GULF OF MEXICO FISHERY MANAGEMENT COUNCIL

FINAL REPORT

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TITLE: Recruitment and Habitat Use of Reef Fishes on Low and High Diversity Coral Reefs in the Northwestern Gulf of Mexico

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PROJECT SUMMARY

This project builds on a previous effort to characterize reef fishes and corals on low diversity, mid and outer shelf banks (Sonnier, McGrail) in the northwestern Gulf of Mexico (Gulf). Previously, we investigated recruitment patterns through fine-scale surveys of low diversity reefs and collected new recruits off experimental settlement structures. The aim of the current work was to expand the scope of our recruitment survey to include both low and high diversity coral reef habitats in the northwestern Gulf. Specifically, we quantified the density and diversity of juvenile reef fishes present on two low diversity (Sonnier, Stetson) and two high diversity (East and West Flower Garden) banks. This work was originally planned for the summer of 2008; however, our first two scheduled trips on the RV MANTA (new vessel of the NOAA Flower Garden Banks National Marine Sanctuary) were cancelled by NOAA due to mechanical problems. In response, our survey period was changed to September when another vessel (RV Fling) was available. Unfortunately, due to Hurricane Ike, which caused the Galveston Campus of TAMUG to close for the entire fall semester, this vessel was no longer available for research during the planned survey period. In response, all surveys were conducted in the summer of 2009 and the sampling effort (number of cruises) and temporal scope increased because we were able to combine vessel time from 2008 and 2009.

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Overall, 11,234 fishes representing 70 species were observed during visual surveys (Appendix I). Six families represented the majority of fishes surveyed with individuals from the families Pomacentridae and Labridae accounting for 89 to 94% of the total fish composition at each bank (Figures 1 and 2). In addition, six species that represented 76% of the total abundance of fishes accounted for 95% of the variability in fish assemblage structure among banks using non-parametric statistical analysis. In order of decreasing importance these species included bluehead, cocoa damselfish, brown chromis, purple reeffish, sunshinefish, and bicolor damselfish. Fish assemblage structure varied across banks and survey months 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, Stetson) banks, but were similar within high and low diversity banks. Moreover, fine-scale associations between reef-fish recruits and habitat characteristics were detected when diver-based counts were linked to specific habitat features, including habitat complexity and substrate type/cover.

INTRODUCTION

The Gulf of Mexico Fisheries Management Council shares responsibility for effective management of coral reef-based resources in the southeastern U.S. The Council has primary responsibility for federally-managed corals and reef fish stocks throughout the Gulf of Mexico, including coral reef habitats from western Florida (e.g., Florida Middle Grounds) to the Texas coast (e.g., Flower Garden Banks). 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 low and high diversity reefs 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 reefs 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 diversity banks with hydrocorals (i.e., *Millepora*) and sparsely distributed individual coral colonies (Sonnier Bank, Stetson Bank) to high 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 diversity (Sonnier, Stetson) and two high diversity (East and West Flower Garden) reefs. Spatial and temporal variability in community structure was examined during 2009, and associations between juvenile reef fishes (i.e., recruits) and habitat variables were also assessed. Unfortunately, data on recruitment to these natural banks and their potential role as nurseries is incomplete, and therefore additional information is needed to fully understand the causes of population change for reef fish populations in the Gulf. As a result, this research is directly relevant to the recommendations outlined in the Magnuson-Stevens Fishery and Conservation Act (Sustainable Fisheries Act 1996) regarding the identification and description of EFH for species under federal fishery management. Furthermore, the lack of detailed information on recruitment to these areas, their importance as nursery habitat, and the quantification of adverse effects from fishing and non-fishing activities have hampered the Council's abilities to take actions to enhance conservation of these essential areas. Continued funding of the Council's coral reef priorities will greatly improve the knowledge needed to address these shortcomings related to documenting essential nursery habitat of reef fishes.

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 (note: original project was based only on two 5-d cruises in June and September), overlapping the focal seasons from previous years. Visual surveys were conducted on the crests of all four banks using a line transect method. A fraction of each bank was accessible for diver surveys (areas < 30 m), and we partitioned diver counts evenly among the available space at each bank. Using 2 to 4 diver teams per cruise, approximately 6-24 transects were completed at each bank during a cruise, and this level of effort provided the statistical sensitivity to detect moderate to large differences in fish abundance.

Habitat characteristics were also investigated by divers. A second diver from each census team completed a series of photographs of randomly selected 0.25-m^2 quadrats (10 per transect) using a standardized grid overlay to account for image distortion. After counts and photographs were completed by divers 1 and 2, surface complexity (i.e. rugosity) was quantified for each transect surveyed. Surface rugosity (defined here as the contour distance of substrate divided by straight line distance) was measured using the technique outlined by Rooker et al. (1997). In addition, photographs were taken along each transect to characterize the fouling community (i.e. percent cover of corals, algae, sponges, etc.) to understand relationships between habitat and juvenile reef fish assemblages. In 2009 surveys, a total of 2654 photographs was obtained, representing 276 transects. Due to safe diving considerations and minor equipment problems some transects had fewer than the target of 10 pictures. In addition, ambient conditions and camera angle limit the information that can be derived from some of these photographs. A sub-sampling routine is currently being used to generate a robust set of samples to compare different sites. The images are undergoing digital processing to characterize habitat based upon percent cover of major sessile benthic species. Distance calibration is being accomplished with an object of known dimensions that was photographed with the plot, and area measurements are being calculated by digitally outlining benthic species (e.g., individual corals and sponges) or groups of species (e.g., mixture of branching, crustose coralline, and lobophora algae) in the image. This work is being accomplished with ImageJ, a JAVA-based image analysis program available from

NIH.

Spatial and temporal variability in community structure

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 (Clark 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).

Species richness (S), Pielou's evenness (J'), and Shannon diversity (H') were calculated and analyzed individually with a two-factor analysis of variance (ANOVA), with bank and survey month as main effects. Densities of the six most abundant species were also analyzed with a two-factor ANOVA (main effects: bank, survey month). The equal variance assumption for each model was assessed by examining plots of the residuals versus the predicted values, and normality was tested with a Shapiro-Wilk test. *A posteriori* differences among means were detected with Tukey's HSD test with an alpha level of 0.05.

RESULTS

Count summary

Overall, 11,234 fishes representing 70 species were enumerated during visual surveys (Appendix I). Nearly 99% of all fishes counted were from six families: Pomacentridae (damselfishes), Labridae (wrasses), Tetraodontidae (puffers), Serranidae (groupers and sea basses), Scaridae (parrotfishes), and Gobiidae (gobies). Pomacentrids and labrids together accounted for 89 to 94% of the total reef fish composition at each bank (Figures 1 & 2). Mean density of pomacentrids ranged from approximately 1.5 to 4.5 indiv./m^2, with densities being significantly higher on low diversity (Stetson and Sonnier) than high diversity (East and West Flower Garden) banks (ANOVA, $P < 0.05$) . In contrast, mean density of labrids were statistically similar among the four banks surveyed (ANOVA, $P > 0.05$), with densities between 1.0 and 1.5 indiv./m^2. Mean densities of remaining families examined were less then 1.0 indiv./m^2 on all banks surveyed and bank-specific differences were negligible (ANOVA, $P > 0.05$).

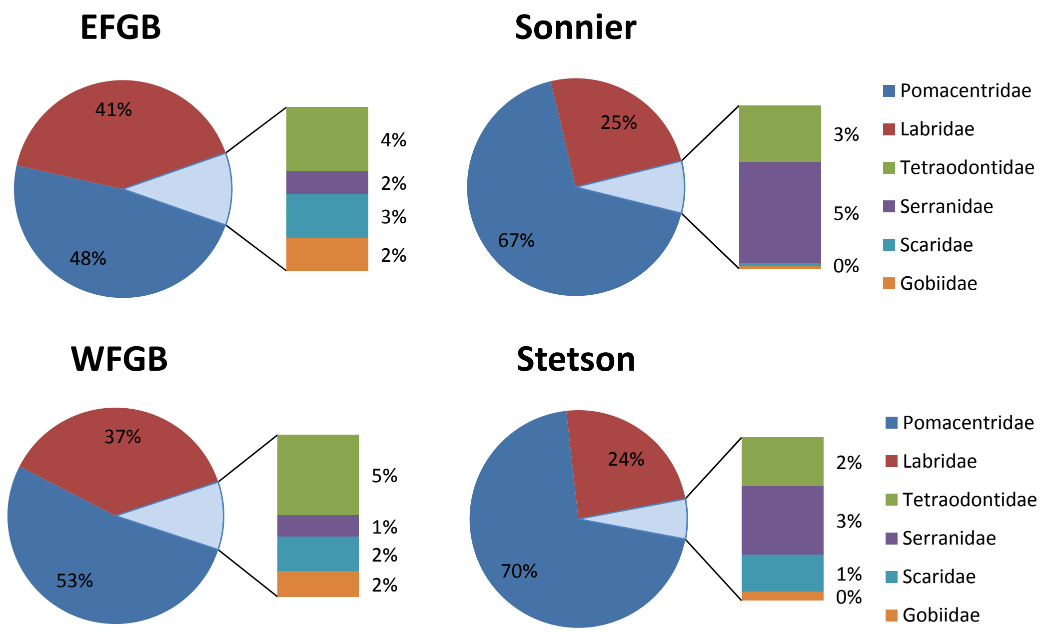

Figure 1.   Percent composition of dominant fish families on high diversity (East and West Flower Garden= EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico.

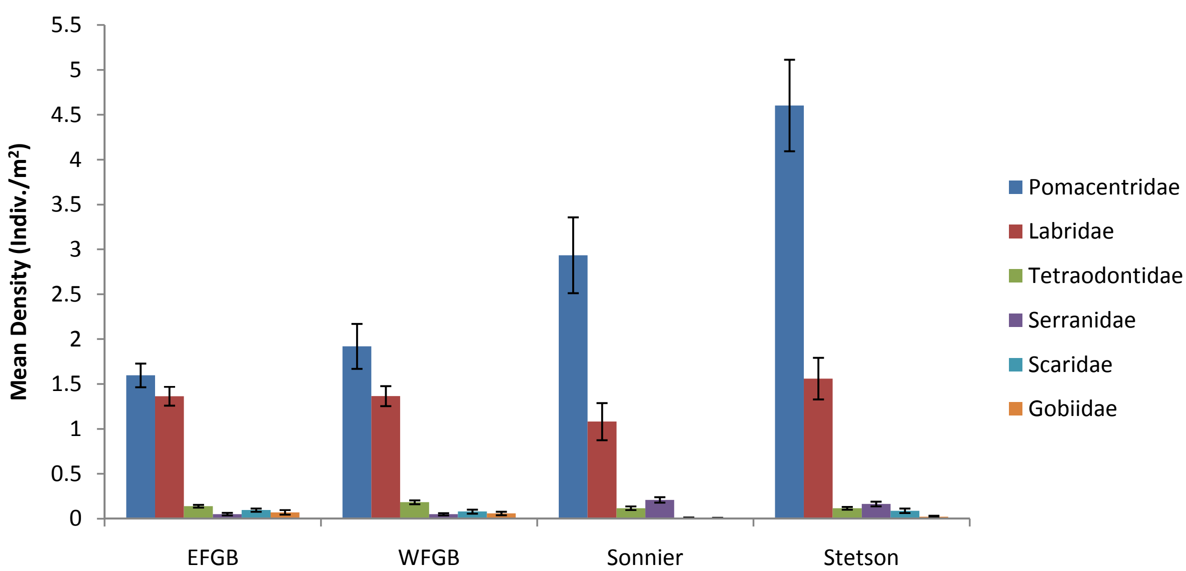

Figure 2. Mean densities of the six most abundant fish families on high diversity (East and West Flower Garden= EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico

The most abundant species were bluehead (*Thalassoma bifasciatum*), cocoa damselfish (*Stegastes variabilis*), brown chromis (*Chromis multilineata*), purple reeffish (*Chromis scotti*), sunshinefish (*Chromis insolata*), and bicolor damselfish (*Stegastes partitus*) (Figure 3, Table 1). Bank-specific differences in mean density were detected for cocoa damselfish and brown chromis with higher densities on Sonnier and Stetson banks (ANOVA, Tukey HSD, $P < 0.05$), and higher density of purple reeffish on Stetson than both high diversity banks ($P < 0.05$). No differences were detected for bluehead and bicolor damselfish; however, density of sunshinefish was significantly higher at West Flower Garden Bank than both low diversity banks (ANOVA, Tukey HSD, $P < 0.05$). Moreover, significantly higher densities of both cocoa damselfish and purple reeffish were found in later survey months (August and September) than earlier months ($P < 0.05$), but monthly density differences were negligible for the other species.

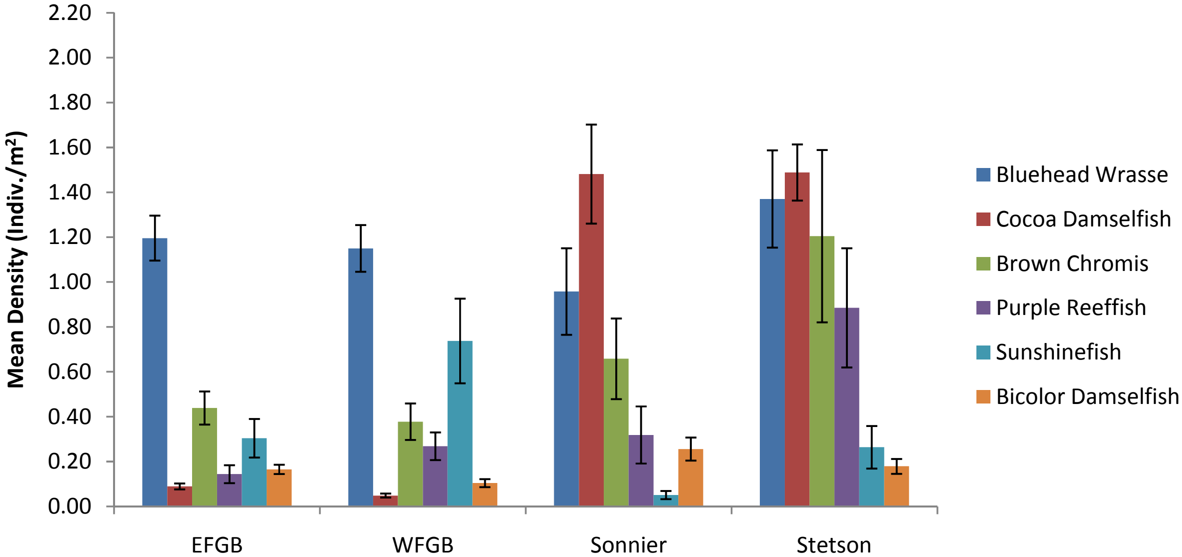

Figure 3. Mean densities of the six most abundant species on high diversity (East and West Flower Garden= EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico.

Community Structure

Fish 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 3 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 3). 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. Specifically, bluehead contributed 16 to 24% of the total dissimilarity in assemblage structure between high and low diversity banks by survey month.

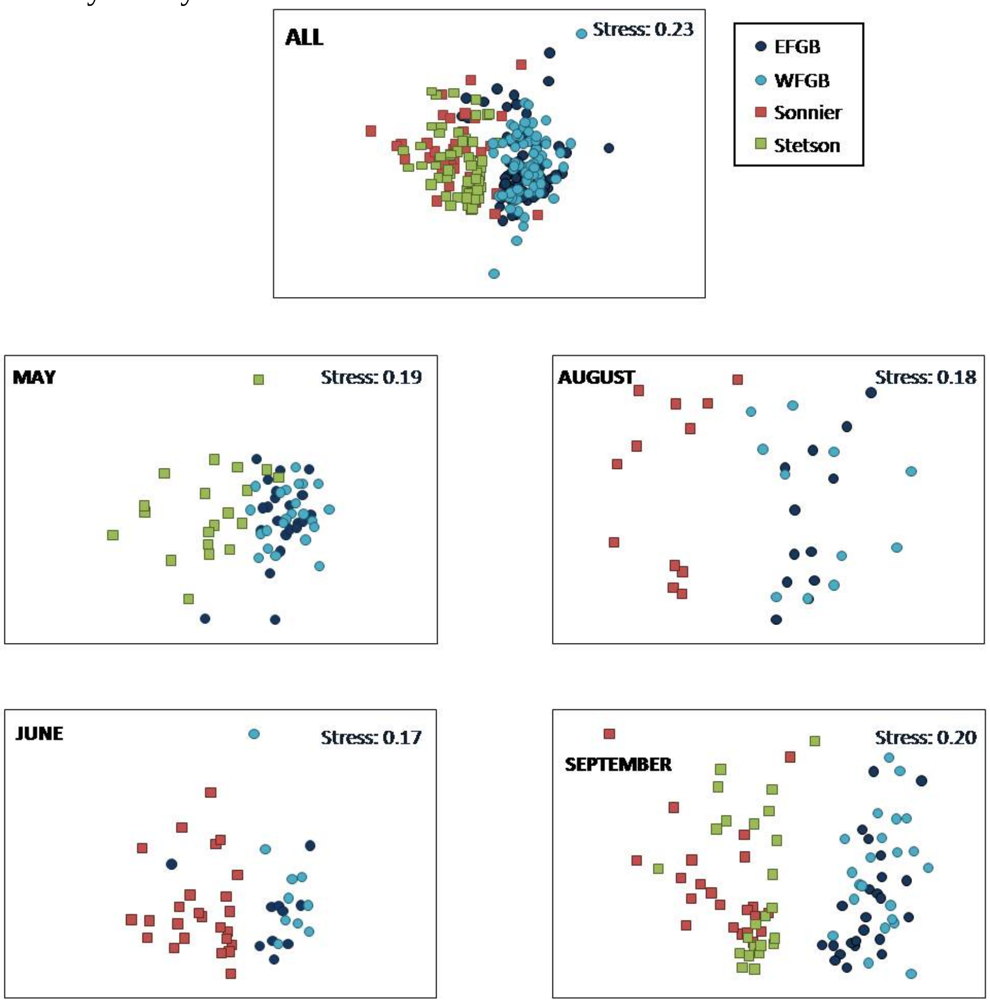

Figure 4. Multi-dimensional scaling plots of fish assemblages surveyed on high diversity (East and West Flower Garden= EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico from monthly surveys (May to September, 2009). July surveys are only shown in the combined plot due to limited surveys that only occurred at EFGB and WFGB. Stress coefficients represent goodness-of-fit criteria.

Diversity indices

Species richness (S) and evenness (J') did not significantly differ among banks (ANOVA, $P > 0.05$). Shannon diversity (H') was significantly lower at Sonnier Bank than the other three banks examined (ANOVA, $P < 0.05$) (Figure 5), but these three banks had similar diversity to one another across survey months. Temporal differences were found for all three indices and *post-hoc* differences showed S was significantly higher in August than May, June, and July, and J' was higher in May than June (Figure 5). Lastly, H' was significantly higher in August and September than earlier months surveyed (May and June) (Figure 5).

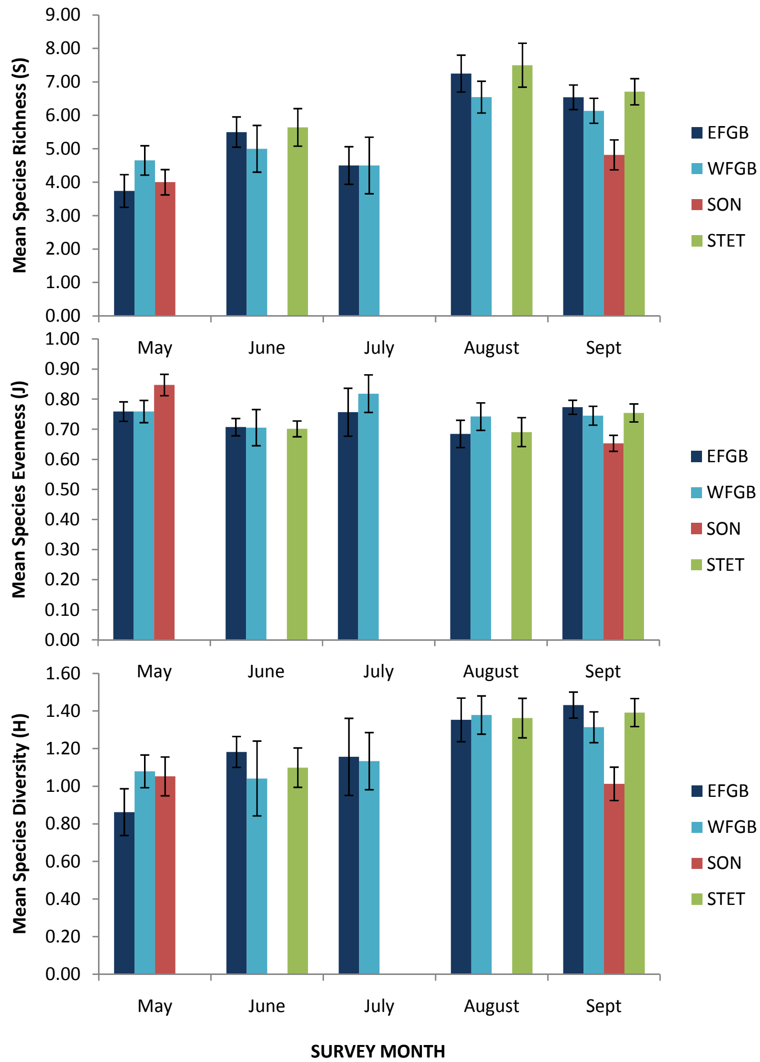

Figure 5. Mean species richness (S), evenness (J'), and Shannon diversity (H') indices at each bank by survey month. Missing bars represent no data. Bank codes: EFGB = East Flower Garden Bank; WFGB = West Flower Garden Bank; SON = Sonnier Bank; STET = Stetson Bank.

Habitat selection

Species richness (S) of reef fishes on high and low diversity banks was positively related to substrate complexity ($P < 0.05$), albeit coefficients of determination were low with less than 10% of the observed variance explained by rugosity (Figure 6). Positive relationships between habitat complexity and species richness have been reported in other natural reef systems (Hixon and Beets 1989, Rooker et al. 1997). Thus, the community structure of juvenile reef fishes present on low and high diversity banks in the northwestern Gulf is likely influenced profoundly by the degree of substrate complexity, with more complexity leading to higher diversity and biomass of reef fish recruits.

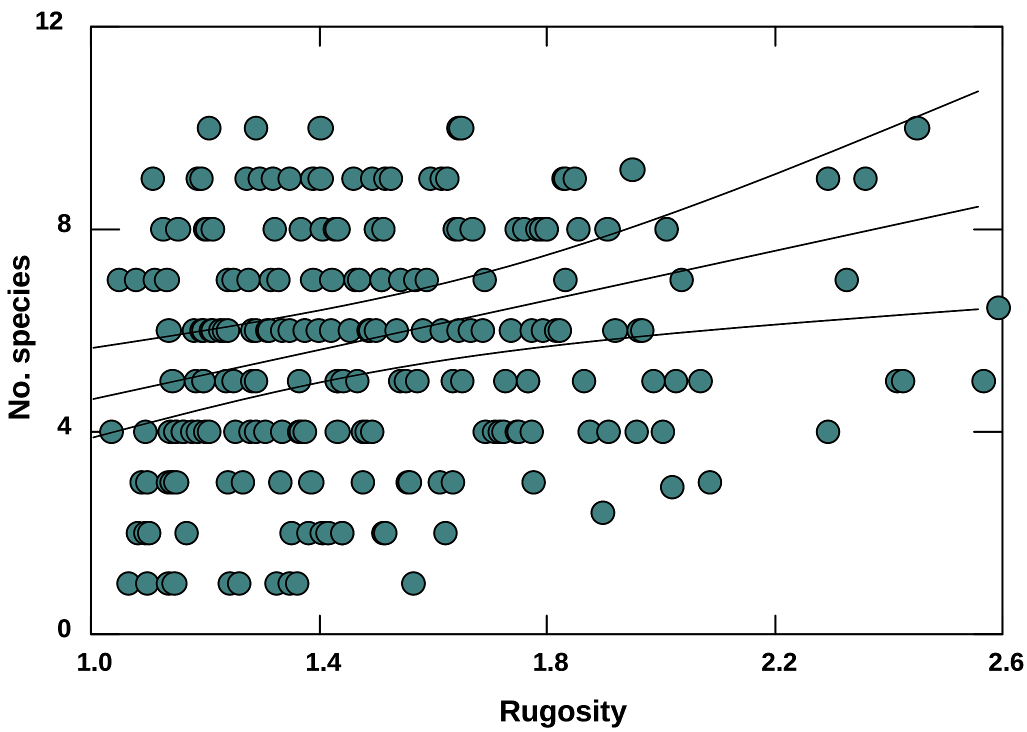

Figure 6. Relationship between rugosity and species richness (S) for all transects conducted on high diversity (East and West Flower Garden= EFGB & WFGB, respectively) and low diversity (Sonnier, Stetson) banks in the northwestern Gulf of Mexico.

We are also completing our image analysis work on photographs collected from May through September during transect surveys to better characterize microhabitats used by recruits. From the 2,654 images, we will quantify habitat based upon percent cover of major sessile benthic species (Figure 7). Distance calibration is being accomplished with an object of known dimensions that was photographed with the plot, and area measurements are being calculated by digitally outlining benthic species or groups of in the image. This work is being accomplished with ImageJ, a JAVA-based image analysis program available from NIH.

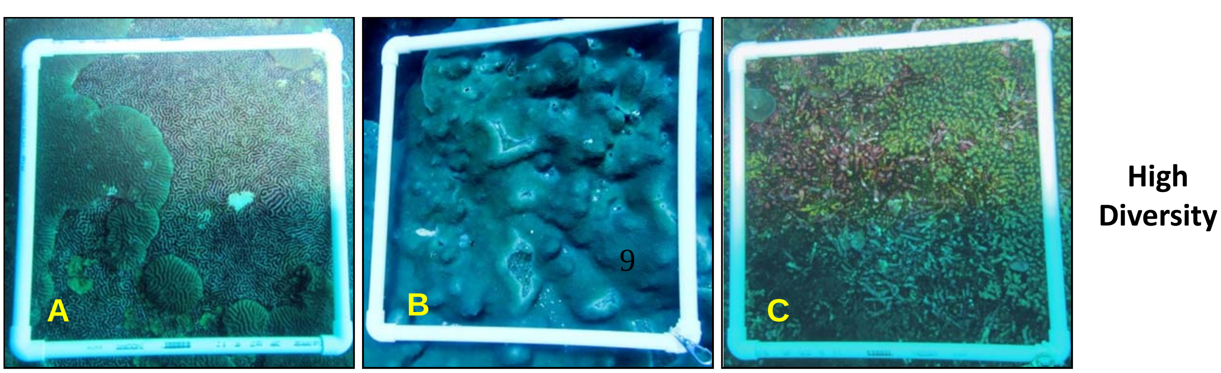

Figure 7. Example of digital images processed to characterize and quantify microhabitats (e.g . percent cover) on high (A, B, C) and low diversity (D, E, F) banks in the northwestern Gulf of Mexico; **A**) brain coral (*Colpolphyllia* spp.), **B**) star coral (*Montastraea* spp.), **C**) finger coral (*Madracis* spp.), **D**) bare rock, **E**) mixed algae (primarily Clorophyta), **F**) sponge (*Irciniidae* spp.).

Final Remarks

Both high and low diversity banks surveyed support diverse assemblages of juvenile reef fishes, with communities comprised primarily of pomacentrids, labrids, tetraodontids, serranids, scarids, and gobiids. Assemblages of reef fish recruits were similar in many respects to adult assemblages reported previously on natural and artificial reefs in the Gulf of Mexico (Rezak et al. 1985, Dennis and Bright 1988), including the numerical dominance of pomacentrids and labrids (Rooker et al. 1997). Despite apparent similarities, significant differences in fish assemblage structure were observed between high diversity (East and West Flower Garden) and low diversity (Sonnier, Stetson) banks, suggesting that the functional role of the two reef types is probably different. Moreover, we found several "indicator species" that may be useful when attempting to evaluate bank-specific assemblage structure or function. We also observed that community structure within high diversity or within low diversity banks was similar, indicating that mid-shelf banks separated by great distances (Stetson and Sonnier ~ 200 km apart) may function similarly in their role as nurseries of reef fishes.

Raw data files (visual counts, digitize images) will be posted on our web site (www.tamug.edu/rooker) in early 2010, and these data will be accessible to the GMFMC, the Flower Garden Banks National Marine Sanctuary staff, and other interested parties.

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Appendix I. Abundance, percent frequency of occurrence (based on transects), and percent juveniles of all fish taxa observed at high diversity (East and West Flower Garden) and low diversity (Sonnier, Stetson) banks throughout the 2009 sampling period.

		High Diversity			*Low Diversity*		
Species	Common Name	N	% freq occur	% juv	N	% freq occur	% juv
Apogon spp.		0	-	-	22	3.8%	13.6%
Diodon holocanthus	Balloonfish	1	0.7%	0.0%	0	-	-
Sphoeroides spengleri	Bandtail Pufferfish	0	-	-	2	1.9%	0.0%
Prognathodes aya	Bank Butterflyfish	1	0.7%	0.0%	0	-	-
Stegastes partitus	Bicolor Damselfish	199	58.5%	53.3%	219	60.6%	72.1%
Melichthys niger	Black Durgon	2	0.7%	0.0%	0	-	-
Mycteroperca bonaci	Black Grouper	1	0.7%	0.0%	0	-	-
Chromis cyanea	Blue Chromis	164	38.1%	61.0%	20	6.7%	85.0%
Acanthurus coeruleus	Blue Tang	14	7.5%	14.3%	1	1.0%	0.0%
Thalassoma bifasciatum	Bluehead	1725	94.6%	93.6%	1248	76.0%	88.4%
Coryphopterus glaucofraenum	Bridled Goby	1	0.7%	0.0%	0	-	-
Chromis multilineata	Brown Chromis	601	53.7%	68.7%	1018	51.9%	79.3%
Centropyge argi	Cherubfish	1	0.7%	0.0%	2	1.9%	100.0%
Halichoeres maculipinna	Clown Wrasse	0	-	-	1	1.0%	0.0%
Stegastes variabilis	Cocoa Damselfish	102	44.2%	49.0%	1545	98.1%	97.9%
Cephalopholis fulva	Coney	1	0.7%	0.0%	0	-	-
Haemulon melanurum	Cottonwick	0	-	-	1	1.0%	0.0%
Clepticus parrae	Creole Wrasse	42	8.2%	83.3%	0	-	-
Paranthias furcifer	Creolefish	31	8.2%	41.9%	9	3.8%	88.9%
Acanthurus chirurgus	Doctorfish	1	0.7%	100.0%	7	4.8%	42.9%
Stegastes adustus	Dusky Damselfish	51	19.0%	80.4%	358	43.3%	98.9%
Pomacanthus paru	French Angelfish	0	-	-	19	13.5%	73.7%
Gymnothorax miliaris	Goldentail Moray	0	-	-	1	1.0%	0.0%
Gnatholepis thompsoni	Goldspot Goby	1	0.7%	0.0%	8	1.9%	25.0%
Lutjanus griseus	Gray Snapper	0	-	-	10	5.8%	0.0%
Balistes capriscus	Gray Triggerfish	0	-	-	6	1.9%	0.0%
Cephalopholis cruentata	Graysby	25	15.0%	20.0%	11	10.6%	72.7%
Prognathodes aculeatus	Longsnout Butterflyfish	7	4.1%	0.0%	0	-	-
Elacatinus oceanops	Neon Goby	93	24.5%	29.0%	7	3.8%	28.6%
Acanthurus bahianus	Ocean Surgeonfish	5	3.4%	0.0%	16	7.7%	25.0%
Canthidermis sufflamen	Ocean Triggerfish	0	-	-	2	1.0%	0.0%
Halichoeres caudalis	Painted Wrasse	0	-	-	3	1.0%	100.0%
Liopropoma rubre	Peppermint Bass	1	0.7%	0.0%	0	-	-
Halichoeres radiatus	Puddingwife	0	-	-	2	1.9%	0.0%
Chromis scotti	Purple Reeffish	301	32.7%	92.7%	677	43.3%	99.1%
Gymnothorax vicinus	Purplemouth Moray	1	0.7%	0.0%	0	-	-
Holacanthus ciliaris	Queen Angelfish	1	0.7%	0.0%	8	7.7%	62.5%

Species	Common Name	N	% freq occur	% juv	N	% freq occur	% juv
Synodus synodus	Red Lizardfish	0	-	-	1	1.0%	0.0%
Amblycirrhitus pinos	Red Spotted Hawkfish	6	3.4%	0.0%	2	1.9%	0.0%
Ophioblennius atlanticus	Redlip Blenny	5	2.7%	0.0%	0	-	-
Chaetodon sedentarius	Reef Butterflyfish	16	8.2%	6.3%	14	8.7%	14.3%
Holacanthus tricolor	Rock Beauty	3	2.0%	33.3%	2	1.9%	50.0%
Epinephelus adscensionis	Rock Hind	2	1.4%	0.0%	145	60.6%	6.2%
Emblemaria pandionis	Sailfin Blenny	0	-	-	1	1.0%	100.0%
Mycteroperca phenax	Scamp	1	0.7%	0.0%	23	17.3%	78.3%
Scarus spp.		68	21.1%	97.1%	26	11.5%	92.3%
Scorpaena plumieri	Scorpionfish	0	-	-	1	1.0%	0.0%
Parablennius marmoreus	Seaweed Blenny	1	0.7%	0.0%	5	1.9%	0.0%
Abudefduf saxatilis	Sergeant Major	0	-	-	36	7.7%	94.4%
Serranus spp.		4	2.0%	0.0%	0	-	-
Canthigaster rostrata	Sharpnose Pufferfish	236	77.6%	36.0%	119	60.6%	33.6%
Lactophrys triqueter	Smooth Trunkfish	13	5.4%	0.0%	2	1.9%	100.0%
Bodianus rufus	Spanish Hogfish	184	53.1%	91.3%	137	50.0%	95.6%
Sparisoma spp.		61	28.6%	83.6%	31	9.6%	100.0%
Chaetodon ocellatus	Spotfin Butterflyfish	5	2.0%	0.0%	7	3.8%	28.6%
Bodianus pulchellus	Spotfin Hogfish	21	7.5%	85.7%	17	9.6%	76.5%
Equetus punctatus	Spotted Drum	1	0.7%	100.0%	0	-	-
Pseudupeneus maculatus	Spotted Goatfish	1	0.7%	0.0%	3	1.0%	0.0%
Gymnothorax moringa	Spotted Moray	2	1.4%	0.0%	0	-	-
Holocentrus adscensionis	Squirrelfish	1	0.7%	0.0%	11	7.7%	9.1%
Chromis insolata	Sunshinefish	759	47.6%	96.0%	183	22.1%	97.8%
Stegastes planifrons	Threespot Damselfish	396	74.1%	82.8%	10	7.7%	80.0%
Mycteroperca tigris	Tiger Grouper	3	2.0%	0.0%	0	-	-
Haemulon aurolineatum	Tomtate	0	-	-	12	1.0%	0.0%
Liopropoma eukrines	Wrasse Bass	0	-	-	1	1.0%	0.0%
Mulloidichthys martinicus	Yellow Goatfish	1	0.7%	0.0%	0	-	-
Halichoeres garnoti	Yellowhead Wrasse	34	12.2%	55.9%	9	3.8%	77.8%
Mycteroperca interstitialis	Yellowmouth Grouper	5	3.4%	0.0%	1	1.0%	100.0%
Microspathodon chrysurus	Yellowtail Damselfish	0	-	-	2	1.9%	100.0%
Chromis enchrysura	Yellowtail Reeffish	6	2.0%	83.3%	2	1.9%	100.0%
Total number of taxa		52			36		
Total number of fishes		5208			6026		
Total number of juveniles		4158			5185		
Total % juveniles		79.8%			86.0%		
Total density (# fish/m^2)		3.54			5.79		

Outreach and Education:

The outreach portion of this project was completed by The Florida Aquarium included the following activities directed to the public, targeting children and guests of The Florida Aquarium:

Theme: Coral Reefs are underwater cities complete with homes, schools, restaurants, dentist offices and spas! The critters that live in this city all have an important job. They are characters acting as landscapers, farmers, teachers even police. If you look close enough you will always find that the city is awake.

Activities:

1. Coral Polyps Model – “One polyp, two polyps, three polyps…wow!”

   Purpose: Help guests understand what a coral polyp is how the animals come together to create communities.

   This consists of a framework where guests can build an individual polyp and then place the polyps together to form a colony. At the beginning of the day, for example, the framework can be completely devoid of polyps, but as each guest builds a polyp and places it on the framework a colony slowly takes shapes. Guest can come back and see how the colony has grown and taken shape as more polyps are constructed. The individual polyps are colorful and constructed so that they can easily “pop” in and out of the coral head.

   Polyps video/photos – the photos/video shows animated live coral polyps “retreating” or the living animals contrasted with their skeletons.

2. Dry erase globe – “Where in the World: Coral Reefs”

   Purpose: Help guests identify where coral reefs are located around the world. In addition to identifying major reefs around the world guests can compare where they live to Fl and the FL keys; specifically the Dry Tortugas (since our reef is modeled after a dive site there). Guests can locate where the penguins and orbicular batfish live or identify areas of the ocean where temperatures allow for reefs to grow.

3. Construct a Coral Reef – “Build an underwater city”

   Purpose: Provide guests with “clues” or steps so they can take a character add it to the reef and build an “underwater city”. We set the scene; the reef at night or the reef during the day. The steps instruct guests as to how the reef is built over time. As the steps progress more and more animals move onto the reef and the city grows.

   Construction: A board with a graphic of an ocean; waves and sun at the top. The conditions needed for a reef to form i.e. temperature and depth, are printed onto the graphic. The characters are created to look like the actual animal. Printed images are glued onto sturdy material withmagnets attached. The clue cards are made from a heavy paper and laminated and contain information such as where on the reef the creature lives, what its role on the reef is and its place in the food chain. There are also clue cards for both natural and artificial structures that provide suitable habitat for a reef to take shape.

Characters

- Coral polyps (different kinds)
- Coralline algae
- Zooxanthellae
- Giant barrel sponge
- Brittle star
- Sea cucumber
- Queen conch
- Damselfish
- Grunts
- Sea turtle
- Reef shark
- Squid
- Eel
- Squirrelfish
- Spiny lobster
- Queen triggerfish
- Orbicular batfish
- Sea urchin
- Crown-of-thorn sea star

Pufferfish
Barracuda
Parrotfish
Cleaner shrimp
pork fish
Octopus
Neon gobi

An example: Giant Barrel Sponge "the redwood of the reef":

- Habitat – mid-range to deep reef often on steep slopes; grow attached to rocks or other substrates
- Food chain- feed on microscopic organic matter and plankton
- Role- important to habitat complexity and reef health; provides shelter for animals like grouper; tissues of the sponge contain cyannobacteria symbionts. The sponges ability to filter particles (e.g. viruses, bacteria, phytoplankton) from the water column contributes to both water clarity, which is necessary to support corals and other coral reef organisms, and for the transport of carbon from the water column to the benthos, also known as benthic-pelagic coupling.
    - Note- not all information is on the clue cards, they are meant to be kid-friendly. Detailed information is included in the lesson plan as background information for education staff and volunteers to use when appropriate.

4. Printing of Coral Farm Tri-fold

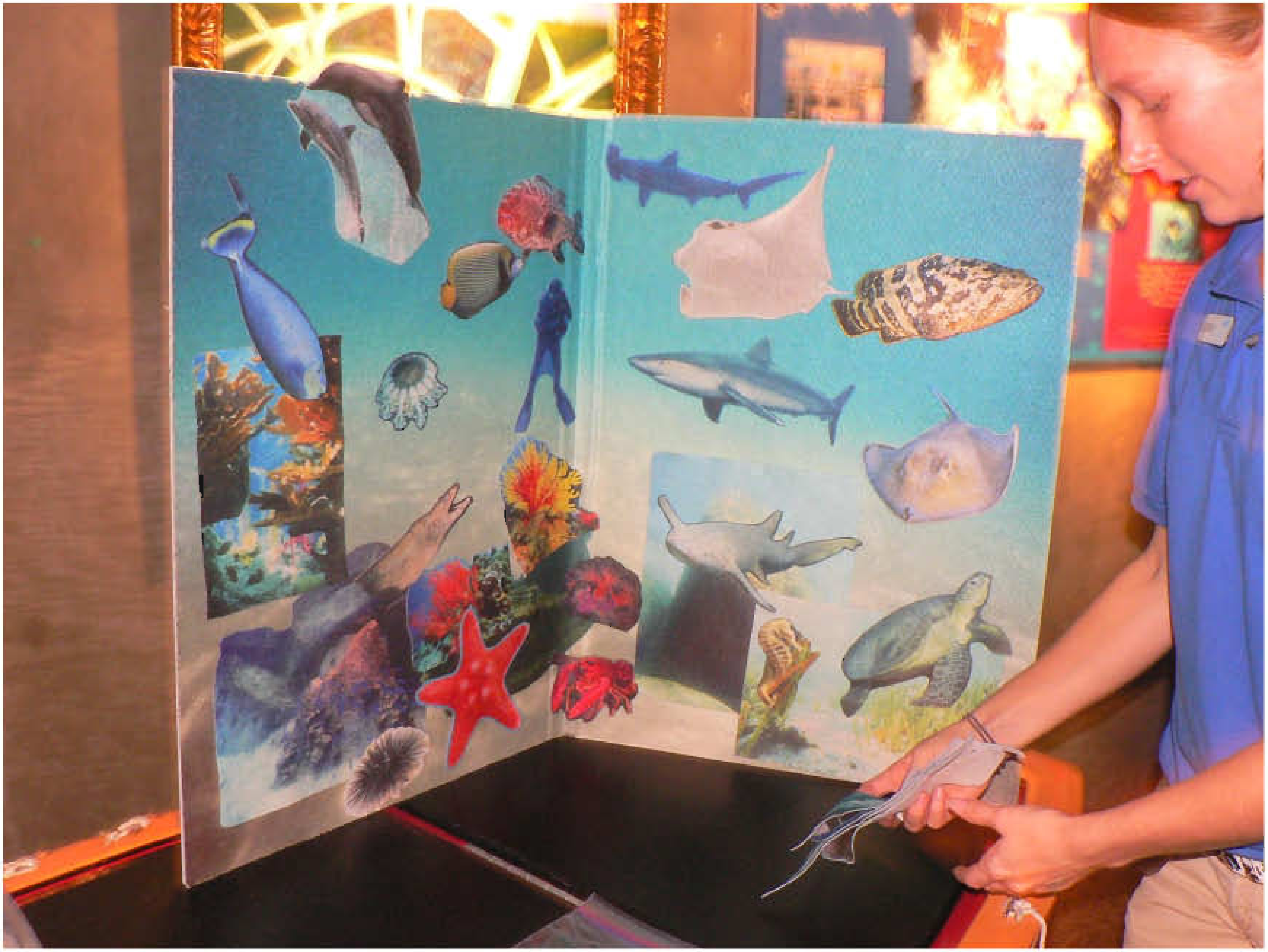
Purpose: The existing tri-fold educates our visitors about our coral farm, why we have it, what coral is, how it is potentially damaged, etc. We updated this piece and reprinted it with revised logos.


CHINA
MYANMAR
THAILAND
LAOS
CAMBODIA
VIETNAM
SINGAPORE
MALAYSIA
INDONESIA
(17000 is.)
PHILIPPINES
AUSTRALIA
PALAU
(BELAU)


Coral Farm


Coral


Coral




SYLVANIA

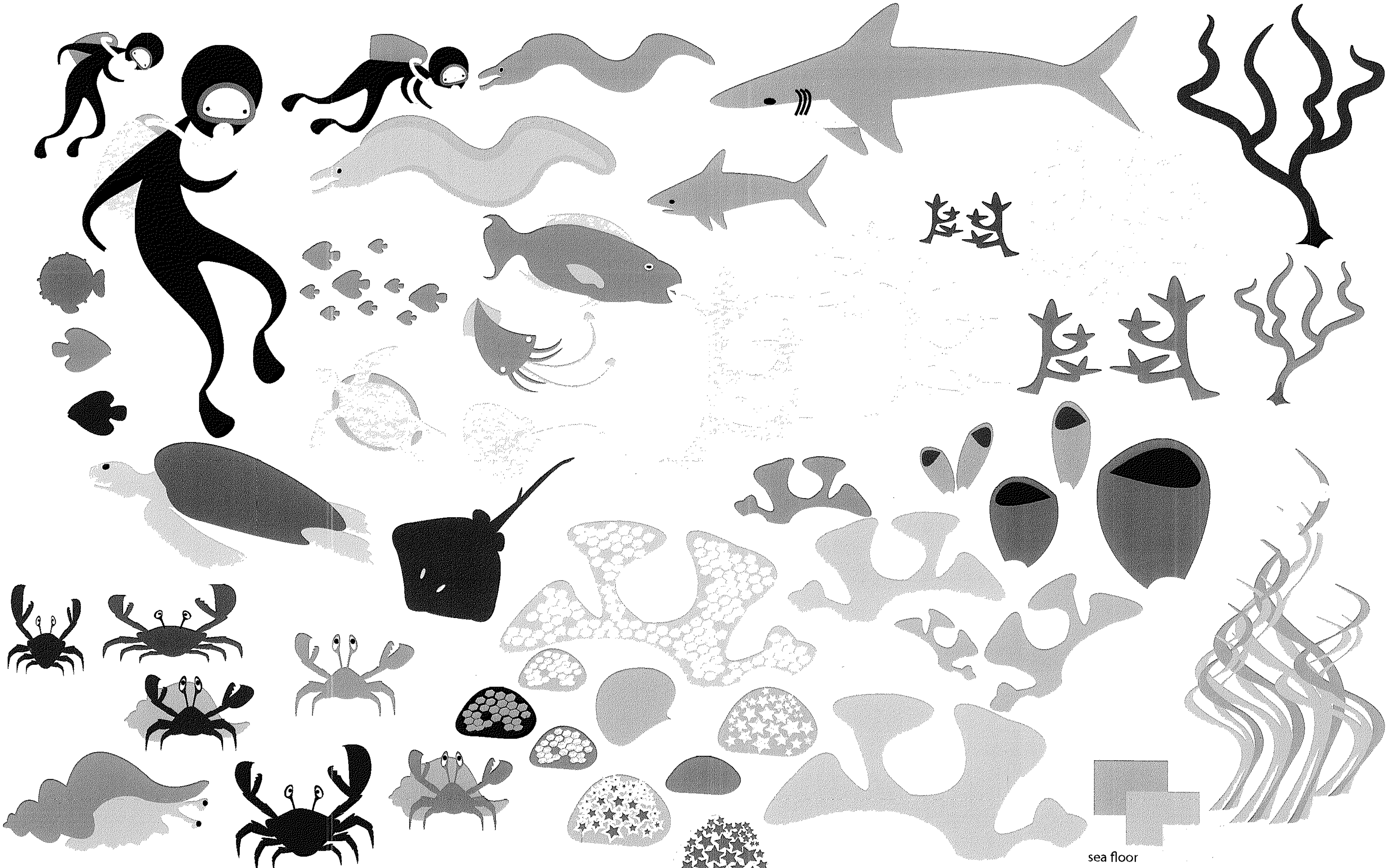

SYLVANIA


World
Treasure Hunt Map
Europe
Africa
Asia
Pacific
Ocean
Indian
Ocean
Australia
Southern
Ocean
Antarctica

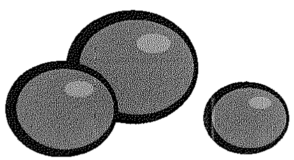
Europe
Asia
Atlantic Ocean
Pacific Ocean
Africa
South America
Indian Ocean
Australia
World
Treasure Hunt


AFRICA


COURTNEY
AFRICA
ANGOLA
ZAMBIA
TANZANIA
MADAGASCAR
SYLVANIA

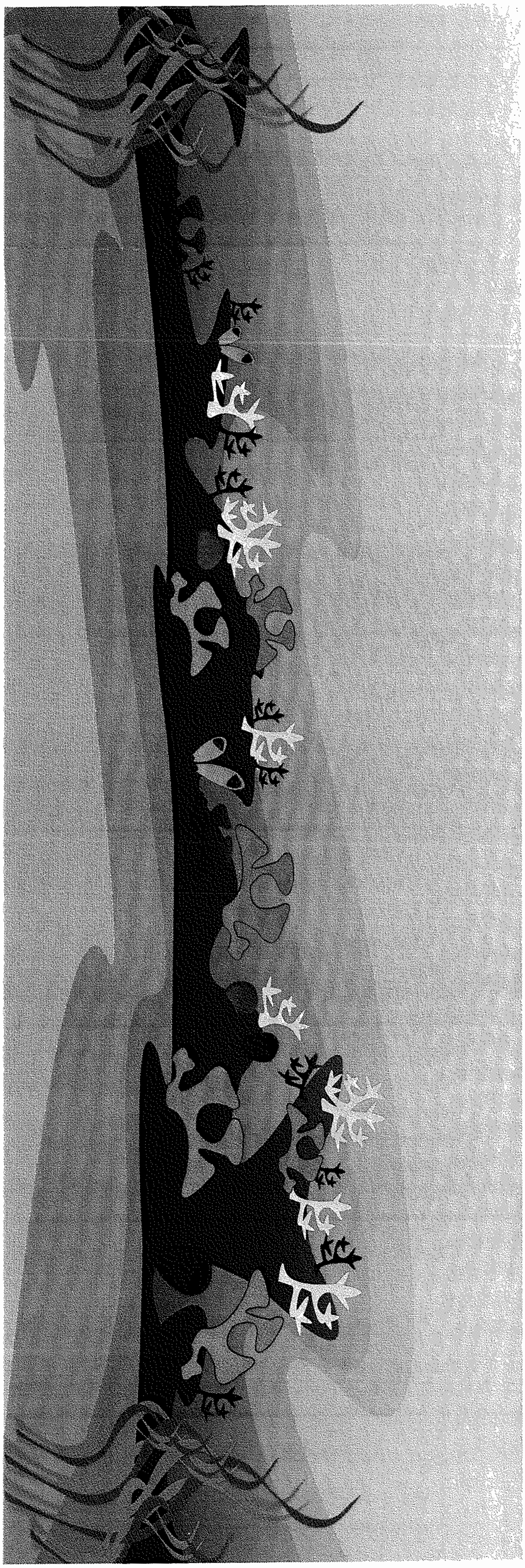

sea floor

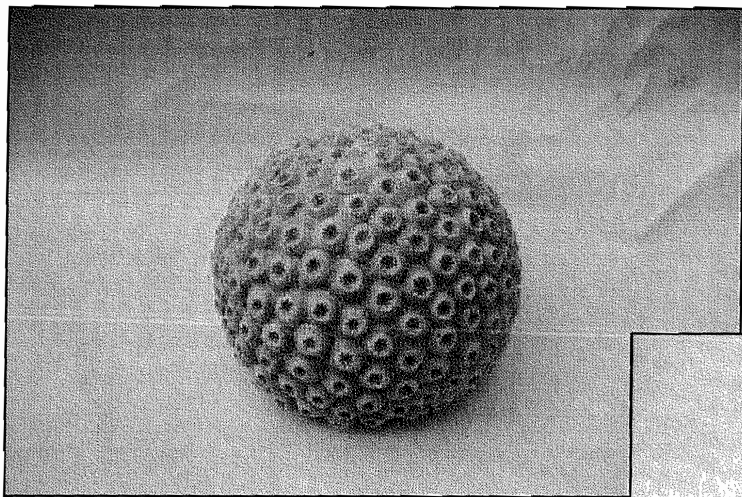
Wizard Character Concept 2



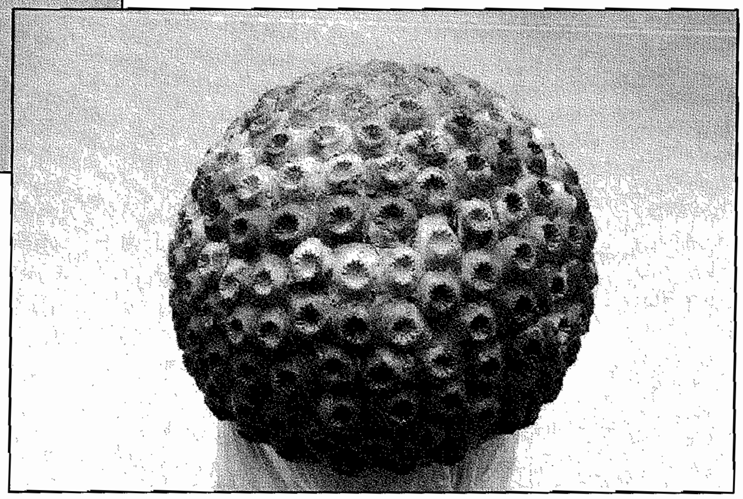
Zoothanthellae

Irish Polyp Character Concept 1





Tom Kopian
Creatures of Delight
www.creaturesofdelight.com



Reef Magic script DRAFT: September 23, 2009

Voices:
Wizard Polyp: an wizard's voice, but energetic, w/ slight English accent
Irish polyp: talks with a brogue
Southern Polyp: a good ol' southern gal
Teacher Polyp: female adult, 'broadcast voice'
Aussie Polyp: Australian accent
Valley Girl Polyp: Valley girl accent
Polyp Chorus: mix of different voices together or one at a time

Opening sequence: a diver underwater, scuba diving. View a coral reef from diver's viewpoint, thru a mask, pan side to side, bob and float, bubbles and breathing sounds. Diver's gloved hand reaches out to touch a coral... Diver hears little voice, Zoom in quickly to this "Wizard Polyp", who then pronounces a spell to stop the hand...

Wizard Polyp: (commanding, pronouncing a Latin spell "*Noli me tangere*" pronounced NO-lee may tahng-GAY-ray

Noli me tangere! Thou shalt not touch the corals!
Do you not realize how powerful we are!?

Wizard is joined by chorus of surrounding polyps: (perhaps zooming out to include other coral colonies, red, purple green etc)

Polyp Chorus, mix of voices will perform different lines:

We corals are wizards of the sea!
We do REEF MAGIC!
We build underwater cities, homes for millions of creatures!
We change the very chemistry of the ocean!

Zoom in close to

Wizard Polyp:

AND YET.... (in a raspy whisper) ***we are also very fragile, just a thin layer of life built on the homes of our ancestors. One touch can render us powerless!***

Cut to diver, who puts up hands, as a sign-language question.
Zoom out to whole reef,

Polyp Chorus VO:

How can this be? We'll tell you how!

Irish Polyp: *(modify words as needed to enhance accent)*

I remember... I was a just wee planula, adrift on the sea currents, a-searchin' for a wee bit o'rock ta call me own!

scene of drifting planula (and several others in different colors), it lands on sunny rock, becomes a settled polyp, clones itself, grows into a shape... Zoom out to multiple polyps in a colony

Polyp Chorus VO:

Where the water is warm, and clean and clear,

and the sunlight shines down just so.

Valley Girl Polyp: *(modify words as needed to enhance accent)*

So like, FINALLY I find a place to settle down, Then, like, I copy myself over and over, again and again, because y'know, like, who wouldn't want more of me!

Polyp Chorus:

And we clone and we grow,
One polyp becomes a colony so
In time a whole coral reef is erected,
Polyps united and interconnected!

Polyp tentacles extending and withdrawing, revealing hard skeletons, waving to catch occasional drifting plankton, ...

Southern Polyp: *(modify words as needed to enhance accent)*

Now, it's true we catch the li'l plankton critters that drift by, jes' for snacks ya' understand... but I reckon we get most of our food from these special tiny plants we got, these algae that live inside us. The scientist folks, now, they call 'em zoozanthellae.

Close-up of a polyp, green red & yellow specks pulsing and sparkling, as if photosynthesizing the sunlight, they dance into the polyps.... (different shape coral colonies have green, red or yellow speckles) then we hear and watch The Zooxanthellae Song* sung to "We Are Family, by Sly &The Family Stones" with bouncing ball over lyrics in text crawl below? See: http://www.youtube.com/watch?v=wSDh94eQTAk Or http://tr.youtube.com/watch?v=jmJjD33eKDU&feature=related

Zoozanthellae (high pitched Techno sound?)

We are zoo-zan-thell-ee
I got all the polyps with me
We are zoo-zan-thell-ee
Get up ev'ry polyp and SING!

Ev'ry coral needs zooxanthellae to grow
And to reach the sky
(SKY!)
and we're inside the polyps you know
I won't tell no lie
(YEAH!)
Coral polyps need some algae inside
So they can have some fun
Just let me say we make energy
We're makin' energy right from the sun

We are zoo-zan-thell-ee
I got all the polyps with me
We are zoo-zan-thell-ee
Get up ev'ry polyp and SING!

as song finishes, pan out to reveal a bustling reef, different colors & shapes of corals, fish, crabs, eels, in fast forward reef grows in height and width,

Wizard Polyp:

And so, after thousands of years pass, one colony of polyps becomes a vast reef of many different coral colonies, growing higher and higher, like an underwater city, spreading across the sea floor.
And like any city, the reef attracts hungry newcomers...

A tentacle holding a wand appears and POOF we see live video of coral polyps, reef creatures etc. show eels in crevices, fish, crabs, tubeworms, big fish & sharks hunt above reef... then wand returns us to cartoon reef.....

Diver floats into view, and shrugs, using diver sign language to ask a question, as if "what good are reefs to ME?"

Wizard Polyp: surprised, slightly annoyed, then explaining with enthusiasm

What's it to YOU??
Coral reefs are bustling hubs of biodiversity! More different kinds of animals and plants live on reefs than in any other ocean habitat.
That biodiversity means reefs are marvelous places to discover new medicines. POOF to images of medicines

Teacher Polyp:

Coral reefs are the largest living structures on the planet! Reefs protect shorelines during storms... POOF to images of storm pounding a reef
And over 500 million people depend on coral reefs for their food and livelihoods. POOF to video of fish & divers on a reef

Wizard Polyp:

Even though we polyps are tiny...
...as a community of millions, we have INCREDIBLE POWER!
(suddenly worried, concerned...)
But now we need your help. Higher ocean temperatures make it hard for our zooxanthellae plants to thrive. Show bleached coral, colorful but sweaty specks grumble about the heat, then drift away out of the polyps

Aussie polyp: *(modify words as needed to enhance accent)*

Crickee, this pollution in the sea t'day, it's makin' the ocean more acidic, and that means it's harder for us to make our hard skeletons. Show cars, pollution, casts cloud over ocean, brown specks float down into sea, corals collapsing

Southern Polyp: *(modify words as needed to enhance accent)*

An' all this trash in the ocean, it's jes smotherin' us! Ya'll's got to do somethin' about this here trash... Old plastic bag entangled on a reef (video or animated) and fish net drifts over reef? Corals coughing...

Diver says in sign language, "but how can I help?"

Wizard Polyp:

How can you help, you ask? You can do much to keep the Reef Magic alive. One thing is to simply put trash where it belongs.

Teacher Polyp:

Recycle whatever you can. Plastic in recycle bin
And even better, just use less stuff in the first place!

Valley Girl Polyp: *(modify words as needed to enhance accent)*

When you like, go SHOPPING, like when-eveuh.., bring your own bags to the store. It's like, totally cool. Cloth bag

Irish polyp:

An' turn the lights off when yer not in the room, now will yeh? A light switched to OFF

Aussie polyp: *(modify words as needed to enhance accent)*

An' if yer fixin' ta go somewhere, use yer car efficiently, or take the bus or train, now!

Teacher polyp:

If we all did these simple things, we'd be helping reefs and the whole ocean too. So find out more about coral reefs…

ALL Polyps: *(modify words as needed to enhance accent)*

…and share what you learn.
Talk to your family and friends about coral reefs!!
(kids Text messaging and talking on cell phones to each other?)

Zoom out to diver, who gives the 2 thumbs up sign and points out to viewers, gestures 'you help too!'

END, while we hear "The Zooxanthellae Song" … credits, FLAq logo etc.
Credit Info to include:

This video was prepared by FLORIDA AQUARIUM with funding assistance by the Gulf of Mexico Fishery Management Council under award number NA07NMF4410115 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

Additional Resources

National Oceanic and Atmospheric Administration: Coral Reef Guide
www.coralreef.noaa.gov

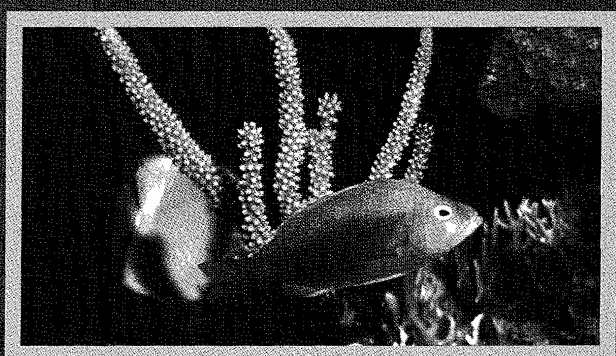
Florida Keys National Marine Sanctuary
www.fknms.nos.noaa.gov/welcome.html

The Florida Marine Research Institute
www.floridamarine.org

Coral Reef Alliance
www.coralreefalliance.org

The Florida Aquarium
701 Channelside Drive • Tampa, Florida 33602
www.flaquarium.org

ASSOCIATION OF ZOOS & AQUARIUMS



This is a publication sponsored by the Gulf of Mexico Fishery Management Council Pursuant to National Oceanic and Atmospheric Administration Award No. NA07NMF4410115.

THE FLORIDA AQUARIUM™

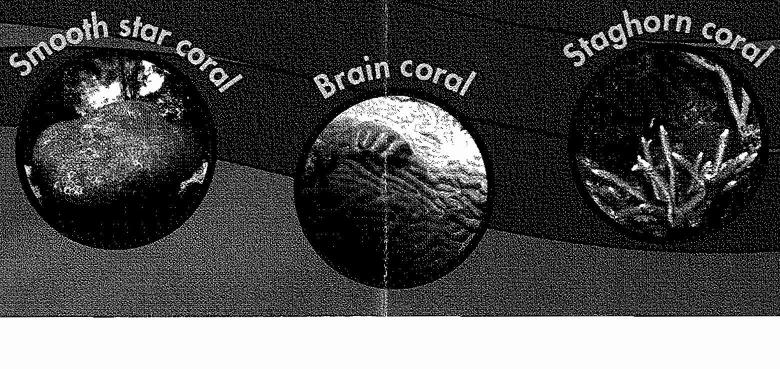
The Florida Aquarium Coral Farm

Our coral farm does not need any fields, barns or tractors, but it's full of live animals!

Photo © Paul Humann

Located on the third floor of The Florida Aquarium, our Caribbean coral farm is home to approximately 15 species of hard coral and 7 species of soft coral.

Our new web cam will allow you to view our corals! Just go to: www.flaquarium.org/splashcams



Why a Coral Farm?

If corals can be found in warm, clear, shallow seas throughout the Caribbean and around the world, why do we grow them here at the Aquarium? Fragments from these corals will be made available to other aquarium and zoo institutions, researchers and reef restoration projects in order to help conserve wild populations.

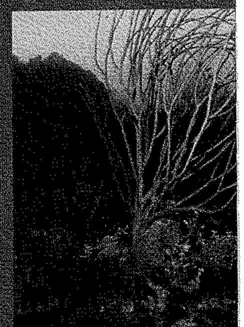
Many scientists research corals, but since they are protected, it can be very difficult to obtain a collecting permit. Our farm allows us to distribute corals to facilities conducting research. For example, many scientists are conducting growth studies on corals in captivity. Do they grow faster in captivity than on the reef? Do seasons impact growth rates? Our farm may help researchers to answer these questions.

In addition to research, our coral farm serves as a recovery site for damaged fragments obtained from ship groundings, confiscations, dredging and storms. When coral reefs are damaged, small fragments of coral are often left behind. Some of these corals are sent to us in hopes that in 4 or 5 years, they can be returned to the reefs.

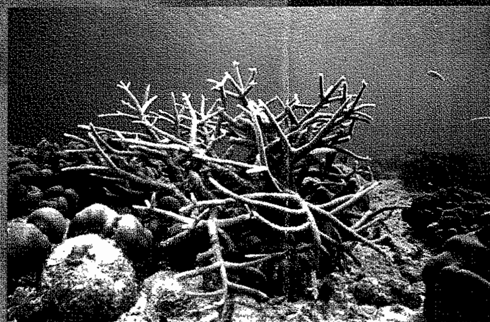
Are Corals At Risk?

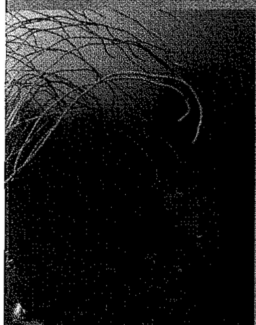
For several decades, scientists have expressed concerns about the status of coral reefs around the world. Reefs that are close to major metropolitan areas are particularly threatened, as are those near popular tourist destinations. Many factors contribute to coral reef degradation, including:

- **Sedimentation:** Occurs when sediment levels increase due to human activity such as dredging, coastal construction, or by land clearance for roads, agriculture or forestry. Corals cannot thrive in cloudy water because it blocks out essential sunlight.



• Pollution:
Environmental contamination with man-made waste. Toxins such as heavy metals (e.g. mercury, iron, cadmium), hydrocarbons (e.g. oil and diesel), synthetic chemicals (pesticides, fertilizers and anti-fouling paints), radioactivity and sewage, affect a coral reef's ability to survive and grow.





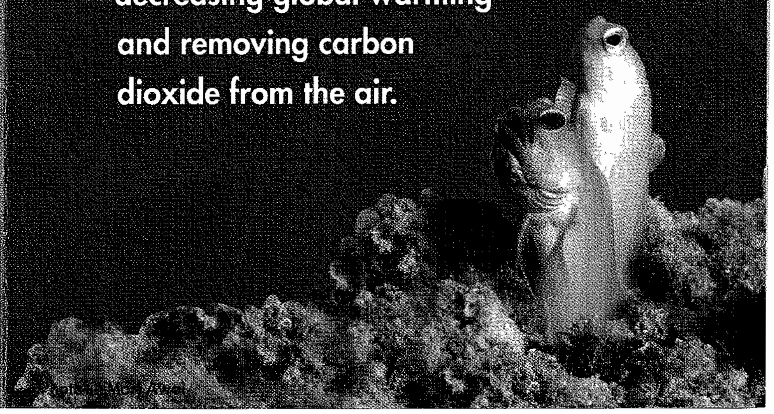
• Physical Damage:
Damage caused by anchors, fishing, dredging, boat groundings, etc. Coral polyps are very delicate animals. Although some corals use fragments as a way of building new colonies, most die when they are broken or crushed.

• Overfishing: Occurs when fish are caught faster than they can reproduce. Fishing has to be managed so that enough animals remain to replace themselves and to fulfill their roles in the coral reef system.

Why Should You Care?

We live in a challenging time. As human populations grow, our impact on the natural environment around us increases. Coral reefs are important ecosystems.

- Coral reefs provide a home for much of the seafood we eat.
- Coral reefs may provide potentially life-saving drugs.
- Coral reefs provide beach and shoreline protection against storms.
- Coral reefs are economically important tourist sites.
- Coral reefs provide a home for many species of plants and animals.
- Coral reefs may improve air quality by decreasing global warming and removing carbon dioxide from the air.



GULF OF MEXICO FISHERY MANAGEMENT COUNCIL

2007-CORAL COOPERATIVE AGREEMENT NO. NA07NMF4410115
as of
December-09
(Dollars in Thousands)

ACCOUNT	OBLIGATIONS INCURRED	2007 Coral	BALANCE REMAINING $	%
			Normal:	0.00%
Personnel Compensation:				
Council Members	0.0	0.0	0.0	100.0%
Staff - Permanents	22.1	17.1	-5.0	-29.2%
Temporaries	0.0	0.0	0.0	100.0%
Overtime Pay	0.0	0.0	0.0	100.0%
	22.1	17.1	-5.0	-29.2%
	22.1	17.1	-5.0	-29.2%
Benefits - Council's Share:				
FICA/Medicare	1.7	1.3	-0.4	-30.8%
Health Insurance	6.2	2.6	-3.6	-138.5%
Life Insurance/Disability	0.3	0.3	0.0	0.0%
Retirement	2.0	1.7	-0.3	-17.6%
	10.2	5.9	-4.3	-72.9%
Travel:				
Council Members	0.0	0.0	0.0	100.0%
Staff	0.0	2.5	2.5	100.0%
Advisory Panels	0.0	0.0	0.0	100.0%
S&S Committees	0.0	0.0	0.0	100.0%
Other	0.0	0.0	0.0	100.0%
	0.0	2.5	2.5	100.0%
Rents:				
Office Space	0.0	0.0	0.0	100.0%
Office Equipment	0.0	0.0	0.0	100.0%
Meeting Rooms	0.0	0.0	0.0	100.0%
	0.0	0.0	0.0	100.0%
Other Expenses:				
Communications-Phone	0.0	0.0	0.0	100.0%
Communications-Other	1.2	3.9	2.7	69.2%
Transportation & Shipping	0.1	0.1	0.0	0.0%
Printing	7.4	6.0	-1.4	-23.3%
Contractual Services	128.5	128.5	0.0	0.0%
Supplies	1.0	1.0	0.0	0.0%
Capital Equipment	2.2	5.0	2.8	56.0%
Non-Capital Equipment	2.4	5.0	2.6	52.0%
	142.8	149.5	6.7	4.5%
TOTAL ADMINISTRATIVE GRANT	175.0	175.0	0.0	0.0%