Marine Sanctuaries Conservation Series MSD-00-3

Flower Garden Banks National Marine Sanctuary

A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Marine Sanctuaries Division

August 2000

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Flower Garden Banks National Marine Sanctuary: A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol

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August 2000

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SUGGESTED CITATION

Pattengill-Semmens, C., S.R. Gittings, and T. Shyka. 2000. Flower Garden Banks National Marine Sanctuary: A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol. Marine Sanctuaries Conservation Series MSD-00-3. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD. 15 pp.

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ABSTRACT

The Flower Garden Banks are topographic features on the edge of the continental shelf in the northwest Gulf of Mexico. These banks are approximately 175 km southeast of Galveston, Texas at 28° north latitude and support the northernmost coral reefs on the North American continental shelf. The East and West Flower Garden Banks (EFG and WFG) and Stetson Bank, a smaller sandstone bank approximately 110 km offshore, are managed and protected as the Flower Garden Banks National Marine Sanctuary (FGBNMS). As part of a region-wide initiative to assess coral reef condition, the benthic and fish communities of the EFG and WFG were assessed using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol. The AGRRA survey was conducted during a week-long cruise in August 1999 that was jointly sponsored by the FGBNMS and the Reef Environmental Education Foundation (REEF). A total of 25 coral transects, 132 algal quadrats, 24 fish transects, and 26 Roving Diver (REEF) surveys were conducted. These surveys revealed reefs with high coral cover, dominated by large, healthy corals, little macroalgae, and healthy fish populations. The percent live coral cover was 53.9 and 48.8 at the WFG and EFG, respectively, and the average colony diameter was 93 and 81 cm. Fish diversity was lower than most Caribbean reefs, but large abundances and size of many species reflected the low fishing pressure on the banks. The benthic and fish assemblages at the EFG and WFG were similar. Due to its near pristine conditions, the FGB data will prove to be a valuable component in the AGRRA database and its resulting scale of reef condition for the region.

Keywords: Flower Garden Banks National Marine Sanctuary, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Protocol, coral reef, reef health, reef fish, monitoring

INTRODUCTION

The East and West Flower Garden Banks (EFG and WFG), located 175 km southeast of Galveston, Texas, are underwater features on the edge of the U.S. Gulf Coast continental shelf (Fig. 1). The banks were caused by the uplift of Jurassic-age salt and rise about 100 m above the surrounding depths to within 18 m of the surface. The banks support reefs that are the northernmost coral reefs in the continental U.S. The reefs of the Flower Garden Banks have been well documented and are characterized by low coral diversity, high coral cover, large coral size, and low macroalgae abundance relative to most Caribbean reefs (Bright and Pequegnat, 1974; Bright *et al*., 1974; Boland *et al*., 1983; Dennis, 1985; Rezak *et al*., 1985; Dennis and Bright, 1988; Gittings *et al*., 1993). The Flower Gardens are dominated by massive coral species and lack gorgonian and acroporid species. Fish diversity is also comparatively low (approximately 260 species), but abundances are high (Pattengill, 1998). Fish families and groups that are notably absent or represented by one or few species in low abundance include grunts (Haemulidae), snappers (Lutjanidae), and hamlets (*Hypoplectrus* sp.). The banks are year-round habitat for manta rays (*Manta birostris* and *Mobula hypostoma*) and whale sharks (*Rhincodon typus*), and serve as a winter habitat for several species of schooling sharks, including hammerhead (*Sphyrna lewini*) and silky sharks (*Carcharhinus falciformis*), and spotted eagle rays (*Aetobatus narinari*) (J. Childs, pers. comm.).

A unique feature of the EFG is a brine seep at 72 m. The seep is the only one of its kind on the continental shelf and the shallowest brine seep documented. It features a brine pool with a chemosynthetic bacterial assemblage that is known to be a significant exporter of carbon to the deeper parts of the bank (Rezak *et al*., 1985). The seep also plays a significant role in the physiographic structure of the bank due to the dissolution of salt, which results in local faulting and subsidence.

The EFG and WFG are managed and protected by the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Sanctuary Program and the Department of Interior's Minerals Management Service, and, together with Stetson Bank, they make up the Flower Garden Banks National Marine Sanctuary (FGBNMS). There is a relatively low level of anthropogenic impact on the Flower Gardens, mainly due to the distance of the banks from land. Very little fishing pressure exists on the reefs. A long-term monitoring program has been in place for approximately 20 years, and historical changes have been attributed primarily to natural events, such as the *Diadema* die-off and periodic coral bleaching. The main source of human-induced disturbance is mechanical damage due to anchors, cable drags (seismic and tow cables), and occasionally long-line fishing tackle. SCUBA diving is allowed on the banks and moorings have been installed to reduce anchor damage. Spearfishing and fishing techniques that disturb benthic habitats, including trawls, traps, and bottom long-lines, are prohibited (15CFR922.122 or http://www.sanctuaries.nos.noaa.gov/oms/pdfs/FlowerGardensRegs.pdf; Subpart L).

During the summer of 1999, an Atlantic and Gulf Rapid Reef Assessment (AGRRA) expedition to the FGB was coordinated by NOAA and the Reef Environmental Education

Foundation (REEF). This expedition was conducted in conjunction with the annual FGBNMS REEF Field Survey for volunteer fish monitoring. The Flower Garden Banks (FGB), with their impressive coral and fish assemblages, were chosen as an AGRRA survey site because the AGRRA program is particularly interested in identifying "end-member" reefs, those that are severely depressed or, like the FGB, those that are unusually luxuriant. This paper reports the results of the Flower Garden Banks AGRRA expedition.

METHODS

In August 1999, an AGRRA assessment was conducted on the reefs of the EFG and the WFG (Fig. 1). The survey team included seven scientists from the National Marine Sanctuary Program and three REEF experts. The surveys were done at the NOAA long-term monitoring sites, EFG Buoy 2 and WFG Buoy 5 (Figs. 2a and 2b). Benthic and fish surveys were conducted simultaneously. Five divers conducted coral transects and algal quadrats. Three divers conducted belt transects and roving diver (RDT) surveys to assess reef fish. All surveys were done during daylight hours, between depths of 20 and 28 m. Due to the deep minimum depth of the banks, only one depth at each site was surveyed. The AGRRA protocol is fully described on the Web site http://coral.aoml.noaa.gov/agra, and a brief description is given below.

For coral sampling, a 10 m transect line was haphazardly laid. Coral cover was estimated to the nearest 10 cm based on the number of meters of live coral beneath the line. The following was then recorded or estimated for each coral greater than 25 cm in diameter underneath the line: genus and species, maximum diameter and maximum height to the nearest 10 cm, mortality, disease, and bleaching level. Mortality was recorded as percent of the colony in plan view and was separated into recent and old death. A portion of a colony was considered recently dead if the calices were still uneroded and showed all septal features without overgrowth of encrusting organisms. The incidence of disease and the amount of recent mortality due to disease were noted. Bleaching was recorded in three categories (pale, spotty bleaching, white) as a percentage of the whole colony. Damselfish maintaining an algal garden on a colony were also recorded.

After completing the coral sampling, a 25 X 25 cm quadrat was used to estimate relative algal abundance at the 3, 5, 7, 9 m intervals along the transect. The sample quadrat was placed next to the transect line in a way that large invertebrates or large living hard corals were avoided. For each quadrat, the following was estimated: percent abundance macroalgae, turf algae, and crustose coralline algae and average macroalgae canopy height. After completion of the quadrats, all *Diadema antillarum* that could be seen in a 1 m belt along the transect line were counted. The AGRRA protocol requires that a minimum of 50 quadrats and 100 coral colonies are measured at each site.

To survey the fishes at each site, surveyors conducted 12 random belt transects (2 m x 30 m). All species of the following groups were counted: grouper (Serranidae), snapper (Lutjanidae), grunt (Haemulidae), parrotfish (Scaridae), surgeonfish (Acanthuridae), leatherjacket (Balistidae), angelfish (Pomacanthidae), and butterflyfish (Chaetondontidae). Five additional

species were also counted: yellowtail damselfish (*Microspathodon chrysurus*), hogfish (*Lacholaimus maximus*), Spanish hogfish (*Bodianus rufus*), barracuda (*Sphyraena barracuda*), and bar jack (*Caranx ruber*). The size of each fish counted was estimated and each was assigned to a size category (<5 cm, 5-10, 11-20, 21-30, 31-40, >40 cm) using a 1 m T-bar with 10 cm increments marked for scale. Grunts and parrotfishes less than 5 cm in length and the greenblotch parrotfish (*Sparisoma atomarium*) were not recorded, per the AGRRA protocol.

At least three roving diver technique (RDT) surveys were also conducted at each site. During RDT surveys, divers swam freely throughout the dive site and recorded every observed species. Average survey time was 40 minutes. At the conclusion of each survey, all recorded species were assigned one of four $\log_{10}$ abundance categories [single (1); few (2-10); many (11-100); and abundant (>100)]. The species data along, with survey time, depth, temperature, and other environmental information, were then transferred to a REEF scansheet. These sheets were returned to REEF and optically scanned into the REEF database.

Data Analysis

The benthic and fish transect data were entered into a custom Excel spreadsheet provided by the AGRRA organizing committee. REEF provided the RDT data in ASCII format.

The percent coral cover, percent mortality, mean colony size, incidence of disease and bleaching, and relative algal cover were calculated and compared between banks using a t-test. A macroalgal index, calculated as:

$$\text{Macroalgal Index} = \%\ \text{relative macroalgal cover} \times \text{canopy height},$$

was also used as a comparison metric. Using the fish transects as replicates, the average density (#/100 m^2) and size (cm) of each fish species and family recorded was calculated for each site. The average density and size of each species and family were compared between banks using a t-test. Transect data were also used to calculate biomass for each species, using standardized conversion equations (P. Kramer, pers. comm.). The RDT survey data provided a species list, and frequency of occurrence and relative abundance data for each bank. Percent sighting frequency (%SF) for each species was the percentage of dives on which the species was recorded. An estimate of abundance (Den) was calculated as:

$$\text{Density score} = ((n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)) / (n_S + n_F + n_M + n_A),$$

where n_S, n_F, n_M, and n_A represented the number of times each abundance category (single, few, many, abundant) was assigned for a given species.

RESULTS

At EFG, 160 coral colonies were surveyed on 14 transects, 67 algae quadrats examined, 15 RDT fish surveys conducted, and 12 fish belt transects conducted. At the WFG 135 coral colonies were surveyed on 11 transects, 55 algae quadrats were examined, 11 RDT fish surveys conducted, and 12 fish belt transects were performed. Survey effort and site details are given in Table 1. Overall, these surveys revealed reefs with high coral cover and large corals with low incidence of disease and mortality. The percent live coral cover was 53.9 and 48.8 at the WFG and EFG, respectively (Table 1).

Table 2 provides a summary of coral colony status, including size, mortality, and incidence of bleaching and disease. Average colony diameter at the WFG and EFG was 93 and 81 cm, respectively. At both sites, most colonies with mortality were less than 10% dead with very low recent mortality (<2.5% of the colony in plan view). Incidence of disease was minimal, but parrotfish bites were reported on approximately 10% of colonies surveyed. Pale bleaching was reported in a few colonies.

Colonies of nine species of coral were recorded in the transects at the WFG and 11 species at the EFG. Dominant corals at the WFG were *Montastraea franksii* (40% of all colonies counted), *Diploria strigosa* (27%), *Montastraea cavernosa* (8%), and *Montastraea faveolata* (7%) (Fig. 3a). Dominant corals at the EFG were *Montastraea franksii* (37%), *Porites asteroides* (16%), *Montastraea cavernosa* (13%), and *Diploria strigosa* (13%) (Fig. 3b).

Macroalgae cover was very low at both sites, representing less than 10% of the algae cover observed (Table 3). Average macroalgal height was 1.0 cm, yielding a very low macroalgal index of 3.9 and 7.8 at the WFG and EFG, respectively. A cyanobacteria mat was observed at the EFG, and was common in the algal quadrats, on the sand flats, and on several coral heads. Cyanobacteria present in quadrats were counted as turf algae in all quadrats but three, where, due to diver error, it was counted as macro.

Most of the benthic parameters were similar between the EFG and WFG. However, t-tests revealed significantly larger coral colonies at the WFG and higher relative turf algae cover at the EFG ($p<0.05$). The difference in turf algae values was most likely due to the cyanobacterial bloom on the EFG.

Average density of fishes, grouped by family, is shown in Figure 4. Parrotfish were the most abundant fish recorded in the transects. Grunts, several species of parrotfish and snapper, hogfish (*Lacholaimus maximus*), and gray angelfish (*Pomacanthus arcuatus*) were absent at both banks, a distinguishing characteristic of the Flower Garden Banks' fish assemblages (Pattengill, 1998). Average density for most families and species was similar between the EFG and WFG. The densities of graysby (*Epinephelus cruentatus*) and Spanish hogfish (*Bodianthus rufus*) at the WFG were approximately twice those at EFG (t-test; $p<0.05$). The density of the reef

butterflyfish (*Chaetodon sedentarius*) was two and a half times greater at the WFG. However, this difference was not significant (t-test; p=0.059).

A total of 117 fish species were seen by the AGRRA team during RDT surveys at the EFG and WFG. The 25 most common species, along with the %SF and Den as calculated from the RDT data, are listed in Table 4. Great barracuda (*Sphyraena barracuda*), sharpnose puffer (*Canthigaster rostrata*), and black durgon (*Melichthys niger*) were documented in all surveys. The most abundant species were: bluehead (*Thalassoma bifasciatum*), threespot damselfish (*Stegastes planifrons*), queen parrotfish (*Scarus vetula*), and the planktivorous creole fish (*Paranthias furcifer*) and brown chromis (*Chromis multilineata*). Species that were relatively common at the FGB but are rarely seen at most other Caribbean reefs include longsnout butterflyfish (*Chaetodon aculeatus*), blue angelfish (*Holacanthus bermudensis*), and several species of jacks (Carangidae). Individuals of the golden phase of the smooth trunkfish (*Lactophrys triqueter*), a phase unique to the FGBNMS (Pattengill-Semmens, 1999), were also sighted. One new record for the banks, a sharptail eel (*Myrichthys breviceps*), was recorded at the WFG. An individual of the same species was also recorded on video earlier in the summer.

An additional 15 REEF volunteers conducted 74 RDT surveys during the cruise. These data were not included in the AGRRA data set. However, they were added to the REEF database, which can be accessed from the REEF Web site (http://www.reef.org). As a result of annual REEF field surveys to the banks since 1993, the REEF database currently contains 1,495 surveys (over 1,100 survey hours) from the FGBNMS and represents a valuable source of information for the Sanctuary management. To date, 257 fish species have been documented at the FGBNMS. A comprehensive fish species list for the FGB has been published using these data (Pattengill, 1998).

Average size of parrotfish and seabass was relatively high (22 and 25 cm, respectively), most likely a result of low fishing pressure on the reefs. This resulted in relatively high biomass (Table 5). Size frequency distributions of two feeding guilds, carnivore (grouper and snapper) and herbivore (parrotfish, surgeonfish, and yellowtail damselfish (*Microspathodon chrysurus*)), are shown in Figure 5. Three-fourths of the carnivores reported were grouper, with gray snapper (*Lutjanus griseus*) making up the remainder. Approximately 45% of the carnivores recorded were greater than 31 cm in length. All size categories were documented in herbivores, with approximately 70% of individuals between 11 and 30cm. For most species, average size of species recorded in the transect surveys were similar between the EFG and WFG. Significant differences in size were detected by a t-test in the blue tang (*Acanthurus coeruleus*), princess parrotfish *(Scarus taeniopterus*), and yellowtail damselfish. Recruitment success appears to be driving these differences, with a high abundance of juvenile blue tang on the WFG and a high number of juvenile princess parrotfish and yellowtail damselfish on the EFG.

DISCUSSION

Based on the general description of a healthy system put forth by the AGRRA organizing committee, the benthos and fish condition data collected during the AGRRA assessment at the FGB indicate that the status of the reef community is relatively healthy. These reefs have low incidence of coral disease and mortality, very little macroalgae, and support a large biomass of fishes, including significant numbers of large carnivores. Data collected during this assessment also corroborate the findings of previous studies on the condition of the FGB reefs-- that these reefs have high coral cover, are dominated by large boulder corals, and support a community of low diversity, high density fishes. Pale bleaching was evident in some colonies, but in general, the Flower Garden Banks are less susceptible to bleaching than other coral reefs because they are fairly deep. The regional mass bleaching event in 1998 did not occur at the FGB.

The physical location of the FGB, as deep reefs on offshore banks far removed from land with minimal anthropogenic disturbance, put this area toward the end of the spectrum of tropical western Atlantic coral reefs. The reefs of the FGB have been and continue to be well studied. A long-term monitoring project has been in place for over 20 years. The FGB have been described as "near pristine," and provide an important piece of the regional picture of meso-American reef health. The importance of the AGRRA data collected there will become more evident when AGRRA data from dozens of sites are compiled to create a more complete picture of the current status of the western Atlantic coral reefs. In addition, the consistent application of survey methods among regional reefs should prove to be valuable for the understanding and management of these ecosystems.

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ACKNOWLEDGMENTS

This project was made possible by the AGRRA research team- S. Bernhardt (Texas A&M University), K. Deaver (REEF), S. Gittings (NOAA), D. Mizell (REEF), C. Ostrom (NOAA), C. Pattengill-Semmens (REEF), G.P. Schmahl (NOAA), T. Shyka (NOAA), P. Souik (NOAA), and M. Tartt (NOAA). The support of the *M/V Spree* crew and Rinn Boats, Inc. is appreciated. Funding support for this cruise was provided by the Flower Garden Banks National Marine Sanctuary, the Science Team of the National Marine Sanctuary Program, and REEF and its volunteers. The surveys provided by the REEF volunteers are also greatly appreciated.

Appendix I
Tables and Figures

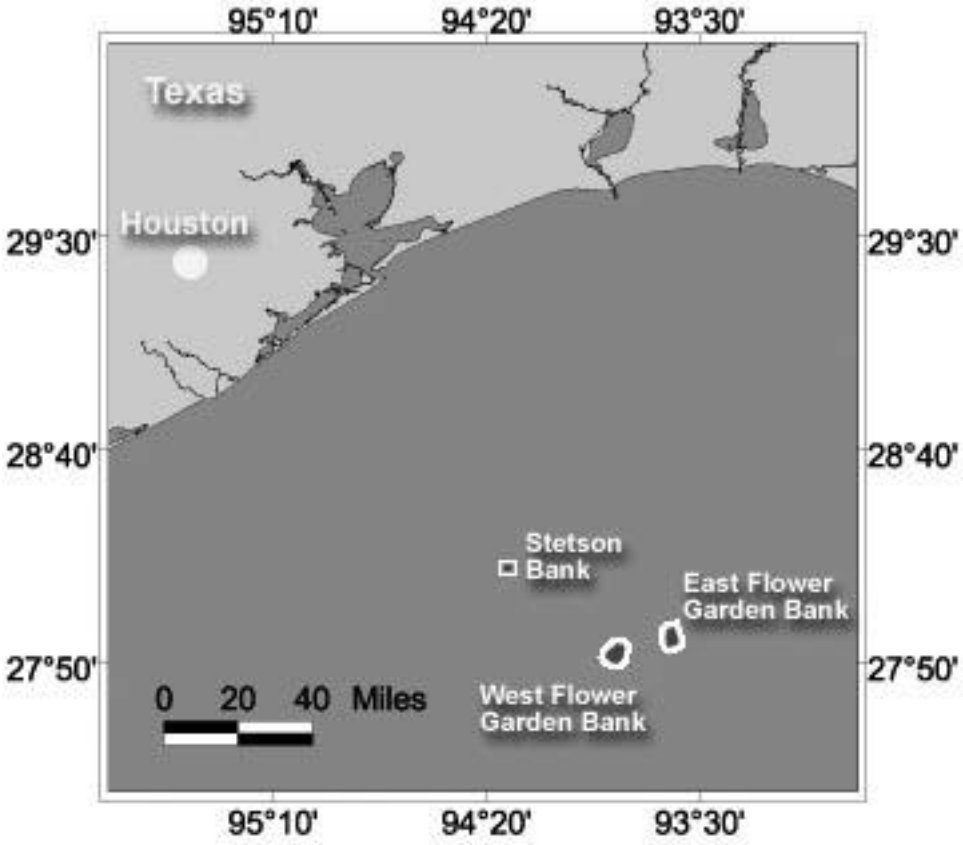

Figure 1. Study Area, showing the three banks of the Flower Garden Banks National Marine Sanctuary.

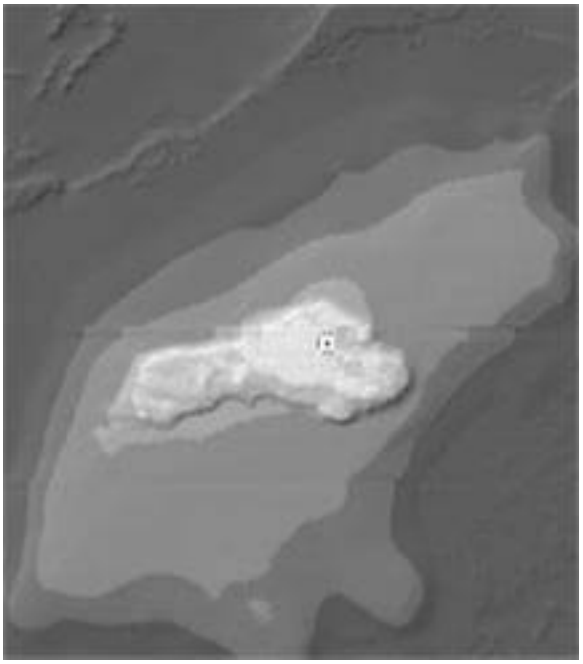

Figure 2a. WFG survey location – buoy 5. The lightest shaded area is the coral reef of the WFG Bank. Darker shaded areas are deeper.

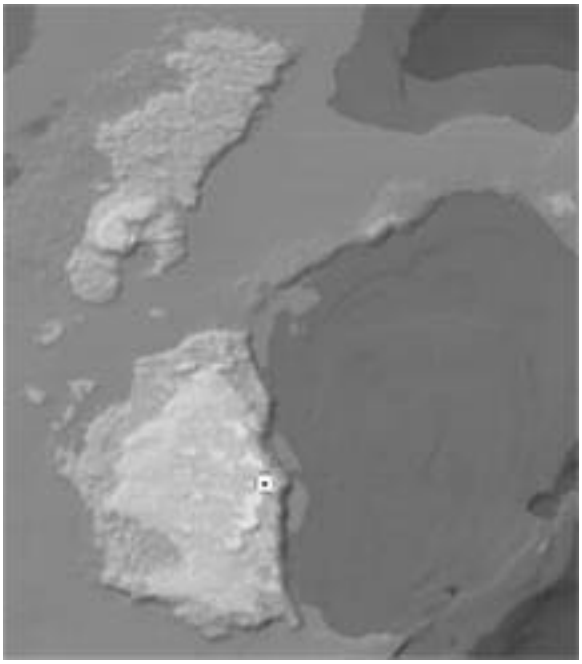

Figure 2b. EFG survey location – buoy 2. The two lightly shaded areas are the reefs on the EFG Bank. Darker shaded areas are deeper.

Table 1. Site information and transect survey effort.

Site Name	Reef Type	Lat/Long	Date of Survey	# Benthic Transects	# Corals (>25cm)/transect	Live Coral Cover (%) (SE)	# Fish Transects	Fish Species Richness*
WFG #5	bank	27° 55.30N; 93° 48.54W	8/17/03	11	12.3	53.9 (16.5)	12	117
EFG #2	bank	27° 54.32N; 93° 35.49W	8/19/03	14	11.4	48.8 (15.8)	12	117

*Species richness value is based on RDT surveys combined for both banks.

Table 2. Summary coral data. Standard error (SE) is provided, when appropriate, in parentheses.

Site Name	# Colonies Surveyed	Mean Colony Diameter (cm)	Mean Colony Height (cm)	Mean Recent Mortality (%)	Mean Old Mortality (%)	Mean Total Mortality (%)	Colonies Bleached* (%)	Colonies Diseased (%)
WFG	135	93.0 (71.8)	36.2 (41.4)	1.57 (4.3)	13.0 (21.0)	13.3 (20.7)	5.2	0
EFG	160	81.1 (53.2)	32.7 (26.5)	2.44 (7.2)	10.6 (18.6)	12.7 (20.6)	16.3	0

*includes all colonies with any level (pale, white, etc.) and amount (partial, complete) of bleaching

WFG

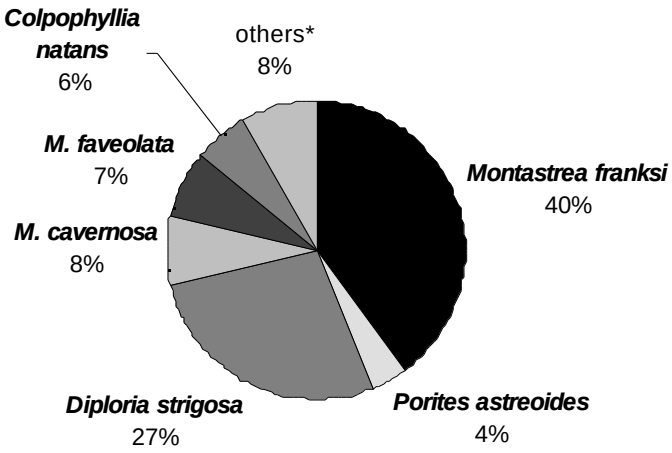

Figure 3a. Coral relative abundance- WFG (*others include *Stephanocoenia intersepta, Madracis decactis,* and *Agaricia agaricites*.)

EFG

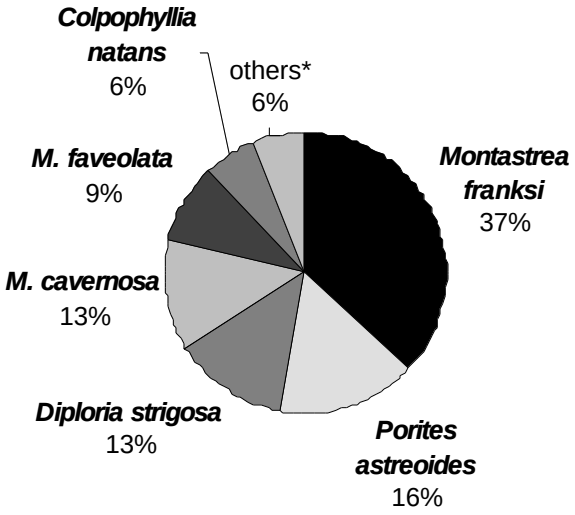

Figure 3b. Coral relative abundance- EFG (*others include *Stephanocoenia intersepta, Madracis decactis, Montastrea annularis, Madracis mirabilis,* and *Siderastrea siderea.)*

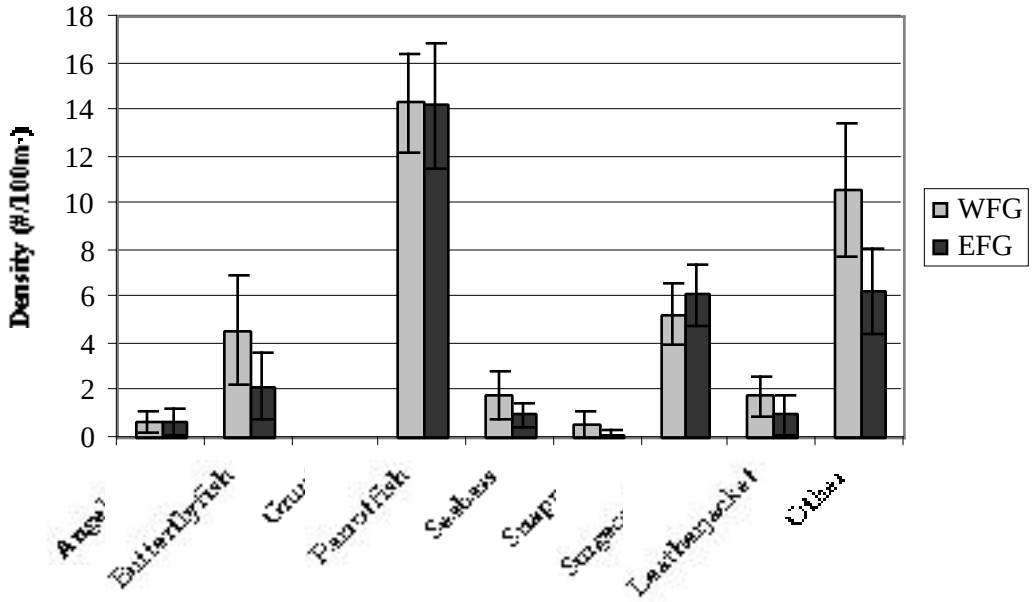

Figure 4. Fish species composition and density.

Table 3. Algal quadrat summary. Variance (SE) is provided, when appropriate, in parentheses.

Site Name	Number Of Quadrats	Relative Macro Cover (%)	Relative Turf Cover (%)	Relative Crustose Cover (%)	Macro Height (cm)	Macroalgal Index[1]	Coral Recruits (#/quadrat)	Diadema (#/quadrat)
WFG	55	4.4 (9.9)	41.0 (30.4)	14.8 (25.3)	0.9 (0.3)	3.9	0.15	0.91
EFG	67	7.1 (12.9)	63.5 (30.5)	10.7 (12.8)	1.1 (0.5)	7.8	0.10	0.01

[1]Macroalgal Index is relative macro algal cover x macro algal height

Table 4. Twenty-five most common fish species. Data are calculated from RDT surveys.

Common Name	Scientific Name	Sighting Frequency	Den
Great Barracuda	*Sphyraena barracuda*	100.0	2.8
Sharpnose Puffer	*Canthigaster rostrata*	100.0	2.7
Black Durgon	*Melichthys niger*	100.0	2.4
Reef Butterflyfish	*Chaetodon sedentarius*	96.0	2.2
Yellowtail Damselfish	*Microspathodon chrysurus*	96.0	1.9
Yellow Goatfish	*Mulloidichthys martinicus*	96.0	2.6
Graysby	*Epinephelus cruentatus*	96.0	1.8
Queen Parrotfish	*Scarus vetula*	96.0	3.0
Stoplight Parrotfish	*Sparisoma viride*	96.0	2.7
Blue Tang	*Acanthurus coeruleus*	96.0	2.3
Smooth Trunkfish	*Lactophrys triqueter*	92.5	1.8
Threespot Damselfish	*Stegastes planifrons*	92.5	3.2
Creole Wrasse	*Clepticus parrae*	92.5	2.8
Bermuda Chub/Yellow Chub	*Kyphosus sectatrix/incisor*	87.5	2.9
Brown Chromis	*Chromis multilineata*	84.5	3.5
Bicolor Damselfish	*Stegastes partitus*	84.5	3.1
Spanish Hogfish	*Bodianus rufus*	84.5	2.8
Bluehead	*Thalassoma bifasciatum*	84.5	3.6
Princess Parrotfish	*Scarus taeniopterus*	84.0	2.7
Orangespotted Filefish	*Cantherhines pullus*	80.0	1.6
Creole fish	*Paranthias furcifer*	80.0	3.8
Yellowhead Wrasse	*Halichoeres garnoti*	77.0	2.3
Rock Beauty	*Holacanthus tricolor*	76.0	1.7
Ocean Surgeonfish	*Acanthurus bahianus*	73.0	2.5
Blue Chromis	*Chromis cyanea*	72.5	2.3

Table 5. Biomass of families. Values are in g/100m^2 with SE in parentheses.

Site Name	Parrotfish	Surgeonfish	Seabass	Snapper	Grunt	Macroalgal Index*
WFG	1689.0 (2282.6)	274.0 (286.1)	591.1 (459.1)	5536.2	0	3.9
EFG	1284.0 (1640.9)	570.0 (503.8)	730.1 (512.6)	2662.0 (1152.7)	0	7.8

*Macroalgal Index is relative macroalgal cover x macroalgal height

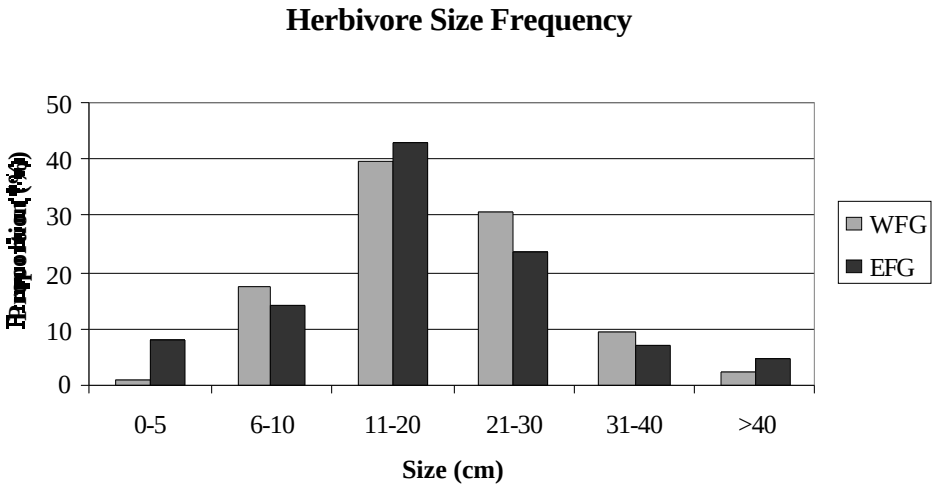

Figure 5a. Carnivore size frequency distribution (includes grouper and snapper species).

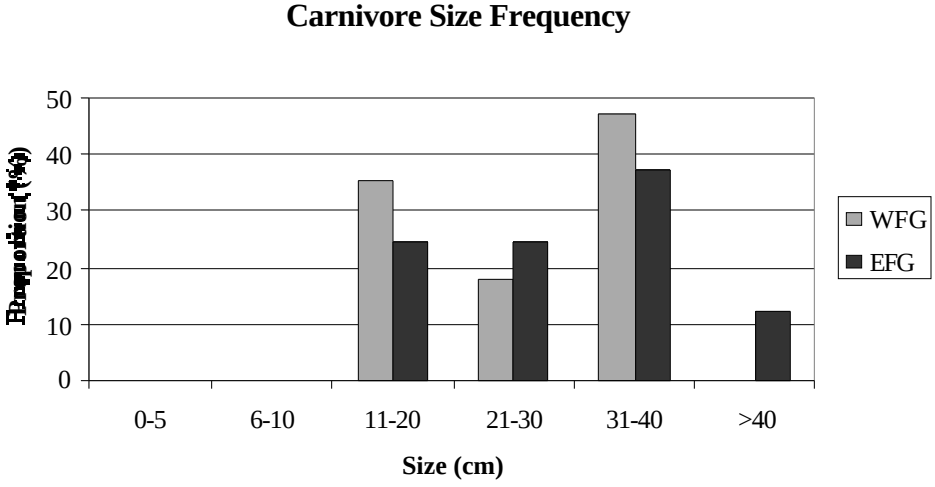

Figure 5b. Herbivore size frequency distribution (includes parrotfish and surgeonfish species and yellowtail damselfish).