs post-bleaching are discussed.

THE ROLE OF FLUORESCENT PIGMENTS: EVIDENCE OF ENHANCED RESISTANCE TO BLEACHING IN FLUORESCENTLY PIGMENTED CORALS.

Salih A*, Cox G, & Larkum AWD. *The School of Biological Sciences A08 and the Electron Microscope Unit, University of Sydney, NSW 2006, Australia. Email: anya@emu.usyd.edu.au

The most common coral-host pigments are the fluorescent pigments (FPs), so-called because they glow intensely under UV-blue light. While the photoenhancing function of FPs in reef-building corals growing under light-limited conditions is well known, their function in corals from sun-lit habitats was previously poorly understood. We have recently shown that FPs may also function in photoscreening of the algal symbionts. Since sunlight is of major importance in mediating mass coral bleaching during periods of elevated seawater temperature, we hypothesised that FPs may confer increased resistance to corals during bleaching events. We measured the degree of bleaching in selected common fluorescent and non-fluorescent corals immediately after the 1998 mass coral bleaching event on reefs of the Central Great Barrier Reef, Australia. Microalgal numbers remaining in coral tissues were normalised to the amount of tissue FPs, the latter analysed by confocal microscopic imaging. While the degree of bleaching susceptibility was found to be highly variable, fluorescently pigmented coral genera and species were significantly less bleached then the non fluorescent ones. This study provides new insights into the understanding of some of the observed differences in the inter- and intraspecific susceptibilities of corals to bleaching.

EFFECTS OF THERMAL STRESS ON CLOSELY-RELATED REEF FAUNA: ASSOCIATIONS-DISSOCIATIONS AS EARLY WARNING SIGNALS?

Syed-Ibrahim, S.N.*. *Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia, 11800 Penang, Malaysia. Email: nora_ibrahim@hotmail.com

The previous *El Nino* phenomenon which contributed to increased sea surface temperature resulted in massive coral bleachings world-wide. Thermal stress also induces other forms of dissociation prior to zooxanthellae dissociation from host corals, which may serve as an early warning system. Thus, this study was undertaken vis-à-vis responses to thermal stress in reef animals that may occur prior to coral bleaching. An ascidian and its associated flatworms (Clavelina sp. and Cycloporus sp.) and an octocoral and its associated poychaetes (Heliopora coerulea and Polydora armata) were investigated when subjected to thermal stress. In the former, experimental results show that a) in preference tests, the flatworms 100% preferred an unstressed host ascidian, and b) the flatworms dissociated from thermally-stressed (>30°C) ascidians. Similarly in the latter, the polydorids dissociated from inside its stressed octocoral host prior to coral bleaching. Dissociations from their stressed hosts may also affect the flatworms and polydorids survival via increased visibility to predators, etc. Thus, the interspecies close associations of ascidian-flatworm and octocoral-poychaete may have greater implications e.g. unaccounted loss of biodiversity due to global warming. Knowledge on association-dissociation can also increase the relevance of biomonitoring and biodiversity studies. Moreover, these association-dissociations can potentially be used as a local and regional early warning signal of reef stress. Thus, they are potentially predictors of impending coral bleaching and biodiversity loss to prompt biodiversity managers into action.

EFFECTS OF THERMAL STRESS ON DEFENCE CAPABILITY OF THE TUNICATE *CLAVELINA FECUNDA*.

Syed-Ibrahim N*. School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia. Email: nora_ibrahim@hotmail.com

This marine chemical ecology study on the ascidian *Clavelina fecunda* at Pulau Payar Marine Park (Kedah, Malaysia) found that its crude extracts seem to have defence properties (e.g. anti-feedant). Based on field and laboratory investigations, it is found that induced thermal stress (>30°C) on the *C. fecunda* affect its defence capability. The affected defence capability pose great implications vis-à-vis the species long-term survival in view of global warming. Currently, work continues on the effects of thermal stress on other properties of this ascidian's secondary metabolites e.g. anti-fouling.

THERMAL-INDUCED DISSOCIATIONS PRIOR TO CORAL BLEACHINGS: AN EARLY WARNING SYSTEM?

Syed-Ibrahim N*. Centre for Marine and Coastal Studies, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia. Email: nora_ibrahim@hotmail.com

Thermal stress may also induce other dissociations **prior** to zooxanthellae dissociation from host corals, which may serve as an early warning system. Dissociations between an ascidian and its associated flatworms (*Clavelina* sp. and *?Pseudoceros* sp.), and an octocoral and its associated polychaetes (*Heliopora coerulea* and *Polydora armata*) were investigated when subjected to thermal stress. In the former, experimental results show that a) in preference tests, the flatworms 100% preferred an unstressed host ascidian, and b) the flatworms dissociated from thermally-stressed (>30°C) ascidians. Similarly in the latter, the polydorids dissociated from inside its stressed octocoral host prior to bleaching. Dissociations from their stressed hosts may also affect the flatworms and polydorids survival e.g. increased visibility to predators. Thus, these associations-dissociations may have greater implications e.g. greater potential biodiversity loss due to global warming, and potential use as a local and regional early warning signal of reef stress. Further studies to determine the threshold levels for dissociations, identification of heat shock proteins (hsps) and other 'biomarkers', and associations between other species are suggested to widen the potential of an early warning system.

CHANGES IN THE LIPID CONTENT AND TISSUE THICKNESS VARIATION IN THE MASSIVE CORAL *PORITES* DURING NATURAL AND EXPERIMENTAL BLEACHING EVENTS.

True, James*. *School of Marine Biology and Aquaculture, James Cook University, Townsville, Q4811, Australia. Email: James.True@jcu.edu.au

Pre-bleaching or sub-bleaching responses to stress in scleractinian corals are seldom quantified or reported. In this study, variation in the thickness of the tissue layer and the lipid content of the tissue layer were investigated as possible precursors of the bleaching response. Variation in the lipid content of the tissue layer versus variation in tissue layer thickness of massive *Porites* corals was measured during natural and experimental bleaching events. The first phase was an investigation of tissue loss and lipid variation during the mass bleaching event of 1998. Colonies of *Porites* were sampled at the start of the bleaching event, when the more vulnerable species were exhibiting profound colour loss, and one month later, when even the *Porites* were bleached. In the experimental phase, colonies were kept in aquaria under conditions of elevated temperature and sunlight until they bleached. In both studies, those colonies with low lipid levels in the tissue layer lost significant amounts of tissue biomass before bleaching. Those colonies with initially high levels of lipids in the tissue lost significant amounts of lipid before bleaching at low tissue thickness. A threshold combination of low lipid and low tissue thickness was identified below which all colonies bleached. When only one parameter fell below the critical level, bleaching was not assured. Energy reserves in these corals may be stored either as lipids or as somatic tissue, depending upon the overall health of the colony.

CORAL BLEACHING: DIFFERENTIAL SURVIVAL EXPLAINED BY PASSIVE DIFFUSION AND WATER FLOW.

van Woesik, Robert*. *Dept. Chemistry, Biology and Marine Science, The University of the Ryukyus, Senbaru 1, Nishihara, Okinawa 903-0213, Japan. Email: b984138@sci.u-ryukyu.ac.jp

Massive and sub-massive coral colonies were more tolerant than branched colonies to the high sea surface temperatures ssts (and unseasonably calm conditions) in the northwest pacific during july-september 1998. Differential effects of passive diffusion (i.e., Not involving energy) and water flow may explain differential coral survival. Since high ssts and high solar irradiation cause photoinhibition of zooxanthellae and a probable accumulation of toxic byproducts, removing such byproducts is essential for colony survival. When two colonies have the same sized boundary layer, which is the narrow zone between the surrounding (bulk) water and the coral, the rate of diffusion will increase as the interstitial space, between the boundary layer and the colony's surface, is reduced. This is apparent as colonies approach massive (hemispherical) morphologies. The rate of passive diffusion is reduced as corals become more intricately branched, within a given boundary domain. If we combine these ideas with newton's law of viscosity we can predict that passive diffusion rates increase in accordance with the square of the flow rate. Thus, passive diffusion and water flow theory suggest that under a unit flow regime, branched corals should disperse fewer metabolic toxins than massive corals, and indeed should be more susceptible to mortality at high ssts. Likewise, small colonies should theoretically survive.

CORAL BLEACHING REDUCES REPRODUCTION OF SCLERACTINIAN CORALS AND INCREASES THEIR SUSCEPTIBILITY TO FUTURE STRESS.

Ward, Selina* Harrison, Peter; and Hoegh-Guldberg, Ove *Centre for Marine Studies, University of Queensland, 4072 QLD Australia. Email: selinaward@bigpond.com

Extensive bleaching of corals occurred at Heron Island Reef (Great Barrier Reef, Australia) in 1998. This study investigated how reproduction and long-term survivorship would be affected by a "natural" mass bleaching event. Bleached colonies of all sampled species had reduced symbiotic dinoflagellates, chlorophyll *a* and total lipid per surface area compared to unbleached colonies. There were significantly fewer eggs, significantly fewer polyps containing eggs and testes and smaller eggs in most species of bleached than unbleached colonies. By July 1998, 23% of the sampled colonies had died. Many of the bleached colonies had regained their colour by this time, suggesting (visually) that they had recovered however, in November 1998, previously bleached colonies still had fewer eggs and reproductive polyps than previously unbleached colonies. In July 1999, in the middle of the Australian winter, many of the corals that had bleached the year before bleached again and many died. In contrast, none of the previously unbleached colonies bleached or died at this time. In November 1999, just prior to the spawning period, there were large areas of coral on the reef slope that were noticeably pale and almost entirely devoid of eggs. These data suggest that bleaching has an adverse and long-lasting effect on coral reproduction and that previously bleached colonies are more susceptible to future stress.

SEASONAL FLUCTUATION IN THE PHOTOSYNTHETIC EFFICIENCY OF REEF BUILDING CORALS.

Warner, M.E. *, Fitt W.K., and Chilcoat G.C.. Department of Botany, University of Georgia, Athens, Georgia, 30602, USA. Email: mwarner@dogwood.botany.uga.edu.

Previous studies of photosynthesis of reef building corals have typically been conducted over relatively short time scales. In this study, the photosynthetic efficiency, as measured by chlorophyll fluorescence analysis, of two species of predominant Caribbean reef building corals, *Montastrea annularis* and *Montastrea faveolata*, was monitored for more than five years in the Bahamas. Replicate colonies were measured at three different depths at least three times per year. Significant seasonal fluctuations in the quantum yield of photosystem II (PS II) were found in both species at all depths, with the highest photosynthetic efficiency consistently recorded in the mid-winter to early spring and the lowest PS II quantum yields occurring in the mid to late summer. Corals residing in shallow depths of 1-2 meters showed the greatest fluctuations in photosynthetic efficiency, while deeper corals (14 m) had consistently higher PS II quantum yields. Fluctuations of photosynthetic efficiency showed a strong correlation to water temperature and, to a lesser extent, light. Seasonal patterns of photosynthetic efficiency will be discussed in relation to biochemical processes within symbiotic dinoflagellates as well as the implications for monitoring the immediate and long term stability of reef building corals.

GLOBAL CLIMATE PATTERNS BEHIND THE 1997/98 MASSIVE CORAL BLEACHING AND MORTALITY EVENT.

Wilkinson, Clive R.* *Australian Institute of Marine Science PMB No. 3, TOWNSVILLE MC QLD 4810, AUSTRALIA Email: c.wilkinson@aims.gov.au

The largest recorded coral bleaching and mortality event occurred during the major 1997/98 El Nino and La Nina swings in global climate. There was severe bleaching in the wider **Indian Ocean** under El Nino (March- June, 1998) in Kenya, Tanzania, Maldives, Sri Lanka, Western Australia, India, Oman and Socotra; and similarly under La Nina (August-October, 1998) in Bahrain, Qatar, UAE, Eritrea and Saudi Arabia (Red Sea). In **Pacific,** there was major El Nino bleaching (May-December 1997, to February 1998) along the Pacific coasts of Colombia, Mexico and Panama and in the Galapagos, and on the Australian Great Barrier Reef; whereas there was La Nina associated bleaching in Federated States of Micronesia and Palau in September-November, 1998. In **South East and East Asia,** bleaching started with El Nino (January-May, 1998) in Indonesia, Cambodia, Thailand and East Malaysia; then followed by La Nina bleaching (July-September, 1998) in Singapore, Sumatra, Indonesia, Philippines, Vietnam, Japan and Taiwan. In the **Atlantic** and **Caribbean Sea** there was El Nino associated bleaching off Brazil in April, 1998; and La Nina bleaching from August-October, 1998 in Florida, Bahamas, Bonaire, Bermuda, Barbados, BVI, Caymans, Colombia, Honduras, Jamaica and Mexico. Thus the coral bleaching and subsequent mortality was strongly correlated with the degree of ENSO (El Nino Southern Oscillation) climate fluctuations, with the extent of bleaching directly dependent on the degree of Southern Oscillation Index shift, provided that this coincided with local marine summer (1 to 1.5 months after solar zenith). The major La Nina pattern has continued with major bleaching events in previously unaffected parts of the Pacific; more can be predicted prior to October 2000, if this pattern is sustained.

PHOTIC STRESS AS A CAUSE OF BLEACHING IN THE REEF-DWELLING FORAMINIFER *AMPHISTEGINA GIBBOSA*.

Williams, D. E.*, Hallock P., And Talge H. K.. *University Of South Florida, Department Of Marine Science, 140 7th Ave. S., St. Petersburg, FL 33701 USA Email: dew@seas.marine.usf.edu

Reef-dwelling larger foraminifers share many characteristics with reef-building corals: both groups are prolific producers of calcium carbonate, both groups are physiologically dependent upon algal endosymbionts, and both groups have exhibited stress symptoms, including symbiont loss (bleaching), worldwide in recent decades. Bleaching symptoms have been observed in populations of *Amphistegina*, the most widely abundant larger foraminiferal genus, since 1991. Peak bleaching years for both foraminifers and corals in the 1990's were 1991 and 1998. The key difference between bleaching in corals and foraminifers is that bleaching in corals correlates most consistently with elevated sea surface temperatures, with solar radiation having a synergistic role, while bleaching in *Amphistegina* appears to be a symptom of photic stress alone. Oxidative stress, which can be caused by elevated temperatures and/or photoinhibition in the zooxanthellae, has been linked to bleaching in corals. Laboratory experiments with *Amphistegina gibbosa* reveal: (1) symbiont loss similar to that seen in field populations can be produced by exposure to elevated intensities of PAR and UVB; (2) these protsists are positively phototactic; and (3) light intensities at depths sampled are orders of magnitude greater than necessary for optimum growth rates and for symbiont loss. Changes in spectral quality and intensity of solar insolation at depth are influenced by both atmospheric conditions and water transparency. Together these factors potentiate the conditions for photoinhibition that may cause bleaching and related symptoms in *Amphistegina*. Recognizing the similarities and differences between these two physiologically similar, though taxonomically very different symbiotic organisms may facilitate understanding the global decline of coral reefs.

Session E2B: Global Climate Change & Coral Reefs, 2. Bleaching Geographic Perspectives

PATTERNS OF RECOVERY OF BLEACHED REEFS IN THE PHILIPPINES: THE IMPORTANCE OF MANAGEMENT STRATEGIES.

Arceo, H.O.*, Quibilan, Miledel Christine C. and Aliño, Porfirio M. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, PHILIPPINES. Email Address: hazel@msi01.cs.upd.edu.ph

Varying levels of susceptibility to bleaching were observed on different reefs in the Philippines during the 1998 mass bleaching event. Monitoring surveys done in four localities with permanent sites provided pre- and post-bleaching benthic conditions, while more recent surveys revealed the status of the same reefs two years after the bleaching event. Preliminary results indicate that differences in recovery among the reefs, from near total recovery in Tubbataha to little or no apparent recovery in Bolinao, Pangasinan were greatly influenced by the level of susceptibility of the reefs to bleaching. Also, sites in different areas that exhibited similar susceptibility patterns showed different recovery rates. This suggests that the same natural and anthropogenic factors that influence the susceptibility of the reefs to stress are key factors for potential recovery. In some cases, the more badly affected but relatively less disturbed sites showed better signs of recovery. Thus anthropogenic stresses could exacerbate the effects of natural stresses and slow down recovery. This information highlights the importance of management measures in reducing the impacts of natural catastrophic events.

A MILLENNIAL-SCALE PERSPECTIVE ON THE 1998 MASS BLEACHING IN BELIZE.

Aronson, Richard B.* and William F. Precht. *Dauphin Island Sea Lab, 101 Bienville Boulevard, Dauphin Island, Alabama 36528, U.S.A. Email: raronson@jaguar1.usouthal.edu

Bleaching has become more frequent on coral reefs worldwide over the past two decades. Although mass coral mortalities related to bleaching have occurred several times in the Indo-Pacific, bleaching in the Caribbean had until 1998 been followed by substantial recovery of the affected populations. In 1998 the highest sea surface temperatures ever recorded, related both to the 1997-98 El Niño—Southern Oscillation and to global warming, caused severe coral bleaching worldwide. In the central sector of the Belizean Barrier Reef, sea temperatures rarely exceed 29 °C, but in 1998 they were >30 °C (maximum 31.5 °C) from 10 August to 14 October. These high temperatures caused complete bleaching and nearly 100% mortality of the dominant coral on lagoonal reefs, *Agaricia tenuifolia.* Complete bleaching and heavy mortality were also observed in almost all large plate- and head-forming species in the central lagoon, from 1 m depth down to the lagoon floor at 21 m. High water turbidity in this environment and the broad depth range over which the effects occurred implicate temperature, rather than solar radiation, in the bleaching episode. The 1998 event was the first bleaching-induced mass mortality of scleractinian corals observed in the Caribbean. Cores extracted from the affected reefs showed that the event was unprecedented in at least the last 3,000 years in the Belizean lagoon. Our results corroborate the prediction that continued global climate change will lead to increasing coral mortality as a result of severe bleaching episodes.

PATTERNS OF RECOVERY FOLLOWING MASS BLEACHING OF CORALS ON THE GREAT BARRIER REEF.

Baird, A.*, Marshall, Paul *School of Marine Biology & Aquaculture, James Cook University, Townsville, Q 4811, Australia. Email: andrewbaird@ozemail.com.au

Considerable variation in the response to bleaching between colonies of the same species, and between species is characteristic of even the most severe bleaching events. The fate of tagged colonies of five common coral species was followed to determine how bleaching influenced colony survivorship and to compare patterns of response and recovery. *Acropora hyacinthus* was most susceptible to bleaching with 88 % mortality compared to 32 % in *A. millepora*, 13.3 % in *Platygyra daedalea*, 7.5 % in *Seriatopora hystrix* and no mortality in *Porites lutea.* However, while whole colony mortality was low, most non-acroporids suffered some partial mortality with 44.0 % of the tissue lost in the population of *P. daedalea*, 32.8 % in *S. hystrix* and 10.7 % in *P. lutea*. In contrast, partial mortality was rare in the acroporids. In the acroporids, mortality was highly dependent on the severity of bleaching. Few severely affected colonies recovered and most moderately affected colonies survived. In contrast, the extent of partial mortality was independent of the severity of bleaching in the other species. Striking difference were apparent in the time it took for the different species to bleach and in the patterns of recovery. The massives, *P. daedalea* and *P. lutea* took longer to bleach, longer to recover and longer to die. Thus the observed patterns of species susceptibility and the extent of bleaching within assemblages, will depend critically on the time since the stress a census is conducted.

TIME-INTEGRATED THERMAL BLEACHING THRESHOLDS OF CORALS AND THEIR VARIATION ON THE GREAT BARRIER REEF.

Berkelmans, R.*. *Australian Institute of Marine Science, PMB 3, Townsville Q4810, Australia. Email: r.berkelmans@aims.gov.au

Defining levels of environmental variables which are likely to cause bleaching in reef corals is important to enable a risk assessment of potential climate change effects on coral reefs to be conducted and for providing an early warning of future mass bleaching events. This study identifies sea temperature as the primary proximate cause of coral bleaching from a suite of four environmental variables, including temperature, solar radiation, wind speed and barometric pressure, using 10-12 years of weather station data at two locations on the Great Barrier Reef (GBR). Predicted bleaching response curves are constructed from high resolution in-situ temperature records and historical observations of coral bleaching and presented for 13 locations on the GBR. These bleaching curves approximate reef-wide stress response limits for bleaching of thermally sensitive (and often dominant) coral species. The results indicate that there are distinct spatial patterns in the thermal sensitivity of coral populations that correlate with shelf position and, for mid- and outer-shelf reefs, with latitude. As members of the genus *Acropora* (most of which are highly sensitive to bleaching) consistently form the dominant coral cover on the GBR, these patterns suggest that considerable thermal adaptation has taken place over small (10's km) and large (100's – 1000's km) spatial scales. Bleaching curves for inshore reefs do not correlate with latitude and are more variable in shape reflecting local-scale variation in temperature regimes.

VARIABILITY IN CORAL BLEACHING AND RELATED MORTALITY AT WITHIN-REEF SCALES, SOUTHERN SEYCHELLES, WESTERN INDIAN OCEAN.

Bradshaw, C*, Spalding MD, Teleki, KA and Spencer, T. *Port Erin Marine Laboratory, University of Liverpool, Port Erin, Isle of Man, IM9 6JA, UK. Email: cbrads@liverpool.ac.uk

One component in an improved understanding of the dynamics of coral bleaching and related mortality is an appreciation of the spatial variability of bleaching impacts at within-reef scales. The reefs of the Seychelles, western Indian Ocean, were severely affected by the exceptional 1997-1998 warming event, with widespread coral bleaching and mortality reported from many localities. However, coral reef surveys in the southern Seychelles, focussed on the reefs of Alphonse Atoll and St Pierre during March-April 1998 and March 1999, showed high variability in the extent of coral bleaching, related mortality and subsequent reef recovery. Quantitative assessments of bleaching impacts, using the Line Point Intercept (LPI) method and videographic imagery, revealed within-reef variation in these impacts: between different coral taxa; at varying water depths; and between reef zones. These are thought to have been partly driven by different water flow regimes, residence times and localised upwellings. It was clear that even with mass bleaching events, the presence of small pockets of surviving corals may be crucial for reef regeneration and recovery. This is likely to be particularly important on isolated oceanic reefs like the southern Seychelles which otherwise rely on recruitment from ocean-borne larvae.

SEA-LEVEL ANOMALIES IN THE EASTERN INDIAN OCEAN AND CORAL BLEACHING.

Brown B.E.*, N. Phongsuwan, R.P.. *Dept Marine Sciences, University of Newcastle, Newcastle upon Tyne. UK. Email: 101515.1267@compuserve.com

Coral reefs in the eastern Indian Ocean are exposed to annual fluctuations in sea level, solar radiation and sea-temperature (ST). During Jan-March corals experience the highest solar radiation of the year and rising ST which maximises in May. Densities of coral symbiotic algae follow these annual ST and solar radiation cycles. During Feb-March shallow reef corals are susceptible to solar bleaching when water levels are low on neap tides at midday or when reefs are aerially exposed on low spring tides. Solar bleaching occurs primarily as a result of damaging high irradiance (PAR; 400-700nm). Later in May corals may suffer a second bout of bleaching if ST is anomalously high. Extensive bleaching was caused in this way in 1991 and 1995, but not in 1998 when STs were also high. Superimposed on these factors in 1994-5 and 1997-8 were anomalous sea-level depressions resulting from coupled ocean-atmosphere dynamics in the Indian Ocean. During 1994-5 sea level was depressed by 20cm in Feb 1995 while in 1997-8 negative sea anomalies exceeded 10cm in February 1997 and 30cm between August 1997 and April 1998. Community analysis of local reefs over the last 20y has shown that shallow reef flats are sensitive to sea level depressions. Solar bleaching and coral mortality were associated with lower sea levels, whilst recovery and rapid growth were detected during anomalously high sea levels in late 1996 and 1998. For corals surviving solar bleaching, exposure to high solar radiation in Jan-March appears to confer some tolerance (through improved photoprotective defences) to elevated sea-temperatures later in April-May.

BLEACHING IN A WESTERN INDIAN OCEAN ISLAND, LA REUNION : A MULTI-SCALE APPROACH

Conand C.*, Larue M., Quod JP., Conand F. & Turquet J. Laboratoire Ecologie marine, Université de La Réunion, 97 715 Saint Denis cedex, France. Email: conand@univ-reunion.fr

The last bleaching event (1998) has stimulated a joint study, to better understand the causes, patterns and consequences of the phenomenon in La Réunion, an island of the Western Indian Ocean, where the phenomenon had not been precedently studied in depth. Temperature maxima and high mean monthly values have been shown to be correlated with the onset of bleaching. Three scales were considered in this study. (1) At small scale i.e. the entire island, using the NOAA-AVHRR satellite data, various thresholds have been analyzed, discussed and compared with subsurface temperatures recorded each hour since 1993. (2) At the medium scale of the local reefs and colonies of different species, data have been collected from observations and through enquiries to better follow the stages of the bleaching, their progression and the different sensibility of the species. An « Alert form » has then been prepared. (3) At the largest scale, following the death of corals (*Pocillopora* for example), different stages of colonisation by filamentous algae have been identified and characterised, in order to identify the epiphytic succession of the microalgae assemblage. Their prevalence is favourable to the growth of toxic dinoflagellates and an increase of ciguatera may occur as a possible consequence of bleaching. These complementary approaches provide the necessary tools, which were lacking, for a better understanding and prevision of future events.

CORAL BLEACHING OCCURED IN THE SUMMER OF 1998 AROUND SOUTHERN JAPAN.

Fujiwara, Shuichi.* *Marine Parks Center of Japan, 1-3-1 Atago, Minato-ku, Tokyo, Japan 105-0005. Email: marpark@blue.ocn.ne.jp

There were severe coral bleaching events ever observed around southern Japan in the summer of 1998. To clarify magnitude of the events, author researched it using questionnaire to 97 municipalities in June 1999. Bleaching was observed from the Ryukyu Islands to Hachijo Island located south of Tokyo through the Amami Islands, the southern part of Kyushu, Shikoku and the southern tip of Honshu. These areas are influenced by the Kuroshio Current. However no bleaching was observed in the western Shikoku, Miyake Island and Ogasawara Islands that are also located in the Kuroshio region. Most bleaching started in August and then July. An earlier start was seen in February in the Okinoerabu I. and in April in Tanegashima I. Although bleaching faded out between October and December at many places, it continued to February 1999 in Kushimoto and in March in Kikaijima I. Beaching at the deepest place was found at a 38m depth in Tokunoshima I. Coverage of the bleached coral was between 40 and 60% in Nansei Is. Koshikijima Is., western Kyushu, eastern Shikoku and Kushimoto had under 20%, but Hachijo I. suffered 30 to 40 % (the most severe area in Hachijo I. was 80 to 90 %). The damage ratio on bleached coral was 70 to 90 % south from Yoron I. and 30 to 60% north from Yoron I. The surface water temperature in the summer of 1998 was about 2 degrees centigrade above normal in the Ryukyu Is. and over 3 degrees centigrade above normal in Yoron I., Amami I., Tanegashima I. and Hachijo I.

INCREASED CORAL AND FISH SURVIVAL ON MINERAL ACCRETION REEF STRUCTURES IN THE MALDIVES AFTER THE 1998 BLEACHING EVENT

Goreau, T.J.*, Wolf Hilbertz, & A. Azeez A. Hakeem Global Coral Reef Alliance, 324 Bedford Road, Chappaqua, NY 10514 USA Email: goreau@bestweb.net

Electrolytic Mineral Accretion (MA) reefs were compared with adjacent natural coral reefs from repeated video records in the Maldives before, during, and after the 1998 bleaching event. Massive corals on MA had higher survival (~80%) than those on natural reef (~1-5%), but almost all branching *Acropora* and *Pocillopora* died in both habitats, indicating that electro-protection was insufficient to overcome thermal stress to the most affected species. MA reefs now have much higher live coral cover, coral growth rates, and coral recruitment than natural reefs. MA reefs have higher proportions of normal reef fish (e.g. butterflyfish, anthias, oriental sweetlips, triggerfish, groupers, and moray eels) than natural reefs (now dominated by algae-eating parrotfish, surgeonfish, rabbitfish, and damselfish), making them an oasis of coral reef biodiversity. However they have also attracted surviving coral-eating *Drupella* and *Acanthaster* from surrounding reefs with high coral mortality, requiring control measures. Electro-protection of coral reefs may become the only way to maintain *in-situ* coral reef biodiversity and ecological function if global warming continues.

AN OVERVIEW OF THE EFFECTS OF THE 1997-1998 EL NIÑO-SOUTHERN OSCILLATION ON EASTERN PACIFIC CORAL COMMUNITIES AND CORAL REEFS.

Glynn, Peter W.*. *Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149-1095 USA. Email: pglynn@rsmas.miami.edu

The effects of two recent, extremely strong El Niño-Southern Oscillation (ENSO) events on eastern Pacific coral communities are compared. In magnitude (+3-4°C anomalies) and duration (3-4 months), the 1997-98 ENSO was comparable to the previous record-setting ENSO event of 1982-83. Both events caused widespread bleaching and mortality of zooxanthellate corals over the entire eastern tropical Pacific region. Direct observations and post-mortem evidence indicate that high coral mortality occurred from 16°N (southern México) to 2°S (Ecuador, including the Galápagos Islands and mainland) in 1982-83, and from 24°N (northern México) to 2°S in 1997-98. The timing and severity of coral bleaching were closely correlated with positive sea surface temperature anomalies obtained by remote sensing and *in situ* recorders. Some areas severely impacted in 1982-83 were unaffected in 1997-98 and vice versa. Coral community recovery since 1982-83 has been reversed in many areas. Certain rare corals, *e.g.* two species of *Millepora* and *Leptoseris papyracea*, suffered extreme reductions in abundance to local extirpations in 1997-98. Delayed disturbances, such as coral reproductive activity, recruitment, corallivory, spatial competitive interactions and rates of bioerosion, are presently under study at several eastern Pacific sites.

CORALS ON THE EDGE IN THE RED HOT SEA: TEMPERATURES AND ANNUAL BLEACHING ON NEARSHORE REEFS IN ERITREA.

Guillaume, M.M.*, J.H. Bruggemann, A. Heruy, M. Futwi. *Muséum National d'Histoire Naturelle, ESA 8044 CNRS, Biologie des Invertébrés Marins, 55 rue Buffon, 75005 Paris, France. Email: guillaum@mnhn.fr

The southern Red Sea is one of the hottest ocean basins in the world. The effects of extreme temperatures on growth and survival of corals have been monitored on 3 reefs in Massawa Bay (Eritrea), and sea temperature (ST) has been recorded *in situ* from 1996 - present at 3m depth. Monthly mean ST ranges from 27.5°C in January to 33.5°C in September. Every summer, ST exceeds 33°C during 2 months or longer. Temperatures on protected inshore reefs are on average 0.4°C higher than on nearby open-water reefs in the bay, while ST on shallow but submerged reef flats close to the shore reaches 41.9°C in summer. In 1998, a year of very high temperatures in tropical seas partly related to severe ENSO, the temperature difference between protected and open-water reefs reversed in spring, summer ST in the bay exceeded 33°C for almost 3 months, and even exceeded 34°C during 10 days in August. Coral bleaching was reported for 1998, but also occurred during 1996, 1997 and 1999, and appears to be a yearly event on these reefs from summer to fall. Growth experiments with coral nubbins of *Stylophora pistillata*, *Montipora* sp. and *Porites* spp. cross-transplanted between protected and open-water reefs, demonstrate that corals coming from open-water conditions can grow on protected reefs, except in summer when the extra 0.4°C temperature elevation turns fatal. In conclusion, reef corals in Massawa Bay yearly face a critical period when extreme summer temperatures come very close to the limits of their temperature tolerance.

DEVELOPMENT OF A SPATIAL INDEX FOR CORAL BLEACHING THRESHOLDS IN THE GREAT BARRIER REEF.

Guinotte,J.*, Skirving, Lewis, and Berkelmans. Australian Institute of Marine Science, PMB 3, Townsville, Queensland 4810, Australia.
Email: j.guinotte@aims.gov.au

The unprecedented 1998 global bleaching event caused severe coral mortality on several inshore and mid-shelf reefs within the Great Barrier Reef (GBR) Marine Park. There is legitimate concern among environmental scientists and GBR-based industries that widespread death and bleaching of corals caused by extremely high temperatures during 1998 may occur more frequently in the GBR region if global climate change unfolds as expected. Fortunately, high-resolution AVHRR satellite data were collected throughout the 1998 bleaching period for the GBR region. The sea surface temperatures, derived from these AVHRR data, were combined with coral bleaching temperature threshold curves and Great Barrier Reef Marine Park Authority aerial survey results to derive a coral bleaching index for the GBR. This paper describes how the coral bleaching index was developed and how it can be used to map coral bleaching on the GBR. Results demonstrate that regional-scale coral bleaching can be identified using this methodology and could potentially be applied to other regions of the world's oceans where coral reefs exist. Future application of the index using real-time AVHRR data may aid in identifying regions prone to coral bleaching.

EASTER ISLAND: REEFS AND BLEACHING WHERE THEY AREN'T SUPPOSED TO BE?

Hubbard, D.K.*, Garcia, M., *Dept of Geology-Oberlin College, Oberlin, OH, USA, 44074. Email: dennis.hubbard@oberlin.edu

Located at 27° 8' S, 4,500 km from the closest major land mass, and surrounded by waters that generally range from 20 to 25°C, Easter Island is understandably a site of low coral diversity (11 species). However, coral abundance is surprisingly high (avg. cover >50%; 100% over large areas) and is restricted to leeward shores away from the dominant approach of oceanic swell. The occurrence and distribution of corals around Easter Island fly in the face of traditional coral-reef dogma. Recent events have shown the fragility of the coral community, regardless of high coral abundance. The 1982-83 El Niño removed much of the local shallow-water algal community. The newly opened space was rapidly occupied by *Pocillopora verrucosa* which, until recently, dominated shallow leeward sites in dense coral carpets. Cover was so complete that local reef enthusiasts lamented the "unhealthy" character of the system now dominated by corals – in marked contrast to the popular and technical reef literature. In March of 2000, water temperatures reached 27°C and remained at that level for a protracted period. While temperatures were lower than those associated with other bleaching events, expulsion of zooxanthellae was nearly complete in *P. verrucosa* shallower than 10 meters. *Porites lobata* at greater depths were variably impacted. The events at Easter Island infer that bleaching will occur at any temperature above "normal" for a particular area rather than at a universal temperature threshold.

BROADSCALE SPATIAL VARIABILITY OF THE 1998 INDIAN OCEAN CORAL BLEACHING EVENT THROUGH CONSIDERATION OF THE LOCAL SCALE VARIABILITY OF THREE CASE STUDY AREAS.

Klaus, R.*, Turner J.R., Hardman, E., and West, F. *Ecology and Epidemiology Group, Department of Biological Sciences, University of Warwick CV4 7AL, UK. Email: bexklaus@aol.com

The extent and severity of damage caused by the Indian Ocean 1998 coral bleaching episode varied at both the local and the regional scale. Post-bleaching surveys have revealed that coral cover has been reduced by over 50% in many areas whereas other areas were little affected. Identification of areas that survived the event and the reason why is important from both a regional and biogeographical perspective, since they may be important sources of recruits for recovery. In this paper we investigate the variation in broad scale bleaching damage by consideration of local scale variation, within and between three case study areas. The areas are well distributed throughout the Indian Ocean and include the Yemeni islands of Socotra (NW Indian Ocean), the granitic islands of the Seychelles (central Indian Ocean) and Mauritius (SE Indian Ocean). Surveys were conducted post-bleaching and each area suffered to varying degrees during the bleaching event. In situ observations are compared with climatic and oceanographic parameters derived from both high and low resolution remote sensing data, to explain the complex spatial variability of bleaching damage found within and between the sites.

IMPACTS OF 1998 BLEACHING ON THE MESOAMERICAN REEF SYSTEM.

Kramer, Philip A.*, Kramer, P. R. Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL, 33149. Email: pkramer@rsmas.miami.edu

The Mesoamerican Reef System (MRS) extends 1000 km along Yucatan, Mexico, Belize, Guatemala, and Honduras. During 1998, unprecedented levels of coral bleaching coincided with high sea-surface temperature anomalies. To assess the extent of transient and lethal impacts of bleaching on scleractinian corals, we conducted a large-scale rapid assessment of 78 shallow (1-3 m) and 72 deep (10-18 m) fore reef sites throughout the region between March and June 1999. Our survey revealed significant spatial variability in remnant bleaching and recent mortality, explained primarily by geographical differences in temperature and interspecific differences in susceptibility to temperature stress. Significant remnant bleaching (44%) was observed at nearly all of the fore reefs sites up to 10 months after the initial bleaching; and was accompanied by high incidences (10%) of coral disease, especially on Belize shallow reefs and Honduran fore reefs. Coral mortality from bleaching averaged slightly higher on shallow (18%) than deep sites (13%), with highest levels in southern Belize (54%). The compounded effects of white band disease and coral bleaching in 1995, 97, and 98 resulted in high total coral mortality for the entire region (49% -shallow, 33% -deep reefs). The extensive loss of certain coral species (e.g., *Agaricia tenuifolia*, *Millepora complanata*, *Montastraea annularis*) is of particular concern given their roles as major reef builders. A complete understanding of the long-term ecological consequences of this bleaching event will depend on the complex interactions between recovery and degradation processes.

SIZE ISN'T EVERYTHING: A TALE FROM TWO BLEACHING EVENTS

Mumby, PJ*, JRM Chisholm, CD Clark, AJ Edwards, J Jaubert. *Centre for Tropical Coastal Management Studies, Ridley Building, The University, Newcastle upon Tyne, NE1 7RU, UK. Email: p.j.mumby@ncl.ac.uk

The 1997/8 ENSO event is widely regarded to be the most severe in recorded history and to have elicited unprecedented levels of coral bleaching world-wide. Here I report on patterns of bleaching-induced coral mortality in two contrasting coral communities. The first is Glovers Atoll, Belize (Central America) where mortality was investigated for juvenile corals with a diameter of 2 mm - 20 mm. The second is Rangiroa Atoll, Tuamotus (French Polynesia) where mortality was documented in massive *Porites* colonies with an average diameter of 3 m and age exceeding 300 y. Surprisingly, bleaching had no net effect on either juvenile density or community structure in Belize although larger corals experienced *ca* 20% mortality. In French Polynesia, bleaching-induced mortality in massive *Porites* was observed for the first time. At one site, 25% of colonies, or 44% of the pre-bleaching cover of living *Porites*, experienced whole-colony mortality. At the two other sites, recently-dead *Porites* accounted for 41% and 82% of the pre-bleaching live cover. The implications of these results for the recovery of coral reefs are discussed together with a meteorological analysis of causative factors.

CORAL BLEACHING, THE VIEW FROM SPACE.

Patzert, William C.*. *Caltech's Jet Propulsion Laboratory, 300-323 4800 Oak Grove Drive, Pasadena, CA 91109 USA. Email: wpatzert@pacific.jpl.nasa.gov

Coral bleaching throughout the tropics during the '97 and '98 El Niño to La Niña event was of international extent and great concern. Throughout the tropics, >29% of all reef sites surveyed experience significant bleaching. Coral mortality ranged up to 95%, with a total of 20% destruction of live corals around the tropics. These El Niño and La Niña induced events clearly demonstrated that corals are highly sensitive to natural interannual climate variability, as well as continuing short-term anthropogenic environmental damage (like pollution, mismanagement, misuse, etc.). Using NOAA's Advanced Very High Resolution Radiometer sensor derived sea surface temperature products and NASA's TOPEX/Poseidon sea level height data, the oceanic "coral bleaching" environment was documented throughout the tropics. These satellite data showed that during the El Niño of 1997, and into 1998, more ocean area in the tropics experienced exceptionally high sea surface temperatures ("hot spots") and both high and low sea levels than have been observed in any full year since the El Niño of 1982. Using these data, available for all oceans for the first time, and REEF CHECK in situ data data, the development of the '97-'98 "bleaching explosion" is mapped in time and space. Preliminary results indicate that high sea surface temperatures (thought to be the prime trigger for coral bleaching) are not always accompanied by higher sea levels. In the western tropical Pacific and SE Asian waters, during some long episodes of high sea surface temperatures, sea levels were anomalously low. These results provide a new dimension to our understanding of coral reef sensitivity to present and future climate changes.

REPEATED CORAL BLEACHING IN THE ANDAMAN SEA, THAILAND, DURING THE LAST DECADE.

Phongsuwan, Niphon * and Hansa Chansang. Phuket Marine Biological Center, P.O. Box 60, Phuket, 83000, Thailand, Email: pmbcnet@phuket.ksc.co.th

Coral bleaching events due to sea surface temperature rising were observed in 1991, 1995 and 1998 on the fringing reefs ranging from the near-shore islands to off-shore islands near continental shelf, in the Andaman Sea. The coral bleaching in 1998 was very variable and not widely extending as those of first 2 events, due to the cool up-welling. The results from fixed line intercept assessment on 30 sites revealed that coral bleaching could cause death of coral ranging from about 0-65% relative to live coral cover. Total of 94 species of hard coral were found to be bleached completely or partially. Most of the *Acropora* spp. were the most susceptible species. The adaptation of corals for tolerating bleaching after repeated bleaching was not obvious. In some places the living bleached corals could recover almost completely. The variation of intensity of bleaching and recovery of living bleached corals depends on localities which were different in 1) coral species composition leading to different in bleaching susceptibility 2) influence of the local environment on coral survival. Recovery of the reefs after death of coral varied from place to place and different zone of the reef. Competition from other organisms for space and human disturbances apparently inhibited the recovery of the reefs at some certain sites.

ECOLOGICAL AND FRAMEBUILDING CONSEQUENCES OF THE 1996 CORAL MASS MORTALITY EVENT IN THE ARABIAN GULF (DUBAI, UAE).

Riegl, Bernhard.* *Institut für Geologie und Paläontologie, Karl-Franzens-Universität Graz, Heinrichstrasse 26, 8010 Graz, Austria. Email: bernhard.riegl@kfunigraz.ac.at

Between May and August 1996, sea-surface temperatures in the southern Arabian Gulf were elevated by 2 degrees above average and led to widespread coral death. The consequences for coral fauna, frame-building potential, coral diseases and coral regeneration were studied between Jebel Ali and Ras Hasyan. In the study area, all 6 *Acropora* species suffered total mortality, thus the coral fauna was reduced from 34 species to 28. The nearest areas with surviving *Acropora* were 30 km to the east (Deira) and 20km to the west (Al Jazira). The *Acropora* overkill turned 7.8 km_ (19.7% of total coral covered area) of previously lush coral gardens into a dead framework that was increasingly bioeroded. *Acropora* recruitment only started in 1998, average recruit size in 1999 was 7±3 cm, and recruits were rare. Presently, bioerosion is faster than recruitment, and the coral framework will likely be eroded before a new generation of framebuilders is present. Since historical data suggest that such mortality events are recurrent, the observed destruction of the framework and slow regeneration explains the absence of lasting coral frameworks, i.e. reefs. Massive coral species suffered negligible mortality, and slowly increased in space cover. Prior to the mass mortality event, coral diseases were common and seasonal (14±5% of corals, mainly *Acropora*, affected in summer, in winter 7±6%, mainly massives), after the mortality event seasonality was lost and infection remained on winter-levels (6±5%, only massives infected).

SATELLITE SEA SURFACE TEMPERATURE AND CORAL BLEACHING: THE 1998 GBR STORY.

Skirving, William*, Guinotte, John and Done, Terry. *Australian Institute of Marine Science, PMB No. 3, Townsville M.C., Qld., Australia. 4810. Email: w.skirving@aims.gov.au

In February, 1998, the Great Barrier Reef (GBR) suffered its largest bleaching event on record. This was also the best documented bleaching event on the GBR. A combination of field observations and measurements, aerial surveys and satellite data collected at the Australian Institute of Marine Science (AIMS), Townsville, Queensland, has helped us piece together a more complete bleaching story than ever before. This paper will concentrate on the oceanographic story as told by the satellite sea surface temperature (SST) data. Three-daily and monthly composites were used to generate animations of satellite SST. The monthly animations cover January 1997 through to December 1999. This animation clearly shows that the GBR was dominated by relatively high SSTs during the bleaching period. The three-daily averages are then used to explain the detailed SST story associated with the bleaching event.

EXTENT AND SEVERITY OF THE 1998 MASS BLEACHING EVENT FROM SATELLITE SST "HOTSPOT" MAPPING.

Strong, A.E.* Toscano, M.A. Guch, I.C.. NOAA/NESDIS/ORA/ORAD E/RA3, 5200 Auth Road, Rm 711, Camp Springs, MD 20746 USA. Email: astrong@nesdis.noaa.gov

During 1998, the strongest El Nino event and warmest ocean temperatures recorded up to that time resulted in the bleaching and mortality of reef corals worldwide, on a scale and level of severity unprecedented by previous events. NOAA/NESDIS satellite-derived SST HotSpots identified areas where SSTs exceeded climatological maximum summertime mean SSTs and predicted most occurrences of coral bleaching worldwide. Numerous field reports confirmed the areas affected by bleaching, as predicted by HotSpot mapping. Retrospective Degree Heating Weeks (DHWs) thermal stress accumulations for 1998 indicated that bleaching corresponded to areas of long-term, elevated SSTs (>16 DHWs in most cases). Correlation between satellite-derived indices and field-verified bleaching and mortality in 1998 was very high, indicating that the combination of HotSpot mapping and DHWs indices represents a reliable early warning system for bleaching events. Although 1999 was a year of near-normal ocean temperatures (apparently associated with the cooler waters accompanying La NiZa), in 2000 several reefs in the south central Pacific had experienced near record levels of bleaching by April. Updated SST trends for all reef areas for the last 16 years (of satellite data) suggest continuing warming and future thermal stress for most coral reef ecosystems.

LARGE-SCALE OCEAN-ATMOSPHERE DYNAMICS OF THE INDIAN OCEAN AND CORAL BLEACHING.

Teleki, K.A.* and T. Spencer. Cambridge Coastal Research Unit, Cambridge University, Cambridge CB2 3EN, UK. Email: kat1003@cus.cam.ac.uk

Large-scale ocean-atmosphere dynamics underlie complex patterns of ocean warming and cooling. Sea surface temperatures (SSTs) from the MOHSST6D database, reveal regional variations in the timing, peak magnitude and duration of warm episodes in the Indian Ocean in 1997-98 which, in turn, aid improved explanation of bleaching incidence at different reef locations. Longer-term analysis of the GISST2.3b and the MOHSST6D datasets for the southern Seychelles and Mayotte, Comores Archipelago show that the 1997-98 warming was exceptional (absolute temperatures and temperature anomalies) for the last 37 years; arguments have been made to link this event to one of the strongest El Niño warmings this century. The relatively sparse documentary evidence of previous SST-related bleaching episodes in the Indian Ocean confirms that such episodes are associated with El Niño years but only in general terms, giving credence to arguments that oscillations in SSTs, precipitation and winds between the eastern and the western Indian Ocean - a tropical dipole mode - are the result of internal ocean - atmosphere dynamics and not a direct response to external ENSO forcing. Coral bleaching may thus occur even in the absence of ENSO extrema. Such a focus on ocean-atmosphere dynamics has further, important implications for the dispersal of coral planulae and thus for the regeneration and recovery of bleached Indian Ocean reefs.

IMPROVED PREDICTION OF CORAL BLEACHING USING HIGH-RESOLUTION HOTSPOT MAPPING AND DHWs.

Toscano M.A.,* A. E. Strong, I. C. Guch, and K. S. Casey. *NOAA/NESDIS/ORA/ORAD E/RA3, NOAA Science Center Rm 711, 5200 Auth Road, Camp Springs, Maryland, 20746 USA. Email: mtoscano@nesdis.noaa.gov

NOAA/NESDIS 50-km HotSpot maps have proven successful in documenting tropical-ocean warming and identifying areas of coral bleaching. The 50-km HotSpot resolution may underestimate SST anomalies within reefs if the pixel temperatures derive from offshore, among other factors. Current HotSpot mapping uses nighttime-only satellite SSTs and a nighttime-only Maximum Monthly Mean (MMM) climatology to calculate HotSpot anomalies, ignoring daytime heating of shallow waters. Because most reef systems occur on smaller spatial scales, as do the temperature anomalies that directly affect reef corals, an increase in HotSpot mapping resolution is warranted. Using NASA/NOAA AVHRR 9-km Pathfinder best SST data and a new day+night 9-km MMM climatology, 15.5 years (1985-present) of high resolution HotSpot and Degree Heating Weeks (DHWs) charts have been computed. Retrospective 9-km time series of Pathfinder SSTs, *in situ* temperatures, HotSpot indices, and DHWs for several sites are combined with field verification of timing, severity, and duration of bleaching, to determine the number of DHWs which force bleaching and mortality. The 9-km day+night approach is also evaluated against the original nighttime-only criteria to define the most robust and realistic predictive capability.

CORAL BLEACHING AND RECUPERATION IN PUERTO RICO: THE EXCEPTION TO THE RULE OR THE COMMON PATTERN?.

Weil, Ernesto*. *Department of Marine Sciences, University of Puerto Rico, PO BOX 908, Lajas PR 00667. Email: eweil@caribe.net

There seems to be wide local and geographic variability in the dynamics and outcome of coral bleaching events. Mass mortalities of reef organisms are not the end result most of the time. The 1998-99 World-wide bleaching event had catastrophic consequences for many reefs in the Indo-Pacific. However, only a few reef areas in the Caribbean were severely affected. The bleaching-recovery dynamics of 386 tagged/mapped colonies from 18 scleractinian species was monitored for 7 months (1998-99) and 5 months (1999-00) during and after bleaching events in southwestern Puerto Rico. Bleaching and recovery were estimated using the percent bleached area of each colony and their changes through time. Many colonies were totally bleached for over 150 days before recovering completely. Only three (0.8 %) small colonies died, 14 (3.6 %) suffered partial tissue mortality, 357 (92.4 %) recovered by February 1999, and 12 (3.1 %) remained pale until March of 1999. A significantly lower number of the tagged colonies (59 or 15 %) bleached again in September of 1999. Compared with the previous year, water temperatures were lower, bleaching was less intense with mostly pale colonies, no partial tissue mortality was observed, 80 % of bleached colonies recovered by December 1999, and all by February 2000. These results, and observations in other areas, indicate that the dynamics (onset, organisms responses, length, and outcome) of these events are complex and vary widely between colonies of the same species, between species, across reefs, across geographic locations and on a temporal scale.

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LINKING CORAL BLEACHING TO GLOBAL WARMING: THE NEXT STEPS FOR CORAL REEF MANAGEMENT.

Causey Billy D.*. *Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, USA 33050. Email: Billy.Causey@noaa.gov

Three decades of coral reef observations in the Florida Keys clearly indicate a pattern of intensification in coral bleaching events. The geographical and temporal extent of coral bleaching episodes have been recorded since 1980. Coral bleaching episodes in 1980, 1983, 1987, 1989, 1990, 1997, and 1998 have been documented in the Florida Keys. While locally these bleaching episodes have shown patterns of increased duration with each new event, they have also exhibited a pattern of geographical expansion that raises concern for coral reef managers. The synchronization of the coral bleaching events offers evidence that coral reefs are responding to global warming or global climate change. While this is only one perturbation that coral reef managers have to address in the management of coral reef environments, it is a major influence on the continued health of coral reefs as they are known today. The ability of coral reef managers to more accurately predict coral bleaching over the past decade has helped raise the public's understanding of this phenomenon and increase their confidence in coral reef science. These are among the first steps in gaining the attention of our global leaders that they need to address global climate change. The future of coral reef management lies at the local, regional, and global scales. While documentation of the decline of coral reefs must continue, science must also serve to focus the management actions of coral reef managers.

FIRST EVALUATION OF THE 1998 CORAL BLEACHING EVENT TO FISHERIES AND TOURISM IN THE PHILIPPINES.

Cesar H.*, Lida Pet-Soede, Imelda V. Bacudo, Herminia Francisco, Porfirio M.Aliño, Miledel Christine C. Quibilan, and Hazel O. Arceo. *Linnaeuspakweg 96 1096 EJ Amsterdam, The Netherlands,. Email: herman.cesar@ivm.vu.nl

The impact of the 1998 mass coral bleaching event on the fishery and tourism sectors was studied from two cases. The case studies focused on Bolinao, Pangasinan, where local communities are highly dependent on reef fisheries and in El Nido, Palawan, which is not only a renowned destination for reef-related tourism, but also supports a considerable fishing community. Declining fish catches in Bolinao seem related to the event and have a relatively large impact on the fishers as there profits were already marginalized and at the subsistence level. According to local tourism operators, the number of tourists that have visited El Nido has also declined since 1998. Besides coral bleaching, other factors such as the Asian financial crisis, El Niño and the passage of major tropical cyclone are deemed to have contributed to the decline in tourism in the area. Considering the difficulty of differentiating between the causative factors, costs of the bleaching event to the Bolinao and El Nido local society are estimated.

THE SCIENCE BEHIND CORAL BLEACHING: PRIORITIES FOR RESEARCH AND MANAGEMENT

Gomez, Edgardo D. *The Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines. Email: edgomez@msi01.cs.upd.edu.ph

The 1998 mass bleaching that occurred on the Indo-West Pacific coral reefs called attention, once again, to the gravity and urgency of the problem, of which we have rather limited scientific understanding. The symbioses among clades or species of zooxanthellae and hundreds, if not thousands, of species of invertebrates no doubt undertake different modes that may have arisen independently along several host taxa. If this is the case, there is no shortcut to understanding the nature and consequence of bleaching. Scientific approaches are necessarily numerous, with the obvious need to start to identify the physical and chemical factors at different spatial scales that initiate the dissociation of host and symbiont. Organismal or physiological processes on the part of the host and of the symbiont need to be better studied. The attendant mortality of associated, non-symbiotic species on the occasion of bleaching events needs to be adequately understood, as this will contribute to the understanding of the morbidity of the hosts of the zooxanthallae. In addition, the ecosystem effects and responses related to bleaching are just beginning to be investigated, but are no less important than the organismal reactions. Managers and decision-makers often call for interventions when disaster strikes. In the case of bleaching, is the science well enough established to justify significant investments of time and resources? Both short-term and long-term responses are considered briefly.

THE VALUE OF DIVING AND THE IMPACTS OF CORAL BLEACHING IN PALAU.

Graham T.*, Idechong, Noah; Sherwood, Kristin. *Palau Conservation Society, PO Box 1811, Koror, Palau 96940. Email: tomgrahampw@yahoo.com

Dive tourism is the most important industry in Palau, Micronesia. Two hundred visiting scuba divers and snorkelers (together called "divers") were interviewed in 1997 and 2000. Contingent valuation questions, using a hypothetical permit fee as a proxy for net value, were used to estimate the net value to divers of their dive experiences. The average willingness-to-pay (WTP) for a dive permit was US$34 among scuba divers and US$26 among snorkelers. With 50,000 divers visiting Palau each year, these figures suggest an industry consumer surplus of about $1.6 million. WTP statements were not very responsive to various contingency scenarios. For example, 70% of the year-2000 respondents would not have been willing to pay more if the reefs of Palau were in better condition. Fifty eight percent of the year-2000 respondents claimed knowledge of the coral bleaching event of 1998-1999 and 52% noticed its effects in Palau. Among those that noticed, 42% said it had a "slightly negative" impact on their experience, 29% said the impact was "very negative," and 16% said it had "no impact." The impact was significantly greater for return visitors than for first-time visitors. The effects of the bleaching event appeared to also be reflected in comparisons of satisfaction scores between 1997 and 2000. Average scores for the attributes "beauty/condition of corals," the "number/diversity/appeal of fishes," and "value of the dive experience" were significantly lower in 2000 than in 1997. These and other findings are useful for policymaking, such as determining permit fee levels that would optimize the share of net value transferred from the consumers to the producers, the people of Palau.

CORAL BLEACHING AND MORTALITY: A CALL FOR SCIENCE-POLICY SYMBIOSIS.

Reaser, Jamie K.* and Peter O. Thomas. U.S. Department of State, OES/ETC, Room 4333, Washington, DC 20520 Email: sprgpeeper@aol.com

The geographic extent, increasing frequency, and regional severity of the mass coral bleaching events in 1998 were a consequence of a steadily rising baseline of marine temperatures, associated with regionally specific El Niño and La Niña events. Global warming compounds the effects of more localized anthropogenic factors that already place reefs at risk and threatens human populations dependent on reef services marine biodiversity, fisheries, and shoreline protection. There is an urgent need for programs to reduce localized stressors, curtail greenhouse gas emissions, research the projected and realized impacts of global climate change, and monitor coral reef ecosystems. The International Coral Reef Initiative (ICRI), Convention on Biological Diversity (CBD), and Framework Convention on Climate Change (FCCC), represent through fora through which scientists and policy makers can work together to develop policies and initiate funding mechanisms to address the causes and consequences of coral bleaching. Here we review the role of science in informing policy recommendations on coral bleaching and mortality and discuss opportunities for the scientific community to engage in further policy development and implementation. If we do not communicate and heed the warning of climate-induced ecosystem collapse provided by mass coral bleaching, similar catastrophic events will surely follow throughout variety of marine, freshwater, and terrestrial systems.

MITIGATING THE IMPACT OF CORAL BLEACHING THROUGH MARINE PROTECTED AREA DESIGN.

Salm, Rodney V.*, Peter Mous and Jos Pet. *Director Asia-Pacific Coastal Marine Program, The Nature Conservancy, 923 Nu'unu Avenue, Honolulu, HI 96817, USA Email: rsalm@tnc.org

The 1998 El Niño-1999 La Niña bleaching event produced some clear patterns in coral bleaching and related mortality. This raises the question of whether these patterns yield useful information that might be incorporated into the design of marine protected areas (MPAs) for coral conservation to help mitigate the impact of bleaching events. We believe that the elevated sea water temperature induced bleaching and subsequent mortality patterns at four sites (Komodo National Park), Palau Rock Islands, Kisite Marine National Park and Chumbe Island Coral Sanctuary) provide insights into the factors influencing these patterns and show us a way to increase the resettlement of corals in communities sustaining near complete mortality. We present some preliminary ideas here for discussion and solicit guidance from participants in this special session on how to use MPA design to enhance recovery of coral communities sustaining high levels of mortality linked to elevated seawater temperature induced bleaching. Our goal is to enhance the survival prospects for coral communities in the MPAs in which we work and, if effective, to provide guidelines for MPA selection and design that could require a review of all coral reef MPAs globally.

MANAGEMENT OF BLEACHED AND SEVERELY DAMAGED CORAL REEFS.

Wells, S. M.*, S. Westmacott, and J. M. West. IUCN-The World Conservation Union, Eastern African Regional Office, P. O. Box 68200, Nairobi, Kenya. Email: SMW@iucnearo.org

The 1997/98 coral bleaching event caused extensive reef damage in many regions of the world. Countries in severely impacted regions such as the Indian Ocean (where coral mortality reached over 90% in some areas) are now at serious risk of losing this valuable ecosystem and associated economic benefits from fisheries and tourism. If average baseline temperatures continue to increase due to global climate change, then corals will be subjected to more frequent and extreme bleaching events in the future. Thus, crucial management questions must be addressed, and potential tools for mitigating bleaching must be analyzed. While more scientific information is needed for precise recommendations, there is also an immediate need to adapt current knowledge into general management guidelines for use as a rapid response measure. Drawing on data from the CORDIO (Coral Reef Degradation in the Indian Ocean) program and from other studies, we have developed a management handbook that: 1) summarizes current scientific opinions on the causes and consequences of bleaching; 2) discusses precautionary and response measures to be taken in light of the bleaching threat; and 3) suggests some positive actions that might aid reef recovery. The analysis is based on specific case studies, but the recommendations are of global applicability.

ASSESSING THE SOCIO-ECONOMIC IMPACTS OF THE 1998 CORAL BLEACHING EVENT IN THE INDIAN OCEAN.

Westmacott, Susie*, Herman Cesar, Lida Pet Soede. *University of Newcastle upon Tyne. Mailing address: 33 Old Priory Close, Hamble, SO31 4QP, UK. Email: s.westmacott@ncl.ac.uk

Coastal populations in the Indian Ocean have been adversely affected by coral reef mortality resulting from the bleaching event in 1998. Assessing the socio-economic impacts focused on the two main coastal activities in the region, tourism and fisheries. Anticipating the full impacts will be vital to enable these countries to adapt and manage the situation. The study found in many cases, the full impacts of the reef degradation are still to be seen. The impacts are also variable across the region, as was the extent of the bleaching. Impacts on fisheries will become apparent as changes occur to the reef structure. In places where the reef structure breaks down, the reef fisheries could collapse affecting millions of small-scale fishermen. The importance of reef fisheries in terms of provision of food and employment was established. Tourism creates both direct and indirect employment for these coastal populations and in many of these countries is an important source of foreign income. The economic costs of the coral bleaching in the Maldives was estimated at US$3 million in 1998-1999, with welfare losses reaching US$63 million. Estimates of the financial cost of the bleaching in Mombasa should dissatisfied tourists not return, was estimated at US$13-20 million and in Zanzibar was estimated at US$3-5 million. Understanding and anticipating tourist behaviour will enable Governments and Tourism Boards to take timely precautions, changing marketing strategies and retaining their tourism industry. The full socio-economic impact of the bleaching will become apparent in the near future.

Session E4: Global Climate Change & Coral Reefs. 4. Response to Projected Sea Level Changes

SOME CONSIDERATIONS FOR VULNERABILITY ASSESSMENT OF REEF ISLANDS TO IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE.

Ali, Mohamed. Environment Research Center, Ministry of Home Affairs, Housing and Environment, Male', Maldives. Email: em_alee@yahoo.com

Low-lying reef islands such as that found in the Maldives have been considered to be amongst the most vulnerable to the impacts of climate change and sea level rise. Vulnerability assessments of reef islands and of their natural capacity to cope with the expected impacts of climate change, including accelerated sea level rise, depend upon many reef and island characteristics, and the extent of human impacts on the natural system associated with reef and island. In an atoll-wide study of all uninhabited islands in the Maldives, the morphometric characteristics were measured and the dynamics aspects of the islands were examined. In order to assess the short-term changes, beach profiles were surveyed over two seasons, while the medium-term changes were examined through comparative mapping of 1969 and 1999 aerial photographs. Vegetation and soil depth patterns, with radiocarbon dating of sediments were used to infer the long-term (Late-Mid-Holocene) development of the islands. When vulnerability assessments of reef islands are carried out, 'internal' factors such as the location, size and shape of the island, the proportion of the reef platform occupied by an island, and island elevation, etc., need to be considered. Such aspects will help to determine how islands will respond to sea level rise. The study establishes that all reef islands are not equally vulnerable and that vulnerability will vary according to a number of factors. The data also confirm that the notion of 'stable' and 'unstable' islands as identified from island dynamics like island growth and island 'movement' is also a useful 'guide' in vulnerability assessment of reef islands in the Maldives.

MODELLING ATOLL ISLAND RESPONSE TO RISING SEA LEVEL: PRINCIPLES AND APPLICATION OF THE MODIFIED SHOREFACE TRANSLATION MODEL.

Cowell P.* and Paul Kench. *Coastal Studies Unit, School of Geosciences, University of Sydney, NSW 2006, Australia. Email: cowell@extra.ucc.usyd.edu.au

Existing principles for perched beaches and rock truncated shorefaces are used to modify Bruun-type concepts in developing principles for prediction of atoll island response to sea-level rise. These principles incorporate the effects of a non-erodable reef surface and its influence on island profile movements, with an appropriate modification to the key concept of closure depth (the elevation of the reef surface). These principles are incorporated into the existing profile-based computer model: the Shoreface Translation Model (STM). The modified STM was applied to selected islands in the Maldives using a range of sea-level rise scenarios. In all simulations islands exhibited shoreline displacement away from the reef edge and overwash processes allowed the island margin to vertical build at the same pace as sea-level rise. Model results indicate that islands will undergo a range of different modes of response to sea level rise (standard Bruun response – Barrier rollover) depending on subtle variations in initial island morphology. Differences in mode of response are shown to control the magnitude of shoreline displacement and stability of reef islands.

ENSO IMPACTS ON CARBONATE SEDIMENT PRODUCTION AND TRANSPORT ON FRINGING REEF ENVIRONMENTS IN SAMOA

Goodwin, I.* *School of Geosciences University of Newcastle, Callaghan, NSW 2380 Australia Email: Ian.Goodwin@newcastle.edu.au

Episodes of carbonate sand accretion on beaches along the southern Upolu coast of Samoa are preserved as beachrock cemented berms. These beachrock berms have been exposed by storm erosion in the last decade. Radiocarbon ages of coral clasts sampled from the beachrock yield clustered ages spanning decadal to multi-decadal ranges. It is interpreted that the carbonate sand in each beachrock berm was contemporaneously eroded from the reef crest and flat, and subsequently deposited as a sand slug, rather than from a mixed age sand reservoir. Comparison of the age ranges and the historical record of El Niño events (Quinn et al. 1987) indicates that sediment-producing reef-erosion episodes may occur during prolonged El Nino events. Relative sea level (RSL) falls by 0.2 to 0.25 m in Samoa during prolonged El Niño events. The lower sea level and hence, greater diurnal sub-aerial exposure, warmer sea surface temperatures (SST) and changes in wind and wave climate result in enhanced erosion of the reef crest and flat. The beachrock berms are aligned with the longshore transport driven by the south-east trade winds, whereas the present eroded beaches are aligned with shore-normal or swash transport. This morphology suggests that coastal erosion is dominant during El Niño events whilst accretion may be enhanced during La Niña events.

VARIATIONS IN SEDIMENT PRODUCTION AND IMPLICATIONS FOR ATOLL ISLAND STABILITY UNDER RISING SEA LEVEL.

Kench, Paul * and Peter Cowell. *International Global Change Institute, The University of Waikato, Private Bag 3105, Hamilton, New Zealand. Email: p.kench@waikato.ac.nz

The physical response of atoll islands to sea-level rise is dependent on both physical readjustment of existing island materials but also on changes in the rate of sediment production and transfer to island shorelines. Sediment production is likely to change significantly as coral reef flat surfaces attempt to respond to changing climate and sea-level. This study combines scenarios of possible changes in sediment production with morphological simulations of shoreline response on a sand island in the Maldives, using the Modified Shoreface Translation model. Results underscore the critical importance of reef flat sediment production to island stability. Of note, small negative changes in sediment supply promote significant island instability and shoreline displacement. Total depletion of sediment supply promotes island destruction. In contrast, increased sediment supply may enhance shoreline stability and lead to island accretion. While STM modelling shows that physical mechanisms allow islands to adjust to sea-level rise, results demonstrate the sensitivity of island response to small changes in sediment budgets and stress the importance of enhanced understanding of rates and controls on reef sediment production.

REEF GROWTH AND SEDIMENT PRODUCTION ON THE SOUTHERNMOST PACIFIC REEFS.

Kennedy David* and Colin Woodroffe. *School of Geosciences, University of Wollongong, NSW 2522, Australia. Email: dkennedy@uow.edu.au

Lord Howe Island, a basaltic island, has the southernmost Pacific reef enclosing a shallow lagoon on the western shore. North of Lord Howe there are two atolls, Middleton and Elizabeth Reefs, in a linear chain of islands/seamounts. There are significant differences in the morphology and sediment characteristics between the volcanic islands of the Lord Howe group and the atolls. On Lord Howe there is a broad shelf covered in calcareous sediments with a temperate composition dominated by rhodoliths and calcareous algae. The fringing reef has been built in mid Holocene from flourishing branching corals, but the lagoon that it encloses is predominantly composed of calcareous algal sediments. By contrast sediments within Middleton and Elizabeth Reefs, and in deeper water around the atolls, are dominated by a tropical carbonate assemblage, although Middleton has been decimated by crown-of-thorns infestation.

VOLUMETRIC CHANGES OF SAND CAY BEACH SEDIMENT AND ITS IMPLICATIONS WITH SEA LEVEL RISE:

Riyaz, Mahmood* *Environment Research Centre, Male`, Maldives. Email: Riyaz5@hotmail.com

This study intends to assess the response of beach sediment volume of low-lying reef islands to projected sea level rise. Standard levelling technique for profiling was used on a vegetated island and an unvegetated sand cay in the Maldives. "Surfer®" was used to calculate the volumetric changes of beach/cay sediment during the study period. The study was conducted during the onset of the western monsoon. The results showed that there were significant changes in sediment volume, in response to the seasonal wave/current changes, which induce sediment movements around the island/cay. The estimated beach volume changed on the island in June was 7.8% less than the volume calculated in May, while on the sand cay, which is more dynamic, the change in beach volume was 66% of that calculated in May. Given the proportion of reef platform occupied and the age of beach sediments, it is assumed that fresh sediment input to the beach is limited on the island. Based on this, it is expected that under the projected sea level rise scenario, the island is likely to loose more sediments in the future. The unvegetated sand cay is more dynamic under seasonal wave/current variations, hence they are likely to be more dynamic in response to sea level rise. The study indicated that island geomorphology such as the location of the island in relation to the reef, the type of sediment, presence or absence of beachrock on islands, island morphometry, in addition to the status of vegetation, are significant aspects in assessing the likely changes and dynamics associated with reef islands in the short term. These aspects also influence the extent and magnitude of subsequent response of reef islands to projected sea level rise in the long term.

REEF-ISLAND SEDIMENTATION ON INDO-PACIFIC ATOLLS AND PLATFORM REEFS.

Woodroffe, Colin*. *School of Geosciences, University of Wollongong, NSW 2522, Australia. Email: colin@uow.edu.au

Indo-Pacific reefs responded to Holocene sea-level change, with rapid vertical reef growth during early Holocene sea-level rise and reef-flat consolidation and readjustment during mid and late Holocene when the sea was slightly above present level. Reef islands, comprising sand cays on platform reefs and motu on atolls, formed during this latter period. Radiocarbon dating of reef islands indicates variation between islands, and around the margin of individual islands. In the Cocos (Keeling) Islands reef-island accumulation occurred over the past 3500 years; on Little Makin Island in the central Pacific foraminiferal sands accumulated over the past 2500 years; whereas on Warraber Island in Torres Strait discrete episodes of accretion occurred between 4000 and 2000 years BP. Sediment source and transport processes, in addition to changes in sea-level, provide important constraints on reef-island sedimentation.

SENSITIVITY OF CORAL REEF FLATS TO SEA-LEVEL CHANGE.

Yamano, H.*. Social and Environmental Systems Division, National Institute for Environmental Studies, Onogawa, Tsukuba, Ibaraki, Japan. Email: hyamano@nies.go.jp

The most conspicuous geomorphological feature of modern reefs is the reef flat. In many areas, it is composed of two distinct zones: a seaward zone dominated by coral growth and framework development, and a landward zone dominated by the accumulation of reef detritus. Studies of the development of reef flats have mostly concentrated on the coral growth and framework development and less is known about the nature and origin of the sediment accumulation. In the Pacific region, reef flats have formed under a relatively stable sea level since ca. 6000 yBP, and so are very sensitive to sea-level fluctuations. This sensitivity makes understanding their past history and development a prerequisite for prognosing their future response to sea level changes, especially considering that back-reef sediment production also controls the development of densly-populated reef islands. Here I analyse sediment production in both framework and sediment zones of a modern back-reef structure and document its development over the last 6000 years. I conclude that the sea-level stabilization and the subsequent relative sea-level fall had a significant effect on the topographical and ecological structure of the reef flat. This response indicates that any future sea-level rise could substantially alter the structure of coral-reef flats.

Session E5: Pathways for Land Based Sources of Pollution and Subsequent Impacts on Coral Reef Environments

CHANGES OVER 23 YEARS IN A CORAL COMMUNITY AT A SEWER OUTFALL IN A FAST-CURRENT AREA OF PALAU.

Birkeland, Charles*. *Hawaii Coop. Fish. Research Unit 2538 The Mall, Edmondson Hall University of Hawaii at Manoa Honolulu, Hawaii 96822. Email: charlesbirkland@hotmail.com

Permanent coral-reef transects at the site of a sewer outfall were surveyed in 1976, before the outfall was constructed, and again in November 1993 and July 1999, after the outfall had been in operation for 17 and 23 years. Living coral cover was 50 – 100%, higher than on most healthy reefs. In 1976, *Acropora* spp. was 47% of the living coral cover on the reef margin, 7.5% in 1993 and nearly absent in 1999. Although there were 46 other species of stony corals along the transects, the space was dominated (96% of living cover) in 1999 by *Porites* spp.

TERRESTRIAL DISCHARGE IN THE GREAT BARRIER REEF (GBR) - 1. DISTRIBUTION OF RIVERWATERS AND POLLUTANT CONC-ENTRATIONS DURING FLOOD PLUMES.

Brodie, Jon * and Devlin, Michelle. *Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville. Q. Australia. Email: jonb@gbrmpa.gov.au

A key research area of the Great Barrier Reef Marine Park Authority is assessment of river pollutant input into the GBR, the importance of flood plumes as a source of nutrients and sediments and the impact of flood plumes on nearshore reefs. Most catchments draining into the GBR are used for agriculture and have been extensively modified since European settlement, leading to concerns on the impacts of terrestrial pollutants on the GBR Since 1991 plume movement has been mapped by aerial flyovers. Plume distribution and pollutant concentrations are controlled by a number of factors, including particularly wind direction and speed. South-easterly winds are dominant, pushing plume water north and close to the coast. High concentrations of sediments and nutrients are initially present in the plume, however sediments tend to settle out rapidly close to the shore. Dissolved nitrogen and phosphorus are transported further offshore into the area of the nearshore reefs.

TRENDS IN THE DISTRIBUTION OF WATER PHYSICAL AND CHEMICAL CHARACTERISTICS IN THE LAGOON OF NEW CALEDONIA : ASSESSING THE SIGNIFICANCE OF TERRIGENEOUS AND ANTHROPOGENIC INPUTS.

Chifflet S*, Fichez, Ferraris, Gérard, Douillet. Centre IRD, BP A5, Nouméa, New Caledonia. E-mail: chifflet@noumea.ird.nc

Coral reef lagoons around high islands are naturally subject to terrigeneous inputs but increasing anthropogenic activities on these islands generate direct and indirect discharges which modify the equilibrium of tropical coastal environments. The study presented in this paper determines the distribution of physical and chemical parameters in the lagoon waters surrounding the city of noumea, new caledonia, and examine the forcing parameters responsible for that distribution. 36 stations were visited monthly from october 1997 to january 1998 and a statistical analysis was conducted on the data set including vertical profiles (temperature, salinity, photosynthetic available radiance, nephelometry, in situ fluorometry) and discrete sub-surface concentrations (no_3+no_2, nh_4, po_4, $si(oh)_4$, total dissolved n and p, suspended particulate matter, chloropigments, particulate organic c n and p). Results show that, during most of the year, water circulation constrained terrigeneous and anthropogenic inputs close to the coast. Chronic sewage effluent discharge resulted in significant but very localised eutrophication signatures in two urban bays. The use of statistical analysis further allowed to combine the complex and extensive data set to extract indexes specifically identifying the respective contribution of the main input sources (oceanic, terrigeneous, anthropogenic).

ASSESSING THE EFFECTS OF RUN-OFF FROM LOGGING ON CORAL REEFS IN SOLOMON ISLANDS.

Cooper, T. F.*; Lincoln-Smith, M. P.; Bell, J. D., and Pitt, K. A. *The Ecology Lab Pty Ltd, 4 Green Street, Brookvale, NSW 2100, Australia. Email: projects@theecologylab.com.au

The fauna of bays at the mouths of rivers in Western Province, Solomon Islands, is being studied to quantify the effects of alternative logging operations on coral reefs. These operations are harvesting of plantations on Kolombangara Island and logging of virgin forests on Vangunu Island. The 4-year study aims to identify effects of run-off on fringing coral reefs by comparing abundance, diversity, growth, survival and recruitment of corals under the influence of actively logged, previously logged and unlogged catchments. Results from a pilot study, which compared diversity and abundance of corals adjacent to actively logged and unlogged catchments, indicated that effects of run-off on corals did not always conform to predictions, and differed between islands. For example, there was more dead coral adjacent to logged catchments at Vangunu, whereas at Kolombangara more live coral occurred adjacent to actively logged catchments. The comparison of bays under the influence of actively logged, previously logged and unlogged catchments over 4 years is expected to provide a robust test of the effect of run-off on diversity and abundance of corals, and the nature of recovery from any such effects. Sentinel colonies will be used to assess any effects of run-off on growth and survival of corals, whereas any effects on recruitment will be gauged using standard settlement plates.

COPPER CONCENTRATIONS IN CORAL GROWTH BANDS: TRACING THE IMPACT OF A MINE TAILINGS SPILL IN MARINDUQUE ISLAND, PHILIPPINES.

David C.P.C.*. *Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115. Email: cdavid@pangea.stanford.edu

In 1996, a mine tailings spill occurred in the island of Marinduque, Philippines. An approximate 1.6 million cubic meters of tailings sludge was released into the Boac River, which subsequently reached the near-shore marine environment along the western coast of the island. Bulk geochemical analyses of marine sediments revealed elevated trace metal concentrations particularly for Cu (>700ppm) and Zn (>100ppm). The tailings in the ocean fanned out from the mouth of the river distributing more than 1cm tailings material within 1km radius. However, sediment contamination is still detected outside of this range. The two nearest reefs are the *Ihatub-Caganhao Reefs* (2km south of Boac) and *Ulan Reef* (5km north of Boac). Five core samples of *Porites sp.* from these reefs were collected in 1998 and 1999. Annual growth bands were established from density banding observed in x-radiographs. Preliminary results from one *Ihatub* coral show high Cu concentrations (>7.3ppm) in the upper 12mm of the coral, most likely representing the period 1996-1998. Except for an unexplained copper concentration spike (7.5ppm) in the section from 15-18mm (1994), background Cu values are less than 2ppm prior to 1996. Additional analysis of corals from *Ihatub* and *Ulan Reefs* as well as the refinement of growth band sampling and GFAAS techniques for trace metal analyses in carbonate samples will further constrain whether metal contamination of the marine environment can be traced in the geochemistry of coral growth bands.

TERRESTRIAL DISCHARGE IN THE GREAT BARRIER REEF (GBR). – 2. THE INFLUENCE OF RIVER WATERS ON POLLUTANT CONCENTRATIONS AT INSHORE REEFS

Devlin, Michelle.* and Brodie, Jon. *Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville. Qld. 4810 Australia Email: m.devlin@gbrmpa.gov.au

An understanding of flood plume interactions with gbr lagoon waters is essential to understanding the influence of river discharge on the nutrient status of coral reefs in the gbr. Monitoring of flood plumes provides insight into how extreme water quality conditions influence aquatic processes and ecosystems in the gbr. Flooding rivers adjacent to the gbr cause elevated concentrations of nutrients and sediments in the inshore regions of the gbr lagoon. By measuring flood plume distribution and pollutant concentration, reef hot spots can be identified. These are areas where the reefs are likely to experience extreme water quality conditions associated with flood plumes on an annual basis, in close proximity to catchments with greatest pollutant export. Inshore reefs are subjected to concentrations of nitrogen and phosphorus up to 100 times greater than ambient in these events. These concentrations exceed those known to cause damage to coral reef ecosystems.

NUTRIENT CONTENT OF MACROALGAE WITH DIFFERING MORPHOLOGY MAY INDICATE NUTRIENT AVAILABILITY

Fong, Peggy*; Kamer, Krista; Boyer, Katharyn E.; and Boyle, Karleen A. *University of California, Los Angeles, 621 Circle Drive South, Box 951606, Los Angeles, CA 90095-1606, Email: pfong@biology.ucla.edu

To investigate whether algal tissue N and P content reflects processes controlling nutrient availability we collected 5 species of algae from 18 stations in southwestern Puerto Rico. Stations were either inshore or offshore with 3 stations/area as nutrient "hot spots". *Acanthophora spicifera* had higher N inshore, and both *A. spicifera* and *Hypnea musciformis* had higher N and P in "hot spots". This suggests algae with upright thalli and open branches have small nutrient-depleted boundary layers and thus a more direct relationship with water column nutrients than other forms. Turf or mat forming algae (*Dictyota dichotoma* and *D. cervicornis*) may require high rates of advection to replace nutrients within a mat. The mat-forming species had higher tissue N and P content offshore, where stronger currents can penetrate dense mats and replenish nutrients. *H. incrassata*, a rhizophytic form with access to sediment nutrients, had greater tissue N inshore and in some hot spots, perhaps reflecting areas of higher sediment nutrients. We conclude that, with careful consideration of other environmental factors, we may be able to develop the tissue N and P content of macroalgae as an indicator of nutrients available to coral reef algae.

THE USE OF REVERSE TRANSCRIPTASE-PCR VIRAL ASSAYS TO DETECT HUMAN WASTE CONTAMINATION OF CORAL REEF WATERS.

Griffin, Dale W.*; Gibson, Charles J. III; Lipp, Erin K.; Riley, Kelley; Rose, Joan B.; and Paul, John H. *University of South Florida, Department of Marine Sciences, 140 7th Avenue South, St. Petersburg, Florida 33701. dgriffin@seas.marine.usf.edu

In order to determine if human waste products are impacting water quality in the Florida Keys, water samples were screened for the presence of human specific viral pathogens and bacterial indicators. Sample sites were located throughout the Florida Keys and included sites in the Dry Tortugas. In contrast bacterial indicator results that indicated acceptable water quality in one group of samples (19 sample sites - Key Largo to Key West), 95 percent of the sites were positive for human viruses. Human viruses were also detected in another group of samples taken around the perimeter of Key West and Fort Jefferson in the Dry Tortugas (12 sites, 75% positive). Of 8 samples taken around Key West, 6 were positive for enteroviruses. Enteroviruses were also detected around Fort Jefferson (3 of 4) in samples located in close proximity to septic tanks (one staff and one visitor septic tank) or the anchorage site (~100m offshore of the fort). These results indicate the screening marine water samples for the presence of human viruses is a useful tool in determining if human wastes are being released into the water column. They also indicate that inadequate waste disposal systems in use in reef environments may pose a risk to both public health (recreational use) and reef health (nutrient loading of the water column).

NUTRIENT DYNAMICS IN A COASTAL CORAL REEF LAGOON: THE RELATIVE SIGNIFICANCE OF SEDIMENT REMINERALIZATION AND GROUNDWATER INPUTS.

Johnstone, Ron *, *Johan Hast. Centre for Marine Studies, University of Queensland, St Lucia, 4072. QLD, Australia. Email: rnje@uq.edu.au

Globally, coral reef lagoons are commonly being subjected to elevated nutrient loads from different anthropogenic sources. In an attempt to understand the significance of internal benthic remineralization processes in a fringing coral reef lagoon, this study examined sediment nutrient dynamics and the input of nutrients via groundwater. Porewater nutrient profiles, sediment chlorophyll content, and calculated sediment-water column nutrient fluxes all fell within the ranges reported for similar coral reef sediments, with the highest chlorophyll levels being observed nearest to groundwater outlets. Elevated sediment chlorophyll levels also coincided with the occurrence of the macroalgae, *Ulva sp*., which was only found at sites of high groundwater input. Nutrient budget calculations suggested that micro-phytobenthos was capable of accounting for any diffusive release of DIN from sediment porewaters and, in general terms, the sediments appeared to play a conservative role with respect to inorganic nutrient release. In contrast, some areas showed strong groundwater release and this contained DIN concentrations that were orders of magnitude higher than that of the overlying lagoon water. Estimates of groundwater input during the wet season suggest that groundwater represents a significant source of DIN to the lagoon and that it may be significant for coral reefs exposed to this water on outgoing tides. Groundwater nutrient levels are largely attributed to human activities associated with coastal aquifers, and this poses clear implications for the management of the lagoon and groundwater resources.

HEAVY METALS IN THE SOFT TISSUES OF BIVALVE MOLLUSKS IN THE GULF OF TONKIN.

Khristoforova N.K. *; Latypov, Yu.Ya.; Xuan Tuyen, Nguyen; Tien, Dam Duc. Zhuravel, E.V. *Far East State University, Vladivostok, 690600, Russia. Email: nadezhda@tigdvo.marine.su

Chemical assessment of the environmental situation in the shallow water of the north part of the gulf of tonkin did not reveal a significant pollution of this basin with anthropogenic and technogenic toxicants. The aim of this investigation was to check obtained data with the using of biological indicators, namely bivalve mollusks.the most common in the coral reef communities in observed area were three species: *septifer bicoloratus, barbatia amylgdalumtostum* and *isognomon isognomon*. Concentrations of zn, cu, pb, cd were determined (two first and two second metals characterize anthropogenic and technogenic presses respectively). Obtained data showed that station von boi is differ from other places with the lowest human activity, but stations hang trai and bo hung are characterized as areas with more heavy influence of both types of man's impact on the environment. Among four metals zn is notable for more high concentrations and pb distinguish with lower concentrations. *I. Isognomon* is a zn accumulator, *b.* ***Amylgdalumtostum a*** is a cd accumulator and *s. Bicoloratus* accumulates high cu amounts.

LAND-BASED SOURCES OF POLLUTION AND THE INITIATIVES OF UNEP IN THE EAST ASIAN SEAS REGION.

Kirkman, Hugh *. *East Asian Seas Regional Coordinating Unit, 10th Floor UNESCAP Building, Rajdamanern Av., Bangkok 10200 Thailand. Email: kirkman.unescap@un.org

The East Asian Seas are the marine borders of at least 12 countries. These countries are rapidly developing and their populations increasing. The resultant disturbance to the land and vegetation has obvious and deleterious effects on coastal ecosystems. The main ecosystems that are considered are seagrass meadows, coral reefs and mangroves, all of which are seriously depleted due to human activity. Sewage, industrial waste, sediment runoff from engineering activities and agriculture all enter the sea but poor monitoring and incomplete inventories of the flora and fauna do not allow objective or complete assesment of the damage. A recent study has integrated the sources and effects of land based activities which pollution the marine environment. The need for integrated efforts by all concerned including valid Environmental Impact Assessments for new development and sensible, enforceable legislation to manage and protect the environment are required. The effects of land-!!based activities are summarised in this paper and the role of the UNEP East Asian Seas Regional Coordinating Unit in coordinating and initiating projects to ameliorate, restore and manage marine environments is explained.

LAND-BASED NUTRIENT INPUTS AND THEIR ECOLOGICAL CONSEQUENCES ON CORAL REEFS IN THE NEGRIL MARINE PARK, JAMAICA.

Lapointe B.E., Thacker, Katy, Getten, Linval; Black, Courtney; Frame, Everton; Gabbidon, Webster; and Gill, Everett. HBOI, 5600 US 1 North, Ft. Pierce, FL 34946. Email: lapointe@hboi.edu

We performed a study throughout a monitoring network that included groundwaters, rivers,and coastal waters to assess nutrient linkages from the watershed to fringing reefs in the Negril Marine Park (NMP) during 1998. DIN was enriched year-around in groundwaters and rivers at the watershed sites compared to SRP that increased significantly during the summer wet season. On reefs, DIN averaged > 1.0 uM, was significantly higher on shallow vs. deep reefs, and did not vary seasonally. SRP concentrations were also higher on shallow vs. deep reefs, and increased significantly in the summer wet season coincident with massive blooms of the filamentous green macroalgae *Chaetomorpha*. Macroalgae averaged > 60 % cover on reefs in the NMP and their $\delta^{15}N$ values were above values for nitrogen fixation and closely matched watershed nitrogen sources that included fertilizers, peat, and sewage. Sea urchin density correlated positively with tissue N of macroalgae and negatively with coral cover, suggesting that land-based nitrogen inputs exerted significant "bottom-up" control on reef community structure.

DETECTION OF HUMAN FECAL CONTAMINATION IN NEARSHORE CORALS AND WATERS OF THE FLORIDA KEYS.

Lipp, E.K.*, Griffin, D., Jarrell, J.L., Lukasik, G., Jacukiewicz, J., and Rose, J.B. Center of Marine Biotechnology, U.Md., Baltimore, MD Email: elipp@seas.marine.usf.edu

Results of recent studies have indicated that nearshore waters of the Florida Keys are impacted by current waste-water management practices. Previous work has also demonstrated that coral mucus can serve as a reservoir for bacteria and potentially for viruses in the marine environment. The present study was undertaken to document preliminary evidence of human fecal contamination in nearshore corals by assessing concentrations of indicators/pathogens in coral mucus and the surrounding waters. Various species of coral were sampled at four nearshore sites. Both water and coral mucus were assayed for the following microorganisms: fecal coliforms, enterococci, *Clostridium perfringens*, and Coliphage. Water column samples were found to have 0-2.5 CFU (colony forming units) /100ml. Mucus samples had significantly higher levels of indicator organisms ranging from 0-1000 CFU/100ml. RT-PCR was utilized to identify enteroviruses present in the mucus samples and cell culture was used to assay for enteroviruses from water column samples. To date, all cell culture results are negative. However, RT-PCR indicates enteroviruses were present in at least 4 of the 15 coral mucus samples. This preliminary data indicates that assays using coral mucus could allow for the detection of land-based inputs into reef environments even if water column samples show little or no evidence of such pollution.

THE ROLE OF ADVECTION IN TRANSPORTING NUTRIENTS TO THE FLORIDA REEF TRACT.

Pitts, Patrick A*. *Harbor Branch Oceanographic Institution, 5600 U.S. Hwy.1 North, Ft. Pierce, Florida, USA. Email: Ppitts@HBOI.edu

Current meter, wind and dissolved inorganic nitrogen (DIN) data from a 1992-93 study are used to describe the advection of nutrients from the Florida Keys to the reef tract, where elevated nutrient concentrations have been shown to adversely affect reef corals. Results indicate a long-term net across-shelf near-bottom flow toward the reef tract at a study site over the middle shelf that averaged 2 cm s^{-1} during the 13-month study. Applying the average flow rate to a cross-sectional area of 1 m^2 and combining a representative DIN concentration of 15µM yields an average DIN transport rate of 55 µmole m^{-2} s^{-1} seaward past the study site. Low-frequency, nontidal across-shelf flow was toward the reef 80% of the time and a mean of 6.3 days was required to transport nutrients 3 km seaward across mid shelf (r.m.s. = 9.5 days, median = 1.7 days). By comparison, tidal ebbs and floods play a relatively minor role in transporting nutrients across mid shelf. Analyses of currents and local winds show an inverse relationship between across-shelf currents and across-shelf winds indicating an upwind return flow in near-bottom layers.

SOURCES AND TRANSPORT OF NUTRIENT-RICH GROUND WATER TO CORAL REEF ENVIRONMENTS, FLORIDA KEYS, USA.

Reich, Christopher*; Shinn, Eugene; and Hickey, Don. United States Geological Survey, 600 Fourth Street South, St. Petersburg, Florida 33701, USA, Email: creich@usgs.gov

Growing concerns in the Florida Keys over coral reef mortality have prompted State and Federal agencies to seek out probable contaminant sources that could impact water quality and hence coral reef health. Hydrogeological examination of the Key Largo Limestone has provided information suggesting ground water is transported in a net direction from the Florida Keys toward the reef tract at ~2md^{-1}. Two circular clusters of nested monitoring wells (6 and 14 m below rock surface), one cluster on each side of Key Largo, were installed and a dye-tracer study was conducted to determine rate and direction of groundwater flow. Ground water contains high concentrations of N and P as well as other pollutants due to numerous wastewater injection, cesspools, and septic-tank sites throughout the Keys. Flushing rates, a result of tidal pumping, are relatively high and therefore propagate the nutrient-rich groundwater from onshore to offshore. Horizontal and vertical groundwater movement was observed with greater rates on the Florida Bay side of Key Largo. The primary driving force is a higher bay water level that is controlled both by meteorological conditions and physiographic boundaries surrounding Florida Bay.

MONITORING SEDIMENT ACCUMULATION AND WATER QUALITY TO LINK REEF DEGRADATION WITH LAND-USE CHANGE: ROATAN, BAY ISLANDS, HONDURAS

Young, Robert S.* and Mehrtens, Charlotte J., *Dept. of Geosciences and NRM, Western Carolina Univ., Cullowhee, NC,28723, Email: ryoung@wcu.edu

The island of Roatan is the largest of the Bay Islands, a chain of islands in the Caribbean roughly 60 km off the north coast of Honduras. Roatan, itself, is approximately 40 km long and usually no more than 3 km wide. It is surrounded by fringing reef, in places directly attached to the shore. Thusfar, the Bay Islands have escaped the intense development that has covered many other Caribbean Islands. This is changing. Roatan now has an international airport with direct flights to the United States, and recently, the Inter-American Development Bank has initiated a multi-million dollar water and management project that will increase the "carrying capacity" of the Island of Roatan. In response to the certainty of increased development, a long-term monitoring program was initiated in the summer of 1998. This program involves the monitoring of sediment accumulation and spatial distribution, fecal coliform bacteria, water quality, and maintaining photo transects. Monitoring stations were established near developed watersheds, watersheds in the process of development, and at remote, control sites. Initial results suggest that reef mortality is more closely tied to increases in sedimentation rather than degradation of water quality. Sedimentation rates show a strong seasonality with the maximum coming during the September through December rainy season. Increases in sedimentation can be directly related to the following practices: 1) road building, 2) dredging and beach construction, 3) mangrove removal, 4) land clearing, and 5) intense, recreational usage of some areas by cruise ship passengers.

Session E6: Destructive Fishing Practices: Towards a Global Understanding of Causes Effects and Management Solutions

COMMERCIAL-SCALE FISHING ON PHILIPPINE CORAL REEFS

Abesamis, Rene A.*; Jocson, Domingo; and Aliño, Porfirio M.. *Marine Science Institute, University of the Philippines Diliman, Quezon City 1101, Philippines. Email: rabesamis@msi01.cs.upd.edu.ph

Coral reefs contribute 15-30% of the total fisheries yield of the Philippines. These habitats are fished using a variety of gears, but none is as effective as the large-scale, drive-in fishing technique referred to as 'pa-aling'. This method was developed to replace 'muro-ami', which was banned in the late 1980s due to the damage it brought to coral reefs. Prior to its approval as an alternative, pa-aling was found to incur minimal physical damage to corals. However, the technique was considered overly efficient and concerns about the sustainability of the fishery were aired. To this date, however, the operation of pa-aling continues in reefs of the South China Sea and the Sulu Sea, in the vicinity of Palawan. This paper reports the first-ever analyses of its three-year catch data gathered from over six hundred records of the commercial reef fishery. Initial findings show an overall annual decline in catch-per-unit-effort (CPUE). Although regulatory measures have been installed to regulate pa-aling fishing, the results suggest that operators of the gear are simply catching 'too much, too fast'. The present regulatory measures are also deemed inadequate and difficult to apply, hence, either Pa-aling should be banned entirely or the concept of establishing marine reserves in key areas is proposed.

THE EFFECT OF FISH TRAPS ON BENTHIC HABITATS OFF LA PARGUERA, PUERTO RICO.

Appeldoorn, R.S.*; Nemeth, M.; Vasslides, J.; Scharer, M. *Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico 00681-9013 USA. Email: r_appeldoorn@rumac.uprm.edu

Wire-mesh fish traps are an important gear in coral reef areas. Traps may damage habitats due to setting, subsequent movement due to wave surge and dragging, and grappling for lost traps. Off La Parguera, Puerto Rico, the potential habitat damage from commercial traps (1.1 m^2) was assessed by determining the distribution of traps relative to different habitat types, and by quantifying the damage to benthic organisms from trap setting and hauling on coral reefs or colonized hard bottom. Of 100 observed traps, 54% were on soft sediment or sand associated habitats; 44% were on hard bottom or reef. All traps observed were set individually. In hard bottom or reef habitats, 23% of the coral colonies (29 cm^2 damage/colony; 70 cm^2 total area), and 34% of the gorgonian colonies (2.8 cm^2 of damage/ colony ; 56 cm^2 total area) were damaged. Sponges were less prevalent, but 30% of observed colonies were damaged. Habitat damage from hauling averaged 12.6 cm^2/trap for coral and 4 cm^2/trap for gorgonians. Estimated total annual damage (116.4 m^2 for all organisms) represents less than 0.001% of living habitat.

THE INDO-PACIFIC DESTRUCTIVE FISHING REFORM INITIATIVE: RATIONALE, STRATEGY AND ACCOMPLISHMENTS, 1998-2000

Barber, Charles Victor* *World Resources Institute and Vaughan R. Pratt, International Marinelife Alliance. Email: cvbarber@ibm.net

As the trade in live reef fish has grown in volume and expanded in its geographic reach over the past decade or more, the use of destructive fishing methods for the capture of both ornamental and live reef food fish species has been widely reported across the Indo-Pacific region. The use of cyanide to stun and capture target species began in the Philippines in the 1960s, has spread throughout Indonesia, and has been reported in Papua New Guinea, parts of Micronesia, Sabah (Malaysia) and Vietnam. Another destructive practice, the targeting and decimation of grouper spawning aggregations, has also been widely reported from areas where live reef food fish collection operations have been undertaken. Since the early 1990s, the International Marinelife Alliance (IMA) has worked in partnership with the Philippines government to implement a national Destructive Fishing Reform Program (DFRP), with the objective of reducing the use of cyanide and making the live reef fish trade more sustainable. Since 1998, IMA has worked with a number of partners throughout the region to carry out a region-wide effort based on the Philippines model. This paper summarizes the methodology and achievements of that regional program and discusses the key issues raised in efforts to eradicate the use of cyanide and move the live reef fish trade towards sustainability.

SHIFTING THE BURDEN OF PROOF: APPROACHES TO SUSTAINABLE AND NON-DESTRUCTIVE COLLECTION OF CORAL REEF RESOURCES.

Best, B.A.* *U.S. Agency for International Development, Global Environment Center, 1300 Pennsylvania Ave. NW, Washington, D.C. 20523-3800, USA. Email: Bbest@USAID.gov

International trade in reef fish, coral, live rock, and other coral reef animals are activities that contribute to the decline and degradation of reefs, primarily through the use of destructive collection practices and overexploitation of resources. An analysis by the United States Coral Reef Task Force found that the United States is the number one consumer of live coral and marine fishes for the aquarium trade and of coral skeletons and precious corals for curios and jewelry. As a major consumer and importer of coral reef organisms, a major player in the world trade arena, and a leader in coral reef conservation efforts, the United States has a critical responsibility to address the degradation and loss of coral reef ecosystems that may arise from commerce in coral reefs species and products, and to encourage more responsible trade. The U.S. government is exploring innovative trade measures that would shift the burden of proof of sustainable use and non-destructive collection practices onto commercial users. Proposed trade measures would require importers and exporters to demonstrate that CITES-listed species were sustainably managed or maricultured, and to certify that coral reef products were not taken through the use of destructive collection practices. Such measures would generate economic incentives that reward and encourage responsible use of these precious resources, and discourage destructive practices that jeopardize the future potential of coral reefs to sustain local communities.

UNNECCESARY COLLECTIONS FOR THE MARINE AQUARIUM TRADE: SPECIES WITH EXTREMELY LOW SURVIVAL RATES.

Borneman E.H.* *Microcosm, Ltd. 2222 North Fountain Valley, Missouri City, Texas, USA, 77459. Email: EricHugo@aol.com

The marine aquarium trade is being examined as a potential threat to coral reefs through over-collection of target species, destructive fishing techniques, growing trade in CITES-listed species, and a lack of regulation governing the fisheries of both importing and exporting nations. To date, the impact of collection is still largely unknown, but initial reports suggest a minor but growing impact on collected reefs. . In many cases, target species may be collected disproportionately to their relative abundance. There is a long-standing view that marine animals, especially scleractinia, have a poor record of survival in aquaria. While this is no longer the case, there are large numbers of species collected which continue to have low to dismal chances of survival in aquaria. Among these are most of the azooxanthellate anthozoans, many filter-feeding invertebrates, and certain fishes. While many issues remain to be addressed regarding the care and survival of tropical marine organisms in the collection and transport processes, the survival of species listed in this report will likely fail despite best efforts by aquarists. The principle reasons for failure are mostly related to diet and the inability of aquaria to provide for sufficient amounts or types of required nutrients. In conjunction with several reports prepared for the U.S. Coral Reef Task Force on species survivability,

ACCUMULATION OF DERELICT FISHING GEAR BY OCEAN CURRENTS THREATENS CORAL REEFS OF HAWAII.

Brainard R.*; Foley, D.; Donohue, M.; Boland, R. *NOAA Fisheries - Honolulu Laboratory, 2570 Dole Street, Honolulu, HI, USA, 96822-2396. Email: Rusty.Brainard@noaa.gov

Over the past four years, surveys have found considerable evidence that the accumulation of derelict fishing gear in the Hawaiian Islands threatens the ecological balance of reef communities by destroying coral reef habitat, entangling reef fauna, and potentially accelerating introduction of alien species. Most of this derelict fishing gear originates from trawl, seine, gillnet, and other fisheries far removed from the Hawaiian Islands. Surveys of other Pacific coral reefs have not reported this level of debris accumulation or the associated damage. To address the question of why accumulations of marine debris are high in the Hawaiian Islands and apparently low in other regions of the tropical Pacific, wind-driven ocean currents were investigated. Surface wind observations from satellite scatterometers were used to compute Ekman convergence/divergence over the Pacific during the period 1992-99. Regions of oceanic convergence indicate areas likely to accumulate marine debris. The Northwestern Hawaiian Islands intersect the region of highest mean convergence. Significant seasonal and interannual variability of both strength and location of convergence zones are observed. Mean convergence is highest during the boreal winter (J,F,M) and weakest during the summer (J,A,S). During strong El NiZo years (1992 and 1998), the winter convergence zone extended south to the main Hawaiian Islands, where debris accumulations increased. Thus, wind-driven ocean currents can be useful in determining where and when derelict gear is likely to encounter and damage coral reefs.

CHANGES IN ZOOXANTHELLAE DENSITY, MORPHOLOGY, AND MITOTIC INDEX IN *ACROPORA MILLEPORA*, *AIPTASIA PALLIDA*, AND *GONIOPORA* Sp. EXPOSED TO CYANIDE

Cervino J.M.*, R. L. Hayes, M. Honovitch, T. J..Goreau , E. Borneman , D. Thoney, S. Jones, P. Rubec , & G. W. Smith . *Marine Science Dept., University of South Carolina, Columbia, SC Dept. of Marine Sciences 29208 Email: cnidaria@earthlink.net

Sodium cyanide (NaCN) is widely used for the capture of reef fish throughout the Pacific and Southeast Asia. The corals *Acropora millepora* and *Gonipora sp.* and anemones *Aiptasia pallida* used in this study were exposed to 50, 100, 300, and 400ppm of NaCN for 1 to two minutes. Concentrations of NaCN used were much lower than those used by fish collectors. Exposed corals and anemones immediately retracted tentacles and mesenterial filaments and discharged copious mucus containing zooxanthellae. Changes in protein content were found in both zooxanthellae and host tissue using gel electrophoresis. Corals and anemones exposed to NaCN showed an immediate increase in zooxanthellae mitotic cell division, and decrease in zooxanthellae density. In contrast, zooxanthellae cell division and density remained constant in controls. Histopathological changes included gastrodermal disruption, mesogleal degradation, and increased mucus in coral tissues. Zooxanthellae show pigment loss, swelling, and deformation. Mortality occurred at all exposure levels. Exposed specimens had a significant increase in the ratio of gram-negative to gram-positive bacteria on the coral surface. The results demonstrate that exposure to lower levels of NaCN than used by fish collectors causes mortality to corals and anemones.

MARKET TRANSFORMATION OF THE LIVE REEF FISH FOOD TRADE IN SOUTHEAST ASIA

Cesar, Herman *; Warren, K.; Sadovy, Y.; Lau, P.; Meijer, S.; van Ierland, E. *Institute of Environmental Studies, Free University Amsterdam, Boelelaan 1115, 1081 HV Amsterdam,The Netherlands. (HCESAR@IVM.VU.NL)

Current practices in the live reef fish trade pose a critical threat to global marine biodiversity. The trade also imperils the food security and income provided by traditional reef fisheries in Southeast Asia. This paper describes today's trade and its underlying destructive and unsustainable fishing practices, which include both the use of cyanide to stun fish as well as overharvesting of juveniles and spawning aggregations. Though cyanide use is outlawed for fisheries in most, if not all countries, high profits and enforcement problems require policy makers to look for innovative ways to manage the supply of live reef fish. To this end, the concept of a marine market transformation is introduced and applied to reef fisheries. In particular, current wild-caught supply mechanisms are described and the potential for aquaculture and sustainable wild-catch are evaluated. Sustainable management of the live reef fish trade requires active participation from both importing and exporting economies. However, action to date has been one-sided, with demand countries shifting responsibility for environmental damage to supply nations. The paper provides suggestions as to how this situation can be remedied and discusses creative market and policy solutions for achieving transformation of the current trade to one which is non-destructive and sustainable.

DESTRUCTIVE FISHING REFORM IN POOR COMMUNITIES IN THE PHILIPPINES: ADDRESSING VILLAGE ECONOMIC ISSUES

Cruz, Ferdinand.* *International Marinelife Alliance, Manila, Philippines Email: ferdie@gatesway.com

As near-shore fish stocks have declined in the Philippines, the time-horizon of the local fisherman has shrunk to meetings the needs of the moment and it has become increasingly difficult to differentiate between the "illegal" and "legal" fishermen. Destructive fishing (explosives or cyanide) usually brings short-term benefits in the form of a larger catch, and the support of local financiers who supply them with credit, cyanide or explosives, and food–all "for free" at the outset, in exchange for a promise of repayment from future catches at the (low) prices set by the financier. Once pulled into this system, the illegal fisherman finds himself in a web of never-ending debt and continuing obligation to this "patron." Most continue to live far below the poverty line, but generally insist that they will not renounce illegal fishing methods unless the alternative can provide them with a better income. Drawing on the extensive field experience that has been gained in 10 years of field work under the International Marinelife Alliance's Philippines Destructive Fishing Reform Program, this paper will document the reality of the daily life of fishermen using destructive methods in the Philippines, and argue that reforming destructive fishers is very difficult unless they can be offered an alternative source of income that can guarantee food on the table for their families and enough cash income for basic necessities. The paper will suggest realistic strategies for addressing this simple economic reality, based on cases from several areas in the Philippines.

REDUCING HUMAN STRESSES TO CORAL REEFS THROUGH ALTERNATE EMPLOYMENT IN SEAWEED FARMING IN THE ISLANDS OF BANGGI AND BALAMBANGAN, SABAH, MALAYSIA.

De Silva, M.W.R.N.;* Rahman, Ridzwan Abdul; and Jeropakal, Ainun Jariah. *Borneo Marine Research Unit, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia. Email: arjan@nara.ac.lk.

A build, operate and transfer (BOT) system for seaweed farming has been adapted as a way of introducing seaweed farming to the hard-core poor fishing families of the islands of Banggi and Balambangan, Sabah. Most participants of this activity have been previously involved in using 'fish bombing' of coral reefs as a means livelihood and to sustain their large families. The BOT system provide hands on training in all aspects of seaweed farming, provide financial support by employing participants as casual labour and continuously monitoring them till they are able to independently manage and get a desirable income prior to the farms being transferred to them. The produce is purchased by the project and a small percentage of the profit is retained by the project for involving new families. The trials and tribulations of introducing seaweed farming to coastal communities unused to this activity are discussed.

DESTRUCTIVE FISHING PRACTICES: TOWARDS A GLOBAL UNDERSTANDING OF CAUSES, EFFECTS AND MANAGEMENT SOLUTIONS.

Erdmann, M. *, L. Pet-Soede, Cabanban, A. and Pet, J. *Univ. of California, Berkeley, CA 94720 USA. Email: flotsam@manado.wasantara.net.id

Destructive fishing practices (DFP) have been recognized as important threats to coral reefs on a regional basis for at least 2 decades, yet the global significance of the DFP problem is perhaps underestimated and continues to take a backseat to such commonly-cited reef threats as sedimentation, eutrophication, overfishing in general, and global climate change. In a number of developing countries, however, DFP is the most immediate and significant threat to the continued existence of coral reefs and steps need to be taken to both eliminate these practices and promote recovery of DFP-damaged reefs. As a means of both summarizing the findings produced in other presentations in the DFP minisymposium and stimulating discussion in the concluding forum, five major questions are addressed in this paper: (1)How do the various forms of DFP rank in terms of their contribution to reef destruction, both among themselves and in relation to other anthropogenic threats on reefs? (2) How do DFP's differ from other anthropogenic impacts on coral reefs in terms of both ecological effects on the reef and especially reef recovery? (3) Is current reef conservation attention (manpower and funds) well-directed with respect to DFP or must priorities change? (4) Are fishers "forced" into DFP under Malthusian overfishing conditions, or is the adoption of DFP more a case of greed rather than need? (5) What types of enforcement and management solutions (including alternative income generation schemes) have proven effective in combating DFP, and are these applicable on a global basis?

RECOVERY IN RUBBLE FIELDS: LONG TERM IMPACTS OF BLAST FISHING.

Fox H.E.*; Pet, Jos S.; Dahuri, Rokhmin; Caldwell, Roy L.. *Department of Integrative Biology, 3060 VLSB University of California Berkeley, Berkeley CA 94720-3140 USA. Email: hfox@socrates.berkeley.edu

While the magnitude of the problem of blast fishing has receivedinternational attention, much less is known of its long-term ecosystem effects. One of the most serious impacts of extensive blast fishing is that new coral colonies are slow to grow back in the shifting rubble fields that result, even when a damaged area is protected from further blasting. This study investigates factors that inhibit or enhance coral recovery in rubble fields in Komodo National Park (KNP) and North Sulawesi, Indonesia. The extent of blast damage throughout KNP has been visually assessed at 185 sites every 2 years starting in 1996. Within 9 rubble field sites monitored since 1998, natural recovery is low, especially in high current areas. The movement of individual pieces of rubble, the changing depth of the rubble field overall, and the effect of these on coral survival is measured. Levels of potential source coral larvae in the rubble fields and comparison high coral cover sites are assessed with settlement tiles. Recovery in blast sites of known age is also being tracked, and is very low. Gaining an understanding of the prognosis for coral recovery is essential not only in order to assess the long-term impacts of blast fishing, but also to inform management decisions about protection of intact reefs and potential restoration of damaged areas.

THE TRADE IN LIVE REEF FOOD FISH: A HONG KONG PERSPECTIVE

McGilvray, Frazer* & Thierry T C Chan *International Marinelife Alliance Hong Kong. Email: frazer@imamarinelife.org

It is well documented that Hong Kong is the major market for the trade in live reef food fish. Since 1997, however, very little has been investigated, and this paper reflects the changes in the Hong Kong market up to the present time. Often, figures are quoted that supposedly reflect the high prices food fish species fetch in Hong Kong. These figures are however, often either hearsay or based on historical data which is unreliable. The Hong Kong public is increasingly becoming aware of the problems associated with reef fish consumption, although this has a great deal more to do with the recent outbreaks of ciguatera poisoning rather than the destructive use of sodium fishing. The Agriculture, Fisheries & Conservation Department (AFCD) of the Hong Kong Government has increased its efforts in educating the public as to the potential health threats of eating certain reef fish species, large specimens in particular. As a result of AFCD's activities, combined with the recent decline in the Hong Kong economy, the demand for those high priced species has dropped, as have their market values. In conclusion, the live reef food fish trade in Hong Kong is in crisis. Overseas markets are still quoting five year old figures, thereby artificially inflating the prices of supply side fish. Due to diminishing stocks and political unrest in certain areas, the local merchants are looking farther afield for a steady supply of fish. The increased costs of transportation to the more remote areas of the Indo-Pacific, coupled with the belief in the source countries that fish prices are still as they were 3-5 years ago, is creating real problems for the Hong Kong merchant.

CYANIDE FISHING ON INDONESIAN CORAL REEFS FOR THE LIVE FOOD FISH MARKET - WHAT IS THE PROBLEM?

Mous, Peter J. *, Pet-Soede, Lida; Erdmann, Mark; Cesar, Herman S.J.; Sadovy, Yvonne; & Pet, Jos S. *Indonesia Coastal & Marine Program, The Nature Conservancy. Jakarta Office, Jln Hang Tuah Raya 42, Jakarta 12120, Indonesia Email: pmous@attglobal.net

According to three precautionary estimations, the reef-degrading capacity of the cyanide fishery for food fish on Indonesia's coral reefs, expressed as a % cover change from the total surface area (%-points), amounts to a loss of live coral cover of 0.047, 0.052 and 0.060%-points per year. These estimates for the rate of coral cover loss are low compared to published rates of natural coral recovery. Differences in growth rate between species of hard coral will cause coral reefs to take longer to recover from the effects of cyanide fishing than a direct comparison of the rate of coral cover loss with published rates of natural coral recovery would suggest. Still, the cyanide fishery for food fish may not be as threatening to Indonesia's coral reefs as is sometimes assumed, especially not as compared to other threats such as blast fishing (responsible for 3.75%-points loss of live coral cover per year, Pet-Soede, Cesar & Pet 1999), or coral bleaching caused by global climate change (cf. Hoegh–Guldberg 1999). Setting the input variables for the estimates at extreme values did not change these conclusions substantively. The depletion of grouper stocks by the trade in live reef food fish, however, is worrying from both fisheries and conservation perspectives. Strategies to abate the depletion of these grouper stocks should not only consider cyanide fishing, but also other fishing methods.

FISH DIVERSITY LOSS AS THE RESULT OF DESTRUCTIVE FISHING IN EAST MALAYSIA.

Oakley, S.G.*, Mackey, G. and Enderby, S.. *Institute of Biodiversity and Environmental Conservation, University Malaysia Sarawak, Kota Samarahan, 93400 Sarawak, Malaysia. Email Soakley@ibec.unimas.my

Coral reefs around the coasts of Sarawak and Sabah East Malaysia were visually surveyed from 1996 to 2000 using standardised belt transects and timed swims. There is ongoing massive damage to reefs by destructive fishing techniques especially blastfishing and cyanide although trawling also damaged many reefs in some areas. The reef structure has been seriously changed and this has had significant impacts on fish species diversity and populations. Fish species diversity was seriously reduced on all reefs but especially those subject to intensive blastfishing. Reefs inside national parks were as badly affected as reefs outside the gazetted areas. The 39 to 42 butterfly fish species which occur on protected reefs in East Malaysia were reduced to one species on many fished reefs. The diversity loss was apparent in all species of reef fish. Fish populations were reduced with many fewer individuals of each species as well as a reduction in size of fish. Very few reefs had breeding sized adults of the larger commercial fish species, while the fish preferred by the live fish trade and actively sought by cyanide fishers were only seen at the reefs protected by ecotourism. These larger fish; the humphead wrasse, *Cheilinus undulatus*, the panther grouper *Cromileptes altivelis*, the bumphead parrotfish *Bolbometopon muricatum*, the chinese grouper *Plectropomus laevis*, the lyre tailed grouper *Variola louti* and the giant grouper *Epinephelus lanceolatus* are certainly endangered if not quite regionally extinct.

REDUCING HUMAN STRESSES TO CORAL REEFS THROUGH ALTERNATE EMPLOYMENT IN SEAWEED FARMING IN THE ISLANDS OF BANGGI AND BALAMBANGAN, SABAH, MALAYSIA.

De Silva, M.W.R.N.;* Rahman, Ridzwan Abdul; and Jeropakal, Ainun Jariah. *Borneo Marine Research Unit, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia. Email: arjan@nara.ac.lk.

A build, operate and transfer (BOT) system for seaweed farming has been adapted as a way of introducing seaweed farming to the hard-core poor fishing families of the islands of Banggi and Balambangan, Sabah. Most participants of this activity have been previously involved in using 'fish bombing' of coral reefs as a means livelihood and to sustain their large families. The BOT system provide hands on training in all aspects of seaweed farming, provide financial support by employing participants as casual labour and continuously monitoring them till they are able to independently manage and get a desirable income prior to the farms being transferred to them. The produce is purchased by the project and a small percentage of the profit is retained by the project for involving new families. The trials and tribulations of introducing seaweed farming to coastal communities unused to this activity are discussed.

THE NEED TO STOP CYANIDE SMUGGLING THAT SUPPORTS CYANIDE FISHING.

Rubec, Peter J.*, Pratt, Vaughan R. and Cruz, Ferdinand
***International Marinelife Alliance-USA, 2800 4th Street North, St. Petersburg, Florida 33704, U.S.A. Email:** prubec@compuserve.com

Cyanide fishing has spread from the Philippines throughout Southeast Asia. Cyanide has been shown to kill corals and is believed to be a major factor contributing to the destruction of coral reefs. Efforts to stop cyanide fishing need to examine the means by which cyanide is transported to the collectors. Companies that buy food fish in Hong Kong claim they are not involved with promoting cyanide fishing. Collectors in Indonesia have been observed using cyanide in squirt bottles mixed with gasoline, kerosene, soap, or colored with a black die. These agents are not necessary to dissolve the cyanide in solution, since sodium cyanide and potassium cyanide are water soluble. The most likely explanation is that cyanide is being smuggled to other countries mixed with other chemicals. The vessels involved in the trade of live food fish should be inspected to determine whether they are transporting fuels or other chemicals laced with cyanide. The International Marinelife Alliance (IMA) maintains cyanide detection laboratories in the Philippines, which can be used to determine the presence of cyanide. The prosecution of individuals and/or companies involved with the illegal distribution of cyanide to fishermen may be the most effective way to stop cyanide fishing, in order to conserve coral reefs and protect their associated fisheries.

BLAST FISHING: VARIATIONS OF CAUSES AND IMPACTS AMONG THREE DIFFERENT REEF REGIONS IN INDONESIA.

Steffen, Jan Henning*. *KEHATI-The Indonesian Biodiversity Foundation, Jakarta, Indonesia. Email: jsteffen@cbn.net.id

Blast fishing represents a major threat for indonesian coral reefs. It occurs widespread throughout the archipelago and appeared again to be increasing in several regions of indonesia during the times of economic crisis in 1997 and 1998. Comparison among blast fishing incidents and techniques, socio-economic appraisals and impact assessments on coral reefs in west-sumatra, east-kalimantan and west-papua reveal distinct differences among the surveyed sites. Variations include the social groups involved , the attitudes of local fishing communities towards surrounding reef areas and towards the individuals using explosives, the impact on coral reef communities, the infrastructure and incentives of regional law enforcing agencies, and finally the reasons for limited success of law implementation. The comparison shows that the commonly used paradigm of the "poor fishermen without alternative income sources and no choice rather than blast fishing" does often not reflect the reality in the three selected areas. The experiences made by the stakeholders in west-sumatra, east-kalimantan and west-papua and the results of the management approaches, which have been applied so far, indicate the need for locally adapted, integrated and stakeholder-based management solutions.

Session E7: Coral Diseases: Pathogens, Etiology and Effect on Coral Reefs

SPATIAL AND TEMPORAL PATTERNS OF TREMATODE INFECTION ON THE REEF CORAL, *PORITES COMPRESSA*, IN HAWAII.

Aeby, GS*, *University of Hawaii, Hono., HI 96744. Email: GretaSA@aol.com

In Hawaii, the dominant coral genus, *Porites*, is susceptible to infection by the digenetic trematode, *Podocotyloides stenometra*. Trematode infections are characterized by the appearance of pink, swollen nodules on the coral colony. Infection by *P. stenometra* can result in significant reductions in colony growth potentially affecting the colony's ability to compete for space on the reef. Surveys were conducted to examine the abundance and distribution of infected colonies on six reefs in Kaneohe Bay, Oahu. The duration and temporal pattern of infection at both the reef and individual colony levels was also examined. All six reefs were found to have corals infected with *P. stenometra*. An average of 35% of the colonies on the reefs were infected. Infected colonies were found from the reef flat down to the bottom of the reef slope. Most colonies were lightly infected, with only a small proportion of the colonies having high levels of infection. Intermediate levels of coral cover had the highest levels of infected coral. Infected corals were evident on the six reefs throughout the duration of the study with no overall change in proportion of infected colonies through time. However, there was variability in duration of the infection among reefs. A one year field survey of individual colonies also showed variability in duration of infection. No seasonal differences (winter vs. summer) in level of infection were evident at the reef or individual colony level.

BIOGEOGRAPHY OF OLD AND NEW CORAL DISEASES.

Arnfried Antonius. Paleontology, University, Althanstrasse 14, A-1090 Vienna, Austria. Email:arnfried.antonius@univie.ac.at

All of the classical, old coral diseases, such as Black Band Disease (BBD), White Band Disease (WBD), Tissue Bleaching (TBL), Shut-Down-Reaction (SDR), *Lobophora variegata* (LOB), and others, were observed in both Atlantic and Indo-Pacific zoogeographic areas. Within a time-span of about thirty years they were registered in many locations of the Western Atlantic, from Bermuda in the North, throughout the Caribbean Sea, to Panama in the South. In the Indo-Pacific they were found in the Red Sea, Seychelles, Mauritius, Philippines, Papua New Guinea, and Australia. The newer, recently discovered syndromes appear to be more restricted : *Pneophyllum conicum* (PNE), a coral-killing red alga occurs throughout the Indo-Pacific in moderate quantities, but was recently observed to destroy an entire reef-crest area in Mauritius. Another new Corallinacea, *Metapeyssonnelia corallepida* (PEY), destroying corals in a very similar way, has so far been documented in Caribbean waters only. The first coral-killing ciliate, however, *Halofolliculina corallasia* (SEB), was found to be restricted to the Indo-Pacific zoogeographic region. Future field-research will show whether these geographic limitations are real, or rather artefacts of insufficient observation time.

ECOLOGICAL AND PALEOECOLOGICAL PERSPECTIVES ON DISEASES OF BENTHIC REEF ORGANISMS.

Aronson, Richard B. * and William F. Precht. *Dauphin Island Sea Lab, 101 Bienville Boulevard, Dauphin Island, Alabama 36528, U.S.A. Email: raronson@jaguar1.usouthal.edu

Since the disease-induced mass mortality of the Caribbean black-spined sea urchin, *Diadema antillarum*, in 1983-84, ecologists and microbiologists have been identifying new diseases on coral reefs at an alarming rate. A rapidly expanding roster of pathologies threatens such important sessile organisms as scleractinian corals, sponges, octocorals, and coralline algae. White-band disease (WBD), for example, was responsible for devastating populations of *Acropora palmata* (elkhorn coral) and *A. cervicornis* (staghorn coral) around the Caribbean from the 1970s through the 1990s. A critical question is whether humans are promoting disease outbreaks on coral reefs. Several indirect lines of evidence from the Caribbean suggest that the answer is yes. First, one emergent disease, a fungal infection of sea fans, is caused by a terrestrial pathogen, perhaps introduced through altered patterns of land use. Second, heavy exploitation of predatory fishes was at least partly responsible for high population densities of *D. antillarum* prior to the dieoff, and these high densities probably facilitated the spread of the pathogen. Finally, paleontological data from Belize suggest that the recent, WBD-induced *Acropora* kill was without precedent in the late Holocene (the last 3,000 years). Links between diseases of reef organisms and land use, pollution, and global climate change require immediate attention.

PREDATION BY *SPARISOMA VIRIDE* AND RELATIONSHIPS WITH CORAL DISEASE.

Bruckner, R.J.* and Bruckner, A.W. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: robin.bruckner@noaa.gov

A condition initially termed "rapid wasting disease"(RWD), characterized by a rapid rate (7.5 cm per day) of tissue destruction and concurrent "dissolution" of the skeleton, was subsequently demonstrated to result from predation by initial phase and terminal phase *Sparisoma viride* (stoplight parrotfish). These fish forage using beak-like jaws to scrape and excavate epilithic and endolithic algae from carbonate substrates, but they also bite live coral. Most commonly, *S. viride* created small lesions (spot biting) that were within a coral's regeneration capabilities. Parrotfish also created deep grazing scars (focused biting), denuding tissue and skeleton through repeated, methodical biting that progressively radiated across colony surfaces. Coral destruction occurred only during daylight, with no additional loss at night; lesions also failed to increase in size when *S. viride* were excluded. Tissue and skeleton removed from areas on colonies affected by active predation did not induce tissue or skeletal destruction when attached to apparently healthy corals. In addition, coral tissue samples collected from the site of injury after predation ceased exhibited regrowth of coral tissue over damaged skeleton. After three years large lesions have failed to fully regenerate, but they have not increased in the absence of continued predation, and coral growth has occurred at the periphery of the injury. Additional studies are needed to determine whether focused biting is related to parrotfish abundance, territorial interactions, or other factors, and whether fish bites serve as a portal of entry for secondary pathogens.

THE PREVALENCE OF CORAL DISEASES ON REEFS SURROUNDING MONA ISLAND, PUERTO RICO

Bruckner, A.W.* and Bruckner, R.J. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: andy.bruckner@noaa.gov

Coral diseases appear to be increasing in frequency in the western Atlantic, however there is insufficient information to verify that diseases are equally affecting remote locations. In this study the condition of reef-building corals was assessed on reefs surrounding Mona Island, to determine whether locations with little anthropogenic pollution have a similar level of disease as do heavily impacted reefs near the Puerto Rico mainland. Coral diseases, especially black-band disease (BBD), white plague (WP) and yellow-blotch disease (YBD) were identified from 0.5-25 m depth. In 1995 and 1996, BBD affected 8-10% of the brain corals (*Diploria* spp.) in six back reef and reef crest environments, with fewer infections recorded on the fore reef. Yellow-blotch disease was rare, except in one location; white plague was not identified along transects or on surrounding colonies. Surveys from 1999 indicate that diseases were more common on the shallow fore reef (2-20 m depth) than previously observed. Colonies were identified with YBD on all reefs, affecting up to 50% of all star corals (*Montastraea annularis* complex), particularly the largest colonies. Although fewer colonies exhibited BBD in shallow locations, this condition was prevalent in the fore reef. An outbreak of white plague was noted for the first time in 1999, primarily among *Colpophyllia natans*, *Dichocoenia stokessi*, *Diploria* spp. and *Montastraea* spp.

GRAZING OF CORAL SURFACES BY THE STOPLIGHT PARROTFISH *SPARISOMA VIRIDE* AND RELATIONSHIPS WITH CORAL DISEASE.

Bruckner, R.J.* and Bruckner, A.W. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: robin.bruckner@noaa.gov

Sparisoma viride (stoplight parrotfish) forage using beak-like jaws to scrape and excavate epilithic and endolithic algae from carbonate substrates, but they also bite live coral, removing tissue and underlying skeleton. A condition initially termed "rapid wasting disease"(RWD), characterized by a rapid rate (7.5 cm per day) of tissue destruction combined with the concurrent "dissolution" of the skeleton, was presumed to be caused by a fungal pathogen. The condition was subsequently demonstrated to result from repeated, overlapping bites by initial phase and terminal phase *Sparisoma viride*. Although *S. viride* prey upon at least 18 species of coral, *Colpophyllia natans*, *Montastraea annularis* and *M. faveolata* are affected most frequently; parrotfish create grazing scars through repeated, methodical biting that progressively radiate across colony surfaces. Identification of *S. viride* as the primary causative agent was accomplished by comparing rates of coral destruction between day and night, by excluding parrotfish from corals with active signs of predation, and through direct observations of parrotfish behavior. Tissue and skeleton removed from areas on colonies affected by active predation that were attached to apparently healthy corals failed to induce tissue destruction. In addition, coral tissue samples collected from the site of injury after predation ceased exhibited regrowth of coral tissue over damaged skeleton.

THE CONDITION OF SCLERACTINIAN CORALS ON REEFS SURROUNDING MONA ISLAND, PUERTO RICO: THE PREVALENCE AND IMPACT OF CORAL DISEASES IN LOCATIONS REMOVED FROM HUMAN POPULATION CENTERS.

Bruckner, A.W.* and Bruckner, R.J. *NOAA/National Marine Fisheries Service, 1315 East West Highway, Silver Spring, Maryland, United States. Email: andy.bruckner@noaa.gov

Coral diseases appear to be increasing in frequency in the western Atlantic, however there is insufficient information to verify that diseases are equally affecting remote locations, or whether this apparent increase is related primarily to anthropogenic disturbances. In this study the condition of reef-building corals was assessed on reefs surrounding Mona Island, to determine whether locations with little anthropogenic pollution have a similar level of disease and subsequent coral reef deterioration as do heavily impacted reefs near the Puerto Rico mainland. Coral diseases, especially black-band disease (BBD), white-band disease (WBD), white plague (WP) and yellow-blotch disease (YBD) were identified from 0.5-25 m depth. In 1995 and 1996, BBD affected 8-10% of the brain corals (*Diploria* spp.) in six back reef and reef crest environments, with fewer infections recorded on the fore reef. Yellow-blotch disease was rare, except in one location; white plague was not identified along transects or on surrounding colonies. Surveys from 1999 indicate that diseases were more common on the shallow fore reef (2-20 m depth) than observed in previous years. Colonies were identified with YBD on all reefs, affecting up to 50% of all star corals (*Montastraea annularis* complex), particularly the largest colonies.

DECREASED ZOOXANTHELLAE DENSITIES AND MITOTIC INDICES IN CORALS AFFECTED BY YELLOW BAND, DARK SPOT, WHITE BAND, AND WHITE POX SYNDROMES.

Cervino J.M.*, G. Smith, T. J. Goreau, R. Hayes, S. Polson, & S. James. Dept. of Marine Sciences., University of South Carolina, Columbia, SC 29208, e-mail:cnidaria@earthlink.net.

Yellow band (YB) **,** dark spot (DS), white band (WB), and white pox (WP) coral syndromes have become prevalent throughout the Caribbean. Belt transects in Bonaire, Grenada, St. John, and Providenciales during 1997-99 showed up to 98% of target coral species affected. Zooxanthellae densities and mitotic indices (MI, % cells appearing as doublets) were measured using a hemocytometer. Zooxanthellae densities in affected tissues were less than in controls: YB-affected tissues of *Montastrea annularis* had 50% of normal zooxanthellae density in the band adjacent to normal tissue and 0.1% adjacent to the dying edge; DS-affected *Siderastrea siderea* had 55.9% of control densities; DS-affected *Stephanocoenia michelinii* had 87.3% of controls; WB-affected *Acropora. Cervicornis* had 11.99% of controls; and WP-affected *Acropora palmata* had 15.33% of controls. Mitotic Indices also decreased in affected tissues. MI of normal *M. annularis* was 1.0%, but 0.18% in YB next to normal tissue and 0.0% in YB near the dying edge. MI of normal *S. siderea* was 1.20% and 0.40% in DS samples. MI of normal *S. michelinii* was 1.54% and 0.23% in DS. MI of normal *A. Cervicornis* was 8.0% and 0.44% in WB. MI of normal *A. palmata* was 8.28% and 0.48% in WP. Intact zooxanthellae were found in tissue and mucus of healthy specimens. Affected tissues were dominated by swollen, vacuolated or disrupted zooxanthellae, and mucus contained fragmented symbionts.

CHANGES IN ABUNDANCE, SIZE, AND FUNGAL INFECTION OF PARROTFISH LESIONS ON CARIBBEAN CORALS, 1996-1999.

Cervino J.M.*, R. L. Hayes, T. J. Goreau, & G.W. Smith. Marine Science Dept., University of South Carolina, Columbia, SC Dept. of Marine Sciences 29208 Email: cnidaria@earthlink.net

Large white patches of recently excavated coral skeleton were conspicuous in the Caribbean corals *Montastrea* species and *Colpophyllia natans* in late 1996-1997, affecting 80 to 90% of all colonies at some sites, but were less evident in 1998-99. Low levels of parrot fish white spot biting (PWSB) has long been known to be caused by *Sparisoma virde*, the stoplight parrotfish, but normally healed without scar formation. During 1996-97, *S. viride* was observed to inflict overlapping bite marks on corals, making unusually large, deep excavations, and frequently returning to the same coral to inflict additional damage. Transect measurements in Bonaire showed a decreasing trend with time: 0.5 cases per linear meter in 1997, 0.075 in 1998, and 0.011 in 1999. The size of the lesions also decreased, from a range of 3 to 60 cm across in 1997 to 1.3 to 10 cm across in 1999. Microscopic examinations in 1997 showed fungal hyphae invading coral epithelia, and the fungus *Rhodotorula rubra* was isolated from these tissues. Fungal hyphae were not observed in specimens collected during 1999. These data suggest that this event exploded during late 1996 and decreased steadily afterwards. The dramatic effect on coral morphology suggests that such events were uncommon or local in the past.

CYANOBACTERIAL DISEASE AFFECTS THE CRUSTOSE RED ALGAE *Peyssonnelia* ON REEFS OF THE CARIBBEAN AND GREAT BARRIER REEF.

Diaz-Pulido G.* *Dept. Tropical Plant Sciences, James Cook University, Australian Institute of Marine Science and CRC: Reef Research Centre, Townsville, Qld 4811, Australia. Guillermo.Diaz@jcu.edu.au.

A previously undescribed disease affecting the calcified crustose red algae *Peyssonnelia* spp. has been observed on coral reefs of the Colombian Caribbean and the central section of the Great Barrier Reef (GBR), Australia. No pathogens have been previously recorded for this genus. Named *Peyssonnelia* Yellow Band Disease due to its banding appearance and yellow colour, the disease attacks the algae *Peyssonnelia* over a wide depth range, from 6 – 9 m in Trunk Reef, GBR, to 10 - 24 m in Santa Marta, Colombia. The disease generally manifests itself as a more or less distinct yellow band of 0.5 to 4 cm wide, composed of densely interwoven gliding filaments of the cyanobacteria *Schizothrix* sp. The yellow band moves across the surface of the crustose algae, followed by a white mat of gliding bacteria, possibly *Beggiatoa* spp., leaving behind dead algal tissue. Both the invasion process and the cyanobacterial and bacterial genera involved in the disease are similar between samples obtained from the Caribbean and GBR, and seem to represent the same infection. *Peyssonnelia* can be the dominant alga in crevices and overhangs of reefs in both the GBR and the Caribbean, and can play a significant role in reef consolidation and construction. Although the disease is apparently currently neither common nor locally abundant, outbreaks of the disease could potentially have significant and widespread impacts on reef communities.

DIFFERENTIAL PREVALENCE OF BLACK BAND DISEASE IN CORAL ASSEMBLAGES FROM THE GREAT BARRIER REEF.

Dinsdale E.*. *School of Tropical Environment Studies and Geography James Cook University Townsville 4811 Australia. Email: Elizabeth.dinsdale@jcu.edu.au

Black Band Disease is a common affliction of corals on the Great Barrier Reef, with at least 24 species in 5 families being infected. The family Acroporidae, in particular *Acropora hyacinthus*, *A. intermedia* and *A. millepora* are important host species for Black Band Disease (BBD). In a survey of exposed reef crest and back reef corals (depth of 1-3m) at Lizard Island 2.8% of the 4569 coral colonies were infected with BBD. Prevalence varied between the exposed crest and back reef habitats; 3.6% of corals were infected on the crest and 2.1% corals on the back reef. The prevalence of BBD was not spread evenly through the coral families. Pocilloporidae and Acroporidae corals had a higher number of infections and diseased corals from these families were found in both habitats. Whereas, Poritidae and Faviidae corals had a lower number of infections and infected corals were found on the reef crest only. The differential prevalence of BBD may influence the coral assemblages within the two habitats.

A NOVEL MOLECULAR BIOMARKER SYSTEM (MBS) TO ASSESS THE PHYSIOLOGICAL STATUS OF CORALS.

Downs C.A.*, E. Mueller, S. Phillips, J. E. Fauth and C. M. Woodley. *Envirion Biotechnologies, Inc., 6319 Mori St., McLean, VA 22101 USA. Email: cadowns@technologist.com

We have developed a novel Molecular Biomarker System (MBS) to assess the physiological status of corals (*Montastraea faveolata and Montastraea annularis*) by assaying specific parameters of coral cellular physiology, indicative of a non-stressed or stressed condition. We have used this new biotechnology to characterize the cellular pathology of coral bleaching. In laboratory studies, the MBS was used to distinguish the separate and combined effects of heat and light on a scleractinian coral and its symbiotic dinoflagellate (zooxanthellae). Our data provides strong evidence to support the hypothesis that oxidative stress plays a central role in the etiology of coral bleaching. We also employed the MBS to examine field samples from colonies of *M. annularis* in the Florida Keys collected March through November 1999. We discovered a strong correlation between oxidative stress and coral bleaching. Further, we showed that the MBS can be used to (1) diagnose whether corals were physiologically stressed, (2) predict the occurrence of coral bleaching at least 3-6 months before visual indications of a bleaching event, and (3) provide evidence that suggests that the chloroplast small heat-shock protein is a significant adaptation against coral bleaching. We are currently expanding the capabilities of the MBS to any coral species and adapting the relatively inexpensive, yet precise MBS biotechnology to a high-throughput robotic system to handle large sample sets.

PATTERNS IN CORAL DISEASE EPIZOOTIOLOGY.

Green, E.P*. and Bruckner, A. *World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, United Kingdom. Email: ed.green@wcmc.org.uk

Epizootiology, a term equivalent to epidemiology in humans, is the study of the incidence, distribution and abundance of disease in animals. If there is a link between human activities and coral epizootiology then patterns of disease incidence are unlikely to be uniformly or randomly distributed at regional scales. An understanding of the global epizootiology of coral diseases would therefore constitute a first step in examining whether any relationship exists. Here we present summary conclusions from a review of *in situ* observations of coral disease and associated mortality from more than 150 sources: (i) a disproportionate amount of disease has been recorded as occurring in the wider Caribbean region, (ii) only white-band disease has caused major changes in the composition and structure of reefs, (iii) only a few studies have quantified the prevalence of disease, or the mortality arising from disease at an instant or over time, (iv) therefore certainty over whether the impact of disease is increasing, or not, is difficult, (v) in general, reefs are not being devastated by biotic diseases in the same way that many were affected by bleaching during the 1997-1998 event, (vi) therefore the global implications of diseases on coral reefs may not be as severe as bleaching, at this time, (vii) black-band disease and white plague affect a large number of different sceleractinian corals. The overwhelming majority of disease in the Caribbean (97% of locations) has been recorded from coral reefs where human activities are expected to have medium to high impacts. Regional scale patterns in the incidence of coral disease may therefore be suitable bio-indicators of anthropogenic disturbance to coral reefs.

ENVIRONMENTAL STRESS AND OPPORTUNISTIC BACTERIAL PATHOGENESIS IN STONY CORALS.

Hayes M.L.*, R.L. Hayes and R.T.Barber. *Duke University Marine Laboratory, 135 Duke Marine Lab Rd., Beaufort, NC USA. Email: mhayes@duke.edu

Emerging infectious diseases have become a serious global threat to the health of human and wildlife populations in recent decades. World-wide, infectious diseases have appeared in coral reefs with an unprecedented increase in frequency, intensity and variety. To investigate causal and unifying mechanisms of the changing ecology of infectious disease, we have developed a novel marine invertebrate disease model based on the temperate scleractinian (stony) coral *Oculina arbuscula* and confirmed bacterial coral pathogens. We can induce bacterial infection and disease in *O. arbuscula* by exposure to innocula of the bacterium *Vibrio alginolyticus. V. alginolyticus* is a facultatively anaerobic gram-negative bacterium and a common resident of the surface mucopolysaccharide layer of healthy corals. Observations suggest that some, perhaps many, emerging infectious diseases in corals need not be attributed to novel or exotic bacterial pathogens. Instead, environmental conditions that cause shifts in the composition, quantity and function of the commensal microbial community on the coral surface may be sufficient to initiate the cascade toward the disease. Results suggest that normal bacterial microflora serve both as infection defense mechanisms in healthy corals and as opportunistic pathogens in stressed corals. Experiments indicate that relatively modest changes in ambient conditions can initiate the shift in microflora function from defense to infection.

CHARACTERIZATION OF TETRODOTOXIN PRODUCTION BY A SEA URCHIN PATHOGEN; AND ITS POSSIBLE ROLE IN PATHOGENICITY.

James, Sara C.*, Ellis Kline, and Garriet W. Smith. *Department of Microbiology and Molecular Medicine, 124 Long Hall, Clemson University, Clemson, SC 29634-1909 USA, Email: scjames@clemson.edu.

Pseudoalteromonas haloplanktis sub sp tetraodonis is a bacterium known to produce the sodium-channel blocker, tetrodotoxin (TTX). This neurotoxin, often associated with puffer fish (fugu) poisoning, is lethal to humans. A strain similar to this bacterium was isolated from diseased *Meoma ventricosa* in Curaçao in 1997. The strain has also been shown to cause disease and ensuing mortality in regular urchin species. The production of TTX by this strain was characterized by cytotoxicity assays on neuroblastoma cell lines, by high-pressure liquid chromatography (HPLC), and monoclonal antibody assays. These tests were performed over time under varying environmental and ionic conditions. Mutational studies were performed in order to produce TTX-negative clones that could be used in further studies.

THE EPIZOOTIOLOGY OF CORAL DISEASES IN THE FLORIDA KEYS.

Mueller, E., D.L. Santavy, E.C. Peters, J.C. Porter, and L. MacLaughlin. *Mote Marine Laboratory, Center for Tropical Research, 24244 Overseas Highway, Summerland Key, FL 33042. Email: emueller@mote.org

The contribution of coral disease to the decline of reef ecosystems has been implied, although no study to date has assessed the prevalence of multiple coral diseases throughout a geographic region. The multi-year survey reports coral diseases affecting 18 species of stony coral and 2 species of gorgonian seafans in the Florida Keys. The survey estimates the frequency and distribution of specific diseases associated with three geographical regions of the Keys and three reef types. Diseases were assessed using the 8-10m segment of a radial arc transect. The greatest preva-lence of disease occurred in the back reef of all the regions. The greatest prevalence of disease almost always occurred in the Lower Keys region, in the vicinity of Key West. The highest disease rate affects the Acroporid corals, and includes white-band disease and white pox disease or patchy necrosis. Other disease syndromes that were frequently encountered include dark spot disease affecting *Siderastrea siderea*, aspergillosis affecting seafans, and yellow-blotch disease affecting large *Montastraea* colonies.

SYSTEMATIC CHARACTERIZATION AND COMPARISON OF VARIOUS BACTERIAL ISOLATES PATHOGENIC, OR PUTATIVELY PATHOGENIC, TO SCLERACTINIAN CORAL SPECIES.

Polson, Shawn W.* and Smith, Garriet W. *Department of Microbiology and Molecular Medicine, 124 Long Hall, Clemson University, Clemson, SC 29634-1909 USA. Email: spolson@clemson.edu.

The recent apparent increases in the number of epizootics affecting coral reef organisms, including reef-building coral species, has encouraged expanding research into coral microbiology. During the past few years the isolation of pathogenic, or potentially pathogenic, bacteria associated with white plague, white band disease (type II), *Porites* ulcerative white spot disease, dark spots syndrome, and white pox syndrome has occurred. Tentative grouping of isolates was performed by subjecting the bacteria to metabolic fingerprinting, using the BIOLOG system, and by Fatty Acid Methyl Ester (F.A.M.E.) analysis. The bacteria were then identified by sequencing of a conserved region of the 16S ribosomal RNA gene. Additional tests that described various morphological, physiological, metabolic, genetic, and biochemical characteristics of the strains were then performed. Results from all tests were statistically analyzed allowing examination of pathogenic diversity and general relatedness among strains. Pathogenic strains tended to be *Vibrio* or *Pseudomonas*-like aerobic, heterotrophic, gram-negative rods that grow and proliferate strictly, or at least optimally, within marine environments.

FUNGAL DEVELOPMENT IN MASSIVE CORAL SKELETONSK.

Priess, T*. Le Campion-Alsumard, S. Golubic, F. Gadel, B.A. Thomassin. *Centre d'Oceanologie de Marseille, Universite de la Mediterranee, UMR-CNRS 6540, Station Marine d'Endoume, F-13007 Email: kathrin.priess@dlr.de

Dark coloured bands are commonly found in fractured massive coral skeletons from Mayotte Island (Mozambique Channel) and from Moorea Island (French Polynesia) but have been also recognized in various places throughout the Indo-Pacific region. These bands are associated with an assemblage of at least two types of microbial endoliths: *Ostreobium queckettii* a common siphonal chlorophyte and an *Aspergillus*-like fungus. Between algae and fungi we observed a parasitic relationship with the fungus attacking the alga. The algae are usually destroyed, darken and show fibrous excrescences. The fungi then develop dark conidiophores spreading into the skeletal pores. They excrete dark-brown membranous veils that stain the surrounding skeleton. Black bands match high-density bands of the coral skeleton and showed a higher concentration in polysaccharides. Reasons for a seasonal outspread of fungi will be discussed as well as possible consequences for the coral.

***Porites* ULCERATIVE WHITE SPOT DISEASE: A NEW DISEASE IMPACTING INDO-PACIFIC CORAL REEFS.**

Raymundo, L.R.*, A.P. Maypa, T. Reynolds. *Silliman University Marine Laboratory, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

Presented here are results of an investigation of a disease affecting Indo-Pacific corals. Lesions characteristic of *Porites* Ulcerative White Spot Disease (PUWS) are multifocal, round, bleached or full tissue thickness ulcerations, 4 mm in diameter. Seventeen-month field monitoring of 25 diseased colonies and five healthy controls revealed that advanced infections result in lesion coalescence, extensive tissue loss and partial mortality (56% of the colonies) or death. Field transfections showed that 95.5% of lesion-free colonies (n=21) developed lesions within three weeks of continued direct exposure to diseased branches, while 60% of field controls (n=15) remained healthy. Host range of PUWS appears to be common poritids; surveys on 10 Central Philippine reefs revealed that 22%±7% (Mean ±SE) of all poritid colonies displayed clinical signs and 82% of the reefs were infected. Prevalence per species was positively correlated with species density. *Porites* spp. are dominant reef builders; a disease targeting this genus could result in major changes in reef community structure.

PORITES ULCERATIVE WHITE SPOT DISEASE (PUWSD): THE ETIOLOGY AND PATHOGENESIS OF A NEW CORAL DISEASE IN THE CENTRAL PHILIPPINES.

Reynolds, T.*, L. Raymundo, G. W. Smith, K. Barry, N. Wainwright. Tufts University School of Veterinary Medicine, 200 Westboro Road, N. Grafton MA 01536. Email: taylor@splusnet.com

PUWSD is manifested as round, multi-focal to coalescing, full tissue thickness erosions of 3-5mm in diameter. Since 1996 it has been observed in 10 of the commonest *Porites* species in the Philippines. Two putative pathogens were selected, using RFLP analysis and the Biolog™ system, from among bacterial isolates taken from the surface of *Porites attenuata* displaying characteristic lesions. These isolates were later identified by 16s rDNA sequence analysis as a strain closely related to *Vibrio carchariae*, and an undescribed *Vibrio* sp. Exposure of clinically healthy *P. attenuata* to a liquid culture (10^7 CFU/ml) of the *Vibrio* sp. isolate resulted in a transient appearance of lesion-like spots and outright death of entire coral fragments. While Koch's postulates were not satisfied, this evidence suggests that this *Vibrio* sp. may be involved in the disease process. A chemical extract of *P. attenuata* had antimicrobial activity against all coral surface bacteria assayed (n=18), and no activity against reference strains of wild type *Escherichia coli* and *Bacillus subtilis*. Sensitivity to the extract was variable, and the putative pathogens were relatively the most resistant. Histologic preparations of five diseased *Porites* species, viewed with the light microscope, revealed necrotic tissue with filamentous algae, bacteria, and other debris adjacent to ulcerations. Using transmission electron microscopy, filamentous structures resembling viral particles were found.

MICROBIOLOGICAL AND PHYSIOLOGICAL PERSPECTIVES ON CORAL DISEASES: DIVERSITY OF MICROBIAL PATHOGENS AND PATHOGEN/HOST INTERACTIONS

Richardson, Laurie L.*. *Department of Biological Sciences, Florida International University, Miami, Florida 33199, U.S.A. Email: richardl@fiu.edu

Recent research in coral disease etiology has revealed an impressive diversity of microbial pathogens. To date the coral microbial pathogens that have been identified and characterized include single pathogens that are either fungal or bacterial in nature, and microbial consortia that range from highly structured to loosely organized and that may contain phototrophic and heterotrophic bacteria as well as fungi. Accompanying this microbiological diversity, investigators are finding that each coral disease has an etiology that demands not only an integrated approach to the study of the disease, but different combinations of techniques and approaches for the study of each disease. As an example, understanding the complex interactions taking place in black band disease, a highly structured microbial consortium that generates and maintains it's own sulfuretum, has required techniques in microbiology, microsensors, advanced microscopy, microbial physiology, and molecular genetics. Studies of the disease white plague must take into account the sporadic nature of disease outbreaks and the emergence of apparently increasingly virulent strains of a single bacterial pathogen. The field of coral disease etiology has also shown very recent and novel results in the areas of host response to pathogens and environmental stress. Continuing efforts in all of these areas are required to provide the understanding necessary to support management of coral reefs.

A PATHOGENIC AGENT OF CARIBBEAN SEA URCHINS.

Ritchie, Kim B.*. *University of North Carolina, Biology Department, Chapel Hill, NC, 27599-3280. Email: kritchie@email.unc.edu

Although disease related mortalities of marine invertebrates have been reported for the past few decades, the identification of responsible pathogenic agents has often been elusive. A massive die-off of the sea urchin *Diadema antillarum* in the early 1980's ultimately resulted in the devastation of many reefs throughout the Caribbean. The causative agent of this epizootic was never discovered. In January of 1997, a die-off of the sea urchin *Meoma ventricosa* was observed in Curaçao, Netherlands Antilles. A bacterium associated solely with affected tissue was isolated and found to cause identical disease symptoms in the urchin *Lytechinus variegatus*. 16S rDNA analysis identified this bacterial isolate as a new species closely related to *Pseudoalteromonas haloplanktis* subsp. *tetraodonis*, a subspecies known to produce tetrodotoxin in pufferfish. We subsequently showed that the pathogenic isolate produces tetrodotoxin. The discovery of this sea urchin pathogen provides an unusual opportunity to study the range of urchins that this pathogen is capable of affecting. The determination of both the phylogenetic relationship of this urchin pathogen among other marine bacteria, as well as it's host range capabilities, will provide insight into the overall potential threat of this pathogen to other Caribbean marine echinoderms.

VIRULENCE MECHANISMS OF THE CORAL BLEACHING PATHOGEN.

Rosenberg, E.*, E. Banin, M. Fine, Y. Ben-Haim, T. Israely, Y. Loya. *Faculty of Life Science, Tel-Aviv University, Israel. Email: eueqene@ccsg.tau.ac.il

The causative agent of the coral bleaching disease of *Oculina patagonica* is *Vibrio shiloi*. The infection proceeds via the following sequential steps: (1) adhesion of the bacterium to a β-galactoside receptor on the coral surface; (2) penetration of the bacterium into the coral epidermis; (3) multiplication of the bacterium in the coral tissue; once inside the coral epidermis *V. shiloi* converts into a viable but not culturable form and, (4) production of (a) a heat-stable toxic peptide that inhibits photosynthesis of the zooxanthellae and (b) heat-labile toxins that bleach and lyse the algae. These virulence factors are produced at much higher levels when the bacterium is grown at elevated temperatures. These virulence mechanisms will be discussed in terms of the general hypothesis that coral bleaching is the result of temperature-dependent bacterial infection.

PATHOGENS OF CORAL REEF ORGANISMS.

Smith, Garriet W.*. *Department of Biology and Geology, University of South Carolina Aiken, SC 29801 USA, Email: smithres@aiken.sc.edu

A number of bacterial and fungal diseases of corals and reef-associated organisms have been described in the past few years. The increase of these pathogenic relationships are indicative of environmental changes which may have resulted in the introduction of new pathogens, lowered resistance of host organisms, increases in the populations of indigenous pathogens, or other reasons. We have taken a number of approaches to attempt to understand the disease processes associated with reef organisms. One has been to study the normal microbiota and how the composition changes under stressed conditions. Results have indicated there is a microbiota associated with various coral species and that the composition changes under stress. Another approach is to attempt to identify the pathogens involved. Results have ranged from positive identifications to none at all. Other approaches that we are pursuing to understand these diseases are to look at host's responses and the pathogenic mechanisms involved. Some diseases appear to involve toxins while others are still mysteries. Host responses to infection were found with some organisms while others appear unable to respond. While we are just beginning to understand microbiological aspects of reef-associated diseases, the physiological, metabolic, biochemical and molecular aspects remain a challenge.

LOCAL AND GEOGRAPHIC VARIABILITY IN THE INCIDENCE OF DISEASES IN WESTERN ATLANTIC CORAL REEFS.

Weil, E.* I. Urreiztieta, J. Garzón-Ferreira, P.Gayle, DL.Gil-Agudelo, A.Croquer and Sven Zea. *Dept. of Marine Sciences, U. of Puerto Rico, PO BOX 908, Lajas, PR. Email: eweil@caribe.net

The number and incidence of diseases associated with coral reef organisms in the Caribbean have increased in the last decade. However, little is known about the pathogens, the etiology, and the local and geographic variability of most diseases. The CARICOMP disease protocol was used to assess the incidence of coral diseases in 19 reefs from 6 widely separated localities in the Caribbean and Bermuda. Surveys were conducted within a six-month window in 1999 to reduce temporal variability of the data. For each coral species, the number of infected, injured, and healthy colonies were counted in several 40 m^2 band transects in three-four depth intervals in each reef. Results indicate that: (a) BBD, YBD, WP and aspergilliosis were present in all localities; (b) average total disease incidence was overall low (0.78-4.74 %) across the region and increased significantly from north to south; (c) average incidence of each disease was low and varied between depth intervals within reefs, between local reefs, and between geographic areas; (d) aspergilliosis had the highest incidence (0.53-5.39 %) in 4 geographic localities followed by YBD (0.04-2.62), DSD (0.25-3.0), WP (0.19-2.96) and BBD (0.04-0.91); (e) WBD, the infection that reduced acroporid populations to very low levels across the Caribbean in the 80's, showed the lowest average incidence (0.03-0.40) across the region. The role that diseases could play in the dynamics of reef communities and the future of reefs in the Caribbean remains obscure.

Session E8: Coral Reef Non-indigenous and Invasive Species

CORALLIMORPHARIANS AS ALTERNATE DOMINANTS TO STONY CORALS ON DISTURBED INDO-PACIFIC REEFS.

Chadwick-Furman N.E.*. *Interuniversity Institute for Marine Science, P.O. Box 469, Eilat, Israel. email: furman@mail.biu.ac.il

Some corallimorpharians form large aggregations of polyps on shallow coral reefs, often in areas where live stony corals have been removed by disturbances such as low tides, bleaching events, or predation by corallivores. In order to determine how corallimorpharians are able to dominate such areas, we examined patterns of reproduction and competition in the common Indo-Pacific species *Rhodactis (=Discosoma) rhodostoma*. Over 2 years, polyps were observed to spread across reef substratum via a combination of 3 modes of clonal replication, one of which leads to the formation of unattached, floating buds that disperse in the water column. Within clones, polyps segregate functions by position: female polyps occurred in the center, and sterile or male polyps occur along the expanding clonal periphery. Upon contact with live stony corals, peripheral polyps induce the formation of specialized bulbuous marginal tentacles that actively damage coral tissues. This combination of rapid clonal replication, long-distance dispersal via planktonic propagules (broadcast gametes and detached buds), and aggressive damage to contacted corals allows some corallimorpharians to rapidly colonize open reef areas and then kill and overgrow resident corals. Polyps of *Rhodactis* also withstand extreme physical conditions such as exposure to air and high temperatures that kill stony corals during low tide exposures. Large monocultures of non-calcifying corallimorpharians may prevent recolonization of reef surfaces by stony corals, and thus impact the species diversity and accretion rates of some disturbed reefs.

NONINDIGENOUS SPECIES INTRODUCTIONS ON CORAL REEFS: A NEED FOR INFORMATION.

Coles S.L.* and L. G. Eldredge. *Bishop Museum, 1525 Bernice St., Honolulu, HI 19673, USA. Email slcoles@bishopmuseum.org

Nonindigenous species invasions are well-documented sources of environment disturbance in temperate marine areas that have caused disruptions of native communities and detrimental economic impacts to fisheries. However, comparatively little information exists for tropical regions, and even less is known about occurrences and impacts of nonindigenous species in coral reef areas. Studies in the tropics to date have been mostly limited to surveys in harbors and ports where the biota may or may not have a significant component of corals and reef organisms, and environmental conditions are usually quite different from those found on coral reefs. Consequently, there is a need for studies of the presence and impacts of nonindigenous species focused on coral reef environments. This presentation will summarize the information that has been derived for nonindigenous species from harbor and port surveys in Hawaii, Guam and Australia that may be relevant to invasions of coral reef environments and will outline procedures for studies to detect species introductions.

HAWAIIAN MARINE BIOINVASIONS.

Eldredge L.G.* and James T. Carlton. *Bishop Museum, 1525 Bernice Street, Honolulu, Hawaii 96817. U.S.A. Email: psa@bishopmuseum.org

The Hawaiian Islands are so located that they have become the principal port-of-call of trans-Pacific travel during the past 150 years. Six of the 14 transoceanic dispersal patterns from ports in the Pacific pass through the Hawaiian Islands, making the area a major receiver. Nearly 340 species of marine and brackish introduced or cryptogenic species have been recorded from the Hawaiian Islands--290 are invertebrates, 20 fish, 24 algae, and 12 flowering plants, using the established criteria to interpret whether a species is introduced. Among the invertebrates the arthropods and the annelids are the most speciose groups. Introductions into the Hawaiian Islands has been either accidental involving fouling and ballast water or intentional through aquaculture or stock enhancement. Fouling and ballast water introductions accounts for about half of all the invertebrates reported; the introduction pathway of many species is unknown. For most species the geographic region of origin is unknown; however, many species are considered cosmopolitan or originate from the broader Indo-Pacific or the Caribbean/Atlantic Ocean. Some now considered as introduced were originally described from the Hawaiian Islands. The dates of introduction are, for the most part, unknown; there are spikes in recognizing introduced species in the 1930s/1940s, 1960s, and 1990s. These dates are primarily a reflection of collecting effort, following periods of increased maritime activities.

THE DISTRIBUTION AND DIVERSITY OF TROPICAL AUSTRALIAN MARINE INVASIONS.

Hewitt C.L.*. *CSIRO Centre for Research on Introduced Marine Pests (CRIMP), GPO Box 1538, Hobart, Tasmania, AUSTRALIA 7001. Email: chad.hewitt@marine.csiro.au

Marine invasions have been identified in virtually all regions of the world, yet relatively few introductions have been detected in the tropics. In part this may be due to an increase in intrinsic native community resistance due to high(er) diversity systems providing strongly interacting food webs. However, recent evidence from surveys in Australia and elsewhere indicate that tropical systems are also susceptible, though detection ability may be limited due to taxonomic difficulties. Preliminary analyses of both literature based and survey information support the pattern of decreased invasion success in higher diversity systems with a strong latitudinal gradient at the mesoscale of Australia. This supports the hypothesis of a decreased relative susceptibility of tropical versus temperate biota to invasions, but confounding factors may include differing vectors and availability of source bioregions.

AN ASSESSMENT OF THE POTENTIAL EXOTIC SPECIES INTRODUCTIONS INTO TROPICAL MARINE COMMUNITIES, WITH SPECIAL REFERENCE TO THE INDO-PACIFIC.

Hutchings, Pat* Rob Hilliard and Steve Coles. *The Australian Museum, 6, College Street, Sydney NSW 2010 Australia. Email: path@austmus.gov.au

Introductions of exotic marine organisms by hull fouling or by ballast water have occurred extensively in temperate areas, often with substantial negative impacts. However, the limited information available suggests that far fewer introductions leading to pestly invasions have occurred in the tropics. A 1997 risk assessment study of twelve Queensland (Australia) ports concluded that the potential for exotic introductions by ballast water was low, and results from recent port surveys in tropical Australia are supporting this conclusion. In contrast, recent surveys of harbours in Hawaii have found many introduced species. We suggest that the geographically isolated and more restricted marine biota of Hawaii are more susceptible to introductions than those of tropical Australia, with the latter being more diverse and already containing widely distributed Indo-Pacific species, thereby limiting their susceptibility to pest invasions. Also, the location of Hawaii in the central Pacific and its long history of receiving world-wide commercial and naval shipping (including more heavily fouled vessels than contemporary merchant ships) may also be a key factor. Hull-fouling rather than ballast water appears to be the vector of the recent introduction of the highly invasive black striped mussel Mytilopsis sallei from an international cruising yacht into enclosed (lock-gate) marinas in Darwin. The cost of eliminating this pest (>U$1.6 million) underscores the importance of managing not just commercial shipping but also pleasure craft, fishing boats and naval ships as vectors of exotic species to ports, harbours and marinas in coral reef areas.

NONINDIGENOUS ASCIDIANS IN TROPICAL WATERS.

Lambert G.*. *Dept. of Biol. Sci., Calif. State Univ., Fullerton, CA Email: 92834 glambert@fullerton.edu

Ascidians are sessile filter feeding invertebrate chordates with a rapid growth rate and usually a short life span, long breeding season and production of large numbers of short-lived non-feeding planktonic larvae. Larvae in ballast water and adults on ship or barge hulls may survive transport over thousands of miles to harbors similar to the ones they left. Marina floats, pilings, buoys and boat bottoms provide vast surface areas often rapidly colonized by nonindigenous ascidians (NIA) that may then become permanently established, providing a large local source for possible invasions into nearby natural marine communities. Invasive ascidians also impact aquaculture operations, which are often located in or near bustling harbors. Recent reports document overgrowth of cultivated shellfish by NIA which thus become a source for further invasions. NIA tolerate wide fluctuations in temperature, salinity, and even pollution. Data and photos of harbor structures in Hawaii, Guam, Palau and other Indo-Pacific areas, and recent U.S. Navy drydock movements between major Pacific ports will be discussed. Some of these studies include companion surveys of neighboring coral reef and other natural shallow environments. Serious invasion of coral reefs by NIA has not yet been reported but more studies are needed. In the tropics, centers of human activity are often adjacent to rich reefs.

NON-INDIGENOUS REEF FISHES IN THE SOUTHWESTERN ATLANTIC,

Moura, Rodrigo L.*, *Museu de Zoologia, CP 42694 Universidade de São Paulo, 04299-970 São Paulo SP Brazil, Email: rlmoura@usp.br

Species introductions are a widely recognized problem in terrestrial ecosystems and a potential source of deleterious impact on reef habitats. The presence of two fish species are reported here as a contribution to the network that is currently being developed to monitor non-indigenous species on reef habitats. During the summers of 1999 and 2000, at least three adult individuals (~35cm SL) and two smaller individuals (~20 cm SL) of the surgeonfish *Acanthurus monroviae* (Acanthuridae) were regularly observed at Laje de Santos, São Paulo State, Brazil (24°20'S). These multiple sightings indicate more than one colonizing or recruitment event. Additionally, this surgeonfish (one adult ~35cm SL, summer 2000) was observed at Papagaios Island, Rio de Janeiro State, Brazil (22°53'S). Golani and Sonin (Aqua 1996, v.2) also recorded this species from the Mediterranean in 1994. The second introduction reported herein is *Heniochus acuminatus* (Chaetodontidae), native from the Indo-W. Pacific. One individual (~20 cm SL) was sighted at Cape Buzios (22°46'S), Rio de Janeiro State, in summer 1999. Any further records of these species would provide valuable information on their capabilities along the Brazilian coast.

INVESTIGATION OF INTERACTIONS BETWEEN AN INTRODUCED SNAPPER AND NATIVE SNAPPERS IN A DEEP-WATER FISHERY.

Parrish, J.D., Aeby, G.S., Conklin, E.J., Ivey, G.L. *Hawaii Cooperative Fishery Research Unit (U.S. Geological Survey), 2538 The Mall, University of Hawaii, Honolulu, HI USA. Email: jparrish@zoology.hawaii.edu

Since its introduction to Hawaii in 1955, the blue-line snapper (taape) *Lutjanus kasmira* has multiplied rapidly and spread widely to include the full archipelago and depths to hundreds of meters. Concern has been expressed about negative interactions with native eteline snappers in the large local fishery. This project investigated cooccurrence of taape and native snappers in the habitat by commercial line fishing methods and by observation using submersibles. Taape were seldom caught or seen with the native snappers and were not common at depths where most native snappers were commonly found. Comparison of gut contents of taape and the native snappers showed considerable overlap at high systematic levels of prey, but little specific evidence of predation by one group on the other or strong indication of potential competition for food resources. Increased interaction may occur if taape become more numerous or move deeper.

ANTHROPOGENIC BIOTIC INTERCHANGE IN A CORAL REEF ECOSYSTEM: A CASE STUDY FROM GUAM.

Paulay, G.*, L. Kirkendale, G. Lambert, C. Meyer. *Marine Lab, University of Guam & Florida Museum of Natural History, University of Florida, Gainesville FL 32611 USA, Email: paulay@flmnh.ufl.edu

Guam is the administrative and economic hub of Micronesia, hosts one of the largest US military bases in the Pacific, and lies at the crossroads among Pacific islands, US, and Asia. Although terrestrial introductions, exemplified by the brown tree snake, have received much attention, marine introductions have been little studied until now. We have documented a diverse assemblage of marine species brought to Guam by human transport − a few intentionally, most unintentionally. Many invaders have circumtropical distributions and their source remains to be determined, others clearly arrived from the west Pacific, Hawaii, and the Atlantic. The majority of nonindigenous species have remained confined to artificial substrata in the harbor, but some have invaded adjacent coral reef habitats and spread island-wide. Some taxa, like hydroids, appear to have spread more readily into natural habitats than others, like ascidians and sponges. Although several nonindigenous species are now well established, major impacts to reefs on Guam remain to be identified. Space on reefs is vastly dominated by indigenous species; in contrast artificial substrata are often dominated by invasive taxa. Because of Guam's tourism-based economy, ballast water is not a major source of introductions, but shiphulls have brought many invaders. A study of the fauna associated with two drydocks demonstrate the large impact of such structures, moved slowly from harbor to harbor after long residence times.

ALIEN ALGAE IN HAWAII: CURRENT DISTRIBUTION AND UNIQUE ECOLOGICAL CHARACTERISTICS.

Smith, Jennifer*, Celia Smith and Cynthia Hunter. Department of Botany, University of Hawaii Manoa, 3190 Maile Way, Honolulu HI, 96822, USA. Email: jemith@hawaii.edu

Some nineteen species of macroalgae have been introduced to Oahu, Hawaii since 1950 with at least four of these species being highly successful. Some of these nonnative species appear to have spread throughout all of the main Hawaiian Islands, while others are only found on Oahu. Quantitative and qualitative surveys were conducted on five of the main Hawaiian Islands to document the current distribution of alien algae and to assess the level of impact that these plants pose to Hawaii's marine ecosystems. Maps were generated to examine the spread of these species from the initial site of introduction and to assimilate information regarding habitat characteristics that appear to make some sites more susceptible to invasion than others. Many alien species possess characteristics that allow them to become invasive or weedy, forming monospecific stands thereby, altering community structure and species diversity. Asexual reproduction, herbivore resistance and other physiological strategies may all influence the success of a given alien species. Vegetative propagation via fragmentation, nutrient uptake and grazing pressure were examined for four of the most successful alien species of algae in Hawaii. This research demonstrates that some species of alien algae that have been introduced to Hawaii possess novel competitive strategies and unique ecological characteristics that may allow them to become highly successful.

PROLIFERATION OF THE BROWN ALGAE *TURBINARIA ORNATA* ONTO THE CORAL REEFS OF FRENCH POLYNESIA: ITS SETTLEMENT IN MORUROA ATOLL (TUAMOTU ARCHIPELAGO).

Stiger, V. and C.E. Payri* *Université de la Polynésie Française - B.P. 6570 FAAA/aéroport, Tahiti, Polynésie Française. Email Payri@ufp.pf

Turbinaria ornata is one of the most obvious macroalgae on Polynesian reefs. During the past 20 years, this species has invaded the coral reefs surrounding several volcanic high islands and extended its distribution to remote atolls. The long-distance dispersal by drifting thalli appears to be the mean through which the neopropagules of *T. ornata* reach new habitats. The settlement of the population is locally controlled by short-distance dispersal of germlings released by attached thalli. The natural settlement of *T. ornata* in Moruroa reef was followed for 16 months at a permanent station. The recruitment was continuous throughout the study period, and recruits settled primarily around parent thalli. Survival varied spatially and temporally among recruits, juveniles and mature plants. At the end of the study a density equilibrium was reached, probably due to a substrate limitation. These results suggest that recruitment from germlings play a significant role in buffering high rates of mortality in adults and contribute to the invasion and the success of *T. ornata*.

DO LOCALS RULE? INTERACTIONS BETWEEN NATIVE INTERTIDAL ANIMALS AND A CARIBBEAN BARNACLE ON OAHU, HAWAII.

Zabin, Chela J.*. *Kewalo Marine Laboratory and University Of Hawaii, Zoology Dept., 41 Ahui St., Honolulu, HI 96813. Email: chela@hawaii.edu

Chthamalus proteus, a high intertidal barnacle from the Gulf of Mexico and Caribbean, is one of the most conspicuous recent introductions to Hawaiian waters. Although this barnacle can attain nearly 100 percent cover on hard substrate in harbors and quiet lagoons, its local distribution appears to be limited in semi-protected waters where it comes into contact with a native barnacle, *Nesochthamalus intertextus*, and a native pulmonate limpet, *Siphonaria normalis*. In Waikiki, individuals of *N. intertextus* far outnumber *C. proteus* and frequently overgrow or undercut them. To determine whether native barnacles are effectively controlling the abundance of the invader, I removed native barnacles from 10 permanent quadrats along a seawall. I have been tracking growth, recruitment and mortality of *C. proteus* in the removal plots and in 10 control plots since October, 1999. *C. proteus* is particularly abundant in Kaneohe Bay, on Oahu's windward side. A survey of a seawall at Coconut Island in Kaneohe Bay showed that the barnacles were less abundant sections of the wall made up of smooth, light-colored rock, and in places where densities of the native limpet, *S. normalis*, were high. Field experiments have been set up to determine if the invasive barnacle has settlement preferences for different rock types and whether the presence of *S. normalis* affects recruitment and/or post-settlement mortality of the barnacle.

Session E9: *Acanthaster* and *Drupella* on Reefs

RESPONSES BY CORALLIVOROUS DRUPELLIDS TO BLEACH-INDUCED CHANGES IN CORAL SPECIES COMPOSITION.

Abeysirigunawardana M.D. and S.U.K. Ekaratne.* *Dept. of Zoology, University of Colombo, Colombo 3, Sri Lanka.

The Hikkaduwa Marine Reserve lagoon in Sri Lanka has *Drupella cornus* (Röding) as the common corallivorous gastropod. The common coral species *Acropora formosa* served as primary host in a drupellid-coral predator-prey relationship. Prior to April 1998 bleaching, *D. cornus* clusters, as numbers per coral head, on *A. formosa* and *Montipora aequituberculata* (as secondary host) were 9±1 and 2±0, respectively. On *A. formosa* bleaching, its predator clusters decreased to 4±1 but increased to 10±1 on *M. aequituberculata*. With post-bleaching 100% mortality of the primary host, a new secondary host (*Pocillopora eydouxi*) began to support clusters of 3±0. *M. aequituberculata* now assumed a primary host role though predator clusters remained unchanged. Host predator-size distributions also recorded changes. Prior to bleaching, widest predator size (shell height) range (4.9 to 36.0mm) was found on *A. formosa* whereas *M. aequituberculata* did not support drupellids below 19.9mm or above 24.4mm. With bleaching, however, *A. formosa* no longer supported predators below 21.9mm. Following *A. formosa* mortality, predator sizes supported by *M. aequituberculata* increased to include the entire range of predator sizes that *A. formosa* had supported as earlier primary host. The new post-bleach secondary host, *P. eydouxi*, supported only a narrow range of predators (20.5 to 28.2mm) as did the earlier secondary host, *M. aequituberculata*. Support from MacArthur Foundation, Biodiversity Support Program and GEF is acknowledged.

RELATIVE GENETIC ISOLATION OF RED SEA POPULATIONS OF CROWN-OF-THORNS STARFISH (*ACANTHASTER PLANCI*).

Benzie, J.A.H.*, De Vantier, L., Turak, E. Ballment, E. and Peplow, L. *Australian Institute of Marine Science, PMB No 3, Townsville, Queensland 4810, Australia. Email: j.benzie@aims.gov.au

Molecular analyses are revealing new insights into marine biogeography worldwide, and increasingly in the Indo-Pacific region. However, there is still little known of the genetic relationships of populations of marine species from the Red Sea and those elsewhere, despite the interesting evolutionary questions surrounding the origin and evolution of the Red Sea fauna. Colour differences between Red Sea populations of *A. planci* and those from elsewhere in the Indian Ocean raise questions concerning the origin and source of the Red Sea populations of this important coral predator. *A. planci* from the Northern Indian Ocean are blue to pale-(pinkish) red while those from the Pacific and Western Australia are grey-green to red-brown. Genetic differentiation between these colour morphs from the Indian and Pacific Oceans is high. Starfish from the Red Sea have the grey-green to red-brown colour normally associated with Pacific animals. Allozyme and mitochondrial DNA data show unequivocally that the Red Sea population is associated with from northern Indian Ocean populations, but the mtDNA haplotype from the Red Sea is basal to those from the northern Indian Ocean. This indicates that the Red Sea population was isolated before the Northern Indian Oceans genotypes evolved. The Red Sea population had low genetic variation consistent with a bottleneck or founder effect, and is highly divergent from the other northern Indian Ocean populations.

DYNAMICS OF A CROWN-OF-THORNS STARFISH OUTBREAK ON A MARGINAL CORAL COMMUNITY, TWO-MILE REEF, SODWANA BAY, SOUTH AFRICA.

Celliers L.* and Schleyer, Michael H. *Oceanographic Research Institute, P.O. Box 10712, Marine Parade 4056, Durban, South Africa. Email: seaworld@dbn.lia.net.

Increasing interest is being expressed in marginal reef systems as opposed to reefs in which abundant carbonate accretion occurs. Marginal reefs present opportunities to elucidate reef processes and systems without the "background noise" of carbonate accretion. The coral communities situated offshore on the coast of Maputaland are the southern-most in Africa. They are unique not only in structure but also in composition. During the 1990s, one of the reefs at Sodwana Bay was subjected to a crown-of-thorns starfish (COTS; *Acanthaster planci*) outbreak. This was limited to the fore-reef environment of Two-Mile Reef (TMR) but the damage was extensive (hard coral cover was reduced from 34 % to 18 %). The present study showed that the event was attributable to a secondary outbreak by a transient population of COTS introduced from higher up in the regional system. The local COTS population was characterised by the dominance of two year-classes (spine pigment band counts) and limited recruitment. The maximum population size at the peak of the outbreak was in excess of 150 COTS and there has been a slow decline in numbers since then. The outbreak appears to have changed the community structure of the fore-reef. Affected regions have shifted from a mixed hard and soft coral community to a reef dominated by soft corals.

PREDATION ON STAGHORN CORAL *ACROPORA TUMIDA* BY CORALLIVOROUS GASTROPOD *DRUPELLA RUGOSA* IN TUNG PING CHAU, HONG KONG.

Choi M.M.*, Choi, L.S., and P.O. Ang, Jr. *Department of Biology, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China.

Monitoring of corallivorous gastropod activities on corals in Tung Ping Chau, a proposed marine park in Hong Kong, started in September, 1999. *Drupella rugosa* was identified as the most dominant corallivorous species which preferred to feed on the staghorn coral *Acropora tumida*. Aggregation density of these gastropods was highest in summer (Sept, 1999 at 28-32 individuals/m^2) and lowest in winter (Dec, 1999 at 0-4 individuals/m^2). The reappearance of these gastropods in March, 2000 was not associated with an increase in the number of smaller individuals, suggesting that their reappearance was not a result of spring recruitment. Their "disappearance" during winter may simply be due to their low activity under colder winter temperature (min 14°C) that most of them were hiding under rock or inside crevices. Signs of *Acropora tumida* tissue regrowth over the damaged areas were observed when the gastropods disappeared seasonally. However, colonization by filamentous algae deterred tissue regrowth. Survival of these staghorn corals ultimately depends on a balance between the rates of predation, the apical growth of their branches, tissue regrowth on damaged area, and algal colonization on exposed skeleton.

FINE-SCALE SURVEYS OF CROWN-OF-THORNS STARFISH (*Acanthaster planci*) PROVIDE EARLY WARNING SYSTEM OF RENEWED AND EMERGING STARFISH OUTBREAKS.

Engelhardt U.*, *Reefcare International Pty Ltd, PO Box 1111, Townsville, Queensland 4810, AUSTRALIA. Email: reefwatch@ozemail.com.au

On the Great Barrier Reef (GBR), intensive transect-based surveys of crown-of-thorns starfish (*Acanthaster planci*) have been used successfully to predict emerging *A. planci* outbreaks some two years prior to reaching their peak of intensity. In 1998-99, fine-scale surveys conducted on 20 mid-shelf reefs in the central GBR region detected a large and geographically widespread recruitment pulse of *A. planci* in an area covering some three degrees of latitude. Based on the early detection of this recruitment pulse, new outbreaks were predicted to develop across the survey area within 18 to 24 months. Analyses of 'pseudo-cohorts' estimated from size-frequency data suggests that the recruitment pulse was the result of the 1997-98 spawning season of *A. planci*. Juvenile starfish (1+ years) were found predominantly in front reef zones with a high degree of exposure to the dominant southeasterly trade winds. Re-surveys in 1999-00 have confirmed earlier predictions with many survey reefs now harbouring unsustainably high densities of sub-adult (2+ years) starfish likely to develop into renewed active outbreaks. As many of the now affected reefs had already experienced *A. planci* outbreaks in the mid-1990's, the predicted renewed outbreaks are suggesting a possible departure from the previously recorded outbreak interval of 15-17 years. A significant shortening of outbreak periodicity could have serious consequences for hard coral recovery and the long-term sustainability of the observed phenomenon.

LARVAL RECRUITMENT AND DYNAMICS OF CORAL COMMUNITIES FOLLOWING AN *ACANTHASTER* OUTBREAK.

Hiroyuki Y.*. *Iriomote Marine Research Station, Tokai University, 165 Sakiyama, Taketomi-cho, Yaeyama-gun, Okinawa, 907-1543 Japan. Email: yokochi@scc.u-tokai.ac.jp

Following an *Acanthaster* infestation in the early 1980's, there were significant differences in the recovery of coral communities at Iriomote Island in the southern Ryukyu Islands. In 1992, I began studying the dynamics of the coral communities and larval recruitment onto settlement plates at five selected sites in and around Amitori Bay: three rapidly recovering sites and two slowly recovering ones. The intensity of larval recruitment varied greatly among sites and years. *Acropora* was the dominant recruit, and was also dominant in the coral communities of the rapidly recovering sites. After a heavy settlement of *Acropora* in 1994, coral density and cover increased rapidly at the two slowly recovering sites. Recruitment and growth was predominantly by *Acropora* species, and successful recruitment of *Acropora* has been the main reason for their improved rate of recovery. After a typhoon in 1997, the coral cover and density at exposed sites decreased significantly, with acroporids suffering the greatest mortality. The coral cover at the most sheltered site also decreased due to the unexplained death of *Acropora*. A severe bleaching event in 1998 also caused high coral mortality, especially in *Acropora*, at the three *Acropora*-dominated sites: one had maintained high coverage since the beginning of this study and the other two had been recovering rapidly after the heavy recruitment in 1994.

HISTORICAL PATTERNS AND CURRENT TRENDS IN THE BROADSCALE DISTRIBUTION OF CROWN-OF-THORNS STARFISH ON THE GREAT BARRIER REEF.

Miller IR*. *Australian Institute of Marine Science, PMB 3, Townsville MC, Qld 4810 Australia. Email: i.miller@aims.gov.au

The Great Barrier Reef (GBR) is experiencing a third recorded series of crown-of-thorns starfish (COTS) outbreaks. Current trends in the broadscale distribution of COTS appear to follow the pattern of the last two series of outbreaks recorded from 1966 to 1974 and 1979 to 1991. As before, the first outbreaks in this current series were observed in the Cooktown/Lizard Island sector in 1993 and 1994. COTS activity in this sector continued to increase until 1999, but has since declined. COTS outbreaks were subsequently observed in the Cairns and Innisfail sectors in 1997 and the Townsville sector in 1999. Since then, COTS activity in the Cairns and Innisfail sectors has continued to increase. Recent surveys have found COTS of more than one distinct size-class, suggesting that there have been several pulses of recruitment on reefs in the Cairns and Innisfail sectors over a number of years. The current pattern of outbreaks is consistent with the hypothesis that COTS outbreaks have their genesis in the Cooktown /Lizard Island sector (north of 16° S) and then cascade southward down through the GBR reef mosaic in subsequent years and generations. This pattern of outbreaks is also qualitatively consistent with numerical models of hydrodynamics and larval dispersal that have previously been used to simulate the large-scale population dynamics of COTS. Implications for reefs currently affected and those recovering from previous COTS outbreaks are discussed.

OUTBREAK OF CROWN OF THORNS STARFISH IN THE RAS MOHAMMED NATIONAL PARK: ROLE OF LARVAL DISPERSION AND FISH PREDATORS.

Salem M.* & Ormond R.F.G. *Ras Mohammed National Park, South Sinai, Egypt. Email: mohammedsalem@hotmail.com

Since 1998 outbreaks of the Crown-of-thorns Starfish (*Acanthaster planci*) have affected many reefs within the Egyptian Red Sea. In that year large aggregations were detected on 18 reefs extending from the Straits of Tiran to the main Egyptian coast, and >40,000 animals were collected by Park rangers and volunteers. We investigated the age composition of populations on different reefs by both size-frequency analysis and counts of pigment rings visible in longitudinal sections of spines. These showed that the oldest populations were present near Ras Mohammed itself, slightly younger populations on reefs about 20 km to the north, and the youngest further north in the Straits of Tiran. This suggests that the wider outbreak was a consequence of a small primary outbreak observed on reefs near Ras Mohammed in 1994. Subsequently further outbreaks of starfish have been reported on reefs in southern Egypt, and in Saudi Arabia, east of Tiran. This pattern is consistent with the view that successive outbreaks occurred as a result of successive waves of larval dispersion. On several occasions predation by the large triggerfish (*Balistoides viridescens*) was observed first hand. The fact that the area where the primary outbreak occurred was that where a special fishery for emperor bream, a suspected key predator of the starfish, was permitted, supports the view that a reduction in the number of fish predators may be a key factor promoting outbreaks.

THE GROWTH OF INDIVIDUAL ADULT SPECIMENS OF *ACANTHASTER PLANCI* IN POPULATIONS OF LOW DENSITY.

Souter David*. *Department of Zoology and Entomology, The University of Queensland, St. Lucia, Qld, 4072. Australia. Email: souter@pi.se

Little contention surrounds the sigmoidal mode of growth of *A. planci* prior to the achievement of sexual maturity. However, descriptions of the growth of adult starfish are available only from specimens maintained in the laboratory. Few repeated measurements of size have been obtained from starfish in the field. As a consequence, the growth of adult *A. planci* has been the subject of considerable debate. At three reefs in the southern Great Barrier Reef, repeated measurements of the growth of 59 individual adult specimens of *A. planci* ranging in size between 28 cm and 59 cm were obtained throughout a period ranging between 65 and 1249 days. The growth of these starfish was extremely plastic. Rates of growth ranged between –2.7 mm_month^{-1} and 4.4 mm_month^{-1}. Consistent growth, stasis or shrinkage throughout the study was rare. Most starfish exhibited periods of growth and/or shrinkage interspersed with periods of stasis that lasted as long as 700 days. Although, the rate of growth declined in larger starfish, in some smaller starfish the exponential phase of growth extended well beyond the onset of sexual maturity and was maintained until the starfish attained a diameter of at least 37.5 cm. Also, significant growth was recorded from several starfish exceeding 55 cm in diameter. The retention of the capacity to grow throughout their size range and the ability to maintain large sizes for extended periods proves that senility does not exist in starfish in the field and that the growth of *A. planci* is indeterminate with the size of the starfish fluctuating according to factors such as food availability, physiological state and population density.

LONG-TERM (17YR.) IMPACTS OF CROWN-OF-THORNS OUTBREAK AND LOSS OF LIVE CORAL COVER ON REEF FISH COMMUNITIES (CENTRAL GREAT BARRIER REEF)

Williams, David McB.* & Peter J. Speare. *Australian Institute of Marine Science, PMB No 3, Townsville MC, QLD 4810, Australia. Email: d.williams@aims.gov.au

Fish and coral communities on semi-exposed reef slopes of three mid-shelf reefs of the central Great Barrier Reef experienced a severe crown-of-thorns outbreak in early 1983 that reduced live hard coral cover from approximately 65% to much less than 5% over a period of 6 months to 3 years. In study sites (0-7m below the reef crest) live coral cover remained at less than 10% until 1990 but had recovered close to pre-outbreak cover by 1996. Live coral cover was significantly reduced in 1997 by a severe cyclone, recovered in 1998 and reduced again in 1999 by an uncertain cause. The abundances of 125 species of reef fish from 7 families (labrids, pomacentrids, chaetodontids, acanthurids, scarids, siganids and caesionids) were monitored annually on these sites from 1983 until the present. The large changes in amount of live coral cover over this period had a significant impact on the fish community as a whole but most species were relatively unaffected. The abundances of algal grazing species did not increase with a massive increase in the availability of turf algae. Most species that are obligate live coral feeders decreased with the loss of live coral and recovered as live coral cover increased. A few other species whose juveniles recruit only to live coral also decreased and then recovered, despite the adults having no other obvious dependence on live coral. The resilience of the fish communities may be related to the maintenance of the coral structure despite the death of the corals.

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OCCURRENCE OF A GIANT *PORITES* COLONY IN ASSOCIATION WITH HOLOCENE CORAL REEF EVOLUTION.

Abe, Osamu *; Yamano, Hiroya; and Matsumoto, Eiji.
Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya 464-8601, Japan. Email: oabe@ihas.nagoya-u.ac.jp

A trench excavated across a modern coral reef to construct a harbor is one of the best locations to investigate the Holocene evolution of coral reefs. We examined the facies and the structure outcropped on a trench wall of a leeward reef of Ishigaki Island, southwest Japan. We collected fossil coral specimens from the outcrop. The reef framework facies and the transported rubble facies were identified. Furthermore, in this trench, we found a massive fossil *Porites* colony about 5.5 m in height at a distance of around 75-80 m shoreward from the reef edge, where the wall was fully composed of this *Porites*. Vertical drilling was done to measure the growth rate of the coral through annual bands. Based on these observations and ^{14}C dating of the collected fossil corals by the accelerator mass spectrometry, we will discuss the paleo-environment and the growth rate of this huge *Porites* in association with the Holocene evolution of this reef consisting of both *in situ* grown corals and coral rubbles transported potentially by typhoon or tsunami events.

A STUDY ON CHARACTERISTIC DISTRIBUTION OF LARGE FORAMINIFERS ON THE CORAL REEFS IN ISHIGAKI ISLAND , THE RYUKYU ISLANDS , JAPAN

Abe, Teruko *, Komazawa Univ. High School, Setagaya, Tokyo Japan_terua@komazawa.com

The relationship between the topography of coral reefs and distribution of 3 species of large foraminifers , *Baculogypsina sp.* , *Calcarina sp*. and *Marginopora sp*. on a fringing reef was investigated Ishigaki Island , the Ryukyu Islands. Two zones ; a reefflat type (Pishi type) and a moat-reefflat type(Pishi-Ino type) were identified and a total of 16 samples were collected. All sand and algae in a quadrat (20cm x 20cm) ware collected by hand. The methods used to preserve and sort foraminifers are described in details. *Baculogypsina sp*. is the most widespread and was present in every sample. *Calcarina sp*. and *Marginopora sp*. , however , were less common.

HOLOCENE OSCILLATIONS IN WESTERN PACIFIC SEA SURFACE TEMPERATURE.

Abram N.J.*, P.J. Davies, J.M. Webster and W-Chr. Dullo. School of Geosciences, Division of Geology and Geophysics, The University of Sydney, Australia 2006. Email: Nerilie.Abram@anu.edu.au

The Holocene (10,000 years BP to present day) is an important period in earth history as it represents the time in which our modern day climate systems were established. Studies of Holocene environmental variations are essential for the development of an accurate and long term understanding of the dynamics of world climate. In turn, this knowledge provides one of the only real prospects of accurately predicting future climate change and its likely effects on global ecosystems. Here we present the high resolution proxy sea surface temperature records derived from six Holocene *Porites* cores collected from the raised Holocene reef terraces of Kikai-jima, Japan. These records document fluctuations in mean sea surface temperatures of almost 3.5°C over the period 6080 years BP to modern day. Significant changes in seasonal SST range and inter-annual variability are also preserved in the sea surface temperature records, and provide insights into the Holocene dynamics of the Asian Monsoon and El Niño Southern Oscillation.

A COMPACT, PORTABLE SEDIMENT CORING SYSTEM FOR DEEP LAGOONS.

Adachi H.*, H. Yamano, H. Kayanne, F. Matsuda, and Y. Tsuji. Geoact, Co., Ltd., 493-5 Higashi-Ainonai, Kitami, Hokkaido 099-0878, Japan. Email: geoact@poplar.ocn.ne.jp

Lagoon floor situated at a depth of greater than 50 m from the sea surface is quite difficult to access. Thus, deep lagoon sediment studies have mainly been conducted on the surface sediments by means of dredging, and sedimentation of deep lagoons has been poorly understood. We developed a compact sediment coring system which can be used for deep lagoons without aid of divers. Using this device, we have succeeded in collecting sediment cores up to 60 cm in length from the lagoon floor whose depth was 58 m in maximum value. A coring tube ca. 80 cm in length and 55 mm in diameter is vibrated by a water-proofed electric hammer. The tube and hammer is set at the center of a trigonal pyramid constructed by aluminum pipes ca. 1.5 m in length, which equipment enables the tube to be set vertically on the lagoon floor. The electric power is supplied from a generator set on a boat. This coring system is connected to the boat by a stainless wire for lifting the device and by an electric wire for supplying the electric power. The total weight of this system is ca. 80 kg, which can be separated and packed into four trunks. So, the system can easily be transported by an airplane to a remote coral reef which needs a lot of time to access by a research vessel. This system should be very useful to extract the history of sedimentation of unconsolidated grains, especially at deep lagoons.

SKELETAL VARIABILITY OF *Favia gravida* (VERRILL, 1868) FROM BRAZIL.

Amaral, F. D.* *Universidade Federal Rural de Pernambuco, Departamento de Biologia, Av. Dom Manoel de Medeiros, s/n, Dois Irmãos, Brazil. Email: famaral@nelore.npde.ufrpe.br

The skeletal variability of *Favia gravida*, a species endemic to Brazil, was quantitatively described among populations from three locations including, Abrolhos (Bahia State), Santa Cruz (Espírito Santo State) and Tamandaré (Pernambuco State). Ten colonies were collected from each population and fourteen morphological characters were measured from ten corallites per colony. The results of univariate and multivariate analyses provide evidence to suggest that *F. gravida* has considerable morphological plasticity, which may explain its ability to adapt to different ecological conditions. The species also displays polymorphism within and between colonies of each population. Number of septa per cm, centers per 9 cm^2, and corallites per meander were found to differ significantly among populations. Canonical discriminant analysis showed that the population farthest offshore (Abrolhos) was distinct from the other two (Tamandaré and Santa Cruz), which were more influenced by terrigenous sediments. Specimens from Santa Cruz displayed the highest degree of meandrinization. Intercolony variation within populations was also found to be significant for most of the variables measured.

NEW FINDINGS ON CORALS AND HYDROCORALS FROM THE MARINE STATE PARK OF THE MANUEL LUIZ PARCEL (MARANHÃO STATE).

Amaral, F. D.*; Hudson, M. M. and Coura, M. F. *UFRPE, Departamento de Biologia, Brazil. Email: famaral@nelore.npde.ufrpe.br;

The aim of this work was to collect information on the diversity of corals and hydrocorals from the Manuel Luiz Parcel (00° 46'S, 44° 15'W). Specimens were collected in June 1998 from depths ranging between 20 and 30 m and transported to the "Laboratório de Ambientes Recifais" at the Federal Rural University of Pernambuco. Samples were cleared in a solution of 30% sodium hypochlorite, dried and then analyzed in stereoscopic microscope equipped with a micrometric eyepiece. Data collected from corals included the growth form, corallite diameter, number of centers per cm^2, height of outer columella and total number of septa. Information on the growth form, surface texture, dactylopores, gastropores and ampullae were recorded from the hydrocorals. Of 12 collected species of scleractinian corals, there were measured and/or counted 10 corallites per each colony. Of 3 studied species of *Millepora*, 25 dactylopores and gastroporores were measured in each sample. All data were submitted to the statistical analyses. The observed corals-hydrocorals and their sample quantities were: *Agaricia agaricites*- 3 samples, *A. fragilis*- 3, *Favia gravida*- 1, *F. leptophylla*- 7, *Madracis decactis*- 12; *Meandrina braziliensis*- 5, *Montastrea cavernosa*- 3, *Mussismilia hispida*- 6, *Porites astreoides*- 5, *P. branneri*- 5, *Scolymia wellsi*- 8 and *Siderastrea stellata*- 8; *Millepora alcicornis*- 5, *M. braziliensis*- 11, *M.* sp.- 12 and *Stylaster roseus*- 1. *M.* sp. is an unidentified species and is being described at the LAR/UFRPE. The geographical distribution of 15 species was enlarged.

CNIDARIANS OF SAINT PETER AND ST. PAUL ARCHIPELAGO, Northeast Brazil.

Amaral F. D.*, M. M. Hudson, F. L. Da Silveira, A. E. Migotto, S. M. Pinto And L. Longo *Ufrpe, Departamento De Biologia, Brazil. Email: famaral@nelore.npde.ufrpe.br

The objective of this study was to collect information on the diversity of cnidarians from the saint peter and st. Paul archipelago, a remote group of rocks lying just north of equator (0º56'n; 29º22'w), located 960 km off the brazilian coast. Most collections were made by scuba diving, but snorkeling was also used. Specimens were collected in august 1998 and in june 1999 from depths between 0 and 45 m, by hand or using chisels and hammers. Anemones and zoanthids were anaesthetized in a 1:1 solution of 7.5% of $mgcl_2$ solution and seawater and preserved in 4% formaldehyde solution in seawater. Coral skeletons were cleared in a solution of 30% sodium hypochlorite, dried and then analyzed under a stereoscopic microscope equipped with a micrometric eyepiece. A total of 18 species of cnidarians were recorded: three species of hydroids (*halopteris alternata*, *aglaophenia rhyncocharpa* and *sertularella* sp.); Three species of scleractinians corals (*scolymia wellsi*, *madracis decactis* and *astrangia braziliensis)*; six species of anemones (*actinia bermudensis*, *aiptasia pallida*, *anemonia sargassensis*, *bunodosoma caissarum*, *b. Cangicum* and *telmatactis roseni*); four species of zoanthids *(zoanthus sociatus*, *z. Nymphaeus*, *palythoa caribaeorum* and *parazoanthus* sp.); One species of octocoral (*carijoa* sp.); And one species of black coral (*anthipathes* sp.). The saint peter and st. Paul archipelago has a lower diversity of cnidarians when compared to the nearest area of fernando de noronha archipelago.

SURVIVAL RATE OF GIANT CLAMS LARVAE INTRODUCED BY ZOOXANTHELLAE ISOLATED FROM DIFFERENT HOSTS: PRELIMINARY STUDY.

Ambariyanto*. Marine Science Dept. Diponegoro University Kampus Tembalang, Semarang, Indonesia. Email: ambari@indosat.net.id

Giant clams (Bivalvia : Tridacnidae) are known to live in association with zooxanthellae which are capable of transferring part of their photosynthetic product to the clams. It has been reported that there are genetic differences among zooxanthellae. This study was aimed to investigate the effect of introducing zooxanthellae isolated from different hosts (i.e. different species of giant clams and coral) on the survivorship of giant clams larvae. Preliminary results showed that there were survival rates differences among the larvae introduced by zooxanthellae isolated from different sources.

TENTACLE BRANCHING PATTERN IN THE SEA ANEMONE GENUS *ACTINODENDRON* (ANTHOZOA: ACTINIARIA: ACTINODENDRONIDAE).

Ardelean, Adorian*. *The University of Kansas, Division of Biological Sciences, Haworth Hall, Lawrence KS 66045, USA. Email: adorian@eagle.cc.ukans.edu

The family Actinodendronidae is a group of three genera of exclusively tropical Indo-Pacific sea anemones that have the oral disc drawn out into highly branched tentacles. The tentacle structure and their growth pattern are species-specific and therefore valuable for taxonomy and evolutionary studies. I have found that parameters of randomness in branching patterns and delays in branch development are responsible for the highly organized three-dimensional structure of the tentacles. In genus *Actinodendron*, which has bifid terminal branches, ramification is the result of several mechanisms. I describe for the first time these branching mechanisms which I believe are unique among sea anemones. I focus on the particular case of *Actinodendron glomeratum* Haddon, 1898, in which I found a continuum of forms in relation to terminal tentacle type and branching mechanism. I analyze the spectrum of morphotypes in terms of structural and branching mechanism transition. The shape of structures is associated with the temporal parameters of tentacle development. My analysis of the tentacle structure and their branching pattern will help in the understanding of the morphology of these animals and provide a better diagnosis of the species. This is the first step in understanding the relation between species borders and phenotypic variability for each of the species in the genus *Actinodendron*. The variability documentation will also provide insights into the evolutionary history of the group.

REPRODUCTIVE ECOLOGY OF A MARINE SPONGE, *PETROSIA* SP.(NEW SPECIES), FROM CORAL COMMUNITIES IN THE GULF OF THAILAND.

Asa, S. *, T. Yeemin, N. Chaitanawisuti and A. Kritsanapuntu.
Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand.
Email: saiprateep@hotmail.com

Sexual reproduction and ecology of a marine sponge, *Petrosia* sp., (new species) have been studied at Khang Khao Island and Nok Island, the inner Gulf of Thailand since December, 1997. The sponge grew mostly on a dominant massive coral, *Porites lutea*, and obviously showed clumped dispersion. Reproductive biology of *Petrosia* sp. was examined by monthly sampling of marked individuals for microtechnically histological analysis in the laboratory. This sponge was viviparous hermaphrodite. Gamete development of *Petrosia* sp. from the two study sites showed the same pattern. Spermatic cyst, oocyte and larva were found during December, 1997-April 1998. The severe coral bleaching phenomenon in the Gulf of Thailand during April-May 1998 resulted in disappearance of gametes and larvae in all samples during May-October, 1998. The fecundity was higher in the sponge from Nok Island. Releasing of parenchymella larvae were observed in the morning in aquaria. Most larvae settled on live colonies of *Porites lutea*. The results from the present study progress debates concerning life history strategies and taxonomy in marine sponges.

REPRODUCTIVE EFFORT IN *Palythoa caribaeorum*.

Acosta, A*. & Asbahr, M. *Pontificia Universidad Javeriana. Kra. 7#43-82. Depto. Biología, Bogotá, Colombia. Email: laacosta@unicamp.br

P. caribaeorum colonies were quantified in Brazil during the maturation peak in order to determine 1) the degree of fertility in the population, 2) reproductive effort -RE- of polyps, and 3) colony size of maturation. We also determined whether RE varied with: colony size, position of polyps within a colony (edge, center or in-between), and the variant of fission from which ramets were derived (Edge Fission -EF, Pseudo-Colony Lift Off -PCLO, or Teardrop Formation -TF). 92.9% of the colonies sampled (n = 70) were fertile. 58.7 $\pm$ 39.0% (sd) of polyps (n = 4,515) exhibited gonads. The minimal colony size for sexual reproduction was 6 cm^2 (range: 0.0006 - 5 m^2). RE increased with colony area (r^2 = 0.13, $p<0.001$). RE varied depending on polyp position within a colony ($p<0.001$, n = 361), and between the three modes of fission ($p<0.001$, n = 98). RE by polyps located at the center and in-between was equal and were higher than at the edge. RE was higher for PCLO than for either EF or TF. RE for EF and TF was equal. Maturation was asynchronous between colonies, polyps within a colony, and mesenteries. *P. caribaeorum* exhibited a high reproductive effort.

EFFECTS OF SEDIMENTATION ON CORAL SETTLEMENT, SURVIVORSHIP AND DEMOGRAPHY.

Babcock, Russ *, Smith, Luke, & Hunt, Marina. University of Auckland Leigh Marine Laboratory PO Box 349 Warkworth, New Zealand. r.babcock@auckland.ac.nz

Sedimentation rates were experimentally manipulated in the field to examine the effects of elevated sediment accumulation rates on settlement and juvenile survivorship of the staghorn coral *Acropora millepora*. The results of these experiments were combined with demographic data for *A. millepora* in order to examine the effects of reduced recruitment rates on population density and recovery rates. Sedimentation rates were 1.8-1.3 $mg.cm^{-2}.d^{-1}$ for control sites and 2.1-11.7 $mg.cm^{-2}.d^{-1}$ in sediment treatments. Both settlement and survivorship over the first three months were significantly reduced in the sediment treatments. Settlement was approximately 28 % lower overall in the sediment treatments, and there was no settlement on the upper surfaces of the plates. Overall survival after 8 months was 2.5 times higher for juveniles at sites without additional sediment. Demographic modeling of *A. millepora* populations, using recruitment levels corresponding to experimental sediment accumulation rates, suggested that sediment effects on recruitment alone are likely to explain differences in population density at low and high sediment sites.

REPRODUCTION OF THREE SCLERACTINIAN CORALS (*Acropora nobilis, A. cytherea, Hydnophora rigida*) OF NORTH-WESTERN LOMBOK.

Bachtiar, Imam*. Universitas Mataram, NTB, Indonesia. Email address: ibachtiar@hotmail.com.

Reproduction of three scleractinian corals (*Acropora nobilis, A. cytherea* and *Hydnophora rigida*) was studied in the Gili Trawangan and Gili Meno, West Nusa Tenggara. The study was carried out by monitoring gonad development histologically every month over four months period. The results suggest that in the three coral populations gametogenic cycles occur more than once in a year, and the spawning is spread over several months. Each coral population spawns several times in several months. The peaks of spawning are different among the three coral populations. Most *A. nobilis* colonies spawn after the full moon of February, while most *A. cytherea* colonies spawn after the full moon of January. The colonies of *H. rigida* mostly spawn after the full moon of November. *H. rigida* is a simultaneous hermaphrodite coral developing egg earlier than testis. The coral spawns their gametes following the full moon of November (broadcast spawners). There were some strong indications, that many colonies of *H. rigida* carry out gametogenic cycle more than once per year. Spawned colonies in November were found to have small oocyte in January. The peak of spawning in *A. nobilis* and *A. cytherea* support the genetic legacy hypothesis that Western Australian corals may be seeded from larval dispersal of Eastern Indonesia Archipelago during the southerly Indonesian Throughflow and the Leeuwin Current from January to April.

DOES TEMPERATURE SYNCHRONIZE REPRODUCTION OF MASS SPAWNING CORAL IN THE GREAT BARRIER REEF.

Bachtiar, Imam*. *Universitas Mataram, NTB, Indonesia. Email: ibachtiar@hotmail.com**.**

The roles of temperature in synchronising gametogenic development in corals from the Great Barrier Reef were investigated experimentally. Colonies of the mass spawning coral *Goniastrea aspera* (Verril 1865) were grown in three different temperature treatments in a four months period. During the entire experimental period the mean water temperatures (!SD) in the summer, winter and ambient (control) treatments were 30.5!1.2° C, 22.2!3.2° C and 27.9!1.3° C respectively. During the same period the average seawater temperature in the field was 26.0!1.0° C. Results from the present study suggest that temperature is important in the regulation of gametogenic development in *G. aspera*. Gametogenesis and spawning were inhibited in corals maintained under constant winter seawater temperatures (21°C). In contrast, spawning were accelerated in some colonies maintained in constant summer seawater temperatures (30°C). Overall, gamete development in summer treatment colonies was not significantly different from gamete development in control colonies maintained under ambient seawater temperatures.

DOES PHOTOPERIOD SYNCHRONIZE REPRODUCTION OF MASS SPAWNING CORAL IN THE GREAT BARRIER REEF.

Bachtiar, Imam*. *Universitas Mataram, NTB, Indoneesia. Email: ibachtiar@hotmail.com**.**

The roles of photoperiod in synchronising gametogenic development in corals from the Great Barrier Reef were investigated experimentally. Maintaining colonies of mass spawning coral *Goniastrea aspera* in either constant winter (10.5L: 13.5D) or constant summer photoperiod (13.5L: 10.5D) regimes for three months prior to the predicted date of spawning did not alter reproduction timing of the coral. After three months, gametogenesis and spawning in both experimental treatments occurred synchronously with that of control colonies. It is possible that corals are more sensitive to changing photoperiods than to fixed photoperiods. It is also possible that photoperiod affects coral reproduction through interactions with other exogenous and/or endogenous factors. Testis maturation was found to be more important than egg development in determining the month of spawning. The proportion of colonies spawning in a given month was highly correlated with the proportion of mesenteries with mature testes. Corals with mature eggs (>300 µm) and unripe testis apparently do not spawn until the testis become fully developed.

VARIABLE PALATABILITY OF CORAL EGGS TO A PLANKTIVOROUS FISH

Baird, A.* Gibson, Deborah; Koziumi, Noriko; Pratchett, Morgan; Marquis, Christopher. *School of Marine Biology & Aquaculture James Cook University, Townsville Q. 4811, Australia. andrewbaird@ozemail.com.au

Despite limited empirical evidence, predation is generally assumed to be the major source of larval mortality and marine invertebrate larvae are considered palatable to a wide range of marine predators. Here we tested whether the planktivorous fish *Pomacentrus moluccensis* would consume coral eggs of 9 species from 3 families and whether the eggs were equally palatable. *P. moluccensis* did not distinguish between eggs of five species from the family Acroporidae, nor two faviid species, however, the eggs of the agaricid, *Pachyseris speciosa*, were often rejected. In total, less than 50% of the *Pachyseris speciosa* eggs were ingested compared to 90 % of those made with other eggs demonstrating unequivocally that not all coral eggs are equally palatable. The scleractinia have traditionally been considered unlikely candidates for a rich chemical ecology however, the difference in palatability of the eggs indicates this assumption may need to be revised.

EFFECT OF LARVAL RETENTION ON CORAL CONNECTIVITY AND SETTLEMENT: A MODELLING APPROACH.

Blanco-Martín, Bernardo*. *School of Marine Biology and Aquaculture, James Cook University, Townsville QLD. 4811, Australia. Email: Bernardo.Blanco-Martin@jcu.edu.au

The degree of larvae retention on reefs and its consequences has counted a lot of controversy. Field and modelling studies have tried to prove and quantify this retention, but the importance of retention for the connectivity and settlement of coral populations remains poorly understood. To study this relationship the spatially realistic model here presented was employed. A G.I.S. coverage of the Great Barrier Reef was used to create a spatial representation of the Capricorn Bunker Group in a Cellular Automata Model. The models were run using five larval competence curves (three brooders *Stylophora pistillata, Pocillorpora damicornis* and *Seriatopora hystrix* and two spawners *Acropora valida* and *Acropora millepora*), two current sets (random and south trend) and 21 retention levels (0% to 100% in 5% increments). The larval outputs and inputs for the whole system and six selected reefs were investigated. As expected larval retention at natal reef increases local and global settlement and decreases the reefs connectivity and the diversity (in reef origins) of the settling larvae. On the other hand, for most of the simulation combinations these decreases are only significant at unrealistically high retention levels. The results for individual reefs and coral species are highly variable.

UNREPORTED FORMS OF ASEXUAL REPRODUCTION IN SCLERACTINIAN CORALS: REPRODUCTION BY "TISSUE DRIPPING" AND "TISSUE BUBBLES."

Borneman, Eric H.* *Microcosm, Ltd. 2222 North Fountain Valley, Missouri City, Texas, USA, 77459. Email: EricHugo@aol.com

Many forms of asexual reproduction have been reported in scleractinian corals; including fragmentation, budding, polyp ball formation, asexually produced planulae, polyp bail-outs, coral polyp expulsion, and others. In this report, two novel forms of asexual reproduction are described in marine microcosms. *Favia* spp. and *Merulina ampliata* have been observed forming strands of tissue which "drip" downward to find attachment to substrate. The strands of tissue then become detached from the parent colony, begin to calcify, and form viable daughter colonies. Until attachment is made, no skeletal material is present as occurs in some types of budding. The entire process takes from weeks to months to complete. *Pavona decussata* has been observed forming vesicles or bubbles on the coenosarc surface that may become fully detached, forming neutrally buoyant balloons of tissue capable of re-attachment on contact with other substrate. Not all tissue bubbles are detached from parent colonies and they are frequently resorbed. The formation and resorption of these vesicles can occur within days, although the growth of vesicles, length of time spent attached to the parent colony, and ultimate detachment process can last from days to months. To date, only a single released vesicle has produced a viable daughter colony despite many observations of vesicle production and release. Further work is required to assess the nature of this behavior.

A SURVEY OF THE REEF FISH COMMUNITIES OF THE BAY ISLANDS (HONDURAS, CARIBBEAN SEA)

Bouchon-Navaro, Y*, Louis, M. Bouchon, C. De Lavigne, S. Thompson, W., And Portillo, P. *Laboratoire De Biologie Animale, Université Antilles-Guyane, Bp 592, 97159, Pointe-À-Pitre, Guadeloupe. Pmaib, Consortio Safège-Moncada, Roatán, Honduras. email: claude.bouchon@univ-ag.fr

The Bays Islands (Utila, Roatán and Guanaja) located off the continental coast of the Honduras are surrounded by well-developed coral reefs of fringing and barrier type. Reef fish communities were studied at fifty-six stations using a semi-quantitative technique (29 in Roatán, 16 in Utila and 11 in Guanaja). A total of 166 species was recorded in the three islands. The distribution of fish communities was investigated using correspondence analyses associated with hierarchical clusterings. On a biogeographical point of view, no clear-cut difference appeared between the fish communities of the three islands. The pattern of fish distribution was mainly related to depth and reef habitats. Moreover, the fish community structure was studied at 8 stations located in Roatán using a quantitative method (10 transects 30 m long by 2 m large per station). The fish communities of the Bay Islands appeared relatively rich and diversified with species richness varying from 38 to 61 species per 600 m^{-2}. Fish abundance reached an average of 253 individuals per100 m^{-2} and an average biomass of about 1132 $kg.ha^{-1}$. The trophic structure was dominated by herbivorous fishes (Acanthuridae and Scaridae) which represented 58 % of the total fish biomass.

A REVISION OF THE GENUS PACIFIGORGIA (OCTOCORALLIA: GORGONIIDAE).

Breedy, Odalisca * & Guzmán, Héctor M.. Universidad de Costa Rica, Centro de Investigación en Ciencias del Mar, San José, Costa Rica. P.O.Box 1962-2100. Email:odalisca@racsa.co.cr

Pacifigorgia was established for reticulated fan-shaped gorgoniids with a thin coenchyme, mainly composed of different types of girdled spindle sclerites, but lacking scaphoid forms. With the exception of one species, *P. elegans* (MilneEdwards and Haime) found in the Atlantic, it is restricted to the eastern Pacific Ocean. Since the establishment of this genus, no comprehensive revision had been undertaken. Although most of the species were described 50 to 150 years ago, no designation of holotypes (apart from *P. irene*) was made and a few illustrations appeared in original descriptions. Hence, the taxonomic status of the majority of them is not clear. The present preliminary revision has been based on original type-material and new material recently collected. The species were identified based on a combination of three characteristics: growth form of the colony; shape of sclerites and the color of both. All the species have been newly described and illustrated in detail with photomicrographs and scanning electron micrographs of the sclerites. Thirteen have been recognized as valid and lectotypes proposed for them. They are *P. adamsii* (Verrill), *P. agazissii* (Verrill), *P. darwinii* (Hickson), *P. englemanni* (Horn), *P. eximia* (Verrill), *P. exilis* (Verrill), *P. irene* (Bayer), *P. media* (Verrill), *P. pulchra* (Verrill), *P. rutila* (Verrill), *P. stenobrochis* (Valenciennes), and *P. tenuis* (Verrill). *P. tabogae* (Hickson) and *P. douglassii* are also redescribed, but they can not be accepted until Hickson's original specimens are located and analyzed.

HEAVY METAL CONCENTRATIONS IN BENTHIC ANIMALS FROM CORAL COMMUNITESS IN THE GULF OF THAILAND.

Buaruang J.*, T. Yeemin, J. Milindalekha, S. Tongumpon, S. Pairagsa, S. Tangkittikasem and S. Sriprajan. Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand.
Email: jamrearn@hotmail.com

Concentrations of Pb, Cu, Zn, and Fe were measured in two different modes of feeding of benthic animals, i.e., a sea urchin, *Diadema setosum*, and a sponge, *Petrosia* sp. from coral communities of Khang Khao Island and Nok Island in the Inner Gulf of Thailand where locate near the mounts of four rivers. For the sea urchin, heavy metal concentrations were measured in gonad and fecal pellet. The standard methods of extraction and acid digestion were applied. All the heavy metals were determined by FAAS. All heavy metal concentrations in fecal pellets were much higher than those in gonads. The heavy metal in gonads of the sea urchin varied significantly between stations and sampling periods and were lower than standard levels of contaminated food. Concentrations of Cu and Zn were much higher in the sponge. *D. setosum* and *Petrosia* sp. could be valuable bioindicators for assessing and monitoring heavy metal concentrations in coral communities in the Gulf of Thailand.

THE EFFECTS OF EXPERIMENTALLY ELEVATED NUTRIENT CONCENTRATIONS ON THE SOFT TISSUES OF ACROPORID CORALS (SCLERACTINIA: ACROPORIDAE).

Bucher, Daniel J*. and Harrison, Peter L. *School of Resource Science and Management, Southern Cross University, P.O. Box 159, Lismore, NSW, Australia. Email: dbucher@scu.edu.au

The structure and organisation of soft tissues were investigated in two species of *Acropora* reef-building corals that were exposed to elevated concentrations of ammonium and/or phosphate in the ENCORE experiment at One Tree Island, southern Great Barrier Reef. Chlorophyll extractions of branch tips revealed that phosphate treatments significantly increased the chlorophyll content of coral tissue, whereas elevated ammonium often decreased chlorophyll relative to ambient nutrient concentrations. In the phosphate-treated corals, light microscopy of thin (0.5-1µm) sections of polyps showed significantly thicker tissue layers in the free body wall and greater surface area of calicoblastic body wall per cross-sectional area of the septotheca, indicating that phosphate also stimulated coral tissue growth. The septotheca of all nutrient-treated corals was significantly more porous than in corals at ambient concentrations. A reduction in the density of mucous bodies in the free body wall of phosphate-treated corals is potentially significant to the survival of corals in polluted water, because of the role of mucus in facilitating removal of sediment from the coral surface. Elevated ammonium decreased the surface area of calicoblastic body wall per cross-sectional area of the septotheca. The corals and their zooxanthellae within the ENCORE patch reefs were phosphorus-limited in their annual growth.

FIRST RECORDS OF A FOSSIL CORAL PLATFORM SURROUNDING THE MARQUESEAS ISLANDS.

Cabioch G*, Carden C. Wallace, Linda K. Ayliffe, Malcolm T. McCulloch, Helmut Zibrowius, Pierre Laboute, Bertrand Richer de Forges. * IRD, BP A5, 98.848 Nouméa cedex, Nouvelle-Calédonie. Email: cabioch@noumea.ird.nc

In September 1997, the MUSORSTOM 9 cruise was carried out in Marqueseas archipelago onboard the French research vessel Alis. Narrow submarine platforms occur seaward of the islands of this archipelago at depths ranging from 90 to 100 m. During this cruise, several dredgings were performed in order to provide useful information on the nature and the significance of this platform. Several fossil corals were collected, studied and dated. The occurrence of corals accompanied by reefal detritus indicates that this platform is a relic of submerged reefs setting about 100 m deep. Moreover, the first results provide two sets of dates measured both on *Porites* spp. and *Acropora* spp.: the first set at around 20 ka and the second one at around 60 ka. The youngest ages correspond to the sea level of the last glacial maximum, around 120-130 m lower than today. The ages around 60 ka are consistent with an interstadial sea level. It is noteworthy that, for the first time, fragments of *Acropora* sp. were collected in this archipelago. This is the first record of occurrence of *Acropora* within the archipelago, as the genus has never been recorded in the Recent fauna of the region. Such an occurrence at this period has a particularly great paleobiogeographic significance in this part of the Pacific Ocean.

PATTERNS AND CAUSES OF ANNUAL OTOLITH INCREMENT FORMATION IN THE TROPICAL WESTERN ATLANTIC.

Caldow, C*. *National Oceanic and Atmospheric Administration, Silver Spring, Maryland, USA. Email: chris.caldow@noaa.gov.

Only recently have managers and scientists begun to collect age and growth information necessary for effective management of tropical marine ichthyofaunal communities. The majority of studies that have taken place in the tropics have focused on the Pacific Ocean, primarily on Australia's Great Barrier Reef. In this study, otoliths collected from small reef associated fish species in the tropical western Atlantic were examined for their ability to provide information on age. Otoliths of two pomacentrids, *Stegastes planifrons* and *S. partitus*, were collected from separate regions with a range in annual temperature variation. These otoliths were examined for the presence of clear and interpretable increments and timing of increment formation. Increment quality varied between species and between regions, with the trend being decreasing clarity with decreasing temperature range. Increments formed in areas with as little as a 3°Celsius annual water temperature range. Marginal increment analysis of *S. planifrons* otoliths revealed that increments formed on the otoliths were deposited once a year during the spring or early summer, suggesting that fish in the tropical western Atlantic may be aged using the same techniques as in other tropical regions and temperate environments. Individuals at both locations were significantly longer-lived than predicted by other methods. Information on age and growth collected for reef fish in studies such as this one should provide managers with the life history information needed to assess population stability and production.

LIGHT QUALITY AND EXPRESSION OF FLUORESCE IN CORALS

Carter, Robert W.*, Mazel, Charles H. *University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Cswy, Miami, FL 33149, USA, rcarter@rsmas.miami.edu

Many scleractinian corals exhibit a blue-green or green fluorescence when illuminated with ultraviolet or blue light. This fluorescence arises from animal-derived proteins similar to the green fluorescent protein originally found in the jellyfish, *Aequorea victoria*. It has been suggested that these proteins play a role in either light attenuation or wavelength transformation as solar radiation passes through the coral tissue to the endosymbiotic zooxanthellae. The coral, *Montastraea faveolata*, is a common species in the Caribbean and can be found with any of several fluorescent proteins. A fluorescent green form of the protein is most common and animals with this form are often green to the eye. We investigated the influence of irradiance on expression of the fluorescent pigment in this species in two experiments. The first experiment involved the collection of tissue from ten colonies of *M. faveolata* at three depths (3, 10, and 20 m). Fluorescence measurements were made on the tissue after it was removed from each skeleton with an airbrush. The second experiment involved exposing ramets of several colonies of *M. faveolata* to three light treatments in an outdoor circulating water table: ambient UV (Control), reduced UV, and reduced PAR. Daily measurements of coral host tissue fluorescence and zooxanthellae photosynthetic capacity were made on each core over a two week period. *In vivo* coral fluorescence measurements were made with a benchtop laboratory spectrofluorometer. Photosynthetic state was determined by measurements of chlorophyll variable fluorescence (Fv/Fm) with a fast repetition rate fluorometer.

BENTHIC PRIMARY PRODUCTION IN A CORAL REEF AT BORA BAY OF MIYAKO ISLAND, OKINAWA, JAPAN.

Casareto B.E.*, Y Suzuki, K. Yoshida, Y. Ishikawa and K. Kurosawa. Laboratory of Aquatic Science Consultant Co., LTD, Meishin BLDG., Kamiikedai 1-14-1, 0ta ku, Tokyo 145-0064, Japan. E-mail address: CASARETOBE@aol.com

Among main primary producers in coral reef ecosystems the importance of macrophytes and symbiotic zooxanthellae have been widely recognized. However the role of epiphytic and endolitic microalgae have been not well considered. The goal of this work is to evaluate the role of benthic microalgae throughout several field experiments. Different sediment types (excluding macrophytes) were incubated in core-type chambers at several station within Bora Bay in July of 1998; the obtained P/R ratios ranged from 1.02 to 2.03. These P/R ratios higher than 1 suggest that production is the predominant metabolic process in these sediments. *Chl a* concentrations of incubated sediment ranged from 7 to 34 µg *Chl a* cm^{-2} of sediment from which7.5 to 45% was found in epiphytic microalgae and the rest was found inside the coral rubble (endolitic algae). Net primary production of endolitic microalgae was measured by bottle incubations in July of 1999. Net primary production estimated per $1m^2$ of rubble surface varied from 2.15 to 3.18 μgO_2 l^{-1} $hour^{-1}$; *Chl a* concentrations varied from 3.38 to 11.36µg *Chl-a* cm^{-2} of rubble surface. Concentrations of *Chl a* of endolitic microalgae in coral rubble (13.7µg*Chl a*/g coral rubble; SD=5.57; n=10) are of the same order of magnitude to that of living corals in association with their symbiotic zooxanthellae (31µg*Chl a/* g coral; SD=31.8 n=34)(Sorokin,1995; Casareto, personal com.).

SEDIMENTOLOGY AND HYDRO-ACOUSTIC SEABED CLASSIFICATION OF LAUTHALA BAY (SUVA, FIJI).

Chevillon C*. Centre IRD., BP A5, 98 848 Nouméa, New Caledonia.
Email: Christophe.Chevillon@noumea.ird.nc

The Lauthala Bay (Suva, Fiji) was explored with a RoxAnn™ acoustic seabed classification system. Some 70 000 acoustic signatures (i.e. couples roughness / hardness) were recorded along regularly spaced tracks. Concurrently, 32 sediment samples were collected with a small Neyrpic grab. These sediment samples were used for classical granulometric analysis (e.g. textural type, mud percentage, mean size, sorting, skewness and kurtosis) and as ground-truthing for the acoustic seabed classification. Additionally, we conducted scuba-diving exploration and description on 15 sites. When comparing acoustic classification versus sedimentological data we observed that acoustic discriminated 5 categories of bottom types *vs* 2 or 3 with classical sedimentology. As a consequence, it is difficult to precisely define and characterize the exact nature of acoustic classification response. Scuba-diving observations provided useful information for interpreting acoustic classification wich is also influenced by habitat structure. As the sediments of Lautahala bay are extremely muddy, we suggest to conduct other kinds of analysis on the samples (as laser granulometry or composition of the fine fraction) in the aim to obtain better correlations between acoustic and sedimentological data.

TAXONOMIC AND BIOGEOGRAPHIC DISCOVERIES FROM THE U.S. NATIONAL CANCER INSTITUTE MARINE COLLECTIONS PROGRAM

Colin P.L.* and Lori J. Bell *Coral Reef Research Foundation P.O. Box 1765 Koror, Palau 96940. Email: crrf@palaunet.com

Numerous new taxa of marine invertebrates from the Indo-Pacific have been described based on collections made for the past 9 years for the U.S. National Cancer Institute marine collections program by the Coral Reef Research Foundation. Collections are identified and described by a group of over 30 taxonomists worldwide. At present 47 ascidians, 4 sponges, 1 soft coral, 1 flatworm and 1 crinoid have been described as a result of this work. Analysis of the collections indicates that at present there still remain at least 500 sponges (11 new genera), 40 soft corals, 16 bryozoans, 7 holothurians, 24 ascidians and a wide variety of other marine invertebrates to be described from the collections. In addition to the new taxa, the project is constantly discovering new information about the geographic distribution, variation and general biology of marine invertebrates from throughout the Indo-Pacific region. Long-term work at a few locations has allowed us to prepare relatively complete inventories of invertebrate groups of special interest. The ultimate objective of this work, beyond the discovery of new treatments for cancer and AIDS, is the preparation of comprehensive volumes covering groups of "difficult" marine invertebrates to allow identification for research and conservation purposes.

ASEXUAL REPRODUCTION IN HOLOTHURIAN (HOLOTHUROIDEA) : A COMPARISON BETWEEN PACIFIC (GBR, Australia) AND INDIAN OCEAN (La Reunion) POPULATIONS OF STICHOPUS CHLORONOTUS.

Conand C.* & Uthicke S. Laboratoire Ecologie marine, Université de La Réunion, 97 715 Saint Denis cedex, France. Email: conand@univ-reunion.fr

Stichopus chloronotus is a widespread holothurian species, in the Indo-Pacific which often occurs in high population densities. Its asexual reproduction by fission was monitored in several populations from the Great Barrier Reef (GBR, Australia, Pacific Ocean) (Uthicke, 1997) and from La Reunion fringing reefs (France, Indian Ocean) (Conand et al., 1998). The results obtained at these locations are compared, to investigate similarities in the fission pattern between the two geographic regions. Fission rates showed distinct seasonality, with maxima occurring during the cold season (May to July), both in La Reunion and the GBR. The processes of external and internal regenerations have been described in view to understand the resumption of the nutrition and the sexual reproduction after fission. Annual fission rates and population densities are positively correlated in all populations studied. In contrast, annual fission rates and modal sizes in the populations are negatively correlated. The consequences of fission in terms of density and size of the individuals are discussed. Several abiotic factors, which may differ between species, have been hypothesized to trigger fission in holothurians. For *S. chloronotus* we suggest that food availability and population densities may be involved in the regulation of asexual reproduction. However, the comparison of more stations remains necessary to substantiate this hypothesis.

ZOOXANTHELLAE MORPHOMETRICS OF FIVE HERMATYPIC CORALS SPECIES (CNIDARIA, SCLERACTINIA) FROM TAMANDARÉ AND GAIBU BEACH, SOUTH COAST OF PERNAMBUCO STATE, BRAZIL.

Costa, C. F*. and Amaral, F. D. *Universidade Federal da Paraíba, Mestrado em Biologia, Campus Universitário, 58059-900, João Pessoa, PB, Brasil. Email: cfcosta@nepremar.ufpb.br

Zooxanthellae are symbiotic algae found within the tissues of many marine invertebrates. In scleractinian corals, these algae are located within the endoderm cells and form a close symbiotic relationship. The objective of this study was to make a comparative analysis of density and diameter of the zooxanthellae in *Agaricia agaricites*, *Favia gravida*, *Montastrea cavernosa*, *Porites astreoides* and *Siderastrea stellata* collected from Tamandaré and Gaibu beach. Approximately 10 colonies of each scleractinians were collected between August 1997 and April 1998 in depths ranging from 0 to 4 m. Zooxanthellae showed significant differences in mean density and diameter among the scleractinians examined. In particular, the mean density in *S. stellata* (Suborder Fungiida) was significantly different from that in *F. gravida* and *M. cavernosa* (Suborder Faviida), and other corals belonging to this suborder. Compared to other species of coral, *F. gravida* and *M. cavernosa* also showed a significant difference in the mean diameter of zooxanthellae in their endoderm cells. The results provide some evidence to show that the density and diameter of zooxanthellae may be used to facilitate scleractinian systematics, since corals are collected across the same temporal and spatial scales.

DENSITY AND SIZE DIFFERENCES IN ZOOXANTHELLAE FROM FIVE REEF-BUILDING CORAL SPECIES FROM BRAZIL.

Costa C.F.* and Amaral, Fernanda. D.. *Universidade Federal da Paraíba, Mestrado em Biologia, Campus Universitario 58059-900 João Pessoa, Paraíba, Brazil. Email cfcosta@nepremar.ufpb.br

Zooxanthellae are symbiotic algae found within the tissues of many marine invertebrates. In scleractinian corals, these algae are located within the endoderm cells and form a close symbiotic relationship. The objective of this study was to make a comparative analysis of the density and diameter of zooxanthellae in the scleractinian reef corals *Agaricia agaricites*, *Favia gravida*, *Montastrea cavernosa*, *Porites astreoides* and *Siderastrea stellata* collected from Tamandaré and Gaibu beach, on the south coast of Pernambuco state, Brazil. Approximately 10 colonies of each species were collected between August 1997 and April 1998 from depths of 0 to 4 m. Zooxanthellae showed significant differences in mean density and diameter among the scleractinians examined. In particular, the mean density in *S. stellata* (Suborder Fungiida) was significantly different from that in *F. gravida* and *M. cavernosa* (Suborder Faviida), and other corals belonging to this suborder. Compared to other species of coral, *F. gravida* and *M. cavernosa* also showed a significant difference in the mean diameter of zooxanthellae in their endoderm cells. The results provide some evidence demonstrating that cell diameter may be a useful character in systematic studies of algal symbionts. Since symbiont density and cell diameter also vary in a host species-specific manner these characters may also be useful in scleractinian coral systematics.

PHOTOSYNTHETIC PIGMENTS OF ZOOXANTHELLAE FROM FOUR BRAZILIAN REEF CORAL SPECIES

Costa C.F.*, Sassi, Roberto and Amaral, Fernanda. D.. *Universidade Federal da Paraíba, Mestrado em Biologia, Campus Universitário, João Pessoa, Paraíba 58059-900, Brazil. Email cfcosta@nepremar.ufpb.br

Despite longstanding interest in zooxanthellae and the symbioses they form with reef corals, virtually no studies have yet been undertaken on Brazilian coral symbioses. Here we investigate the photosynthetic pigments of four Brazilian reef-building corals (*Montastrea cavernosa*, *Mussismilia harttii*, *M. hispida* and *Siderastrea stellata*) collected at Picãozinho reef North coast of Paraiba state, Brazil (07º07'00"S, 34º48'30"W). The study was undertaken to investigate the photosynthetic capacities of zooxanthellae from different corals species over a period of seven months. The data indicate high differences in zooxanthellae pigments among the corals species studied. The values of zooxanthellae pigments were highest for *M. harttii* (58.45 $\mu g/cm^2$ of chlorophyll *a* and 76.2 $\mu g/cm^2$ of chlorophyll *c*) and lowest for *S. stellata* (20.88 $\mu g/cm^2$ of chlorophyll *a* and 48.11 $\mu g/cm^2$ of chlorophyll *c*). These results suggest a higher photosynthetic capacity in *M. harttii*, which may provide a strong contribution to overall reef primary productivity. The possible ecophysiological implications of photosynthetic pigment concentrations of zooxanthellae are discussed.

CORAL REEFS IN THE DISCOVERY COAST OF BRAZIL: I. BENTHIC MACROALGAE DISTRIBUTION.

Costa O.S. Jr.*; Attrill, M.J.; Nimmo, M. *Department of Biological Sciences, University of Plymouth, Drake Circus, PL4 8AA, Plymouth, Devon, U.K. Email: ocosta@plymouth.ac.uk

The Discovery Coast is a small section in the South of the Bahia State, Brazil, where Portuguese sailors first set foot in the country on April 22, 1500. Despite of being the birthplace of Brazil, the region remains practically unknown holding the less studied coral reefs of the entire Bahian coast. To assess the distribution of algae communities throughout both coastal and offshore reefs a quantitative and qualitative survey was performed during the dry season (July/August 1999) and the rainy season (February/March 2000). Samples were taken from the reef wall (at 1, 3 and 5 m depth) and from the exposed reef flat. Algae counts were undertaken using a 25x25-cm quadrat. Algal growth forms exhibited a distinct separation between reef habitats, the reef flat and the internal reef wall being the preferred place for most of the branched species whilst the external reef wall supported predominantly encrusting and turf species. The best-represented division is Phaeophyta, followed by Rhodophyta and then Chlorophyta. The largest number of infrageneric taxa recorded was during the rainy season (February/March 2000) and the most abundant genera were *Sargassum*, *Padina*, *Dictyota*, *Dictyosphaeria*, *Caulerpa* and *Amphiroa*.

SEDIMENTARY AND HYDRODYNAMIC PROCESSES AT GREAT BARRIER REER INNER SHELF CORAL REEFS: A CASE STUDY

Costen, Andrew*; Larcombe, Piers and Woolfe, Ken. *Marine Geophysical Laboratory, James Cook University, North Queensland, 4811, Australia. Email andrewc@gbrmpa.gov.au

Paluma Shoals and Phillips Reef are inner shelf platform reefs located in Halifax Bay, GBR. Taxonomic, seismic and sediment (core and surface) data along with 28 days of continuous high resolution hydrodynamic and turbidity data were collected. Mean coral cover at Paluma Shoals was 53.4±3% on the reef flat. Coral cover at Phillips Reef was not recorded but appeared to be 'high'. Maximum NTU values were an order of magnitude greater at Paluma Shoals (175 NTU) than Phillips Reef (15 NTU). The wind, wave and tidal data suggest that the same regional hydrodynamic processes influence both systems with wind and swell waves generated by the south east trades inducing most turbidity maximum events. The surface sediment seaward of Paluma Shoals consists of fine-grained mud and sand with those surrounding Phillips Reef, mostly gravelly muddy sand. Variations in near bed turbidity values at the sites appear to be a function of local surface sediment texture and distribution, water depth, wind direction and hydrodynamics. At Paluma Shoals the complex interaction between these processes results in 'high' turbidity values (which may persist for days/weeks) but limited sediment settling. At Phillips Reef the 'low' NTU values may be attributed to water depth and the coarse grained nature of the sediment. The sediment core data suggests that both reefs may have experienced similar sedimentary regimes since initiation. In summary, Paluma Shoals currently exists in a 'highly' turbid water environment and may have initiated under similar water quality conditions 3-3.5kya.

SURVIVAL RATES OF *TRIDACNA SQUAMOSA* LARVAE EXPOSED TO DIFFERENT SUBSTRATES: IMPACT OF SUBSTRATES COLONISED BY CRUSTOSE CORALLINE ALGAE.

Courtois de Vicose, G. Singapore. Email: gtricor@hotmail.com

Giant clams mariculture research and culture methods have been developed over the last two decades. Hatchery and farming methods are now well known and applied, however heavy mortality at larval and early juvenile stage still remains a major concern. This study attempt to address aspects of the impacts of different substrates on *Tridacna squamosa* larvae with an aim towards improving larval and juvenile survival. The larvae were obtained from a spawning that occurred naturally in our tanks. The larvae were put in culture and used for the study at day 10. During the 14 days of the experiment replicates of four treatments; smooth plastic, rough plastic, smooth plastic colonised by coralline algae, rough plastic colonised by coralline algae; were monitored and survival rates were recorded. Overall, substrates colonised by coralline algae showed to have a significant positive impact on *T. squamosa* larvae survival. Further studies need to be completed to better understand the effect of the coralline algae. It is still to determine whether coralline algae have an impact on settlement and metamorphosis of the larvae or on the benthic algae responsible for biofouling and known to smother the clams. If further proven to have a significant impact; the technique of colonisation of substrate by crustose coralline algae could be used as a tool to maximize larval settlement, metamorphosis and juvenile survival in order to increase natural recruitment in the wild for conservation and mariculture purposes.

NUTRIENT DELIVERY TO AN EUTROPHICATED CORAL REEF.

Cuet, P*. and D. Mioche. *Laboratoire d'Ecologie Marine, Université de la Réunion, BP 7151, 97487 Saint-Denis messag. Cedex 9, France. Email: cuet@univ-reunion.fr

The nutrient status of the reef flat at Planch'Alizés, a degraded area of the Saint-Gilles/La Saline fringing reef (Reunion, Indian ocean), was assessed measuring monthly, during one year, dissolved inorganic nitrogen (DIN) and phosphorus (DIP) at this site, and at an undisturbed area of the reef. Salinity and reactive silicate, therefore freshwater inputs, were similar on the two reef flats. However, DIN was significantly higher at Planch'Alizés than at the control site (respectively 0.50 and 0.36 µM NO_3^- + NO_2^- ; 0.26 and 0.19 µM NH_4^+) ; in contrast, DIP was significantly lower at the former site (respectively 0.07 and 0.10 µM). Besides, we measured O_2, DIN and DIP fluxes on the two reef flats, in summer and in winter, using a Lagrangian flow respirometry technique. In summer, there was a release of NO_3^- at Planch'Alizés (6.2 $mmol.m^{-2}.d^{-1}$), and of NH_4^+ at the control site (3.3 $mmol.m^{-2}.d^{-1}$). An uptake of NO_3^- occurred whatever the season at the control site (–2.4 to –3.6 $mmol.m^{-2}.d^{-1}$). DIP flux was always nil at both sites. N fluxes at Planch'Alizés mainly reflected the gross production to respiration ratio (0.87 in summer, about 1 in winter). On account of current direction, organic matter originating from the back reef might therefore constitute a source of N at this site. This might link macroalgal dominance on the reef flat to an indirect impact of groundwater discharge in the back reef. The resulting N enrichment to the reef flat remains moderate, but does not necessarily reflect the magnitude of the increase in N availability.

REPRODUCTIVE BIOLOGY OF MULLET (FAMILY MUGILIDAE) IN AMERICAN SAMOA.

Curren, E. Flinn*, *Department of Marine and Wildlife Resources, P.O. Box 3730, Pago Pago, American Samoa, USA. Email: flinnc@hotmail.com

Mullet caught by gill net and cast net were identified to species. Staged condition of mullet gonads based on macroscopic characteristics was verified by microscopic examination of H&E stained gonad sections. Spawning appeared to be widespread during the year, based on gonad condition. Fecundity estimates, based on hydrated egg counts, were obtained for for four mullet species: *Chelon melinopterus*, *Moolgarda engeli*, *M. perusii*, and *M. seheli*. These estimates do not take into account atresia, which is especially significant for *C. melinopterus*.

COPPER AND ZINC CONCENTRATIONS AND SKELETAL EXTENSION RATE IN *PORITES LOBATA* AT AN ANTHROPOGENICALLY IMPACTED SITE IN HAWAII.

Daly, Geoffrey*. *University Of San Diego, CA. U.S.A. Email: geoffreydaly@earthlink.net

Annual growth bands of *Porites lobata* skeletal material were analyzed for copper and zinc, a primary component in anti-fouling boat paints and a supplement in fertilizers, to evaluate anthropogenic effects on geochemistry and skeletal extension at two sites along the west coast of Hawaii. Keauhou Bay, the impacted site, is affected by land degradation, human development, agriculture, and boating activities. The control site, Makalawena is a more pristine setting which experiences minimal human impact. The Cu and Zn concentrations and average annual skeletal extension rates where compared within different growth bands of a coral colony, between corals from the same site, and between two sites. Eight corals were collected, sectioned, and X-rayed. Bulk aragonite samples from single annual growth bands were extracted and the metal concentrations measured by flame atomic absorption. Copper and zinc concentrations ranged from 0.3 ppm to 7.5 ppm, and 0.1 ppm to 2.5 ppm, respectively. Mean Cu and Zn concentrations were significantly higher in corals from the impacted site (3.1 +/-0.3 ppm Cu, 1.5 +/-0.2 ppm Zn) compared to the control site (1.0 +/-0.2 ppm Cu, 0.2 +/-0.1 ppm Zn). In general, Cu and Zn concentrations do not vary significantly among years within a single coral but differ between a few of the corals at a single site. Copper and zinc concentrations in *P. lobata* reported for other anthropogenically-polluted locations, ranged in Cu from 2.4 ppm to 18.4 ppm, and Zn from 0.8 ppm to 122.1 ppm. Possible sources of Cu and Zn in Keauhou Bay include anti-fouling boat paints and golf course fertilizers, which are not present at Makalawena. Extension rates measured for corals from Keauhou Bay and Makalawena were generally consistent with *P. lobata* measured elsewhere on Hawaii (~1 cm). The extension rates recorded in this study found no significant difference between corals from the same location, although between sites, extension rates where significantly higher (0.81 +/-0.02 cm vs. 0.64 +/-0.02 cm) at the impacted site, Keauhou Bay. Records of anthropogenic nutrients entering Keauhou Bay have been linked previously to golf course fertilizers. It is possible that the input of nutrients to the nearshore environment from golf course fertilizers may contribute to the increased skeletal extension rate of *P. lobata* observed in this study. Further research could involve a proxy record of trace metal incorporation in *P. lobata* throughout the history of human activity at Keauhou Bay.

STRUCTURE AND DISTRIBUTION OF ZOOPLANCTON AT THE BAI THU LONG ARCHIPELAGO.

Dautov S.Sh.* *Institute of Marine Biology, RAS, Vladivostok, Russia. Email: daut@mail.primorye.ru

The Ba i Thu Long Archipelago (Gulf of Tonkin, South China Sea) is close to the mouths of several large rivers, which carry out a lot of silt and fresh water which lower the salinity of sea water (to 29-30‰) in this area. The plancton at the Bai Thu Long Archipelago was characterized by an abundance of phytoplancton and diversity of protozoans. By the number of taxa distinguished, the plancton was the most diverse at Bo Hon (Station 10), Cong Tay, Bo Hom, and Cong Do Islands, which at the open seaside extremities of islands situated. The least number of species was recorded in plancton at the closed bay of Bo Hon Island and at a isolated lake with sea water at Bu Xam Island. The density of zoo- and phytoplancton was much lower in the lake, neverthelesss, the plancton community consisted of copepods, pteropods, chaetognaths, appendicularians, jelly fishes, larvae of gastropod, and bivalve molluscs and of ascidians. Most often copepods, chaetognaths, pteropods, and siphonophores in holoplancton, and larvae of polychaetes, crustaceans, bivalves, and ophiurs in meroplancton occurred at the Bai Thu Long Archipelago. Actinotrochae, tornariae, and sea urchins plutei were recorded at stations with the most divers plancton. The presence of these larvae could indicate of the quality of sea water at seaside island coasts with water is more often exchanged during the tide.

ONSET OF SYMBIOSIS IN *FUNGIA SCUTARIA*: CHANGES IN PATTERNS OF GENE EXPRESSION.

DeBoer, M.L.* and Weis, V.M. *Department of Zoology, Oregon State University, Corvallis, OR. 97331, USA. Email: deboerm@bcc.orst.edu

Partners in a symbiosis, such as cnidarians and dinoflagellates, engage in genetic regulation of their association. Carbonic anhydrase expression, for example, is upregulated as a function of symbiosis in the temperate sea anemone *Anthopleura elegantissima*. Since, in many cnidarians, the symbiont takes up residence within host tissue during larval development, it is likely that changes in gene expression resulting from the symbiotic state are initiated during the larval stage. Little is known, however, about biochemical and molecular changes occurring in larvae upon the onset of symbiosis. The coral *Fungia scutaria* acquires its dinoflagellate symbiont (*Symbiodinium* spp.) during the larval stage, after formation of the mouth and upon commencement of feeding. To examine gene expression patterns during symbiosis onset, we first isolated and sequenced carbonic anhydrase (CA) cDNA from *F. scutaria*. Subsequently we used RT-PCR to monitor CA expression in young non-feeding larvae, as well as in older aposymbiotic and symbiotic larvae. We have found CA to be expressed in all three larval types, regardless of symbiotic state or age. However, preliminary results also indicate trends toward differential expression of the gene as a function of both symbiotic state and age, which would suggest that genetic interplay between partners does indeed commence in developing larvae upon the establishment of the symbiosis.

SEXUAL REPRODUCTION OF THE CORAL *MADRACIS MIRABILIS* (SCLERACTINIA: POCILLOPORIDAE) IN BERMUDA

de Putron S.* and Smith, S.R.. *Bermuda Biological Station for Research, St. Georges, Bermuda. Email: sputron@bbsr.edu

Sexual reproduction in many scleractinian coral species is still unknown. *Madracis mirabilis* is an abundant reef coral in the Western Atlantic, but there was previously no available information on the mode and timing of sexual reproduction. In the sub-tropical environment of Bermuda, this species often forms dense aggregations on inshore reefs. Reproductive patterns of Bermuda's corals are of interest as winter temperatures fall well below those reported for minimum coral growth and survival. Gametogenesis was examined by histological sections of tissue samples collected over two summers. Colonies were also held in the laboratory for evidence of any gamete or planulae release. Preliminary results indicate that this species is a simultaneous hermaphrodite with eggs and spermaries often occurring within the same mesentery. The largest gamete diameters were present following the full moons in August and September, corresponding with maximum seawater temperatures in Bermuda. No planulae have yet been detected within polyps which may imply that it is a broadcaster. Further analysis is in progress to accurately define the reproductive cycle and timing of gamete release.

THE ABUNDANCE OF BIOACTIVE SPONGES IN THE SPERMONDE ARCHIPELAGO.

de Voogd N.J.*;. van Soest, R.W.M.; Noor, A.; and Hoeksema, B.W. *Institute for Biodiversity and Ecosystem Dynamics (Zoological Museum), University of Amsterdam, P.O. Box 94766, 1090 GT, Amsterdam, The Netherlands. E-mail: ndevoogd@indosat.net.id

Sessile marine invertebrates are sources for a wide variety of substances with bioactive properties. Many of these substances have a potential as pharmaceuticals or as a biochemical tools for a variety of useful applications. Of all marine invertebrate taxa, sponges are doubtless the most diverse in both numbers and types of compounds. It is thought that sponge bioactivity is enhanced in tropical environments. It is predicted that the species-rich Indonesian reefs harbour the highest diversity in sponge chemical compounds. As the supply-matter is a major problem, a growing interest for alternative ways to obtain these compounds is rising. In the near future, an attempt will be made to set up a sponge mariculture in the Spermonde Archipelago, SW Sulawesi, which is presently one of the best marine explored regions of Indonesia. Presently, a descriptive-correlative inventory is made of sponge bioactivity and the factors that are hypothesised to act as important regulators. These results will eventually contribute in choosing a habitat where sponge growth and production of the bioactive substances is optimal. A first survey is made of the abundance of 12 sponge species, which are known to have bioactive properties in two ecological different shelf zones. So far, the most bioactive individuals have been found in the second shelf zone, whereas the third zone harbours the highest number of sponge species and sponge individuals.

A WINDOWS-BASED PROGRAM FOR IMAGE PROCESSING CORAL SKELETAL DENSITOMETRY.

Dodge, R.E.* and Kohler, K. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania, FL. 33004 USA. Email: dodge@ocean.nova.edu

Coral skeletal density information is a useful growth parameter and may be coupled with extension rates to determine calcification rates. The conventional process for density determination is often cumbersome and requires some parameters which are difficult to precisely specify (e.g., Mass absorption coefficients). We have developed a technique and windows based computer program which enables the rapid collection of coral density data. The coral skeleton slab is x-radiographed with an aluminum wedge. Thickness and density of the aluminum wedge, thickness of the coral slab, density of pure coral aragonite, and digitized images of the coral and wedge x-radiographs provide necessary input. The program uses the wedge image and an empirically determined ratio of relative mass absorption coefficients, (thus removing difficulties with absolute values) in an equation relating wedge optic density and thickness to coral skeletal density. A transect is defined on the coral x-radiograph image, normal to growth band boundaries. Optic density of pixels are converted to skeletal density, averaged, and plotted. Variations of skeletal density along the transect are expressed as peaks and valleys corresponding to high and low density band portions. Measurements of extension, density, and calcification can be calculated for a variety of characterizations of annual and subannual band portions.

MASSIVE CORALS FROM THE CAPE VERDE ISLANDS AND THE GULF OF GUINEA: PHYSICAL AND CHEMICAL PARAMETERS WITH POTENTIAL FOR RECONSTRUCTION OF PROXY CLIMATE / ENVIRONMENTAL RECORDS

Dodge R.E.*, Swart, P.K., Enfield, D., Gilliam, D., White, K., Moses, C., *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania, Fl 33004, USA. Email: dodge@ocean.nova.edu

In the eastern Atlantic at the islands in the Gulf of Guinea and at the Cape Verde Islands massive scleractinian corals have been located. Specimens within the genera *Siderastrea*, *Montastrea*, and *Porites* can be long-lived and have density band records in excess of several hundred years. Growth parameters of these corals including annual and subannual extension rate, density, calcification rate, and skeletal fluorescence co-vary over time. Growth parameters in the Gulf of Guinea show a regular cycle on the order of approximately 10 years. We have examined variations of the Atlantic Dipole and the Gulf of Guinea and Cape Verdes which have particularly strong association with temperature variations in the north and south sub-tropical Atlantic. At the Gulf of Guinea location variations in the oxygen isotopes, density, and fluorescence are correlated with discharge from the rivers draining the Sahel region of West Africa. At the Cape Verde location, corals are at the edge of their range and appear suitable for determination of long-term histories of the temperature of the northern sub-tropical Atlantic Ocean. In addition, the location of the Cape Verde Islands makes the corals there excellent candidates as well for monitoring dust derived from Africa.

POPULATION STRUCTURE OF THE CORAL REEF FISHES OF THE GULF OF PAPAGAYO, GUANACASTE, COSTA RICA.

Dominici-Arosemena, A.*; Brugnoli-Olivera, E.; Molina-Ureña, H.; Cortés-Nuñez, J.; Quezada-Alpizar, M. *Smithsonian Tropical Research Institute, P.O Box 2072, Balboa, Panama, Republic of Panama. Email: dominia@naos.si.edu

We described the taxonomic composition and relative abundance of the reef fish populations in relation to physical parameters and types of habitats in Culebra Bay, Gulf of Papagayo, Costa Rica. We measured the density of fishes and the percent coverage of different types of substrates in four different sites. The four sites differed in depth and coverage of coral. A total of 75 species representing 28 families of reef fishes were recorded. The diversity parameters, with the exception of species richness, differed between different sites, while evenness and diversity indexes showed significant correlations with some substrates. The relative abundance of some species differed between sites showing a higher β diversity compared to other studies in the eastern Pacific. The most abundant species at all the sites was *Chromis atrilobata*, a plankton feeding pomacentrid, followed by *Thalassoma lucasanum*, *Abudefduf troschelii* and *Halichoeres dispilus*, which were predominant in the shallower sites, together with *Serranus psittacinus* and *Canthigaster punctatissima*. *Haemulon steindachnederi* and *Haemulon maculicauda* dominated the deeper site. Coral feeding balistid species like *Sufflamen verres* were significantly correlated with the percent coverage of pocilloporid corals. Some herbivorous species like *Stegastes acapulcoensis* were associated with shallower habitats, while others like *Stegastes flavilatus* were associated with deeper habitats. The chaetodontids *Chaetodon humeralis* and *Jhonrandallia nigrirostris* were significatively correlated with the octocoral *Carijoa* spp. and the ahermatipic coral *Tubastrea cocccinea* in the deeper site.

MODELISATION OF THE TRANSFER OF DISSOLVED AND PARTICULATE MATERIAL IN THE SOUTH-WESTERN LAGOON OF NEW CALEDONIA.

Douillet P*, Ouillon, Cordier. *Centre IRD, BP A5, Nouméa, New Caledonia. Email: douillet@noumea.ird.nc

The lagoon of New Caledonia is one of the largest in the world and represents a rich and diverse ecosystem sensitive to human induced environmental change. A good knowledge of lagoon functioning is required to limit damage from open cast mining exploitation and from the reinforcement of urban influence around the city of Noumea. For the past 20 years, extensive work on the environment of the New Caledonia lagoon has been conducted at IRD (Institut de recherche pour le développement) including the determination of tidal and wind-driven circulation. This paper presents additional work on the transport of dissolved and particulate matter. The approach chosen is based upon the joint development of numerical methods linked to field data gathering including currents, water levels, wind and water physico-chemistry. A 2-D model weas used to calculate current generated by tide and 3-D models were used to calculate wind driven currents, tide and wind being the two major current driving forces in this lagoon. By combining hydrodynamic modelling with diffusion equations we simulated the transfer of dissolved. Further implementation of transport equations were developed to determine the transport of particulate matters. Results from various typical cases are presented and confronted with field data. Finally, we studied the possible impact of freshwater inputs delivered by the main rivers on the transfer of dissolved and particulate matter.

BACTERIOPLANKTON IS A POOR TROPHIC RESSOURCE FOR THE PEARL OYSTER *PINCTADA MARGARITIFERA* ; EVIDENCE FROM SPATIAL DISTRIBUTIONS.

Dufour P.* and Jean-Pascal Torréton. *I.R.D., Station Marine d'Endoume, rue de la Batterie des Lions, 13 007 Marseille, France. Email: dufour@ird.fr

Farming of the black-lipped pearl oyster, *Pinctada margaritifera*, is the main economic resource of the Tuamotu Archipelago. Cultivated pearl oysters are hung on long-lines and can feed only on suspended particles. Bacterioplankton represents about half the live suspended organic particulate matter in Tuamotu atoll lagoons. Bacterioplankton abundance and activity are similar in lagoons sectors and at levels with and without dense *P. margaritifera* populations. It confirms other studies showing that *P. margaritifera* cannot retain free bacteria and feed mainly on particles above 3 µm in size. Heterotrophic protists channel a large part of the bacterioplankton production towards ***P.** margaritifera*, but this intermediate trophic level lowers the contribution of bacteria to pearl oyster diet. Therefore, by immobilizing a large part of suspended organic particulate matter and nutrients in a class size that is not retained by *P. margaritifera*, bacteria should decrease the carrying-capacity of the Tuamotu lagoons for oyster farming. This does take into account the indirect role of bacteria, which mineralize more than 90% of the dissolved organic matter they uptake in Tuamotu lagoons and therefore fuel the primary production and the trophic network that supports the pearl oysters production.

SPATIAL HOMOGENEITY IN ATOLL LAGOONS OF THE TUAMOTU ARCHIPELAGO.

Dufour P.* and Jean-Pascal Torréton. *I.R.D., Station Marine d'Endoume, rue de la Batterie des Lions, 13 007 Marseille, France. Email: dufour@ird.fr

Vertical profiles of particulate organic matter concentrations, bacterioplankton and phytoplankton biomass show usual homogeneity in atoll lagoons of the Tuamotu, except in the near bottom layer. Coefficient of variations are typically < 20% with no coherent structure along the water column. A vertical stratification is only observed in the deepest lagoons, > 30 meters. Surveys show even distributions for the same parameters with CV usually < 30 %. Perturbations are limited to the immediate vicinity of some areas like villages, reef-flat spillways and channels through coral rims, patch reefs, and shallow or confined waters. Such an isotropy was observed in 12 atoll lagoons in spite of their different morphology – from 1 to 400 km2, 2 to 50 m deep - and wide range of hydrological conditions –water residence time from few days to years. This spatial monotony may be related to some favorable circumstances: mixing by nearly constant eastern trade winds ($5 m.s^{-1}$ annual average), regular currents induced by wind or tide, strong stability of the oceanic surrounding waters of the South Pacific Gyre, limited organic matter and nutrients input from coral rim and bordering islands.

SOFT CORALS AND SEA FANS: A COMPREHENSIVE GUIDE TO INDO-PACIFIC CORAL REEFS.

Fabricius, Katharina * and Alderslade, Philip. *CRC for the Great Barrier Reef World Heritage Area, Australian Institute of Marine Science, PMB No. 3, Townsville MC, Qld 4810, Australia. Email:k.fabricius@aims.gov.au

Soft corals and sea fans are beautiful and abundant inhabitants of the World's coral reefs. To date, there has been no comprehensive guide which has allowed interested people to categorise soft corals beyond "soft coral sp.", or "others". We have produced a user-friendly field and laboratory guide which will open the door to the understanding and identification of the 23 families and 95 genera known from the warm shallow waters of the Central and Western Pacific, the Indian Ocean, and the Red Sea. Each genus is represented by: (1) a plate of underwater photographs, displaying the major growth forms with close-ups of characteristic details, (2) detailed drawings of the skeletal elements, and (3) accompanying text documenting their distinctive morphological and ecological characteristics, habitat and abundance, and zoogeographic distribution. The present-day knowledge of the biology and ecology of octocorals is summarised in the 40-page introduction, and a glossary explains the few technical terms used. Soft corals comprise a wide range of taxa with drastically different ecological characteristics, which may be used as environmental indicators. The ability of non-experts to identify soft corals and sea fans in species inventories and surveys will significantly advance our knowledge about this abundant and important group in Indo-Pacific coral reefs.

SEXUAL REPRODUCTION IN THE ELLIPTICAL STAR CORAL, *Dichocoenia stokesi* MILNE-EDWARDS AND HAIME, (ANTHOZOA: SCLERACTINIA) - PRELIMINARY RESULTS.

Feingold J.S.* and S. M. Hoke. Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania Beach, FL 33004 USA. E-mail Address: joshua@polaris.nova.edu

This study will document the seasonality and lunar periodicity of *Dichocoenia stokesi* sexual reproduction in populations located off Dania Beach, Florida. Details of gametogenesis and oogenesis, and the relationship, if any, between colony size and fecundity will be described. Gonadal development over time is being documented by analysis of histoslides prepared from *Dichocoenia* polyps collected several times per month on or near the full and new moons between 9/7/99 and 9/7/00. The relative abundance of gonads belonging to each of five oogenic and six spermatogenic stages will be plotted against date, *in-situ* temperature, and colony size over the course of one year. It is anticipated that *Dichocoenia* will exhibit reproductive patterns similar to other Caribbean scleractinian coral species with activity concentrated in the late summer. If brooding occurs, planula release is expected to peak in August and September. The study population is recovering from mortality associated with an epizootic of Plague Type II disease that began affecting South Florida scleractinians in the summer of 1995. Reduced populations of reproductively active *Dichocoenia* colonies in affected areas may have long-term consequences on recruitment and coral cover of this species.

EFFECTS OF DIFFERENT ENVIRONMENTAL FACTORS ON THE CELL-SPECIFIC DENSITY OF SYMBIOTIC DINOFLAGELLATES.

Ferrier-Pagès C.*, Allemand D., Shick M, Hoegh-Guldberg O., Muscatine L. Observatoire Océanologique Européen, Centre Scientifique de Monaco, Av. Saint-Martin, 98000 Monaco

Symbiotic dinoflagellates are abundant in the endoderm cells of marine anthozoans and play an important role in the nutrition of their host and the primary productivity of the communities in which they reside. The standing stock of these dinoflagellates in a given host is most often characterized in terms of areal or protein-specific density. The changes in standing stock can also be described in terms of the cell specific density (CSD) which is the number of dinoflagellates contained in a given host cell. We investigated the effects of different environmental factors on the CSD in the scleractinian coral *Stylophora pistillata*. CSD was measured during a series of conditions including separate nitrogen (ammonium and nitrate) and iron enrichment as well as under the influence of increased levels of ultra-violet radiation (UV). Control conditions were also performed. In the control corals, host cells containing a single dinoflagellate predominate (singlet), followed in decreasing frequency by those containing two (doublets), three (triplets) and up to six cells. The average CSD for control corals was 1.4 ± 0.2 (mean ± standard error). The enrichment of seawater with nitrogen or iron as well as the increase in the UV levels resulted in a dramatic increase in the CSD (10 to 30% compared to a control value), mostly due to an increase in the doublets and triplets. The potential consequences of environmentally induced increases in CSD in tropical anthozoans include decreased cell-specific photosynthesis and decreased rates of calcification.

PICO- AND NANOPLANKTON PREDATION BY THE ZOOXANTHELLATE CORAL *STYLOPHORA PISTILLATA*.

Ferrier-Pagès C.*, Denis Allemand, Jean-Pierre Gattuso, Jean Jaubert and Fereidoun Rassoulzadegan. *Observatoire Océanologique Européen, Centre Scientifique de Monaco, Av. Saint Martin, MC 98000 Monaco (Prioncipality), Email: ferrier@unice.fr

The ability of the zooxanthellate coral *Stylophora pistillata* to feed on microbes such as bacteria and protozoa has been investigated under experimental conditions. For this purpose, a new method was developed to obtain clean cultures of ^{3}H-thymidine labeled bacteria and ciliates. Coral colonies were incubated during 4 h with labeled microbes and appearance of radioactivity in coral tissues indicated that 7% and 90% of the labeled bacteria and ciliates were ingested respectively. In additional experiments, coral colonies were incubated in medium containing different concentrations of unlabelled ciliates (200, 500, 800 cells ml^{-1}) and were exposed to three different light levels (0, 80, 250 µmol m^{-2} s^{-1}). Feeding rates were dependent on prey concentrations and varied between 1.40 and 4.10 $x10^{4}$ ciliates for an initial food concentration of 200 and 800 ciliates ml^{-1} respectively. A plateau was observed after a total ingestion of 4 x 10^{4} ciliates, independent of the initial prey concentration. Feeding rates were also light dependent, the amount of carbon ingested during dark experiments was twice as high as the amount ingested during light experiments. This result suggests that the food capture may be complementary to the autotrophic nutrition, with a supply of nitrogen, phosphorus and vitamins.

COMMUNITY STRUCTURE, ECOMORPHOLOGY AND FEEDING OF INTERTIDAL FISHES FROM THE FERNANDO DE NORONHA ARCHIPELAGO, NORTHEASTERN, BRAZIL (PERCIFORMES: GOBIOIDEI, BLENNIOIDEI)

Figueiredo Mendes, Liana de* *Zool. Dept., IBUSP, São Paulo, SP, Brazil. CEP 05422-970, CP 11461 Email: limendes@usp.br

A major component of the high species diversity in tropical Western Atlantic coral reef fishes communities are the small, cryptic, sedentary species such as the blennies and gobies. The Fernando de Noronha Archipelago, situated in northeastern Brazil, houses five Gobioidei (Gobiidae) species and eight Blenioidei species (Labrisomidae, Blenniidae, Tripterygidae). These fishes were studied with the main focus being the relationship between community structure, ecomorphology and feeding. Transects were made through visual census in the field for the analysis of community structure, with a total of 490 samples, each 2 x 2 m. The species and units samples were ordered in function of environmental gradients, using multivariety analysis (PCA and CCA).The ordination diagrams indicated the association type between the species and substratum and these associations can be related to the feeding and defense strategies. In the ecomorphology analysis, the corporal form of the fish can be interpreted as indicative of the fishes' behavior and its adaptations to the habitat. The results obtained on community structure and ecomorphology were interpreted together, considering the obvious relationship among the approaches used and the fact that the ecomorphological associations are repeated in the community structure diagrams. In the analysis of the species' diet, calculations were made of niche overlap on the values of percentile composition. The high indexes found for niche overlap can be minimized analyzing differences in the space and temporary distribution.Finally, the present study seeks to understand these intertidal fishes, a fundamental component of the ecological sea web, specialized in facing the oscillations of this turbulent ecosystem.

HISTORICAL BIOGEOGRAPHY OF THE SHRIMP GENUS *PONTONIA*, (CRUSTACEA, PONTONIINAE) WITH EMPHASIS ON INDO-PACIFIC SPECIES.

Fransen C.H.J.M.*. Nationaal Natuurhistorisch Museum – Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. Email: fransen@naturalis.nnm.nl

Species of the genus *Pontonia* occur in tropical and subtropical waters around the world. They associate with ascidians and molluscs. The phylogeny and biogeography of the 26 presently recognised species have been analysed. Analysis was performed using PAUP and McClade software. Characters in which the apomorphic state is a reduction of a structure (an adaptation to the associative life-style) were avoided to keep homoplasy indices low. The basal dichotomy splits the Indo-West Pacific from the Atlantic and East Pacific species. Within the latter group the successive dichotomy divides the species in a mollusc- and an ascidian-associated group. The rather recent isolation of West and East Atlantic and East Pacific populations can be found high in the tree. As far as known the Indo-West Pacific species are all ascidian associates except for two associated with molluscs. These two mollusc-associated species are not closely related, neither are their hosts, indicating a separate introduction to the mollusc host.

FISH LARVAE FROM THE JORDANIAN COAST OF THE GULF OF AQABA- RED SEA.

Froukh, T.*. *Marine Science Station (Mss), *University Of Jordan, P.O. Box 195, Aqaba, Jordan. email: TAWFIQFE@YAHOO.COM

Gulf of Aqaba the Northeast branch of the Red Sea. Characterised by extensive fringing reefs, which provide wide range of niches. Fishes are dominant group of coral Fauna with regard to the both biomass and diversity. Despite the Gulf of Aqaba Ichthyofauna is quite well known there was few studies on the fish larvae in the Gulf and no previous studies in the Jordanian Coast. Light traps were used to collect fish larvae for one-year cycle (weekly) from May 1999 to May 2000. Morphometric and meristic characters with the help of double staining and radiographic techniques were taken to identify the samples using the Indo-Pacific literatures. The present study indicated 32 genera belonging to 22 families and 11 species out of the 32 genera were positively identified. Clupiedae, Apogonidae, Pomacentridae and Blennidae are the most dominant families in the study.

SPECIES-AREA CURVE OF SOME CORAL COMMUNITIES IN SOUTHWESTERN JAPAN.

Fujioka, Y*. *National Research Institute of Fisheries Science, 6-1-21 Sanbashi-St., Kochi 780-8010 JAPAN. Email: fujioka@affrc.go.jp

Twelve representative hermatypic coral communities were investigated by means of a large quadrat method of 50 m X 50 m around Ishigaki Island, southwestern Japan, in order to compare the community structure and species diversity. The coral coverage was 5.1-89.8 %, in which the highest one was observed in the *Acropora digitifera* community on the outer reef flat. Totals of ranging from 31 to 132 species were recorded in each community. Coral species diversity increased from the coastal side to the reef margin through the reef flat, was highest at the *Acropora hyacinthus* and the *Mycedium-Oxypora* complex communities on the reef slope of approximately 5-15 m depth, and began to decline below 15 m depth. Ramous *Acropora* and *Montipora* species formed diverse communities consisting of several allied species of the same genera, while *Galaxea astreata*, *Leptoseris gardineri* and *Heliopora coerulea* formed less diverse communities predominantly consisting of one or a few species only. Coral colonies distributed with more or less aggregated patterns, in which approximately 10 % species of each community were present in 1 m^2 quadrat. The species-area curve was approximated to logarithmic functions for each community.

CARBON SOURCE FOR CORAL CALCIFICATION AND PHOTOSYNTHESIS

Furla, Paola *, Isabelle Durand & Denis Allemand*Observatoire Océanologique Européen, Centre Scientifique de Monaco, Avenue Saint-Martin, MC-98000 MONACO Email: Denis.Allemand@unice.fr

Sources and mechanisms of inorganic carbon transport for scleractinian coral calcification and photosynthesis have been studied by using a double labelling technique with $H^{14}CO_3$ and ^{45}Ca. Independently of lighting conditions, the major source of dissolved inorganic carbon (DIC) for calcification is the metabolic CO_2 (70-75 % of total $CaCO_3$ deposition), while only 25-30 % originated from the external medium (sea water carbon pool). Sea water DIC is transferred from the external medium to the coral skeleton by two different pathways: from sea water to the cœlenteron, the passive paracellular pathway is largely sufficient while a DIDS-sensitive transcellular pathway is likely present to cross calicoblastic cells. Independently of the source, an anion exchanger performs the secretion of DIC toward the site of calcification. Concerning DIC supply for symbiotic Dinoflagellates photosynthesis, the presence of a DIC pool within the tissues was demonstrated. The size of this pool increases by 39-fold within 3 hours upon illumination. Passive DIC equilibration through oral tissues between sea water and the cœlenteric cavity is insufficient to supply this DIC pool suggesting that there is an active transepithelial absorption for photosynthesis sensitive to DIDS, EZ and iodide sea water as demonstrated in sea anemone. These results confirm the presence of CO_2-concentrating mechanisms in coral cells. This tissue pool is however not used as a source for calcification since no significant lag phase in the incorporation of external sea water DIC was measured.

PALAEOCLIMATE DYNAMICS: EXPLORING THE CORAL RECORD

Gagan, M.K.*, Ayliffe, L.K., Hantoro, W.S., Hopley, D., Lynch, H.S., McCulloch, M.T. and Sieh, K. Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia. Email: Michael.Gagan@anu.edu.au

Massive corals growing in the reef ecosystems of the tropics provide some of the richest palaeoclimate archives in the world. Seasonally resolved palaeoclimate data are essential for reconstructing dynamic climate changes on time-scales that are immediately relevant to society. The purpose of this poster is to demonstrate the remarkable ability of corals to record climate processes that are closely linked to the annual cycle. We are developing a multi-proxy approach ($\delta^{18}O$, Sr/Ca, $\delta^{13}C$, $\delta^{14}C$) to coral-based palaeoclimatology that is revealing surprisingly accurate, detailed records of the following climatic processes:

- The seasonal expression of the ENSO in the tropical western Pacific;
- The seasonal dynamics of the Asian-Australian monsoon;
- The seasonal magnitude of surface-ocean evaporation;
- Wind-induced coastal upwelling and changes in atmospheric circulation;
- Volcanic aerosol-induced ocean cooling and reduced solar irradiance.

We will first present fortnightly resolved data sets for modern corals that have been calibrated with instrumental data (temperature, rainfall, salinity, wind velocity, solar irradiance) to demonstrate the accuracy of the proxy records. We will then present data sets extracted from fossil corals (8 ka to present) that reveal subtle (but important) changes in the palaeoclimate dynamics of the past.

A BIOGEOGRAPHICAL STUDY OF PARASITIC GASTROPODS AND THEIR CORAL HOSTS IN THE INDO-WEST PACIFIC.

Gittenberger, A., B.W. Hoeksema* & E. Gittenberger. Nationaal Natuurhistorisch Museum / Naturalis, Postbus 9517,
2300 RA Leiden, The Netherlands. Email Hoeksema@naturalis.nnm.nl

Little is known of the cause and maintenance of the high level of biodiversity at the central Indo-Pacific. Two main factors have been distinguished: (1) many Indo-West Pacific species have, vast wide-spread distributions that overlap in the Indo-Malayan Triangle of maximum diversity; and (2) many species have complex symbiotic and parasitic relationships. However, the evidence for these hypotheses is scant and the details are unclear. In the first case, how can gene flow be maintained over such long distances in putatively widespread species, whose pelagic larvae are nonetheless relatively short-lived? And in the second case, is it true that symbiotic relationships among marine organisms lead to co-evolution, co-speciation, and hence elevated biodiversity? Mushroom corals (Fungiidae) and their parasitic gastropod snails (Epitoniidae and Coralliophilidae) are ideally suited to answer these questions. Understanding the population genetics and evolutionary history of these animals will reveal: (1) whether gene flow and the integrity of widespread species are maintained across the Indo-Pacific; (2) to what degree the snails and their coral hosts are co-evolving; and (3) whether the historical biogeography and geologic timing of reconstructed speciation events can shed light on the evolutionary mechanisms that have led to the present diversity. We plan to sequence multiple DNA markers for these mushroom corals and their gastropod parasites so as to reconstruct the historical phylogeny of host-parasite pairs and to understand the population genetics of widespread species.

SITE- AND DEPTH-SPECIFIC VARIABILITY IN THE CHEMISTRY OF THE CARIBBEAN SPONGE *PLAKORTIS* SP.

Gochfeld D.J.*, Marc Slattery, Bonnie A. Avery and Mark T. Hamann. Department of Pharmacognosy, University of Mississippi, University, MS 38677-1848 USA. Email: deborahg@olemiss.edu

In many parts of the Caribbean, sponges form a major component of the exposed coral reef fauna. Many of these sponges are able to persist in these exposed habitats by virtue of their chemical defenses against diverse predators. Sponges of the genus *Plakortis* contain a diversity of biologically-active secondary metabolites, and are extracts of these sponges are deterrent to Caribbean reef fishes. We collected individuals of the sponge *Plakortis* sp. from various sites and depths along the north coast of Jamaica, in the Bahamas, and on the barrier reef in Belize. Chromatographic fingerprints indicated variation in the chemical profiles of sponges from the two locations, as well as from different sites and depths within those locations. We are presently testing the hypothesis that variability in chemical constituents of this sponge is the result of differential predation regimes; spongivorous fishes are virtually absent from Jamaican reefs but are abundant on Bahamian and Belizean reefs.

INFRALITTORAL MALACOFAUNA BIODIVERSITY ON THE NORTH COAST OF QUINTANA ROO, MEXICO.

Gonzalez, Alicia *, Torruco, Daniel; and Axis, Javier. *CINVESTAV-IPN Laboratory of Coral Reef, Center for Research and Advances Studies, A.P. 73 Cordemex, 97310 Merida, Yucatan, Mexico. Email: alitor@mda.cinvestav.mx

Infralittoral malacofauna was analyzed from three locations on the coast of Quintana Roo, Mexico: Chemuyil, Akumal and Pamul. The Linear Transect method, with stations every 2 m, was used to sample abundance and biomass. Of the 60 total recorded species, gastropods were the most abundant and diverse class. The most dominant species in all three locations was *Cittarium pica*, and the location with greatest species richness was Chemuyil. In the cluster analysis, Akumal and Chemuyil had the greatest affinity and Pamul the least. There was a marked regional variation in community composition. High gastropod densities were found in physical habitats with topographic depressions and biotics with filamentous algae congregations. Refuge quality for these organisms increased as a function of slope, and thus biodiversity levels within the transects increased as they neared the breaking waves zone, with the highest diversity levels being found at the end of the transects.

COLONY SIZE, FISSION, AND EFFECT OF RAMETS TO POPULATION GROWTH IN THE ZOANTHID *Palythoa caribaeorum*.

González, M*; & Acosta, A. *Pontificia Universidad Javeriana Kra. 7#43-82. Depto. Biología, Bogotá, Colombia. Email: aqua06@altavista.net

Colombian populations of *P. caribaeorum* were quantified during the summer of 1998 to determine whether 1) colony size is related to frequency of fission, 2) there is a minimum colony size for fission, and 3) ramet production *via* three variants of fission affects population growth. A significant positive linear relationship was found to exist between colony size and the number of ramets produced per colony ($r^2 = 0.2$, $p < 0.01$). The low correlation coefficient suggested that factors other than colony size may also control fission frequency. The minimum size of a colony involved in fission was 4 cm^2; the regression model predicted that the average size of first fission would be 10 cm^2 area. Fitness in *P. caribaeorum* may increase with colony size. 71% of 383 colonies exhibited at least one variant of fission. Edge Fission was the dominant fission mode (87%). 273 colonies produced a total of 1474 ramets during the summer, implying that asexual reproduction is most likely responsible for a substantial contribution to population growth in this species.

INDO-PACIFIC DISTRIBUTION PATTERNS IN STROMBIDAE,
A SINGLE MOMENT IN A DYNAMIC WORLD.

Goud J.* &Gittenberger,E.. *Nationaal Natuurhistorisch Museum / Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. Goud@naturalis.nnm.nl

Among the five extant genera of the Strombidae, *Strombus* is world-wide the most speciose, with appr. 55 species, 40 of which have an Indo-Pacific distribution. The family contains about 80 species world-wide. Originating in the Eocene, the genus *Strombus* flourished during the Pliocene and early Pleistocene in the area of Southeast Asia. They are usually herbivorous or detritus-feeders, living in shallow waters which are warm enough to support the growth of coral reefs. About 50% of the *Strombus* species living in the Indo-Malayan Triangle of maximum diversity area are Indian Ocean species; 70% have (also) a Pacific distribution; 7 endemic species occur additionally. Based on fossil records there is some knowledge of historical distribution patterns. These can be combined with supposed phylogenies, so far largely based on shell morphologies, resulting in hypotheses on the evolution of this group. Certainly the diversity peak is partly caused by overlap of two biogeographic regions. Some species probably originated from isolated populations at the periphery of their ranges after which they dispersed by predominant surface currents and accumulated in the Triangle. Other species might have originated within the area in localised basins in which isolation took place during periods of sea level changes. Some of these hypotheses will be tested against the fossil record, especially if geologic timing is possible. In general molecular techniques will be used, both to get estimates of divergence time ('biological clock' model) and to achieve more reliable phylogenies.

BRAZILIAN REEF FISHES: SCARCE DOCUMENTATION AND PREDATORY EXPLORATION.

Guimarães R.Z.P.*. *Laboratório de Biodiversidade de Recursos Pesqueiros, NIGP/UFRJ, Depto Biologia Marinha, Cidade Universitária, 21941-569, Rio de Janeiro, Brazil. Email: ricardo@biologia.ufrj.br

Although the Brazilian reef-fish fauna has been subject to study since pre-Linnean times, it stands today as one of the least known in the world. From Marcgraff's 1648 bizarre drawings to the present profusion of SCUBA enthusiasts, very little has changed. Much of the investigation process still depends upon the curiosity of foreign scientists and native amateurs. Grants and fellowships are exiguous, as research programs are irregularly launched by our meager agencies. From the yat-owner spear-fishermen to the modest hook and line fishermen, Brazilian reef fishes have been inadvertently exploited as a food source. Combine that with our long history of predatory capture of ornamental organisms and unplanned occupation of the coastal zone and we get the unpleasant scenery of local extinction of many species. Such silent destruction has been generally overlooked by both national and international agencies. The *IUCN Red List* includes only two Brazilian endemics and Brazilian official lists of threatened species are both deficient and ignored. Overexploitation of Brazilian reef resources are also barely reported in the scientific literature. As it seems hard to believe that the national government is capable of financing or planning a serious research and development program on the subject, those who depend upon Brazilian reef-fishes are eager to see some international help.

VICARIANT SCENARIOS UNDERLYING ENDEMISM IN BRAZILIAN REEF FISHES.

Guimarães R.Z.P.* & Nunan, Gustavo W. *Laboratório de Biodiversidade de Recursos Pesqueiros, NIGP/UFRJ, Depto Biologia Marinha, Cidade Universitária, 21941-569, Rio de Janeiro, Brazil. Email: ricardo@biologia.ufrj.br

Examination of specimens belonging to several supposedly Western Atlantic species (*e. g.* the blenioids *Scartella cristata* and *Malacoctenus triangulatus* and the gobioid *Elacatinus randalli*) revealed these are in fact species complex, with distinct representatives present in the Caribbean, the Brazilian continental margin, and two insular complexes: Atol das Rocas-Fernando de Noronha and Trindade-Martin-Vaz. Appearance of such zones of endemism within the tropical western Atlantic has been associated with Pleistocene glacial cycles, when available habitats were compressed and expanded as the sea level varied. As it has been suggested for reef corals, the presence of Caribbean-sibling reef-fishes endemic to the Brazilian coastline is a result of a pleistocenic refugee of a tertiary fauna. Both insular complexes mentioned are the outposts of a series of continental-ward sea-mounts that were exposed in the last glacial peak (16.000 - 14.000 yr B P). Subsequent rising of the sea level extinguished populations in the intermediate sea mounts, thus isolating those in the outposts.

BIOSEDIMENTOLOGY, TAPHONOMY AND CARBONATE BUDGET FOR *HALIMEDA* (CHLOROPHYTA) ON REEFS IN FIJI.

Gussmann O. A.* University of Otago, Department of Marine Science, PO Box 56, Dunedin, New Zealand. Email: GUSOL423@student.otago.ac.nz

The green algae *Halimeda* is well known as a producer of loose carbonate sediment in warm-water reef areas. The important contribution *Halimeda* makes to a coral reef carbonate sediment budget is well documented by geo-sedimentological evidence, but there is only scant information available on growth and production rates. Due to the tropical affinities of *Halimeda*, its presence in sedimentary deposits has been used as a diagnostic feature in the interpretation of palaeoenvironments, but little detailed attention has been paid to its preservation potential (taphonomy). This poster, based on Ph.D. research in progress, will present research which addresses the issues of growth, production and taphonomy through field and laboratory work in order to define the important processes in the carbonate sediment budget of *Halimeda* on two shallow-water reefs in Fiji. Particular attention is paid on determining growth and production parameters (growth rate, turnover rates, potential carbonate production), and the relative importance of abrasion and dissolution on preservation potential and taphonomic signature of several species of *Halimeda*.

MORPHOLOGIC AND GENETIC VARIATION OF THE GORGONIAN *PSEUDOPTEROGORGIA ELISABETHAE*.

Gutiérrez-Rodríguez, Carla * and Howard R. Lasker. Department Of Biological Sciences, University At Buffalo, Buffalo, N.Y. 14260, Usa.
Email: CG8@BUFFALO.EDU

Colonies of the Caribbean gorgonian *Pseudopterogorgia elisabethae* vary in appearance between and among populations, and it is unclear whether the observed morphologic variation is genetically based. Anecdotal evidence of differences in time of spawning in different sites, and the fact that the environmental conditions are similar between sites suggests that the differences may be caused by factors other than phenotypic plasticity. We compared colony morphology and genetics of *P. elisabethae* from three islands of the Bahamas to determine if the observed pattern of morphological variation is genetically based. We measured branchlet length, angle, curvature, internode distance between branchlets of the same and opposite side as well as total colony height of individuals from Hog Cay and Abaco. Discriminant function analysis and principal component analysis identified differences in morphology of colonies between Abaco and Hog Cay. DNA sequences of the internal transcribed spacers (ITS-1 and ITS-2) of the ribosomal DNA multigene family also varied between islands. Maximum parsimony and distance analyses of the ITS sequences identified clear differences between colonies from Hog Cay versus those from Abaco or San Salvador.

PATTERNS OF CORAL SPAWNING ON SUBTROPICAL REEFS FROM EASTERN AUSTRALIA.

Harrison, Peter L. * *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

Reproductive patterns have been well documented for many tropical coral communities, however, little is known about sexual reproduction in subtropical corals. Accordingly, patterns of sexual reproduction and spawning periods were studied at three subtropical reef regions along the East Coast of Australia. At Moreton Bay (27ºS) in southeast Queensland, faviid species spawned gametes in December, while other faviid and mussid species probably spawned in January. Coral communities at the Solitary Islands (30ºS) in northern NSW had an extended spawning season. Some *Acropora* and *Acanthastrea* species spawned during the week following the full moon in February, while other corals still contained maturing gametes after full moon periods in March and April. These are the first records of coral reproduction along subtropical eastern Australia, south of the Great Barrier Reef. More extensive studies of coral spawning have been completed at Lord Howe Island (31ºS), located 630 km east of the subtropical East Coast of Australia. Synchronous multispecific spawning by a range of *Acropora*, faviid, and other species occurred following full moon periods in January and February, and sometimes resulted in coral spawn slicks. Spawning on subtropical reefs tended to be less synchronous among species, and in some cases less synchronous within populations, compared to the more highly synchronised mass coral spawning events on the Great Barrier Reef. Furthermore, spawning periods are delayed compared to the GBR, and appear to follow the later rise in sea temperatures down the East Coast. These data show that many subtropical corals are capable of successful reproduction, and may contribute significantly to local recruitment.

TECHNIQUES FOR DETERMINING THE IMPACTS OF NATURAL AND POLLUTION STRESSORS ON SEXUAL REPRODUCTIVE SUCCESS IN SCLERACTINIAN CORALS.

Harrison P.L.* *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

Sexual reproduction processes have a narrower tolerance to natural and pollution stressors than other life functions such as growth and survival. Therefore, studies of the effects of stress on critically important reproductive processes can provide sensitive indicators of sublethal impacts of natural and pollution stress on reef corals, which are key elements of coral reef ecosystems. Knowledge of predictable gamete spawning and planulae release periods in many corals provides access to vast numbers of spawned gametes, embryos and larvae for experimental purposes. This paper details a recently developed method for quantifying the impacts of stressors on fertilization success in broadcast spawning scleractinian reef corals. Spawned coral gametes are collected, groups of ~100 eggs are photographed and placed into replicate glass vials, sperm density is adjusted to quantify any decrease or increase in fertilization response, and aliquots of sperm are added to another set of replicate glass vials. The replicate vials of eggs or sperm are exposed to various treatments including control conditions and a range of altered water quality or pollutant conditions for 30 minutes. Eggs and sperm are then combined, and after a 5 hour incubation, the percentage fertilization and normal embryo development are determined.

SPAWNING PATTERNS AND THE EFFECTS OF STRESS ON REPRODUCTIVE SUCCESS IN REEF CORALS FROM KUWAIT.

Harrison P.L.*, Alhazeem, Shaker H.; Alsaffar, Adel H.; and Al-Sabah, Iman. *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

Despite the harsh environmental conditions in the northern Arabian Gulf, scleractinian reef corals from Kuwait are capable of successful reproduction. The coral species studied exhibited an extended spawning pattern, with *Acropora arabensis* and *Acropora downingi* colonies spawning gametes during May. Spawning began prior to the full moon in May, with more extensive spawning observed during the week after the full moon. Thousands of *Acropora* larvae were reared from spawned gametes, and some of these larvae survived for more than one month. One *A. arabensis* larva was able to settle successfully four weeks after spawning, hence there is considerable potential for dispersal of *Acropora* larvae within the Arabian Gulf. Colonies of the brain coral *Platygyra daedalea* spawned synchronously mainly 4-5 nights after the June full moon, while colonies of *Porites* and *Favia* species probably spawned in August or September. An experiment on the effects of altered salinity on fertilization success of *A. downingi* gametes indicated that the elevated salinity around Kuwait's coral reefs does not inhibit fertilization, whereas fertilization rates were reduced at 27 ppt, and blocked at 21 ppt and below. An experiment on the effects of the water accommodated fraction of Kuwait crude oil on settlement rates of *A. arabensis* larvae, showed that larval settlement was significantly reduced at relatively low hydrocarbon concentrations of 0.1-0.3 ppm, while larval settlement was blocked at 1 ppm.

EFFECTS OF SEDIMENTATION ON GENE EXPRESSION OF THE SCLERACTINIAN CORAL *POCILLOPORA DAMICORNIS*.

Hashimoto K.*, Eiko Kayano, Toshiaki Kayano, Takuro Shibuno, Osamu Abe and Yoshitake Takada. Ishigaki Tropical Station, Seikai National Fisheries Research Institute, Fukai-Ohta 148-446, Ishigaki, Okinawa 907-0451, Japan. Email: hashimot@snf-its.affrc.go.jp

Differential display was used to identify specific coral genes induced or suppressed under sediment loading. Four-centimeter branches of the scleractinian coral *Pocillopora damicornis* were exposed to 500ppm of reddish silt-clay. Total RNA was extracted from the branches using a commercially available AGPC-based RNA extraction kit. Following the DNase treatment, first-strand cDNA synthesis was performed. The cDNA was then amplified in a PCR mixture containing an arbitrary primer (10-mers). The PCR products were visualized on an 8% denaturing polyacrylamide gel. There were several bands appearing only in the control or in the sediment-treated sample, which imply that sedimentation changes the pattern of gene expression of the coral. The sequences and deduced functions of these candidate bands will be discussed.

ORGANIC CARBON FLUX IN SHIRAHO REEF (ISHIGAKI ISLAND, JAPAN).

Hata H.*, Setsuko Kudo, Hiroya Yamano and Hajime Kayanne. Japan Science and Technology Corporation, 113-0033 Japan. Email: hata@eps.s.u-tokyo.ac.jp

The studies of coral reef productivity have been conducted in many sites. Recent results indicate that many reefs have excess community production of organic materials (i.e. P/R>1.0). On the other hands, few data on the fluxes of organic materials are available at present and little is known about the fate of organic materials produced on the coral reef. We studied organic carbon flux together with community production rate in Shiraho reef (Ishikgaki Islands, Japan) during 21-23, Sep. 1998. Estimation of daily community production rate was carried out using the data of total inorganic carbon (TIC) and total alkalinity (TA) in seawater during slack-water period, with the data of photon flux density and water depth. The concentrations of dissolved organic carbon (DOC) and particulate organic carbon (POC) in seawater generally increased during slack-water period both in daytime and nighttime, attributable to exudation of organic materials by the reef organisms. We estimate that about 60 % of excess community production of organic carbon are released to water column and the rest (40 %) are stored as biomass.

ELECTRON MICROSCOPIC OBSERVATIONS ON THE SETTLEMENT OF *ACROPORA* PLANULAE.

Hayashibara T.* Iwao, K.; Sano, M.; Minagawa, M.; Tamaki, M.; Fukuoka, K.. *Ishigaki Tropical Station, Seikai National Fisheries Research Institute, 148 Fukai-Ohta, Ishigaki, Okinawa 907-0451, Japan. Email: hayat@snf-its.affrc.go.jp

In order to understand the mechanism of larval settlement, laboratory-reared planula larvae of reef-building corals *Acropora* spp. were examined by electron microscope prior to and immediately after the settlement. The surface of free-swimming larva was uniformly ciliated and apical tuft of elongate flagella was not observed. At least two types of cnida (basitrichous isorhiza and spirocyst) were observed in the ectodermal layer. Particularly the spirocysts were found on the surface of aboral region where a larva attached with substratum, and also on the substratum vicinity of the settled larva. Thus the spirocysts in *Acropora* planula might be used for the settlement, along with the gland cells which secrete the adhesive substances.

GORGONIAN AND SCLERACTINIAN CORAL COMMUNITIES OF THE TURKS AND CAICOS ISLANDS.

Hoshino, K.*; Manfrino, C; & Riegl, B.. *Bren School of Environmental Science and Management, University of California, Santa Barbara, Santa Barbara, CA 93106-5131. Email: khoshino@bren.ucsb.edu

Shallow-water (4-21m) coral communities were surveyed at 24 sites spanning over 100km of reef around the Turks and Caicos Islands (TCI) in August 1999. Line transects were used to survey scleractinian and gorgonian communities in the vicinity of Grand Turk, Providenciales, South Caicos, West Caicos and the Mouchoir Bank. A total of 26 scleractinian species among 18 genera and 11 gorgonian genera were recorded in 68 transects. Scleractinian coral species diversity (H') was 1.77 on average, ranging from 1.04 to 2.29. Comparison among different locations revealed that Providenciales and West Caicos had higher scleractinian diversity than other locations. The number of Gorgonian genera was also highest in West Caicos, but overall scleractinian and gorgonian diversity did not show a correlative relationship. Q-mode cluster analyses of scleractinians, gorgonians and the whole coral communities all showed the formation of distinct communities separated mainly by locations (islands). However, scleractinians and gorgonians showed a somewhat different way of clustering: gorgonian communities were characterized more strongly by the location, suggesting overall environmental conditions to be an important determinant in gorgonian communities. On the other hand, water depth seemed to play an important role in structuring scleractinian communities. These results implicitly support the hypothesis that different factors are responsible for structuring scleractinians and gorgonians communities.

HAWAIIAN PELAGIC PORTHOLE.

Hughes, Marc*. *University of Hawaii at Hilo, P.O. Box 390414 Kailua Kona, Hawaii 96739. Email marchugh@hawaii.edu

The diversity of marine organisms surrounding the Hawaiian Islands is limited due to the archipelagos' isolation. A photographic diary of animals that inhabit the marine environment of Hawaii reveals a variety of specialized food webs. The nekton that navigate in the pelagic areas of Hawaii include cetaceans such as the humpback whale (*Megaptera novaeangliae*) and Hawaiian spinner dolphins (*Stenella longirostris*). The ocean currents also carry with them an amazing menagerie of zooplankton. Many types of zooplankton make a vertical migration from the deeper waters of the mesopelagic region at night. The zooplankton represented by these photographic images reveal relatively unknown secrets about the lives of these animals. Many types of gelatinous zooplankton are hosts to symbiotic crustacean larvae. Certain larval fish display trailing dorsal and anal fin rays (Trachipteridae family), that are a mirror image of poisonous siphonophore (*Physophora hydrostatica*) tentacles, to discourage hunting predators. The bioluminescence, mimicry, symbiotic relationships and food webs associated with these animals' rivals that of any other ecological niche.

DEGRADATION OF ORGANIC CARBON IN CORAL REEF SEAWATER.

Ikeda Y*, Hiroshi Hata , Kimio Fukami, Hajime Kayanne. Hazama Technical Research Institute, Tsukuba, Japan. E-mail yikeda@hazama.co.jp

Seawater of Shiraho Reef on Ishigaki Island, Okinawa Japan was incubated with initial volume of 10 litters. Degradation of organic carbon in the coral reef seawater was followed for about three months in the dark statical condition by monitoring the concentration of organic carbon, nutrients, cell density and biomass of bacteria etc. in the seawater. The concentration of dissolved organic carbon (DOC) gradually decreased remaining the refractory gradients. The ratio of labile organic carbon to total organic one (TOC) was 19 to 31 percents in the reef water and 31 percents in the offshore. The rates of particle organic carbon (POC) to TOC were 3.0-4.6% at the initial stage and 0.6-1.0% after incubation. This suggests that labile organic matter is mainly composed of POC. On the other hand, the concentration of inorganic nutrients was increased gradually with the decomposition of the organic matter. In terms of the cell density and cell biomass, they became at the top within one day, however, then slowly decreased until less than the initial value.

COMPOSITION AND DISTRIBUTION OF RELATIVELY FINE-GRAINED SEDIMENTS OFF MIYAKO-JIMA, RYUKYU ISLANDS, JAPAN.

Iryu, Yasufumi*; Ogoshi, Takayuki; and Tsuji, Yoshihiro. *Institute of Geology and Paleontology, Graduate School of Science, Tohoku Univ., Sendai 980-8578, Japan. Email: iryu@dges.tohoku.ac.jp

Examined were composition and distribution of relatively fine-grained (< 4 mm in diameter) sediments in reef to shelf areas off Miyako-jima, Ryukyu Islands, Japan. The sediments from selected 50 sites were embedded in an epoxy resin and then made into thin sections. Composition of organic skeletons (benthic foraminifera, planktonic foraminifera, corals, bryozoans, molluscs, coralline algae, *Halimeda*, and other bioclasts) and intra-/extraclasts were determined by point counting method. Eight sedimentary facies were discriminated by Q-mode cluster analysis. They are: coralline algal-molluscan facies (no particular environment), coral facies (reef), intra-/extraclast facies (shelf edge to upper shelf slope), benthic foraminiferal gravelly facies (outer shelf), benthic foraminiferal sandy facies (reef to inner shelf), planktonic foraminiferal facies (shelf slope), fine bioclast facies (shallow (< 50 m) restricted environment and deep (> 200 m) shelf slope), and coarse bioclast facies (shelf to upper shelf slope). Our investigation will provide a useful basis to determine paleoenvironment of ancient reef deposits such as Pleistocene Ryukyu Group.

GROWTH AND FORMATION OF *Vibrio Shiloi* VBNC STATE INSIDE THE CORAL EPIDERMIS.

Israely, T.*, E. Banin, Y. Loya And E. Rosenberg. *Faculty Of Life Science, Tel-Aviv University, Israel. Email: EUEQENE@CCSG.TAU.AC.IL

The causative agent of bleaching of the coral *Oculina patagonica* along the shores of Israel in the Mediterranean Sea is the bacterium *Vibrio shiloi*. The bacterium becomes virulent at elevated temperatures, adhering to the coral through a specific receptor. After *V. shiloi* adheres to the coral, the bacteria penetrates into the epidermis as observed by electron microscope and the use of specific anti - *V. shiloi* antibodies. Using the gentamicin invasion assay, we were able to measure the kinetics and extent of *V. shiloi* penetration into the coral. Shortly after penetration, the bacteria are converted to a viable but not culturable (VBNC) state. Although *V. shiloi* can not be detected by the usual plating techniques they can be detected by fluorescent microscopy using a polyclonal antibody and a viability kit (LIVE/DEAD Kit) that confirms that they are alive inside the coral tissue. The bacteria multiply, reaching an intracellular concentration of ca. 10^8 per cm^3. The high concentration of intracellular bacteria, close to the zooxanthella, should facilitate the targeting of the *V. shiloi* toxins. One implication of the VBNC state is that isolation of other bleaching pathogens may require techniques other then direct plating on agar media.

INDUCTION OF METAMORPHOSIS WITH LW-AMIDE NEUROPEPTIDES IN THE GENUS *ACROPORA*.

Iwao, Kenji*, Fujisawa, Toshitaka and Hatta, Masayuki. *Akajima Marine Science Laboratory, 179 Aka, Zamami-son, Shimajiri-gun, Okinawa, Japan. Email: address: iwao@amsl.or.jp

Coral larvae may sense appropriate environments and start metamorphosis by converting external signals into internal cues. A family of neuropeptides, LW-amides, can induce metamorphosis in some hydrozoans, and are thought as internal metamorphosis cues with hormonal properties. We tested various peptides isolated from freshwater hydra for metamorphosis inducing activity on coral larvae in culture. Three members of the LW-amide family peptides induced metamorphosis of acroporids in a concentration dependent manner. Metamorphosis processes seemed normal. One of the active peptides was further investigated. The planulae were irreversibly entered the metamorphosis pathway by incubation with the peptide for more than 4hrs. The peptide was effective only for *Acropora* but not for the other genera so far tested. It is still unclear whether the genus specific action is due to differences of metamorphosis mechanisms or structure of active peptides. The LW-amide motif was detected by immunohistochemistry in neurons in acroporid's planulae. LW-amide neuropeptides may act as internal messengers to start metamorphosis also in *Acropora*. This finding potentially provides application of LW-amides to produce primary polyps for reconstruction of reefs by transplantation.

THE MICROBIAL ECOLOGY OF BIOHERMS IN THE TIMOR SEA.

Johnson, Johanna E. *. *Department of Tropical Studies & Geography, James Cook University, Townsville, Qld, 4810, Australia. Email: johannaj@gbrmpa.gov.au

The northwest shelf of Australia is a region within the Timor Sea known for its petroleum reserves. Recent geological investigations have revealed carbonate knolls postulated to be of biological origin. The bioherms have been investigated for their diversity of invertebrate organisms and found to support large communities of hard and soft corals, algae and bryozoans at great depth. The microbial ecology of sediments at three sites on the northwest shelf, Pee Shoal, Mermaid Reef and Scott Reef, were investigated for the presence of hydrocarbon-degrading bacteria. 246 bacterial isolates were purified from two sampling trips and 182 of these isolates displayed preferential growth on hydrocarbon selective media. Isolates were tested for nutrient specificity using single hydrocarbon fermentations. Metabolic profiles were constructed using biochemical testing, fatty acid analysis and metabolic rate experiments. Three particularly active isolates were also tested for metal tolerance. 16S rRNA gene sequence analysis of five strains identified these strains as members of the genera *Sphingomonas*, *Bacillus*, and *Microbacterium*, one strain as a member of the Alpha-proteobacteria and another closely related to the methanogens. These results indicate that the natural hydrocarbon seepage is locally eutrophicating the area and supporting a unique assemblage of microbes and higher invertebrates.

PATCH REEF ISOLATION AFFECTS FISH ASSEMBLAGE STRUCTURE- A STUDY USING REPLICATE REEF MODULES.

Jordan, L.K.B.*, D.S. Gilliam, R.L. Sherman and R.E. Spieler. *Nova Southeastern University Oceanographic Center, National Coral Reef Institute, Guy Harvey Research Institute, 8000 North Ocean Drive, Dania Beach, Florida 33004 USA. Email: JordanL@ocean.nova.edu

To examine the effects of patch reef isolation on fish assemblage structure, replicate concrete reef modules ($1m^3$) were positioned at the apices of four equilateral triangle configurations. These four triangular treatments (each with two replicates) had module isolation distances of: 25m, 15m, 5m, and 0.33m. In order to examine fish abundance and richness with regard to substrate surface area two additional treatments: 1) a solitary module and 2) two modules 1/3m apart, also with two replicates, were deployed and compared with the 0.33m triangular treatment. Scuba divers censused fishes monthly, recording the species present, their abundance and sizes (tl). Statistical analysis on 22 months of ranked data revealed that the 0.33m triangular treatment yielded the highest mean abundance and species richness, however, the next highest abundance and richness values appeared on the 25m treatment, followed by the 15m and 5m treatments. It appears that the 0.33m treatment acted as a larger, single patch reef where as modules in the other triangular treatments performed as three separate patch reefs negatively interacting with each other. Examination of treatments differing in substrate surface area (*i.e.*, Number of modules) revealed a positive, nonlinear correlation with fish abundance and richness.

TERRIGENOUS INFLUENCE ACROSS THE CENTRAL GREAT BARRIER REEF SHELF DETECTED FROM CORAL SKELETAL FLUORESCENCE.

Kan, H.*, Hopley, D., Isdale, P., Rasmussen, C.E. *Faculty of Education, Okayama University, Okayama 700-8530, JAPAN. Email: kan@cc.okayama-u.ac.jp

Cross-shelf gradient in terrigenous influence in the central Great Barrier Reef is examined by fluorescence intensity of five *Porites* cores collected from a research transect between Barnett Patches and Orpheus Island. Fluorescence bands in coral skeletons show that the river plume and its influence reached to the outer Great Barrier Reef shelf at the major flood events of Burdekin River in 1974, 1979, 1981 and 1991. The fluorescence intensity decreases drastically off the continental island and then gradually decreases to the middle shelf reef at each flood event. This gradient conforms to the terrigenous bottom sedimentation in the Great Barrier Reef lagoon, which causes another terrigenous influence by resuspension in case of strong SE trade wind and cyclones. Detected from the maximum fluorescence intensity, strength of terrigenous influence at resuspension events is estimated to be around 60% against the strength at the major flood events.

EFFECTS OF 1997-98 EL-NINO SOUTHERN OSCILLATION ON CORAL REEF ECHINODERMS FROM NORTHERN BAHIA, BRAZIL.

Kelmo, Francisco*, & Attril, Martin. *Coral Reef Ecology, Benthic Ecology Research Group, Department of Biological Sciences, University of Plymouth, Drake Circus, PL48AA, United Kingdom. Email: fkelmo@plymouth.ac.uk

The present study commenced in 1995 throughout the coral reefs of Northern Bahia, Brazil. The aim was to assess the effects of the 1997-98 El-Nino Southern Oscillation on the structure and composition of the echinoderm community. Two different reef structures were investigated: (1) Coastal Reefs: (i) shallow pools and meandering channels from the reef top (exposed during low tide); (ii) reef walls (6-14 m depth) and (2) Shallow bank reefs (a few kilometres off the coast, 10-40m depth range). Annually from 1995-99 (April/May), the echinoderm community and associated physico-chemical conditions were assessed. The echinoderms were randomly quantified with 35 $1m^2$ quadrats at each site. Twenty-four species were recorded from all five main classes (Asteroidea, Ophiuroidea, Echinoidea, Holonthuroidea and Crinoidea). Their densities were significantly different (ANOVA, $F=31.338$, $P<0.0001$) between pre and post El-Nino years, and multivariate analysis suggested siginificant changes in community composition. BIOENV analysis identified turbidity ($r=0.653$), mean temperature variance ($r=0.641$) and cloud cover ($r=0.641$) as the main factors best explaining changes in the community. Most of the asteroid and ophiuroid species were unrecorded in 1998 and 1999. In contrast, the densities of *Echinometra lucunter* and *Diadema antillarum* (Echinoidea) increased significantly during and after El-Nino disturbance (ANOVA, $F=57.698$, $P<0.0001$), suggesting that this stressor had a differential effect on the investigated community.

A SPECIES-LEVEL MOLECULAR PHYLOGENY OF THE UNICORNFISHES (GENUS: *NASO*).

Klanten, Selma O. *, Lynne van Herwerden, and Howard Choat. *James Cook University, Dept. of Marine Biology, Douglas QLD. 4811, Australia.
Email: Selma.Klanten@jcu.edu.au

The unicornfishes (Genus: *Naso*) are one of six genera in the family Acanthuridae. This genus is well established as a basal clade of the acanthurids which include the genera of *Zebrasoma*, *Ctenochaetus* and *Acanthurus*. Nuclear (ETS2) and mitochondrial (16S) genes were sequenced for 8 species of *Naso*, 8 species of *Acanthurus*, and 2 species of *Ctenochaetus* and *Zebrasoma* respectively. Preliminary phylogenetic relationships were inferred for the *Naso* and acanthurid genera from each marker. Morphological characters were mapped onto the phylogenetic trees and these results are presented.

CORAL-ASSOCIATED BIVALVE *PEDUM*: HOST CHOICE, POPULATION DENSITY AND FACIES INDICATOR.

Kleemann, Karl * & Martin Zuschin, Institute of Palaeontology, University of Vienna, Geocentre, Althahnstr. 14, A-1090 Vienna, Austria. Email: karl.kleemann@univie.ac.at

Pedum spondyloideum occurs in living corals, where it lives embedded and byssally attached as a facultative borer. The host-specific *Pedum* seems to reach extraordinarily high densities in the northern Red Sea. There, it inhabits a wide range of host corals from seven families, partly causing intra-specific competition. In the Northern Bay of Safaga, it was the most abundant molluscan species >2 cm on reef associated hard substrata (reef flats, reef slopes, coral carpets, coral patches, and rock grounds): A total area of 340.5 m_ was investigated and 2846 molluscan individuals were counted at 68 sample localities ranging from shallow subtidal to 40 m water depth. *Pedum* made up >25 % of the total molluscan content and showed a mean density of 1.6 individuals per m_. Its distribution, however, is not uniform, but shows a clear preference for water depth <20 m and areas with high densities of living massive (e.g. *Goniastrea*) to foliate corals (e.g., *Pachyseris*). *Pedum* is preferentially associated with *Montipora* spp., followed by *Porites* and *Cyphastrea*, while occurring in fewer numbers in *Turbinaria*, *Pavona*, and *Hydnophora*. *Pedum* density ranged within a single host from 1.9 to 18.6 individuals per 100 cm_, occupying up to 12.5 % of the live coral surface. *Pedum* density seems to depend on the amount of available host area and nutrition, rather than specific hosts. Heavy infestation indicates a rather near-shore locality with an ample nutrient content suspended in the water. When corals live longer than the bivalves, the hosts may carry several generations of *Pedum* or their traces on the surface and within the skeleton. Yet, so far no fossil record is known.

ORIGIN AND TRANSPORTATION OF BIOCLASTICS ON THE REEF FLATS OF SOUTHERN BALI ISLAND, INDONESIA.

Koba*, M., T. Kaigara, And K. Yoshida. *Department of History and Geography, Faculty of Letters, Kansai University, Suita-shi, Osaka, Japan 564-8680. Email: moto@ipcku.kansai-u.ac.jp

Many structures for beach protection are distributed in the southern coast of Bali Island, where tourist hotels stand together in large numbers and coastal erosion is a great distress to them. Environmental surveys in "Bali beach conservation project", were carried out to restore rich beach landscapes here by the Indonesian government in 1992/93 and 1997/98. Koba was in charge of aerial photo interpretation and monitoring of coral and bioclastics on the reef flat then, as requested by Nippon Koei. Beach nourishment is thought to be most effective to restore beaches. The following results 1 to 3 stated in the meeting will contribute to the beach management. 1.The distributional comparison of sea-weed/sea-grass, living coral, reefs rock and bioclastics in 1992 and 1997 showed that coastal structures enhanced turbidity on reef flat for the duration, and it increased the coverage of sea-weed/sea-grass considerably. 2.The route of transportation of bioclastics showed that, although longshore sand drifting often explained erosion and accretion of beach deposits, most of beaches were strongly affected by transportation perpendicular to shorelines. 3.The shallow subsurface radiocarbon structure off Kesuma-sari, Sanur, obtained by a small engine drilling, showed that the top layer of a relatively broad sand cay was only one meter thick or so, and the time gap between the top and its subordinate layers was big.

CORAL COMMUNITIES AND CORAL REEFS OF THE SEYCHELLES ISLANDS.

Kosmynin V*. *Institute of Paleontology Russian Academy of Sciences, Moscow, Russia. Email: kosmyninv@cofc.edu

Coral reefs of the Seychelles Republic spread over the vast area in the Western part of the Indian Ocean between 3º30´S and 10º30´S, and 46ºE and 58ºE. The study of this area was conducted in several expeditions of the USSR Academy of Sciences and Moscow State University in the 1970s and 80s. Reefs in this region develop in the environment close to optimal for reef building corals. Coral reefs of northern area develop in the moderate wave energy condition, while southern groups of reefs are exposed to waves of high energy and lie in the area of hurricane tracks. Most of major morphological types of reefs, including atolls, fringing reefs, variety of uplifted and submerged reefs, can be found around the Seychelles. The zonation of reefs is characterized by asymmetry. In the open oceanic reefs and atolls, windward slopes are gentle and lack almost all coral growth. Leeward sides are steep and have high projective cover by reef building corals. Some atolls like Farquhar possess well-developed algal ridge and reef-flat on windward side, though others do not have these relief features. The development of rhodolithes fields in outer terraces or on the flat of submerged reefs is another characteristic feature of Seychelles reefs. Numerous submerged wave-cut forms demonstrate inheritance of major morphological features from Pleistocene growth. The total list of reef building corals in Seychelles comes close to 200 species, which is considerably more than the number listed before.

STEROID LEVELS IN A BI-DIRECTIONAL SEX CHANGING GOBY.

Kroon* and Munday. NSW Fisheries, Private Bag 1, Nelson Bay, NSW 2315, Australia. Email:kroonf@fisheries.nsw.gov.au

The phenomenon of bi-directional sex change in adult individuals provides an excellent opportunity to study the physiological mechanisms underlying sex determination and differentiation in teleosts. In particular, it enables the relationship between the concentrations of the steroid hormones and sex change in each direction (ie male to female and female to male) to be investigated in the same species, thereby avoiding problems inherent with interspecific comparisons. In this study, we detect and describe correlations between steroid concentrations and sexual function in the coral goby, *Gobiodon histrio*, a bi-directional sex changer. Sex change was induced by placing two adult fish of the same sex on a coral colony. After sex change, we confirmed sex of individual fish using histology, and examined whole-body concentrations of the gonadal steroids testosterone (T), 11-ketotestosterone (11-KT), and 17β-estradiol (17β-E_2). Our results show that T, 11-KT and 17β-E_2 are naturally occurring steroids in *G. histrio*. We discuss our results in light of recent theory in reproductive endocrinology.

EFFECTS OF OIL POLLUTANTS ON SURVIVORSHIP OF LARVAE OF THE SCLERACTINIAN REEF CORALS *ACROPORA TENUIS*, *GONIASTREA ASPERA* AND *PLATYGYRA SINENSIS* FROM THE GREAT BARRIER REEF.

Lane, Alison.* and Harrison, Peter L.. *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore, NSW, 2480 Australia. Email: pharriso@scu.edu.au

Coral reefs are highly vulnerable to impacts from oil pollutants due to production, refining and transportation of oil products in coral reef areas, and the shipping hazards presented by the reefs themselves. Oil hydrocarbons and dispersants are known to stress adult reef corals, and adversely affect a range of reproductive processes in corals. This study examined the effects of various concentrations of the water accommodated fraction (WAF) of fuel oil, Ardox 6120 dispersant and dispersed fuel oil on 3 day old larvae of the faviid corals *Goniastrea aspera* and *Platygyra sinensis*, and 3 and 9 day old larvae of the branching coral *Acropora tenuis*. The results clearly showed that dispersed oil was far more toxic than fuel oil WAF or dispersant alone to larvae of these species. Dispersed oil 96-hour LD_{50} values ranged from 0.6 to 1.5 ppm, which is far lower than would be likely to occur where an oil slick had been chemically dispersed in a reef environment. In contrast, LD_{50} values ranged from 3.8 to 5.9 ppm for fuel oil WAF, and 8.3 to 25.4 ppm for dispersant alone. Both dispersed oil and dispersant alone generally resulted in very high larval mortality at low concentrations within 12 to 24 hours of dosing, whereas mortality in larvae exposed to fuel oil WAF was generally not evident for at least 48 or 96 hours after exposure. These findings have important implications for oil spill management in coral reef areas, and indicate that the use of chemical dispersants during coral spawning periods would be likely to result in high rates of larval mortality in a range of scleractinian coral species.

REGIONAL VARIATION IN INTERNAL TIDAL FORCING ON FLORIDA, BAHAMAS, AND JAMAICAN REEFS.

Leichter, James J.* Department of Biology, MS #34, Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA, jleichter@whoi.edu

Forcing by internal tides and broken internal waves represents an important mechanism of cross shelf transport and delivery of cool, subsurface water to coral reefs throughout the Florida Keys, USA. Near bottom hydrographic time series data collected at 10 to 35 m depth between 1991 and 2000 show repeated arrival in summer of cool water fronts. Cooling events are characterized by sharp temperature drops (2 - 8 ºC within 1 - 20 min), increased salinity, increased concentrations of dissolved nutrients and chlorophyll *a*, and the onset of rapid upslope flows. One to several such events can occur per day with typical durations of one to four hours. Thus, a significant portion of overall hydrographic variability on Florida Keys reef is concentrated at daily time scales. This high frequency variability may have important impacts on a range of benthic ecological processes including larval transport, suspended particle delivery, and nutrient uptake rates for corals and benthic algae. By contrast, comparative studies on reef slopes in the Exuma Keys, Bahamas, and on the north coast of Jamaica show much more constant oceanographic conditions with variability concentrated at seasonal but not at daily time scales. Differences between Florida, Bahamas and Jamaica reefs result from differences in regional hydrographic regimes as well as local reef morphology and slope angles.

EVALUATION OF THE USE OF OOCYTE NUCLEUS SIZE ON STUDIES OF CORAL REPRODUCTION.

Lins de Barros Monica M., Clovis B. Castro and Débora O. Pires. Museu Nacional, Universidade Federal do Rio de Janeiro, Departamento de Invertebrados, Quinta da Boa Vista, s/n, São Cristóvão, 20940-040, Rio de Janeiro, Brazil. Email: mlbarros@acd.ufrj.br

This paper proposes the use of measurements of nucleus axis to evaluate the reproductive cycle development of corals, instead of oocyte axis, which is most used on this studies. A correlation analysis between the variation of oocytes and nuclei mean sizes throughout the oogenesis of *Siderastrea stellata* showed a high positive coeficient (r = 0,92). Therefore both structures could be useful to illustrate and quantify the development of the reproductive cycle. However, in some cases, oocytes do not seem to be an adequate quantitative variable, due to microanatomical characteristics which are not found in the nucleus. These include: 1) oogonia are characterized by an agglomeration of cytoplasmatic components, without clearly defined limits, which are difficult to measure; 2) by the end of the oogenesis, mature oocytes ofme coral species may present extremely irregular shapes, which makes it difficult to determine which axis should be measured; 3) in most coral species oocytes are ovoid in shape, with a potential high variability of any measurements taken from histologi sections. This last feature was tested on five coral species (*S. stellata*, *Mussismilia braziliensis*, *M. harttii*, *M. hispida* and

PLEISTOCENE AND RECENT CORAL AND MARINE INVERTEBRATE COMMUNITIES IN THE SOUTHERN BAJA CALIFORNIA PENINSULA: CHANGE OF BIODIVERSITY THROUGH TIME.

Lopez-Forment M.* Schwennicke T. and Hickman C. Integrative Biology, University of California Berkeley. 3060 VLSB, Berkeley, CA 94720. Email: mforment@socrates.berkeley.edu

Pleistocene fossil records found in marine terraces are an excellent database from which to gauge responses of coral communities to global changes. The Mexican Eastern Pacific area contains well studied marine invertebrates and the Gulf of California is one of the richest zones in coral species diversity in the tropical eastern Pacific (12 species, 5 genera) (Reyes-Bonilla, 1990). Pleistocene marine invertebrate communities in Southern Baja California provide a good ecological baseline with which to compare modern marine invertebrate and coral communities. Several well- preserved marine terraces at Cabo Pulmo and near La Paz provide data on what communities looked like in the Pleistocene. Preliminary transect information from Pleistocene deposits indicate a biozonation of marine invertebrates on different terraces. Terraces were found to be dominated by a molluscan-rhodolith associations (i.e. *Chione*, *Pinctata* and *Lithophyllum*), an echinoderm associations (*Encope*, *Echinometra* and *Diadema*) or coral associations (*Pocillopora*, *Porites* and *Astrangia*). Fossil data are to be compared to Recent marine invertebrate assemblages in the southern Gulf of California to determine the changes in species composition and ecological interactions amongst communities, since the late Pleistocene.

FAUNAL TURNOVER AND EXTINCTION SELECTIVITY OF EASTERN PACIFIC CORAL GENERA IN THE CENOZOIC.

López Pérez R.A.* and H. Reyes Bonilla. *Universidad del Mar. Ap. Postal 47, CP 70902. Puerto Angel, Oaxaca, México. Email: alopez@angel.umar.mx

In spite of recent advances in the knowledge of the biogeography of reef coral communities of the eastern Pacific, there is still a patent lack o studies on fossil communities of this region. We made an exhaustive bibliographic review of the Cenozoic fossil record of hermatypic coral genera reported for the eastern Pacific, Indo West Pacific and Atlantic Ocean. Fifty-seven coral genera, from 17 families, have lived in the eastern Pacific between the Paleocene and Recent. Today, only 10 genera exist, from seven families. The maximum richness at genera level occurred in the Eocene (39 genera), but since then richness have decreased drastically, reaching its lowest value in the Pleistocene (8 genera). The biogeographic affinities of the scleractinian genera have changed from almost entirely Atlantic to Indo Pacific taxa, completed after the closing of the Central American seaway. During the Cenozoic there have been three important periods of origination and also three periods of extinction. Extinction have been the most important macroevolutionary event in the history of scleractinian corals of the eastern Pacific in the Cenozoic. This process has not been random. Brooders survived preferentially over broadcasters and other genera with mixed reproductive modes. This differential survival was caused by the greater tolerance of brooding corals to cold, high-nutrient waters, conditions established in the eastern Pacific especially after the Miocene.

EFFECTS OF NUTRIENT ENRICHMENT ON PHOTOSYNTHESIS AND RESOURCE USE IN SYMPATRIC MANGROVE SPECIES.

Lovelock C. E. *, I. C. Feller. Smithsonian Environmental Research Center, PO Box 28, Edgewater MD 21037, USA. Email: lovelock@serc.si.edu

The effect of nutrient enrichment of mangrove environments on delivery of nutrients to near shore marine environments will depend on the response of the component members of mangrove forests. Alterations in competitive interactions among mangrove tree species could influence the quality of organic material exported to marine environments. We tested whether nutrient enrichment alters competitive interactions among mangrove tree species. In a hypersaline mangrove scrub forest in northern Florida, coexisting trees of *Laguncularia racemosa* and *Avicennia germinans* were either fertilized with nitrogen or phosphorus, or not fertilized (controls). *Avicennia germinans* responded to fertilization with nitrogen by increasing leaf nitrogen concentrations and rates of photosynthesis such they were equivalent to photosynthesis in *L. racemosa*. *Laguncularia racemosa* did not show a response to nitrogen additions. Neither species showed strong responses to phosphorus fertilization. *Avicennia germinans* had high photosynthetic water use efficiency (photosynthesis/transpiration), but low photosynthetic nitrogen use efficiency (photosynthesis/leaf nitrogen), while *L. racemosa* had comparatively low photosynthetic water use efficiency and high photosynthetic nitrogen use efficiency. Leaf level characteristics led us to hypothesize that *A.germinans* is likely to be a better competitor in highly saline, nutrient rich environments.

CARTERINA SPICULOTESTA FROM ARTIFICIAL SUBSTRATE.

Machado Altair J.* and Facelucia B. C. Souza. Laboratório de Estudos Costeiros, CPGG/IGEO/UFBA. Rua Caetano Moura 123, Salvador, 40210-340, Bahia, Brazil. Email altair@cpgg.ufba.br

The biomonitoring study of benthic communities from the northern part of the coast of the State of Bahia (Brazil) was undertaken throughout 10 sampling stations between the isobates of 24 to 34 m of depth. The sampling stations were placed in an area under influence of two industrial outfalls (Arembepe Beach). Compositional analysis were performed on artificial substrate (aluminum plates of 19 X 19 cm), submerged and trimestrially analyzed between 1997 and 1998. On these plates was recorded the foraminifera *Carterina spiculotesta*, represented by 91 live specimens. 55% were living in direct contact with the plate and 45% was found on incrusting bryozoans: *Rhyncozoon verruculatum*, *Celleporaria ahubarti* and *Schizoporella* sp. The recorded specie has a trocospiral test with lobulate and round periphery. Dark-brown color found in the first chambers, changes gradually to soft brown. In the following chambers, the color becomes softer until the hyaline white. The walls of the test are thin and transparent (hyalines) and they are composed by glassy spicules, which are more evident in the whitish chambers. *Carterina spiculotesta* was recorded in 6 of the 20 plates investigated throughout the summer of 1997 (78,2% of the individuals), and only in one plate of the control station (21,9%) during the spring 1998. The higher frequency of this foraminifera (60.4%) was recorded in the area closest to the organic compounds outfall (CETREL), and at the ciaphyllic side of the plates (93,3%). In the area closest to the MILLENNIUM outfall (chemical) no specimens of this organism were found. The species demonstrated resistance to a stressed environment, as well as its preference for low luminosity.

GROWTH RATE AND LIFE CYCLE OF JAPANESE GORGONIAN *MELITHAEA FLABELLIFERA* (KÜKENTHAL, 1908).

Matsumoto A.K.* Ikegami Lab., College of Arts and Sciences, University of Tokyo, Komaba 3-8-1, Meguro-ku, Tokyo, 153-8902, Japan. Email: amatsu@sacral.c.u-tokyo.ac.jp

The shallow water gorgonian *Melithaea flabellifera* (Octocorallia) is a typical and predominant gorgonian species of sublittoral communities in shore of Japan. Colonies grow below 3-5 m water depth, and thrive on vertical and overhanging surfaces. Although *Melithaea flabellifera* is one of the most common gorgonian species in shallow bottom communities of Japan, little is known of its life history, pattern of growth. Annual growth rate and monthly growth rate were calculated by field measurements at 138º 56'E, 34º 39'N. In addition, the relationship between growth and development of a fan was investigated by field measurements and observation of life history. In November and December, the growth rate was highest through the year, in which water temperature was about 16-19 ºC. However, the growth rate was not so high between mid-April and May, in which water temperature was about 16-19 ºC. The lowest temperature during the year was about 12.5-14ºC in February or March, and the highest temperature was about 24-25 ºC in August and September. Based on these data, it considered that there are no direct relations between water temperature and monthly growth rate.

CARBON-13 ISOTOPIC FRACTIONATION DURING ORGANIC CARBON PRODUCTION OF CORAL.

Miyahira, K.*, H. Fujimura, T. Oomori. *Graduate School of Engineering and Science, Univ. of the Ryukyus, Senbaru 1, Nishihara, Okinawa 901-0213, Japan. Email: koze@wonder.ocn.ne.jp

The purpose of this study is to present the relationship between coral organic carbon production(OP) and $\delta^{13}C$ variation in sea water in the incubation experiments and to apply for the estimation of organic carbon production of the natural coral reefs. Diurnal variation of DIC, $\delta^{13}C$ of DIC, total alkalinity, pH and dissolved oxygen in seawater were measured for 48 hours, and then determined $\delta^{13}C$ of zooxanthellae. The OP value calculated from DIC, $\delta^{13}C$ of DIC and $\delta^{13}C$ of zooxanthellae was consistent with that of calculated from pH-alkalinity or dissolved oxygen methods(correlation coefficient=0.64). The $\delta^{13}C$ value of produced organic carbon from seawater estimated by Reyleigh distillation model were –18.2‰ in April and –13.6‰ in August 1999, respectively, which are consistent with that $\delta^{13}C$ in zooxanthellae were –18.2 in April and –13.5‰ August. This agreement of $\delta^{13}C$ value suggests that the source of photosynthetic CO_2 taken up by zooxanthellae is mainly derived from DIC in seawater. Net primary productions obtained by DIC and $\delta^{13}C$ of DIC were –6 mmol m^{-2} day^{-1} in April, and 3 mmol m^{-2} day^{-1} in August, respectively. In the natural coral reefs, $\delta^{13}C$ in zooxanthellae and coral tissue were measured. The values of $\delta^{13}C$ in zooxanthellae and coral tissue range –13.3~ –10.0‰, –14.2~ –11.8‰ respectively. Estimated net primary productions were 5~8 mmol m^{-2} day^{-1} in coral reefs from June to November.

SECONDARY METABOLITES FROM BAHAMANIAN BLUE-GREEN ALGAE.

Molinski, Tadeusz F. *, ***Department of Chemistry, University of California, Davis, CA 95616, USA. Email:** tfmolinski@ucdavis.edu

Blue-green algae (cyanobacteria) occupy several niches in coral reef environments including symbiotic relationships with sessile invertebrates such as sponges and tunicates. Occasionally, blue-green algae occur in massive form in relatively axenic states. These are commonly seen as filamentous red-brown or greenish patches, filamentous films or larger aggregations of mixed speciation. Marine blue-green algae, like their fresh-water counterparts, may be indicators of the water quality, or the state of health of coral reefs. The secondary metabolites of blue-green algae have attracted interest not only for their interesting biological activities but for the interesting relationships with the metabolites of reef-dwelling sponges. We present in this poster recent investigations of blue-green algae, mainly *Lyngbya majuscula*, collected from reefs in the Southern Bahamas in August, 1999. The molecular structures and chemistry of chemical constituents will be described along with bio-geographic variations in chemical structures and content among specimens obtained on an approximate north to south transect from Nassau to San Salvador Island.

EFFECTS OF A SITE-ATTACHED PREDATORY FISH ON THE RECRUITMENT OF GORGONA ISLAND REEF FISHES.

Mora, C.* Zapata, F. *Departamento de Biologia, Universidad del Valle, Cali, Colombia. A. A. 25360. Email: moracamilo@hotmail.com

Understanding the influence of predation on fish postrecruitment mortality may improve our knowledge about population dynamics of coral reef fishes. To document the effects of predation on the recruitment of reef fishes, we manipulated the presence of a small site-attached predator fish (*Serranus psittacinus*) on four isolated standard coral units (ISCU) at Gorgona Island (Tropical Eastern Pacific). We used other four ISCUs without *S. psittacinus* as controls. Recruitment of *Scorpaenodes xyris*, *Canthigaster punctatissima* and three combined species of Antennariidae was similar on control and *S. psittacinus*-present-ISCUs. The even recruitment on treatment and control ISCUs indicates an absence of predation by *S. psittacinus* that can be due to antipredatory traits of these species such as poisonous fins, body toxins and cryptic appearance. *Lutjanus guttatus*, *Halichoeres dispilus*, and *S. psittacinus* exhibited lower recruitment in *S. psittacinus*-ISCUs than in control ISCUs. Furthermore we obtained direct observational evidence of predation of *S. psittacinus* on *L. guttatus* and *H. dispilus*. In *P. psittacinus*, that showed mean recruitment size larger on conspecific than controls-ISCUs, we support a complex mechanics of habitat preference without predator by the settlement larvae and a subsequent competent-size recruitment into the adult habitat, for explain the low recruitment of small *S. psittacinus* fishes at conspecific-ISCUs. This study indicate the importance of predation on postrecruitment survival of some reef fishes and antipredatory characteristics and behaviors determining a successful recruitment of some other species.

THE SCLEROSPONGE GROWTH BAND AND THE CARBON AND OXYGEN ISOTOPES

Mori M.*, T. Omori. *Graduate School of Engineering and Science, University of the Ryukyu's, Senbaru 1,Nisihara, Okinawa, 901-0213, Japan Email: k9886561@sci.u-ryukyu.ac.jp

Sclerosponge inhabits in the shallow part of sea nearby reef front where the direct sunlight radiation is restricted. They form high magnesium carbonate skeleton with annual growth bands, however symbiotic alga(zooxanthellae) doesn't exist within the tissue. The growth rate is about 1mm/yr which will be advantageous for analysis of long term palaeo environmental change. In this study, modern sclerosponge specimen from Zamami Island of Okinawa was shaved along annual growth bands in different manner. The $\delta^{13}C$,$\delta^{14}C$ and $\delta^{18}O$ of the each samples were determined. One was shaved into 1mm depth in order to study annual change for about sixty years during 1920's-1980's. Other was shaved into 0.1mm depth in order to study for seasonal variation for about three years at 1980's. As a result, annual $\delta^{13}C$ change showed an obvious decrease since about 1960. The decrease in $\delta^{13}C$ will be caused by mighty fossil fuel ^{12}C through industrial activity . Other results will be presented.

EVOLUTIONARY INSIGHTS FROM THE EVALUATION OF ASSOCIATED REEF FISH DISTRIBUTION PATTERNS DERIVED FROM NATIONWIDE FISH CENSUS INFORMATION.

Nañola, Cleto L. Jr*, Arvin L. Dantis, Vincent V. Hilomen, Domingo G. Ochavillo, Maria Catalina G. Rañola and Porfirio M. Aliño. College of Arts and Sciences, University of the Philippines-Mindanao, Buhangin, Davao City, Philippines. Email: tingnanola@yahoo.com

Previous reviews on the community structure of reef fishes in the Philippines highlighted the significance of ecological forcing to explain the emergent distribution patterns. The suggestion of an evolutionary mechanism for this distribution has often been derived based on inferred life history features taken from the literature and also the concordance of community structure affinities with the archipelagic classification based on clinal depth analyses. Recent analyses of the relative proportions of the number of species in the families Pomacentridae, Labridae, Scaridae, Acathuridae, Serranidae and Chaetodontidae based on fish visual observations from around the country suggests the following: a) that the relative proportions of the families can show a consistent biogeographic trend (i.e., East to West and North to South) for most of these families; b) the proportion of the Pomacentridae and Labridae in the Luzon Archipelago seems to be different from the rest of the marine biogeographic areas; and c) an assemblage associated with the South China Sea basin and Pacific Ocean seems apparent. The significance of these patterns in relation to their consistency with the tectonic origins of the Philippine Archipelago and the island arc hypothesis vis-à-vis the dispersal hypotheses of previous authors is discussed.

SHOREFISHES OF THE TROPICAL EASTERN PACIFIC: AN INFORMATION SYSTEM FOR IDENTIFICATION AND BIOLOGICAL ANALYSIS.

Navin, K.* and Robertson, D.R. *Vagabond Odyssey, PO Box 139, Berridale, NSW 2628, Australia . Email :kim@vagabondoddysey.com.au

An electronic, bilingual (English and Spanish) information system that allows the identification of the shorefishes of the tropical eastern Pacific (TEP) biogeographic region and comparison of their biological attributes is presented. A taxon page for each of 1,184 species includes: an illustration(s) with key features indicated; links to illustrations & pages of similar species; a TEP range map; link to a comprehensive bibliography; text on identification, geographic range, habitat, diet, size, synonymies. An engine allows identification of species using data on range, habitat, shape and color pattern. Similar taxon pages are included for 134 families and 470 genera. A zoogeographic engine allows: comparison of TEP range-maps of up to 5 species; assembly of taxon lists for locations at different spatial scales (coastal sites, islands, countries, provinces); comparison of similarities of faunal lists from different locations; display of relative and absolute species richness of coastline segments and islands based on range-limits data; assembly of lists of endemic species by location. "Access" databases on biological attributes (zoogeographic, habitat-use, diet, size, reproductive mode) allow complex comparisons to be made of the structure of fish faunas of different locations. A checklist of the shorefishes of the TEP is included. This system initially will be available in as a CD, with a web-based application to follow shortly thereafter.

NOTES ON LARVAE RELEASING AND SETTLEMENT BEHAVIOR OF BRAZILIAN *SIDERASTREA STELLATA* VERRILL, 1868: A TAXONOMICAL APPROACH.

Neves, EG* & da Silveira, FL. *Universidade de São Paulo, Inst. Biociências - Depto. Zoologia, Rua do Matão trav. 14, n° 321, CEP: 05508-900 - São Paulo, Brasil. Email: egneves@acd.ufrj.br

The present study provides first evidences on planula releasing and settlement behavior of *Siderastrea stellata*, an endemic reef-building species which occurs along the northeastern and southeastern coast of Brazil. *Siderastrea radians*, *Siderastrea siderea* and *Siderastrea stellata* form the Atlantic *Siderastrea* complex, presenting patterns of morphology highly variable. Ecomorphs of the three species show overlapping of characteristics resulting taxonomical misunderstanding. It has been suggested that differences in reproductive trends may be useful to distinguish between morphollogically similar species. *Siderastrea siderea* is a hermaphroditic broadcasting species, whilst *Siderastrea radians* is a gonochoric brooding species. Colonies of *Siderastrea stellata*, collected in coral communities situated at Rio de Janeiro, were kept in aquaria, where they released larvae. Larvae extrusion and settlement process followed the observations described for *Siderastrea radians*. Data on larvae behavior may indicate a probable relationship between *Siderastrea stellata* and *Siderastrea radians*. After complete extrusion, the ciliated larvae stayed for a long time among the oral tentacles. Larvae presented zooxanthellae, and lecithotrophic pattern of development. Peculiar bentonic behavior during free early stage provided some likely important clues on the ability of dispersion of the Brazilian species.

SEDIMENT QUALITY ASSESSMENT STUDIES AT THE FLOWER GARDENS NATIONAL MARINE SANCTUARIES, GULF OF MEXICO.

Nipper, M* and Carr, RS. *Texas A&M University-Corpus Christi Center for Coastal Studies, NRC Suite 3200, 6300 Ocean Dr., Corpus Christi, TX 78412 USA, Email: mnipper@falcon.tamucc.edu;

Coral reef communities are endangered worldwide and can be deleteriously affected by exposure to anthropogenic contaminants. Sediments in the vicinity of coral reefs can accumulate contaminants and porewater toxicity tests from such areas can be used as early warning signals of chemical contamination with potential deleterious effects to the biota, as shown in previous studies in Hawaii and Mexico. Small amounts of polycyclic aromatic hydrocarbons and organochlorinated hydrocarbons were measured in semi-permeable membrane devices deployed at the East and West Flower Garden Banks coral reefs, in the Gulf of Mexico. These could have been introduced by the numerous petroleum production platforms in close proximity to the Banks, the Mississippi River plume which extends a considerable distance into the Gulf, or by aerial deposition, among other potential sources. In the present survey, pore water from sediments at several stations in the Flower Garden Banks was collected by two different vacuum extraction methods and analyzed for toxicity with sea urchin fertilization and embryological development tests. No toxicity was observed, and therefore there was no evidence of bioavailable contaminants that could threaten the health of these coral reefs at present.

PARTIAL MORTALITY AS INDICATOR OF SEDIMENT STRESS IN MASSIVE REEF CORALS.

Nugues, M.M.*. *Environment Department, University of York, York YO10 5DD, UK. Email: mmn100@york.ac.uk

Concern over the decline of reef ecosystems has promoted the need to develop practical and "one-shot" means of assessing reef condition. This study examined partial mortality and fission in colonies of four common massive coral species along nearshore-to-offshore gradients differing in their exposure to river sediments in St. Lucia, West Indies. Results indicated a strong increase in rates of partial mortality at the nearshore reefs exposed to river sediments in three coral species, while frequency of fission did not strongly increase approaching river mouths. Results did not differ after correcting for variation in colony size. In addition, the percent of change in coral cover from 1994/5 to 1998 was highly correlated with rate of partial mortality (surveyed in 1998) in one species ($p < 0.001$) and was nearly significant in the other species ($p < 0.1$). I suggest that partial mortality in massive reef corals, as measured by the amount of dead surface area per colony, could provide a reliable indicator of sediment stress from river runoff.

REEF FISHES EXPLOITATION IN TELUK BANTEN WEST JAVA, INDONESIAWITH SPECIAL REFERENCE TO THE DOMINANT SPECIES *Epinephelus coioides, Lutjanus johni* and *Pomadasys kaakan*.

Nuraini, Siti *; Machiels, Marcel; van Densen, Wim; and Linde Boom, Han. *Balai Penelitian Perikanan Laut Jakarta Jakarta, Indonesia. Email: nuraini@indo.net.id

Teluk Banten is a shallow bay located about 80km northwest from Jakarta, where recently industrial area and port container development take place in the west part of the bay. While the fishery in the bay characterized by multi gear targeted for all species and all sizes. This study explained the exploitation of reef species taken from Teluk Banten, west Java Indonesia. In seagrass, the juvenile of dominant reef species that caught by bondet (beach seine) and sudu (push net) were Green grouper (*Epinephelus coioides*) and Russell's snapper (*Lutjanus russelli*). Larger fish were caught at deeper water using trap, hook & line. In trap catches, we determined 123 species. Among those 45 species of reef fishes were caught contributed 67% of total catch. *E. coioides*, and *Plectropomus maculatus* appeared to be the most dominant species representing 14.3%, and 7.87% of the total catch. Of the 77 species caught by H&L, 34% (46 species) of the catches consist of reef fishes. The dominant species caught were *Pomadasys kaakan* and *Lutjanus johni* representing 13.0% and 10.5% of the total catch. From their size distribution, the *E. coioides, L. johni* and *P. kaakan* used seagrass as their nursery ground. Grouper and snapper inhabit in seagrass up to the size at about 30 and16 cm in TL, each respectively. They migrate to deeper water of the reef or rocky area. Size selective gear appeared for grouper, and snapper in the bay. Destructive fishing techniques are sometime practice in the bay such as blasting and use of cyanide to catch ornamental fish, grouper and other marine resources. From monitoring gear used in the area, indicated that serious over exploitation occur in the bay.

CALIBRATION OF STRONTIUM/CALCIUM AND OXYGEN ISOTOPIC RATIOS VERSUS SEA SURFACE TEMPERATURE FOR *PORITES* CORAL SKELETONS.

Ohuchi, Takefumi, Abe, Osamu. * Typhoon LEE and Eiji MATSUMOTO. *Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya, 464-8601, Japan. Email: oabe@ihas.nagoya-u.ac.jp

Since 1996, we have monitored the sea surface temperature (SST) at Yasurazaki, Ishigaki Island, southwestern Japan, a site of luxuriant growth of long-lived massive *Porites* colonies. In 1999, we obtained a core from the upper portion of a *Porites lutea* colony using hand drill driven by the SCUBA tank. The colony is identical with the one used in Mitsuguchi et al. (1996). The Sr/Ca and oxygen isotopic ratios were analyzed at 0.5-mm intervals for the latest 3 years to obtain precise relationships between these proxies and measured SST. The Sr/Ca was measured by thermal ionization mass spectrometery with the double-spike isotope dilution method, which used ^{43}Ca and ^{84}Sr spikes and is more convenient than the conventional triple-spike method. We obtained a precision better than 0.3 °C (2δ) adequate for practical use of SST reconstructions. The Sr/Ca-SST calibration line for coral thermometer deduced by us for *Porites lutea* is Sr/Ca = -0.05553SST + 10.46, which is in excellent agreement with the calibration of Shen et al. (1996).

ASSAY OF INTER-SPECIFIC INTERACTION OF CORALS USING DISSOCIATED CELLS AND CELLULAR AGGREGATES.

Oshiro W*. and M. Hidaka. Department of Chemistry, Biology and Marine Science, University of the Ryukyus, Nishihara, Okinawa, 903-0213 Japan. E-mail Address: hidaka@sci.u-ryukyu.ac.jp

We attempted to establish a short-term assay system of inter-specific interaction of corals using dissociated cells and cellular aggregates. When dissociate cells of a coral were incubated, they aggregated to form spherical bodies (tissue balls), which began to swim by ciliary movement. When high concentrations of dissociated cells were incubated in a round-bottom multi-well plate, they accumulated at the bottom of the well and formed a large aggregate. However, when dissociated cells from different species were mixed, they never formed large aggregates. Instead they remained dispersed on the bottom of the well or formed many small tissue balls. In such cases, tissue balls of two distinct characters were observed. They could be distinguished based on color, zooxanthella density and surface texture. Hence they might consist of cells derived from one of the corals. When dissociated cells from different colonies of the same species were mixed, large aggregates were formed in some combinations but were not formed in other combinations. When two spherical bodies derived from the same coral were brought into contact, they fused after a few hr and formed a spherical body. In contrast, those derived from different species did not fuse. The present method using dissociated cells or cellular aggregates provide a useful tool to study inter- and intra-specific interactions of corals.

COMMUNITY STRUCTURE OF CORAL REEFS AT CIENAGA DE OCUMARE DE LA COSTA BAY, VENEZUELA.

Paul s S.M.* *Instituto de Zoologia Tropical, UCV, A.P. 47058, Caracas 1041-A, Venezuela. Email: smarquez@strix.ciens.ucv.ve

The central coast of Venezuela is a marginal area for development of coral reefs due to the input of terrestrial freshwater and sediments. The Cienaga de Ocumare de la Costa Bay (67° 48' 30'' W and 10° 28' 15'- 10° 29' 20'' N) is an exception with two developed reefs. Surveys were made at 17 stations in depths of 0.3 to 20 m, using transects perpendicular to the coast with 1 m_ quadrats. Diversity and percent cover were estimated at 2 m intervals along the transects. The coral communities were two coastal reefs, a shoal and a community associated with rocks in the mouth of the bay. The western coast reef was more developed and complex than the eastern reef. Thirty- two corals species were recorded including 3 hydrocorals. The coral assemblage observed in the bay is similar to species lists from others Venezuelan coastal coral communities. The diversity decreased from 19 species in the mouth of the bay to 6 species in the inner communities. This gradient may be related to environmental factors, such as sedimentation and low turbulence. Coral cover varied between 6.3 and 34.5 % and coral cover death varied between 24.7 and 68 %. *Millepora alcicornis*, *Diploria strigosa*, *Colpophyllia natans* and *Montastrea annularis* constituted more than 70 % of all cover. In the depth gradient, the highest diversity was recorded between 7 and 9 m with 17 species. The results suggest that the coral communities of the bay are comparable to some others Venezuelan coral communities.

BIOEROSION OF CORAL REEFS: RELATIONSHIPS BETWEEN BORING ORGANISMS AND PHYSICAL CHARACTERISTICS OF THE SUBSTRATE.

Peyrot-Clausade M*, Fallot L, Tribollet A, Zubia M and MP Etcheverry. Centre d'Océanologie de Marseille, Station Marine d'Endoume. Rue de la batterie des Lions, 13007 Marseille (France). Email: peyrot@com.univ-mrs.fr

Porosity and rugosity were determined on *Hydrolithon onkodes*, *Porites lobata* and *Acropora formosa*, in Moorea Island (Pacific Ocean) and La Reunion Island (Indian Ocean) in order to relate the endolithic community with the properties of the substrate and to define the ability to be eroded of this different substrates. Porosity was determined using the mercury intrusion method with pressure from 0.0036 to 200 Mpa. Mosaics of back-scattered electron images of polished sections of the samples were digitalized from a Scanning Electron Microscope in order to observe and analyse the microstructures (microporosity) of the substrates and to determine their surface rugosity. Four classes of micro-porosity have been established to differentiate the erosion effects of each organism. The endolithic species were the microboring flora with *Plectonema terebrans*, *Mastigocoleus testarum*, *Ostreobium quekettii* and *Hyella caespitosa* and the boring fauna which included the polychaetes *Polydora* sp, *Dodeceria* sp and the sipunculans *Aspidosiphon* sp., *Phascolosoma* sp. and *Apionsoma* sp.

SEXUAL REPRODUCTION OF THE SOLITARY CORAL SCOLYMIA WELLS LABOREL (CNIDARIA: SCLERACTINIA) FROM THE ABROLHOS REEFS, BRAZIL.

Pires, Débora O.*, Clovis B. Castro, Cláudio C. Ratto. *Museu Nacional/Universidade Federal do Rio de Janeiro, Departamento de Invertebrados, Quinta da Boa Vista, s/n, São Cristóvão, 20940-040, Rio de Janeiro, RJ, Brasil. Email: dopires@openlink.com.br

Brazil has the only true coral reefs known in the South Atlantic. Abrolhos (18° S) is the largest and the most diverse reef area in Brazil. The sexuality, reproductive mode, and timing of reproduction of *Scolymia wellsi* from the Abrolhos Reef Complex were assessed by collecting specimens bimonthly during 1996 and sporadically in 1997 and 1999. Specimens were studied histologically and by a dissecting microscope.

MOLECULAR IDENTIFICATION OF ENDOSYMBIOTIC DINOFLAGELLATES OF SORITID FORAMINIFERA.

Pochon, Xavier*, Jan Pawlowski, Louisette Zaninetti, Rob Rowan *Department of Zoology and Animal Biology, University of Geneva, 154, rte de Malagnou, 1224 Chêne-Bougeries, Switzerland. Email: xavierpochon@hotmail.com

Soritidae are a family of large calcareous benthic foraminifera known to host *Symbiodinium*-like zooxanthellae. Soritids are common in all Indo-Pacific coral reefs, however, it is unknown if they share their endosymbionts with corals and other zooxanthellae-bearing invertebrates. In order to identify the genotypes of symbionts present in foraminiferal hosts and compared them to other symbionts, we have obtained and analysed the sequences of a 1700 bp fragment of the ribosomal DNA, including partial SSU, ITS1, 5.8S, ITS2, and partial LSU, from 20 foraminiferal specimens and 20 coral samples collected in Guam (Mariana Islands). Additionally, we have examined 36 foraminiferal and 90 coral samples by RFLP analysis. The phylogenetic analysis of our data show that foraminiferal symbionts group in six different clades. Five clades are specific for foraminifera. One clade, previously identified as type C, group together symbionts from foraminifera, corals, sea anemones, and ciliates. 80% of symbionts from Guam scleractinian corals belong to type C, while the remaining 20% form a new clade that branch between clade A and B.

LOW-TECHNOLOGY FEEDING SYSTEM FOR REARING SETTLEMENT-STAGE REEF FISHES.

Power, Robert M.*. *The University of Plymouth School of Biological Sciences and International Center for Living Aquatic Resources Management (ICLARM), Caribbean/Eastern Pacific Office 158 Inland Messenger, Road Town, Tortola, British Virgin Islands. Email: rpower@surfBVI .com

Late pelagic stage reef fish experience very high predation when they settle onto juvenile habitats. Capture of reef fish with light traps before settlement, may be a sustainable method for concurrently avoiding this mortality and harvesting fish for the aquarium trade. Potentially, this harvest method could replace existing commercial methods, some of which are destructive to reefs and damaging to reef fish populations. Late pelagic stage reef fish are very fragile and prone to stress-related mortality. A short rearing program could grow them to a size where they may be robust enough for sale to the aquarium trade. Very young fish often require live food, which may be technically difficult or expensive to supply. This poster describes a simple airlift pump with a light attraction component, which can be used to supply naturally occurring plankton for rearing very young fish in floating cages or tanks. This technology is intended for small-scale community based aquaculture in developing countries. Composition of plankton collected by this 'Plankton Pump' is compared with composition of stomach contents of wild caught fish. Alternative applications are discussed; in particular, rearing juvenile reef fishes past the early juvenile mortality hurdle for subsequent release in order to rebuild wild populations.

BACKSTEPPING OF HOLOCENE REEFS ALONG FLORIDA'S EAST COAST

Precht, William F. *, Ian G. Macintyre, Richard E. Dodge, Kenneth Banks, and Louis Fisher. PBS&J, 2001 NW 107th Ave., Miami, FL 33172, USA. Email: bprecht@pbsj.com

The northern end of the Florida Reef Tract is comprised of numerous shore-parallel ridges and terraces that crest at depths of about 15m, 10m, and 5m. The deepest ridge is most distinct and the shallow terraces are often more gradational. A hard-bottom community of octocorals, sponges and corals characterizes the present-day surfaces of these bathymetric highs. By contrast, exposures in at least two of these ridges indicate that they were formed by rapidly accreting, shallow-water facies dominated by *Acropora palmata*. In the 1970's the construction of a sewage outfall near Hillsboro Inlet, exposed a cross-section of the deepest ridge. Earlier studies have shown that radiocarbon dates of corals from the lower ridge range from 8900±95 to 7145±80 ybp. In 1993 a submarine ran aground on a more shallow terrace near Dania Beach, exposing a 3m deep by 28m long trench. Radiocarbon dates of corals collected from this exposure at depths of 9.8m to 7.8m yielded dates ranging from 6520±60 to 5950±90 ybp. When compared with well-established sea-level curves for the western Atlantic, the dates from these exposures show these shallow-water reefs intermittently tracked the rising sea. There appears to be a backstepping pattern of the reefs, possibly related to local or global stresses from a variety of causes. Inimical conditions related to these events could have abruptly halted reef growth. As more hospitable conditions returned, a 'new' reef apparently formed in a shallower, shoreward position from its predecessor.

BRAZILIAN REEF FISHES OF THE FAMILY BLENNIIDAE (TELEOSTEI: BLENNIIOIDEI).

Rangel, Carlos A.*, Gasparini, João L., Mendes, L. F. & Guimarães, R. Z. P. *Laboratório de Biodiversidade de Recursos Pesqueiros, Núcleo de Inovação em Gerenciamento Pesqueiro, Departamento de Biologia Marinha – CCS, Universidade Federal do Rio de Janeiro – UFRJ Cidade Universitária, CEP: 21941-569, Rio de Janeiro, RJ, BRAZIL Email: caugusto@mn.ufrj.br

Seven reef-associated species of the family Blenniidae are currently recognized in Brazilian waters: *Scartella cristata*, *Hypleurochilus fissicornis*, *H. pseudoaequipinnis*, *Parablennius pilicornis*, *P. marmoreus*, *Entomacrodus vomerinus* and *Ophioblennius atlanticus*. In this work, we're informing the discovery of four new species, three belonging to the genus *Scartella* and one belonging to the genus *Entomacrodus* and indicating geographical range extension of other four. The species of the genus *Scartella* from the Brazilian coast is, in fact, an undescribed species. The other two new species identified are one from Trindade Island and the other from Fernando de Noronha Archipelago. A fourth new species belonging to the genus *Entomacrodus*, was recorded from Trindade Island. *Hypleurochilus pseudoaequipinnis* and *Ophioblennius atlanticus*, previously known from the Northeastern coast of Brazil were collected 600 kilometers to the south, *Hysoblennius invemar* and *Parablennius marmoreus*, previously known only in the Caribbean area were recorded as south as Rio de Janeiro State. The purpose of this study is to clarify the systematics and distribution of the Brazilian family members and emphasize the importance of preserving the National reef environment.

REDUCED IMPACT OF PARROTFISH SCHOOLS ON TERRITORIES OF DAMSELFISH IN HIGH DENSITY AGGRIGATIONS

Rassweiler, A J; Hamilton, S L; Samhouri, J F; Sandin, S A; and Pacala, S W. *Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544-1003 USA. Email: arass@alumni.princeton.edu

Three-spot damselfish, *Stegastes planifrons*, aggressively defend territories, preventing other herbivores from taking advantage of the high quality grazing within. In this study, we demonstrate that the movements of large schools of marauding parrotfish are affected by damselfish aggregation. Damselfish living in high density aggregations are visited less often and for a smaller amount of time than those living at low density. To illuminate these effects, we observed schools of striped parrotfish, *Scarus iserti*, mapping 630m of their trajectory in total. We measured the speed of the school, the position of nearby damselfish, and the local substrate type and height. We then fit a biased random walk model from our data using maximum likelihood methods. *S. iserti* tended to slow down in algae rich habitat, speed up in areas of high damselfish density and turn away from high concentrations of damselfish. We approximated the effect of these biases on individual damselfish through simulation. We found that damselfish at high densities experienced 40% less feeding by *S. iserti* and 50% fewer visits than those at low densities. Because large schools of parrotfish are often observed overwhelming even the highest natural densities of damselfish, previous investigators have concluded that damselfish are not effective at deterring such schools. We demonstrate that incursions by even these large schools are reduced by damselfish aggregation. This deterrent effect of high damselfish densities may well provide an explanation for their clustered distribution on the reef.

SPECIFIC RICHNESS OF THE MACROBENTHOS IN THE FIDJIAN LAGOONS (VITI LEVU).

Richer de Forges, B.*, Garrigue, Laboute, Bernard, Ferraris, Newell, Lapetite, Mohammed, Nating. Centre IRD BP A5, Nouméa, New Caledonia Email: richer@noumea.ird.nc

In 1998 And 1999, Two Cruises Of The Ecotrope Program (Suva 2 &4) Were Carried Out Onboard The French Research Vessel Alis To Sample The Macrobenthos Of The Fidjian Lagoons. The Aims Were To Describe A Very Poorly Known Benthos, To Compare It With The New Caledonian One And To Evaluate The Anthropogenic Effects Of The Suva City. The First Results Concerns The Specific Richness In Different Lagoons : Near Suva, Between Nadi And Lautoka And In Beqa Atoll. A Total Of 124 Samples Was Collected With 3 Different Gears That Worked At Different Scales : A Smith Mac-Intyre Grab (1/10m_), A Waren Dredge (About 100 M_) And A Beam Trawl (> 8000 M_). The Morphospecies Were Counted For Each Station And Recognised At The Family Level. The Specific Richness Defined As The Number Of Morphospecies Is Very Variable Between 9 And 352 By Station. For A Same Site, 15, 85, 50 Morphospecies Were Obtained Respectively With The Grab, The Dredge And The Trawl. The Western Lagoon Situated Between Nadi And Lautoka Is Significantly Richer Than The Suva Lagoon That Suffer From Anthropogenic Effects. It Is Also Richer Than The Beqa Atoll Lagoon.

A RECORD OF RIVER DISCHARGE IN CORAL SKELETONS FROM MORETON BAY, SOUTHEAST QUEENSLAND, AUSTRALIA.

Roberts,Lisa.* *School of Resource Science and Management, Southern Cross University, PO Box 157, Lismore NSW Australia. 2480 Email: lroberts@scu.edu.au

Coral skeletons from Moreton Bay were examined to determine their ability to record environmental signals. One such environmental signal is the discharge from nearby rivers. Large discharge events often produce lines in the coral skeleton that are luminescent under ultra-violet light. Moreton Bay is a large semi-closed body of water located in South-east Queensland and is under the influence of two large river systems (the Brisbane and Logan Rivers). The catchment has undergone major changes in land use over the last 100 years and provides an ideal site to study the incorporation of substances into coral skeletons. Luminescence was measured using image analysis and the intensity of the luminescence was compared with discharge/flow data for the Brisbane River catchment. X-radiographs were used to determine the age of the corals. Luminescent bands found to correlate with major discharge events for the Brisbane River.

CHANGES IN GORGONIAN MORPHOLOGY ALONG A DEPTH GRADIENT.

Rodriguez-Lanetty, Mauricio*; Losada, Freddy; Marquez, Luis M.. *Centre for Marine Studies. University of Queensland. St Lucia QLD 4072. Australia. Email: m.Rodriguez@mailbox.uq.edu.au

It has been suggested that water currents may determine gorgonian morphology. Under a high current, gorgonians tend to grow with a fan shape (flattened vertically) and facing perpendicular to the current. Alternatively, gorgonians grow with an arborescent morphology under low current regimes. Changes in this morphology along a depth gradient seems to mirror the changes in hydrodynamic regime associated with this gradient. In this study, we evaluate the changes in morphology of several species of gorgonians in terms of shape (fan vs. arborescent) along a depth gradient. Our study site was a fringing Caribbean coral reef located in a coralline key on the coast of Venezuela. Within forty-two 3x2 m quadrats placed between 6m and 19m depths, we measured the longest and shortest diameter of each colony from the five most abundant species of gorgonians in the location. To quantify colony morphology we used the coefficient or ratio between the longest (LD) and the shortest diameter (SD). When LD/SD was equal or greater than 2, colonies were considered "fan" and they were considered "arborescent" when LD/SD< 2. The results suggest that the effect of hydrodynamic regime on gorgonian morphology is species-specific. Only two out of five species showed the morphology pattern predicted on the basis of hydrodynamic changes along the depth gradient. The other three species showed different patterns, which can be related to differential trophic selective pressures along the depth gradient. Our results call the attention to the risks involved in generalizing ecological processes from observations on single species.

BIOEROSION CAUSED BY GRAZING ACTIVITIES ON CORAL COMMUNITIES IN THE GULF OF THAILAND.

Ruengsawang, Nisit* and Thamasak Yeemin. Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand.
Email: nruengsawang@hotmail.com

The over exploitation and poor management of coastal ecosystems in Thailand led to the deterioration of many coral reefs. Studies in detail concerning coral reef science in Thailand are very limited. The process of bioerosion has been recognized as an important role in coral reef ecology. *Diadema setosum* is a dominant echinoid species in coral communities in the Gulf of Thailand. The aim of the present study is to estimate bioerosion rates by *D. setosum* in coral communities at Khang Khao Island, Inner Gulf of Thailand in February, June, and November 1998 by acidification method. Bioerosion rates were in the range of 0.34-1.43 g $CaCO_3$/individual/day or 1.64-5.50 Kg $CaCO_3/m^2$/year. The highest bioerosion rates were found in the shallowest zones due to mainly high population density of *D. setosum*. The first severe coral bleaching event in the Gulf of Thailand during April-May 1998 was a factor which resulted in increasing of population densities of *D. setosum* and consequently enhancing bioerosion rates during that period. In general, bioerosion rates by *D. setosum* obtained from the present study were in the same range of those reported by previous workers from several localities. Bioerosion caused by grazing of *D. setosum* plays a major role on calcium carbonate budget in coral communities in the Gulf of Thailand.

PLEISTOCENE REEF DEVELOPMENT AND SEA-LEVEL CHANGES: EVIDENCE FROM THE RYUKYU GROUP OF SOUTHWESTERN JAPAN.

Sagawa, Natsume; Nakamori, Toru; and Iryu, Yasufumi. *Institute of Geology and Paleontology, Graduate School of Science, Tohoku Univ., Sendai 980-8578, Japan. Email: nasa@mail.cc.tohoku.ac.jp

Conducted were sedimentological studies of the Ryukyu Group, Pleistocene reef complex deposits, by investigating 13 cores as well as surface outcrops in Irabu-jima and Shimoji-jima, Ryukyu Islands, Japan. Ten carbonate lithofacies were recognized and their depositional environment was determined in comparison with the present-day marine sediments and biota around the Ryukyus. Five coral assemblages were defined based on species composition and morphology of fossil forms within the coral limestone, each indicating particular environment. The group is up to 110 m thick and comprises 13 units. The reconstructed relative sea-level curve clearly shows that this area was subsided during the deposition of units 1 to 12 and then uplifted while unit 13 was deposited. Calcareous nannofossil biostratigraphy suggests that the group was deposited at 1.5 to 0.3 Ma. These 13 units seem to respond the 4th-order global eustasy and may be correlated with oxygen isotope stages 49 to 9. Our investigation strongly suggests that there exist considerable variations in coral reef developments, in relation to the Quaternary sea-level changes and local tectonic movement.

ORIGINAL OXYGEN ISOTOPIC COMPOSITION OF PLANKTIC FORAMINIFERS PRESERVED IN DIAGENETICALLY ALTERED PLEISTOCENE SHALLOW-MARINE CARBONATES.

Sakai, Saburo*. *Graduate School of Science and Technology, Kumamoto University, 2-39-1, Kurokami, Kumamoto, 860-5555, Japan. Email: saburo@aso.sci.kumamoto-u.ac.jp

Shallow-marine carbonates are potential materials for a high-resolution climatic analysis, however the primary isotopic composition as climatological signals are normally erased by the effects of post-depositional diagenesis. In order to solve the problem of diagenesis, the author carefully examined the diagenetic effect of shallow-marine carbonates (the Ryukyu Group; Okinawa, Japan). The result indicates that the planktic foraminifer tests (low-Mg calcitic skeletons) have a significant po-tential in preserving their oxygen isotopic composition, despite the meteoric diagenesis altered the oxygen and carbon isotopic compositions of the whole-rock samples. The downcore dlta18O records of the planktic foraminifers represent a cyclic change which is adjusted to Middle Pleistocene glacial/interglacial stages. By comparison, isotopic measurements based on whole-rock samples can be obtained diagenetic environmental signals, but misleading with regard to paleoclimatic inferences.

CONFOCAL MICROSCOPY AND THREE-DIMENSIONAL IMAGING OF SYMBIOTIC DINOFLAGELLATES FROM CORALS REVEALS THEIR MORPHOLOGICAL DIVERSITY.

Salih, Anya* and Guy Cox. *School of Biological Sciences A08 and Electron Microscope Unit F09, University of Sydney, Sydney NSW 2006, Australia. Email: anya@emu.usyd.edu.au

Despite considerable molecular, biochemical and physiological diversity among the symbiotic dinoflagellates from scleractinian corals, morphological approaches have provided relatively few useful criteria for their effective systematic resolution. Mature coccoid zooxanthellae from various coral species all possess a peripheral multilobed chloroplast, a large nucleus, a single stalked pyrenoid and a large accumulation body. We used confocal and multi-photon microscopy, combined with serial reconstruction of optical sections through individual cells, to image zooxanthellae in three-dimensional (3-D) mode. Samples from several coral species from the Great Barrier Reef, Lord Howe Island (Australia) and Red Sea (Egypt) were fixed in glutaraldehyde and the extracted algae confocally imaged by their autofluorescence. The 3-D imaging of the chloroplast envelope revealed distinct variability in the shape, number and thickness of the chloroplast lobes of zooxanthellae extracted from different coral species. Moreover, multi-photon microscopic images of DAPI stained algal chromosomes also revealed high species-specific variability in their number and morphology. Results of this preliminary study suggest that zooxanthellae show a greater morphological diversity than has been previously shown.

ANNUAL VARIABILITY OF WATER TEMPERATURES FROM BEACH TO OCEAN IN A CORAL REEF ECOSYSTEM, MOOREA, FRENCH POLYNESIA.

Salvat, B.*, J. Algret, Y. Chancerelle, B. Delesalle. *EPHE, ESA CNRS 8046, Université de Perpignan, France, and CRIOBE, B.P. 1013 Moorea, Polynésie Française. Email: bsalvat@univ-perp.fr

The water temperature has been recorded each hour along a 1500 m transect from the shore to the ocean in Tiahura sector (north west of Moorea Island) for several periods between 1991 and 1999. In the context of potential bleaching events, the aim of this study was to determine the high frequency variations of temperature endured by the living communities (corals, algae, molluscs, echinoderms and fish) in various geomorphological units (fringing reef, channel, barrier reef and the outer slope at 4 depths). As expected, the fringing reef community experienced the most extreme temperature (21.3 to 33.0°C), with a maximum of 6°C in 24 hours. The barrier reef community was subjected to less extreme temperature (23.1 to 30.9°C) and the maximum variation in 24 h never exceeded 4.7 °C. On the outer slope, there was little difference according to depth and the maximum within-day variation was 2.0-3.4°C. At the depth of 14 m where the living communities were the most diversified and coral cover c.a. 50%, the minimum and maximum recorded values were 25.8°C and 30.6°C respectively. The highest temperatures occurred in the afternoon of the first 3 months (austral summer) whereas the lowest ones were observed at the end of the night in August and September (austral winter). If mean daily temperatures are considered instead of hourly ones, the range of variation is lower by 2.4 to 4.4 °C in the lagoon and by 1.0 to 2.7 °C on the outer slope. This expected smoothing effect must be taken into account when analysing long-term series of data.

GENERATIONAL ORDER AND MODULE HIERARCHY: BRANCHING PATTERNS AND COLONIAL DEVELOPMENT OF GORGONIAN CORALS.

Sanchez, Juan A.* & Howard R. Lasker. Dept. Biol. Sci., SUNY at Buffalo, NY 14260, USA. Email: js15@buffalo.edu

The branching pattern of colonial marine invertebrates is one of their fundamental characters but it is poorly understood. Models that mimic colony development and architecture are often species specific and based on rules with little biological meaning. We followed growth of taxonomically diverse gorgonian species using series of digital photographs of marked colonies (Plexauridae: *Muriceopsis flavida* and *Muricea pinnata*; Gorgoniidae: *Pseudopterogorgia elisabethae, P. americana* and *Gorgonia ventalina*; Caribbean, Bahamas). Colony development among these branching species followed a common pattern. It can be characterized as the production of generations of polyps, which are linearly linked forming a branch. New generations arise when a branch forms as a tributary to the source branch. As a self-similar structure, each generation has the capability of producing daughter branches (sub-generations). Older generations (e.g. main stem) continue to grow producing a colony composed of overlapping generations of polyps. This pattern occurs among species with sub-apical growth (production of branches below the apex), which is the case for most gorgonian corals. Using this generational ordering system, branching ratio for gorgonian colonies is a non-linear function, which differs from the fixed branching ratio found using other ordering systems (e.g. Horton-Strahler and Tokunaga).

THE DISTRIBUTION OF MASSIVE *PORITES* IN THE MIYARA FRINGING REEF, ISHIGAKI ISLAND, JAPAN: POPULATION MAINTENANCE THROUGH FRAGMENTATION.

Satoh, Takanori*. *Tokyo Metropolitan University, Tokyo, Japan. Email: kiko@comp.metro-u.ac.jp

The spatial distribution, size frequencies and morphologies of massive *Porites* colonies were investigated over a large area (1100 m x 200 m) in the sandy moat of Miyara Reef, Ishigaki Island, Japan. Large massive *Porites*, > 50 cm, showed a preferential distribution for deeper depths (i.e., 2 to 3 m) while small colonies (50 to 100 cm) tended to be found in shallow areas (<2 m). This distribution pattern suggests that large colonies do not survive in shallow habitats or, and more likely, that large colonies are transported to deeper more stable habitats, like 'rolling stones'. Twenty-three percent of the large colonies were mushroom shaped, with narrow necks attached to the substratum. Significant portions of the mushroom shaped colonies (69%) were dislodged and 66% of them were tilted toward the direction of net water flow. The mushroom morphologies appear related to the high mobility of sandy sediments around the colonies, which interferes with ordinary growth of the colony base through sand abrasion. Fragmentation and/or mobile colonies seem to maintain local coral populations in sandy habitats, which are often unsuitable habitats for larval settlement. In this case, physical environmental factors, such as water movement and micro-geomorphology, regulates the distribution and population structure of coral communities in the sandy shallow habitats.

SPONGES OF THE '*CLIONA VIRIDIS* COMPLEX'

Schönberg, CHL. Carl von Ossietzky University Oldenburg, Dept. of Zoosystematics & Morphology, FB 7 - Biology, Geo- & Environmental Sciences, D-26111 OLDENBURG, Email: christine.schoenberg@mail.uni-oldenburg.de

The '*Cliona viridis* complex' is a group of clionid sponges sharing important taxonomic characters: a spiculation of tylostyles and spirasters, and symbiosis with zooxanthellae, which cause brown to olive-green clour. Identifying and separating species belonging to this group has caused much confusion in the past. However, through thorough study of spicule morphology in comparison with that of other species respectively, makes it possible to identify a given species of the '*Cliona viridis* complex'. Additional characters including bioerosion traces are listed and may help, where variable spicule features impede the decision. Characters of *Cliona orientalis* from the Australian Great Barrier Reef are portrayed to illustrate the problem as an example. A summary table of species characters and a key are provided to facilitate future work on the '*Cliona viridis* complex'.

CARBON TRANSFERS BETWEEN A REEF ECOSYSTEM AND THE OCEAN THROUGH A LAGOONAL PASS (MOOREA, FRENCH POLYNESIA)

Schrimm, M.*, R. Buscail, B. Delesalle, T. Courp, S. Heussner. EPHE, ESA CNRS 8046, Université de Perpignan, France. Email: schrimm@univ-perp.fr

The export of particulate organic (OC) and inorganic carbon (IC) was quantified at the annual scale, from the inshore part of a reef system to the ocean, through a lagoonal pass. The study area, the Tiahura reef, was divided into 3 compartments: (1) the lagoon, source of the material exported (2) the sandy plain, intermediate compartment and (3) the open ocean, considered as a definitive carbon sink. For each compartment, the hydrological and nephelometrical water masses structures (water samples and CTD/transmissometry profiles) and the particle fluxes (sediment traps) were investigated. The export of turbid lagoonal water is revealed by surficial nepheloids, which spray around outside the pass. The concentrations of particulate OC and IC decreased from the pass offshore. The fluxes recorded in sediment traps showed that the particulate lagoonal export increased 5 fold the ambiant external flux on the outer reef sandy plain. Meanwhile, fluxes were 10 times lower in the deep compartment than in the vicinity of the pass. Finally, the net annual amount of particulate carbon exported in the water masses can be estimated at 6.2 10^8 g OC y^{-1} and 3.2 10^8 g IC y^{-1} (i.e. respectively 26% of P, the organic net production and 30% of G, the net calcification evaluated in the lagoon). The OC and IC collected by sediment traps represents up to 5% of P and 15% of G. Thus, export is far from being negligeable and should be taken into account in carbon and carbonate budgets.

SELECTION OF MARINE ORGANISMS FOR CHEMICAL ANALYSIS BASED ON ECOLOGICAL TESTS, OBSERVATIONS AND PHARMACOLOGICAL SCREENS.

Schupp, Peter J.* *Center for Marine Biofouling and Bioinnovation, University of New South Wales, Sydney 2052, Australia. Email: P.Schupp@unsw.edu.au

There are few studies that examine the correlation between the ecological and pharmaceutical activities of secondary metabolites from marine organisms. To assess possible correlations between ecological and pharmacological activities a total of 21 marine invertebrates from the Indo-Pacific region were examined. Organisms were selected if they were brightly colored, had unusual growth forms, or had symbiosis with other organisms, or were dominant. Ecological activity was assessed using fish feeding experiments in the field and laboratory. The pharmaceutical activity of samples was determined at the Institute for Pharmaceutical Biology at the University of Würzburg. Tests screened for insecticidal activity with the polyphagus pest insect *Spodoptera littoralis*, cytotoxicity using L5178y mouse lymphoma cells and 11 different cyclin and tyrosine kinases. Antimicrobial activity was assessed using the gram-positive bacteria *Bacillus subtilis* 168 (BS), *Staphylococcus aureus* ATCC 25923 (SA) and the gram-negative bacteria *Escherichia coli ATCC* 25922 (EC) and *Escherichia coli* HB 101 (HB). Antifungal activity was assessed using the phytopathogenic fungi *Cladosporium cucumerinum*. Results demonstrated a strong trend, with extracts which are active in fish feeding assays exhibiting pharmacological activity.

OLIGO/MIOCENE EXAMPLES OF *ACROPORA* DOMINATED PALEO-ENVIRONMENTS: MESOHELLENIC BASIN (NW GREECE) AND NORTHERN GULF OF SUEZ (EGYPT).

Schuster, Frithjof*. *Research Institute Senckenberg, Senckenberganlage 25, D-60325 Frankfurt, Germany. Email: fschuste@sngkw.uni-frankfurt.de

Assemblages dominated by *Acropora* are rare during the Paleogene and the early Neogene. The emergence of *Acropora* as a dominant species is thougth to have begun during the Pliocene. Two examples of much older *Acropora* dominated assemblages are presented from Late Oligocene shallow sublittoral environments of the Mesohellenic Basin and Early Miocene (Burdigalian) lagoonal deposits of Egypt. Both examples show stratified deposits with accumulations of mainly redeposited branches. In situ growth of *Acropora* colonies is rarely observed. It is suggested that the formation of these deposits was caused by storm events which destroyed densely growing thickets. In the Mesohellenic Basin the lateral extension of such layers of several hundreds of meters and associated sediments indicate environments without major relief and of shallow water depth. Burdigalian *Acropora* layers of the northern Gulf of Suez are thinner and of less lateral extent. They co-occur with *Halimeda* layers and corallinacean red algal float- to rudstones. Both examples show that *Acropora* was more abundant during the Paleogene and early Neogene than previously thougth. It seems to occur preferentially in shallow lagoonal or lagoonal like environments where it formed extensive thickets mostly preserved in stratified, redeposited layers. These environments represent calm, low energy hydrodynamic conditions and show that *Acropora*, which is regarded today as a moderate to high energy coral, probably shifted its ecological adaption from low to higher energy environments.

COMMUNITY STRUCTURE AT THE ABROLHOS ARCHIPELAGO, BRAZIL.

Segal, Bárbara * and Clovis B. Castro. *Museu Nacional/Universidade Federal do Rio de Janeiro, Departamento de Invertebrados, Quinta da Boa Vista s/nº, São Cristóvão, 20940-040 – Rio de Janeiro RJ, Brasil. Email: bsegal@pobox.com

The Abrolhos Reefs, Brazil, form the most developed and diverse reef assemblages in the South Atlantic Ocean. The Abrolhos Archipelago is located inside the area of Abrolhos National Marine Park. Patterns of coral community structure were analyzed at three sites in the Abrolhos Archipelago at depths (stations) between 1.9 and 4.0 m. Five replicates of 20m point intercept transects, marked with 500 random points, were surveyed at each station. The size of 30 random colonies of the most frequent or abundant coral species was measured at each site. A non-metric MDS analysis was undertaken to test zonation patterns in each site. Sites were compared with a multivariate similarity test (ANOSIM). Simpson's diversity index and Heip evenness index were used to compare coral diversity among the three areas. Dominant reef building organisms were the endemic coral *Mussismilia braziliensis* (1.8 to 24.5% cover) and calcareous algae (12.3 to 19.5% cover). Total coral coverage was low (7.4 to 31.8%). Eleven coral species were recorded for the entire area studied. Shannon diversity indices were also low, ranging from 0.28 to 0.53. No zonation parn was detected among depths (stations) analyzed. The main biotic differences among the three sites referred to total coral cover and diversity parameters. We suggest that some of these factors may be affected by physical differences between the three ss, mainly wind direction and intensity.

IMPACTS OF SOME NATURAL AND ANTHROPOGENIC PERTURBATION ON THE REEF FISH ASSEMBLAGES IN THE SOUTHERN TIP OF TAIWAN.

Shao, K.T.*, C.Y. Lin and J.P. Chen. Institute of Zoology, Academia Sinica, Nankang, Taipei, Taiwan. Email: zoskt@gate.sinica.edu.tw

Fish assemblages in the southern tip of Taiwan were monitored during November 1997 to March 1999 to study their short-term and long-term temporal and spatial fluctuations as well as the impact of nature (typhoon and global warming) and human disturbances (sand-mining, explosive fishing). The results shown: 1. Spatial effect is more important than temporal effect to the fish assemblage and no seasonal variation was shown. 2. Two typhoons passed by within one month had caused the decrease of fish abundance and the recruitment of juvenile fishes temporarily. 3. In 1998, due to the global warming, the coral bleaching decreased the species and individual number of reef fishes, but they are now gradually recovering. 4. Sand-mining will affect certain groups of fishes. 5. A station destroyed by the dynamite fishing in 1990 has so far not recovered yet. 6. Diving activities apparently damage those near-shore reefs more than those off-shore reefs.7. The intake area of the Nuclear Power Station function like a no-take zone (MPA) create the most prosperous coral reefs in Taiwan. The reef fish assemblages here are unique and much dominant by zooplankton feeders.

A DECADE OF STUDY ON CORAL SPAWNING AT AKAJIMA ISLAND, OKINAWA, JAPAN.

Shimoike, K.* and T. Hayashibara. Akajima Marine Science Laboratory, 179 Aka, Zamami-son, Okinawa 901-3311, Japan. Email: shimoike@amsl.or.jp

Spawning behavior of scleractinian corals around Akajima Island was observed in the field consecutively from 1989 to 1999. In total, 108 species belonging to 27 genera and 11 families spawned from May to early September during the 11 years. Most of the spawning events occurred during the period from four nights before the full moon to eight nights after the full moon, but 4 species of *Acropora* (*A. divaricata*, *A. latistella*, *A. subulata*, *A. willisae*) and 2 species of *Merulina* (*M. ampliata*, *M. scabricula*) spawned around the new moon from July to September. The date of mass spawning of *Acropora* spp. in all years but 1998 when serious breaching occurred showed a clear relationship to the temperatures experienced since March lst of each year. The water temperature apparently influences maturation of gonad. Thus, the cumulative water temperature will be a useful indicator to predict the date of mass spawning.

CHEMICAL AND STRUCTURAL DEFENSES MEDIATE GORGONIAN PREY PREFERENCE OF *CYPHOMA GIBBOSUM*.

Slattery, Marc*. Deborah J. Gochfeld, Bryan C. DeBusk, Gary R. Gaston, Daniel K. Schlenk. *The University of Mississippi, Department of Pharmacognosy, NCNPR & RIPS, School of Pharmacy, Oxford MS 38677-1848. Email: mslatter@sunset.backbone.olemiss.edu

Grazers can play an important role in benthic community structure; their impact is directly related to the abundance of their prey species and to their own prey preferences. The -grazing mollusc *Cyphoma gibbosum* is a common member of Caribbean reef systems and exhibits distinct prey preferences in the field. We tested the feeding deterrent activities of extracts and sclerites from 10 species of gorgonians against *C. gibbosum*. The species-specific differences in feeding deterrence explained much of the prey preference data based on our field observations. The aftermath of natural stresses, Hurricane Mitch and a sea fan fungal pathogenesis event, resulted in significant changes in the gorgonian community composition which led to changes in host preference by the *C. gibbosum* populations in Belize C.A. We re-examined feeding deterrence in *Briareum asbestinum* and *Gorgonia ventalina*, two species that exhibited changes in extract and sclerite levels following these events. These results further support chemical and structural defenses as mediators of gorgonian prey preference and community-level grazing patterns by *C. gibbosum*. Recent shifts in the gorgonian prey preferences back to pre-stressed grazing patterns indicates that *C. gibbosum* responds to plastic changes in its host in a manor consistent with optimal foraging strategies.

CALIBRATION OF GULF OF MEXICO CORAL SKELETAL PARAMETERS WITH *IN SITU* PHYSICAL MEASUREMENTS.

Smith, J. M. *, N. C. Slowey. *Texas A&M University, Department of Oceanography – 3146, College Station, Texas 77843, Email: jennifer@ocean.tamu.edu

The Flower Garden National Marine Sanctuary is located in the northern Gulf of Mexico, 180 km off the Texas-Louisiana coast at the shelf edge. The Flower Gardens are isolated from significant riverine influence and disturbance from human coastal activities and are therefore an ideal site to investigate how temporal changes in environmental conditions are reflected by coral skeletal material. A suite of short coral cores was collected from *Montastrea faveolata* and *Diplora strigosa* corals. These cores were cut into slabs and X-rayed, allowing their density bands to be analyzed and the skeletal material to be sampled by micro-drill for geochemical measurements. Variations in the stable isotopic ($\delta^{18}O$, $\delta^{13}C$) compositions of the skeletal material (determined by mass spectrometry) will be compared with *in situ* measurements of light, salinity and temperature taken from a period of up to eight years. Empirical relations established from this comparison will contribute to our understanding of how corals monitor environmental change and will provide a framework for using corals to study the regional history of inter-annual and inter-decadal climate change.

THE IMPACT OF HERBIVORES ON THE SURVIVAL AND GROWTH OF RECENTLY SETTLED CORAL RECRUITS.

Smith Luke. Australian Institute of Marine Science PO BOX 264, Dampier Western Australia 6713 Email: l.smith@aims.gov.au

These studies assesses whether herbivorous fishes enhanced the survival and growth of coral recruits by reducing the standing crop of turf algae or, alternatively increase coral mortality through accidental grazing. Conditioned settlement plates were seeded in the field with cultured coral larvae (*Acropora hyacinthus*), removed two days later and the recently settled larvae mapped. The cultured corals upon the settlement plates were re-deployed upon the reef into one of three treatments 1. cages that excluded herbivorous fishes 2. cage controls or 3. open to herbivores. In the treatment excluding herbivores, turf alga thrived, while no differences were seen in the standing crop of turf algae within the open or cage control treatments. Coral recruits survived best in the open and cage control treatments, with 45% and 42% remaining alive after 3 weeks, respectively. Alternatively, coral recruits excluded from herbivores survived poorly, with only 22% surviving in the corresponding period. Furthermore coral recruits excluded from herbivores, had substantially lower growth compared to those either in the open or cage controls. The higher mortality and lower growth rate of coral recruits excluded from herbivores was attributed to recruits being smothered by sediment rather competition with the algae. Sediment load was far greater on settlement plates excluded from herbivorous fishes due to sediment becoming trapped in the higher standing crops of turf algae found upon these plates. Herbivores are likely to play a vital role in enhancing the survival and growth of coral recruits by preventing the accumulation of sediment within turf algal communities.

SPATIAL VARIATION OF CORAL RECRUITMENT IN TAIWAN.

Soong K.*, Chen, Ming-hui; Chen, Chao-lun; Dai, Chang-feng; Hsieh, Herhyi Fan, T.Y.; Kuo, Kun-ming; Li, Jan-jung. *Institute of Marine Biology, National Sun Yat-sen University, Kaohsiung, Taiwan 804, Rep. of China. Email: keryea@mail.nsysu.edu.tw

Coral settlement at Nanwan Bay, southernmost Taiwan was investigated using artificial substrates between 1997 and 1999. Eleven 15 x 15 cm plates were placed at each of 2 spots (10 m apart) at each of 2 sites (about 1 km apart) at each of the 4 regions, i.e., East, North, West and Out of the 10-km-across bay, for 1.5-2 months (covering the annual mass spawning time between April and May for 1997 and 1999). Scales of spatial variation in Nanwan Bay were analyzed for the above nest-design for 3 consecutive years. A similar design was extended to isolated coral reefs around Taiwan, covering north-east Taiwan, Orchid Island, Nanwan, Hsiao-liu-chiu, Penghu and Yun-an, with a total span of 400x200 km, in 1999. Overall densities of coral recruits were low, when compared to that of the Great Barrier Reefs, and most recruits belonged to brooding species, i.e. pocilloporids with some acroporids. Significant spatial variation occurs among sites, at the scale of about 1000 m, in 1997 and 1998. However, in 1999, significant spatial variation occurred at a lower level of among spots (10 m apart). In Nanwan, the highest recruitment occurred at Hobihu for 3 consecutive studies, whereas other sites locations had virtually no recruits. The pattern of settlement variation suggests that self-seeding is a possible explanation for broodings species. And the spatial scale of distribution may be limited to restricted areas even within a reef.

THE EFFECTS OF PREDATION ON CORAL SURVIVORSHIP IN MALINDI / WATAMU MARINE NATIONAL PARKS, KENYA.

Starger, C. J.* *Center for Environmental Research and Conservation – Columbia University, MC 5557, 1200 Amsterdam Ave. New York, NY 10027, USA. Email: cjs52@columbia.edu

Global warming is the greatest threat to coral reef ecosystems worldwide. It is also the most difficult to manage on an effective scale. Coral reef restoration may prove to be an effective method for restoring reef communities which have suffered otherwise irreversible damage from the effects of hurricanes and bleaching events; communities where the natural recruitment of corals is inadequate. In working towards developing protocols for reef restoration, it is necessary to study the survivorship of coral colonies with respect to many variables. My study, part of a larger project of the Wildlife Conservation Society's Coral Reef Conservation Project, takes place the Summer of 2000 in Malindi and Watamu Marine National Parks, Kenya. I study the survivorship of transplanted and naturally occurring colonies of *Porites*, *Acropora*, *Galaxea*, and *Pocillopora* species. Treatments include predation pressure, and reef zone. I hypothesize that the greatest survivorship will occur among colonies of large size, intermediate depth, rugose substrate, and low predation pressure.

SPECIES DISTRIBUTION AND ABUNDANCE OF BIOERODERS, AND EFFECTS IN AN EUTROPHICATION GRADIENT WITHIN CORAL FRAMEWORK AT ZANZIBAR, TANZANIA

Stromberg H* *Zoology Department, Stockholm University, 10691 Stockholm, Sweden. Email: helena.stromberg@zoologi.su.se

In February to April 1999 a study of the distribution and abundance of bioeroders was conducted across an eutrophication gradient from the runoff of Zanzibar town situated on the west coast of Zanzibar (Unguja), Tanzania. Four sites were chosen in a gradient from town: outside the Island Capwani with a reef nearest the runoff, outside Bawe Island 2 NM from town, In the Chumbe marine park 7 NM from town and at Mnemba reef outside the east coast of Zanzibar. Dead standing corals of three genera (*Acropora* spp., *Porites* spp.and *synaraea* spp.) were collected plus coral-rubble from the bottom. From each of the different types replicates were collected at two different depths. All corals were cut into slabs and photographed. The percentage erosion from different eroding groups i.e. sponges, polychaetes, sipunculans, bivalves and balanoides were analyzed and representation of the benthic taxa in the dead coral was collected in an attempt to identify higher-level interactions between water quality and community composition. Preliminary results show that the variance of bioeroding organisms within and among sites was very high. This indicates that the common method of using corals for bioerosion studies were the time of mortality is unknown can be questioned.

CONTRIBUTION OF METABOLIC ACTIVITY BY CORAL TO THE BALANCE IN ORGANIC MATTER

Suzuki, Y.*; Casareto, B.E.; Kurosawa, K.; and Katsumi, Y. *Department of Biology and Geosciences, Graduate School of Science, Shizuoka University, 836 Oya Shizuoka, 422 Japan. Email: seysuzu@sci.shizuoka.ac.jp.

A large part of the organic matter produced and released in coral reef communities is introduced into the coral reef ecosystems. The organic matter produced enters into the food chain as suspended, and also as dissolved organic matter. Carbon cycle in coral reef depends upon the "biodynamic convertor" related to the production and decomposition of organic matter. We performed a metabolic experiment on the balance between inorganic and organic carbon for the coral *Montipora digitata* in an incubation tank. The tank was filled with unfiltered and Whatman GF/F filtered sea water, and temperature (27°C), flow rate of water (5 $ml.min.^{-1}$) and light intensity (50 µMes, light/dark 12/12 hrs.) were monitored. The organic fraction of coral was divided into two fractions: zooxantellae and organic tissue. Total inorganic carbon concentration decreased under the light, and increased under the dark. The increase of total organic carbon concentration (TOC) was 2.41 $gC.m^{-2}day^{-1}$ under both light and dark conditions. This value is in the same range than the primary production rate (1.82 $gC.m^{-2}.day^{-1}$) measured by the ^{13}C-isotope method. The translocation and respiration of organic matter measured using the ^{13}C-isotope method were 0.48 $gC.m^{-2}.day^{-1}$, and 1.34 $gC.m^{-2}.day^{-1}$, respectively. Therefore, the uptake of organic matter by coral was 2.89 $gC.m^{-2}.day^{-1}$ (translocation + uptake of TOC related to the metabolic activity of coral). This suggests that the metabolic activity of coral plays an important role in the carbon balance within coral reef ecosystems.

"WHERE DO THE BETTER CONDITION CARANGID LARVAE GET THEIR NUTRIENTS FROM?"

Syahailatua, A* and Suthers, I. *School of Biological Science, The University of New South Wales, Sydney NSW 2052, Australia.
Email: augy@student.unsw.edu.au

Two species of Carangidae (*Pseudocaranx dentex* and *Trachurus novaezelandiae*) were sampled along the north and central coast of NSW during two cruises on the CSIRO RV "Franklin" in November 1998 and January 1999. On both cruises dramatic upwelling was observed with 2-4°C cooler water off Foster and a strong East Australian Current offshore. These two carangid species were found with higher abundance in November 1998 than January 1999. However there were only slight differences in their length distribution (1.5-16.0 mm) between species and among regions, providing ideal material to investigate the effect of oceanographic nutrient upwelling and sewage discharge. Determining growth and condition, and also source of its food will be conducted by using three methods (recent otolith growth increments, RNA:DNA and stable isotope analysis). Recent otolith growth over the past 3-7 days pre capture provide a robust back-calculated estimate of growth, while RNA:DNA ratio indicates the amount of protein synthesis relative to the number of cells. Stable isotopes analysis of carbon and nitrogen show distinct signatures of upwelled versus sewage derived nutrients.

THE GENETIC STRUCTURE OF POPULATIONS OF THE UBIQUITOUS CORAL, *STYLOPHORA PISTILLATA* IN TWO CONTRASTING REEF SYSTEMS.

Takabayashi, M.*, Ridgway, T., Hoegh-Guldberg, O., Carter, D.A.
Centre for Marine Studies, The University of Queensland QLD 4072 Australia. Email: misaki@bio.usyd.edu.au

The genetic structures of marine populations are driven by the reproductive characteristics of an organism, as well as the oceanography of the reef habitats within which populations exist. We studied the population structure of Indo-Pacific reef-building coral, *Stylophora pistillata*, within two contrasting reefs the Great Barrier Reef (Raine Island, RI; 12°S, 144°E and One Tree Island, OTI; 23°S, 152°E). Multilocus allozyme analysis and nucleotide sequence analysis of the internal transcribed spacer-1 (ITS-1) in the ribosomal RNA gene were used. A substantial genotypic diversity at the local scale was found at RI. G_o values were similar to those expected for outcrossed sexual reproduction (mean G_o:G_e = 0.81), although single-locus heterozygote deficits indicate small amounts of inbreeding on reefs. Genetic subdivision was evident among sites within RI. The relatively high level of genetic divergence at RI was also reflected in the ITS-1 sequence variability. The analyses of molecular variance (AMOVA) showed that the proportional variance of among populations 8.23% for RI compared to 0.17% for OTI. The low variance of populations at OTI is probably due to the enclosed nature of lagoonal water masses, which is likely to promote within population mixing and hence greater homogeneity.

VARIATION ON THE CEMBRANOID DITERPENES IN *SARCOPHYTON* SOFTCORALS IN OKINAWA.

Tanaka, Junichi* Takumi Yoshida, and Yehuda Benayahu. University of the Ryukyus, Okinawa, Japan Email: jtanaka@sci.u-ryukyu.ac.jp

Chemical constituents of softcorals have been intensively investigated in the last three decades, and species of the genus *Sarcophyton* are known to be rich in unique secondary metabolites. In 1979, Kobayashi reported sarcophytol A from *S. glaucum*, and the compound was later found to have an antitumorpromoting activity. In early 90s, we investigated the bioresources of sarcophytol A in Okinawa and found that the compound was contained not only in *S. glaucum*, but in two other species *S. trocheliophorum* and *S. crassocaule*. Furthermore, some specimens of *S. glaucum* did not contain the compound suggesting that chemical contents of *Sarcophyton* species are not so simple. Recently, we started chemical investigation on the biogeographic variation of cembranoids in *Sarcophytons* species using a gradient HPLC and other spectral methods together with morphological characterization. We have found that there is considerable variation on diterpene constituents of Okinawan *Sarcophytons* species. Results on the chemical characterization of the studied softcorals will be reported.

SMALL-SCALE MORPHOLOGICAL VARIATION IN THE SCLERACTINIAN CORAL *FAVIA SPECIOSA* (DANA 1846) AROUND SINGAPORE.

Todd, P.A.*, Sanderson, P.G., Chou, L.M. Department of Geography, National University of Singapore, 1 Arts Link, Kent Ridge, Singapore, 117576. Email: artp8501@nus.edu.sg

A photographic technique was used to examine morphological differences in the polyps of *Favia speciosa* sampled from three sites around Singapore. Eight characters were measured, seven of which differed significantly between sites. Characters tended to decrease in size with increasing distance from the mainland shore. Land reclamation and dredging contribute to high sediment rates in Singapore waters; these rates also decrease with increasing distance from shore. Large polyps close to the main island of Singapore are possibly an adaptation to high levels of sediment.

SCLERATIN CORALS IN THE CAMPECHE SOUND, MEXICO.

Torruco, Daniel *, Gonzalez, Alicia and Axis, Javier. *CINVESTAV-IPN Laboratory of Coral Reef, Center for Research and Advances Studies, A.P. 73 Cordemex, 97310 Merida, Yucatan, Mexico. Email: dantor@mda.cinvestav.mx

The spatial distribution of 33 hermatypic coral species was analyzed for six coral reefs in the Campeche Sound, Mexico. For the statistical analysis, the grouping technique was employed using the Second Order Information Content division criteria, coded with qualitative and quantitative data. The total information content was 130 natural beles/ind. Three large groups were produced in the cluster analysis, with very narrow affinities. The multifactorial analysis showed strong associations between Arcas Key – Triangulos Oeste Reef and Arenas Key – Obispo Bank, the remaining stations all associating with this second group. The ecological architecture is solid, with strong interspecies interactions. The low diversity in the area is principally attributed to meteorological events in the area, though recuperation from these impacts, as well as anthropogenic impacts from oil exploitation, was noted.

STATUS OF KNOWLEDGE OF THE INDO-PACIFIC SOFT CORAL GENUS *SINULARIA* (OCTOCORALLIA: ANTHOZOA).

van Ofwegen, L.P.*. *Nationaal Natuurhistorisch Museum / Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. Email: Ofwegen@naturalis.nnm.nl

For several coral groups and other reef-associated fauna, centres of species diversity have been recognized. Due to lack of taxonomic knowledge, such diversity patterns for soft corals are so far only based on rough estimations. Of all soft coral genera found on the Indo pacific reefs, the genus *Sinularia* undoubtedly is the largest. More than 125 species have been described so far. Occasionally, species of this genus have been observed even dominating vast regions of the reef. Much additional research has to be done before all species are sufficiently well known, but after a taxonomic revision of this genus in 1980, species of *Sinularia* can be identified with reasonable certainty. After this revison, a number of papers with data about *Sinularia* have been published, providing additional information about the genus. This information and the revision are used together to examine patterns of species diversity for *Sinularia* in the Indo Pacific. The outcome of this examination gives a picture of the present status of knowledge of the genus. The results are compared with the diversity patterns known for hard corals. The differences found and regions that need further research are discussed.

REPRODUCTIVE AND SPAWNING PATTERNS IN SIX CLOSELY RELATED MADRACIS SPECIES

Vermeij, M., K., Nijgh-deSampayo, E. and Bak, R.P.M.*, *Netherlands Inst. for Sea Research, Landsdiep 4, Texel, The Netherlands.Email: rbak@nioz.nl

To study the relatedness between six species comprising the Caribbean coral genus Madracis we studied the reproductive cycles of six closely related Madracis species whose taxonomical status is uncertain at the moment. Temporal variation in reproductive cycles might result in reproductive isolation between species excluding introgression or hybridization as an explanation for the observed similarity between species. All species proved to be hermaphroditic brooders whose male and female gonads are found within the same septa. Spawning and presence/absence of gonads was monitored (daily, monthly) in all species over a 13-month period. The production of female gonads starts in May whereas the production of male gonads begins in August. Both mature and immature gonads (male and female) are found in all species from September till November when seawater temperature reaches its yearly maximum. During these months all species release larvae in low numbers (0.02-0.05 larvae/cm^2/day) with no obvious relation to lunar, tidal or temperature cycles. *M. senaria* showed a exceptional pattern. It spawned large numbers of larvae (1.34 larvae/cm2/day) three days after the last quarter moon and spawning of larvae was observed in May when no gonads could be found. The two Madracis species producing the lowest number of larvae are characterized by a life history depending on fragmentation. We show that reproductive behavior is plastic within the genus but temporal reproductive isolation is absent in our six Caribbean Madracis species.

THE EFFECT OF REDUCED SALINITY, COPPER, AND IRON ON FERTILIZATION SUCCESS OF GAMETES OF *ACROPORA SURCULOSA*.

Victor, S.* and. Richmond, R.H. *Marine Laboratory, University of Guam, UOG Station, Mangilao, Guam USA 96923. svictor@uog9.uog.edu

Fertilization of gametes from reef-building corals is an important life history event leading to successful larval production and eventually recruitment of new corals to maintain populations. Fertilization can be inhibited by the presence of pollutants, such as heavy metals in the water column and/or altered salinity. Tropical islands surrounded by coral reefs, have come under tremendous development pressure that has increased runoff which carries pollutants and fresh-water to affect coastal waters. Inhibition of fertilization by reduced salinity and heavy metals (copper and iron) was assessed using laboratory-based bioassay. Gametes of *Acropora surculosa* were exposed to reduced salinity and nominal concentrations of copper and iron. Reduced salinity at 29.3 ppt (15% fresh-water dilution) and 27.7 ppt (20% fresh-water dilution) caused 13% and 78% reduction in fertilization success compared to 96% successful fertilization in the control, respectively. Nominal concentrations of copper (as $CuSo_4$) at 100 ppb and 200 ppb caused a statistically significant decrease in fertilization from 89% in the control to 61% and 60 %, respectively. Iron (as $FeSo_4$) produced no appreciable effects on fertilization success up to nominal concentrations of 10 ppm. As spawning events are predictable, management initiative can be developed to protect coastal waters during these critical periods.

ENERGETIC IMPLICATIONS OF THE SYMBIOTIC ASSOCIATION BETWEEN *Tetralia fulva* (XANTHIDAE) AND *Acropora millepora* (SCLERACTINIA) ON THE GREAT BARRIER REEF, AUSTRALIA.

Vytopil, Elaine*; Willis, Bettte. *Dept Marine Biology, James Cook University, Townsville, Australia, 4811. email: elaine.vytopil@flinders.edu.au

Branching corals of the genus *Acropora* dominate mid- and outer-shelf reefs of the Great Barrier Reef and provide discrete microhabitats for a variety of symbiotic epifauna. Despite the abundance of *Acropora* in the reef environment, little is known of the energetic implications of these associations to the success of the coral genus. The role of *Tetralia* crabs in the health of their *Acropora* hosts was assessed over a two-month period using a crab removal experiment. The production of mucus by *Acropora millepora* was significantly increased by the presence of a *Tetralia fulva* pair. This did not have an energetic cost to the corals in terms of either tissue health or growth. In fact, colonies supporting a crab pair showed trends for increased growth and tissue health, although trends were not statistically significant. It is possible that the stimulation of mucus production by *Tetralia* acts to keep the coral surface clean thereby enhancing tissue health, and that crab excretory products provide their coral hosts with a supplementary nitrogen source which may act to enhance growth. Thus, we suggest that *Tetralia* have no obvious energetic costs to their coral hosts (although reproductive output was not measured), and that since crabs benefit nutritionally from coral mucus production, this association may be considered energetically commensal and possibly mutualistic in nature.

FIRST DATA ON COMMUNITY STRUCTURE AND TROPHIC FUNCTIONING OF UVEA (WALLIS AND FUTUNA) CORAL REEF FISH ASSEMBLAGES.

Wantiez L*, Chauvet C, Coutures E, Allendach M. Lervem, University Of New Caledonia, Bp 4477, 98847 Noumea, New Caledonia. email: wantiez@univ-nc.nc

The first quantitative study of the coral reef fish communities of Uvea, main island of Wallis and Futuna archipelago, was conducted in 1999. Visual censuses techniques were used on 4 transects. On each transect, fringing reef, mid-lagoon reef, inner barrier reef slope and outer barrier reef slope were sampled. A total of 194 fish species in 32 families were censused. The main families being the Labridae (34 species), Pomacentridae (33 species) and Chaetodontidae (23 species). Several common commercial reef species in tropical Indo-Pacific coral reefs (*Epinephelus* spp, *Plectropomus leopardus*, *Lethrinus nebulosus*, *Gymnocranius* spp, *Naso unicornis*, *Siganus* spp) were not recorded during this survey. Mean density (2.5 fish m^{-2}) was comparable to other Pacific reefs fish communities whereas mean biomass (43 g m^{-2}) was within the smallest known values. Four assemblages have been identified along an inshore-offshore gradient and linked to substrate characteristics: One coastal assemblage located in a coral reef and seagrass bed environment; Two lagoonal assemblages, one in an algae and rubble environment, and one in a live coral and coral stone environment. The third assemblage was located on the outer barrier reef slope and linked to live coral substrate. The main path for the transfer of energy was microalgae → grazers → piscivores. Macrocarnivores and zooplanctivores were the other important trophic groups.

SETTLEMENT, MOVEMENT AND EARLY MORTALITY OF YELLOWTAIL SNAPPER *OCYURUS CHRYSURUS*.

Watson, Maggie*. *ICLARM CEPO, 158 Inland Messenger, Road Town, Tortola, British Virgin Islands. Email: iclarm@candwbvi.net

Light trapping near fringing reefs in the British Virgin Islands documented a clear pulse of late pelagic stage yellowtail snapper (*Ocyurus chrysurus)* in September 1999. Daily visual censuses of a grid covering 1250 m^2 of shallow seagrass (*Thalasia testudinium)* revealed a concurrent peak of newly settled fish. Censuses continued while the cohort was distinguishable from older juveniles (approximately four weeks while length was <= 3.5cm). Abundance declined exponentially: $y= 74.831\exp^{-0.045x}$ R^2 0.83. Three experiments were undertaken to separate post settlement movement from mortality. Firstly, total lengths of censused fish were estimated to the nearest 0.5cm. Fish <= 8cm were regularly observed in the seagrass but individuals <8cm were never recorded from schools of older juveniles in adjacent rocky habitat. Thus fish <=3.5cm were considered resident in seagrasses. Secondly, 96 late pelagic stage *Ocyurus chrysurus* caught in light traps were tagged (tagging mortality 13.6%) and released at the centre of the grid between 6th and 9th September. Eight fish (the maximum seen on one day) were resighted on the 9th. Between the 9th and the 17th only one of 32 resightings was more than a few meters distant from a sighting on the 9th, providing a convincing picture of site fidelity after settlement. Thirdly, average home range was estimated at 2.27m^2 for fish 2 – 2.5cm (convex polygon method). Thus movement of newly settled individuals is minimal, and immigration was assumed to balance emmigration. Post settlement mortality was estimated as at least 80% of peak settlement abundance in the first month.

FEEDING ECOLOGY AND FUNCTIONAL MORPHOLOGY OF WESTERN ATLANTIC GROUPERS (SERRANIDAE: EPINEPHELINAE) .

Weaver D.C.*. *United States Geological Survey, Biological Resources Division, 7920 NW 71st Street, Gainesville, FL, USA. Email: doug_weaver@usgs.gov

Groupers are common apex predators that occur on tropical and warm-temperate reef systems throughout the world. The genus *Mycteroperca* and *Cephalopholis* exhibit an early onset of piscivory, and have diets dominated by fishes throughout the majority of their life history. In contrast, crustaceans dominate the diets of juveniles and remain important in the diets of adults for members of the genus *Epinephelus*. Patterns of dentition, jaw morphology, and lever ratios of the lower jaw were compared for representative species within each genus to identify potential morphological adaptations for feeding. All members of the genus *Mycteroperca* examined have enlarged teeth in the upper jaw, a reduced number of fixed teeth in the lower jaw, and relatively low lever ratios (.10 closing/.17 opening). In contrast, *Epinephelus* spp. have teeth of reduced size in the upper jaw, a greater number of teeth in the lower jaw, and higher lever ratios (.17 closing/.24 opening). Members of the genus *Cephalopholis* have high numbers of greatly enlarged teeth, low closing lever ratios (0.9) and high opening lever ratios (0.26). Increasing tooth size, a reduction in tooth number, and decreased jaw lever ratios are likely to increase capture success of evasive, soft-bodied prey, particularly fishes and squids, and reflect the dietary patterns observed. Groupers exhibit ecomorphological trends in feeding morphology that parallel more "specialized" reef fishes, such as wrasses (Labridae).

COMMUNITY STRUCTURE, HABITAT ASSOCIATION, AND TROPHIC RELATIONSHIPS OF REEF FISHES ON A STAGHORN CORAL (*ACROPORA CERVICORNIS)* REEF IN BROWARD CO., FLORIDA, U.S.A.

Weaver, D. C.*, D. S. Gilliam, D. Anderegg, and R. E. Dodge. *United States Geological Survey, Biological Resources Division, 7920 NW 71st Street, Gainesville, FL, USA. Email: doug_weaver@usgs.gov

The recent demise of *Acropora cervicornis* populations throughout the Florida Keys and Caribbean requires an investigation of the population dynamics and community ecology of this once dominant reef type. Simultaneous surveys involving high-resolution coral mapping/ monitoring and fine-scale spatial reef fish censuses will not only lead to increased understanding of processes that drive colony dynamics, including mortality and subsequent erosion, but identify impacts on the diverse assemblage of reef fishes associated with these monotypic populations of *A. cervicornis* "thickets" or "haystacks". Photoquadrat analysis and belt transect surveys were initiated in April 1999 on a broadly distributed, high-latitude *A. cervicornis* reef off Broward County, FL to document spatial distribution and percent cover of living coral colonies and associated reef fishes. Ongoing research efforts will document the food web structure of reef fishes associated with living and dead *A. cervicornis* reefs to identify associated shifts in species abundance, spatial distribution and trophic ecology of resident reef fishes. This project will provide a more comprehensive understanding of the biological processes linking hard coral and reef fish community dynamics in this geographically unique biological assemblage.

JUVENILE CORALS: SEWAGE IMPACT AND THE DETECTION OF POPULATION RESPONSE TO STRESS.

Webster, Graham*, S.R. Smith. *Bermuda Biological Station for Research, 17 Biological Station Lane, Ferry Reach, St. George's GE 01, Bermuda. Email: gwebster@sargasso.bbsr.edu

Detection of the impact of a stressor can be achieved by observation of those individuals most susceptible to the mechanisms in operation. A major effect of sewage impact on coral reefs is indirect through increased competition from enhanced benthic macroalgal growth; consequently, the most susceptible individuals will be the smaller or juvenile corals. Coral community and population parameters were investigated among replicate reef sites impacted by untreated macerated sewage and control sites off Bermuda. Surveys of juvenile (≤50mm) coral abundance in marked permanent quadrats at impact and control sites in 1997 indicated mean densities of juvenile *Diploria* spp., the major framework building corals, to be less than half as abundant at impact sites than at control sites (0.50 m^{-2} compared to 0.97 m^{-2}; $p<0.01$). Total juvenile coral densities of all species varied from 8.6 to 10.3 m^{-2}, with *Porites astreoides* comprising approximately 70% of all juveniles. No significant difference was detected between size-frequency distributions of *Diploria*, although size-frequency distributions of juvenile *P. astreoides* were skewed toward larger sizes at impact sites. Re-sampling of the same quadrats in 1999 revealed no statistically significant trends over time among sites.

BIOGEOGRAPHY AND TAXONOMY OF THE INDO-PACIFIC REEF CAVE DWELLING CORALLINE DEMOSPONGE *ASTROSCLERA WILLEYANA* – NEW DATA FROM NUCLEAR ITS GENE SEQUENCES.

Woerheide, G.*; Degnan, B. M.; Hooper, J.N.A.; Reitner, J. Queensland Museum, P.O. Box 3300, South Brisbane, Q 4101, Australia & Molecular Zoology Lab., Dept. of Zoology and Entomology, University of Queensland. Email: GertW@qm.qld.gov.au

Astrosclera willeyana Lister, 1900 is a pyriform-half spherical, predominantly bright orange colored, coralline demosponge commonly living in cryptic and light reduced environments of Indo-Pacific coral reefs, with the taxon *Astrosclera* present at least since the Triassic. Variability in spicule morphology of the allegedly 'cosmopolitan' *A. willeyana* from different geographic localities has been reported and the idea of there being more than one species of *Astrosclera* has been discussed. In a previous study we have undertaken empirical testing of the question whether variation in spicule morphology represents geographic variation or separate species, with examination of spicule morphology of specimens from 26 geographically distinct populations. Furthermore, we carried out a study on restriction fragment length analysis of the nuclear ITS regions for twenty specimens from five geographically distinct populations - this analysis supported the 'cosmopolitan' distribution of *A. willeyana*. We have now undertaken to sequence about 860 base pairs of the nuclear ITS regions of the previously investigated specimens and present a phylogenetic analysis of these sequences shedding new light on the biogeographic and taxonomic relationships of *Astrosclera*, with additional evidence on the old question: is there more than one species in *Astrosclera*?

PLANULATION PERIOD OF *STYLOPHORA PISTILLATA* AND *SERIATOPORA HYSTRIX*.

Yamazato, K.*, M. Sai, H. Tioho and S. Sultana. *Meio University, Nago, Okinawa, Japan 905. Email: ris-yama@ii-okinawa.ne.jp

Planulation of *Stylophora pistillata* and *Seriatopora hystrix* are known to take place monthly throughout a year in tropical areas, but they were found to planulate only during three months, namely May, June and July or June, July and August in Okinawa. The purpose of this study is to make clear the reason for this. It was assumed that they do not planulate in August and September because of high water temperature, and because of low sea water temperature during the rest of a year, with the critical temperature being about 26C. In order to test this assumption, four to five colonies of *S. pistillata* were kept at a constant temperature of 26C during April, 1995 to June, 1996. The planulation was observed in some months when control corals kept in natural condition did not. The result showed the assumption was correct, but was not conclusive. Further studies for both species are in progress.

PATTERNS OF CORAL RECRUITMENT IN THE GULF OF THAILAND.

Thamasak Yeemin* *Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand. Email: thamasakyeemin@hotmail.com

Composition and rate of coral recruitment and their spatial and temporal variations in the Gulf of Thailand were examined by using appropriate experiments. Species richness and density of juvenile colony of corals observed in natural habitats were comparatively low. Several coral species were very abundant in terms of number of large colony and percentage of live coral cover but only a few juvenile colonies of them were found. The most important factors controlling distribution pattern and mortality rate of juvenile colonies were position of available substrate, sediment, grazing activity of a sea urchin, *Diadema setosum*, and territory of damselfish. The data of coral recruitment on settlement plate experiments revealed that rates of coral recruitment in the Inner Gulf of Thailand were very low, compared to other reports from different geographic regions. Most coral recruits on the settlement plates were spats of *Pocillopora damicornis*. Recruits of other dominant coral species were rarely observed on the settlement plates. The important limiting factor of coral recruitment was shortage of larval supply. Clearly, grazing activities of *D. setosum* and territory of damselfish played significant roles on coral recruitment in a small scale. The coral bleaching event in 1998 affected coral recruitment rates as well as mortality rates of juvenile colonies.

SEXUAL REPRODUCTION OF TWO DIFFERENT POPULATION STRUCTURES OF *ACROPORA HYACINTHUS* IN THE GULF OF THAILAND.

Yeemin T.*, J. Buaruang, P. Nopchinwong, S. Asa and N. Ruengsawang *Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand. Email: thamasakyeemin@hotmail.com

Sexual reproduction, especially patterns of gametogenesis and fecundity of a scleractinian coral, *Acropora hyacinthus*, from Khang Khao Island and Nok Island, in the inner Gulf of Thailand were examined during March 1997-January 1999. Marked colonies of the coral were collected monthly for histological studies. Colony sizes of *A. hyacinthus* from Nok Island were much larger. *A. hyacinthus* was a simultaneous hermaphrodite and had a single annual gametogenic cycle. The gamete releasing was asynchronous and lasted for several months. The commencement of gametogenesis and gamete releasing times of *A. hyacinthus* from the two study sites were different. The fecundity was much variation between colonies and study sites. *A. hyacinthus* from Khang Khao Island had higher fecundity. This exhibited the difference in energy allocation for colony growth and gamete production. The fecundity of *A. hyacinthus* from Nok Island was much lower than that of other *Acropora* species. The result supported the data on recruitment of *Acropora* in the Gulf of Thailand which were comparatively low. The coral bleaching phenomenon in the Gulf of Thailand during April-May 1998 had profound effects on gonad development and population structure of *A. hyacinthus* from the two study areas.

B: RESOURCE MANAGEMENT

STATUS AND PROSPECTIVE OF CORAL REEF MANAGEMENT IN CUBA.

Alcolado, Pedro M.*. *Instituto de Oceanología, Ave 1ª No. 18406, Reparto Flores, Playa, Ciudad de La Habana, Cuba. Email: alcolado@unepnet.inf .cu and alcolado@oceano.inf.cu

Main human induced impacts on Cuban coral reefs are land based organic pollution and sedimentation, as well as reduction of stocks (due to both commercial and illegal fishing and probably regional scale mismanagement) of some predators and herbivore fishes, which enhance algal proliferation and coral damage and disease. These factors act in synergy with the *Diadema* sea urchin pandemic dye-off, coral bleaching due to increased temperatures during ENSO, and several pathogenic coral diseases. The term "coral reef" begins to appear explicitly in a currently improving Cuban environmental legislation since 1997. A recently approved Decree-law on Protected Areas, among others, opens the way to the urgent protection of several coral reefs in Cuba. Agreement between fishery and tourism stakeholders is converting diving sites in "no take areas" but illegal fishing still poorly controlled in some of them. A great effort is being devoted to organic pollution control after increasing awareness about its importance for coral reef health and for tourism development. Enhancing public awareness (mainly directed to decision-makers) and extending undergoing coral reef rapid assessment have to be next prioritised actions. Lacks of funding and yet insufficient public and decision-makers awareness are among the main constraints for achieving reef protection and sustainable use in Cuba.

CORAL REEF MANAGEMENT IN THAILAND

Chansang H.*. Phuket Marine Biological Center. P.O. Box 60, Phuket 83000, Thailand. E-mail: pmbcnet@phuket.ksc.co.th

Two main government agencies are responsible for management i.e. Department of Fisheries which is responsible for aquatic resources management and Department of Forestry which is responsible for marine park management. The Department of Fisheries has set up a coral reef management program since 1995. The project include research, management, training of government officials and public education. Reefs are distributed in 13 coastal provinces both in the Gulf of Thailand and the Andaman Sea. The management of reefs are under responsibility of Provincial Fisheries Offices and Division of Fisheries Resource Conservation. Training program on reef management has been conducted for the officials. Public education has been conducted both in general level and with certain target groups. The program has achieved only limited success. Research has provided valuable information. The management is still effective only in certain provinces. Twelve marine parks have coral reefs as their valuable resources. Management is carried out entirely by park officers. Reef management is still limited to only certain activities. Public education centers are established. Reef management in Thailand is mainly on hand of government officials. Thus new strategies will evolve including local district government and/or concern parties to have more direct share in manage their own reef resources. However, lack of public awareness and involvement in resources management is a major obstacle.

SHOULD CORAL REEF MPAS INCLUDE LARGE PELAGIC MIGRATORY FISHES? THE CASE OF WHALE SHARKS AND THE BELIZE BARRIER REEF.

Graham, Rachel T. *, Callum M. Roberts and William D. Heyman. University of York (UK) & Darwin Initiative, Box 170, Punta Gorda, Belize. Email: rtg@btl.net

Large pelagic migratory fish are rarely if ever considered in coral reef MPA design. This is primarily due to the species' peripatetic natures and lack of information on their foraging, migratory and reproductive behaviours in coral reef areas. Yet reefs are well known to attract pelagic fish and several large pelagic species show predictable reef visitations. Working with local fishermen can help to identify and characterise the movements of pelagics in reef areas. Yet, this information is poorly documented. Recent research on the foraging and migratory behaviour of whale sharks at Gladden Spit, a promontory on the Belize Barrier Reef, prompted by one such collaboration, reveals strong links between this species and coral reef fish. Every April and May full moons, since local fishermen can remember, whale sharks aggregate at Gladden Spit to feed on the spawn of Lutjanids and several other reef species. As a result, this is the first site in Belize proposed as an MPA based, in part, on the temporary but predictable visitations of a large pelagic migratory species. MPA designation and management meets the objectives of protecting both coral reefs and large pelagics. Well-managed tourism associated with the whale sharks will help to offset the operational costs of this coral reef reserve.

THE FORMATION OF MARINE PRESERVES ON THE PACIFIC ISLAND OF GUAM.

Gutierrez, Jay T. * and Trina J. Leberer. Division of Aquatic and Wildlife Resources, 192 Dairy Road, Mangilao, Guam 96923, U.S.A. Email: jgut@ite.net

Based upon the need to restore fish stocks in the coastal areas of Guam, five marine preserves, representing 11 % of the coastline, were created in May, 1997 (Public Law 24-21). To monitor their effectiveness, baseline surveys of the reef flat and fore reef slope were conducted at two of the five marine preserve sites and appropriate control sites. Eight strip transects, each 50 m x 5 m, were surveyed for each habitat type (reef flat or fore reef slope) at each site. Permanently marked transects were located at different depths and microhabitats. Fish counts and video transects were performed to determine fish densities and substrate composition. Preliminary data indicate low fish densities and coral cover for both experimental and control sites. Transects will continue to be surveyed for two years, in order to assess the effect of marine preserves on the restoration of fish populations.

CAN NEW LARGE-SCALE ECOLOGICAL STUDIES ENHANCE THE DESIGN OF A NONFUNCTIONAL MARINE PROTECTED AREA? A CASE STUDY FROM BOCAS DEL TORO, CARIBBEAN PANAMA.

Guzmán, Héctor M*. *Smithsonian Tropical Research Institute, PO Box 2072, Balboa, Republic of Panama. Email: guzmanh@naos.si.edu

The structure, distribution and conservation status of 71 coral reefs along 564 km of coastline were described between 1997 and 1999 in the Province of Bocas del Toro, Panama. The region encompasses an archipelago of nine large forested islands, 251 mangrove cays, and a 11,730 ha marine protected area. Coral cover averaged 26% (range 2.7-74.7%) for the entire region. Species diversity of three major taxa was 61 scleractinian corals (91% of national diversity), 58 sponges, and 32 octocorals. The Parque Nacional Marino Isla Bastimentos includes extensive mangrove forests, seagrass beds and coral reefs, and was created in 1988 with the goals of protecting marine ecosystems, and endemic and endangered species. Twelve years later, no management plan has been designed or implemented for the area. Moreover, the conservation status of reefs and diversity are considerably higher outside the protected area. Of the local entire diversity, 96%, 94% and 97% of the total number of species of corals, octocorals and sponges, respectively, are recorded inside a "hot spot" located further east. Based on the results, we have recommended the modification of the existing limits of the park to include reef areas with highest diversity and abundance of threatening species (e.g., *Acropora palmata*, *A. cervicornis*), and/or the creation of a network of marine protected areas within the archipelago. Lack of political will and potential social problems have precluded the modification of park boundaries.

USING ENVIRONMENTAL EMBEDMENT ANCHOR BUOY SYSTEMS FOR GLOBAL REEF ECOSYSTEM PROTECTION.

Halas J.C.* and Judith F. Halas. Florida Keys National Marine Sanctuary, P. O. Box 1083, Key Largo, FL 33037, USA Email: John.Halas@noaa.gov

Using environmentally sensitive embedment anchor buoy systems began almost twenty years ago. Now widely accepted for reducing anthropo-genic pressures to marine ecosystems, buoys have become a widespread management tool in marine protected areas for diminishing impacts to sensitive sea bottoms. More than 60 projects in over 35 countries have resulted in over 3,000 environmental mooring installations throughout tropical waters of the world. Many benefits and challenges result from using these systems which are positive when managers provide adequate funding for materials, education, and maintenance. In newly formed MPAs, a mooring buoy system often becomes one of the first planned visible reef protecting tools to be implemented. Many existing MPAs already have ongoing mooring system programs or plan to establish them. At some highly visited reef destinations without MPA status, local dive shop or environmental groups have initiated efforts to establish mooring buoy programs which may be integrated into future managed areas. With multiple use zoning practices becoming more commonplace, embedment anchor technology is now being used to permanently establish zone and boundary buoy markers with GPS accuracy for enforcement of regulations.

PROTECTING THE ENVIRONMENT.

Herlinger, Cathy. U.S. Army Program Manager for Chemical Demilitarization (PMCD) Public Outreach and Information Office (POIO). SFAE-CD-P, Building E4585, Aberdeen Proving Ground, MD 21010-4005. Email: catherine.herlinger@pmcd.apgea.army.mil

The U.S. Army partners with the U.S. Fish and Wildlife Service and Sponsors the Ornithological Council and the Boston University Marine Program to study Johnston Atoll's seabird and shorebird populations, and to conduct long-term environmental studies on the atoll's aquatic life, such as fish, coral reefs, and endangered species.

WHY LIST CORAL REEFS UNDER THE RAMSAR CONVENTION?

Jenkins, Aaron * Wetlands International –Oceania. GPO Box 787, Canberra A.C.T. Australia. Email: aaron.jenkins@ea.gov.au

For the past 30 years, the Ramsar Convention on Wetlands has been the principal instrument for international cooperation on conservation and wise use of wetlands. Adopted in Ramsar, Iran in 1971 by 18 countries, it was the first of the modern global conservation treaties and is still the only one dedicated to a particular ecosystem type. The current 122 country members have achieved international recognition for 1031 wetland sites totalling more than 78.2 million hectares. The Ramsar Convention's definition of "wetlands" is intentionally broad and includes coral reefs and associated ecosystems. Despite the tremendous growth of the Convention coral reefs and associated ecosystems are very poorly represented. Many of the more important reef systems are in countries that are not party to the Convention especially in Oceania and the Caribbean. The Ramsar approach emphasises, not the strict preservation of wetland resources, but rather the "wise use" for the benefit of humans without compromising their potential value for future generations. As existing country members can attest, there are many advantages to listing coral reefs and associated ecosystems under the Convention. A few of the most important are:

- Greater access to site management expertise and training opportunities
- Greater access to development aid, small-scale project funding and assistance in the preparation of larger-scale project proposals
- Synergy with other Conventions
- Regional solidarity and cooperation
- A voice on the international stage
- To safeguard specific wetland resource.

The popularly accepted definition of wetlands should not be an obstacle to nominating coral reef sites to the Convention. The inclusion of coral reef sites in the "Ramsar List" of wetlands of international importance encourages more coordinated and holistic management of freshwater, estuarine and near-shore marine ecosystems as an interconnected water resource.

CONSERVATION STATUS ASSESSMENT OF THE BACKREEF AT PUNTA NIZUC, CANCUN, MEXICO.

Lara M*, Padilla C, Loreto R.M. And Gutiérrez, D. *Semarnap, Km 4.8 Z.H. Cancún 77500, Q. Roo, México. Email: pncontoy@prodigy.net.mx

Punta Nizuc coral reef is part of Cancun Marine National Park. It represents an important economic and biological resource because is located in the main tourist destination of México and it's one of the best well-developed reef crest in the Mexican Caribbean. Many tourist activities are made in this reef. It has been considered that in one portion of this reef, called first barrier, the use intensity is the highest in the world. This small reef, with an approximate area of 4 hectares, has over 1,700 tourist per day. This study has an assessment of conservation status considered the framework development and community structure. Some properties of communities and populations like diversity, biomass, healthy conditions, size structure, trophic and taxonomic guilds are analysed. In addition, the effect of reef distance to the tourist activities, backreef framework and intensity use is correlated to this evaluation. Judgement elements and criterions for the management of these reefs are provided. The major cause of degradation in Nizuc reef is tourist activities intensity. These take the form of physical damage, over sedimentation, wave runner or other boats collisions and pollution. The assessment of the present status showed that algae cover are negative correlated with scleractinian richness and cover, otherwise is positive correlated to the number of both unhealthy hard and soft coral colonies.

CONSERVATION STATUS OF THE PSEUDOATOLL BANCO CHINCHORRO, MEXICO.

Loreto R. M*, Lara M, Padilla C, Bezaury J, Loreto A. AMIGOS DE SIAN KA'AN A.C. A.P. 770, Cancún 77506, Q.Roo, México. Email: sian@cancun.com.mx

...Banco chinchorro is located 40 km offshore of quintana roo coast, in mexican caribbean. This reef has a 145 km perimeter, making it the longest reef in the meso-american reef system. In 1996 it was declared a biosphere reserve (bcbr). Since there was no management plan in place, illegal fishing increased human settlements and tourism development became threats to the area. To provide input to the management plan, from 1997 to 1999, a detailed assessment of the present status was made based on reef framework and community structure analysis, within 1 to 40 m depth range. Some properties of communities and populations of scleractinians, macroalgae, gorgonians and sponge, as well as fish trophic guilds and reef framework traits were analysed. Four structural zones were described and 17 areas were defined within the lagoon and slopes. This resulted in identification of 107 algae species, 3 seagrasses, 51 scleractinians, 2 hydrocorals, 45 gorgonians, 74 sponges and 136 fish species. Four areas are well conserved with exceptional characteristics, however, in some areas of the lagoon, overfishing is evidenced by the reef condition and fishes structure assemblages. Two areas are at south and north of fore reef and showed highest reef framework development. The third area is at leeward slope, with high scleractinians cover and reproductive queen conch and black coral populations. The fourth area, located at the lagoon, shows a well development coral ridge parallel to reef ring with highest coral cover and spiny lobster populations. These characteristics are critical to the management plan, which is being approved by the authorities and users of the bcbr, as an effort to reduce anthropogenic and natural impacts to these valuable resources.

MARINE CONSERVATION PRIORITIES AND NEEDS IN PAPUA NEW GUINEA AND THE SOLOMON ISLANDS – A WAY FORWARD.

Mangubhai, Sangeeta.* *World Wide Fund For Nature – South Pacific Program, Private Mail Bag, Gpo, Suva, Fiji Islands. email smangubhai@wwfpacific.org.fj

The coral reefs of Papua New Guinea and the Solomon Islands harbour a wide concentration of marine species, forming part of the richest centres for coastal marine biodiversity on earth, and provide subsistence, livelihood and income for coastal communities. In contrast to other neighbouring countries, both solomon islands and Papua New Guinea are fortunate to have marine ecosystems in relatively pristine condition, though the movement to a cash economy and limited human resource and institutional capacity to manage resources in a sustainable way, is undermining the long-term protection and sustainable use of coastal and marine resources. This paper will provide an overview of the outcomes of a planning exercise undertaken by world wide fund for nature to identify conservation priorities and needs for coastal and marine resources in solomon islands and Papua New Guinea, and the feasible strategies for addressing those needs. The gaps in knowledge that were identified, the anthropogenic factors that influence the conservation of coastal resources and the conservation work being undertaken by different organisations will be summarised, as well as the role world wide fund for nature will play in addressing conservation priorities and needs in the two countries.

OVERLAP OF TOURISM AND FISHERIES SITES IN A FRINGING REEF IN KENYA; OPPORTUNITIES FOR MULTIPLE USE ZONATION.

Obura, D.O*. and Mwaura, J.M. *Coral Reef Degradation in the Indian Ocean, P.O.Box 10135 Mombasa; Email: dobura@africaonline.co.ke

Mapping the use and activity patterns of coral reef resource users can contribute to management of multiple users. This poster site use by local fishermen and tourism operators, in the diani-chale reef system 20 km south of mombasa on the kenya coast. The study area is characterized by an active tourism industry and small scale indigenous fishing communities, in growing conflict over use of reef sites. The two primary issues are a) conflict over extraction versus conservation, and b) beach and reef access determined by land ownership. While the area is a gazetted marine reserve, there has been no active management due to opposition engendered by fishers' fear of losing their fishing rights in a protected area system oriented towards tourism and protection over traditional resource use. Mapping was conducted using handheld g.p.s., Digitized base maps, aerial digital video imagery and field surveys. Local site names and information were gathered through informal interviews and participant observation, accompanying boat operators and local fishers during their daily activities on the reef. Types of tourism and fishing use, approximate value and access to these sites is indicated in the maps, and offer a number of options for discussing multiple use and access among reef users. The analysis also focuses attention on the small proportion of sites of greatest importance to each user group. With growing pressure on marine resource from both of these principal activities, it is hoped that these types of analyses will assist in conflict resolution. The paper discusses the need for establishment of multiple use zones/area that will control the pressure on these important resource base.

CORAL REEF MANAGEMENT IN MOZAMBIQUE.

Pereira, M. A. M.*, Gonçalves, M., Motta, M., Rodrigues, M. J. *Ministry for the Coordination of Environmental Affairs, P.O. Box 678. Maputo, Moçambique. Email: coastal@tropical.co.mz

Mozambique is situated in the eastern African region and possesses the third longest coastline, extending for 2,700 Km. Part of which adjoins extensive areas of coral reefs. This ecosystem constitutes an important biological resource in terms of its complex biodiversity and is the basis for the artisanal fisheries and marine ecotourism in Mozambique. In 1998 Mozambique, in conjunction with a number of institutions and donors, initiated its Coral Reef Management Program (MCRMP). The core aim was to ensure the long-term sustainable utilization of the coral reef resources in Mozambique. Within the programmed activities the most important included capacity building, research and the monitoring of coral reef communities. As a result, several Mozambique young scientists are being trained in coral reef ecology and management. Baseline ecological descriptive and applied studies were and are currently being undertaken especially regarding natural and human-induced damage to coral reefs (e.g. bleaching, ornamental fish trade and the effects of the recent floods on the reef communities). In 1999, the first monitoring program initiated and already showed that the few protected reefs are in much better condition than those unprotected. Mozambique has also joined the Global Reef Check program. Thus, the MCRMP is giving added impetus to the national effort on research and management of natural resources although there is much to be accomplished yet.

CORAL REEF MARINE PROTECTED AREAS IN INTERNATIONAL CONVENTIONS (WORLD HERITAGE - MAB BIOSPHERE RESERVES - RAMSAR) : A POORLY REPRESENTED ECOSYSTEM.

Salvat, B.*, Haapkyla, J. *EPHE, ESA CNRS 8046, Université de Perpignan, France, and International Coral Reef Initiative Secretariat. Email : bsalvat@univ-perp.fr

Globally, there are over 1300 Marine Protected Areas, of which about 400 have coral reefs as primary or as secondary components in 65 countries. One third of the sites either have a management plan applied in practice or are paper parks. Three international conventions contain coral reef sites. UNESCO's Man and the Biosphere Programme (MAB) was launched in 1970 and aims to achieve a balance between nature conservation, maintenance of cultural values and economic development. It has 368 reserves in 91 countries, and only 14 of them include coral reefs. UNESCO's World Heritage Convention, launched in 1972, aims to protect sites of cultural, natural and mixed heritage worldwide. Cultural sites dominate the 630 sites situated in 118 countries with 15 containing coral reefs. The Ramsar Convention (Convention on Wetlands of International Importance) came into force in 1975. It concerns primarily wetlands, but became more aware of coral reefs in 1996. There are 119 countries who have signed the convention and a total of 1018 sites of which 22 include coral reefs. A total of 51 coral reef sites are protected in these three conventions, and most of these sites do not have coral reefs as a primary component. This is a poor score compared to other ecosystem types. More coral reef reserves should be created in order to enhance the protection of the coastal environment in the hundred developing countries having coral reefs.

ARE SMALL MARINE RESERVES EFFECTIVE ? A CASE STUDY IN THE SOUTHWEST LAGOON OF NEW CALEDONIA

Sarramegna* S & Chauvet C. LERVEM, University of New Caledonia, B.P. 4477, 98847 Nouméa New Caledonia, Email: sarrameg@univ-nc.nc

The effects of marine protected areas on commercial reef fish community were studied in the southwestern lagoon of New Caledonia, on two small coralline islets protected from fishing since 1981, and two unprotected reefs. Length, density and biomass of fish were estimated using underwater visual censuses. MPA allows the return of species particularly sensitive to fishing and the increase of overall biomass (360.3 $g.m^{-2}$ vs. 155.2 $g.m^{-2}$), particularly for Serranids (18.2 $g.m^{-2}$ vs. 2.8 $g.m^{-2}$; 0.02 fish. m^{-2} vs. 0.004 $fish.m^{-2}$), Scarids (90.5 $g.m^{-2}$ vs. 39.6 $g.m^{-2}$; 0,24 $fish.m^{-2}$ vs. 0.16 $fish.m^{-2}$) and Acanthurids (40.9 $g.m^{-2}$ vs. 12.4 $g.m^{-2}$; 0.08 $fish.m^{-2}$ vs. 0.04 $fish.m^{-2}$). On the other hand, there are no significant variation in overall density with the status of protection, while certain species such as Lethrinids are more abundant in fished reefs. Biotope caracteristics (% of living coral, habitat complexity) and distance to coast were the major factors which explained the distribution and the abundance of the species. Three fish communities were identified. The first occurred on the reef flat, the second on the reef slope and the third on the lagoonal soft bottoms. Other natural temporal variations such as El Niño or recruitment intensity appear to play an important role in the fluctuation of abundance of theses communities. At least, the comparison between protected and unprotected areas shows that the small reserves concentrate larger fish.

MARINE CONSERVATION IN PAPUA NEW GUINEA.

Seeto, Pamela*. Conservation International. P.O Box 106, Waigani, Port Moresby, P.N.G. Email: cimoresby@dg.com.pg

Papua New Guinea comprises the eastern half of the island of New Guinea and over 600 offshore islands. The country and its surrounding waters lie within the “coral triangle”, the global epicenter of marine biodiversity. In contrast to neighboring Indonesia and the Philippines, PNG’s marine ecosystems are in relatively pristine condition and boast some of the best examples of the world’s most biologically rich coral reefs. However, increasing environmental pressures resulting from overfishing, destructive fishing, pollution, logging and mining threaten to extinguish global conservation benefits. Milne Bay Province, located on the eastern tip of the mainland, contains an especially rich endowment of coastal and marine habitats. Two rapid biological assessments (RAP) sponsored by Conservation International have shown that coral reef biodiversity in Milne Bay is exceptional. The surveys documented greater than 362 species of reef corals (a higher diversity than that of the Great Barrier Reef), 1,109 species of reef fishes (surpassing all other areas in the coral triangle), and 860 species of molluscs (which compares favorably to other marine RAPs). During the surveys, one new species of fish (*Chrysiptera cymatilis)*, 5 additional endemics and as many as 14 new reef corals were identified. The present status of coral reefs in Milne Bay was also found to be superior to previously surveyed areas in Indonesia and the Philippines. Conservation International will continue to work closely with the local community and government to promote community-based conservation efforts in Milne Bay Province.

REEF CONSERVATION UK: CARRYING THE PHILOSOPHY OF INTERNATIONAL YEAR OF THE REEF INTO THE FUTURE.

Teleki, K.A.*, A.R. Harborne, H. Hall and E.M. Wood. *Department of Geography, University of Cambridge, Downing Place, Cambridge, CB2 3EN, U.K. Email: kat1003@cus.cam.ac.uk

In 1996, individuals and organisations involved with, and having interests in, coral reefs came together to discuss International Year of the Reef (IYOR). Not only was this a forum to formulate the UK IYOR strategy, but it also opened new lines of communication and collaboration between individuals and groups in the UK who had rarely been in contact yet had similar interests and were involved in similar activities. It seemed both beneficial and appropriate to maintain and expand these established links. The advantages of increased communication between coral reef people in the UK are obvious, maximising efforts for conservation and awareness, while minimising the time and money which is required. For this reason, Reef Conservation UK (RCUK) evolved out of the original IYOR-UK committee. RCUK aims to promote multidisciplinary conservation, public awareness and education about coral reefs, as well as ensuring that all reef related activities are conducted in a responsible manner. RCUK is currently co-ordinated via a central committee and is comprised of over 100 individuals representing a range of interests, organisations and institutions. RCUK receives no core funding but achievements to date include an annual conference to facilitate networking within the UK reef community and a biannual newsletter. These activities, along with limited private donations, provide funds for a small grant scheme. Future aims include a website, an increasing role as a focus for UK media agencies and providing advice and guidance to UK based NGOs and governmental institutions.

C: SOCIO-ECONOMIC ISSUES

MANAGEMENT OF HAWAIIAN PRECIOUS CORALS USING MOLECULAR GENETIC METHODS.

Baco-Taylor Amy R.*, Craig R. Smith, and George K. Roderick. *Department of Oceanography, University of Hawaii, 1000 Pope Road, Honolulu, Hawaii 96822, USA, Email: abaco@soest.hawaii.edu

Hawaiian deep-sea precious corals support an extremely profitable fishery, yet little is known about the life history and dispersal of the exploited species. Recent indicate significant genetic structure between shallow-water coral populations, including several species capable of long distance dispersal. If significant genetic structure exists in populations of precious corals, this could suggest that the elimination (through overharvesting) of a bed of precious corals would result in loss of overall genetic diversity in the species. We are studying three species of Hawaiian deep-sea precious corals to determine the appropriate management units (or "stocks") for each species. Stocks will be identified using a recently developed microsatellite technique. Microsatellites are segments of DNA which consist of repeated units of short (di- or tri-nucleotides) sequences. Microsatellites are highly variable, making them ideal for kinship and population-level studies. By determining the stock structure of the harvested species and providing information on dispersal and recruitment in these species as a function of life history, this project will elucidate the effectiveness of the designated "Refugium" bed in the Northwest Hawaiian Islands for re-seeding exploited populations of precious corals. This information will substantially improve our ability to manage the Hawaiian coral fishery as a sustainable resource.

COLLECTING IMPACT OF MASSIVE *PORITES* CORALS ON THE MAYOTTE REEFS (SW INDIAN OCEAN) FOR CARVING OF CORAL BLOCK-TABLES USED BY MAHORESE WOMEN FOR BEAUTY FACE MAKE-UP: THE "MZINDZANO" TRADITIONAL HABIT

Chanfi Dhahabia*, THOMASSIN Bernard A.* *CNRS-UMR n° 6450 "Dimar", C.O.M., Univ. de la Méditerranée, 13007 Marseille, France & G.I.S. "Lag-May". E-mail: thomassi@com.univ-mrs.fr

The "mzindzano" is a beauty face make up (face painting with various mo-tifs) that dress most of the mahorese maried women at Mayotte I. (90-95% among them, as near 23,000 women in 1997). They use it also at home in France, but less frequently. To draw this daily make up women use a wet coral block-table to make an unctuous paste, rasping a wood piece (more often as santal) or other vegetals, mixed with scented dry flowers, saffron, seeds, or a lichen. The coral block-tables (side sizes: 11 to 27cm) are handycraft making in massive *Porites* (*P. lutea, solida, lobata*) living in pools on the inner reef flats. To estimate the impact upon reefs of this *Porites* collecting an inquiry was made into mahorese women living at Mayotte (Sada village) and also in France (Marseilles town). From this, it was estimated that these women, 20 to 60 years old, used about 1 table per 7 years for make up. To carve the near 2,250 coral tables required per year (just 3 or 4 carved in a 40 cm colony), it is estimated that between 350 up to 1,000 *Porites*, near 16.5 years old, as 20-59 dry tons of corals, are collected on the reefs. So about 14 up to 38 hectares of *Porites* flats would be destroyed each year on fringing reefs, with all the severe environmental consequences for the whole coral reef and lagoonal ecosystems.

BUILDING THE CAPACITY TO MONITOR CORAL REEFS: INTERNATIONAL EXPERIENCES.

Cheal A.* and Miller, Ian. *Australian Institute of Marine Science. PMB 3, Townsville, 4810. Australia. Email: a.cheal@aims.gov.au

Coral reefs are a resource under threat. In general, a lack of baseline information is inhibiting effective management of the world's reefs. Systematic collection of ecological data is needed to apply integrated management approaches and assess the effects of anthropogenic influences, natural disturbances and global climate change. Monitoring studies are not always possible due to a lack of in-country expertise. The Australian Institute of Marine Science (AIMS) long term monitoring program has run a number of international workshops designed to increase the capacity of local people to monitor their coral reefs. The main goal of these "train the trainer" programs is to produce a pool of personnel throughout the Asia-Pacific region who can train fellow nationals to gather data in a consistent and standard manner, and be able to analyse and interpret these data to assist marine resource managers. Field techniques covered in workshops include manta tow and line intercept for broad scale and site specific benthic surveys respectively, and visual census for fish assemblages. Reducing inconsistencies in the identification of marine life-forms between observers is a major aspect within workshops. A new interactive CD-ROM, "C-NAV", developed at AIMS will help to clarify common misidentifications of benthic life-forms. The importance of data extraction, checking and interpretation are emphasised using a patented data base program, ARMDES©. Experiences and outcomes from a number of training workshops are discussed.

DIVING FISHERMEN; THE HEALTH IMPACT OF INDIGENOUS DIVING FISHING PRACTICES.

Cross, Maurice R *, Dawson Richard, Newman Helen.The Diving Fishermen Project, Tamar Science Park, Derriford, Plymouth UK MauriceC@Phase1ctu.com

The Diving Fishermen Project is a UK based Charitable Trust which aims to investigate and document the extent of diving-related injury in indigenous diving communities and to provide help and assistance to the divers themselves to avoid injury. In the five years of our existence, we have worked alone or with others in the Philippines, in Thailand and most recently in Indonesia. We estimate that in the Asia Pacific area there are 50,000 to 80,000 such fishermen mostly in Indonesia and the Philippines. Our studies to date have shown that most villages, irrespective of national origin, have similar problems. The mortality amongst indigenous divers is about 4% per annum. Approximately one in five of the divers will have clinically detectable signs of spinal cord injury and half of these (1 in 10) will have obvious difficulty in walking. In our studies, 18% of men have experienced some degree of paralysis at some time and shoulder pain is almost ubiquitous being present in more than 80% of individuals at any one time. We carried out X-ray studies of the divers in the villages of Nocnochan and Madridejos in the Philippines and diagnosed aseptic necrosis of bone in 38% of the men. Hookah diving is a dangerous and injurious way of earning a living. Most divers regret their lifestyle and few want their children to follow them. This provides a useful pointer to the incentives that need to be given to abolish this destructive practice. In our presentation we describe the project, it's findings and achievements to date.

UNDERSEA EXPLORER TOURISM FUNDED RESEARCH & EDUCATION ORGANISATION

Dunstan, Andrew*; and Rumney, John *Undersea Explorer, Port Douglas, Qld, 4871, Australia. Email: adunstan@ozemail.com

Undersea Explorer pioneers an innovative concept, which uses adventure diving tourism to conduct and fund reef research and ecological education. Our constant ready access to reef study sites and provision of field equipment and berths for scientists is our commitment to extend opportunities to the scientific fraternity. Undersea Explorer research projects investigate a diverse range of coral reef subjects including dwarf minke whales, reef sharks, cephalopods, state of the reef monitoring programs, water quality, bioerosion and coral bleaching. Some projects are run completely by Undersea Explorer scientists, while others are collaborative or fully external projects with support from Undersea Explorer. An example is the collaborative dwarf minke whale project, with a team of scientists from Museum of Tropical Queensland, James Cook University, University of California, Santa Cruz and Undersea Explorer. This has resulted in identifying many aspects of the dwarf minke whales' biology, acoustics, population dynamics and human interactions. Working with the community, industry, management agencies and scientists produces practical conservation guidelines as a direct result of this research.

Undersea Explorer - a call for cooperation

THE ROLE OF COMMUNITY INITIATIVE AND TRADITIONAL LEADERSHIP IN THE ESTABLISHMENT OF MARINE PROTECTED AREAS (*Ra'ui*), ON RAROTONGA, COOK ISLANDS.

Evans, Jacqueline*. *World Wide Fund for Nature – South Pacific Program, P.O. Box 649, Rarotonga, Cook Islands. Email: wwfcooks@oyster.net.ck

In 1998, the traditional chiefs of Rarotonga Lagoon in Cook Islands agreed to re-establish the *ra'ui* - a customary prohibition on the harvesting of certain marine species or access to a particular area, that was once practised widely in Polynesia. The decision to revive *ra'ui* was triggered by community concern about the significant decline of reef fish stocks and the lack of a fisheries management regime on Rarotonga Lagoon. *Ra'ui* had not been practised on the Rarotonga reef for four decades. Support from chiefs, government departments, non-government organisations, schools and churches contributed to a strong community awareness of the *ra'ui* and compliance with it. In February 2000, the second anniversary of the *ra'ui*, communities showed their support for the practice by establishing a permanent marine sanctuary in one area of the lagoon and imposing five-year fishing bans in two other areas. Possible reasons for the widespread support for *ra'ui* and compliance with it, include recognition by the community of the need for reef management, widespread awareness of the *ra'ui* and the fact that the decision to have a *ra'ui* was reached by the community, with leadership by the traditional authorities.

FROM THE FIELD TO THE CLASSROOM: COMMUNICATING YOUR RESEARCH TO STUDENTS NATIONWIDE.

Foote Liz*. Project S.E.A.-LINK, 3740 Lower Honoapiilani Hwy. #G206, Lahaina, HI 96761. E-mail address: lfoote@maui.net.

Most scientists recognize the importance of ef fective communication. However, this communication usually focuses on and remains within the scientific community. Scientists conducting marine research now have a wonderful opportunity to share their work with K-12 students nationwide. Project S.E.A.-LINK, a nonprofit organization, has designed an educational website that profiles professionals in the fields of marine research, education, and conservation. From these profiles, students learn about careers related to the marine environment, and can write in questions to be answered on the site. Based on these profiles, Project S.E.A.-LINK develops curricular materials which teachers are able to download for use in their classrooms. Other unique features of the site are the "Online Mentoring Program," where students with particular interests are matched with an appropriate professional "pen-pal," and the "Classroom Connection," where professionals can interact with teachers and students from science classrooms nationwide. Through this effort, students learn of exciting career opportunities in marine science, while being exposed to the human side of science and the nature of science itself, and teachers are able to incorporate hands-on activities based on current marine science investigations into their curriculum. Project S.E.A.-LINK is committed to the reform in science education and its emphasis on inquiry-based learning, and all materials are developed according to national science education standards.

THE ROATAN INSTITUTE FOR MARINE SCIENCES: A CARIBBEAN LABORATORY FACILITATING RESEARCH AND EDUCATION.

Keck, J. R. *. *Roatan Institute for Marine Sciences, Sandy Bay, Roatan, Bay Islands, Honduras, Email: rimsed@globalnet.hn.

The Roatan Institute for Marine Sciences (RIMS) is located on the northwest coast of Roatan where fringing reefs, lagoons, mangroves and shoreline are home to an astounding diversity of life. The primary objective of this facility is the conservation of Roatan's marine resources through research and education. RIMS has implemented a long-term ecological monitoring program designed to monitor coral populations and their changes over time. Species diversity, relative abundance, variability in coral cover and growth, incidences of disease and bleaching and the general health of the reef are being assessed. Reef fish and benthic invertebrate populations as well as certain abiotic parameters are also being monitored. We have obtained a substantial database on the status of our reefs in the five years that the project has been in motion. This information is the first step toward understanding more about the natural processes and human impacts on our reefs, which in turn will help us to better manage and protect these vital areas. In the past decade RIMS has also become an established educational facility hosting college and university groups studying tropical marine and terrestrial ecosystems. Programs run from one to three weeks and can include lectures and guided field experiences by staff biologists. While students are invited to participate in our monitoring program, RIMS can also accommodate faculty and students pursuing independent research projects. This presentation describes the educational program at RIMS and provides information on our monitoring project design and sampling techniques.

GLOVER'S REEF MARINE RESEARCH STATION: A FOOTHOLD FOR CONSERVATION IN THE CARIBBEAN SEA.

Lauck, Elizabeth W.* *Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, New York 10460 USA. Email: llauck@wcs.org

The Belize Barrier Reef is an outstanding example of a barrier reef system, including three offshore atolls, hundreds of sand cays and patch reefs, mangrove forests, coastal lagoons, and estuaries. It is the largest barrier reef in the northern hemisphere and provides habitat to 500 species of fish, 134 bird species, three species of sea turtles, and a large population of West Indian manatee (*Trichechus manatus*). Despite its conservation and scientific importance, the reef has come under increasing anthropormorphic pressure, including fisheries depletions, coral bleaching, outbreaks of fleshy algae, and increases in reef-dependent tourist activities. This paper describes a long-term, science-based approach to coral reef conservation at the Belize Barrier Reef's southernmost atoll, Glover's Reef Atoll. This atoll was declared a Marine Reserve by the Government of Belize in 1993. The Wildlife Conservation Society established the Glover's Reef Marine Research Station on one of the atoll's cays in 1993. The Station's primary goal is to promote the long-term conservation and management of the Belize Barrier Reef through *in-situ* research, cooperative management, training and education. Several ongoing initiatives and lessons learned from them will be described, including an assessment of the effectiveness of the three-zone system on commercially and ecologically important species, a survey of the atoll's elasmobranch fauna, and long-term monitoring of human and natural disturbances to the coral reef.

THE LOCAL GEOGRAPHY OF AN ARTISANAL FISHERY IN KENYA

Obura, David O. * and Innocent N. Wanyonyi. *Coral Reef Degradation In The Indian Ocean (CORDIO), Box 10135, Mombasa, Kenya; Email: dobura@africaonline.co.ke

Fishers have accumulated generations of knowledge that has enabled them to exploit reef resources. Parts of their knowledge base refers to the geography of the reefs they use and catch characteristics associated with different sites. This study examines the geographic patterns of site use by fishermen, in terms of catch characteristics and their impressions of the sites, in the Diani-Chale reef system 20 km south of Mombasa on the Kenya coast. The study uses catch data collected over a period of two years through participatory monitoring with the fishers, and indigenous knowledge recorded through informal conversations. Fishermen do have strong preferrential use of sites, according to the fishing gear used, season and individual preferences. Some of the preferred sites do not result in the highest per capita catches, due perhaps to short- and/or long-term overuse. Understanding site use patterns of fishers will be an important contribution to management, as all user activities are highly location-specific, be they fishery or tourism related. The area has a history of resource use conflict between fishing and tourism interests, exacerbated in 1994 by its gazettement as a Marine Protected Area. The knowledge possessed by the fishermen is different from that used by policy makers, resource managers, and researchers, thus true dialogue is not possible until the different parties understand one another. It is hoped that this mapping and monitoring exercise will contribute to greater understanding between resource users and management.

RESOURCE MANAGEMENT AND SOCIO-ECONOMIC VALUE IN GULF OF MANNAR CORAL REEF ECOSYSTEM, SOUTHEAST COAST OF INDIA.

Patterson Edward, J.K.*, *Suganthi Devadason Marine Research Institute, 44-Beach Road, Tuticorin – 628 001, Tamil Nadu, India. Email: jkpatty@hotmail.com

Gulf of Mannar (GOM) of southeast coast of India is predominantly coral reef ecosystem with rich diversity of flora and fauna. There are 21 islands in GOM. About 40,000 people live along this ecosystem and most of them are dependent on its resources for their livelihood. GOM received Biosphere Reserve status in 1989. This precious ecosystem is under severe threat due to various factors, mainly coral mining, industrial pollution, destructive and indiscriminate fishing, tourism, population growth and poverty, illiteracy, lack of awareness, inadequate legislation and lack of coordination. In fact, the socio-economic condition of the villagers does not allow them to think about their environment as more than 50% people live below poverty line. India's diverse culture, conventional food habits and social structures have also much impact and therefore careful planning and alternate income generation are key to the success in any management practices. There is always scope for sustained income through the exploitation of natural resources in any ecosystem to fulfil the dependents. A long term community based coastal resources management programme in Gulf of Mannar with the objectives "Development, management and sustainable utilization of coastal resources with community participation" would solve the problem substantially. It also gives an opportunity to the community to manage their environment and to enhance their socio-economic conditions.

ASSESSMENT, MONITORING AND REHABILITATION

MULTIVARIATE CLASSIFICATION OF THE BERMUDA PLATFORM USING SATELLITE DATA.

Apprill A.*, Nelson, Norman B.. *Bermuda Biological Station for Research, St. George's GE 01, Bermuda. *Present Address: University of San Diego, 5998 Alcala Park, San Diego, CA 92110 USA. Email: aapprill@acusd.edu,

Monitoring large habitat areas effectively using remote sensing presents a trade off between spatial and temporal resolution and cost. While high spatial resolution data is ideal for detailed studies, obtaining it at the frequency necessary for monitoring is expensive. In this study, we developed a low-cost method to map a shallow coastal area (the Bermuda platform, centered near 32.4° N, 64.8° W) using freely available data from moderate and low resolution multispectral satellite sensors, MOS-B (520 m) and SeaWiFS (1.1 km). We developed a multiple classification model based on component reflectance spectra and clear water optical properties which quantifies the relative coverage of soft and hard bottom and estimates the mean depth of each pixel. This model differs from most classification algorithms because it allows multiple classes to be assigned to an individual pixel. We conducted a site survey and used aerial photographs to test the accuracy of the model. The model differentiated between the actual locations of dense reef, sparse reef, and sand or mud habitats, but overestimated reef coverage by about 16% for SeaWiFS and 20% for MOS-B. The model slightly underestimated depth. A refined algorithm that uses hyperspectral data or an idealized reference spectra might further increase the effectiveness of the present model for temporal monitoring studies.

LANDSCAPE ANALYSIS OF MARINE FLOOR BIOLOGICAL DIVERSITY IN REEF ZONES SUBJECT TO HUMAN EXPLOITATION.

Axis, Javier*, Torruco, Daniel and Gonzalez, Alicia. *CINVESTAV-IPN Laboratory of Coral Reef, Center for Research and Advances Studies, A.P. 73 Cordemex, 97310 Merida, Yucatan, Mexico. Email: axisarroyo@hotmail.com

The effects were determined of development and large draft vessel use on reefs near the port of Calica, in the state of Quintana Roo, Mexico. An analysis of the temporal variation in biological diversity was done from May, 1996 to December, 1998. A total of four samples were taken, one every six months, with a total of 216 photographs taken of the sea floor for each sample. The biological diversity was determined to species level using geostatistical techniques which produced spatial distribution maps constituting a geographical information system for demonstrating variation in time. Biological diversity change rates in the area were: 76.21% from the first to the second sampling, with a tendency towards increase in most levels; 61.23% from the second to the third sampling, with a tendency towards increase in most levels; and 43.92% from the third to the fourth sampling, with a tendency towards decrease in most levels. The temporal variation in biological diversity indicates that, even four years after the expansion and use of Port Calica, the ecosystem feels the effect, and highly variable, with tendencies towards recuperation of its biological complexity, despite use.

HABITAT MAPPING OF THE ANDROS BARRIER REEF SYSTEM USING REMOTE SENSING AND TAXONOMIC SURVEYS.

Brumbaugh, Daniel R.*, Mikkelsen, Paula M. , Peter J. *Ctr. Biodiv. & Cons., Amer. Mus. Nat. Hist., Central Park West at 79th St., New York, NY 10024, USA. brumba@amnh.org

Spectral remote sensing (RS) and rapid ecological assessments (REAs) have become increasingly important approaches for both broad scale and quick surveys of shallow tropical marine ecosystems. Although RS relies on the spectral reflectance of a given areal unit (followed by some degree of ground-truthing) and REAs generally involve more quantitative field surveys, both approaches draw on the more conspicuous elements of the benthos for their respective assessments. Since much of marine biodiversity is small, infaunal, or otherwise cryptic, however, RS and REA approaches to habitat assessment frequently assume that inferences from the more conspicuous taxa such as corals, macroalgae, and fishes are somehow representative of other more diverse but cryptic assemblages. To test this assumption, we recently started a new habitat mapping and assessment project on Andros Island, Bahamas. Using combinations of multispectral satellite (LANDSAT 7 & IKONOS) and aerial (CASI) data, we are constructing habitat maps according to a consensus habitat scheme. Additionally, we have undertaken habitat-stratified surveys of both conspicuous and various "cryptic" taxa (echinoderms, molluscs, polychaetes, and crustaceans) to determine (1) the degree to which remotely sensed habitats serve as proxies for these components of biodiversity and (2) the degree to which conspicuous taxa serve as indicators for cryptic assemblages.

REEFS AT RISK IN SOUTHEAST ASIA – A SPATIAL ANALYSIS OF THREATS, PROTECTION AND CONNECTIVITY.

Burke Lauretta *, Ken Kassem. World Resources Institute, Washington, DC, USA. E-mail Address: lauretta@wri.org

Due to the lack of quantitative information on the condition of coral reefs within Southeast Asia, a map-based analysis of threats to coral reefs within the region has been performed. The analysis maps and models threats from coastal development, overfishing, destructive fishing, marine pollution, and sedimentation from upland activities. The analysis also incorporates management factors and natural features which influence the coral reef condition in light of human pressure (threats) on the ecosystem. Using a geographic information system and over twenty input data layers, the analysis estimates pressure on coral reefs by individual threat category and as cumulative threat. During the project, collaborators have improved data sets reflecting coral reef locations, marine protected areas, management effectiveness, tourism pressure, and use of destructive fishing techniques have been developed. In map form, the poster presents a visual estimate of threats to coral reefs for a range of threats as well as a cumulative estimate of pressure on coral reefs throughout the region.

COMBINING *IN-SITU* SPECTRAL ANALYSIS, SATELLITE IMAGERY, AND GIS FOR CORAL REEF HABITAT MAPPING.

Call K.* and John T. Hardy. *Center for Environmental Science, Huxley College, Western Washington University, Bellingham, WA 98225-9181 USA Email: jhardy@cc.wwu.edu

Coral reefs are important both biologically and economically but are under increasing pressure from pollution and human-induced disturbance. Coral reefs are often remote, relatively large, and shallow. Thus, optical remote sensing techniques may provide the most efficient and cost-effective approach to mapping and monitoring the condition of reefs. We tested the hypothesis that in-situ measured spectral signatures, together with satellite imagery can be used to accurately map benthic substrate types. *In situ* upwelling irradiances were collected for coarse descriptive habitat types near Lee Stocking Island, Bahamas. Down-looking spectral scans from 300 to 750 nm were taken 1 m above the substrate and 1 m below the water surface, using a LiCor-1800 underwater spectroradiometer. Principal Components Analysis of upwelling irradiances indicated that wavelengths between 515 and 580 nm are most useful in distinguishing between substrates. Landsat TM multispectral imagery was geo-registered and an unsupervised classification was used to delineate reef features and associated communities. Geo-coordinate data collected for each substrate type (July 11- July 19, 1999) was used to aggregate spectral classes in image classification and as a means of assessing the accuracy of the habitat map. Using this method we achieved an overall accuracy of 74% for coarse descriptive resolution mapping of seven substrate types (i.e. ocean, deep sand, shallow sand, deep coral, shallow coral, seagrass, and mixed sand and seagrass) within a 590 km^2 area of the Exuma Cays.

LARGE-SCALE SURVEYS INDICATE POOR RECOVERY BY URCHINS IN THE FLORIDA KEYS.

Chiappone M.*, D.W. Swanson and S.L. Miller. The National Undersea Research Center, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, Florida, 33037, USA. E-mail address: mark@benthos.cox.miami.edu

Understanding the causes of community change continues to remain problematic in many coral reef environments. Florida Keys coral reefs are particularly challenging in this sense, not only because of their high latitude, but also because of the myriad of human disturbances that have affected the ecosystem this century. Although there is consensus that reefs have changed in recent decades, there are continuing debates concerning the mechanisms. Population densities of *Diadema antillarum*, for example, were similar to other Caribbean reefs, and have failed to recover to pre-1983 densities. The consequences of this phenomenon may be related to current algal abundance patterns. As part of a long-term assessment and monitoring program, a large-scale survey of sea urchins was conducted during 1999 that encompassed four hard-bottom habitat types at 80 sites in the fore reef environment of the Florida Keys. A survey of 640 transects (25-m x 0.4-m in area) yielded three species: *D. antillarum*, *Echinometra viridis*, and *Eucidaris tribuloides*. Only 56 urchins were found during the study, representing a mean density of 0.09 urchins/10 m^2, and *E. tribuloides* accounted for 68% of all individuals recorded. While water quality concerns in Florida are a major topic of debate and are often used to explain increased coverage of algae on reefs (bottom-up control), the continued low densities of urchins suggests that top-down controls on benthic community structure also need to be recognized.

LOW-TECH REEF RESTORATION: POSSIBLE TECHNIQUES FOR TRANSPLANTATION OF ACROPORA CERVICORNIS.

Chilcoat G.C.*, W.K. Fitt, and M.E. Warner. *University of Georgia, rm 711 Biosciences, Athens GA, 30602 EMAIL: gcc7314@arches.uga.edu

Two techniques for transplantation of *Acropora cervicornis* were attempted at Lee Stocking Island, Bahamas. Fifty *A. cervicornis* nubbins were secured to dead coral branches by Cable Ties or with a small quantity of epoxy (Z-Spar 788). The corals were transplanted in March, 2000 and evaluated in May, 2000 and again in Sept, 2000. Survival rate, attachment, as well as costs in labor and materials for each technique will be discussed.

IKBS: A TOOL FOR BUILDING COOPERATIVE KNOWLEDGE BASES ON THE INTERNET: APPLICATION TO CORALS AND HYDROIDS OF THE MASCARENE ARCHIPELAGO

Conruyt N.*, D. Grosser, Y. Geynet, G. Faure, M. Pichon, N. Gravier-Bonnet, M. Guillaume. *IREMIA, University of La Réunion, B.P. 7151, 97715 Saint-Denis, France. Email: conruyt@univ-reunion.fr

Systematics is the scientific discipline that deals with listing, describing, naming, classifying and identifying living beings. In creating information systems that are accessible on the internet, there is a need for enhancing the systematician's expertise. Our aim is to deliver to them a collaborative tool to widely manage, share and transmit their knowledge. We have designed an Iterative Knowledge Base System (IKBS) for achieving these goals. It applies the scientific method in biology (conjecture and test) with a natural process of knowledge management: 1/ acquisition of a descriptive model and related descriptions, 2/ processing of this knowledge for classification and identification, 3/ experimentation and validation. The product of such a tool is a collaborative knowledge base of a domain, that can evolve (by updating the knowledge) and be connected to distributed databases (bibliographic, photographic, geographic, taxonomic, etc.) that which yield information on species after the identification process of a new specimen. Moreover, the objective of IKBS is to offer more robust descriptive work in systematics in order to facilitate the identification of species by non specialists: we are faced with the problem of knowing, defining and reaching a consensus on: 1/ what to describe (taxonomic level of descriptions), 2/ how to represent descriptions (the choice of descriptive logics), 3/ what terms to use for creating an illustrated thesaurus to be presented as a reference for specialists of a domain. This study was effectuated on different families of corals (*Pocilloporidae*, *Fungiidae*, *Poritidae*, *Siderastreidae*) and on a family of hydroids (*Sertulariidae*) of the Mascarene Archipelago.

ENVIRONMENTAL MONITORING OF A CORAL REEF AREA, BAHIA CULEBRA, COSTA RICA.

Cortés J * and Alberto León. *Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Ciudad de la Investigación, Universidad de Costa Rica, San Pedro, San José 2060, Costa Rica. Email: jcortes@cariari.ucr.ac.cr

Bahía Culebra is located on the northwest coast of Costa Rica, Central America. It is a seasonal upwelling region with coral communities and coral reefs. The following have been set up at Bahía Culebra: a meteorological station, underwater temperature sensors at different depths, photo stations of coral communities, permanent plots and marked colonies. The area is exposed to low temperatures (between 18 and 22°C) during the upwelling season from December to April, even so, the growth rates of most corals are the highest in the eastern Pacific, and coral reefs are thriving.

RESTORATION OF A SOUTHEAST FLORIDA U.S.A. CORAL REEF INJURED BY THE GROUNDING OF A NUCLEAR SUBMARINE.

Dodge, R.E.*, R. E. Spieler, D. Gilliam, P. Quinn, A. Rogerson, E. Glynn, K. Banks, L. Fisher, D. Stout, W. Jaap. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania Beach, FL, 33004 USA. Email: dodge@ocean.nova.edu

The United States submarine Memphis grounded in approximately 10 m depth on a coral reef off southeast Florida in February, 1993. The grounding caused extensive physical damage to the reef substrate and biological injury to the coral community. As part of a claim by the State of Florida against the United States Government, the impact of the grounding was assessed, and the area of damage was determined through field and photographic studies. The claim was settled in April, 1997 by an award to the State of Florida. A three year plan to perform hypothesis testing of restoration strategies of the damaged reef within economic constraints has been developed and involves comparison of settlement, growth, and survival rate of corals amongst artificial reefs treated with potential attractants (iron, algal extract, coral transplants), and control reefs (no attractants). The reefs are divided into four treatments of gross structural complexity (greater than 1 cm) to allow the determination of the interactive effects of four different fish communities on coral settlement and growth. In addition, the work allows the investigation of microbial biofilms as settlement precursors. Transplant treatments include identical replicates (same numbers of each species) to allow the determination of species specific differential survival and growth rates of coral transplants. The four complexity treatments are formulated to test the hypothesis that multiple refuge size and the resultant diverse fish assemblages may affect coral recruitment, survival, and growth.

REMOTE TRACKING OF THE WHITETIP REEF SHARK, *TRIAENODON OBESUS*

Dunstan, Andrew*; Medway, Tracey; and Matthews, Monique. *Undersea Explorer, Port Douglas, Qld, 4871, Australia. Email: adunstan@ozemail.com

Osprey Reef is an isolated seamount in the Coral Sea. This study of a resident population of whitetip reef sharks, *Triaenodon obesus*, at the North Horn of Osprey Reef has been conducted since 1995. Twenty-five *T. obesus* individuals have been identified through color and scar patterns, of which twenty have been tagged with identification microchips. For a shark which spends considerable time within the small confines of coral reef habitats, internal implantation of transmitters proved to be the most effective long term method to track the sharks' movement patterns.Intermittent pulse transmitters, were implanted to the animals' main body cavity. Mature females were initially chosen to gain data on breeding times and to locate birthing areas and habitat sites for newborn pups. Datalogging receivers, were deployed underwater with a permanent receiver at the North Horn site and other receivers placed at strategic distances from North Horn to track movement patterns. Transmitter tagged animals were detected when within 300-500 metres of the receiver. The data shows whitetip females to be extremely site attached to the North Horn site during daylight hours. Routine departures from the site occur during the night with regular passes to sites over 1km distant. This corresponds to reported nocturnal feeding behaviour of *T. obesus* and observations in the wild. Longer absence times are seen during the November to January period which is consistent with pregnancy observations and the previously reported birthing season.

ANNUAL RECORDS OF TROPICAL SYSTEMS (ARTS).

Eakin C.M.*, Robert B. Dunbar, Julia E. Cole. NOAA/National Geophysical Data Center, 325 Broadway, E/GC, Boulder, CO 80303. Email: mark.eakin@noaa.gov

Tropical ocean-atmosphere interactions provide the dominant signal in interannual climate variability, and also vary over periods of decades to centuries. The tropics interact with higher latitude climate systems via atmospheric and oceanic teleconnections that appear to have changed substantially at time-scales longer than the past few decades. Paleoclimate reconstructions offer the only source of information on long-term changes in tropical variability and its teleconnections and derive an even broader utility when interfaced with numerical simulations. In 1996, the International Geosphere-Biosphere Programme core project on Past Global Changes (IGBP-PAGES) supported a meeting in 1996 to design an initiative to provide records and reconstructions of past changes in tropical systems. The goals of the Annual Records of Tropical Systems (ARTS) program are to: (1) document and understand the behavior of the tropical ocean-atmosphere and its teleconnections, with seasonal to annual resolution, over the past several centuries; and (2) assess the stability of tropical climate systems and their teleconnections as the background climate and associated forcing phenomena change over seasons to centuries. The ARTS initiative promotes the synthesis of paleoclimate data with instrumental and modeling perspectives to address uncertainties in our understanding of tropical climate variability and its impacts. This poster provides information on the scope of the ARTS initiative, on efforts being made to advance the ARTS initiative and scientific progress that has been made under the ARTS initiative.

SOME CONSIDERATIONS ON THE USE OF GIS APPLIED TO A TROPICAL MARINE ECOSYSTEM : THE SOUTHWESTERN LAGOON OF NEW CALEDONIA (SOUTH PACIFIC).

Ferraris, J.*, Garrigue, Virly, Richer de Forges. Centre IRD BP A5, Nouméa, New Caledonia. Email: ferraris@noumea.ird.nc

In course of a pluridisciplinary program managed by IRD and carried on the anthropogenic and terrigeneous influences on tropical marine coastal environments, a database is developed with a GIS. Its aims are 1) to integrate the data collected in the last 20 years by different scientific programs on the same geographical space : the southwestern lagoon of New Caledonia and 2) to improve the knowledge and the understanding of the ecosystem (the structure and its mechanisms) using spatial analyses of the multi-sources data. A case study on benthic ecology is presented in order to illustrate the different methodological steps required for a GIS application. Data about sediments, macrofauna, micro and macro phytobenthos are integrated and analysed in the aim to characterised benthic habitats and to built useful indicators for environmental approach. The modelling approach in terms of constraints related to geographical database conception, statistical analyses of data and restoration of results in maps are shown. The prospective offered by remote sensing and GIS in the synthesis of a pluridisciplinary program dealing with marine environment is highlighted.

NEW APPROACHES TO MAPPING CORAL REEFS: LIDAR IMAGES FROM HAWAI'I

Field M*, Pat S. Chavez, Miguel Velasco, and Susan Cochran, US Geological Survey, *Santa Cruz, California U.S.A and Flagstaff, Arizona U.S.A. Email: mfield@usgs.gov and

Accurate depth information on depths and detailed morphology of coral reefs is crucial for a number of reasons, including baseline maps; interpreting aerial photographs; avoiding ship groundings; and modeling wave forces on the reef. A new airborne technique (LIDAR--Light Detecting and Ranging) for rapidly and accurately measuring the depth of coral reefs from the shore down to depths of 35 m has recently been used in Hawaii. As part of a major USGS project to map coral reefs and evaluate the processes causing their degradation, airborne digital data were collected in 1999 along the southern coast of the island of Molokai using SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey). Resulting images provide new information about over-all morphology, spur-and-grove structure, reef holes and channels, and isolated blocks, pinnacles and slides. Width, slope, and relative relief of spurs can be accurately measured and statistically correlated. The shape and depths of each blue hole on the reef can now be quickly and accurately mapped. Sand channels, which commonly have an important role in the physical dynamics of a reef habitat, are common features crossing reefs. The LIDAR data off Moloka'i show three dimensional views of the channels that yield insight into their origin and slow segmentation, ultimately, into a series of isolated, elongate features.

SCLERACTINIAN CORAL REATTACHMENT SUCCESS AND RECRUITMENT ON A SHALLOW-WATER SHIP GROUNDING SITE IN SOUTHEAST FLORIDA, USA.

Gilliam, D. S.*, R. E. Dodge, S. L. Thornton, W. Jaap, and J. Wheaton. *National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania Beach, FL 33004 USA. E-mail address: gilliam@ocean.nova.edu

The 348' vessel *C/V Hind* ran aground off southeast Florida, USA, during a storm in March 1998. As a result, 781 m^2 of reef habitat and 4,258 m^2 of live hardbottom were reported injured from hull scarring and anchor drag. Impacts to scleractinian corals included fragmentation and dislodgment. Many of these corals were reattached into twelve zones for monitoring shortly thereafter. These reattachment zones lie in 3-12 meters of water and were placed near impacted areas. During summer 2000, two years post-reattachment, mapping and monitoring of the reattached corals were initiated. The health and condition of the reattached corals were compared to that of similar corals in nearby non-impacted areas. Additionally, coral recruitment on scarified areas was compared to that on non-damaged reef habitat near the impacted areas. Long-term monitoring of this site will document the effectiveness of reattaching fragmented and dislodged corals. Additionally, this study will provide comparisons of coral recruitment and success on both impacted and non-impacted reef habitat off southeast Florida.

ECOTOXICOLOGY TECHNIQUES USING MARINE INVERTEBRATES: DEVELOPMENT OF THE SEA URCHIN BIOASSAY IN SINGAPORE.

Goh, Beverly *. Tropical Marine Science Institute, National University of Singapore, 14 Kent Ridge Road, Singapore 119223. Email: tmsgohb@nus.edu.sg

The development and use of ecotoxicology techniques in pollution assessment is new in Singapore, where water quality and discharge standards for various chemical pollutants have been largely determined from toxicity tests with glass fish, and standard LC_{50} values. In this study, the use of fertilization, and larval development of the sea urchin, *Diadema setosum* was examined as a possible tool for the testing of various pollutants, including petroleum, and the heavy metals, nickel and cadmium. *Diadema setosum* is a common echinoderm found in the coral reefs of Singapore, and is also used as an important indicator of stress in the ecosystem. It has a regular spawning cycle following a lunar periodicity, and is therefore a suitable organism for use in regular ecotoxicity assays. Fertilization and the various stages of larval cleavage of the urchin were examined to determine their relative sensitivity and suitability for use as end points for the ecotoxicology tests.

THE INTEGRATED GIS DATABASE FOR INTEGRATED COASTAL ZONE MANAGEMENT PLANNING IN THE CENTRAL-NORTHERN PART OF THE SAUDI ARABIAN RED SEA COAST.

Gomi Y, A. A. Ali, A S. Saleh, A. A. Aiyed. Address: JICA-NCWCD Study Team, c/o National Commission for Wildlife Conservation and Development, P.O. Box 61681 – Riyadh 11575, Kingdom of Saudi Arabia. Email address: ys.gomi@diz.ajiko.co.jp

In order to facilitate the integrated information management of the coastal biodiversity data with precise habitat maps on the central-northern part of the Saudi Arabian Red Sea Coast, GIS Database system was developed. Arc View 3.0 was customized for user friendly operation environment. Habitats coverage were assessed in 15 minute mesh by GIS database developed. Hatibat categories, extent of hatibat, extent of coral, seagrasses, algae, mangrove, cyanophyceae, tidal flats were used for positive index and industrial plants, fishing boat were used negative index. Five ranking were applied for the assessment and three key area were identified. The developed GIS database should provide the coastal zone management and Marine Protected Area planning and monitoring survey.

MAPPING OF MARINE HABITATS WITH REMOTE SENSING IN COLOMBIA.

Gonzalez A*. Gutierrez*.Rendón. Instituto de investigaciones Marinas y Costeras INVEMAR, A.A 1016 Santa Marta, Colombia. Email: Agonzalez@invemar.org.co

The utilities that the teledetección in investigations provides on marine and coastal ecosystems are varied; for the case of this study images of satellite SPOT XS and pancromatics aerial photographs were used to delimit coral reefs and seagrass on the Golfo de Morrosquillo, including Isla Fuerte and part of the Archipelago de San Bernardo. The images were interpreted multispectral and visually resorting to different procedures like classifications, index, enhancements, filters and mix in color and also a technical procedure was determined to delimit ecosystems of long extension which that can be usefull for baseline inventories, long-term monitoring programs and management of coastal zones. As result appears a thematic map on scale 1:100.000. On the other hand, was provide the utility of taken true-color aerial photographs from one kite, to characterize and to delimit on detailed scale seagrass and coral reefs presents in Isla Maravilla (Archipíelago de San Bernardo), defining some environmental, metereologics and technical conditions that favor the quality of the photographies, like height of the equal cámara: ≥50m on the marine surface - depending on the scale of the work -, Wind speed: ≥10 Nudos, Hour: 2:00 p.m. - 4:00 p.m., etc. Also the photographies were managed to identify spectral signature of each thematic; nevertheless was not possible to consider any parameter that described the structure of these. In addition with the help of a mosaic to aerial photographies to color and pancromatic was possible to develop a map on scale 1:5.000 where one is to the distribution of the ecosystems of the island and the environments.

ACOUSTIC TECHNIQUES FOR RAPID BROAD-SCALE SEABED MAPPING.

Gordon S.R. *, T.D. Skewes, I.R. McLeod, C.R. Pitcher, R.J. Kloser. *CSIRO Marine Research. PO Box 120, Cleveland, Q 4163, AUSTRALIA. Email:scott.gordon@marine.csiro.au

Sampling techniques for mapping the seabed using cameras, dredges, and grabs are limited to relatively few sites, due to the time and costs of deploying the gear. Using these techniques, broad-scale maps of seabed type are difficult to produce because only a fraction of a study area can be sampled. While above water remote sensing tools allow broad-scale mapping, they are severely limited for sampling deeper seabeds. In order to address these limitations, we have developed seabed mapping techniques that use the acoustic signals from echosounders, to sample the seabed. Combined with traditional sampling methods, acoustic techniques permit rapid broad-scale and continuous mapping of seabed type even over rugged terrain, such as coral reefs. We outline the use of acoustic techniques for seabed classification and rapid broad-scale seabed mapping, for a study of the shoal areas (15 to 50 m deep) of Scott Reef, North Western Australia. The fieldwork was conducted during September 1998; it took three days to sample the 400 km^2 study area. Maps of seabed type obtained using the acoustic technique, show the delineation of deep coral reef from other inter-reefal seabed types, such as sand, coarse sand, rubble and rock.

COMPARISON BETWEEN COMPLEX AND SIMPLE REEF SURVEY TECHNIQUES: IS THE EFFORT JUSTIFIED?

Harding, S.P.*, S.G. Oakley, C. Lowery and M. Colmer. Greenforce, 11-15 Betterton Street, Covent Garden, London, WC2H 9BP, UK. Email: simonharding@yahoo.com.

Reef check and GCRMN survey techniques were compared between the same volunteer divers on the same reefs after different periods of training. Greenforce volunteers with no prior reef surveying experience who were participating in an expedition in Sabah, East Malaysia were firstly taught to dive and then trained in reef fauna and flora identification and surveying techniques. After a few weeks of training, volunteers used both the Reef check and the more detailed GCRMN survey techniques at a number of sites. Four to six weeks later, the volunteers resurveyed the same transect lines. In addition, the same transects were surveyed by the on-site science staff. Reef check species were identified and counted correctly at all levels of experience. Useful information could also be collected by volunteer divers using the more detailed GCRMN fish transect methods. Fish were easily identified to family and most common species were identified correctly. Experienced surveyors recorded a few additional species, but there was no difference between the numbers of common species seen by the two groups. The two techniques gave similar results for bottom cover estimates even though Reef check generally records far fewer sampling points per transect than the GCRMN technique. For data on benthic cover only, reef check techniques were adequate, while the increased effort required for coral morphology may be justified for more detailed studies.

OLDEST LIVING STAR CORAL? GROWTH HISTORY AND RESTORATION OF A GIANT *MONTASTREA FAVEOLATA* IN THE FLORIDA KEYS NATIONAL MARINE SANCTUARY.

Hudson, J. Harold* and Halley, Robert B.. *Florida Keys National Marine Sanctuary, P. O. Box 1083, Key Largo, Florida, USA. Email: harold.hudson@noaa.gov

The longest growth record previously reported for living *Montastrea faveolata (annularis)* is 242 years. Here we report on a specimen that has survived for more than four centuries with its growth history intact. The purpose of this study is to document and compare growth history of this colony with other old-growth *M. faveolata* from Florida, and to describe its restoration. The latter necessitated by a vessel collision with the coral in 1997. Total length of core recovered was 3.174 meters. Analysis of core slab X-radiographs revealed a growth history that extended back to 1595. Maximum vertical growth was 12.5mm per year and minimum extension 2.9mm per year. Mean annual vertical extension was determined to be 7.3mm per year. Restoration of the colony began in 1999. Stainless steel rods and hydraulic cement were used to construct a reinforced "skin" to repair the injury. To promote tissue regrowth, live tissue plugs 5cm in diameter were implanted at random across the repair.

CHANGE DETECTION OF CORAL REEFS USING OPTICAL AND REMOTE SENSING TECHNIQUES

Karpouzli Evanthia *, Tim Malthus, Chris Place, Department of Geography, University of Edinburgh, Edinburgh, U.K. EH8 9XP Email: E.Karpouzli@hw.ac.uk

Optical remote sensing offers a non-invasive technique with which to rapidly monitor changes in the cover and health of submerged habitats. Its full potential is still to be exploited in littoral environments, where the strong attenuating influence of the water column has been a limiting factor. The littoral habitats of the Archipelago of San Andres and Providencia (western Caribbean) have been markedly affected by coral bleaching, abnormal tropical storms, and increased tourism, with negative impacts on both seagrass and coral reef communities. The overall aim of this study is to evaluate remote sensing for its ability to detect qualitative and quantitative changes in these communities using a time series of Landsat TM scenes spanning over 13 years. Objective measurement of habitat change requires processing of the images to enhance the bottom reflectance signal. This process typically uses correction techniques to remove the influence of the water column on bottom reflectance, and to enable the accurate correction of the imagery for varying bathymetry.

LONG-TERM CHANGE IN BENTHIC COMPOSITION OF CORAL REEFS ON THE NORTHWEST COAST OF ROATAN.

Keck, J.R.*, R.H. Houston, K.K. Hermans. Roatan Institute for Marine Sciences, Sandy Bay, Roatan, Bay Islands, Honduras. rimsed@globalnet.hn

Long-term ecological monitoring of coral reef communities on the northwest reefs of Roatan, Bay Islands has been implemented to quantify dramatic changes observed in benthic community composition over the past four years. Data was collected using a chain-link transect technique at four monitoring stations in 1996 and again in 1999. Data collected includes percent cover of live and dead corals, macro-algae and other sessile organisms using life-form categories. Scleractinian corals were identified to species when possible to examine changes in diversity over time. Live hard coral cover at the 4 sites combined has declined significantly from 38.4% (±10.5) in 1996 to 25.7% (±7.3) in 1999 ($p=<.001$). Total macro-algae increased from 54.7% (±10.2) in 1996 to 60.7% (±8.7) by 1999 ($p= .007$). There was also a significant increase in recently dead coral from 1.4% (±2.3) in 1996 to 7.2% (±5.0) in 1999 ($p= < .0001$). The results of this study include data from transects that were sampled at the same localities before and after an extensive bleaching event in 1998-99 and Hurricane Mitch which struck in late October of 1999. Roatan has also experienced rapid population growth and increased coastal development in the past decade. The results of our study clearly warrant the need for continued monitoring. This monitoring will be critical in assessing long-term effects of these natural and human disturbances and will be of great importance in the future management of Roatan's reef ecosystem.

LIMITS OF ACCEPTABLE CHANGE (LAC) PROCESS; A FRAMEWORK FOR MONITORING RECREATIONAL IMPACTS TO A CORAL REEF.

Kooistra, David *; Schultz, Eric; McCool, Stephen F.; *Manager, Saba Marine Park, Fort Bay, Saba, Netherlands Antilles. Email: smp@megatropic.com

Growing interest in recreational diving on coral reefs challenged marine parks to develop systematic management and monitoring frameworks. This is particularly interesting because many such parks have two overlapping, yet conflicting goals: (1) protection of the pristine character of the reef; and (2) providing recreational access to the area. Indicators are selected that reflect the types of impacts recreational diving and snorkeling create; monitored over time and space needed to determine the effectiveness of management actions designed to reduce impacts, and linked to quantified standards of acceptable change. The LAC process incorporates various interests and values in a public exploration of values, issues and management actions for the marine park. This process was used in the Saba Marine Park and included 10 specific steps, in which a public task force was directly involved in each of the steps. The task force identified several indicators of impact and for each indicator a standard was also identified. Besides being useful in identifying indicators that are relevant to management decision-making, the planning process also demonstrates that LAC can help parks to develop a management plan that can be implemented, create opportunities for better relationships with those who have interests or are affected by the plan.

MEASURING CHANGES TO MANTLE COLOUR IN GIANT CLAMS.

Kumar Lynette *, Johann Bell. Marine Studies Programme, University of the South Pacific, Suva, Fiji. Email: s93004854@student.usp.ac.fj

Cultured giant clams are becoming increasingly popular in the tropical marine aquarium trade. The popularity of cultured clams is due largely to the fact that several species can exhibit iridescent blue and green mantle colours, and the trend for aquarists to purchase products that have "ecolabelling". Despite the strong incentives for hatcheries to produce juvenile giant clams with bright mantles, the factors that control mantle colour are not yet well understood. Consequently, research is now underway to identify the genetic and environmental factors likely to be involved in the expression of mantle colour. A major requirement of such research is the ability to record changes in mantle colour accurately. In this paper, we describe a method for measuring changes in the mantle colours of giant clams from digital images. The method involves standardisation of the images using computer routines and sampling colour, in terms of its Red, Green and Blue (RGB) components, with commercial image analysis software. We have used this method in experiments on mantle colour in *Tridacna maxima* and it has proved to be inexpensive and reliable. Above all, however, it removed all human error in the assessment of colour. The unequivocal data produced by this method is expected to be of great value in the identifcation of factors responsible for colour change in giant clams, and a variety of other species.

STATUS OF BLACK CORAL POPULATIONS AT THE MEXICAN CARIBBEAN.

Padilla C*, Lara M, Loreto R. M. and Lara I. CRIP Puerto Morelos, INP. A.P. 580 Cancun 77500, Quintana Roo, Mexico. Email: cpadilla@ww2.net.mx

Black coral is an important resource in the Mexican Caribbean, but the main banks have been over-exploited. The major problem for the regulation of this activity is that basic biological and ecological aspects of these organisms are unknown; even the taxonomic identity of the exploited species are uncertain. Therefore, a study was conducted for to describe the actual status of these populations in terms of its abundance and some demographic aspects. A general overview was obtained by videotransects using a control remote videocamara (Phantom HD2), and more detailed information was obtained by subaquatic survey using gas mix diving. Also preliminary experiments was conducted in order to evaluate the regeneration ability of this organisms and apical growth. The black coral colonies used commercially belong to the species *Antipathes pennacea* and *A. caribbeana*, and other five species were detected in the study area, any of which are considered into the black coral protected species in the Mexican legislation. The highest abundance is in the south, while the populations in the north part and Cozumel Island are scarce. The preliminary results indicate that fragments artificially fixed with epoxic had high survival and significant growth. The demographic analysis shows a very slow population growth, which make these populations very sensible to changes due to extraction. A strategy is proposed looking for the conservation of this resource including: propose to change the Mexican legislation, close over exploited areas, reduce the assigned quotas, and to restrict the kind of organism to extract.

RAPID REEF MAPPING – AN ATTEMPT WITH HYDROACOUSTIC METHOD.

Lee, Wah Sze*. *Elcee Instrumentation Sdn. Bhd. Malaysia. Email: lyj@pc.jaring.my

A new approach was applied to mapping out the reef substrate of the Pulau Payar Marine Park which consists of Payar and Segantang group of island. An acoustic ground discriminating system was able to translate the echo signals into hardness and roughness indices which then exhibit unique characteristic for each bottom type recorded. Six major reef substrates were identified. Live hard coral represents a total coverage of 19.30% from the 157.68km total length of transect recorded from Payar group of island. The four main growth forms found were the massive (10.11%), branching (7.11%), encrusting (1.51%) and foliose (0.57%). As for Pulau Segantang group of island, soft coral was the dominant coral type contributing to 34.65% of the total 4.12 km of track run. The real time track data were also interpolated using Surferâ 6.2 for thematic maps showing depth contour, 3D depth profile and bottom surface area. The results were satisfactory. In this survey, hydroacoustic method shows strongly to be a better alternative to the conventional transect line method and satellite images in terms of time and cost spent and the results gained in return, especially for large scale survey.

HYPERSPECTRAL REMOTE SENSING OF BAHAMAIAN REEFS.

Lesser Michael P. * and Robert Maffione. University of New Hampshire, Department of Zoology, Durham, NH 03824. Email: mpl@christa.unh.edu

Hyperspectral remote sensing is emerging as a promising means of mapping shallow reef habitats and characterizing them based on the dominance of certain functional groups of coral reef organisms. We extensively measured the light environment of a coral reef habitat near Lee Stocking Island, Bahamas to relate the bottom spectral signatures with the spectral signatures observed at the water's surface. The spectral irradiance reflectances of the dominant substrates and flora and fauna of the study area (e.g., sand, live corals, macrophytes, turf algae) were measured and categorized with a fourth derivative analysis. Just below the water's surface, the upwelling spectral radiance was measured simultaneously with the downwelling irradiance just above the surface. A fourth derivative analysis of the surface remote-sensing reflectance clearly identified major bottom types and dominant organisms on the reef when compared with the bottom reflectances. Water column inherent optical properties were also measured and used to model the propagation of solar light from the surface to the bottom and back to the surface. Good agreement was found between the measured and modeled light field. Analysis of airborne hyperspectral imagery of the study site also indicates that bottom classification of reef habitats can be achieved with this type of sensor and platform.

NOAA'S SATELLITE-BASED CORAL REEF EARLY WARNING SYSTEM FOR PREDICTING TROPICAL OCEAN WARMING, BLEACHING, AND MORTALITY.

Meyer, J.E. * Toscano, M.A.; Guch, I.C.; Strong, A.E.; Hendee, J.C. and Casey, K.S. *NOAA/NESDIS ORA/ORAD E/RA3, 5200 Auth Road, Rm 711, Camp Springs, MD 20746 USA. Email: jmeyer@nesdis.noaa.gov

Since 1997, NOAA/NESDIS experimental tropical SST HotSpot charts have provided a compelling predictive tool for defining oceanic areas experiencing thermal stress and consequent occurrences of coral reef bleaching. NESDIS coral reef monitoring SST products will be transitioned from experimental to operational status through a new program - Coral Reef Watch. Toward this end 1) current HotSpot analytical resolution and climatology (50km globally) will be upgraded to 9km, improving spatial detail for monitoring; 2) coral reef bleaching e-mail alerts will be automated directly from the HotSpot indices; 3) coral reef bleaching observations will continue to be collected via email or web form; and 4) data management/accessibility will be expanded. Planned expansion of *in situ* coral reef monitoring (CREWS buoy) stations in the Atlantic/Caribbean and Pacific, (through NOAA/ORA/AOML; partner in Coral Reef Watch), is designed to provide field verification of oceanographic conditions in key reef areas. CREWS data will be used to calibrate NESDIS satellite-based coral reef monitoring indices and their defining thresholds. Coral Reef Watch directly addresses the United States Coral Reef Task Force National Action Plan mandate to monitor, assess, and inventory coral reef health.

NUMERICAL INVESTIGATION OF CURRENT FIELD ON A CORAL REEF WITH HIGH-RESOLUTION BATHYMETRY DATA OBTAINED BY A SATELLITE IMAGE ANALYSIS.

Nadaoka K., Yasuo Nihei* and Ryoko Kumano. Department of Civil Engineering, Faculty of Science and Engineering, Science University of Tokyo, 2641, Yamazaki, Noda-shi, Chiba, 278-8501, Japan. Email: nihei@ rs.noda.sut.ac.jp

Hydrodynamic environments of a coral reef may be strongly governed by topographic characteristics of the reef. Therefore one needs to obtain high-resolution bathymetry data for accurate computation of current field on a coral reef. However the spatial resolution of the bathymetry data of a coral reef is usually quite limited. In the present study, we have employed the method of satellite image analysis for bathymetry mapping developed by Nadaoka and Tamura (1991; 1992), which is based on an optical theory of light transmission and reflection. LANDSAT-TM images are used to give the bathymetry data with the resolution of 30 m. The SDS-2DH model _Nadaoka and Yagi, 1998_, a shallow-water turbulent flow model, is used for numerical simulation of currents on a coral reef to examine the significance of the bottom effects on the current field and therefore of the spatial resolution of the batymetry data. The computational experiments, in which the resolutions are given to be respectively 30, 90 and 210m, show the strong dependence of the spatial distribution of the tidal residual currents, vorticity field and others on the difference in the spatial resolution of the bathymetry data. It is found that this difference is provided by the bottom friction effect, which may vary with the bathymetry resolution.

SATELLITE IMAGE ANALYSIS OF CORAL REEFS BASED ON SPECTRAL BOTTOM REFLECTANCE.

Nadaoka, K.*, Y. Nihei, T. Yokoyama, T. Oomija, K. Shimoike.
Graduate School of Information Science and Engineering, Tokyo Institute of Technology, 2-12-1 O-okayakma, Meguro-ku, Tokyo 152-8552, Japan. Email: nadaoka@mei.titech.ac.jp

In the Okinawa Islands of Japan, the erosion of red-soil from the land surface and its subsequent discharge and deposition onto the surrounding coral reefs have caused serious environmental problems such as the extinction of the coral and the deterioration of the beach landscape. Recent aggravation of these problems needs more comprehensive and quantitative methods to monitor and analyze the degree of the sediment deposition on the coral reefs and its spatial distribution. For further extension of the applicability of the method developed for this purpose by Nadaoka and Tamura (1991,1992), which analyses the satellite remote-sensing data in visible-light bands based on the light transmission and reflection theory, the spectral reflectance of various sea-bottom conditions such as live and dead coral, sea grass, seaweed, coral sand and red silt was investigated by performing field observations. Then the spectral reflectance was examined in terms of the remote sensing bands to find the possibility of the classification of the various sea-bottom conditions based on remote sensing data. Finally the validity of this idea was checked by analyzing a LANDSAT-TM data with the method proposed.

AUTOMATION OF DATA ANALYSIS FOR CORAL REEF BENTHIC VIDEO TRANSECTS.

Osborne K , Ellis R, Culverhouse, P and L Coombs. Australian Institute of Marine Science, PMB 3, Townsville MC, Qld 4810 Australia. Email: kosborne@aims.gov.au

The Australian Institute of Marine Science Reef Monitoring Project collects benthic video transects from sites on 48 reefs of the Great Barrier Reef annually. Benthic video transects are quick and easy to collect in the field but data analysis is time consuming and expensive. The data analysis process significantly affects the ability of the project to deliver real time data to management. Automation of data analysis via an expert system would not only speed up analysis but also allow greater sample sizes and thus improve the power to detect change.m As a first step toward implementing an expert system, a software package based on neural networks was tested. A training set of three hard coral species was presented. Two species of Pocilloporidae and *Stylophora pistillata* were chosen. These species are variable in appearance but can be distinguished reliably by human observers. The work is in progress and preliminary results will be presented.

CORAL CHANGE DETECTION USING LANDSAT SATELLITES: A CASE STUDY FOR CARYSFORT REEF IN THE FLORIDA KEYS.

Palandro, David *, Andréfouët, Serge; Muller-Karger, Frank; Dustan, Phillip. *University of South Florida, Dept. of Marine Science, 140 7th Ave. South, Saint Petersburg, Fl. 33701, USA. Email: palandro@seas.marine.usf.edu

Satellite remote sensing is increasingly being used to map and monitor coral reefs. Satellite data allow for the relatively quick assessment of benthic habitats and can be used for change detection studies. Landsats 5 and 7, with the Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors, respectively, on board provide the longest time series of satellite observations available for coastal researchers. From 1984 to the present, TM (for the U.S.) and ETM+ (worldwide), images are abundant for change detection analysis over coral reefs, especially since the inception of the NASA/USGS Long Term Acquisition Plan (LTAP). The LTAP is implemented to gather Landsat 7/ETM+ data for specific remote sensing niche communities, of which coral reefs are one. To properly use this data, minimum corrections need to be made; namely atmospheric correction, bathymetric correction, radiometric correction and noise reduction. We have merged the data from Landsats 5 and 7 to produce a 16-year (1984-2000) time-series for Carysfort Reef in the Florida Keys. A supervised classification of the bottom was undertaken for four benthic habitats: sand, live coral, seagrass/algae and a hard-bottom substrate, which included rubble. A large database of *in situ* data exists for Carysfort Reef for the same time period of our study; a comparison of the satellite data and *in situ* data indicates a strong correlation between the changes in benthic cover.

CREATION OF A CORAL GARDEN TO RESTORE A DAMAGED REEF SITE (BORA-BORA, FRENCH POLYNESIA)

Porcher, M. B. Salvat, R. Morancy, Y. Chancerelle, M. Schrimm*. CAREX Environnement, Avenue de l'Armée d'Afrique, Résidence Les Collines de Cuques, 13100 Aix-en-Provence, France. Email: carex.environnement@wanadoo.fr

One of the most wonderful reefscape of French Polynesia: Matira Point in Bora Bora Island, has been degraded by coastal erosion and excavations dredged on the reef flat. The French Polynesian Ministry of Environment planned a study to define technical solutions to restore and protect this site. An original experimentation was conducted on a test zone, where 3 modules were placed. Each module includes 2 or 3 concrete units, simulating coral heads. Shape, general aspect, colour, location of concrete modules have been studied, taking into account the natural reefscape (from aerial photography and underwater observations). These concrete modules held support for the coral transplants. 311 colonies of corals were removed from donor sites and were cemented on the concrete modules or seabed between them. Since the end of all transplantations (July 1999), the site was biologically monitored every 3 months: determination of mortality and growth rates, evaluation of coral health, taking of photographs, estimation of algal cover and record of echinoderms, molluscs and fishes assemblages. Recovering rate of coral colonies was high, with a mortality of only 3%. No stress was noticed (bleaching, disease). Moreover, this coral garden seems to be very attractive with an increasing colonisation, especially by fishes. Finally, natural colonisation of corals on artificial modules was observed.

DAMAGE ASSESSMENT PROTOCOL AND RESTORATION OF CORAL REEFS INJURED BY VESSEL GROUNDINGS

Precht, William F.*, Deis, Donald and Mulcahy, Robert. *PBS&J, 2001 NW 107th Ave., Miami, FL 33172, Email: bprecht@pbsj.com

After a coral reef is impacted by a vessel grounding, an assessment should be prepared to quantify and qualify the resultant injury. Because many of the damage actions result in litigation between the trustee and the responsible party, the assessment must also substantiate or refute the description of events that caused the injury. The site should initially be treated much like that of a crime scene. Accordingly, physical evidence needs to be documented, collected, and quantified. Coral reef triage efforts should be implemented in concert with the injury assessment for salvaging the living resource. Following these tasks, a detailed damage assessment and restoration plan (DARP) should be performed. The DARP should quantify the injury to both the living and non-living resource. Once the injury assessment portion of the DARP is completed, a variety of primary restoration alternatives should be outlined. Calculating monetary damages requires an assessment of not only the injury and its restoration, but a determination of the length of time for the injured area to functionally return to pre-impact levels. These damages are based on scaling of the restoration over time to compensate for interim ecosystem losses. This approach to impact assessment and restoration will provide an ecologically defensible basis upon which to document the injury, set restoration goals, implement the appropriate restoration program, and gauge overall project success.

OBJECT-ORIENTED SYSTEMATICS INFORMATION SYSTEM: TOWARD SYSTEMATICS DOMAIN OBJECTS

Rousse, G.*, N. Conruyt, D. Grosser, R. Vignes. IREMIA, University of La Réunion, B.P. 7151, France. Email: Guillaume.Rousse@univ-reunion.fr

Current systematics databases rely upon relational model. Although well-known and widely used, the relational model presents heavy weaknesses regarding implied semantic, complex structures support and multimedia data manipulation. However, biosystematics is precisely a domain with very rich content, such as complex relationships, hierarchical classifications, images, etc.. The Fishbase database application is an illustration of this complexity. Object model is another way to model the world reality and can adress some of these points above. We are currently evaluating it for building an integrated information system about systematics of the Mascarene coral reef ecosystem. This system will include data and knowledge bases for full covering of information acquisition procedure, from specimen identification to the corresponding taxonomic data. It will also cover a wide range of information types: nomenclatural, taxonomical, geographical, ecological, etc.. The inter-operability with external systems is also an important concern. Current proposals deal with establishing reference conceptual schemes. Although necessary, these proposals only adress static structure of information. Object model allows to extends this shared ontology to dynamic behaviour of our concepts, that will lead to the definition of systematics domain objects.

IMPACT OF FISHING ACTIVITY HAVE ON NEARBY MARINE RESERVE?

Sarramegna S, LERVEM, University of New Caledonia, B.P. 4477, 98847 Nouméa New Caledonia. Email: sarrameg@univ-nc.nc

Marine protected areas are suppose to be sources of emigration of fish to surrounding exploited zones. This hypothesis was studied on the Abore marine reserve in the Southwest lagoon of New Caledonian (25 km long, 0.5 to 2.5 km width barrier reef). Two surveys of coral reef fish populations were performed using underwater point count visual census. The first one in 1993, when the reef was protected. The second one, two years later, when two thirds of the reef were opened to fishing. The overall species richness (77.85 vs. 69.47), density (3.68 vs. 1.72 fish.m^{-2}) and biomass (277.59 vs. 128.39 g.m^{-2}) of fish decrease between these two surveys. The same trend was observed in each part of the reef (protected and unprotected area). The decrease of species richness (3.4% in protected zone and 16.9% in unprotected one) and biomass (106.6% in protected area and 130.9% in unprotected one) observed in the unprotected area is more important than in the reserve zone. On the other hand, the variation of density is similar in these two areas (derease of 110.3% in protected one and 109.6% in unprotected one). These results suggest that the reserve could supply the fishing part of the reef by emigration of adult fish so the fishing activities could affect all the reef. The analysis of the trophic structure suggest that the decrease in food resource linked with climatic accident such as El Niño, could also play an important role to explain the results observed.

IS SKELETAL STRENGTH A GOOD CRITERION FOR THE SELECTION OF CORALS TO BE SEEDED ONTO ARTIFICIAL PROTOREEFS?

Schuhmacher, Helmut* *Institute of Ecology, University of Essen, D-45117 Essen, Germany, Email: h.schuhmacher@uni-essen.de

The carbonate budget of a coral reef mainly depends on the ratio of accummulation versus erosion. These gross parameters are influenced - among others - by the specific life expectancy of the coral colony i.e. its persistence to calcify, by the mechanical strength of the skeleton to resist hydrodynamic impacts, and by the mode of desintegration after death of the colony. Field observations on community composition and laboratory experiments on mechanical properties of the skeleton such as porosity, bending and compressive strength as well as on resistance of fragments against abrasion are presented. The importance of skeletal strength is discussed in relation to colony morphology and physiological properties such as regenerative potential in order to derive recommendations for the seeding of reef nuclei as stepping stones

SPECTRAL SIGNATURES OF BLEACHING FROM HARD AND SOFT CORALS IN FIJI.

Siciliano, D. *, Potts, D.C. Martini, B.A. Lind, R. Morrow, J.H.. *Ocean Sciences Department, University of California, Santa Cruz, CA 95064, USA. Email Address: siciliano@biology.ucsc.edu

Many corals have characteristic spectral signatures indicating differential absorption or reflection of particular wavelengths. While signatures of healthy corals can be attributed almost entirely to properties of their symbiotic zooxanthellae, bleached corals without zooxanthellae may also have distinctive signatures. During a major bleaching event in Savusavu Bay, Fiji in March 2000, two multispectral radiometers were used to measure reflectance spectra *in situ* from a variety of hard and soft corals in varies stages of bleaching (from healthy to completely bleached). The instruments, both handled by divers and an operator in a small boat, were: a GER 1500 portable hyperspectroradiometer, with the sensor on a 10 m underwater fiberglass cable (350-1150 nm in 3.0 nm FWHM increments); and a Biospherical Instruments PRR-800 profiling reflectance radiometer (340-785 nm in 10 nm FWHM wavebands). Spectra were recorded from several species of *Acropora, Pocillopora, Porites, Symphyllia, Sinularia* and *Sarcophyton* at a standardized distance of ca. 10 cm, and at depths ranging from 0.5 to 8 m. There were consistent spectral differences between some taxa, among both bleached and unbleached corals. In addition, some bleached corals had strong peaks that appear to indicate auto-fluorescence in one or more wavelengths associated either with UV-protective or similar molecules within the host's tissues (in *Pocillopora* sp.), or with photosynthesis (in *Symphyllia*).

THE USE OF AVHRR AND ATSR DATA FOR MAPPING CORAL BLEACHING ON THE GREAT BARRIER REEF.

Skirving, William* and Barton, Ian. *Australian Institute of Marine Science, PMB No. 3, Townsville M.C., Qld., Australia. 4810. Email: w.skirving@aims.gov.au

The Great Barrier Reef (GBR) experienced its most intensive and extensive coral bleaching event on record in early 1998. There is concern among environmental scientists and GBR-based industries that widespread death and bleaching of corals caused by extremely high temperatures during 1997-98 may occur more frequently in the Great Barrier Reef region if global climate change unfolds as expected during the 21st Century. The need for accurate environmental monitoring techniques that are of use in studying coral bleaching is of utmost importance among coral reef researchers. Currently NOAA-NESDIS are using AVHRR data to produce a near-real-time 'coral bleaching hot spot' product, which is proving to be of great benefit to researchers studying coral bleaching in the GBR. AVHRR (NOAAs 12, 14 and 15) and ATSR (ERS-1 & 2) have similar spectral and spatial resolutions but differ in their radiometric and temporal resolution. This paper compares and contrasts each of these sensors for monitoring SST in the GBR with a view to studying temperature related coral bleaching.

RECENT CHANGES IN CORAL COVERAGE ON OUTER FRONTS OF THE FRINGING REEFS AROUND MAYOTTE I. (SW INDIAN OCEAN) ASSOCIATED WITH THE ISLAND DEVELOPMENT: A TOOL TO MONITOR AND MANAGE COASTAL ENVIRONMENTS

Thomassin B. A.*, Durand D., Fertille J.C., Pichon M., Marshal C., Arnoux A., Bechemin C., Berland B. CNRS-UMR n°6450 "Dimar", C.O.M., Univ. de la Méditerranée, 13007 Marseille, France & G.I.S. "Lag-May". Email: thomassi@com.univ-mrs.fr

Mayotte I. (N Mozambique channel, 12°-13°S) is an eroded volcanic island with a very jagged coastline, surrounded by a large coral reef lagoon (near 1,500 km^2) isolated from the ocean by a near continuous ribbon barrier reef system. Fringing reefs are well developped along most of the coast all around the "Main Island" (360 km^2), as well around the volcanic lagoonal islets, even along inner parts of some deep bays today in muddy environ-ments and with mangroves: near 186 km of fringing reefs fronts for 197 km of "Main Island" shoreline. As the vitality of the coral assemblages on the fringing reef outer fronts represents a good ecological indice to estimate the impacts of land disturbances linked to the recent development (huge increase in population, associated with deforestation for agriculture, littoral road works, coastal villages growth, car park extensions, increase of oil impact, etc.) surveys at long intervals were planned for the island manage-ment. First, island shoreline was subdivided in 35 districts according geomorphology. Two surveys were conducted in 1989 and 1997, while the island population blows up during these 8 years from about 70,000 up to 135,000 inhabitants.

SUCCESS AND GROWTH OF CORALS TRANSPLANTED TO CEMENT ARMOR MAT TILES IN SOUTHEAST FLORIDA: IMPLICATIONS FOR REEF RESTORATION.

Thornton*, S. L., D. Gilliam, R. E. Dodge, R. E. Fergen and P. Cooke. National Coral Reef Institute, Nova Southeastern University Oceanographic Center, 8000 North Ocean Drive, Dania Beach, FL, USA 33004. Email: sthornto@ocean.nova.edu.

In 1997, 265 scleractinian corals growing on a sewer outfall pipe were used in a transplantation study offshore from North Dade County, Florida, USA. Corals were removed and transplanted onto concrete armor mat tiles used to cover the pipe. Success (number of corals still attached and alive), mortality (number of dead corals), and growth rates of the transplants were assessed between December 1997 and December 1999. Colony surface area coverage and radius length were measured on scanned photographs to estimate horizontal growth rate. After two years post-transplantation, success rate and overall mortality were 89% and 7.3% respectively. Used as a comparison, three groups of nearby natural substrate corals had success rates of 84-89% and mortality rates of 11-25%. The two most numerous coral species of the transplants, *Solenastrea bournoni* and *Siderastrea siderea*, had comparable success and mortality rates; however, *S. bournoni* had a significantly faster growth rate (increase in horizontal radius and surface area). The colony size at time of transplant was not related to the rate of growth; however, mortality and partial mortality rates increased with smaller size colonies. The methodology used in this investigation is useful for transplanting corals in impacted areas because it is non-invasive and allows continual monitoring. The technique is applicable to monitoring of corals growing on natural and artificial substrates.

PROSPECTS FOR CORAL RECOVERY THROUGH TRANSPLANTATION AND NATURAL RECRUITMENT, KENYA

Visram S*, Tamelander J, Kilonzo J, Obura D. *Coral Reef Degradation in the Indian Ocean (CORDIO), P.O. Box 10135, Mombasa, Kenya. Email: dobura@africaonline.co.ke,

Coral reefs are increasingly threatened by degradation from several sources, both natural and anthropogenic. The 1997-98 El Nino caused coral bleaching and a mortality of 50-95% on most reefs in the western Indian Ocean. The subsequent reef degradation will have strong secondary impacts on the livelihoods of coastal populations. Reef recovery is vital, and in some areas active restoration may be necessary. This study was started in July/August 1998, to assess the restoration potential for a degraded coral reef by transplanting corals and monitoring natural settlement and recruitment. A secondary objective is the development of low-tech, economical and practical means of restoring degraded reefs. Further developments of the study will include increasing the three-dimensional complexity and studying secondary effects on, e.g., biodiversity in the vicinity of the study plots. Two sites are used in lagoon patch reef habitats, one adjacent to a channel through the fringing reef, the other further inside the lagoon, characterised by weaker tidal currents and slower water exchange. Coral nubbins were transplanted onto natural substrate and moveable racks using epoxy putty, and growth is measured monthly.

MARINE DEBRIS, A PROBLEM FOR CORAL REEFS AND ISLANDS - A LOOK AT ASHMORE REEF

Whiting, Scott D.* and Michael L. Guinea, *Biomarine International, 376u NT University Darwin, NT, 0815. Australia. Email: s_whiting@site.ntu.edu.au

Marine debris refers to the persistent anthropogenic debris found in the marine environment. It is a global problem that impacts on all aspects of the marine environment including coral reefs. It causes the death and debilitation of many types of fauna as well as impacting on human activities such as tourism and shipping. Coral reefs and islands are natural collection sites for marine debris and provide discrete sampling units in the oceanic environment. In 1998, a survey of marine debris was conducted on West Island on Ashmore Reef, in the eastern Indian Ocean. Ashmore Reef is a remote, shelf-edge platform coral reef located 800km from Darwin, Australia, and 140 km from Roti Island, Indonesia. Approximately 90% of the items were synthetic in origin, 68% of which were fragments under 5 cm in diameter. An estimated 690 items/km washed ashore each day. Large amounts of discarded fishing net were observed both on the beaches and in the water at Ashmore Reef. Fishing debris had obvious impacts on the Ashmore Reef fauna and included: corals covered by discarded fishing nets and turtles and birds entangled by nets and ropes. Small plastic fragments, when ingested, also pose a serious threat to animals. Marine debris is a serious problem in the marine environment. Beach and in-water surveys of reefs should be conducted in a range of geographically and ecologically diverse habitats to determine the types and sources of marine debris and assess its impact on marine systems. A reduction of marine debris will require an integrated international approach.

PROSPECTS FOR CORAL REEF REHABILITATION: A PHILIPPINE CASE STUDY.

Helen T. Yap*, A. Rex F. Montebon, Marlowe G. Sabater, Edgardo D. Gomez. The Marine Science Institute, University of the Philippines, Diliman, 1101 Quezon City, Philippines. Email Address: hty@msi01.cs.upd.edu.ph

The Hundred Islands comprise a unique coral reef ecosystem in the northwestern Philippines, and are one of the first officially declared national parks in the country. Unfortunately, they have experienced steady degradation since about the 1970's. The island chain stretches roughly from north to south, with the major land mass of Luzon to the west and south. There is a gradient in exposure and siltation, resulting in better water quality going northwards. This seems to be reflected in better reef development in the north as well. Two species of hard corals, *Porites cylindrica* and *Pavona* sp., were transplanted into three demonstration areas in the islands of Quezon, Clave and Children's located roughly along the north-south gradient of environmental conditions. The sites at Quezon and Children's were fenced with a 5-cm plastic mesh, enclosing an area of about 100 m^2, and also had several individuals of giant clams introduced along with the corals. Coral growth and survival were better in the northernmost study site than in the other two. This confirms the north-south gradient in environmental conditions which affect reef development. The presence of corals and giant clams significantly enhanced fish diversity and abundance, with these parameters being much higher within the transplant areas as compared to comparable areas outside. Thus, coral reef rehabilitation involving coral and giant clam transplantation has significant potential for enhancing diversity in degraded coral reef areas.

THE STUDY OF CORAL TRANSPLANTATION USING THE FRAGMENTATION METHOD AT PARI ISLAND-KEPULAUAN SERIBU, INDONESIA.

Yarmanti, Kartika Dwi*; Johan, Ofri*. *Bogor Agricultural University. Email: glubglub13@yahoo.com.

The research was conducted in Pari Island, Kepulauan Seribu- Indonesia, starting December 1999 until June 2000. There were two kinds of treatments for each species, which are three different amount of branches (single branch, two branches, and three branches) and three different locations (leeward, windward, and lagoon) in 5 m depth. The aim of this research is to investigate the succesful of transplanting corals of *Acropora formosa*, *Acropora donei*, and *Acropora acumilata* on artificial substrate. Growth, mortality, increase in the amount of axial corallites, and encrust on artificial substrate of transplants was recorded every month. From the three different locations, the fastest growth rate of coral transplants was found in leeward (2.335E-02 cm day^{-1}), and the lowest was found in goba (0.0727E-02 cm day^{-1}). From the three different species, the most rapidly growth was found in *A. formosa* (1.549E-02 cm day^{-1}), *A. acumilata* (1.536E-02 cm day^{-1}), and *A. donei* (0.569E-02 cm day^{-1}). The mortality rate of coral transplants were : goba-64.44%, leeward-8.89%, and windward-2.22%. Coral transplants with three branches treatment was increasing more rapidly compare to the single and two branches. *A. donei* in winward was encrusted more rapidly compare to the other species.

D1 STATUS

THE CONDITION OF CORAL REEFS IN PAPUA NEW GUINEA.

Allen, GR*, A Anas, M Huber, A Jenkins, BL Kojis, U Kolkolo, G Kula, L Kumoru, P Lokani, T Maniwavie, PL Munday*, J Opu, NJ Quinn, M Srinivasan. *School of Marine Biology and Aquaculture, James Cook University, Townsville, QLD, 4811, Australia. Email: philip.munday@jcu.edu.au

Papua new guinea (png) provides an important opportunity for the conservation of significant areas of coral reefs in the western pacific region of maximum marine biodiversity, before they become severely impacted by local anthropogenic activities. Png's coral reefs are characterised by high species diversity, with the number of fish and coral species recorded during rapid ecological surveys often among the highest in the pacific region. The diversity of most other marine organisms is poorly documented. Recent surveys and anecdotal accounts indicate that most reefs are in good condition. Most reefs surveyed in the past few years had relatively high coral cover and little evidence of damage from human activity. In addition, reef fish populations are generally thought to be harvested below sustainable levels. There is, however, good evidence of overfishing of sedentary invertebrates and overfishing of reef fishes near large coastal towns. The recorded export from reef fisheries is relatively low in comparison to some other pacific countries but has increased substantially in recent years. Some of the most serious threats to coral reefs in png appear to come from terrestrial activities, such as large-scale forestry and agriculture. The apparent increase in the frequency of bleaching events in png is also of concern. Attempts to assess anthropogenic impacts and threats to coral reefs in png are limited by a lack of data, therefore, the apparent good condition of png's reefs must be considered in this context.

THE STATUS OF CORAL REEF IN THE GULF OF AQABA (JORDAN).

Al-Moghrabi, Salim M.*. *Marine Science Station; PO Box 195; Aqaba 77110 Jordan. Email: Moghrabi_sam@hotmail.com

The Gulf of Aqaba embraces highly diverse coral reef communities, which are one of the northernmost extensions of the world's coral reefs. The Jordanian coastline covers about 27 kilometer along the northeastern part of the Gulf characterized by reefs of the fringing type. It is the only maritime exit for Jordan and actively used for industry, Port activity, transportation and tourism. Furthermore, natural disturbances like bio-erosion, predation, diseases and extreme low tides affect the reef communities in the Gulf. A very high number (212 m^{-2}) of the predatory muricid gastropod *Drupella cornus* was recorded from the Gulf of Aqaba in 1994. Black Band Disease was found to infect 61 colony, within a circle of 10 m in diameter, at the industrial area compared with 6 colonies at the marine reserve. In addition, the reef flats are subjected approximately twice a year, around February and September, to extreme low tides. Nonetheless, the coral reefs in Jordan are still in good conditions. The bathymetric distribution of scleractinian corals was determined at 15 sites along the Jordanian coast using the line intercept technique. Maximum scleractinian coral cover reached up to 90% with a mean cover ranging between 9% and 42%. Furthermore, the crown-of-thorns starfish *Acanthaster planci* is rarely seen and no bleaching events were recorded from the Gulf of Aqaba untill now.

STATUS OF CORAL REEFS OF MEXICO: PACIFIC, GULF OF MEXICO AND CARIBBEAN

Arias GJE*, Bezaury J, Carricart JP, Carriquiri J, Gutierrez CD, Horta PG, Lara PSM, Leyte MG, Medina, P Reyes H, Vargas JM *CINVESTAV-U. Mérida 97310, Mérida, México Email: earias@mda.cinvestav.mx

Mexico has very diverse coral reefs along both Atlantic and Pacific coasts, which are threatened by poorly regulated fisheries and coastal development. The Veracruz Reef System may be the most heavily impacted in the northern Caribbean from: mining of coral and sand; chemical and sewage pollution; overfishing; unrestricted tourism; oil spills and ship groundings; and natural freshwater inflows, winter cold fronts and high solid suspended matter. Campeche Banks are well conserved platform reefs, except for Cayo Arcas which is damaged by oil shipping and extraction, and nearby large-scale fisheries. The most important Mexican reefs extend 350 km along Quintana Roo being part of the Mesoamerican Reef System (through Belize, Guatemala and Honduras) consisting of fringing or discontinuous coastal type reefs. Tourism is approximately 70% of the Quintana Roo State economy concentrated in the north (Cancún, Isla Mujeres, Cozumel and the Cancún-Tulum Corridor). Most reefs are threatened by explosive tourism growth, except for Sian Ka'an and Chinchorro Biosphere Reserves and isolated reefs. Pacific reefs are small and localized with mostly natural stresses, such as El Niño coral bleaching and hurricanes. Human impacts are increasing with some tourism in Huatulco and Puerto Vallarta. Reef management is poor in Mexico, but community and governmental efforts are increasing and 8 of 12 coral reef protected areas were created after 1994. Mexico is active in the Meso-American Coral Reef and ICRI Initiatives and has formed a National Coral Reef Scientific and Technical Advisory Committee (STAC).

A 4-YEAR CORAL STATUS MONITORING IN THE SITES OF THE COASTAL ENVIRONMENT PROGRAM IN CENTRAL VISAYAS, PHILIPPINES.

Bagalihog, Solon D.*, Rizaller C. Amolo And Homer Hermes Y. De Dios. Department Of Environment And Natural Resources, Mandaue City, Philippines 6000. Email:ECOSCI@MOZCOM.COM

Coastal environment program of the department of environment and natural resources was implemented in 1993 to manage sustainably the country's marine and coastal resources and protect marine biodiversity through the active participation of the local community. To asses impact of the coastal resources management interventions of the program, annual monitoring of the marine resources was conducted in eight (8) sites in central visayas, philippines. These sites were distributed in the 4 provinces of the region. This paper presents the results of the coral reef status in a 4-year time frame. The monitoring were done in the established marine protected areas and other areas with relative good live hard coral cover in these identified sites. Line intercept transect method (english and wilkinson, 1994) was used to determine coral cover and other components of the benthic community. Monitoring was conducted from 1996 to 1999. Status of corals were determined based on its percentage live coral cover. Results showed that status varied in every site in different years of the monitoring. Coral falls under poor to excellent category with a percent cover ranging from 7.6% to 91%. However, significant increased of live cover was noted on corals ranging from 0.3% - 37.35%. A uniform decreased of cover was noted in most sites in 1998 attributed to the coral bleaching event brought about the el niño phenomenon.

CORAL COMMUNITIES OF THE NORTHERN GULF OF ADEN: A STUDY OF VARIATION IN COMMUNITY STRUCTURE RELATED TO ENVIRONMENTAL FACTORS.

Benzoni F.*, Bianchi, C.N., Morri, C. *Civico Acquario e Stazione Idrobiologica di Milano, Piazza San Fedele 35, 22100 Como, Italy. Email: zerozero@tin.it

Until recently coral communities of the Gulf of Aden have been almost entirely unstudied, but were believed to be sparse and poorly developed due to the effects of the cold, nutrient-rich water of the Arabian Sea upwelling. Recent studies have shown that although biogenic coral reefs are very rare in the northern Gulf of Aden, previously unexpected extensive and high cover coral carpets occurred in a number of areas throughout the region. In early 1998 a total of 29 sites with high coral cover were surveyed in the north-eastern Gulf of Aden. The benthic community at each of these sites was surveyed using replicated line-intercept transects, recording life-form categories, and with dominant hard and soft corals identified to genus. Environmental parameters including depth, degree of exposure, horizontal visibility, substrate topography and geographic location were recorded for each site. Data were analysed using classification and ordination techniques. Geographic location and depth appear to be the major factors influencing benthic community structure in this region. Striking patterns along the surveyed region and features as the presence of extensive monospecific coral areas suggest the need of further investigation.

DEVELOPMENT AND STRATEGY OF WESTERN INDIAN OCEAN REGIONAL CORAL REEF NETWORK (ISLANDS STATES) IN THE GCRMN

Bigot* L., Charpy L., Aumeeruddy, R., Abdou Rabi, F., Maharavo, J., Paupiah, C.V. *ARVAM, 14 rue du stade de l'Est, 97490, Ste Clotilde, Ile de La Réunion Email: arvam@guetali.fr

The overall objective of the Regional Environment Program of the Indian Ocean Commission (PRE-COI/EU) is to promote a regional policy for the sustainable management of the natural resources in the five member states: Comoros, Madagascar, Mauritius, Réunion Island, Seychelles. In particular, the program provides support for national policies on Integrated Coastal Zone Management (ICZM), and encourages the development of a coherent global approach to the management of natural resources in these island states. Coral reefs of IOC countries are subject to increasing pressures, particularly from human activity. As a result, the monitoring of these ecosystems has become a major priority for the COI countries. Therefore, a reef-monitoring program was launched in 1997 through a regional reef monitoring network based on a methodological handbook (in French and English) entitled 'Coral Reef monitoring in the Southwest Indian Ocean' and a specialized reef database 'Armdes-COI'. Today, 44 stations are being surveyed and the IOC reef network is now a node of the GCRMN for the South Western Indian Ocean islands. Results, strategy and enforcement, funding and recommendations of this network are finalized within a regional report for 1999-2000 developed by the PRE-COI/UE. Methodologies, results of the survey monitoring and other information about the Regional program are also available in a CD-ROM (French and English) launched in April 2000.

STATUS OF THE CORAL REEFS AND CORAL COMMUNITIES OF THE BAY ISLANDS (HONDURAS, CARIBBEAN SEA).

Bouchon, C*, de Lavigne, S.; Bouchon-Navaro, Y.; Louis, M.; Thompson, W.; Portillo, P. *Laboratoire de Biologie animale, Université Antilles-Guyane, BP 592, 97159, Pointe-à-Pitre, Guadeloupe. PMAIB, Consortio Safège-Moncada, Roatán, Honduras. Email: claude.bouchon@univ-ag.fr

The Bays Islands (Utila, Roatán and Guanaja) located off the continental coast of Honduras are surrounded by well-developed coral reefs, which geographically belong to the Meso-American Reefs. The coral communities of these reefs were qualitatively studied in 56 stations. Nine stations were investigated using a line-transect technique in order to establish the quantitative structure of the benthic communities. Forty-five species of coral were identified. Analysis of the qualitative data revealed different coral assemblages occupying respectively the reef flats, the shallow parts of the outer reef slopes and their deeper parts. Quantitative results showed that the coral coverage rate of the reefs varied from 13 to 33%. Between 50 and 80% of the coral colonies presented signs of necrosis of their living tissues and the total surface representing the dead parts of the colonies fluctuated between 34 and 73%. Algae occupied between 52 and 85 % of the reefs. The causes of this worrying situation are a bleaching event, which occurred in 1998 and induced an important mortality of corals, associated to an eutrophication of the coastal waters of the islands, which favors the development of algae to the detriment of corals.

ASSESSMENT OF CORAL REEFS IN THE WESTERN PART OF THE GULF OF THAILAND.

Chankong A.*. Chumphon Marine Fisheries Development Center, Moo 8, Paknam, Muang District, Chumphon, 86120 Thailand. pmbcnet@phuket.ksc.co.th

Survey of reefs along in the western part of the Gulf of Thailand to map reef location, boundary, area and study reef condition was carried out in 1995-1997. Reefs along this area are mainly fringing reefs. Due to geographical variation, they are arbitrarily groups into 3 groups: fringing reefs on the island groups are the most common reefs found under this study, fringing reefs along the shoreline of mainland and patch reefs in mid waters. Together reefs are found in 130 islands, which are about 94 % of islands under investigation. Total area of coral reefs is about 47 square kilometers. Base on information available until 1997, the condition of coral reefs in the western part of the Gulf of Thailand were almost fair to excellent, consist of the percentage covering of life coral on reef slope 40-90 % and dead coral 10-50%. The species compositions of coral reefs in the middle part of the western part of the Gulf of Thailand were more variable than the species composition of coral reefs in the north. In comparing with available information from the past, the overall condition of coral reefs in 1995-1997 were worse than in 1987-1991, especially in the middle part of area under investigation. The main causes of damage of coral reefs were storms. Other causes were man made activities such as boat anchoring and destructive fishing practice.

CORAL REEF MAPS OF THAILAND

Chansang H.*, *et.al.* Phuket Marine Biological Center, PO Box 60 Phuket 83000 Thailand. Email: pmbcnet@phuket.ksc.co.th

During 1995-1998 coral reef mapping in Thai waters both in the Gulf of Thailand and the Andaman Sea were conducted with the objectives of producing coral reef maps which include distribution of coral reefs in Thai waters, extent of reefs, reef condition and general morphology of reefs. Field surveys were conducted by using manta tow technique Reef maps were made on scale 1: 10,000 and 1: 15,000. Reef conditions are expressed as excellent, good, fair, poor and very poor base on ratio of live and dead coral cover. The total 251 islands and reef sites in the Gulf of Thailand were surveyed and mapped and the total 169 island and reef sites in the Andaman Sea. All reefs reported are fringing reefs which vary on extent and scale. However most are small fringing reefs with area less than 1 km^2. The total reef areas in Thai waters are 453.46 km^2 i.e. 74.90 km^2 in the Gulf of Thailand and 78.56 km^2 in the Andaman Sea. In the Gulf of Thailand during 1996-1998, reef conditions were as follow : 16.4% excellent, 29.0% good, 30.8% fair, 10.9% poor and 12.9% very poor. Thus condition of reefs in the Gulf of Thailand became more degraded than during 1980s. For reefs in the Andaman Sea during 1996-1998, reef conditions were as follow : 4.6% excellent, 12.0% good, 33.6% fair, 26.5% poor and 23.3% very poor. However comparing with condition of the same reefs in previous years most reefs in the Andaman Sea during 1996-1998 were either in the same condition or better than during 1989-1993.

STATUS OF CORAL REEFS OF SINGAPORE.

L.M. Chou * and Jeffrey K.Y. Low. Dept of Biological Sciences, Faculty of Science, National University of Singapore, Blk. S2, 14 Science Drive 4, Singapore 117543. Email: dbsclm@nus.edu.sg

Singapore reefs show the impact of over four decades of land reclamation and coastal development. Sedimentation rates as high as 44.64 g cm^{-2} day^{-1} reduced visibility from 10m in the 1960s to 2m today. The problem shows no sign of abatement causing live coral cover to decrease at almost all sites monitored since 1986. Live coral cover at Lazarus Island, close to a high sediment source, dropped from 60.7% to 21.48% in seven years. The outermost reef at Pulau Satumu with less sedimentation impact also registered a decrease in live coral cover from 76.35% to 48% in ten years. The widespread bleaching event of 1998 affected Singapore reefs on a scale never observed before. Exceptionally elevated water temperature up to 35^0 C coinciding with low tides, resulted in 90% of hard corals bleached of which 25% failed to recover. Overall reduction in the total percent live coral cover through bleaching was most evident at the reef crest. Recovery rates varied between genera and growth form. The submassive coral, *Goniopora*, showed the most complete recovery, while massive corals recovered at a slower rate.

CHANGES IN REEF CORAL COVERAGE AT KAHE POINT, OAHU, HAWAII DURING 19 YEARS OF MONITORING.

Coles, S.L.* and Brown, E.. *Bishop Museum, 1525 Bernice St., Honolulu, HI 19673, USA. Email slcoles@bishopmuseum.org

Coral coverage on 10 quadrats at each of four stations near kahe point, leeward oahu was measured yearly from 1981 through 1999 by re-photographing marked areas on the reef. This 19-year period included the occurrences of two major hurricanes, which impacted the area in 1982 and 1992, and other periods of high wave turbulence. Repeated measures anova indicates significant differences among stations, time and station-time interaction that correspond to different periods of ocean turbulence at three of the stations. By, contrast, no significant change in coverage with time occurred at the station closest to the thermal outfall of the kahe power station. Hurricane-related decreases in coral coverage are indicated which extended well after the times of the storms. Lag time for the onset of recovery in coral coverage after a major disturbance was two to five years.

CHANGES IN THE CORAL REEFS OF COSTA RICA.

Cortés J.* *Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Ciudad de la Investigación, Universidad de Costa Rica, San Pedro, San José 2060, Costa Rica. Email: jcortes@cariari.ucr.ac.cr

Costa Rica is located on the Central American Isthmus and has coral reefs on the Caribbean and on the Pacific Ocean. Some of these reefs have been studied for the last 20 years and significant changes have been observed. On the Caribbean coast, live coral coverage at one reef has dropped from 40 to less than 10% due to sedimentation. Other reefs on that coast have been affected by anthropogenic (coastal development, sewage and increased tourism) and natural causes (warming events, diseases and coastal uplift). On the Pacific side, coastal reefs have been affected mainly by human activity (deforestation, coastal development and organisms extraction) and by natural causes (warming events), while offshore reefs have been impacted, almost exclusively, by natural phenomena (warming events and phytoplankton blooms). In all cases reductions of live coral coverage has resulted but in reefs with only natural impacts, recovery has been recorded.

THE STATUS OF CORAL REEFS IN VENEZUELA

Cróquer–Pedrón, Aldo*. *Universidad Simón Bolívar, Caracas – Venezuela. Email: croquer@telcel.net.ve

Venezuela has 2875 km of coastline; approximately 67% are in the caribbean sea and 33% in the atlantic ocean. The highest reef development in venezuela is reached in the oceanic islands, such as archipiélago de aves, archipiélago los roques, la orchila and la blanquilla. There is a lack of updated information about the status of coral reefs in most of these oceanic islands. The main species reported so far are *montastraea annularis*, *m. Faveolata*, *colpophyllia natans*, *diploria strigosa* and healthy populations of *acropora palmata* and *a. Cervicornis*, although 58 species have been reported to los roques national park. Coral communities are common at the islands of the venezuelan continental shelf like margarita, coche, cubagua, islas caracas, islas chimanas, islas borrachas and isletas de piritu. In these areas, reefs could arise but their development might be limited by upwelling conditions. Regarding the venezuelan mainland, the best development of reef communities used to be found at morrocoy national park, prior to the mass mortality event occurred on january 1996, live coral cover ranged from 35 to 45 %; today coral cover lost reach 98 % in some reefs. In mochima national park, corals are quite abundant but reefs are not important, a total of 26 coral species has been reported so far.

AN INTEGRATED SURVEY OF COLOMBIAN CORAL REEFS

Díaz J.M.*, Fernando Parra-Velandia, Mateo López-Victoria, Lina M. Barrios and Fernando Zapata. *Instituto de Investigaciones Marinas y Costeras, Santa Marta, Colombia, A.A. 1016. Email: jmdiaz@invemar.org.co

The 23 Recent reef areas occurring in Colombia occupy a total surface of about 2,850 km^2 (including besides living coral also other associated habitats). More than 98% of this surface corresponds to 20 reef areas in the Caribbean, whereas Pacific reefs are small and patchy in distribution. In the Caribbean, nearly 75% of the surface is represented by 7 oceanic atolls and reef-complexes, around 700 km. off the Colombian continental coast. Along the Caribbean mainland coast, reefs are best represented in three offshore areas in the central region. Twenty one habitat types, including 14 coral associations, were recognized on the basis of dominant sessile biota and substrate features. The diversity of habitats and coral species between the areas is more related to the variety of wave exposure regimes within areas as wells as to reef morphology and water turbidity rather than to the size of the areas. The 23 areas were classified into eight categories: (1) Five Caribbean oceanic banks and atolls with high diversity; (2) two Caribbean oceanic reef-complexes with very high diversity; (3) five Caribbean offshore reef-complexes with very high diversity; (4) one Caribbean coastal area with high diversity; (5) one Caribbean coastal area with medium diversity; (6) six Caribbean coastal/offshore reefs and coral carpets with low diversity; (7) one Pacific oceanic reef with low diversity; (8) two Pacific coastal/offshore reefs with medium diversity. The representativity of these categories and of the habitat types within the existing marine protected areas in Colombia is discussed.

LONG-TERM MONITORING OF THE FLOWER GARDEN BANKS CORAL REEFS; GULF OF MEXICO, U.S.A.

Dokken Q.R.* Ian R. MacDonald, John W. Tunnell, Jr., Carl Beaver, Susan Childs. Center for Coastal Studies, Texas A&M University-Corpus Christi, 6300 Ocean Drive, Corpus Christi, TX 78412,USA. Email: dokken@falcon.tamucc.edu.

The Flower Garden Banks (FGB) in the northwestern Gulf of Mexico comprise the most northerly coral reefs on the continental shelf of North America. Sitting atop geological peaks that rise from the seabed at a depth of 122 m, the upper most surface of the corals is at 18 m, and the deepest coral growth is at 36 m. These reefs are relatively isolated, approximately 180 km from the nearest land. Combined, these banks support approximately 204 km^2 of coral habitat. Coral coverage exceeds 50% at each bank. Coral diversity, with 23 species, is low – dominated by *Montastrea* spp. and *Diploria* spp. Compared to the nearest coral reefs of the Florida Keys, southern Gulf of Mexico, and Caribbean Sea, the FGB are a healthy habitat only minimally showing signs of bleaching, disease, and anthropogenic impacts common on the more southern coral reefs. Bleaching is sporadic, not massive, and confined to a short period usually near the end of August. Disease is found on less than 1% of the coral colonies. As a National Marine Sanctuary, human impacts are strictly controlled; and, isolated from land, non-point source impacts are virtually non-existent. Intense monitoring efforts have been underway since 1989, including photographic measures of coral coverage, coral growth, substrate cover by non-coral flora/fauna, water quality, and herbivore populations. The monitoring strategy is continuously critiqued and upgraded to provide the most effective database for management.

CORAL REEFS IN THE INTERNATIONAL BIODIVERSITY OBSERVATION YEAR: 2001-2.

Done TJ*, Ogden, JC, Wilkinson CR, Hodgson, G, Linden, O. *Australian Institute of Marine Science, PMB #3, Townsville MC. Qld., Australia. Email Address: t.done@aims.gov.au

The coral reef community is invited to become involved in IBOY - the International Biodiversity Observation Year of 2001-2 (www.nrel.colstate.edu/IBOY). IBOY is an initiative of Diversitas, a international program for biodiversity science sponsored by a raft of international agencies. The authors have proposed a project entitled 'The Recovery of Coral Reef Biodiversity Following Bleaching'. The project aims are to establish the extent to which coral reefs have recovered from the globally widespread coral bleaching of 1997-8, associated with the warmest sea surface temperatures of the 20th Century. We plan to work through international coral reef networks such as CARICOMP, CORDIO, GCRMN and Reef Check. We will ask participants to apply simple field and database protocols to produce a useful data set with a global scope. Observers will record the abundance and size of small corals easy to see with the naked eye to complement standard observations on coral cover and damage. This project is significant because by 2001, the places and extent to which natural processes are beginning to restore coral growth and diversity should be starting to become evident. There is great concern that natural recovery processes will have been compromised by widespread and direct human degradation of coral reefs, their local environments, and their resources. Your observations will contribute to an important report at a critical time for coral reefs.

BASELINE STUDIES OF THE NINGALOO REEF TRACT

, B.M.* and Miller, Ian R. *Australian Institute of Marine Science, PMB No. 3, Townsville, QLD 4810, Australia. Email: b.fitzpatrick@aims.gov.au

The Ningaloo Reef Tract runs for nearly 270km along the North West Cape of Western Australia. Its the longest fringing reef in Australia. Scientific studies of its marine ecosystems are limited to small geographical scales or are species specific. In June 1998 a long-term study of coral communities commenced. Participants in the 1999 re-survey included the Australian Institute of Marine Science and the Western Australian Departments of Conservation and Land Management and Environmental Protection. Sampling was conducted at a fine scale using transect methods including visual fish census and underwater video; and at a broad scale using manta tow. The coordinates of study sites were plotted using GPS. Results show, low to moderate coral cover typifies the Ningaloo Reef Tract. Coral cover is generally highest around drainage channels that intersect the reef crest and drain the lagoon. Coarse calcareous sand and a moderate to high cover of algae dominate the benthos. The results of this study are still in analysis however they will contribute towards revision of the Ningaloo Marine Park Management Plan.

STATUS OF CORAL REEFS OF PALAU.

Golbuu, Yimnang.* *Palau Community College-Cooperative Research and Extension, P.O. Box 9, Koror, Palau 96940. Email: ygolbuu@yahoo.com

Palau has the most diverse coral fauna of any other areas in Micronesia. Within the whole Indo-Pacific region, Palau's coral diversity is comparable to the highest coral diversity areas of the Philippines, Indonesia, and Australia. Within Micronesia, Palau has the most number of reef fish species. Before 1998 bleaching event in Palau, the remote reefs were generally healthy and in good condition. The reefs closer to population centers or areas where developments are occurring were showing signs of degradation due to anthropogenic disturbance. After the bleaching event, most reefs in Palau were severely affected. There was high mortality of corals from the bleaching. Mortality varied considerably by taxonomic group and habitat, with offshore reef slopes having the highest mortality. Corals in the genus *Acropora* were especially susceptible to bleaching and in many places mortality was high. The reef fish populations in the main islands of Palau are showing signs of overfishing compared to the Southwest Islands where there are less fishing pressures. Highly desirable species of fish are either absent or present in low numbers in the main islands compared to the Southwest Islands of Palau. The main natural threats to Palau's coral reefs are crown-of-thorns and warming of seawater temperature. Anthropogenic threats include erosion and sedimentation due to poor land use practices, overfishing, sewage outfalls and dredging.

STATUS OF THE FISH COMMUNITY OF THE TURKS AND CAICOS ISLANDS: RESULTS FROM THE ATLANTIC & GULF RAPID REEF ASSESSMENT (AGRRA).

Hoshino, K. *, C. Manfrino, B. Riegl, & S.C.C. Steiner. *Bren School of Environmental Science and Management, University of California, Santa Barbara, Santa Barbara, CA 93106-5131. Email: khoshino@bren.ucsb.edu

Coral reef fish communities were surveyed at 28 sites in the vicinity of the Turks and Caicos Islands (TCI) and the Mouchoir Bank in August 1999, using the AGRRA protocol. This study provides the results of the fist systematic census of fish communities in TCI, which are located at the southeastern extent of the Bahamian Archipelago. Two census methods were employed for this study. Belt transects was used to determine abundance and size distribution for selected fish families and Roving Diver Technique was used to measure overall fish diversity and density. The surveys revealed that TCI have a healthy reef fish community with a total of 43 species recorded in transects and 120 species by Roving Diver Technique surveys. Comparison among the locations (Grand Turk, South Caicos, West Caicos, Providenciales and the Mouchoir Bank) revealed that West Caicos had higher fish density, larger size of fishes and higher species richness than other locations. In contrast, the Mouchoir Bank had lower density and smaller size in most fish families with the lowest species richness. High fishing pressures there appeared to have impacted the fish community structure. The overall results suggest that current fishing pressure is generally low in TCI, and coral size and diversity appear to play an important role in structuring the fish community.

MARINE MONITORING OF THE COMMONWEALTH OF THE NORTHERN MARIANAS ISLANDS.

Houk, Peter.* *Division Of Environmental Quality, P.O. Box 501304, 3rd Floor Morgan Bldg., Saipan, Mp. 96950. Email: p_houk@hotmail.com

Marine monitoring in tropical areas has helped scientists and managers to better understand coral reefs and the environmental factors that affect them. Over the years techniques have improved due in part to global cooperation and sharing of information. Better monitoring techniques lead to better data collection, which in turn leads to more answers for questions and solutions for problems. The Commonwealth of the Northern Marianas Islands (CNMI) consists of a chain of several islands located along the Marianas Trench, southeast of Japan. CNMI's marine monitoring plan consists of gathering baseline data of the benthic and fish community, and using a GIS system for displaying the results by location. Specifically, benthic cover is estimated using video surveys and in situ quadrats analyzed to the genus level, coral communities are looked at using point quarter techniques to species level, and fish abundance and diversity are estimated using belt transects and random swims. In addition water quality measurements consisting of temperature, turbidity, sedimentation, salinity, pH, dissolved oxygen, and ecoli counts, are continuously recorded from monitoring stations. These data will help to understand and assess changes, differences, and problems in the various reef communities that may occur over time. In addition, when proposals are submitted for development projects to the Division of Environment Quality these baseline data will aid in making recommendations to insure minimal environmental impact. While the Australian Institute of Marine Science has standardized methods for surveying reefs, there is a need for standardizing entire marine monitoring programs.

A RESEARCH ON THE CHANGE OF CORAL REEF ENVIRONMENT IN ISHIGAKI ISLAND OF SOUTHERN RYUKYU ISLANDS

Ichikawa K.*. Hasegawa, Hitoshi; Mezaki, Shigekazu;. Nakamori, Toru;. Sagawa, Natsume;. Sato, Takanori;. Suzuki, Rintaro.; Abe, Teruko;. Kobayashi, Miyako.; Hirota, Kiyoshi;. Kobayashi, Takashi;. Yasumura, Shigeki;. Hoshino, Makoto. *Department Of Geography, Kokushikan Univ., Setagaya, Tokyo, JAPAN. Email: YHQ01474@nifty.ne.jp

We have carried out the investigation of coral reef environment in every five years since 1989 in Ishigaki Island of southern Ryukyu Islands. This area is rich in the variety of a creature look, and corals grow in the high density. It paid attention to such a coral reef environment, and that area character had been analyzed. Investigation did the visual observation of the constant time about Twenty-seven places around Ishigaki Island. The range of covered with living coral , the life style of corals, regenerated conditions, a kind of *Chaetodontidae* and *Pomacentridae* and the number of individuals were examined along with it. It was recognized that the aggravation of coral reef environment progressed on the whole due to the progress of the past ten years. The influence which the food harm of *Acanthaster planci*, those recovery conditions and soil drain gave to it was explained at 1989 and 1994. And, it was proved that even the point where the growth of coral was good suffered big damage due to the bleaching in 1998. It became clear that the recovery of corals weren't sufficient from bleaching.

STATUS AND CONDITION OF CORAL REEFS IN SOME LOCATION IN INDONESIA FOR THE PAST TEN YEARS (1990-2000).

Iskandar, Febriany*, *Flamboyan II no 16-Depok Jabar-Indonesia Email : ade.fee@mailcity.com

As a country wich located in a tropical area, Indonesia has a very high biological diversity. Among them is, the diversity coral reefs, wich spreads out in all Indonesias oceanic waters from Sabang to Merauke. Coral reefs can be catagoried as a spesific oceanic tropical ecosystem wich has a very important function such as physic, biological and also chemical function. As a physical function the coral reefs is a natural protection along the coast line, as a biological function the coral reefs helps many organism in providing habitats for their living, and as chemical function the coral reefs are provider of medical aparatus and also cosmetic aparatus. Managing coral reefs in an integrated manner is needed to maintain the existence of the ecosystem, so that it can be usefull in time. To obtain certain aim in managing it requires a complete and accurate data. The existence of coral reefs which spreads out widely in all Indonesia's oceanic waters caused the hardness of collecting complete data. Through scientific research in some areas of coral reefs has been done by many authorities, either government or non government authorities. The result of scientific research are usually kept by certain authority and are not compillated publicly so that it's hard to have the real picture of the coral reef's condition of Indonesia comprehensively. The efforts in compilating data into such information is hopefully usefull as a reference in taking responsibilities action on managing the coral reefs area.

STATUS OF CORAL REEFS OF JAPAN.

Kawagoe Hisashi* *International Coral Reef Research and Monitoring Center, The Environment Agency of JAPAN, Yashima-cho, Ishigaki-City, Okinawa, Japan.

The Japanese Islands are located in the western Pacific Ocean and form a long island arc extending north to south for over 2,800km. Most of reefs of Japan distribute at Nansei Islands and Ogasawara Islands, which are classified as fringing reefs. Approximately 400 species of the hermatypic corals have been reported in Japan. As the results of "4th National Survey on the Natural Environment" conducted by the Environment Agency in 1990-1992, it revealed that the coral communities cover approximately 34.2 thousand-hectare in moats in Nansei Islands. In Ogasawara Islands, coral communities covering 456 hectare were recorded. Even for the waters around main land Japan where no coral reefs are found, the area of coral communities is approximately 1,400 hectare. In the summer of 1998, there were severe coral bleaching events ever observed around southern part of Japan. The damage ratio on bleached coral was 70 to 90% south from Yoron Island and 30 to 60% north from Yoron Is. The fisheries statistics for coral reef fishes in Okinawa Prefecture indicate the tendencies of decrease in both catch and number of fishing units in several recent years. The anthropogenic threats to coral reefs in Japan include terrestrial run-off of the red-soil, development in coastal areas and land reclamation etc. For conservation of coral reef ecosystems, 23 marine parks in the coral reef areas were designated under the Natural Parks Law. The total area of these marine parks cover 1,615.5 hectare, which is estimated to be approximately 1.7% of the coral reef area in Japan.

STATUS OF THE CORAL REEFS OF LAKSHADWEEP, INDIA.

Koya M.S. Syed Ismail *, M. Wafar and E.V. Muley Department of Science and Technology, Kavaratti island P.O. U.T. of Lakshadweep, 682 555, India Email: dst@hub1.nic.in

The Lakshdweep islands, with 12 atolls, 5 submerged banks and 36 islands, lie off the central west coast of India. The reefs are important to the local population mainly in terms of fisheries and building material. Though the reefs were healthy two decades back, continued human interference and the bleaching in 1998 have caused a severe loss of coral biodiversity. Recovery is still not significant. The major fishing activity is for tunas and sharks. Fishing in the reefs and lagoons is only for sustenance. Recreational fishing and ornamental fish trade do not exist. The main causes of decline in coral health, at least in shallow waters, are coral mining, collection of souvenir corals and shells, dredging for navigational channels, resuspension of silt consequent to mechanized boat traffic, unsustainable fishing practices, especially for bait fishes, and non-respect of carrying capacity. Neither the local government agencies nor the local population seem to have realized the impacts of the 1998 bleaching. No atoll in the Lakshadweep has been declared so far as protected though ban on coral removal and hunting for some marine animals like turtles and dolphins exist. Despite the ban, coral removal still occurs regularly. As of now, there is no clear management strategy and systematic monitoring has only now begun. The current status of the coral reefs at Lakshadweep is far from satisfactory. Still it is possible to reverse the situation provided some serious collective efforts on the part of all stakeholders are made.

PHILIPPINE CORAL REEFS, REEF FISHES, AND ASSOCIATED FISHERIES: STATUS AND RECOMMENDATIONS TO IMPROVE THEIR MANAGEMENT.

Licuanan W.Y.*and E. D. Gomez Biology Department, De La Salle University 2401 Taft Avenue, Manila, Philippines. Email: licuanan@edsamail.com.ph

Philippine reefs are among the richest and most diverse in the world and has a considerable contribution to the nation's economy in the form of fisheries, tourism, and coastal protection. Despite the increased awareness about local reefs and the ensuing management and conservation efforts, the present inventory show that only 4.3% of the reefs are in excellent condition (at least 75% live coral cover), with an overall average of 32.3% hard coral cover. *Acropora* covered only an average of 8.1%. Patterns in changes suggest that the reefs in the Visayas (central Philippines) are most at risk. Destructive fishing (blast fishing, cyanide fishing, muro-ami, etc.) and poor land management leading to sedimentation and poor water quality remain the primary causes of reef declines, which appear related to sizes of nearby populations centers. Blast fishing has moved on to farther, less depleted areas. Cyanide fishing also appears to have also declined, driven by testing and education programs. Increased vigilance remains necessary however. The 1998-99 bleaching event has been unprecedented, affecting most reefs in northern Luzon (which appears hardest hit), Palawan, most of the Visayas, northern and eastern Mindanao. Impacts due to *Acanthaster* and druppelids remain unstudied.

STATUS OF CORAL REEFS IN THE FEDERATED STATES OF MICRONESIA.

Lindsay, SR* & Edward, A,.*Micronesian Aquaculture & Marine Consultant Services, PO box 2178, Kolonia, Pohnpei, FSM. Email: slindsay@mail.fm

The condition of reefs within the FSM are in good to excellent health with natural processes controlling reef condition and natural reef biodiversity. There is growing concern, especially in the urban centers of reef degradation and the loss of reef biodiversity due to various anthropogenic sources. Localised coral reef dredging, sandmining and deforestation have contributed to increases in sedimentation and eutrophication of reefs whilst overfishing, destructive fishing practices and lack of community reef preservation awareness are depleting resource stocks. Reef damage from petrochemicals and ship groundings have only been recorded in isolated cases. Recent community awareness programs highlighting specific management plans through education and enforcement and the development of new marine conservation legislation and marine conservation plans are positive steps towards reducing negative anthropogenic impacts. There is a real need to enhanced capacity building for marine environmental managers and the community at large. The establishment of protected areas, conservation parks and well developed coral reef management plans will help to protect coral reefs within the FSM. The development of commercial activities such as mariculture, eco-tourism and fisheries are encouraged if properly planned, implemented and managed.

A DECADE OF CORAL REEFS MONITORING OF THE SIAN KA'AN BIOSPHERE RESERVE, MEXICO.

Loreto R. M*, Lara M, Padilla C. and Gutiérrez, D. AMIGOS DE SIAN KA'AN A.C. A.P. 770, Cancún 77506, Q.Roo, México. Email: sian@cancun.com.mx

The sian ka'an biosphere reserve (skbr) was declared in 1986 to protect reef and wetland systems. The northern fringing reefs of skbr comprise exceptional reef zones, in terms of scleractinian cover and diversity as well as topographic complexity. Since 1992, have been implementing a coral reef monitoring program in this region of skbr to define reef condition as input to the reserve´s a conservation strategy and management initiatives. The methodology uses belt-quadrant and linear transects in 3 permanent stations. The reef assessment utilizes to 3 indicator organisms: macroalgaes, scleractinians and fishes, as well as water temperature. To scleractinians were register living tissue, density, maximum large and wide per colony and general condition (bleaching, diseases, fouling). To macroalgaes coverage per species and fishes density and size. Monitoring has provided information on coral condition due to significant natural events. In 1995, hurricane roxanne hit approximately 12 km south of the monitoring sites with little affects since the offshore winds reduced waves and tide impacts. During the 1998, bleaching phenomena, impacts were sited within the study area. Observations showed that some coral colonies were bleached within the monitoring sites. Other results indicates that variations in coral coverage are cyclic, however, there is no statistical significance.

STATUS OF THE REEFS IN THE CAYMAN ISLANDS.

Manfrino, C.*, B. Riegl, C.V. Pattengill-Semmens, J.L. Hall, B. Semmens, K. Hoshino, R. Graifman, C. Hermoyian. Kean *University, Department of Geology and Meteorology, 1000 Morris Avenue, Union, New Jersey, 08540. Email: ckievman@turbo.kean.edu

As with many of the reefs in the Caribbean, the reefs in the Caymans have been under continuous natural and anthropogenic stresses (80 % of the corals on the walls were bleached in 1998). In June, 1999 the reefs around Little Cayman and Grand Cayman Islands were assessed using the AGRRA protocol at 33 sites. A total of 4521 corals in 330 transects, 1807 algal quadrats, and 341 fish transects were measured. Assessment and habitat data are presented in a GIS. The coral reefs of the two Cayman Islands appear to be in similar good condition but there are some differences. Differences include higher frequency and average cover of macroalgae and higher incidence of coral diseases on Little Cayman. Algal competition does not appear to be a problem for corals at most sites. Thirteen (87 %) of the sites on Grand Cayman had standing dead coral and only 4 sites (22 %) on Little Cayman. Recent coral mortality was twice as high on Grand Cayman as on Little Cayman (5.0 % vs. 2.1 %). Coral recruitment was patchy, but present, mostly at low levels across the region. Live coral cover averaged 19.8 ± 3.3 % on Grand Cayman and 23.2 ± 5.4 % on Little Cayman. No old *Acropora palmata* stands occur, however, low density patchy new growth occurs frequently. The average abundance of fish was greater and the frequency of certain fish, especially grouper and snapper were up to eight times higher on Little Cayman. Grouper spawning aggregations are still harvested in the Cayman Islands.

MONITORING CORAL REEFS AND SEABIRD POPULATIONS AT THE TUBBATAHA NATIONAL MARINE PARK, PHILIPPINES.

Mejia, Manuel N.* and. Ledesma, Micaela C. *WWF Philippines. 23-A Maalindog St. UP Village, Diliman, Quezon City, Philippines. Email: wwf-pal@mozcom.com

Tubbataha Reef lies in the middle of the Sulu Sea and is one of the last pristine marine areas in the region. Because of its globally significant biodiversity, UNESCO declared it a Natural World Heritage Site in 1993. Over the years, however, Tubbataha has experienced both anthropogenic and natural destruction. To mitigate threats, the Tubbataha Protected Area Management Board and WWF Philippines are implementing conservation measures. Coral, bird and fish surveys were conducted to monitor the Park's ecological condition and to see if these conservation measures were effective and to help in park management decision-making. From 1997 to 1999, total live coral cover at the seven transects decreased by an average of 26%. This decline is attributed largely to the bleaching caused by the 1998 El Niño phenomenon. Interestingly, compared to bleaching reports from near-shore reefs, Tubbataha suffered relatively less damage. In spite of the decrease in corals, fish biomass increased significantly at these sites. Various factors explaining the significant changes in the reef community structure and seabird populations will be discussed. On the other hand, migratory seabird populations have decreased greatly both in terms of numbers and diversity during this time period. This paper offers possible reasons for these observations and explores more effective management regimes and conservation measures for this World Natural Heritage Site.

ASSESSMENT OF CORAL REEFS IN THE EASTERN PART OF THE GULF OF THAILAND.

Monanunsap Somchai *, R. Boonprakob and P. Sinanunt. Sea Turtle Conservation Station, Mannai Island, Klaeng District, Rayong 21190, Thailand. Email: PMBCNET@PHUKET.KSC.CO.TK

Survey on structure and boundary of coral reefs in the eastern part of the Gulf of Thailand was carried out during 1995-1997 using "manta-tow technique". Maps of coral reefs on 95 islands along the eastern part of the Gulf of Thailand were made and reef areas were also estimated. The reef structure could be classified into two patterns, coral reefs on near shore islands and on offshore islands. Total coral reef area estimated on 95 islands is 27.7 km^2. These are mainly are coral reefs on off shore islands. Results from manta tow survey show that 12% in excellent condition, 24.6% in good condition, 31.6% in fair condition, 15.3% in poor condition and 16.4% in very poor condition. Thus it can be said that the condition of coral reefs during 1995-1997 was still fair to good. Information available from the last decade indicated that most of islands in this area used to have excellent coral reefs. The deterioration of some reefs in this area is due to tourism. Besides the impacts related to human activities, coral reefs are also subjected to natural damage. Storms such as typhoon Gay hit to the Gulf of Thailand in November 1989. The latest natural cause of damage in the Gulf of Thailand which caused degradation in many reefs especially in Acropora dominated reefs is coral bleaching that was appeared in 1998.

STATUS OF CORAL REEFS OF TANZANIA

Muhando, Christopher A. and Mohammed, Mohammed S. *Institute of Marine Sciences, P.O. Box 668 Zanzibar, Tanzania Email: muhando@zims.udsm.ac.tz

Coral reef surveys conducted in the 1980s and early 1990s indicated that coral reefs were being degraded by over exploitation and destructive resource harvesting methods, specifically dynamite fishing and dragnets. Recent coral reef surveys (1999 and 2000) indicated that the live coral cover (or healthy of reef corals) has been further degraded by the 1998 coral-bleaching event. The extent of coral mortality differed between areas and species. Although the relative contribution of some species such as Acroporids and Pocilloporids was lowered on most reefs surveyed, there is no evidence of species distinction. Despite extensive coral mortality, there is little evidence to suggest decline on reef fish abundance or decline on fish catch by commercial and artisanal fishers. Coral recovery through growth of the survived coral colonies and new coral settlement has been observed in all sites, but at different levels. *Montipora*, *Echinopora* and some *Fungia* doing better than other species. Full recovery will however depend on incidences of natural and human disturbances in the near future. Appropriate reef management strategies, such as enforcement of existing regulation, backed up by adequate scientific information would help the recovery process. Capacity building and appropriate infrastructure and support for coral reef ecosystem conservation, including declaration of marine protected areas may help protect coral reefs from total collapse.

STATUS OF CORAL REEFS OF INDIA

Muley*E.V., B.R.Subramanian, K.Venkataraman, M.Wafar Ministry of Environment and Forests, Lodhi Road, New Delhi 110 003 Email: muley@vsnl.com

The major reef formations in India are restricted to the Gulf of Mannar, Gulf of Kutchh, Andaman and Nicobar and Lakshadweep Islands. The reefs at present are important to the local community only to the extent of sustenance fishing. The health of corals has been on steady decline mainly due to stress from anthropogenic pressures. Sedimentation, dredging and coral mining are damaging near shore reefs , while the use of explosives and bottom nets in fishing are damaging off shore reefs in specific sites. The bleaching event of 1998 has reduced live coral to about 40-80%. Quantitative data and studies on monitoring health of coral reef are inadequate. Post-bleaching surveys in Lakshadweep and Gulf of Mannar have shown slow recovery of some of the coral species. Impact of bleaching on other reef organisms and reef fisheries have not been evaluated. With a view to monitor health of coral reefs Government of India has recently launched Indian Coral Reef Monitoring Network (ICRMN). Monitoring Action Plans prepared in the first phase of Global Coral Reef Monitoring Network (GCRMN) have been integrated with ICRMN and their implementation initiated. Database Network and Website on Coral Reefs have been launched. Some of the major international initiatives on Indian Coral reefs include UNDP/GEF PDF B Projects on Gulf of Mannar and Andaman and Nicobar Islands and the CORDIO Project. Ministry of Environment and Forests has recently been designated as the National Focal Point of International Coral Reef Initiative (ICRI).

CHANGES IN SPECIES DIVERSITY AND COVERAGE OF CORAL COMMUNITIES DURING ECOLOGICAL SUCCESSION IN ISHIGAKI-JIMA, SOUTHWESTERN JAPAN.

Nakamori Toru * and Kaoru Sugihara. Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Aobayama, Aobaku, Sendai, Japan. Email: nakamori@dges.tohoku.ac.jp

Changes in species diversity of coral communities during ecological succession are reconstructed on the basis of species richness (*S*) / community coverage (*A*) plots obtained by quadrat (1 x 1 m^2) method on the reef flat of the Ishigaki-jima, southwestern Japan. The species richness of the *Acropora formosa* community starts from 0, and attains to it's maximum (9 species) halfway of the succession. It finally decreases due to monopolization by superior species in competition, if the coverages of the communities might keep on increasing as time goes by. The *S/A* curve of *Montipora digitata* community also indicates same pattern as *A. formosa* community. Dynamic model of the species richness and the coverage during the succession is proposed here. Changes in species richness (*S*) is defined as a sum of rates of increasing richness by invasion of new species into a quadrat and decreasing richness by extinction of some species. Richness curve which shows it's maximum at 5 years and converges to several species within duration longer than 20 years was obtained. The similarity of the curve to the actual data strongly suggests that the model reflects the real processes occurred in the coral reef ecosystem.

A LONG TERM CORAL REEF MONITORING IN THE SEKISEI LAGOON, YAEYAMA ISLANDS, SOUTHERN RYUKYUS, JAPAN.

Nomura Keiichi *, Tadashi KIMURA and Hisashi KAWAGOE. *Kushimoto Marine Park Center, 1157 Arita, Kushimoto, Wakayama 649-3503, Japan. Email: alpheus.nomura@nifty.ne.jp

The monitoring of coral reef in the Sekisei Lagoon, Southern Ryukyus, has been carried out every year since 1983 by the Yaeyama Marine Park Research Station. Although the monitoring aimed at effective extermination of crown-of-thorns starfish in the beginning, its purpose has been changed since 1998 for the conservation of coral reefs corresponding to the very low population density of starfish. The method is to observe coral conditions and factors of disturbance by snorkeling at 110 points in the Lagoon. The advantage of the method is that anyone can carry out easily because of no expensive equipment and specialized technique required. As the results of the long-term monitoring in the Sekisei Lagoon, it was found out the followings; coral community is not stable due to the damage by crown-of-thorns starfish, unusual high water temperature, and red soil erosion from the land; and the recovery of coral community takes more than 15 years when serious damage is suffered by starfish. Under such conditions to conserve the coral reef in Sekisei Lagoon, a present conservation system should be reconsidered, and the new system needs to be established preparing for the various disturbances to the coral community.

THE STATUS OF CORAL REEFS IN SABAH, LABUAN AND SARAWAK, EAST MALAYSIA

Pilcher, N.J.*; Cabanban, A.S.; Oakley, S.G.; Abdul Rahman, R.; & Harding, S. *Institute of Biodiversity and Environmental Conservation Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Email: nick@tualang.unimas.my

Between 1996 and 1999 reefs in East Malaysia were surveyed using methods in keeping with the GCRMN standards. An indicator of reef condition was obtained by performing a simple analysis using 7 key indicators to determine overall reef condition, graded from 1 to 6. The condition of the coral reefs spanned a wide range, but rarely were reefs devoid of all life-forms. Dead coral accounted for 10 % to 20 % of the benthos cover at nearly 70 % of sites, and only 10 % of reefs had less than 10 % dead coral. A combination of natural (sedimentation & storms) and anthropogenic (cyanide fishing and blast fishing) effects threaten the survival of coral reefs. Coral reef destruction and over-fishing has caused the destruction of vast tracts of coral reefs, accounting for the loss of more than 80 % of original coral cover in many areas. Remoteness of the reefs makes protection and enforcement of regulations rarely possible or effective. There are inadequate personnel, logistics and financial resources to effectively patrol the areas and enforce regulations. Conservation of East Malaysia's reefs can be improved by: improving enforcement; gazetting additional Marine Reserves, and; the development and implementation of education programs that include alternative livelihood projects. The development of a local reef ownership concept may the one of the best conduits towards effective enforcement of management guidelines.

CORAL REEFS OF THE COOK ISLANDS: NATIONAL STATUS REPORT.

Ponia, Ben.* *Ministry Of Marine Resources Government of the Cook Islands PO Box 85, Avarua, Rarotonga, Cook Islands. Email: rar@mmr.gov.ck;

The Cook Islands are a group of 15 Islands located in the southern Pacific between Samoa and Tahiti. The total landmass is 237 km^2 and the total Economic Exclusive Zone (EEZ) of its waters is ca. 2 Million km^2. It is a self-governing nation of ca. 20,000 people. Half of the population reside on the capital Island of Rarotonga. The economy is based on Tourism, Black Pearls, Offshore Banking and Agriculture. Gross domestic product per capita is Aus$7,000 (1996). In terms of marine biodiversity the Cook Islands are at the lower end of a west-east gradient of marine diversity in the Pacific. For example, according to the taxonomic database established by the Natural Heritage Project there are 552 bony fishes in the Cook Islands, this compares to ca. 1800 species at Great Barrier Reef, ca. 1400 species at Fiji and ca. 900 species at Samoa The Cook Islands encompasses several geographical Island types with varying levels of natural biodiversity. Generally the diversity (number of species and abundance) at High Islands > Atoll Islands > Sand Cays > Uplifted Islands. For example, there is a greater diversity of *Echinoderms* and *Holothorians* at the high Island of Rarotonga compared to the uplifted Island such as Mauke. The coral reef is used extensively for subsistence purposes. In 1996 about 70% of all households in the country engaged in some form of subsistence fishing (including reef gleaning). A total of 1,291 fishing boats/canoes were recorded (26% located on Rarotonga).

STATE OF CORAL REEFS IN MAURITIAN WATERS

Poonyth, A. D.*, R. Badal, R. Nursimhulu *Mauritius Oceanography Institute, 4th Floor, France Centre, Cr. St Jean & Victoria Streets, Quatre Bornes, Mauritius. Email: moi@intnet.mu

The Exclusive Economic Zone of the Republic of Mauritius extends from Tropic of Capricorn to equatorial latitudes, and includes about 25% of the Mascarene Plateau. These provide opportunities for the study of corals over a wide range of latitudes. The island of Mauritius alone is surrounded by 150 km of coral reefs. These reefs have suffered degradation from activities, such as coral quarrying and harmful fishing practices, over the years following human settlement in the 17th century. Extensive destruction of mangroves on the littoral zone has enhanced the siltation of the coastal coral habitats. The increased pressure on the coral reefs from diving, pleasure boating and fishing resulting from the rapid growth of the tourist industry has also negatively affected the reefs. In 1998 a rise in sea surface temperature bleached about 10-12% of the corals around Mauritius. The corals around St. Brandon, a group of atolls found at about 250 M north of Mauritius are still largely unaffected by human activity. With increasing awareness on the importance of coral reefs, there has been improved legislation to ban harmful fishing practices and establish marine parks. Research on various aspects of the coral ecosystem is one of the priorities of the Mauritius Oceanography Institute, which has been recently set up to coordinate ocean-related scientific research in Mauritius.

STATUS OF CORAL REEFS OF THE BRITISH VIRGIN ISLANDS.

Petrovic, C.*, T. Baily. *HLSCC, P.O. Box 3097, Road Town, Tortola, BVI. Email clivep@surfbvi.com

There are >7,500 ha of coral around the eight major islands in the BVI, and total coral habitat is much greater. Anthropogenic impacts are moderate as the islands and populations are small. However, explosive economic development in the last two decades has caused significant impacts, particularly around populated islands. Hurricane activity has increased since 1995. Bleaching and disease reports are primarily anecdotal, however substantial bleaching was reported during 1998. Despite initiatives such as Reef Check, coral reef monitoring is minimal. Few reef areas are actively managed. A 'no fishing' marine protected area at the Rhone National Park, has limited enforcement. Increasing demand has impacted valuable species such as Spiny Lobster (*Panulirus argus)*, Queen Conch (*Strombus gigas)*, Grouper and Snapper. The total catch for all species in 1998 was estimated at 819,329 kg. BVI has installed moorings to minimizing anchor damage, but more are needed for the growing yachting industry. The greatest threat to BVI reefs comes from sediment erosion. Government and private developments proceed unchecked. Coastal protection laws are still in the planning stage. In 2000 a multi-million dollar runway extension began with little or no erosion control, and severely affected nearby bays. The territory's reputation as an unspoiled eco-tourism destination is increasingly in the balance, and may depend on government responses to these increasing pressures.

STATUS OF CORAL REEFS IN SRI LANKA; COMMUNITY INVOLVEMENT AND USE OF DATA IN MANAGEMENT.

Rajasuriya A.*, M.M.Chaminda Karunarathna, Shamen P. Vidanage and A.B.A.K. Gunarathna.
National Aquatic Resources Research and Development Agency, Crow Island, Colombo 15, Sri Lanka. Email: arjan@nara.ac.lk

Reef monitoring in Sri Lanka has revealed that much of formerly dominant reef building corals such as *Acropora* spp, *Pocillopora* spp and *Echinopora lamellosa* among shallow reefs have been destroyed due to the coral bleaching event in 1998. Overall, recovery of bleached corals among shallow reefs is poor, however, most corals below 10 m have recovered successfully. The crown-of-thorns starfish is a major problem for recovering reefs in the northwest and east coasts of Sri Lanka. Damage to marine habitats due to human activities is also widespread. Recent developments in resource management has recognised the need to involve local resource user communities but actual involvement has been lacking, except in isolated processes. Furthermore there is a lack of appreciation of the influence of external market forces on resource exploitation. There is a dearth of information for effective management, particularly the socioeconomic status of user communities and that of external market forces. Problems also exist in collecting, accessing and using data in management. This report presents the current status of coral reefs in Sri Lanka, resource management issues, data requirements and discusses issues involving user communities in resource management.

MONITORING AND STATUS OF CORAL REEFS OF COLOMBIA.

Rodríguez-Ramírez, A.* & J. Garzón-Ferreira. *Instituto de Investigaciones Marinas y Costeras, INVEMAR, A.A. 1016, Santa Marta, Colombia; Email: betorod@invemar.org.co

A national report on the status of coral reefs in Colombia is presented as a contribution to the "Status of Coral Reefs of the World: 2000" GCRMN report. The territorial sea of Colombia has about 892,617 Km^2. (59% Caribbean Sea and 41% Eastern Pacific), but only 0.3% contains coral reefs areas distributed mainly in the Caribbean. Through the CARICOMP program since 1993 and the development of SIMAC (The National Monitoring System for the Coral Reefs of Colombia) since 1998, up to date information about the status of four areas has been obtained, based on the abundance of live coral cover, coral diseases and fish populations. In the Caribbean, mean coral cover in 1999 was 24.2% (Islas del Rosario Archipielago) to 35% (Tayrona Natural Park). Disease incidence ranged between 1.2% (Islas del Rosario Archipielago) and 8.6% (San Andrés Island) and fish populations were characterized by the abundance of herbivorous and the paucity of commercial species at all sites. In contrast, live coral cover in the Pacific (Gorgona Island) reached 60%, the incidence of diseases was comparatively low (2,5%) and fish community showed abundant commercial species. At Chengue Bay (only site monitored since 1993), coral cover has not changed during the last seven years. Coral reef degradation in Colombia include natural and anthropogenic disturbances, but none of these have been appropriately studied. Although most coral reefs areas in the Pacific and some areas in the Caribbean are protected within of the System of Natural National Parks, more resources and infrastructure are necessary for an effective control in these areas.

REEF OUTER SLOPE MONITORING NETWORK AND RESULTS IN FRENCH POLYNESIA.

Salvat, B.*, Y. Chancerelle. *EPHE, ESA CNRS 8046, Université de Perpignan, France, and CRIOBE, B.P. 1013 Moorea, Polynésie française. Email : bsalvat@univ-perp.fr

Early in the 1990 s a long term monitoring program was launched in French Polynesia concerning outer slopes of 14 high volcanic or atoll coral reef ecosystems all over French Polynesia (Aratika, Bora Bora, Marutea sud, Mataiva, Moorea, Nengo Nengo, Raiatea, Rangiroa, Tahiti, Takapoto, Tetiaroa, Tikehau, Tubuai, Ua Uka). The sampling method consists of photographing one square meter quadrats along a 20 meter permanent transect. Genus and total coral cover percentages are compared after each survey at 2-3 year intervals or each year if natural events occurred. The outer slope has until now been unaffected by human impacts. Some outer slope coral cover percentages are very low, normal (Tubuai, 10%). Some others have moderate and stable cover percentages even after cyclones and bleaching events where mortality has been compensated by rapid recruitment (Moorea, 30-39%). Cover percentages on some reefs are regularly increasing over time, recovering progressively from cyclone destruction (Marutea sud, 37 to 54%). Some reefs show a progressively moderate decreasing percentage cover after cyclone and bleaching events with recruitment (Tetiaroa, 47 to 31%). Some others have shown drastic decrease following recent cyclones (Mataiva, Tikehau, 39 to 4%). The monitoring network gives us a precise estimation of coral cover over time and allows modifications to be related to the major natural events affecting the communities (cyclone and bleaching mortality).

STATUS OF FRENCH POLYNESIAN CORAL REEFS.

Salvat, B.*, P. Hutchings, A. Aubanel, M. Tatarata, C. Dauphin. *EPHE, ESA CNRS 8046, Université de Perpignan, France, and CRIOBE, B.P. 1013 Moorea, Polynésie Française. Email : bsalvat@univ-perp.fr

The French Polynesian government has responsibility for environmental policy all over 34 high and 84 low islands, with 220,000 inhabitants. Very diverse coral reef ecosytems occur with some studied for many decades and well known. Infrequent cyclones and crown-of-thorns infestations have been documented (1970s and 1980s), as well as bleaching events (1990s). Coral mining is prohibited. There are no real signs of overfishing. Black pearl production occurs in 37 atolls and represents 97% of total french polynesia exports (in value), with some ecological crises in lagoons. Introduced species of nacreous gastropods are of economic importance. Tourism (3500 beds, 210,000 people) has impact on islands where it occurs and ecotourism is just developing. On developed islands (mainly Tahiti, Moorea, Raiatea, Bora Bora), anthropisation of the shoreline is important as well as land run off and sedimentation with occasionally eutrophication events. Reef protected areas are only 1%. Management Plans for Marine Areas are underway on Moorea, Bora Bora and Fakarava. Monitoring programs exist, both scientific and technical, for tracking short and very long term modifications. International conventions, government policies and legislation are important with EIA and an increasing private association power. More protected areas and coastal zone management plans, greater commitment to coral reef sustainability and reinforcement of regulations are desirable.

THE STATUS OF THE CORAL REEFS OF TUVALU

Sauni, Samsoni.* *Marine Studies Programme The University of the South Pacific Suva, Fiji Islands

Tuvalu's shallow marine environment is predominantly of fringing and patch reefs. Five of the islands are true coral atolls, with a continuous eroded reef platform surrounding a central lagoon. Three islands comprised of single islet encompass of sand and coral materials. All the atolls and islands are low-lying, with an average elevation above sea level of about 3 m. Five islands have small stands of mangroves consisting of two species with *Rhizophora mucronata* being the dominant. The most significant marine plant components of patch reefs and coral heads are crustose coralline algae (Corallinaceae). *Halimeda* species are the main primary producers and the dominant components in most lagoon areas. The infauna of the lagoon consists largely of worms, molluscs and foraminifera. The epifauna includes hermit crabs, holothurians (7 spp.), pearl oysters (2 spp.), giant clams (2 spp.) and sponges (4 spp.), that are relatively sparse but in abundance. At least 400 species of reef fishes have been documented with emperors, cods and groupers being the main targeted groups. The benthic cover in lagoons includes *Acropora* species and high algal cover of *Dictyota* sp., while other macroalgae are found in the front reef slope. Coral bleaching and crown-of-thorns outbreaks are occasionally recorded from the lagoon and ocean terraces. Crown-of-thorns starfish density ranges from 0-119 cots/ha, however, anecdotal evidence suggests that over 100 cots/ha have been reported from some areas. Ciguatera poisoning is a serious problem in Tuvalu and is suggested to relate to ship-wrecks, channel blasting, dredging and storms, however, no concrete evidence exists to support this.

THE STATUS OF THE CORAL REEFS AND MARINE RESOURCES OF SAMOA

Skelton Posa A.*, Lui J. Bell, Atonio Mulipola & Anne Trevor *Marine Studies Programme, The University of the South Pacific, PO Box 1168, Suva, Fiji. Email: *skelton_p@student.usp.ac.fj

The coral reefs of Samoa (13-17 ^{o} S, 171-173° W) are limited and fringing in nature due to past volcanic activities and subsequent sea level rise. The near-shore reef fisheries are degraded, however, they continue to provide for the well being of the people. The coral reef systems have recovered from cyclones in the early 1990s. The current knowledge of the marine biodiversity is inadequate with past studies largely undertaken by foreign scientists. The marine flora is better known than the fauna, however the fishes of Samoa have been thoroughly documented. Of the known species, the fishes consist of 991 species, benthic algae 287 species, coastal littoral plants 76, 3 mangrove communities, two seagrass species and 3 marine turtles. A number of target species for fisheries have declined over the years which include marine turtles, giant clams, giant triton, grey mullets, milkfish, and mangrove crabs. There are no known endemic or rare organisms, which may be partly attributed to the lack of knowledge on the marine biodiversity. There is only one extinct species known, the giant clam *Hippopus hippopus*, with shells and shell fragments found in some parts of Samoa. The Fisheries Division has undertaken conservation and management efforts with further initiatives undertaken by the Division of Environment and Conservation. The main legislation dealing with coral reefs is the Fisheries Act 1988. The customary marine tenure, which exists in most villages of Samoa, provides further mechanisms to enhance and strengthen coral reef conservation and management efforts.

PEOPLE, CORAL AND TURTLES

Sofyan Andi SP*, Abigail Moore MSc, Yayasan Adi Citra Lestari, Jl Setia Budi No 14D, Palu Timur 94111, Sulteng, Indonesia, Email: rosontapura@palu.wasantara.net.id

The poster will present the background to, carrying out of, and results from a Reef Check and Manta Tow survey event at Pulau Pasoso, a Marine Protected Area and Turtle Nesting Ground, in Central Sulawesi, Indonesia. Background details will include brief references to geographical, bio-diversity, historical and socio-economic aspects, including existing local conservation initiatives. Details of the event itself will be shown, including preparations, team selection and training, and the actual survey. Data collected, conclusions drawn from data analysis, lessons learnt and resulting on-going activities/plans at the site and in Central Sulawesi more generally will be highlighted. This event will result in the training of a local survey team, and it is hoped that this team will become part of the basis for on-going survey and monitoring programmes. Anticipated benefits from this event include local capacity building through training and actual survey work, and increased intersectoral co-operation through practical experience of learning and working together, as trainees are to be selected from a variety of local community, government and NGO sources. It is hoped there will be awareness building at a variety of levels, and increased support for further survey and monitoring activities at both this site and throughout the Province.

STATUS OF CORAL REEFS OF THE PHOENIX ISLANDS, REPUBLIC OF KIRIBATI

Stone G., Obura D.*, Bailey S., Yashimoto A., Holloway C., Barrel R. CORDIO East Africa, P.O.Box 10135, Mombasa Kenya, dobura@africaonline.co.ke

The Phoenix Islands group, at 2-4 ^{o}S and 171-174 ^{o}W, is one of the three island groups making up the Republic of Kiribati. The Phoenix Islands Expedition (June 24 – July 15, 2000) was conducted by NAI'A Cruises and the New England Aquarium on the islands of Nikumaroro (Gardner), McKean, Manra (Sydney), Canton (Aba-Riringa), Enderbury (Rawaki), Orona (Hull) and Phoenix. Only Canton Island bears a small administrative human population of about 50. Corals, fish, algae, sea turtle nests, sea birds and marine mammals were surveyed at each site. Deep-sea life was sampled using an autonomous video system to 1,000 m at 3 islands. Coral reef and fish communities were surveyed using rapid assessment methods, marine algae was collected by hand, and small benthic fish were collected using rotenone. The reefs are controlled by ocean swell on 75% or more of the island perimeters, dominated by rubble and coralline algae on windward sides. On average, coral cover was 34%, rubble 18% and coralline algae 17% at all sites combined. Dominant coral genera included *Pocillopora*, *Favia*, *Pavona* and *Millepora*. A coral species count of 90 was obtained, with collection of 3 so far unidentified, potentially new species. The fish fauna attests to the complete absence of reef fishing with high abundance of reef sharks, large predators and schooling herbivores. Preliminary observations of the small benthic fish collection revealed a number of range expansions and unknown species for the islands. The complete absence of man-induced (fishing, pollution, coral mining) and complex (crown-of-thorns, coral bleaching) threats to reefs was notable. The unimpacted status and extreme remoteness of the Phoenix Islands reefs give them high conservation value.

THE STATUS OF SOLOMON ISLANDS' CORAL REEFS

Sulu, Reuben* Cameron Hay, Peter Ramohia, and Michelle Lam *Institute of Marine Resources, University of the South Pacific, Suva, Fiji. Email: rjsulu@welkam.solomon.com.sb

The coral reefs along the shores of the double archipelagic chain of steep, mountainous and commonly volcanic islands comprising solomon islands (5-12°s, 152-170°e; 28,370 km^2) are mainly narrow, fringing and intermittently distributed. Their collective biomass is, however, large because of the coastline length of the 1000 islands. Long barrier reefs and expansive intertidal reef flats are uncommon; and ontong java, a northern outlier, is the only large atoll (70 by 11-36 km). The largest coral reefs usually occur where large lagoons are protected by raised or semi-submerged barrier reefs or by raised limestone islands, e.g. Marovo and roviana lagoons and marau sound. Threats to coral reefs are: coral bleaching coincident with recent higher than usual sea temperatures, volcanic activities and cyclones. Immediate human threats are over fishing both for subsistence and income generation due to rapid population growth, urban developments, industrial activities in particular logging, gold mining, oil palm extraction plants and fish canneries. What little protection for the coral reefs are embodied in the fisheries act 1998, the environment act 1998 and the wildlife protection and management act 1998. There exists only one marine protected area (mpa). Very little scientific work has been carried out on the coral reefs of the solomon islands. There is an urgent need to describe, quantify and catalogue the biota of the reefs.

EXPLORATORY CORAL REEFASSESSMENT OF THE OFF SHORE ISLANDS OF THE EGYPTIAN RED SEA.

Tilot de Grissac, V. *, E. Saadalla, B. Saleh, A. Afifi, Y. Audalla, G. Jobbins. *Ras Mohammed National Park, P.O. Box 19, Sharm el Sheikh, Egypt, vtilot@sinainet.com.eg

An exploratory survey of five offshore islands in the Egyptian Red Sea (El Akhawin or Brothers, 26º 18' N, 34º 52' E, Abu El Kizan, 24º 56' N, 35º 52' E, El Zabarghad or Saint John, 23º 36' N, 36º 12' E, and Rocky Island, 23º 33 N, 36º 15' E) has been undertaken in December 1997 by the Egyptian Environmental Affairs Agency, Nature Conservation Sector and financed by the European Commission and the USAID agency to evaluate the importance of natural resources in terms of biodiversity and serve as baseline study to monitoring studies prior to opening on 30 May 1998 to recreational diving. These offshore islands declared protected since 1985 have not been investigated coralwise since the expedition of commandant J.Y. Cousteau in 1951-52 focusing mainly on geomorphology. Results attest that these islands are of great interest to science and to underwater tourism. The total cover of living epi-benthos ranged from 44.5% for El Zabarghad to 75.4% for Abu El Kizan. Pooled data for all the sites gave an average cover varying from 63% at 15m to 52.4% at 2.5m. Scleractinian corals, mainly *Montipora sp.*, prevailed in all sites except at the 15m zone mostly colonized by soft corals. Hard and soft coral diversity at the genus level was greatest at Small Brother (20 genera). Reef fish diversity at the family level was greatest at Big Brother. Factor and cluster analysis were used to identify and describe epi-benthic community assemblages.

PRELIMINARY REPORT ON THE STATUS OF CORAL REEFS OF VIETNAM: 2000

Tuan Vo Si* Institute of Oceanography Nha Trang, Vietnam. E-mail: thuysinh@dng.vnn.vn

The report reviews information concerning with surveys, monitoring and activities to understand and to manage coral reefs of Vietnam. The results obtained during 1996 - 1999 have been emphasized. Up to present, there are 28 coral reef areas known in the coastal waters of Vietnam. The collected data allow to assess human impacts to almost coral reefs composing of overcatching commercial and aquarium reef organisms, blasting and poisoning fishing, sedimentation, uncontrolled tourism with different levels. More detail data on percentage cover of corals and reef fish population at 15 areas are presented. Natural catastrophes such as typhoon and bleaching were recorded at some places in 1997 & 1998. Data collected at Con Dao and Cat Ba islands show rather serious decline of coral cover and density of butterfly fish in 1999. Since 1996, activities to promote coral reef conservation have been paid more attention. Institute of Oceanography and staffs of some protected areas have developed three sites of coral reef monitoring since 1998. In the framework of the Project ADB-5712, the proposed system of coastal and marine protected areas was planned and waited to be approved by the Government. Ministry of Fishery is also compiling strategy for developing marine protected areas.

MAIN CHANGES IN THE LAST 30-40 YEARS ON CORAL REEFS AND COASTAL AREAS INDUCED MOSTLY BY HUMAN PRESSURE: THE TULEAR REGION EXAMPLE (S.W. MADAGASCAR, INDIAN OCEAN)

Vasseur Pierre*,Thomassin Bernard A., Randriamanantsoa. Bemahafaly, Pichon, Michel. *Université de. Provence, 13331 Marseille Cedex 03 France. Email: bioplank@newsup.univ-mrs.fr

During the years 1961-73, coral reefs and marine coastal areas (mangroves, muddy flats and beaches) of the tulear region (23°s, semi-arid climate) were intensively studied for geomorphology, sedimentology, environmental parameters and community assemblages (about 400 papers published presently; up to 6,000 species identified). During that period, on a very narrow inshore shelf, benthic communities were highly diversified (up to 19 communities with 23 subcommunities). Natural marine resources were traditionally exploited in respect of these environments. At present, a drastic overfishing of all types of marine resources occurs, resulting from the increase of the littoral population (for the tulear town, from 40,000 inhabitants up to >140,00 inhabitants in 30 years), economic crisis and episodic famines, deforestation inducing sediment run off around river mouths, etc… too many fishermen, spear fishing, overturning and smashing of coral colonies on the reef flat, collecting of juvenile fish and invertebrates, as well mangrove destruction (for timber and cattle provender) all contribute to the degradation of the coastal communities. The major changes induced are : (a) on reefs, a decrease of the coral dominated areas, replaced by shingle and sandy flats, outbreaks of zoanthids, algae and sea-urchins and a general decrease of the biodiversity; (b) on the inshore flats, development of large bare sand banks, sometimes stretching over fringing reef flats, destruction of mangroves and beach-rocks (for housing and road construction).

STATUS OF CORAL REEFS OF GULF OF MANNAR, INDIA.

Venkataraman, K. *Marine Biological Station Zoological Survey of India, 100 Santhome High Road Chennai-600028, India. Email: dugong@ md2.vsnl.net.in

The Gulf of Mannar Biosphere Reserve (GoMBR) encompasses 21 coastal islands located between 8°49' to 9°15' N lat. and 78°11' to 79°15' E long on the south east coast of India. These uninhabited islands, ranging in size from 25-130 hectares are strung along the coast for 140 km, with the closest being 500 m from shore and the furthest over 4 km. The Gulf's 3600 species of plants and animals make it biologically one of the richest coastal regions in India. A total of 96 species of coral belonging to 37 genera have been reported from this area and the coral reefs are mostly of fringing type. Although the richness of this area is documented qualitatively by many, the quantitative data on fauna and flora of this region which is very much needed for effective management of this unique ecosystem is lacking. Therefore, from 1998-2000, surveys had been conducted to estimate the present status of the coral reefs of this region.The results of the Line Intercept Transect study on the status of coral reefs of Gulf of Mannar Biosphere Reserve show 24.67% live coral cover and the rest dead coral, rubble and sand. The percentage of lifeform categories of coral reefs of GOMBR (all the three groups of Islands) was as follows: ACB 5.30 $\pm$ 4.64%, CB 0.38 $\pm$ 0.54%, CF 2.90 $\pm$ 2.13%, CE 1.31 $\pm$ 1.64%, CS 5.78 $\pm$ 8.15% and CM7.67 2.23%.

REEFBASE 4.0: IMPROVING POLICIES FOR SUSTAINABLE MANAGEMENT OF CORAL REEFS.

Vergara, S. G. ,* McManus, J.W., and J. Bell . *International Center for Living Aquatic Resources Management-Philippines, 2nd Floor, Collaborator's Center, IRRI, Los Baños, Laguna, Email: s.vergara@cgiar.org

ReefBase 4.0 will be launched at the 9 th International Coral Reef Symposium in Bali, Indonesia. The latest version of this electronic encyclopedia contains information on 9 300 coral reefs. The main features of ReefBase 4.0 are: ecological information on corals and fish communities, coral reef fisheries and mariculture activities, reports of stresses affecting coral communities, dive tourism information, descriptions of management practices and legislation and marine protected areas. The standard digital maps in ReefBase 4.0 include most of the charted coral reefs of the world in global, regional and subregional maps, and show many individual reefs in detail. Low-level space shuttle satellite images are linked to 207 reefs and aerial, underwater, and terrestrial photographs of uses and misuses of coral habitats are provided for 904 reefs. The reference section has > 8 000 references on coral reefs, including papers in scientific journals, conference proceedings, technical reports and informal articles. At this symposium, the developers of the database will solicit feedback on the ReefBase goals of promoting global improvements to the health of coral reefs, addressing the needs for policy development, strengthening database capacity, and striving for relevance and application to informed strategies for managing coral reefs worldwide.

SOFTWARE ARMDES-COI FOR THE CORAL REEFS MONITORING IN WIO ISLANDS STATES

Villedieu*C, Bigot L., Tessier E. *ARVAM, 14 rue du stade de l'Est , 97490, Ste Clotilde, Ile de La Réunion. Email: arvam@guetali.fr

The management system of data base « armdes-coi » has been developed within the regional environment program of indian ocean commission (pre-coi/eu). This software allows for storage and treatment of data coming from the observations of the coral reef monitoring. This database serves as an interpretation tool for the sustainable management of natural ressources on the integrated coastal zone managment (iczm). The data stored in the armdes data base are collected according to the methodologies developed in the guidelines « coral reefs monitoring in wio island states » by c. Conand, l. Bigot p. Chabanet, j-p quod. The analysis of the database allows appreciation of coral reefs. This monitoring should allow us to survey the spatio-temporal evolution of reference stations and to compare neighbouring geographical regions or areas. The differents results (lists, boards, graphics, ..) Can be used by technicians for reports and publications. The collected datas are « scubadiving observations », for rapid evaluation of reefs health. « transect benthos observations » for evaluation of coral reef covered, categories and forms. « fish counting observations » for evaluation of species, bio-indicators, distribution of major food diets. « quadrats observations » for monitoring of benthic populations in time, growth, recruitment. The software armdes –coi permits different formats : screen consulting, editing of lists, printing of graphics as well as transfers of data according to other software formats (excel, word,…). This software can easily be adapted to other regions, and it is easy friendly use for various level stakeholders (e.g divers or experts).

STATUS OF FIJI'S CORAL REEFS

Vuki,V.C.* and Naqasima,M.R. *Marine Studies Programme, University of the South Pacific, P.O. Box 1168, Suva, Fiji. Email:
Vuki_V@usp.ac.fj

Fiji has some of the largest and best developed coral reef systems in the South West Pacific region. Pollution, elevated nutrients and crown of thorns starfish outbreaks have significantly degraded coral reefs off Suva. The Laucala Bay and Suva lagoons have very high level of nutrients from sewerage and runoff. They are moderately to heavily polluted and have extremely high level of tributyl tin. The chronic crown of thorns situation on Suva Reef may have been contributed by anthropogenic factors. The high fishing pressure on some of the most isolated reefs in the Lau Group have caused outbreaks of crown of thorns starfish because of the removal through fishing of predators of the juvenile and adult stages. Most reefs are moderately to heavily fished. Reefs closest to villages and urban areas are subject to heavy fishing pressure because of commercial fishing. Stocks of reef fish and invertebrates such as giant clams, trochus and beche-de-mer have been reduced. The highly targeted reef fish species have been overfished. There is generally no systematic reef monitoring to detect early signs of overfishing despite moderate research effort at the University of the South Pacific. Mass coral bleaching has recently occurred on most reefs in Fiji. Aquarium fish, live coral and curio coral export are permitted under licence. These activities are common on the inshore reefs of Viti Levu.

STATUS OF THE CORAL REEFS OF THE GULF OF KACHCHH, INDIA.

Wafar, M*, E.V. Muley and P. Yennawar *National Institute of Oceanography, Dona Paula, Goa 403 004, India Email: wafar@csnio.ren.nic.in

The fringing reef surrounding 42 islands on the southern flank of the Gulf of Kachchh are the northernmost of the Indian reefs and thrive in extreme environmental conditions (high temperature and salinity ranges, high suspended load). The diversity of corals is much less, with only 37 species and a total absence of ramose forms. Direct dependence by the local population on the reef resources is minimal, except for sustenance fishing. Tourism has not been developed so far. Human interference has been mainly in the form of collection of coral sands for cement industries until the 80s and later in the form of impacts from a number of onshore developmental activities (deforestation, mega-industries, ports and SPMs). The cumulative impact over the years has led to an alarming reduction of coral cover, down to <50% in many reefs. Though the entire Gulf of Kachchh reefs have been declared as a Marine National Park, enforcement is lacking. Some matters of concern are the probability that some stretches of the Marine Park may be denotified to accommodate industrial needs and the lack of a buffer zone. Bleaching has not significantly affected the Gulf of Kachchh coral reefs, though it is little consolation given the present extent of degradation. There is no systematic monitoring in place even now, except for occasional EIA studies. The Gulf of Kachchh reefs have been the most neglected until now and with the increasing pace of industrial development and lack of concern on the part of all stakeholders, it would not be long before these reefs totally whither away.

REEF BIOTOPES AND CORAL COMMUNITIES OF THE PROPOSED SEMPORNA ISLANDS PARK, SABAH, MALAYSIA

Wood, Elizabeth* *Marine Conservation Society, 9 Gloucester Road, Ross-on-Wye, Herefordshire HR9 5BU. UK. Email: ewood@globalnet.co.uk

Surveys and assessments of the reefs of Pu Bodgaya and surrounding islands were carried out as a preliminary to establishing the Semporna Islands Marine Park, off the east coast of Sabah, Malaysia. The site includes fringing, patch and bank reefs associated with ancient volcanic features now partially inundated by the sea. The proposed park is ranked as one of the most biologically diverse and important reef sites in Malaysia. Of particular interest and conservation value are a number of wave-sheltered habitats which support unusual coral communities. These include a deep (30-45m) shelf with up to 100% coral cover comprising large laminar colonies and open bowls (e.g. *Montipora* spp; *Pavona explanulata*); steep faces with *Acropora elegans* and other deep water species; mid-depth (25m+) gentle outer slopes with calcareous algae and delicate unattached corals such as *Acropora russelli* and *Anacropora* spp., and upper reef slopes dominated by extensive banks of the branching oculinid *Acrhelia horrescens.*

STATUS OF THE CORAL REEFS IN THE MALDIVES.

Zahir, Hussein* & Mariyam Saleem. *Marine Research Centre, Ministry of Fisheries Agriculture and Marine Resources, Male, Republic of Maldives. Email: marine@fishagri.gov.mv

In the Maldives, coral reefs are an essential backbone for the existence of its 22 low-lying atolls, providing coastal defense from adverse environmental conditions. Maldives perhaps has the greatest coral reef diversity in the Central Indian Ocean. This paper provides an overview of the current status of the coral reefs in the Maldives. The status of the coral and coral reef benthos are given from the perspective of the 1998 coral bleaching event that significantly reduced live coral cover up to depths of 10 meters throughout the Maldives. Natural impacts such as elevated temperature, sea level and increased storminess that is expected to accompany global climatic change may well have severe impacts on these low lying islands. In the last 15 years there has been an increase in marine resource exploitation, characterized by a growing reef fishery, well developed commercial, subsistence and aquarium fisheries and growing research in mariculture both in the private and public sector. In addition, a number of anthropogenic activities, such as coral mining, land reclamation and dredging and coastal pollution continue to threaten the reefs and these impacts are highlighted. Government policies and regulations in environmental conservation and management and their effectiveness are also discussed, giving special emphasis on gaps in institutional and national capacity for coral reef conservation and management. Recommendations for enhancement of the current coral reef conservation efforts are highlighted.

E: THE FUTURE OF CORAL REEFS

THE NUMBER OF *ACHANTASTER PLANCI* INDIVIDUALS JUST BEFORE/AFTER BLEACHING EVENT AND THEREAFTER

Arakaki, Yuji*, *Department of Tourism, Faculty of International Studies, Meio University, Okinawa, Japan. Email: arakaki@tor.meio-u.ac.jp

The rise of sea temperature around the world was observed in 1998. And the result of this rise, coral reef bleaching supposed to be the effect of this rise reported around the world. Coral reef bleaching was reported in the South-East Asia and the East Asia, Indonesia, Singapore, Malaysia, Thai, Vietnam, Philippines, Taiwan, and Japan; in the West Pacific, the Grate Barrier Reef; and in the East Pacific, Panama, Galapagos, and as well as the other part of the world, the Caribbean and the Atlantic Ocean. The bleaching event in Japan was from the Ryukyu Islands in the south to south of Kyusyu in the north. Corals around Okinawa Island, one island of the Ryukyu Islands, were devastated due to the coral breaching. It is not difficult to consider that living organisms inhabited coral reef area should get very serious effect owing to bleaching of corals which constitute fundamental component of coral reefs. It is reported that behaviors of crustaceans inhabited coral and fishes which feed in coral reef area were changed along with bleaching event. *Acnathaster planci* is one of coral reef dwellers and it feed on corals themselves. It is obvious that this sea-star seriously effect by coral beaching. In this report, the number of *A. planci* individuals just before and after bleaching and thereafter, 1999 and 2000, when environmental condition become stable, is present and consider *A. planci* population around Okinawa Island. The number of the sea-star diminished in 1998, however, it is increasing again in 1999 and 2000.

AN INCREASE IN CORAL DISEASE FOLLOWING HIGH TEMPERATURES ON THE GREAT BARRIER REEF.

Baird A*. *School of Marine Biology & Aquaculture, James Cook University, Townsville Q. 4811, Australia. Email: andrewbaird@ozemail.com.au

The Great Barrier Reef (GBR) has yet to experience coral outbreaks which have devastated reefs in many other parts of the world. While recent work has confirmed the presence of a number of coral diseases on the GBR few corals are affected under normal conditions. However, the sudden appearance of a number of diseased corals in the Palm Islands ($18^0$46S, $146^0$15E), including Black Band Disease and White Band Disease Type I and Type II, following historically high sea water temperatures early in 1998, demonstrates that under certain conditions, disease could emerge as a genuine threat to corals on the GBR. Many aspects of coral disease, such as the novelty of many disease syndromes and the low incidence of disease in affected populations, make it difficult to include disease in existing monitoring programs. Consequently, a specific monitoring program is required to asses the threat of disease to corals on the Great Barrier Reef.

BIOACCUMULATION OF TERRIGENEOUS METALS IN SOME BIVALVES OF THE SOUTH-WEST LAGOON OF NEW –CALEDONIA.

Breau L.*, Fernandez, J.M., Fichez, R., Magand, O., Miramand, P., Fichet, D. *Centre IRD, BP A5, Nouméa, New Caledonia. Email: breau@noumea.ird.nc

The lateritic soils of new caledonia represent an important natural source of metal inputs to the lagoon. These natural inputs are enhanced by anthropogenic additional erosion due to open cast mining. Within the framework of the ecotrope programme, the fate of these terrigeneous metals in the south-west lagoon of new caledonia has been investigated. The study of their bioaccumulation in the most common benthic species has been initiated with the aim to identify some possible bioindicators allowing the monitoring of long term trends of these inputs. This poster presents first results obtained on bivalves.

THE BIOGEOGRAPHY OF CORAL REEF DISEASES.

Churcher T.*. *Department of Geography, U.C. Berkeley, Berkeley, CA 94720, USA,. Email:tpaige@uclink4.berkeley.edu

Coral reefs contain some 25% of all identified marine life, and almost 60% of the world's reefs are threatened because of human-induced factors as well as extreme physical conditions such hurricanes and increases in sea surface temperature. One of the most serious threats to these ecosystems is the appearance and rapid spread of coral reef diseases. Since 1973, fifteen new coral reef syndromes have been documented, three of which have been identified as diseases. The emergence and spread of these new diseases have a specific geography and spatial ecology, which may lead to some insight on cause and transmission. This research will investigate for the first time the geography of coral diseases at both global and local scales, combining key scientific factors such as sea surface temperature anomalies, water nutrient data, reef geography, disease prevalence and macro-level political ecology, such a conservation practices and marine resource utilization. Global data sets such as the World Conservation Monitoring Centre's coral disease database, and ocean color data from SEAWIFS will be combined with original research in Fiji and the Philippines to examine the emergence and spread of coral reef disease in the recent past with human and natural impacts by way of mapping the distribution and pattern of coral disease outbreaks and creating a GIS database.

USING SELECTIVE EXTRACTION OF METALS IN THE SEDIMENTS OF THE SUVA LAGOON (FIJI) TO ASSESS THE MAIN SOURCES OF TERRIGENEOUS AND ANTHROPOGENIC INFLUENCES.

Fernandez J.M.*, Cadiou, Magand, Moreton, Fichez, Chandra, Togamana. Centre IRD, BP A5, Nouméa, New Caledonia. Email: jmfa@noumea.ird.nc

The lagoon surrounding the city of suva, fiji, is subject to significant terrigeneous inputs and the significance of additional anthropogenic inputs in such a system was questioned. A joint study on metals in sediment was conducted by ird and the university of the south pacific to trace the sources and distribution of these inputs. More than 50 surface sediment samples were studied to assess the distribution of recent inputs and two sediment cores were sampled to reconstruct past evolution in sediment and metals deposition. Sequential extraction under microwave oven exposure were conducted to determine metal concentrations in the main geochemical compartments. Analysis conducted on ca, fe, mn, ni, zn, cu, co, cr attested that terrigeneous inputs essentially discharged by the rewa river were of major significance. Anthropogenic signatures were also identified in some specific area close to a sewage out fall, a dump site and the harbour area of suva city. The analysis of sediment cores used as archives of past environmental conditions showed that in laucala bay, close to the mouth of the rewa river, a constant high sedimentation rate was sustained during the last century and the geochemical distribution of metals identified constant terrigeneous inputs. Above this natural background, sediment deposition together with anthropogenic signature significantly increased during the past 30 years in suva harbour.

A GEOCHEMICAL APPROACH OF METALS AS TRACERS OF NATURAL AND HUMAN INDUCED TERRIGENEOUS INPUTS IN THE SOUTH-WEST LAGOON OF NEW CALEDONIA.

Fernandez J.M.*, Magand, Moreton, Fichez, Douillet, Chevillon. Centre IRD, BP A5, Nouméa, New Caledonia. Email: jmfa@noumea.ird.nc

The high island of new caledonia is a natural source of terrigeneous inputs to the lagoon but open cast mining has been suspected to enhance the background level of sediment discharge. A study based on the geochemical tracers in recent sediments and in suspension collected by filtration of large volumes or by sequentially collecting sediment traps was conducted to assess the importance and variability of terrigeneous inputs. The confrontation between sediment trap data and water current measurement and modelling demonstrated that in normal non-flooding conditions wind-driven currents are strongly influencing sediment deposition. An analysis of the mineralogy of particles further demonstrated the importance of resuspension in the long term transport of terrigeneous inputs which are mainly delivered to the coastal embayments during exceptional flooding events. Sequential extraction and analysis of metals in the various geochemical forms allowed to precisely discriminate between terrigeneous and marine sources and trace the transport and distribution of these respective inputs. The rations ni/cu and co/sr in the oxyde and residual geochemical compartments proved to be especially informative to assess the respective contribution of oceanic versus terrigeneous influences.

VARIABILITY IN THE PHYSICAL AND CHEMICAL CHARACTERISTICS AND PARTICULATE MATTER DEPOSITION IN A CORAL REEF LAGOON SUBJECT TO IMPORTANT TERRIGENEOUS INPUTS (SUVA, FIJI).

Fichez R*, Fernandez, JM; Chifflet, Gérard, Rao, Gangaiya. Centre IRD, BP A5, Nouméa, New Caledonia. Email: fichez@noumea.ird.nc

The lagoon surrounding the city of suva in fiji is subject to significant terrigeneous inputs discharged by the rewa river. A joint study was conducted by ird and the university of the south pacific to determine the nature of environmental conditions generated in such an environment where extensive river plumes and coral reefs co-occurred. Three oceanographic cruises provided data on the physical and chemical structure of the lagoon system under various meteorological conditions. Additonally, 3 sequentially collecting sediment traps were deployed in the back reef area for two periods of 24 days which included significant flooding events. The data obtained provided more detailed information on the significant short term variability of sediment deposition rates. From these results it was possible to establish that environmental conditions in this lagoon were strongly impacted by terrigeneous inputs either of natural origin or enhanced by human land use. In the vicinity of the city and a sewage discharge, environmental conditions were further altered and displayed unambiguous signature of anthropogenic inputs. Comparison with data from other coral reef lagoon environment demonstrated that the suva lagoon represents a rather extreme environment as far as coral reef lagoons are concerned.

IMPACTS OF DOMESTIC SEWAGE ON THE BENTHIC ECOSYSTEM IN A TROPICAL BAY (NEW CALEDONIA, SOUTH PACIFIC).

Garrigue*, Richer de Forges, Laboute, Berthault, Lapetite. Centre IRD BPA5, Nouméa, New Caledonia. Email: garrigue@noumea.ird.nc

The benthic ecosystem of a tropical bay situated in the city of Noumea (New Caledonia, South Pacific) was studied in order to evaluate the impacts of domestic sewage. Six stations were sampled from the outfall to the outside of the bay. One station was situated near the outfall in the intertidal area. The others were located on muddy or sandy bottoms, in the subtidal area from 9 to 21 m depth. Sampling were carried on in summer 1997. Diversity in term of specific richness, density and biomass were measured on a zoological and trophical basis. A total of 266 morphospecies of macrofauna was recognised from which the polychaetes were the most abundant group both with regard to the species number and density. The area near the primary sewer was subject to eutrophication that induced green tide with an important development of the seaweed *Ulva* sp. and occurrence of small size polychaetes. The family of Eunicidae dominated in terms of density and biomass. The macrofaunal diversity expressed as Shannon's index increased as a function of the distance from the sewer. The trophic structure was characterised by filters-feeders in the intertidal area and deposit feeders in the subtidal area.

EXPERIMENTAL STUDIES OF SEAFAN (*GORGONIA VENTALINA*) RESISTANCE TO DISEASE (*ASPERGILLUS SYDOWII*).

Harvell, D.*, K. Kim, A. Alker, D. Dube. *Department of Ecology and Evolutionary Biology. Cornell University, Ithaca, NY USA. American University, Washington, DC, USA. Email: CDH5@Cornell.edu

Reports of new coral disease in the Caribbean are high and yet little is known about coral resistance to disease and few data are available to estimate potential for evolution of resistance to disease. For two species of gorgonians, *Gorgonian ventalina* and *Briareum asbestinum*, we documented levels of mortality from disease significant enough to cause microevolutionary shifts in populations. In exploring the potential for evolution of resistance in seafans, we have documented inducible structural and chemical mechanisms of resistance. Norm of reaction fungal inoculation experiments reveal significant between clone differences in anti-fungal activity against *A. sydowii*, suggesting the potential for microevolutionary change in resistance. Similarly, populations across the Florida Keys and Bahamas differ significantly in anti-fungal resistance.

METAL EFFLUENT INHIBITS CORAL RECRUITMENT?

Hawkridge J.M.* and B.E. Brown. Mote Marine Laboratory, Center for Tropical Research, 24244 Overseas Highway, Summerland Key, FL 33042, USA. Email: jhawkridge@mote.org

Between 1965 and 1989 a tin ore dressing plant on Ko Phuket, Thailand, regularly discharged metal-enriched effluent on to an adjacent inter-tidal reef flat at low tide. In 1989 the dressing plant was closed down. Regular reef surveillance over the period 1979-2000 suggests that both coral community structure and juvenile coral recruitment patterns were affected by the discharge from the plant. Between 1990 and 1995 many new coral species appeared on the reef flat adjacent to the plant which previously had not been recorded. In addition, large numbers of juvenile *Goniastrea aspera* colonies appeared subsequent to the plant closure. By 1996 marked differences in colony numbers and size-age distribution patterns were evident between this site and a reference site nearby. In particular there was a striking absence of larger (> 20 cm diameter) *G. aspera* colonies and significant juvenile recruitment of colonies of age class between 4-6 years at the ore-dressing site. These findings are discussed in relation to the possible effects of heavy metals upon reproductive development, fertilization success, and juvenile recruitment of corals.

THE NCAR COMMUNITY CLIMATE SYSTEM MODEL - CHARACTERISTICS, RESULTS, AND APPLICABILITY IN PREDICTING MARINE ECOSYSTEM RESPONSE TO GLOBAL CLIMATE CHANGE

Kleypas, Joan * And Scott Doney, National Center For Atmospheric Research, Po Box 3000, Boulder, Co 80307-3000, Usa. Email: kleypas@ucar.edu

In terms of assessing future climate change impacts on ecosystems, scientists and ecosystem managers are often faced with integrating output from large climate system models into their decisions. Usually there is a large mismatch between both the temporal and spatial resolutions of the model, and the scales at which ecosystems operate. This is particularly true of coral reefs: most reefs are less than 1 km diameter, while most global models operate on scales of greater than 1 deg (>100 km). Also, ocean models generally do not resolve coastal dynamical processes well. However, many modeled predictions can and should be used by reef scientists, as they provide a best estimate of how climate will change both globally and regionally. We present some of the significant results of ncar's community climate system model (ccsm), a non-flux corrected model that couples ocean, atmosphere, land and ice. Results from three climate simulations are presented, using greenhouse gas forcing scenarios for the preindustrial period, 20th century and 21st century. Among other things, these simulations predict an increase in tropical sea surface temperatures of up 2 degrees c, an increase in stratification, and a decrease in solar input (increased cloudiness). The applicability of each of these results is evaluated in terms of model scales, assumptions, and performance (e.g. Means versus variability). These specific examples are provided as guidelines for how large-scale models can be used with (or without) confidence for the most common future climate questions posed by reef scientists (e.g., Temperature, upwelling, enso, storm frequency/intensity).

ENVIRONMENTAL AND WATER QUALITY FACTORS ASSOCIATED WITH THE DISTRIBUTION OF BLACK BAND DISEASE ON CORAL REEFS OF THE NORTHERN FLORIDA KEYS.

Kuta Kevin G. and Laurie L. Richardson*. *Department of Biological Sciences, Florida International University, Miami, Florida 33199, U.S.A. Email: richardl@fiu.edu

The increase in coral diseases in recent years has been postulated to be at least in part a result of increased environmental degradation, with declining water quality particularly implicated. Despite the importance of such a correlation, however, very little quantitative data have been gathered to investigate the relationship between these factors and the incidence of coral disease. Over a period of five months of an active black band disease season in the Florida Keys, 190 sites on 12 reefs were surveyed to determine which, if any, of eleven environmental parameters measured were correlated with the presence or absence of black band disease. Each of the 190 sites was centered around either a black band diseased coral colony (n = 22) or a healthy colony of a species known to be susceptible to black band disease (n = 168). Of the eleven environmental parameters measured, five exhibited a statistically significant correlation with the presence (vs. absence) of black band disease. These were low salinity, elevated nitrite, and low coral diversity ($p<0.05$), as well as shallow water depth and high temperature ($p<0.0005$). No statistically significant differences were found for the other six parameters measured (nitrate, ammonium, soluble reactive phosphate, total phosphate, turbidity, and percent coral cover).

DEGRADATION OF FRINGING CORAL REEFS IN THE GULF OF THAILAND

Nordemar, I.* Department of Systems Ecology, Stockholm University, Sweden. Email: ingridn@system.ecology.su.se

Deteriorating water quality and excessive resource exploitation have raised concern for the coastal environment in the gulf of thailand. The aim of this study was to present an overwiev of anthropogenic disturbances and degradation on some coral reefs along the east coast of the gulf of thailand. In 1995, 11 fringing reefs around islands in 3 areas (si chang, samet and man) were surveyed. The cover of living corals was highest in the samet area (>40%), while the two other areas had much lower coverage (<20%). The cover of dead corals was highest in the man area (>40%), while the si chang area had the highest cover of rock (~40%). The abundance of infesting macroinfauna (bivalves and polychaetes) in the corals was highest in the si chang area and lowest around the samet islands. Low salinity was likely responsible for much of the low coral cover and the high rates of bioerosion in the inner gulf. The high cover of dead corals in the man area were likely due to degrading effects of construction building and dynamite fishing, while the high cover of living corals in the samet area were either an effect of park management or naturally more favorable conditions. Although reefs in the si chang area had the lowest coral cover, and recruitment seemed impaired, the more well-developed reefs in the man area are in greatest need of management, as degradation has escalated recently and water quality seem worse than in the inner gulf.

EXPERIMENTAL EVIDENCE OF EL NIÑO AND LA NIÑA EXTREME TEMPERATURES ON THE SURVIVAL OF A WRASSE REEF FISH AT GORGONA ISLAND (EASTERN PACIFIC).

Ospina, F. Mora, C*. Departamento de Biologia, Universidad del Valle, A.A. 25360 Cali-Colombia. Email: moracamilo@hotmail.com

The eastern Pacific reefs are affected at irregular time intervals by extreme temperatures that occur principally during El Niño and La Niña events. To assess the effect of these extreme temperatures on the survival of a reef fish, we determined the high and low temperature tolerance of *Thalassoma lucasanum* (Pisces: Labridae) in all its benthic stages (from juvenile to adults). The experimental individuals were collected at the Gorgona island reefs in the Colombian pacific coast. The high temperature tolerance of *T. lucasanum* was between 35.6 and 36.2 ºC (X=36ºC) which was superior to the highest sea temperature recorded during past El Niño events (32 ºC). The low temperature tolerance was between 18.9 and 14.3 ºC (X=16.3ºC), in this case, a 18 ºC temperature record during the last La Niña event could have affected the survival of some *T. lucasanum* individuals at the reefs. These results indicate the tolerance of *T. lucasanum* benthic population to the El Niño thermal conditions and the influence of La Niña events on the survival of *T. lucasanum* at the reefs.

DEFINING "OUTBREAKS" OF CROWN-OF-THORNS STARFISH.

Pratchett, Morgan*. *School of Marine Biology and Aquaculture, James Cook University, Townsville Q4811, Australia. morgan.pratchett@jcu.edu.au

The crown-of-thorns starfish, *Acanthaster planci* (L.), has attained considerable notoriety because it periodically undergoes population explosions, termed 'outbreaks'. Outbreaks of coral feeding crown-of-thorns can potentially cause immense destruction to live corals on tropical coral reefs. Outbreaks of *A. planci* are however, a highly variable phenomenon and there has been little effort to ascertain what actually constitutes an 'outbreak population'. This study examined the density and size-structure of *A. planci* across a hierarchy of spatial scales, at regular intervals over a period of three years. The impact of starfish populations on coral cover and composition was assessed during this time, in an attempt to define outbreak densities based on their ecological impacts. Starfish densities as low as 120 starfish per hectare were sufficient to cause a noticeable change in coral composition, and caused a detectable decline in coral cover at some sites. However, at sites which started with very low coral cover (<10%) or high coral cover (>60%), there was no detectable decline in coral cover until starfish densities exceeded 400 starfish per hectare. Evidently, there is no single density above which starfish populations can be considered to be undergoing an outbreak. Rather, the impact of starfish populations varies greatly between sites with different coral cover and composition. In addition, the ability to detect impacts of crown-of-thorns starfish, and other such disturbances, are very much dependant upon the precision and power of sampling methodologies.

MOTILITY PATTERNS OF *BEGGIATOA* IN BLACK BAND DISEASE.

Viehman, T.S.* and L.L. Richardson. *Department of Biological Sciences, Florida International University, Miami Florida 33199, U.S.A. Email: tviehm01@fiu.edu

Black band disease of scleractinian corals is composed of a microbial consortium that generates and maintains an active sulfur cycle. The consortium includes the cyanobacterium *Phormidium corallyticum*, the sulfide-oxidizing bacterium *Beggiatoa* spp., sulfate-reducing bacteria and other microbes. Together the respective metabolisms of these bacteria are responsible for producing vertical gradients of oxygen and sulfide within the 1 mm thick band. Members of the genus *Beggiatoa* are typically located at oxygen/sulfide interface environments, which is thought to be due to a combination of negative photo- and aerotaxes. However, black band disease *Beggiatoa* are commonly found on the surface of the black band community in an environment that is both aerobic and highly illuminated, thus displaying a unique vertical migration that does not correspond to well-documented motility patterns found in other *Beggiatoa*. The vertical migration of black band *Beggiatoa* was investigated both *in vitro* in laboratory oxygen/sulfide gradient cultures and *in situ*, within active black band on the coral reef, by manipulating both light intensity and oxygen concentration. The unique motility pattern of this sulfide-oxidizer may be important in maintaining the stability of the oxygen/sulfide microenvironment present within the band, and thus contribute to the overall functioning of the black band microbial consortium.

E2: BLEACHING

CHANGES IN CORALLIVOROUS AND HERBIVOROUS FISH ASSEMBLAGES ASSOCIATED WITH CORAL BLEACHING AT A MARINE RESERVE IN SRI LANKA.

Abeysirigunawardana M.D. and S.U.K. Ekaratne.*
***Dept. of Zoology, University of Colombo, Colombo, Sri Lanka.**

Corallivorous and herbivorous fish assemblages inhabiting the reef lagoon at Hikkaduwa Marine Reserve (HMR) were studied before and after a coral bleaching and mortality event of April 1998. Transect studies were used to study fish composition over similar 3-month periods (January to March) of the pre-bleaching year, 1998, and in the 2 post-bleaching years, 1999 and 2000. Butterflyfish (7 spp. with 3 corallivorous species in the pre-bleaching period) were the corallivores studied and angelfish, damsels, parrotfish and rabbitfish made up the herbivore assemblage. Over the 3 years, fish densities decreased from 310±6 (mean±s.e.m. 250sq.m.$^{-1}$) to 238±4 to 197±4. Prior to bleaching, 7.2% of these fish were corallivores and 24.5% herbivores. 41.8% were omnivores. During the first post-bleaching period of study, species composition of corallivores and herbivores remained unchanged, although corallivore abundance became reduced by 78.0% and that of herbivores increased by 31.4%. In the second post-bleaching-year study period, 1 corallivore species was altogether absent and corallivore numbers declined further to comprise only 1.2% of all fish. Herbivores, however, increased to make up 48.0% of the fish assemblage, with 1 herbivorous angelfish appearing for the first time. Omnivores decreased to 26.5% and to 18.3% in the first and second post-bleach years. Support from MacArthur Foundation, Biodiversity Support Program and GEF is acknowledged.

NATURAL DISTURBANCES AND THE INTERANNUAL VARIABILITY OF CORAL REEF COMMUNITIES OF TIAHURA (MOOREA, FRENCH POLYNESIA): 1991-1997.

Adjeroud, Mehdi*, Augustin, David; Galzin, Ren_; Salvat. Bernard. *Ecole Pratique des Hautes Etudes, ESA CNRS 8046, Universit_ de Perpignan, 66860 Perpignan, France Email: adjeroud@univ-perp.fr

We analysed the interannual variability of the major reef communities on the outer slope of the Tiahura sector of Moorea, and we examined the impacts of natural disturbances. A sharp decrease in the percent cover of corals was observed from 1991 to 1993, as a direct result of the cyclone and the coral-bleaching event that occurred in 1991. Since 1993, a slight increase of coral cover was recorded, which can be interpreted as a sign of recovery. Despite the same proportion of bleached colonies at the beginning of the event in 1991 and in 1994, the bleaching in 1994 had no significant impacts on the coral cover. This demonstrates the importance of understanding the ecological history of the reefs for the interpretation of the specific impacts of a particular disturbance. The decline in the coral cover was accompanied by the increase in the percent cover of turf algae, but surprisingly, the percent cover of macroalgae did not show any significant change. Thus, the decrease in the coral cover, which opens up new substrate, is not always a sufficient condition for the increase of macroalgal coverage. The fish community was characterized by: 1) the high variability in the recruitment of juveniles; 2) the slight increase in the density of adult species; and 3) the decrease in the density of corallivores Chaetodontids from 1991 and 1994. Despite these variations, the species richness and density of the overall fish community did not show any significant upward or downward trend during the 7 year period.

INDICATORS OF UV EXPOSURE IN CORAL: RELEVANCE TO GLOBAL CLIMATE CHANGE AND CORAL BLEACHING.

Anderson, S. *, R. Zepp, J. Machula, D. Santavy, L. Hansen , G. Cherr and E. Mueller. University of California Davis, Bodega Marine Laboratory, Bodega Bay, CA 94923 USA Email: (susanderson@ucdavis.edu)

Increased exposure to solar UV radiation and elevated water temperatures are believed to play a role in the bleaching of corals. To provide additional tools for evaluating the role of UV radiation, we have examined UV-specific effects in coral and have characterized factors that alter the penetration of UV radiation over coral reefs at sites located in the Florida Keys. Using an immunoblotting assay to examine UV-specific lesions (thymine dimers) in coral and zooxanthellae DNA, we observed dose-dependent increases of thymine dimers in purified coral (*Porites porites*) DNA exposed to UV-C in the laboratory and with live *P. porites* exposed in a solar simulator. Field studies conducted at the Florida Keys (Maryland Shoals and Eastern Sambo) during July 1999 further demonstrated the utility of this technique in evaluating UV exposure of corals. For example, amounts of thymine dimers in *P. porites* collected at Maryland Shoals at the time of peak UV exposure (1300 hrs) were significantly higher than at 0830 hrs (p=0.04). UV measurements indicated that the coral reefs at Eastern Sambo (at 3-4 meters) were exposed to UV-B radiation that corresponded to 25-30% of surface UV irradiance. However, the water just inside the reef in Hawk Channel and closer to land was considerably more opaque to UV. This water photobleached with loss of UV absorbance and fluorescence when it was exposed to simulated solar radiation.

ADAPTIVE SIGNIFICANCE OF POST-BLEACHING RECOVERY OF REEFS IN THE LAKSHADWEEP ISLANDS, INDIAN OCEAN.

Arthur, R*, Turak, E., and Done, T. *TESAG, James Cook University, QLD 4811, Australia. Email: rohan.arthur@jcu.edu.au

The global mass bleaching of coral in 1998 resulted in a dramatic reduction in the cover of living coral in atolls along the Lakshadweep-Chagos chain. The reefs of the Lakshadweep, India, at the northern end of the archipelago, suffered large mortality of corals in the wake of the bleaching. Rapid assessments conducted a few months after the temperature maximum, reported between 5-8% cover of living coral. The genus *Acropora*, among the most abundant genera prior to the bleaching, was the worst affected, with only 0.8% cover recorded in October 1998. Surveys carried out two years after this mortality, indicate that live coral cover is still comparatively low, and accounts for 7.9% of the substratum on average. Dead standing coral and rubble, covered with turfing and coralline algae, dominate the benthic habitats. Despite the reduced cover of living corals, small colonies occurred in high densities in the reefs surveyed (3.6 individuals.m^{-2}), and were dominated by small *Acropora* (2.8 individuals.m^{-2}). A large proportion of the individuals is between 3cm and 7cm in diameter, and may represent juvenile coral that recruited before the 1998 bleaching. This suggests that the bleaching response of coral may be size-dependent, with recruits and smaller colonies being less susceptible to bleaching mortality than older coral. Young corals may have escaped bleaching mortality because of a lower initial zooxanthallae density, or by settling in more shaded locations..

NEW ORAL PRESENTATIONS

OCCURRENCE OF CORAL BLEACHING IN THE GULF OF THAILAND IN 1998.

Boonprakob R.* and Chankong, A.. *Eastern Marine Fisheries Development Center. Banphe, Muang district, Rayong 21160, Thailand. Email: pmbcnet@phuket.ksc.co.th

In 1998, the phenomenon of coral bleaching took place in the Gulf of Thailand, and lasted for 3 months from May to July. The cause of coral bleaching was an increase in seawater temperature. Most of corals in shallow water (1-2 m. depth) and deep water (>10 m. depth) were effected. In addition, others marine life such as giant clam, sea anemone and soft coral were sensitive to the increase of seawater temperature. The survey to evaluate the condition of coral reefs in Gulf of Thailand was done using Manta tow and Lifeform line intercept transect. Comparison of results from manta tow survey of selected islands in the Gulf of Thailand with total distance of 72 km prior to bleach, 1996-1997 to after bleaching in 1998, it is found that bleaching affected reef condition significantly. Prior to bleaching reef conditions were 29.1% excellent, 32.6% good, 23.4% fair, 6.9% poor and 7.9% very poor. After bleaching in 1998 reef condition were 0.5% excellent, 7.2% good, 17.2% fair, 28.8% poor and 46.3% very poor. In comparison of the survey result before and after the bleaching, 30-50% decrease in living coral was found in most of the area, and in some area up to 80-90% decrease was found. Branching coral and *Acropora* spp. coral were most affect. The least effected was mushroom coral. In general, a percentage cover of dead coral increased by 50-60% and this area was occupied by other marine life such as sea anemone, sea urchin and seaweed etc. This result showed that the condition of coral reef in the Gulf of Thailand has becoming deteriorating in general.

THE 2000 CORAL BLEACHING EVENT IN FIJI: FATES OF BLEACHED COLONIES.

Cumming R.L.*. *Department of Biology, School of Pure and Applied Sciences, The University of the South Pacific, PO Box 1168, Suva, Fiji. Email: cumming_r@usp.ac.fj

At the end of April 2000, Fiji was in the midst of a major coral bleaching event. The bleaching was widespread and severe, and coincided with a region of hot water over southern Fiji. Corals on the barrier reefs near Suva were bleached on the reef flats, crests and slopes. In the intertidal areas, almost all *Pocillopora damicornis* and *Acropora* spp. colonies were bleached on both the reef flat and the reef crest, whereas the dominant *Porites* microatolls were mostly unbleached. Monitoring studies were established to determine the fates of bleached colonies at both intertidal and subtidal sites, and I present results from those studies.

GEOGRAPHIC EXTENT OF THE 2000 CORAL BLEACHING EVENT IN FIJI IN RELATION TO WATER TEMPERATURE.

Cumming, R.L.*, E.R. Lovell, C. Hay. *Department of Biology, School of Pure and Applied Sciences, The University of the South Pacific, PO Box 1168, Suva, Fiji. Email: cumming_r@usp.ac.fj

Coral bleaching was first noticed in Fiji in February 2000, and by the end of April was widespread and severe. Seawater temperatures were over 30ºC for much of this time. Satellite data showed a region of hot water sitting over the southern half of Fiji, extending to the south-east over Tonga and the Cook Islands. The hot water did not extend to the northern side of Vanua Levu, in northern Fiji, and in this area there was little or no bleaching. We present aerial photographs of the northern and southern reefs, taken in late April 2000.

EXTENT AND DEGREE OF CORAL BLEACHING IN SELECTED REEFS IN CENTRAL PHILIPPINES.

Divinagracia M.B.*, H.P. Calumpong, A. White, and R. de . *Biology Department, Silliman University, Dumaguete City 6200, Philippines. Email: mlsucrm@mozcom.com

Extent and degree of coral bleaching among genera, among growth forms and with water depth were determined in four selected reefs in Central Philippines during May-June 1999. The reef area (km^2) affected by bleaching was estimated using systematic snorkeling method; the rest using transect-quadrat method. Apo was significantly affected at 35% (0.37 km^2), Sumilon at 32% (0.16 km^2), Balicasag at 13% (0.04 km^2), Pamilacan at 6.4% (0.16 km^2). Mean bleached cover was significantly highest in Apo at 39% $\pm$ 6. No significant differences were found between Sumilon (20% $\pm$ 4), Balicasag (16% $\pm$ 4) and Pamilacan (6% $\pm$ 2). *Galaxea* in Apo had significantly highest mean bleached cover (41% $\pm$ 5), *Seriatopora* in Sumilon (35% $\pm$ 8), *Montipora* and *Pocillopora* in Balicasag (16% $\pm$ 6, 10% $\pm$ 1, respectively), and *Pocillopora* in Pamilacan (13% $\pm$ 6). In terms of growth forms, massive forms were significantly affected in Apo (42% + 7), branching forms in Sumilon, Pamilacan, and Balicasag (32% $\pm$ 6, 13% $\pm$ 3, 16% $\pm$ 4, respectively) with the foliose forms (15% $\pm$ 6) statistically similar to branching forms in the latter. Bleaching occurred at all depths (10 - 50 ft). There was significant variation in the degree of bleaching among depths in Sumilon and Balicasag whereas, in Apo and Pamilacan, degree of bleaching did not vary significantly. Most of the affected colonies were already colonized by small filamentous and encrusting algae and were observed to be dead. Some coral colonies had white spots all over the surface (probably white band disease).

THIRTEEN MONTHS MONITORING CORAL BLEACHING ON BAHIA'S NORTH COAST, BRAZIL.

Dutra, Leo X. C. *, Kikuchi, Ruy K. P. and Leão, Zelinda M. A. N. *Laboratório de Estudos Costeiros, Universidade Federal da Bahia, Bahia, Brazil. Email: leo@bahianet.com.br

On January 1998 an abnormal increase of sea surface temperature, caused by the El Niño Southern Oscillation, was detected on the north coast of the state of Bahia. Field monitoring observations, along belt transects, evaluated consequences of this high temperature on reef coral communities from reefs around 10m depth. Total, partial or absence of bleaching was identified in at least 100 colonies, along at least 4 (10m x 1m) belt transects at each expedition. After thirteen months a total of 1109 colonies were observed and seven species of reef corals were found: *Siderastrea stellata* (43,19% of occurrence frequency), *Mussismilia hispida* (30,84%), *Agaricia agaricites* (17,58%), *Montastrea cavernosa* (4,69%), *Favia gravida* (2,61%), *Porites branneri* (0,99%) and *Mussismilia braziliensis* (0,09%). A maximum of 1ºC increase in sea surface temperature was sufficient to cause total bleaching in 100% of *A. agaricites* colonies and 95% of *Mussismilia hispida* colonies in April 1998. Total bleaching affected less than 45% of *Siderastrea stellata* colonies in the beginning of the mass bleaching episode in April 1998. Though most severely affected, *Agaricia agaricites* and *Mussismilia hispida* showed a high regeneration rate, with 100% "healthy" colonies in May 1999, when there still were more than 50% of partially bleached colonies of *Siderastrea stellata*. No dead colony was detected during the monitoring period.

NEW ORAL PRESENTATIONS

STATUS OF SCLERACTINIAN CORAL COMMUNITIES ON THE REEFS OF THE INNER GRANITIC ISLANDS OF THE SEYCHELLES ONE YEAR AFTER THE 1998 MASS CORAL BLEACHING.

Engelhardt U.*, *Reefcare International Pty Ltd, PO Box 1111, Townsville, Queensland 4810, AUSTRALIA. Email: reefwatch@ozemail.com.au

Recently, coral reefs around the inner granitic islands of the Seychelles have suffered widespread hard coral mortality as a result of a variety of major ecological disturbances. In 1998, the most widespread and severe mass coral bleaching event on record as well as previously active outbreaks of crown-of-thorns starfish (*Acanthaster planci*) combined to cause severe system-wide degradation of local coral communities. Intensive transect-based benthic surveys conducted across 15 individual reef sites in November and December 1999 found that remnant communities of scleractinian corals were characterised by both low percent live cover and low diversity. The mean percent cover of live hard coral ranged from 0-5% recorded at 12 of the 15 sites surveyed (80%) to a maximum average value of 0-10% recorded at the remaining 3 sites (20%). Hard coral diversity was low across the entire survey area with a maximum of 15 scleractinian genera and 10 families being recorded at any one site. This compares to up to 47 genera recorded during scientific surveys conducted in the 1980's and 1990's, suggesting that, at a generic level, local scleractinian diversity has been reduced by as much as 50% as a result of the identified disturbances. Preliminary analyses have identified excessively high abundances of black-spined sea urchins (*Diadema* and *Echinometra* spp.), high sedimentation levels and low coralline algal cover as key local factors with a potential to prevent future hard coral recovery from achieving optimal rates.

CHANGE OF CORAL METABOLISM BY BLEACHING EVENT.

Fujimura, H. * T. Maehira, K. Miyahira and T. Oomori. *Graduate School of Engineering and Science, University of the Ryukyus, Senbaru 1, Nishihara, Okinawa 901-0213, Japan Email: k988558@sci.u-ryukyu.ac.jp

Coral bleaching events have been frequently observed since 1980's in global coral reefs and caused serious problems for ecosystems and environment. Anomalous high water temperature and coral bleaching were observed in an extensive area of the western Pacific Ocean in 1998. It is interesting to study a change of coral metabolism caused by the lost of symbiotic relationship between coral and zooxanthellae. To investigate how has been affected the carbon cycle in coral metabolism, inorganic and organic carbon productions, air-sea CO_2 flux and carbon budget were measured before and after coral bleaching at an experimental aquarium. A great depression was observed in inorganic carbon production (*i.e.*, calcification) in the daytime after coral bleaching, as well as organic carbon production (*i.e.*, photosynthesis). Increase of alkalinity in the nighttime was observed both before coral bleaching and after coral bleaching, showing the dissolution of $CaCO_3$. After coral bleaching, the amount of $CaCO_3$ dissolved was greater than that of $CaCO_3$ calcified, resulting a negative value of daily carbon budget in the aquarium that suggest the dissolution of carbonate skeleton. Direct measurements of air-sea CO_2 flux showed CO_2 absorption that was enhanced by dissolution of carbonate skeleton.

BLEACHING AND HURRICANE EFFECTS ASSESSMENT IN MAHAHUAL REEF, MEXICO.

Garza-Pérez, J. R.* & J.E. Arias-González. *Laboratorio de Ecología de Ecosistemas de Arrecifes Coralinos CINVESTAV-I.P.N. Unidad Mérida. Ant. Carr. Progreso km 6. A.P. 73 Cordemex C.P. 97210 Mérida Yucatán, México. Email: rodgarza@pibil.finred.com.mx

Mahahual reef is located in the south of the Mexican Caribbean (18º 42" N, 87º42"W.) is part of the Mesoamerican Reef System along with the reefs from Belize, Guatemala and Honduras. By its biodiversity, this system recently acquired the status of World Heritage. Mahahual is a small fishermen village with a population of ca. 300 inhabitants and the ecological importance of Mahahual reef relays on being one of the most developed coral reefs in the area. It is subjected to human exploitation as artisanal fisheries of economically important species, tourism and natural impacts. Besides, it is considered as a new pole of attraction by the new big-scale tourist development in this region known as "Costa Maya". This study is part of a far ranging comparative study between reefs of the south-central portion of the Mexican Caribbean. This article is mainly focused on the following of the state of the scleractinean coral community, prior and after two major natural events: hurricane "Mitch" during October 1998 and a massive bleaching event since September 1998. The results show a significant change in the cover and health of the scleractinean corals from the pre-bleaching state in May '98 to the last follow up in February '00. Throughout the study different health condition can be observed, from a well preserved coral community to an impacted one and then to an almost recovered status that presents a shift in the proportions of some of the most important reef building groups.

CORAL BLEACHING- SO WHAT? RECOLONIZATION OF A REEF AFTER EL NIÑO IMPACT.

Heeger, T.*; Langevoord, M.; Gatus J. and F. Sotto. University of San Carlos -Marine Biology Section- P.del Rosario St., Cebu City, Cebu, Philippines. Email: theeger@mangga.usc.edu.ph

Coral reefs in the world are threatened by natural and anthropogenic impacts. Outbreaks of Acanthaster planci reaching plaque levels, diseases, extreme physical forces following storms and unusually high sea surface temperature (SST) may have dramatic consequences for reefs locally. The recruitment of corals following a massive death due to bleaching during the strong El Niño phenomenon in 1998 was studied. 93% of the scleractinian corals in Cordova reef, Mactan, Philippines, were affected by bleaching. 16 months later the reef was resurveyed counting coral recruits of three size categories (<3cm; 3.1-5cm; >5cm) on dead Acropora tables (Acropora valenciennesi) and rocky substrate. Results have shown that both number and diversity of recruits on dead corals with colony size less than 3cm are significantly higher compared to those on rocky substrate per unit area. The data suggest that the elevated position of the dead Acropora tables (average of 45cm height) combined with their intact skeleton serves as protection against predators. Bleaching considered as a natural threat to coral reefs may not be a threat at all because it provides new chances for coral recruits in terms of increased abundance and diversity, triggering successive micro-evolution.

NEW ORAL PRESENTATIONS

EXPERT SYSTEM GENERATED CORAL BLEACHING ALERTS FOR MYRMIDON AND AGINCOURT REEFS ON THE GREAT BARRIER REEF, AUSTRALIA.

Hendee, James C.* and Ray Berkelmans. Atlantic Oceanographic and Meteorological Laboratory; National Oceanic and Atmospheric Administration; 4301 Rickenbacker Causeway; Miami, FL 33149-1026; USA. Email: Jim.Hendee@noaa.gov

An expert system shell, termed the Coral Reef Early Warning System (CREWS), was employed at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami, Florida, USA, to provide interpretations of combinations of near real-time meteorological and oceanographic data, thought to possibly be conducive to coral bleaching, collected via a HF radio at the Australian Institute of Marine Science from Myrmidon and Agincourt Reefs. At Myrmidon Reef, CREWS was useful in "predicting" coral bleaching using previously collected February, 1998 data; alerts produced from real-time data during the end of January, 1999 could not be validated. During the end of January and early February, 2000, alerts were produced and sent for Agincourt Reef and Myrmidon Reef. Although bleaching did not occur at Agincourt Reef, bleaching occurred on a small scale for a few species of *Acropora* at Myrmidon Reef; these incidences were not predicted using NOAA's HotSpot Sea Surface Temperature anomaly technique.

CHANGES IN CORAL POPULATIONS ON ROATAN REEFS SUBSEQUENT TO 1998 BLEACHING AND HURRICANE MITCH.

Hermans K.K., and J.R. Keck*. Roatan Institute for Marine Sciences, Sandy Bay, Roatan, Bay Islands, Honduras. Email: rimsed@globalnet.hn

Long term monitoring of Roatan's coral reefs, aimed at assessing environmental and human impact factors on biodiversity, includes photographic surveys of permanently marked locations. In 1996, twenty photographic quadrats (each 0.33 m^2) were installed approximately 12 m deep at each of three dive sites located on the northwest coast of Roatan (sixty quadrats total). Photographs have been taken at six or twelve month intervals beginning in Sep. 1996. The observation period includes a massive bleaching event starting in Sep. 1998, concomitant with Hurricane Mitch in Oct. 1998. Colony number and projected surface area (PSA) of all scleractinian coral colonies were determined. PSA was used to estimate total percent coral coverage. A small reduction in the number of live colonies was observed from Sep. 1996 to Oct. 1998 with 36 of 554 colonies observed (6%) suffering complete mortality. Four new colonies were also observed. Total hard coral coverage decreased slightly from 32% $\pm$ 16% in 1996 to 29% $\pm$ 16% in 1998 (N.S.). A significant decline was observed subsequent to Oct. 1998: by Sep. 1999, an additional 92 colonies (16%) suffered complete mortality and hard coral coverage had declined to 20% $\pm$ 14 % ($p < 0.0001$). An additional 15 new colonies were observed during this period. Predominate species *Montastrea annularis*, *M. faveolata*, and *M. franksi* suffered the greatest decline accounting for approximately 56% of the total hard coral coverage in 1996 and only 34% in 1999 ($p < 0.05$). While the most marked decline in coral vitality was observed following natural catastrophic events, human factors may also be playing a role in the more gradual decline observed over time.

CORAL COMMUNITY STRUCTURE CHANGES IN RESPONSE TO DEVELOPMENT ACTIVITIES AND NATURAL BLEACHING: IWAYAMA BAY, REPUBLIC OF PALAU.

Houk Peter. P.O. Box 501304, 3rd Floor Morgan Bldg., Saipan, MP. 96950. Email: p_houk@hotmail.com

Coral communities were examined before and after development activity and a natural bleaching event following the 1998 El Nino. Data from test sites were compared with reference sites to discover added effects that turbidity or sediment deposition rates may have had on coral communities exposed to a natural bleaching event. Significant regressions were found between turbidity levels during development activities and loss of coral cover. The dredging of an artificial channel to allow boat traffic via the Ngerkeseuaol Channel was the source of turbidity associated with the affected sites. These data suggest that increased turbidity over the time period noted had an added effect on coral communities exposed to a natural bleaching event. Control measures consisted of sediment retention dams for terrestrial sediments and siltation curtains for dredging. Rates of sedimentation were similar at test sites to those at reference sites. Sedimentation rates varied from 0.33 – 11.7 mg/(cm^2 x day). The major natural bleaching event that coincided with the time frame of the study resulted in 35 – 65 % decreases in coral cover at reference sites. The following were especially affected: *Anacropora spinosa, Seriatopora hystrix, Porites cylindrica, Pocillopora damicornis, Acropora formosa, Montipora digitata, Montipora aequituberculata, Echinopora lamellosa,* and *Oxypora lacera.*

A WATER TEMPERATURE MONITORING NETWORK AROUND THE RYUKYU ISLANDS, JAPAN.

Kakuma S.*, Moromizato, K., Nadaoka, Y., Nihei, Y., Ikema, T., Oomija, K., Iwao and Y. Nakano. Okinawa Fisheries Experimental Station, 1-3-1 Nishizaki Itoman Okinawa Japan. Email: skakuma@fish.pref.okinawa.jp

In summer 1998, water temperature around the Ryukyu Islands was extremely high and many coral reefs suffered bleaching. We have monitored the water temperature, one of the main causes of the bleaching, in coastal waters at every 10 minutes, 20 minutes or one hour; and expanded the monitoring points throughout Okinawa to 71 in May 1999 using 88 small temperature loggers. Local fishermen placed and retrieved most of the loggers. The water temperature showed different fluctuation patterns among locations, depths and geographical features. At one coral lagoon, the water temperature in August 1998 averaged 31.0 C. (28.4 C. in 1997 and 28.0 C. in 1999). The coastal water temperature seemed to be affected by atmospheric temperature, precipitation and the number of typhoons attacked Okinawa, but also affected by off-shore water temperature and current. Accordingly, we started monitoring the off-shore environment at 10 huge Fish Aggregating Devices (FADs) around the Ryukyu Islands in April 2000. These coastal and off-shore monitoring points have formed a effective monitoring network for coral reef environment.

NEW ORAL PRESENTATIONS

IMPACT OF CORAL BLEACHING ON BUTTERFLY FISHES IN SRI LANKA

Karunarathna, MMC*, National Aquatic resources Research and Development Agency, Crow Island, Mattakkuliya, Colombo 15, Sri Lanka. Email: chaminda@nara.ac.lk

Loss of live corals due to the coral bleaching event in 1998 and the impact on the butterfly fishes in Sri Lanka.

QUANTITATIVE ASSESSMENT OF CORAL BLEACHING IN GUARAJUBA'S REEF, NORTHERN BAHIA, BRAZIL.

Kelmo, Francisco*; Attrill, Martin & Leao, Zelinda. *Coral Reef Ecology, Benthic Ecology Research Group, Department of Biological Sciences, University of Plymouth, Drake Circus, PL48AA, United Kingdom. . Email: fkelmo@plymouth.ac.uk

The consequences of bleaching are of particular concern for the large number of reef-building corals. The aims of this study were: (i) to provide an inventory of living scleractinian corals from nearshore reef at Guarajuba beach, Northern Bahia, Brazil; (ii) to record the temperature, salinity, pH and water transparency during the sampling period; (iii) to quantify and characterize the occurrence of bleaching at the studied site, and (iv) to determine the abiotic parameters responsible for coral bleaching in these Bahian reefs. Throughout twelve months (May 96/April 97), seventy quadrats of 1m2 were sampled (35 on the reef top and 35 at the reef walls) to quantify the relative frequency of bleached, normal and dead coral colonies. Seven species of scleractinian corals were recorded from the studied reef: *Agaricia agaricites, Siderastrea stellata, Porites astreoides, Favia gravida, Montastrea cavernosa, Mussismilia harttii* and *Mussismilia hispida*. The analysis of the relative abundance data highlights *S.stellata* as the most abundant species on the reef top, with *M.hispida* the dominant species on reef walls. All species recorded were bleached during the sampling period. The quantification of the coral densities, in combination with the relative frequency of bleached colonies, suggest this to be a chronic phenomenon. BIOENV analysis suggests mean temperature, turbidity and cloud cover variation as the main factors best explaining the oscillation in the density of bleached and dead colonies. *S.stellata* and *F.gravida* appear to be the species most resistant to bleaching in Guarajuba.

SIMULATION STUDY OF RISING WATER-TEMPERATURE AT RYUKYU'S CORAL REEF IN 1998.

Kudo Kimiaki *. Japan Marine Science and Technology Center, 237-0061 Natsushimacho 2-15, Yokosuka, Japan. Email : kudok@jamstec.go.jp

Coral reefs around the Ryukyu islands were heavily damaged due to the worst bleaching in 1998. Elevated sea surface temperature was supposed to have played the key role in the bleaching processes. The mass bleaching episodes were linked to global warming in journalism, which is not yet confirmed. Simulation study was made to understand and estimate the SST elevation due to not only the external warm current but the local daily variation. Increased solar irradiance, calm weather and stagnant tide are superimposed to enhance the local SST elevation. In the summer of 1998, the amount of clouds was observed 20% lower and the mean velocity of wind was 50% weaker than those of normal year. The simulation showed that the offshore SST is about 2_ higher than that at the normal conditions and the nearshore daily variation of water temperature at neap tide is maximum 0.9_ higher and minimum 0.5_ lower than the offshore base. In normal year, wind-driven currents dominate the horizontal heat advection, but in 1998, the vertical mixing of waters mainly affects the SST variation.

THE DISTRIBUTION PATTERN OF CORALLIMORPHARIANS (CNIDARIA: ANTHOZOA) ON TANZANIA REEFS AFTER THE 1998 CORAL BLEACHING EVENT.

Kuguru, Baraka L.,* and Muhando, Christopher A.. *Institute of Marine Sciences, P.O. Box 668, Zanzibar, Tanzania. Email: kuguru@zims.udsm.ac.tz

The distribution patterns of Corallimorpharians after the 1998 coral bleaching event in Tanzania was assessed in five reefs in Zanzibar and Dar es Salaam. Four corallimorpharian species were encountered: *Rhodactis rhodostoma, Actinodiscus unguja*, *Actinodiscus nummiforme*, and *Ricordea yuma*. Higher cover of corallimorpharians was observed on the reef flat (28.35 %) and reef crest (30.30%) than on the reef slope 2m (10.70%) and 4m (12.06%) below the reef crest. *Rhodactis rhodostoma* was the dominant corallimorpharian in both cover (30% on reef flat to 6% in reef slope) and frequency of occurrence. Corallimorpharians were found associated more with dead coral, rock and rubble. Their abundance was found to be negatively correlated with water visibility ($r = -0.9$, $P < 0.05$) and they were more abundant in disturbed reefs Mbudya (15.2%), Bongoyo (18%) and Changuu (22%) than in less disturbed reefs, Chumbe (9.9%) and Bawe (8.8%). The information obtained indicates that corallimorpharians especially *Rhodactis rhodostoma* may be a threat to disturbed reefs in Tanzania.

NEW ORAL PRESENTATIONS

20TH CENTURY CLIMATE CHANGE AND THERMAL STRESS ON CORAL REEFS.

Lough J.M. * Australian Institute of Marine Science, Townsville, Qld 4810, Australia. Email: j.lough@aims.gov.au

1997-1998 witnessed the most intense el niño-southern oscillation (enso) event on record, which resulted in major climatic anomalies throughout the tropics and extending into extra-tropical regions. 1998 has also been reported to be the warmest year in the past century and possibly the past millennium. During 1997-1998 there was an unprecedented number of reports of mass coral bleaching affecting most of the world's coral reefs. Although a variety of environmental stresses can cause corals to bleach, the evidence for 1997-1998 clearly implicates unusually warm ssts during the respective warm seasons as the primary cause at affected reefs. Two indices of warm season ssts are presented for 47 reef sites where bleaching occurred during 1997-98. The level of thermal stress at these coral reef sites during 1997-98 was unmatched in the period 1903-99. Warm season ssts at these coral reef sites have significantly warmed over this period and the frequency of warm season sst extremes has increased since the late 1970s.

EFFECT OF THE CORAL BLEACHING PHENOMENON IN 1998 ON GAMETOGENESIS OF A SOFT CORAL, *CLADIELLA* SP., IN THE GULF OF THAILAND.

Nopchinwong, Parnhathai* and Yeemin, Thamasak. *Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand. Email: parnhathai@yahoo.com

The alcyonacean is a very important member of coral communities in the Gulf of Thailand. Sexual reproduction of the soft coral, *Cladiella* sp., has been studied in coral communities of Khang Khao Island, Chonburi Province, in the Inner Gulf of Thailand and Samet Island, Rayong Province in the Eastern Gulf of Thailand since September, 1998. Monthly sampling of tagged colonies and microtechnique analysis of histological samples in the laboratory were carried out. *Cladiella* sp. was a gonochoric species, separated male and female colonies. Several developmental stages of oocytes were found in each sampling period. According to the severe coral bleaching phenomenon in the Gulf of Thailand in April-May 1998, gemetogenesis of *Cladiella* sp. was interrupted in several months. Moreover, partial mortality of several colonies was obviously recorded. Recover of gonodal development of the soft corals between the two study sites were absolutely different because of the different environmental factors, such as turbidity, sedimentation rate and population structure.

BLEACHING AND RECOVERY AT LAYANG LAYANG, SOUTH CHINA SEA.

Pilcher, N.J.* & K. Atack. *Institute of Biodiversity and Environmental Conservation Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Email: nick@tualang.unimas.my

Layang Layang is a remote atoll among the Spratly islands in the South China Sea. It is occupied by Malaysia with overlapping claims from China, Vietnam and the Philippines, and supports a small Navy base and a diving resort. The atoll is 7 km long on its SE-NW axis and 2.5 km wide. Permanent photographic sampling of 55 one sq. m quadrats has been carried out biannually since 1996. The quadrats were divided into 11 sites, nine on the outer edge of the atoll and two within the lagoon, with five replicates per site, between 5 and 15 m water depth. The site was chosen due to its remoteness and lack of anthropogenic impacts. To determine the impact of the global sea surface temperature rise in 1998 in the South China Sea which resulted in bleaching and death of many scleractinian corals, quantitative spectral image analysis was performed on the quadrat photographic records, which include pre-bleaching, bleaching and post-bleaching periods. The results are a source of quantitative data on bleaching extent and qualitative data on the recovery process. In general recovery was fast, with the majority of bleached spots either recovered or overgrown by early 1999. Major recolonising individuals were *Didemnum mole* ascidians and *Xenia* sp. soft corals. Hard corals in deeper water recovered more extensively than those in the shallows.

ANALYSIS OF OZONE SATELLITE DATA : NO RELATION BETWEEN UV AND REEF MASS BLEACHING.

Pêcheux, Martin*. Nice University, 15bis rue des Roses, 06100 Nice, FRANCE. Email : martinpecheux@minitel.net

Mass bleaching of reef symbioses is a recent and worldwide phenomenon. With the advent of the ozone hole at the same time, many researchers have supposed that UV trigger bleaching events, and have realized experiments. This hypothesis is still often mentionned. Here I analyze the satellite Nimbus 7 TOMS ozone data above reef areas from 1979 to 1991. As already known, there is no trend in ozone amount in tropics at month, season nor year time scale. I found nor more frequent or more pronounced low ozone values. Twenty bleaching events for which the date were sufficiently known were examined. It did not reveal any correlation with lower ozone level, nor with particular drawdown. Bleaching events occurs generally when the sky is clear, but this condition is not new. Water transparency can not be a relevant factor, as bleaching happens often in very shallow water, where long term change can be only negligeable. Thus, the UV hypothesis must be discarded, and this lets Global Warming and/or CO2 rise as the last explanations of reef mass bleaching.

NEW ORAL PRESENTATIONS

THE 1998 MASS CORAL BLEACHING EVENT IN THE PHILIPPINES: ECOLOGICAL IMPACT ASSESSMENT.

Quibilan, Miledel Christine C.*; Arceo, Hazel O.; Aliño, Porfirio M. and. Licuanan, Wilfredo Y. *Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, PHILIPPINES. Email: mags@msi01.cs.upd.edu.ph

The 1998 mass bleaching event caused an unprecedented mortality of corals and coral-associated organisms in the Philippines. Previous studies by the authors have shown that the mass bleaching event was coincident with elevated sea surface temperatures affecting reef areas in the Philippines to varying degrees. To assess the ecological impact of bleaching in the country, both qualitative and quantitative approaches were used. Qualitative information on the severity and extent of bleaching in the Philippines was collected using forms sent to respondents from various sectors (government agencies, non-governmental organizations, recreational divers, etc.) nationwide. Coral and reef fish surveys were also conducted in key reef areas categorized as low, medium, or high bleaching impact areas (CBIAs) to collect quantitative information on reef condition. Shifts in reef community structure was determined and compared across CBIAs based on the relative changes in benthic cover and their associated reef fishes (i.e. species diversity, abundance, and biomass).

THE IMPACTS OF THE 1998 CORAL BLEACHING EVENT IN THE INDIAN OCEAN ISLANDS.

Quod, Jean Pascal*, Westmacott, Susie, *ARVAM, 14 rue du stade de l'Est, 97490 Ste Clotilde, Réunion, France. Email: arvam@guetali.fr

The Indian Ocean Islands of Comores, Madagascar, Mauritius, Mayotte, Reunion, Rodrigues, and Seychelles were affected differently by the 1998 coral bleaching. Biophysical and socio-economic assessments, carried out as part of the CORDIO programme, have been used to make a first assessment of the impact of the coral bleaching event. Mauritius and Reunion apparently escaped any adverse effects from the coral mortality potentially due to good hydrodynamic and climatic conditions at the time. Mayotte and Seychelles were severely affected by the bleaching with coral mortality reaching over 90% in places. Some areas appeared to have partially recovered, for example, in the lagoons where corals have adapted to wide fluctuations in temperature. The state of the reef carries huge economic significance when considering the tourism and fishing industries. Tourism in Mauritius and Seychelles is heavily reliant on the coastal and marine environment, whereas other islands, such as Madagascar and Reunion, have alternative attractions for tourism. Fisheries are an important source of food as well as foreign earnings in the region. These regions do, however, face increasing human pressure on the reefs creating over-extraction of the reef resources in turn causing reef degradation.

EL NIÑO 1997/98: DEATH AND BIRTH OF CORALS IN THE GALAPAGOS ISLANDS, ECUADOR.

Rivera, Fernando E.*. *Zoology Departmet, University of Melbourne Parkville Victoria 3052, Australia. E.mail Address: f.rivera@pgrad.unimelb.edu.au

During the El Niño event of 1997/98, seawater temperatures in the Galapagos Islands remained at or above 29 ^{o}C for more than 4 months, causing extensive coral bleaching and the recruitment of one species. Colonies of the dominant reef-building coral species *Porites lobata*, *Pavona clavus*, *P. gigantea*, *P. varians*, *Psammocora spp*, *Pocillopora damicornis*, *P. inflatans*, and *P. elegans* were surveyed during and after the event in several islands of the archipelago. Surveys results showed different levels of bleaching among species and islands; the most affected species was *P. lobata* with 90% of colonies bleached, whereas less than 10% of *P. elegans* were bleached. These contrasted with the previous El Niño in 1982/83, where *P. elegans* suffered the highest mortality (more than 90%). Besides suffering a lesser degree of bleaching, *P. elegans* also recruited successfully during the last El Niño. This is the first time that I have detected recruitment of *P. elegans* on the west side of Galapagos since their disappearance after the 1982/83 El Niño. New recruits were found around the central, south and the west side of the archipelago towards the end of the 1997/98 El Niño. The presence of coral recruits in the western islands of Isabela and Fernandina, upwelling zones where seawater temperatures are normally between 14- 20 degrees Celsius during the year, is unusual. This suggests that the coral reef patches that occur in this area could be the result of past severe El Niño events.

THE EFFECTS OF BLEACHING EVENTS ON GEOCHEMICAL PROXIES IN CORALS.

Roark, Brendan*, Lynn Ingram, and Malcolm McCulloch. Geography Dept., U.C. Berkeley, Berkeley CA, 94720, Email: ebroark@socrates.berkeley.edu

Coral reef ecosystems worldwide have been subjected to increasing anthropogenic and natural perturbations over the last few decades leading to an apparent increase in the magnitude and extent of coral bleaching events. In order to understand the immediate and long term consequences of these bleaching events it is important to compare them to long term records of natural variations. We have begun a study to see if it possible to identify past bleaching events in coral cores geochemically and to correlate these events with proxy records of environmental data such as SST and salinity (δ^{18}O, Sr/Ca). Several studies have suggested that changes in the δ^{13}C values of coral may be a proxy for bleaching events, but the sampling resolution was not high enough to conclusively prove this idea. Here, we present a high resolution (near weekly) δ^{13}C, δ^{18}O, and Sr/Ca record from two *Porites* corals from Moorea, French Polynesia during the period 1985-1997. We compare the geochemical data in these coral cores to locally measured SST and salinity, and to two documented bleaching events in 1991 and 1994. Sr/Ca measurements are used to quantify seasonal variations in SST, and to correct for any variation in the δ^{18}O signal due to changes in salinity from precipitation or runoff. Preliminary observations of the records to date show a decrease in δ^{18}O and δ^{13}C values and a change in the seasonal amplitude of Sr/Ca values caused by an increase in SST, and a decrease in photosynthesis due to the loss of the zooxanthellae during the two bleaching events.

NEW ORAL PRESENTATIONS

CHANGES IN THE STRUCTURE OF FISH COMMUNITIES FOLLOWING CORAL BLEACHING IN THE SUMMER OF 1998 AT URASOKO BAY, ISHIGAKI ISLAND, JAPAN .

Shibuno, Takuro *, Abe, O. Hashimoto, K. and Takada, Y.. *Ishigaki Tropical Station, Seikai National Fisheries Research Institute. 148-446 Fukai-Ohta, Ishigaki, 907-0451, Japan. Email: shibunot@snf-its.affrc.go.jp

The fish fauna at permanent transects on an outer reef and a moat at Urasoko Bay, Ishigaki Island were monitored in October 1998, January, March, July and November 1999, after severe coral bleaching in the summer of 1998. Coral bleaching and its effects on the fish community differed between the two habitats. At the outer reef, most of living corals consisted mainly of *Acropora* spp. had died by late September 1998 and their dead coral skeletons were coated with filamentous algae. The number of herbivores, particularly two acanthurids (*Ctenochaetus striatus*, *Acanthurus nigrofuscus*), increased after the coral bleaching. The number of individuals increased, but the number of species and species diversity (Shannon-Wiener index, H') decreased after the coral bleaching. At the moat, where the benthic substrata consisted mostly of dead coral rubble and sand with several microatolls of massive *Porites*, most of living corals were not affected by severe bleaching. The number of acanthurids did not differ before and after the coral bleaching. Both the number of individuals and species, and species diversity (H') increased after the coral bleaching. The size distributions of acanthurids completely differed between the outer reef and the moat. At the outer reef, small sized acanthurids were not found. These results suggest that the two acanthurids responded to the increase in algal biomass by migrating from adjacent habitats to the outer reef after the coral bleaching.

CHANGES IN OPTICAL REFLECTANCE AND PIGMENTATION OF THE CORAL *MONTASTRAEA FAVEOLATA* IN RESPONE TO ELEVATED TEMPERATURE AND ULTRAVIOLET-B RADIATION.

Steely, Teresa*; Schmidt, Carl; Hardy, John; Strom, Suzanne; Bynagle, Maria; Miller, Adrienne and Peterson, Emily. *Shannon Point Marine Center, Western Washington University, Bellingham, WA 98225-9181. Email: jhardy@cc.wwu.edu

Elevated temperature and ultraviolet-B (UVB) radiation can induce coral bleaching, i.e. the loss of symbiotic zooxanthellae and their pigments. It may be possible to detect bleaching by remote sensing through measured changes in the reflectance spectra. We examined the relationship between coral pigments and *in vivo* optical spectra. We collected 2.1 cm diameter cores of *Montastraea faveolata* at 15 ± m depth (29.5 °C) from Lee Stocking Island, Bahamas. Replicate samples from three colonies were exposed in an outdoor incubator for 96 hours at 31 °C to: 1) *in situ* reef doses of photosynthetically active radiation (PAR) and UVB, 2) *in situ* PAR and enhanced UVB, and 3) enhanced PAR and UVB. Coral pigments were measured by HPLC analysis and *in vivo* reflectance of coral was measured using a portable fiber optic spectrofluorometer. After 96 hours exposure, coral showed a linear increase in reflectance with decreasing surface density of chlorophyll-a. Results suggest that small changes in pigmentation can be detected *in vivo* as changes in optical reflectance. A UVB dose rate of 43 kJ m^{-2} day^{-1} for 4 days, i.e. a cumulative dose of 172 kJ m^{-2} was sufficient to induce bleaching. When the water column attenuation coefficient is applied to this dose, our results indicate that at 31 °C the time for severe bleaching to occur increases exponentially with depth.

PRESENT CONDITION OF REEF-BUILDING CORALS IN AKAJIMA ISLAND AFTER THE HEAVY CORAL BLEACHING IN 1998.

Taniguchi, H.*, Iwao, K. and Omori, M. *Akajima Marine Science Laboratory, 179, Aka, Zamami-son, Okinawa 901-3311 Japan. Email: taniguchi@amsl.or.jp

An unprecedented event of coral bleaching hit the Okinawan waters including Akajima Island in summer 1998. Percentage bleaching of reef building corals relative to the total coverage ranged from 56 to 97% at 15 sites in late September 1998. Three out of 4 sites that showed over 90% bleaching were located in either a moat or inside of a bay where the water exchange rates were low. Another site was characterized by dominant occurrence of branched type of the genus *Acropora* that was damaged by bleaching heavier than other types. Geographical features, rate of water exchange, and composition of coral species seem to be responsible for the differences in extent of bleaching. We continued observation at 4 sites around the Island. At the Maenohama site where 91% of total colonies were bleached in September 1998, however, 25% had dead, 15% were still partially bleached, and other 44% of total colonies recovered completely by March 1999 after 6 months. This situation is much better than the corals in other areas of Okinawa. The survived corals are now recovering and increasing the coverage significantly.

MEASURING CHANGES IN PIGMENTATION OF THE CORAL *MONTASTRAEA FAVEOLATA* VIA PHOTOGRAPHIC ANALYSIS.

Thorpe, Mike *, Hardy, John and Frostad, Jonathan *Shannon Point Marine Center, Western Washington University Bellingham, WA, 98225-9181, Email: Thorpem@cc.wwu.edu

Algal symbionts (zooxanthellae) are critical to the growth and survival of reef-building corals. Elevated temperature and ultraviolet radiation can cause coral to lose their algal symbionts and pigmentation in a process known as coral bleaching. Photoanalysis may provide a convenient and rapid method for quantifying coral bleaching without extensive chemical or biological analysis. Experiments were performed at the Caribbean Marine Research Center, Lee Stocking Island, Bahamas in July, 1999. Two cm diameter plugs of coral *Montastraea faveolata* were collected from a reef at 16 meters depth, placed in an incubator and exposed to combinations of enhanced PAR (photosynthetically active radiation), UVB (ultraviolet-B), and elevated temperature for 96 hours. After treatment the coral plugs were individually photographed against a white scale and then analyzed for pigments, nitrogen, carbon, and photosynthetic rates of zooxanthellae. We quantified the mean and variance of the luminosity for each coral sample using Adobe PhotoShop, and examined the changes in these values as the level of bleaching increased. Initial data shows that coral bleaching is easily detected and differentiated by comparing the mean and variance of luminosity. Further analysis will examine the relationships between luminosity and changes in pigmentation, and photosynthetic rates.

NEW ORAL PRESENTATIONS

CORAL BLEACHING ON OKINAWA IN 1988: THE EFFECTS OF TYPHOONS AND SEA TEMPERATURE CHANGES FROM 1997-1999.

Tsukayama, Seiko*; Nakaza, Eizo; Kawamitsu, Yasutomo; Kitamura, Koji; and Makino, Toshiaki. *University of the Ryukyus, Shembaru 1, Nishihara, Okinawa, Japan. Email: enakaza@tec.u-ryukyu.ac.jp

The seas around the Okinawan islands of southern Japan are well known as one of the most beautiful coral seas in the world. In 1998, the coral around the Okinawan islands suffered from an historic case of bleaching. The main reason is thought to have been the extremely high sea temperature due to El nino. In addition to this global sea temperature rise, the southern part of Japan, in particular, had far fewer typhoons in that year than it normally did. This factor is also believed to have contributed to coral bleaching. Typhoons usually contribute to a decrease in the temperature of the surrounding sea. Even if the sea surrounding the islands is warm, the event of a typhoon passing means that the seawater remains less than 30 degrees centigrade. Unfortunately, the Okinawan Islands were hit by typhoons just three times in the summer of 1998, which was much less than the seasonal average, and the sea temperature was able to exceed 30 degrees. The sea temperature in 1987 was considerably lower than in previous years, so coral was able to grow at a faster rate. The sea temperature rise in 1998 then simply killed this new coral growth. In this study, the sea temperature changes around the Okinawan islands from 1997 to 1999 will be shown in detail. The influence of passing super Typhoons on sea temperature will then be discussed, based on field measurement data. The causes of the 1998 coral bleaching will be revealed.

RE-SURVEY OF CORAL REEFS IN SAUDI ARABIA (ARABIAN GULF) AFTER THE 1997/98 CORAL BLEACHING EVENTS

Vogt, Helge Peter*, Khalid Al-Shaik *Zentrum für Marine Tropenökologie (ZMT), Fahrenheitstr. 1, D-28359 Bremen, Germany, Email: HP_Vogt@compuserve.com

In August 1999, a re-survey of the island reefs of Karan and the inshore reefs near the peninsula of Abu Ali was conducted to compare live coral cover before and after the bleaching episodes. A comparison of underwater video recordings of reef benthos along three unmarked transects in the shallow lagoon of Karan showed a reduction in live coral cover from 23 % in 1994 to less than 1 % in August 1999. Another comparison of live coral cover was conducted using two permanent transects placed perpendicular to the shoreline of Karan in depths from 2-6 m. During three periods of investigations from 1992-94, the average value for live coral cover at both transects was 33 %. The August 1999 survey indicated only a minor reduction to 31 %, which supports the general impression that coral communities on the reef slope showed no signs of deterioration. The re-survey of the shallow inshore reefs at Abu Ali revealed that more than 99 % of colonies were dead with only small pockets of surviving coral tissue of the previously dominant reef builder *Porites compressa*. The death of corals in the shallow waters of both the offshore and inshore reefs is most likely to have been caused by extremely high sea surface temperatures exceeding 34 δC in the summer of 1998, as well as increased solar radiation.

CORAL COMMUNITIES RECOVERY AT MAYOTTE I. (SW INDIAN OC.) FOLLOWING THE 1998 BLEACHING EVENT AND/OR RECENT *ACANTHASTER* PLAGUES

Wendling, Bertrand*, Dahalany, Youssouf ; Descamp, Pierre ; Priess, Kathrin ; Thomassin, Bernard A. *Fisheries & Marine Environment Service (SPEM), D.A.F., B.P. 103, 97600 Mamoudzou, Mayotte, France O.M. Email: daf.spem@wanadoo.fr

Mayotte (12°-13°'S, 376 km^2 of lands, alt. max. 660m) is the pattern for eroded high volcanic island surrounded by near continuous ribbon barrier reefs that rim a very large lagoon (here near 1,500 km^2). All coral reef types occured, even a double barrier reef system. Fast population blowing-up is the main source of island development problems, with effects upon coral reef communities (silting of the innest reefs and lagoonal bottoms, fishery decrease). In addition, during last 20 years, everywhere coral communities suffer by *Acanthaster* outbreaks, and in April-June 1998 by the huge bleaching event, destroying near 80% or more of the corals (from surface down to 30m deep). Following this event, a Coral Reef Observatory was set up which task is to survey the reefs and to monitor outer slopes assemblages on 9 selected fronts. At the 1999-year end, one year after the "point 0" survey, it is observed that the recovery rate of corals is highest on some fringing reefs, even in muddy environment (20%), and on lagoonal reefs (all reefs average rate = 5%). Highest living corals coverage ratios reach 49% on fringing reefs, and 33% on lagoonal ones. New corals are mainly non-Acroporid forms (23% for fringing reefs down to 10% for barrier ones). Acroporids are mostly growing on outer flats (11%).

BLEACHING PHENOMENA IN AMED'S REEF, BALI: MONITORING ACTIVITIES SINCE 1997- 2000.

Zamani, Neviaty P.*, M. Nurlidiasari, A. Wijonarno, and K.Sarjana Putra., *Center for Coastal and Marine Resources Studies, Bogor Agriculture University. Gedung Marine Science Lt. 4, Fakultas Perikanan dan Ilmu Kelautan, Institut Pertanian Bogor, Kampus IPB-Darmaga, Bogor, Indonesia. P.O.Box 286. Email: learningtm@bogor.indo.net.id

Coral bleaching is considered as a loss or reduction in the population density of zooxanthellae, loss or reduction of photosynthetic pigment, or a combination of both as a response to environmental stress. Increases in sea temperature have been reported worldwide as one factor, which causes coral bleaching. Mass bleaching might have resulted in significant lost of live corals in many parts of the world. Mass coral bleaching was reported in 1997/98 in Indonesia (for example North Sulawesi, Lampung-South Sumatera, Karimun Jawa, Bali and Taka Bonerate-south Sulawesi). However, there was no comprehensive study conducted to document the ecological and socio-economic impact of this event. The purpose of this study is to evaluate the ecological impact of bleaching in terms of changes in percent coral cover and mortality in Amed Coast, Bali. The observations were carried out at three-stations, i.e. Reef Checkpoint, Tebing and Kebun Coral. The results of the 1998 monitoring activities show that coral cover in Amed's reef decreased by 50 % to 80 % in 6 months. This loss corresponds to increases in dead coral by as much as 60 % and of other biotic components by as much as 50%. These 1998 findings will be compared with results from 1999 and 2000 monitoring studies at the conference.

FIELD STUDIES ON GREAT BARRIER REEF BIOERODING SPONGES.

Schönberg. CHL* *Carl von Ossietzky University Oldenburg, Dept. of Zoosystematics & Morphology, FB 7 -

Biology, Geo- & Environmental Sciences, D-26111 Oldenburg, christine.schoenberg@mail.uni-oldenburg.de.

Some bioeroding sponges appear to be good bioindicators. Their densities can greatly increase in eutrophicated waters. However, natural levels of abundance are understudied. Considerable difficulties with field work are: 1. overlooking because of their cryptic life style; 2. problems with *in situ* species identification; 3. intrusion by removal of reef framework, and 4. complex laboratory studies necessary. An extensive small-scale survey was conducted on the Central Great Barrier Reef. The distribution of *Cliona orientalis* and *Aka mucosa* is presented as example. Both species are very common and can invade live coral. Whereas *A. mucosa* colonies is common on the sand flat, *C. orientalis* requires uncovered substrates and cannot tolerate smothering. *C. orientalis* is dominant near the reef edge, where it can benefit from high light levels and flow. Both species can withstand exposure to air but have developed different strategies. *A. mucosa* is specialised to occur in fragments or blocks buried in sediments. *C. orientalis* small, porous erosion patterns retain water and are likely to protect it better than sponges producing larger chambers. *C. orientalis* endolithic tissue can be estimated from the surface. This may be a common phenomenon in bioeroding sponges.

Minisymposium A11, Rm 6, Tuesday 24/10, 16:00hrs

THE FATE OF BLEACHED CORALS: PATTERNS AND DYNAMICS OF ALGAL RECRUITMENT.

Diaz-Pulido Guillermo* & McCook Laurence J. *Dept. Tropical Plant Sciences, James Cook University, Townsville, Qld 4811, Australia. Email: Guillermo.Diaz@jcu.edu.au.

The massive bleaching of corals which occurred on the Great Barrier Reef (GBR) in early 1998 was one of the most severe on record. Bleached corals may either regain their zooxanthellae and recover, or may die, in which case they generally become overgrown by algae. However, very little is known about the dynamics of this overgrowth, its effect on the corals, the composition and nature of the overgrowing algae, or the consequences for reef recovery. The present study monitored the trajectory and composition of algal recruitment for 2 years on massive corals *Porites lobata* with different conditions or degrees of bleaching. *P. lobata* were significantly affected by the bleaching event and were almost universally overgrown by turf algae. The trajectory and the abundance of algal turf recruitment were affected by the degree of bleaching but only quantitatively: the more coral bleaching the more algal turf overgrowth. It is difficult to determine if the algae actually contributed to mortality of the bleached corals. It is clear that the algae were not the initial cause of coral mortality, but potentially contributed to the failure of corals to recover. The species composition of the algal turfs that colonised the bleached corals is described. Members of all major groups of benthic algae were common, but were quickly dominated by two species of the brown filamentous alga *Sphacelaria*, which also dominate algal turfs throughout the study area.

Minisymposium A22, Rm 13, Thurs 26/10, 15:20 hrs.

NEW ORAL PRESENTATIONS

REGIONAL STATUS OF CORAL REEFS IN THE RED SEA AND THE GULF OF ADEN – MIDDLE EAST- 2000

Pilcher, Nicolas *& Alsuhaibany, Abdullah * Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia Email: nick@tualang.unimas.my

The status of coral reefs in Egypt, Sudan, Djibouti, Somalia, Yemen, Saudi Arabia and Jordan are presented. These countries all belong to the Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA), which commissioned this report. Corals in this region are primarily found on fringing reefs along the mainland and island coastlines, barrier reefs, pinnacles and atolls. A wide range of other habitats contain corals, including submerged patch reefs, coralline red algal beds, relic reef formation and volcanic rock flows. In general reef health was considered good, with 30 % to 50 % live coral cover at most locations, and > 50 % total cover on average. Coral bleaching caused extensive die-offs in the Arabian Gulf and the northern – central Red Sea in 1998, and on the Sudanese coasts a red algal film was present over most shallow reefs. Coral diversity and reef-associated fauna was considered among the highest in the Indian Ocean region. Major threats to coral reefs include landfilling and dredging for coastal expansion; destructive fishing methods; damage by the recreational SCUBAdiving industry, shipping and maritime activities, sewage and otherpollution discharges; lack of public awareness, and insufficientimplementation of legal instruments that affect reef conservation. A number of international, regional, bilateral and multilateral agreementsand other legal instruments have been adopted by the States, and eachpossesses a relatively complete set of national Laws and Regulations. However, the implementation of these remains generally poor and in somecases there is no implementation and enforcement whatsoever. For coral reef conservation to improve and be effective in the Region, there is a need for increased public awareness, increased enforcement andimplementation of national and international legal instruments, and theimplementation of coastal management plans that integrate coastal development, industrial effluents, and tourism with the maintenance of environmental quality in marine habitats.

Minisymposium D1, Rm 6, Mon 23/10, 16:30 hrs.

NEW ORAL PRESENTATIONS

CAN FLUCTUATING ASYMMETRY (FA) BE USED AS AN INDICATOR OF STRESS ON REEF-BUILDING CORALS?

Todd, P.A.*, Sanderson, P.G., Chou, L.M. *Dept Geography, National University of Singapore, 1 Arts Link, Kent Ridge, Singapore, 117576. Email: artp8501@nus.edu.sg

Fluctuating asymmetry (FA) is a term used to describe small, non-directional, random deviations from perfect symmetry. These deviations are thought to be a result of minor developmental 'accidents', possibly reflecting the developmental instability of an organism and the influence the environment has upon it. Thus, it has been argued that FA is a reliable and sensitive indicator of environmental stress. FA has mostly been used as a gauge of developmental instability in bilaterally symmetrical animals and plants with only a few studies of radial organisms published. To test for FA in coral polyps, a photographic method was used to collect samples of the *Montastrea annularis* complex from three sites around Utila Island, Honduras, and *Diploastrea heliopora* and *Favia speciosa* from three sites around Singapore. Measurements were taken from the projected images and analysed for symmetry. Although many polyps appear to be radially symmetrical, the application of FA methods to the above coral species revealed that generally their polyps were in fact antisymmetrical and therefore not suitable subjects for this technique.

Minisymposium A19, Rm 5, Fri 27/10, 09:50 hrs.

THE STATUS OF CORAL REEFS IN THE NORTHERN CARIBBEAN & WESTERN ATLANTIC.

Woodley, Jeremy*, Pedro M. Alcolado, Timothy Austin, Rodolfo Claro-Madruga, Gina Ebanks-Petrie, Reynaldo Estrada, Francisco X. Geraldes, Floyd Homer, Eleanor Phillips, David Shim, Kathleen Sullivan, Monica B. Vega, Jean Wiener. Centre for Marine Sciences, University of the West Indies (Mona), Kingston 7, Jamaica W.I. <woodley@uwimona.edu.jm>

Deterioration of reef resources is reported from all countries. The most extensive direct human impact is over-fishing; acute in Jamaica, Haiti and the Dominican Republic, where narrow fringing reefs are easily accessible. Reef fish stocks dispersed over broad shelves are less depleted, as in Cuba and, especially, in the Bahamas and the Turks & Caicos Islands. Higher standards of living in the Cayman Islands and Bermuda result in less fishing pressure. Mass mortality of the sea-urchin *Diadema antillarum*, throughout the region in 1983, resulted in excessive growth of macroalgae, especially where over-fishing had already depleted herbivores. This, and white-band disease in the *Acropora* spp, led to catastrophic declines in coral cover; notably in Jamaica, but there has been some recovery in recent years. In 1998, coral bleaching was severe in Cayman and Cuba, but mortality seems to have been low. Sediment run-off and nutrient pollution are especially prevalent in the three high islands. Careless coastal development for tourism has impacted reefs in most countries, while increasing pressures of diving tourism are apparent in Cayman and the Turks & Caicos Islands. There is increasing local awareness of the need for coastal conservation, and all countries, except Haiti, have declared Marine Protected Areas. There is generally little enforcement of conservation laws, and most agencies need more resources, trained personnel and political support.

Minisymposium D1, Rm 6, Mon 23/10, 11:30 hrs.

NEW POSTERS

THE ARK SHELL, *ARCA VENTRICOSA*, A POTENTIAL COMPETITOR OF THE MOTHER-OF-PEARL OYSTER, *PINCTADA MARGARITIFERA* IN THE LAGOON OF TAKAPOTO ATOLL (TUAMOTU, FRENCH POLYNESIA).

Addessi L.* & F. Bourdelin *Laboratory of Marine Ecology, University of French Polynesia BP 6570 Faa'a Tahiti French Polynesia Email: bourdeli@ufp.pf

The General Research Programme (PGRN) on *Pinctada margaritifera* was developed to study the pearl oyster and its environment. As a second step, particular interest was granted to investigate potential competitors of *P. margaritifera*. A study assessing stocks of the principal bivalves in the Takapoto lagoon shows numerical dominance by *Arca ventricosa*. We are considering *A. ventricosa* a potential competitor as this species represents 75% of the population of sessile bivalves in this area. It is necessary to determine the impact of the ark shells on spatial and trophic resources, and the competitive role this species has on *P. margaritifera*. *A. ventricosa* is not a well known species, and as a starting point, shell growth rates according to depth and filtration rates are being investigated. Results indicate very slow growth rates varying with settlement depth. The ark shell is able to adapt to different environmental conditions, explaining its profusion throughout all lagoon areas. From the point of view of trophic competition, the consumption of the ark shell is restricted to a level below those of the other competitor species.

LABORATORY CULTIVATION OF CORAL JUVENILES.

Bausoch K. J.*, S. Leota, S. Victor, and R. Richmond. University of Guam Marine Laboratory, UOG Station, Mangilao, GU 96923 USA. Email: ililau@hotmail.com

Coral reefs depend on successful reproduction and recruitment of corals. Three Acropora species (surculosa, humilis, danai) and two Faviids (Goniastrea retiformis, Leptoria phrygia) were grown from larvae in the laboratory. On June 1999, adult colonies were collected from four different reefs around Guam a week before spawning which started four days after the June full moon. For each species, eggs and sperm collected from different colonies were mixed in 14L containers and fertilization started within 24 hrs. Four to five days after fertilization, substrata, consisting of coral rubble covered with coralline algae, were placed in containers. Substrata were collected from a nearby reef flat, cleaned and kept in flowing seawater tank before use. After five days, substrata with newly settled larvae were moved into tanks in the shade for further growth and observations. Tanks were maintained at least twice a week. Algae on substrata were removed using a small nylon brush and tweezers. An initial count of substrata with juveniles was made in December followed by measurements made in January and April. The number of polyps in each colony was counted and the longest dimension was measured under a microscope. Survivorship for all species between December and April ranged from 18-100% with a mean of 57%. Colony size of Acropora species in April was 102.8um/polyp. Colony size of Goniastrea retiformis was 24.8um/polyp and, Leptoria phrygia was 22.3um/polyp. Maintenance of juveniles was very important for survivorship and growth. Algal competition appeared to have an important affect on growth and survivorship of colonies.

REEFAL SEDIMENTATION IN THE GULF OF AQABA, RED SEA EGYPT.

El-Sammak, Amr* Mahmoud Kh. El-Sayed, Mahmoud Kh. Alexandria University, Faculty of Science, Oceanography Dept. Egypt.
*United Arab Emirates University, Faculty of Science, Geology Department, Al-Ain P.O. Box 17551, United Arab Emirates. E-mail: **a.elsammak@uaeu.ae.ae**

A total of 68 sediment samples were collected from five profiles covering the Ras Muhammad National Park area (3 profiles), Nabp and bu Qalum Protected Areas. Texture, Mineralogical (XRD), geochemical (AAS) and petrographical (thin section and SEM) analysis were done on the collected sediments. Description of samples indicates that samples were range from coarse to fine sand, mostly composed from biogenous constituents. Terrigenous grains are mostly quartz and feldspars. Aragonite is the most abundant carbonate minerals, represents about 50-60% from the total carbonate minerals, followed by Mg-calcite, calcite and tracers of dolomite. Most of the carbonate grains are fresh. SEM indicates that the fundamental unit of the scleratinian corals consists of aragonite ibers, qabout 15 _m long and 0.5 to 1.0 _m wide. Nabq area is characterized by the omnipresence of terrigenous sand. Abu Qalum sediments also contain terrigenous grain associated with carbonate grains, however the percentage of Terrigenous/carbonate grain decrease as follows: Nabq/Abu Qalum/Ras Muhammad. For chemical analysis, Mg, Fe, Cr, Cu, Mn, Co, Zn, Cd, Pb and Ni were analyzed. The results of different profiles were compared with each other as well as with similar areas. Results were statistically treatment in order to develop a model for reef sedimentation in the Gulf of Aqaba, Red Sea, Egypt.

HOLOCENE SEA LEVEL IN INDONESIAN ISLAND ARC DEDUCED FROM EMERGED CORAL REEFS AND SEA NOTCHES

HANTORO Wahyoe Soepri*, Gagan Michael Kevin; Lafont Raymond, Bieda Sophie, Yudawati Sri Cahyarini, Soeprapto Tjoek Aziz, *RDCG-LIPI, Sangkuriang, Bandung 40135, Indonesia, 002503654 Email: hantoro@geotek.lipi.go.id

Emerged reef fossils are found in almost consistently 2-3 m above mean spring low tide at any coast along active arc of Indonesian Island. Some dating method (^{14}C, Th/U and ESR) give the age ranges under the Holocene time. Those reveal that Holocene sea level was relatively higher 2-3 m above present sea level in that area. Slight difference position of the reef from place to the other place in the archipelago can be explained due to the local rheological and tectonic setting. To the west, where the plate convergence give a continuous down slab of Indian - Australian plate beneath SEA plate, the outer non volcanic arc tends to be under the negative tectonic pulse, then the Holocene reef is found at a lower position than the normal one. To the east, the witness of Holocene sea level had been found at higher position than to the west due to the uplift, produced by the tectonic collision between Australian crust that move to the north against the island arc. In the relatively stable zone e.g. from inner basin to epicontinental sea and cratonic island, there are few emerged coral reefs as witnesses of Holocene highstand sea level can be found. This can be explained as the stable zone is less sensitive to rheological reaction as well as the sea around the island is quite shallow. Relatively high Holocene sea level in the stable area can be seen as the presence of an extensive of wetland that covered large coastal plain of the stable island and the thick Holocene peat that found in the relatively high position above sea level (5 - 10 m) upstream the estuary. Isotopic data from *Porites* sp. from Sumba island showed an enrichment of about 0.55‰ on ^{18}O that reveals the SST slightly was warmer about 0.5 C° than to day.

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SST RECORDS FROM CORAL BANDING PORITES SP MICRO ATOLLS: BASELINE DATA FOR PALEO-OCEANOLOGY AND PALEO-SEISMICITY RESEARCH IN INDONESIA

Hantoro W.S,* Gagan M.K., Widoyoko B., Mutholib A., Nganro N., Harsono, Shofiyah S., Handayani L., Sebowo E., Widoyoko B., Narulita I., Indarto S., Sanyoto A., Prayudi D., dan Suyatno.
***Research and Development Center for Geotechnology-Indonesian Institute of Sciences RDCG-LIPI, Sangkuriang, Bandung 40135, Indonesia, 002503654, hantoro@geotek.lipi.go.id**

Some *Porites* sp. micro atolls can be found abundantly in shelter coast of Indonesian Sea e.g. at Mentawai Island west off Sumatra. Its rapid growth of 1-2 cm/yr. allows producing a massif micro-atoll of 4 to 6 meters big. Living and dead *Porites* sp. micro atolls usually show outside and or inside-stepping morphology that reveals an interruption in vertical growth during their life. This unique stepping had been produced by relative vertical changes of coral position to sea level due to vertical land movement and perhaps climatic deterioration too. The movement is syncontemporaneus to the big seismic shock related to the subduction under Sumatra, take place in the plate boundary. ^{14}C and Thorium dates of the emerged micro atolls reveal that the vertical movement is active continuously since the Holocene. Two centimetres thick of repeated density banding on living and fossil's coral may allow following annual record within more than 75 years. Absence in fluorescence banding on living *Porites* sp. may be due to high flood of organic acid in a whole year. Abrupt change on ^{13}C variations reveal a sudden uplift due to coseismic event while drop on its density may be related to the decrease of albedo related to big Tambora eruption.

TECTONIC AND CLIMATIC INFLUENCES TO THE SPATIAL AND TEMPORAL DEVELOPMENT OF CORAL REEF LIMESTONE IN INDONESIAN MARITIME ISLAND: ASSESSEMENT ON TERTIARY TO QUATERNARYCOASTAL EVOLUTION TO LONGTERM CARBON STOK IN EPICONTINENTAL SHELF

Hantoro W.S.* Handayani L.; Narulita I; Suprijanto D; Soeprapto T.A.; Sri Yudawati Cahyarini; Masduki A. Research and Development Center for Geotechnology-Indonesian Institute of Sciences RDCG-LIPI, Sangkuriang, Bandung 40135, Indonesia, 002503654, Email: hantoro@geotek.lipi.go.id

The Indonesian Maritime Continent phisiographically belongs to shallow continental platform and deep sea, there physiographically consists a stable cratonic island, inner volcanic island arc and outer non volcanic ridge, which coastal evolution patterns are slightly different. Situated between two continents and oceans, these islands may be called "the maritime continent". It has the largest coastal plain in the world which extensive lowland area is subject to eustatic and tectonic sea level change, as well as two important large, shallow and stable continental platforms (Sunda and Sahul) that cover more than one third of the archipelagic area. Owing to the geological setting of the junction of three plate movements, Indonesian island arc shows a unique geodynamic evolution. Convergence of the Indian-Australian crust to north produces the subduction plate to the western part and collision in the eastern part of the South East Asian epicontinental island arc. Vertical deformation in subduction zone produces mainly the subsidence of the outer arc before the uplift while the continous uplift process is produced in the collision zone. Tertiary reefal carbonate is reported by some oil explorations, had developed since lower Tertiary along marginal basin, starting from shallow clastic carbonat to the reefal limestone.

CORAL COMMUNITIES AND CORAL REEFS OF THE SEYCHELLES ISLANDS.

Kosmynin V*. *Institute of Paleontology Russian Academy of Sciences, Moscow, Russia. Email: kosmyninv@cofc.edu

Coral reefs of the Seychelles Republic spread over the vast area in the Western part of the Indian Ocean between 3º30´S and 10º30´S, and 46ºE and 58ºE. The study of this area was conducted in several expeditions of the USSR Academy of Sciences and Moscow State University in the 1970s and 80s. Reefs in this region develop in the environment close to optimal for reef building corals. Coral reefs of northern area develop in the moderate wave energy condition, while southern groups of reefs are exposed to waves of high energy and lie in the area of hurricane tracks. Most of major morphological types of reefs, including atolls, fringing reefs, variety of uplifted and submerged reefs, can be found around the Seychelles. The zonation of reefs is characterized by asymmetry. In the open oceanic reefs and atolls, windward slopes are gentle and lack almost all coral growth. Leeward sides are steep and have high projective cover by reef building corals. Some atolls like Farquhar possess well-developed algal ridge and reef-flat on windward side, though others do not have these relief features. The development of rhodolithes fields in outer terraces or on the flat of submerged reefs is another characteristic feature of Seychelles reefs. Numerous submerged wave-cut forms demonstrate inheritance of major morphological features from Pleistocene growth. The total list of reef building corals in Seychelles comes close to 200 species, which is considerably more than the number listed before.

ASSEMBLAGE PATTERNS OF SOFT CORALS IN INDIAN OCEAN REEFS – A CASE STUDY FROM THE CHAGOS ARCHIPELAGO.

G.B. Reinicke*. German Oceanographic Museum, Katharinenberg 14, 18439 Stralsund, Germany. E-mail: Goetz.Reinicke@meeresmuseum.de

Soft corals and gorgonian corals, together with the scleractinian stony corals and calcareous algae, represent the major components in the benthic shallow water reef communities of the Chagos Archipelago. The 1996 expedition yielded a collection of c. 70 octocoral species, including 5 species new to science. Alcyonacean corals were regularly observed in various reef sites at Peros Banhos, Salomons and the Great Chagos Bank, from atoll or backreef

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lagoons and reef flats to shallow and deep reef slopes at 40-50 m depth. They can provide large proportions of benthic communities - in some sites only few soft coral species monopolise the living coral coverage (overall cover < 1-5%). Distribution patterns are related to predominant environmental conditions (viz. current energy regime, light, sedimentation). In sites with high soft coral abundance, characteristic species assemblages could be identified. Examples from strong current regime habitats on shallow and deep seaward slopes, and from moderate current regime habitats and lagoon slope habitats were surveyed and related to the predominant 'stress gradient' of environmental conditions (after Rosen 1981). The combined observation and interpretation of soft and scleractinian coral assemblages provides a more complex, but more distinctive view reef coral community structures. A more complex, but more distinctive view on distribution patterns of reef coral community structures can be achieved from synchronous observations of soft and scleractinian coral assemblages.

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GENETIC POPULATION STRUCTURE OF THE OCTOCORAL *BRIAREUM STECHEI* (KÜKTH.) ALONG THE GREAT BARRIER REEF (ALCYONACEA).

G.B. Reinicke*, J.A.H. Benzie, K.E. Fabricius. German Oceanographic Museum, Katharinenberg 14, D-18439 Stralsund, Germany. E-mail: Goetz.Reinicke@meeresmuseum.de

Nine populations of the briareid octocoral *Briareum stechei* were sampled during August and December 1999, and in February 2000 over about 1300 km along the Great Barrier Reef from the Torres Strait to the Whitsundays group. Allozyme electrophoresis was applied to test six polymorphic loci for genetic population differentiation. The lack of significant deviation from Hardy-Weinberg expectations indicated the predominant mode of reproduction in these populations was sexual. There was significant differentiation among populations ($F_{st} \leq 0.0468$, $p = 0.05$), but no indication of isolation by distance. The lack of spatial pattern in the genetic differentiation of populations suggest stochastic influences on recruitment to give rise to localised differentiation of some populations.

STUDIES ON THE CHEMICAL ECOLOGY AND REPRODUCTIVE BIOLOGY OF SARCOPHYTON TROCHELIOPHORUM VON MARENZELLER (COELENTERATA: ALCYONACEA) ON GUAM, MARIANA ISLANDS.

Starmer, John A.* *University of Guam Marine Laboratory: P.O. Box 3035: Koror: PW: 96940: Palau. Email: jstarmer@yahoo.com

Sarcophyton trocheliophorum colonies collected in Guam were found to contain organic chemicals and calcium carbonate spicules which deterred predation by sympatric reef fishes. Bioassay guided fractionation identified the compound isosarcophytoxide B and a multicompound fraction to be responsible for the chemical deterrence. The effectiveness of either sclerites or chemistry was found to vary among different reef fish species tested in the laboratory. Observations on the spawning and egg and larval development of S. trocheliophourm showed many similarities with previously studied alcyonarian corals.

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CORAL REEF FISHES AND REEF RELATED FISHERIES IN ANDAMAN N NICOBAR ISLANDS

Rajan Pt*, Zoological Survey Of India - Haddo, Port Blair 744102 - India. Email: rajan08in@yahoo.com

The Andaman and Nicobar islands consists of about 348 islands having a total Geographical area of 8249 Sq Km, surrounded by coral reefs, rocky, sandy areas and mangrove swamps. Of the 324 islands of the Andaman district 27 are inhabited and 13 of the 24 Islands in the Nicobar district are inhabited. The coastline of this union territory extends to 1962 Km, which is _th of mainland India. The exclusive economic Zone (EEZ) is about 0.6 million Sq Km. The coastline supports the coral reef fishers and several groups of animals of commercial importance. The Reef shark fishery, Grouper fishery, Sea cucumber fishery, Lobster fishery and Molluscan fishery are some of the major fisheries that occupy a significant position in the socio-economic fabric of these islands, by providing the population not only the nutritious food but also income and employment opportunities. The regions around these Islands is the least studied for potential fisheries resources around the country there is hardly any intensive fishing at the reefs. Only poaching by Burmese, Indonesians and Thailanders for Trochus spp and other valuable reef organisms is seen as a serious problem. One common problem associated with all these fisheries was inadequate monitoring of the fishery. Catch and effort data were not collected regularly in any of the fisheries. Limited management measures are in place for the most of the fisheries.

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CORAL REEF MAPPING USING REMOTE SENSING AND GIS IN INDONESIA: AN OVERVIEW OF FIRST RESULT

Hantoro W.S.*, Soeprapto T.A., Suprijanto D. *Research and Development Center for Geotechnology-Indonesian Institute of Sciences RDCG-LIPI, Sangkuriang, Bandung 40135, Indonesia, 002503654, Email: hantoro@geotek.lipi.go.id

Now days, there have been available enough data and information about reef in Indonesia, but it has not been spatially covered the whole area neither continuously updated, and it is sparsely and is not well documented under the standard format. So that, the present status of reef in Indonesia is not really known. To manage data and information of reef and its environment; data of physical reef it self and other related information (social, economy, etc.), are necessarily needed and it must be produced and managed under the standard format so that the output information can be accepted and optimally applied to the program of the reef management and rehabilitation, and other program related to reef environment (spatial planning, coastal management, tourism, etc,). To build a standard format of spatial data, one to be prepared; is the good base map, produced by using and under the GIS format. To have a national reference of Indonesian reef map, COREMAP (Coral Reef Rehabilitation and Management Program) launched a reef-mapping program. This work, to covered the whole region of Indonesia, the reef base map has to be ready in just short time (2 years since May 1999), so it has been agreed to support the rapid mapping, by choosing remote sensing method and using TM satellite data as the raw material. Available bathimetric and other physiographic map are used to be referred as the geometric standard. This product will inform the coverage of reef ecosystem in Indonesia, and as the basic map it will be implemented as the standard reference to any information related to the reef management in Coremap program.

STATUS AND TRENDS OF CORAL REEFS IN THE FLORIDA KEYS NATIONAL MARINE SANCTUARY: 1996-1999: USEPA CORAL REEF MONITORING PROJECT.

Kosmynin, Vladimir*, Phillip Dustan, James W. Porter, Walter C. Jaap; Jennifer Wheaton, Matt Patterson. *Department of Biology, University of Charleston, Charleston, SC 29412. Email: kosmyninv@cofc.edu

The Florida Keys Coral/Hardbottom Monitoring Project (CRMP) has identified significant losses in species richness and coral cover between 1996 and 1998 at 40 sites distributed from Key Largo to Key West. Since 1996: Thirty-four of forty sites (88%) exhibited losses in scleractinian coral taxa; there has been an epidemic of coral diseases as evidenced by increases in spatial and habitat distribution of diseases, more types of diseases, and more coral species infected. Between 1996 and 1998, percent cover of living coral decreased 19.4% across all 40 sites in the Florida Reef Tract (Wilcoxin Matched Pairs Test $p=0.000001$). Losses in coral diversity and percent coral cover occurred throughout the Reef Tract although it was more pronounced in the Middle Keys. The Lower Keys had net loss at 17 of 20 sites, the Upper Keys had net loss at 12 of 13 sites, and loss at the Middle Keys occurred at 6 of 7 sites. It is expected that the 1999 and 2000 sampling, which occurred after Hurricane Georges, will demonstrate further losses. It is important, however, to point out that these hurricane losses only exacerbate the downward trend in coral coverage, they are not the cause of it. Continued monitoring and directed studies are needed to further elucidate the causes of decreased coral vitality and loss of biomass.

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DATABASE ON ISOLATED CARBONATE BANKS

Vecsei A.*. Geologisches Institut der Universität, Albertstr. 23B, 79104 Freiburg i. Br., Germany. Email: adam@perm.geologie.uni-freiburg.de

Isolated offshore banks are important for carbonate production and for physical and chemical oceanography. I present a new database on the geographic and depth distribution of low-latitude isolated carbonate banks. Banks > 170 km^2 in summit area were mapped at a 10' x 10' scale from sea charts. There are ca. 197 isolated low-latitude carbonate banks in 0-200 m depth. Their total size is 534000 km^2. The banks cluster in the Caribbean, SW Indian Ocean, N Indian Ocean, SE Asia, the Carolines, between the Coral Sea and New Caledonia, the Melanesian Borderland, and the Hawaii chain. Many banks have elevated rims, suggesting they are drowned rimmed carbonate platforms. The distribution of the bank summit areas shows a steady increase of the number of banks with decreasing size, suggesting that there may be 600 banks in the 10 to ca. 170 km^2 range (75% of a new total of 797 banks). Most bank summits are in 0-70 m depth. The 0 to 10 m depth interval is most common because of the great size of the Bahama Banks. Summit depths > 70 m are only common in SE Asia. The 0-70 m depth window shows that most banks grew up to -70 m or higher during the course of their Pleistocene history. The area of shallow reefs on the isolated banks is around 24500 km^2. This is approximately 10% of the world's reef area (ca. 255000 km^2, Spalding & Grenfell 1997). Around 10% of the reefs on banks are on the Little and Great Bahama Banks. 32% of all bank reefs are in the Maldives.

ARE VIRUSES INVOLVED IN CORAL BLEACHING PROCESSES?

Wilson W.H.*, I. Francis, K. Ryan & S.K. Davy *Marine Biological Association, Citadel Hill, Plymouth, PL1 2PB, UK. Email: whw@mba.ac.uk

Coral bleaching is the loss of symbiotic dinoflagellates (zooxanthellae) and/or photosynthetic pigments from corals, as a result of environmental stress. Temperature-induced, large-scale bleaching episodes have been frequent in recent years and have potentially catastrophic ecological and socio-economic impacts. However, the precise mechanisms of bleaching are still poorly understood. Viruses are present in large concentrations in seawater and it is likely that all aquatic microbial organisms have specific viruses that infect them. Viral attack has yet to be considered as a coral bleaching mechanism. We will present preliminary evidence that reveals virus-like particles are induced following heat shock of zooxanthellae isolated from the temperate sea anemone *Anemonia viridis*. Furthermore, the filtered infectious agent is transferable and can re-infect isolated zooxanthellae without prior heat shock, thus fulfilling Koch's postulates. The implication of these results will be discussed.