



International Society for Reef Studies (ISRS)

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Abstracts Volume

**Hosted by:
Cambridge Coastal Research Unit
Department of Geography
University of Cambridge**

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ISRS European Meeting Robinson College, Cambridge 4th – 7th September 2002

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Abstracts

Abstracts are presented in the order: plenary addresses, oral presentations and poster presentations. Abstracts for both oral and poster presentations are arranged by first author.

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Plenary Addresses

REEFS IN TURBID AND POLLUTED WATERS: WHY THE FUSS?

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Great beauty, high diversity and healthy recolonisation characterise the few turbid inshore coral reefs of the Great Barrier Reef that remain in near-pristine condition. By contrast, other inshore reefs are severely degraded, and some consider pollution, in the form of increased supply of land-derived nutrients, sediments and pesticides, to be a major cause of their degradation. At local scales, pollution impacts are well documented and accepted, however, at regional scales, pollution is frequently denied to be a cause of reef degradation, and indeed causal links have been difficult to demonstrate. This is due to factors such as (a) a lack of historic data, (b) high spatial and temporal variability in pollutants, (c) the background of other forms of disturbances, and (d) non-linear responses of organisms to pollution. Overall, pollution appears to be a lesser threat for coral reefs than coral bleaching or destructive fishing. However, unlike many other forms of disturbances, many pollutants accumulate and are stored in the system, thus system responses may become chronic once the system's buffering capacity is exhausted.

Here, I will examine various links between inshore reef degradation and pollution. This will comprise a review of field and laboratory data from many parts of the world, followed by presentation of new experimental and reef ecological studies. It will include the characterisation of the ecological properties of near-pristine inshore reefs, and will contrast these with reefs frequently exposed to river plumes from agricultural areas. I will then identify the two most likely mechanisms for reef degradation in regions exposed to pollution. Additionally, potential secondary mechanisms of pollution will be discussed, such as the enhanced survival of crown-of-thorns larvae, which may have profound effects on the wider ecosystem.

Pollution and reef degradation is a complex issue and there are many threads of evidence of varying strengths to be considered, e.g. field studies with notoriously imperfect controls and laboratory experiments that oversimplify natural systems. It is not surprising that simple hypothesis tests are unable to resolve such complex questions. After all, it took decades of extensive and expensive research until epidemiologists established sufficient weight of evidence linking cigarette smoking with lung cancer— a link that is obvious in hindsight. As scientists, we need to synthesize multiple and complex sources of information, weigh the evidence, quantify effect sizes, and predict the ecological consequences and socio-economic costs of alternative actions. It is then up to a better informed society to decide how much ecological change is acceptable.

UNNATURAL REEFS

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Basic ecological understanding of coral reefs is based on an unnatural mix of mostly small species whose trophic relations are greatly distorted by overfishing. Large megafauna, including fishes, sharks, sea turtles, crocodiles, sea cows, and seals have disappeared from entire reef systems worldwide. Vertebrates in general are greatly reduced and comprise less than 2% of the total free-living animal biomass on most reefs where the structure of food webs is dominated by very small fishes and invertebrates. The habitat complexity of reefs and seagrass beds is also greatly reduced over wide areas. Historical analyses demonstrate that virtually all reefs are affected by overfishing including partially protected areas like the Great Barrier Reef. Historical trajectories of the decline in reef ecosystems in the Indo-Pacific have the same slope as those from the tropical western Atlantic. The only difference is the initial starting date of intense exploitation that was much earlier in the Atlantic. Successful restoration and management require a more realistic and historically informed understanding of the ecology of pristine coral reefs that can only be obtained by a combination of retrospective analyses, modeling, and intensive studies of ecosystem structure and function of the very few isolated reefs that have escaped intensive exploitation.

LINKING ZOOXANTHELLA FUNCTION TO REEF HEALTH

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It is accepted that zooxanthella function, especially photosynthate release to the coral, underpins shallow water coral reefs, and that the breakdown of the zooxanthella-coral symbiosis at coral bleaching is a response to anthropogenic factors. A key development in recent years has been the appreciation that zooxanthellae are not functionally uniform. The purpose of my talk is twofold. First, the extent to which molecularly-distinct zooxanthellae vary in ecologically-important traits, including photosynthetic parameters, susceptibility to bleaching and acclimatory capabilities, will be addressed. Second, the ecological consequences of this variation at scales from the individual colony to the reef will be explored, especially in the context of anthropogenic factors.

**ENVIRONMENTAL VARIABILITY AND CHANGE:
HIGH RESOLUTION RECORDS FROM CORALS AND CORAL REEFS**

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As they grow, massive reef-building corals record environmental information in the physical structure and chemical composition of their aragonitic skeletons. This attribute, combined with annual skeletal growth bands, rapid growth rates, and colony longevity, makes corals valuable palaeo-environmental archives, capable of yielding records with a temporal resolution of \pm a few months over several centuries. In addition, since the aragonitic skeletons are suitable for high-precision U-series and ^{14}C dating, analysis of 'fossil' corals provides an opportunity to extend the records back into the late Quaternary. These palaeoenvironmental records serve two purposes. Firstly, corals may be used to extend beyond the instrumental record of environmental change, thereby yielding crucial new insights into the coupled processes that control climatic and oceanographic variability and change on decadal to millennial timescales. Secondly, the records provide an essential context against which to view the current status and predicted decline of modern reefs.

A major research effort has been directed towards reconstructing variability in temperature, salinity and terrestrial run-off from analysis of annually-banded massive corals. In most cases, chemical tracers in the skeleton are used as a proxy for the environmental parameter of interest. These records are particularly powerful for investigating interannual variability. For example, coral data has shown that the El Niño Southern Oscillation climatic phenomenon has varied significantly in its strength over time, with modern ENSO probably stronger than at any other time over the past 130,000 years. Coral geochemistry is also used to reconstruct variations in 'mean' conditions (e.g., change in mean temperature, salinity, rainfall etc.). This has proven to be more difficult, due to uncertainties in assumptions about individual tracers. Nonetheless, significant progress is being made through the use of replication of records and use of multiple and new proxies. For example, combined trace metal and stable isotope measurements are producing consistent patterns of temperature change on decadal to glacial-interglacial timescales; there is exciting new work on the use of barium as a proxy for suspended sediment input to the coastal zone over the past few centuries (McCulloch et al, this meeting); and coral growth rates are being successfully used to reconstruct SST change over the past few centuries. Analysis of the structure, age and elevation of corals and coral reefs also continues to yield new insights into the magnitude, timing, rates and mechanisms of sea-level change on decadal to 10^5 year timescales.

These coral data are contributing to a picture of tropical environments that have varied substantially, and rapidly, over much of the past few hundred thousand years. In many ways, the last few thousand years appear anomalous, having relatively stable (warm) mean climate and sea-level, but relatively large interannual (ENSO) variability. These data provide a crucial testing-ground for models that attempt to predict future climate, and the impact of natural and anthropogenic environmental change on coral reefs.

Oral Presentations

SR/CA IN CORAL ARAGONITE: IS NIGHT CARBONATE A GOOD INDICATOR OF SEA SURFACE TEMPERATURES?

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Sr/Ca in coral skeletons has potential as an indicator of past seawater conditions but exhibits geochemical heterogeneity on a small spatial scale (<100 μm) that does not reflect variations in sea surface temperature (SST) or chemistry. Skeletal Sr/Ca is affected by variations in skeletal calcification rate which may be dependent on the photosynthetic activity of the zooxanthellae in coral tissue. The skeleton deposited at night may be unaffected by these variations and may be a more reliable indicator of SST (Cohen *et al.* 2001).

We used secondary ion mass spectrometry with a 10 μm diameter analysis spot to construct records of Sr/Ca in a *Porites lobata* specimen from Lanakai, Oahu, Hawaii. Analyses were performed on sections cut perpendicular to the growth surface of the coral skeleton, spanning annual bands. Parallel tracks were analysed following fasciculi (material deposited during the day) and centres of calcification (deposited at night).

The Sr contents of the day and night material follow similar seasonal trends but are offset with night carbonate typically enriched by 350-400 ppm Sr. The day carbonate profile is characterised by large spiky Sr fluctuations, which are deposited approximately days apart and are superimposed on the general Sr seasonal trend. These fluctuations may relate to daily variations in coral calcification rate which is in turn affected by light intensity and water temperature. The Sr range observed in day carbonate (~900 ppm) is equivalent to ~5°C on the Sr palaeothermometer for *Porites* day carbonate (Cohen *et al.* 2001) which is in good agreement with the observed seasonal temperature range.

The Sr range in the night carbonate profile (~600 ppm) is much larger than that reported previously and is equivalent to ~16°C on the Sr palaeothermometer for night carbonate (Cohen *et al.* 2001). Calcification at night is slower than in the day and previous studies suggest that the slope of the Sr-SST relationship in night carbonate approximates to that seen in inorganic aragonite precipitates. This is inconsistent with our data. While the Sr range in the night carbonate is reduced compared to that of day material, some short term Sr spikes are still present. Sr varies by up to 300 ppm over distances of <100 μm , which is nominally equivalent to <1 week skeletal growth. These spikes do not reflect variations in SST. We suggest that while biological effects on Sr incorporation are minimised in night carbonate, significant biological effects may still occur in this material.

Cohen AL *et al.*, Kinetic control of skeletal Sr/Ca in a symbiotic coral: implications for the palaeotemperature proxy, *Paleoceanography*, 16, 20-26, 2001.

LONG TERM CHANGES IN MALDIVIAN CORAL REEF COMMUNITIES

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The author has studied community change in Maldivian coral reefs since 1990. Rasdu and Addu Atolls were repeatedly surveyed during the period 1991 to 2001. Included in the survey sites at those atolls are sites surveyed during the Xarifa (1958) and Indian Ocean (1964) expeditions. Survey methods included line intercept and point transects, video transects, photo-quadrats and visual surveys. The different quantitative methods were tested to assure comparable results. COADS SST data was obtained for the period 1980 – 2000.

Comparison of 1991 survey data with the data obtained some three decades earlier showed that large declines in coral cover had occurred at most of the Xarifa and IOE survey sites. Acroporidae and Pocilloporidae had declined the most. Large areas of dead branching corals in growth position were also observed in many other parts of Maldives. During the period 1991 – 1998 coral cover generally increased in Rasdu and Addu although there was little change at most of the IOE sites in Addu and one site in Rasdu. In April – May 1998 a large proportion of the corals in both atolls and the Maldives died during a severe bleaching event. Hardest hit were Acroporidae, Pocilloporidae, soft corals (except dendronephthids) and Millepora. Although mortality was very high, "extirpations" were not observed. At a few locations coral cover and dominant type seemed to change little in 1998, but one large patch of coral that had apparently survived since 1958 died in 1998. Large massive coral colonies, especially Porites, declined significantly in abundance over the entire period.

Reef bleaching and mortality in 1998 were highly correlated with elevated SST's in April and May of that year. It seems probable that the elevated SST's and bleaching observed in 1988 contributed to the state of reef communities documented in 1991. Anthropogenic effects were also involved in some locations, most clearly at Gan in Addu and probably at Veligandu in Rasdu.

ALLOCTHONOUS STORM GENERATES DISPLACED DAMAGE ON DEEP REEFS IN BONAIRE (N.A.)

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Shallow reefs were destroyed and deep reefs suffered high coral mortality by displaced hurricane effects. Hurricane Lenny never came near the island of Bonaire (N.A.) but waves generated by the storm hit the leeward coast of the island. There were three main effects on the fringing reefs: 1 where westerly waves hit the reefs frontally all living organisms were cleaned off the reef at depths from 0 to 6 m. 2 Dislodged corals, debris and coarse sediment was deposited between 6 to 20 m on the reef slope. 3 Fine sediment (diam 100 μm) was transported to the reef at greater depth (> 30 m). This sediment accumulated at the deep reef in front of the damaged shallow reefs and, through deep lateral transport along the reef slope, also at locations that were unharmed in the shallow reef. Sediment was efficiently cleared off living surfaces by most corals at the reef slope shallower than 25 m but not at greater depths. Surveys (random quadrats) at 35 m depth showed the impact of fine sediment to depend on coral species, and high mortality of dominant species such as *Agaricia lamarcki*. The deep reef may be a stable habitat in terms of wave movement but rare events such as sedimentation will cause catastrophic damage.

**SYMBIONT COMMUNITIES IN REEF CORALS FOLLOWING THE 1997-98 EL NIÑO:
WILL RECOVERING REEFS BE MORE RESISTANT TO A SUBSEQUENT BLEACHING
EVENT?**

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Coral bleaching as a result of sustained seawater warming is a major threat to coral reef ecosystems worldwide. The long-term capacity of reef corals to survive these episodes is likely to be dependent, at least initially, on the diversity and specific identities of the symbiotic dinoflagellates (“zooxanthellae”) they contain. Because different algal symbionts appear to vary significantly in their susceptibility to bleaching, we hypothesized that the symbiont community structure of coral reefs following a severe bleaching event: (1) differs from that of the same reefs prior to bleaching; (2) more closely resembles the community structure of reefs found at higher temperatures; and (3) has a higher bleaching threshold than before and is consequently more likely to survive future temperature anomalies of similar magnitude. We tested the first two of these hypotheses by using Restriction Fragment Length Polymorphisms (RFLPs) in large subunit ribosomal RNA genes to identify the symbionts of reef corals from Kenya (Indian Ocean), Panama (far eastern Pacific) and Saudi Arabia (Arabian Gulf and Red Sea) after the 1997-98 El Niño event. We found that scleractinian corals in Kenya, Panama and the Arabian Gulf contained symbionts in two clades of *Symbiodinium* (*C* and *D*). The high relative abundance of one of these clades (*Symbiodinium D*) in Kenya and Panama, combined with its virtual dominance in high-temperature Arabian Gulf reefs and comparative scarcity in Panama prior to the El Niño, suggest this symbiont lineage may have global importance in determining the response of reef corals to future thermal bleaching events. Red Sea reefs that were relatively unaffected by bleaching contained relatively little *Symbiodinium D* but also contained significant numbers of a third *Symbiodinium* clade (*A*), perhaps due to their high latitude location. These results indicate that, although an absolute upper limit must exist, we should not assume that bleaching temperature thresholds remain constant over time. Recent bleaching history, regional symbiont diversity and time between bleaching events may be important factors in determining the long-term response of coral reefs to global climate change.

**BLEACHING AND LYSIS OF THE CORAL *POCILLOPORA DAMICORNIS* BY THE
NOVEL PATHOGEN *VIBRIO CORALLILYTICUS***

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Coral bleaching and other diseases of corals have increased dramatically during the last few decades. A high correlation has been reported between increased sea temperature and the incidence of coral diseases. A new coral pathogen was isolated from diseased *Pocillopora damicornis* corals near Zanzibar in the Indian Ocean. Based on its 16S rDNA sequence, genomic DNA fingerprinting analyses, and phenotypic characteristics, the pathogen was classified as a novel species of *Vibrio*, named *Vibrio corallilyticus*. Infection of corals in controlled aquaria at 26-29°C, with a pure culture of *V. corallilyticus* caused tissue lysis of *P. damicornis* fragments. At 29°C, lysis began as small white spots after 3-5 days, rapidly spreading so that by 2 weeks the entire tissue was destroyed, leaving only the intact bare skeleton. When an infected diseased coral was placed in direct contact with a healthy one, the healthy coral lysed in 2-4 days, further indicating that the disease was contagious. Inoculation with as few as 30 bacteria per ml was sufficient to infect and lyse corals. Seawater temperature was a critical environmental parameter for the infectious process: infection and lysis occurred rapidly at 27-29°C, slowly at 26°C but tissue lysis was not observed at 25°C. At 24-25°C, pure cultures of *V. corallilyticus* caused bleaching of all 16 corals infected within 2-4 weeks. The pathogen was reisolated from the diseased tissues of the infected corals. Uninoculated control corals at 24-25°C showed no bleaching. The bacterial bleached corals contained less than 12% zooxanthellae concentration compared to healthy corals.

During the summer of 2001 when seawater temperature in the Red Sea (Eilat, Israel) reached over 27°C, there was considerable diseased corals. High numbers of *V. corallilyticus* were found in diseased tissues, whereas it was not detected in healthy corals. *V. corallilyticus* was found to be geographically distributed. Five additional strains of *V. corallilyticus* have been isolated, three from diseased *P. damicornis* in the Red Sea, and additional two strains from bivalve larvae, from the Atlantic Ocean (Brazil) and Europe (Kent Region). These five strains showed high genotypic and phenotypic similarities to *V. corallilyticus* type strain, and all were also pathogenic to *P. damicornis*. These findings support the bacterial hypothesis of coral bleaching, and indicate a relationship between temperature and the outcome of bacterial infection of corals.

DETERIORATION INDEX: A NEW APPROACH TO CORAL REEF MONITORING

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Coral reefs are deteriorating globally. Concern to the future of coral reefs drove governments, NGOs and scientists to enhance reef monitoring worldwide. Monitoring would be valuable if it can point to changes in the state of the examined coral community. The value of this indication can be especially high when deterioration begins, since at early stages of deterioration the chance of reversing the process is higher. Some widely used monitoring methods compare coral community parameters such as live cover, mortality rate, size-frequency distribution, species richness and diversity. Coral communities differ naturally from each other due to their depth, location, exposure to water flow and their history of disturbances. It is expected to find significant differences in all of the above-mentioned parameters when comparing different coral communities. In many cases however, these differences are not indicative of the state of the coral community, do it remains stable or is it changing. Only repetitive monitoring exactly at the same site can accurately and objectively point out if the examined reef state is changing.

Here, we suggest a practical approach that offers a solution to the above problem by providing an indication of the relative state of the community in addition to an indication of the trend of reef health (developing or deteriorating). This approach is based on an index (Deterioration Index; DI) that compares community parameters (i.e. mortality and recruitment rates) within the community as opposed to comparing the same parameter between different reefs.

The DI was developed during a study of young coral communities developed on artificially laid rocks in shallow water along the coast of Eilat (Gulf of Aqaba), where it was relatively straightforward to identify the disturbed communities.

Subsequently, we examined this method on natural coral reefs at Eilat and the Seychelles. The DI values obtained at Eilat clearly indicate that some of the examined reefs are experiencing deterioration while others are in a relatively reasonable shape. High DI values were calculated for the southern part of Eilat's Nature reserve (i.e. the Japanese Gardens) indicating a declining community. This part of the Nature Reserve reef is of high species diversity and live cover. However, the recruitment rate is very low and the mortality rate is relatively high. The DI, therefore, indicates a problem despite the illusive image of a well-preserved reef community, as may be misinterpreted from the high live cover and species diversity. This indication acquired from the DI during a single monitoring occasion shows the same results obtained by the reserve management team, after a long term monitoring.

Results from the Seychelles surveys demonstrate that most reefs were severely damaged during the last bleaching event. The DIs obtained there, show that most of these reefs are rehabilitating. However, at some sites the DI values were quite high. Among them are sites that were bleached and now have a high algal cover, and sites where the bleaching rate was relatively low but now experience low recruitment. The results show that the DI approach can serve as an efficient tool for MPA selection and management. This is due to the low-cost, fast-yielding and reliable data, which can be obtained by inexperienced surveyors within a short-time (one hour) training.

CORAL COMMUNITIES OF THE HADRAMAUT AND SHABWA PROVINCES, YEMEN**Francesca Benzoni, Carlo Nike Bianchi, Carla Morri****Acquario Civico e Stazione Idrobiologica di Milano
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The coral communities of the Gulf of Aden have been traditionally believed to be sparse and poorly developed due to the effects of the cold, nutrient-rich water of the Arabian Sea upwelling. Recent studies, however, have shown that they are actually significant and diverse. A survey of the coasts of Hadramaut and Shabwa provinces, Republic of Yemen, in early 1998, found extensive coral communities at all hard-bottom sites examined along a 130 km stretch of coast, from Al Mukalla (14°31'N 49°9'E) westwards to Belhaf (13°58'N 48°11'E). Due to the lack of detailed cartography of the region, hard bottom sites were located within the study area by means of spot check surveys. Coral communities were assessed using line intercept transects carried out at sites with high coral cover at different depths. Coral life-form categories were recorded, while dominant hard and soft corals were identified to genus level. A diverse array of coral communities was found through the study area. The main type, particularly at depths greater than 4 m, was a high cover *Porites* community, typically composed of very large massive and sub-massive colonies. Large monospecific areas of branching corals, especially *Pocillopora damicornis*, were common on shallower hard substrates, a feature these coral communities share with those of Oman to the east. Islands, both near-shore and offshore, tended to have better developed and more diverse coral communities than were found fringing the mainland shore. The main factors influencing the presence, structure and composition of coral communities in the study area seem to be the presence of available substrate, depth and distance from the Arabian Sea upwelling. At the time of the 1998 survey the Hadramaut and Shabwa coral communities were in excellent general health conditions, with no sign of bleaching mortality in the recent past. True coral reefs have been reported to be very rare in the northern Gulf of Aden, and this applies to our study area as well. Nonetheless, unexpected extensive and high-cover coral carpets have been found in Hadramout and Shabwa. These surprising features of coral communities in Yemen, as well as the striking patterns revealed in recent years in other sites of the Gulf of Aden claim for further investigation in the whole area.

PATTERNS OF CORAL MORTALITY, SURVIVAL AND RECRUITMENT IN MALDIVIAN CORAL REEFS, FOLLOWING THE 1998 BLEACHING EVENT

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The 1998 bleaching event, which followed abnormally high sea surface temperatures (up to 34 °C), caused widespread mortality in the reefs of the Maldives. Mortality rates were highest (approaching 100 % in certain sites) for branching and tabular species of the genus *Acropora*, for the Pocilloporidae and for the hydrocoral *Millepora*, particularly in shallow water. Mortality rates were lower below 20 m and in general for massive species, for which colonies affected by bleaching mostly displayed only partial discoloration of the tissues and death. No mortality at all was observed on the octocoral *Heliopora caerulea*. A recent (April 2002) survey of coral populations in 12 sites (reef slopes in inner and outer locations as well as within passes) has shown that a majority of colonies, for nearly 140 species belonging to virtually all reef coral families and especially Poritiidae, Agariciidae, Fungiidae, Mussidae and Faviidae, presented adult sizes and minor or no sign of mortality - an observation which suggests that most of them had survived the bleaching event. Very large colonies of *Porites* sp.p. and *Diploastrea heliopora* have managed to survive although only in relatively small patches over the whole colony, with average patch size ranging from 5 to 15 cm in diameter. Patterns of recruitment were followed through yearly surveys. As early as April 1999, two different size classes of *Acropora* had settled on the reefs. Largest recruits were up to 14 cm tall, suggesting that the first wave of recolonization arrived soon after the mortality event. No *Pocillopora* recruits were observed until 2000. In 2001, *Pocillopora* recruits were recorded mostly above 5 m depth on the outer slopes and in the passes, with densities up to 5 recruits m⁻². The density of recruits was similar for *Acropora*, but the recruits were spread over a larger depth range, and were also observed in other types of reef environment than outer slopes and passes. In 2002, the abundance of *Acropora* recruits did not change, while a relative lower number of *Pocillopora* recruits were recorded. Small-sized colonies (< 5 cm in diameter) were the most represented in both years, suggesting renewed recruitment waves. A relative higher proportion of comparatively large-size colonies (up to 25 cm in diameter for *Acropora*) would indicate rapid growth. Faviidae, Poritidae and Agariciidae were the most abundant recruiters other than *Acropora* and *Pocillopora*, and the genera *Pachyseris* and *Leptoseris*, in particular, showed the highest number of non-branching recruits. No *Millepora* recruits have been observed to date. Overall, these data allow for cautious optimism with respect to the recovery capacity of Maldivian coral reefs following a major bleaching event.

**SEA -LEVEL CONTROL ON REEF ACCRETION:
THE HISTORY OF RIBBON REEF 5, GREAT BARRIER REEF**

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A new deep borehole, drilled to a depth of 210 mbsf (metres below sea floor), on Ribbon Reef 5 on the Great Barrier Reef off Cooktown, NE Australia, reveals a shallowing-upwards succession punctuated towards the top by a series of erosion surfaces. Reef accretion has been controlled by the response of the system to changing sea level.

Carbonate deposition began about 770 ka ago, during isotope stage 16, with a series of debris flows. These reflect deposition on a relatively deep slope or ramp rather than a shallow platform and are represented in the core from 210 to around 180 mbsf. Lithoclasts indicate that carbonate deposition began in the area before the period represented by the cored succession, and was followed by a period of lower sea-level that resulted in erosion. However, the cored succession shows no evidence of erosion at these depths.

Overlying carbonates, from 178-mbsf to 155 mbsf are fine-grained grainstones with few relatively large coral fragments and rhodoliths dominated by melobesioids. These originated in water less than about 60 m deep but deposition was probably at greater depth. From 155 mbsf the succession is dominated by locally coarse grainstones and wackestones, again with intervals of rhodoliths. An upward transition from melobesioids to lithophylloids implies a progressive warming and shallowing of waters, reflecting progradation of the platform margin. Downslope sediment movement may have resulted from local oversteepening or storm activity on the shallower platform. The corals present from 120-95 mbsf imply derivation from shallower water, but steeply inclined laminae suggest continuing downslope transport. Rhodoliths, *Halimeda* and symbiont-bearing benthic foraminifera indicate derivation from waters less than 60 m depth.

Typical reef assemblages were probably not established until about 100 mbsf depth in the core, isotope stage 11. Grainstones are typical of the succession from 100-74 mbsf. Coral fragments in these are predominantly of massive forms with bored surfaces and crusts of coralline algae. They suggest derivation from quiet and/or relatively deep (15-30 m) water.

An upwards transition to an assemblage of robust branching corals, is paralleled by a change in the dominant algae, from melobesioids and lithophylloids to mastophoroids. These changes imply a progressive shallowing, and deposits probably reflect reworking on a shallow slope. More coral-bearing limestones were deposited during isotope stages 11 and 9. The lack of evidence of a progressive shallowing to emergence implies that the upper part of the succession has been removed by erosion. The apparently unbroken succession to 36 mbsf and the lack of evidence of emergence below this indicates a progressive accretion in which changes in sea level in the vicinity of the borehole did not fall below the depositional surface.

CHLOROPHYLL AS AN INDICATOR OF NUTRIENT STRESS ON REEFS OF THE GREAT BARRIER REEF

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Phytoplankton chlorophyll *a* has been monitored monthly since 1992 at 86 stations in the Great Barrier Reef (GBR) lagoon. The stations are located on eight transects across the shelf from 13° S to 23° S. A primary objective of the monitoring program is to detect changes in the inshore environment of the GBR resulting from the rapidly increasing loads of nutrients being exported from the catchment of the GBR. Data were analysed using generalized additive models and accounted for spatial and temporal effects. In the analyses stations were grouped by 'inshore' (< 25 km from the coast), likely to be influenced by terrestrial runoff, and 'offshore' (> 25 km), unlikely to be strongly influenced, and by five latitudinal regions of the GBR.

Strong differences in chlorophyll *a* exist across the shelf with inshore stations mean concentrations in most transects significantly greater than offshore except in the north. In northern transects mean chlorophyll concentrations are low (~ 0.25 µg/L) both inshore and offshore. Mean concentrations in offshore stations in the rest of the GBR are similar (0.15 – 0.27 µg/L) except in the Capricorn region in the far south where offshore mean chlorophyll is 0.55 µg/L. In contrast to northern transects inshore mean chlorophyll concentrations from Port Douglas south fall in the range 0.45 – 0.75 µg/L. Strong seasonal effects are evident with mean summer/wet season (December – April) values ~ 50% greater than those in winter/dry season (May – November). Significant temporal patterns in the data over the ten year period in each transect were observed and these may be correlated with the influence of ENSO on river discharge but analysis of this possibility is not complete.

Mean chlorophyll concentrations in inshore areas adjacent to catchments highly developed for agricultural and urban uses are more than double mean concentrations in inshore areas adjacent to Cape York catchments in the north which are largely undeveloped. Discharge of nitrogen and phosphorus from developed catchments has increased approximately fourfold over the last 150 years, with the largest increase occurring in the last 50 years. Phytoplankton appears to be responding to this enrichment. This signal of nutrient enrichment is of significance to the ecosystem health of inner-shelf reefs of the GBR. In addition mean concentrations of chlorophyll above 0.6 µg/L in the inshore Townsville to Port Douglas region of the GBR are relevant to theories which link the initiation of crown-of-thorns starfish outbreaks to nutrient enrichment.

FLORIDA'S DEEP-WATER CORAL REEFS: PROTECTION, RESEARCH AND RESTORATION

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The Ivory Tree Coral *Oculina varicosa*, forms extensive bioherms or “banks” of azooxanthellate colonies at depths of 70-100m along the edge of the Florida Hatteras slope. Healthy reefs support invertebrate and fish communities as diverse as those of tropical coral reefs, and are a critical spawning habitat for a number of commercial fisheries species. In 1984 the *Oculina* Banks were declared a Habitat Area of Particular Concern (HAPC) and were protected from damaging benthic activity. During the 1990's it became apparent that despite protected status, large areas of the banks had been physically damaged and fisheries were in decline. In 1994, the OHAPC status was changed to Experimental *Oculina* Research Reserve to protect snapper and grouper fisheries, and a coral restoration effort was initiated. Several types and configurations of concrete structure were deployed over several years along damaged reef tract using large concrete structures. These structures were intended to promote coral settlement in areas of denuded substrate, but after several years, most showed no signs of coral recruitment. In 1998, study of reproduction and larval development was initiated in order to assess natural re-colonisation potential and optimise restoration efforts. Research revealed that *O. varicosa* is a gonochoristic broadcast spawning species, with small eggs (~100µm) and an average fecundity of 850 (sd: 478) eggs per polyp. The gametogenic cycle begins in the early summer and spawning occurs during late summer and fall, with no obvious relationship to lunar or tidal phase. Planulae are small, approximately 160µm in length, and settle approximately 21 days after spawning. Larval planktonic duration was integrated with hydrodynamic information to estimate larval dispersal potential. It appears that larvae not only have the potential to be transported between the deep reef tracts, but may also contribute larvae to near-shore zooxanthellate populations during summer upwelling events. Preliminary genetic research supported ecological evidence that gene exchange occurs between deep reefs and shallow water populations of *O. varicosa*. Unfortunately, despite the protected status of the *Oculina* banks, and reproductive criteria conducive to re-colonisation, the Banks have not recovered, and the healthy reef tracts have been reduced to two small areas at the southern extent of the range. Possible explanations for the continued demise and lack of regeneration of the *Oculina* reefs include illegal trawling, unknown natural causes and very low coral recruitment rate

**STUDIES ON THE ASSOCIATED COMMUNITIES OF *SERPULA VERMICULARIS* (L.)
REEFS (POLYCHAETA: SERPULIDAE)**

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The serpulid polychaete, *Serpula vermicularis*, is a common member of the marine encrusting community in Europe. Throughout most of its range *S. vermicularis* occurs in the form of individual tubes or occasionally as intertwining bundles of a few tubes, cemented to hard substrata, such as rock and mollusc shells. However, at just three sites in northwest Europe massive reefs, often exceeding a height of 50 cm and a width of 60 cm, they develop in shallow, sheltered waters.

The greatest development of these serpulid reefs is found in Loch Creran, Scotland, where their presence has been instrumental in the designation of Loch Creran as a Special Area of Conservation (cSAC) under the EC Habitats Directive. This will necessitate the development of a programme to monitor the status of the reef habitat, which is under potential threat from fishing, aquaculture and mooring activities.

From previous observations by divers it is believed that serpulid reefs provide a habitat for a diverse associated community, although no detailed studies of the community have been published. The aim of this study is to characterise the community, to provide a monitoring baseline and to provide information to underpin the development of a monitoring strategy. The conservation importance of the habitat will also be assessed by comparisons with the associated community of other biogenic reef habitats.

Ten entire serpulid reefs were removed by diver from Loch Creran, selected to represent a broad spectrum of reef size. Reef size was measured *in situ* by determination of height and width and in the laboratory by measurement of weight. Sessile and motile fauna and flora retained on a 0.5 mm screen were identified and counted.

The presentation will describe the nature of the reef community and will illustrate the relationship between reef size and community diversity and species richness. By employment of multivariate statistical techniques the relationship between species composition of the community and reef size will be examined. The conservation importance of the habitat will be discussed and the implications of the work for future monitoring programmes established.

TOWARD CHARACTERIZATION OF MITOCHONDRIAL HEAT SHOCK PROTEINS IN THE SEA ANEMONE ANEMONIA VIRIDIS

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Organisms respond to stress, which causes damage to cellular proteins, by inducing synthesis of Heat Shock Proteins (HSPs). Induction of HSPs is one of the most familiar mechanisms of reaction to various stressful environmental conditions (e.g. adverse temperatures, increased UV irradiation, osmotic stress and xenobiotics). These proteins play a major role in modulating protein folding, transport and repair during normal conditions, with higher levels of their expression being induced under stress. The relationship between environmental tolerance of organisms and the expression of HSPs has been studied in diverse aquatic and terrestrial organisms. However, in some groups of organisms, such as sessile marine invertebrates, some HSPs are not well characterized and their function and significance to adaptation are not well understood. As a major step towards characterizing the stress response of marine invertebrates, we set out to develop general protocols for purifying the mitochondrial (mt) HSP60 and HSP70 of the sea anemone Anemonia viridis. We also examined the role of mt-HSP60 and mt-HSP70 in adaptation of marine invertebrates to thermal stress through a study of the influence of changes in seawater temperature on the expression of these proteins in A. viridis. Laboratory and field experiments reveal for the first time the existence of mt-HSP60 and mt-HSP70 in sea anemones; and furthermore, that their expression varies with changes in temperature. A. viridis displayed high levels of both proteins when extreme temperature conditions (31°C) prevailed in stressful habitats, such as tide pools. Further, we have developed purification methods, based on several chromatography columns and western blot analysis, for both mt-HSP60 and mt-HSP70. These methods allow purification of large amounts of the proteins for further sequence analysis. We also found new antibodies that indicate changes in the expression levels of mt-HSP60 and mt-HSP70. Partial sequence data were obtained for the purified mt-HSPs. The amino acid sequences for both proteins are homologous to amino acid residues of the mt-HSPs of several organisms, including Drosophila and mammals, which show the proteins to be highly conserved between organisms. However, these fragments showed less similarity when compared to plastid HSPs from plants and to bacterial HSPs. We further found mt-HSP60 expression for the first time in various marine invertebrates, including scleractinian corals. These results may be particularly significant for coral reefs, which constitute one of the most spectacular and diverse ecosystems on the planet. Our study may offer a useful tool for detecting mt-HSP60 and mt-HSP70 in marine invertebrates, and contributes to the understanding of the role of HSPs in the adaptation of organisms to stressful environments. Identification of new HSPs of marine invertebrates is expected to enable rapid and accurate quantitative monitoring of short-term and long-term fluctuations in marine ecosystems. The importance of such research lies in using the expression of specific stress proteins as an early warning system for changes in community structure in disturbed marine habitats, and in assessing the ability of reef ecosystem to withstand global changes.

CHARACTERISATION OF THE BACTERIAL CONSORTIUM ASSOCIATED WITH BLACK BAND DISEASE IN CORAL USING MOLECULAR MICROBIOLOGICAL TECHNIQUES

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An increasing number of reports have documented dramatic changes and continuing declines in coral reef communities which have been attributed to both natural and anthropogenic factors. It is widely accepted that diseases of reef corals are an important factor in determining coral reef community structure, and that diseases may make a significant contribution to the observed coral reef degradation. Although these diseases are a major ecological problem, their aetiology and pathogenesis is poorly understood. In fact, the overall knowledge of the microbial communities associated with diseased and non-diseased corals remains poor, as most studies to date were constrained by the limitations of traditional microbiological techniques based on microscopy and cultivation.

The bacterial community associated with black band disease (BBD) of the scleractinian corals *Diploria strigosa*, *Montastrea annularis* and *Colpophyllia natans* was examined using culture-independent techniques. Two complementary molecular screening techniques of 16S rDNA genes (Amplified 16S Ribosomal DNA Restriction Analysis [ARDRA] of clone libraries and Denaturing Gradient Gel Electrophoresis [DGGE]) were used to give a comprehensive characterisation of the community. Findings support previous studies indicating a low bacterial abundance and diversity associated with healthy corals. A single cyanobacterial ribotype was present in all the diseased samples, but this was not the same as that identified from *Phormidium corallyticum* culture isolated from BBD. The study confirms the presence of *Desulfovibrio* spp. and sulfate-reducing bacteria that have previously been associated with the BBD consortium. However, the species varied between diseased coral samples. We found no evidence of bacteria from terrestrial, freshwater or human sources in any of the samples. We report the presence of a previously unrecognised potential pathogen (an α -proteobacterium identified as the etiological agent of Juvenile Oyster Disease [JOD]) which was consistently present in all the diseased coral samples. The molecular biological approach described here gives an increasingly comprehensive and more precise picture of the bacterial population associated with BBD.

**CONTRASTING EFFECTS OF TEMPERATURE ON THE REPRODUCTION OF A
BROODING SCLERACTINIAN AND BROADCASTING GORGONIAN FROM THE SUB-
TROPICAL CORAL REEFS OF BERMUDA**

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This study examined the sexual reproduction of the brooding Scleractinian *Porites astreoides* and the broadcasting Gorgonian *Pseudoplexaura porosa* in Bermuda. Variations in seawater temperature at the study sites and across the years are related to a contrasting pattern of temporal and spatial reproductive effort between the species. The lagoon of the Bermuda pseudo-atoll can be divided into three physiographic reef zones that have different annual temperature profiles. The temperature at the inshore reefs fell to 15.5 °C during winter and rose to 30.5 °C in the summer. Oceanic waters buffer the outer rim reefs, which moderated the temperature range to 19-29 °C. Inter-annual variability of seawater temperature profiles occurred over the study period, with summer temperatures in 1998 being relatively warm, those in 1999 being moderate and those in 2000 being relatively cool. *P. astreoides* released planulae in July and August of 1999 and 2000 from all three reef zones, extending into September both years at the cooler offshore reefs. Overall, planulae production was greatest at the Rim Reef each year and an inclined temperature gradient is shown across the reef zones to the Inner Lagoon with a corresponding decrease in reproductive effort. There is a significant negative relationship between reproductive effort and the average temperature for the preceding month. There was no inter-zone difference detectable in *P. porosa* reproductive effort; however, there was inter-annual variation. In 1998, when the temperature was slower to rise and remained high throughout the summer, spawning occurred only during September and October. In 1999 and 2000, when the temperature rose earlier in the year and remained high for a short period, spawning was restricted to July and August. Reproductive effort was lowest in the cool summer of 2000. In contrast to *P. astreoides*, there is a positive relationship between reproductive effort and the average temperature for the preceding month over the study years, although the correlation is only significant for spermary production at the rim reef. The study of the reproductive biology of corals in Bermuda is of particular interest because these reefs are the most northerly in the Atlantic (32N 65W), a distribution extreme for many species. The control of temperature on reproductive cycles is important in the context of changing global conditions, increasing the need for a greater understanding of the effects of temperature on this sensitive part of the coral life cycle.

**CORAL AND CORAL COMMUNITIES OF HONG KONG, CHINA 2001-2002:
ECOLOGICAL VALUE, STATUS AND MANAGEMENT**

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We undertook an ecological assessment of coral communities of Hong Kong in 2001-02 to assess their distribution, community structure and status, and to identify sites of high conservation value. Here, corals and coral communities occur near the physico-chemical tolerance limits for their survival and for reef growth. The communities exhibit strong gradients in distribution, species diversity and abundance, all being highest in northeastern waters - more oceanic, being further away from the estuarine influence of the Pearl River Delta. Hong Kong waters do not support major reef development, rather the best developed coral communities form incipient reefs, but with substantial biogenic accretion. Some of the coral communities are characterized by high coral cover (> 50 %), and are comprised of a much richer coral fauna than known previously: 88 species in 30 genera of 12 families of the Scleractinia, including approximately 45 new distribution records and an undescribed species of the astrocoeniid *Stylocoeniella*. The corals form five major community types with strong geographic and environmental affinities and key indicator species. Approximately one quarter of species are ubiquitous, occurring in moderate - high abundance in more than one-third of survey sites and across several of the community types. By contrast, over one third of species have locally restricted distributions (occurring in < 10 % of sites) and low relative abundances, and thus are particularly prone to local extinction following disturbance. Hong Kong's naturally marginal conditions for coral and reef growth are exacerbated by turbidity, salinity and temperature fluctuations (bleaching), predation, bio-erosion and further compounded by trawling activity, fishing traps and nets, anchoring, sewage, dredging, dumping and land-fills. Minimizing the controllable local impacts (trawling, netting, anchoring, run-off, pollution from local sources, land-fills, dredging and dumping) through continued proactive management will help to sustain these communities and increase their resilience to larger scale climatic impacts beyond local control. The study demonstrated that the present marine parks were well selected in terms of conserving high quality examples of two coral-dominated community types. Management recommendations include continued expansion of the established marine parks, development of additional marine parks encompassing a coral-dominated community type not well represented in the park system at present, improved surveillance and policing of designated marine parks, continued implementation of 'no anchor' areas, raising of community awareness and other measures to help minimize human impacts at key sites.

ASSESSING PATCHINESS IN CORAL SURVIVAL FOLLOWING BLEACHING ON THE GREAT BARRIER REEF AND MODELING ITS IMPLICATIONS

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Impacts of coral bleaching and patterns of survival of corals are patchy at spatial scales from oceans to a single patch of reef. Reefs of the Great Barrier Reef are mostly several kilometers in length and breadth. Following a bleaching event, their appearance and ecological structure in the short term are affected by the relative abundance of coral species that are more and less bleaching-prone. Coral species composition is also likely to affect each habitat's future attractiveness and productivity under regimes of increased frequency and severity of heat and light stress predicted to occur with global climate change. We are exploring the likely appearance of the Great Barrier Reef in coming decades by combining temperature monitoring, ecological assessments, a climate impact model and an ecological disturbance and recovery model. Daily sea temperatures recorded at two AIMS reef weather stations for a decade combined with Berkelmans' bleaching threshold curves were used in the CSIRO weather simulator 'ReefClim' to simulate various bleaching indices for the years 2010, 2030 and 2050. Post-2002 ecological assessments of coral survival were used to define six levels of bleaching impact, (from cosmetic to catastrophic) in terms of 'set-back' of the coral community, and to link these to the bleaching thresholds predicted for the future. The future scenarios generated for coral communities near the two AIMS weather stations will be presented, and the sensitivities of the modeling approach discussed.

DOES COLOUR REALLY MATTER: HOST PIGMENTS AND BLEACHING?

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Recently it has been suggested that host pigments may reduce the susceptibility of reef-building corals to bleaching by offering their symbiotic dinoflagellates shade. Whilst elevated temperature is the primary cause of bleaching, the rate at which corals bleach has been shown to be faster under higher levels of irradiance. In an experimental study with three colour morphs of *Acropora aspera* collected from adjacent positions on the reef flat of Heron Island GBR, we demonstrated that a heavily pigmented coral morph whilst offering greater shade to their symbionts, bleached at a faster rate than less pigmented morph and underwent significantly higher mortality if left to recover for a month after heat is withdrawn. The experimental data suggests that the response to temperature of these three colour morphs was highly variable with differential rates of zooxanthellae and/ or tissue loss. Cytochrome b analysis of host failed to discriminate colour morphs and gross cladistic analysis of symbionts revealed no distinctions. The properties of bacterially expressed host pigments suggest a novel shading mechanism for these pigments that could be significantly affected by elevated temperature.

PREDATOR REMOVAL CAUSES PHASE SHIFTS**Nicholas K. Dulvy, R. E. Mitchell, N.V.C. Polunin****Department of Marine Sciences & Technology
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The search for ecosystem features and processes that maintain resilience remains the Holy Grail of ecology. The traditional view is that 'bottom up' factors such as recruitment, nutrients and disturbance drive the structure and functioning of producer communities, e.g. corals and algae. More recently, theory suggests ecosystem resilience is maintained by numerous weak trophic links among species. But in reality a few strong links between predators and producers (known as trophic cascades) may also exist. On reefs, the fulcra linking predators and producers are either herbivorous urchins, or the coral-feeding starfish *Acanthaster planci*. These relatively strong trophic cascade interactions have the potential to short circuit energy flow throughout ecosystems resulting in a phase shift and therefore reducing resilience. While the importance of 'top down' predatory control for ecosystem resilience has been suspected for a long time, the evidence has been elusive. We demonstrate increasing densities of *Acanthaster* along a gradient of increasing fishing pressure, consisting of 13 Fijian islands. At the two most heavily fished islands, with lowest predator densities, the benthic communities had phase shifted from domination by calcifying organisms to domination by non-calcifying organisms, e.g. algae, sponges, soft corals. We theoretically demonstrate how fishing reduces coral reef resilience by removing predatory controls of starfish populations.

CHANGES IN DIFFERENT FORMS OF CELL DEATH ACTIVITY OVER TIME IN RESPONSE TO DIFFERENT AMOUNTS OF HYPERTHERMIC STRESS DURING EXPERIMENTALLY INDUCED BLEACHING OF THE SYMBIOTIC SEA ANEMONE *AIPTASIA* SP.

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Changes in activity of different forms of cell death in the symbiotic sea anemone *Aiptasia* sp. were measured in response to different amounts of hyperthermic stress over time. Programmed cell death (PCD) and cell necrosis activity within the host and zooxanthellae were identified using established techniques (Dunn *et al.* 2002). The results indicated the amount of cells undergoing PCD within anemone host tissue increased from an underlying cell turnover rate within hours of treatment. The increase in PCD activity was temperature dependent and correlated to the onset of zooxanthellae release from degraded endoderm. As different temperature treatments continued, the level of PCD declined and the amount of cell necrosis increased indicating a thermal threshold for PCD activity. Both PCD and cell necrosis of zooxanthellae increased exponentially, from an underlying cell turnover rate, with time in all temperature treatments. Host cell degradation, zooxanthellae release and degradation was correlated to bleaching in response to different amounts of hyperthermic stress. Changes in activity of programmed cell death pathways within host cells and zooxanthellae is important to the understanding of bleaching events, raising interesting questions regarding the evolution of this process and the activation of the cellular trigger mechanisms involved.

S.R. Dunn, J.C. Bythell, M.D.A. Le Tissier, W.J. Burnett, J.C. Thomason (2002) Programmed cell death and cell necrosis activity during hyperthermic stress-induced bleaching of the symbiotic sea anemone *Aiptasia* sp. *J. Exp. Mar. Biol. Ecol.*, **272** (1) 29-53.

**RESULTS OF THE “CONTRAST” PROJECT:
TRANSPLANTATION OF CORAL FRAGMENTS FROM SHIP GROUNDINGS ON
ELECTROCHEMICALLY FORMED REEF STRUCTURES - TOOLS FOR REEF
REHABILITATION?**

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We report here on a research project aiming to develop rehabilitation measures for mechanically degraded reef areas with a minimum of environmental harm and interference with living resources. The CONTRAST project (**C**oral **N**ubbin **T**Ransplantation **S**Tudy) – jointly run with the Egyptian Environmental Affairs Agency (EEAA) and the Ras Mohammed National Park authorities – mainly focuses on the application and further development of an environmentally friendly technology for reef rehabilitation including trials to select suitable coral species for transplantation.

We used the ERCON (**E**lectrochemical **R**ef **C**ONstruction) technology to build the substrate for coral transplantation. Through electrolysis, minerals from the seawater, mainly calcium carbonate, can be precipitated onto a given matrix (preferably made of steel mesh) by connecting the mesh as cathode; a titanium grid serves as anode. Installations with various designs were applied to follow the development of the coral transplants.

Coral fragments (“nubbins”) were derived from ship groundings and other damaged reef sites. In total, 597 nubbins were transplanted: 506 acroporids (*Acropora hemprichii*, *A. digitifera*, *A. eurytoma*, *A. granulosa*, *A. squarrosa*, *A. valida*, *A. hyacinthus*, *A. cytherea*, *A. clathrata*) and 91 milleporids. Despite heavy grazing by the coralivorous snail *Drupella cornus* and strong algal blooms during spring time 65% of all nubbins survived the first year. The lowest mortality rates were observed in *Millepora dichotoma* (2%), *Acropora hemprichii* (19%) and *A. eurytoma* (18%). Axial growth rates significantly varied between species. Among the acroporids, *A. hemprichii* exhibited the highest values (19,4 mm/year), *Millepora dichotoma* grew 14,2 mm/year. All nubbins developed a strong holdfast at their bases by overgrowing the grid and were hereby fixed in addition to the electrochemical accretion process itself. Some nubbins extended their bases over more than 25 cm².

The promising results could be the base for the creation of “stepping stones” characterized by stable, spaciouly heterogeneous substrates carrying donor colonies transplanted onto these small “protoreefs”. These protoreefs are intended to serve as receiver and provider of coral recruits. In this way, the dispersal of sexual propagules could be enhanced over a large area. Apart from the application of completely new structures in degraded reef areas (as demonstrated in this study) single units could be inserted as “reef prostheses” in partially impoverished reefs.

FACULTATIVE CORALLIVORY BY THE CUSHION STARFISH *PENTACERASTER CUMINGI*, GALÁPAGOS ISLANDS, ECUADOR

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The cushion starfish *Pentaceraster cumingi* was observed feeding within a free-living coral community located adjacent to Devil's Crown, Galápagos Islands, Ecuador. Here, numerous individuals of the fungiid coral *Diaseris distorta* and unattached branching colonies of *Psammocora stellata* occur in 15m depth on calcareous sand and coral rubble substrata. Of 440 *Pentaceraster* seen within the coral community during 13 different observation periods 58.2% were feeding (cardiac stomach everted onto substratum and/or coral) and 41.8% were not feeding. During 4 observation periods 39 *Pentaceraster* displayed strong avoidance of *Diaseris* individuals and preferentially consumed colonies of *Psammocora*. Although *Diaseris* composed 29% of the bottom cover around these feeding *Pentaceraster*, it was a food item 5% of the time. In contrast, *Psammocora* composed 36% of the bottom cover, but was a food item 64% of the time. No preference was shown for feeding on *Psammocora* skeletons that commonly supported growths of macroalgae, bryozoans and other encrusting macro-invertebrates. Dead *Psammocora* composed 32% of the bottom cover and was a food item 31% of the time. The relative importance of *Pentaceraster* corallivory in this community will be assessed with special reference to coral population dynamics following disturbances associated with El Niño-Southern Oscillation.

SIGNATURES OF LARGE-SCALE ATMOSPHERIC TELECONNECTIONS IN MIDDLE EAST CORAL RECORDS

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The northern Red Sea is one of the rare locations where massive annually banded corals grow at 28-29°N. A coral oxygen isotope record from this subtropical region revealed the strong influence of mid- to high-latitude climatic modes on Middle East climate variability during the past 250 years. An oscillation with a period of 5-6 years in the coral record reflects atmospheric teleconnections associated with the Arctic Oscillation/North Atlantic Oscillation, the Pacific Decadal Oscillation, but also with the El Niño-Southern Oscillation.

Fossil corals from the northern Red Sea provide the opportunity to investigate whether these teleconnections were active during selected time windows throughout the late Quaternary. A 5-6-year periodicity is detected in a 44-year coral oxygen isotope record from the last interglacial period. This could indicate Arctic Oscillation-like atmospheric variability during Marine Isotope Stage 5e. With respect to late Holocene climate variability a new 100-year coral oxygen isotope record from about 3000 calendar years BP will be presented.

The application of the coral Sr/Ca paleothermometer in conjunction with oxygen isotopes indicates cooler and fresher mean conditions in the northern Red Sea during the last interglacial, with a higher sea surface temperature seasonality of about 50%. Coral records for time windows during the mid-Holocene indicate an increased seasonality in the hydrologic balance between 6000 and 4500 calendar years BP.

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EXCESSIVE SEDIMENTATION AND REEF DEGRADATION, MOLOKA'I, HAWAI'I

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Terrigenous sediment run-off and deposition on coral reefs is recognized to potentially have significant impact on coral condition in Hawai'i and other high islands in the tropical Pacific and Caribbean. Human habitation of these islands has resulted in significant changes in the drainage basins and to coastal areas, and these changes have in turn influenced the volume of terrigenous and carbonate sediment released to the reefs. Within the past century, significant changes in land use have accelerated the amount of sediment transported to and stored on the reef off south Moloka'i. Deforestation, agriculture, domestic and feral grazers, hillside housing construction, and coastal development have exacerbated historical run-off of sediment.

The south coast of Moloka'i contains an extensive fringing reef nearly 50 km in length, the longest and most extensive reef tract in the Hawaiian Islands. The reef exhibits a richness and density of live coral that are amongst the highest in the islands; many areas of the reef exhibit more than 80 % live coral cover. A contributing factor to the success of corals in constructing a major reef structure on south Moloka'i is its setting. The reef is protected from damaging northerly storms, from persistent northeast trade winds, and from most southerly swell events by its south-facing exposure and shielding by neighbor islands.

Our approach to understanding sedimentation and its impact on the Moloka'i coral reef system includes three primary efforts: mapping terrigenous deposits and their sedimentologic and geochemical characteristics; measuring relevant processes that inject and redistribute sediment to the reef system; and real-time monitoring of sedimentation "events" on the reef.

The inner most reef flat (within 50 m of the shoreline) is characterized by a 10- to 30-cm thick muddy sand layer. Farther seaward (>500 m) sediment thickness over the hard substrate is highly variable (0 to 50 cm, and in places > 1.0 m) owing to the variation in relief of the ancestral reef platform. Areas of exposed limestone and exposed old coral ridges are barren of sediment and intervening low areas and small reef holes are sites of accumulation. Mud, mostly terrigenous in origin, dominates in the nearshore zone; elsewhere on the reef flat sediment is mostly carbonate sand with minor amounts of admixed terrigenous-carbonate mud.

Terrigenous mud is transported to the coast during major rain events that occur on annual to decadal time scales. Fine sediment deposited on the reef flat is trapped in a ~200-m wide belt where it resides for periods of years to decades. Measurements of waves, currents, turbidity show that a portion of the fine sediment stored on the reef flat is resuspended daily by trade wind waves occurring during high tides. Thus fine sediment is effectively recycled and small additions have repeated effects in blocking light, abrading and mantling live coral, and decreasing recruitment sites. An added impact from hillside erosion is an apparent increase in nutrients associated with sediment particles, which leads to rapid growth of fleshy algae. Some impacted areas of the reef during the last century now appear to be recovering, while others are not.

COLONY INTEGRATION AND RESOURCE TRANSLOCATION DURING CORAL BLEACHING

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Bleaching of corals results in the loss of their symbiotic algae (zooxanthellae) and/or their pigments. Coral bleaching is often linked to global climate change, especially elevated seawater temperature and high solar irradiance. When the coral loses its zooxanthellae, it loses its main energy resource, putting at risk its essential biological functions. Certain coral species survive severe bleaching events better than others, leading to major structural shifts in some coral communities. One of the most intriguing questions consequently being asked by coral reef researchers is why are some coral species more resilient to bleaching events and better survive them than others?

Integration within hermatypic corals has long been the focus of scientific interest. Resource integration is a basic life-preserving ability and one of the most important advantages of clonal and colonial organisms. Nevertheless, this ability has never been investigated in corals undergoing bleaching. In the present study, we focused on resource integration and translocation of ^{14}C -labeled photoassimilates in the temperate Mediterranean stony coral *Oculina patagonica* during and between bleaching events.

Using point labeling (^{14}C) techniques, we labeled healthy parts of the colony and examined oriented translocation of photoassimilates towards regions of high demand, such as regions of the colony that undergo lesion repair and regions interacting with competing neighboring organisms. In each experiment, we labeled colonies at different bleaching stages. Lesion recovery rate, competitive abilities with neighboring organisms and translocation of photoassimilates during these processes were studied at different bleaching stages. We have showed that lesion recovery and competitive superiority are coupled with oriented resource translocation. We also found the existence of a bleaching threshold that postpones intra-colonial integration in *O. patagonica* at bleaching percentage greater than 40%. Bleached colonies of *O. patagonica* with >40% bleached surface area showed low resource integration and low translocation rates of photosynthetic products. This is reflected in low lesion recovery rates of bleached colonies and competitive inferiority (with neighboring organisms) of bleached colonies compared with non-bleached colonies. At the same time, it is possible that such disintegration between the healthy sections of the colony and the bleached ones contributes to overall colony survival by preserving the resources within the section with greatest chances of recovery after the bleaching event. Indeed, over 90% of bleached *O. patagonica* colonies survive and recover from bleaching during winter. We suggest that coral species with low bleaching threshold are better survivors of bleaching events as they cease translocation of resources at earlier stages of bleaching, maintaining a reservoir of resources for survival and recovery.

CORAL CHROMOSOME NUMBERS: TESTING THE RETICULATE EVOLUTION HYPOTHESIS

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Human cells contain 23 pairs of homologous chromosomes; this chromosome number is an invariant of our species. Much information regarding our biology can be read directly by looking at our chromosomes: for instance, biological gender depends in most case on the presence or absence of sexual chromosomes, recognizable by their shape. The origin of our species can be inferred from the morphological comparison of our chromosomes with the ones from apes and monkeys. In plants such as wheat, loss and gain of chromosomes and hybridization lead to network-like (and not tree-like) phylogenies.

In spite of the huge interest on chromosomes numbers and morphologies in other groups of living organisms, there is little information available concerning scleractinian coral chromosomes. Up to now, chromosome numbers in tropical reef corals have only been published for 29 species out of about 800, which represents less than 4%. These researches have addressed so far only 6 genera (out of about 110), in 3 families (out of 18) (Heyward 1985; Kenyon 1997).

Existing protocols all make the task of determining chromosome numbers very cumbersome and time-consuming, as the starting material is living coral embryos and the method yields only a small fraction of exploitable chromosome preparations. In this research, we have been trying to improve existing protocols and to find new methods to quickly produce accurate and reliable chromosome preparations that may allow us not only to determine chromosome numbers but also to study their morphologies.

Coral embryos were collected at James Cook University's Orpheus Island Research Station, in the central section of the Great Barrier Reef Marine Park (North Queensland, Australia), from December 1st to 12th, 2001; at the Akajima Marine Science Laboratory, Japan from May 26th to June 2nd, 2002; and at the Hawaii Institute of Marine Biology at Coconut Island, Oahu, from June 16th to August 14th, 2002. 10-11 hours embryos were put in seawater containing 3% colchicine for two hours, which was followed by a 30-minute osmotic shock treatment in a mix of 65% seawater and 35% tap water. Embryos were then fixed and their chromosomes observed using a wide array of different methods.

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EXPERIMENTAL ASSESSMENT OF THE INFLUENCE OF SETTLEMENT STRATEGY ON PREDATION ON CORAL REEF FISH

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The settlement stage of coral reef fish, period during which larvae coming from the ocean take up residence in a particular population, represents a relatively short time (just a few weeks) in the life cycle. But it has been proposed as the crucial stage of the life cycle, because it can determine the dynamic and structure of the adult communities. This stage is characterised by the high mortality of coral reef fish new settlers (80 to 95 % of the population decrease by predation within one to two months) and by a specific settlement strategy (selective choice of suitable habitat). In the present work, we investigate the influence of specific factors of settlement strategy (shelter availability, interaction with conspecifics or competitors, and density of new settlers colonising the lagoon) on predation on coral reef fish new settlers. We choose to use *Chromis viridis* of 10 mm (fish just settled) and 20 mm long (fish already adapted in the reef) as study model. Our results demonstrated a significant variation in the mortality of 10 and 20 mm new settlers according to substratum. This influence may be due to the characteristics of shelter: adaptability of shelter to the size of the new settlers, quality of shelter which corresponds to the possibility of access to the habitat for the fish, and acclimatization of fish to an artificial habitat, identical to their natural habitat. Alternatively, predation could inhibit interaction between conspecifics and competitors during the settlement stage, when predation pressure is strong on the new settlers. Finally, the density of new settlers could influence predation (density-dependent mortality) when the density is high. But when the density becomes low, this mortality does not seem to be influenced by the density of new settlers (density-independent mortality). This means that, according to the larval supply, either the density-dependent mortality (pattern of competition) or the density-independent mortality (pattern of recruitment limitation) determines the juvenile population stock. This study, then, shows this high mortality by predation and the determinant factors of settlement strategy influence each other, and thus determines the dynamic and structure of the adult communities. This conclusion also finds a field of application in projects of coral reef replenishment.

INSTITUTIONAL EVALUATION OF CARIBBEAN MPA'S AND OPPORTUNITIES FOR PRO-POOR MANAGEMENT

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In the Caribbean, MPA's are seen as a prominent means of addressing coastal resource management. Ecological impacts of MPA's have been well researched and are usually shown to be positive for biodiversity (Dixon *et al.*, 1993) and fisheries management (Roberts and Polunin, 1993; Wantiez *et al.*, 1997). Amongst advocates of MPA's there has been a tendency to extol their potential value in socio-economic terms. In reality, the establishment of protected areas often generates deep resentment in communities that find themselves excluded from resources to which they have traditionally had access, undermining the viability of those protected areas (Horrill *et al.*, 1996). Over the last ten years, management of MPA's has evolved from being a preservation tool to integrating considerations of development, sustainable use of resources and stakeholder participation (Meffe *et al.*, 1997). With this focus, it is believed that they can play a key role in conserving natural ecosystems and contribute substantially to sustainable development (IUCN, 1997).

The purpose of this research is to identify current institutional constraints to, and development options for, successfully implementing MPA's in a way that leads to a sustained improvement in the livelihoods of poor people in the Caribbean. A key premise of this work is that successful implementation and beneficial stakeholder outcomes, including outcomes for the poor, are inextricably linked and priority will be given to understanding the dynamic relationship between processes and outcomes. Particular attention has been paid to systems that include community participation in decision-making to see what benefits this brings to the poorer groups and to understand the structures and processes needed to achieve it.

An initial review of institutional and ecosystem characteristics of 80 MPA's in the Central and Antillean biogeographic zones of the Caribbean took place mid 2001 (Geoghegan *et al.*, 2001) and was succeeded by an analysis of operational and non-operational MPA case studies in Belize, Jamaica, Turks & Caicos Islands and Dominica to investigate factors contributing to successful and unsuccessful outcomes of MPA management. The participatory basis to all methods of enquiry and series of facilitated workshops has brought researchers and a range of stakeholders together to address key issues and explore solutions. Research at the operational MPA case studies involved evaluation of the impacts of successfully implemented MPA management on poor people's livelihoods and included PA (participatory appraisal) exercises (e.g. wealth and well being; trends in capital assets; changes in livelihood opportunities; ease of access to local institutions to improve livelihood options) to understand poorer groups' perceptions of MPA impacts. A series of biophysical studies were undertaken by the University of the West Indies (UWI) to assess the environmental sustainability of MPA's. A legal review was also conducted to understand how the external policy environment influences MPA management.

This presentation will explore research findings, including the overall review of institutional and ecosystem characteristics of Caribbean MPA's and a more in-depth evaluation of the factors contributing to successful and unsuccessful outcomes of MPA management and evaluation of the impacts of successfully implemented MPA management.

GLOBAL DISTRIBUTION OF MICROBIOERODERS AND THEIR NORTHERNMOST TROPICAL REEF COMMUNITY AT 30⁰ N – EILAT, ISRAEL

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The distribution and abundance of carbonate-eroding microorganisms was investigated along a bathymetrical gradient in waters of the Red Sea adjacent to Eilat, Israel. Experimental carbonate substrates were deployed in depths of 0m, 6m, 15m and 30m, placed in clear and shaded habitats for a period of 6 months. The community of microendoliths that had colonised the substrates by then was taxonomically analysed. It shows a large correspondence with microendolithic communities from Atlantic, Caribbean and Pacific marine environments. The same array of species of Cyanobacteria, Chlorophyta, Rhodophyta and Fungi was found to colonise comparable water-depths in Eilat. This study concludes and summarizes a series of investigations on the impact of microendoliths in marine tropical environments.

IS IT CURTAINS FOR CORAL REEFS IN THE SOUTHERN ARABIAN GULF?

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Most coral reefs in the southern Arabian Gulf are shallower than 10m and normally are subject to very high summer seawater temperatures and year-round high salinities. In fact the southern Gulf has the highest global summer seawater temperatures and the corals (or their symbiotic zooxanthellae) are probably surviving near their upper physiological tolerance limits. These reefs are composed primarily of the branching coral *Acropora* or of colonies of mound-forming *Porites*. In many cases inshore reefs fringe the outer edge of shallow-water limestone platforms that often extend seaward for many kilometres from a landmass, be it the mainland or an island. Offshore patch reefs form a cap on a base of limestone, sandstone or fasht.

In the summer through to the autumn of 1996 we observed that approximately 98% of the *Acropora* bleached and subsequently died along the coast of Abu Dhabi and adjacent Dubai, although the non-branching corals were largely unaffected. The death of the *Acropora* coincided precisely with a prolonged period of higher-than-normal seawater temperatures. Later a similar mass mortality of *Acropora* was reported by divers in Qatar and Bahrain where summer seawater temperatures were also abnormally high for an extended period. An even more prolonged incidence of abnormally high seawater temperatures occurred in the summer of 1998 and this resulted in the majority of the remaining reef-forming corals in Abu Dhabi being severely affected; an estimated 50-80% mortality being observed in the western and central regions of the Emirate.

A consequence of the coral death has been a dramatic increase in cover of the once relatively inconspicuous non-geniculate red coralline algae and mat or turf forms that have now colonise the dead coral skeletons. The most abundant and conspicuous coralline alga overgrowing the dead coral (*Lithophyllum kotschyannum*) is slowing the disintegration of the branching *Acropora* skeletons in particular, by providing them with a coating of limestone. Nevertheless, the relentless activities of boring clionid sponges and bivalve molluscs along with the grazing of greatly increased numbers of the sea urchin *Echinometra mathaei* are gradually reducing the *Acropora* thickets to rubble and in some places are significantly reducing the volume of the dead *Porites* mounds.

Some coral regeneration and recruitment has taken place since the 1998 incident. However, the gradual increase in average seawater temperatures in the region over the last 30 years and the more frequent occurrence of prolonged higher-than-normal summer seawater temperatures leads us to believe that the future of coral reefs in the southern Arabian Gulf is bleak. We speculate that in the next few decades the once coral-dominated reefs will become transformed into ones composed essentially of coralline and turf-forming algae with shallower areas becoming overgrown during the cooler winter months by dense forests dominated by fleshy brown macroalgae.

HIGHER LATITUDE CORAL REEF COMMUNITIES OFF DENSELY POPULATED SOUTHEAST FLORIDA, USA

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Significant coral reef community development along the eastern shelf of the United States is often described as stopping north of the Florida Keys (Latitude 25° 30'N). Nevertheless, a coral reef ecosystem continues northward (160+ km) of the Keys, through Miami-Dade, Broward, and into Palm Beach Counties, Florida (Latitude 27° N). The coral communities associated with this high latitude reef system have approximately 30 species of stony corals with a coverage of 2-3% and includes a diverse assemblage of soft corals, sponges and fishes. NSU OC and NCRI are working with local resource managers (BC DPEP) on a reef monitoring program that collects information on stony (species richness, cover, mortality and disease) and soft corals (abundance), sponges (abundance), fishes (abundance and species) and sedimentation (rate and grain size). The reef system of Southeast Florida is typically described as having three reef ridges/terraces that run parallel to shore in sequentially deeper water. The general depth of the crest of the inshore (or first) reef is 5 m; the middle (or second) reef is 10 m; and the offshore (or third) reef is 17 m. Water temperatures were measured in 2000 and 2001 and ranged from a minimum of 19.5 °C in the winter months (December – February) to a maximum of 31.0 °C in the summer months (July – September). This reef system occurs near a highly urbanized area (the population of Broward County exceeds 1.6 million people, two inlets discharge offshore, and the reefs are within 3 km of the coast). As such, commercial and recreational fishing and diving, major shipping ports, ship groundings and dredging activities influence the system. The unique features of this reef system, and its proximity and value to the urban community of Southeast Florida, demand continued monitoring and increased investigation into the processes that affect it.

**POPULATION DYNAMICS IN THE MEDITERRANEAN SOLITARY CORAL
BALANOPHYLLIA EUROPAEA (SCLERACTINIA, DENDROPHYLLIIDAE)**

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Studies performed to date on the population dynamics in scleractinian corals refer, mainly, to tropical species. Although scleractinian corals are common to the Mediterranean benthic fauna, data concerning demography in species of this area are rare. *Balanophyllia europaea* is a solitary zooxanthellate coral living off the rocky Mediterranean coast at depths ranging from 0 to 50m. Its reproductive biology is characterized by simultaneous hermaphroditism and brooding. We studied individual growth rates and the structure of the population living off the coast of Leghorn at Calafuria (eastern Ligurian Sea). *B. europaea* individuals living in this area were found at depths ranging from 1 to 13 meters with an average population density of 16 individuals m² (SE = 3); maximum density was reached at 6 m depth with a peak of 113 individuals m² (SE = 33). At this depth, we studied the growth patterns in 62 individuals for a two-year period. The linear growth rate was found to be inversely correlated to the individual size of the polyps. As the polyps length increased (= major diameter of the polyp's oral disc) growth rate decreased. This correlation held true to a maximum length of 21 mm at which point growth rate became practically zero. Von Bertalanffy's theoretical growth function obtained on the basis of measurements taken in the field was confirmed by counting the annual skeletal growth bands on specimens scanned using CT (computed tomography). From growth data, we estimated the ages of 1814 individuals. The resulting survival curve showed that average age of individuals in this population was 4 years with a maximum longevity of 20 years. Compared to populations of *B. elegans* living off the north American Pacific coast, the other congeneric species for which data on population dynamics and reproductive biology are known, individuals of *B. europaea* achieve greater lengths and longevity (about two and three times, respectively) and a lower population density (about 35 times lower). The difference in existing demographic features pertaining to the two species summed to the actual differences in their ecology (*B. europaea* is zooxanthellate and *B. elegans* is azooxanthellate) and in their reproductive biology (hermaphroditism in *B. europaea* and gonochorism in *B. elegans*; and an elevated fecundity, short incubation period with small planktonic planulae in *B. europaea* and the exact opposite in *B. elegans*) point to the fact that in the two species exist two opposite life strategies.

POPULATION STRUCTURE OF DEEP-SEA CORAL *LOPHELIA PERTUSA* IN THE NORTH EAST ATLANTIC SEEN THROUGH MICROSATELLITES

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The azooxanthellate scleractinian coral, *Lophelia pertusa*, is distributed globally on continental slopes, mid-oceanic ridges and in fjords. In the North East Atlantic, it is the main reef constructing species in the upper bathyal zone on continental margins and offshore banks. These cold, deep coral reefs are associated with a highly diverse animal community. These ecosystems are still poorly understood, but under increasing threat from the expanding human activities beyond the continental shelf, and notably bottom-trawling. Recommendations are needed to monitor Europe's deep-water coral margin. In order to understand the capacities of the coral to withstand human impacts and to recover from them subsequently, data concerning the population genetic variability, mode of reproduction and dispersal must be gathered.

Efficient molecular tools can be used to address such population genetic structure issues. Microsatellites are non-coding DNA sequences constituted by short tandemly repeated motifs dispersed throughout the genome. Because they are inherited in a Mendelian manner, selectively neutral and very variable among individuals, they can be used as high-resolution molecular markers for investigating population substructure. For this purpose, a genomic library enriched for microsatellites was constituted for *Lophelia pertusa* and ten specific microsatellite markers were developed to screen a set of individuals sampled at different sites distributed along the European margin. Comparison with a model population, described by Hardy-Weinberg principle as panmictic and under no selection force, showed a marked departure from this state of equilibrium. This reveals the substantial contribution of asexual reproduction to the maintenance of the population and suggests the existence of local, isolated sub-populations in the considered geographic area.

In order to check these preliminary hypotheses, a more detailed analysis, involving inter-site comparisons and using bigger sample sizes, was performed. As a result, North East Atlantic *Lophelia* population appeared highly structured, suggesting a very low gene flow between areas. The relative contribution of sexual versus asexual reproduction to the maintenance of populations showed considerable variation among sites. These results have strong implications for the recovery of the reefs following human impact; recolonisation of a disturbed area is likely to be slow. Moreover, the observed heterogeneous distribution of the genetic diversity across the margin means that the loss of a specific population can affect the overall genetic diversity for the species across the entire area. Further statistical analysis is to be performed on the existing data and the microsatellite approach will be combined with other molecular methods to check the validity of these conclusions and to get a broader view of the genetic history of *Lophelia* populations along the European margin.

GLOBAL PROTECTION OF CORAL REEFS

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With increasing global environmental degradation calls for ‘protection targets’ are being made more frequently. For example the 4th World Congress on National Parks and Protected Areas in 1993 advised that 10% of each biome receive protection. Likewise, the 1st Symposium on Marine Conservation Biology in 1997 called for an increase in the number and effectiveness of MPAs so that 20% of all nations’ Exclusive Economic Zones and the High Seas be protected by the year 2020. One problem with such recommendations for marine ecosystems is that the data have not been available to calculate the quantity protected and to estimate when targets for protection have been reached.

Increases in the accuracy and resolution of global coral reef maps have recently been possible through the International Coral Reef Action Network (ICRAN) and the research behind the World Atlas of Coral Reefs. Considerable improvement to global information on those marine protected areas (MPAs) which contain coral reefs has been made through the same initiatives. Consequently our understanding of the global distribution of coral reefs and the efforts being made to manage them through the use of protected areas has never been better. New estimates of global coral reef area have been produced and the inventory of data on coral reef MPAs – location, size, boundaries - is more complete.

The results of ongoing analysis which has combined coral reef maps and MPA data will be presented. The amount of coral reef presently being managed within MPAs will be estimated, and variations by region and management regime will be calculated. A comparison will be made between protection offered by nationally and internationally designated MPAs. The utility of global ‘protection targets’ for coral reefs will be discussed in relation to management effectiveness, which for most MPAs remains unknown.

CORAL REPRODUCTIVE SYNCHRONY ON SINGAPORE'S REEFS**Guest JR, Baird AH, Goh BPL, Chou LM****Department of Biological Sciences
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There are very few reports of multispecific, synchronous coral spawning from reefs in Southeast Asia. It has been suggested that on low latitude reefs the 'mass spawning' phenomenon may be absent, or significantly reduced. Singapore is a small, industrialized and heavily populated Southeast Asian country, located approximately 1° north of the equator. Despite there being high levels of sedimentation and turbidity in the coastal waters, reasonably diverse coral communities can be found around some of the islands to the south of the mainland. Histological analysis of selected coral species sampled between September 1999 and October 2000 showed the presence of mature gametes at two times of the year (Feb – April and Sept – Nov). Sampling of *Acropora* species to determine the extent of reproductive synchrony within the population was conducted at Singapore's southern most reef (Raffles Lighthouse, 1° 10'N 103° 45'E). Sampling was carried out by breaking off a branch from the middle of the colony and noting the presence or absence of mature eggs (which are pigmented) or immature eggs (which are white). In March 2002, a few days prior to the full moon, 48.5% of the *Acropora* population had mature eggs, 10% had immature eggs and the rest had none (n = 113). In April 2002, 23% of the *Acropora* population contained mature eggs (n = 74), and in May 2002 none of the sampled colonies contained mature eggs (n = 79). On the 3rd, 4th and 5th nights after the March 2002 full moon, synchronous spawning of corals was observed on the reef at Raffles Lighthouse. At least 18 different coral species from 10 genera and 5 families (Acroporidae, Faviidae, Merulinidae, Oculinidae and Pectiniidae) were observed releasing gametes over the three nights. This observation demonstrates that mass coral spawning can indeed be a characteristic of equatorial reefs. The possible environmental cues involved in synchronizing corals on low latitude reefs will be discussed.

DEEP CORAL REEFS, BOTH SIDES OF THE ATLANTIC: FISHERIES, EVOLUTION AND CLIMATE CHANGE ASPECTS

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The continental shelves of both Europe and North America support thriving deep-water “reefs.” Their distribution is puzzling: northern Europe and the southern USA have *Lophelia* reefs, whereas Canada has gorgonian forests. Hovland has suggested that *Lophelia* reefs are nourished from below, via hydrocarbon seepage. All reefs, deep and shallow, may therefore be classified as to their relative dependence on energy sources:

-**sunlight**: via zooxanthellae-most modern offshore coral reefs.

-**seepage**: via bacterial remobilization-northern Europe, Western Australia, Louisiana.

-**exogenous**: zooplankton; POM and DOM from terrestrial sources- inshore reefs, Paleozoic rugosan reefs.

Deepwater reefs are under at least as much stress as shallow reefs, with reports ranging from widespread damage to complete extirpation (usually from trawling). They need protecting, because of their immense value in fisheries, the priceless climate archive in the coral skeletons, and (last but not least) as possible sources of gametes to recolonise and re-establish reefs on the shelves if we ever clean up our act.

Both types of reef-*Lophelia* bioherms and gorgonian forests-represent habitat complexity, and hence are deep-water FAD's. The *Lophelia* reefs are sometimes large accumulations of skeletal debris, with a reticulate surface coral veneer-these seem to attract monkfish and demersal roundfish (esp. grenadiers). The Canadian coral forests, B. T. (Before Trawling) formed extensive thickets, with individual corals to 10 m in height. These were select areas for halibut, cod and redfish. The decrease in fish catches concomitant with habitat destruction has caused erection of deep-water MPA's in Norway and off Tasmania. Canada has done nothing.

Evolution of the deep coral fauna is a mystery. Atlantic zonation may be temperature dependant, but temperature alone does not explain the disjunct distribution of *Lophelia*. Reproductive habits of individual corals will be important. Some “deep” species can range from 4 km to 4 m in depth, and some exist in zooxanthellate and azooxanthellate forms. If indeed dire predictions come true, and we lose all our shallow reefs in the next few decades, the only hope of natural recolonisation of the shallow shelves will be the deep survivors.

Verification of some of these predictions will come from the corals themselves. Deep-water corals are far better climate recorders than are reef corals: they live at all depths in all oceans, and have equivalent lifespans (several centuries). They are reliable (and KIE-free) temperature recorders, with monthly precision. Our research group has just retrieved a 250-year record of the North Atlantic Oscillation, which drives the location of the Gulf Stream.

**ECOLOGY, SEDIMENTOLOGY AND HYDRODYNAMICS OF A REEF FLAT AND
CORAL CAY BEACH, WARRABER ISLAND, TORRES STRAIT.**

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This paper reports on a PhD project concerning the nature of contemporary ecological, sediment and hydrodynamic interactions within a reef flat system, the relationship between different reef flat environments and the adjacent island beach and, in particular, the present sediment sources of the beach.

Fieldwork for the investigation was conducted on Warraber, a small, oval-shaped coral cay and large platform reef system with a combined total area of 11 km², in the central Torres Strait, Australia. An array of beach profiles and reef flat transects were surveyed, beach and reef flat sediments were sampled and an ecological census was conducted on the reef flat. Wave, current and tide measuring instruments were used to examine water flows across the reef flat and longshore and cross-shore flows around the island margin. Twelve sets of four-directional sediment traps were employed in conjunction with the hydrodynamic instruments.

Initial analyses indicate that water flows across the reef flat were dominated by topographically modified tidal flow. Reef flat exposure and submergence reflected the interaction of platform morphology with water levels and exerted strong controls on the energy conditions, and the ecological and sedimentology characteristics of each reef flat zone. Eight distinct ecological-sediment reef flat zones were identified. These include muddy-sandflats with brown algae, large areas of sandflat covered with gastropods, broad bands of dense branching corals and a diverse, encrusted, coral-algal rim. The size and composition of *insitu* reef flat sediments was diverse, variable and related to the local carbonate producers. The beach sediments, in contrast, were less variable, being dominated by gastropods and, to a lesser extent, coral and calcareous algae fragments. The present supply of beach sediments originated from a limited area of the reef flat, including elevated sandflats to the east and dense branching coral zones to the west of the island. Sediment transport rates around the island were very variable and dominated by longshore movement. Small seasonal changes were observed in the island beaches whilst significant seasonal differences were observed in reef flat sediment deposits.

Initial findings indicate that important factors controlling the variability of gross sediment transport rates across the Warraber reef flat were exposure and submergence, the strength of tidal currents and the availability of *insitu* material. The potential for material from each reef flat zone to contribute to beach deposits was, in part, a function of proximity to the island. However, this potential was also strongly controlled by more complex interactions between the tides, reef flat water levels and topography, and by the availability of appropriately sized sediment. Further analyses will aim to (1) determine the rate of sediment production in the various zones of the reef flat; (2) refine the sediment pathways across the reef flat and onto the island beach; and (3) tease out the relative roles of tides, topography, hydrodynamic patterns and distance as determinants of reef flat and beach sediment sources and sinks.

***IN VIVO* MONITORING OF A CORAL-BACTERIAL ASSOCIATION**

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Research interest in the association between corals and microbes has increased dramatically in recent years, particularly in response to evidence of disease emergence in the world's coral reef ecosystems. Here, we explore the potential of using bacteria labelled with fluorescent proteins in experimental studies of bacterial interactions with the coral mucosal surface and the underlying epithelium. Three fluorescent-protein expression vectors (p519gfp, p519cfp and p519rfp) have been successfully transferred via tri-parental conjugation to a bacterial strain implicated in the white plague type II disease in scleractinians. The genes encoded on these plasmid vectors differ in the spectral signal of their fluorescent products, thus providing flexibility when dealing with problems of coral autofluorescence. In our studies, the temperate stony coral, *Oculina arbuscula*, serves as the host organism for closed-system inoculation experiments. We show that fluorescent-protein expression does not adversely affect bacterial survival and activity and that maintenance of the plasmid vector remains stable even in the absence of the counterselectable marker. Epifluorescence and confocal laser scanning microscopy are used to visualize the presence of pathogenic bacterial cells in association with coral cells. In principal, this approach may promise a rapid and non-destructive method to track bacterial adhesion, colonization, and perhaps even invasion of coral tissue *in situ*.

GLOBAL CORAL REEF HEALTH: FIVE YEARS OF STEADY DECLINE**Gregor Hodgson, Jennifer Liebler, Georg Heiss****Reef Check, Institute of the Environment
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During the five-years from 1997 to 2001, 1081 reefs in all oceans were monitored using the Reef Check protocol. The results of the 1997 survey were the first to demonstrate that there was a global coral reef crisis due to overfishing. Subsequent results have shown a continuing decline in many of the 25 Reef Check indicators of reef health such as butterflyfish, grunts, grouper, parrotfish and sea cucumber. Several indicators such as lobster and Tridacna clams are missing from most reefs. Over the five-year period, the percentage of living hard coral has been consistently higher in the Pacific than the Atlantic. Recently killed coral was four times higher in the Pacific than the Atlantic in 1998 following the global bleaching event, but is now equal in the two regions. Since 53% of the monitored reefs have some form of legal protection, and 90% are in developing countries, enforcement appears to be a continuing challenge. In these protected sites, diver damage was ranked as a major perceived impact in both oceans, with fishing and sewage also important. The theory that participation in Reef Check would lead to increased stewardship has been demonstrated by teams helping to establish and maintain successful marine parks in Africa, Asia and the Caribbean.

IOC/UNESCO-WB TARGETED WORKING GROUP ON CORAL BLEACHING

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The growing link between mass coral bleaching and global climate change is driving an urgent need for information on how changes in global sea temperature, the major factor driving coral bleaching events across the globe, will affect the viability of the world's coral reef ecosystems. The potential scale of this ecological change is of major concern in both developing and developed nations. In response to this concern, UNESCO's Intergovernmental Oceanographic Commission (IOC) established an expert Study Group focused on Coral Bleaching and Related Indicators of Coral Reef Health in 2000. The aim of this group was to integrate and develop research that will allow more reliable predictions of climate impacts and the development of better bioindicator tools for managers. At the first meeting held 9-11 April 2001 at IOC, Paris wide ranging discussions between the group and the representative of a related World Bank project led to the fusion of the group to become the IOC/UNESCO-World Bank Targeted Working Group on Coral Bleaching. The immediate goals of the reconstituted group are to identify critical gaps in our knowledge of the molecular to ecological processes involved in mass coral bleaching, and to develop specific, testable hypotheses that will be the focus of targeted investigations in four key ocean areas. The ocean areas selected are located in East Africa (Zanzibar), the Philippines (Bolinao), Eastern Australia (southern GBR) and Mexico (Puerto Morelos). In addition to targeted research activities, the work plan is aiming to involve local scientists and students in a series of activities that will range from training workshops to collaborative experiments. The project development is partially funded by a World Bank Block B grant, in addition to funding from host institutions like the University of Queensland and is designed to explore how a full work plan can be implemented to pursue a complex set of questions over 5 years. A 2002 workshop on Heron Island was the first step in testing the concept of targeted research within one of the four ocean areas. A large group (32 scientists and 18 postgraduate students) collaborated on testing hypotheses developed during the April 2001 discussions in Paris. The coincidence of a major bleaching event across the Great Barrier Reef during the workshop led to some unusual opportunities for the targeted working group to pursue questions associated with a "natural" bleaching event. Among the highlights of this successful workshop were a major audit of symbiotic dinoflagellate strains, the discovery of new coral diseases for the GBR region, new insights into the role of cell suicide and apoptosis in bleaching and the important role of clonal variability in coral stress tolerance.

**THE RELATION OF BLEACHING SUSCEPTIBILITY TO ZOOPLANKTON FEEDING
BEHAVIOUR IN THE CORAL GENUS *MONTASTRAEA***

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Reef-building corals can complement their nutrition needs in many different ways. The two most important are translocation of photosynthetic products from the endosymbiotic zooxanthellae and capture of zooplankton by the tentacles of the polyps. Corals bleach under temperature stress conditions; the density of their symbionts declines and the corals lose not only their colour but also their main nutritional source. Two massive species of the genus *Montastraea* from the Caribbean coast of Puerto Rico were selected to conduct feeding experiments under temperature stress; *M. faveolata* with relatively small polyps and *M. cavernosa* with larger polyps. Two distinct morphs of *M. cavernosa* were separated, M1 has very large polyps, and M2 has significantly smaller polyps. However, both M1 and M2 morphs have significantly larger polyps than *M. faveolata*. Experiments were designed to compare the role of feeding by tentacle capture under temperature stress conditions and a control. Non-bleached coral pieces were collected from the field and exposed to elevated water temperature in an aquarium to compare the effects of enhanced zooplankton feeding (with nauplii of *Artemia salina*) on bleaching induction. Pieces of the same colony were kept in an aquarium with normal temperature. Zooxanthellae counts were made in tissue samples to quantify the extend of bleaching. The amount of ingested *Artemia* was determined to assess feeding activity, and the nitrogen content was also measured. *M. cavernosa* M1 exhibited the least bleaching susceptibility whereas *M. faveolata* (with smaller polyps) showed a fastest decrease in the density of zooxanthellae. The most resistant species was *M. cavernosa* with higher zooplankton feeding rates at higher temperatures compared to ambient temperature conditions. The less tolerant coral was *M. faveolata* which showed the same trend of increasing feeding rates at higher temperatures but, this trend was less consistent over time.

The results suggest that zooplankton feeding can partly substitute the loss of the zooxanthellae up to a certain degree and duration of bleaching. It is proposed that corals with bigger polyps and larger tentacles, like *M. cavernosa*, can increase zooplankton feeding during bleaching for a certain time period and therefore, can better compensate the decline of zooxanthellae and the resulting nutritional deficit during sea warming episodes. This may be an explanation of why *M. cavernosa* bleaches, when it does, later during intensive bleaching events.

DEFINING SUCCESS IN MARINE PROTECTED AREAS

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Marine protected areas (MPAs) are the primary form of protection in the marine coastal zone and are being used by many as a spearhead for marine conservation. However, there is much debate with regard to their effectiveness. This paper addresses a key question in this debate, namely, “What defines MPA success?”, and in doing so will highlight areas for potential research and discussion.

Reef communities are both biologically and socially dynamic systems which form complex interactions. This complexity is often not fully recognised, and hence leads to complication in the operation of many MPAs. Through a review of the objectives and outcomes of a large number of Caribbean MPAs, we show that an understanding of context is essential for effective analysis and hence recommendation. This is further supported by a detailed examination of the social and natural systems of three Eastern Caribbean MPAs; Barbados, Bonaire and St. Lucia. We show that the use of *a priori* performance criteria in the evaluation of MPA success requires careful consideration before implementation. This is a highly relevant exercise considering the increasing number of attempts from both the social and natural sciences to assess MPA success using such methods. The use of most performance criteria implies an inherent assumption that the system under study should match a predefined template. However, the objectives stated on paper during MPA establishment may not often match real outcomes due to the complex nature of institution-ecosystem interactions.

We suggest that defining the success of reef-encompassing MPAs depends very much on the responsible and intelligent use of criteria. A precursor to their implementation, which will lead to a more realistic appraisal, is to take into account constantly shifting social intentions and the ability of the whole system to respond to change. To accurately define success will depend on a thorough understanding of the natural and social environment, which can only come about through a balanced interdisciplinary approach.

**THE EVOLUTION OF CORAL-ZOOXANTHELLA SYMBIOSIS IN TURBID HABITATS
AND IMPLICATIONS FOR RESPONSE TO GLOBAL CHANGE**

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Appreciation for the long-term consequences of global change on coral reefs and the coral-zooxanthella symbiosis may be constrained by a late Holocene perspective that tends to limit thinking about scleractinian ecology and evolution to predominantly oceanic settings, without considering either the conditions under which scleractinians and coral-zooxanthella symbiosis evolved during the Triassic or those experienced since then. We propose that a variety of turbid, inshore habitats have been continuously available to scleractinians through geological time, that these have provided both ecological and evolutionary continuity, and that they have served as both refugia for scleractinian corals during non-reefal periods and as primary habitat. We propose such turbid, inshore environments have influenced the evolution of scleractinian corals and the evolution of coral-zooxanthella symbiosis. Since these coastal habitats are now strongly influenced by human activities, it is important to consider the consequences for long-term coral survival in these habitats, especially since anthropogenic activities on land are degrading coastal ecosystems and may be increasing the distribution of turbid habitats. With the ever-increasing stresses on coral reef ecosystems, consideration of how corals respond, and of possible advantages that may be conferred by the coral-zooxanthella symbiosis in inshore environments may enhance understanding of the capacity of scleractinians to adapt to global change.

PREDICTING THE LONG TERM EFFECTS OF CORAL BLEACHING AND CLIMATE CHANGE ON THE STRUCTURE OF CORAL COMMUNITIES

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Because coral species show differential susceptibility to bleaching, and coral communities are so variable, predicting the effects of coral bleaching on benthic coral reef communities requires developing predictive models of particular reef locations. We developed a spatial (cellular automaton) model of shallow benthic communities on two midshelf reefs on the Great Barrier Reef (GBR). We considered only corals, turf algae, and non-geniculate coralline algae since these are the principal space occupants. The dynamics of the model is driven entirely by local processes, namely, outcomes of neighbour-specific interactions, neighbour-specific growth rates, and recruitment and mortality rates. These parameters were estimated from observations in 140 fixed quadrats photographed every 6 months over 3 years.

Despite that the potential state-space of predicted communities is very large, actual community structure of the real reefs in terms of the absolute cover of 12 life-form (physiognomic) categories was predicted accurately as an emergent property of the models. Having derived a model that predicts community structure of the real reefs, we simulated several scenarios of coral mortality as a result of bleaching and climate change. In all simulations, bleaching events occur at intervals of 10 years over a 100 year period, and there is annual recruitment of all 12 life-form groups. The effect of bleaching events on coral mortality was as observed in the 1998 bleaching event on the GBR when maximum water temperatures rose to 31.5 °C.

For all scenarios, the model predicts significant degradation of reefs in <100 years. With no further warming and a single bleaching event each decade, cover of turf and coralline algae increases to ~75% while coral cover declines to ~25% in 60 years. If ocean warming continues at 0.1 °C per decade, and assuming 100% mortality of corals at 32.5 °C (based on recent observations of thermal tolerance thresholds over the latitudinal range of the GBR), then coral cover declines steadily to <15% after 100 years. Control reefs without bleaching support 60% coralline and turf algal cover, and 40% coral cover. Notably, different guilds of corals respond differentially to bleaching. Some groups decline gradually with successive bleaching events (e.g. most Acroporidae), others show little effect for several decades before declining suddenly (e.g. Faviidae), while groups little affected directly by bleaching (e.g. massive Porites) can increase in abundance under some bleaching scenarios. The abundance of thermally 'tolerant' genotypes may persist at relatively constant levels for several decades of bleaching before suffering sudden reductions in cover.

Because this type of spatial model can readily integrate processes from the molecular to community level, it is a strong candidate for further refinements of predictions of the effect of climate change on the community structure and dynamics of coral reefs.

MONITORING CHANGES IN THE FULLY PROTECTED ZONES OF THE FLORIDA KEYS NATIONAL MARINE SANCTUARY

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The Florida Keys National Marine Sanctuary is a 9,850-km² marine protected area managed by the U.S. National Oceanic and Atmospheric Administration and the State of Florida. A comprehensive management plan was implemented in 1997 to protect and conserve marine resources of the Florida Keys. One aspect of the management plan is the creation of a network of 23 fully protected zones (marine reserves); the Tortugas Ecological Reserve was implemented in 2001 as the 24th fully protected zone, the largest marine reserve in U.S. waters (518 km²). An ongoing monitoring program is designed to determine effects of “no-take” protection on heavily exploited fishes and invertebrates, benthic communities, and human activities. Data on the abundance and size of reef fish, spiny lobster, and queen conch; algal cover; and coral cover, diversity, and recruitment are collected from fully protected zones and adjacent reference sites. Socioeconomic analyses are also being conducted. Preliminary reports indicate increases within the fully protected zones in the number and size of heavily exploited species such as spiny lobster and certain reef fishes. Slower-growing benthic species such as corals and sponges have not shown significant changes within fully protected zones, possibly because the zoning plan was implemented less than five years ago.

UPWELLING REFUGIA IN TIMES OF ENVIRONMENTAL STRESS

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Efforts to map and assess the global extent of coral reefs at risk have ignored the significant extent of non-reefal coral communities. Although lacking the classical geomorphological structures of a 'true' reef, these communities can harbour diverse and unique assemblages and confer many of the same benefits. In addition, non-reefal coral communities typically occur in marginal locations, subject to unusual physical regimes, which may confer additional resilience during times of environmental stress. Glynn proposed the theory that upwelling areas could act as refugia for species diversity during mass coral bleaching events in the Pacific. Mass coral bleaching events have been linked to both prolonged exposure to solar radiation and elevated sea temperatures associated with large-scale disturbances in ocean-atmospheric dynamics. The theory that zooxanthellate coral communities in areas subject to cool upwelled water could act as potential species refugia is investigated with respect to the severe 1997-1998 Indian Ocean wide coral bleaching event, with particular reference to the islands of Socotra (Republic of Yemen), including Samha and Darsa, Abd Al Kuri, Sabunya, and Kal Farun, located in the extreme northwest Indian Ocean (12-13°N, 52-55°E). The islands of Socotra are exposed to a wind-driven upwelling system, known as the Great Whirl, resulting from the northwards passage of the Somalia current along the east African coast during the boreal summer months. Recent surveys have found that these islands support a diverse (250+ species) scleractinian coral fauna. Coral dominated communities found along the northern shores of these islands naturally intergrade with mixed macroalgal and coral communities on exposed southern shores. Bleaching induced mortality of coral communities around the islands of Socotra was spatially variable and ranged from negligible around the outer islands to severe (>90% mortality) along northern shores. The spatial distribution of bleaching induced mortality around the islands was compared with high resolution (9km daily AVHRR Pathfinder) sea surface temperature (SST) to determine whether upwelling had influenced bleaching outcomes.

LITHOPHAGA (BIVALVIA: MYTILIDAE), INCLUDING A NEW SPECIES, BORING IN MUSHROOM CORALS (SCLERACTINIA: FUNGIIDAE) AT SOUTH SULAWESI, INDONESIA

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Bivalve species of the mytilid genus *Lithophaga*, including a new one, are recorded from Indonesian mushroom corals (Scleractinia: Fungiidae). True associations with live hosts include *L. laevigata*, *L. lessepsiana*, *L. lima*, *L. punctata* spec. nov., and *L. simplex*, while specimens of *L. malaccana* and *L. mucronata* have been found in bore holes in encrusted or dead parts of infested corals.

Diagnosis for *L. punctata* n.s.: Valves with minute, elevated dots antero-laterally to postero-ventrally, periostracum darker above that area. Largest available specimen: 13.5-5.0-4.7 mm. Host corals are *Fungia (Pleuractis) paumotensis*, *F. (Verrillofungia) repanda*, *F. (V.) scabra*, *Halomitra pileus*, *Lithophyllon mokai*, and *Sandalolitha robusta*.

Host corals of *L. laevigata* are *Fungia (V.) scabra*, and *F. (V.) spinifer*.

Host corals of *L. lessepsiana* are *Fungia (Danafungia) horrida*, *Halomitra pileus*, *Herpolitha limax*, and *Lithophyllon undulatum*.

Host corals of *L. lima* are *Fungia (P.) moluccensis*, *F. (V.) scabra*, *Lithophyllon undulatum*.

Host corals of *L. simplex* are *Fungia (Wellsofungia) granulosa*, and *Sandalolitha robusta*.

It is obvious that there is no clear host-specificity in the associations of *Lithophaga* and mushroom coral species.

The present results suggest that the *Lithophaga* species recorded from mushroom corals at the Spermonde Shelf, South Sulawesi, predominantly occur on nearshore reefs.

GROWTH CHARACTERISTICS OF THE CORAL-ASSOCIATED BACTERIAL COMMUNITY IN HEALTHY, STRESSED, AND DISEASED CORALS

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Coral disease incidence has increased dramatically since first being reported in the early 1970s. Increasing numbers of coral colonies and species over wider geographical ranges are affected by disease, resulting in extensive mortality throughout the Caribbean. Despite the major ecological impact of coral disease, the etiology of most coral diseases remains unclear. Corals harbor unique, associated microbial communities. These coral-associated bacterial communities are diverse, species specific, and similar in corals from widely separated reefs. The nature of the relationship between corals and their associated bacteria has yet to be established. The balance of a symbiotic relationship is not static, and under stressful environmental or physiological conditions it is possible that the associated symbionts can multiply and cause disease. Whether any of the uncharacterized coral diseases are caused by imbalances in the regulation of the normally associated microbiota remains to be determined. Mitchell and Chet (1975) demonstrated that certain stresses kill corals via bacterial overgrowth (i.e., coral treated with antibiotics did not die when exposed to crude oil, copper sulfate, or dextrose). However, the Mitchell and Chet study used concentrations of stressors that are unlikely to occur even on extremely polluted reefs. This study expanded upon the work of Mitchell and Chet (1975) by testing a greater range of environmental and anthropogenic stresses, at more environmentally relevant concentrations. To elucidate the nature of the relationship between a coral and its associated bacteria, methods were developed to determine bacterial growth rates and numbers on corals. These methods were used to determine how the bacterial community growth characteristics change with anthropogenic stress and disease. Our results indicate that the coral-associated bacterial community is tightly regulated, possibly through nutrient limitation, and this regulation breaks down with carbon (glucose) addition and disease.

**GENETIC POPULATION STRUCTURE OF THE LIONFISH
PTEROIS MILES (SCORPAENIDAE: PTEROINAE) IN THE GULF OF AQABA AND
NORTHERN RED SEA**

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Fishes on coral reefs, such as the lionfish *Pterois miles*, have a life history with two totally different phases: adults are relatively strongly side-attached, whereas larvae of virtually all species are planktonic. Therefore, large-scale dispersal and high gene flow could be expected. However, due to the fjord-like hydrography and topology of the Gulf of Aqaba isolation of populations might be possible. The gulf is a 180 km long and 6-25 km wide northern extension of the Red Sea and separated by a shallow sill. The aim of this study is to reveal genetic population structure, genetic diversity, and gene flow between populations of the lionfish *P. miles* in the Gulf of Aqaba and northern Red Sea. The applied molecular marker is a 166 bp sequence of the 5' mitochondrial control region. It is the most variable mitochondrial gene in fishes and a suitable marker to investigate genetic population structure. Among 94 *P. miles* specimens 32 polymorphic sites were detected, yielding 38 haplotypes. Sequence divergence among haplotypes ranged from 0.6% to 9.9% and genetic diversity was high ($h=0.85$, $\pi=1.9\%$). AMOVA indicates no restriction of gene flow between the Gulf of Aqaba and northern Red Sea ($\Phi_{ct} = 0.05258$). Consideration of observed high genetic diversity, paleoceanography of the Red Sea, and life history of *P. miles* indicate that the revealed genetic population structure reflects high gene flow and panmixia. However, it is not possible to estimate on which time-scale gene flow operate. Therefore, coastal zone management in the Gulf of Aqaba has to follow the precautionary principle and should not rely upon fast replenishment or re-colonisation.

**STRATEGIES IN SURVIVAL OF CORALS FROM STRESSED ENVIRONMENTS:
FUNGIA GRANULOSA A CASE STUDY**

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Coral reef degradation due to anthropogenically induced stress has recently been the cause of much concern. For corals found in these areas, the ability for sustaining the population depends on the survival at the individual (clone) level as well as at the genet level. Survival at the individual level is a result of the individual's capacity for physiological plasticity. Reproduction and the ability to repair damage are two aspects of the coral's physiology that play cardinal roles in their ability to survive stress. In the Red Sea the solitary free living fungiid coral *Fungia granulosa*, is common in areas of high sedimentation and physical abrasion, thus providing a good model system for studying the mechanisms for overcoming stress. To ascertain what physiological adaptations may aid these corals to survive, the reproductive cycle and capacity for repair following damage was followed for a period of three years using standard histological techniques and *in situ* observations. Moreover the effect of tissue damage on reproductive effort and conversely of reproductive state on the capacity for repair was examined in experimentally manipulated corals. Results showed that *F. granulosa* is a gonochoric broadcast spawner. Gametogenesis begins in early March at a time of high productivity in the Gulf of Aqaba. Only individuals over 5.0 cm in diameter are reproductive. Spawning occurs in July-August when the water in the Gulf is relatively calm. This led to the choice of spring and fall as the experimental periods for inflicting tissue lesions. Lesions were inflicted on mature and immature corals using an air pick and the corals were maintained *in situ*. This procedure was carried out on one set of corals during gametogenic months (spring), and on another set during post reproductive months (fall). Tissue repair and regeneration were monitored using photography and computerized image analysis. Corals that underwent damage during post reproductive months, underwent complete repair within 8 weeks, while those that were damaged at the beginning of gametogenesis did not. Immature corals did not undergo complete repair regardless of season. Moreover when reproductive effort was investigated two months following removal of 30% of surface tissue, results showed that fecundity was reduced by 50%, though gametogenesis continued, indicating cellular and energetic trade-offs between the two processes. The relationship between amount of tissue damage and tissue repair in this coral was also studied. Corals that had up to 50% of the oral surface tissues removed underwent complete repair providing at least part of the polyp mouth remained. When the polyp mouth was removed coral tissues began developing new mouths buds. In addition following periods of "catastrophic" disturbances where many individuals underwent extensive damage to their tissues the corals survived by a reorganization of the remnant tissues and the formation of buds which then grew into new polyps. A model illustrating how environmental disturbance affects the relationship between regeneration and reproduction is proposed.

CYCLONE PUMPING AND SEDIMENT PARTITIONING IN THE DEVELOPMENT OF THE GREAT BARRIER REEF SHELF SYSTEM

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Understanding the relative impact on shelf sediments of daily low-energy versus episodic high-energy phenomena (e.g. cyclones, tsunami) is crucial to our understanding of how shallow water sedimentary systems function. Around 30-40% of today's continental margins lie in the tropics and sub-tropics, where cyclones are major mechanisms of sediment supply to the shelf, and sediment transport upon it. Understanding the sedimentary dynamics of tropical shelves at various stages of sea level is therefore a fundamentally important issue. However, current sedimentation models for tropical shelves are strongly influenced by studies of ocean plateaux such as the Bahamas, and often do not fit well with the characteristics displayed by mixed terrigenous-carbonate systems, which are geologically common and important in petroleum exploration.

The modern Great Barrier Reef (GBR) is part of the world's largest and best known mixed terrigenous-carbonate continental margin. The GBR shelf contains three shore-parallel sedimentary belts. An inner shelf zone of terrigenous sedimentation at depths of 0-22 m; a middle shelf zone of sediment starvation at depths of 22-40 m; and an outer shelf reef tract with its inner edge at c. 35-40 m depth. These zones are controlled by the dynamics of northward, fair-weather, alongshelf drift, driven by southeasterly trade winds, and by the regular passage of tropical cyclones. Cyclones cause wind-driven north-directed middle shelf flows in excess of 130 cm/s, which erode the seabed, concentrate the sparse mobile sediment into sand ribbons, and advect suspended mud onto the outer part of the nearshore terrigenous sediment prism and into inter-reef depocentres within the reef complex. Cyclones largely control the input of new sediment into the Great Barrier Reef system, via river flooding, seabed erosion or reef breakage. They also help to control the partitioning and dispersion of the main shore-parallel belts of terrigenous inner shelf, sediment-starved middle shelf, and outer shelf carbonate reef tract sediment. Acting as a sediment pump, especially during interglacial highstands, cyclones have exerted great control on the development of the modern GBR province and its sediments by maintaining a broad shelf-parallel zone of episodically mobilised sediment and scoured seabed, upon which coral reefs have been unable to form.

Contrary to current models, (i) GBR storm beds are most likely to be preserved intact close to the shoreline, and they also become coarser-grained away from the shoreline; and (ii) for the central GBR, "highstand shedding" only applies to carbonate sediment at the scale of local reefs; system-wide, oceanographic controls cause high rates of carbonate sedimentation on the slope during both sea-level rise and highstand; concomitantly, terrigenous sediment accumulates fastest on the slope during sea-level rise, and slowest during sea-level lowstand and highstand.

**THE SUCCESS OF DANJUGAN ISLAND MARINE RESERVE AND SANCTUARIES
LEADS TO A NETWORK OF PROPOSED MARINE PROTECTED AREAS IN NEGROS
OCCIDENTAL, WESTERN VISAYAS, PHILIPPINES**

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The Danjugan Island Marine Reserve and Sanctuaries (DIMRS) (Cauayan municipality, Negros Occidental, Philippines) was established via a collaborative project that pioneered a unique approach to marine resource management. The Philippine Reef and Rainforest Conservation Foundation, Inc. (PRRCFI) has been working in partnership with Coral Cay Conservation (CCC) since 1995, in order to carry out survey and education work to create the DIMRS, which was fully gazetted in February 2000 by the provincial council. Baseline surveys and training of fisherfolk, community members and government personnel has expanded since 2000 to the adjacent municipalities of Sipalay and Hinoba-an where further potential reserve areas have been proposed. This work has come under the umbrella of a provincial environmental programme called The Southern Negros Coastal Development Programme (SNCDP). A local community (Barangay Elihan) has requested to have their own marine sanctuary due to the success of DIMRS, and with the assistance of PRRCFI and CCC scientists, surveys have been carried out together with trained local community members to help establish reserve boundaries. This area has particularly high coral cover for Negros Occidental, and good potential for future coral accretion through recruitment and adult coral growth. Similarly, after initial CCC surveys in early 2000, further marine reserves have been recommended in other municipalities, and PRRCFI aim to continue the work of the SNCDP within the municipalities of Sipalay and Hinoba-an. Therefore, as a result of baseline marine biological surveys coupled with community education and technical training by the PRRCFI/CCC partnership, there has been an increase in the number of potential and existing marine protected areas in Negros Occidental as a knock-on effect of the successful establishment of the DIMRS

COLD-WATER CORAL REEFS ALONG THE NORTHERN NORWEGIAN MARGIN**Björn Lindberg, Christian Berndt, Jürgen Mienert****Dept. of Geology, University of Tromsø 9037****Tromsø, Norway****Bjorn.Lindberg@ibg.uit.no**

The University of Tromsø studies the northernmost known occurrences of cold-water reefs as a contributor to the EU-funded program ECOMOUND (Environmental Control on Mound Formation along the European Margin). The presence of cold-water coral reefs along the entire coast of Norway has been known for some time, but the reefs have only recently been subjected to thorough studies. Several prerequisites for the existence of the reefs are known, including water temperature, current activity and the presence of hard substrate on which reef-growth can initiate. Several of the reefs found on the Norwegian margin seem to be closely linked to micro-seepage of hydrocarbons from deeper-lying reservoirs, but elevated HC-levels have not been proved at all locations. The question still remains, whether or not the presence of the reefs is linked to the local (and regional) sub-surface geology.

High-resolution acoustics (seismics and side-scan sonar), video-imaging, coring, HC-analyses and isotope-analyses provide a solid data-set for the study of the Fugløya reefs (first discovered by *Hovland et al.* during a pipeline survey). The reefs can be more than 30 m high and are dominated by *Lophelia pertusa*. They are found from 130 to 180 mbsl, consistently located on topographic highs of morainic material deposited during the last glaciation. The oceanic conditions are strongly influenced by the influx of Atlantic water (Norwegian Current) with temperatures of $\sim 7.7^{\circ}\text{C}$ and salinity of 34.7‰, and tidal currents with velocities up to >30 cm/s were measured. A local basin containing primarily sandy sediments nearby the reefs displays circular depressions of ~ 5 m depth and ~ 20 m diameter, interpreted to be pockmarks due to migration of fluids from the sub-seafloor. The region is on the boundary to the Barents Sea, and existing geologic maps indicate that the underlying bedrock is crystalline, thus pointing towards a non-thermogenic origin of the migrating fluids causing the pockmarks in the area.

Further studies of the reefs can assess their value as an indicator of the sub-surface geology as well as a possible paleoclimatic proxy, given that the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values are linked to the environment in which the corals grow, and the parameters are recorded in the skeleton.

REEF GROWTH AND ACCRETION IN A TURBID LAGOON ENVIRONMENT

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Turbid reefs have been the subject of many ecological investigations and have commonly been associated with lower living cover of benthic organisms, decreased diversity of organisms and a general range reduction of fore-reef bathymetric zonation. Whilst these studies stress the impacts of increased sedimentation on reef composition, the longer-term potential for carbonate accumulation and the processes controlling accumulation under these conditions remain poorly understood.

This study examines these processes within a lagoon environment at Discovery Bay, Jamaica. The site is naturally turbid, and these conditions are exacerbated by additional external inputs of bauxite dust. This results in high mean sedimentation rates (average $5.2 \pm 2.2 \text{ mg.cm}^{-2}\text{d}^{-1}$), although at times these reach the proposed threshold levels ($10 \text{ mg.cm}^{-2}\text{d}^{-1}$) beyond which reef development is suppressed. *In-situ* measurements of light also indicate high attenuation rates, such that the surface illumination is reduced to 9.5% at 15m depth. Models are presented which illustrate patterns of reef development, community structure and framework preservation for shallow (0-10 m) and deep (15-25 m) parts of the site.

Shallow sites are characterised by a rigid reef structure of dead *in-situ* *Acropora* sp. Live coral cover is minimal (3.7%) with *Siderastrea* sp. (domed morphology) and *Madracis mirabilis* dominating. Sediment production is dominated by the calcified green algae *Halimeda* sp. (5m – 19.7%; 10m – 39.0%) and the articulated coralline algae *Amphiroa* sp. (5m – 37.6%; 10m – 16.0%). Framework preservation is influenced by high rates of internal bioerosion (mainly by sponges and worms) and low encrustation rates (coralline algae and the foraminifera *Gypsina plana* dominate the secondary framework community). In combination these factors contribute to a predicted low accretion rate.

Deep sites are characterised by loose sediment with little solid reef structure. Live coral cover is very low (5.4%). *Montastrea annularis* dominates the coral community and exhibits flat tiered growth morphologies. Partial mortality and rejuvenation are common. Sediment production is dominated by bivalves (20m – 36.5%; 25m – 39.5%). Framework preservation is influenced by high infestation by internal bioeroders (particularly sponges and bivalves) and by minimal encrustation (mainly serpulids). In combination these factors contribute to a predicted very low accretion rate.

This study demonstrates restricted framework development under conditions of high sedimentation and turbidity, coupled with only a small effect from secondary framework contributors and an infestation of borers. The major sediment contributors (*Amphiroa* sp., *Halimeda* sp., and bivalves) also differ from typical fore-reef (coral dominated) assemblages. Overall, low carbonate accumulation rates are predicted for these reefs.

TROPICAL REEF COMMUNITIES OFF NORTH CAROLINA: AT THE NORTHERN LIMIT ALONG THE US EAST COAST

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Two species of zooxanthellate or tropical reef corals occur in patches on flat rock outcrops in Onslow Bay, North Carolina. *Solenastrea hyades* (Dana) and *Siderastrea siderea* (Ellis and Solander) were found in water depths of about 20 to 40 meters. These corals survive temperatures of less than 16degC for three months of the year (mid-January to mid-April), which is the generally accepted minimum tolerance limit for the survival of tropical reef corals. These corals were found scattered on mostly Miocene quartz sandstone outcrops and are not forming a reefal framework. Dominantly tropical benthic macro algae and a variety of tropical reef fish are associated with these reef patches. Rock outcrops are abundant in Onslow Bay because of a restricted sediment supply related to limited river outflows. These suitable substrates and the inshore migration of the Gulf Stream during summer months are major factors that allow these tropical reef communities to exist so far north. The inner depth limit of about 20 meters is related primarily to a lack of suitable hard substrate and suspended sediments caused by water turbulence. More work is needed to study the life histories of the two coral species to reveal if they are capable of reproducing under these hostile conditions and also to document the settlement periods for their planulae. In addition, more information is needed on other groups that are associated with these tropical coral patches, particularly octocorals and sponges.

RELATIONSHIP OF $\delta^{13}\text{C}$ VERSUS $\delta^{18}\text{O}$ IN CORAL SKELETONS. A NEW PROXY FOR ECOLOGICAL ADAPTATION?

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Scleractinian corals hosting endosymbiotic algae (zooxanthellae) occur over a wide depth range within the photic zone of coral reefs. Different species are distinct in their distributional depth range, with some species being confined to a narrow depth range while others can be found over the whole reef slope. We investigated the skeletal $\delta^{13}\text{C}$ versus $\delta^{18}\text{O}$, zooxanthellae densities and photopigments of three different species of the genus *Madracis*. The species *M. pharensis* is abundant over a wide range between 5 and > 60 m depth, while *M. mirabilis* and *M. formosa* are restricted to a narrow range growing shallow (<20 m) or deep (> 40 m), respectively. We hypothesize, that the distinct distributional depth range of the three species is due to adaptation to the respective light regimes. Because coral $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ are both controlled by kinetic isotope effects and, because $\delta^{13}\text{C}$ is in addition affected by the coral / zooxanthellae metabolism (P:R ratio), any species specific adaptation to particular depth regimes must be reflected in the skeletal $\delta^{18}\text{O}$ versus $\delta^{13}\text{C}$ ratios. Apart from environmental factors (temperature and salinity), photosynthesis and calcification rate are controlling factors in coral isotope fractionation. The efficiency with which corals under various light regimes photosynthesize and calcify, and the linkage between photosynthesis and calcification, become apparent when applying skeletal $\delta^{13}\text{C}$ versus $\delta^{18}\text{O}$ of the 3 *Madracis* species. The $\delta^{13}\text{C}$ vs. $\delta^{18}\text{O}$ ratios of e.g. *M. pharensis* (broad depth range) and *M. formosa* (narrow range, deep) - both sampled at 50 m depth - indicate that *M. pharensis* has hardly been growing and is hence at its distributional depth limit, while *M. formosa* has even in 50 m depth a positive P:R ratio and skeletal growth. We consider the ratio of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ a useful 'proxy' to determine the ecological adaptation of single species to various depth or light regimes. Moreover applying skeletal $\delta^{13}\text{C}$ versus $\delta^{18}\text{O}$ may be a vital tool in reconstructing past conditions of reef health and reef growth.

BENTHIC COMMUNITY STRUCTURE AND SEDIMENT PRODUCTION IN A FLUVIALLY IMPACTED EMBAYMENT , RIO BUENO, JAMAICA.

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This study examines the structure and composition of fluvially impacted coral reef communities and associated sediment production in Rio Bueno, Jamaica. Rio Bueno is a small (*ca.* 0.5 km wide) embayment, located on the northern coast of Jamaica (N 18° 28', W 077° 27'). The area is characterised by clastic sediment and freshwater inputs from the Dornock River, resulting in abiotic conditions exhibiting pulsed fluctuations (*e.g.* variation in salinity, turbidity, light attenuation). Detailed fieldwork during the summer of 2001 demonstrated that mean (\pm SE) sedimentation rates in the central western embayment area were 10.6 (\pm 0.98) mg cm⁻² day⁻¹. Outer embayment areas demonstrated a mean (\pm SE) sedimentation rate of 3.1 (\pm 0.40) mg cm⁻² day⁻¹. In addition to continual natural disturbances, the study area has historically been subjected to mangrove and seagrass clearance, whilst the over-exploitation of fisheries resources continues.

Inner embayment areas appear heavily impacted by the Dornock River, with a substrate composition of close to 100% silt (occasional patches of seagrass (less than 1%) occur). No other habitat types occurred at these innermost sites. Framework production was bathymetrically restricted to areas shallower than 27 - 35 m within the central, fluvially impacted sites. In contrast, the outer, less impacted sites have been demonstrated to support drop-offs to = 200 m, with corals present to depths of =60m. The spatial and bathymetric restriction observed in the central embayment areas can be considered an effect of a highly turbid, reduced-light environment.

Macro algae and turf dominated the community composition, comprising between 25% and 30% of benthic cover in the central fluvially impacted sites, and between 40% and 70% at less impacted sites. However, hard coral cover comprised 9% to 11% of benthic cover at the central fluvially disturbed sites and 8% to 12% at less impacted outer sites.

The results of the study are discussed in the light of ongoing work, which is focused on developing a carbonate budget for inner and outer regions of the Rio Beuno embayment area.

GFP-LIKE PROTEINS AND EVOLUTION OF COLORATION IN REEF ANTHOZOA

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Coral reef ecosystems are characterized by the amazing variety of colors, but the evolutionary roots of this diversity remain largely unknown. Anthozoa represent a unique case when each visually perceptible basic color is essentially determined by the sequence of a single protein, homologous to green fluorescent protein (GFP) from *Aequorea victoria*. This provides unique opportunity to address the question of color evolution in the environment directly by applying the tools of molecular phylogenetics, and in addition, to characterize and monitor variations in coloration in terms of expression of individual genes. GFP-like proteins of Anthozoans are a very diverse family that existed in the form of at least four separate lineages even before separation of sub-classes Zoantharia and Alcyonaria. The most surprising fact is that, notwithstanding these ancient diversity roots, origination of new colors seems to happen right now: there are multiple independent events of color diversification observed in the most terminal parts of the phylogenetic tree. Combining this fact with the molecular data obtained for the proteins of different colors, such as results of site-specific and random mutagenesis and X-ray crystallography, we hypothesize that the phylogenetic pattern and color polymorphism in reef Anthozoa is a result of a balance between selection for GFP-like proteins of particular colors and mutation pressure driving the color conversions. An in-depth phylogenetic analysis will clarify whether the color diversification process goes on continuously within the protein family, or we are witnessing a unique one-time event triggered by some environmental changes in the recent past.

CORAL RECORD OF RIVER RUNOFF AND HUMAN IMPACTS ON THE INNER GREAT BARRIER REEF OF AUSTRALIA

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The impact of European settlement on water quality in the Great Barrier Reef (GBR) of Australia is a longstanding and still highly controversial issue. Studies of erosion and sediment transport in river catchments have shown substantial increases since European settlement; a consequence of large-scale modification of the river catchments from grazing, agriculture, mining and associated activities such as land clearing. The magnitude and scale of these anthropogenic induced changes and importantly their impact on the marine environment, however remains highly uncertain. Here we describe a new approach to assist in the quantification of both anthropogenic and natural (pre-European) sediment fluxes entering the GBR. This approach is based on the application of in-situ geochemical tracers in corals and has the advantage of providing a direct quantitative measure of the sediment/nutrient (P) fluxes that are actually reaching coral reefs.

Using the relatively new technique of high resolution (weekly to fortnightly) laser ablation ICP-MS, continuous scans of the trace element compositions were undertaken on 300-400 year old *Porites* coral cores (growth rate of ~1-2 cm per year) from the GBR of Australia. During high intensity rainfall events, there are massive discharges of freshwater and suspended sediments into the GBR lagoon, particularly from the Burdekin River. Barium concentrations in corals, a tracer of suspended sediment load, reveals two distinctive patterns. In the 1770's when Captain Cook first explored the east coast of Australia, there is only limited evidence for flood-plume related suspended sediment fluxes entering the inner GBR. However, immediately following European settlement in 1870, there is a sustained increase in the Ba during flood events. This is indicative of a significant increase in suspended load being delivered to the inner GBR, coincident with the first grazing activities by European settlers in the river catchments of the GBR. These results therefore provide unequivocal evidence for river flood-plumes transporting substantially increased fluxes (x4 to x8) of suspended sediment and hence nutrients into the inner GBR reef. Sediment fluxes are modulated by land-use intensity and climate, principally droughts. Following the drought of 1968/69, the suspended sediment load increased x3 during the subsequent 1970 flood, presumably due to enhanced erosion of the highly denuded catchments. In the 1970's and 1980's sediment loads in the Burdekin River further increased following the introduction of more drought resistant cattle breeds such as *Bos indicus*.

This study provides both a 'natural' pre-European baseline as well as a quantitative measure of anthropogenic fluxes against which reduction of sediment loads to the GBR can be targeted. Reducing terrestrial runoff into coral reefs is essential if they are to survive the lethal combination of direct anthropogenic impacts and now climatic stresses from unusually warm ocean temperatures.

**‘EACH REEF ITS OWN STORY’
SEA-LEVEL, ISLAND EROSION AND TWO OF J S GARDINER’S ATOLLS: FUNAFUTI
(TUVALU) AND GOIDHOO (MALDIVES)**

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At the age of 24, J Stanley Gardiner joined the ‘Coral Reef Boring Expedition’ to Funafuti atoll for the first of the three expeditions to test Darwin’s subsidence theory of coral reefs. Gardiner spent upwards of three months on Funafuti. His 1898 publication appeared in the same year the third expedition ended and six years before the major results of the expedition were published by the Royal Society/British Museum. Among other things, Gardiner concluded that Funafuti ‘had been elevated by about 10 feet’ and that the islands on the atoll were ‘now being washed away’. In 1899 Gardiner spent 10 days on Goidhoo atoll, the first of the Maldivian atolls he visited during his six month expedition to the Maldives. On Goidhoo, he came to the same conclusions as on Funafuti, viz he found ‘proof of elevation’ as well as the ‘slow but steady erosion’ of islands. Three decades later, in reviewing his own and others work on reefs and islands in the Pacific and Indian Oceans, Gardiner admitted that he ‘had not materially altered his views’, though he had become much more precise about the timing of the higher sea level, endorsing Daly’s deduction that it was 3500-4000 years ago. What was Gardiner’s evidence for these conclusions on Funafuti and Goidhoo? Were his interpretations similar to those of his contemporary expeditioners and later researchers? And, how does his sea-level history and island erosion hypothesis stack-up now, after 100 years?

This paper addresses these three questions. Generally Gardiner’s conclusions have been endorsed. Indeed, on the face of it they stack-up pretty well. For instance, Dickinson, in a recent paper (*Quaternary Research*, 1999) indicates that the shoreline morphology of Funafuti ‘reflects a relative mid-Holocene-sea-level high stand’, and that the shoreline erosion, which is presently occurring on Funafuti, foreshadows the potential impact of global warming on atoll islands. Dickinson’s evidence on is based primarily on field observations and data from secondary sources, as well as a notion of where Funafuti fits within the regional sea-level context.

An extensive geomorphic survey, including levelling profiles and mapping all of the islands on Funafuti, and a more modest survey using similar techniques on Goidhoo atoll has been carried out by the author and colleagues. These surveys, showed no indisputable evidence for a higher mid-Holocene-sea-level high stand nor any evidence for chronic island erosion, apart from shorelines that have been subject to substantial modification from human impact. Radiometric dates from reef flats and islands of both atolls are consistent with this view, which is contrary to the conclusions of Gardiner and other workers on Funafuti and Goidhoo. Reasons for this situation are advanced, including the views of some of Gardiner’s contemporaries which were more ambiguous about the field evidence.

DOES SUBSISTENCE FISHING INFLUENCE SEA URCHIN POPULATIONS IN FIJI?

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If fishing alone determines sea urchin abundance through removal of predators and grazing competitors, then urchin density will be greater on reefs with higher exploitation pressure where other anthropogenic impacts do not exist. We tested whether sea urchin abundance differed across a gradient of fishing pressure among thirteen traditional fishing grounds, in a region of Fiji where additional human disturbances are negligible. The abundance of sea urchins in Lau was low, ranging from 0.1-0.8 urchins m^{-2} , and although differences in both their total abundance and diversity were evident among grounds, these differences did not relate systematically to variations in fishing pressure or benthic variables. Only the abundance of juvenile urchins indicated a positive relationship with fishing pressure. Multiple regression models were used to explain relative influences of benthic variables alongside fishing pressure, but significant results with juvenile urchins appear to be influenced primarily by the most heavily fished ground. We conclude that in the absence of other anthropogenic inputs, recruitment to adult urchin populations at low subsistence-levels of fishing is more likely to be driven by a combination of processes rather than by predation alone.

**PETROGRAPHIC AND GEOCHEMICAL ANALYSIS OF A NON-TROPICAL
MEDITERRANEAN CORAL (*Cladocora caespitosa*): IMPLICATIONS FOR ITS USE AS A
PALAEOCLIMATIC PROXY**

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Many palaeoclimatic studies focus on the atmosphere-ocean relationship as the major point to understand decadal and longer-term climate variability. Although the most evident effects of climate changes on seawater mainly concern the oceans, also in minor basin, such as in the Mediterranean Sea, deep and complex changes are commonly observed and therefore they could be analysed, studied and related to the global climate system.

The highly seasonal nature of the Mediterranean climate regime makes this region particularly sensitive, and potentially very vulnerable, to climate changes. Thus there is a need for rigorous assessment of the patterns, causes and impacts of Mediterranean climate fluctuations. Such understanding needs reliable measurements of relevant parameters, such as sea surface temperature (SST), for an adequate interval of time; in the lack of both instrumental observations and historical records of relevant meteorological parameters we have to rely on indirect measurements (proxy data), such as corals.

A living non-tropical coral (*Cladocora caespitosa*) (L.) from the North-western Mediterranean Sea, has been examined by optical polarized light (PL) and scanning electron microscopy (SEM) and chemically analysed by electron (EMPA) microprobe with the aim to define in detail its microstructural features and determine the reliability of its use as a palaeo and living environmental and climatic proxy. Petrographic observations and geochemical data show different morphological and compositional portions of the primary aragonitic texture of the coral and the presence of a secondary aragonitic precipitation (interseptal filling). Aragonitic crystals that form interseptal filling, show lamellar arrangement completely different from trabecular structure that forms septa, paliform lobes and theca wall. Different morphological features were analysed, and geochemically characterised. The aim of the research was to carry out a detailed investigation on the calcification centres, the needle-shaped crystals and the interseptal fillings, by studying the distribution of minor and trace elements such as Sr, Mg, S, Si and Al, in order to recognise possible microchemical differences in small coralline areas and reveal little scale heterogeneities which are averaged in conventional bulk sampling techniques.

Minor and trace element distribution between centres of calcification and the surrounding fibres in different areas of the corallite has been pointed out. Small spatial scale study has allowed to determine the microstructural geometry of the coral and its geochemical features, improving the analytical methods for the future use of *C. caespitosa* as an environmental proxy (SST, Salinity, anthropogenic inputs, etc.). This study has been extremely important to understand how to obtain geochemical information from primary aragonite, without a contamination of a secondary aragonitic contribution. Since *C. caespitosa* is the only shallow coral existing in the Mediterranean Sea, such petrographic and geochemical characterization is fundamental to prove the reliability of this species as a climate proxy, and it offers the possibility to obtain long time series, never documented before in the Mediterranean marine environment.

EARLY MARINE DIAGENESIS IN CORALS AND CONSEQUENCES FOR PALEO-RECONSTRUCTIONS OF CARBONATE SATURATION STATE IN CORAL REEFS AND ATMOSPHERIC CO₂

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A major and recently topical question concerns the effect of increasing atmospheric CO₂ on coral calcification rates. Coral calcification rates have been used to derive information on carbonate saturation state in the ocean and to derive conclusions on atmospheric CO₂ levels in the past and future. We present coral skeletal density, extension, calcification, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ data for two long coral cores spanning ~ 1840-1994 AD at Ningaloo Reef Marine Park, Western Australia, one of which includes significant secondary precipitation of marine inorganic aragonite. We show that this secondary aragonite can lead to the incorrect conclusion of reduced calcification in the 20th. In our coral, a 30% cementation at the start of the century corresponds to the decrease in calcification towards the present derived from modeling and experimental studies. While calcification rates alone are ambiguous for conclusions on reef calcification and coral growth, calcification rates in combination with $\delta^{13}\text{C}$ values allow to see diagenetic alteration in recent corals. Furthermore, the combined use of coral density, growth rate and calcification data supports correct conclusions on coral calcification. We show that diagenesis can seriously effect paleoceanographic reconstructions from calcification rates and $\delta^{13}\text{C}$ and may have serious implications for paleo-CO₂ reconstructions and conclusions on past episodes of coral bleaching.

**THE KEY LARGO LIMESTONE REVISITED: PLEISTOCENE SHELF-EDGE FACIES,
FLORIDA KEYS, USA**

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The southern margin of the Pleistocene Florida Platform is well known from the coral-bearing Key Largo Limestone and the ooid-rich Miami Limestone that crop out along the island chain of the Florida Keys between Miami and Key West. These units were deposited during the last interglacial highstand of sea level ca. 125 yr BP (oxygen-isotope stage 5e). Based on sedimentological and chronological (U-series dating) investigations of 12 long and 57 short cores, the youngest of the Pleistocene Q-units (Q1-Q5) of the Key Largo Limestone of south Florida was further subdivided into Q5e and post-Q5e. Individual units correspond to highstands of sea level, and units are, to a large part, separated from each other by subaerial exposure horizons reflecting sea level lowstands of the Pleistocene. Units Q1 and Q2 are characterized by abundant quartz and to a lesser extent by skeletal fragments of molluscs and foraminifera. We speculate that units Q1 and Q2 may have been deposited during the high sea levels of oxygen-isotope stage 11 between 420-360 ka. Abundant carbonate production and reef development occurred during deposition of unit Q3, presumably during isotope stage 9. The abundance of corals and coral boundstone decreases in unit Q4 (corresponding to isotope stage 7), which can be subdivided in a lower quartz-rich and an upper carbonate-rich succession. Unit Q5e (equivalent to isotope stage 5e), which forms the present day emergent Florida Keys, is again rich in massive corals (*Montastrea annularis*) and reefs. The seaward-dipping geometry of this unit and the scarcity of the Atlantic breakwater *Acropora palmata* support the contention that this Q5e platform margin had a ramp-type character. Shelf-margin reefs with *Acropora palmata* developed during deposition of post-Q5e units and correspond to highstands of sea level during isotope stages 5a and 5c. These deposits, which exhibit shelf margin wedge and offshore outlier reef geometries, act as foundations of the Holocene bank barrier reefs at the modern south Florida shelf edge.

DO COMPETITIVE HIERARCHIES EXIST IN CORAL-ALGAL INTERACTIONS?**M. M. Nugues, M. van der Geest, H. Waska, R.P.M. Bak****Netherlands Institute for Sea Research (NIOZ), PO Box 59,
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Over the past two decades, many coral reefs in the Caribbean have experienced an increase in the abundance of macroalgae which has resulted in a greater frequency of direct encounters between corals and macroalgae. Yet, few studies have examined how these interactions and their effects vary with species characteristics and anthropogenic influence and whether they form definite and consistent hierarchical structure. Here, naturally occurring interactions between corals and three species of macroalgae, *Halimeda opuntia*, *Dictyota menstrualis* and *Lobophora variegata*, were surveyed at two different depths on six reefs along the South coast of Curacao, Netherlands Antilles. Reefs were chosen upstream and downstream of local human impacts to represent a gradient of human influence. Damage to both parties in interactions was recorded in the form of recently dead, bleached or discolored coral tissue or physical damage to the alga. In addition, experimental field contacts between corals and algae were conducted to study the competitive abilities of different coral species and the mechanisms of damage to the algae. The survey showed the number and impact of interactions to depend on both coral and algal species, but also on reef location along the gradient. Upstream reefs showed fewer interactions and less damaged coral tissue per interaction at both depths compared to downstream reefs, suggesting a strong influence of local human factors. The forced interactions experiments did not always reflect the pattern observed in the reef survey. Results indicated differences in aggression among corals, with some species able to damage algal blades by extrusion of mesenterial filaments. However, in the field, overgrowth and damage of these corals by macroalgae was conspicuous. The complexity of the development of dominance pattern over time and variation in environmental factors may preclude any consistent competitive hierarchies between corals and algae.

**DYNAMICS OF FISH ABUNDANCE ACROSS BOUNDARIES OF A NO-TAKE ZONE IN
NABQ MANAGED RESOURCE PROTECTED AREA, SOUTH SINAI**

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Underwater visual census counts were conducted across a small no-take zone and its adjacent open fishing zones in Nabq with the aim of analysing fish abundance and size distribution across boundary areas at three depths and for eight fish families. Although fishing pressure from the artisanal Bedouin fishery is considered moderate, differences in fish abundance since reserve creation have been found and this study provides a more detailed examination of the reserve dynamics. The families Serranidae (groupers) and Lethrinidae (emperors) displayed higher abundance in the no-take zone over all depths whereas Acanthuridae (surgeonfishes) showed the reverse pattern of increased abundance in the open areas. Fishing gear is predominantly gill and trammel nets leading to differential fishing pressure at the various depths surveyed with deeper areas of reef slope too deep for the nets, resulting in altered patterns of abundance with depth. Seven of the eight families showed significantly higher abundance in the no-take zone in the backreef lagoon, whereas only two families showed significant differences in abundance at 10m depth. Gradients of abundance from the centre of the reserve outwards were also influenced by depth, with Siganidae (rabbitfishes) showing a decrease in abundance from the centre in the lagoon but an increase at 3m and 10m. One species each of snapper and grouper (*Lutjanus ehrenbergi* and *Cephalopholis argus*) showed a significant decrease in abundance with distance from the reserve centre (over the combined depths) whereas four species of surgeonfish (*Acanthurus nigrofuscus*, *Ctenochaetus striatus*, *Zebrasoma desjardini* and *Naso unicornis*) and one species of rabbitfish (*Siganus argenteus*) showed significant increases in abundance. Habitat differences coupled with differential fishing pressure (both between depths and areas), the small size of the no-take zone and imperfect enforcement of fishing regulations have led to varying dynamics across this no-take zone.

**EARLIEST STEPS OF DIAGENESIS IN LIVING SCLERACTINIAN CORALS:
EVIDENCE FROM ULTRASTRUCTURAL PATTERN
AND RAMAN SPECTROSCOPY**

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In carbonate skeletons, including corals, the presence of organic matrices is well known. These skeletal matrices have been recognized to play a major role in skeletogenesis and formation of biocrystals. Scleractinian skeletons are therefore characterized by a compositional heterogeneity which is fundamentally based on this organo-mineral duality. Effects of early diagenesis on scleractinian skeletons are primarily controlled by their initial ultrastructural patterns and the composition and spatial distribution of these skeletal organic matrices.

The earliest stages of diagenesis in coral skeletons have been investigated by comparing microstructural and ultrastructural features from the uppermost skeletal parts of living colonies (i.e. previously occupied by the living soft tissues) with those obtained from the older part of the same skeleton. The various ultrastructural and diagenetic patterns observed with SEM have been analysed by Raman microspectroscopy in order 1) to characterize mineral and organic skeletal phases *in situ*, and 2) to detect transformation of any of these mineral or organic phases due to very early stages of diagenesis.

Microstructural and ultrastructural patterns:

In addition to its organo-mineral duality, the initial heterogeneity of a scleractinian skeleton is shown by the occurrence of a micron-scale zonation of fibres resulting from incremental growth during elementary cycles of biomineralisation, and also by the presence of two basic structural features, fibres and calcification centres, clearly differentiated from each other. Within the species analysed, micro- and ultrastructural data reveal an additional fine-scale diversity related to taxonomy. At the timescale of colony life, the earliest processes of diagenesis produce a thin fringe of syntaxial aragonite cements, alteration of the incremental zonation of scleractinian fibres and also preferential diagenetic changes within calcification centres. These first modifications of coral skeletons are obviously controlled by the biological ultrastructural characteristics of scleractinian taxa and also suggest that early diagenesis does not necessarily imply drastic changes of environmental conditions.

Raman microspectroscopy:

The characteristic 155 & 1085 cm⁻¹ bands common to both aragonite and calcite were evident in all spectra and attention was thus focussed on the other bands in order to distinguish these two polymorphs. Most spectra revealed no specific trace of calcite. Organic matter has been recognised in some spectra on the basis of several bands in the range typical of C-H vibration. A few extra bands in various spectra have not yet been identified as belonging to organic or mineral matter or to yet further parasites. Hence, at the present time, the existence of organic material is detected with confidence, but no chemical assignment is yet possible.

CORAL REEFS IN A SILICICLASTIC BARRIER ISLAND SETTING: REEF DEVELOPMENT AND SEDIMENT PRODUCTION, INHACA ISLAND, SOUTHERN MOZAMBIQUE

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Inhaca Island, southern Mozambique (lat: 26°S, long: 33°E) is located towards the southerly latitudinal limits of coral reef growth in the Indian Ocean. The island forms part of a small barrier island complex produced by the northward transport of sediment along the Natal coast. The island comprises a series of high (up to 115 m) vegetated dunes, interspersed by low, freshwater marsh areas. High energy conditions and significant clastic sediment transport occurs along the eastern (Indian Ocean) side of the island, whilst western shores of the island (Maputo Bay) represent areas of deposition and are characterised by low energy conditions, and the development of extensive intertidal sandflats and seagrass beds.

Reef development around the island is at best patchy and restricted to the margins of channels which dissect the extensive intertidal flats on western and southern fringes of the island. Three main sites of coral growth are currently identified but, at all sites, active framework accumulation is severely restricted (both spatially and bathymetrically). Coral growth is limited to the upper 4–6 m, but framework accumulation is only significant in the upper 1–3 m. In many cases large *Porites* sp. ‘bommies’ produce a basic reef structure, with other common coral genera including *Acropora* sp., *Favia* sp., *Platygyra* sp., *Pocillopora* sp. and *Montipora* sp.. In addition, the diversity of the reef-associated fauna is severely restricted. In contrast to lower latitude reef systems, reef development is therefore both spatially and bathymetrically constrained and reflects low carbonate production rates in these marginal (high latitude) and high turbidity sites.

Sediment samples recovered from reef and reef-related areas also indicate very low productivity of carbonate sediments. Three main carbonate sediment producing environments are identified, 1) intra-reef areas, 2) intertidal coral rubble zones, and 3) seagrass beds. Intra-reef sediments comprise predominantly coral (40–50%) and mollusc (15–30%) grains, with secondary coralline algae (5–10%), echinoid (~5%) and foraminifera (1–2%). Coral rubble zones are characterised by mixed carbonate:siliciclastic sediments, with corals (~25%), molluscs (~10%) and coralline algae (~5%) again representing the dominant carbonate constituents. Siliciclastics comprise around 50% of the substrate. Seagrass beds are also characterised by mixed carbonate:siliciclastic sands, but with lesser amounts of carbonate (typically <20%). Predominant carbonate grains are molluscs (10–15%) and foraminifera (10–15%). *Halimeda* which is typically an important reef sediment producer is absent at all sites. Areas of open, intertidal sands, which occur between these carbonate producing areas, are siliciclastic dominated (80–90% quartz) with lesser amounts of glauconite, feldspars and lithoclasts. Carbonate grain assemblages do not, therefore, conform to typical chlorozoan (tropical) associations, further emphasising the marginal nature of carbonate production in these high latitude reef systems.

GRAZER CLUES TO REVERSING PHASE SHIFTS ON CARIBBEAN REEFS**Nicholas Polunin, Ivor Williams****School of Marine Science & Technology,
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Can we extrapolate the events of the 1980s on shallow N Jamaican reefs to other Caribbean reefs, what does 'phase shift' imply, and what do we really know about underlying mechanisms and their reversibility? On deeper (12-15m) reefs where it seems *Diadema* was never abundant, a strong negative correlation across 19 sites in 5 Caribbean locations between herbivorous fish biomass and macroalgae hints at a gradual, not step-wise, transition via grazing from high- to low-coral states. However there appears to be a limit to the amount of substratum (~60% cover) scarids and acanthurids can keep macroalgal-free at the present time. Further, an experiment in Belize with 'pseudocorals' suggests that loss of coral and limited herbivore pressure can contribute to macroalgal overgrowth through spatial escape from grazing. We suggest that (i) the consequences of coral bleaching, disease and hurricane impacts and (ii) loss of grazing fish through fishing contributed to large scale algal overgrowth on deeper reef tracts. The Jamaican phase shift (i) appears not to be a systemic switch between alternative states more (ii) a dramatic change which occurred in a short space of time. Systematic comparison of protected reefs with those unprotected from fishing tends to remind us that at shallow and deep reefs the connection between fishing and the phase shift has been indirect; reef degradation will not simply be reversed by excluding fishing.

**DEVELOPING CORAL REEF DATABASE WITH WEB-BASED GIS
CASE STUDY AT TELUK CENDRAWASIH MARINE NATIONAL PARK, INDONESIA**

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Coral reef ecosystem at Teluk Cendrawasih Marine National Park, Papua, Indonesia has inside very big potential resources, unfortunately its exploitation bring about damaged. The exploitation and development need more planning in an integrated manner, with rationally coral reef management. Former step in this management system is developing coral reef spatial database in digital format that rounds up its existing, distribution, wide area, conditions, type, and its species. Coral reef data that having spatial and temporal references need a system for collecting, storing, and management. Geographic Information System (GIS) as a computer-based system with four capabilities to handle geographical reference data, i.e. entering, data management, manipulating and analyzing, along with output; most appropriate to apply. GIS product also could be published on World Wide Web that can be accessed by everyone in everywhere through internet browser.

The development of coral reef spatial database, with Web-based GIS (Geographic Information System) application, rounds up activity: (1) Digital mapping of area restriction and management zones are carried out over digitizing, editing, UTM transformation, tabulation of attribute data, and map's layout process; (2) Coral reef condition mapping is carried out by image processing of Landsat Thematic Mapper base on Lyzenga's algorithm application. Field surveys for classify determining are carried out base on line intercept transect (LIT) method for remote sensing purpose; (3) Coral tabular database in digital format is arranged base on US Fish & Wildlife Service Division of Law Enforcement (1991) and Australian Institute of Marine Science (1994) standard; (4) Web pages are taken for relate on map and tabular database in an interactive manner with internet mapping software and to publish database on internet.

The result of this research can be accessed pass through :

<http://www.wwf.or.id/sahul/tcmnp/mapdb/coralmap.asp>

INHERITED ASPECTS OF MODERN BARRIER REEF MORPHOLOGY

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The Darwinian model for the successive evolution of fringing reefs, barrier reefs and atolls with progressive subsidence has been generally accepted following the indisputable proof of subsidence provided by drilling results on Pacific atolls. Nonetheless, there is no proof that subsidence ever produced such a genetic succession of reef types. Instead, there are data that don't fit the expectations of the model, such as the similar lagoon depths of barrier reefs and atolls as opposed to the subsidence theory's prediction that atolls should have significantly greater depths.

As in the case with atolls, the maximum lagoon depth of 69 modern barrier reefs is statistically correlated with the lagoon catchment area for modern rainfall. Present day, low latitude, oceanic rainfall patterns would seem to be an appropriate proxy for relative geographic differences in glacial lowstand rainfall, even though the absolute amounts of rainfall are unknown. Consequently, the correlation suggests the importance of Pleistocene subaerial solution in contributing to barrier reef morphology. Further support for antecedent influence occurs in the form of barrier reef passes in which the depth of the reef pass is correlated with onshore drainage volumes. Choked or partially blocked reef passes seem likely to represent breaching of a pre-existing drainage divide that separated seaward from lagoonward directed meteoric drainage during glacial low stands of sea level.

The role of carbonate deposition in contributing to lagoon morphology relates to lateral infilling of the lagoon by rim-derived sediment and the vertical accentuation of antecedent relief. In at least one instance bilateral progradation in both a seaward and lagoonward direction can be demonstrated.

Resulting barrier reef morphology reflects the alternating consequences of Pleistocene fluctuations in sea level. During sea level rise, there is an accentuation of antecedent relief followed by highstand progradational infilling of the lagoon by rim-derived sediment. During lowstands the infilling is terminated and the lagoonward facing infilled edge is eroded, commensurate with the development of solution morphology on the subaerially exposed carbonates. The consequences of the numerous Pleistocene and perhaps earlier fluctuations of sea level are the barrier reef morphologies that we see today.

CLASSIFICATION, ACCURACY ASSESSMENT AND UTILITY OF REEF-TOP BENTHIC HABITAT MAPS DERIVED FROM LANDSAT DATA OF THE EGYPTIAN RED SEA**Samuel Purkis, Jeroen Kenter****Dept. Sedimentology
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Presented is a technique to monitor benthic assemblages on the fringing coral reef tops of the central Egyptian Red Sea using Landsat TM imagery calibrated by field measurement. Above water spectral reflectance measurements of reef top substrates were made on a section of reef top surrounding Marsa Shagra using an OceanOptics spectrometer. An analytical model was formulated and proven capable of removing the influence of a water column of known thickness from an above water measurement provided that values for the water's inherent optical properties were available. Both the field spectra and atmospherically corrected TM image were corrected for the influence of the intervening water column using the model to retrieve values of substrate reflectance. Unlike the field spectra, depth was not known for every pixel in the satellite imagery, as ancillary bathymetric data for the area was not available. Instead, a simple generic model of reef topography and in situ tidal measurements were combined to provide an estimate of depth. The processed field spectra were assembled into 7 classes representing the dominant substrate assemblages present on the reef top and resampled to the bandwidths and sensitivity of the 3 visible bands of Landsat TM. Image classification was afforded using a maximum likelihood method based on a normal probability density function. Each image pixel was assigned to the substrate class to which the probability of membership was greatest based on the covariance distribution of the field spectra. Accuracy assessment of the resulting benthic habitat maps was performed against 87.3 km² of metre-scale ground-truth data using both Kappa and Tau coefficients calculated from standard error matrices. In areas where bathymetry was absent, classification accuracy was calculated to be 47% higher than would be expected through chance agreement. In the limited areas where bathymetry was known, classification was found to be significantly ($P=0.01$) more accurate and over 70% better than chance. The work indicates that in areas where bathymetry data is absent, but predictable using a simple topographic model, Landsat TM can be used to resolve both the geographic extent and geomorphological and ecological zonation of the reef top at a regional scale. In areas where an independent measure of bathymetry is available, it is shown that benthic habitat distribution can be predicted with a high degree of accuracy and that quantitative analysis is possible. As differentiation between optically similar substrates such as seagrass and green algae is displayed, the detection of community phase-shifts of such classes can be used as a sensitive proxy for environmental stress. Landsat offers a 25 year archive of imagery with which to investigate the seasonal, annual and decadal dynamics of the reef-top. Such information is valuable to quantify the temporal dynamics of carbonate depositional environments, as well as the impact of construction and habitat alteration related to tourism development in the area. The results highlight the utility of spaceborne remote sensing techniques to monitor short-term events in real time that could not be tackled through in situ survey for logistical reasons.

SPATIAL AND TEMPORAL VARIABILITY OF CORAL COMMUNITY DYNAMICS IN THE RED SEA

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Coral reef benthic community structures reflect the temporal integration of species specific ecological demands over prevailing environmental conditions. Dynamic processes, such as recruitment, colony fragmentation, growth and retreat or mortality, however, create within-community fluctuations in composition and abundance on the species level. The quantification of the natural „noise“ in community dynamics is essential for the status evaluation of recent coral reefs and coral community recovery (succession) after natural perturbations or anthropogenic disturbances.

Repetitive surveys of test squares (25 m²) were used to estimate rates of species and area turnover in the living benthic coverage. Four pristine reef sites (wind- and leeward outer reef and lagoon slopes respectively, all at 10-12 m depth) at the Sanganeb-Atoll/Sudan were first mapped in 1980 (Mergner H & Schuhmacher H 1985 Helgol Meeresunters 39: 375). Resurveyed in 1991, the data analysis revealed relative species turnover values (T_{rel} , Schoener TW 1983 Oikos 41: 372) ranging 1.97-3.24 %yr⁻¹ (median 2.67 %yr⁻¹). They largely agree with values calculated from transect data of Caribbean coral communities: 2.28 ± 1.04 %yr⁻¹, n=21 (Carysfort Reef, Florida, Dustan P & Halas JC 1987 Coral Reefs 6: 91).

Rates of areas colonised or cleared by new or disappearing species during the census interval were used to estimate areal turnover periods of living coral communities: the overall recruitment periods calculated from newly recruited species in the test areas (median 416 ys, ranging 323-755 ys) exceeded the overall clearing periods calculated from disappearing species (median 342 ys, ranging 312-527 ys). Assuming a balanced overall area budget of colonising and clearing processes (with rather stable ratios of unoccupied substrate, Sheppard CRC 1985 Mar Ecol Prog Ser 25: 259) the difference most likely is compensated for by recruitment and vegetative propagation of persistent species.

Comparison with a coastal fringing reef near Aqaba/Jordan (Gulf of Aqaba, test square first mapped in 1976, by Mergner H & Schuhmacher H 1981 Helgol Meeresunters 34: 115) revealed significant differences in community turnover parameters. Different clearing rates during two census intervals of 6 and 7 ys resulted in a high value for T_{rel} (4.3 %yr⁻¹) during the first interval with a subsequent period of increased recruitment. Calculated periods of overall area turnover (205 ys for species recruitment, 22 ys (!) for clearing) lay well below the reference values from the central Red Sea and appear to reflect onshore anthropogenic impact.

Results demonstrate the relevant time scale of several hundreds of years for coral community development and highlight their vulnerability to short term impacts.

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CHARACTERIZATION OF SUPEROXIDE DISMUTASES IN SYMBIOTIC ANTHOZOANS

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Plants have acquired, through their evolution, defense mechanisms against oxidative stress, which mainly act against ROS generated consequently to the photosynthetic O₂ production. Such a ROS production is however not limited to plants but also to some animals living in symbiosis with chlorophyllian organisms. One of the best-known symbiotic systems is the phototrophic association between Cnidarians and Dinoflagellates (*Symbiodinium sp.* known as zooxanthella). Among these, hermatypic Scleractinian corals and sea-anemones are largely distributed in the oceans. The aim of the present study is to characterize the first enzyme involved in the cellular oxidative defenses, the superoxide dismutase (SOD), in a Mediterranean sea anemone (*Anemonia viridis*) and in a hermatypic coral (*Stylophora pistillata*). During oxidative stress conditions, the SOD act by dismutating O₂^{•-} in H₂O₂, which is subsequently transformed in H₂O and O₂ by another enzyme, the catalase. First results have confirmed the presence of cœlenteric oxygen variations in a tentacle of the sea anemone, with a hyperoxia state during the daytime (60 % of dissolved O₂) and an anoxia state during the night-time. The isozymes of Cnidarian SOD were visualized on native polyacrylamide gel and the specific activities were measured by spectrophotometry. In *Anemonia viridis*, three classes of SOD have been identified using specific inhibitors. They differ from each other by the metallic co-factor (Cu/Zn-SOD, Mn-SOD and Fe-SOD) and tissue-specific isozymes have also been shown for each class. An active Cu/Zn-SOD isozyme was restricted to animal compartment (ectodermal and endodermal cells), although an inactive one was localized by Western Blot in the zooxanthellae. Four Mn-SOD isozymes were distributed among symbiotic partners. One of those was common to both Cnidarian and zooxanthella cells and located in the mitochondrial compartment, three others were restricted to endodermal cells and to the zooxanthellae. Finally, two Fe-SOD are located not only in the zooxanthella compartment but also in the endodermal cells. The apparent molecular weight (MW_{app}) and isoelectric point (pI) were determined for each isozyme. Analysis of the *Stylophora pistillata* SOD isozymes shows a different pattern of the electrophoretotypes, which suggests a species-specificity of the SOD isozymes. Nevertheless, *S. pistillata* presents also at least 7 isozymes with three main electrophoretotypes having pharmacological Mn-SOD characteristics. The presence of high isozyme diversity, typical to photosynthetic organism, is supposed to be involved in the extraordinary adaptation of the symbiotic Cnidarians to oxygen variations.

EXTREME CLIMATIC EVENTS AND HIGH-LATITUDE REEF-BUILDING: WHAT CONSEQUENCES FROM GLOBAL CLIMATIC CHANGE?

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Particularly in high latitudes (and on reefs in extreme settings) reef-building by *in situ* framework production is strongly influenced by extreme climatic events that can cause coral mass mortality. Subsequent break-up of coral skeletons and heavy bioerosion remove the framework and can thus lead to a reef switch-off. Examples of such events are sea-surface-temperature anomalies, frequently associated with ENSO events, and extreme-wave-energy events frequently associated with tropical cyclones (hurricanes). For a series of high-latitude coral areas (Florida, South Africa, Red Sea, Arabian Gulf) in comparison with some tropical reef areas (Indonesia, Cayman, USVI) the effects of climatic teleconnections in the predicted global warming scenarios is explored. Factors examined for possible importance for high-latitude reef building processes are: increase in frequency of ENSO and teleconnected events, latitudinal changes in the tropical cyclone (hurricane) belts. Also warm-water delivery into the South Atlantic via Agulhas rings and the North Atlantic thermohaline circulation as well as the possible link between increased SST and emergent diseases is briefly revisited.

REEF MANAGEMENT IN THE 21ST CENTURY: EFFECTIVE MONITORING AND LEGISLATIVE GUIDELINES FOR LAND-BASED SOURCES

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Despite recent emphasis on the effect of “global change” on reefs, the evidence of relative impacts is quite clear: the world’s coral reefs have already suffered widespread damage. Managing this decline will require effective community-based monitoring, coupled with objective criteria by which discharges from the land may be regulated. The first criterion in MPA location should be distance from land-based sources.

Virtually every monitoring protocol uses some variant of the line transect method (Risk, 1972), with video records scored by trained biologists. These efforts are technology-intensive, require taxonomically-trained personnel, and are inappropriate for Third World settings (where most of the reefs are). In addition, almost all of them fail to include several critical aspects of reef health, such as bioerosion. This is a particularly serious oversight, as bioerosion rates increase in lockstep with coastal eutrophication. We should therefore abandon traditional monitoring, in favour of bioindicator-based methods that can be used by untrained people. These “early warning” indicators can then be policy triggers linked to programs to identify and quantify sources of stress.

Community-based monitoring using stomatopods is very effective in Indonesia: village women are trained to classify and count these organisms as they glean for food at low tide (Erdmann’s work). Kate Holmes and co-workers, in both the Caribbean and Indo-Pacific, have demonstrated that local people can quickly be trained to assess extent of bioerosion in coral rubble. The method is quick, cheap, and can be linked directly to coastal contamination levels. Whatever method the local community uses, there needs to be a level of change that triggers a policy response.

The major anthropogenic stresses on reefs are sedimentation, sewage, industrial discharge and fishing. Inappropriate fishing techniques (blast-fishing, cyanide, muro-ami) are a problem worldwide, are always “illegal”, and hence require effective application of existing policies rather than enactment of new legislation. In regions where the bulk of incoming sediments are siliciclastic, sediment stress may be cheaply and quickly assessed by determining insoluble residues of coral samples. In general, residues exceeding 0.2% signal stress, and this can be the trigger level to involve policy measures. Reef growth is clearly inhibited at SPM values >10 mg per litre; where these values occur, mitigation may include watershed reforestation and modification of agricultural practices. Sewage stress will be detected by bioerosion bioindicators, and the levels assessed via analysis of $d^{15}N$ in coral tissue. For legislative purposes, an increase of 2 per mil over time on any given reef, or between affected and comparison reefs, can trigger policy interventions such as sewage treatment plants. Assessment of the relative impacts of sediments and sewage costs about \$300 per reef.

Although trigger levels for industrial discharge levels have not been worked out, corals themselves can serve as monitors. Levels of heavy metals and POP’s can be determined over time, via analysis of coral and gorgonian skeletons. Once water/coral partition coefficients have been determined, corals can be used to determine safe levels for human habitation.

MONITORING ENVIRONMENTAL VARIABILITY AROUND COLD-WATER CORAL REEFS USING A BENTHIC PHOTO LANDER

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Current estimates of the environmental sensitivity of cold-water corals and their associated biota are limited by our incomplete understanding of the variability of the cold-water coral reef environment. The sensitivity of reef biota to sedimentation and resuspension events is largely unknown and the influence of seasonal phytodetrital deposition has not been studied *in situ*. Here we describe the use of a benthic photo lander to monitor this variability by the Sula Ridge reef complex on the mid-Norwegian continental shelf. The photo lander provides a platform for time-lapse digital and film cameras to image the seabed while the optical characteristics (light transmission, backscatter and fluorescence) of the seawater and the current regime are recorded. At a water depth of 280m, the photo lander recorded a dynamic environment with a tidal current regime and mean estimates of sediment resuspension 0.5m above the bed of 136 μ g/l (maximum 771 μ g/l) over a four day period. Initial analysis of the seabed photographs shows intense feeding activity of echiuran worms (probably *Bonellia viridis*) pointing to rapid bioturbation of the sediment around the reef areas. Only with longer term monitoring of cold-water coral reef environments *in situ* can informed inferences about their environmental sensitivity and eventual management be drawn.

DIVERSITY AND DISTRIBUTION OF CORAL-ASSOCIATED BACTERIA

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Coral reefs are the most biodiverse of all marine ecosystems, however very little is known about prokaryotic diversity in these systems. To address this issue, we sequenced over 1,000 bacterial 16S rDNAs from three massive coral species (*Montastraea franksi*, *Diploria strigosa*, and *Porites astreoides*) in Panama and Bermuda. Analysis of only 14 coral samples yielded 430 distinct bacterial ribotypes. Statistical analyses suggest that additional sequencing would have resulted in a total of 6,000 bacterial ribotypes. Half of the sequences shared <93% identity to previously published 16S sequences and therefore probably represent novel bacterial genera and species; this degree of novelty was substantially higher than that observed for other marine samples. Samples from the Panama corals were more diverse than those from Bermuda, paralleling diversity gradients seen in metazoans. The coral-bacteria associations were non-random. Different coral species had distinct bacterial communities, even when physically adjacent, while bacterial communities from the same coral species separated by time (~1 year) or space (3,000 km) were similar. Analysis of the branching coral *Porites furcata* showed that bacterial ribotypes are also structured spatially within colonies. Therefore, corals and reefs represent landscapes of diverse, ecologically structured prokaryotic communities.

THE *VIBRIO SHILOI*/OCULINA PATAGONICA MODEL SYSTEM OF CORAL BLEACHING

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Vibrio shiloi is the aetiological agent of the coral bleaching disease of *Oculina patagonica* in the Mediterranean Sea. During the last ten years, 80-90% of the *O. patagonica* colonies off the coast of Israel bleached during the summer when sea-water temperatures reached a maximum of 29-31°C. During the winter, the corals recovered. In controlled aquaria experiments, it was shown that *V. shiloi* infection and the resulting bleaching were temperature dependent, occurring only at summer sea-water temperatures. The first step in the infection process is adhesion of *V. shiloi* to a β -galactoside-containing receptor in the coral mucus. The bacteria then penetrate into the epidermal layer of the coral and multiply intracellularly reaching ca. 10^9 cm⁻³ coral tissue. Inside the coral, *V. shiloi* differentiates into a viable-but-not-culturable (VBNC) state. The intracellular bacteria produce toxins which inhibit photosynthesis, bleach and lyse zooxanthellae. One of the toxins is the peptide PYPVYAPPPVVP, which forms NH₃ channels in algal membranes, thereby destroying the pH gradient across the membrane and blocking photosynthesis.

Temperature plays a key role in regulating the production of *V. shiloi* virulence factors. When the bacteria are grown at winter sea-water temperatures (16-20°C), they do not produce (i) the adhesin required for initial binding to the coral, (ii) anti-algal toxins and (iii) superoxide dismutase (SOD). An SOD⁻ mutant adhered to corals, penetrated into corals cells, multiplied intracellularly for a short time and then died, aborting the infection. Laboratory and field experiments indicate that SOD protects the intracellular *V. shiloi* from oxidative stress caused by supersaturated concentrations of oxygens produced by zooxanthellae photosynthesis. During the winter when SOD is not produced by *V. shiloi*, the bacteria cannot survive in corals. Thus, a fresh infection cycle is required each spring-summer. Recent observations suggest that the marine fireworm *Hermodice carunculata* serves as a winter reservoir and potential vector for *V. shiloi*.

The generality of the bacterial hypothesis of coral bleaching will be discussed.

THE RELATIONSHIP BETWEEN WATER QUALITY AND THE PREVALENCE OF DISEASED CORALS IN THE FLORIDA KEYS

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Coral cover has significantly declined in the Florida Keys over the last 20 years, the causes of which remain elusive and ill defined. Coincidentally, there has been an increase in coral diseases reported not only in the Keys but also throughout the wider Caribbean. This trend is most prolific in the Western Atlantic with many new disease conditions recently reported in the literature and previously described diseases found affecting different and additional coral species.

This study assessed the distribution and frequency of diseased scleractinian and gorgonian corals between 1998 and 2000 using radial belt transects incorporating an area of 113m² at each station. The disease surveys were conducted at stations throughout the Florida Keys and the Dry Tortugas, and only included coral colonies more than 10 cm in size. The total number of coral colonies for each scleractinian species, gorgonian species, the presence or absence of disease, and disease type were recorded by pre-qualified disease observers. Preliminary results, presented elsewhere, indicated that there were differences in disease distribution between reef types and geographic areas, with the highest prevalence of disease on reefs near Key West when compared with reefs from New Grounds and the Dry Tortugas. These results suggested a possible link to anthropogenic activities in the Key West geographic region on back reefs.

Water quality was suspected as a potential factor contributing to the declining health of reefs in the Key West region. Therefore, water samples and measurements were made at the same time that the coral disease assessments were conducted. Depth profiles for temperature, salinity, dissolved oxygen, and pH were taken with a HydroLab[®] deployed above the corals. Water samples were analyzed for total chlorophyll *a*, dissolved ammonium, dissolved nitrate and nitrite, dissolved nitrate, soluble reactive phosphorous, total organic phosphorous, total organic nitrogen, dissolved silica, total organic carbon, C:H:N ratio, total number of bacteria, and total number of viable *Enterococci*. Additional water quality monitoring data were available from other programs. Data obtained in close proximity to our stations and during the same sampling months were used for establishing relationships.

The associations between specific diseases-species and water quality parameters were examined using non-parametric multivariate statistical procedures, including analysis of similarities and multiple dimensional scaling. The coral and gorgonian diseases and water quality parameters were mapped using GIS. The distributions of different diseases were associated with different water quality parameters. The specific relationships between these factors will be presented. These differences could have implications for future management activities designed to protect this resource.

MICROBIAL GRAZING AND NUTRIENT FLUXES WITHIN THE CORAL REEF FRAMEWORK

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The coral reefs of Curaçao, Netherlands Antilles, are riddled with cavities and crevices, providing a hard bottom surface area, which exceeds the projected surface area of the reef by 1.5- 8 times. This cryptic hard substratum surface (HSS) area is for up to 60% covered by sessile filter feeders, which have a potentially large impact on planktonic organisms and chemistry in ambient water. We examined changes in bacteria and dissolved inorganic nutrients (DIN, DIP, Silicate) in 2 artificially closed coral reef cavities (± 70 l volume) over a 30-minute time period. Cavity main openings were closed with a tight woven linen cloth. Closure efficiency was checked after insertion of Fluorescein. Samples were taken from the middle of the cavity with 60 ml syringes attached to a fixed tube. Depending on cavity and initial concentrations, bacterial abundance dropped rapidly. After 30 minutes, between 50-60% had gone, which coincides with clearance rates of 1.36×10^{12} - 3.93×10^{12} bacteria $\cdot \text{m}^{-2}$ HSS $\cdot \text{d}^{-1}$. Higher initial concentrations of bacteria resulted in higher clearance rates. NO_x concentrations increased significantly during the time of enclosure. Efflux rates varied between 1.02- 9.77 $\text{mmol} \cdot \text{m}^{-2}$ HSS d^{-1} . Ammonium concentrations did not significantly change. Silicate concentrations significantly decreased after enclosure with 241.21- 384.74 $\text{mmol} \cdot \text{m}^{-2}$ HSS $\cdot \text{d}^{-1}$. Dissolved Inorganic Phosphate (DIP) concentrations showed a tendency to increase with estimated effluxes of 0.46-6.97 $\text{mmol} \cdot \text{m}^{-2}$ HSS $\cdot \text{d}^{-1}$. Comparison of bacterial disappearance rates and NO_x production rates suggests that additional sources of N than bacteria, were used by the cryptofauna. The experiments show that coral reef cavities are a major sink for heterotrophic bacteria and silicate and a source for NO_x . The latter points to strong nitrification in cavities in which sponge-symbiotic cyanobacterial nitrification may play a role.

THE IMPACTS OF SEDIMENTATION ON THE REPLENISHMENT OF CORAL REEF COMMUNITIES

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This study addressed sediment impacts on reefs of the west coast of St. Lucia, in four different bays. Two bays had low sedimentation levels and two bays received high sedimentation input from rivers. In each bay, three to five locations were selected between the head of the bays and their headlands. Monitoring work carried out since 1995 shows that decreases in coral cover were highest close to the river mouths. Algal turf was the main component of the algal assemblage on reefs with higher sedimentation rates, whereas reefs with less sedimentation showed higher cover of macroalgae. The present study focuses on the impacts of sedimentation on the replenishment of coral communities by coral larval settlement and examines the survival and growth of settled corals. Settlement rates were estimated using artificial settlement plate arrays. Additionally, permanent photoquadrats were established to study mortality, settlement and growth rates of juvenile corals on natural reef substrata. Observations were repeated twice over a one-year period. The results show that settlement, mortality and growth rates of juvenile corals were very variable over time. Settlement rates on artificial substrata were similar between bays. However, within bays, settlement rates were higher at the headlands ($0.4 \text{ settlers} \cdot 225\text{cm}^2 \cdot 100\text{d}^{-1} \pm 0.08 \text{ SE}$) than at their heads ($0.1 \text{ settlers} \cdot 225\text{cm}^2 \cdot 100\text{d}^{-1} \pm 0.03 \text{ SE}$). Settlement rates to natural substrata were also significantly higher at the headlands of the bays ($0.5 \text{ settlers} \cdot 600\text{cm}^2 \cdot 100\text{d}^{-1} \pm 0.07 \text{ SE}$) than at their heads ($0.23 \text{ settlers} \cdot 600\text{cm}^2 \cdot 100\text{d}^{-1} \pm 0.06 \text{ SE}$). In contrast to findings from artificial substrata, the bays differed significantly in their settlement rates to natural substrata. Mortality rates of juvenile corals did not differ between bays with different sedimentation levels, neither did the location in the bay play an important role. Juvenile coral growth rates were higher on reefs with low sedimentation ($0.15\text{cm} \cdot 100\text{d}^{-1} \pm 0.02 \text{ SE}$) than with high sedimentation ($0.09\text{cm} \cdot 100\text{d}^{-1} \pm 0.01 \text{ SE}$). Total mortality rate for all locations for the 1-year study was 40.7%. and the settlement rate to natural substrata was equivalent to 18.8% of the original coral number. Comparing mortality rates and settlement rates, it was clear that settlement rates observed could not compensate for high mortality rates during the study. In summary, this study showed that sedimentation has a negative effect on the replenishment of coral reefs by reducing settlement and growth. However, it is difficult to determine the mechanisms that act on juvenile coral survivorship and growth, since many factors are correlated with each other. Sedimentation decreases macroalgae, but macroalgae might be a more detrimental threat to juvenile corals than sedimentation, by causing coral mortality through competing for space and shading them. Herbivorous fish reduce algal cover, but may damage juvenile corals due to unselective grazing. Additionally, prior to this study, in 1999 Hurricane Lenny impacted coral reefs of the low sedimentation bays more severely than high sedimentation bays, which caused high coral mortality and enhanced algal growth (especially blue-green algae) reducing suitable substrata for coral larval settlement and presumably decreasing juvenile coral survivorship.

LONG-TERM MONITORING OF A MARGINAL CORAL COMMUNITY IN NORTHERN KWAZULU-NATAL, SOUTH AFRICA

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Southern African coral communities form a continuum from the more typical, accretive reefs in the tropics of Mozambique to the marginal, southernmost African distribution of this fauna in KwaZulu-Natal. While the South African reefs are limited in size, they are gaining increasing attention. They provide a model for the study of corals at latitudinal extremes and in terms of many of the stresses to which these valuable systems are being globally subjected. Soft coral cover, comprising relatively few species, exceeds that of scleractinians over much of the southern reefs and the coral communities attain a biodiversity peak at this latitude (27°S) on the East African coast. Data will be provided in this regard. The marginal distribution of these coral communities provides an opportunity for monitoring the effects of climate change and a long-term monitoring site was established for this purpose. Quadrats of 0.25 m² have been photographed annually within fixed transects since 1993 and hourly temperatures have been logged on the reef since 1994. While a consistent increase in sea temperature of 0.27°C p.a. has been measured on the site over the last nine years, summer maxima associated with high irradiation have caused only limited bleaching. The current temperature increase appears to reflect a cyclical phenomenon as IGOSS NMC data indicate that it was only 0.01°C p.a. over the last 50 years. A combination of GIS mapping and merging of the quadrats with subsequent image analysis was developed for the study and has revealed that the coral community structure is changing and the scleractinian cover is increasing. The technique has also provided measurements of recruitment, colony growth and mortality. Some published projections on the long-term effects of climate change indicate that more reefs will become marginal as a result of global warming. Current monitoring on the South African reefs is being expanded to include oceanographic measurements, PAR light intensities and aragonite saturation state. It is hoped that the combined studies on these marginal reefs will elucidate the future of more typical reefs.

CLIMATE CHANGE AND CORAL REEFS: A REMOTE SENSING PERSPECTIVE

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There is much talk about how current climate change will and is affecting coral reef ecosystems. This talk will use of satellite and other data to help describe the state of the art in our understanding of the relationship between climate and coral bleaching. It will then go on to review recent climatic change and will describe the current climatic situation and what this means for reefs around the world.

CORAL POPULATION DYNAMICS ON BERMUDA'S REEFS: A KEY TO UNDERSTANDING REEF DEVELOPMENT AND PERSISTENCE AT HIGH LATITUDE

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Bermuda's coral reefs are a unique high-latitude ecosystem in the Western Atlantic. Reef monitoring programmes were initiated in the early 1990's, using permanent and random quadrat and transect techniques. For the past ten years coral populations have remained healthy and stable, despite repeated bleaching events, coral diseases and frequent hurricanes. The extensive offshore reef zones (8-16 m) are characterized by high coral coverage (20-60%) and low coral species diversity. The large lagoon system supports extensive shallow patch reefs with low coral coverage (10-20%) but increased coral diversity due to a proliferation of branching corals (*Madracis* spp., *Oculina diffusa*, *Porites porites*).

The massive growth forms of the dominant offshore corals (*Diploria* spp, *Montastraea* spp. and *Porites astreoides*) appear to survive well through frequent hurricanes and winter gales. The low mortality and injury rates are sufficient to maintain large reproductively-active populations, resulting in recruitment rates that are fairly consistent over time. Brooding corals such as *Porites astreoides* are the most abundant recruits but broadcasting corals, such as *Diploria* spp., also recruit successfully. Recruitment may be enhanced by larval retention within the lagoon system due to physical oceanographic conditions that reduce water mixing with the open ocean in the summer.

These characteristics of Bermuda's coral populations, adequate recruitment and high adult survival rates, appear to offset the effects of strong seasonality in water temperature (16-30 °C) and day-length (10-14 hours) at 32 °N that restrict coral growth rates to half that of Caribbean conspecifics. It is the ability of Bermuda's corals to maintain robust population structures that account for successful reef development at high latitude. It is unclear whether Bermuda's coral populations can continue to thrive in an era of climate change where elevated $p\text{CO}_2$ levels may compromise already reduced skeletal growth rates. If Bermuda's corals can continue to sustain current fecundity and recruitment rates then reef development may likely continue.

HOLOCENE GROWTH HISTORY OF A NEARSHORE TURBID-ZONE CORAL REEF: PALUMA SHOALS, CENTRAL GREAT BARRIER REEF

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Paluma Shoals are a group of nearshore coral reefs located ~50 m seawards of the base of the beach in Halifax Bay, ~50 km north of Townsville. Paluma Shoals and other coral reefs close to the mainland coast along the inner Central Great Barrier Reef appear confined to a narrow zone (representing sediment erosion and/or shore-parallel translation) between an erosional shoreline and the landward edge of a muddy terrigenous sediment prism located between the 5 and 20 m isobaths. The landward limit of this prism is controlled by wave-induced sediment resuspension in the shallow subtidal zone, which limits terrigenous sediment accumulation but generates high and prolonged turbidity. This sediment prism is believed to have migrated landward across the inner GBR shelf during the Holocene transgression, and thus its occurrence and movement, and that of the associated nearshore zone of sediment erosion, appear to be primary controls on the location and timing of reef initiation and of the environmental conditions experienced during reef development.

We report on the late Holocene growth history of the largest, southernmost shoal, whose reef flat extends 500 m from seaward to leeward, and 750 m alongshore. Live coral cover on the reef flat is 40-60%, and abundant *Goniastrea retiformis* microatolls up to 2 m diameter dominate the surface. Three cores, taken along a shore-normal transect, all terminate with a stiff grey Pleistocene clay at ~ 3 m below the reef surface. The stratigraphy, composition and radiometric dates returned from the cores indicate a young but complex growth history. The cores contain discrete interbedded units of carbonate detritus and terrigenous muds; the terrigenous units include articulated bivalves in growth position, indicating that the reef has experienced muddy conditions over much of its history. The oldest date (1657 \pm 83 BP, ^{14}C years uncorrected and uncalibrated) was obtained from a coral clast at the base of the central core, with second oldest date (1328 \pm 44 BP) ~ 1m above base. Dates from the seaward core are younger (1199 \pm 46 BP at base, to 912 \pm 61 BP ~ 1 m above base), but the youngest dates come from the core at the landward edge of the reef (all dates <541 \pm 90 BP). Based on the size and likely growth rate of the larger microatolls, and the lack of disturbed and fossil counterparts, the contemporary reef flat is probably less than 150 years old.

This continuing work offers insights into recent reef initiation and growth in turbid nearshore waters, and by implication those of the early Holocene marine transgression. The results clearly show that this reef has developed under an environmental regime speculated by some to be threatening to nearshore coral reefs.

SYMBIONT DIVERSITY IN *CONDYLACTIS GIGANTEA* (ACTINIARIA)**Stoletzki, N., Schierwater, B.****ITZ – Ecology and Evolution, Tierärztliche Hochschule Hannover,
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The symbiotic association between the caribbean sea anemone *Condylactis gigantea* and its zooxanthellae, *Symbiodinium sp.* was investigated at a molecular level.

Sequencing of the nuclear ribosomal DNA complex was used to analyse genealogical relationships of zooxanthellae within and between individuals. Despite the fact that dinoflagellates are known to reproduce asexually (and no mode of sexual reproduction is known for *Symbiodinium sp.* so far) the molecular data reveal high genetic diversity of *Symbiodinium sp.* with genotypes belonging to clade A and clade B. Only rarely identical sequences could be identified.

Genetic analyses of the symbionts of two distinct host populations, and of bathymetrically transplanted hosts were performed in order to address mechanisms of adaptation, acclimation, and the flexibility of the association. Clade belonging showed that reef site and depth correlate with zooxanthellae strains. This supports the idea that zooxanthellae type may play a role in adaptation to different environments.

Additionally, physiological adaptations were investigated. Photosynthesis of the zooxanthellae requires that the animal tissue is transparent, thus both, algae and host are exposed to harmful UV radiation. Physiological stress responses of the holobiont are indicated by amount and properties of UV absorbing substances (whose identity is currently examined) that vary with depth.

Whether differences in UV protection are attributable to physiologically different *Symbiodinium* genotypes or clades is currently under investigation.

NEW INSIGHTS INTO THE CARBON ISOTOPIC SYSTEMATICS OF SCLERACTINIAN CORALS

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The origin of ^{13}C variations within coral skeletons is still a matter of considerable debate and in particular the role that respiratory CO_2 plays in controlling the eventual isotopic composition of the skeleton. In this study the temporal variability of the $\delta^{13}\text{C}$ of respired CO_2 produced by *Montastraea faveolata* was measured over a 12 month period. In these experiments specimens were incubated for 24 hour periods and samples of the incubation water analyzed for the $\delta^{13}\text{C}$ of the dissolved inorganic carbon (DIC) every three to four hours. Incubations were repeated from May 1993 to April 1994 at approximately monthly intervals on corals maintained on a platform at 8 m depth near Molasses Reef in the Florida Keys. Throughout the incubation the amount of oxygen was measured within the chamber. These results indicate that during daylight, the $\delta^{13}\text{C}$ of the DIC becomes isotopically positive as a result of fixation of carbon during photosynthesis, while at night the $\delta^{13}\text{C}$ of the DIC becomes more negative. The $\delta^{13}\text{C}$ of the respired CO_2 can be calculated using a simple mass balance approach, taking into consideration the relevant fractionation factors between the various carbon bearing species which comprise the DIC. The calculated $\delta^{13}\text{C}$ values for the respiratory CO_2 range from -18 ‰ in the late spring to as negative as -23 ‰ in the autumn and are significantly more negative than that reported by previous workers for coral tissue and zooxanthellae. An explanation for this discrepancy may be that corals are respiring a significant proportion of isotopically depleted substances, such as lipids which are known to have values up to 10‰ lighter than other compounds. The seasonal cycle in the $\delta^{13}\text{C}$ of the CO_2 suggests that there is variability in either the isotopic composition of the coral tissue or the type and/or amount of organic material being respired. A similar pattern and magnitude of change was observed in coral tissue and zooxanthellae samples collected from a nearby reef at monthly intervals between 1995 and 1996, although the $\delta^{13}\text{C}$ of the tissues have a mean value of -13.25‰ compared to -20.5 for the respired CO_2 . At least part of the pattern of enrichment during the early summer and depletion during the autumn might be related to changes in the productivity of the reef, with high productivity causing a decrease in CO_2 and consequent isotopic enrichment not only of the corals but the entire food chain. During the late summer, enhanced respiration relative to photosynthesis causes an isotopic depletion in the DIC. It may also be relevant that the timing and amplitude of the patterns in the $\delta^{13}\text{C}$ of the respired CO_2 and the tissue are similar to that observed in the skeleton.

PREDICTING BIODIVERSITY “HOTSPOTS” IN CORAL REEFS: COMBINING AMPHIPOD PHYLOGENIES AND GEOTECTONICS AS A PROXY TO IDENTIFY AREAS OF COMPOSITE EVOLUTIONARY DIVERSITY

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While reports and evidence of large-scale change and decline in coral reefs and associated reef communities increase, scientists and marine resource managers often view and assess reef biodiversity through a narrow lens of “spatially obvious” species such as corals, fish, and mollusks while paying little attention to the multitude of small cryptic invertebrates found on reefs. Often these larger candidate organisms have long-lived dispersive larvae capable of long distance transport prior to settlement. In contrast, many of the smaller, more cryptic reef organisms such as amphipod crustaceans lack dispersive larvae and have restricted distribution patterns that help define subtle and important differences in biodiversity among reefs. This is best seen in island archipelagos where each island may have an endemic cryptofaunal form or species while larger, more widely distributed taxa show little or no variation at the same spatial scale. While numerous surveys and taxonomic lists are being compiled they are rarely followed with detailed systematic studies capable of explaining fine scale evolutionary relationships. Such information is crucial in identifying important areas of lineage-driven hyper diversity that could serve as potential long-term sources of propagules for nearby impacted reefs. Merely compiling lists and species numbers provide little or no detail in this regard but are often used in decision-making such as locating marine protected areas. Inventories and lists provide information on species presence, but not the processes that could have resulted in observed patterns that could be informative in analyzing evolutionary diverse reef systems. Research that incorporates evolutionary scenarios and geological process information at a variety of spatial and temporal scales has been used to identify composite distribution patterns found in reef systems along plate boundary margins. Therefore, knowledge of geotectonic processes is pertinent to the interpretation of diversity in reef assemblages. This is evident where once distant and remote reef systems are docked and amalgamated by multiple collision and subduction events along plate boundaries. Using amphipod crustaceans from reefs in the South Pacific and Indian Ocean reef systems proved highly informative in suggesting where similar patterns of what were likely to be found. Predictive and testable hypotheses blending biological and geological components can provide plausible explanations of evolutionary diversity and result in levels of detail and discrimination that most current biodiversity and assessment activities cannot achieve. This combined approach can help explain examples of widespread paleoendemic fauna, high levels of regional endemism, areas of composite biodiversity, and *ex-situ* vs. *in-situ* evolutionary patterns and processes. Data resulting from this blending of geological processes and biodiversity patterns can suggest avenues of further research such as molecular genetics that can further test assumptions about biodiversity pattern in coral reefs.

ENVIRONMENT INDUCED PHENOTYPIC CHANGE IN TWO MASSIVE CORALS OFF SINGAPORE

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Environment induced phenotypic change, or phenotypic plasticity, refers to an organism's morphological, physiological and behavioural responses to its biotic and abiotic surroundings. On contemporary, rapidly changing reefs, phenotypic plasticity may be advantageous to corals that might not be able to survive through adaptation alone. To test for morphological plasticity in the massive species *Favia speciosa* (Dana 1846) and *Diploastrea heliopora* (Lamarck 1816), colony fragments (clone-mates) were transplanted over two environmental gradients: a depth cline and a nearshore to offshore gradient in sedimentation rates and total suspended solids (TSS). After seven months all fragments were collected, cleaned and ten morphometric characters extracted from randomly chosen corallites. Reaction norms and analysis of variance (ANOVA) indicate that both species experienced environment-induced changes in small-scale morphology. Highly significant genotype \times environment ($G \times E$) interactions verify that corallite structure is both genetically and environmentally determined, and that genotypes vary in the level of plasticity expressed. Multivariate analyses identified similar responses in both species, though trends were more pronounced for *Favia speciosa*. Light and TSS emerge as the primary factors influencing morphological change.

**TEMPORAL VARIABILITY AND GRADIENT OF BIOEROSION
ALONG A CROSS SHELF TRANSECT ON THE GBR (AUSTRALIA)
- IMPORTANCE OF MICROBORERS**

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Increasingly, it is being shown that coral reefs are under a variety of stresses from both anthropogenic and natural impacts. These impacts include rising sea temperature leading to bleaching effects, eutrophication, pollution, over-fishing, sedimentation, increased frequency of cyclones, and plagues of COTS. Thus, the amount of coral substrate available for colonisation by borers and subsequently for grazers increases which potentially destroys the equilibrium between reef growth and reef destruction, leading to physical loss of reefs. This may lead to loss of fisheries resources, economic consequences from loss of tourism and the destruction of low lying areas previously protected from storm damage by reefs. To date, few studies have focussed on the impact of factors such as increased rates of sedimentation on rates and agents of bioerosion, especially the microflora. Thus, this study concentrated on the role of micro- and macroborers as well as grazing organisms, and how they varied with different sedimentation regimes.

An experimental study was conducted over a 4 years period using coral blocks cut from recently killed *Porites* colonies. Blocks were laid at six sites located along a cross shelf transect (200 km) from onshore to offshore on the northern Great Barrier Reef. At each site two grids were firmly attached to the substrate on which replicate blocks were laid, in order to study the intra-site bioerosion variability as well as the variation between sites. After one and three years of exposure, the main boring organisms were identified and total bioerosion (including micro- and macrobioerosion, grazing) and accretion rates were quantified using petrographic sections, scanning electronic microscopy and image analysis to determine the calcium carbonate balance sheet of the experimental substrate. Rates of microbioerosion ($0.13 \text{ kg.m}^{-2}.\text{a}^{-1}$ to $1.35 \text{ kg.m}^{-2}.\text{a}^{-1}$) as well as grazing rates ($0.004 \text{ kg.m}^{-2}.\text{a}^{-1}$ to $0.77 \text{ kg.m}^{-2}.\text{a}^{-1}$) increase from inshore sites to the oceanic, and over time of exposure although not proportionally (by about 3 times). These variations are probably due to differential rates of sedimentation across the transect, with higher rates of sedimentation occurring inshore than offshore. The variability in rates of macrobioerosion between sites is small, in contrast more variation occurs within a site. Rates increase with increasing exposure (0.05 kg.m^{-2} after one year to 0.83 kg.m^{-2} after three years of exposure). Microborers are the principal agents of bioerosion after one year of exposure (47% to 90%) while after three years of exposure, they play a secondary role (20% to 47%). After three years, macroborers are the main agent of erosion at the inshore sites and grazing activity primarily by scarid fish is dominant at the other sites. Accretion rates due to calcareous algae are negligible in comparison to total bioerosion rates. Thus, total bioerosion rates as well as net bioerosion rates vary between sites according their distance from the coast, and increase with increasing time of exposure. In conclusion, many physical and ecological processes interact in determining rates of bioerosion, including terrigenous inputs. This study highlights the important role played by microborers in the bioerosion of dead coral *Porites*, and the relationship between microborers, macroborers and grazers.

SPATIAL AND TEMPORAL DIVERSITY IN *SYMBIODINIUM* COMMUNITIES IN *ACROPORA* SPP. AND THEIR PHOTO-PHYSIOLOGICAL PROPERTIES**Ulstrup, Karin E., van Oppen, Madeleine J.H.****University of Copenhagen, Botanical Institute, Department of Phycology
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Global warming and increased radiation may have a direct and detrimental effect on the ubiquitous symbiotic relationship between reef building corals and unicellular algae of the genus *Symbiodinium* (zooxanthellae) and often cause coral bleaching. Hence, the extent of coral bleaching may be used as an indicator for environmental change. However, the adaptive mechanisms of the coral-algal symbiosis and the complexity of combinations of symbionts and host that are continually discovered are poorly understood. The patterns in distribution of genetically distinct *Symbiodinium* strains harboured by individual coral colonies of the genus *Acropora* suggest that a selective mechanism exists to obtain the best functioning unit in the local environment. The community structure of zooxanthellae in two distinct species of *Acropora* was examined from different reef habitats as well as microhabitats within single host colonies. Also, temporal changes in zooxanthellae communities were followed in a UV-eliminating experiment. The identity of the *Symbiodinium* strains was determined using an electrophoretic screening methods (Single Strand Conformational Polymorphism; SSCP) and the relative abundance of distinct clades of zooxanthellae was determined using quantitative PCR. Photochemical responses of specific zooxanthellae communities were estimated with pulse amplitude modulation (PAM) technology. The data suggest that a relationship exists between symbionts present in the tissue of *Acropora* and the light regime under which they are found in the microhabitats of individual corals. However, this relationship appears to occur on a local geographic scale and is not stable over regional distances in the central Great Barrier Reef region. The reason for this is unclear. Moreover, the results show that a reduction of UV radiation may erase this relationship and a possibly adaptive change towards one homogenous symbiont community occurs. Relative differences in optimum quantum yield (F_v/F_m) of photosystem II (PSII) of distinct zooxanthellae communities are opposite when UV-light is removed from the ambient light regime of the corals. Differentiation in relative electron transport rates (ETR) is more significant in corals that harbour heterogenous zooxanthellae communities than in corals that harbour a homogenous endosymbiont population. Non-photochemical quenching data from zooxanthellae in distinct light environments in *Acropora valida* show that some populations of zooxanthellae have lower heat stress tolerances than others. This differentiation does not occur in UV free environments.

INORGANIC NUTRIENT CYCLING IN CRYPTIC HABITATS ON CORAL REEFS

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Cryptic habitats such as cavities, holes and crevices make up an important part of the volume of coral reefs encompassing an internal surface of up to 8 m² per projected m² reef. Cryptic organisms cover ca 95% of the hidden hard substratum surface on reefs in Curaçao (Netherlands Antilles). Particularly filter feeders such as encrusting sponges, which are well represented in cavities, are supposed to take up a considerable amount of organic matter and mineralize part of it. To quantify the mineralization in cavities in situ we measured the inorganic nutrient concentrations in- and outside 3 caves in the fore reef slope at 15 m depth at different mainstream flow velocities. Simultaneously the water exchange rate of cavities was determined with fluorescent dye. Selected caves had inner volumes of 50-75 l with an inside hard substratum surface area of ca 1m² and a sandy bottom. The flux of inorganic nutrients was determined on basis of the concentration difference in and outside cavities and the residence time of the water in cavities. Dissolved inorganic phosphate (PO₄) and nitrogen concentrations were enhanced in cavities. Particularly NO₃ and NO₂ (NO_x) were significantly higher in cavities than outside cavities. Surprisingly NH₄ concentrations were usually lower inside than outside cavities. Concentration differences in NO_x between in- and outside of the cave were negatively related to the exchange rate coefficient. This means that the NO_x concentration in caves increases with increasing residence time of the water. Residence time was usually short, 2-8 min, but could extend to several hours for short periods of time. The exchange coefficient increased linearly with the main current velocity and relations differed between caves. This suggested that cavity characteristics, apart from the main current flow velocity, were important in controlling the concentration differences inside and outside cavities. The average net efflux rates of NO_x from caves ranged between 2 and 4 mmol.m⁻² cave substratum area.d⁻¹ with maximum values of 8 mmol.m⁻² cave substratum area.d⁻¹. Net influx of NH₄ was on average 1-2 mmol.m⁻² cave substratum area. d⁻¹ with maximum values of 14. Results suggest that coral cavities are net sources of NO_x and net sinks of NH₄. There is a net average efflux of DIN from caves ranging between 1 and 1.7 mmol.m⁻² cave substratum area.d⁻¹. DIP efflux was on average 0.4-0.5 mmol.m⁻² cave substratum area.d⁻¹. Apparently cavities are significant net exporters of DIN and DIP, suggesting that cryptic habitats on the reefs of Curaçao can be considered as reef water fertilizers.

**BIOEROSION OF REEF SUBSTRATES BY HERBIVOROUS FISH –
MAJOR FACTOR STRUCTURING REEF COMMUNITIES**

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The importance of bioerosion within dynamics of reef limestone is unquestionable. Especially the bioerosion potential of classical bioeroders such as sponges, sea urchins, and parrot fish has been documented profoundly. Other grazers such as acanthurids and pomacentrids were considered to be rather herbivorous and not efficient bioeroders. Results from a study in the Northern Gulf of Aqaba (Red Sea) show that especially the guild of browsers can significantly contribute to the erosion of reef framework. Due to this certain reef zones of the study area exhibit a negative carbonate budget. Thus, from a functional point of view coral reefs appear as grazer-controlled communities and show more similarities to savannas or other grazer-induced systems than to rain forests – an often stressed analogy.

**ACROPORA CERVICORNIS ASSESSMENT IN A HIGH LATITUDE ENVIRONMENT OFF
THE COAST OF FORT LAUDERDALE, FLORIDA, USA**

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During previous research by NCRI personnel and NSU OC graduate students, aggregations of staghorn coral (*Acropora cervicornis*) were found along coastal waters off Fort Lauderdale, Florida. As part of a larger-scale characterization and monitoring program, this study was aimed at mapping and collecting data on percent cover and demographics of *A. cervicornis* in the region. Results presented herein are preliminary, since characterization studies are still underway. Presence of healthy *A. cervicornis* ‘thickets’ was confirmed and georeferenced in more than a dozen sites, and quantitative surveys were conducted at selected locations (7 sites) to ascertain the spatial variation in mean percent cover, algal cover, species richness, density of juveniles, and the density and size of colonies and fragments. At each site, benthic community surveys were conducted along 4, 50-m haphazardly-selected transects. Staghorn coral aggregations ranged between 700 and 7000 m², and mean coral cover varied between 5 and 30%, with *A. cervicornis* accounting for 87–97% of all scleractinians. Differences in coral cover among sites were statistically significant. Thickets of *A. cervicornis* exhibited higher species richness, topographic complexity, and percent cover than adjacent areas of comparable depth. Demographic studies revealed that colonies comprised nearly 60% of the *A. cervicornis* population. Mean density of colonies and fragments ranged between 1.2–3.2 colonies m², and 0.5–2.3 fragments m² respectively. Percent cover was positively associated with colony density and size. Number of recruits varied between 0–1.0 individuals/m², with a mean of 0.08. Prevalence of disease-like conditions and predation were also studied. Densities of the fire worm *Hermodice carunculata* ranged between ~18 and 86 ind ha¹, and percent damage to *A. cervicornis* was close to 0.2%. Incidences of white-band disease or bleaching were not detected. The flourishing *A. cervicornis* populations off Fort Lauderdale thrive in a high-latitude environment, beyond known temperature constraints and in the midst of significant anthropogenic stressors. They are perhaps the largest and northernmost in the continental U.S.A. This situation provides an interesting counterpoint to the decline and disease-stricken *A. cervicornis* populations in seemingly more favorable conditions further south in the Florida Keys.

ON THE NATURE OF SPECIES IN SCLERACTINIAN CORALS: THE *MADRACIS* SPECIES COMPLEX

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The evolutionary and ecological status of six Caribbean *Madracis* species reveals mechanistic species that can be used to describe the genus dynamics through evolutionary time. Within a limited spatio-temporal scale (defined by the duration of the research (1998-2001) and the locations it was carried out: Bonaire and Curaçao, 9375km²), we investigated patterns observable at present to reveal processes relevant through time. Three paradigms that are currently used in coral biology were combined: morphometrics, genetics and ecology. The organization of the genus can be portrayed as a multidimensional graph which axes represent various paradigms. For *Madracis* we used the paradigms: genetics (based on (Diekmann et al. 2001), colony morphology and ecological characteristics. Ideally, such projection of multiple species characteristics would be performed in an n-dimensional graph, where n represents the number of characteristics that were studied simultaneously. “True” species *sensu* (Veron 1995) are separated at each single axis from the others. We found that *M. mirabilis* and *M. senaria* are indeed distinct from each other and all other *Madracis* genetically, ecologically and morphologically. They are therefore “true” species that obtained a specialist strategy on the reef followed by reproductive isolation (Vermeij et al. A). Although, *M. mirabilis* and *M. senaria* provide excellent evolutionary units for ecological, morphological or genetical studies, they are useless to describe speciation processes in corals. The remaining four species show interspecific overlap in morphological, genetic and ecological characteristics and provide a much better opportunity to study organizational processes in coral evolution. Two organizational processes were observed: introgressive hybridization and the controlled expression of genetic polymorphisms. *M. pharensis*/*M. decactis*-complex is a genetical polymorphism organized by habitat heterogeneity at a small spatial scale (Vermeij et al. B). The scale, at which environmental variation occurs, that causes organization within species gene pools is surprisingly small and was found between closely, located islands. Secondly, introgressive hybridization between *M. formosa* and the *M. pharensis*/*M. decactis* complex resulting in a new species: *Madracis carmabi* (Vermeij et al. C, Diekmann et al. 2001). The participation of the *M. pharensis*/*M. decactis* complex in both processes clearly illustrates the evolutionary dynamics of these species. In the genus we then have an example of a group where speciation could potentially occur (*M. pharensis*/*M. decactis* complex), but also where existing species reintegrate due hybridization (*M. pharensis*/*M. decactis* complex and *M. formosa*). The concurrence of fusions and splits in *Madracis* gene pools as they are organized through evolutionary time, supports the presence reticulate evolution in *Madracis* (*sensu* Veron 1995). We now see that when the organizational processes are known and multiple paradigms are combined simultaneously, species become visible. They can not be defined *a priori* and evolve as patterns from processes that respond to upper and lower constraints through time.

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THE USE OF CORAL NURSERIES AS A CORAL REEF MANAGEMENT TOOL OFF THE COAST OF SOUTHEAST FLORIDA, USA

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Natural and anthropogenic damage to coral reefs, especially those in environmentally sensitive and densely populated areas like Broward County, Florida, USA, is a growing concern for reef managers and scientists. The Coral Nursery Project was established as a cooperative effort between local scientists (NCRI), resource managers (State of Florida and Broward County Department of Planning and Environmental Protection), resource users (Ocean Watch Foundation Dive Club), and federal resources managers (National Oceanic and Atmospheric Administration through the National Fish and Wildlife Foundation) to utilize corals of opportunity (i.e., overturned, loose, or dislodged corals) that may otherwise perish, for use in transplantation to damaged coral reef habitat. Transplanting scleractinian corals to damaged coral reefs has been shown to accelerate the early stages of recovery after reef habitat has been damaged. Until recently, however, donor corals for coral reef restoration were only obtained from two sources: those grown in laboratories and those taken from existing reef surfaces. The process of growing corals in a laboratory can be time consuming and expensive. Removing attached corals from one reef for transplantation elsewhere may result in no net gain. Instead, the Coral Nursery Project locates, collects, and transports corals of opportunity, which have become detached from the reef through various means, to an established nursery ground (artificial reef). These corals are then tagged, affixed to the substrate, and monitored for growth and survivorship. Corals from this nursery can provide a source of transplant donors for future restoration of coral reef habitat. During the first year of the project, over 150 corals of more than 15 species have been transplanted to the nursery. The survival rate of these colonies has exceeded 95%, a much larger success rate than what would be expected if these loose corals were left unattached. The results of the Coral Nursery Project study will provide resource managers information on coral species and colony size specific transplantation success. Future restoration activities can benefit from the use of the rescued corals of opportunity. Coral nurseries may become important tools in future coral reef habitat restoration projects.

DEEP WATER GORGONIANS FROM THE NORTHEASTERN US COAST

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Gorgonians are a conspicuous feature of the deep water fauna when hard substrates are present. The United States northeast coast (defined as the area from Cape Hatteras to the Gulf of Maine) is home to about 28 species of gorgonians. Most are found at slope depths (200- 2500 m), but a few can be found in relatively shallow water (15-165 m) in the Gulf of Maine. In a recent paper, Cairns and Chapman recorded 15 species of scleractinians from the same region, most from depths greater than 200 m. An Alvin dive in Oceanographer Canyon (south side of Georges Bank) revealed large numbers of *Paramuricea grandis*, *Anthothela grandiflora*, and *Thouarella* ?n. sp. The *P. grandis* were often overgrown by a zoanthid, probably in the genus *Amphianthus*. Whether overgrown or not, the *Paramuricea* skeletons were host to brittle stars, *Asteronyx* sp. As with Southern Ocean representatives of *Thouarella*, each colony of the *Thouarella* ?n. sp. from Oceanographer Canyon was host to an unknown species of polynoid polychaete. We have also compiled historical data going back to early Alvin dives, but including primarily data from cameras tows made by Barbara Hecker. These historical records show that some canyons, such as Lydonia, have very high diversity of gorgonians, whereas others, like Oceanographer, seem to have a low number of gorgonian species. Our work will continue in the Gulf of Maine, with studies on the reproduction and genetics of *Primnoa resaediformis* and *Paragorgia aborea*.

This work was supported by a grant from the NOAA Ocean Exploration initiative and a Mia Tegner grant from the Marine Biology Conservation Institute.

**DROWNED CARBONATE PLATFORMS IN THE HUON GULF, PAPUA NEW GUINEA;
MORPHOLOGY, COMPOSITION AND IMPLICATIONS FOR REEF DEVELOPMENT ON
A RAPIDLY SUBSIDING MARGIN**

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Collision between the South Bismarck Plate and the northern edge of the Australian Plate has produced an actively subsiding foreland basin in the western Huon Gulf. A series of drowned coral reef platforms and pinnacles are preserved on this margin as a result of this rapid subsidence. Previous data and models suggest that these platforms drowned due to the combined affects of rapid relative sea-level rise associated with glacial terminations and continual subsidence (up to 5.6 mm/year) over the last 400 ky. To better constrain our understanding of short term subsidence rates, sea-level change and carbonate platform development in the Huon Gulf, we undertook a multidisciplinary cruise on the R/V Melville (Aug-Sep 2001). We mapped and sampled nine platforms and pinnacles using; (1) Seabeam 2000; (2) detailed side-scan mapping (DSL120) and (3) the ROV Jason for outcrop sampling. To determine the timing of each drowning event and the paleoenvironmental settings prior to drowning, sampling focused on the tops of each platform. We present preliminary data concerning the structure and morphology, radiometric ages and composition of the platforms. Two U-Th ages (348 ka from -1950 m and 60 ka from -240 m) confirm the platforms get progressively older and deeper NE towards the Markham Fault. Additional dates should allow us to directly determine the age of the intervening platforms, the timing of drowning and thus the likely timing of the glacial terminations. Preliminary analysis of coral assemblages and microfacies data indicate significant differences in paleoenvironmental settings between some of the platforms. In summary, the Huon Gulf provides an important natural laboratory for understanding reef drowning and backstepping platform development in response to episodic rapid relative sea-level rise.

DO SEAWATER TEMPERATURES LIMIT CORAL DISTRIBUTION IN SOUTHERN ARABIA?

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In Southern Arabia, coral rich areas can be classified into a range of biotopes: coral communities, coral carpets (veneers), incipient reefs and true reefs. Their distribution is patchy and primarily reflects the availability of suitable hard substrates. Coral rich communities in the Arabian Sea and the Gulf of Oman are largely limited to seven discrete areas of Oman and Yemen. Along with high nutrient concentrations, low light penetration and biological factors, extreme seawater temperatures have been identified as one of the major constraints to coral reef development in the region.

Summer seawater temperatures in Southern Arabia are extreme: in the Gulf of Oman the maximum seawater temperature recorded is 39°C, while in the Arabian sea the minimum temperature recorded is 16.9°C, indicating that both the upper and lower thermal tolerances occur concomitantly in contiguous seas. However, these extremes are moderated by the dynamic influence of upwelling. In the Gulf of Oman, high temperatures are reduced by the very shallow and sharp thermocline that rises and falls with the daily cycle of thermic winds, whereas in the Arabian Sea, the intensity of upwelling varies over a cycle of about 2 weeks to give an average seawater temperature of ~20°C over the summer months. Summer upwelling along the northern coast of the Arabian Sea coast of Oman provides a mechanism for protection from extreme high temperatures for corals in the northern Indian Ocean. Further research is required to investigate if this area might act as a refuge during the predicted extreme bleaching events in future years.

PHYSICAL AND ECOLOGICAL DIFFERENCES IN THE IMPACT OF RECENT HURRICANES AT DISCOVERY BAY, JAMAICA, BEFORE AND AFTER THE ONSET OF REEF COMMUNITY DEGRADATION

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13 hurricanes have passed within 40 nautical miles (c. 73 km) of Discovery Bay since 1870, with median interval of 7 years. The condition of the fore-reef community has oscillated irregularly between recently smashed and, to varying degrees, recovered. At the former extreme, coral cover was relatively low and dominated by resistant massive corals: at the other, coral cover was high and dominated by the fast-growing *Acropora* species. The latter situation prevailed in 1980, when hurricane Allen passed about 45 km to the north, generating waves which smashed most *Acropora* colonies. In 1988, hurricane Gilbert ran the length of Jamaica, passing 40 km to the south of Discovery Bay. There had been little recovery from hurricane Allen, partly because only 8 years had elapsed, but also because the reef communities had begun to suffer other impacts, entering a phase of degradation. These included white-band disease in *A. cervicornis*, mass mortality of *Diadema antillarum* with consequent excessive growth of macro-algae, and mass coral bleaching.

Gilbert brought high winds onshore which the island mass caused to blow in the same direction for several hours. They generated huge waves which scoured linear features on the reef, oblique to the downslope channels, that persisted for months. Large amounts of sediment were transported downslope; the shallow terrace was swept clean and intermittent Pleistocene hardgrounds were revealed. Cool water, brought from below the thermocline, mixed with the surface waters and probably averted a bleaching event.

By 1988, most massive *Montastraea annularis* were becoming overgrown by macroalgae. Scouring by hurricane Gilbert largely removed macroalgal growth, but not for long. The fore-reef was quickly carpeted by the red alga *Liagora*, although brown and green algae soon dominated again. A few colonies of *A. cervicornis* had developed in some areas, but hurricane Gilbert smashed them again. The slabs and sticks of *Acropora* rubble created by Allen had become cemented together. Under Gilbert, much of this was re-mobilized, scrubbed clean and re-distributed. Many gorgonians and sponges were torn off or broken, and piles of rotting corpses accumulated in channels and sills on the deep reef slopes.

After hurricane Gilbert, as algal overgrowth resumed, coral cover at 10m depth declined to about 4%. Subsequently, *Diadema* has reappeared above 10 m, and coral cover has risen to at least 15%, but the assemblage is different from that which prevailed in the centuries before hurricane Allen. The *Acropora* species are scarce and *Montastraea annularis*, suffering from algal overgrowth, yellow-blotch disease and bleaching, is reduced in abundance. The next hurricane will hit an alga-dominated community in which the commonest corals are the opportunists *Porites astreoides*, *P. porites* and *Agaricia agaricites*.

**NESTED CLADE ANALYSIS AND PHYLOGEOGRAPHY OF WESTERN PACIFIC
LEUCETTA 'CHAGOSENSIS' (PORIFERA: CALCAREA): CLUES FOR CONSERVATION
OF THE GREAT BARRIER REEF WORLD HERITAGE AREA (AUSTRALIA)**

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Phylogeography investigates the geographical distribution of genealogical lineages, including those at the intraspecific level. While phylogeographic relationships of terrestrial taxa have been quite well studied during the last years, marine phylogeography is still in its infancies. In the present study we explore phylogeographic relationships of the widespread calcareous sponge *Leucetta 'chagosensis'*, occurring in shaded habitats of Indo-Pacific coral reefs. It provides a good model system to investigate marine phylogeographic relationships due to its allegedly limited dispersal capabilities. Maximum parsimony analysis of 19 ribosomal sequencetypes from 28 locations in the western Pacific revealed phylogeographic structuring into 4 major clades, corresponding to the northern/central GBR with Guam and Taiwan, the southern GBR and subtropical regions south to Brisbane, Vanuatu, and Indonesia. Subsequent nested clade analysis confirmed this structure with a probability of >95%. A pattern of range expansion from the internal Indonesian clade was inferred at the total cladogram level, supporting the 'Centre of Origin' hypothesis. Two distinct clades were found on the GBR, which narrowly overlap geographically in a line approximately from the Whitsunday Islands to the northern Swain Reefs. At various clade levels, the northern GBR clade was influenced by past fragmentation and contiguous range expansion events, presumably during/after sea level low stands in the Pleistocene, after which the northern GBR might have been recolonised from the Queensland Plateau in the Coral Sea. The southern GBR clade is most closely related to subtropical *L. 'chagosensis'*, and we infer that the southern GBR was recolonized from there after sea level low stands. Our results have important implications for conservation and management of the GBR, as they highlight the importance of marginal transition zones in the generation and maintenance of species rich zones, such as the Great Barrier Reef World Heritage Area.

LITTLE ICE AGE SEA SURFACE TEMPERATURE VARIABILITY RECORDED IN A MADAGASCAR CORAL RECORD

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A coral from the lagoon of Ifaty off southwest Madagascar in the Mozambique Channel was examined. Based on temporal variability of skeletal oxygen isotopes annual mean sea surface temperatures (SST) are reconstructed for the period from 1658 to 1995. This includes part of the Little Ice Age (LIA) covering the period between 1658 to 1850. Sr/Ca ratios were measured for selected windows with monthly resolution (1973 to 1995, 1860 to 1910, 1780-1810, 1690 to 1710) to validate the SST reconstructions derived from oxygen isotopes. The coral proxy data were validated against gridded SST data sets.

The coral indicates that during the coolest period of the entire record from 1670 to 1730, annual mean SST were 0.4°C cooler than the long-term average. Seasonal extremes present in the oxygen isotopes and the Sr/Ca ratios show that cooling was more pronounced during southern hemisphere summer (January-March). During the time interval from 1730-1850, annual mean SST were on average similar to the industrial period from 1850 to the present. This agrees well with observations from various Southern Ocean subtropical corals.

Interannual variability in the Madagascar coral record was identified in form of a characteristic period of about 3.9 years most probably due to El Niño-Southern Oscillation (ENSO) cycles appearing in the southern Indian Ocean. The amplitude variations in interannual SST are strongly enhanced during cool climatic periods (1670 to 1730, 1870-1930). A strong interdecadal period of about 17 years is prominent throughout the entire record, which is a characteristic period found in SW Indian Ocean SST anomalies and South African rainfall anomalies. It was also reported in other long time series from Pacific and Indian Ocean corals situated between 20-30°S and for global SST anomalies in the Southern Ocean. Interdecadal excursions in the coral record were in the order of 0.3 to 0.5°C. They are very pronounced during the coolest period between 1670 to 1730 and also from 1850 to 1920.

Our results suggest that SST during the Little Ice Age in the SW Indian Ocean show marked interdecadal regime shifts of warm and cold periods. However, SST during the period between 1670 and 1730 were significantly lower than average SST during the LIA.

THE RETICULATED REEFS IN GOLFO DE GUACANAYABO, CUBA AND BIOCONSTRUCTIONS IN THE “URGONIAN,” BULGARIA

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Coral reefs in the Golfo de Guacanayabo in southeastern Cuba are unique in many respects—shape, structure, builders, biodiversity, endemic forms and origin. Observed from the air, they exhibit complex reticulated contours. These 20- to 25-metre-high reefs have grown vertically in murky, stagnant waters in a muddy bottom bay. Here, the usual Caribbean reef-building Scleractinia (*Acropora palmata*, *Montastraea annularis* complex, *M. cavernosa*, *Diploria spp.*) are not present. Instead, there exist abundant small branchy colonies of non-reef-building *Oculina spp.*, *Cladocora arbuscula* and *Porites porites f. divaricata*; very delicate *A. cervicornis*; the strictly endemic *Eusmilia fastigiata f. guacanayabensis*; and a rare form of the Hydrozoa *Millepora alcicornis f. delicatula*. These small bushy stony corals, together with numerous sponges, combine to form unusual reefs such that some reef parts appear almost “gelatinous.” It has not been shown that the Guacanayabo reefs developed on top of older positive structures. Instead, their origin may be understood as arising from delicate branchy coral colonies that have grown on soft bottom together with sponges, gradually compensating for the submergence of the sea floor. A survey performed west of the Golfo de Guacanayabo found incidences of coral branches with sponges and other invertebrates providing a base for buildups on soft bottom, showing how this unusual construction can develop in various locales. By studying the Guacanayabo reefs, we can learn how to work more effectively toward their sustainability and the protection of their unique biodiversity. The preservation of these unusual reefs requires public education and the putting into place of special restrictions. The positive experience of the adjacent park, a protected part of the Archipelago Jardines de la Reina reefs, suggests extending that park eastward to include the Guacanayabo reefs.

The Guacanayabo reefs are not only intriguing in terms of understanding a rare type of “marginal” reef, but also provide a model for understanding fossil reefs in analogous conditions. The “Urgonian” sedimentary rocks (Lower Cretaceous) in the Central Fore-Balkan in northern Bulgaria offer many examples of bioconstructions, varying in dimension, external morphology and internal architecture, and enclosed in both terrigenous and limestone formations. Some are built not on the hard substrata, by dendroid and small colonies of scleractinian corals as the primary constructors, and Hydrozoa, Brachiopoda, Pelecypoda, Gastropoda, Echinodermata, Algae as other builders. The bioconstructors’ roles vary from isolated coralla and other fossils disseminated in the rocks to fully-constructed frameworks. According to the origin of the bioconstructions, they can be classified as monocentric, polycentric or superficial.

The Guacanayabo reefs and the “Urgonian” examples of fossil bioconstructions demonstrate the opportunistic and resilient character of some coral-dominated settings.

**PALAEOECOLOGICAL AND TAPHONOMICAL SIGNATURES OF CORAL-REEF
ASSOCIATED MOLLUSCS – AN ACTUALISTIC APPROACH**

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Molluscs are quantitatively important and diverse colonizers of subtropical-tropical shallow-water coral reefs. The palaeoecological and taphonomical informations that can be derived from molluscs in these coral reef environments, however, is not uniform but strongly depends on life habits of the respective taxa. Therefore, three case studies (two from the northern Red Sea, one from the Seychelles) show distinct differences between molluscan life and death assemblages, which are due to distinct biases in the death assemblage.

Bivalves that lived in close contact to living corals are preferentially overgrown after death and should provide considerable temporal and ecological information in a potential fossil record as they will be preserved (mostly *in situ*) within a rapidly growing reef framework. Some gastropod taxa are preferentially transported into surrounding soft substrata post-mortem. Here they will be affected by time-averaging and taphonomic disintegration typically occurring in sediments resulting in the associated loss of much temporal information. Most gastropod shells, however, are inhabited by hermit crabs post-mortem, which may strongly alter the fossil gastropod community structure. Molluscs that colonize dead surfaces preferentially accumulate on rock grounds.

The sedimentary facies surrounding coral reefs are characterized by distinct and highly diverse mollusc associations which probably represent long-term time-averaged assemblages. Despite the loss of much temporal information, these mollusc associations accurately reflect the spatial relationships of the sedimentary facies and a variety of environmental parameters like water energy, grain size and food supply.

Poster Presentations

TEST OF A SIMPLE SYSTEM FOR INCIDENTAL MONITORING OF FAUNAL PARAMETERS BY RECREATIONAL DIVERS

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The scope of changes occurring to reef systems as a result of environmental impacts and change is beyond the capacity of formal monitoring systems, yet even non-biologically inclined recreational SCUBA divers tend to take an interest in highly charismatic fauna, such as clownfish, grouper or shark. An indirect measure of the abundance of a species will be the length of time into a recording period after which it is first observed; the more abundant a species is within a reef area, the sooner it will, on average, first be recorded during the course of variably structured dives. This suggests the use of time of first observation (TFO) of selected charismatic fauna as a recreational diver friendly monitoring tool, since all SCUBA divers are taught to monitor time during dives for safety reasons. To test the validity of the relationship between abundance and TFO, and to assess the ability of TFOs for selected fauna to discriminate between different reef types within the same region, both actual abundance and TFOs for 11 conspicuous fauna were recorded during 32 dives in 3 adjacent reef areas within the Sharm El Sheikh region of the Egyptian Red Sea. Across all species there was a highly significant correlation over 32 dives between TFO and measured abundance, as there was for 10 species analysed individually. Also for all of the 32 dives there was a correlation between TFOs and measured abundance of the different species as recorded on each single dive. For 7 of the 11 species used there was no difference in either mean observed abundance or mean TFO between the 3 areas, but for 1 of the 3 species in which a difference in mean abundance between areas was evident, there was also a difference in mean TFO. This suggests that with improvements and where adequate data is available mean TFO may be useful as a means of detecting to detect spatial or temporal differences in abundance of conspicuous fauna where these exist.

POPULATION STRUCTURE OF THE CORALLIVOROUS SNAIL *CORALLIOPHILA ABBREVIATA* (GASTROPODA:CORALLIOPHILIDAE)

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The corallivorous gastropod *Coralliophila abbreviata* (Gastropoda: Coralliophilidae) can alter coral community structure by feeding on scleractinian corals. Declining numbers of important prey species (*Acropora*) in the Florida Keys (and throughout the Caribbean) led us to investigate parameters of the population structure and the feeding physiology of this gastropod. The two major frame-building Caribbean corals, *Acropora palmata* and *Montastraea* spp are some of the preferred prey. Previous results indicated that compared to snails on *Montastraea* spp. hosts, snail populations on *A. palmata* show a lower infestation rate, larger mean individual size, fewer snails per colony and higher growth rates. *Acropora* colonies with snails showed larger areas with visible tissue-damage than *Montastraea* spp. colonies. The differences in snail populations could be in part attributed to host effects: snails transplanted from *A. palmata* to *Montastraea* spp. showed a decrease in growth rates whereas snails transplanted from *Montastraea* spp. to *A. palmata* showed equally high growth rates as the native snails. Since *Montastraea* spp. tissue provides more carbon per area than *A. palmata* the nature of the host effect remains unclear. Host-specific characteristics of snail populations are comparable across the Caribbean. Taken together, host-specific differences suggested the possibility of cryptic snail species. Microsatellite markers are being developed to investigate genetic population structure of *Coralliophila abbreviata* Caribbean-wide. Preliminary data shows a high abundance of long (9-75) AC repeats in the *Coralliophila abbreviata* genome, confirming their potential as polymorphic markers. The finding of differentiation between snail populations from different hosts has implications for the protection of threatened *A. palmata* populations.

IS ZOOPLANKTON CAPTURE AN IMPORTANT TROPHIC PATHWAY IN REEF CORALS?

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The *in situ* rate of zooplankton capture and its trophic importance were assessed under natural conditions in a variety of coral species. Close-up video surveillance was examined from 51 individual coral colonies of four species feeding under natural conditions at night using far red and infra red lighting (fig 1). There were significant differences in zooplankton prey capture rates between three coral species, with *Montastraea cavernosa* and *Meandrina meandrites* feeding at approximately 3 and 4 times the rate of *Montastraea annularis*, respectively. These differences were attributable to

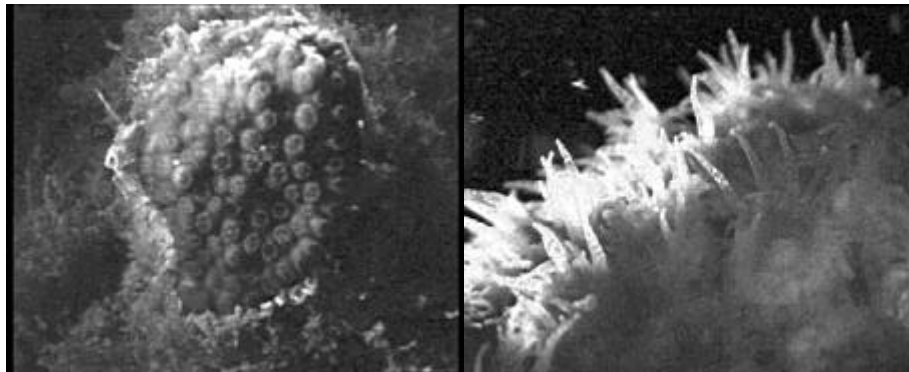


Figure 1. Whole-colony (A) and close-up (B) video captures of corals feeding *in situ* at night. A zooplankton is viewed just before capture (arrow). A = *Montastraea annularis*, B = *Montastraea cavernosa*. Scale bars 1 cm.

prey encounter rates, rather than differences in capture efficiency, which was virtually identical between species. This can be explained by the much greater polyp and tentacle expansion observed in *M. cavernosa* and *M. meandrites* compared to *M. annularis* (fig 1), resulting in more

frequent prey encounters. In general, there was also close correlation between the encounter rate and capture rate of specific zooplankton taxa. There was no significant difference in the frequency of zooplankton captures by taxonomic group, so any prey specificity by coral species can be explained by different encounter rates. The organic fraction of zooplankton represents a high quality diet, with C:N ratios of between 3.8 and 4.6. Preliminary estimates of C and N supply from zooplankton feeding were: 0.7 gC.cm⁻².y⁻¹ and 0.17 gN.cm⁻².y⁻¹ in *M. annularis*, 2.1 gC.cm⁻².y⁻¹ and 0.5 gN.cm⁻².y⁻¹ in *M. cavernosa* and 3.0 gC.cm⁻².y⁻¹ and 0.7 gN.cm⁻².y⁻¹ in *M. meandrites*. These values represent 20-80 times the annual total C budget and 112-460 times the N budget calculated previously for shallow water *Acropora palmata*. While not all the ingested ration would be assimilated, the supply of zooplankton clearly represents a substantial part of the overall C and N budget of these corals.

**INCORPORATION OF STRONTIUM IN THE SKELETON OF THE SCLERACTINIAN
CORAL, *STYLOPHORA PISTILLATA***

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Calcification in corals has been a topic of interest for over 100 years but yet the processes involved are not entirely known. Most of the studies are related to calcium uptake, and few explored the incorporation of strontium (Sr^{2+}). It is however essential for paleoclimatologists to understand calcification processes in corals because the ratio of Sr/Ca has been widely used to determine the temperature of the ancient seas. Experiments were therefore performed to gain a better understanding on the processes involved in strontium incorporation. For this purpose, we used ^{85}Sr and a NaI detector as a non-destructive method. Sr^{2+} skeletal incorporation was found to be linear during the 9 days of incubation with natural concentration of Sr^{2+} . We found a linear relationship in the rates of Sr^{2+} incorporation vs external Sr^{2+} concentration up to 3.4 mM (*i.e.* a concentration 37.5 times higher than normal seawater concentration). However, the incorporation of Sr^{2+} was also strongly dependent of the Ca^{2+} concentration in seawater as well as on the rate of calcification. The uptake of strontium indeed decreased with the increase in the calcium concentration in seawater. In addition, uptake of Sr^{2+} was sensitive to verapamil, a calcium channel inhibitor, and showed a maximal half inhibition (IC_{50}) for a verapamil concentration of 12 μM , a value close to that observed for calcium uptake. All these results suggest that care should be taken before optimal interpretation of the Sr/Ca ratios.

CHARACTERISATION OF SR CO-ORDINATION IN CORAL ARAGONITE BY EXAFS**Adrian Finch, Nicola Allison, Steven Sutton, Matthew Newville****School of Geography & Geosciences,
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Sr/Ca ratios of some coral skeletons have been successfully linked to local SSTs. However the Sr concentration of coral aragonite is approximately 7000 ppm and exceeds the thermodynamic solubility of Sr in aragonite. Preliminary Sr K-edge EXAFS of bulk coral powders indicated that Sr in some corals is present in two structural environments: as Sr distributed ideally in aragonite and as Sr clustered in SrCO₃ (strontianite) domains (Gregor et al. 1997). The incorporation of Sr as strontianite is likely to complicate the expected relationship between aragonite Sr/Ca and SST, since the thermodynamics of a two-phase mixture is different from that of a solid solution. Variations in the proportion of Sr present as strontianite may also affect the palaeotemperature equation, leading to significant uncertainties in the prediction of SSTs from coral aragonite.

We have investigated the co-ordination of Sr in a range of coral skeletons including *Porites lobata*, *Pavona gigantea*, *Pavona clavus* and *Montastrea annularis* using Sr K-edge Extended Absorption X-ray Fine Structure (EXAFS). We compared these with aragonite, strontianite and mechanically mixed standards. We performed bulk analyses and compared the data with equivalent microEXAFS analyses on small (~400 μm³) analytical volumes using a microfocussed x-ray beam. As a result of the architecture of the coral skeleton, the crystals within the microanalytical volume are not randomly oriented, and the microanalytical x-ray absorption spectra show orientational dependence. However, refinement of bulk and microanalytical data provided indistinguishable interatomic distances and thermal vibration parameters in the third shell (indicative of Sr speciation).

The Sr K-edge EXAFS of all the coral samples refine, within error, to an ideally substituted Sr in aragonite, in contrast to previous studies, in which significant strontianite was reported. Some samples from that study were also analyzed here. Strontianite may be less widely distributed in corals than previously thought.

R.B. Gregor et al., Strontianite in coral skeletal aragonite, *Science* 275 (1997) 1452.

MAPPING AND PROTECTION OF DEEP-WATER CORAL REEFS IN NORWAY

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The deep-water coral *Lophelia pertusa* builds large reefs, which are very sensitive to fishing activities with bottom trawl. It is estimated that 30-50 % of the *Lophelia* reefs in Norwegian waters has been damaged by trawling, and the impact is both on areal extent and quality. It is shown that there is a considerable overlap between the distribution of corals and impacted reefs and the trawl fields on the shelf. In 1999 the Norwegian Fisheries authorities decided upon regulations to protect coral reefs in Norway by enforcement of the Fisheries Act. Since 1998 the Institute of Marine Research has carried out a mapping program of the distribution and the status of the deep-water reefs in Norwegian waters. This paper presents updated results from the mapping activities and describes the principles behind the regulation of the fisheries in coral areas.

**MACROBENTHIC BIODIVERSITY AT THE DARWIN MOUNDS, NE ATLANTIC, A
DEEP-WATER HABITAT FOR COLD-WATER CORAL, *LOPHELIA PERTUSA***

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A very large number of invertebrate and fish species have been recorded from samples of the living and dead framework of cold-water corals. However, understanding of sensitivities of the cold-water coral ecosystem are limited by incomplete understanding of the composition of this associated biodiversity at different sites and whether or not these species are obligatory or facultative associates with cold-water coral. The present work analysed nine box core samples obtained in 2000 from the Darwin Mounds at ca 950 m depth in the northern Rockall Trough. Samples were taken from either a mound, or the unique associated 'tail' areas (discriminated by their characteristic acoustic signature). It was not possible to include in the analysis samples from mounds where living coral was present in the core, but our analysis clearly shows the enhanced benthic biodiversity present with dead coral rubble. A total 290 macrobenthic species among 1775 individuals were identified, this indicating considerably greater species diversity compared to those box cores (from either 'mound' or 'tail') not containing coral rubble and a previously obtained sample from the background sediment. Yet very many species were common to all samples, and only 20 of the present species were included in the total of 886 species listed by Rogers (1998) as living on or in *Lophelia pertusa* reefs. We conclude that very few species may be restricted to the cold-water coral habitat. Rather it seems that the vast majority of species possess a generic requirement for one or more of the mix of sub-habitats provided by coral rubble mixed with sediment, and will certainly include species known from both hard surfaces and soft muddy sediment.

COOL MICROBORINGS

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This study concentrates on the traces that microboring organisms leave in cold water carbonates. For this purpose the carbonate skeletons of *Balanus balanus* and *Balanus crenatus* were investigated along a bathymetrical gradient at Tromsø (Norway, 69° N) and Spitzbergen (Norway, 76°N). Specimens were taken from 0m, 16m, 23m, and 44m waterdepth at Tromsø and 55m, 72m and 85m waterdepth at Spitzbergen.

The substrates were impregnated with a high-viscous resin. The carbonate was then removed and the resulting three dimensional resin-cast analysed under the SEM. Results show a depth-dependent distribution pattern of microendolithic traces, very much like results obtained from experiments in tropical reef environments. Only that trace communities colonise much narrower zones here than they do in tropical waters. The concept of trace communities is described in detail by Vogel et al. 2000. In short it states, that different trace communities exist for certain water depths, depending on the availability of light. Simplified these are the cyanobacterial dominated Euphotic Zone I, the algal dominated Euphotic Zone II, the algal and fungal dominated Dysphotic Zone and the fungal dominated Aphotic Zone. (Please note, that above stated organisms are the assumed producers of the traces identified here).

The following zones were identified in our localities: The Euphotic Zone I is restricted to 0m. The Euphotic Zone II extends from 0m to 16m. The Dysphotic Zone starts at 23m and extends to 72m. From there on only traces of fungal microendoliths are found, which is characteristic for the Aphotic Zone. A total of 26 ichnotaxa was identified in approx. 100 samples.

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**THE ECOLOGY OF A GROUP OF CRYPTIC FISH, THE MORAY EELS (MURAENIDAE),
DETERMINED BY A MODIFIED VISUAL CENSUS METHOD**

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We studied moray eels as potentially important predators that are often underestimated or neglected in studies of coral reef fish due to their cryptic and nocturnal habits. We aimed to determine their diversity, abundance, biomass, microhabitat use and activity patterns on reefs in Barbados. We used a modified underwater visual census (UVC) during day and night in order to better detect moray eels in different habitats. Seven species were present in the study area, 5 of which were seen frequently. *Gymnothorax moringa*, *G. miliaris* and *Enchelycore nigricans* were the most abundant species. There were significant differences in the numbers visible during day and night censuses. *G. miliaris* was seen most frequently during the day and all others were seen exclusively or in higher numbers at night. *G. moringa* appears to make up most of the moray biomass. We propose an index to better estimate the abundance of cryptic fauna based on repeated runs of the same transect. This study suggests that morays are more abundant than previously reported and that the use of night transects, repeated runs and other modifications to traditional UVCs increase the detection of these cryptic fish. This could have important implications for studies trying to determine predator abundance and biomass on reefs. Because *G. moringa* is readily trapped and fairly site-attached, marine reserves may develop considerably higher biomass of predatory morays than fished areas.

SCLEROCHRONOLOGY AND ISOTOPE GEOCHEMISTRY OF A CORAL FROM KUWAIT, NORTHERN ARABIAN GULF: A PILOT STUDY

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The coral reefs of Kuwait occur in a marginal setting between 28°-29° north, and are under the influence of clastic input by rivers (Shatt Al-Arab) and by wind. Arid conditions prevail with some 100 mm of rain per year. Water temperatures fluctuate highly between 13-34°C. Salinity is elevated above normal marine values and ranges from 38.5-42.5‰. A total of 29 reef-building species of Scleractinian corals have been described from the waters of Kuwait. The largest and best developed coral reefs of the country fringe three offshore sand islands named Kubbar, Qaro, and Um A-Maradem. Small patch reefs occur at the southern coast of the country (e.g., Carpenter et al. 1997, Downing 1985).

During this pilot study, we investigated a giant colony of *Porites lutea* at Qaro, which is 6 m in diameter and 5 m high. The top of the colony is in 2 m of water and mostly dead. We took three horizontal cores from the living sides of the colony with lengths of 0.8 m, 1.1 m, and 1.6 m. We measured growth-rates on radiographies and we are in the process of measuring stable isotopes of oxygen and carbon along one of the cores. The goal of the project is to get a record of environmental change for the northern Arabian Gulf for the past few decades. The impact of the 1990 Gulf War on the reefs including massive oil spills is of special interest. First results show that growth-rates average 1 cm per year, however, there is strong variation. From the radiographies alone, no impact from the Gulf War oil spills are visible in that the 1990 growth band would show abnormal patterns. Results from the geochemical (isotope) analyses of one core are in progress and will be presented on the conference.

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GROWTH AND SURVIVORSHIP OF SCLERACTINIAN CORAL TRANSPLANTS AND EFFECTIVENESS OF PLUGGING CORE HOLE SITES

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Eighty core plugs containing living tissue (coral transplants) of two species of scleractinian coral *Meandrina meandrites* (n=40) and *Montastrea cavernosa* (n=40) were transplanted to forty Reef Ball™ modules between March and June, 2001. The cores were obtained from forty individual coral colonies, on an adjacent natural reef, using a hydraulic drill fitted with a four-inch core barrel. Two cores were sampled from each of the forty donor colonies. All donor core holes were filled with pre-fabricated, numbered concrete plugs to prevent the detrimental effects of bioeroders. Core hole sites and transplant corals, as well as control corals of comparable size (to both the large donor colonies and the small transplant corals), were monitored for growth and survivorship. Coral skeletal growth has been defined as an increase in surface area or linear radius and has been measured quarterly using photographic techniques. The large donor corals and comparable controls were photographed using a Nikonos V camera with 20mm lens and a 0.75m² PVC framer marked in 10cm increments. The core hole sites, coral plug transplants and comparable controls were photographed with a 28mm lens and close up kit. SigmaScan Pro4 image analysis software (Jandel Scientific Corporation) was used for the photographic analysis. This monitoring method is suitable for continuous monitoring and causes no apparent harm to the coral colony.

After nine months of sampling, 100% of the *M. cavernosa* and 71% of the *M. meandrites* transplants maintained their original tissue surface area or showed evidence of an increase in surface area. The remaining 29% of the *M. meandrites* transplants have shown varying degrees of partial tissue mortality.

The donor colonies have experienced 100% colony survival. The core hole sites have not regenerated tissue over the concrete plugs. There has been little tissue die back from the plug sites and so regeneration remains possible. Although it is too early in the study to draw firm conclusions, the species specific differences in transplant growth and mortality may be an important consideration in future coral reef restoration efforts.

**UPTAKE OF AMMONIUM BY THE SCLERACTINIAN CORAL *STYLOPHORA PISTILLATA*:
EFFECT OF FEEDING, LIGHT, AND AMMONIUM CONCENTRATIONS**

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$^{15}\text{NH}_4\text{Cl}$ was used to measure the uptake rates of ammonium by the scleractinian coral *Stylophora pistillata* depending on its feeding regimes (highly fed, slightly fed and starved) and ammonium concentration in seawater (0.2, 1 and 5 μM). Nubbins were prepared from three parent colonies and incubated under the different feeding regimes during 4 weeks. They were then incubated 12 h in seawater enriched with a known concentration of $^{15}\text{NH}_4\text{Cl}$. At the end of the incubation, zooxanthellae were separated from the animal cells so that uptake rates could be measured in each fraction separately. Results obtained showed that the algal fraction was enriched with ^{15}N at up to 10 times the rate of the host, suggesting that the zooxanthellae are the primary site of assimilation. Uptake rates in the algal fraction varied according to the nitrogen concentration in seawater. They were ca. 20 times lower at 0.2 than at 1 or 5 μM $^{15}\text{NH}_4^+$ enrichment (2 - 30 vs 120 - 510 $\text{ng N h}^{-1} \text{cm}^{-2}$), for both fed and starved nubbins. These rates were also affected by the feeding history of the host, since they were significantly lower for fed than for starved nubbins (ANOVA, $p < 0.005$), at both high and low ammonium concentrations. According to the nitrogen content of the zooxanthellae, an external concentration of ammonium equal to 0.6 μM can sustain the growth of the zooxanthellae population.

SATELLITE TRACKING TRAWLERS TO PROTECT DEEP-WATER CORAL HABITATS

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Surveys over the past five years have revealed extensive coral habitats (scleractinians and gorgonians) in deep waters, below the photic zone. Off Europe, reefs constructed by cold-water corals such as *Lophelia pertusa*, *Madrepora oculata* and *Solenosmilia variabilis* attract commercial fish such as monkfish (*Lophius* spp.), redfish (*Sebastes* spp.) and roundnose grenadier (*Coryphaenoides rupestris*). Video surveys and *in situ* measurements are revealing the structural and ecological complexity of these reefs all along the NE Atlantic continental shelf break area, but these surveys have also shown widespread damage due to deep-sea trawling. Similarly, the complex habitats created by gorgonians (to 10 m in height) off the US and Canada have supported handline and longline fisheries for cod and halibut for centuries but have been damaged extensively by deep-sea trawling over the past decade.

Habitat destruction and fish stock collapses have prompted the establishment of deep-water Marine Protected Areas off Tasmania and Norway but most countries (including Canada and members of the EU) have done nothing. It has been argued that these deep-water habitats occur too far offshore for us to be able to manage their conservation effectively. However, we now have the technology to protect fragile deep-water corals and the long-lived fish that they attract.

In the wake of hostilities between the high seas fishing fleets of Canada and Spain a satellite-based vessel-monitoring scheme was introduced. Now 'black boxes' are fitted to all vessels greater than 24 m in length and operating more than 12 miles offshore from Canada, Iceland, Greenland, Russia, Norway, the Faroes and EU member states. This talk will draw attention to the international extent of trawling damage to cold-water coral habitats and then focus on how the vessel-monitoring scheme works. Satellite tracking offers an excellent means with which to protect deep-water coral provinces whilst helping fishermen sustain fisheries and avoid damage to their nets and catches.

This research was supported by The Royal Society.

A SHORT-TERM SPATIAL COMPARISON OF NET CARBONATE CHANGE AND PERCENT COVER OF SMALL-SCALE BIOACCRETERS AND BIOERODERS ON HOLOCENE TILES PLACED ON THE REEFS OFF FT. LAUDERDALE, FL, USA

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In Ft. Lauderdale, Florida, USA, three reef lines parallel the coast. The goal of this study was to differentiate the early stages of bioaccretion/bioerosion by measuring net weight changes of 40 tiles made of coral placed on the first and second reef lines. The study also aimed at identifying small-scale bioaccreters and bioeroders. Twenty tiles were placed on the first reef at 4 m and on the second reef at 6 m depth where they were left for 4 months. Tiles were attached to a PVC-pipe frame in such a way that both tops and bottoms were exposed. After 4 months, all tiles gained weight and there was a significant difference in net weight change between the two locations ($p < 0.05$). Quantification of bioeroders/accreters was done by point-counts (5 mm^2). Tops, bottoms, and overall pooled values were evaluated. Most common bioaccreters were coralline algae (41.4% on 1st reef, 15.6% on 2nd reef, $p < 0.001$), bryozoa (15.3% on 1st reef, 19.6% on 2nd reef) and serpulids (10.9% on 1st reef, 14.9% on 2nd reef). On tile tops, crustose corallines were the dominant bioaccreter (61.8% on 1st reef, 30.6% on 2nd reef), while on the underside bryozoa (30.6% on 1st reef, 36% on 2nd reef) and serpulids (21.9% on 1st reef, 29.7% on 2nd reef) were dominant. Bioeroders were rare, the most common being boring polychaetes (0.14% on 1st reef, 0.19% on 2nd reef). Clionid sponges were found only on tiles from 2nd reef (0.09%), while boring bivalves were found only on tiles from 1st reef (0.75%). There was no correlation ($R^2 = 0.12$) between the percentage cover of calcareous organisms and net weight gain. This suggests that weight gain is caused by layering of fauna, which is not adequately expressed by point-counting only the surficial organisms. The location of tiles on the different reefs, i.e. depth, had a significant effect on net weight change and percent cover of the main colonizer, crustose coralline algae.

SCLEROCHRONOLOGY AND ISOTOPE GEOCHEMISTRY OF CORALS FROM THE REEFS OF BELIZE, CENTRAL AMERICA

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Eighteen cores from the scleractinian corals *Montastraea faveolata*, *Siderastrea siderea*, and *Solenastrea bournoni*, collected in a variety of different environments and depths in the modern reefs of Belize, are currently being studied regarding variations in growth-rates, and stable isotopes of carbon and oxygen. The goal of this project is (1) to evaluate the influence of a variety of environmental factors such as temperature, salinity, water depth, and turbidity on coral growth, and (2) to acquire a historical climate record for this major reef area in the tropical Atlantic Ocean.

Results of the investigation of a core of *M. faveolata* from the Belize barrier reef, which has a record from AD 1907-2000, show that growth-rates were more or less constant around 10 mm/year from 1900 to 1960 and then decreased to 7-8 mm/year in the late 1990ies. Oxygen isotopes ($\delta^{18/16}\text{O}$) exhibit a decreasing trend from -3.8‰ PDB to -4.0‰ PDB which would correspond to an increase in temperature of ambient seawater of 1°C during the past 100 years. Carbon isotopes ($\delta^{13/12}\text{C}$) show a decreasing trend from around 0.0‰ PDB at the beginning of the past century to -1.0‰ PDB in the 1990ies, which could be attributed to the increase of anthropogenic input of CO_2 into the atmosphere by the burning of fossil fuel. There are no statistically significant correlations between average annual growth-rates and isotopic compositions of C and O and available climate data sets (COADS) in the core investigated. Time series analyses of average annual growth rates and C and O isotopes reveal cycles of 6 and 21 years, however, much more data will be needed to relate such cycles to climatic and/or oceanic circulation cycles.

First results from analysis of a core of *M. faveolata* from the restricted interior lagoon of the isolated carbonate platform Turneffe Islands exhibit growth-rates that fluctuate around 1 mm/year from AD 1820-1930. From AD 1930-2000 growth-rates decrease to 3 mm/year, which is probably a consequence of the fact that the top of the colony came close to sea level. Oxygen isotope values fluctuate along the core, and reach highest values around the year 1860 (-3.6‰ PDB) and lowest values in the late 1980ies to early 1990ies (-4.2‰ PDB). This difference would correspond to a temperature increase of 3°C . Carbon isotope values fluctuate between values of 0.0‰ to -2.0‰ PDB, and there appears to be no global signal involved as compared to the core from the barrier reef. Growth-rates and carbon isotopes fluctuate more or less parallel from AD 1820-1930, which might be a consequence of the interrelationship of growth and photosymbiotic activity.

NEW RECORDS OF *FUNGIACAVA EILATENSIS* GOREAU ET AL., 1968 (BIVALVIA: MYTILIDAE) BORING IN INDONESIAN MUSHROOM CORALS (SCLERACTINIA: FUNGIIDAE)

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New observations on endosymbionts in mushroom corals at South Sulawesi and Bali resulted in eight new coral host records of the mytilid bivalve *Fungiacava eilatensis* Goreau et al, 1968, bringing the total to 14. The host corals were observed in various habitats, most frequently on sandy substrates. The largest numbers of parasitic bivalves (> 10 individuals) were found in large attached colonies of *Podabacia*.

The mytilid *Fungiacava eilatensis* is only known to occur in mushroom corals. In a review, Hoeksema & Achituv (1993) listed six species of fungiid host corals from various localities, belonging to five subgenera in *Fungia* Lamarck, 1801: *F. (Cycloseris) fragilis* (Alcock, 1893), *F. (C.) tenuis* Dana, 1846, *F. (Fungia) fungites* (Linnaeus, 1758), *F. (Lobactis) scutaria* Lamarck, 1801, *F. (Verrillofungia) repanda* Dana, 1846, and *F. (Wellsofungia) granulosa* Klunzinger, 1879.

In 1994 and 2001, additional specimens were collected at the Spermonde Archipelago, South Sulawesi (Indonesia) during surveys on endosymbionts in Fungiidae. *Fungiacava eilatensis* not only appeared to be more common than expected but also to occur in three additional host genera (i.e., *Halomitra* Dana, 1846, *Sandalolitha* Quelch, 1884, and *Podabacia* Milne Edwards & Haime, 1849) and one additional subgenus, *Fungia (Pleuractis)* Verrill, 1864. The eight newly recorded host species are *Fungia (Cycloseris) costulata* Ortmann, 1889, *F. (Pleuractis) moluccensis* Van der Horst, 1919, *F. (P.) paumotensis* Stutchbury, 1833, *Halomitra pileus* (Linnaeus, 1758), *Sandalolitha dentata* Quelch, 1884, *S. robusta* (Quelch, 1886), *Podabacia crustacea* (Pallas, 1766), and *P. motuporensis* Veron, 1990. For descriptions of the host coral species, see Hoeksema (1989, 1993).

During a recent survey at Bali specimens of *F. eilatensis* were also observed in *Podabacia crustacea*, *P. motuporensis*, *Sandalolitha dentata* and *S. robusta*. At South Sulawesi, most of the endoparasitic bivalves were found at lower reef slopes and reef bases, especially in specimens of *Fungia fragilis*, *F. costulata* and *F. moluccensis* on sandy bottoms. Among these host corals, individuals of *F. moluccensis* appeared the most frequently infested. Corals of *Sandalolitha* and *Podabacia*, which become large in adult stage, usually contained the largest numbers of the mytilid parasite, particularly *Podabacia* species with over 10 bivalves per coral. With regard to habitat preference of *F. eilatensis*, there is no clear preference in distance offshore, since the animals were found on reefs near river mouths (2 km offshore) and on barrier reefs that are most remote from the river outlets (36 km offshore). With the new records from South Sulawesi and Bali taken into account, the total number of host species infested by *Fungiacava eilatensis* has become 14. Since these species belong to several genera and subgenera, we conclude that although the host specificity of this bivalve is limited to only one scleractinian family, the Fungiidae, the total number of host species is quite large for a single parasitic species.

SEXUAL REPRODUCTION IN THE ELLIPTICAL STAR CORAL, *DICHOCOENIA STOKESI*, MILNE-EDWARDS & HAIME, (CNIDARIA: SCLERACTINIA)

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This study involves the determination of the seasonality, lunar periodicity, and modality of the reproductive cycle of *Dichocoenia stokesi*. A total of 88 *D. stokesi* colonies were sampled along the east coast of south Florida, USA, at the Dania Beach Second Reef, near the city of Fort Lauderdale. Samples were collected at a mean depth of 10m from Sept. 30, 1999 to Sept. 25, 2000 at approximately new and full moons. Histological analysis indicates this species is a broadcast spawner, and that the study population is predominantly gonochoric with a small percentage of hermaphrodites. Gametes begin to appear in June. One yearly breeding season is apparent, most likely culminating in at least two spawning episodes around the full moon: one each in September and October as evinced by mature spermatozoa in tissues. The *Dichocoenia stokesi* reproductive pattern is similar to those of other previously reported Caribbean broadcasters in that gametogenesis begins during seawater warming in May and June. A single breeding season culminating with one or more spawning events during the warmest months of the year also emulates this trend. Locally (in the Florida Keys), this species has been affected by the disease Plague Type II, which shows a preference for larger colonies. Regression analysis correlating colony size and initial fecundity estimates will be presented with regards to potential disease effects on the population ecology.

**EFFECT OF ZOOPLANKTON AVAILABILITY ON THE METABOLISM OF THE
SCLERACTINIAN CORAL *STYLOPHORA PISTILLATA* (ESPER, 1797)**

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This work investigated the effect of zooplankton and light availability on the tissue composition as well as on the rates of photosynthesis and calcification of the zooxanthellate coral *Stylophora pistillata* (Esper, 1797). Coral colonies were cultivated under three light levels (80, 200, 300 $\mu\text{moles m}^{-2} \text{ s}^{-1}$) and two feeding regimes (fed one or four times per week for “control” and “fed” corals respectively). Corals were fed both natural plankton and *Artemia salina*. The rates of dark and light calcification as well as the rates of photosynthesis were measured after two, five and nine weeks of incubation. After five weeks of incubation, fed corals, at all light levels, displayed 4 to 7 times higher chlorophyll a concentrations ($7 - 21 \mu\text{g cm}^{-2}$) than control corals. The amount of protein was also significantly higher in fed ($2.11 - 2.50 \text{ mg cm}^{-2}$) than in control corals ($1.08 - 1.52 \text{ mg cm}^{-2}$). Rates of photosynthesis in fed corals were 2 to 10 times higher ($1.24 \pm 0.75 \mu\text{mol O}_2 \text{ h}^{-1} \text{ cm}^{-2}$) than those measured in control corals ($0.20 \pm 0.08 \mu\text{mol O}_2 \text{ h}^{-1} \text{ cm}^{-2}$).

For the three sampling period, dark calcification rates were significantly lower than the rates of light calcification, independent of the trophic status. This confirms the previous results showing an effect of light (and therefore photosynthesis) on the calcification process. For the first time, we showed a strong effect of feeding on the rates of both dark and light calcification. Fed corals experienced calcification rates 50 to 75 % higher (60 ± 20 and $200 \pm 40 \text{ nmol Ca}^{2+} \text{ cm}^{-2} \text{ h}^{-1}$ for dark and light calcification respectively) compared to control corals (30 ± 9 and $124 \pm 23 \text{ nmol Ca}^{2+} \text{ cm}^{-2} \text{ h}^{-1}$). We therefore suggest that feeding increases calcification without affecting the light-enhancement process.

PREDICTED IMPACTS OF CLIMATE CHANGE ON THE RESILIENCE AND VULNERABILITY OF CARIBBEAN CORALS

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Effects of climate change on coral communities remain largely unknown, though it may be a major contemporary threat to coral reefs. Following the global mortality event of 1998, concern for the causes of reef degradation have broadened from agents operating at local scales to global effects: climate change, and warming events inducing large-scale coral bleaching in particular. At present no comprehensive system is available for predicting effects of global impacts manifest at local scales, and currently community and population responses are generalised. We addressed this problem by applying a previously developed coral community model to predict resilience properties and vulnerability of corals to climate change. A spatial (CA) model was applied to this problem as reef system complexity can be reduced to the simple behaviour of its components. There is a wealth of information on the biology of individual coral species and their environmental responses, but interactions generating complexity and responses to climatic influences are less well understood at a community level.

The study design was two-fold: 1) community resilience was investigated by applying single warming events to the coral community model and 2) responses to predicted future climate were assessed by running simulations in combination with SST predictions for the next 100 years (derived from a global climate model, HadCM3). Susceptibility to bleaching during warming events was parameterised using individual species thermal tolerances extracted from reports of warming events in 1987, 1995 and 1998 in the Caribbean. Assumptions were made that corals will not acclimate or adapt within the temporal scale of predicted events.

The modelled community demonstrated resilience to mild events, but events of increasing severity required >16 years for recovery. A shift in community structure was apparent immediately following such events, with large increases in algal abundance. After a 7 year lag, *Agaricia spp.* increased in abundance. Full recovery of *Montastrea annularis* populations took >40 years. This illustrates differential resilience of species populations to warming events; individual susceptibility to bleaching was mediated by life history strategy investment. Two distinct community responses to the sequence of predicted warming events were detected. Between 0-40 years the community composition changed from persistent, large, slow growing species to small, fecund fast growing species. After 40 years algae dominated the community, constituting a phase shift. Population responses, quantified as changes in population size structure of colonies, were categorised into four types, these are discussed within the context of individual life histories. It is concluded that the future is likely to herald declines in some of the main reef-building species of Caribbean coral reefs, such as *Montastrea annularis*. Populations of most coral species could be composed primarily of small colonies in as little as 30 years. This has serious implications to diversity of corals and other reef organisms, including commercially important species, and is likely to be accompanied by decreased rates of reef accretion that could influence coastal erosion in some places. These predictions are likely to be exacerbated by other features of climate change such as changes in aragonite saturation level and sea level rise.

HOW DO CORAL REEF FISH LARVAE SENSORIALLY RECOGNISE THEIR LOCATION OF SETTLEMENT?

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Many coral reef fish produce pelagic larvae that develop in the ocean from days to weeks prior to returning to the benthos, a complex life cycle common in the marine environment. Settlement by these larvae onto the reef habitat is a critical step in the life cycle of coral reef fish. During this step, fish larvae go through a selection of suitable habitats according to the refuge they can provide, and to their co-existence with conspecifics as well as other species. But how can these larvae recognise sensorially, at night, their location of settlement, and in particular how do they detect the presence of conspecifics? We tested in experimental tanks, the role of 4 sensory aspects of fish larvae (vision, smell, hearing and vibration) in the recognition of conspecifics and of suitable habitats. Larvae are captured with crest nets and are then introduced into experimental tanks, which allow testing of each sensory aspect separately. We carried out various types of experiments on 22 coral reef fish species: (i) sensory recognition of conspecifics and (ii) of habitat, and (iii) competition between the recognition of conspecifics and of habitat, (iv) between conspecifics of *Moorea* and of *Rangiroa* (two island of French Polynesia), and (v) between the various sensory aspects used by larvae for the recognition of habitat and (vi) of conspecifics. The results are variable according to studied species and attraction factors. Some species use all the sensory aspects (except hearing) in the recognition of habitat or of conspecifics (e.g. *Ctenochaetus striatus*, *Acanthurus triostegus*), others use only smell (e.g. *Parupeneus multifasciatus*, *Rhinecanthus aculeatus*) or vision (*Lutjanus fulvus*), and finally some use no sensory aspect (e.g. *Apogon novemfasciatus*, *Abudefduf sexfasciatus*). Smell is the sensory aspect used in priority by fish larvae in the recognition of habitat and of conspecifics. And these larvae are attracted more by conspecifics than by habitat (regardless of the sensory aspect tested). On the other hand, no difference is observed in the recognition of conspecifics of *Moorea* or of *Rangiroa*. These experiences in experimental tanks have been validated *in situ* for the species *Chromis viridis*. These results demonstrate that many coral reef fish larvae could in practice use sensorial cues for effective habitat selection during their settlement stage, and have the ability to discriminate species-specific sensorial cues. The use of sensorial cues is put in relation to the greater or lesser importance of the factors of habitat and conspecifics in the settlement strategy of the species concerned.

**GENETIC EVIDENCE OF AN UNUSUAL BREEDING SYSTEM IN THE
MEDITERRANEAN SOLITARY CORAL *BALANOPHYLLIA EUROPAEA*
(SCLERACTINIA, DENDROPHYLLIIDAE)**

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Histological studies performed on samples of *Balanophyllia europaea* have shown that it is a simultaneous hermaphrodite with no physical separation between male and female gametogenesis and a brooder species. We also observed that when the gonads reach full maturity encounters may occur between gametes of the opposite sex produced by the same individual, an indication of possible self-fertilization. A gene-enzyme systems analysis has been undertaken on polyps collected at Calafuria (Leghorn, eastern Ligurian sea) through cellulose acetate electrophoresis. We assayed eighteen enzymes using three buffer systems, but resolution was good for only 10 of them (PGI, PGM, PGD, HK, ME, MPI I, MPI II, AK, SOD, LDH). Population genotypic frequencies for the ten loci scored differed significantly from Hardy-Weinberg's equilibrium, showing a marked deficiency of heterozygotes. Preliminary studies on the existing genetic relationship between adult polyps and brooded offspring were performed on 6 homozygous adults with 2-15 young per adult. The offspring were identical to their parents. We have not up to now examined offspring of heterozygous adults. On the whole, we have identified an unusual breeding system in *B. Europaea* in which cross-fertilization is rare; the data thus far collected does not, however, let us to determine which among the different reproductive modes, i.e., self-fertilization, parthenogenesis, and asexual reproduction, is the prevailing breeding system in this species. Studies in progress will contribute to the understanding of the selected reproductive strategy in *B. europaea*.

DETERMINATION OF DIFFERENT BENTHIC REEF COMMUNITIES IN BROWARD COUNTY, FLORIDA (USA) USING ACOUSTIC REMOTE-SENSING AND *IN SITU* TECHNIQUES

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Typical Caribbean reef communities of variable composition and density exist on four parallel ridges, at varying depths along the Broward County (FL, USA) coast. Two of these ridges, at 7-13m and 15-30m depth, are drowned early Holocene coral reefs of 5 ky and 7 ky uncorrected radiocarbon age, respectively. Previous work has shown that the reef communities overlying these reef-ridges can be detected and mapped using acoustic remote sensing and has suggested that different benthic assemblages may exist between each of the reef ridges. In this study, *in situ* community data was taken for each reef-ridge using traditional 50m line-intercept transects. These data were analyzed and clustered using multi-dimensional scaling (MDS) and compared with similarly clustered data obtained from an acoustic survey of the same area. The *in situ* community data show four distinct benthic communities, each corresponding to a single reef-ridge. This clustering agrees well with the acoustic data which, when using principle components analysis (PCA), similarly show a unique habitat type on each of the four reef-ridges. The reef-ridge community closest to shore (5-7m depth) showed 38% live cover, and was dominated by Alcyonaceans (15% total cover). The second reef-ridge (7-13m depth) was dominated equally by Macroalgae and encrusting zooanthids, with each group representing 15% of the total cover. Total live cover on the second reef-ridge community was about 49%. The third reef-ridge community from shore (13-16m depth) had about 60% living cover and was dominated by Macroalgae, which accounted for 30% of total cover. On the fourth and deepest (15-30m) reef-ridge community, Alcyonaceans were the dominant fauna (20% total cover), however, sponges were nearly as abundant (14% total cover). Total living cover on the deepest reef-ridge community was 42%. Total Scleractinian cover was generally low on all reef ridges (4% mean cover for all reef-ridge communities), with the first reef-ridge having the highest total scleractinian cover (6%) and the second reef-ridge having the lowest (3% total cover). This total data set suggests a depth-dependant zonation pattern that does not occur across a single-reef ridge, but rather on a larger spatial scale across the entire reef-ridge system of Broward County.

**THE MICROBIAL ECOLOGY OF A PLAGUE-LIKE DISEASE AFFECTING
MONTASTREAE ANNULARIS COLONIES IN THE CARIBBEAN**

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Since the mid-1970's when the first coral disease was classified in the Caribbean, the level of interest and work carried out in this field has risen. Since their discovery and classification, attempts have been made to identify the cause of diseases found affecting coral reefs around the world. Different methods have been used to identify microbial communities association with disease but it is still not clear whether those found are causal agents, or whether they are secondary invaders. Microbes associated with diseased corals have been investigated using microscopy, culturing and inoculation experiments but these methods have not proved successful in every case. A disease similar to White Plague disease, which was reported and described by Dustan in 1977, was identified on several reefs off the coast of Barbados and St Croix in the Caribbean. Patchy areas of clear white skeleton were found on colonies of *Montastreae annularis* where areas of tissue had recently sloughed off. There is no obvious starting point for the tissue loss. The surrounding tissues appear healthy with no signs of surface tissue degradation. Histological studies have shown that the tissue remains intact and still contains zooxanthellae up to the skeletal interface although the lower tissue layers have been found to be absent. A defined line exists between the tissue and the bare skeleton with tissue remnants still present on the skeleton. There is no obvious microbial biomass present at this interface, similar to White Plague and White Band Disease. With the use of modern molecular techniques, the microbial ecology of the diseased and healthy tissue of *M. annularis* colonies collected from St Croix and Barbados have been identified. Sequence data of the bacterial community from diseased and healthy tissue showed a change in the bacterial group diversity. Fluorescence *in situ* hybridisation was used to identify bacteria present within the coral tissue. Results showed that bacteria were not found in the healthy control tissue samples or in the tissue adjacent to the bare skeleton but were found on the remnant tissue patches that were found on the bare skeleton. Although these diseased corals share symptoms similar to both types of White Band Disease and Plague, we suggest that this disease is unique to those previously described as no similar microbes were identified and some differences in pathology exist.

**THE MEDITERRANEAN CORAL *CLADOCORA CAESPITOSA*: A PROXY
FOR PAST CLIMATE FLUCTUATIONS?**

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Sclerochronology was applied to recent, Holocene and Pleistocene samples of *Cladocora caespitosa*. Late Pliocene samples were recrystallised and thus unsuitable for sclerochronology. Quaternary samples showed a clear, alternating banding pattern as in the living coral, confirming a marked seasonality of past climate. The computed mean annual growth rates ranged from 2.1 to 6.9 mm · year⁻¹, with highest growth rates during the warmer phase (isotope stage 5e) of the first climate cycle. It is hypothesised that the largest fossil banks of *C. caespitosa* grew in a coastal environment with considerable alluvial inputs and warmer temperatures than today.

DIFFERENTIAL REEF-BUILDING CAPACITY OF CORAL-DOMINATED ASSEMBLAGES IN THE LATE MIOCENE CARBONATE PLATFORM OF MELLILA-NADOR (MAROC)

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The last decade has seen an increasing interest for the detailed study of reef architecture and internal structure. Mapping of spatial distribution of reef-builders within individual sedimentary bodies has shown the high variety of three-dimensional frameworks and the existence of a continuous spectrum from scattered potential reef-builders to true dense frameworks. Characterization of reef frameworks and reef-building capacity of fossil assemblages also allow the relative importance of bioaccumulation rate and reef-growth in carbonate production to be quantitatively estimated.

The Late Miocene carbonate complex of Mellila-Nador, which evolved from a bioclastic carbonate ramp to a reef-rimmed carbonate platform, show a very gradational development of coral frameworks in the prograding and aggrading units of the upper carbonate sequences. Individual sedimentary bodies containing coral-dominated assemblages were carefully mapped in the field and sampled. Particular attention was paid to organisms with preserved growth position. These individual sedimentary bodies include: prograding non reef-building coralgal sigmoids, which have been previously described as coral reefs, fringing coral reefs, and metric coral patches alternating with oolites and stromatolites in the upper carbonate unit.

Prograding non reef-building coralgal sigmoids typically show a basal thin layer mainly composed by serpulids occurring either in growth position or as fragments, followed upwards by well-bedded *Halimeda* facies. This is overlain by branching *Porites* rudstones and packstones, which form the main volume of the sigmoid. Scattered colonies of branching and massive *Porites* are found most frequently near the top and the seaward margin of the sigmoid where they occur with branching and encrusting coralline algae, but never constitute a reef-framework. In addition, mapping revealed that the proportions of *Porites* and coralline algae in growth position within individual sigmoids tend to increase upward in the overall sequence. By contrast, the overlying prograding fringing reefs display well-developed coral framework dominated by large colonies of branching *Porites*.

Although the sedimentary and biological components and the general geometry of the bioclastic sigmoids and the overlying fringing reefs remain very similar, their internal architecture, which depends on the reef-building capacity of their coralgal communities, strongly differs suggesting different bioaccumulation / growth rates for these bodies.

**LET'S SEE UNDERWATER PARADISE
AT TELUK CENDRAWASIH MARINE NATIONAL PARK**

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The Teluk Cendrawasih Marine National Park (TCMNP) is located in the southwest quarter of Cendrawasih Bay on the north of Papua, and lies within the coordinates 1°43' - 3°22' S and 134°06' - 135°10' E. The park covering 1.453.500 ha extends from just east of Kwatisore Peninsula in the south, to just above Rumberpon Island in the north and includes approximately 500 km of mainland coastline and reefs. TCMNP also includes the 18 islands of the Kepulauan Auri island chain. The Teluk Cendrawasih area was first proposed as a marine reserve in 1982. Its status was later recognized as a Marine National Park by Decree of Forest Ministry No. 472/Kpts-II/1993 in September 2nd, 1993.

The park holds large potential on marine tourism due to its highly diverse of marine natural resources. Outdoor activities such as diving, snorkelling, underwater photography, and fishing are the most common in the area. This potential should be well managed, planned and design, through appropriate authority to guarantee the vision and mission of nature conservation. Tourism should be design to improve benefit for local people. Main objective of the management of the park is to support sustainable natural resource exploration by local people and to conserve the marine biodiversity. The best way to explore the area is from a well-equipped boat. Additionally the tourist can go a shore for jungle/bird watching safari or to visit the local cultural communities. The ideal time for a visit to the area is about 10 days.

The TCMNP's scleractinian corals show a high diversity with 67 genera and sub-genera and 145 species represented. Coral colonies, such as *Porites lutea*, *P. cylindrica*, and *Acropora palifera* are occasionally dominant on the reef crest and upper reef slope. The fish fauna of the TCMNP shows a high diversity including estuarine, mangrove, coral reef, and schooling species. The common important families include lethrinids, lutjanids, serranids, carrangids, and reef/shoal-associated species such as *Scomberomorus* and *Katsuwonus*. There are diverse molluscs fauna of the 196 species so far identified, contain of: 153 species of gastropod mollusc (36 families and 58 genera), 40 species of bivalve mollusc (18 families and 30 genera), and 3 cephalopod molluscs (2 families and 2 genera). Hawksbill turtles (*Eretmochelys imbricata*) and Green turtles (*Chelonia mydas*) are frequently encountered swimming or resting on the reefs and nest on the mainland coastline. Olive ridley (*Lepidochelys olivecea*) and Leatherback turtles visit to the area occasionally.

SEXUAL REPRODUCTION IN SOLITARY CORALS OF THE GENUS *BALANOPHYLLIA* (SCLERACTINIA, DENDROPHYLLIIDAE): IS THERE A CORRELATION BETWEEN SEXUAL CONDITION AND MODE OF ENVIRONMENTAL COLONIZATION?

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Balanophyllia pruvoti is a common azooxanthellate scleractinian coral living in the Mediterranean Sea and along the Atlantic coast from Portugal to southwestern of England. It lives in shaded habitats at depths ranging from shallow water to a depth of more than 100 meters. We are currently studying the annual cycle of the sexual reproduction in this coral in Calafuria (Leghorn, Tuscany, Italy), the same locality where we studied the reproductive biology of the Mediterranean congeneric species *B. europaea*, a zooxanthellate coral living in shallow water in open habitats. *B. pruvoti* is a gonochoric species with a 1:1 sex ratio and very high population density. On the contrary, *B. europaea* is a simultaneous hermaphrodite with very low population density. We hypothesize that the presence of opposite sexual conditions in these congeneric species could be related to their different modes of environmental colonization. In the case of *B. pruvoti*, the adaptive sexual condition could be gonochorism because, in conditions of high population density, it allows for reproductive success with low energy cost for the individual. On the contrary, although energetically more expensive for the individual, in conditions of low population density, the adaptive sexual condition could be hermaphroditism in *B. europaea* because it maximizes the rate of fertilization.

**EFFECTS OF THE PHYSICAL ENVIRONMENT ON THE CROSS-SHELF
BIODIVERSITY AND SPATIAL DISTRIBUTION OF REEF CORALS FROM THE GREAT
BARRIER REEF AND THE NORTH WEST SHELF OF AUSTRALIA**

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In recent years there has been much concern over reduction of biodiversity and degradation of coral reefs due to sedimentation, turbidity and associated factors (e.g. decreased light levels). However, many coral reefs prosper in naturally high sediment regimes where suggested thresholds for sedimentation/turbidity stress are frequently exceeded. These conflicting observations raise important questions as to the role of abiotic environmental factors on coral community structure, species distribution and biodiversity. In an effort to answer these questions, we examine the relationship between a suite of physical and spatial factors (including reef location, slope, aspect and depth; sediment type and wave exposure) and the distribution of 100 coral species along inshore-offshore gradients on the Great Barrier Reef and on reefs of NW Australia. GIS techniques were used to combine these data sets over a range of spatial scales and multivariate statistical techniques were employed to group species in relation to their occurrence along gradients of the physical variables. Although some species groups were ubiquitous, a number of groups showed characteristic relationships along gradients of water depth and sediment regime. Species-environment associations were consistent across the continent, strongly suggesting that physical regime in particular sediment regime and depth our key forcing factor shaping the cross-shelf structure of coral assemblages. These results have important implications applications for habitat classification and reef zoning.

VILLAGES OF THE CHAGOS ARCHIPELAGO

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The islands of the Chagos Archipelago have been much in the news over the past two years following the court ruling that the original population of the region, removed when Diego Garcia became a US military base in the 1970's, should be permitted to return home.

This poster will present a historical perspective on the inhabitation of Chagos, and a photographic tour of the villages of the archipelago. This tour will be illustrated with photographs taken shortly after the islanders were removed, and some twenty years later, when the buildings have fallen into ruin.

UNEXPECTED TEMPERATURE AND LIGHT INFLUENCE UPON RESPECTIVELY CARBON AND OXYGEN ISOTOPIC COMPOSITION OF THE CORAL SKELETON

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The coral cultures were carried out in order to support the great laws, commonly admitted by geochemists, linking stable isotopes and environmental parameters. Since in such laboratory experiments, we were able to change only one parameter at a time, it was possible to investigate specifically the effect of this single factor on the coral skeletal isotopic composition. Thus, the skeletal $^{18}\text{O}/^{16}\text{O}$ and $^{13}\text{C}/^{12}\text{C}$ isotopic ratio were tested respectively against SST and light. Although usually the mass spectrometer measured both carbon and oxygen isotopes, we only considered the effect of temperature on $\delta^{18}\text{O}$ or the influence of light on $\delta^{13}\text{C}$. Then, highlighted by *in situ* results, we unearthed the laboratory measurements and we reconsidered the influence of temperature and light upon respectively carbon and oxygen isotopic composition.

As it was expected, *Acropora* results showed a highly significant linear relationship confirming the skeletal oxygen isotopic composition dependence versus the seawater temperature. Curiously, carbon isotopic ratio exhibits also a significant correlation with temperature. On the other hand, almost all the long time oxygen and carbon isotopic series published, show a strong co-variation. Moreover this signal, which may be extracted by a mathematical treatment, follows the long-term sea surface fluctuations. Oxygen and carbon co-variation can be explained by a kinetic process, which modulates oxygen and carbon isotopic disequilibrium. The carbon response to different light intensities was more difficult to explain. As for other *in situ* experiments, the isotopic consequence of light and photosynthetic activity was not associated with a clear isotopic increase. In opposite, an increase of oxygen ratio appeared significant. Except in area where seasonal temperature excursion exceeds 4°C, the slope calculated for oxygen calibrations against temperature, based on seasonal samples, are lower than the same value derived from interannual samples.

In the field, the oxygen ratio increased according to light intensity, which one increases temperature. On the other hand, this elevation of temperature induces a decrease of the oxygen ratio. Therefore, the light effect is partly masked by temperature consequences. The process governing this mechanism is not yet totally understood.

OXYDATIVE STRESS IN SYMBIOTIC CNIDARIAN?

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Symbiotic Cnidarians, as well as photosynthetic organisms, are daily submitted to O₂ variations due to the photosynthetic activity of the endosymbiotic Dinoflagellates. Tissues of those symbiotic system go through an anoxia state in dark period (0.82 % O₂) to hyperoxia (60 % O₂) during the day-time, two conditions which can likely induce an oxidative stress. Superoxide dismutase (SOD) has been characterized as one of the first enzyme occurring in the anti-oxidant defense. Previous results have demonstrated a high SOD diversity in the symbiotic cnidarians, which is typical to photosynthetic organisms. In the present study, we analyzed the oxidative stress state of the Cnidarian and Dinoflagellate cells (using biomarkers such as lipid peroxidation and protein carbonylation) and the variation of isozyme SOD activities. Measurements have been performed during the nyctemeral cycle and during environmental stress such as elevated temperature, UV, pO₂, pCO₂ conditions. Experiments have been performed comparing symbiotic Cnidarians (the sea anemone, *Anemonia viridis* and the hermatypic coral, *Stylophora pistillata*) with the azooxanthella sea anemone (*Actinia equina*). The results show a high resistance of the symbiotic organism to both natural anoxia/hyperoxia transition and environmental parameter variations. In control conditions (defined as the day-time period), the animal cells (ectodermal and endodermal cells) and the zooxanthellae present specific characteristics in protein or lipid degradation. However, no variation within the same compartment is observed during the light/dark transition or during any of the environmental stress. Analyze of isozymes on native polyacrylamide gels confirms the stability of SOD activities during natural and induced stress. The azooxanthellate species studied, *Actinia equina*, is however sensitive to the environmental parameter variations such as an increase in hyperoxia and temperature. Those results show a high adaptation of the symbiotic models to environmental stress compared to an asymbiotic one without hyperoxia adaptation system. This adaptation could be explained by over-expression and diversity of SOD in both partners of the symbiosis.

RECORD OF NATURAL AND ANTHROPOGENIC CHANGES IN REEF ENVIRONMENTS BARBADOS WEST INDIES, USING LASER ABLATION ICP-MS AND SCLEROCRONOLOGY ON CORAL CORES.

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Rates of growth of corals are affected by environmental parameters such as water temperature, depth and light intensity. The natural reef environment is also disturbed by human influences such as anthropogenic pollutants which in Barbados are released close to the reefs. Here we describe a new method to assess how the pollution effects have influenced the coral communities off the west coast of Barbados. We have evaluated the relative impact of both anthropogenic pollutants and natural stresses. Sclerochronology documents framework and skeletal growth rate and records pollution history (recorded as reduced growth) for a suite of sampled *Montastrea annularis* coral cores. X-radiography shows annual growth band patterns of the corals extending back over several decades and shows significantly lower growth rate in polluted sites. Results using Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICP-MS), on the whole sample (aragonite, organic, trapped sediment etc.) has shown contrasting concentrations of the trace elements (Cu, Sn, Zn, and Pb) within the corals at different locations. Deepwater corals 7km apart record element levels for Pb 2ppm/20ppm, and Sn 10ppm/220ppm indicative of flow of pollution and current direction. A climatic event, the 1995/96 hurricane is indicated by anomalous values for Sn and Cu for all sites.

BIOEROSION: TO CUT THE GROUND FROM UNDER ONE'S FEET – AND TO TAKE PRECAUTIONS

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A bioeroding sponge was found on a sabellariid worm reef in Florida, USA. It was identified to be the clionid *Pione lampa* (Laubenfels, 1950), which is better known as a fast-growing, strong eroder on Caribbean coral reefs. The sponge contained numerous gemmules, which were attached to erosion chamber walls. They were subspherical to lentil-shaped and had an aspicular, unstructured, smooth and rigid coat. It enclosed dense cell material and various spicule types. Gemmules are dormant structures likely to ensure survival under adverse conditions such as smothering, exposure to air and high temperatures. Gemmules from this site might occasionally be freed and scattered, since the Florida reef can suffer severe damage during periods of heavy wave activity such as that created during hurricane season. Bioerosion activity of the sponge increases the chance to free gemmules, as the sponge not only etches into calcareous particles cemented into the matrix produced by the worms, but also into the matrix itself. This ability enables the sponge to utilise the worm reef as substrate.

Within the Clionidae, *Cliona annulifera* and three species of the genus *Pione* are the only species known to produce typical gemmules. Possible reasons are 1. reproduction of bioeroding sponges is understudied and asexual bodies may have been overlooked in other species, and 2. clionid gemmules are an adaptation to survive life in risky environments. Sponges of the genus *Pione* are comparatively successful in environments, in which they are close to their physical limits or in potentially unstable or mobile substrates.

PROBABILITIES OF REPEAT EPISODES OF THE 1998 MORTALITY IN THE INDIAN OCEAN

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A spreadsheet with associated macros was constructed to generate SST curves (monthly data) for any location for 230 years (1871-2099). SST input data are the Hadley Centre's HadISST (1871-1999) and HadCM3 (1950-2099). Other data sets can be substituted. Techniques including standardisation of residuals adjusted forecast SSTs to historical SSTs in terms of mean trends and annual fluctuations. Curves are also generated showing the probability that any month or year will reach the critical temperatures of 1998 (or other temperature, if required). Only lats and longs of any location are needed to generate these curves, for any reefal site.

Indian Ocean patterns were explored. Corals there were worst affected in 1998, with > 90% dying to 40 m depth in many locations. Critical temperatures differ by >6°C across the region; corals in the Arabian Gulf for example experience temperatures every year which were fatal to the same species in oceanic atolls. Patterns along three latitudinal transects and one sub-region are plotted: (1) east Africa, (2) Seychelles, 'Shoals of Capricorn', Mascarenes, (3) Lakshadweep, Maldives, Chagos, with Sri Lanka and Cocos Keeling, and (4) the sub-region of Arabia. Two consistent 'terminal points' are selected to allow for comparison between and within transects: the probability of 0.1 recurrence for all months, and the probability of 0.5 recurrence for the warmest month at each location. Both correspond roughly to a certainty of the critical SST being reached each year: in the all-months approach there are 12 'throws of the 0.1 dice' each year; for the latter, months either side of the warmest add smaller probabilities to the total.

In each transect or group, curves of latitude with time to terminal point are highly significant. Highest latitude sites (N and S) reach their terminal points after 40-80 years, and sites central in each after only 25-35 years. Curves are not symmetrical about the equator in transects 1-3; sites between 5-20° South reach terminal points soonest. The Arabian group have a similar curve, with sites of highest and lowest latitudes (temperature controlled both by high latitude and Arabian Sea upwelling) reaching this point after 50-80 years, with central sites reaching it as soon as 2010.

Adaptation by corals to warming is examined. An optimist's view is that raising critical temperature at the most precarious sites by only 1°C prolongs the time to terminal point by >30 years. The pessimist's view, however, is that the critical temperature for a site does not need to be reached every single year, and that temperatures started rising 35 years ago yet corals did not adapt sufficiently to survive 1998.

SUSPENSION FEEDER-DOMINATED BIOHERMS ON SUBLITTORAL SOFT BOTTOMS IN THE NORTHERN ADRIATIC SEA

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The aggregated biomass of sublittoral soft-bottom epifaunas can show interesting parallels to coral-dominated communities. In particular, the build-up and destruction of bioherms is a general process that is not limited to reef corals. In the Northern Adriatic Sea, for example, the biomass is strongly concentrated on benthic islands (isolated and small-sized rockgrounds and shellgrounds embedded in or lying on the sediment). As in coral reefs, the “background fauna“ consists of low biomass deposit-feeders and predators. Moreover, the sessile fauna of the bioherms is exclusively represented by suspension feeders. Serpulids are strongly dominant, followed by ascidians, sponges, anemones and bivalves. The associated vagile organisms are also mostly made up by suspension feeders. The brittle star *Ophiothrix quinquemaculata* and the sea cucumber *Ocnus planci* are the two dominant forms; crustaceans and echinoids are of subordinate importance.

The bioherms grow on clayey-silty soft-bottoms with very high sedimentation rates of up to 5mm/year and the supply of benthic substrates is clearly a limiting factor for their development. They are interpreted to form in response to the abundant food supply provided by the extreme high pelagic productivity in the Northern Adriatic Sea. Thus, in contrast to coral reefs, the biomass is adapted to a nutrient-rich environment. On this flat sediment bottom, important advantages for the organisms concentrated in these complex build-ups include access to unexploited and more oxygen-rich water levels.

In the past few decades, oxygen crises, marine snow events and benthic fisheries have severely altered the bioherm-dominated community, reducing total biomass and changing species composition. A key perturbation is hypoxic or anoxic conditions, which typically affect the lower, subpycnocline layer.

**DEVELOPMENT AND APPLICATION OF A GIS-BASED MULTI CRITERIA
EVALUATION (MCE) MODEL TO ANALYSE AND MAP PRESSURE IMPOSED ON
CORAL REEF SYSTEMS IN THE FLORIDA KEYS**

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Much of the uncertainty in describing and predicting environmental change and its implications on sustainable management of coral reefs and associated ecosystems stem from a lack of adequate tools and methodologies for the integration of data associated with the spatial and temporal pattern of naturally occurring ecosystem variations and human activities.

This research project looks to address these issues through the development and application of a raster based impact evaluation model. The impact model is based on the creation of a GIS database and the integration of GIS based data processing and spatial analysis methods with state of the art Multi Criteria Evaluation (MCE) techniques. Applied to the Florida Keys the model is used to spatially analyse and map the level of pressure imposed on coral reef systems within the Florida Keys National Marine Sanctuary (FKNMS).

**CORAL DAMAGE AND RECOVERY AT ALDABRA ATOLL, SEYCHELLES,
FOLLOWING THE 1998 EL NIÑO EVENT**

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The 1998 El Niño event caused extensive bleaching and severe damage to coral reefs in the Indian Ocean. Following this event the Aldabra Marine Programme (AMP) set up eleven permanent monitoring sites to follow reef recovery at Aldabra Atoll, southern Seychelles. Sites were surveyed using permanently marked video transects in November 1999 and February 2001 and 2002. In February 2002 further permanent monitoring sites were also established at Assomption, Astove and St. Pierre East of Aldabra. Comparison of coral cover data collected by the Cambridge Southern Seychelles Atoll Research Programme just after the bleaching, with data collected by AMP, indicates that the event caused at least 22% mortality of corals in shallow (10m) water, but that mortality in deeper water (20m) was negligible in spite of very severe bleaching in 1998. At St. Pierre, an island approximately 450 kilometres ENE of Aldabra, bleaching led to in excess of 50% mortality. Percent live coral cover at sites around Aldabra ranges between 3-28% in shallow water and 0.2-36% in deep water. Coral cover is greatest on the sheltered north western tip of the atoll and decreases steadily towards the more exposed south eastern coastline. Coral cover at islands east of Aldabra ranges between 12-32% in shallow water and 17-30% in deep water. Live coral cover at Aldabra has not increased significantly between 1999 and 2001, though the percentage figures are tending to rise from year to year suggesting recovery. Coral recruitment is high at Aldabra, colonies <5cm diameter ranged from 1-13 per metre square in 2001 and 1-14 in 2002. St. Pierre and Assomption islands also have high recruitment but levels at Astove are low at only 1% in both shallow and deep water. There are good indicators that reef recovery is underway at Aldabra Atoll and healthy recruitment should accelerate the process in the next few years. Aldabra Atoll is a UNESCO world heritage site and has recently been identified as a marine biodiversity hotspot. Reefs around Aldabra are as free from anthropogenic disturbance as one could hope to find, study of their recovery will therefore provide a benchmark for measuring changes and recovery of impacted reef systems. The AMP is committed to the long term monitoring of reefs at Aldabra Atoll and other locations in the Seychelles.

EVOLUTION AND ECOLOGY OF CLOSELY RELATED *MADRACIS* SPECIES

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To understand variation between coral species we studied six closely related *Madracis* morphospecies, whose taxonomical status is uncertain at present for their interaction between environmental factors and species life-history strategies (e.g. reproductive isolation, distributional patterns, morphological variability and ecological characteristics). Population structure and depth distribution prove to be species specific. The distribution of colonies relates to the light they receive at a small spatial scale (<10cm) and three different ecological strategies towards light exist affecting both morphology and distribution. Depth can be a useless proxy for light in species whose light strategy is not determined first. We studied gametogenesis on a monthly basis and coral larvae (planulae) release on a daily basis. All species are hermaphroditic brooders and show similar patterns in gamete development. Temporal reproductive isolation is absent in the genus and all species show gamete-maturation in relation with increasing seawater temperature. Based on the absence of planulae in thousands of fertile polyps (histological analyses), we hypothesize that the term “brooding” does not apply for *Madracis* species and propose the term “quick-releasing” as its alternative. *Madracis senaria* differs from all other species because it (mass) released planulae according to a lunar cycle, whereas all other species release planulae gradually and in a non organized pattern. Our data defines *M. mirabilis* and *M. senaria* as “true” species, since they differ in ecological characteristics and morphology from all other species. *M. formosa* relates to *M. decactis* through hybridization resulting in a new species: *M. carmabi*. The new species shares morphological characteristics with *M. decactis* (10 septa) and *M. formosa* (branching morphology) as well as intermediate ecological characteristics (depth distribution). The status of two species remains unclear: that between the genetic similar species *M. pharensis* and *M. decactis*. Encrusting colonies are (sigmoidally) increasing with the increasing availability of vertical surface. Maximum likelihood analysis indicates that a polymorphism model describes the observed relation best. We show that underlying genetic variation for colony morphology responds to habitat complexity at a small spatial scale (i.e. reef). Only *M. mirabilis* and *M. senaria* represent discrete evolutionary units to study coral ecology, morphology or genetics. Since they do not relate to other species, they are useless to describe speciation processes. The other four morphospecies show interspecific overlap in morphological, genetic and ecological characteristics. Therefore they provide a much better opportunity to study organizational processes in coral evolution. We found indications of two of such organizational processes in *Madracis*: introgressive hybridization (*M. carmabi*) and the controlled expression of genetic polymorphisms (*M. pharensis*/*M. decactis*-complex). The evolutionary status of coral morphospecies can therefore not be determined *a priori* because of differences in their ecological and evolutionary dynamics.

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THE QUANTIFIABLE ECONOMIC VALUE OF CORAL REEFS IN MAURITIUS

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Coral reefs are a valuable natural resource and an important source of revenue particularly for small island nations. In Mauritius, the reefs and the extensive lagoons of the various islands provide fishing grounds which form the livelihood of many fishermen. Tourists enjoy the beauty of the reefs and international tourism provides a major contribution to the country's economy. This article summarises the main economic values of coral reefs in Mauritius, and quantifies the benefits in monetary terms wherever possible. The major reef fishing grounds surround the islands of Mauritius (300 km²), Rodrigues (240 km²), Cargados Carajos (190 km²), Agalega and smaller islands. In 1997, about 2,400 artisanal fishermen from the main island of Mauritius account for 1,246 t or about 10 % of the total fish catches in Mauritius. The financial value of these catches was estimated at €4.5 million. Bad weather and closed season allowances worth a total of €870,000 provided an additional source of income to registered fishermen. The overall economic importance of reef fishery on the main island is low if compared to other sectors of the economy such as tourism or sugar cane production. However, in Rodrigues reef fishery constitutes a major part of the economy of the island and provides the livelihood to about 2,000 registered fishermen and their families, approximately one third of the island's population. In Mauritius, international tourism has developed into a major economic force. In 2000, about 915,200 arrivals were registered in Mauritius and tourism generated € 605 million as gross receipts. Every year, approximately 50,000 tourists and Mauritians enjoy Scuba diving in the reefs which is estimated to earn Scuba dive tour operators about €4,180,000/year. The quantifiable economic value of reefs in Mauritius based on artisanal fishery in Mauritius (main island only) including bad weather allowance and SCUBA diving by tourists amounts to €9,550,000/year. This means that the coral reefs in Mauritius generate €10,977 of income per square kilometre every year. The true total economic benefits of reefs in Mauritius are considerably higher if (1) costs for tourist travel, accommodation, food, (2) reef fishery off other Mauritian islands and (3) the value of coral reefs for the protection of the shoreline would be included in an evaluation.

GLOBAL MARINE ANIMAL DATING – GMAD, THE GLOBAL MARINE AQUARIUM DATABASE

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The Convention on International Trade in Endangered Species of Flora and Fauna (CITES) attempts to assess the trade in species, listed in Appendix II of the Convention, which are believed to be vulnerable to exploitation but not yet at risk of extinction. All species of hard coral and giant clams are listed under Appendix II of CITES and parties to CITES are then obliged to produce annual reports specifying the quantity of trade that has taken place in each listed species. The magnitude and taxonomic composition of the international trade can then be calculated.

By contrast no marine ornamental fish or invertebrates, other than clams or corals, are listed under CITES. Therefore existing calculations of 15-30 million fish from approximately 1000 species (Wood, 2001) are based on extremely limited quantitative data, indicating these figures should be used with caution. The trade in individual species of fish and invertebrates, other than corals and clams, is unknown. Since April 2000 the UNEP-World Conservation Monitoring Centre (UNEP-WCMC) and the Marine Aquarium Council (MAC) have been collaborating with members of trade associations (e.g. AKKII, OFI and OATA) to establish a Global Marine Aquarium Database (GMAD) as a freely available source of information on the global aquarium industry. Our common objective is to centralise, standardise and provide fast and easy access to information on the aquarium trade.

The core data in GMAD are the sales records of wholesale import and export companies, specifically:

- Species traded (fish, corals, invertebrates)
- Quantity traded (numbers)
- Country of export
- Country of import
- Date (year)

As of June 2002 a total of 43 wholesale export and import companies including many industry leaders, and 4 national management authorities, have provided their data to GMAD.

To date, surprisingly little information has been compiled about the marine ornamental market in Europe, especially when compared to the wealth of information available about their trade in the USA. Thus, since early 2002, efforts have been concentrated on 'mapping' the aquarium industry in Europe by developing a detailed list of wholesalers for individual countries. Data collection will continue throughout the summer. Topics discussed will cover:

- principal species in trade
- trade links between European markets
- trade links between European and international markets
- how the marine ornamental trade differs between European countries

CORRELATING QUATERNARY SEA-LEVEL RISE TO PROBABLE ANCIENT HOLOCENE REEF MORPHOLOGY USING REMOTE SENSING TECHNIQUES

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Two bathymetric surveys were recently conducted in Southeast Florida (Broward County) using remote sensing devices: Laser Airborne Depth Sounder (LADS) and Multibeam sonar. The two surveys were at four-meter resolution and encompassed an area defined by approximately 28 km in the N-S direction along the coast (from northern Dade County, along the Broward County coastline, North to Pompano) and from the shore eastward 7-9 km. Depths ranged from 0 to approximately 240 m. The georeferenced xyz data was merged, gridded, and sun-shaded at 45° angle and azimuth, and draped with a NOAA NAPP 1:24,000 georeferenced air photograph mosaic for coastal reference. The model was zoomed and tipped to desired orientations and processed into three-dimensional perspectives. Multiple view options were useful for identifying benthic features including coral reefs and associated habitats.

These three-dimensional perspectives, resultant maps, and reef profiles derived from the multibeam SONAR and LADS surveys were used as a basis in GIS to detect probable Holocene reef morphology formed during different Quaternary sea levels resulting from the meltwater pulses estimated by Bard et al. (1996). The deepest assumed reef is visible at approximately 85m depth and seems to have initiated shortly after the end of the first meltwater pulse (Meltwater Pulse 1A) (~13,000 yr BP). This reef may have “given up” (drowned) during the initiation of the second meltwater pulse (Meltwater Pulse 1B) (~11,000 yr BP) or may have occurred as sheet growth upslope during the rapid sea-level rise. The base of another reef-consistent morphological structure occurs in approximately 45 meters depth. This correlates to sea-level height at the end of the second meltwater pulse (1B) (~10,500 yr BP). In more shallow water, a clear Holocene reef is present cresting in approximately 16-20m depth. This is a substantial *Acropora palmata* structure originally formed in shallow water (Lighty et al., 1978). *A. palmata* growth ceased here about 7000 yrs BP (¹⁴C date) (Lighty et al., 1978). Presently, this reef sustains a low density Scleractinian community interspersed between high densities of octocorals and sponges. More shallow reefs, some containing an *A. palmata* framework are present westward. All of these reefs may be a result of backstepping during the Holocene rising sea levels. This work demonstrates the utility of remote sensing for identifying features of potential importance in determining Holocene sea level rise history.

Further productive work on this topic may involve subbottom profiling to characterize the sand-draped Holocene reef morphology as well as *in situ* coring for determining stratigraphy and timelines.

DYNAMIC INTERACTIONS BETWEEN CARBONATES AND SILICI/VOLCANICLASTICS IN EQUATORIAL AREAS

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In active tectonic areas of humid equatorial regions near-shore, shallow-water environments are commonly sites of near-continuous siliciclastic influx and/or punctuated volcanoclastic input. Despite significant clastic influence, considerable Neogene carbonate successions developed in SE Asia adjacent to major deltas or volcanic arcs, and are comparable to modern mixed carbonate-clastic deposits in the region. Research into delta-front patch reefs from Borneo and fore-arc carbonate platform development from Java is described and used to evaluate the effects of clastic influx on regional carbonate development, local changes in carbonate producing biota and sequence development. Regional carbonate development in areas of high clastic input was influenced by the presence of antecedent highs, changes in amounts or rates of clastic input, delta lobe switching or variations in volcanic activity, energy regimes and relative sea level change. A variety of carbonate producing organisms, including larger benthic foraminifera, some corals, coralline algae, echinoderms and molluscs could tolerate near-continuous clastic influx approximately equal to their own production rates. These organisms adopted various 'strategies' for coping with clastic input, including a degree of mobility, morphologies adapted to unstable-substrate inhabitation, shedding sediment or low-light levels. Locally carbonate production was also affected by energy regimes, clastic grain sizes and associated nutrient input. Clastic input influenced the inhabitable depth range for photoautotrophs, the zonation of light dependant assemblages, and the morphology and sequence development of mixed carbonate-clastic successions. This study provides data on the dynamic interactions during mixed carbonate-clastic sedimentation and, when combined with information from comparable modern environments, allows better understanding of the effects of clastic influx on carbonate production.

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PROGRAMME AT-A-GLANCE

Wednesday 4th September

1200 onwards	Registration
1300	Lunch
1415	Meeting Opening
1430	Plenary 1 - Fabricus
1530	Coffee
1600	Scientific Sessions (Marginal Reefs/Disease)
1830	Drinks Reception
1900	Dinner
2030	After-Dinner Talk

Thursday 5th September

0830	Plenary 2 - Jackson
0930	Scientific Sessions (Reef Dynamics/Marginal Reefs)
1050	Coffee
1130	Scientific Sessions (Reef Dynamics/Marginal Reefs)
1250	Lunch
1400	Scientific Sessions (Reef Dynamics/Marginal Reefs)
1520	Tea
1600	Scientific Sessions (Reef Dynamics/Bioerosion)
1820	Poster Session and Drinks Reception
1930	Dinner
2030	After-Dinner Talk

Friday 6th September

0830	Plenary 3 - Douglas
0930	Scientific Sessions (Environmental Stress/Reef Geology)
1050	Coffee
1130	Scientific Sessions (Environmental Stress/Reef Geology)
1310	Lunch
1400	Scientific Sessions (Management/Molecular Biology)
1520	Tea
1600	Scientific Sessions (Management/Molecular Biology)
1830	ISRS General Meeting
1930	Conference Dinner

Saturday 7th September

0830	Plenary 4 - Tudhope
0930	Scientific Sessions (Palaeoclimatology/Cold Water Corals)
1050	Coffee
1130	Scientific Sessions (Palaeoclimatology/Cold Water Corals)
1300	Lunch