Reef Fish Community Structure at Natural versus Artificial Reefs in the Northern Gulf of Mexico

Estructura Reef Fish Comunidad en Natural contra Artificial Reefs en el Norte del Golfo de México

Structure Reef Communauté Poisson au Naturel contre les Récifs Artificiels dans le Nord du Golfe du Mexique

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ABSTRACT

Natural (n = 23) and artificial (n = 26) reefs were sampled in the northern Gulf of Mexico with a micro remotely operated vehicle (ROV) in 2009-10 to examine reef fish community structure. A total of 25,065 individuals was enumerated among ROV video samples; 91 fish taxa were identified, with 91% identified to species. Both habitat type and depth stratum (strata: < 30, 30 - 45, and > 45 m) significantly affected reef fish community structure (PERMANOVA, $p \leq 0.002$). Overall, greater diversity was observed among communities at natural reefs. Small demersal species, such as damselfishes, bigeyes, wrasses, butterflyfishes and Anthiinae basses, were among the more abundant species on natural reefs, yet were nearly absent from artificial reefs. Conversely, exploited species, such as red snapper and gray triggerfish, tended to have higher densities at artificial reef sites. These larger species may have been attracted to the higher profile of artificial (2 - 5 m) versus natural (typically < 2 m) reefs, or they simply may been more able to exploit those habitats due to less reliance on reef structure to avoid potential predators. Trophic ecology and growth rates should be compared between natural and artificial reefs to test for differences in the ecology of individual species. However, the community structure data alone are invaluable given they predate both the appearance of invasive red lionfish, *Pterois volitans*, and the occurrence of the Deepwater Horizon oil spill in this region.

KEY WORDS: Artificial reef, Gulf of Mexico, Fish community

INTRODUCTION

Artificial reefs are manmade structures placed on the seabed to mimic natural reef habitat. There are numerous reasons for constructing artificial reefs, such as habitat restoration, enhancing production of reef fish species, or providing increased access to fishing or diving opportunities (Baine 2001). Fishermen tend to be the most vocal advocates of artificial reef creation due to perception that higher catch rates following reef construction indicate enhanced productivity of exploited species (Lindberg 1997). However, the likelihood that artificial reef creation will actually enhance fish production is dependent on aspects of a given species' life history and ecology, such as reef-dependency, site fidelity and home range, dispersal of eggs and larvae, and degree of fishery exploitation (Bohnsack 1989).

There has been considerable research effort expended to examine reef fish ecology at northern Gulf of Mexico (nGOM) artificial reefs (e.g., Strelcheck et al. 2005, Lindberg et al. 2006, Dance et al. 2011), but comparisons with natural reef habitat, which are critical to understand the effect of artificial reefs on reef fish ecology (Carr and Hixon 1997), have been lacking. Therefore, we began a study in 2009 to examine several aspects of reef fish ecology at artificial and natural reefs in the nGOM. Here, we present an aspect of this work in which we tested whether habitat type or depth significantly affect reef fish community structure in this region. Results have important implications for exploited and non-exploited species alike, and also represent invaluable data to evaluate the effect of invasive red lionfish, *Pterois volitans*, and the Deepwater Horizon oil spill (DWH) on nGOM reef fish communities.

MATERIALS AND METHODS

Video sampling of reef fish communities was conducted at natural (n = 23) and artificial (n = 26) reefs on the nGOM continental shelf between June 11, 2009 and May 20, 2010. Reefs ranged in depth between 18 and 72 m (Figure 1). Sampling was conducted with either a VideoRay Pro3 (dimensions: 30 cm long, 24 cm tall, 22 cm wide; mass = 3.8 kg) or Pro4 (dimensions: 36 cm long, 28 cm tall, 22 cm wide; mass = 4.8 kg) micro remotely operated vehicle (ROV). Both ROVs have a depth rating of 170 m and a wide angle lens (105° or 116°, respectively) on a 570-line forward-looking color camera. Each ROV was tethered to the surface where it was controlled by a pilot via an integrated control box that contains a 38-cm video monitor to observe video captured by the ROV's camera during sampling.

Video sampling was conducted at study reefs with either a point-count or transect method, depending on habitat type and dimensions. The point-count method, which is described in Patterson et al. (2009), was used to sample a 15-m cylinder around isolated reef habitat, such as artificial reef modules. In that method, the ROV was positioned 1 m above the seafloor and approximately 5 m away from a given reef. The ROV was slowly pivoted 360º and then moved to the opposite side of the reef. Once there, it was positioned 1 m above the seafloor and approximately 5 m away from the reef and pivoted 360º. The ROV then was flown to 1 m directly above the reef and pivoted 360º to video fishes in the water column above the reef. Next, the ROV was flown to ~10 m above the reef and pivoted 360º. Once all sample segments were completed, the ROV was flown back down to the reef and positioned such that fishes inside the reef structure were captured on video.

A transect sampling method was utilized for reef habitat that was more broadly distributed, such as was characteristic of natural reef habitat examined in this study (Figure 2). The goal of that method was to video sample a 5-m wide transect as the ROV moved forward along multiple 25-m long transects. Given a known viewing angle for the forward camera of the Pro3 (105º) or Pro4 (116º) ROV, the ratio of the height of an ROV off the seafloor to the width of a video transect (i.e., distance across field of view) can be controlled by changing the camera's tilt (Figure 2). This was accomplished prior to deployment for the Pro3 ROV, but the Pro4 ROV's operating system has the capability of controlling the camera's tilt within the software. Either way, simple trigonometry allowed for the field of view along a given transect to be estimated from the ROV's height off bottom, thus permitted the total area video sampled to be computed (Figure 2). Typically, three transects were sampled at a given reef site, with transects being offset from adjacent transects by a heading of 120º.

Analysis of video samples was performed with a Sony DVCAM DSR-11 digital VCR and a Sony LMD-170 high resolution LCD monitor. When the point-count method was employed, fish counts were summed among all sampling segments and then divided by the area of the base of the sampling cylinder (176.7 m^2) to estimate fish density. Fish density for transect samples was computed by summing taxa-specific fish counts and then dividing by the total area estimated to have been sampled among transects.

Differences in reef fish community structure were tested between habitat types (natural versus artificial reefs) and among three depth strata (< 30 m, 30 - 45 m, and > 45 m) with a two-factor permutational analysis of variance model (PERMANOVA; $\alpha = 0.05$) in Primer (v.6; Anderson et al. 2008), with taxa-specific fish densities (fish $10^3/m^2$) as dependent variables. Fish density was square-root transformed and a dummy variable with value = 1 added to each sample. Then, a Bray-Curtis similarity matrix was computed, which consisted of all of the individual similarity coefficients computed between sites. The PERMANOVA was computed to test if patterns in Bray-Curtis similarity were significantly different from random with respect to habitat or depth stratum variables.

RESULTS AND DISCUSSION

A total of 25,065 fish was enumerated among ROV video samples. Ninety-one fish taxa were identified, with 91% of taxa being identified to the level of species. There was a significant difference in fish community structure between natural and artificial reefs (PERMANOVA; $p < 0.001$; Table 1) and among depth strata (PERMANOVA; p = 0.002; Table 2), but the interaction between habitat and depth effects was not significant (PERMANOVA; $p = 0.065$). Highest mean density tended to occur in the mid (30 - 45 m) depth stratum for several of the more abundant species (Table 2). For exploited species, shallow reefs are closer to shore and may receive greater fishing pressure, while deeper reefs could be beyond the typical depth range for species such as

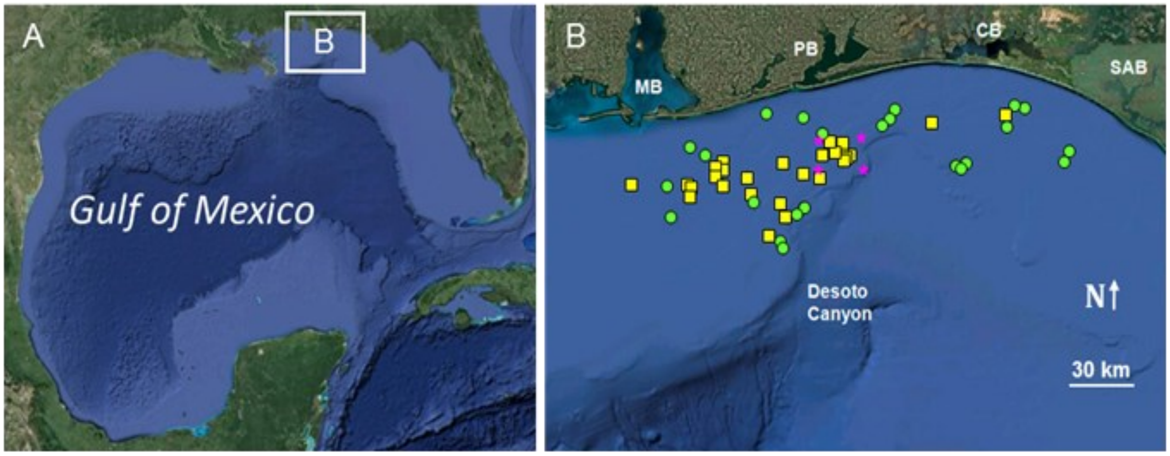

Figure 1. A) Map of northern Gulf of Mexico with study region indicated as inset. B) Natural (green circles) and artificial (yellow squares) reef study sites sampled during 2009 - 2010. Pink stars demarcate the corners of the Escambia East Large Area Artificial Reef Site. Bay abbreviations: MB = Mobile Bay, PB = Pensacola Bay, CB = Choctawhatchee Bay, and SAB = St Andrews Bay.

tomtate, *Haemulon aurolineatum*, or gray triggerfish, *Balistes capriscus*. However, many of the small (< 10 cm total length, TL) demersal species, such as damselfishes, also tended to display higher densities at mid-depth reefs. The shallower reefs experience colder bottom temperatures in winter, which may impact the distribution of more tropical species. Only a few species, such as greater amberjack, *Seriola dumerili*, scamp, *Mycteroperca phenax*, and yellowtail reeffish, *Chromis enchrysura*, displayed an increased density with depth, while roughtongue bass, *Pronotogrammus martinicensis*, was only found at natural reefs deeper than 45 m (Table 2).

Differences in fish communities between habitat types were driven by small demersal reef fishes being much more abundant on natural than artificial ones (Table 1). The starkest difference in this context was observed for damselfishes, which had the third highest density and the second highest number of species observed (n = 10) on natural reefs, yet were rarely observed on artificial reefs. Other small, obligate reef fishes, such as bigeyes, wrasses, butterflyfishes and Anthiinae basses, also had higher densities on natural than artificial reefs, and some small, cryptic fishes, such as gobioid fishes, likely occurred on natural reefs but went undetected due to the higher rugosity and structural complexity of those habitats (Stoner et al. 2008). Of the gobioid fishes that were identified, gobies, blennies, and jawfishes had much higher densities on natural reefs (Table 1).

Table 1. Habitat-specific mean density (fish•$10^{3/}$m^{2}) of the 20 most abundant reef fish taxa observed at natural (NR; top) or artificial (AR; bottom) reef sites during 2009-2010. Residency: R = reef resident, RA = seasonally reef-associated pelagic species, S = demersal or benthic shelf species, and T = transient. Trophic ecology: P = planktivore, I = invertivore, F = piscivore; multiple letters for trophic ecology indicate feeding on more than one trophic level. Life stage: J = juvenile and A = adult; multiple letters indicate more than one stage present. Reef dependency: O = obligate reef resident likely to demonstrate habitat-limited populations and G = fishes for which reefs may function to increase growth or decrease natural mortality.

Scientific name	Family	Residency	Trophic ecology	Life stage	Reef dependency	Density on NRs	Density on ARs
Natural Reefs:							
Haemulon aurolineatum	Haemulidae	R	I	A	G	510.3	711.6
Rhomboplites aurorubens	Lutjanidae	R	PI	J,A	G	328.5	15.8
Pomacentridae	Pomacentridae	R	PI	J,A	O	88.2	0
Lutjanus campechanus	Lutjanidae	R	IF	A	G	84.2	502.7
Seriola dumerili	Carangidae	RA	F	A	G	56.0	19.4
Lutjanus griseus	Lutjanidae	R	IF	A	G	55.7	46.4
Chromis scotti	Pomacentridae	R	P	J,A	O	37.2	0
Stegastes fuscus	Pomacentridae	R	P	J,A	O	26.4	0
Pagrus pagrus	Sparidae	R	I	A	G	22.0	2.2
Chromis enchrysura	Pomacentridae	R	P	J,A	O	14.8	0
Paraques umbrosus	Sciaenidae	R	I	A	O	14.4	4.6
Halichoeres bivittatus	Labridae	R	I	A	O	13.9	2.3
Lutjanus synagris	Lutjanidae	R	IF	A	G	13.6	10.2
Mycteroperca phenax	Serranidae	R	F	A	G	12.7	7.2
Caranx crysos	Carangidae	T	IF	A	G	8.9	0
Pronotogrammus martinicensis	Serranidae	R	P	J,A	O	8.5	0
Balistes capriscus	Balistidae	R	I	A	G	7.0	23.7
Chaetodon sedentarius	Chaetodontidae	R	PI	A	O	4.4	0
Priacanthus arenatus	Priacanthidae	R	PI	A	O	4.4	0
Blenniidae	Blenniidae	R	PI	J,A	O	4.3	0
Artificial Reefs:							
Haemulon aurolineatum	Haemulidae	R	I	A	G	510.3	711.6
Lutjanus campechanus	Lutjanidae	R	IF	A	G	84.2	502.7
Lutjanus griseus	Lutjanidae	R	IF	A	G	55.7	46.4
Chaetodipterus faber	Ephippidae	R	I	A	G	1.73	25.2
Balistes capriscus	Balistidae	R	I	A	G	7.0	23.7
Seriola dumerili	Carangidae	RA	F	A	G	56.0	19.4
Rhomboplites aurorubens	Lutjanidae	R	PI	J,A	G	328.5	15.8
Lutjanus synagris	Lutjanidae	R	IF	A	G	13.6	10.2
Rypticus maculatus	Serranidae	R	I	A	G	2.6	9.6
Mycteroperca phenax	Serranidae	R	F	A	G	12.7	7.2
Equetus lanceolatus	Sciaenidae	R	I	A	O	4.1	5.0
Pareques umbrosus	Sciaenidae	R	I	A	O	14.4	4.6
Chaetodon ocellatus	Chaetodontidae	R	PI	A	O	0.9	3.6
Parablennius marmoreus	Blenniidae	R	I	A	O	1.7	2.5

Table 1. continued

Scientific name	Family	Residency	Trophic ecology	Life stage	Reef dependency	Density on NRs	Density on ARs
Halichoeres bivittatus	Labridae	R	I	A	O	13.9	2.3
Pagrus pagrus	Sparidae	R	I	A	G	22.0	2.2
Archosargus probatocephalus	Sparidae	RA	I	A	G	0	2.0
Sphyraena barracuda	Sphyraenidae	RA	F	A	G	0	1.7
Centropristis ocyurus	Serranidae	S	I	A	G	3.5	1.6
Holacanthus bermudensis	Pomacanthidae	R	I	A	G	4.0	1.5

Table 2. Mean estimated density (fish•10^3 m^{-2}) of the 20 most abundant fish observed at northern Gulf of Mexico natural and artificial reefs in 2009 - 2010 by depth stratum. Depth strata: shallow (< 30 m), mid depth (30 - 45 m) and deep (> 45 m).

Scientific Name	Family	Shallow	Mid	Deep
Haemulon aurolineatum	Haemulidae	773.0	1152.7	83.9
Lutjanus campechanus	Lutjanidae	305.7	150.8	321.3
Rhomboplites aurorubens	Lutjanidae	58.2	593.1	197.2
Lutjanus griseus	Lutjanidae	58.1	63.6	33.6
Pomacentridae	Pomacentridae	7.6	244.3	23.1
Seriola dumerili	Carangidae	35.9	14.3	52.3
Chromis scotti	Pomacentridae	0.2	114.5	10.0
Balistes capriscus	Balistidae	22.8	10.5	3.9
Stegastes fuscus	Pomacentridae	0.0	46.9	22.5
Chaetodipterus faber	Ephippidae	24.0	0.4	0.0
Pagrus pagrus	Sparidae	1.7	4.9	34.1
Lutjanus synagris	Lutjanidae	18.2	9.1	2.2
Mycteroperca phenax	Serranidae	6.2	12.6	15.7
Pareques umbrosus	Sciaenidae	6.4	23.7	9.1
Halichoeres bivittatus	Labridae	5.9	25.2	4.9
Chromis enchrysura	Pomacentridae	0.2	2.5	22.6
Rypticus maculatus	Serranidae	9.3	4.0	1.2
Equetus lanceolatus	Sciaenidae	5.8	4.9	2.2
Caranx crysos	Carangidae	2.6	0.5	9.7
Pronotogrammus martinicensis	Serranidae	0.0	0.0	13.8

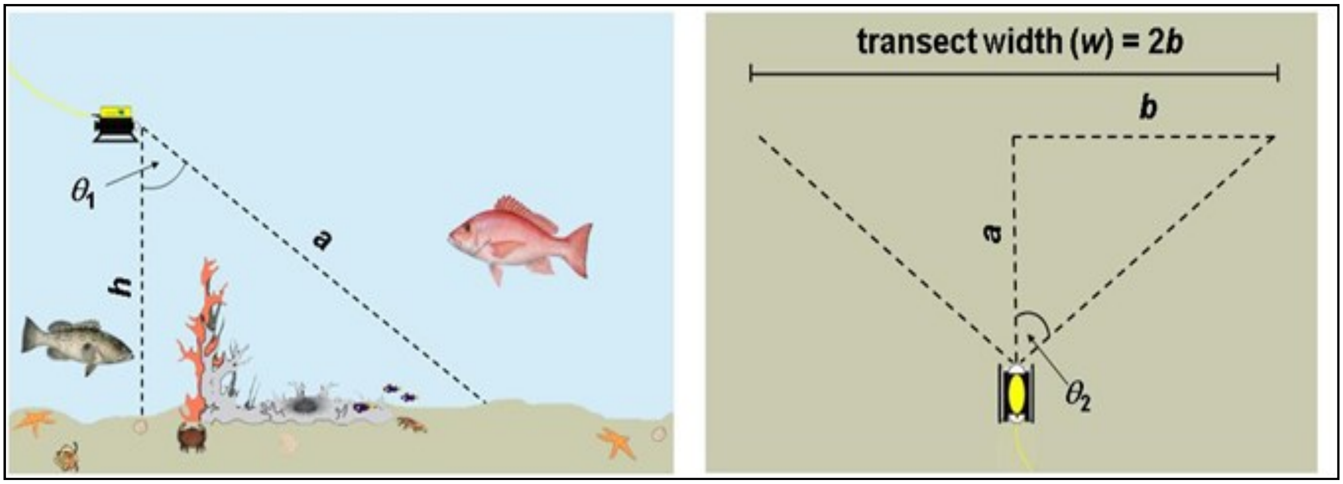

Figure 2. Trigonometry of estimating the width of a video transect given the height a remotely operated vehicle (ROV) is above the seafloor, the angle of its camera's tilt (θ_1), and the angle of the camera's view. The view angle (θ_2) is 105° for a VideoRay Pro3 ROV and 116° for a Pro4 ROV; therefore, θ_2 would be 52.5° and 58°, respectively, for the ROVs. By setting the camera's tilt angle (θ_1) to 45°, the ratio of transect width (w) to ROV height off the seabed (h) is 3.69 for a Pro3 ROV and 4.53 for a Pro4 ROV.

Larger (> 300 mm TL) reef fishes, such as snappers, jacks, grunts, and gray triggerfish tended to have higher densities on artificial reefs than on natural reef habitat (Table 1). Vermilion snapper, *Rhomboplites aurorubens*, whose density was approximately 20x greater on natural reefs, was an exception to that trend. While study artificial reefs tended to have higher vertical profiles (2 - 5 m) than natural reefs (typically < 2 m), the footprint of artificial reefs (10^2 - 10^3 m^2) typically was much smaller than observed for natural reefs (10^4 m^2 to km^2). Therefore, relatively tall artificial reefs may have attracted larger reef fishes, which in turn occurred at higher densities than the same species on natural reefs, but those high densities occurred over spatial scales that were typically orders of magnitude smaller than natural reefs.

Higher abundances of larger reef fishes at artificial reefs may imply those species are less dependent on reef structure than smaller species to avoid predators. Artificial reefs may not have offered sufficient cover or structural complexity for smaller fishes to effectively avoid predators. That issue also may have been exacerbated by high densities of larger fishes which may prey on the small demersal species that were observed in higher densities at natural reefs.

Many of the larger fishes observed at higher densities on artificial reefs, such as red snapper, are targeted by both commercial and recreational fishermen. Fish density alone is inadequate to determine whether artificial reefs enhance production for these exploited species. However, high fish density at artificial reefs does make these species more vulnerable to fishing mortality given their biomass is concentrated over a much smaller area than on natural reefs and the exact location of artificial reef sites is often publically known. Again, more research is required to test for differences in population ecology and vulnerability of exploited reef fishes at nGOM artificial versus natural reefs.

Data presented herein clearly demonstrate differences in reef fish community structure between nGOM natural versus artificial reefs, as well as the effect of depth on reef fish communities. However, perhaps the most valuable contribution of this study is in providing data on pre-lionfish and pre-DWH reef fish community structure over a broad (8,000 km^2) of the nGOM shelf. Moving forward, these data should prove to be invaluable in examining impacts of the ongoing lionfish invasion, as well as acute and chronic effects of the DWH oil spill.

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