Reef Fish Recruitment to Low and High Diversity Banks in the Northwestern Gulf of Mexico

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ABSTRACT

Natural banks represent the only naturally occurring hard-bottom structured habitat on the continental shelf in the Northwestern Gulf of Mexico and as such, may represent critical habitat for reef-associated fish species. However, the relative nursery values and functional roles of different natural bank types for reef fish in the Gulf are currently unknown. In 2009, we conducted monthly (May-Sept) visual surveys on SCUBA to quantify the density and diversity of reef fish recruits on two mid-shelf low coral diversity banks (Sonnier, Stetson) and two shelf-edge high coral diversity banks (East and West Flower Gardens). Overall fish density was highest at the two low diversity banks , and density, species richness (S), and Shannon diversity (H') were significantly higher at Stetson than any of the other study sites. Analysis of similarities (ANOSIM) was used to compare fish assemblage structure among bank types, and pairwise comparisons showed significant differences in reef fish communities between low diversity and high diversity banks but no significant differences within a given bank type. Furthermore, significant differences in the densities of specific trophic guilds among study sites suggests that habitat partitioning may occur between bank types, particularly for upper-level trophic groups (*i.e.* piscivores, carnivores). Overall, preliminary analysis of the 2009 data suggests that both bank types support large and diverse communities of reef fish recruits and that high coral diversity and low coral diversity banks may support distinct fish assemblages and trophic community structures.

KEY WORDS: Natural banks, reef fish, community structure

Reclutamiento de Peces Coralinos en Bancos de Baja y Alta Diversidad del Noroeste del Golfo de México

PALABRAS CLAVE: Bancos de baja y alta diversidad, peces coralinos, reclutamiento

Recrutement de Poissons Coralliens aux Banques de Basse et Haute Diversité au Nord-Ouest du Golfe du Mexique

MOTS CLÉS: Banques de basse et haute diversité, poisons coralliens, recrutement

INTRODUCTION

Although recruitment to many systems present in the eastern Gulf have been studied (e.g., Allman and Grimes 2004, Fitzhugh et al. 2005), the relative value of putative nursery areas for reef fishes in other regions have not been well documented or characterized, including mid-shelf and shelf-edge reef banks in the northwestern Gulf. This is particularly alarming because many 'overfished' stocks require these habitats to successfully complete their life cycles, and changes in the quality or quantity of these reef s may lead to declines in survival during early life (settlement or nursery period). In addition, these habitats may be lost or degraded by coastal development and fishing activities before their value as essential fish habitat (EFH) is even assessed.

Several low and high diversity banks are present in mid and outer shelf environments in the northwestern Gulf (Rezak et al. 1985). These natural banks range from low coral diversity banks with hydrocorals (*i.e.*, *Millepora*) and sparsely distributed individual coral colonies (Sonnier Bank, Stetson Bank) to high coral diversity banks covered with hermatypic corals (East and West Flower Garden Bank). Since the aforementioned banks represent the only naturally occurring structured habitat on the continental shelf in the northwestern Gulf of Mexico, they represent critical habitat of reef-associated species (Dennis and Bright 1988). Moreover, the complexity afforded by these habitats likely enhances early life survival by reducing predation-mediated mortality and enhancing prey availability (Rooker et al. 1997). If this assumption is valid, survival and recruitment success of certain reef-dependent species will be linked to the distribution, abundance, and general condition of reefs. In response, these banks potentially play a critical role sustaining marine fisheries throughout the Gulf.

Here, we comprehensively examined recruitment to both low and high diversity banks in the northwestern Gulf. Visual SCUBA surveys were used to quantify the density and diversity of juvenile reef fishes present on two low coral diversity mid-shelf (Sonnier, Stetson) and two high coral diversity shelf-edge (East and West Flower Garden) banks. Spatial and temporal variability in overall reef fish community structure were examined during 2009, and associations between specific trophic guilds, bank types and habitat variables were also assessed. Unfortunately, data on recruitment to these natural banks and their potential role as nurseries is incomplete, and additional information on the causes of population change for reef fish populations in the Gulf is needed to enhance conservation of low diversity and high diversity reef habitats.

METHODS

Field Surveys

Fish assemblages associated with low diversity (Sonnier, Stetson) and high diversity (East and West Flower Garden) banks were evaluated during five cruises conducted in May, June, July, August, September of 2009. Visual surveys were conducted by pairs of divers on SCUBA as 5 m x 2 m band transects, with all individual fish observed within the transect area quantified by species and age class. Sampling effort ranged from 10 - 12 transects at each bank per sampling trip with a total of 251 total transects conducted over the course of the study. East Flower Garden Bank (EFGB) and West Flower Garden Bank (WFGB) were sampled during all five survey months (May-Sept), Stetson Bank was sampled during four survey months (June-Sept), and Sonnier Bank was sampled twice in May and September.

Spatial and Temporal Variability in Community Structure

Estimates of mean overall density, species richness (S), Pielou's evenness (J'), and Shannon diversity (H') were calculated and a one-factor analysis of variance (ANOVA) was used to test for differences among study sites. Normality was tested with a Shapiro-Wilk test and *a posteriori* differences among means were detected with a Tukey's HSD test with an alpha level of 0.05. Estimated mean densities of specific trophic guilds were also calculated, with ANOVA and Tukey's HSD used to detect differences among study sites.

Fish assemblage data were analyzed with the Plymouth Routines in Multivariate Ecological Research (PRIMER) statistical package (Clarke and Warwick 2001). Densities were ln-transformed to down-weight the abundant species and to retain information regarding some of the less abundant species. A Bray-Curtis similarity matrix was then computed among all samples using density data. Two-factor non-metric multi-dimensional scaling (MDS) models were computed for each survey month to visualize similarities and dissimilarities in fish assemblage structure among banks and survey months. Stress coefficients (residual modeling error) of 0.2 were treated as critical values to test goodness-of-fit of a given MDS model in two dimensions (Clarke and Warwick 2001). A stepwise data reduction procedure in PRIMER, BV-STEP, was performed with a Spearman rank correlation coefficient of 0.95 as the threshold to determine which species explained the majority of the variability in assemblage structure. The analysis of similarities (ANOSIM) permutation procedure was used to test for differences in fish assemblage structure among banks and survey months (Clarke and Warwick 2001). To assess species-specific contributions, Similarity Percentages (SIMPER) was used as the *post-hoc* analysis to indicate the contribution of a particular species to the overall fish assemblage structure among banks and survey months (Clarke and Warwick 2001).

RESULTS AND DISCUSSION

There appeared to be some distinct bank-specific trends in overall fish density and diversity indices. Density was significantly higher at Stetson than at the other three banks examined, and both species richness (S) and Shannon diversity (H') were significantly higher at Stetson and significantly lower at Sonnier, with intermediate values at EFGB and WFGB (ANOVA; Tukey's HSD, $p < 0.05$) (Figure 1). Evenness did not differ significantly among bank types. This result was somewhat unexpected, as Sonnier and Stetson are most similar to each other in habitat type and should theoretically have more similar fish assemblages but instead showed the greatest differences between sites. The two high diversity shelf edge banks show the expected trend, being statistically similar in all four indices. It is notable that Sonnier was the only study site not located within the boundaries of the Flower Garden Banks National Marine Sanctuary and thus, the lower richness and diversity values of this site may represent something of a reserve effect.

Analyses comparing species composition rather than overall density and diversity values did show distinct separations between high diversity and low diversity bank fish communities. Assemblage structure varied among banks (ANOSIM; Global R = 0.421, $p < 0.05$) and among survey months (ANOSIM; Global R = 0.197, $p < 0.05$) over the period investigated in this study. When combined across survey months, pairwise comparisons showed significant differences in fish assemblage structure between high diversity (East and West Flower Garden) and low diversity (Sonnier and Stetson) banks ($p < 0.05$ for all comparisons), but were similar within high and low diversity banks ($p > 0.05$). Figure 2 shows the MDS plots of all transects with natural groupings of similar assemblage composition of high diversity banks contrasted with the low diversity banks. Results of SIMPER analysis identified bluehead, threespot damselfish, Spanish hogfish, and sunshinefish as the most important species structuring the high diversity banks. In contrast, cocoa damselfish, purple reeffish, and dusky damselfish were most influential in determining fish assemblage structure on the low diversity reefs. Bluehead accounted for 63% and 62% to the total species contribution within each of the high diversity banks (East and West Flower Garden, respectively) (Figure 2). Likewise, the low diversity banks of Sonnier and Stetson were dominated by the cocoa damselfish, with total contributions at 64% and 49%, respectively. Species assemblage structure was most similar among all banks in June compared to other survey months. Significant temporal differences were only found when June was contrasted with July ($p < 0.05$), but was similar when compared to May, August, and September ($p > 0.05$). Species assemblage structure between high and low diversity banks was significantly different during all months ($p < 0.05$ for all comparisons), with density differences of bluehead contributing most to survey month differences.

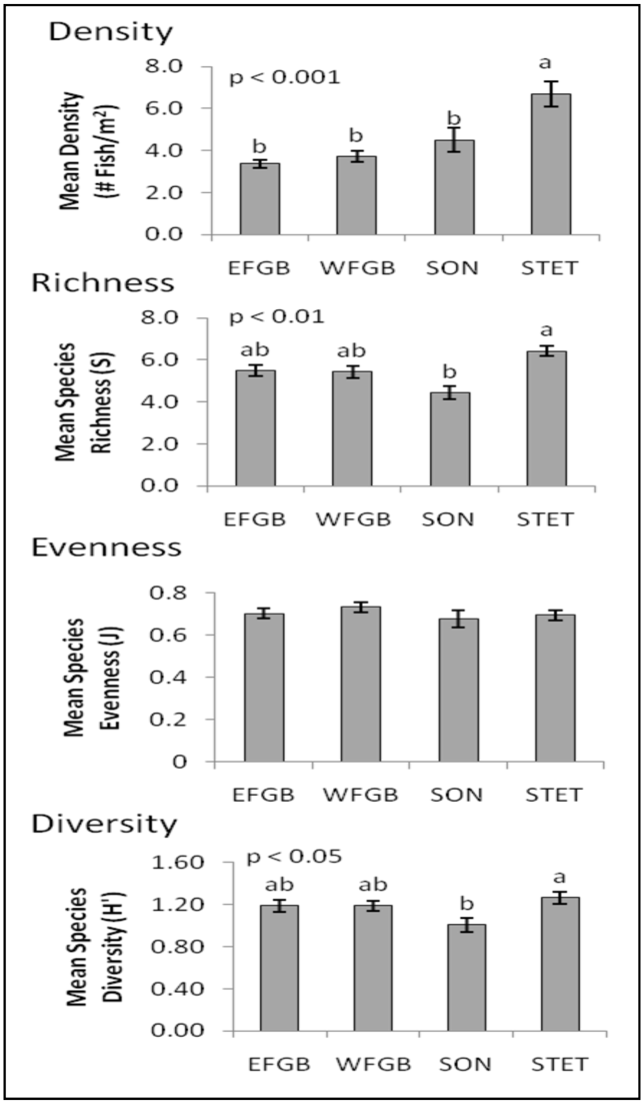

Figure 1. Mean species density, richness (S), evenness (J'), and Shannon diversity (H') indices at each bank. Error bars represent one standard error. P-values denote analyses that showed significant differences among banks (ANOVA), and lowercase letters denote bank groupings based on post-hoc tests (Tukey). Bank codes: EFGB = East Flower Garden Bank; WFGB = West Flower Garden Bank; SON = Sonnier Bank; STET = Stetson Bank.

For trophic analyses, all species observed in the study were classified into one of six feeding categories based on their published dietary preferences in the literature (Table 1). Comparisons of trophic guild density across study sites showed strong evidence of habitat partitioning, particularly among the upper level predatory trophic groups (Figure 3). Four of six trophic guilds showed significant differences across study sites (ANOVA, $p < 0.05$), and in the two groupings where highly significant ($p < 0.0001$) differences were found, there was a clear division between low diversity and high diversity bank types, with both lower level carnivores and herbivores showing significantly higher densities at both Sonnier and Stetson. The only trophic group with higher observed mean densities at the high diversity banks was the piscivore group, which was also the only group absent from Stetson. The relatively low overall densities and patchy distribution of the large groupers that made up this trophic group (characteristic of upper level predators) prevented the trend from showing statistical significance. However, it is important to recognize the non-numerical ecological important of such species and it is conceivable that their presence or absence may be driving differences across the other two predatory groups through competitive interactions or predation. Densities of smaller carnivores were significantly lower at banks where larger groupers were encountered on transects, and only one single species of smaller carnivores was even regularly observed at banks where large groupers were present.

Associations between specific trophic guilds and bank types provide further evidence that high and low diversity banks have different functional roles in determining fish assemblage structure. Futhermore, the relative densities of the piscivore and carnivore trophic guilds suggests that low vs. high diversity bank types may be particularly critical in structuring the assemblages of the higher level predatory fish species that are generally targeted and managed as fisheries. The results of this study indicate that both types of banks support large, diverse fish assemblages, but suggest that each bank type (high diversity or low diversity) may be associated with a distinct fish assemblage and trophic structure that appear to remain consistent even across fairly large geographical distances. Furthermore, analysis of specific trophic guilds appears to suggest differences in the functional role and relative nursery value of high and low coral diversity banks in the northwestern Gulf. Including 2010 data in this analyses will expand our sample size and allow us to further examine these trends. However, it is apparent that the different ecological roles of these two bank types need to be taken into account for informed ecosystem-based management efforts.

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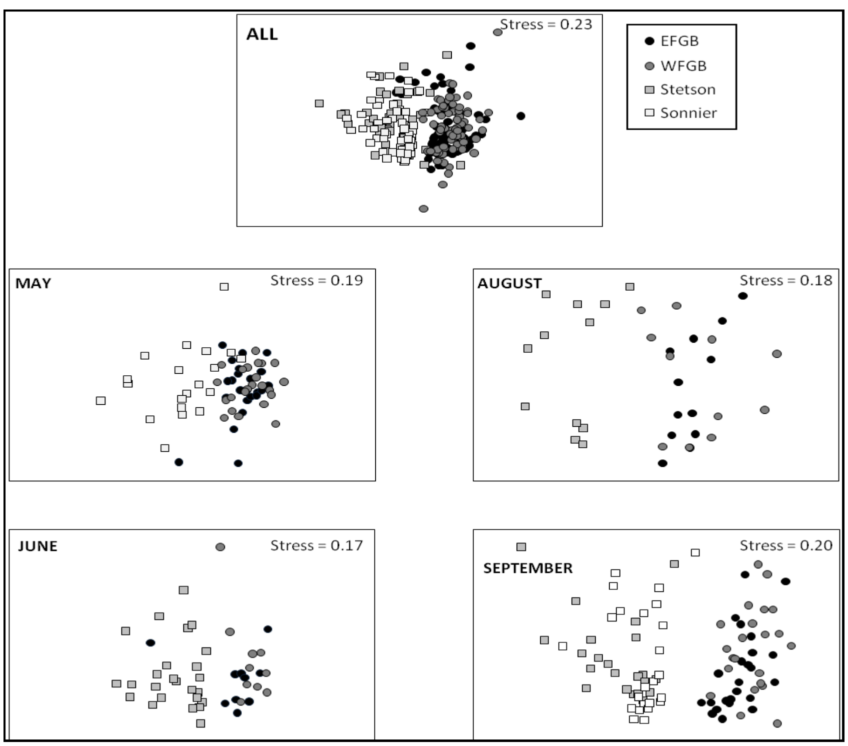

Figure 2. Multi-dimensional scaling plots of fish assemblages surveyed on high diversity (East and West Flower Garden = EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico from monthly surveys (May to September, 2009). July surveys are only shown in the combined plot due to limited surveys that only occurred at EFGB and WFGB. Stress coefficients represent goodness-of-fit criteria.

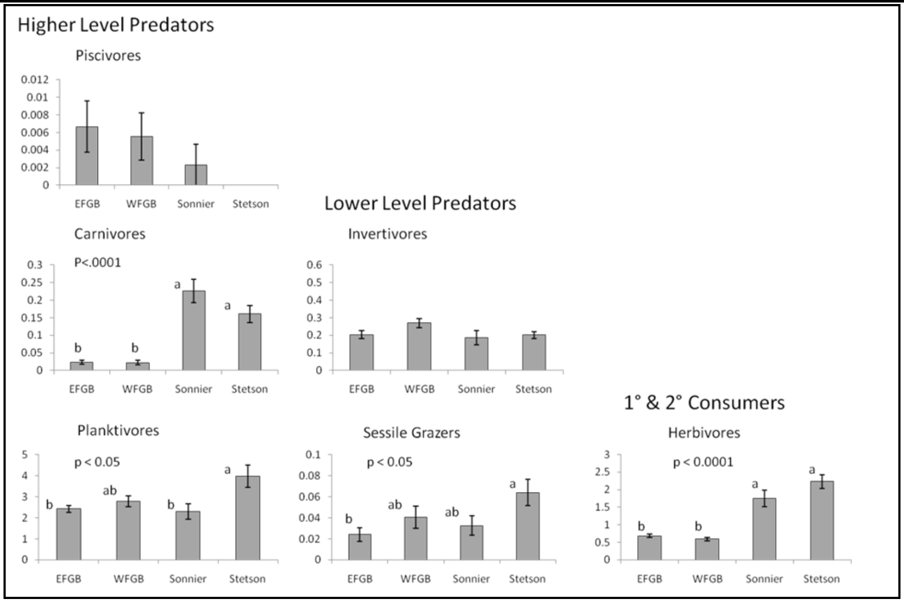

Figure 3. Overall mean densities of each feeding guild at each study site. Densities are reported as the number of individual fish per square meter. Error bars represent one standard error. P-values denote feeding guilds that showed significant differences in density among banks (ANOVA), and lowercase letters denote bank groupings based on post-hoc tests (Tukey).

Table 1. Description of major categories used for trophic guild analysis (derived from Bohnsack et. al. 1999 and Newman et. al. 2006).

Trophic Categories			
Predators	Piscivores	Higher level predators, feed almost exclusively on fish	e.g. black grouper
	Carnivores	Lower level generalist predators, feed on smaller benthic invertebrates and fish	e.g. rock hind
	Invertivores	Lower level predators, feed almost exclusively on mobile benthic invertebrates	e.g. tomtate
1˚ & 2˚ Consumers	Planktivores	Feed on small zooplanktonic organisms, forage midwater and often form schools	e.g. bluehead wrasse
	Sessile Grazers	Feed on sedentary benthic organisms such as coral, sponges, tunicates, etc.	e.g. queen angelfish
	Herbivores	Primary consumers, feed on algae, plant material, and detritus	e.g. yellowtail damsel