ARTIFICIAL REEF RESEARCH OFF COASTAL ALABAMA

ANDREW J. STRELCHECK
Florida Fish and Wildlife Conservation Commission
Division of Marine Fisheries

INTRODUCTION

Most artificial reef studies to date have focused on environmental, ecological and physical factors influencing reef productivity. However, very few studies have focused on how reef location, and specifically reef densities, influence reef fish assemblages. In fact, reef placement remains one of the most neglected variables, and potentially one of the most important, affecting artificial reef fish-assemblages (Bortone 1998). Therefore, as an integral first step in understanding the attraction-production debate, this study took advantage of Alabama's extensive artificial reef program to help understand how artificial reef placement effects reef fish population dynamics.

The primary objective of this study was to examine variability in measures of reef fish demographics (fish abundance, biomass, etc.) among replicate artificial reef designs and determine what factors (location, reef density, reef design, etc.) might contribute to this variability. Because the artificial reefs used in this study were prefabricated, they were considered to be replicates and therefore were expected to support similar abundances and biomasses of reef fish. However, this was not the case and differences in fish abundance, biomass, and total length were partially explained by the abundance, distribution, and area of artificial and natural reefs surrounding each experimental reef.

METHODS

During March 1998, 14 prefabricated concrete artificial reefs were deployed off coastal Alabama. Seven Grouper Ghetto? reef designs (volume = 3.5 m^3) and seven Reefballs? (volume = 1.8 m^3) were deployed south of Mobile Bay approximately 1-16 km apart, at depths of 24-31 m. These reefs were deployed without consideration of artificial and natural reefs residing in their vicinity.

Beginning in February 1999, sampling began at each of the 14 experimental reef sites. Sampling was conducted quarterly from February 1999 – December 2000. Techniques included catch-per-unit-effort (CPUE = no. of fish per angler per hour) sampling by hook-and-line and diver visual census (diver surveys were only conducted during spring and summer). Two sampling techniques were used because each of the techniques suffers from sources of bias (i.e. – seasonal differences in catchability, limited visibility during diving, see Strelcheck 2001).

During quarterly CPUE fishing trips, each experimental reef was sampled for 30 minutes. CPUE fishing trips consisted of 8-10 anglers. While over an experimental reef site, anglers caught reef fish by hook-and-line, one researcher measured and released all reef fish caught, and a second researcher recorded data. After each CPUE fishing trip, CPUE and reef fish biomass were calculated for each reef. Biomasses were estimated using known length-weight relationships (Bohnsack and Harper 1988; Patterson – unpublished).

During spring and summer, diver visual censuses were conducted at each experimental reef location. The diver visual census method used was a modification of Bohnsack and Bannerot's (1986) stationary visual census technique and is described in detail by Strelcheck (2001). Briefly, divers conducted two four-minute visual surveys at each reef. During each survey, divers were positioned 3.1 meters away from the reef. Divers recorded the abundance of reef fish, number of fish species, and reef fish sizes to the nearest 5 cm interval on a plastic slate. Reef fish abundances and biomasses were later calculated for each experimental reef as described above.

After estimating reef fish demographics at each experimental reef location, a digital side-scan sonar was used to quantify the abundance, distribution, and amount of bottom area (m^2) covered by artificial and natural reefs (nearest-neighbor variables) within 1 km^2 each experimental reef. The side-scan sonar consisted of a digital duel frequency tow fish, a Klein T2100 transceiver, and a coaxial tow cable. The tow fish was towed at a survey speed of 3-5 knots. Images were generated acoustically and side-scan imagery was later processed by technical support staff at Louisiana State University. Data consisted of fourteen 1 km^2 images, corresponding to the area surrounding each experimental reef site. This data was viewed using ArcView™ GIS software. Images were divided into 0.01, 0.05, 0.1, 0.25, 0.5, 0.75, and 1.0 km^2 concentric circles (**Figure 1**), and the abundance and total bottom area (m^2) of both artificial and natural reefs were quantified within each concentric circle. Additionally, linear distances (m) were measured to the five closest artificial reefs, and the closest natural reef, surrounding each experimental reef.

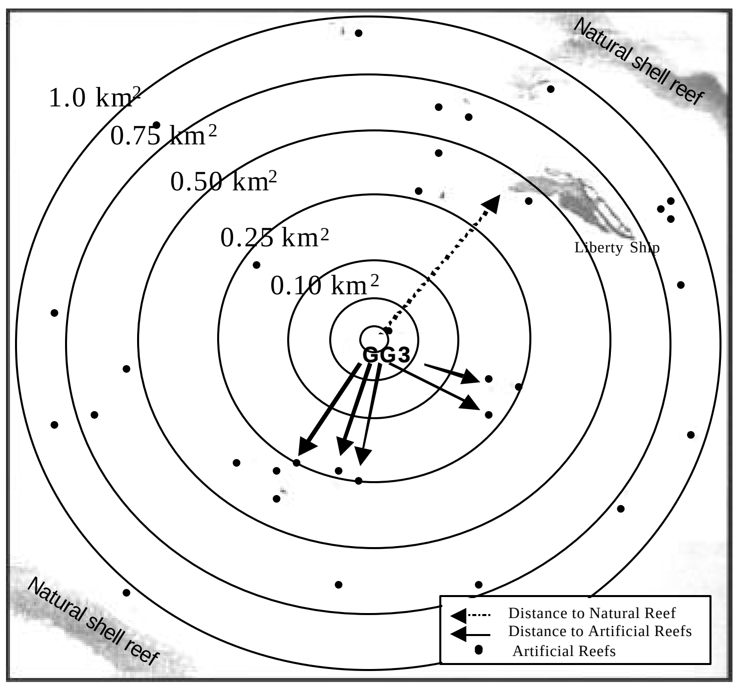

Figure 1-Illustration of 1 km^2 side scan image. Concentric circles represent the area of seafloor surrounding each experimental reef.

Analyses of variance and mixed general linear models (PROC MIXED) were performed using Statistical Analysis Software™ (SAS) to determine statistical significant differences (alpha = 0.05) in reef fish abundance, biomass, and total length among replicate reefs, between artificial reef designs (Grouper Ghettos™ vs. Reef Balls™), and among sampling seasons (spring, summer, fall, winter). To compare reef fish demographics with variables obtained from the side-scan sonar, stepwise regressions (alpha = 0.05) were performed to determine the proportion of variability in reef fish demographics explained by nearest-neighbor variables.

RESULTS

Catch-per-unit-effort. – A total of 3,330 fishes representing 26 species were caught at experimental reefs during this study. Red snapper, *Lutjanus campechanus*, and gray triggerfish, *Balistes capriscus*, were the most abundant species caught, comprising 83.2% and 6.57% of all fish species, respectively. Of the 26 species caught by hook-and-line, 10 species accounted for >99% of all species caught at experimental reefs.

Mean CPUE was highly variable among seasons and reeftypes. Mean CPUE at Grouper Ghettos (mean = 8.55 fish angler^{-1} hr^{-1}) was 70% greater than mean CPUE at Reef Balls™ (mean = 5.03 fish angler^{-1} hr^{-1}), and CPUE was greatest during fall sampling. Similar patterns were observed for reef fish biomass. Mean reef fish biomass was greatest during fall and lowest during spring and summer. Two-fold differences in biomass were observed between reef designs (Grouper Ghettos™: 25.27 kg, Reef Balls™: 13.28 kg).

Table 1. – Summary of the percent variability in biomass, CPUE, and red snapper total length explained by nearest-neighbor variables. AR = artificial reef; Linear distance 2 = distance from experimental **reefs** to the second closest artificial reef.

Independent Variables	Dependent Variables: CPUE fishing trips – Biomass	CPUE fishing trips – CPUE	CPUE fishing trips – Mean TL	Diver visual censuses – Biomass	Diver visual censuses – Fish Abundance
reef design					7.29%
season	5.17%	21.26%			
substrate					16.33%
AR abundance 0.10 km^2	34.06%	18.05%		24.46%	
AR bottom area 0.01 km^2		2.36%		8.13%	
AR bottom area 0.05 km^2					11.96%
AR bottom area 0.10 km^2			40.18%		
AR linear distance 2	7.18%				
other variables	4.18%		4.66%	5.51%	
TOTAL	50.59%	41.67%	44.82%	38.10%	35.88%

Mean total lengths (TL) were also significantly different among reef designs. Mean TLs of red snapper caught at Grouper Ghettos™ (mean = 342 mm) were significantly larger than mean TLs of red snapper caught at Reefballs (mean = 314 mm). The percentage of legal-sized red snapper also differed among reef designs; 15.5% of red snapper caught at

Grouper Ghettos™ were > 406 mm TL (legal size limit), in comparison to only 9.6% at Reef Balls™.

Visual Census. – A total of 2144 fishes representing 24 species were observed during diver visual censuses. Similar to the results of CPUE sampling, red snapper and gray triggerfish were the two most abundant fish species. Gag, *Mycteroperca microlepis*, and greater amberjack, *Seriola dumerili*, were also commonly observed and comprised > 4.5% of all fishes, respectively.

Mean reef fish abundances were significantly different between reef designs, but biomasses estimated from visual sur veys were not. Grouper ghettos™ supported 28% more reef fish (mean = 41.8 fish per reef) than Reef Balls (mean = 30.2 fish per reef). Although biomasses did not statistically differ between artificial reef designs, mean reef fish biomass was 6.7 kg heavier at Grouper Ghettos.

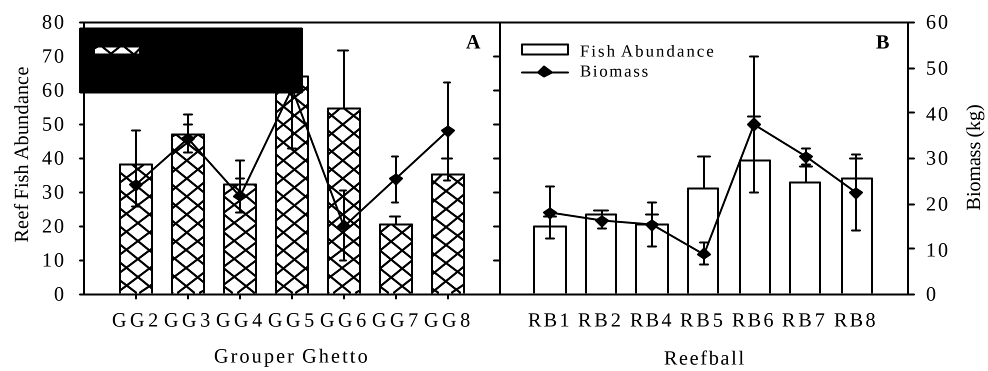

Figure 2 - Mean fish abundances and biomasses estimated during visual censuses for (A) Grouper Ghettos and (B) Reefballs. Note the variability in reef fish abundance and biomass within replicate reef designs.

Variability among replicate reef designs. – Comparison of reef fish abundance and biomass among replicate artificial reefs revealed 2-3 fold differences in fish abundance and biomass (**Figure 2**). Seasonal differences in reef fish abundance and biomass, as well as differences between reef designs, only accounted for 5-22% of the observed variability in reef fish demographics within replicate reef designs. Of the seven Grouper Ghetto™ reefs, Grouper Ghetto™ 5 supported the highest mean abundance and biomass of reef fish during this study, while Grouper Ghetto 6 supported the lowest biomass of reef fish, and Grouper Ghetto 7 supported the lowest abundance of reef fish. Reef Ball 6 supported the highest abundance and biomass of all Reef Balls™, while Reef Ball 5 supported the lowest biomass of reef fish, and Reef Ball 1 supported the lowest abundance of reef fish.

Side-scan sonar. – A total of 685 artificial reefs, comprising approximately 7,700 km^2 of seafloor, were observed within 1 km^2 of my experimental reefs. Seven-fold differences in artificial reef abundance and 16-fold differences in artificial reef bottom area were observed among experimental reef sites. Of the 14 km^2 mapped, approximately 4% was composed of low-relief natural shell bottom (relic oyster reefs). The extent of natural shell within 1 km^2 of each experimental reef site ranged from < 0.01% to > 17.3%.

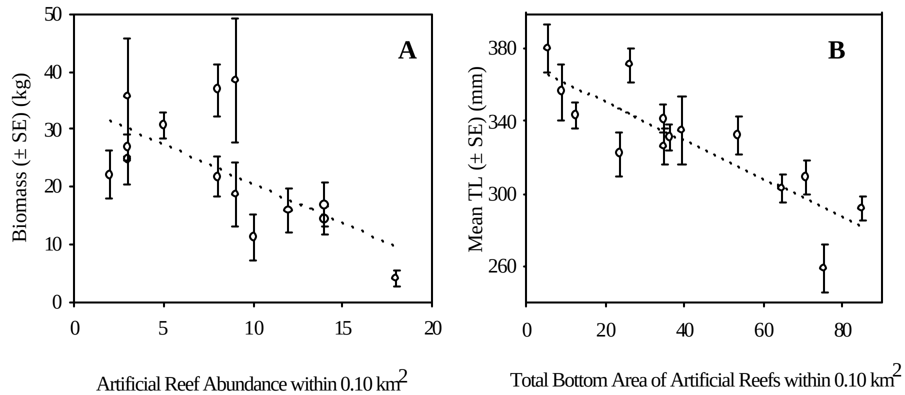

Figure 3 - Scatterplots of (A) reef fish biomass versus artificial reef abundance and (B) red snapper total length versus artificial reef bottom area. Note the decline in biomass and total length with increasing abundance and area of artificial reefs surrounding experimental reefs.

Artificial reef proximity also varied greatly by reef site. Mean linear distance from each experimental reef site to the five closest artificial reefs ranged from 22.9 - 126.2 m. Similarly, distances from experimental reefs to natural reef varied greatly, ranging from 0 to > 600 m.

Results of stepwise regressions revealed that 35-51% of the observed variability in reef fish abundance and biomass was explained by nearest-neighbor variables, season, and reef design. The abundance of artificial reefs within 0.10 km^2 of experimental reefs explained the greatest portions of variability in reef fish biomass and abundance, while the area of artificial reefs within 0.10 km^2 explained the greatest portion of variability in red snapper total length. Reef fish abundances, biomasses, and total lengths all decreased with increasing artificial reef abundances and areas (**Figure 3**). **Table 1** summarizes the amount of variability explained by nearest-neighbor variables for each of the reef fish demographics measured.

DISCUSSION

As an integral first step in understanding whether artificial reefs attract or produce fish this study took advantage of Alabama's extensive artificial reef program and sought to understand how artificial reef characteristics, such as reef size, reef densities, and reef location, affect reef fish demographics. The results presented in this manuscript agree with the finding of previous studies (Frazer and Lindberg 1994; Lindberg 1996), which found reef spacing and reef densities to have the greatest influence on artificial-reef fish demographics. My observations of 2-3 fold differences in reef fish abundance and biomass were only partially explained (5-22%) by seasonal changes and reef design. Analysis of side-scan sonar data revealed that reef fish demographics were significantly associated with nearest-neighbor variables. I show that nearest-neighbor variables explained 35-51% of the observed variability in reef fish demographic measures, with artificial reef abundance having the most significant effect on reef fish biomass, abundance, and CPUE. In all cases, increases in reef fish abundance (densities) and area resulted in decreased reef fish abundance, biomass, and total length. This may result from increases in density-dependent interactions and/or depletion of benthic prey when artificial reef densities are high (Lindberg et al. 1990). However, more research is needed to determine if this is occurring off coastal Alabama. Based on data reported by Strelcheck (2001), increased densities of artificial reefs do not appear to be limiting the growth rates or site fidelity of red snapper tagged off Alabama.

MANAGEMENT IMPLICATIONS

Issues related to artificial reef abundance and density are especially critical to coastal Alabama, which boasts the largest artificial reef program in the United States (Minton and Heath 1998). The deployment of 20,000 artificial reefs since 1950 has inevitably changed the structure and function of Alabama's coastal ecosystem. Although the deployment of artificial reefs has expanded the range in which reef fishes may forage, the potential impacts of artificial reefs are yet unknown. High catch rates and the presence of reef fish soon after deployment of an artificial reef does not automatically translate into increased production. If fishing mortality exceeds production then coastal Alabama may be acting as a net sink for reef fish production (Schirripa and Legault 1999).

In addition, little is known as to whether reef fishes off coastal Alabama are habitat or recruitment limited. If in fact reef fish, specifically red snapper, are recruitment limited then the deployment of artificial reefs has resulted in a reduction of juvenile nursery habitat (Cowan et al. 1999). If reef fish are not recruitment limited, but rather habitat limited, then the deployment of artificial reefs may result in increased biomass production of reef fishes, as long as fishing mortality is less than production. High artificial reef densities may limit or reduce productivity (growth) by decreasing site fidelity, promoting overgrazing of benthic prey, and increasing bioenergetic demands of reef fishes, however there is no evidence, based on the results of Strelcheck (2001), that artificial reef densities are limiting or reducing red snapper growth or site fidelity off Alabama.

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