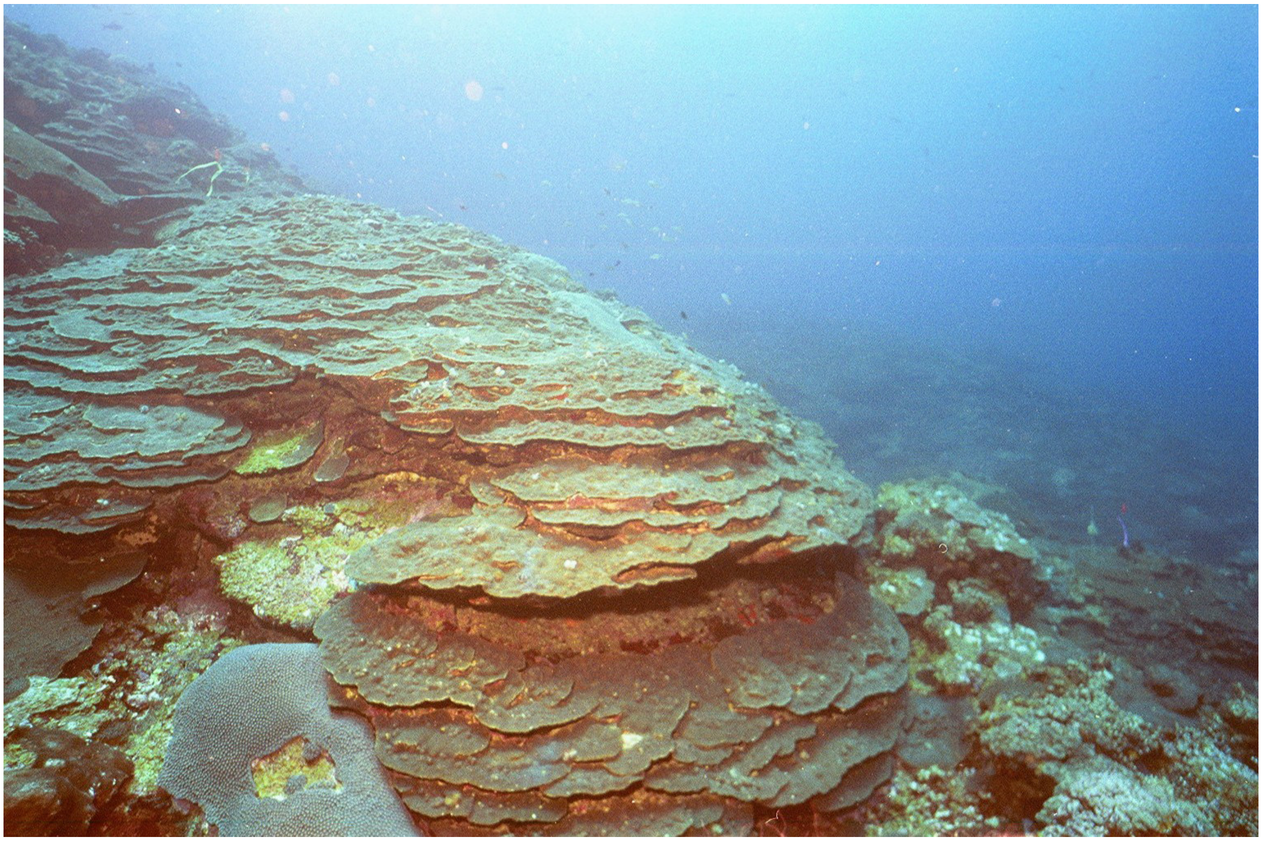
OCS Study
MMS 2006-035

Long-Term Monitoring at the East and West Flower Garden Banks National Marine Sanctuary, 2002-2003

Final Report



U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Final Report

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EXECUTIVE SUMMARY

The Flower Garden Banks (FGB), remotely located on the continental shelf in the Gulf of Mexico, are afforded a certain measure of protection due to their geographic distance from land. Problems that affect coral reefs throughout the region, including land-based sources of pollution and coral disease have not had a measurable effect at the FGB. In addition to their relative isolation, the depth of these reefs, 18-48 m, has protected corals from bleaching events that have had devastating effects on most western Atlantic reefs.

Monitoring results for 2002-2003 highlighted the continued health of these reefs, expressed as consistently high coral cover, with a mean of 56.43% ± 2.36 at the East Bank in 2002, 53.20% ± 3.01 in 2003, 49.67% ± 3.35 at the West Bank in 2002 and 57.13% ± 3.81 in 2003. The continuing trend of coral growth is also apparent in repetitive quadrat stations and lateral growth of individual colonies of the brain coral *Diploria strigosa*. Robust fish populations and oligotrophic water conditions persisted while occurrences of disease and bleaching were low, 0.004% and 0.002%, respectively - averaged for both banks in both years. Sea urchins continued to occur at low densities, averaging 0.01/m^2 (both banks, both years); however, herbivorous fishes appear to keep algal cover under control as they represented the largest fish guild on both banks for both years.

Random transect results revealed high coral cover at both banks, consistent with previous monitoring results, with 53.05% ± 2.11 (SE) coral cover in 2002 and 55.16% ± 2.41 coral cover in 2003. Macroalgal cover was also stable at 11.60% ± 1.65 and 12.58% ± 1.45, but showed a significant site X year interaction ($P<0.0005$). Crustose corallines, turf and bare (CTB), the largest cover category after coral cover, was at 32.35% ± 2.22 and 29.87% ± 1.83 for 2002 and 2003, and also showed a significant site X year interaction ($P=0.023$). Macroalgae and CTB were inversely related at both banks in both years.

The *Montastraea annularis* complex was the predominant component of coral cover at both banks in both years, with 33.59 ± 3.86% and 28.47 ± 2.98% cover at East Bank in 2002 and 2003 and 31.73 ± 3.57% and 33.80 ± 4.31% at the West Bank in 2002 and 2003. Due to difficulty in differentiating the three species of the complex in the videographic images, *M. annularis, M. faveolata* and *M. franksi* were combined. *Diploria strigosa* was the next most abundant species, ranging from 3.20 ± 0.91% at the West Bank in 2002 to 9.04 ± 2.68% in 2003. The East Bank estimates were 6.96 ± 1.69% and 6.19 ± 1.55% in 2002 and 2003.

Videographic transects, still photographs and linear-point-intercept (LPI) transects, used as redundant measures to estimate coral coverage along fourteen random transects, produced coral cover estimates within 3.5% of each other and were not significantly different ($P=0.564$).

The Shannon-Weiner diversity index, H', was calculated from species-specific coral-cover data from each video transect. H' ranged from a low of 1.35 at the West Bank in 2003 to a high of 1.51 at the East Bank in 2003, H' = 1.37 was calculated for the West Bank in 2002 and H' = 1.45 at the East Bank. A two-way ANOVA showed no significant effect of year or site, and the site×year interaction was also not significant.

Repetitive quadrats were photographed to monitor 8-m^2 areas and their coral communities over time. Repetitive quadrats showed changes in coral species cover and coral condition (disease, paling, bleaching, and fish biting) from 2002 to 2003 (20 pairs at East Bank, 31 pairs at West Bank). The incidence of disease, paling and bleaching were low at both banks in both years; none of these metrics was above 0.61%, and there was no evidence of disease in any of the repetitive quadrats analyzed. Planimetry results of select colonies within repetitive quadrats showed a percent cover increase from 2001-2002 and from 2002-2003 at both banks. Percent cover increase of all colonies and the *Montastraea annularis* complex showed greater percentage increases at the East Bank than the West Bank.

Nine deep repetitive quadrats (32-40 m depth) were established on the East Bank in April 2003 and photographed in August 2003. Coral cover was high, at 75.14% overall. The *Montastraea annularis*

complex (42.37%) and *M. cavernosa* (14.74%) were the dominant species at these sites. Algae cover was relatively low (12.20%) and 91% of algae was CTB.

Lateral growth stations were monitored to measure changes in *Diploria strigosa* colonies. *Diploria strigosa* is important at the FGB because it is the second largest contributor to coral cover within the 100-m^2 monitoring sites. In April 2003, 60 new stations were established on each bank, because of this a limited number of temporal comparisons were made between 2001-2002 and 2002-2003. Overall there was a 3-5% increase in *Diploria strigosa* margins from 2001-2002, but the sample size for the 2002-2003 comparison was not sufficient to draw conclusions.

Sclerochronology was used to measure the accretionary growth rates of *Montastraea faveolata*. Cores taken at both banks revealed annual growth bands spanning 1997-2003. Yearly growth rates ranged from 7.3 to 10.7 mm and differed significantly (P=0.02) between banks. Interestingly, a disruption in accretion was seen in one quarter of the samples from both banks within the 1997-1998 (the year of widespread bleaching throughout western Atlantic coral reefs) growth band.

Water quality parameters including photosynthetically active radiation (PAR), turbidity, temperature, salinity, pH, and dissolved oxygen were recorded using YSI datasondes. Chlorophyll *a*, as well as nutrients and trace metals, were recorded using water samples. No anomalous water quality parameters were measured during the study period. However, YSI datasondes failed post-deployment calibration after each deployment period and/or were not recording valid measurements at the end of their deployment periods.

Fish surveys were conducted using the Bohnsack and Bannerot (1986) method. A mean of 51 fish species were observed per bank per year in 2002 and 2003. Herbivores were the dominant fish guild, with Scaridae (parrotfish) and Acanthuridae (surgeonfish) representing the largest portion of these. Bell-shaped size distribution curves suggest that herbivore populations are healthy with the largest proportion of fish being in the 11-20 cm range at both banks in both years. Carnivorous fish were represented by fewer families than herbivores and were comprised mainly of Serranidae and Lutjanidae. While Sphyraenidae and Carrangidae species were present, their abundance was comparatively low. Sixty percent or more of carnivores were estimated to be above 21 cm, suggesting a robust population of carnivores at both banks.

Urchin surveys documented low densities of *Diadema antillarum* at both banks in both years. Density ranged from 0 - 0.014 individuals/m^2. Only one *Panulirus argus* (lobster) was documented along transects at the East Bank in 2002.

The FGB coral reefs remain in good condition and productive in comparison to reefs throughout the region. This may be due in part to their remote location. Continued monitoring of these reefs will document their long-term condition and be useful for studies focused on the dynamics of the robust benthic communities and the fish populations they support. The following are recommendations for the improvement of the monitoring protocol:

- Monitor areas outside of the 100-m^2 study sites. In particular, *Madracis mirabilis* field located near the southeast corner of the East Bank study site should be cored to chronicle environmental disturbances, such as hurricanes.

- Replace YSI datasondes or datasonde sensors to obtain more consistent and accurate results for water quality parameters.

- We recommend that the YSI datasondes be mounted on the reef cap to more accurately measure water quality parameters in the reef community. Remove YSI datasondes from sand flats, where they are currently located. Certain parameters, in particular, PAR and turbidity, may be affected by the sandflat environment, where sedimentation and reflectance influence these parameters. Furthermore, dissolved oxygen is potentially greater on the sand flats.

- Increase YSI changeouts to 5-8 times per year, to more precisely monitor water quality parameters.

- Monitor the concentration of trace metals in bivalves to evaluate the bioavailability of trace metals at the FGB. Filter-feeders are known to concentrate the heavy metals they ingest from surrounding waters.

1.0 INTRODUCTION

1.1 FLOWER GARDEN BANKS IN THE GULF OF MEXICO

1.1.1 Habitat Description

The Flower Garden Banks (FGB) are located in the northwestern Gulf of Mexico and form part of a discontinuous arc of reef environments along the outer continental shelf (Rezak et al. 1985) (Figure 1.1.1). These coral reef banks are the largest charted calcareous banks in the northwestern Gulf of Mexico (Bright et al. 1985) and are the northernmost coral reefs on the continental shelf of North America (Bright et al. 1984). Although coral and non-coral communities exist on neighboring banks (e.g. Sonnier Bank, Stetson Bank), the reefs at Cabo Rojo, Mexico and Middle Grounds, Florida, are the closest developed coral reefs in the Gulf of Mexico.

The topographic features of the FGB were created by salt diapirs of Jurassic Louann origin and the consequent uplifting of sedimentary rocks (Rezak 1981). The caps of these salt domes extend into the photic zone in clear oceanic water where conditions are ideal for colonization by coralline algae, hermatypic corals, invertebrates and fish species typical of Caribbean basin coral reefs. Though coral species richness is more depauperate at the FGB than that of Caribbean reefs, 21 species of scleractinian corals and 177 species of tropical Atlantic fish are present at the banks (Pattengill-Semmens and Gittings 2003). Oceanic salinity conditions prevail at FGB and range from 34 to 36 PSU, with water temperatures ranging from 18℃ (mid-February) to ~ 32℃ (August). Water clarity at the Banks is excellent, commonly 30 m or more, providing light to photosynthesizing organisms.

1.1.2 East and West Banks

The East Bank (27º 54.5’ N, 93º 36.0’ W) is located approximately 193 km southeast of Galveston, Texas. East Bank encompasses 67 km^2, sloping from the shallowest point at 20 m to the terrigenous mud seafloor at a depth of 100-120 m. The eastern and southern edges of the bank slope steeply whereas the northern and western edges slope more gently (Figure 1.1.2). The West Bank (27º 52.4’ N, 93º 48.8’ W) is located 20 km west of East Bank, is located 172 km southeast of Galveston and is more than twice as large (137 km^2) as the East Bank (Figure 1.1.3). The three peaks that comprise the East Bank are aligned along an east-west axis. The middle high rises from a depth of 100-150 m to within 18 m of the surface and supports coral reef habitat from 18 - 48 m. Coral species diversity at both banks is low, with 21 species from 12 genera represented (Bright et al. 1984), compared to 67 species found on some Caribbean reefs (Goreau and Wells 1967). Shallow-water corals, including gorgonians and acroporids were not found in the past. Notably, one colony of *Acropora palmata* was discovered in 2001 at the West Bank and was still present and growing at the time of this writing.

In the past, three biological zones were described at the FGB: the *Montastraea-Diploria-Porites* Zone (< 36 m), the *Stephanocoenia-Millepora* Zone (36-52 m), and the algal-sponge zone (46-88 m) (Rezak et al. 1985). All monitoring at both banks is conducted within the *Montastraea-Diploria-Porites* Zone, except for the deep stations at the East Bank (32-40 m), which were established in 2003. In contrast to the previous descriptions of species dominance in the *Stephanocoenia-Millepora* Zone, these new deep stations are dominated by the *M. annularis* species complex (*M. annularis, M. faveolata*, and *M. franksi*) and *M. cavernosa*. The difference in coral dominance at these newly established deep sites illustrates the high degree of variability at small spatial scales.

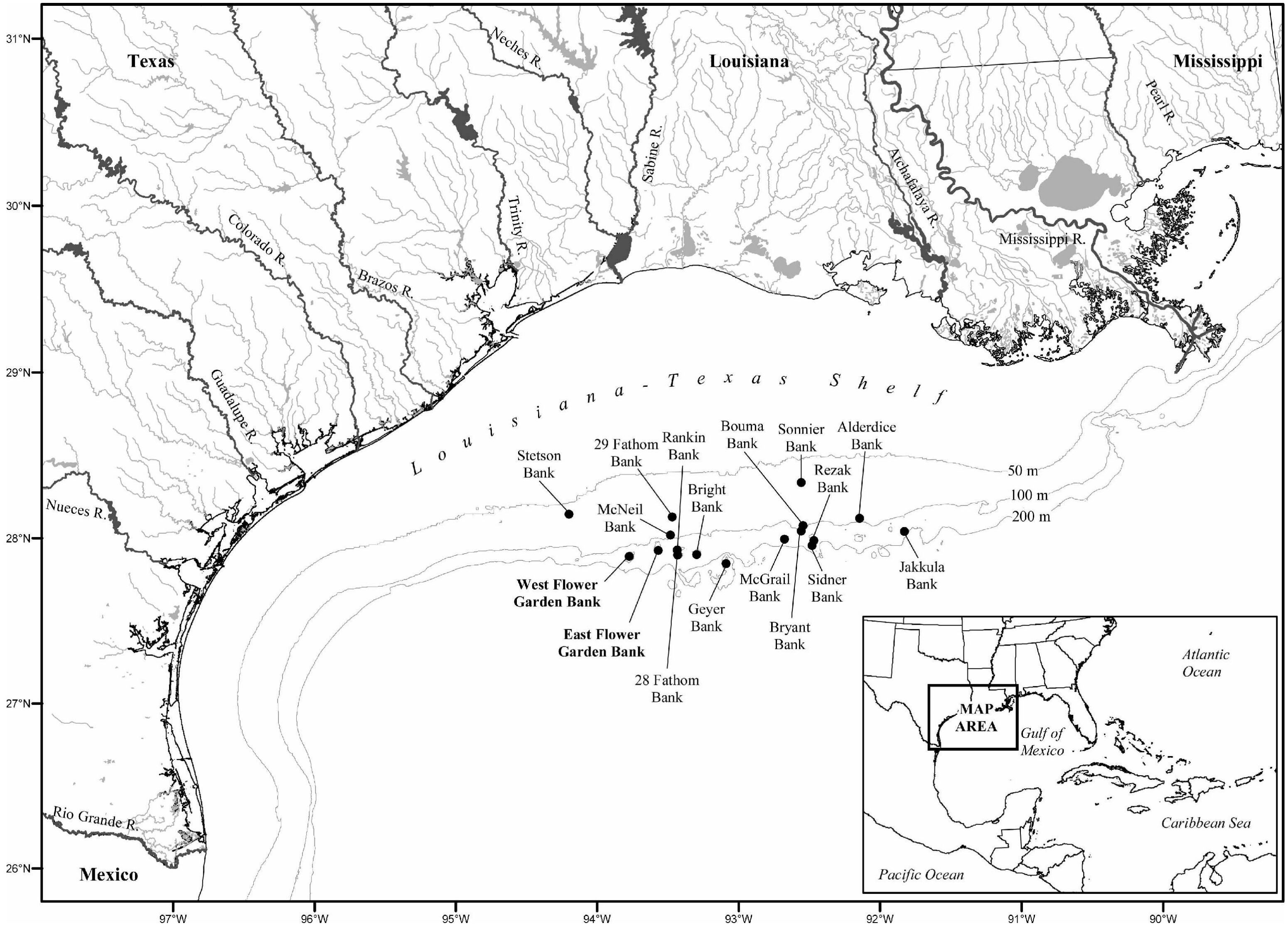


Figure 1.1.1. Location map of the East and West Flower Garden Banks in relation to the Texas-Louisiana continental shelf and other topographic features of the northwestern Gulf of Mexico (map courtesy of Ken Deslarzes).

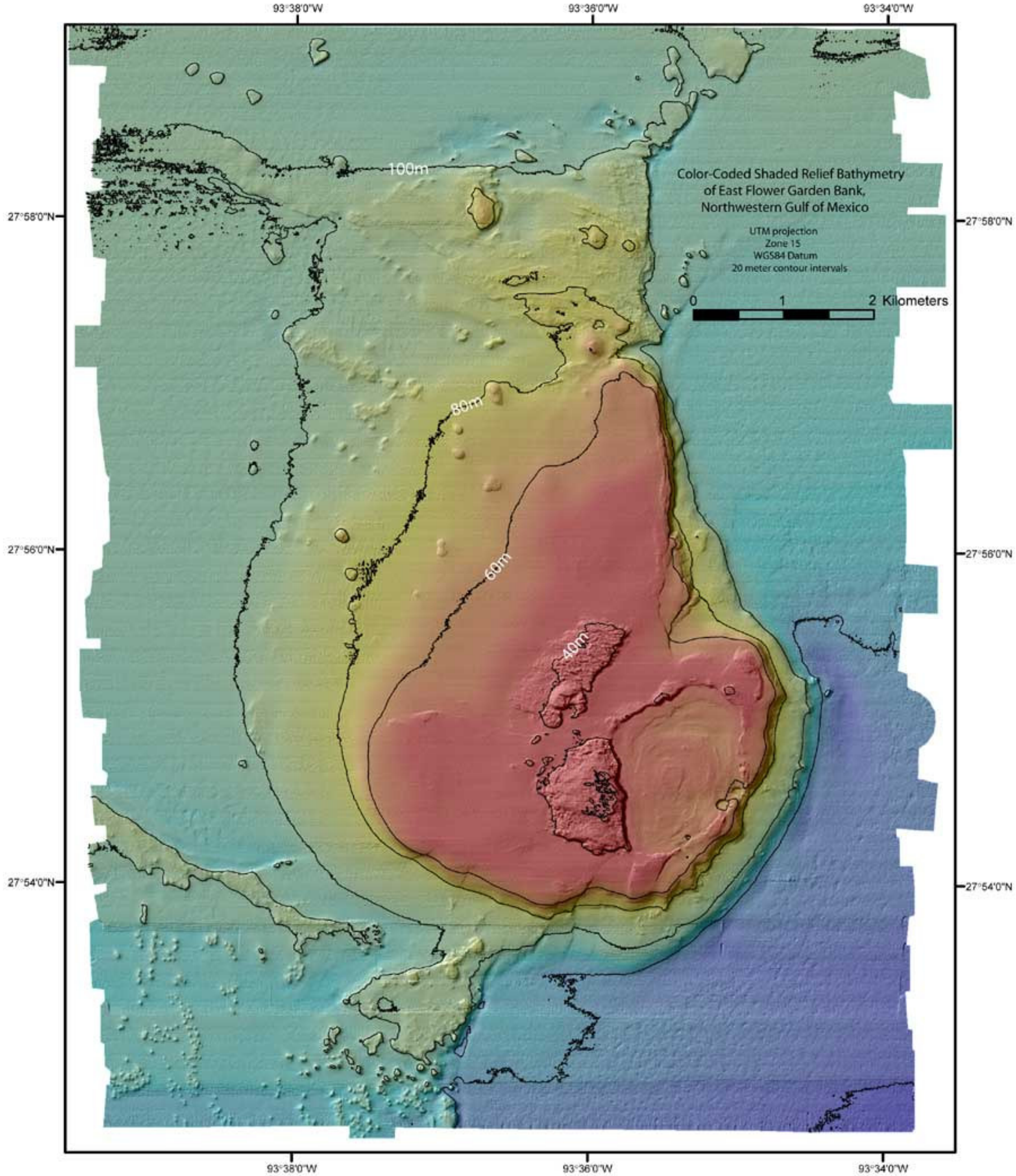


Figure 1.1.2. Topographic contour map of the East Bank (Gardner et al. 1998).

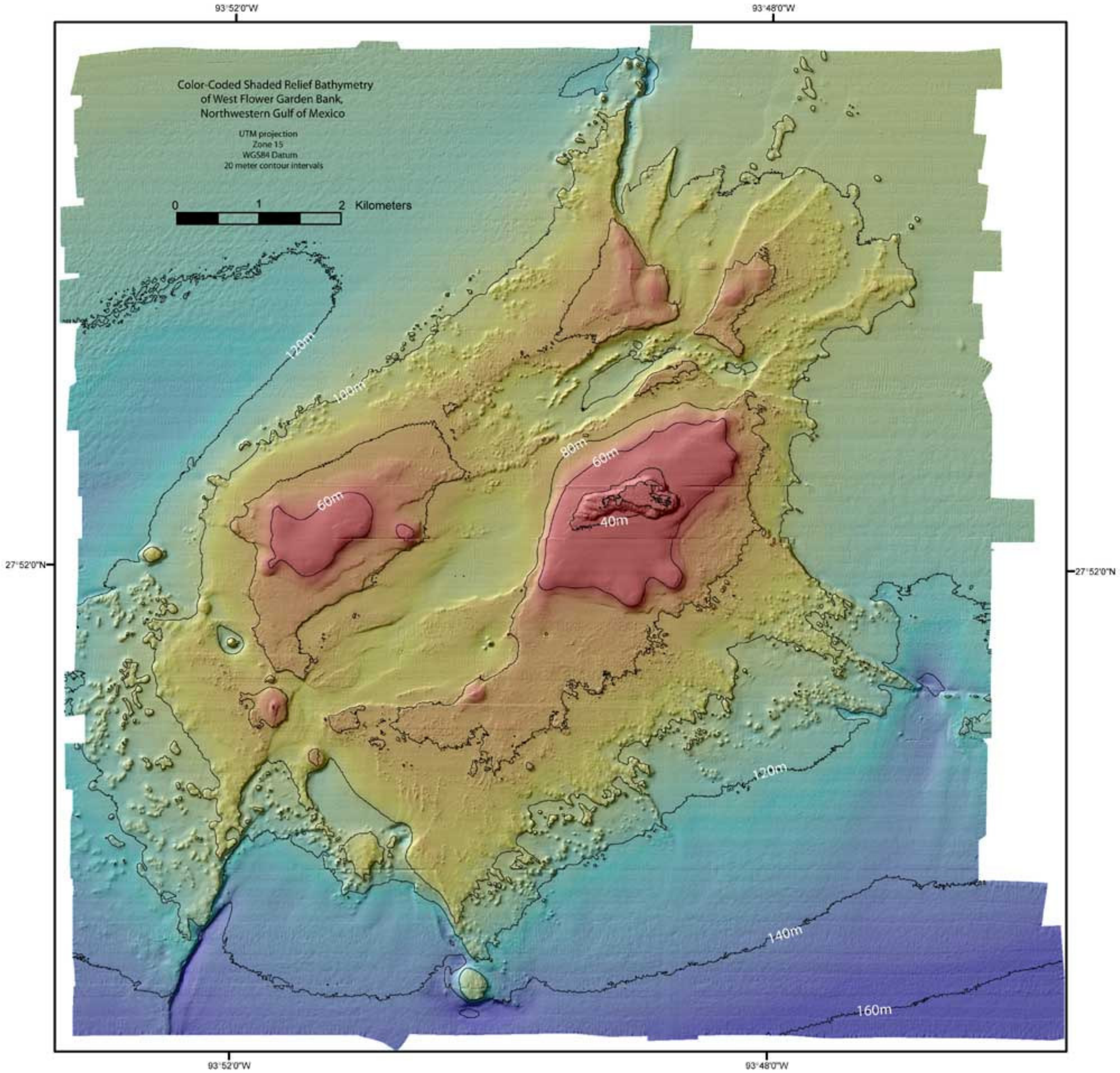


Figure 1.1.3. Topographic contour map of the West Bank (Gardner et al. 1998).

1.2 MMS AND FGBNMS PROTECTIVE MEASURES

Oil and gas activity in the vicinity of the FGB has been ongoing since the 1970s. The Minerals Management Service (MMS), under the U.S. Department of Interior (USDOI), has regulated the development of the oil and gas industry within the Gulf of Mexico outer continental shelf. In addition, MMS has, since 1973, conducted a program of protective activities at the FGB coral reefs. The topographic features stipulation (since 1973) as applied to the FGB was designed to protect sensitive biological resources from the adverse effects of routine oil and gas activities (MMS 2002). The stipulation specifically protects the biota of the FGB from physical damage associated with oil and gas activities including anchoring, rig emplacement and potential toxic and smothering effects from drilling muds and cuttings discharges (MMS 2002). The stipulation defines a No Activity Zone (NAZ) around each of the banks. The boundary of the NAZ overlaps the 100-120 m isobaths at the West Bank and the 100-130 m isobaths at the East Bank. No oil or gas structures, drilling rigs, pipelines, or anchoring are allowed within the NAZ. The stipulation also defines a "4-Mile Zone" outside the No Activity Zone within which operators are to shunt all drill cuttings and drilling fluids to within 10 m of the seafloor.

In addition to the protective measures provided by MMS, the FGB were designated as a United States National Marine Sanctuary in 1992 (Code of Federal Regulations, 15 CFR Part 992, Subpart L Section 922.120). The Sanctuary regulates, restricts ands/or prohibits:

(1) Anchoring or mooring of all vessels within the Sanctuary boundaries
(2) Discharge of any material or matter within the Sanctuary boundaries
(3) Any alteration of the seabed within the Sanctuary boundaries
(4) Any injury or removal or attempt of injury or removal of any living or non-living Sanctuary resource,
(5) Taking of marine mammals and sea turtles
(6) Possessing or using within the Sanctuary boundaries any fishing gear except conventional hook and line gear
(7) Possessing or using explosives within the Sanctuary boundaries or releasing electrical charges within the Sanctuary boundaries

From 1988 to 1992, the MMS had the FGB coral reefs monitored on an annual basis to detect any incipient changes that may be caused by oil and gas activities, as well as by any other disturbances that may occur (Gittings et al. 1992; Gittings 1998). Starting in 1996, the National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary (FGBNMS) and the MMS partnered to continue the long-term monitoring at the FGB.

1.3 FLOWER GARDEN BANKS CORAL REEF MONITORING

Remarkably, no significant long-term changes have been detected in coral reef populations, cover, or diversity at the FGB since quantitative surveys of the reefs began in 1988. These reefs presently have among the highest estimated live coral cover in the western Atlantic (Pattengill-Semmens and Gittings 2003). Monitoring results and other studies (Gittings et al. 1992; CSA 1996; Dokken et al. 1999, 2001, 2003; Pattengill-Semmens and Gittings 2003) have shown that the assemblages on East Bank and West Bank are low-diversity, high-coral cover and low-algal cover communities, with robust fish assemblages including representation of all fish guilds (Pattengill-Semmens and Gittings 2003).

Gittings et al. (1992) established 10000-m^2 study sites at the East and West Banks to monitor benthic community structure from 1988 to 1991—measured by coral cover, relative dominance, diversity, evenness, and accretionary and encrusting growth rates—as well as water quality parameters. Comparisons between the 1988-1991 results and those of previous studies from 1978 - 1982 showed no significant differences in any of the parameters, indicating ecological stability at the FGB over the period examined. Coral cover was ~50% and dominated by the *Montastraea annularis* species complex and *Diploria strigosa* at ~25% and ~8% cover, respectively (Gittings et al. 1992). Gittings et al. (1992) considered spills from oil tankers, leaking mud and drill cuttings from oil and gas operations, seismic activity due to oil and gas exploration and platform accidents to hold the greatest threat of reef degradation.

No long-term changes in coral community structure were reported by CSA (1996). However, variation in individual coral species was detected between banks and between the sampling years, which were 1992, 1994 and 1995. Bleaching in corals was documented in 1990, 1992, 1994, and 1995 when water temperatures rose above 30°C (Hagman and Gittings 1992; Dokken et al. 1999, 2001, 2003). *Montastraea cavernosa* and *Millepora alcicornis* were the species most affected by bleaching, but post-bleaching mortality rates were low at 0.2%-2.8% from 1992-1995 and occurred patchily. Although small-scale spatial variation exists at the FGB, as it does on other coral reefs, it is apparent that at the larger scale of the reef landscape (km), the biota exhibit relative stability.

Dokken et al. (1999, 2003) continued the monitoring effort from 1996-2001 and documented no significant changes in coral growth or condition. Biodiversity inventories were conducted for algae and mollusks: 73 species of algae were documented as well as over 230 species of mollusks (Dokken et al. 2001, 2003). Fish assemblages were also studied in detail (Pattengill 1998).

Using the AGRRA protocol in 1999, Pattengill-Semmens and Gittings (2003) showed high coral cover, ~50% at 20-28 m, dominated by large (mean diameter 81-93 cm) head corals with a partial coral colony mortality (recent and long-dead) of only 13%. In concordance with former findings, turf was the predominant algal group, whereas macroalgae accounted for less than 10% cover (Pattengill-Semmens and Gittings 2003).

Monitoring results for 2002-2003 highlighted the continued health of these reefs, expressed as consistently high coral cover, with a mean of 56.43% ± 2.36 at the East Bank in 2002, 53.20% ± 3.01 in 2003, 49.67% ± 3.35 at the West Bank in 2002 and 57.13% ± 3.81 in 2003. The continuing trend of coral growth is also apparent in repetitive quadrat stations and lateral growth of individual colonies of the brain coral *Diploria strigosa*. As repetitive quadrat and lateral growth (*Diploria strigosa*) stations were missing markers, displaced, or otherwise degraded in 2002, a site rehabilitation cruise was completed in April 2003. The goal of this cruise was to reestablish the initial sample size of forty repetitive quadrat stations and sixty lateral growth stations on the East and West Banks. A new numbering system was established and old stations were refurbished with new pins and tags, while a small number of new stations were established at each bank. At the East Bank thirty-one old stations were refurbished and 9 new stations were installed, for a total of 40 repetitive quadrat stations. At the West Bank thirty-six stations were refurbished and 4 new stations were installed, for a total of 40 repetitive quadrat stations. The lateral growth stations were also refurbished and new stations were established to return the sample size to 60 on each bank. At the East Bank forty-eight old lateral growth stations were refurbished and 12 new stations were established, for a total of 60 lateral growth stations. At the West Bank forty-three lateral growth stations were refurbished and 17 new stations were installed, for a total of 60 lateral growth stations. Since the majority of stations were refurbished, the long-term dataset should not be affected for either the repetitive quadrat or lateral growth stations. The robust fish populations and oligotrophic water conditions persisted while occurrences of disease and bleaching in corals were low. Sea urchins continued to occur at low densities; while herbivorous fishes kept algal cover under control as they represented the largest fish guild on both banks.

In nearly 15 years of continuous monitoring, the coral reefs of the FGB have maintained high levels of coral cover, suffered minimally from bleaching and disease, and supported diverse and abundant fish populations as well as other vertebrate and invertebrate species. While the rest of the Caribbean has experienced a decline in coral cover, subsequent increases in macroalgal cover, and decreased fish stocks due to overfishing, the FGB remain a stable coral reef system in the northwestern Gulf of Mexico. As such, these reefs are potentially excellent study sites for understanding the causes of stability and change in reef systems through time and space.

2.0 METHODS

The FGB being roughly 190 kilometers (km) offshore submerged in more than 18 meters (m) of water, the monitoring effort had to be conducted from a dive vessel that remained at each bank for about two days. The benthos (with an emphasis on corals) was examined along visual, photographic and videographic transects, and in stationary repetitive photographs. Fish surveys were conducted at haphazardly located stations. Urchins and lobsters were surveyed on perimeter lines. Sclerochronology was used to document the accretionary growth of corals, and photography was done at permanent stations to monitor the lateral growth of corals. Water quality was assessed to characterize the FGB reef cap and water column environment.

2.1 STUDY SITES

All data were collected within the established 100m x 100m site at East Bank and West Bank in October 2002 and August 2003, except for a set of deep repetitive quadrats at East Bank, which were established in April 2003. The general locations of the study sites are marked by permanent mooring buoys: FGBNMS permanent mooring number 2 at the East Bank (27° 53' 35.80" N, 93° 38' 23.90" W) and mooring number 5 at the West Bank (27° 52' 50.86" N, 93° 52' 25.34" W) (Figures 2.1.1 and 2.1.2). Subsurface buoys were installed at the corners of the sites to facilitate underwater relocation. Geographical Positioning System (GPS) positions taken of the site corners in 2002 allowed for quick site relocation and initial mapping of the four corners (Table 2.1.1) and (Figures 2.1.1. and 2.1.2). Buoys were dropped from a launch to visually mark the corners from the surface and for quick location by divers. Divers used polypropylene lines to temporarily mark the perimeters of the study sites and the north/south and east/west center lines (commonly referred to as "cross-hairs"). Establishment of the perimeter and crosshairs subdivided each site into four quadrants. They also aided divers in orientation and to complete monitoring tasks efficiently. Each dive team was supplied with detailed underwater maps of the study sites. Additionally, master maps were updated on the dive vessel with new data on station numbers, locations, replacements and revisions. These revisions are reflected in the current site maps (Figures 2.1.3 and 2.1.4).

Table 2.1.1.

GPS coordinates for East and West Bank study site corner markers.

East Bank			**West Bank**		
Corner	North	West	Corner	North	West
NE	27º54'32.8	93º35'48.1	NE	27º52'31.8	93º48'53.6
NW	27º54'32.2	93º35'51.6	NW	27º52'31.5	93º48'56.9
SE	27º54'29.6	93º35'48.6	SE	27º52'28.7	93º48'53.2
SW	27º54'30.1	93º35'52.1	SW	27º52'28.5	93º48'56.8

Metal rods were previously installed in the reef to demarcate monitoring stations. There were two types of permanent monitoring stations: (1) lateral growth stations on *Diploria strigosa* colonies marked by two short rods per station, and (2) $8m^2$ repetitive quadrats, the centers of which were marked by a tall rod (0.5 m long). Due to the poor condition of many of the existing rods, a site-rehabilitation was conducted in April 2003. At the East Bank, 60 lateral growth station pins were installed, 48 of these were replacements for existing pins and 12 were new stations. At the West Bank, 60 lateral growth station pins were installed and 43 of these were replacement pins, while 17 were new station pins. Forty repetitive quadrat station pins were installed at the East Bank in April 2003 and 31 of these were replacements for existing pins. At the West Bank, 40 repetitive quadrat station pins were installed and 36 of these were replacement pins, while 4 new repetitive quadrat pins were installed. A new numbering system was assigned to the new rods. Eighty new repetitive quadrats (Station numbers 1-40 at East Bank and 41-80 at West Bank) and 120 new lateral growth stations (1-60 at East Bank, 61-120 at West Bank) were established. Additionally, in April 2003 nine deep repetitive quadrat stations (station numbers 81-89) were established at East Bank in 33-40 m water depth (Figure 2.1.5).

2.2 RANDOM TRANSECTS

2.2.1 Methodological Rationale

To estimate the areal coverage of benthic components such as corals and macroalgae, fourteen 10-m long fiberglass surveyor's tapes were positioned at each study site. Coverage was estimated from these transects in three ways: still photography (the method used in previous monitoring studies at the FGB), videography, and visual assessment in the field. The Scope of Work in the contract for this study expressed a well-founded desire to move away from still photography for recording the 14 transects at each site. Digital videography provides a logistically simpler and more reliable alternative. In addition to continuing the long-term record of transect assessment at the study sites, this component of the project was intended to assess the utility of videography for surveying transects at the FGB and the comparability of video to still photography. The linear-point intercept (LPI) (see Section 2.2.5) method was used as well, to ascertain whether data recorded directly in situ (i.e., on the reef) were different than data derived from either of the photographic methods (stills or videos).

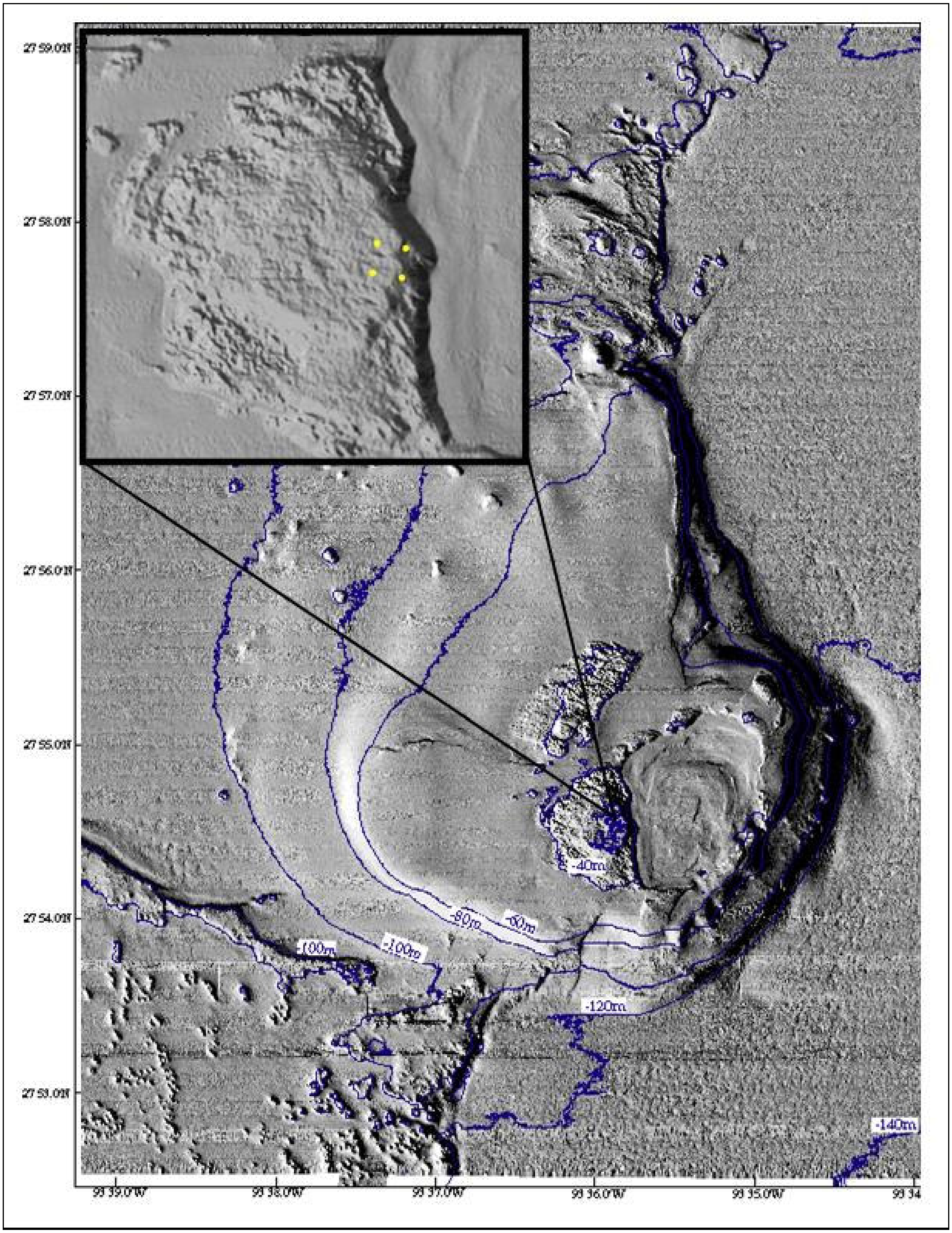


Figure 2.1.1. East Bank topographic map. The inset shows the locations of the study site corners.

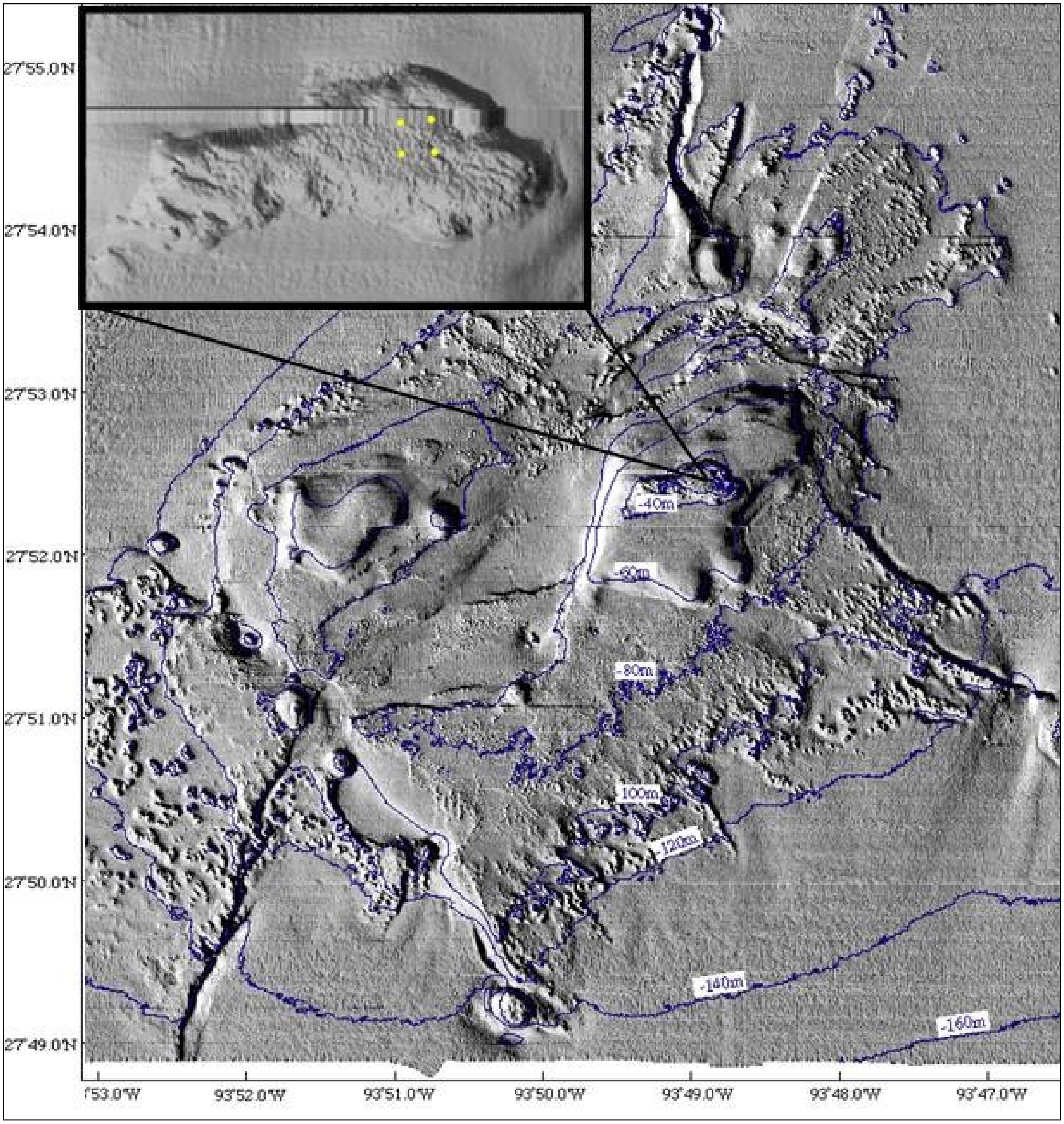


Figure 2.1.2. West Bank topographic map. The inset shows the locations of the study site corners.

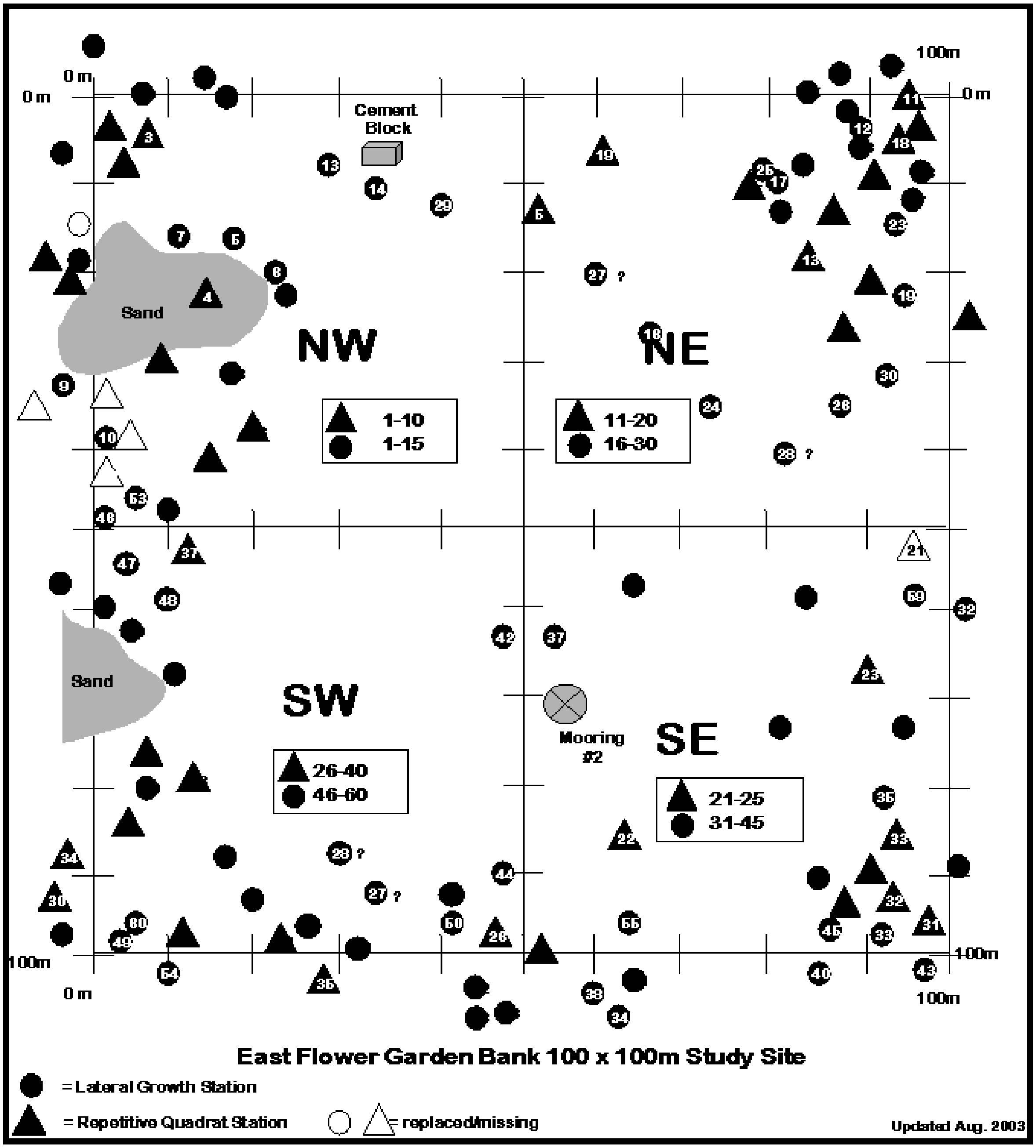


Figure 2.1.3. Locations of monitoring stations at East Bank, 2003.

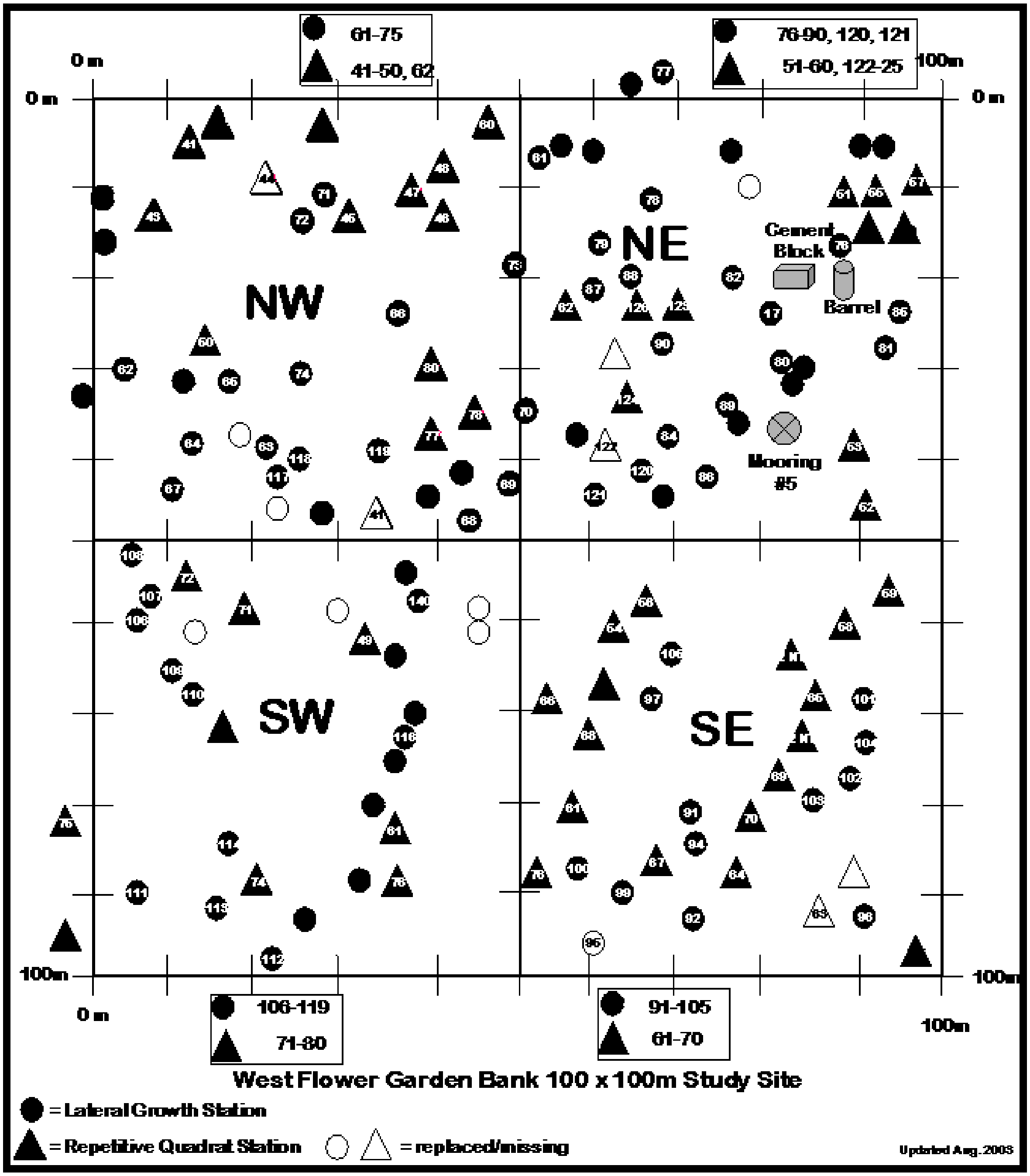


Figure 2.1.4. Locations of monitoring stations at West Bank, 2003.

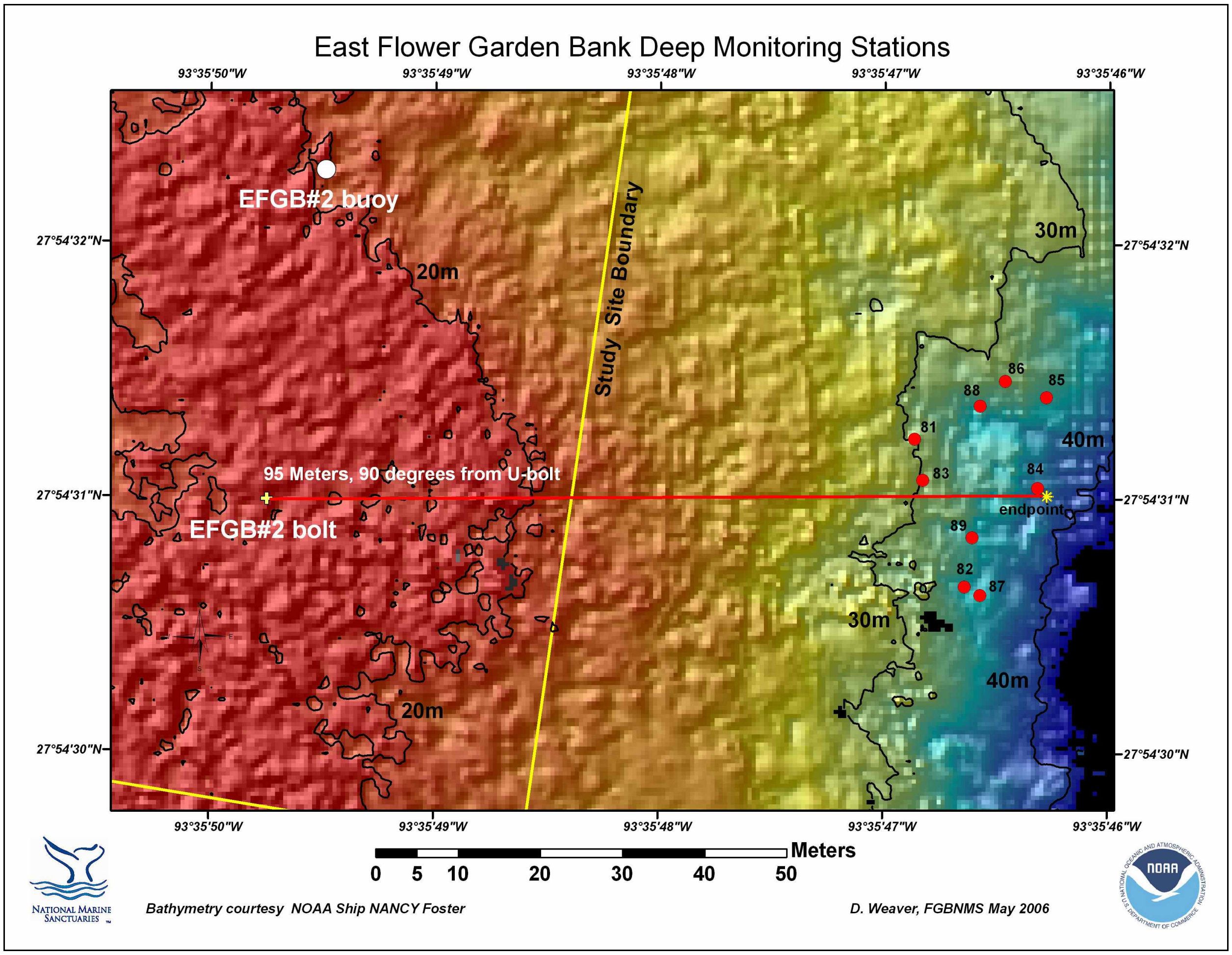


Figure 2.1.5. Bathymetric map with the deep repetitive quadrat stations in relation to the permanent study site at the East Bank (32-40 m), established in 2003. Contour lines at 20, 30 and 40 m. (Courtesy of Doug Weaver, NOAA/FGBNMS).

Data collected using video transects, still photography, and LPI transects were categorized as follows. Corals were identified to species; sponges were combined into a single group; macroalgae were identified to species where possible and included anything longer than ~3 mm; crustose coralline algae turfs, fine turfs and bare rock were grouped as "CTB." These components are difficult to distinguish visually in still photographs and video transects. All three connote high levels of physical disturbance and/or herbivory, and so it is reasonable to combine them (Aronson and Precht 2000). These methods are a refinement of past methods at the FGB and have been used successfully in a separate, NOAA-funded study comparing Fully Protected Zones (FPZs) and reference sites within the Florida Keys National Marine Sanctuary (Murdoch and Aronson 1999).

2.2.2 Positioning of the Transects

Due to time constraints on diver bottom time, transects were placed haphazardly rather than randomly (e.g., Aronson and Swanson 1997). It was essential for divers to be able to move easily between transects, quickly locating each after sampling the previous one. In addition, previous investigators avoided large areas of sand within the study sites, because the sand microhabitat was of less interest than hard substratum; the present study adopted this constraint as well, to assure comparability with the earlier data.

The transects in this study were laid haphazardly in a trapline pattern. The first transect was positioned at random within one quadrant of the study site and laid in a randomly chosen compass heading. Each end of the transect was marked with a subsurface buoy so that it could be located easily by divers. The beginning of the next transect was positioned approximately 10 m from the end of the first and laid haphazardly at an obtuse angle to the direction of the first. The third transect was laid in the same manner relative to the second, and so on. If a transect reached the border of the study site, it was reflected off the border and continued as a "bent" line.

The patterns of transects that were generated covered all four quadrants of the study areas and sampled them with approximately equal intensity. This outcome was considered more desirable than the sparse sampling of areas that sometimes occurs when transects are positioned at random. Regardless, there was no expectation that benthic components were distributed in any sort of regular pattern, so the placement of transects in a pattern that was more even than a truly random pattern was not considered biased.

2.2.3 Still Photography

The first method of estimating benthic coverage, still photography, involved using a Nikonos V camera equipped with a 28-mm lens and dual strobes, mounted on an aluminum framer, that allowed the camera lens to be 1.0 m above the substratum. The bottom of the framer was wrapped in foam to protect the reef from damage. Cameras were loaded with Kodak Ektachrome EliteChrome 200 ASA 36-exposure color slide film and set to f11 and a distance of 0.8 m. One strobe was set on TTL and the other on slave. Seventeen photographs were taken on the right side of the transect in a consecutive, non-overlapping fashion along each transect at each site (Figure 2.2.3). Earlier reports reported that each photograph captured 44 x 63 centimeters (cm) of the benthos (2772 cm^2). Through visual assessment of the photographs in 2002 and 2003, we noted that the foam edge of the framer appeared along one or more edges of the photograph in some instances. With the framer measurements and information on the camera lens, we determined that each photograph in fact covered an area of 78 x 52 cm (4056 cm^2) using the factory lens information from Nikonos. Since coral cover was calculated as percent cover, a relative measure, this did not affect results except for the total area surveyed.

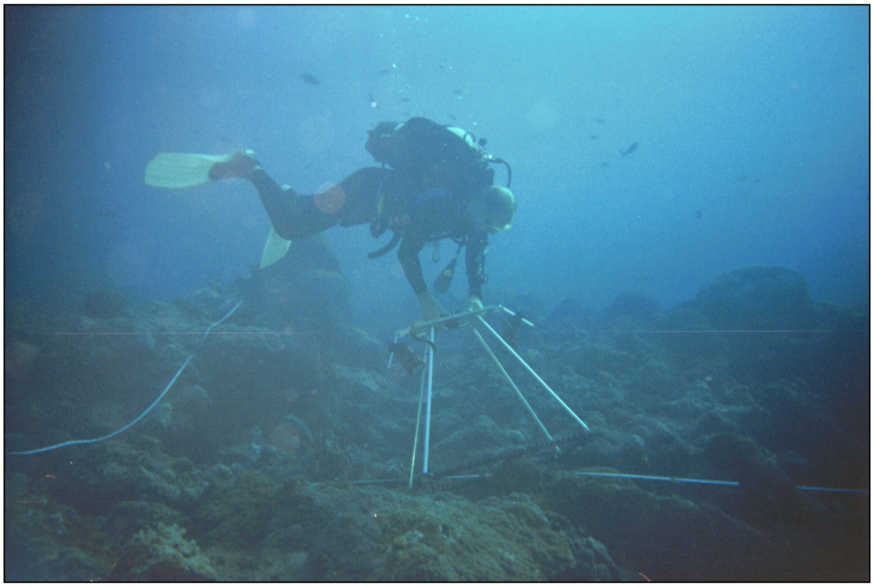


Figure 2.2.3. Random still photographs being taken in October 2002 at the FGB.

Still photographs were analyzed using planimetry (Sigma Scan Pro®) to obtain estimates of the coverage of benthic components. The three sibling species of the *Montastraea annularis* complex were analyzed separately using the judgement of the trained analyzer. For statistical purposes the three species were combined in analysis. Data from the photographs were pooled within transects to provide one estimate of each parameter per transect (i.e., n=14 per site per survey). Pooling the data in this way obviates any concerns about the positions at which the photographs were taken along the transects, and more general concerns that subsamples along transects may not be independent.

2.2.4 Videography

The second method, digital videography provides a logistically simpler and more reliable alternative to still photography. In the videographic protocol, a diver swam slowly along each transect, videotaping at a height of 40 cm from the substratum, using a digital video camera in an underwater housing fitted with a wide-angle lens and underwater video lights. A depth gauge and scaling bar were attached to an aluminum bar that projected forward from the video housing. The gauge and bar ensured that the camera remained a constant distance from the bottom. By holding the video camera perpendicular to the substratum and swimming slowly along the transect it was possible to produce clear stop-action images for analysis (Aronson et al. 1994; Murdoch and Aronson 1999).

The video frames covered a 40-cm wide swath along each of the 10-m transects, for a total area of 4 m^2 per transect, or 56 m^2 videotaped per site per year. Each video frame was 40 x 27 cm, or 1080 cm^2. These dimensions were smaller than those of the still photographs. The reason for the difference is that the videographic technique is designed to enable investigators to identify corals and many other sessile invertebrates to species down to a colony size of approximately 3 cm. This level of precision is not currently possible using video frames that record larger areas of the substratum.

Data from the digital videotapes were collected and analyzed according to the Murdoch Automated Video Analysis method, as follows. A set of 42 video frames was captured from each video transect using a Macintosh PowerBook G4 with the software Adobe Photoshop® version 6.02 and the PhotoDV image capture plug-in software produced by Radius®. The time taken to film each transect was measured and divided into 42 equal time divisions and rounded down to the nearest 1/60th second time interval. Once the software captured each set of frames for each transect, a series of digital filters was applied to each image to enhance image quality. Substrate cover was assessed from the 20 evenly numbered, non-overlapping frames from the set of 42 images. Odd-numbered frames were intentionally captured so as to overlap even-numbered frames. Odd frames were only used to allow the researcher to obtain an alternate view of the area around objects in the analyzed frames when objects were obstructed or unclear in the even frames. Otherwise, odd-numbered frames were not used in the analysis. Unused odd frames were deleted from the digital image set after analysis.

After image capture and enhancement, the image frames from each site had an image of a randomly placed set of 25 dots added as a separate layer. In the 2002 analysis the dot images added to the captured video frames were selected at random from a previously produced batch of 100 random-dot images. A program developed by Murdoch automatically carried out the process of randomly selecting each image of random dots and placing it on each frame of the entire data-set for each reef site. In 2003, unique random-dot images were generated and pasted automatically to each video frame after capture using a new program. After random-dot placement the image files from each transect were visually assessed and the data entered into project-specific Microsoft Excel spreadsheets.

Quality assurance/quality control (QA/QC) for the video method consisted of multiple, trained individuals (Aronson, Precht and Murdoch) diving together on the study sites and identifying corals and other taxa. Captured video frames were then examined to ensure that (1) they agreed on species identifications (particularly an issue with respect to the *Montastraea annularis* species complex) and (2) the taxa were recognizeable on the frames. Previous QA/QC exercises indicated that data derived from the video transects by Murdoch are of high quality, with <1% error in the identification of corals to species and similar errors in the assignment of benthic components to their correct categories.

2.2.5 Linear Point-Intercept Estimates

The third method of assessment, visual estimation, consisted of a diver swimming along each transect, recording the substratum component underlying each 10-cm mark along the tape, for a total of 100 points recorded per transect. The linear point-intercept (LPI) method has proven effective at estimating areal coverage of benthic components on coral reefs, particularly where the diversity of corals and other taxa is low (Ohlhorst et al. 1988; Rogers et al. 1994; Aronson and Precht 1995, 1997), as it is at the FGB (Figure 2.2.5).

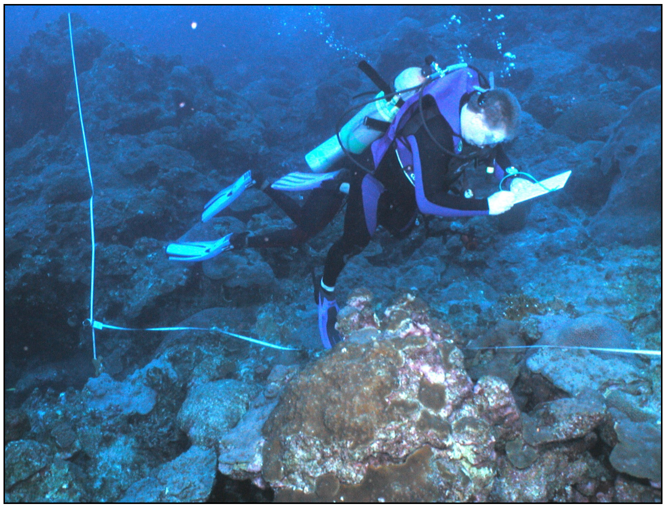


Figure 2.2.5. Linear-point intercept data collection in progress along random transects at the FGB.

2.2.6 Statistical Analysis of the Transect Data

Each transect was treated as a replicate at the scale of the study site, yielding an estimate of coral cover and the cover of other benthic categories. Percent covers were calculated for each transect from the resulting set of 500 points. Data were collected on the point-counts of each coral species; sponges as a group; macroalgae to species; turf (>3 mm), fine turf, crustose coralline algae and bare rock as a single category, “CTB”; and sand and other inanimate categories of substrate. Graphs were produced to allow the comparison of each reef in the average percent cover of major substrate types, coral species, coral functional types and algal functional types. Previous examination of means and variances, using different numbers of random dots, suggested that 500 dots per transect provide accurate and precise estimates of the coverage of benthic components, regardless of the length of the transects (Aronson et al. 1994; Carleton and Done 1995).

Analyses of Variance (ANOVAs) were performed to test the null hypothesis that the two reefs did not differ in each type of univariate substratum cover. After tests for normality and homogeneity ANOVAs were calculated for each substratum variable with the statistical software Systat® 5.0., only the data on macroalgae had to be transformed, using the arcsine transformation. Multivariate statistical techniques were used to compare how the two banks differed in coral species composition using the software package PRIMER® 5.0.

To place the data on coral cover in a regional context, we analyzed the species-specific coral cover data using multidimensional scaling (MDS). We pooled the species-specific point-count data for hard corals from the 14 transects from each survey at a site in one year. Square-root-transformed Bray-Curtis dissimilarity matrices were calculated from the vectors representing species-specific point-count values from the pooled transect data. Dendrograms and multidimensional scaling (MDS) plots were produced. Additionally the similarity matrices were analyzed to detect multidimensional differences between the two reefs using the non-parametric Analysis of Similarity ANOSIM (PRIMER® 5.0). We included in the analysis pooled point-count data from random transects videotaped in three fully-protected zones (FPZs) of the Florida Keys National Marine Sanctuary during the same period (10, 25-m transects per site per year; 13.5-17.4 m depth; 50 frames analyzed per transect using 10 point-counts per frame; from separate work by Aronson, Murdoch and colleagues.

The three methods of estimating of areal coverage (still photography, videography, and LPI) were compared using a randomized complete-block (repeated-measures) ANOVA design. The transects were the blocks, and the three estimates of coral cover from a given transect were treated as repeated measures. Transects from both banks in both years were pooled for this analysis.

The random sampling approach to videography has provided sufficient statistical power to test hypotheses of change in community composition in previous studies in Florida and the Caribbean. Differences on the order of 3-5% in univariate coral cover were detectable at the 5% level (i.e., at $P<0.05$) with 80% power (Aronson et al. 1994; Murdoch and Aronson 1999). The technique has also performed well in multivariate analyses (Aronson and Swanson 1997). Power analysis was conducted to compare the performance of the videographic approach to its performance elsewhere in the western Atlantic.

2.3 SCLEROCHRONOLOGY

2.3.1 Methodological Rationale

Sclerochronology is the determination of annual growth rates through the measurement of accretionary growth bands in coral core samples taken perpendicular to coral growth. The area between two sequential high-density growth bands was considered an annual growth increment, and measurement of linear extension can be compared within the same coral, between corals, and between banks. Skipped or stressed bands are commonly observed during years of significant coral bleaching or other stresses (including cold air outbreaks, freshwater pulses, damselfish territories) (Wells, 1963; Kaufman 1977; Buddemeier et al. 1974; Dodge, 1975; Hudson et al. 1976; Highsmith 1979; Dodge 1980; Hudson 1981a, 1981b; Hudson et al. 1989; Smith et al. 1989; Heiss 1996; Insalaco 1996).

2.3.2 Field Methods

Four cores were extracted from *Montastraea faveolata* colonies at each bank during the 2003 monitoring cruise. A SCUBA tank-powered pneumatic drill, fitted with a diamond tipped 7.62-cm lapidary bit, was used to extract cores from the center of large *M. faveolata* heads. Cores were 30 millimeters (mm) in diameter and 50 mm long, providing seven years of growth. The hole left from core extraction was filled with a preformed limestone plug inscribed with the date of core extraction (Figure 2.3.2).

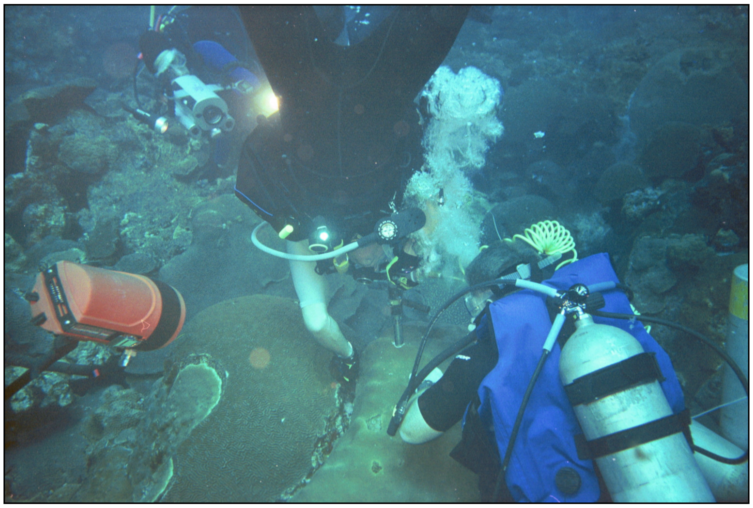


Figure 2.3.2. *Montastraea faveolata* coring 2003 at the FGB.

2.3.3 Laboratory Methods

Cores were longitudinally sectioned into 3- to 4-mm thick slabs using a single-blade diamond impregnated rock saw. Coral slabs were arranged on Kodak brand Industrix 400 x-ray film and exposed to x-rays (70kV 15ma with an exposure time of 7 sec) to reveal annual density bands.

Growth of the *Montastraea faveolata* colonies sampled was determined directly by measuring distances from high density to high density band. Three measurements were made along a single growth band and averaged for an estimate of growth rate per year.

2.3.4. Data Presentation and Statistical Analysis

Overall mean growth rates with standard errors were calculated for each bank and year (1997-2003) from the four cores at each bank. Data are presented for each year by bank in tabular form. A t-test assuming unequal variance was completed comparing East and West Bank growth rates.

2.4 LATERAL GROWTH

2.4.1 Methodological Rationale

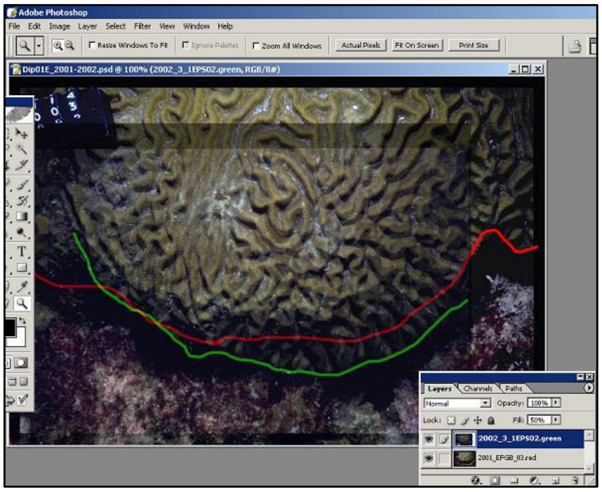
Diploria strigosa is the second largest contributor to coral cover at the FGB (Bright et al. 1984). For this reason *D. strigosa* lateral growth margins are monitored to detect changes, either as retreat or growth of margins.

2.4.2 Field Methods

In 2002, 54 and 43 lateral growth stations were photographed at the East Bank and West Bank, respectively. During the site rehabilitation cruise in April 2003 sixty lateral growth stations were refurbished and/or installed on each bank. At the East Bank 12 new stations were established and 48 old lateral growth stations were refurbished with new pins and tags, for a total of 60 lateral growth stations, numbered 1-60. At the West Bank 17 new stations were installed, while 43 old lateral growth station pins were refurbished with new pins and tags, for a total of 60 new lateral growth stations, numbered 60-120. Divers tagged and photographed all lateral growth stations that they saw in August 2003, even if they did not have a new tag, therefore the number of photographed lateral growth stations exceeded 60 at each bank in 2003, and included new stations, refurbished stations as well as old untagged stations. Sixty-two colonies of *Diploria strigosa* on East

Bank and 64 colonies on West Bank were photographed to assess coral margin growth rates in August 2003.

Divers were equipped with a Nikonos V camera with a 28 mm lens (underwater application, 144x216 mm field, 1/6 reproduction ratio), Nikonos close-up kit and strobe. The camera was set at f22 and a distance of infinity, and the strobe set to TTL. This produced 13.3 x 19.7-cm (262.01-cm^2) photographic images (Figure 2.4.2). The framer was placed on corner pins at each station, ensuring a repeated image of the station. Many stations had missing station identification tags. Those stations that did have tags were photographed with the tag in the frame. For stations without tags, the current photographs were matched with past photographs using the ridge patterns of the *Diploria* colonies.



Dip01E_2001-2002.psd @ 100% (2002_3_1EPS02.green, RGB/8#)

Normal

Opacity: 100%

Fill: 50%

2002_3_1EPS02.green

2001_EFGB_03.red

Figure 2.4.2. Image for analysis of *Diploria strigosa* lateral growth station at the East Bank, showing 2001 (red line) and 2002 (green line) comparison, using Adobe Photoshop.

2.4.3 Image Analysis of Lateral Growth

Images corresponding to a specific lateral growth station were compared for consecutive years. Specifically, comparisons were made between the 2001 and 2002 images, and between the 2002 and 2003 images. Lateral changes in the margins of the *Diploria strigosa* colonies were evaluated by overlaying the photograph pairs and calculating the area of advance or retreat laterally, using Sigma Scan Pro 5®. Successive photographs of a given colony were lined up using the colony's ridge patterns.

Comparisons between 2001 and 2002 lateral growth stations resulted in 18 matches at the East Bank and 11 matches at the West Bank. Comparisons between 2002 and 2003 photographs resulted in eight matches at the East Bank and four matches at the West Bank. The lower number of matches in 2002-2003 was the result of unanalyzable slides, which were too dark in 2002 and the fact that many of the photographs taken were new stations in 2003. New stations established in 2003 were not included in the analysis, because they were photographed only once, but these will contribute to the analysis in the future and should result in a more robust dataset.

2.4.4 Data Presentation and Statistical Analysis of Lateral Growth Stations

Two-tailed binomial probability tests were conducted to test the null hypothesis that lateral accretion (+) or loss (-) of tissue were equally likely in *Diploria strigosa* at East Bank and West Bank from 2001-2002 and 2002-2003. P-values were calculated for each bank in 2001-2002, and for pooled data from both banks for 2002-2003 due to low sample size at each bank individually. Proportional annual changes in growth of the individual *Diploria* colonies, whether positive or negative, were examined by site (East Bank and West Bank) and by year (2001-2002 and 2002-2003) using non-parametric statistical tests.

2.5 REPETITIVE QUADRATS

2.5.1 Methodological Rationale

To monitor changes in coral reef community structure, repetitive 8m^2 quadrats were photographed and analyzed in two ways. The first method of analysis measured percent benthic cover components in 2002 and 2003 using random dot analysis. To determine whether specific coral colonies grew or lost tissue laterally, selected corals within repetitive quadrats were analyzed using planimetry to measure growth or loss of tissue of available matches between 2001, 2002, and 2003. Due to the variability from year to year in photographs, dominant frame building corals that predominate the FGB (*Montastraea* spp., *Diploria strigosa, Colpophyllia natans*) were selected based on their visible margins, these corals tended to be closer to the center of the photograph.

2.5.2 Field Methods

In 2002, 31 and 34 repetitive quadrat stations were photographed at East Bank and West Bank respectively. In April 2003 during the site-rehabilitation cruise pins and tags were refurbished for established repetitive quadrat stations, as well as the installation of new stations to return the sample size to 40 repetitive quadrats at each bank. At the East Bank thirty-one existing repetitive quadrat stations were refurbished and 9 new stations were installed, for a total of 40 repetitive quadrat stations, numbered 1-40. At the West Bank thirty-six stations were refurbished and 4 new stations were installed, for a total of 40 repetitive quadrat stations, numbered 40-80. Because divers tagged and photographed all repetitive quadrat stations they saw, whether they had a new tag or not, the number of stations photographed in 2003 exceeded 40 at each bank, these included refurbished stations, old non-refurbished stations and newly established stations. In 2003, 41 and 44 repetitive quadrats were photographed at East Bank and West Bank, to track changes of 8m^2 repetitive quadrats over time.

Twenty image pairs for the East Bank and 31 image pairs for the West Bank were analyzed between 2002-2003. Less than forty quadrats were analyzed at each bank because the rehabilitation cruise replaced old pins as well as establishing new pins, therefore the same 40 repetitive quadrats were not necessarily photographed between 2002 and 2003. The rehabilitation cruise has corrected this for future analysis. Stations were photographed using a T-bar camera frame with a Nikonos V camera mounted in the middle, loaded with Kodak Ektachrome EliteChrome 200 ASA, 36-exposure slide film and a 15mm lens (distance = 2 m, f-stop = 8). Two Ikelite 225 watt-second strobes were mounted on the ends of the T-bar and set on TTL and slave (Gittings et al. 1992). The camera was positioned in a due north direction to ensure repetitive photographs from year to year. The consistent orientation of the camera was achieved with a compass and a bubble level.

Nine additional deep stations at 32-40 m depth were established at East Bank by MMS and NOAA in April 2003 and photographed in August 2003 using the technique described above. The first comparison data will be available in 2005. The deep repetitive quadrat pins were mapped in relation to each other and in relation to the U-bolt at the base of FGBNMS mooring number 2, for ease of location. Depths were recorded for each pin, while distances were not measured and remain relative.

2.5.3 Image Analysis of Repetitive Quadrats

Study Site Quadrats. Percent cover of coral species and other benthic components including, coral species, algae, bleaching, paling, concentrated fish biting or isolated fish biting and disease were determined by overlaying 300 random dots on each photograph with CPCe point count software, with Excel extensions. Percent coverage data was calculated from 2002 and 2003 images. Twenty image pairs were analyzed for the East Bank and 31 image pairs were analyzed for the West Bank.

Planimetry was used to measure change between select coral colonies within quadrat matches between 2001 and 2002 and between 2002 and 2003. Four to six coral colonies were chosen within each repetitive quadrat, colonies were chosen based on the ability to decipher boundaries and importance to reef accretion (i.e. frame builders such as *Montastraea annularis* spp., *Diploria strigosa*, *Colpophyllia natans*). Seven matches were made at the East Bank for 2001-2002 and nine matches were made at the West Bank. For the 2002-2003 comparison 16 matches were compared at the East Bank and 27 comparisons were made for the West Bank. Areal measurements were created using Sigma Scan Pro 5 planimetry software in each year (2001, 2002, 2003) for matched coral colonies (Appendix 4).

Table 2.5.3.

Coral species in repetitive quadrat growth comparison analysis.

Coral Species
Montastraea annularis spp. complex
Diploria strigosa
Porites astreoides
Madracis mirabilis
Montastraea cavernosa
Colpophyllia natans
Siderastrea siderea
Mussa angulosa
Millepora alcicornis

Deep Station Quadrats. Deep stations percent cover of coral species and other benthic components including, coral species, algae, bleaching, paling, concentrated fish biting or isolated fish biting and disease were determined by overlaying 250 random dots on each photograph with CPCe point count software, with Excel extensions. Percent coverage data was calculated from 2003 images. Species richness curves flattened out after 225 dots to characterize species composition at the deep stations. In this way 250 dots were sufficient to accurately describe species composition at the deep stations. The *Montastraea* sibling species were combined for analysis.

2.5.4. Data Presentation and Statistical Analysis of Repetitive Quadrats

Mean percent coral, algae, bleaching, disease and fish-biting cover were calculated for each species or category of benthic cover using random-dot analysis with CPCe® software. Because the *Montastraea annularis* species complex was the dominant substratum occupant in the repetitive quadrats, the cover of this taxon (planimetry measurements) was compared between banks and through time using both parametric and nonparametric approaches.

2.6 PERIMETER VIDEOGRAPHY

2.6.1 Methodological Rationale

Perimeter lines were videotaped each year to document change at known locations along the perimeter and within the study site. A general sense of coral condition and fish populations is obtained and compared year to year.

2.6.2 Field Methods

Divers videotaped two 100 m segments of the perimeter lines at the East (north and east) and West Bank (south and west) in 2002 and 2003. At the East Bank, divers started at the NW corner and videotaped the north line to the NE corner, then swam the east line to the SE corner. At the West Bank, divers captured footage of the south and west lines, starting at the SE corner and ending at the NW corner. The videographer maintained ~2 m distance above the benthos using a weighted line, attached to the video housing. The camera was held at a 45° angle to capture the substratum. At each corner divers recorded a 360° panoramic view of the reef before continuing on to video the line.

2.6.3 Laboratory Methods

The video footage was reviewed to record the general condition of coral health and fish populations along the perimeter of the study sites using IMovie (Macintosh software). Individual coral heads displaying disease, bleaching, paling, and tissue loss due to fish biting were identified and recorded. Analysis categories were as follows: bleaching, paling, healthy colony, concentrated fish biting, isolated fish biting (damselfish territory), increased tissue loss due to concentrated fish biting, increased tissue loss due isolated fish biting, growth infilling (tissue regrowth), new incident of concentrated fish biting, surface replaced by turf algae, and unchanged. Concentrated fish biting (CFB) is the concentrated biting which removes the coral polyps completely from an affected area, and may be due to activity of the parrotfish, *Sparisoma viride.* Isolated fish biting describes less dense and smaller scale fish biting, typically representative of damselfish territories. No disease was documented and therefore was not characterized. Affected coral colonies were compared between 2002 and 2003, and changes in their condition were recorded. In addition, coral species composition and fish counts were documented. These analyses were qualitative and therefore no statistical analyses were conducted.

2.7 WATER QUALITY

2.7.1 Methodological Rationale

Physical and chemical characteristics of the seawater recorded over the reef cap and in the vicinity of the FGB characterize local water quality (Gittings et al. 1992; CSA 1996; Nowlin et al. 1998; Dokken et al. 1999; Dokken et al. 2003; this study). From October 2002 to March 2004, the water quality overlying the reef caps at the FGB was assessed by monitoring temperature, salinity, dissolved oxygen, pH, turbidity, and content in chlorophyll *a*, dissolved inorganic nitrogen (ammonia [$NH_4^+$and NH_3], nitrate [NO_3^-], and nitrite [NO_2^-]), dissolved organic nitrogen (Total Kjeldahl Nitrogen [TKN]), inorganic phosphorous (soluble reactive phosphorous, a soluble inorganic form of phosphorous directly taken up by plant cells), and trace metals (chromium, mercury). These water quality parameters were selected to characterize the environmental background in which the FGB coral reef resources exist. As well as serving as a valuable record of environmental parameters, any changes in coral reef biota which may be linked to water quality changes, could be verified by looking at the water quality data.

2.7.2 Field Methods - YSI Datasondes

The FGBNMS provided PBS&J with the YSI 6600 series datasondes required to record water quality at the FGB. The YSI 6600 Series datasondes recorded the following parameters: temperature, depth, pH, dissolved oxygen, specific conductance, turbidity, and photosynthetically active radiation. The sondes typically have up to a 75-day battery life (at 15-min sampling intervals) and store 150,000 individual parameter readings. The sondes are 51.8 cm long (20.4 in) and have a 8.9 cm (3.5 in) diameter. The sondes are internally powered by eight, C-size, alkaline batteries. The following were the datasonde measurement methods used in this analysis:

Specific Conductance. The sondes utilize a cell with four nickel electrodes to measure conductance. Two of the electrodes are current driven, and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (millimhos). The sonde records the conductance value as specific conductance, a calculated value that corrects for the effect of temperature. The reported salinity values are also calculated values. The values are calculated from the conductivity and temperature readings according to accepted algorithms and reported as Practical Salinity Units (PSU).

Temperature. The sondes utilize a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built into the sonde software, and accurate temperature readings in degrees Celsius, Kelvin, or Fahrenheit are provided automatically. No user calibration or maintenance of the temperature sensor is possible.

pH. The sondes employ a field replaceable pH electrode for the determination of hydrogen ion concentration. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at approximately pH 7 and a Ag/AgCl reference electrode that utilizes electrolyte that is gelled. A silver wire coated with AgCl is immersed in the buffer reservoir. Protons (H+ ions) on both sides of the glass (media and buffer reservoir) selectively interact with the glass, setting up a potential gradient across the glass membrane.

Depth. The sondes are equipped with depth sensors which measure depth by non-vented methods. The sensor uses a differential strain gauge transducer to measure pressure with one side of the transducer exposed to the water and the other side of the transducer is exposed to a vacuum.

Dissolved Oxygen. The sondes employ a proprietary YSI Rapid Pulse system for the measurement of dissolved oxygen (DO). The Rapid Pulse system utilizes a Clark-type sensor that is similar to other membrane-covered steady-state dissolved oxygen probes. The system measures the current associated with the reduction of oxygen which diffuses through a Teflon membrane. This current is still proportional to the partial pressure (not the concentration) of oxygen in the solution being evaluated. The membrane isolates the electrodes necessary for this reduction from the external media, encloses the thin layer of electrolyte required for current flow, and prevents other non-gaseous, electrochemically active chemical species from interfering with the measurement.

Turbidity. Turbidity is the measurement of the content of suspended solids (cloudiness) in water and is typically determined by shining a light beam into the sample solution and then measuring the light that is scattered off of the particles which are present. For turbidity systems capable of field deployment (including YSI), the usual light source is a light emitting diode (LED) which produces radiation in the near infrared region of the spectrum. The YSI turbidity system sondes consist of a probe which conforms to ISO recommendations. The output of the sonde turbidity sensor is processed via the sonde software to provide readings in nephelometric turbidity units (NTUs).

One YSI datasonde was deployed at the East Bank (23 m water depth) and one at the West Bank (27 m water depth). Sandflats were used as deployment locations to accommodate the secure attachment of the datasondes to iron train wheels. Water quality data were gathered every 30 min to every 1.5 hours [hr] depending on battery life. The deployment schedule of the YSI datasondes is shown in Table 2.7.2. There were large gaps (3 months or more) in the data sets because of YSI logging failures, or the data collected were determined to be invalid measurements.

YSI data sonde maintenance was scheduled on a quarterly basis. The quarterly retrieval schedule was met with the exception of one cruise, which was rescheduled due to inclement weather conditions. YSI data sondes under marine conditions such as those encountered at the FGB need to be changed out on a more frequent basis (2-4 weeks) in order to ensure consistent accurate data quality. When datasondes are retrieved on a quarterly basis there is a substantial portion of data that is unusable due to heavy biofouling and subsequent hardware failures. Prolonged exposure to open-ocean conditions are not suitable for this type of water quality recording equipment used here. Once datasondes are retrieved and data is processed, decisions on what to analyze must be made by a qualified analyst. Sometimes there is a clear point at which sondes have started to fail to collect accurate data, and sometimes this line is unclear. Data presented here are the best estimation of the analyst as to what constituted usable accurate data. To obtain accurate consistent water quality data for the FGB on a long-term basis requires more frequent changes of YSI datasondes or alternative hardware considerations.

Table 2.7.2.

Schedule of YSI water quality datasonde deployments, change outs, and retrievals at the East Bank and West Bank in 2002 and 2003.

East Bank	Deployment	West Bank	Deployment
10/29/2002-02/18/2003	1	10/30/2002-02/01/2003	1
02/18/2003-5/14/2003	2	02/01/2003-05/16/2003	2
5/14/2003-8/26/2003	3	5/16/2003-8/28/2003	3
8/26/2003-11/03/2003	4	08/28/2003-03/11/2004	4

2.7.3. Field Methods - HoboTemp Thermographs

A HoboTemp thermograph was attached to each of the YSI instruments as a backup recorder of water temperature. HoboTemp recorders have an accuracy of plus or minus two degrees Celsius (°C). Resolution is 0.02 at 25°C. The HoboTemp recorders were deployed in water depth of 23 m at the East Bank and in a 27 m water depth at the West Bank. Temperature was recorded every hour. The HoboTemp deployment schedule is presented in Table 2.7.3. HoboTemp temperature records were continual at the West Bank (February 2003 to March 2004). At the East Bank, HoboTemp temperature records were gathered from October 2002 to March 2004 with a prolonged interruption lasting from May to August 2003. This interruption was due to loss of the HoboTemp unit at East Bank during deployment.

Table 2.7.3.

Schedule of HoboTemp thermograph deployments, change outs, and retrievals at the East Bank and West Bank in 2002 and 2003.

East Bank	Deployment	West Bank	Deployment
10/29/2002-02/18/2003	1	02/01/2003-05/16/2003	1
02/18/2003-05/14/2003	2	05/16/2003-03/11/2004	2
05/14/2003-8/26/2003	3		
08/26/2003-03/11/2004	4		

2.7.4. Field Methods - Chlorophyll *a*, Nutrients, and Trace Metals

Surface (< 1 m), midwater (~ 9 m), and near bottom (~ 18 m) water samples were acquired at five different times at the East Bank and West Bank from August 2002 to March 2004 (Table 2.7.4). During each sampling event, water was sampled twice at each sampling depth using a vertical sampling bottle (Wildco®). Samples were taken off the bow of the dive vessel while the vessel was moored over the monitoring site. Water samples were immediately transferred into pre-cleaned polyethylene containers (tested monthly using nanopure water) provided by an independent, EPA-certified analytical laboratory (Anacon, Inc.). Cholorophyll a water samples were collected in 1000 ml containers with no preservatives, while reactive phosphorus (no preservative) and Total P, Hg, and Cr (HNO_3 preservative) samples were collected in 250 ml bottles. Total Kjeldahl Nitrogen (TKN), ammonia, nitrate and nitrite were collected in 1000 ml containers with H_2SO_4 as preservative. During each water sampling effort, one blind duplicate water sample was taken at one of the sampling depths on one of the banks. Within minutes of sampling, labeled containers were stored in an iced-cooler at 4 °C and a chain of custody record was initiated. Once back onshore the water samples were sent to the laboratory for analyses. Water samples were analyzed using standard USEPA methods (Table 2.7.5) to assess concentrations of chlorophyll *a*, nutrients (ammonia, nitrate and nitrite, Total Kjeldahl Nitrogen [TKN], soluble reactive phosphorous), and trace metals (chromium and mercury).

Table 2.7.4.

Water sampling schedule and depth, and number of samples taken at the FGB from August 2002 to March 2004.

East Bank			West Bank		
Sampling Date	**Depth**	**Samples**	**Sampling Date**	**Depth**	**Samples**
10/29/02	< 1 m	4	10/30/02	< 1 m	4
10/29/02	~ 9 m	4	10/30/02	~ 9 m	4
10/29/02	~ 18 m	4	10/30/02	~ 18 m	4
02/18/03	< 1 m	4	2/19/03	< 1 m	4
02/18/03	~ 9 m	4	2/19/03	~ 9 m	4
02/18/03	~ 18 m	4	2/19/03	~ 18 m	4
05/14/03	< 1 m	4	05/16/03	< 1 m	4
05/14/03	~ 9 m	4	05/16/03	~ 9 m	4
05/14/03	~ 18 m	4	05/16/03	~ 18 m	4
08/26/03	< 1 m	4	08/28/02	< 1 m	4
08/26/03	~ 9 m	4	08/28/02	~ 9 m	4
08/26/03	~ 18 m	4	08/28/02	~ 18 m	4
03/11/04	< 1 m	4	03/11/04	< 1 m	4
03/11/04	~ 9 m	4	03/11/04	~ 9 m	4
03/11/04	~ 18 m	4	03/11/04	~ 18 m	4

Table 2.7.5.

Standard U.S. Environmental Protection Agency methods used to analyze water samples taken at the FGB from August 2002 to March 2004.

Parameter	Method	Detection Limit
Chlorophyll *a*	10200H	1 mg/m^3
Ammonia (as nitrogen)	350.3	0.20 mg/l (10/02, 2/03, 5/03, 8/03) 0.03 mg/l (3/04)
Nitrate and nitrite (Total)	353.3	0.15 mg/l
Total Kjeldahl Nitrogen (TKN)	351.3	0.10 mg/l
Soluble reactive phosphorous	300.0	0.40 mg/l
Chromium	200.8	1 µg/l
Mercury	200.8	30 µg/l

2.8. FISH SURVEY

2.8.1 Methodological Rationale

Surveys of fish assemblages have been conducted at the FGB since at least the 1980's (Boland et al. 1983; Rezak et al. 1985; Dennis and Bright 1988; Pattengill 1998). Generally, the fish assemblage of the coral reef zone at the FGB is composed of Caribbean reef fishes; however, the total number of species is reduced and certain families such as the Lutjanidae and Haemulidae are underrepresented or absent at the banks (Jones and Clark 1981; Lukens 1981; Rezak et al. 1985). The influence of offshore gas and petroleum production platforms has been and is continuing to be investigated (Rooker et al. 1997). Continued monitoring of the FGB is vital to increase and continue the understanding of this unique habitat in light of ongoing, as well as changing, natural and anthropogenic pressures on fish populations. Stationary visual fish surveys were conducted at the FGB at both East Bank and West Bank in October of 2002 and August of 2003.

2.8.2 Field Methods

Reef-fish surveys were conducted in October of 2002 and August of 2003. Fishes were visually assessed using SCUBA and a stationary visual census technique (Bohnsack and Bannerot 1986). Observations of fishes were restricted to an imaginary cylinder with a radius and height of 7.5 m from the diver. All fish species observed within the first five minutes of the survey were recorded. Immediately following, additional time was used to record abundance (number of individuals per species) and total length (cm) (minimum, maximum, and average) of those species noted in the first five minutes. Surveys lasted from 10 to 15 minutes. When necessary, species identifications were verified using Humann (1994) and Humann and DeLoach (2002). Depth, visibility, temperature, and survey location were also recorded.

An average of 16 surveys each were performed at East and West Banks in 2002 and 2003. The fewest surveys (14) occurred at the East Bank in year two. Survey dives began in the early morning, before other dive activities were started, generally between 0700 and 0900, and were repeated by two to three divers throughout the day until dusk. Two days were spent surveying each bank, except at the West Bank in year one (2002), in which all 16 surveys were completed in one day. Individual survey locations were spread evenly within the 100m x 100-m study site to achieve maximum coverage of the reef habitat while excluding sand patches. The visibility for all surveys was greater than 10 m, with 25 to 30 m being most common in year one and 20 m being the average in year two. Survey depths ranged from 19 to 25 m at the West Bank and 16 to 23 m at the East Bank.

2.8.3 Analysis and Statistical Methods

Fish densities are expressed as the number of fish per 100-m^2 horizontal area. For each bank and year, densities were calculated as the mean number of individuals recorded per species, with each diver survey acting as a replicate, divided by the horizontal area of the survey cylinder (176.7 m^2).

Relative abundance for each species is expressed as the percentage of the total number of times the species was recorded out of the total number of surveys for the site (bank and year). Species richness is the expression of the total number of species for each site (bank and year).

Size frequency distributions for two trophic guilds, herbivores and carnivores, were calculated as the proportion of the total number of herbivores or carnivores and represented as a percentage of individuals in the guild falling within different size categories (0-5 cm, 6-10 cm, 11-20 cm, 21-30 cm, 31-40 cm, and >40 cm), based on average fish lengths recorded during the surveys. Parrotfishes (Scaridae), surgeonfishes (Acanthuridae), and yellowtail damselfish (*Microspathodon chrysurus*) comprised the herbivore guild, while snappers (Lutjanidae) and select groupers (Serranidae) comprised the demersal carnivore guild. The select groupers of the carnivore guild included yellowmouth grouper (*Mycteroperca interstitialis*), tiger grouper (*M. tigris*), graysby (*Epinephelus cruentatus*), and coney (*E. fluvus*) (Claro and Cantelar Ramos 2003; Pattengill-Semmens and Gittings 2003).

Diversity was calculated using the Shannon-Wiener diversity index and from it, species evenness for each site and year was determined. The Shannon-Wiener diversity index,H', was calculated as:

$$H' = -\sum_{i=1}^{k} p_i \log p_i$$

where k was the number of species present and p_i was the proportion (n_i/N) of the i-th species. Evenness (J') was calculated as:

$$J' = \frac{H'}{H'_{\max}}$$

where H'_{max} was the maximum possible diversity (H'_{max} = log k, with k=number of data categories).

To allow the valid application of parametric analyses of variance, fish abundances were $\log_{10}+1$ transformed to make them normal, homoscedastic, and additive (Zar 1984; Aronson et al. 1994; Edmunds and Carpenter 2001). Two-sample t-tests (two-tailed) were used to compare the fish densities and species richness by bank and sampling year.

2.9 SEA URCHIN AND LOBSTER SURVEYS

2.9.1 Methodological Rationale

Sea urchins, specifically *Diadema antillarum*, were important herbivores on coral reefs throughout the Caribbean until 1983-84. At that time, an unknown pathogen decimated populations throughout the region, including at the FGB. Their recovery has been documented in the Caribbean (Edmunds and Carpenter 2001). *D. antillarum* populations at the FGB pre-1984 were near 1 individual/m^2 (Gittings et al. 1992). Lobsters are commercially important but their population dynamics at the FGB are not well understood.

2.9.2 Field Methods

The sea urchin *Diadema antillarum* and the spiny lobster *Panulirus argus* were surveyed at night, at least 1.5 hours after sundown. Two belt transects were surveyed along the northern and western boundaries in 2002 and the southern and eastern boundaries in 2003 at the East and West Bank. Each belt transect was 100 m long and 1 meter wide for a total of 200 m^2 surveyed along site boundaries each year. Additional sea urchin and spiny lobster surveys were conducted along the 14 random transects (140 m^2), for a total of 340 m^2 surveyed per bank per year.

2.9.3 Statistical Methods

Due to low sample numbers, only qualitative analyses were possible for the sea urchin and lobster surveys.

2.10 MAPPING OF THE FLOWER GARDEN BANKS

2.10.1 Methodological Rationale

Accurate maps showing individual coral heads and sand patches of the FGB monitoring sites were deemed necessary for use in the field as well as for long-term analysis. Once a more detailed and accurate map is established the individual station markers (repetitive quadrat and lateral growth stations) can be georeferenced using GPS. Two mapping techniques, sector-scan and side-scan sonar were tested to produce the best quality map of the study sites at FGB.

Sector-scan sonar relies on a mechanically rotated transducer, mounted on a tripod at a fixed position above the seabed, to produce an acoustic image of an area surrounding the sensor. Side-scan sonar involves towing a sensor (towfish) behind a moving boat. The towfish contains two transducers, which scan opposite sides of the towfish path through the water column.

2.10.2 Sonar Technology

Sonar technology relies on acoustic energy transmitted at specific frequencies and intervals from a transducer, which in turn makes contact with the seabed where portions of the energy are reflected back to the transducer and interpreted into a visual display. The amplitude of the returning acoustic signal is a function of the contrast between the seabed and the water column and depends on factors such as the composition of the seabed and the angle of incidence between the sound waves and the seabed. The amplitude of the acoustic signal reflected from the seabed is, therefore, dependent upon factors affecting density and phase velocity of the seabed, such as porosity, water content, compaction and degree of lithification. Soft sediments produce low-amplitude return signals. Hard materials, including coral and exposed rock, return high-amplitude acoustic signals to the transducer. Air bubbles, such as found in the air bladders of fish, also return high amplitude signals because of the high contrast between air and water in both density and sound velocity.

Returning acoustic signals are converted in the transducer to analogue electrical waveforms and digitally sampled at a rapid rate. Each cycle of acoustic transmission and reception is referred to as a ping. Each returning ping is subdivided into samples, each of which is represented by a single pixel when the data are displayed at their highest screen resolution. Data acquisition software assigns screen coordinates to the discrete digital samples of each returning wave. The signal amplitude (i.e., voltage) at each point sampled along a return wave determines pixel color. Geographic coordinates are assigned to pixels by estimating the position of the transducer at the moment each acoustic wave is received, then by calculating the lateral offset of the sample from the transducer based on the transducer heading and the two-way travel time of the sample from the transducer to the seabed and back. The offset distance calculation for each sample assumes a constant velocity of sound in seawater. The role that angle of incidence plays in determining the returning signal amplitude is analogous to sunlight illumination of a land surface. Low angles of light or sound reflect less energy than do high angles, while areas blocked by vertical relief are left in shadow. These are the characteristics that give sonar data its strong resemblance to aerial photography.

2.10.3 Sector-Scan Sonar Methods

Sector-scan sonar was deployed only at East Bank in August 2003. The MS1000 sonar (Kongsberg Simrad Mesotech, Ltd.), and the MS1000 acquisition software were employed and sonar images displayed on the computer screen in a radial pattern, resembling radar. The software stored images as bitmaps, so image quality adjustments were made prior to capturing the screen display. Resolution was dependent upon the scan speed selected in the acquisition software and on the physical specifications of the sonar head. The slowest scan speed (X1) correlated with the highest screen resolution and was used for data acquisition at East Bank.

A model 1071-series high-resolution sonar head (P/N 974-23030000), was deployed at the East Bank. This transducer operated at an acoustic frequency of 675 kHz and rotated mechanically at intervals of 0.225 degrees. It has a horizontal beam width of 0.9 degrees and a vertical beam width of 30 degrees. The MS1000 data acquisition software was set to image the seabed out to a range of 40 m from the transducer, so the entire East Bank study site could be recorded by four overlapping scans. A full rotation of the transducer lasted 1.5 minutes. At this range each screen pixel represents a geographic area measuring 0.17 by 0.17 m; however, the circumferential resolution ranges from 0.17 (equivalent to the beam width at a range of 10.8 m) to 0.63 m at the maximum range of 40 m. This resulted in resolution degradation beyond a range of 10.8 m.

The transducer head was deployed at an approximate height of 2.1-2.4 m above the seabed using an aluminum tripod with adjustable legs. Two divers deployed the tripod using a lift bag for assistance. Tripod legs were padded to minimize damage to substratum. The tripod was positioned near the center of each study quadrant prior to recording each series of scans. The tripod was oriented using a magnetic compass so that the top of each image would be directed toward magnetic north. Diver air bubbles marked the location of the nearest study site corner pin as quadrants were scanned, since the geographic positions of these corners had been previously mapped using GPS. Knowing the orientation of each image and having one known geographic location marked in each image would allow scans to be overlaid on the study area boundary. Balloons were partially inflated by divers and suspended above each monitoring pin prior to recording images. Since air produces strong acoustic reflections, it was hypothesized that these balloons would be visible in the images against the background of coral, revealing the exact position of markers (repetitive quadrat pins).

2.10.4 Side-Scan Sonar Methods

Side-scan sonar was used to map both East Bank and West Bank. The side-scan towfish (Edgetech DF1000) operated at a frequency of 500 kHz, with a horizontal beam width of 0.5 degrees and a vertical beam width of 50 degrees tilted down 20 degrees from horizontal. The DF1000 sampled an analogue signal and transmitted a digital data stream through the tow cable. This process eliminated signal attenuation due to the length of the cable and reduced disruption by electrical noise on board the survey vessel. The towfish was deployed from a 50 m length of cable off the starboard stern. The towpoint at the stern was locating 2.5 m above the water and 13.4 m directly aft of the GPS antenna. The horizontal layback distance of the towfish behind the stern varied with vessel speed from 47.9 to 48.9 m, averaging 48.4 m, as the towfish ranged in depth beneath the surface from about 8 to 12 m.

The towfish was powered and controlled by an Edgetech Digital Control Unit (DCU). The DCU controls the range of the towfish, its operating voltage and the timing of the pings. The digital signal received from the towfish was converted back to an analogue waveform by the DCU in preparation for transmission to the data acquisition computer. A Coda Model DA75 computer, running Coda Geosurvey software, was used to display and record the raw sonar data arriving from the towfish via the DCU. The DCU and Coda software were set to a 50 m range. Range refers to the maximum distance recorded by the sonar relative to the transducer positions. The complete data record, including the entire range of return signal voltage, was digitally recorded directly to DVD disks, allowing adjustment of image quality at any time during or following data acquisition.

Vessel positions were provided by a Trimble Ag132 GPS system receiving differential corrections from the U.S. Coast Guard. Vessel navigation along desired tracks was accomplished using a HydroPro Version 2.1 by Trimble. HydroPro was also used to record the position of the GPS antenna and to estimate the towfish position at one-second intervals. Towfish position estimates were exported in real time to the Coda sonar acquisition computer where they were integrated with the raw sonar record.

Resolution of raw side-scan sonar data has two independent components: range and azimuthal resolution. The number of samples digitized per ping limits the range (across-track) resolution of the raw data. The Coda DA75 computer (set to a 50-m range) produced 2560 geo-referenced pings per transducer, resulting in an across-track pixel dimension of 0.021 m. The azimuthal (along-track) resolution is limited by the beam width of the sonar transducers. The DF1000 transducers produce tightly focused waveforms with the peak energy concentrated within a 0.5-degree horizontal beam width. The minimum resolvable dimension increases as the distance from the transducer increases. For example, at a slant range of 10 m (the average towfish altitude for this survey) the beam width (along-track resolution) would be 0.087 m. The beam width at a slant range of 25 m would be 0.218 m, and the width at a range of 50 m would be 0.436 m. It is important to remember that the minimum along-track pixel dimension of the raw sonar data (0.09 m) is not representative of the along-track resolution except at a slant range of 10 m. The accuracy of sonar imagery is perhaps more important than its resolution. Accuracy refers to how closely the image represents reality. While resolution is a component of accuracy, more important factors include towfish position and heading estimates.

3.0 RESULTS

3.1. RANDOM TRANSECTS

The random transects were analyzed using both univariate and multivariate statistical techniques. Emphasis was placed on the videographic records of the transects, because the intent was to test videography as a replacement technology for still photograph transects in the long-term monitoring at the Flower Garden Banks National Marine Sanctuary.

In general, random transect results revealed high coral cover, relatively low macroaglae cover, high levels of CTB (crustose corallines, fine turf, and bare rock) and low coverage of sponges, consistent with past monitoring results (Table 3.1.1).

At the East Bank coral cover remained stable from 2002 to 2003 (56.43% ± 2.36 to 53.20% ± 3.01), while macroalgae increased and CTB decreased. Sponge cover remained low for both years. Macroalgae (mainly *Dictyota* and *Lobophora* spp.) was low in 2002 (4.06% ± 0.75 SE) and increased in 2003 (16.74% ± 2.04), and the site X year interaction was significant (Table 3.1.3.C). The *Montastraea annularis* complex continued to dominate the East Bank in 2002 (33.59% ± 3.86) and 2003 (28.47% ± 2.98). *Diploria strigosa* (6.96% ± 1.69 and 6.19% ± 1.55 in 2002 and 2003, respectively) and the brooding coral *Porites astreoides* (6.79% ± 0.83 in 2002 and 5.69% ± 0.98 in 2003) were the next most abundant species (Table 3.1.1. and Figure 3.1.1). The remaining coral cover was made up of eleven separate species, none of which exceeded more than 5% individually in either 2002 or 2003 (Table 3.1.1). Shannon-Weiner diversity values were highest at the East Bank (H'=1.45 and H'=1.51 in 2002 and 2003, respectively). No disease or bleaching was noted in the random transect footage.

The West Bank random transect data revealed an increase in coral cover from 2002 to 2003 (49.67% ± 3.35 to 57.13% ± 3.81) over the two year sampling period, a decrease in macroalgae from 2002 to 2003 and an increase in CTB over the same period, while sponge cover was low (Table 3.1.1). The dominant corals were the *Montastraea annularis* complex in 2002 (31.73% ± 3.57) and 2003 (33.80% ± 4.31). *Porites astreoides* (3.44% ± 0.74) and *Diploria strigosa* (3.20% ± 0.91) made up the next largest percentages of coral cover in 2002, while *D. strigosa* (9.04% ± 2.68) increased in 2003 and *P. astreoides* (3.77% ± 0.46) remained stable. The increase in *D. strigosa* from 2002 to 2003 and the small increase in *M. annularis* complex from 2002 to 2003 account for the overall increase in coral cover for the sampling period at the West Bank. Of the remaining eleven coral species that made up the remaining coral cover, no individual species accounted for more than 4% coral cover in either year. Relative dominance of the ten most common species at the West Bank shows the predominance of the *Montastraea annularis* complex (Figure 3.1.2). Shannon Weiner diversity Indices values (H') were lower at the West Bank overall, (H'=1.37 and H'=1.35) in 2002 and 2003 respectively. Bleaching and disease were not noted in the random transects.

The *Montastraea annularis* species complex (*M. annularis, M. faveolata*, and *M. franksi*) has been difficult to differentiate in the field and even more so in photographic and videographic techniques (Dokken et al. 1999; 2003; this study). As part of the comparison of the three methods of data analysis (still photography, videography, and linear-point intercept [LPI], the relative abundance of the three species are presented here as a result of the LPI transect results, whose species determinations were made in the field (Figure 3.1.3). *M. faveolata* and *franksi* were combined because their differentiation continues to be problematic. The results show *M. annularis* to be the least represented species of the complex. *M. annularis* appears to be more abundant at the West Bank.

Table 3.1.1.

Random transect coral cover by species, macroalgae, CTB (crustose coralline, turf, and bare rock), sponge, and sand cover categories at the East and West Bank in 2002 and 2003. Values are expressed as percent cover ± SE. Values are calculated from videography.

Cover category	**East Bank**	**East Bank**	**West Bank**	**West Bank**
	2002	**2003**	**2002**	**2003**
Agaricia agaricites	0.53 ± 0.15	0.33 ± 0.11	0.43 ± 0.11	0.24 ± 0.08
Agaricia fragilis	0	0.01 ± 0.01	0	0
Colpophyllia natans	0.57 ± 0.39	3.29 ± 1.40	1.67 ± 1.21	2.17 ± 0.84
Diploria strigosa	6.96 ± 1.69	6.19 ± 1.55	3.2 ± 0.91	9.04 ± 2.68
Madracis decactis	0.66 ± 0.41	0.82 ± 0.34	0.7 ± 0.47	0.37 ± 0.29
Millepora alcicornis	2.19 ± 0.56	2.23 ± 0.43	2.16 ± 0.70	1.94 ± 0.54
***Montastraea annularis* complex**	33.59 ± 3.86	28.47 ± 2.98	31.73 ± 3.57	33.8 ± 4.31
Montastraea cavernosa	3.9 ± 1.08	4.24 ± 1.41	2.74 ± 1.16	2.67 ± 1.10
Mussa angulosa	0.37 ± 0.16	0	0.29 ± 0.16	0.07 ± 0.04
Porites astreoides	6.79 ± 0.83	5.69 ± 0.98	3.44 ± 0.74	3.77 ± 0.46
Porites porites* forma *furcata	0.06 ± 0.04	0	0.01 ± 0.01	0
Scolymia cubensis	0	0.01 ± 0.01	0	0.04 ± 0.03
Siderastrea siderea	0.44 ± 0.25	0	1.9 ± 1.08	2.04 ± 1.10
Stephanocoenia intersepta	0.31 ± 0.13	0.76 ± 0.32	1.39 ± 0.36	0.96 ± 0.45
Total Coral	**56.43 ± 2.36**	**53.20 ± 3.01**	**49.67 ± 3.35**	**57.13 ± 3.81**
Macroalgae	4.06 ± 0.75	16.74 ± 2.05	19.14 ± 1.4	8.41 ± 1.41
CTB	37.07 ± 2.69	28.12 ± 2.05	27.63 ± 3.14	31.63 ± 3.04
Sponge	0.79 ± 0.36	1.54 ± 0.4	1.31 ± 0.32	1.56 ± 0.38
Sand	1.57 ± 0.58	0.33 ± 0.17	2.19 ± 0.1	1.23 ± 0.61

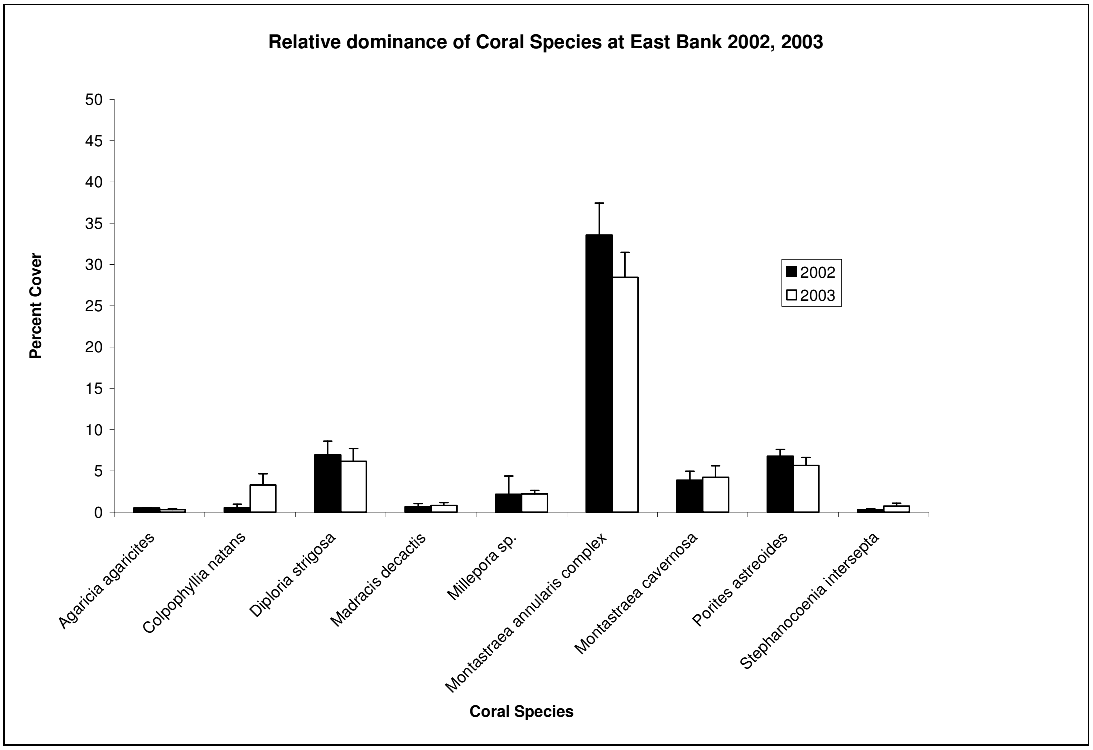


Figure 3.1.1. Relative dominance of coral species at East Bank in 2002 and 2003, expressed as percent cover with ± SE. Values are calculated from random transect videography.

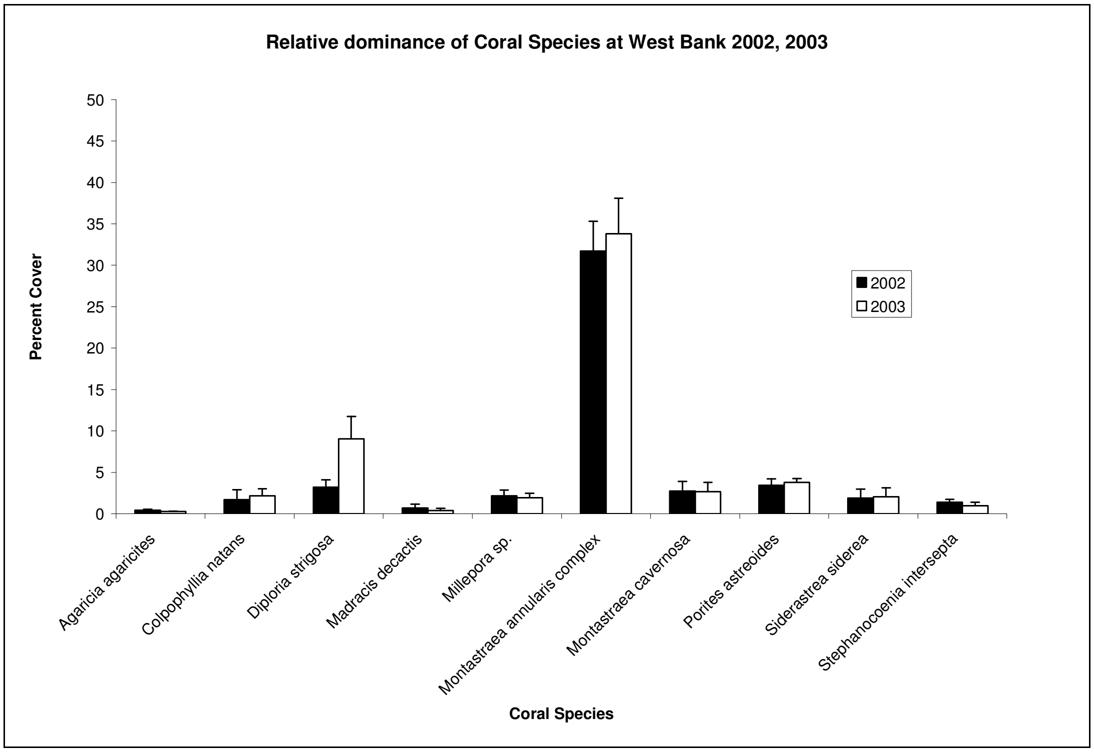


Figure 3.1.2. Relative dominance of coral species at West Bank in 2002 and 2003, expressed as percent cover with ± SE. Values are calculated from random transect videography.

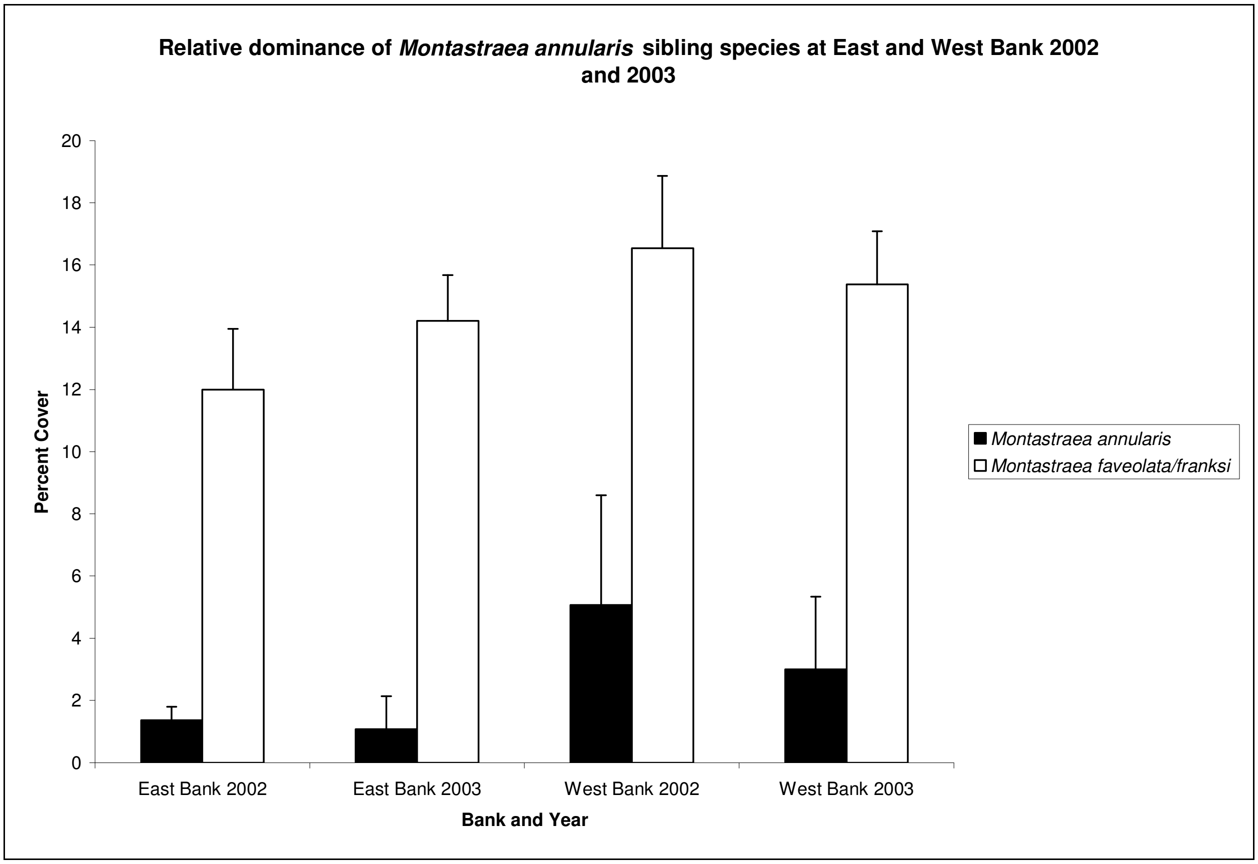


Figure 3.1.3. Relative dominance of *Montastraea annularis, M. faveolata*, and M. *franksi* (combined) at East and West Bank 2002 and 2003. Values are calculated from Linear-Point-Intercept data (± SE).

3.1.1. Comparison of Methods for Estimating Coral Cover

In addition to the point counts from the video transects, coral cover was estimated by two other methods: the linear point-intercept (LPI) method (Rogers et al. 1994; Ohlhorst et al. 1988), which was used to assess coral cover during the 1970s and 1980s (Gittings et al. 1992); and planimetry of digitized still photographs, which was used during the period 1988-2002 (Gittings et al. 1992, CSA 1996, Dokken et al. 1999, 2003). In the LPI method, a diver swam along each 10-m transect and recorded the substratum component under each 10-cm mark, for a total of 100 point counts per transect. The diver was William F. Precht, who has many years of training and experience in identifying benthic organisms on coral reefs. For the still photographs, 17 non-overlapping photographs were taken along each transect at each site. These photographs were digitized and estimates of substratum cover were computed from the digital images using planimetry. Because survey techniques evolve over time, it is critical that their comparability be assessed. In the context of monitoring at the FGB, statistical scrutiny is required especially to justify the transition to videography from still photography, which was used to capture most of the historical data that we have available.

The three methods were compared using a randomized complete-block (i.e., repeated-measures) ANOVA design, in which the transects were the blocks. Still photographs were not available for 8 of the 56 transects due to the loss of film when cameras flooded; this left 48 transects for which coverage estimates were available for all three survey methods. We compared the three methods for three benthic categories that differed markedly in percent cover: the total cover of hard corals (Scleractinia and Milleporina), which was a common category at >50% cover; the cover of *Montastraea annularis* species complex, an intermediate-abundance category at approximately 30% cover; and *Diploria strigosa*, a rare category at approximately 7% cover. The coverage estimates from the individual transects were expressed as proportions for analysis, and it is immediately obvious from Table 3.1.2 that the means and standard errors are remarkably similar within categories and across methods (See Appendix 1A, B, and C for complete datasets for all three methods).

Table 3.1.2.

Proportional percent cover estimates for three substratum categories, as estimated by three methods at the EFG and WFG during 2002 and 2003. Means are tabulated ± standard error (SE).

Category	**Videography**	**Still Photography**	**Visual LPI**
Total Coral Cover	0.542 ± 0.018	0.521 ± 0.015	0.563 ± 0.013
Montastraea annularis complex	0.318 ± 0.020	0.284 ± 0.019	0.325 ± 0.017
Diploria strigosa	0.065 ± 0.010	0.072 ± 0.011	0.071 ± 0.010

For total coral cover, Anderson-Darling tests revealed the (untransformed) proportional coverage data to be normally distributed for all three methods (P>0.13 in all cases). Tests for homogeneity of variances, however, gave equivocal results: Bartlett's test, which assumes normal distributions, yielded P=0.077; and Levene's test, which is valid for any continuous distribution, yielded P=0.095. When the data were arcsine-transformed, both tests for homogeneity of variances were non-significant (P>0.06 in both tests), and the normality assumption again was not violated (P>0.14 in all cases). Pairwise F-tests on the untransformed data revealed only one significant difference: the LPI data were significantly less variable than the videographic data (P=0.028). P=0.37 for comparison of variances between videography and still photography, and P=0.19 for comparison of still photography and LPI. ANOVA is robust to minor violations of the assumptions of normality and homogeneity of variances, and the randomized-block ANOVA was run on both the transformed and untransformed data.

The ANOVA results were virtually identical for the untransformed and arcsine-transformed data (Table 3.1.3A). There was a significant block effect, meaning that there was variability among transects that was consistent across methods. There was also a significant effect of method. *A posteriori* Tukey simultaneous tests showed that the LPI method gave a significantly higher estimate of total coral cover than still photography, but that the videographic estimates were not significantly different from either the LPI or the still-photography estimates. For both the untransformed and transformed cases, Tukey comparison showed the photographic and videographic differences to be non-significant at P=0.39. The actual difference in mean percent-cover estimates between the LPI and photographic methods was only 4%, which cannot be considered biologically meaningful (Aronson et al. 2005; Section 3.1.3).

For the *Montastraea annularis* species complex, Anderson-Darling tests revealed the (untransformed) proportional coverage data to be normally distributed for all three methods (P>0.10 in all cases). Both Bartlett's and Levene's tests showed the variances to be homogeneous (P>0.40 in both tests), and homogeneity was further confirmed by pairwise F-tests (P>0.35 in all cases). Randomized complete-block ANOVA on the untransformed data again showed a significant block effect, and the estimates from the three methods were marginally non-significant at P=0.056 (Table 3.1.3B). Tukey comparisons showed no significant pairwise differences of course, and the videographic and photographic differences were non-significant at P=0.13. Arcsine transformation had no effect on the conformity of the data to the assumptions of parametric statistics. ANOVA on the transformed data yielded a significant block effect and a significant effect of method. Tukey comparisons showed that the LPI method gave a significantly higher estimate of total coral cover than still photography, but that the videographic estimates were not significantly different from either the LPI or the still-photography estimates. The videographic and photographic differences were non-significant at P=0.096. As for total coral cover, the actual difference in mean percent-cover estimates between the LPI and photographic methods was only 4%.

For *Diploria strigosa*, Anderson-Darling tests revealed the (untransformed) proportional coverage data to be non-normally distributed for all three methods (*P*<0.005 in all cases). Both Bartlett's and Levene's tests showed the variances of the untransformed data to be homogeneous (*P*>0.98 in both tests), and homogeneity was further confirmed by pairwise F-tests (*P*>0.80 in all cases). Arcsine transformation corrected the normality problem for all but the still-photography data (*P*=0.014 for the still-photography data; *P*>0.20 for the other two transformed data sets), and the variances remained homogeneous after transformation (*P*>0.75 for both tests). Randomized-block ANOVAs gave virtually identical results for the untransformed and transformed data: a significant block effect and no effect of method (Table 3.1.3C). The maximum difference in mean percent-cover estimates was <1%.

From these analyses, it is clear on statistical grounds that estimates of substratum cover based on point-count data from videographic transects are interchangeable with estimates based on planimetry of still photographs. The LPI method yielded slightly higher estimates of percent cover for the high- and intermediate-cover categories, but those differences were smaller than the 5–10% changes in coral cover considered to be biologically meaningful, and the differences were also smaller than the minimum detectable difference using the videographic method (Aronson et al. 2005; Section 3.1.3). Methodological changes in the long-term monitoring program from visual LPI assessment, to planimetry of still photographs, and then to videography (for which the analysis is far less labor-intensive than planimetry) are entirely justified and will not compromise the utility of previous years' data. On the contrary, it is legitimate to compare estimates of coral cover from 2002 to 2003 and future video transects to existing records, without concern that methodological considerations are confounding our understanding of benthic dynamics at the FGB.

Table 3.1.3.

Results of randomized complete-block ANOVAs comparing proportional coverage estimates at the EFG and WFG in 2002 and 2003 using the three methods. The blocks are the transects.

A. Total Coral Cover

Untransformed Data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	1.0754	0.0229	3.8000	<0.0005
Method	2	0.0423	0.0211	3.5100	0.0340
Error	94	0.5664	0.0060		
Total	143	1.6841			

Arcsine-transformed Data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	1.1276	0.0240	3.8000	<0.0005
Method	2	0.0432	0.0216	3.4200	0.0370
Error	94	0.5933	0.0063		
Total	143	1.7642			

B. *Montastraea annularis* species complex

Untransformed data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	1.6910	0.0360	4.8600	<0.0005
Method	2	0.0440	0.0220	2.9700	0.0560
Error	94	0.6957	0.0074		
Total	143	2.4308			

Arcsine-transformed Data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	2.2828	0.0486	4.8400	<0.0005
Method	2	0.0692	0.0346	3.4500	0.0370
Error	94	0.9430	0.0100		
Total	143	3.2950			

C. *Diploria strigosa*

Untransformed data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	0.5669	0.0121	6.6500	<0.0005
Method	2	0.0012	0.0006	0.3300	0.7230
Error	94	0.1704	0.0018		
Total	143	0.7384			

Arcsine-transformed Data

Source	df	Sum of Squares	Mean Square	F	*P*
Block	47	1.6885	0.3593	3.9700	<0.0005
Method	2	0.0090	0.0045	0.5000	0.6090
Error	94	0.8508	0.0091		
Total	143	2.5483			

3.1.2 Univariate Analysis

The point counts from the video transects taken in 2002 and 2003 were grouped into major functional categories and expressed as percent covers. Examination of Figure 3.1.4 suggests that there were no systematic differences in the percent cover of these categories, either between the East Bank and the West Bank or from 2002 to 2003. The univariate data were expressed as proportions and analyzed by two-way analysis of variance (ANOVA), with site and year as fixed factors. Prior to ANOVA, the data were tested for conformity to the parametric assumptions of normality and homogeneity of variances, using the Lilliefors and F_{max} tests, respectively.

The data on proportional cover of all living hard corals (Scleractinia and Milleporina) conformed to the assumptions of parametric statistics, so the data were not transformed. A two-way ANOVA showed no significant effect of either site or year, and the site X year interaction was also not significant (Table 3.1.5.A). ANOVA using arcsine-transformed, proportional cover data yielded virtually identical results.

The data on proportional cover of sponges satisfied the assumption of homogeneity of variances, and all but one of the four data sets (two banks in two years) were normally distributed. Arcsine transformation of the data corrected the normality problem. A two-way ANOVA showed no significant effect of site and no significant site X year interaction (Table 3.1.5.B). There was an increase in sponge cover from 2002 to 2003 that was non-significant at $P=0.06$, but with five ANOVAs in Table 3.1.5, adjustment of α to maintain an overall experimentwise error rate of 0.05 makes this result decidedly non-significant rather than marginally so.

The data on proportional cover of macroalgae were normally distributed, but the variances were not homogeneous. Arcsine transformation homogenized the variances. A two-way ANOVA revealed a highly significant site X year interaction (Table 3.1.5.C). That interaction is clearly visible in Figure 3.1.5: macroalgal cover increased at the East Bank from 2002 to 2003 and decreased at the West Bank during the same period. The significant interaction makes it difficult to interpret the significant effect of site.

The fourth univariate cover category that was analyzed combined crustose coralline algae, fine algal turfs and bare rock (abbreviated CTB). The CTB data conformed to the assumptions of normality and homogeneity of variances and were not transformed. A two-way ANOVA revealed a marginally significant site X year interaction (Table 3.1.5.D), in the opposite direction from that in macroalgal cover: for CTB, cover declined at the East Bank and increased at the West Bank from 2002 to 2003.

Finally, the Shannon-Wiener diversity index H' was calculated from the species-specific coral cover data from each video transect. Mean H' ranged from a low of 1.35 at the West Bank in 2003 to a high of 1.51 at the East Bank in 2003 (the means were 1.37 at the West Bank and 1.45 at the East Bank in 2002). The data conformed to the assumptions of normality and homogeneity of variances. A two-way ANOVA showed no significant effect of either site or year, and the site X year interaction was also not significant (Table 3.1.5.E).

In summary, coral cover exceeded 50% at the two banks in both years. These values are consistent with measurements of coral cover in previous years (Dokken et al. 2003) and they are high compared to other western Atlantic reefs (e.g., Aronson et al. 1994; Gardner et al. 2003). The CTB category was the next most abundant category in terms of cover, indicating high levels of herbivory and a generally healthy reef ecosystem. Macroalgal cover and the cover of CTB fluctuated in a reciprocal fashion. The cover of sponges was extremely low.

3.1.3 Minimum Detectable Difference

The goal of the video transecting methodology is to be able to detect the smallest biologically meaningful changes in percent coral cover with high power at the standard type-I error rate. We consider a change of 5-10% coral cover to be biologically meaningful, which is stricter than the 10-20% figure obtained by Risk and Risk (1997) in a poll of reef scientists.

The minimum detectable difference, δ, was calculated for the two-way ANOVA on proportional coral cover from the video transects, following Zar (1984). The significance level was set at the conventional $\alpha=0.05$ and the desired power at the conventional $(1-\beta)=0.80$. For videographic surveys of two sites over two years, with 14 transects per site per year, $\delta=0.074$. In other words, we can expect to be able to detect a 7.4% change in coral cover between any two years at the Flower Garden Banks, or a 7.4% difference in cover between the East and West Banks in a two-year study.

3.1.4 Multivariate Analysis

The point counts falling on hard corals in the videotapes of the random transects were further analyzed by species using multivariate techniques. Multivariate coral cover was compared between sites and years using analysis of similarity (ANOSIM). There were no significant differences between either sites (Global R=0.026, P=0.19) or years (Global R=0.033, P = 0.15). A single-factor ANOSIM on the four sets of 14 transects also showed no significant differences (Global R=0.04, P=0.07), meaning that there was no multivariate interaction; this conclusion was borne out by pairwise ANOSIM tests on the four sets of transects (see Clarke and Gorley 2001). As in previous surveys at the Flower Garden Banks, the dominant species were *Montastraea faveolata* (mean cover 21.46%; this is the mean in the 56 transects from both sites in both years), *M. franksi* (mean cover 9.55%), *Diploria strigosa* (mean cover 6.35%), *Porites astreoides* (mean cover 4.92%) and *M. cavernosa* (mean cover 3.39%).

The Multidimensional Scaling (MDS) analysis placed the data from the Flower Garden Banks in a tight group, well-separated from the FPZs in the Florida Keys, for which one site, South Carysfort Reef, clearly separated from the rest (Figure 3.1.5). The stress level of the MDS was low at 0.01, indicating high confidence in the pattern displayed. These results agree with the observation that, from reef to reef, coral cover at the Flower Gardens is much higher and much more uniform in terms of species composition than coral cover on the reefs of Florida (e.g., Murdoch and Aronson 1999). The mean cover of hard corals ranged from 1.00 to 7.10% in the six data sets of transects from Florida in Figure 3.1.6.

There is one caveat that applies in interpreting these multivariate patterns, as well as in the analysis of H' in section 3.1.2. It proved difficult to distinguish *Montastraea faveolata* from *M. franksi* in the video transects from the Flower Gardens. Aronson and Murdoch have also become progressively less confident in the prospects for separating those two species in videotaped transects from the FPZs in Florida. It should be noted, however, that reanalyzing the multivariate and H' data with *M. faveolata* and *M. franksi* combined did not appreciably alter the quantitative results or the conclusions drawn from those results.

Table 3.1.5.

Results of two-way ANOVAs on proportional cover estimates from the random video transects taken at the East and West Flower Gardens in 2002 and 2003.

A. Hard Corals (untransformed)

Source	Sum of Squares	df	Mean Square	F-ratio	*P* value
Site	0.00	1.00	0.00	0.20	0.66
Year	0.01	1.00	0.01	0.44	0.51
Site*Year	0.04	1.00	0.04	2.83	0.10
Error	0.73	52.00	0.01		

B. Sponges (arcsine transformed)

Source	Sum of Squares	df	Mean Square	F-ratio	*P* value
Site	0.00	1.00	0.00	1.18	0.28
Year	0.01	1.00	0.01	3.71	0.06
Site*Year	0.00	1.00	0.00	0.97	0.33
Error	0.02	52.00	0.00		

C. Macroalgae (arcsine transformed)

Source	Sum of Squares	df	Mean Square	F-ratio	*P* value
Site	0.05	1.00	0.05	6.63	0.01
Year	0.01	1.00	0.01	1.09	0.30
Site*Year	0.55	1.00	0.55	668.01	<0.005
Error	0.43	52.00	0.01		

D. CTB (untransformed)

Source	Sum of Squares	df	Mean Square	F-ratio	*P* value
Site	0.01	1.00	0.01	1.16	0.29
Year	0.01	1.00	0.01	0.80	0.38
Site*Year	0.06	1.00	0.06	5.49	0.02
Error	0.56	52.00	0.01		

E. Shannon-Wiener Diversity, H' (untransformed)

Source	Sum of Squares	df	Mean Square	F-ratio	*P* value
Site	0.20	1.00	0.10	1.85	0.18
Year	0.01	1.00	0.01	0.07	0.79
Site*Year	0.02	1.00	0.02	0.18	0.68
Error	5.50	52.00	0.11		

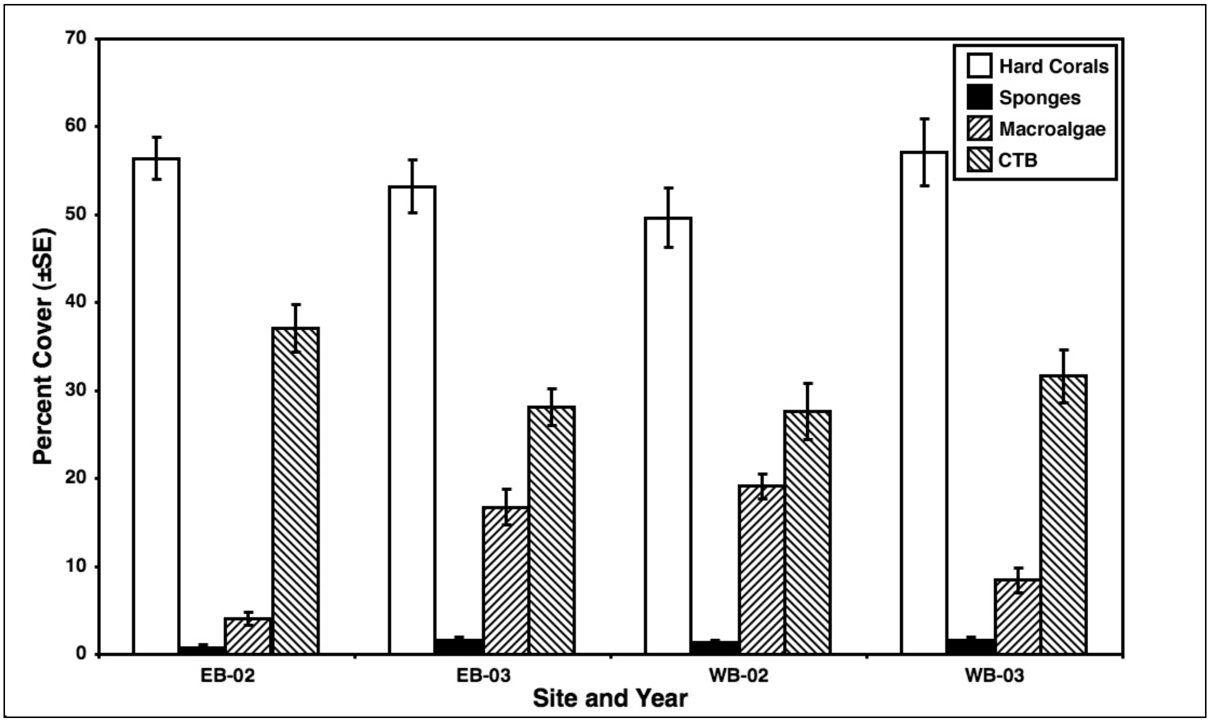


Figure 3.1.4. Percent cover (± SE) of four functional categories of sessile benthos at the FGB in 2002 and 2003. Error bars represent standard errors. Abbreviations: EB, East Bank; WB, West Bank; CTB, crustose coralline algae and bare rock. Values are calculated from videography data.

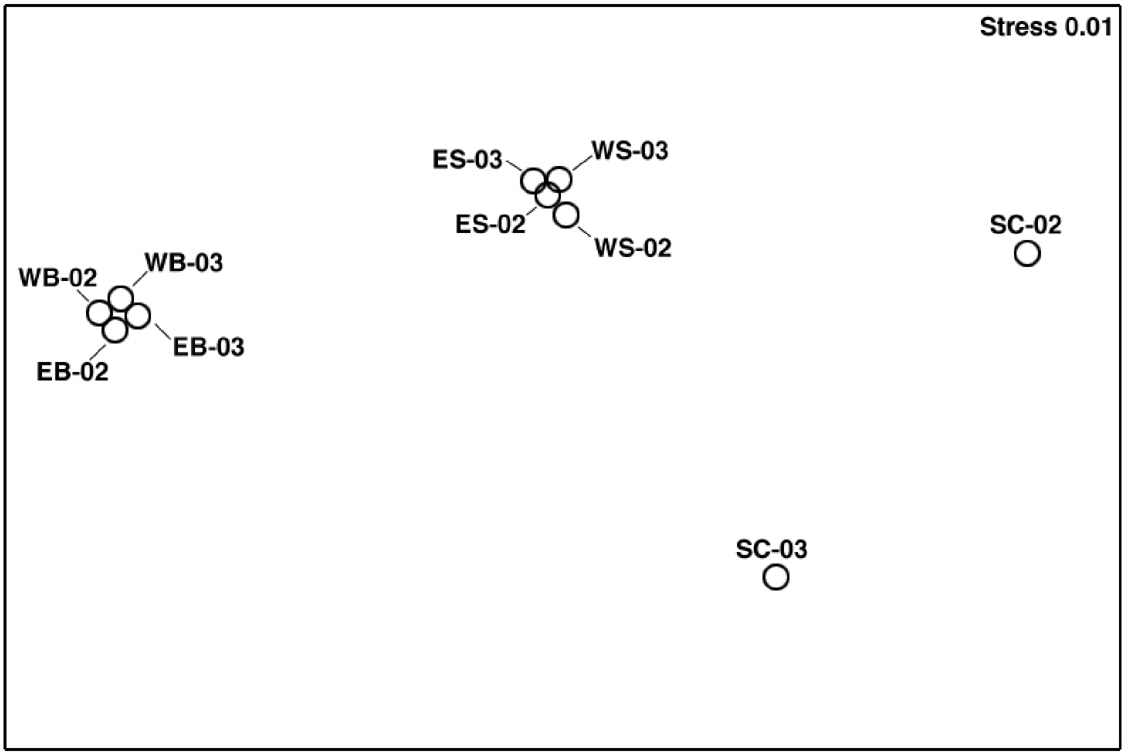


Figure 3.1.5. Two-dimensional MDS plot based on square-root-transformed Bray-Curtis dissimilarities, comparing multivariate coral cover from video transects between the FGB and three Fully Protected Zones (FPZs) in the Florida Keys National Marine Sanctuary (FKNMS). The video transects were shot in 2002 and 2003. Coral cover is low and species composition is more variable at the FKNMS sites. The FGBNMS sites form a discrete, tight cluster of points well away from the Florida sites, reflecting high coral cover and low variability in species composition. Abbreviations: EB, East Flower Garden Bank; WB, West Flower Garden Bank; SC, South Carysfort Reef FPZ; WS, Western Sambo Reef FPZ; ES, Eastern Sambo Reef FPZ.

3.2 SCLEROCHRONOLOGY

Eight cores were taken from separate *Montastraea faveolata* colonies at both the East Bank (4 cores) and West Banks (4 cores) in August 2003. Cores were longitudinally sectioned to reveal accretionary growth bands. The distance between low density (light colored) and high density (dark colored) bands are considered a single growth increment (one year) and were measured for the years 1997-2003. See Appendix 2 for a complete list of growth rates for all eight cores at both banks.

3.2.1 East Bank Cores

Four cores of *Montastraea faveolata* were removed from the East Bank in August 2003. Estimated annual growth ranged from 7.7-10.7 mm year $^{-1}$ from 1997-2003, with an overall mean of 9.2 mm ± 1.1 SE at the East Bank. The highest growth rate occurred between 1999-2000 and the lowest occurring in 2002-2003 (Table 3.2.1). One core showed a partial mortality line in 1999; however growth was reestablished by surrounding polyps (Figure 3.2.3).

Table 3.2.1.

Mean annual growth (mm) (± SE) of four *Montastraea faveolata* cores from East and West Banks, August 2003.

Growth year	East Bank	West Bank
2002-2003	7.7± 2.9	6.3 ± 1.0
2001-2002	10.1 ± 2.7	7.8 ± 1.5
2000-2001	8.3 ± 2.2	7.3 ± 1.5
1999-2000	10.7 ± 2.7	8.5 ± 1.3
1998-1999	9.3 ± 3.3	8.0 ± 0.5
1997-1998	8.3 ± 0.3	8.3 ± 0.3

3.2.2 West Bank Cores

Four cores were taken from *Montastraea faveolata* heads on the west bank in August 2003. Estimated growth ranged from 6.3-8.5 mm year $^{-1}$, with an overall mean of 7.6 mm ± 1.02 at the West Bank. The highest mean growth rate occurred in 1999 and the lowest in 2002, the same as found for East Bank cores (Table 3.2.1). Like the East Bank, one core showed partial mortality in 1999, and subsequent recovery in later years (Figure 3.2.3).

3.2.3 Analysis

A Student t-test was performed to compare East and West Bank growth rates from 1997-2003. East Bank growth rates were significantly higher than West Bank growth rates for the period of comparison (t=2.38, df=6, P=0.02).

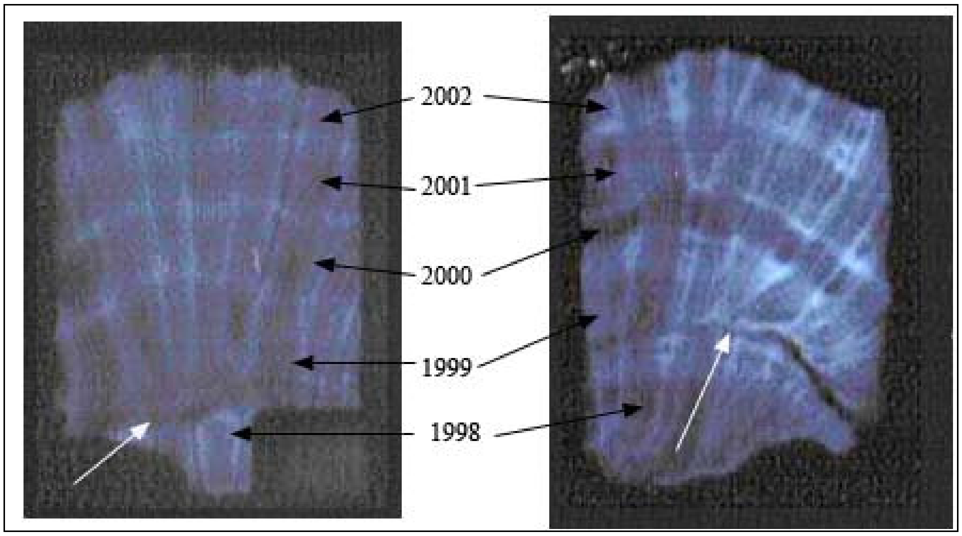


Figure 3.2.3. X-ray image of *Montastraea faveolata* from East (left) and West (right) Banks showing an interruption (arrow) in accretionary growth sometime in 1998-1999.

3.3 LATERAL GROWTH

3.3.1 Quantitative Planimetry Analysis

Proportional annual changes in lateral growth of the individual *Diploria* colonies, whether positive or negative, were examined by site (East Bank and West Bank) and by year (2001-2002 and 2002-2003).

Due to a low sample size from 2001-2003 a repeated-measures analysis with sufficient power was not possible for the entire time span. Instead, we used a factorial design to compare the two banks in terms of the 2001-2002 data and, separately, in terms of the 2002-2003 data. Figure 3.3.1 indicates an overall 3–5% increase in colony area at both banks from 2001-2002. Anderson-Darling tests showed the data from 2001-2002 to be normally distributed (P=0.582 for the East Bank and *P*=0.318 for the West Bank). An F-test revealed no significant difference in the variances of the two groups ($F_{17,10}$=0.200). A two-sample t-test revealed no significant difference in *Diploria* growth between the East and West Banks (t=0.740, df=27, P=0.468). A non-parametric Mann-Whitney U-test led to the same conclusion (U=113.5, P>0.20).

The 2002-2003 data set was quite different from the previous year's data set. The two banks appeared very different as well (Figure 3.3.1), and generalizations are not possible with a sample size of only four from the West Bank. This data set could not be analyzed using parametric tests. The Anderson-Darling test showed that the four data from the West Bank were not normally distributed (P=0.020). Levene's test detected no significant difference in the variances (P=0.186), despite the large variance in the data from the West Bank caused by the low sample size. The normality problem could not be corrected by transformation. A Mann-Whitney U-test again detected no significant difference in *Diploria* growth between the two Banks (U=22.0, P>0.20).

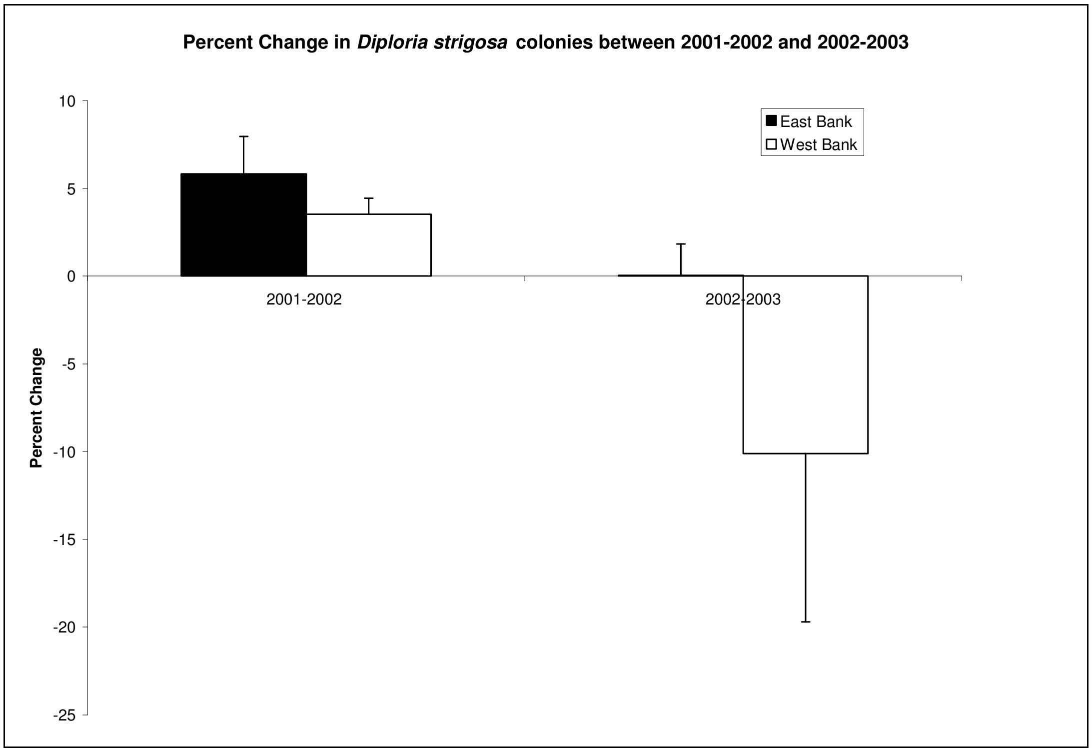


Figure 3.3.1. Percent change (± SE) in *Diploria strigosa* colonies at East and West Bank between 2001 and 2002 and between 2002 and 2003. Sample size for East Bank 2001-02, n=18; West Bank 2001-02, n=11; East Bank 2002-03, n= 8; West Bank 2002-03, n= 4.

3.4. REPETITIVE QUADRATS

To measure benthic cover components a total of 51 quadrats pairs were analyzed for 2002 and 2003: 20 from the East Bank and 31 from the West Bank. These photographs were analyzed for benthic community structure using random dots to determine cover estimates, including benthic cover, bleaching, disease and fish biting.

Planimetry was used to quantify change between select coral colonies within quadrat matches between 2001 and 2002 and between 2002 and 2003. Four to six coral colonies were chosen within each repetitive quadrat match, colonies were chosen based on the ability to decipher boundaries and importance to reef accretion (i.e. frame builders such as *Montastraea annularis* spp., *Diploria strigosa*, *Colpophyllia natans*). Seven matches were made at the East Bank for 2001-2002 and 9 matches were made at the West Bank. For the 2002-2003 comparison 16 matches were compared at the East Bank and 27 comparisons were made for the West Bank (see Appendix 4 for complete dataset).

3.4.1. Repetitive Quadrat Percent Cover Analysis

In both 2002 and 2003 coral cover was high (Figure 3.4.1). The incidences of bleaching, disease, paling and mortality from fish bites were low (Table 3.4.2). In both 2002 and 2003 the dominant species in the repetitive quadrats were the *Montastraea annularis* species complex, *Diploria strigosa* and *M. cavernosa* (Figures 3.4.1 and 3.4.2). Due to the scale of photographs and the difficulty of accurately identifying the separate *Montastraea annularis* sibling species from photographs in general, the *Montastraea annularis* complex was combined for analysis.

Table 3.4.1.

Percent coral, algae and bare cover categories at 8 m^2 repetitive quadrats at the FGB in 2002 and 2003 (random dot analysis).

Benthic Cover Type	2002		2003	
	EFG	**WFG**	**EFG**	**WFG**
Corals	72.9	70.3	71.1	68.6
Algae (macro, filamentous, turf and calcareous)	10.7	13.5	19.6	9.6
CTB (crustose, corallines, turfs, bare rock)	14.9	15.4	5.8	20.1

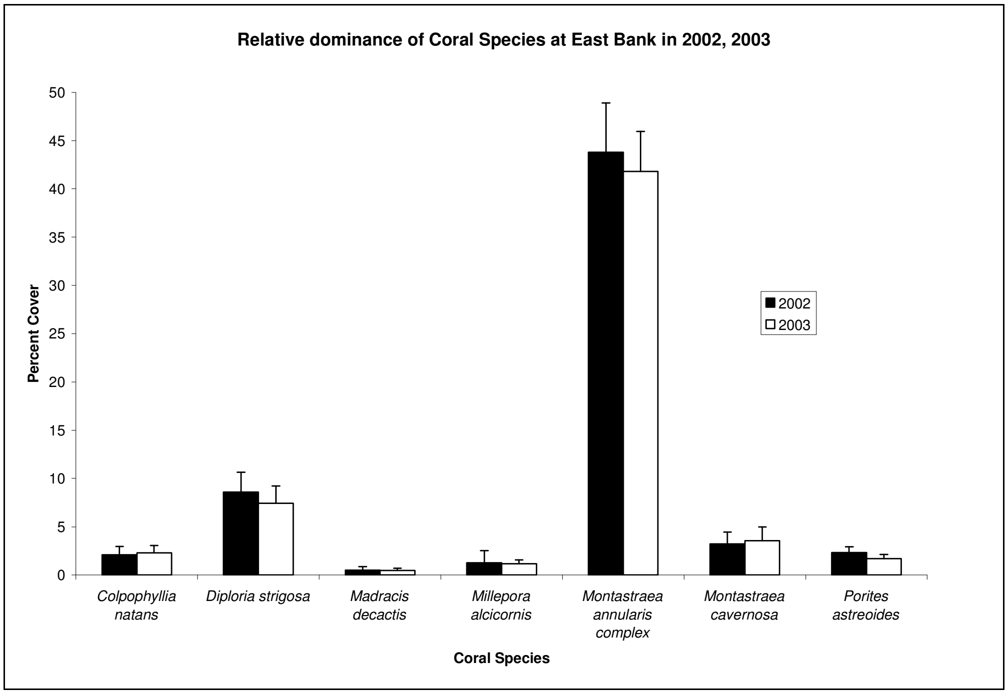


Figure 3.4.1. Relative dominance of coral species at East Bank in repetitive quadrats, expressed as percent cover, including ± SE (random dot analysis).

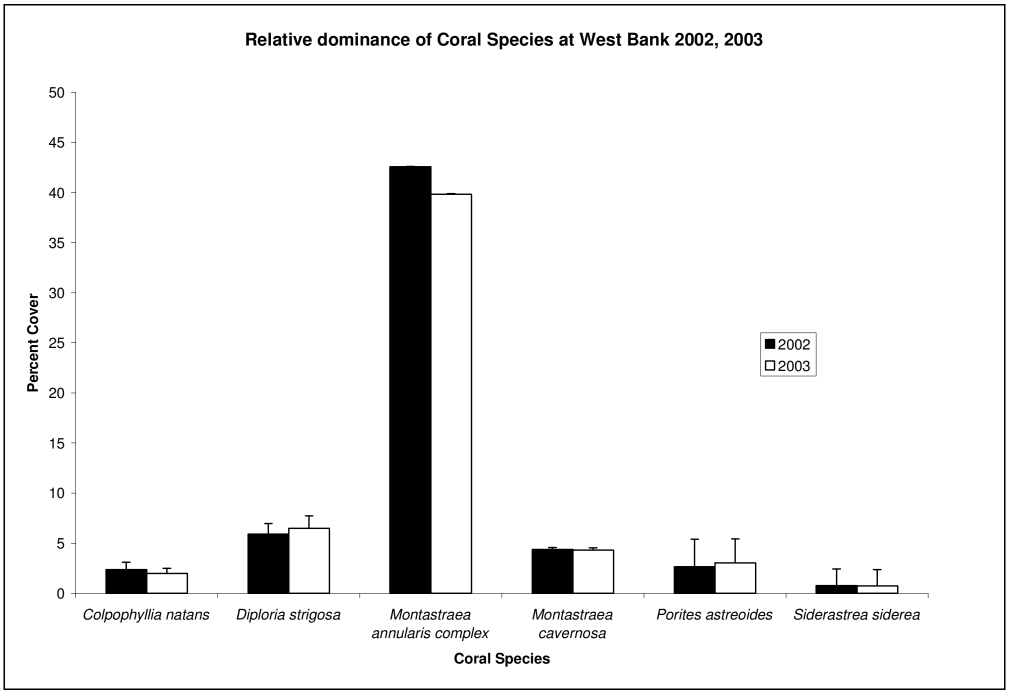


Figure 3.4.2. Relative dominance of coral species at West Bank in repetitive quadrats, expressed as percent cover, including ± SE (random dot analysis).

Coral disease was absent from analyzed photographs at both banks in both years (Table 3.4.2). Paling and bleaching were extremely low at both banks, ranging from 0.05-0.61% (Table 3.4.2). Concentrated fish biting and isolated fish biting were similarly low at each bank, ranging from 0.34-0.61% in both years (Table 3.4.2). Bleaching occurred most frequently on colonies of *Millepora alcicornis* at the East Bank in 2003 (Table 3.4.3), while paling showed no pattern and occurred less frequently. Fish biting occurred primarily on the *M. annularis* complex, and appeared to be more common at the West Bank in both years (Table 3.4.3).

Table 3.4.2.

Percent paling, bleaching, concentrated fish biting, isolated fish biting and disease ± SE, in 8 m^2 repetitive quadrats at the East and West Banks, 2002 and 2003 (random dot analysis).

Observation	East Bank 2002	East Bank 2003	West Bank 2002	West Bank 2003
Paling	0.14 ± 0.11	0.11 ± 0.02	0.02 ± 0.02	0.05 ± 0.02
Bleaching	0.14 ± 0.10	0.61 ± 0.10	0.10 ± 0.06	0.16 ± 0.08
Concentrated Fish Biting	0.34 ± 0.12	0.36 ± 0.06	0.41 ± 0.15	0.41 ± 0.11
Isolated Fish Biting	0.41 ± 0.21	0.38 ± 0.06	0.61 ± 0.23	0.35 ± 0.10
Disease	0.00	0.00	0.00	0.00

Table 3.4.3.

Frequency of paling, bleaching, concentrated fish biting, isolated fish biting and disease at East and West Banks, 2002 and 2003. IFB= isolated fish biting, CFB= concentrated fish biting, P= paling, BL= bleaching, East Bank 2002 and 2003 n= 6000, West Bank 2002 and 2003 n = 9300 (random dot analysis).

Observation	East Bank October 2002				East Bank August 2003				West Bank October 2002				West Bank August 2003			
	IFB	CFB	P	BL	IFB	CFB	P	BL	IFB	CFB	P	BL	IFB	CFB	P	BL
Unidentified coral species	0	0	0	0	0	0	0	3	0	1	0	0	0	3	0	1
Colpophyllia natans	0	0	6	0	0	0	0	0	1	0	0	0	0	1	0	0
Diploria strigosa	1	3	1	0	4	1	3	0	6	1	1	0	1	0	1	0
***Montastraea annularis* complex**	20	11	0	0	14	18	2	1	40	29	1	3	27	26	0	7
Montastraea cavernosa	0	0	0	0	1	0	1	0	3	2	0	0	2	3	1	1
Madracis decactis	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0
Millipora alcicornis	0	0	0	7	0	0	0	28	0	0	0	1	0	0	0	5
Porites astreoides	0	1	0	0	0	0	0	0	1	1	0	4	0	1	1	0

3.4.2 Repetitive Quadrat Quantitative Planimetry Analysis

Because the *Montastraea annularis* species complex was the dominant substratum occupant in the repetitive quadrats, we compared the cover of this taxon between banks and through time (Figure 3.4.3). For each repetitively-photographed quadrat that contained one or more colonies of *M. annularis* species complex, we calculated the average proportional change in planar area for the colonies that were measured. For change from 2001–2002, this procedure yielded seven quadrats from the East Bank and nine quadrats from the West Bank. For change from 2002–2003, there were 16 quadrats for the East Bank and 27 for the West Bank. Due to logistical problems, only five quadrats from the East Bank and eight quadrats from the West Bank were photographed in 2001, 2002 and 2003; therefore, in the interest of maximizing sample sizes, we compared the two one-year intervals separately. Given sufficient sample sizes, multi-year comparisons should be possible in the future.

For the 2001–2002 quadrats, the Anderson-Darling test showed that the data violated the normality assumption for the West Bank ($P<0.005$), although not for the East Bank ($P=0.329$). In addition, Levene's test showed that the variances for the two banks were heterogeneous ($P=0.016$). Arcsine transformation was not an option because some of the data were negative values. The normality problem could not be corrected by logarithmic transformation (Anderson-Darling test, $P=0.013$ for the West Bank and $P=0.360$ for the East Bank), although logarithmic transformation homogenized the variances (Levene's test, $P=0.223$). A two-sample t-test detected no significant difference between the banks ($t=0.08$, $df=14$, $P=0.940$). Likewise, the less powerful, non-parametric Mann-Whitney U-test detected no significant difference between the banks ($U=49.9$, $0.10<P<0.05$).

For the 2002–2003 quadrats, the Anderson-Darling test again showed that the data violated the normality assumption for the West Bank ($P<0.005$), although not for the East Bank ($P=0.205$). In addition, Levene's test showed that the variances for the two banks were homogeneous ($P=0.678$). Logarithmic transformation decreased the departure of the West Bank data from normality, although those data still departed significantly from normality (Anderson-Darling test, $P=0.043$ for the West Bank and $P=0.160$ for the East Bank). The variances of the log-transfomed data were homogeneous (Levene's test, $P=0.589$). A two-sample t-test detected no significant difference between the banks ($t=1.14$, $df=41$, $P=0.260$). A Mann-Whitney U-test detected no significant difference between the banks ($U=285.5$, $0.10<P<0.05$).

The two banks appear uniform with respect to change in the cover of colonies of *Montastraea annularis* species complex. The cover of *Montastraea* in the quadrats increased at both banks in both years. In both of these respects, the results from the repetitive quadrats mirrored the results of the lateral growth study with *Diploria strigosa* (section 3.3). Although the *M. annularis* complex increased in both 2001-2002 and 2002-2003, the amount of increase decreased in 2002-2003 (Figure 3.4.3). The *Diploria* in the lateral growth study showed a similar trend, although sample size was a problem, as mentioned in section 3.3.2. Comparison with data from future years will reveal whether or not this reduction in growth rate is cause for concern.

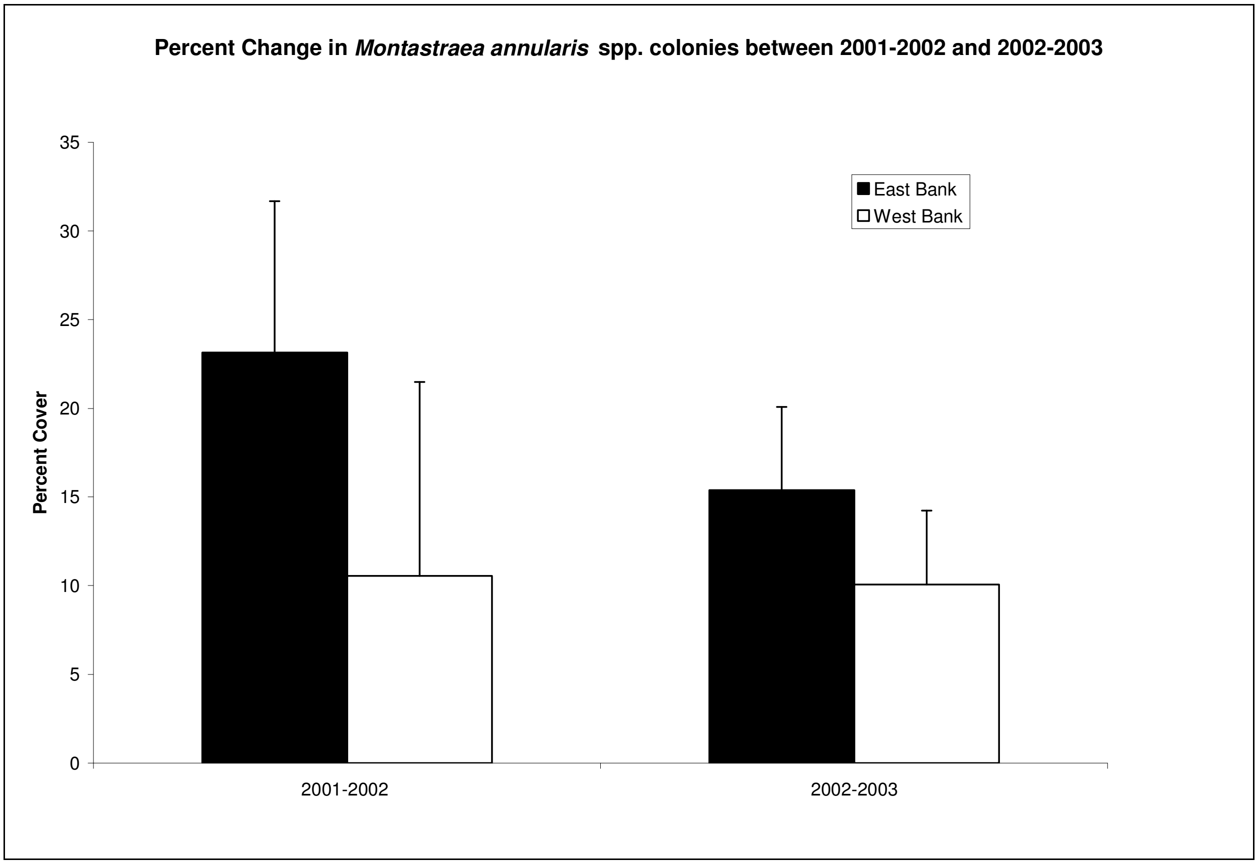


Figure 3.4.3. Percent change ± SE in *Montastraea annularis* species complex colonies from repetitive quadrats planimetry results between 2001-2002 and 2002-2003 at East and West Banks.

3.4.3. Deep Repetitive Quadrat Planimetry Analysis

The deep stations were analyzed for benthic cover type using random dot analysis (Figure 3.4.4). Coral cover was high at the deep stations, while algal cover was low and consisted mostly of CTB. The *Montastraea annularis* species complex was combined for analysis, but was the predominant coral group in addition to *M. cavernosa*. *Diploria strigosa* was not as prevalent as in the shallow sites (Figure 3.4.5). An example of a deep station repetitive quadrat is shown in Figure 3.4.6.

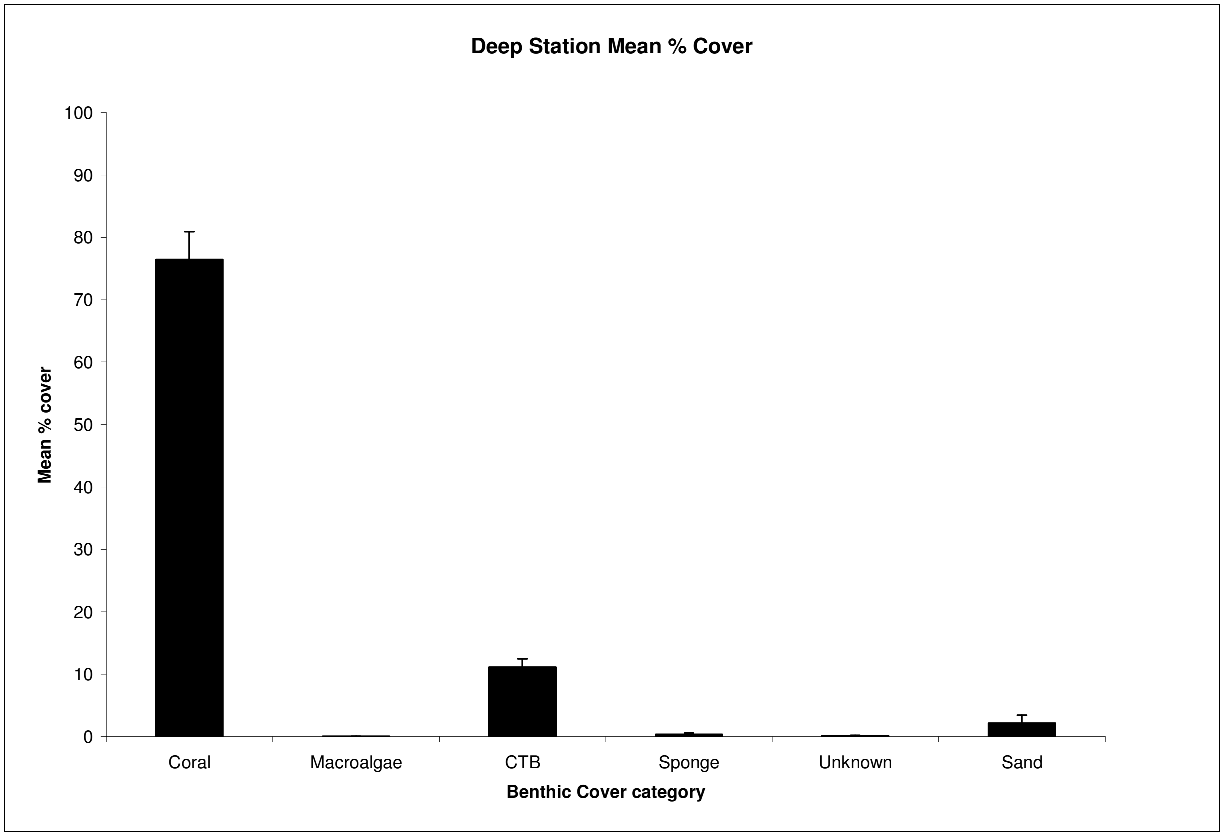


Figure 3.4.4. Percent cover (± SE) data for six benthic categories in the EFGB deep repetitive quadrats in 2003 (random dot analysis).

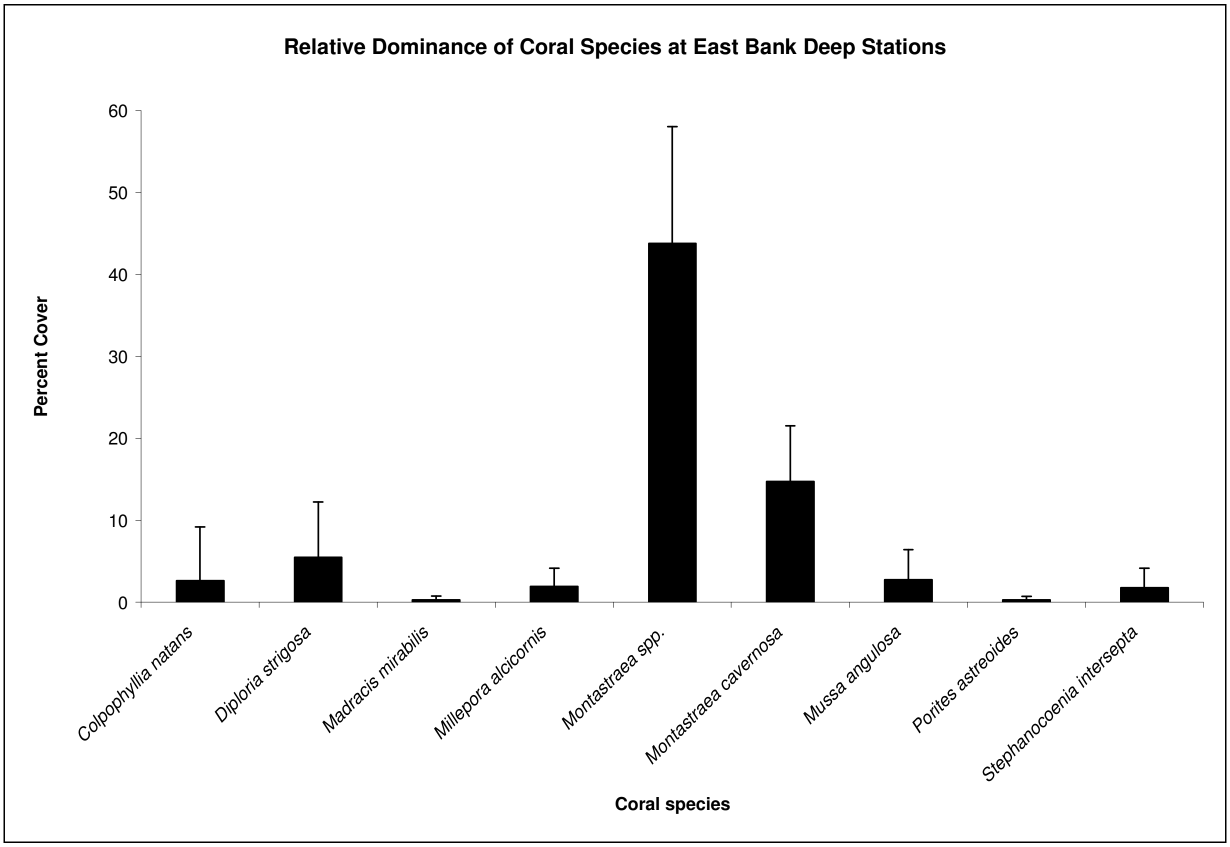


Figure 3.4.5. Relative dominance (± SE) of coral species at East Bank deep repetitive quadrats in 2003 (random dot analysis).

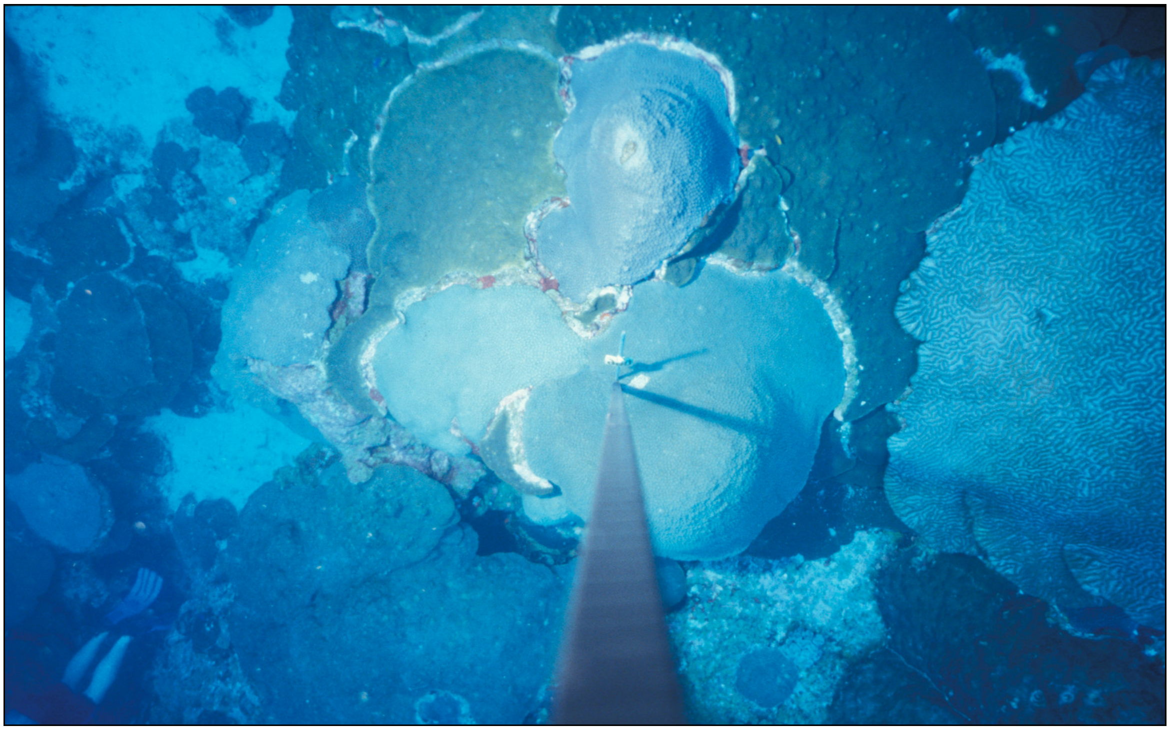


Figure 3.4.6. Deep repetitive 8 m^2 quadrat at East Bank in August 2003.

3.5. VIDEO PERIMETER

Overall, the coral condition and fish population levels along the perimeters of the East and West Bank in 2002 and 2003 were good. These areas displayed low levels of stress, high levels of coral cover, and were comparable to random transect footage, although no statistical comparisons were made. Most distressed corals were affected by fish biting, with only a few incidences of paling and bleaching, these results reflect the trend found in the repetitive quadrat data. Furthermore, no evidence of disease was observed at either bank during 2002 or 2003. No other invertebrates were observed along the perimeter of either bank.

3.5.1 East Bank Perimeter Lines

No incidences of disease or bleaching were observed at the East Bank in 2002. Concentrated fish biting was documented on 21 colonies, isolated fish biting on 16 colonies, and paling of five colonies was seen along the East Bank north and east perimeter lines in 2002. *Montastraea faveolata* and *Montastraea franksi* were the most impacted coral species. The most abundant fish species were Creole wrasse, bluehead wrasse, and blue chromis. All values in parantheses refer to number of colonies affected by a particular stress, which could include bleaching, paling, concentrated fish biting, or isolated fish biting.

In 2003 no incidences of disease were observed. Stresses included concentrated fish biting (27), isolated fish biting (11), paling (7), and bleaching (2). *Montastraea faveolata* and *Montastraea franksi* were the two most affected coral species. A comparison of corals affected by fish biting, paling, and bleaching in 2002 and 2003 at the East Bank is shown in Table 3.5.1. Fish populations were similar in 2002 and 2003 video footage, with the most abundant fish species being brown chromis, Creole wrasse, and blue chromis. However, the East Bank in 2003 had the highest number of fish (901 individuals) recorded at either bank during the monitoring period (Table 3.5.2).

Table 3.5.1.

Comparison of observations of the condition of individual coral colonies at East Bank between 2002 and 2003 (CFB= Concentrated fish biting, IFB= Isolated fish biting, B= Bleaching, P= Paling, H= Healthy colony, ICFB= Increased tissue loss due to concentrated fish biting, IIFB= Increased tissue loss due to isolated fish biting, GI= Growth in filling [tissue regrowth], new CFB= new incident of CFB, U= Unchanged condition, T= Surfaced replaced by turf algae).

Number of Colonies	Coral Species	East Bank 2002	East Bank 2003
1	*Diploria strigosa*	CFB	ICFB
1	*Diploria strigosa*	CFB	GI
1	*Montastraea annularis*	H	CFB
1	*Montastraea annularis*	IFB	IIFB
1	*Montastraea annularis*	IFB	U
1	*Montastraea annularis*	CFB	New CFB
1	*Montastraea cavernosa*	P	U
1	*Montastraea cavernosa*	H	CFB
2	*Montastraea faveolata*	CFB	ICFB
1	*Montastraea faveolata*	IFB	GI
3	*Montastraea faveolata*	H	CFB
1	*Montastraea faveolata*	IFB	IIFB
1	*Montastraea faveolata*	CFB	GI
1	*Montastraea faveolata*	CFB	U
1	*Montastraea faveolata*	CFB	New CFB
1	*Montastraea faveolata*	IFB	U
1	*Montastraea franksi*	H	CFB
2	*Montastraea franksi*	CFB	GI
1	*Montastraea franksi*	CFB	ICFB
1	*Porites asteroides*	IFB	IIFB
1	*Porites asteroides*	H	CFB
1	*Siderastrea siderea*	CFB	T
1	*Siderastrea siderea*	H	CFB

Table 3.5.2.

Fish species composition and individual counts for the East Bank and West Bank in 2002 and 2003 along perimeter lines and 360° circular panoramic views at corner markers. Some individuals belonging to the Labridae (1 individual), Pomacentridae (55), Scaridae (14), and Serranidae (10) could only be identified to the family level.

Species	**Common Name**	**East Bank 2002**	**East Bank 2003**	**West Bank 2002**	**West Bank 2003**
Acanthurus bahianus	Ocean surgeonfish	6	13	0	7
Acanthurus chirurgus	Doctorfish	0	0	1	0
Acanthurus coeruleus	Blue tang	5	11	7	6
Canthidermis sufflamen	Ocean triggerfish	4	0	0	0
Melichthys niger	Black durgon	3	2	3	9
Caranx ruber	Bar jack	0	1	0	0
Chaetodon aculeatus	Longsnout butterfly	0	1	0	1
Chaetodon ocellatus	Spotfin butterfly	2	8	5	5
Chaetodon sedentarius	Reef butterfly	5	0	0	0
Diodon hystrix	Porcupinefish	0	1	0	0
Kyphosus sectatrix/incisor	Bermuda/Yellow Chub	6	4	0	3
Bodianus rufus	Spanish hogfish	11	3	6	4
Clepticus parrae	Creole wrasse	225	172	32	26
Halichoeres cyanocephalus	Yellowcheek wrasse	0	7	0	0
Halichoeres garnoti	Yellowhead wrasse	0	2	0	0
Halichoeres radiatus	Puddingwife	0	0	2	0
Thalassoma bifasciatum	Bluehead wrasse	179	89	252	51
Ocyurus chrysurus	Yellowtail snapper	0	0	0	1
Mulloidichthys martinicus	Yellow goatfish	0	0	0	1
Lactophrys triqueter	Smooth trunkfish	0	1	1	0
Holacanthus ciliaris	Queen angelfish	1	1	0	0
Holacanthus tricolor	Rock beauty	0	0	1	1
Pomacanthus paru	French angelfish	1	0	0	0
Abudefduf saxatilis	Sergeant major	0	4	0	0
Chromis cyanea	Blue chromis	75	158	65	154
Chromis multilineata	Brown chromis	47	209	78	66
Microspathodon chrysurus	Yellowtail damselfish	7	3	5	3
Stegastes partitus	Bicolor damsel	20	49	7	19
Stegastes planifrons	Threespot damselfish	7	1	7	2
Stegastes variabilis	Cocoa damselfish	19	8	3	7
Scarus croicensis	Striped parrotfish	0	0	0	2
Scarus taeniopterus	Princess parrotfish	0	3	1	3
Scarus vetula	Queen parrotfish	11	10	7	20
Sparisoma viride	Stoplight parrotfish	1	4	4	5
Mycteroperca bonaci	Black grouper	2	1	1	1
Mycteroperca microlepis	Gag	0	1	0	0
Mycteroperca tigris	Tiger grouper	0	1	0	0
Paranthias furcifer	Creole fish	25	98	12	25
Sphyraena barracuda	Great barracuda	4	2	5	3
Canthigaster rostrata	Sharpnose puffer	3	1	2	0
Labridae	Wrasses	0	0	0	1

Species	Common Name	East Bank 2002	East Bank 2003	West Bank 2002	West Bank 2003
Pomacentridae	Damselfishes	9	27	9	10
Scaridae	Parrotfishes	4	2	5	3
Serranidae	Sea Basses	4	3	2	1
Total		686	901	523	440

3.5.2 East Bank 360° Panoramic Views

At the northwest corner corals were in good condition in both 2002 and 2003. In 2003 there were four new *Montastraea* spp. colonies where tissue loss occurred due to concentrated fish biting. The fish populations were similar from 2002 to 2003, and included ocean triggerfish, Creole fish, barracuda, black durgon and schools of brown chromis and Creole wrasse. Noticeably, in 2003 no ocean triggerfish were present, and the number of fish increased, especially of schooling fish (Table 3.5.2).

At the northeast corner the only signs of stress that appeared in 2003 were three new incidences of concentrated fish biting on colonies of *Montastraea faveolata*. The relative size and composition of fish populations were similar between years and included Creole wrasse, Creole fish, jacks and barracuda.

At the southeast corner there were no conspicuous signs of stress in either year. The fish populations were similar between years and included Creole wrasse, Creole fish, jacks and barracuda. In 2003 the number of Creole wrasse and other schooling fish increased (Table 3.5.2).

3.5.3 West Bank Perimeter Lines

During 2002 no incidences of disease were observed at the West Bank. Colonies were most impacted by concentrated fish biting (16), isolated fish biting (13), paling (5), and bleaching (1). *Montastraea faveolata* and *Diploria strigosa* were the two most affected corals. The most abundant fish species were bluehead wrasse, brown and blue chromis.

No colonies showed disease during 2003 at the West Bank. Colonies were most effected by concentrated fish biting (19), isolated fish biting (3), paling (2), and bleaching (1). *Montastraea faveolata* and *Diploria strigosa* were the two most impaired corals. Comparisons of maladied coral colonies at the West Bank are shown in Table 3.5.3. Fish populations were similar in 2003, with blue and brown chromis and bluehead wrasse representing the majority of fish recorded.

Table 3.5.3.

Comparison of observations of the condition of individual coral colonies at West Bank between 2002 and 2003 (Abbreviations are as follows: CFB= Condensed fish biting, IFB= Isolated fish biting, B= Bleaching, P= Paling, H= Healthy colony, ICFB=Increased tissue lost to concentrated fish biting, IIFB= Increased tissue lost to isolated fish biting, GI=Growth in filling [tissue regrowth], new CFB= new incident of CFB, U=Unchanged condition, T=Surfaced replaced by turf algae).

Number of Colonies	Species	West Bank 2002	West Bank 2003
1	*Diploria strigosa*	CFB	U
1	*Diploria strigosa*	P	U
1	*Diploria strigosa*	CFB	GI
1	*Diploria strigosa*	CFB	T
1	*Diploria strigosa*	IFB	CFB
1	*Diploria strigosa*	CFB	ICFB
1	*Diploria strigosa*	H	B
1	*Diploria strigosa*	IFB	T
1	*Montastraea annularis*	IFB	GI
1	*Montastraea cavernosa*	H	CFB
1	*Montastraea cavernosa*	P	H
1	*Montastraea cavernosa*	CFB	T
2	*Montastraea faveolata*	CFB	ICFB
1	*Montastraea faveolata*	CFB	T
3	*Montastraea faveolata*	IFB	GI
1	*Montastraea faveolata*	CFB	U
4	*Montastraea faveolata*	H	CFB
1	*Montastraea franksi*	P	H
1	*Montastraea franksi*	IFB	U
1	*Montastraea franksi*	IFB	IIFB
1	*Montastraea franksi*	CFB	T
1	*Siderastrea siderea*	CFB	GI

3.5.4 West Bank 360° Panoramic Views

The northwest corner coral health was good during 2002 and 2003, only one conspicuous coral head had concentrated fish biting in 2002. The fish populations were also similar in both years, consisting of Creole wrasse, black durgon, chromis and Creole fish.

The southeast corner coral condition was good from 2002 to 2003, with only one *Montastraea faveolata* colony showing new tissue loss due to concentrated fish biting in 2003. The fish populations were also similar from year to year, with relatively small schools of Creole wrasse, chromis, and the occasional black durgon and Creole fish.

The southwest corner coral health was relatively stable from 2002 to 2003, with only two *Montastraea faveolata* colonies showing new tissue loss due to concentrated fish biting in 2003. The fish populations were also similar from year to year, with relatively small schools of Creole wrasse, chromis, as well as the occasional black durgon and Creole fish.

3.6. WATER QUALITY

3.6.1 YSI Water Quality

The YSI datasondes deployed at the FGB failed post-deployment calibration after each of the deployment periods. The sensors were not recording valid measurements at the end of their deployment period. As a result, there are large amounts of invalid data within each of the datasets. The YSI datasonde uses readings from the conductivity-temperature sensor to calculate other measurements such as dissolved oxygen concentrations. Thus, failure of the conductivity-temperature sensor results in erroneous readings by other sensors, even when these other sensors are otherwise functioning correctly. These factors contributed to the difficulty of assessing the validity of each of the datasets. Since there were no obvious breakpoints within the data separating the credible from the erroneous data, we reviewed and validated the data using published values of each water quality parameter (Pickard and Emery 1982; Valiela 1984; Gittings et al. 1992; Sorokin 1995; Lugo-Fernández 1998; Nowlin et al. 1998; Dokken et al. 2003).

YSI sonde data that appeared acceptable are presented in Tables 3.6.1., 3.6.2., Figure 3.6.1., 3.6.2 and in Appendix 5. Figures for parameters other than temperature are not presented due to lack of reliable data. In addition to the analysis herein, raw data were provided to MMS and NOAA as they were retrieved. Out of the 371 total calendar days of deployment at the East Bank, the YSI sonde was able to acquire useful data from 2 to 219 days (Table 3.6.1). The longest data records were for temperature, turbidity, and photosynthetically active radiation (PAR). Few data were gathered for salinity, pH, and dissolved oxygen. All water quality data can be seen in Appendix 5.

Depth. In-situ sea surface height at the FGB can be estimated from the depth sensors on the YSI instruments since they record ambient pressure every half hour, these results are presented in Table 3.6.1. and 3.6.2. Yet, remote sensing using altimetry satellites, is a preferred method to document local and regional changes in sea surface height in offshore areas since in the nearshore altimetry sensors have problems detecting accurate sea surface heights (Carton and Chao 1999; CCAR 2005). Sea surface height at the FGB is influenced by several factors including gravity, seafloor topography, tides, wind patterns, eddies (Loop Current eddies, slope and cyclonic eddies with smaller spatial scales), seasonal changes of seawater density, evaporation and precipitation, and river runoff (Pickard and Emery 1982; Lugo-Fernández 1998; Nowlin et al. 1998). Of particular interest in the upper slope region (offshore of the shelf break) of the northwestern GOMEX is the influence of Loop Current (LC) and smaller eddies on sea surface height and shelf edge circulation (Lugo-Fernández 1998; Nowlin et al. 1998; Sturges and Leben 2000). LC eddies are anticyclonic vortices that can be up to 400 km in diameter (Nowlin et al. 1998). While these eddies generally move in a southwesterly direction, some travel near the shelf edge where they influence sea surface circulation. It takes approximately one year for eddies to decay sufficiently from the time they are shed from the LC. Altimetry shows elevated sea surface height toward the center of LC eddies since this is where warm water is accumulated and acts like a high pressure center. Currents at the shelf edge are heavily influenced by small eddies (anticyclonic and cyclonic). These eddies cause highly variable sea surface currents at and near the FGB (Lugo-Fernández 1998; Nowlin et al. 1998).

Temperature. The YSI datasonde recorded a range of temperature values from 18.94 to 31.18 °C at the East Bank and 19.24 to 29.94 °C at the West Bank (Figures 3.6.1.-A and 3.6.2.-A; Appendix 5). A sudden increase in temperature from 23.13 to 31.18 °C was recorded at the East Bank in mid-December 2002 (12/10-12/13/02), but was likely a glitch in the temperature probe (Figure 3.6.1.-A; Appendix 5). Around the same time, temperature increased at the West Bank from 22.4 to 25.5 °C. Although this would be an anomaly, because the YSI sondes at both banks almost simultaneously recorded an increase in temperature, the FGB reef caps may have been exposed to a brief episode of unusually warm water. Unfortunately, no HoboTemp data is available for this time period to further verify. Temperature rose again at the West Bank in late January 2002 (1/20-1/27/02; 21.3-24.2 °C; Appendix 5) but did not at the East Bank. YSI temperature records after 8/25/03 appear to be more consistent between banks (Figures 3.6.1.-A and 3.6.2.-A).

Salinity. Salinity data at the East Bank were too few (16 mean daily values) to characterize the East Bank reef cap environment. The data collected at the East Bank during those 16 days do, however, appear to be within accepted limits of salinity for coral reefs of the Western Atlantic (31-38 ppt; Coles and Jokiel 1992). At the West Bank, salinity averaged 36.48 ppt (± 0.04 SE) (Table 3.6.2). There was one anomaly during the 134 days of salinity data collection. On 4/30/03, salinity dropped from 37 to 35 ppt and then returned to 37 ppt the following day (Appendix 5).

pH. Hydrogen ion concentration (pH) in seawater typically ranges from 7.5 to 8.4 (Sverdrup et al. 1970). At the East Bank, two days of pH data yielded a mean value of 8.3 (Table 3.6.1). West Bank pH data collected during 107 days varied very little from the daily mean of 8.24 (± 0.01 SE) (Table 3.6.2).

Dissolved Oxygen. The few dissolved oxygen (DO) data collected at the East Bank averaged 6.64 mg/l (± 0.05 SE) (Table 3.6.1., Appendix 5). At the West Bank, mean DO was 6.18 mg/l (± 0.14 SE). The West Bank DO data collected from October to December 2002 ranged from 0.78 to 5.81 mg/l and seemed unusually low and erratic compared to the East Bank 2002 values (Appendix 5), the 4.94-7.78 ml/l DO range reported by Gittings et al. (1992), and bottle DO of 5 ml/l Nowlin et al. (1998) found at 20 m in the vicinity of the FGB (LATEX A hydrographic station 90) in spring, summer and fall. The DO data we collected in 2003 from February to mid-May ranged from 3.51 to 8.94 mg/l but were for the most part close to 7 mg/l. On February 12 and 13, DO dropped from 7 mg/l to 4 mg/l and then went back up to 6 mg/l on February 14 and on to 7 mg/l on February 15.

Turbidity. The turbidity data collected at the East Bank from October 2002 to April 2003 resemble those collected at the West Bank during the same time. On November 27, at the West Bank turbidity rose from 8 to 13 NTU and then back down to 5 NTU the next day. Further, turbidity rose sharply from 6 to 30 NTU around February 9-11, 2003 and dropped to 6 NTU for the rest of the 2003 record. At the West Bank, turbidity was a steady 8 NTU for most of October 2002 to March 2003, and then a steady 6 NTU from August through November 2003. The constantly low turbidity at the West Bank was interrupted by two events of brief increases in turbidity. On December 4, turbidity rose from 8 to 40 NTU and went back down to 8 NTU on December 8. On January 25 and 26, turbidity went from 8 to 24 NTU and then back down to 8 NTU. The zigzagged turbidity data taken at the East Bank from September through October 2003 (range: 0-79 NTU) are probably flawed considering the stability of turbidity at the West Bank (Appendix 5).

Photosynthetically Active Radiation. Mean daily photosynthetically active radiation (PAR) on the East Bank, PAR = 26.36 µmoles/m^2/sec (± 1.55 SE), was similar to what was found on the West Bank, PAR = 20.14 µmoles/m^2/sec *m^2 (± 1.07 SE) (Table 3.6.2). The PAR data had similar trends on both banks for the October 2002 through March 2003 period (Figures 3.6.1.-F and 3.6.2.-F). The PAR values declined from October to January (approximately 60 to 10 µmoles/m^2/sec) and then rose again to 50 µmoles/m^2/sec by mid-February. Dokken et al. (2003) recorded a similar trend during three consecutive years (1997-2000) at the West Bank. The PAR data collected at the West Bank from the end of August 2002 through November 2003 probably started off with a false peak (185 µmoles/m^2/sec). The PAR values following this peak appear to be in line with what was collected before in 2002 and 2003.

Table 3.6.1.

Summary of results of YSI water quality parameters: mean daily depth, temperature, salinity, pH, dissolved oxygen (DO), turbidity, and photosynthetically active radiation (PAR) collected at the East Bank from October 2002 to November 2003.

Statistic	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Dissolved oxygen (mg/l)	Turbidity (NTU)	PAR (µmoles/m^2/sec)
Minimum	22.96	18.94	35.46	8.26	6.13	0.03	2.73
Maximum	23.89	31.18	35.89	8.27	7.32	79.02	72.44
Mean	23.23	23.64	35.76	8.26	6.64	11.39	26.36
SE	0.01	0.21	0.03	0.00	0.05	0.94	1.55
n	219	219	16	2	32	218	149

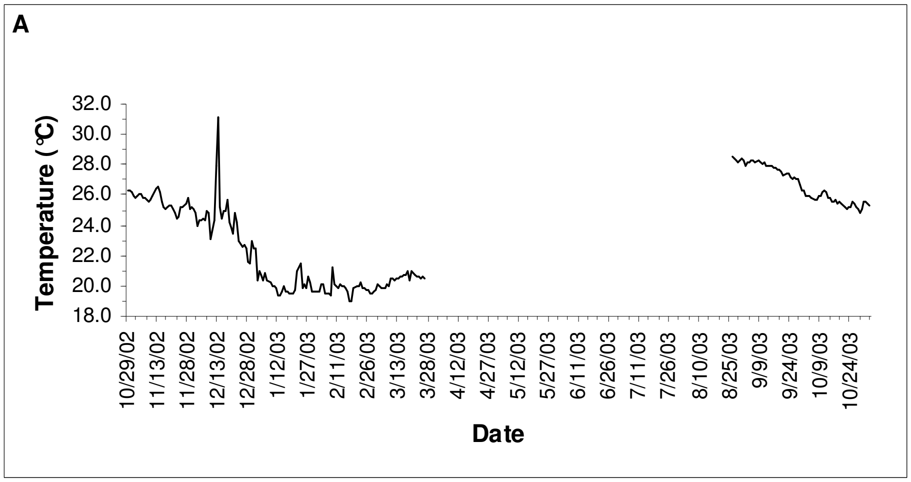


Figure 3.6.1. YSI datasonde records of mean daily temperature (A) on the East Bank reef cap from October 2002 to October 2003.

Table 3.6.2.

Summary of results of YSI water quality parameters: mean daily depth, temperature, salinity, pH, dissolved oxygen (DO), turbidity, and photosynthetically active radiation (PAR) collected at the West Bank from October 2002 to March 2004.

Statistic	**Depth (m)**	**Temperature (°C)**	**Salinity (ppt)**	**pH**	**Dissolved oxygen (mg/l)**	**Turbidity (NTU)**	**PAR (µmoles/m^2/sec)**
Minimum	25.29	19.24	35.02	7.92	0.78	3.79	1.06
Maximum	28.43	29.94	37.01	8.30	8.94	39.98	185.03
Mean	27.36	23.43	36.48	8.24	6.18	7.29	20.14
SE	0.03	0.15	0.04	0.01	0.14	0.20	1.07
n	396	395	134	107	157	290	290

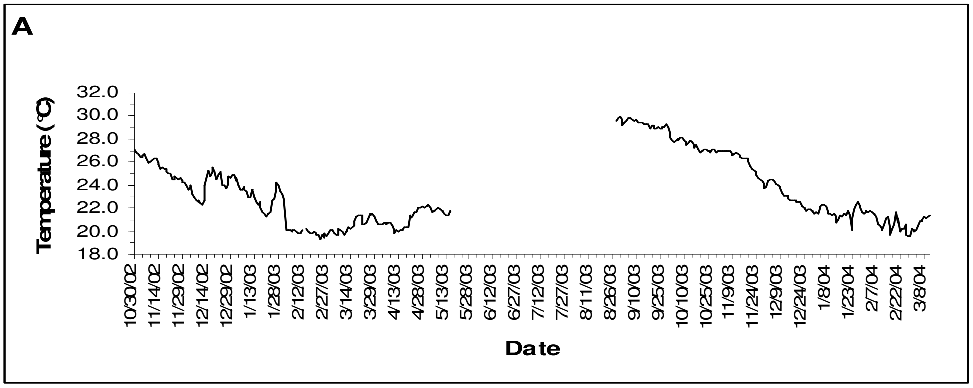


Figure 3.6.2. YSI datasonde records of mean daily temperature (A) at the West Bank from October 2002 to March 2004.

3.6.2 HoboTemp Temperature

A HoboTemp thermograph was used to record temperature at the East Bank from 10/29/02 to 2/12/04. The seawater temperature records were incomplete with a gap in recording time from 5/15/03 to 8/25/03 (Table 3.6.3, Figure 3.6.3). During the remainder of the time 10/29/02 - 5/15/03 and 8/25/03 – 2/12/04, minimum mean daily temperature was 19.30 °C (1/24/03) and maximum mean daily temperature was 29.97 °C (8/26/03). Mean daily seawater temperature on the reef cap over the entire period was 23.05 °C (± 0.15 SE; n = 397). During two weeks (8/26/03-9/11/03) water temperature on the reef cap was greater than 29.5°C and therefore close to the 30 °C coral bleaching threshold at the FGB (Hagman and Gittings 1992).

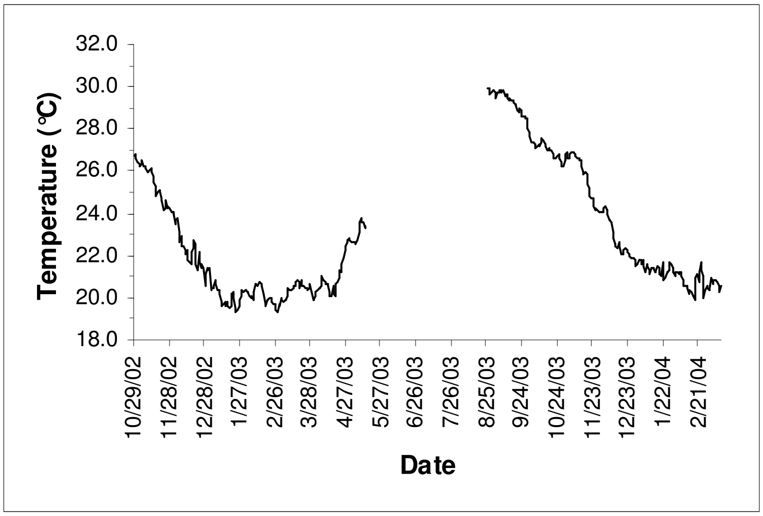


Figure 3.6.3. Mean daily temperature as measured on the East Bank reef cap using a HoboTemp thermograph.

For the West Bank HoboTemp thermographs recorded temperature data from 2/1/03 to 3/11/04. The mean daily water temperature at the West Bank ranged from 19.34 to 29.86 °C over this time period. Mean water temperature was 23.82 °C (± 0.17 SE; n = 405) (Table 3.6.2., Figure 3.6.4). Minimum mean daily water temperature at the West Bank was 19.34 °C (2/23/04) and maximum mean daily temperature was 29.86 °C (8/30/03). During the seasonal warming of the water column (April-September), a sudden drop in temperature (~3.5 °C) occurred in mid-July and it lasted for about a week. Very much like at the East Bank, summer water temperature exceeded 29.5 °C for two weeks.

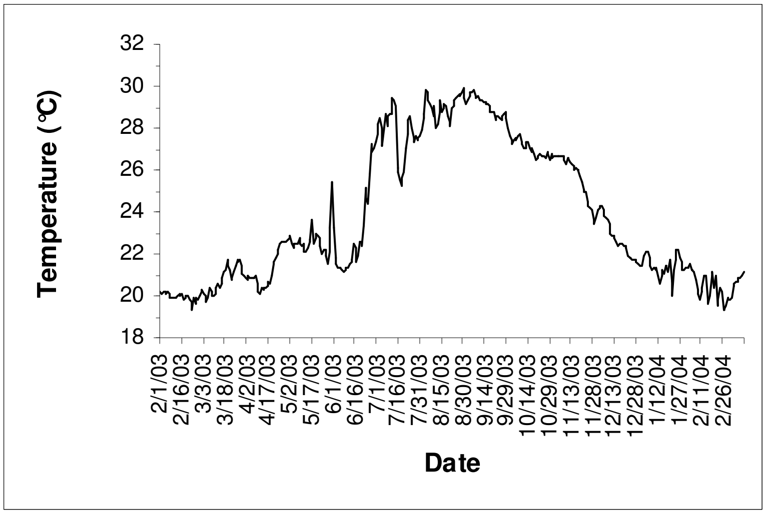


Figure 3.6.4. Mean daily temperature as measured on the West Bank reef cap using a HoboTemp thermograph.

3.6.3 Water Samples - Chlorophyll *a*

Ninety percent of the water samples collected contained concentrations of chlorophyll a that were below detectable limits (< 1 mg/m^3). The only samples containing detectable concentrations of chlorophyll a were those collected at the East Bank in February and May 2003 immediately above the reef (~ 18 m) and at the West Bank in May 2003 near the sea surface. Each of these samples contained 1.07 mg/m^3 (1070 ng/l) of chlorophyll *a* (Table 3.6.3).

Table 3.6.3.

Chlorophyll *a* concentrations in water samples taken at the East Bank and West Bank during 2002 through 2004. Highlighted values were above detection limits.

Chlorophyll *a* (mg/m^3)	10/29/2002	2/18/2003	5/16/2003	8/26/2003	3/11/2004
East Bank Surface	< 1	< 1	< 1	< 1	< 1
East Bank Midwater	< 1	< 1	< 1	< 1	< 1
East Bank Bottom	< 1	1.07	1.07	< 1	< 1
West Bank Surface	< 1	< 1	1.07	< 1	< 1
West Bank Midwater	< 1	< 1	< 1	< 1	< 1
West Bank Bottom	< 1	< 1	< 1	< 1	< 1

3.6.4. Water Samples - Nutrients

All samples except those collected in March 2004 contained ammonia levels below detection limits. Ammonia was detected in all March 2004 samples (range: 0.10-0.26 mg/l) and not in any of the other samples for two reasons: (1) Samples collected in March 2004 were analyzed using the same EPA method but with a lower detection limit (0.03 mg/l as opposed to 0.10 mg/l), and (2) ammonia concentrations were in fact higher at the East Bank in March 2004 compared with all other samples (Table 3.6.4). In ninety percent of the water samples, the nitrate and nitrite concentration was lower than

0.15 mg/l. The only samples that contained detectable levels of nitrate and nitrite were those collected in February 2003 at the East Bank (midwater) and West Bank (midwater and bottom) (Table 3.6.4). The total Kjeldahl Nitrogen (TKN) was measurable in almost all samples except for those collected in May 2003 (Table 3.6.4). The TKN level in the surface water sample collected at the East Bank in February 2003 (1.23 mg/l) was more than 1.8 times higher than in any other sample. Soluble reactive phosphorous concentrations were below detectable limits in all samples (Table 3.6.4).

Table 3.6.4.

Nutrient (ammonia, nitrate and nitrite, total Kjeldahl nitrogen, and phosphorous) concentrations in water samples taken at the East Bank and West Bank between 2002 and 2004. Highlighted values were above detection limits.

Ammonia (mg/l)	10/29/2002	2/18/2003	5/16/2003	8/26/2003	3/11/2004
East Bank Surface	< 0.15	< 0.15	< 0.15	< 0.15	0.26
East Bank Midwater	< 0.15	< 0.15	< 0.15	< 0.15	0.25
East Bank Bottom	< 0.15	< 0.15	< 0.15	< 0.15	0.16
West Bank Surface	< 0.15	< 0.15	< 0.15	< 0.15	0.13
West Bank Midwater	< 0.15	< 0.15	< 0.15	< 0.15	0.10
West Bank Bottom	< 0.15	< 0.15	< 0.15	< 0.15	0.12
Nitrate and Nitrite (mg/l)	10/29/2002	2/18/2003	5/16/2003	8/26/2003	3/11/2004
East Bank Surface	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
East Bank Midwater	< 0.15	0.15	< 0.15	< 0.15	< 0.15
East Bank Bottom	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
West Bank Surface	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
West Bank Midwater	< 0.15	0.22	< 0.15	< 0.15	< 0.15
West Bank Bottom	< 0.15	0.18	< 0.15	< 0.15	< 0.15
Total Kjeldahl Nitrogen (mg/l)	10/29/2002	2/18/2003	5/16/2003	8/26/2003	3/11/2004
East Bank Surface	0.56	1.23	< 0.10	< 0.10	0.42
East Bank Midwater	0.22	< 0.10	< 0.10	< 0.10	0.51
East Bank Bottom	0.56	0.11	< 0.10	0.28	0.37
West Bank Surface	0.34	0.22	< 0.10	0.28	0.19
West Bank Midwater	< 0.10	0.22	< 0.10	0.28	< 0.10
West Bank Bottom	0.67	0.11	< 0.10	0.28	0.19
Phosphorous (µg/l)	10/29/2002	2/18/2003	5/16/2003	8/26/2003	3/11/2004
East Bank Surface	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40
East Bank Midwater	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40
East Bank Bottom	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40
West Bank Surface	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40
West Bank Midwater	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40
West Bank Bottom	< 0.40	< 0.40	< 0.40	< 0.40	< 0.40

3.6.5. Water Samples - Trace Metals

Concentrations of chromium or mercury were undetectable in all water samples collected at East and West Banks between October 2002 and March 2004. Water samples were collected from surface, midwater and bottom water at each bank on 10/29/02, 2/18/03, 5/16/03, 8/26/03 and 3/11/04. The concentrations of chromium for all samples was less 30.0 µg/l, while mercury levels were less than 1.00 µg/l for the entire sampling period.

3.7. FISH SURVEYS

A mean of 51 fish species (± 3.5 SD) per bank and year were observed in 2002 and 2003. Fish abundances showed no significant differences between banks and years (Table 3.7.3). The mean species richness per diver survey was significantly different (t=2.308, df=63, P=0.0243) between the East Bank (16.72 species per diver survey) and the West Bank (18.55 species per diver survey). Only surveys at the West Bank proved to be significantly different (t=2.338, df=31, P=0.026) between years with 19.71 species per diver survey in 2003 and 15.72 species per diver survey in 2002. The observed species richness values in 2002 at the East Bank and West Bank were 54 and 53, respectively, and in 2003 were 46 and 52, respectively. Fish data can be seen in Appendix 6.

Shannon-Weiner diversity indices were very similar between banks and years. The highest value was for West Bank in 2003 (1.19) and lowest for East Bank in 2003 (0.90). Diversity indices for 2002 were 1.14 and 1.16 for West Bank and East Bank respectively (Table 3.7.1).

Table 3.7.1.

Shannon-Weiner diversity index (H') and Evenness (J') values for fish populations at East and West Flower Garden Banks 2002-2003.

Index	**2002**		**2003**	
	East Bank	**West Bank**	**East Bank**	**West Bank**
Diversity (H')	1.16	1.14	0.90	1.19
Evenness (J')	0.67	0.66	0.54	0.69

Expressed as density values, overall fish abundance values for the East Bank and West Bank in 2002 were 82.78 and 73.29 per 100 m^2, respectively, and in 2003 were 157.53 (East Bank) and 84.62 (West Bank) (Table 3.7.2). The high density at the East Bank in 2003 was attributed to the abundance of *Clepticus parrae* (63.66 per 100 m^2) and *Chromis multilineata* (32.94 per 100 m^2). This contrasts with the observed density of *Clepticus parrae* at the West Bank in 2003 and at the East Bank and West Bank in 2002 (7.19, 14.59, and 9.02 per 100 m^2 respectively); and the observed density of *Chromis multilineata* at the West Bank in 2003 and at the East Bank and West Bank in 2002 (14.35, 5.50, and 8.45 per 100m^2 respectively). *Thalassoma bifasciatum*, *Clepticus parrae*, and *Paranthias furcifer* were consistently among the top five most abundant fishes. Also among the most abundant fishes regularly encountered in diver surveys were *Chromis cyanea*, *C. multilineata*, *Stegastes planifrons*, and *S. partitus*.

A mean of 21 fish families (± 0.82 SD) were recorded. Labridae, Pomacentridae, and Serranidae were consistently the three most abundant families observed at the FGB, with densities ranging from 6.92 serranids per 100m^2 at the East Bank in 2002 to 70.74 labrids per 100 m^2 at the East Bank in 2003. Pomacentrids, Serranids, and Labrids are also the three best represented families with 12, 10, and 6 species having been recorded for each respectively. The labrids are represented primarily by *Clepticus parrae* and *Thalassoma bifasciatum*. The pomacentrids are represented by *Chromis multilineata* and *C. cyanea* as well as the damselfish species *Stegastes partitus* and *S. planifrons* and to a much lesser degree other species of *Stegastes* as well as *Microspathodon chrysurus* and *Abudefduf saxatilis*. *Paranthias furcifer* was the serranid species that by far accounted for the Serranidae ranking in the top three most abundant families at the FGB, ranging from 6.35 to 16.23 per 100m^2. Other serranids observed were at much lower densities (e.g., 0.0666 to 0.17 per 100 m^2), including *Cephalopholis cruentata*, *C. fulva, Epinephelus adscensionis*, *E. guttatus, Mycteroperca interstitialis, M. tigris, M. venenosa, Dermatolepis inermis*, and *Serranus phoebe*.

Observed at moderate densities (1.38 to 7.32 per 100m^2) were members of the families Scaridae, Kyphosidae, Inermiidae, and Acanthuridae. *Scarus taeniopterus, S. vetula*, and *Sparisoma viride* were the most abundant scarid species observed on diver surveys at the FGB. The family Kyphosidae was represented by the indistinguishable species *Kyphosus sectator/incisor*. The Inermiidae, represented singly by *Inermia vittata*, were not frequently encountered (sighting frequencies of 5.56% and 17.65%) and not recorded at all at the West Bank in 2002 or at the East Bank in 2003. The high abundance and low sighting frequencies of *Inermia vittata* were attributable to the schooling behavior of this species. Acanthurid densities were consistent at both banks in each year, varying between 1.38 per 100 m^2 at the West Bank in 2002 and 1.80 per 100 m^2 at the West Bank in 2003. Their densities recorded at the East Bank in 2002 and 2003 remained constant at 1.73 per 100 m^2. *Acanthurus coeruleus* was the most abundant Acanthurid species recorded; however the family was also represented by *Acanthurus bahianus* and *A. chirurgus*.

Sighting frequencies varied between banks and years, but seven species remained consistently in the 50-100% range and ranked at least once in the 90-100% range: *Stegastes partitus, S. planifrons, Paranthias furcifer, Bodianus rufus, Thalassoma bifasciatum, Acanthurus coeruleus*, and *Scarus vetula*. *Sphyraena barracuda* was consistently sighted on at least 50% of the diver surveys at both banks and in each year and was sighted on 75% of the surveys at the West Bank in 2002 and on 82% of the surveys in 2003. *Canthigaster rostrata* and *Melichthys niger* were also consistently in the 50-100% sighting range.

Species in the families Acanthuridae and Scaridae as well as the Pomacentridae species *Microspathodon chrysurus* are grouped here in an herbivore category comprised of scraping/denuding algae consumers (after Steneck 1988 and Pattengill-Semmens and Gittings 2003). Fish census techniques included juveniles in the counts of these herbivore species (and all fish species). As noted above, three species of acanthurids were recorded in the surveys and five species of scarids were recorded to make a total of nine species in this herbivore group. The mean richness of these herbivore species was 3.6 per diver survey (± 1.5 SD). No significant difference was found in herbivore richness between banks (t=1.858, df=63, P=0.068) or between years (t=1.622, df=63, P=0.110). Densities of the herbivore group ranged from 3.96 per 100 m^2 at the East Bank in 2002 and 4.56 per 100 m^2 at the West Bank in 2002 to 4.89 per 100 m^2 at the West Bank in 2003 and 5.46 per 100 m^2 at East Bank in 2003(Table 3.7.2). No significant difference was found in herbivore densities between banks (t=0.848, df=63, P=0.400) or between years (t=1.483, df=63, P=0.143). The most abundant scarid as noted above was *Scarus vetula* with densities ranging from 1.10 to 1.53 per 100 m^2 (sighting frequencies of 72 to 86%). The most abundant acanthurid was *Acanthurus coeruleus* with densities ranging from 0.66 to 1.60 per 100 m^2 (sighting frequencies of 61 to 100%). *Microspathodon chrysurus* densities ranged from 0.20 to 0.71 per 100 m^2 (sighting frequencies of 22 to 50%).

Sizes of herbivorous fishes observed at the FGB exhibited a normal distribution curve. Few fish (0-2%) fell in the 0-5cm size range and a little more (1-11%) fell in the greater than 40cm category. Most herbivorous fishes (60-80%) fell in a midsize range of 11-30cm (Figure 3.7.1).

Select carnivore species were grouped and included serranids (*Epinephelus* spp., *Cephalopholis* spp. and *Mycteroperca*) and all lutjanids (after Claro and Cantelar Ramos 2003 and Pattengill-Semmens and Gittings 2003). A total of nine species were observed at the FGB in this carnivore group: two lutjanids and seven serranids. A significant difference was found in carnivore species richness at the FGB between 2002 and 2003 (t=2.022, df=63, P=0.047). The mean species richness of this carnivore group recorded in 2002 was 0.82 carnivore species per diver survey (± 0.72 SD). The richness recorded in 2003 was 0.48 carnivore species per diver survey (± 0.63 SD). The densities recorded for this carnivore group ranged from 0.28 per 100 m^2 at East Bank and 0.30 per 100 m^2 at West Bank in 2003 to 0.42 per 100 m^2 at West Bank and 0.66 per 100 m^2 at East Bank in 2002. A significant difference (t=2.138, df=63, P=0.036) in carnivore densities was found to exist between 2002 (2.02 per 100m^2) and 2003 (1.42 per 100 m^2). *Epinephelus adscensionis* was the most abundant serranid (densities from 0.067 to 0.17 per 100 m^2) and also most commonly seen serranid (sighting frequencies of 12-28%). Lutjanids were rarely recorded at the FGB (only recorded in 2002). *Lutjanus jocu* density between the East Bank and West Bank in 2002 ranged from 0.03 to 0.13 per 100 m^2 and sighting frequency was constant at 6%.

The size distribution of carnivores at the FGB did not consistently exhibit a normal curve. Most fishes (60-100%) were recorded as 21 cm or greater. Many of these fishes (20-50%) fell in the greater than 40 cm category. The next most abundant category was the 21- to 30-cm size range (14-60%) (Figure 3.7.1).

Analysis of selected species showed some significant differences in abundances between banks and years. Observed *Sphyraena barracuda* abundances show significant difference ($t_{0.05(2),63}$=3.054, P=0.003) between East Bank (1.68 per 100 m^2) and West Bank (3.93 per 100m^2); however, no significant difference in abundance was found between 2002 and 2003 at either bank. The difference in observed abundance of *Kyphosus sectator/incisor* was found to be significant (t=3.869, df=63, P=0.0003) between East Bank (13.19 per 100 m^2) and West Bank (2.64 per 100 m^2); however, no significant difference was found between 2002 and 2003. Examination of the abundance of garden-tending damselfishes showed no significant difference between banks; however, significant difference (t=2.211, df=63, P=0.031) was found between 2002 (5.04 per 100 m^2) and 2003 (5.99 per 100 m^2). Damselfishes included in this garden-tending group include species from *Stegastes, Pomacentrus*, *Eupomacentrus*, and *Microspathodon* (Steneck 1988; DeLoach 1999).

Table 3.7.2.

Densities of fishes at the FGB in 2002 and 2003 (Densities in number of fish per 100 m^2).

Category	**2002**		**2003**	
	East Bank	**West Bank**	**East Bank**	**West Bank**
Herbivores	3.96	4.56	5.46	4.89
Carnivores	0.66	0.42	0.28	0.30
Garden Tending Damselfishes	4.87	5.23	5.82	6.13
Sphyraena baraccuda	0.47	1.20	0.57	1.20
All Fishes	82.78	73.29	157.53	84.62

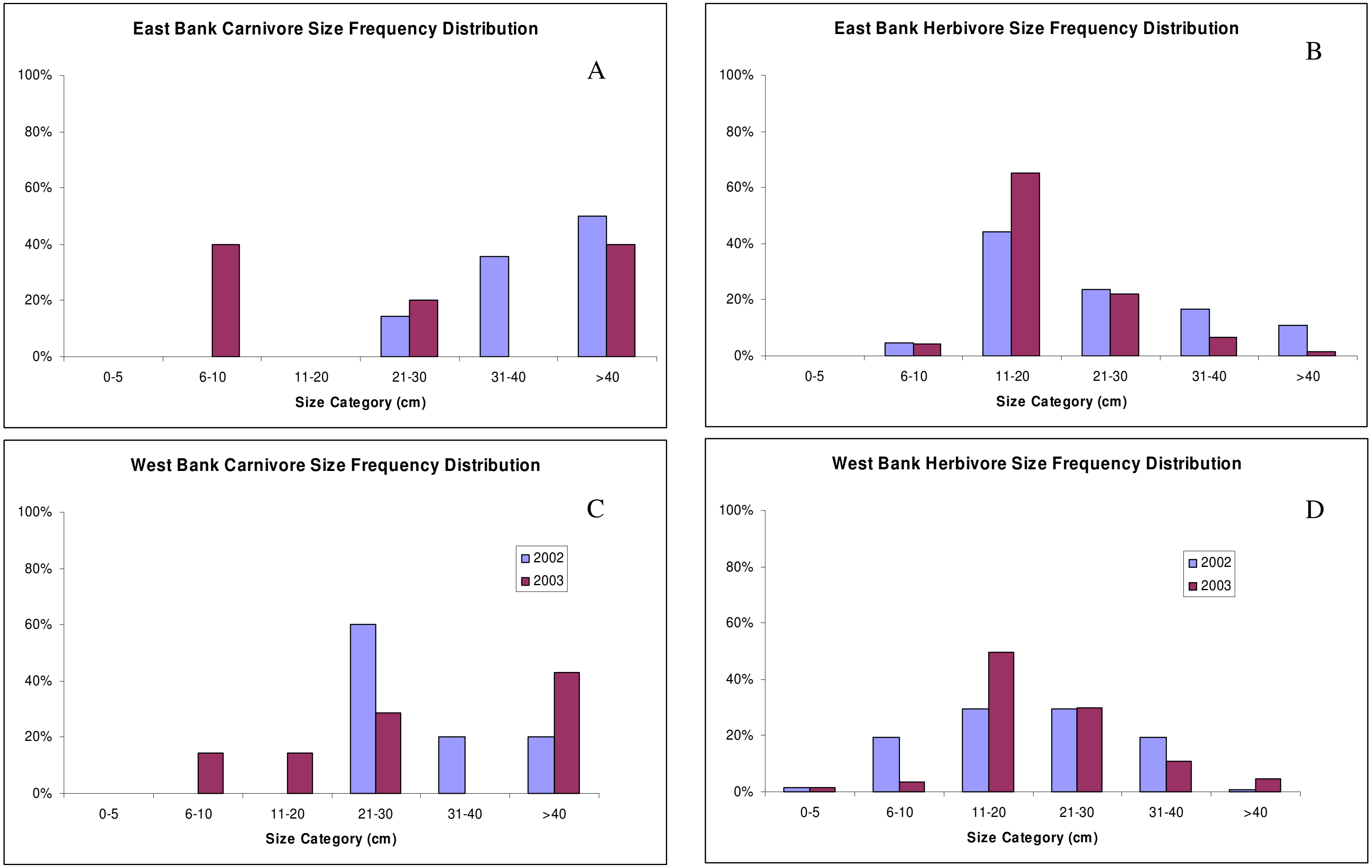


Figure 3.7.1. Fish size distributions at the FGB in 2002 and 2003: East Bank carnivores (A), East Bank herbivores (B), West Bank carnivores (C), and West Bank herbivores (D).

Table 3.7.3.

Species list of fishes recorded in stationary visual surveys conducted at the East and West Flower Garden Banks in October 2002 and August 2003. Trophic Guild indicates selected species as defined in the text.

Fish Species	Fish Common Name	Family Name	Trophic Guild
Acanthurus bahianus	Ocean surgeonfish	Acanthuridae	Herbivore
Acanthurus chirurgus	Doctorfish	Acanthuridae	Herbivore
Acanthurus coeruleus	Blue tang	Acanthuridae	Herbivore
Atherinidae	Silversides	Atherinidae	
Aulostomus maculatus	Trumpetfish	Aulostomidae	
Canthidermis sufflamen	Ocean triggerfish	Balistidae	
Melichthys niger	Black durgon	Balistidae	
Malacoctenus triangulatus	Saddled blenny	Blenniidae	
Ophioblennius atlanticus	Redlip blenny	Blenniidae	
Caranx crysos	Blue runner	Carangidae	
Caranx hippos	Crevalle jack	Carangidae	
Caranx latus	Horse-eye jack	Carangidae	
Caranx lugubris	Black jack	Carangidae	
Caranx ruber	Bar jack	Carangidae	
Elagatis bipinnulata	Rainbow runner	Carangidae	
Chaetodon aculeatus	Longsnout butterflyfish	Chaetodontidae	
Chaetodon ocellatus	Spotfin butterflyfish	Chaetodontidae	
Chaetodon sedentarius	Reef butterflyfish	Chaetodontidae	
Chaetodon striatus	Banded butterflyfish	Chaetodontidae	
Amblycirrhitus pinos	Redspotted hawkfish	Cirrhitidae	
Diodon holocanthus	Balloonfish	Diodontidae	
Diodon hystrix	Porcupinefish	Diodontidae	
Gnatholepis thompsoni	Goldspot goby	Gobiidae	
Gobiosoma oceanops	Neon goby	Gobiidae	
Holocentrus adscensionis	Squirrelfish	Holocentridae	
Holocentrus rufus	Longspine squirrelfish	Holocentridae	
Myripristis jacobus	Blackbar soldierfish	Holocentridae	
Inermia vittata	Boga	Inermiidae	
Kyphosus sectator/incisor	Chub, Bermuda/Yellow	Kyphosidae	
Bodianus rufus	Spanish hogfish	Labridae	
Clepticus parrae	Creole wrasse	Labridae	
Halichoeres garnoti	Yellowhead wrasse	Labridae	
Halichoeres maculipinna	Clown wrasse	Labridae	
Halichoeres radiatus	Puddingwife	Labridae	
Thalassoma bifasciatum	Bluehead	Labridae	
Lutjanus griseus	Gray snapper	Lutjanidae	Carnivore
Lutjanus jocu	Dog snapper	Lutjanidae	Carnivore
Cantherhines macrocerus	Whitespotted filefish	Monocanthidae	
Cantherhines pullus	Orangespotted filefish	Monocanthidae	
Mulloidichthys martinicus	Yellow goatfish	Mullidae	

Fish Species	Fish Common Name	Family Name	Trophic Guild
Gymnothorax moringa	Spotted moray	Muraenidae	
Lactophrys bicaudalis	Spotted trunkfish	Ostraciidae	
Acanthostracion polygonius	Honeycomb cowfish	Ostraciidae	
Lactophrys triqueter	Smooth trunkfish	Ostraciidae	
Holacanthus ciliaris	Queen angelfish	Pomacanthidae	
Holacanthus tricolor	Rock beauty	Pomacanthidae	
Pomacanthus paru	French angelfish	Pomacanthidae	
Abudefduf saxatilis	Sergeant major	Pomacentridae	
Chromis cyanea	Blue chromis	Pomacentridae	
Chromis insolata	Sunshinefish	Pomacentridae	
Chromis multilineata	Brown chromis	Pomacentridae	
Chromis scotti	Purple reeffish	Pomacentridae	
Microspathodon chrysurus	Yellowtail damselfish	Pomacentridae	Herbivore
Stegastes diencaeus	Longfin damselfish	Pomacentridae	
Stegastes adustes	Dusky damselfish	Pomacentridae	
Stegastes leucostictus	Beaugregory	Pomacentridae	
Stegastes partitus	Bicolor damselfish	Pomacentridae	
Stegastes planifrons	Threespot damselfish	Pomacentridae	
Stegastes variabilis	Cocoa damselfish	Pomacentridae	
Scarus iseri	Striped parrotfish	Scaridae	Herbivore
Scarus taeniopterus	Princess parrotfish	Scaridae	Herbivore
Scarus vetula	Queen parrotfish	Scaridae	Herbivore
Sparisoma aurofrenatum	Redband parrotfish	Scaridae	Herbivore
Sparisoma viride	Stoplight parrotfish	Scaridae	Herbivore
Cephalopholis cruentata	Graysby	Serranidae	Carnivore
Cephalopholis fulva	Coney	Serranidae	Carnivore
Dermatolepis inermis	Marbled grouper	Serranidae	
Epinephelus adscensionis	Rock hind	Serranidae	Carnivore
Epinephelus guttatus	Red hind	Serranidae	Carnivore
Mycteroperca interstitialis	Yellowmouth grouper	Serranidae	Carnivore
Mycteroperca tigris	Tiger grouper	Serranidae	Carnivore
Mycteroperca venenosa	Yellowfin grouper	Serranidae	Carnivore
Paranthias furcifer	Creole-fish	Serranidae	
Serranus phoebe	Tattler bass	Serranidae	
Sphyraena barracuda	Barracuda, great	Sphyraenidae	
Canthigaster rostrata	Sharpnose puffer	Tetraodontidae	

3.8 SEA URCHIN SURVEYS

In 2003 no *Diadema antillarum* were documented on the two perimeter lines sampled at East Bank or along random transect lines; however one *Echinometra viridis* was recorded along the random transects. Three juvenile *Diadema antillarum* were recorded along perimeter lines at West Bank, for a density of 0.008 individuals/m^2 at the West Bank. Two *Diadema antillarum* and one *Panulirus argus* were documented at random transects at East Bank in 2002, for a density of 0.005 individuals/m^2. Five *D. antillarum* were found along random transects at West Bank in 2002, for a density of 0.014 individuals/m^2.

D. antillarum populations at the FGB pre-1983 were between 0.54 and 1.63/m^2 while post-1984 urchin densities dropped to 0 individuals/m^2 (Gittings and Bright 1987). No statistical analyses were carried out due to low sample size.

3.9 MAPPING RESULTS

The primary objective of the mapping effort was to produce monitoring site maps that could be used by divers to aid in the location of station markers. The existing study site maps (Figures 2.1.1 and 2.1.2) show the approximate locations of pins, marking lateral growth and repetitive quadrat stations, within the four quadrants of the 100 X 100 m study sites. Very few landmarks and no coral structures are included on these maps, so divers experienced difficulty in finding specific pins. The time spent by divers searching for station markers impinged upon bottom time available for conducting scientific investigations.

Bitmap images of the study site maps were geo-referenced in Microstation (Version 8) using the differential GPS positions (from buoys) for the corner markers. It was necessary to warp the shape of the study site maps so they would conform as closely as possible to their actual shapes on the seabed. This was accomplished using the Warp function (Affine method) in Microstation Raster Manager. Once the approximate station locations were geo-referenced, they were overlaid on sonar imagery.

Two types of sonar, side-scan and sector-scan, were utilized in PBS&J's efforts to map the FGB study sites (see Section 2.9). Mosaic images of the two FGB study sites and of a portion of Stetson Bank are illustrated in Figures 3.9.1 (East Bank sector-scan images), 3.9.2 (East Bank side-scan) and 3.9.3 (West Bank side-scan). Side-scan sonar proved to be the better of the two tools for mapping the areas of dense coral formations and high topographic relief on the FGB. It quickly became apparent that the side-scan sonar produced superior imagery of the reef, thus use of the sector-scan sonar was discontinued once work was completed at the East Bank study site.

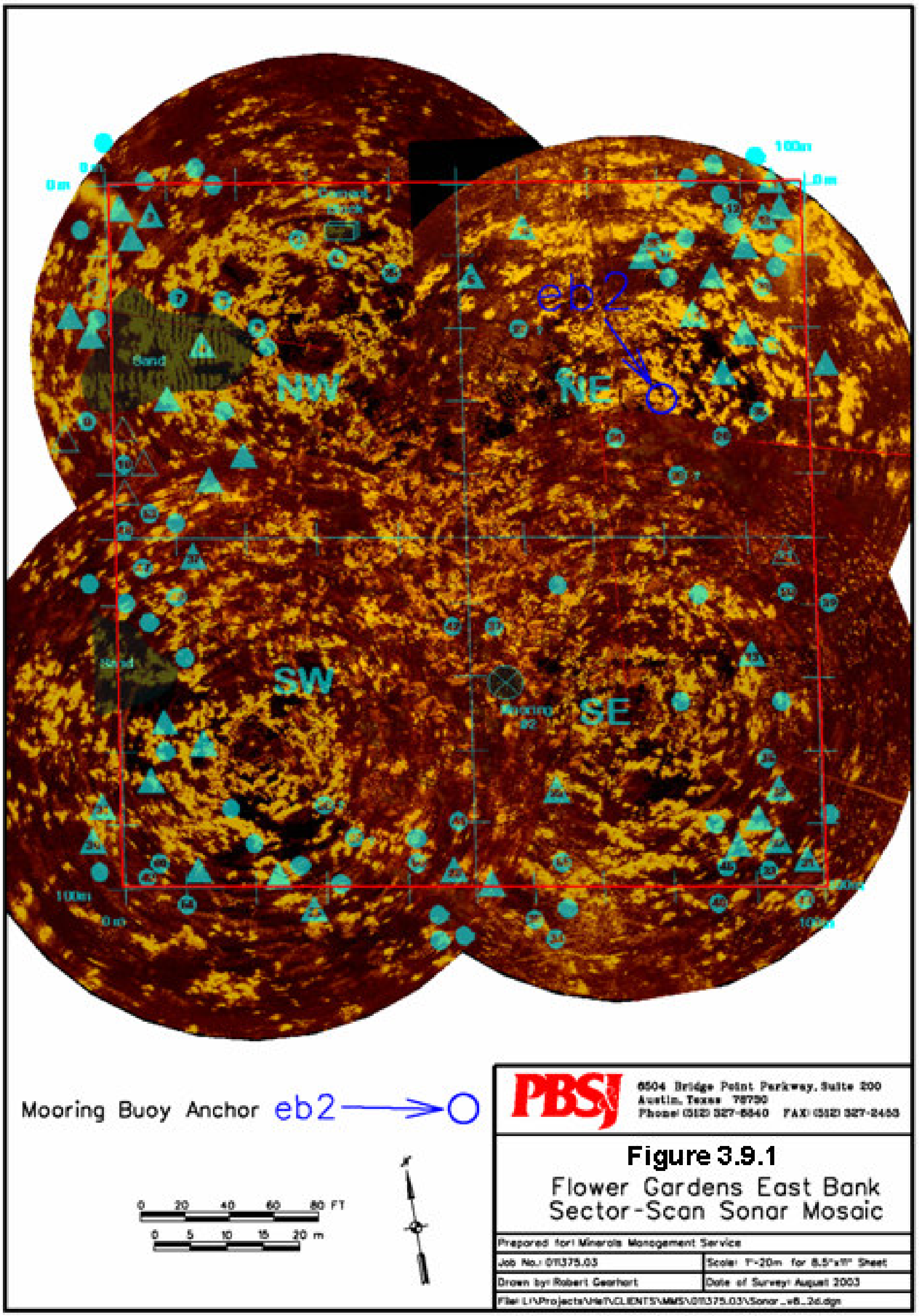


Figure 3.9.1. East Flower Garden Bank sector-scan sonar mosaic in 2003.

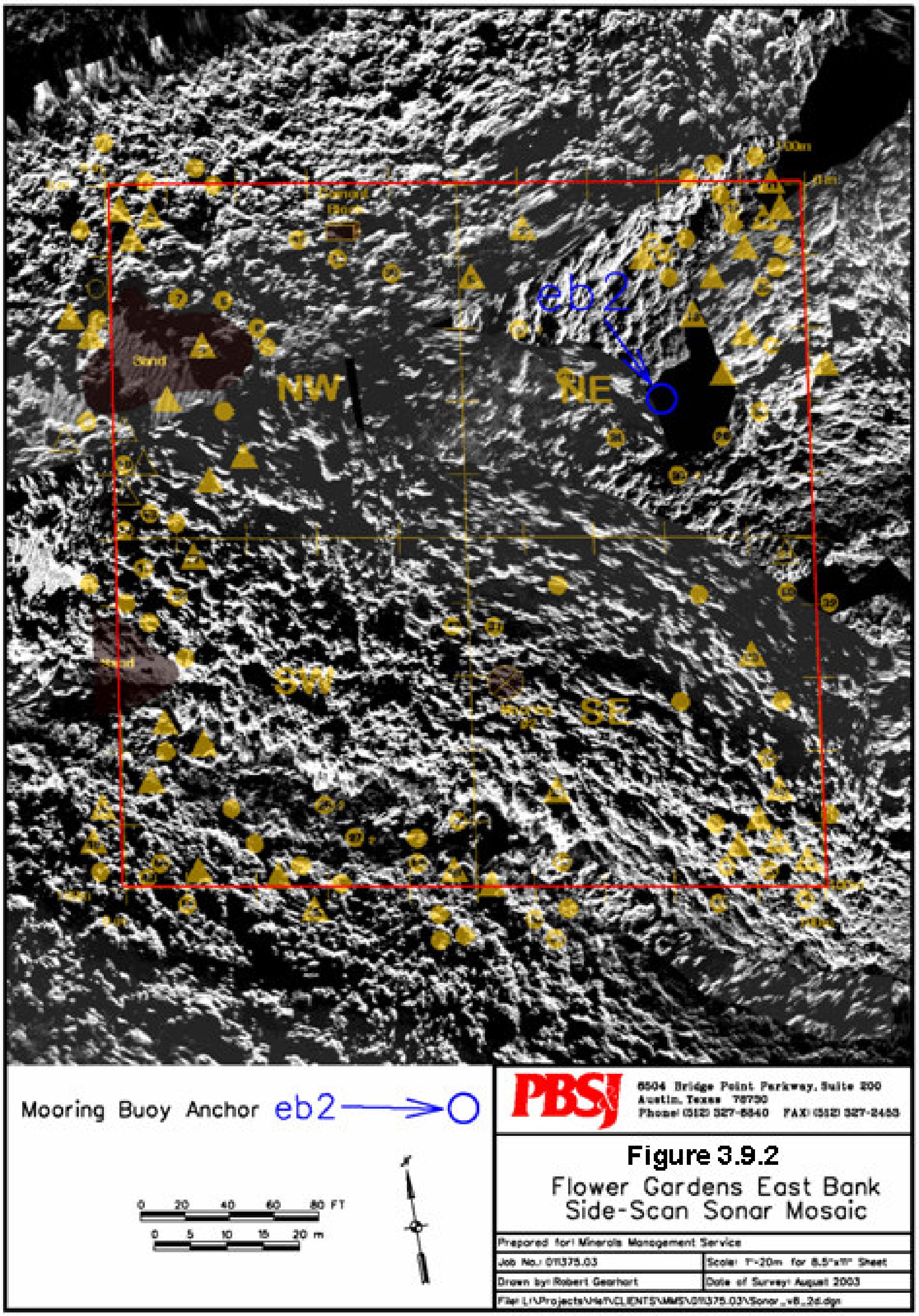


Figure 3.9.2. East Flower Garden Bank side-scan sonar mosaic in 2003.

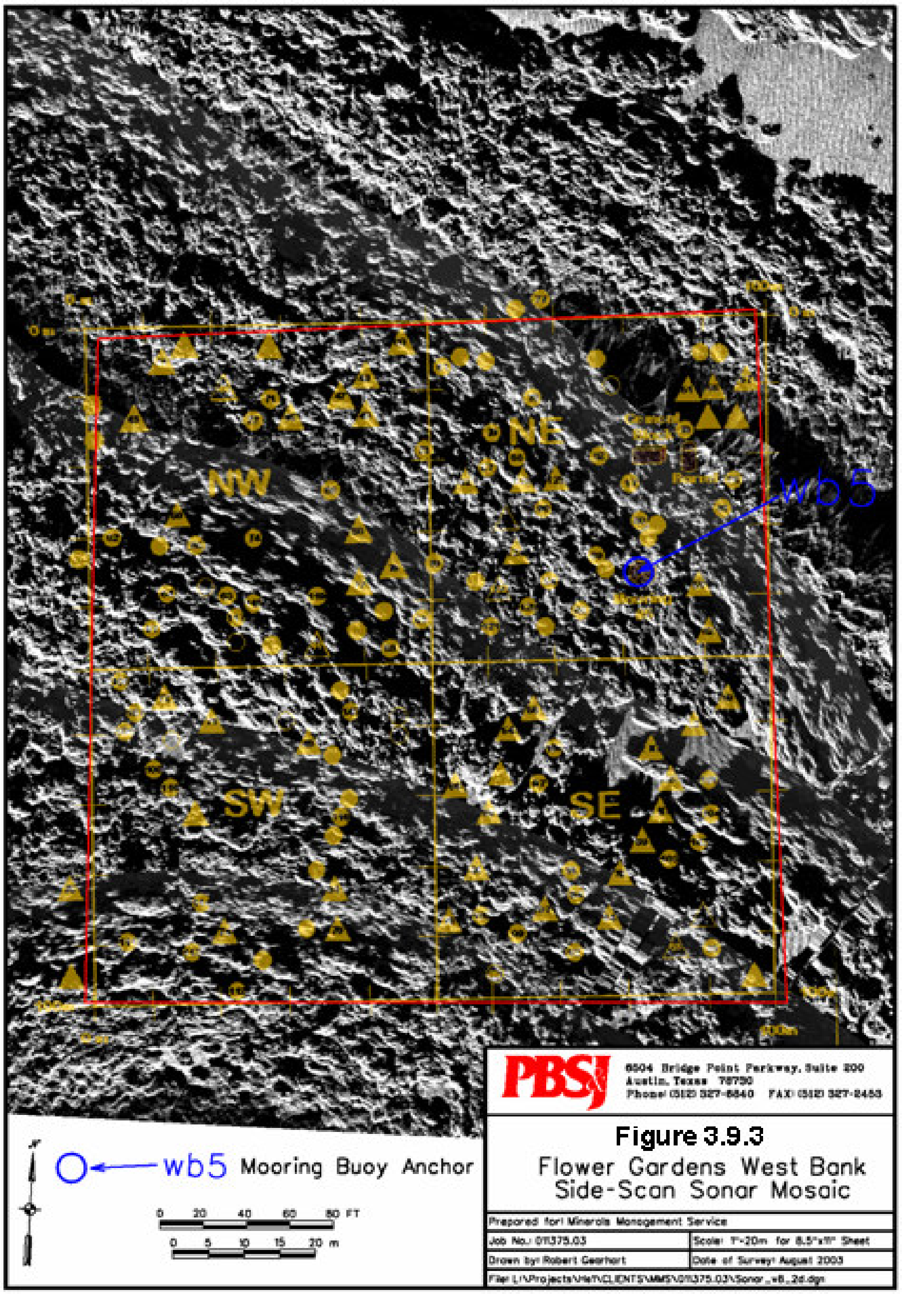


Figure 3.9.3. West Flower Garden Bank side-scan sonar mosaic in 2003.

4.0 DISCUSSION

4.1. CORAL

4.1.1. General

The East and West Flower Garden Banks, located 193 km and 172 km offshore from Galveston, Texas are reef communities situated at the northernmost range of Atlantic coral reefs. The first coral reef assessment of the FGB took place at the West Bank in 1972 (Bright and Pequegnat 1974). In 1973, the MMS (then Bureau of Land Management) instituted a Topographic Features Stipulation to protect topographic features in the NWGOM such as the FGB, from oil and gas activities (exploration and development) and in particular from the discharge of drilling effluents. The stipulations developed for the FGB consist of a No Activity Zone outside of the 100 m isobath based on the ¼, ¼, ¼, system (MMS 1998). Additionally, a 4-Mile Zone was implemented around the East and West Bank, such that shunting of drilling effluents is restricted to within 10 m of the seafloor. In 1978, exploratory drilling began 1.7 km southeast of the East Bank (Gittings 1998). As a result, the MMS required that the benthic communities of East Bank be formally surveyed and monitored. Monitoring at the East Bank lasted until 1983. In 1983, NOAA funded a survey of anchoring damage at the East Bank (Gittings and Bright 1986). From 1988 to 1995, the MMS funded the annual monitoring of the East and West Flower Gardens. After the National Marine Sanctuary designation of the FGB in 1992, NOAA and MMS co-funded the annual monitoring of the FGB beginning in 1996. Since 1988, the FGB coral reefs have changed little in terms of coral cover, dominance and diversity, prevalence of coral disease, condition of water quality, and fish population dynamics. Results from the 2002-2003 monitoring data indicate continuation of that stability.

The FGB coral reefs exhibited high coral cover during the 2002-2003 monitoring period (Table 4.1.1.). The *Montastraea annularis* complex and *Diploria strigosa* continued to be the dominant coral species at both banks. Crustose coralline, fine turf, and bare rock (CTB) was the most abundant non-coral cover type. Crustose coralline algae, a component of CTB, is thought to be a cue for settlement of coral recruits (Morse et al. 1988). Macroalgae was less abundant, ranging from ~4-20%, with an increase from 2002 to 2003 at the East Bank and a decrease for the same time period at the West Bank (Figure 3.1.4). Low levels of macroalgae also indicate moderate to high levels of herbivory. High levels of herbivory are known to occur at the FGB, with robust herbivorous fish populations and the occurrence of fish biting on hard corals. Disease and bleaching were not detected in random transect videography, and the repetitive quadrat data also showed extremely low levels of bleaching (<0.61%) and disease (0%) for both years. Low levels of macroalgae, high cover of CTB, high coral cover, and low levels of coral disease and bleaching are all attributes of the excellent condition of the coral reefs at the FGB. Newly established deep repetitive quadrats at the East Bank (32-40 m depth) revealed high coral cover (mean 75.14%), with different species abundance patterns than at the shallower sites: *M. annularis* complex spp. and *M. cavernosa* were the top contributors to coral cover.

Coral accretion is measured through the coring of *M. faveolata* at the FGB. Sclerochronology results revealed growth rates comparable to growth rates of past observations at both banks (Dokken et al. 2003). One out of four cores at each bank showed an interruption in linear extension in 1997-1998, a year known for bleaching-related stress and mortality worldwide. To study the lateral growth of an important contributor to coral cover at the banks, the margins of colonies of *D. strigosa* were photographed. Photographs of *Diploria strigosa* showed lateral growth from 2001 to 2002, whereas comparisons made from 2002 to 2003 showed approximately equal extensions and retreats for a net zero gain.

Water quality parameters indicated good water quality when measurements were valid. Numerous problems occurred with YSI datasondes failing, creating uncertainty in the quality of data. We recommend refurbishing datasondes and or datasonde probes as well as using technology other than YSI.

Fish surveys showed robust fish assemblages, that were dominated by herbivorous fish and included healthy carnivore populations. Urchin surveys detected low densities of *Diadema antillarum* at both banks in both years. These populations have not recovered to pre-1984 levels, which ranged from 0.54-1.63 individuals/m^2 between 1970 and 1983 (Bright and Pequegnat 1974; CSA 1984).

Mapping efforts resulted in the mapping of coral heads at each of the banks. More information is needed to map individual station markers to particular coral heads. GIS based maps using the four known geographic corner locations of the study sites at East and West Bank are being developed. Using photographs of the repetitive quadrat markers and lateral growth station markers and their known relative positions we are creating a photomosaic for each site. This photomosaic will have considerable gaps between photostations, but each successive year can be added to the map and in this way a user can see a map of the repetitive and lateral growth stations for any given year. Eventually, each repetitive and lateral station may be mapped using GPS to obtain the exact and true geographic location. It is possible to georeference random transects (although it is costly), and in this way gradually develop a complete visual map of the coral reefs within the 100 m^2 at East and West Bank.

Table 4.1.1.

Percent coral cover (± SE) at both banks for both sampling years from random transect videography data.

East Bank 2002	East Bank 2003	West Bank 2002	West Bank 2003
56.43 ± 2.36	53.20 ± 3.01	49.67 ± 3.35	57.13 ± 3.81

4.1.2 Random Transects

East Bank Comparison 2002-2003. The random transect data for the East Bank in 2002 and 2003 showed similar values for all parameters measured, except for macroalgae and CTB categories (Table 3.1.1). Macroalgae increased from 4.05% to 16.74% from 2002 to 2003 [the site X year interaction was significant (P= <0.0005)], while CTB decreased from 37.07% to 28.12% from 2002 to 2003. While macroalgae and CTB changed during the monitoring period, this did not appear to have an effect on coral cover during the sampling period, which remained stable from 2002 to 2003 (56.43% to 53.20%) [the site X year interaction was not significant (P= 0.099)].

All coral species, including the *Montastraea annularis* complex, remained stable from 2002 to 2003 at the East Bank (Table 3.1.1). In 2003, *Colpophyllia natans* increased slightly; however, this is most likely due to transect placement and may or may not reflect an increase in *C. natans* cover at the FGB overall. Past studies have shown similar variations in relative abundance from year to year (Dokken et al. 2003, 1999). These variations are believed to reflect the placement of transects and not be a true increase in the relative abundance of particular species. Diversity (H') did not change significantly at the East Bank during the sampling period. H' is low at the East Flower Garden Bank due to the low species richness values and the dominance of a few species, namely the *M. annularis* complex and *Diploria strigosa*.

West Bank Comparison 2002-2003. Percent cover data for random transects at the West Bank in 2002 and 2003 showed similar values for all parameters overall. Macroalgae decreased in transects from 19.14% to 8.41% from 2002 to 2003 [the site X year interaction was significant (P= <0.0005)], so the effect of site is difficult to interpret. The opposite trend was true for CTB at the West Bank, during the 2002-2003 sampling period. This inverse relationship at both the West Bank and the East Bank may be expected since these two components make up the majority of non-coral substratum at the FGB.

Coral cover increased slightly at the West Bank from 2002 to 2003 according to random transect data (Table 4.1.1). The dominance of the *Montastraea annularis* complex continued through this monitoring period. LPI data showed that *M. annularis* was more prevalent at the West Bank, compared to the East Bank (3-5% vs. 1-2%) (Figure 3.1.3). *Diploria strigosa* increased slightly during this period at random transects and accounted for the overall increase in coral cover (Table 3.1.1). Like *C. natans* at the East Bank, this increase may or may not represent an actual increase in dominance of *D. strigosa*, an answer that only future monitoring will reveal. Diversity (H') at the West Bank was lower than measured at the

East Bank and the relatively low diversity is due to low species richness and dominance of a few coral species.

Qualitative Comparison of Random Transect Results from 1992-2003 for Selected Parameters. A qualitative comparison of the dominant cover components from random transects at the East and West Flower Garden Banks showed interesting results for several cover categories. It should be noted that the data analyzed herein were collected by three different groups: Continental Shelf Associates, Inc. from 1992 to 1995, Dokken et al. from 1996 to 2001, and PBS&J from 2002 to 2003 (Table 4.1.2). The algae category from 1992 to 2003 were roughly equivalent to macroalgae analyzed in 2002-2003. The reef rock category from 1992 to 1995 and 1998-2001 included bare substrate. In 1996 and 1997 no data were recorded for the reef rock category. In 2002-2003 the reef rock category is included in the CTB category.

The *Montastraea annularis* complex, showed an overall increase in cover during the period 1992-2003 at the West Bank, while the complex has decreased in the last two years at the East Bank (Table 4.1.2). At the East Bank the *M. annularis* complex ranged from 21.3% to 44.8% cover between 1992 and 2003. The values calculated from the random transect data in 2002 and 2003 were 33.59% ± 3.86 and 28.47%± 2.98, respectively. At the West Bank, the *M. annularis* complex ranged from 23.02 to 35.1% from 1992 to 2003, and transect values were 31.73% ± 3.57 SE and 33.8% ± 4.31 for the complex in 2002 and 2003, which continue the increasing trend for the complex. Interestingly, there were slight decreases in the *M. annularis* complex cover in 1999 at the East Bank and in 2000 at the West Bank. These decreases coincide with increases in the algal component and decreases in the reef rock category. However, the upward trend was reestablished after one year of decreasing cover at both banks (Figure 4.1.2.A, B).

Diploria strigosa, important as the second most common species at the FGB, showed variation over time, but never decreased below 4.69% in 1992 or exceeded 12.4%, measured in 1999 at the East Bank. In 2002 and 2003 *D. strigosa* cover was ~6-7% for both years at the East Bank and ranged from ~3-9% at the West Bank (Table 4.1.2).

Porites astreoides, the smallest contributor to percent cover analyzed was lowest at the West Bank and showed no change in relation to other coral species, algae or reef rock categories at either bank. It has increased slightly since 2001 at the East Bank (Table 4.1.2).

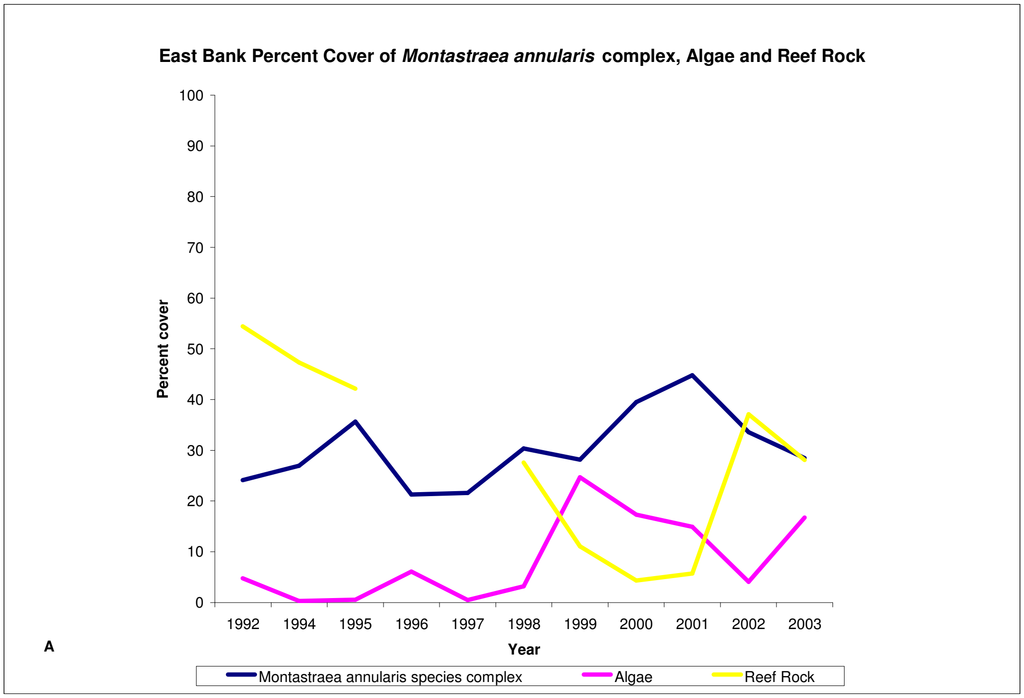
The change over time among algae, reef rock and the dominant corals of the *Montastraea annularis* complex showed interesting patterns (Figure 4.1.2). The influence of season on algal cover must be considered and therefore timing of monitoring events is important. Algae tend to be ephemeral, with different species abundant under different seasonal conditions. With this in mind we looked at algal cover data collected throughout the monitoring period 1992-2003. Monitoring events for the time period 1992-2003 have taken part for the most part in the fall. The monitoring events in 1992 and 1995 took place in late August. In 1993 no monitoring took place. Cruises for 1994 and 1996-2003 took place from September to October, after the warmest part of the year. Because monitoring for the time period analyzed was conducted at similar times of year, we can surmise that seasonal fluctuations were not influential in interpreting patterns of algae abundance from 1992-2003.

Algal cover, here taken to mean macroalgae, remained relatively low from 1992 to 1998, never reaching more than 4.78% at either bank until it increased dramatically in 1999 at both banks (Table 4.1.2). While algae increased, reef rock declined (Figure 4.1.2). Concurrent with the increase in algae, the reef rock category declined from ~27% to 11% at the East Bank in 1999, and from ~21% to 8% in 2000 at the West Bank. In 2001 the reef rock category began an increasing trend at both the East and West Banks, while algae began to decline. At the same time that algae increased and reef rock decreased, the *Montastraea annularis* complex decreased slightly in 1999 (East Bank) and 2000 (West Bank), but continued to trend upward a year later (Figure 4.1.2). The timing of the shifts in algae, *M. annularis* complex and reef rock coincide with the aftermath of the strong ENSO event of 1998, which caused widespread bleaching throughout the Caribbean. Many areas affected by severe bleaching and hurricane events have experienced partial mortality and increased turf and macroalgae cover, and a subsequent decline in live coral cover in the weeks and months proceeding the event (McField 2000; Ostrander et al. 2000). At Mexico Rocks in Belize six months after the 1995 bleaching event, corals that had paled recovered their zooxanthellae, while dead substrate covered by turf and macroalgae increased significantly, due to coral mortality (Burke et al. 1996). A significant increase in dead substrate (turf and macroalgae covered) at Mexico Rocks was also seen after the 1993 bleaching event and the 1997 bleaching event, decreasing coral cover overall after each event, resulting in an eventual degradation of the reef framework (Burke et al. 1996). In contrast to these events, the FGB saw a dip in cover of the *M. annularis* complex, concurrent with the increase in algae and a return to an increasing trend in coral cover. Such trends have not been documented at other reefs in the Caribbean/western Atlantic region to the knowledge of the authors at this time. These slight shifts in community dynamics continue to be an interesting avenue of research and the coral reef system of the FGB continues to be one of the most dynamic places to study the subtleties of these patterns.

Table 4.1.2.

East and West Bank random transect data for predominant cover categories including, *Montastraea annularis* complex, *Diploria strigosa*, *Montastraea cavernosa*, *Porites astreoides*, Algae, and Reef Rock as reported in CSA (1996) for data from 1992-1995 and Dokken et al. (2003) for data from 1996-2001. No standard deviations were presented for data from 1992-1995. Standard deviations are shown in parentheses for 1996-2001 and standard errors are shown for 2002 and 2003. Different data analysis teams are connoted as follows:*** = CSA, ** = Dokken, * = PBS&J. Algae and reef rock are defined in section 4.1.2.

East Bank	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
M. annularis spp. complex	24.12	26.93	35.65	21.3 (14.2)	21.6 (8.1)	30.4 (11.1)	28.2 (11.7)	39.5 (9.6)	44.8 (12.9)	33.59 (3.86)	28.47 (2.98)
Diploria strigosa	4.69	8.92	7.92	10.1 (7.1)	5.1 (4.4)	8.3 (3.7)	12.4 (6.0)	6.2 (2.8)	3.9 (4.1)	6.96 (1.69)	6.19 (1.55)
Montastraea cavernosa	1.49	4.80	3.20	3.7 (5.3)	4.7 (4.9)	3.5 (2.9)	2.4 (2.8)	4.8 (5.7)	3.6 (5.0)	3.9 (1.08)	4.24 (1.41)
Porites astreoides	4.57	3.89	2.71	3.6 (1.5)	5.3 (3.0)	4.2 (3.0)	3.4 (1.7)	2.6 (1.7)	4.6 (2.7)	6.79 (0.83)	5.69 (0.98)
Total Coral	34.87	44.54	49.48	38.7	36.7	46.4	46.4	53.1	56.9	51.24	44.59
Algae	4.78***	0.29***	0.57***	6.1** (5.2)	0.5** (0.6)	3.2** (2.6)	24.7** (13.2)	17.3** (4.9)	14.9** (5.6)	4.06 (0.75)*	16.74 (2.05)*
Reef Rock	54.46***	47.31***	42.15***	-	-	27.6** (5.9)	11.1** (8.2)	4.3** (1.7)	5.7** (3.6)	37.07 (2.69)*	28.12 (2.05)*
West Bank	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
M. annularis spp. complex	23.02	24.95	31.00	27.2 (8.3)	27.7 (9.9)	28.4 (11.9)	31.7 (8.6)	30.9 (11.6)	35.1 (12.0)	31.73 (3.57)	33.8 (4.31)
Diploria strigosa	6.15	10.15	6.66	7.9 (3.5)	9.1 (5.9)	9.6 (4.8)	10.9 (7.8)	8.1 (6.7)	9.5 (5.8)	3.2 (0.91)	9.04 (2.68)
Montastraea cavernosa	0.87	3.15	2.33	1.5 (2.2)	4.3 (4.2)	2.6 (2.4)	2.4 (3.5)	5.8 (11.7)	2.1 (3.7)	2.74 (1.16)	2.67 (1.10)
Porites astreoides	1.49	2.55	2.44	2.5 (1.4)	2.7 (2.3)	2.4 (2.0)	2.7 (1.9)	2.5 (1.6)	2.0 (0.9)	3.44 (0.74)	3.77 (0.46)
Total Coral	31.53	40.8	42.43	39.1	43.8	43.0	47.7	47.3	48.7	41.11	49.28
Algae	4.45***	0.42***	2.7***	4.5** (2.9)	0.1** (0.1)	2.3 (1.3)**	18.8 ** (6.2)	22.6** (14.0)	25.4 ** (7.3)	19.14* (1.4)	8.41* (1.41)
Reef Rock	56.56***	51.08***	45.85***	-	-	20.7 ** (11.2)	21.1** (9.8)	8.5** (3.7)	4.6 ** (2.9)	27.63* (3.14)	31.63* (3.04)



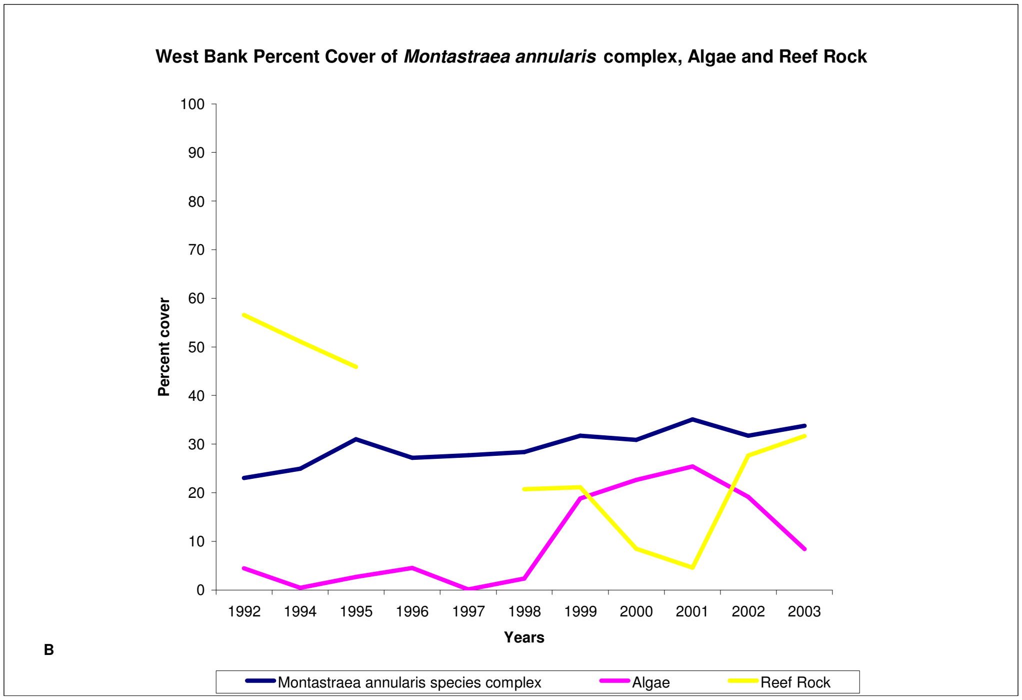


Figure 4.1.2. Percent cover of *Montastraea annularis* complex, algae, and reef rock from 1992-2003: East Bank and West Bank.

Random Transect Data. The statistical comparison of the methods of random transect data collection was an important component of the work performed. To address this, comparisons of random transect data collected using three methods, videography (point count), still photography (planimetry), and linear point-intercept methods were conducted. Three categories including total coral cover, the *Montastraea annularis* complex, and *Diploria strigosa*, were chosen to represent common, medium, and rare cover categories at the FGB.

Total Coral Cover. All three methods showed a normal distribution for total coral cover, revealed by Anderson-Darling (*P*>0.13 in all cases). Pairwise F-tests on the untransformed data revealed only one significant difference: the LPI data were significantly less variable than the videographic data (*P*=0.028). Comparisons of variances between videography and still photography was not significant (*P*=0.37).

The ANOVA results were virtually identical for the untransformed and arcsine-transformed data (Table 3.1.3A). There was a significant block effect, meaning that there was variability among transects that was consistent across methods. There was also a significant effect of method. *A posteriori* Tukey simultaneous tests showed that the LPI method gave a significantly higher estimate of total coral cover than still photography, but that the videographic estimates were not significantly different from either the LPI or the still-photography estimates. For both the untransformed and transformed cases, Tukey comparison showed the photographic and videographic differences to be non-significant at *P*=0.39. The actual difference in mean percent-cover estimates between the LPI and photographic methods was only 4%, which cannot be considered biologically meaningful (Aronson et al. 2005; Section 3.1.3).

***Montastraea annularis* complex cover.** For the *Montastraea annularis* species complex, Anderson-Darling tests revealed the (untransformed) proportional coverage data to be normally distributed for all three methods (*P*>0.10 in all cases). Tukey comparisons on the untransformed data showed no significant pairwise differences between the videographic and photographic techniques for cover of the *Montastraea annularis* complex *P*=0.13.

***Diploria strigosa* cover.** For *Diploria strigosa* the randomized-block ANOVAs gave virtually identical results for the untransformed and transformed data: a significant block effect and no effect of method (Table 3.1.3C). The maximum difference in mean percent-cover estimates was <1%.

Considering these results, it is reasonable to switch permanently to video transects using point count analysis for future FGB monitoring. Importantly, these results show that statistical comparisons of data from previous photographic records can be made to current and future video images. Now that results have shown that still photographs and video frames along transects produced statistically indistinguishable results, we recommend the permanent move to videography as the preferred method of data collection along random transects.

As part of the monitoring protocol, the goal of the random video transects was to detect the smallest biologically meaningful changes in coral cover at the FGB. A change of 5-10% coral cover is considered biologically meaningful and is more conservative than the 10-20% change that Risk and Risk (1997) published from a poll of reef scientists. The minimum detectable difference (δ) was calculated for the two way ANOVA on proportional coral cover for the video transects for two banks during two years (2002-2003), following Zar (1984). The analysis for 14 transects each year at each bank (56) revealed δ= 0.074, which represents a detectable difference of 7.4% change in coral cover between any two years or between two banks in a two-year study. In this way, biologically significant changes within 7.4% coral cover can be detected using the video transect methodology. This level of detection is better than the 10% change which is considered biologically significant (Risk and Risk 1997). Aronson et al. (1994) calculated similar δ values (5.2-9.8%) for four sites in the Caribbean and Florida that ranged in coral cover from 3-21% coral cover. The FGB results are slightly higher than results obtained for a comparison of three sites in the Florida Keys (2.4-3.8%); however, these sites contained 30 transects per site with low coral cover, which reduced the error variance and therefore the δ value (Murdoch and Aronson 1999).

Univariate analysis of the random transect data revealed that coral cover at the East Bank and West Bank remained stable in 2002 and 2003 (Figure 3.1.4). Percent cover for the East Bank was 56.43% and 53.2% in 2002 and 2003 respectively, while the West Bank had 59.67% and 57.13% coral cover in 2002 and 2003. Percent coral cover for this time period compared with previous studies (Dokken et al. 2001, Dokken et al. 1999, CSA 1996, Gittings et al. 1992) revealed the stability over time of the coral community at the FGB (Figure 4.1.3). Coral cover varied from year to year, however over time it did not vary more than ~20% among banks or years. It is not clear what the reason for this difference is, however, if anything, coral cover may be increasing (Figure 4.1.3). The lowest coral cover recorded at the banks by random transect methods was 37.2% at the West Bank in 1992, while the highest occurred in

2001 at the East Bank (Figure 4.1.3). Additionally, the FGB continue to have high coral cover compared to other reefs of the western Atlantic (Gardner et al. 2003; Aronson et al. 1994).

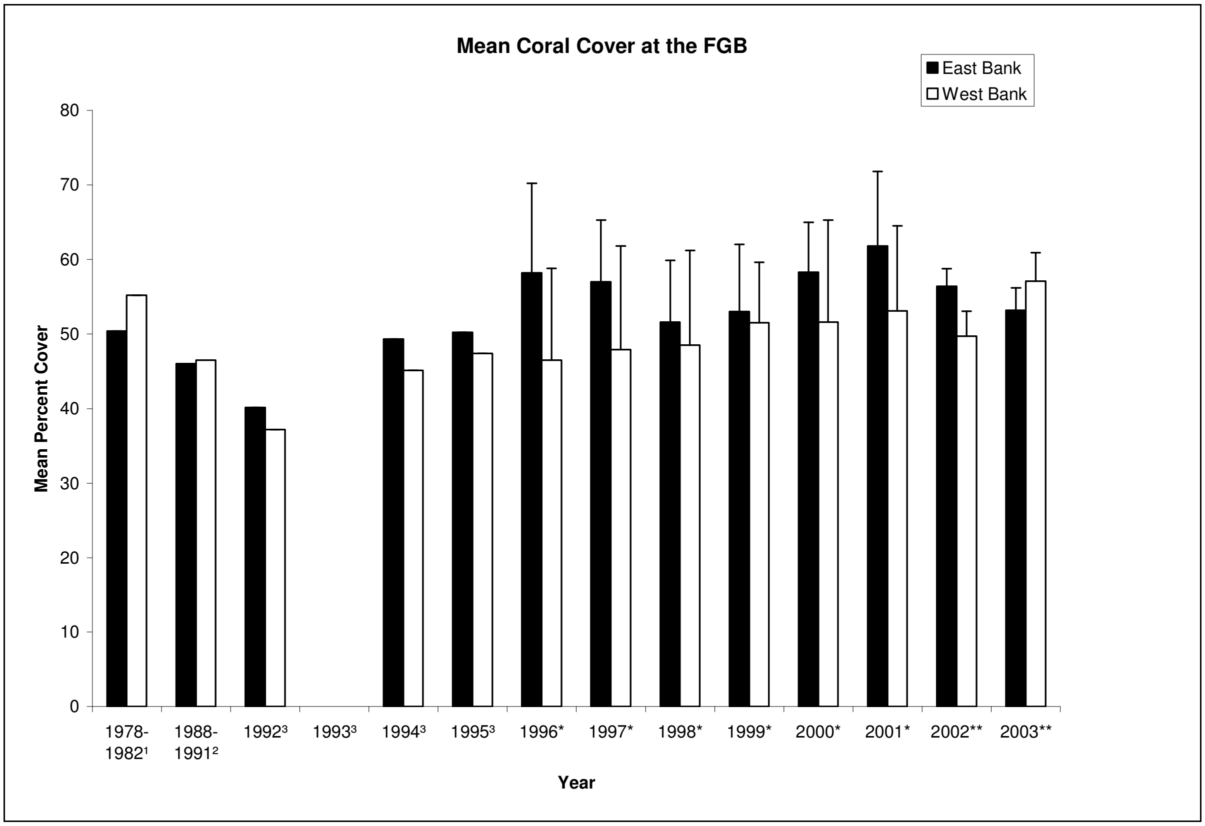


Figure 4.1.3. Mean percent coral cover at the FGB over time (± SE), showing the consistently high coral cover. In 1993 there was no percent cover data reported. Data from historical monitoring data as follows: [1]1978-82 from Gittings et al. 1992 (Monitoring report for 1989-1991) who reported data from Kraemer 1982 (Master's thesis Texas A&M). [2]1988-1991 from Gittings et al. 1992 (Monitoring report for 1989-1991). [3] 1992-1995 from MMS et al. 1996 (Monitoring report prepared by CSA 1992-1995). *1996-2001 from Dokken et al. 2003 (Monitoring report for 1998-2001). **2002-2003 from the current monitoring period, performed by PBS&J.

Macroalgae and CTB (crustose coralline algae, fine turfs, and bare rock) were inversely related for the sampling period 2002-2003. Macroalgae increased at East Bank from 2002 to 2003, while decreasing at the West Bank for the same time interval [the site X year interaction was significant (P= <0.0005)]. The CTB category was the second highest cover category after coral, connoting high rates of herbivory and an overall healthy reef system (the site X year interaction here was also significant [P= 0.023]). Crustose coralline (CC) algae, a large component of the CTB, has been shown to be a settling cue for coral spat (Morse et al. 1988). Whether or not years with higher levels of CC than macroalgae may have higher coral recruitment is a possible direction for future study.

The FGB coral reefs were distinct from other protected reefs as shown by multi-dimensional scaling (MDS) (Figure 3.1.5). Species specific random transect data was pooled and compared to three other fully protected reef zones (FPZ) within the Florida Keys National Marine Sanctuary: South Carysfort reef, Western Sambo reef, and Eastern Sambo reef. Two-dimensional MDS showed the Flower Garden East and West Bank 2002 and 2003 data grouped tightly, reflecting high coral cover and low variability in species composition, while the three Florida reefs showed lower coral cover and higher variability in coral species composition. Significantly, coral cover was eight to ten times higher at the FGB than at any of the protected reefs in Florida. This contrast in coral cover of these two protected reef areas does not reflect upon their management. Causes of coral decline such as cold water events, bleaching, and coral disease have affected the reefs of the Florida Keys at a level not seen at the FGB.

4.1.3 Sclerochronology

Coral growth rates are known to vary due to depth, salinity, temperature, and light, and relative position along the coral colony as well as genetic factors (Knutson et al. 1972; Weber and White 1977; Highsmith 1979; Hudson 1981a; Hudson et al. 1989; Smith et al. 1989). Accretionary growth rates of *Montastraea annularis* were documented over a wide geographic range of reefs throughout the Caribbean and varied from 3-12 mm/yr (Weber and White 1977). Growth rates were shown to vary with depth, with faster growth rates occurring in shallower water (Weber and White 1977). Differentiation between the three possible sibling species, *M. annularis*, *M. faveolata*, and *M. franksi* were not made at the time of these studies and thus it is not known which Hudson (1981a) reported growth rates of *M. annularis* in the Florida Keys to be 6.3 mm/yr at offshore reefs and 8.2 mm/yr at mid-reef from 1928-1978. The accretionary growth of *M. annularis* at the FGB was documented by Hudson and Robbin (1980), with estimated average annual growth rate of 8.46 mm/yr and a range of 7.15-10.58 mm/yr from 1887 to 1979. These colonies were likely *M. faveolata* and agree with more recent estimates of coral accretion measured from *M. faveolata*. Dokken et al. (2001) showed a lower growth rate for the period 1985-1999, with an average of 6.80 mm/yr at the East Bank and 5.13 mm/yr at the West Bank. The shorter sampling period was offered as an explanation for the observed differences. However, Dodge and Lang (1983) used data from Hudson and Robbin (1980) to correlate growth rates at the FGB to temperature and discharge from the Atchafalaya River. They found an overall decline in temperature and growth rates from 1950 to 1960 and variable growth values from the early 1960s to 1979, which were lower than pre-1957 rates (Dodge and Lang 1983).

For the 2003 sampling period, *M. faveolata* growth ranged from 7.7 to 10.7 mm/yr at the East Bank and 6.3 mm/yr to 8.5 mm/yr at the West Bank for the time period 1997-2003. Cores at the East Bank revealed a significantly higher growth rate on average than the West Bank (9.0 mm/yr versus 7.7 mm/yr [P=0.02]). These results differed slightly from the growth rates reported by Dokken et al (2003), who reported a wider range of growth rates at East and West banks. As mentioned earlier coral growth rates vary depending on environmental conditions. Dokken et al. (1999) took cores from the sides of *M. faveolata* colonies, rather than from the apex at the East and West Bank in 1997. These four coral cores (2 at each bank) showed lower rates of growth (2.76-6.56 mm/yr), which may be due to different environmental conditions experienced at the margins of the coral colony as opposed to the peaks of colonies. Growth rates for *M. faveolata* at the East Bank, and less so at the West Bank, continued to be in the middle to upper range of FGB growth rates as recorded by Hudson and Robbin (1980). One out of four cores at each bank showed a break in continuous accretion within the 1997-1998 growth band. This discontinuity may be a sign of stress or partial mortality which the colonies subsequently recovered from. Stress or partial mortality may have been caused by bleaching which was prevalent throughout the Caribbean region, and present at the FGB in 1997-1998 or fish biting (Dokken et al. 2001, 2003).

The current sampling protocol which calls for four cores to be taken from each bank every other year is useful for tracking the short-term growth rates (~10 years) of large *Montastraea faveolata* heads and monitoring physical changes within the cores. Long-term growth rates (10+ years) or information that might be gleaned from them are not possible to obtain using this method. Longer cores on which stable isotope analysis can be conducted, such as the ones taken by Amy Bratcher at the Texas A&M University, Department of Oceanography, will show salinity and temperature data over time. This information will be a valuable addition and reveal regional influences, such as the Mississippi river output, on water quality affecting the coral reefs at the FGB.

4.1.4 Lateral Growth

Lateral growth measurements have been used for much of the monitoring history of the FGB and results have shown lateral extension or growth of monitored margins overall, with high variability among individual colonies (Dokken et al. 2001, 2003, this study). Lateral growth measurements do not take into account the fact that individual corals may grow at different rates along different margins. While some margins may be advancing, others on the same colony may be retreating, potentially altering the overall picture of lateral change in a given colony and by extension a given bank and year. Additionally, lateral growth measurements do not take into account the height extension of *D. strigosa*, which is also an indicator of growth or recession of a colony and is not accounted for using the current methodology.

Overall *Diploria strigosa* colonies showed a 3–5% increase in colony area at both banks from 2001-2002. The 2002-2003 data set was quite different and the two banks appeared very different as well (Figure 3.3.1). The East Bank appeared to be stable, with a possible increase, but generalizations are not possible for the West Bank with a sample size of only 4. The low sample size was due in part to dark slides that were not analyzable. During the site rehabilitation sixty lateral growth stations were refurbished and/or newly established on each bank. At the East Bank 12 new stations were established and 48 old lateral growth stations were refurbished with new pins and tags, for a total of 60 lateral growth stations. At the West Bank 17 new stations were installed, while 43 old lateral growth stations were refurbished, for a total of 60 lateral growth station pins. The added stations will not compromise the integrity of the long-term dataset, as most of the existing stations are the original (pre-2002) stations. As pins are removed and degraded over time they will need to be rehabilitated periodically. *D. strigosa* colonies appeared to be stable or increasing at both banks from 2001-2003.

4.1.5 Repetitive 8 m^2 Quadrats

Study Site Quadrats. Repetitive 8 m^2 quadrats were analyzed for percent cover of benthic components, including percent coral species cover, algae, and coral health indicators (bleaching, paling, concentrated fish biting, isolated fish biting, and disease), and were compared for 2002-2003. Fifty-one photographs were analyzed in 2002 and 2003 (20 pairs at the East Bank and 31 pairs at the West Bank). Forty stations were refurbished or established on both banks during the site-rehabilitation in April 2003, with the goal of restoring the initial sample size of 40 on each bank. At the East Bank thirty-one repetitive quadrat stations were refurbished and 9 new stations were installed, for a total of 40 repetitive quadrat stations. At the West Bank thirty-six repetitive quadrat stations were replaced and 4 new stations were installed, for a total of 40 repetitive quadrat stations. The added stations will not compromise the integrity of the long-term dataset, as most of the existing stations are the original (pre-2002) stations. As pins are removed and degraded over time they will need to be rehabilitated periodically. Coral cover from the repetitive quadrats was higher than that calculated using the random transect methodology (an average of 59.62% versus 54.10%, respectively, at both banks in both years). The reasons for this difference is not clear, however, higher percent coral cover at repetitive quadrats relative to random transects was also documented in previous reports (Dokken et al. 2003). One potential reason for this difference is the placement of repetitive quadrat markers, which are placed in areas with large coral heads in a non-random fashion.

Species distribution was similar to random transect findings, with the predominant corals being *Montastraea annularis* complex, *Diploria strigosa*, and *Montastraea cavernosa*. The *M. annularis* complex had higher cover estimates at the repetitive quadrats (East Bank average from 2000-2003: 40.02% and West Bank average for same time period: 36.5%) than random transect estimates. *Porites astreoides* and *M. cavernosa* are roughly equivalent, but *M. cavernosa* is consistently higher than *P. astreoides* in repetitive quadrat estimates, which is the opposite of trends in the random transect data (Dokken et al. 2003, this study). These differences may be small and caused by an artifact of the methodologies employed.

Coral disease was absent from analyzed quadrats at both banks in both years (Table 3.4.2). This appears to signify a decrease in disease from past monitoring, when disease levels were found to be low (West Bank 2000-2001: 0.3-0.4%) (Dokken et al. 2003). This difference is likely due to the inclusion of fish biting as part of the disease estimates by past authors. Fish biting is not included in the disease section here and is instead considered separately. It should also be noted that disease identification from photographs is problematic (Zimmer pers. comm.). Paling and bleaching were extremely low at both banks, ranging from 0.5-0.61% and these values are similar to findings from previous investigators (Dokken et al. 2003). Bleaching occurred most frequently on colonies of *Millepora alcicornis* at the East Bank in 2003 (Table 3.4.3), while paling showed no pattern and occurred less frequently. Concentrated fish biting and isolated fish biting were similarly low between banks, ranging from 0.34-0.61% in both years (Table 3.4.2). It should be noted that fish biting is more prevalent at the FGB than at other coral reefs in the region (pers. Comm. G.P. Schmahl). Fish biting occurred primarily on the *M. annularis* complex, and appeared to be more common at the West Bank in both years (Table 3.4.3).

To document the dynamics of particular coral colonies at the FGB, repetitive quadrats were analyzed quantitatively using planimetry. Four to six coral colonies from frame building corals, whose margins were clearly defined were chosen for analysis. The *Montastraea annularis* species complex, the main contributor to coral cover at the FGB appeared to increase from 2001 to 2002 and from 2002 to 2003 at both banks, with no significant differences between banks (2001-2002: t=0.08, df=14, P=0.940; 2002-2003: t=1.14, df=41, P=0.260). When considered together, the East and West Banks showed a net growth of the *M. annularis* complex similar to the *Diploria strigosa* colonies documented at the lateral growth stations.

Deep Station Quadrats. At the East Bank, nine deep stations (32-40 m) were established in April 2003 and eight of them were photographed in August 2003. While temporal comparisons will only be possible beginning with our next report, initial analysis showed high coral cover (76.5%) at these deeper sites. This area is dominated by *Montastraea annularis* complex and *M. cavernosa,* unlike the shallower one hectare survey sites, and unlike the deeper *Stephanocoenia-Millepora* zone (36-48 m) described by Rezak et al. (1985). This sample size of 72 m^2 is small, and the difference between this area and the one described by Rezak et al. (1985) is probably due to small-scale spatial variability and/or a small sample size.

4.1.6 Perimeter Videography

Videography of the perimeter lines and 360° panoramic views of the corner markers at the East and West Banks provided a general overview of coral condition and fish populations at the study sites in 2002 and 2003. Similar to the findings from the random transects, coral condition was very good at both banks for both years. There were no signs of disease and only a few isolated incidences of bleaching. The main impact to coral colonies, observed at both banks during the sampling period, was concentrated fish biting most likely caused by individuals from the genus *Sparisoma* (Bruckner and Bruckner 2000). Initial and terminal phase *Sparisoma viride* are known to remove coral polyps in their foraging, creating deep lesions on coral heads (Bruckner and Bruckner 2000). When *Sparisoma viride* were removed from affected areas, lesions healed completely or ceased to increase in size (Bruckner and Bruckner 2000). The next largest contributor to adverse effects on corals was isolated fish biting, which was most likely caused by damselfish territories.

Fish populations were similar at both banks during both years (Table 3.5.2). Fish were more abundant at the East Bank in both years. In 2003, the East Bank had the most fish with over 900 individuals documented. Species recorded in the 360° panoramic views were largely represented by demersal species, including Creole wrasse, Creole fish, brown and blue chromis. Due to the angle of the video camera, species recorded along the perimeter lines included these species as well as damselfish. For this reason, fish cylinders are more representative of actual fish populations at the Banks, although uncommon species such as grouper were documented in the video. Slower videographic surveys may reveal a more representative distribution of fish species at the FGB for a permanent visual record. Additionally, it is not possible to ascertain fish sizes with this surveying technique because there is no scale reference.

It is important to note that a number of human errors may have influenced the data. First, while the perimeter lines at both banks were generally in the same location, there was a 1 to 2 m difference from 2002 to 2003 between the successive locations of the perimeter lines; this difference decreased as the diver approached the perimeter corner marker. As a result, it was not always possible to compare the same colonies from year to year because the video footage did not overlap. Similarly, the 2m height above the substratum was not always maintained, which changed the view and therefore the corals analyzed.

4.1.7 Disease and Bleaching at the FGB

Beginning in the 1970s and continuing through today, diseases and disease-like syndromes have appeared in many coral species throughout coral reefs worldwide. Within the Caribbean and Western Atlantic there has been a higher prevalence of disease (82% of corals species susceptible to disease) as compared to the Pacific (25% of Indo-Pacific corals) (Wilkinson 2002). Previous annual monitoring reports at the FGB (Gittings et al. 1992; CSA 1996; Dokken et al. 1999, 2001, 2003) have documented the presence of coral diseases at the FGB, with a low prevalence in comparison to other reefs throughout the region. However, only one survey has been published that documented white plague, with a low prevalence of 0.08% (Borneman and Wellington 2005). It is important to note that substantial questions relating to the characterization of many coral diseases remain unanswered (e.g., identification of pathogens, modes of transmission, pathogenic mechanisms, etc.). Environmental stressors such as pollution, nutrient loading, African dust, and elevated temperature have been associated with disease outbreaks, yet no causal connections have been firmly established (Bruno et al. 2003; Richardson 1998).

While coral cover in the FGB has remained essentially unchanged since monitoring began, the short- and long-term impacts of coral diseases on populations remain difficult to assess. Disease-like syndromes were observed during the 2002 and 2003 monitoring cruises (Appendix 7). Specifically, plague-like signs were observed on a number of coral species including the *Montastraea annularis* species complex, *Montastraea cavernosa, Colpophyllia natans*, *Diploria strigosa*, and *Siderastrea siderea*

In addition to disease, widespread coral bleaching in response to anomalously high summer-season temperatures has become more frequent since the 1980s throughout the region and the association of thermal stress with coral disease is of particular concern. At the FGB, the only major bleaching episode reported was in 1997-1998, with minor bleaching having occurred in 1990, 1992, 1994, and 1995. These episodes were followed by recovery (Gittings et al. 1992; Hagman and Gittings 1992; CSA 1996; Dokken et al. 1999, 2001). Bleaching episodes on reefs in the western Atlantic-Caribbean region have also generally been followed by recovery, with partial or whole mortality events affecting populations locally (Aronson and Precht 2000).

Disease monitoring and assessment methods have been developed by a number of scientists working in the Caribbean and on coral reefs throughout the world (Porter et al. 2001; Santavy et al. 2001). In general, disease research has focused on areas with high disease prevalence, such as the Florida Keys (Richardson et al. 1998). Methods for monitoring coral diseases in these areas has consisted of a combination of sampling techniques, including belt transects and radial arc transects, as well as tissue sampling for pathogen identification (Porter et al. 2001; Santavy et al. 2001). At the FGB disease prevalence is low, none was recorded in transects or repetitive quadrat stations in 2002 and 2003. Diseased corals were photographed in 2002 and 2003, but these were found in systematic swims that were looking for corals exhibiting disease by a trained diver (Appendix 7).

Developing a monitoring protocol for coral disease is important to managers at the FGB in light of disease rates within the Caribbean region. To properly design a protocol, a pilot study should be conducted and a power analysis done to calculate the minimum detectable differences (δ). Because the average coral colony size at the FGB is large, 86.9 cm in diameter (Borneman & Wellington 2005), 100 x 1 m random belt transects should be conducted to maximize the number of coral colonies surveyed ($n = 1$). A minimum of 10 transects should be evaluated, five at both the East and West FGB. Within each transect, discrete coral colony counts by species should be recorded. In addition, old and new mortality should be noted for each discrete colony and the source of mortality, if distinguishable, should be categorized (i.e., disease, bleaching, paling, and fish biting - spot/concentrated parrotfish biting and damselfish biting). A minimum of two sampling events should be conducted, likely in the spring and summer. Those colonies within the transect exhibiting disease signs should be photographed. Once the pilot study is completed a monitoring protocol can be implemented to monitor for disease at the FGB. It should be noted that if disease prevalence were higher, disease would be evident in random transects, currently used to record coral cover and other parameters.

4.1.8 Other Coral Mortality Factors at the FGB

Other causes of coral mortality in the FGB include predation by mobile fauna, inter- and intraspecific aggression by coral species, toppling of colonies due to bioerosion, concentrated fish biting, the impacts of damselfish territories, resulting in patchy areas of coral mortality and algal growth on affected colonies. Concentrated fish biting possibly due to the abundance of *Sparisoma* spp., which are responsible for concentrated scrape marks on corals elsewhere (Bruckner and Bruckner 2000) has been shown in earlier monitoring photographs (Dokken et al. 2003) but has not been specifically studied at the FGB and should be investigated to better understand the phenomenon and its impact on the reefs. Although numerous sources of mortality are present, coral growth and recruitment appear to be in balance with coral loss, as coral cover continues to be consistently high. Photographs of all types of coral mortality described are shown in Appendix 7.

4.2 WATER QUALITY PARAMETERS

Water quality parameters acquired in this study at the FGB (October 2002 to March 2004) included temperature, turbidity, photosynthetically active radiation (PAR), salinity, dissolved oxygen, pH, nutrients, and trace metals. Water color and circulation were not part of the scope of work and are not discussed here. The accuracy of the water quality reported here depended largely on the performance of the instruments used to measure water quality, and in particular the YSI sondes deployed on the FGB reef cap. The YSI datasondes deployed at the FGB failed post-deployment calibration after each of the deployment periods. Since the sensors were not recording valid measurements at the end of their deployment period, there are large amounts of invalid data within each of the datasets. To assess the validity of the data collected here and perhaps identify valid outliers, we compared replicate data when they existed, and compared the collected data with independent reference data.

4.2.1 Physical Parameters

Temperature. To evaluate our 2003 and 2004 seawater temperature data, we compared concurrent (i.e., gathered on the same date) YSI and HoboTemp data, and then compared these data with the 1990-1997 mean temperature gathered on the reef caps at the East Bank and West Bank (Gittings et al. 1992; Lugo-Fernández 1998). Mean seawater temperature collected by HoboTemp from 1999-2001 (Dokken et al. 2003) do not deviate from the data collected between 1990 and 1997. The reef cap temperature data were also compared with sea surface temperature collected during 2002, 2003, and 2004 at 0.6 m below mean sea level on the buoy station 42019, located 152 km west of the West Bank (27°54'47"N 95°21'36"W) and moored in 82 m of water (National Data Buoy Center 2004). Finally, we compared reef cap temperature between banks. A summary of the data used in this analysis is presented in Tables 4.2.2.A and 4.2.2.B. The YSI and HoboTemp temperature data collected in 2003 covered the broadest calendar range (Table 4.2.1). At the East Bank, YSI temperature ranged from 18.9 to 28.5 °C and at the West Bank from 19.2 to 29.9 °C (Table 4.2.2.-A,B). The HoboTemp temperature ranged at the East Bank from 19.3 to 30.0 °C, and at the West Bank from 19.4 to 29.9 °C (Table 4.2.2.-B). In 2003, sea surface temperature varied from 18.8 to 30.3 °C (Table 4.2.2.-C). Minimum reef cap temperature (~19 °C) occurred in mid- and late February and lasted less than a week. At the sea surface, water temperature minima (16-19 °C) occurred early in the year (mid-January, early February) but were scattered amongst winter temperatures ranging from ~19-20 °C from late December to mid-March. From the available reef cap temperature records, seawater temperature maxima (~ 30 °C) occurred in late August and so did the sea surface maxima (~ 30 °C). Considering the sea surface temperature record at buoy station 42019 and the absence of extensive coral bleaching on the FGB, we suspect that temperature on the reef cap remained at or above 30 °C during a few days at the most. Bleaching of corals is known to occur at the FGB when sea water temperature exceeds 30 °C for more than seven continuous days (Hagman and Gittings 1992).

Table 4.2.1.

Calendar dates of reef cap (YSI and HoboTemp) and sea surface (Buoy station 42019; National Data Buoy Center 2004) temperature data used in this study from 2002 to 2004.

Year	East Bank YSI	East Bank Hobo	West Bank YSI	West Bank Hobo	Buoy Station
2002	Oct 29-Dec 31	Oct 29-Dec 31	Oct 30-Dec 31	NA	Jan-Dec
2003	Jan-Mar 26 Aug 26-Nov 3	Jan-Dec	Jan-May 16 Aug 28-Dec 31	Feb 1-Dec	Jan-Dec
2004	NA	Jan-Mar 11	Jan-Mar 11	Jan-Mar 11	Jan-Mar 31

Table 4.2.2-A.

Reef cap seawater temperature statistics at the East Bank: 1990 to 1997 (Gittings et al. 1992; Lugo-Fernández 1998); YSI temperature probes in 2002 and 2003; and HoboTemp probes in 2002, 2003, and 2004.

East Bank	Mean '90-'97	Minimum '90-'97	Maximum '90-'97	YSI '02	YSI '03	Hobo '02	Hobo '03	Hobo '04
Minimum	19.60	18.46	19.60	21.49	18.94	20.57	19.30	19.91
Maximum	29.77	29.40	30.24	31.18	28.51	26.83	29.97	21.81
Mean	24.65	23.89	25.43	24.95	23.09	23.90	23.40	21.00
SE	0.17	0.17	0.16	0.18	0.28	0.23	0.21	0.06
N	366	366	366	64	155	64	262	71

Table 4.2.2-B.

Reef cap seawater temperature statistics at the West Bank : 1990 to 1997 (Gittings et al. 1992; Lugo-Fernández 1998); YSI temperature probes in 2002, 2003, and 2004; and HoboTemp probes in 2003 and 2004.

West Bank	Mean '90-'97	Minimum '90-'97	Maximum '90-'97	YSI '02	YSI '03	YSI '04	Hobo '03	Hobo '04
Minimum	20.10	17.76	20.79	22.33	19.24	19.56	19.35	19.34
Maximum	29.17	28.92	30.06	27.05	29.94	22.48	29.86	22.23
Mean	24.31	23.35	25.37	24.82	23.73	21.09	24.44	20.87
SE	0.16	0.17	0.16	0.15	0.20	0.09	0.18	0.09
N	366	366	366	63	261	71	334	71

Table 4.2.2-C.

Sea surface temperature statistics at the Buoy station 42019 (located 152 km west of the FGB) for 2002, 2003, and 2004 (National Data Buoy Center 2004).

Buoy Station 42019	'02	'03	'04
Minimum	17.45	18.75	16.18
Maximum	30.47	30.34	22.41
Mean	24.76	24.79	19.82
SE	0.19	0.20	0.15
n	349	365	91

Comparing concurrent YSI and HoboTemp temperature data, we found that at the East Bank temperature recordings (arcsine-transformed data) were significantly different between gauges in 2002 (two-tailed paired-sample t-test; t=5.24; df=63, P>0.05;) and 2003 (t=10.93; df=154, P>0.05;). The East Bank YSI sonde probably incurred recording errors during 2002 considering the anomalous temperature recorded in December compared with the HoboTemp records of 2002 and the 1990-1997 maximum temperature record (Figure 4.2.1). The 2003 YSI data also appeared to be unusually low particularly during the second deployment (Figure 4.2.1).

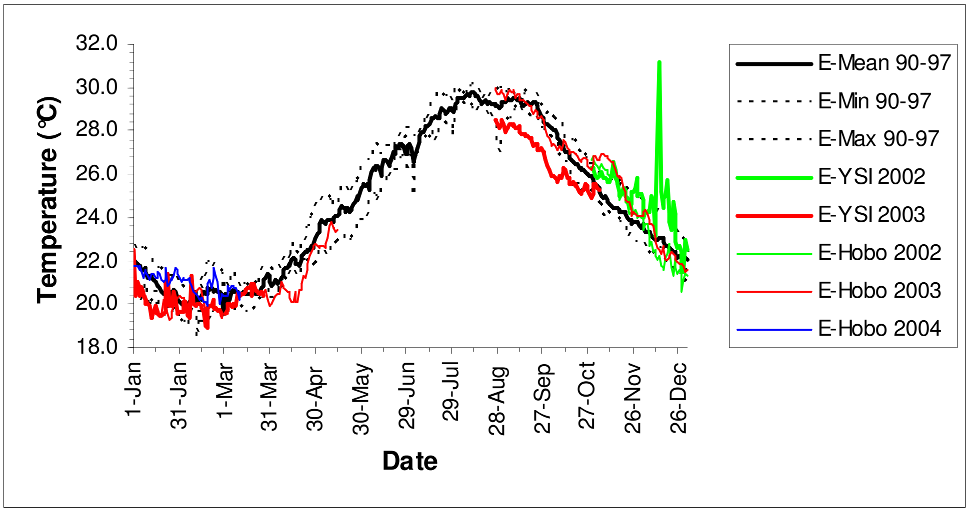


Figure 4.2.1. Reef cap seawater temperature recorded at the East Bank from 1990-1997 (Gittings et al. 1992; Lugo-Fernández 1998), and during this study in 2002, 2003 and 2004.

At the West Bank, there were no 2002 HoboTemp temperature records to compare with the YSI data. The YSI and HoboTemp data (arc sine-transformed data) at the West Bank did not differ in 2003 (t=1.04; df=229; P<0.20;) but did differ significantly in 2004 (t=12.17; df=70; P>0.05;). The 2002 YSI temperature records at the West Bank included anomalously high values in December, somewhat comparable to what was observed at the East Bank (Figures 4.2.1 and 4.2.2). Since the East Bank and West Bank YSI sondes sampled temperature independently, there is a possibility that a temperature anomaly might have occurred in December on the FGB reef cap. During 2003, temperature data exhibited some unusual values both for the YSI and HoboTemp gauges: the YSI January data seem to be anomalously high compared with 1990-1997 values and the June HoboTemp data exhibited a sharp drop in temperature (~ 4 ℃) followed by a gradual seasonal warming (Figure 4.2.2). These unusual temperature values could not be compared between gauges since there were no concurrent data. The 2004 data, even though different between gauges, were within the 1990-1997 temperature range.

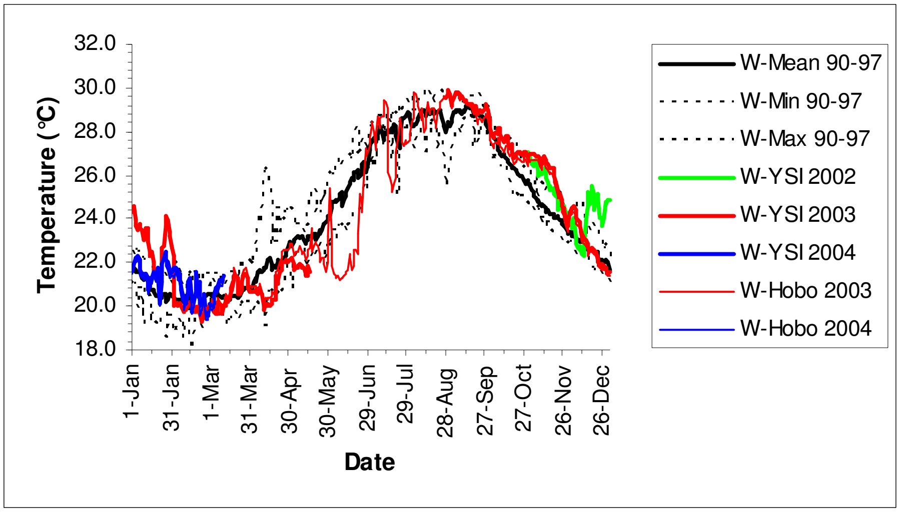


Figure 4.2.2. Reef cap seawater temperature recorded at the West Bank from 1990-1997 (Gittings et al. 1992; Lugo-Fernández 1998), and during this study in 2002, 2003 and 2004.

Overall, the YSI temperature data sets included probable errors and suspicious data. The HoboTemp probes seem to have recorded more accurate data, since HoboTemp data agreed with past observations. Further, previous reliable temperature records reported from the FGB were partially based on the use of HoboTemp gauges (Gittings et al. 1992; Lugo-Fernández 1998). Therefore, HoboTemp 2002-2004 records are used to further discuss seawater temperature variation at the FGB during this study.

Concurrent sea surface (buoy station 42019; National Data Buoy Center 2004) and reef cap temperatures (HoboTemp) were significantly different from each other on both banks (arc sine transformed data, two-tailed paired-sample t tests; P>0.05). Further, we observed predictable seasonal heat-budget patterns (Pickard and Emery 1982) of rapid warming and cooling of sea surface temperature coinciding with gradual warming and cooling, respectively, at a deeper depth (i.e., reef cap). From January through March, seawater temperature was significantly greater on the reef cap than it was at the sea surface (arc sine transformed data; one-tailed t-test; P>0.05). From April through August, the sea surface temperature was greater than on the reef cap (arc sine transformed data; one-tailed t-test; P> 0.05). From September through December, the reef cap temperature was greater than at the sea surface (arc sine transformed data; one-tailed t test; P>0.05) (Figures 4.2.3 and 4.2.4).

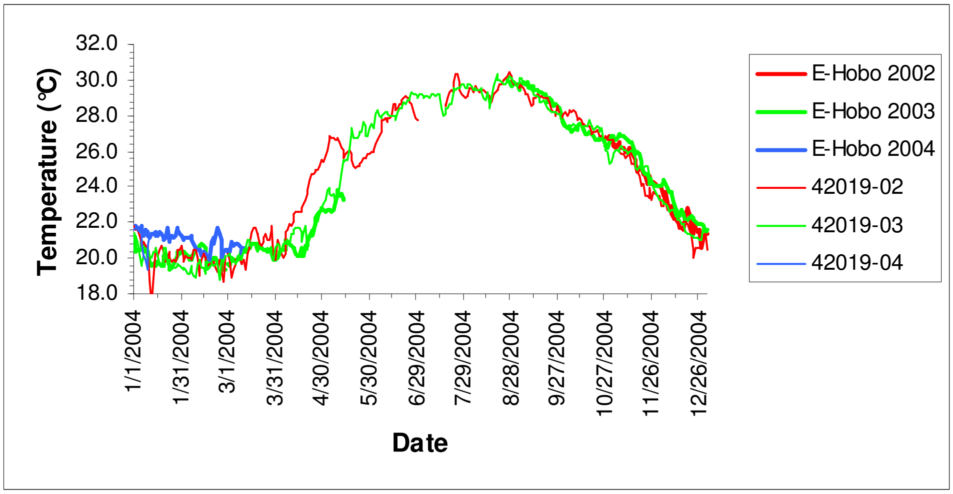


Figure 4.2.3. Sea surface temperature at Buoy station 42019 (National Data Buoy Center 2004) and East Bank reef cap temperature (HoboTemp) in 2002, 2003, and 2004.

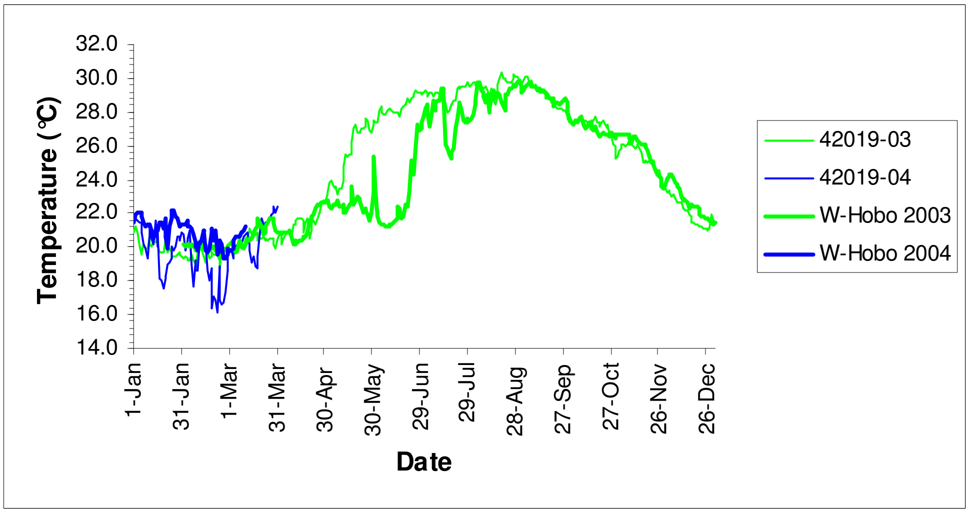


Figure 4.2.4. Sea surface temperature at Buoy station 42019 (National Data Buoy Center 2004) and West Bank reef cap temperature (HoboTemp) in 2003 and 2004.

Turbidity. As defined in Telesnicki and Goldberg (1995), turbidity here refers to "the decrease in water clarity due to particles in suspension." Turbidity on the reef cap measured by the YSI sensors recorded mean values of 11 NTU (± 1 SE; n=218) at the East Bank and 7 NTU (± 0.2 SE; n=290) at the West Bank during 2002 and 2003. YSI instruments placed on sand flats and not on the reefs themselves may have recorded the resuspension of sediments in the sand flats in addition to other sources of turbidity. Turbidity values obtained in this study are roughly 10 times greater than those reported by Dokken et al. (2003) at the FGB using the same YSI instruments. In both studies, however, turbidity followed similar trends: a steady turbidity level interrupted by brief increases.

Relatively high turbidity took place in February, September, and October 2003 at the East Bank (2/8-2/12/03: 12-31 NTU; 9/16-10/3/03: 2-63 NTU; 10/10-10/28/03: 18-79 NTU), and in November 2002, December 2002, and January 2003 at the West Bank (11/24-12/10/02: 8-40 NTU; 1/24-1/26/03: 18-24

NTU). The timing of each of the high turbidity events appears to coincide with increased significant wave height as measured at the buoy station 42019 (Figure 4.2.5).

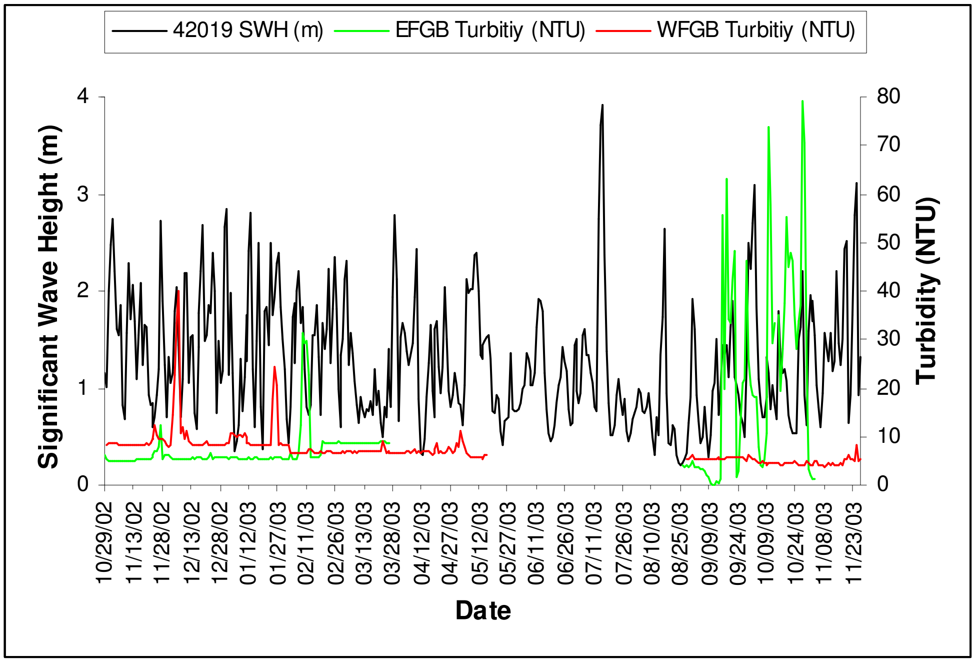


Figure 4.2.5. Comparison of significant wave height at buoy station 42019 (National Data Buoy Center 2004) and turbidity measured on the reef cap at the East Bank and West Bank in 2002 and 2003.

Average turbidity values found at the FGB (< 11 NTU) correspond to turbidity levels that do not affect the photosynthesis and respiration of corals (Telesnicki and Goldberg 1995). However, the elevated turbidity recorded in this study (24-79 NTU) possibly caused brief episodes of stress during which corals increased their respiration rates (but no decrease in photosynthesis), possibly maintained expanded polyps as long as the water remained turbid, and possibly increased the mucus secretion to remove fine particles from the surface of the colony (Telesnicki and Goldberg 1995). Given that the turbidity events were brief, the heightened mucus production was temporary and probably did not affect the overall energy budget of individual colonies. Should high turbidity events last more than three weeks, the photosynthesis to respiration ratio (P:R ratio) of coral colonies could remain less than 1 for that prolonged period and cause stress since more carbon would be consumed than fixed (Telesnicki and Goldberg 1995). Further, prolonged turbidity would cause the prolonged increased production of mucus which would also stress the corals (Sorokin 1995) and make them more vulnerable to diseases (Bruckner 2002).

In addition to the high turbidity events recorded here, others may coincide with recurrent episodes of light attenuation and low salinity (April through September), when nearshore LATEX waters are transported over the shelf edge (Deslarzes and Lugo-Fernández in press). Corals may be affected during their exposure to the nearshore water reaching the FGB, should the freshwater be associated with increased sedimentation, increased turbidity, nutrients, pollutants, and pathogens originating from nearshore processes and the terrigenous runoff of the Mississippi and Atchafalaya Rivers and Texas regional rivers (Coles and Jokiel 1992; Richmond 1994; Veron 1995; Kleypas 1996; Peters et al. 1997; Kleypas et al. 1999a; Lipp et al. 2002; Bruckner 2002; Szmant 2002; McCulloch et al. 2003; Wolanski et al. 2003).

Turbidity can also be inferred from light attenuation as calculated using Beer's Law, $I_z = I_0 e^{-kz}$, where I_0 is the radiation intensity above the sea surface, I_z is the radiation intensity measured on the reef, z is the depth at which the radiance is measured on the reef, and k is vertical light attenuation coefficient. While we had access to radiation intensity on the reef measured as PAR, we did not have the incident radiation intensity at the sea surface, and thus could not assess the variation of light attenuation. Having both turbidity measurements and light attenuation would have enabled us to verify the frequency and intensity of turbidity on the reef cap.

PAR. The PAR records obtained during this study on the reef cap at the East and West Banks (Figure 3.6.1-E and 3.6.2-F, respectively) were similar to what Dokken et al. (2003) found at the West Bank during the same months of the year (October 2000-September 2001): a gradual decline in average daily PAR from summer to winter, a minimum PAR in December, and a gradual increase in PAR to reach high values in August. These PAR trends are expected seasonal changes due mostly to the varying azimuth of the sun. It should be noted that the summer PAR values of ~80 µmol/m^2/sec we recorded at the West Bank were attained in March at the East Bank. Yet in March, the YSI instrument recorded PAR levels of less than 25 µmol/m^2/sec at the West Bank. The difference in PAR values between banks, assuming that they are accurate measurements, could be caused by the different water depth between banks (YSI sensor was in a 23 m water depth at the East Bank and 27 m at the West Bank) and the varying influence of the upwelling irradiance caused by the reflection of downwelling light by sand flats on which the sondes were deployed (Falkowski et al. 1990).

In addition to PAR (visible light, 400-700 nm), the reef cap on the FGB (down to at least a 20 m water depth) can at times receive ultraviolet (UV) radiation from the sun, particularly when the seas are calm and skies are clear of cloud cover (Warner et al. 1999; Falkowski et al. 1990; Gleason and Wellington 1993). UV radiation is known to contribute to coral bleaching in conjunction with high water temperatures (Shick et al. 2005, Glynn et al. 1993, D'Croz and Mate 2000). By producing reactive oxygen species (ROS) within organismal tissue UV exposure can lead to widespread cellular damage (Kohen et al. 2000). For example, UV radiation is known to cause decreased levels of larval survivorship in coral and fishes (Wellington and Fitt 2003, Lesser et al. 2001). For these reasons, considering the effects of UV radiation, particulary at times of high irradiance (summer), is important to the FGB coral reef community.

During the course of this study, episodes of elevated PAR, and possibly UV radiation, reached the reef when significant wave height was relatively low and steady. Comparing PAR results and significant wave height at the buoy station 42019 (Figure 4.2.6), PAR peaked in March 2002 and in August/September 2003 when sea conditions were relatively calm compared to the rest of the year. The October 2002 peak did not necessarily co-occur with calm sea conditions. Reviewing the significant wave height record, the reef cap (down to 20 m) received the highest amount of UV radiation in March 2003 and July/August 2003 (Figure 4.2.6). Although bleaching at the monitoring sites in 2002-2004 was low, the possibility of the combined effects of UV and elevated sea surface temperatures contributing to bleaching in the future at the FGB should not be ignored. Bleaching has been observed in the past at the FGB (Hagman and Gittings 1992) and the causes for this bleaching may not have solely resulted from unusually prolonged events of high water temperature, but could also have been due to UV radiation affecting corals.

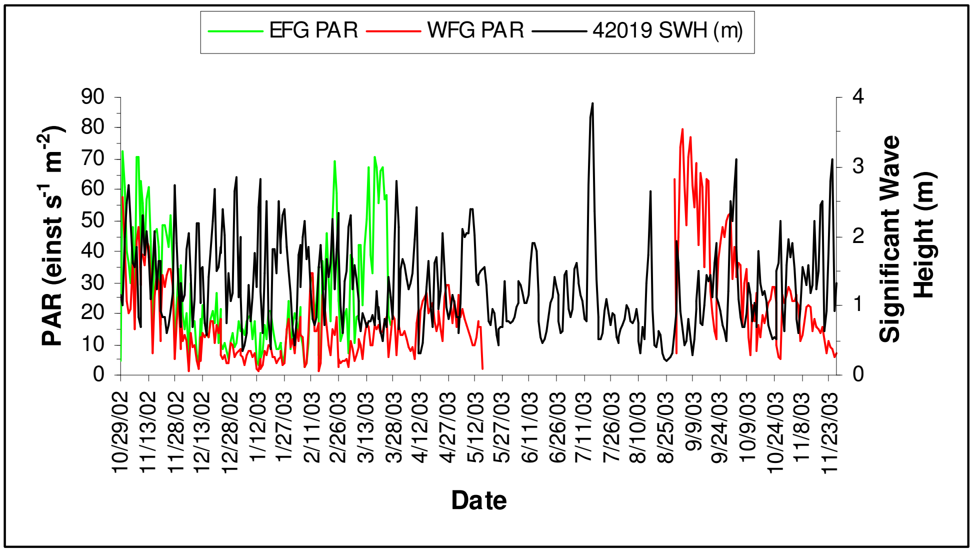


Figure 4.2.6. Comparison of significant wave height at buoy station 42019 (National Data Buoy Center 2004) and PAR levels measured on the reef cap at the East Bank and West Bank in 2002 and 2003.

Sea State. During the course of this study, heavy sea conditions, tropical depressions, and hurricanes occurred at the FGB. Hurricane season in 2002 and 2003 was fairly active in the Atlantic tropical cyclone basin compared with historical data. In the past, close to four tropical cyclones affected the Gulf of Mexico in one year (MMS 1988). In 2002 and 2003, six tropical cyclones either entered or were formed in the Gulf of Mexico. During each of those years, two of the cyclones developed into hurricanes (Weatherunderground 2004). In 2002, the eyes of Hurricane Isidore (Category 3, September 14-16, 125 mph winds) and Hurricane Lili (Category 4, September 21-October 4, 145 mph winds) passed within 250 km east of the FGB. In 2003, Hurricane Claudette (Category 1, July 8-16, 80 mph) passed over the FGB and the eye of Hurricane Erika (Category 1, August 14-17, 70 mph winds) passed within 100 km of the FGB. The tropical storms in the Gulf of Mexico during 2002 and 2003 passed within 100-700 km of the FGB (Table 4.2.3). The comparison of the record of weather extremes for 2002-2003 in the Gulf of Mexico and the significant wave height at buoy station 42019 (Figure 4.2.7) shows (1) that a Category 4 hurricane passing 250 km east of the FGB will have a regional impact on the sea state, i.e., 4 m significant wave height at buoy station 42019 and possibly the FGB; (2) that a Category 1 hurricane (Hurricane Claudette) passing over the FGB will produce a significant wave height of 4 m; and (3) that tropical storms may cause brief and significant increases in significant wave height.

Table 4.2.3.

List of tropical storms that occurred in the Gulf of Mexico region in 2002 and 2003.

Name	Date	Wind Speed (mph)	Trajectory
Tropical Storm Bertha	8/4-9/2002	40	Passed ~ 250 km north of the FGB
Tropical Storm Edouard	9/1-6/2002	65	Stopped more than 500 km east of the FGB
Tropical Storm Fay	9/5-7/2002	60	Passed within 100 km west of the FGB
Tropical Storm Hanna	9/12-14/2002	50	Passed more than 400 km east of the FGB
Tropical Storm Bill	6/29-7/1/2003	60	Passed within 200 km east of the FGB
Tropical Storm Grace	8/30-31/2003	40	Passed within 100 km of the FGB
Tropical Storm Henri	9/3-8/2003	50	Passed 700 km to the east of the FGB
Tropical Storm Larry	10/2-6/2003	60	Took place in the southern GOMEX

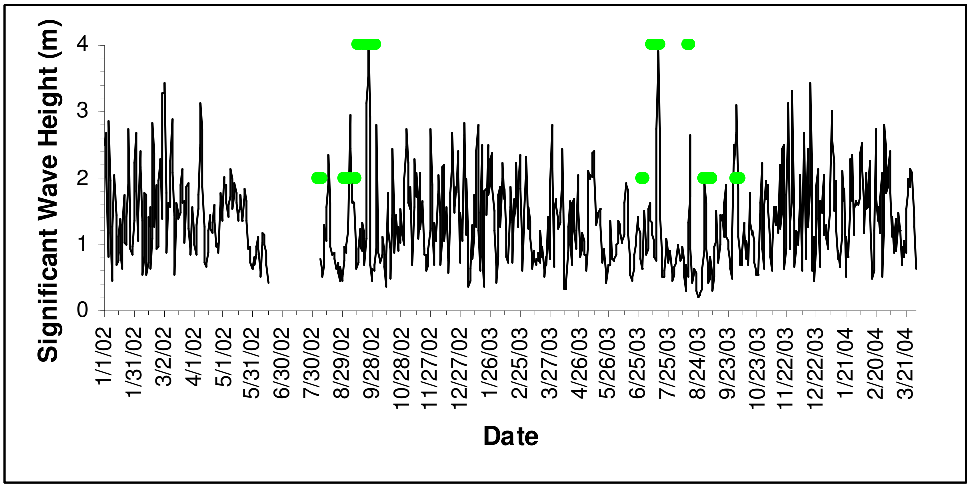


Figure 4.2.7. Significant wave height at the buoy station 42019 (National Data Buoy Center 2004) and incidences of tropical storms (green-filled circles, significant wave height = 2 m) and hurricanes (green-filled circles, significant wave height = 4 m) (Weather Underground 2004).

4.2.2. Biological Parameters

Chlorophyll *a*. Spot checks of chlorophyll *a* concentrations were conducted during the course of the study. The majority of the water samples contained chlorophyll *a* levels below detection limits (1 mg/m^3). On three occasions, however, we found chlorophyll *a* levels of 1.07 mg/m^3, on the East Bank reef cap on February 18 and May 16, 2003 and at the West Bank sea surface on May 16 2003. Nowlin et al. (1998) found comparable amounts of chlorophyll *a* on the shelf edge at the sea surface in spring and summer (≤0.8 mg/m^3 and ≤ 1.0 mg/m^3, respectively). Since most of the water samples we gathered contained less than 1 mg/m^3 of chlorophyll *a* and since the predicted concentration of chlorophyll *a* at the NWGOM shelf edge is 0.1-0.3 mg/m^3 (Nowlin et al. 1998), more useful information would be obtained by using an analytical method with a lower detection limit. Further, to have a better understanding of the variability of chlorophyll *a* concentrations at the FGB, more samples need to be gathered within each of the seasons. Lowest chlorophyll *a* values may occur in the fall and winter (≤ 0.4 mg/m3), and higher levels in spring and summer (≤ 1.0 mg/m^3). Samples acquired during this study do not suggest any seasonal trends.

4.2.3 Chemical Parameters

Naturally-occurring physical-environmental factors that influence the distribution of coral reefs include temperature, salinity, nutrients, light availability, and hydrodynamic conditions (including circulation, sea state, extreme events) (Kleypas et al. 1999a). Coral reefs as marine ecosystems in which "a prominent ecological functional role is played by scleractinian corals" (McManus 2001) or "normal" coral reefs as biogenic "production-dominated reefs" (Kleypas et al. 2001) occur at the FGB (Rezak et al. 1985). Coral reefs survive within the following environmental extremes: a temperature range of 16 to 34.4 °C, a salinity range of 23.3 to 41.8 PSU, a nitrate concentration range of 0.00 to 3.34 µmol/l, a phosphate concentration range of 0.00 to 0.54 µmol/l, and a maximum light penetration range of 7 to 91 m (Kleypas et al. 1999a). Hydrographic conditions and nutrient concentrations found in this and previous studies show that coral reefs exist at the FGB because of favorable physical-environmental parameters and because they do not exist in marginal conditions *sensu* Kleypas et al. (1999a). Light availability is the most ecologically significant latitude-correlated physical-environmental parameter limiting the occurrence of coral reefs (Veron 1995). Light levels at the FGB are obviously supporting a productive coral-zooxanthellae symbiosis and substantial coral growth and accretion (Barnes and Chalker 1990).

Salinity. Very few salinity data points were obtained during this study in large part due to the poor performance of the YSI probe. The few data that were reported here were within the known salinity range for the FGB region (~33-36.5 ppt; Nowlin et al. 1998). Salinity results from the West Bank from February to May 2003 include data points that appear to be unusually high (> 36.5 ppt).

Salinity variation at the FGB is probably of high importance since recurrent low salinity events are known to occur along the Northwestern Gulf of Mexico shelf edge (Nowlin et al. 1998). Since the low salinity water occurring at the shelf edge probably originates from the nearshore and may be associated with riverborne materials (including contaminants), it is essential to improve the monitoring of salinity to capture in detail the intensity, frequency, and duration of low salinity events. Critical salinity data logging months span from April to June (Nowlin et al. 1998).

Dissolved Oxygen. The few dissolved oxygen (DO) data we collected on the East Bank reef cap (6.64 mg/l ± 0.05 SE; Figures 3.6.1-C and 3.6.1.-D) were, for the most part, within the range of concentrations observed by Gittings et al. (1992) and Nowlin et al. (1998). The DO range of 0.78-5.81 mg/l found at the West Bank, however, was probably based on erroneous data. More reliable DO probes are needed to accurately monitor DO levels on the FGB. Further, it would be preferable to place the DO probe on the reef cap itself considering that the productivity of microorganisms and algae in the FGB sand flats on which the YSI sonde are installed is greater than that of the sessile organisms on the reef (Gregory S. Boland unpublished data).

pH. A mean pH of 8.24 (± 0.01 SE) collected at the West Bank is probably accurate and representative of the NWGOM outer shelf. Seawater acts as a buffering solution that resists changes in pH and seawater pH generally ranges from 7.5 to 8.4 (Sverdrup et al. 1970). The pH at the FGB may decrease in the future as a result of increased atmospheric carbon dioxide (Kleypas et al. 1999b; Anderson et al. 2003). Such pH changes are predicted for shallow ocean environments. As pH decreases, so will the concentration of the carbonate ion concentration and the calcification of corals and algae (Kleypas et al. 1999b).

Nutrients. Nutrient monitoring at the FGB revealed the presence of minute amounts of dissolved inorganic nitrogen (Table 3.6.4). No detectable levels of inorganic phosphorous (soluble reactive phosphorous), which is characteristic for western Atlantic reefs (D'Elia and Wiebe 1990), and above detection limit levels of dissolved organic nitrogen (Table 3.6.4). Because these data are from spot checks, they offer very limited information on the variability of inorganic and organic nutrient levels in the water column at the FGB. It is worth noting, however, that water samples taken on May 16, 2003, could have originated from the Northwestern Gulf of Mexico nearshore environment since previous salinity records show the recurrence of low salinity water at the Northwestern Gulf of Mexico shelf edge from April to June (Nowlin et al. 1998). Yet, none of the May 2003 samples contained detectable inorganic or organic nutrients (Table 3.6.4). In fact, the most commonly detected nutrient, dissolved organic nitrogen

(TKN), was found in most samples but not in any of the May 2003 samples. Further, all samples other than those of May 2003 were acquired outside the April-June time frame. It is quite possible that the dissolved inorganic nutrients that are contained in nearshore waters are not quantifiable at the FGB because they are incorporated by organisms soon after their release into the nearshore environment. Further, the extensive assessment of nutrient concentrations in the Northwestern Gulf of Mexico by Nowlin et al. (1998) shows low levels of nitrate, phosphate, and silicate on the outer shelf. Sources of nutrients to the FGB coral reefs probably include those advected from nearshore sources (including terrigenous runoff), but are more likely to be from nutrient reserves accumulated in sediments (Entsch et al. 1983), from benthic organisms, and planktonic organisms (D'Elia and Wiebe 1990; Sorokin 1995). As mentioned earlier, anthropogenic sources may include the cumulative regional discharge of sewage from oil and gas related operations (vessels and platforms) in the Northwestern Gulf of Mexico and from other vessels moored at and transiting through the FGB.

The spot checks of dissolved nutrients are not intended to provide information on the nutrient dynamics of the FGB reef system. They can at best quantify the presence of dissolved nutrients. The nutrient characteristics we found are those of an oligotrophic environment. An increased sampling frequency spread out over the year is needed to better characterize nutrient concentrations in the water column.

Trace Metals. Given the very dilute environment of the FGB, chromium and mercury could not be detected in the few water samples taken at the FGB (Table 3.6.5). It would be more feasible to examine selected metals in filter feeders (e.g., thorny oyster, goose barnacle) or apex predators (e.g., grouper) and perhaps combine these results with further analyses of water samples at lower detection limits to monitor the bioaccumulation of metals, if any, in living organisms on the reef. Corals and sediments should also be analyzed for their content in trace metals (Guzmán and García 2002). Among the metals to be analyzed, cadmium and zinc should be considered since their regional input by oil and gas operations continues beyond the cessation of drilling operations (Kennicutt et al. 1996).

4.3. FISH

Stationary visual fish surveys conducted at the FGB in 2002 and 2003 revealed a thriving reef-fish assemblage in this high-latitude, remote coral reef system in the Gulf of Mexico. While the species richness reported in these surveys was lower than reported in previous surveys (Pattengill-Semmens and Gittings 2003, Boland et al. 1983), it is similar to a reef-fish survey conducted at the FGB in 1994 by Rooker et al. (1997). The extensive surveys of 1980-1982 conducted by Boland et al. (1983) used numerous techniques, including remote video surveys on eight cruises on the East and West Banks, these results provided a robust dataset on fish communities at the FGB. The species total reported by the AGRRA survey (Pattengill-Semmens and Gittings 2003) was achieved using the roving diver technique (RDT), while the surveys reported in this document, as well as the Rooker et al. (1997) surveys, were conducted using the stationary visual census technique (Bohnsack and Bannerot 1986). A comparison of visual census techniques (Bortone et al. 1989) reveals that surveys using the RDT record more species and the stationary surveys are useful for recording fish counts, sizes, and densities (number of fishes per area). Analysis of the rate of new species accumulation shows the curve approaching a level (zero) slope after 10 diver surveys (14 to 17 were conducted) at the West Bank in 2002 and both banks in 2003. At the East Bank in 2002, the species accumulation curve approaches a level slope after 17 diver surveys (18 were conducted).

As a remote outpost of the Caribbean coral reef biota, and following the pattern of coral species present at the FGB, the fish assemblage has been reported to be low in diversity yet high in biomass (Pattengill-Semmens and Gittings 2003). It has been speculated that the presence of a large number of oil and gas production platforms in the Gulf of Mexico and mooring buoys has assisted additional species to reach the FGB and establish themselves permanently (Gittings 1998; Rooker et al. 1997; Boland et al. 1983). Also, herbivore populations have appeared to respond to the drastic decline in *Diadema antillarum* at the FGB in 1983 and 1984 (Gittings et al. 1992).

The FGB fish populations on the reef cap were dominated by the families Pomacentridae, Labridae, and Serranidae. Of these, the pomacentrids were the most diverse, with larger populations among the 12 species recorded. The labrids and serranids, while being represented by a moderate number of species, were highly abundant due to a single species in each family. *Clepticus parrae* were present in large schools at times (especially in surveys conducted in 2003). *Paranthias furcifer* were ubiquitous at the FGB throughout the surveys, this species was also found to be the most abundant species on the reef cap by Boland et al. (1983). Similar to other Caribbean coral reef communities, *Chromis cyanea* and *C. multilineata* were commonly seen in small- and medium-sized schools above coral formations. Also as expected in Caribbean communities, groups of female or male intermediate or juvenile phase *Thalassoma bifasciatum* were regularly seen on diver surveys in low areas between and just above coral formations, with one or two males in close association. Although lower in number because of their solitary nature, *Canthigaster rostrata* actively explored crevices and low areas. The Blenniidae species, *Ophioblennius atlanticus*, was commonly seen perched upon the face of coral formations. As for other Blenniidae and Gobbiidae species, the survey technique employed is likely to have underestimated the number of species and individuals of these small cryptic families. Surveys also intentionally excluded sand-covered bottom areas and so diver surveys were less likely to have recorded species associated with that habitat such as *Malacanthus plumieri* and *Opistognathus aurifrons.*

Disturbance caused by multiple divers present in the study sites while fish surveys were being conducted was minimized by conducting censuses before other divers entered the water and away from other diver activity. However, some degree of disturbance to the natural density and distribution of the local fishes is likely to have occurred. The disturbance more likely affected mid-water pelagic predators such as carangids and carcharinids. Low counts of larger reef-associated predators such as the serranids may have been due to the presence of divers at the study site. Although not recorded in any fish censuses, several *Manta birostris* were seen during the surveys.

Sphyraena barracuda were active throughout the study sites, regularly patrolling the reef. Many were curious of diver activity and were attracted to the surveyors. On any swim to a stationary fish survey location, two or three *S. barracuda* could be expected, and often there would be more swimming in groups. They were observed in half (sighting frequency 50%) of all diver surveys and as indicated before, there were significantly more *S. barracuda* at the West Bank than at East Bank (t=3.054, df=63, P=0.003). The mean length of *S. barracuda* at the FGB was 57 cm. While this species reaches lengths up to 183 cm (Humann and DeLoach 2002) the maximum recorded length at the FGB in 2002 and 2003 was 110 cm and just over half of all individuals recorded were under 55 cm. It has been suggested that a greater than expected number of *S. barracuda* seen at the FGB have been of small to medium sizes and that the FGB is a possible nursery habitat.

One striking difference between the FGB and Caribbean reefs is the reduced representation of lutjanids and the near absence of the haemulids at the FGB (Rooker et al. 1997). No haemulids were recorded at either bank in 2002 or 2003 and very few lutjanids were observed.

A healthy assemblage of herbivorous fishes was recorded. As a group, acanthurids, scarids, and *Microspathodon chrysurus* were relatively high in density at both banks in 2002 and 2003. While the FGB has lower species richness (including fewer scarid species) and a lower overall abundance of herbivorous fishes than Caribbean reefs (Rezak 1985; Dennis and Bright 1988), the percentages of acanthurids and scarids is similar to deep/fore reefs of far western Cuba and Akumal, Yucatan, Mexico (Table 4.3.1; Claro and Cantelar Ramos 2003; Steneck and Lang 2003). The size distribution is similar to those reported for the FGB in 1999 by the Pattengill-Semmens and Gittings (2003) AGRRA report. The low algal cover, despite the lack of a *Diadema antillarum* population, may be due to the presence of these herbivores. Garden-tending pomacentrids (*Stegastes*, *Pomacentrus*, *Eupomacentrus*, and *Microspathodon*) were abundant as well. There were more gardeners recorded in 2003 than 2002 at the FGB.

Table 4.3.1.

Percentage of fishes observed in the listed families at reefs around the Gulf of Mexico and the Caribbean Sea. Combined herbivore percentages shown at bottom ([1]Claro and Cantelar Ramos 2003; [2]Steneck and Lang 2003; *Not including *Microspathodon chrysurus*).

Family	Maria La Gorda, Cuba[1]	Akumal, Yucatan, Mexico[2]	FGB, USA
Acanthuridae	17%	22%	23%
Balistidae	37%	0%	14%
Chaetodontidae	7%	5%	14%
Lutjanidae	5%	7%	1%
Pomacanthidae	4%	2%	6%
Scaridae	25%	58%	37%
Serranidae	6%	6%	5%
Herbivores* (Acanthuridae, Scaridae)	42%	80%	60%

While the species richness of reef-associated carnivores (select serranids and lutjanids) was high, density values were somewhat low (Table 3.7.2). Carnivore richness was significantly lower at both banks in 2003 than in 2002 by nearly half, and density values were less by about a quarter from 2002 to 2003. The size distribution of these carnivores was similar but slightly larger than that reported by the 1999 AGRRA report (Pattengill-Semmens and Gittings 2003).

In summary, the reef species assemblage described by the surveys conducted in October of 2002 and August of 2003 at the FGB indicates a healthy system with a strong contingent of herbivores and garden-tending damselfishes. The density of reef associated carnivores, however, appears depressed in relation to previous studies. It is not possible to say this is due to recreational fishing pressure, which is allowed within the FGBNMS by hook and line only. The survey method used here may be a cause of this reduced density.

4.4 MAPPING

The sector-scan sonar was limited in altitude by the height of the tripod. As a result of its proximity to the seabed, tall coral structures near the transducer tended to block the view of coral at greater distances. Thus, large portions of the seabed remained in shadow. Sector-scan images are biased toward showing the tallest coral structures. This might prove useful for producing a simplified map of coral landmarks, except that shorter coral structures also are visible wherever the uneven terrain provided a line-of-sight from the transducer. Differentiating coral structures by height above the seabed is not possible based upon the geometry of their acoustic shadows, since the terrain is very uneven. Shadows tend to be prematurely truncated by the next adjacent coral structures. Attempts to directly capture pin locations in sector-scan images by suspension of air-filled balloons above them also proved unsuccessful due to a combination of uneven terrain and the presence of a highly variable, strongly reflective background (coral). At ranges much exceeding 10 m, attempts were unsuccessful due to the resolution of the sector-scan sonar as compared to the size of the air pockets in each balloon.

The sector-scan sonar had a lower resolution than that of the side-scan sonar, despite the higher frequency of the sector-scan sonar and the fact that its transducer remains at a fixed location. In fact, the sector-scan image resolution at a range of 40 m (0.17 m radially by 0.63 m circumferentially) is significantly less than that of the side-scan sonar raw data recorded at the same range (0.02 m across track by 0.35 m along track). Furthermore, the differences in resolution were exaggerated by the problem discussed above regarding the low altitude of the sector-scan transducer with respect to the surrounding terrain. Large areas of the terrain remain completely in shadow, while nearly vertical faces of tall coral structures dominate those areas that do appear. The resolution of the sector-scan imagery can best be assessed by comparing the two views (Figures 3.9.1 and 3.9.2) of the sand waves occurring along the northwestern margin of the East Bank Study Site. By this comparison that the sector-scan sonar produces a reasonably accurate representation of the site; however, areas with high topographic relief appear abstract because the intervening seabed lies in shadow. Side-scan sonar seems to produce a truer approximation of the seabed than the sector-scan sonar largely because the greater height of the towfish allows ensonification of low-lying areas while still providing sufficient shadowing behind vertical structures, creating a three-dimensional surface image.

Another advantage of the side-scan sonar is that the data were geo-referenced as they were acquired. While it is possible to geo-reference sector-scan sonar data, to do so would require additional equipment to determine the transducer location and orientation on the seabed. The fact that side-scan data is geo-referenced readily allows creation of mosaic images in which all of the data from a single survey is combined into a single composite image. Mosaics allow recognition of features and patterns on a larger scale than would be readily accomplished by viewing sonar records from individual lines or sector scans. The most striking example from this study occurs in the mosaic of Stetson Bank (Figure 3.9.4). The patterns of eroded claystone and sandstone strata, uplifted and fractured by an underlying salt diapir, are clearly visible. Creation of a mosaic from the sector-scan images, on the other hand, is a manual process. The relative position and orientation of each sector-scan image with respect to adjacent images was estimated based on common patterns appearing in areas of overlap.

Side-scan image mosaics were created using Coda's Geosurvey Mosaic software module. Mosaic pixels measure 0.02 x 0.16 m as compared with 0.02 x 0.09 m in the raw data. The resolution of these mosaics is comparable to that of the raw data. The across-track pixel dimension of the mosaics (0.02 m) is the same as that of the raw data. The along-track pixel dimension of the mosaics (0.16 m) remains narrower than the DF1000 towfish beam width at ranges exceeding 18.3 m. Geotiff images of sonar mosaics were exported from Coda's Geosurvey software for illustration in this report with a pixel size of 0.05 x 0.05 m, representing a compromise between the across-track and along-track resolutions and exceeding the resolution of printers used in their reproduction. The smallest discrete features recognizable in the side-scan sonar mosaics appear to be individual coral heads measuring about 0.4 m across. While coral heads of this size are undoubtedly common throughout the study sites, they are most recognizable when occurring in isolation from other coral on a sand flat. Sand waves are visible in most sand flats and appear to have wavelengths of approximately 0.8 m.

The challenge in producing quality mosaics is to find the optimal order in which to layer the imagery from overlapping lines, as data from only one line can be effectively displayed at any given location. Inevitably, compromises must be made and some areas will have data of high quality overlapped by data of lower quality. The quality (or accuracy) of an image depends upon the reliability of geographic coordinates calculated for each pixel. Slight changes in towfish layback distance due to variations in vessel speed or currents would affect towfish position estimates. Provided such changes are gradual and systematic, the relative position of pixels should still reflect reality even though dimensions and absolute positions of objects might be inaccurate. Sudden and random changes in towfish position estimates due, for example, to erratic position updates from the GPS, can result in confusion of pixel patterns such that they no longer reflect reality. Rapid changes in towfish heading can result in stretching and smearing of data near the outer margin of a curve (where resolution is already at its lowest due to the beam width) and in simultaneous compression and mixing of data on the corresponding inner edge of the record.

The transference of station marker locations to a sonar-based image necessarily would involve a process of diver feedback; however, given the inherent compromises of a mosaic image, this might not be the best type of map for divers to carry when ground truthing pin locations in the study sites. While a mosaic is excellent for achieving a broad area perspective, the accuracy of details at any given point on the mosaic might range from poor to excellent. The best map from a diver point of view would arguably be one that is the most realistic representation of what the seabed looks like at any given location. To accomplish the primary mapping objective, divers must be able to locate themselves on a map when swimming over the corresponding seabed terrain. This might be achieved through utilization of the optimum imagery for each area of interest. In other words, rather than producing a single plot of a mosaic image, separate plots of each data line would be prepared and laminated with plastic. Prior to each dive, a diver would select the map that illustrates the highest quality image covering the portion of a study site to be investigated during that dive. Such a system would improve the chances of divers correctly correlating shapes on the imagery with the corresponding coral features on the seabed. Once such correlations are made, station marker locations could be properly plotted by the diver with respect to coral landmarks on the imagery. It would not matter whether the refined pin locations were absolutely accurate in a geographic coordinate system provided that future investigators could easily relocate them by reference to sonar-based imagery.

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Appendix 1a
Percent Cover Data for Random Transect Still Photographs

	East Flower Garden Bank 2002													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
CORAL														
Agaricia sp.	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Agaricia agaricites	0.22			0.43	0.15			0.01	0.21	0.58	0.30	0.15		
Agaricia fragilis	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Agaricia humilis	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Colpophyllia natans	0.17			2.09	0.00			0.00	5.37	3.03	0.00	5.18		
Diploria strigosa	10.83			3.68	17.63			0.97	9.71	9.48	1.82	12.54		
Madracis decactis	0.03			0.37	0.16			0.04	0.00	0.86	0.00	0.00		
Madracis formosa	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Millepora sp.	0.00			0.44	0.23			1.75	0.48	0.00	4.28	0.00		
Millepora alcicornis	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Montastraea sp.	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Montastraea annularis	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Montastraea cavernosa	3.26			4.35	4.72			0.00	0.60	0.00	0.04	7.54		
Montastaea faveolata	0.12			2.72	0.00			4.89	17.02	3.91	2.62	11.04		
Montastraea franksi	17.38			12.78	21.34			55.29	16.77	26.46	30.09	20.47		
Mussa angulosa	0.60			0.25	0.00			0.18	0.00	0.14	0.00	0.00		
Mycetophyllia lamarckiana	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Porites astreoides	6.88			9.65	6.54			5.03	5.75	6.07	1.59	2.64		
Porites porites forma *furcata*	0.00			0.00	0.09			0.00	0.00	0.07	0.00	0.00		
Scolymia sp.	0.01			0.01	0.00			0.00	0.00	0.01	0.00	0.00		
Scolymia cubensis	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Siderastrea siderea	0.00			0.00	0.00			0.00	0.00	0.00	17.20	0.00		
Stephanocoenia intersepta	0.00			0.22	0.26			0.00	0.00	0.00	0.00	0.00		
Bleached coral	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Diseased coral	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
OTHER	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
CBT	48.13			55.62	42.29			29.03	34.20	43.15	32.61	34.32		
CCA	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Crustose coralline red	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Dictyota sp.	0.13			0.22	0.03			0.16	0.19	0.06	0.00	0.08		
Filamentous Algae	0.35			1.41	0.87			0.41	2.00	2.07	6.15	4.47		
Filamentous Red Algae	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Fish	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Fish bites	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Halimeda sp.	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Lobophora sp.	1.04			0.48	0.00			0.50	2.83	1.28	0.00	0.00		
Macroalgae (puffball)	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Sand	3.03			0.95	0.12			0.00	0.00	0.00	0.00	0.00		
Serpulids	0.03			0.01	0.01			0.05	0.08	0.08	0.01	0.00		
Shell	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.00		
Sponge	0.25			1.19	0.32			0.00	2.81	0.12	0.14	0.00		

Appendix 1a
Percent Cover Data for Random Transect Still Photographs

	East Flower Garden Bank 2002													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
Sea Urchin	0.00	▨	▨	0.00	0.00	▨	▨	0.00	0.00	0.00	0.00	0.00	▨	▨
Undefined	7.54	▨	▨	3.12	5.11	▨	▨	1.61	1.99	1.98	2.77	1.57	▨	▨
Transect tag/line	0.00	▨	▨	0.00	0.12	▨	▨	0.08	0.00	0.66	0.37	0.00	▨	▨
Total Cover	**100.00**	▨	▨	**100.00**	**100.00**	▨	▨	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	▨	▨
Total Coral	**39.50**	▨	▨	**37.00**	**51.13**	▨	▨	**68.16**	**55.92**	**50.60**	**57.94**	**59.55**	▨	▨
Total Algae	**49.65**	▨	▨	**57.73**	**43.20**	▨	▨	**30.10**	**39.21**	**46.56**	**38.77**	**38.87**	▨	▨
▨ **No data due to flooded camera**														

Appendix 1a
Percent Cover Data for Random Transect Still Photographs

	East Flower Garden Bank 2003													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
CORAL														
Agaricia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.09	0.00	0.00	0.07	0.03	0.00	0.00
Agaricia agaricites	0.38	0.11	0.74	0.22	0.41	0.65	0.03	0.44	0.24	0.51	0.58	0.14	0.23	0.09
Agaricia fragilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00
Agaricia humilis	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colpophyllia natans	2.77	3.36	7.02	0.00	0.00	0.00	0.00	0.00	0.40	2.49	0.00	1.15	6.98	4.32
Diploria strigosa	6.94	4.60	2.45	3.42	5.54	3.44	0.00	0.00	2.73	1.21	5.45	26.06	20.01	12.17
Madracis decactis	5.18	0.00	0.93	0.00	0.00	0.51	0.83	0.00	0.02	1.20	0.31	1.15	4.55	0.48
Madracis formosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00
Millepora sp.	0.95	0.03	3.76	1.98	3.82	4.05	0.00	0.00	3.29	3.39	0.00	0.00	0.00	0.00
Millepora alcicornis	0.00	0.00	0.00	0.00	0.00	0.00	3.78	2.17	0.00	0.00	6.43	0.00	3.11	5.87
Montastraea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00	0.00
Montastraea annularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.67	0.47
Montastraea cavernosa	0.64	12.01	9.49	2.17	0.65	4.53	16.61	2.35	7.13	1.41	0.00	15.10	9.48	8.37
Montastaea faveolata	0.00	0.00	4.05	24.08	36.29	22.75	10.24	26.11	0.00	0.00	16.61	6.99	0.60	10.78
Montastraea franksi	18.92	39.63	7.94	11.24	0.00	8.53	19.47	6.54	33.42	22.76	15.63	0.38	4.04	17.71
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00
*Mycetophyllia lamarckiana **	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Porites astreoides	3.73	2.28	4.53	3.08	6.77	4.37	4.04	3.37	19.40	8.25	7.56	3.80	7.14	5.09
Porites porites forma *furcata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scolymia sp.	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderastrea siderea	0.00	0.00	1.83	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Stephanocoenia intersepta	2.09	0.89	0.00	0.98	0.00	0.27	0.00	0.24	0.01	0.48	3.05	0.63	0.68	0.00
Bleached coral	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.10	0.04
Diseased coral	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTHER	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.00	0.00	0.02	0.18	0.22	0.01
CBT	30.09	28.89	38.28	42.72	26.93	37.67	11.00	5.83	18.85	37.48	23.08	17.69	3.31	1.11
CCA	0.00	0.00	0.08	0.25	0.54	0.00	9.14	21.69	0.00	0.00	7.36	7.85	19.10	15.98
Crustose coralline red	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00
Dictyota sp.	0.74	0.09	0.11	0.00	0.00	0.02	0.14	0.00	0.10	0.11	0.00	0.00	0.00	0.00
Filamentous Algae	1.33	0.71	1.58	2.81	0.83	0.66	17.74	27.60	1.13	1.15	2.71	2.42	16.64	13.61
Filamentous Red Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish	0.00	0.00	0.56	0.16	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish bites	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.09	0.03
Halimeda sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lobophora sp.	17.38	3.17	12.51	2.75	14.43	11.05	0.00	0.00	8.96	15.60	3.42	6.06	0.00	0.00
Macroalgae (puffball)	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	2.15	0.00	0.00
Sand	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.93	0.00	0.56	0.04
Serpulids	0.00	0.07	0.08	0.04	0.04	0.15	0.12	0.10	0.02	0.07	0.06	0.00	0.06	0.09
Shell	0.00	0.00	0.01	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0.33	0.00	1.16	0.18	0.23	0.28	0.10	0.07	0.11	0.16	0.42	0.27	1.09	0.44
Sea Urchin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Undefined	7.11	4.38	2.62	3.54	3.30	0.82	6.21	2.47	3.99	3.52	4.54	6.37	0.64	3.09
Transect tag/line	0.72	0.12	0.06	0.03	0.09	0.25	0.00	0.00	0.16	0.18	0.00	0.00	0.00	0.00
Total Cover	**100.05**	**100.35**	**99.77**	**100.01**	**100.00**	**100.00**	**100.00**	**99.99**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**99.97**
Total Coral	**41.60**	**62.93**	**42.74**	**47.25**	**53.51**	**49.10**	**55.42**	**42.12**	**66.69**	**41.70**	**57.46**	**55.41**	**58.29**	**65.56**
Total Algae	**49.57**	**32.86**	**53.11**	**48.69**	**42.73**	**49.40**	**38.13**	**55.11**	**29.04**	**54.38**	**36.57**	**37.77**	**39.14**	**30.73**

* First sighting of this species at the East Bank, laboratory verification needed.

Appendix 1a

Percent Cover Data for Random Transect Still Photographs

	West Flower Garden Bank 2002													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
CORAL													0.00	0.00
Agaricia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Agaricia agaricites	0.98	0.57	0.30	1.31	0.97	0.17	0.13	0.63	0.19	0.00			0.81	0.75
Agaricia fragilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Agaricia humilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Colpophyllia natans	0.00	1.17	0.00	0.00	4.27	2.16	7.85	0.00	0.00	0.00			0.00	0.00
Diploria strigosa	1.94	5.00	2.00	2.62	9.18	1.19	5.41	1.38	4.90	5.48			1.33	2.72
Madracis decactis	0.37	0.00	0.59	0.00	0.00	0.07	0.00	0.00	0.00	8.16			2.28	0.00
Madracis formosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Millepora sp.	0.38	0.42	1.32	1.30	0.48	0.06	3.56	8.40	5.35	0.59			0.00	1.02
Millepora alcicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Montastraea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Montastraea annularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.76			0.00	0.00
Montastraea cavernosa	0.00	0.85	3.92	0.14	0.13	0.08	1.66	10.49	0.00	5.12			9.03	0.00
Montastaea faveolata	13.92	0.00	0.00	21.72	13.46	3.18	19.37	14.52	9.14	0.00			0.00	0.00
Montastraea franksi	22.57	24.23	9.95	6.21	16.80	44.62	32.26	2.65	23.12	20.59			11.42	34.66
Mussa angulosa	0.02	0.00	0.00	0.00	0.00	0.38	0.00	0.03	0.00	1.28			0.00	0.71
Mycetophyllia lamarckiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Porites astreoides	3.74	4.03	5.25	1.58	0.80	5.05	2.41	2.35	3.96	1.97			6.65	5.99
Porites porites forma *furcata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Scolymia sp.	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Siderastrea siderea	1.69	2.97	18.26	9.69	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Stephanocoenia intersepta	0.00	0.00	0.00	0.50	4.48	0.00	0.73	0.00	0.00	0.20			7.47	0.12
Bleached coral	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Diseased coral	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
OTHER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
CBT	42.25	46.36	45.11	46.82	39.03	36.41	21.54	53.03	49.72	38.31			52.13	48.93
CCA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Crustose coralline red	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Dictyota sp.	0.22	7.45	0.39	0.01	1.81	1.01	0.10	0.17	0.00	0.00			0.78	0.00
Filamentous Algae	9.18	5.73	6.25	7.11	6.33	4.47	1.25	3.17	2.44	0.09			4.12	3.19
Filamentous Red Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06			0.00	0.00
Fish bites	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Halimeda sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Lobophora sp.	0.64	0.27	1.82	0.27	0.04	0.00	0.00	0.09	0.14	0.00			0.00	0.00
Macroalgae (puffball)	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Sand	0.23	0.00	0.00	0.00	0.00	0.29	3.24	0.00	0.00	0.00			3.97	0.00
Serpulids	0.01	0.04	0.00	0.00	0.01	0.03	0.06	0.01	0.00	0.00			0.00	0.00
Shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Sponge	0.25	0.00	0.15	0.46	0.05	0.00	0.27	1.59	0.49	0.00			0.00	0.00
Sea Urchin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00
Undefined	1.63	0.20	4.62	0.18	1.68	0.83	0.16	1.24	0.42	0.29			0.00	1.79
Transect tag/line	0.00	0.12	0.06	0.09	0.49	0.00	0.00	0.26	0.11	0.12			0.00	0.11
Total Cover	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**			**100.00**	**100.00**
Total Coral	**45.61**	**39.24**	**41.30**	**45.05**	**50.57**	**56.96**	**73.38**	**40.45**	**46.67**	**61.13**			**39.00**	**45.97**
Total Algae	**44.63**	**60.41**	**53.57**	**54.22**	**47.20**	**41.89**	**22.89**	**56.46**	**52.30**	**38.46**			**57.03**	**52.12**
No data due to flooded camera														

Appendix 1a
Percent Cover Data for Random Transect Still Photographs

	West Flower Garden Bank 2003													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
CORAL														
Agaricia sp.	0.00	0.00	0.00	0.15	0.19	0.00	0.00	0.00	0.22	0.37	0.00	0.00	0.00	0.53
Agaricia agaricites	0.52	0.15	0.01	0.29	0.00	0.09	0.29	0.27	0.00	0.32	0.49	0.27	0.14	0.30
Agaricia fragilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agaricia humilis	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colpophyllia natans	0.00	0.00	0.37	0.00	2.05	0.00	0.00	0.00	1.35	4.31	0.00	0.00	2.81	0.00
Diploria strigosa	3.95	7.10	4.71	8.62	9.04	4.19	10.31	36.69	24.91	5.39	3.23	5.26	3.98	13.41
Madracis decactis	1.67	0.01	0.25	0.92	0.01	0.01	0.28	0.00	0.00	0.72	0.00	0.00	0.55	0.00
Madracis formosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Millepora sp.	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.38	0.00	0.00	2.93	2.71	0.63	1.30
Millepora alcicornis	4.50	0.33	0.00	2.59	4.09	2.35	0.00	0.00	0.00	1.74	0.00	0.00	0.00	0.00
Montastraea sp.	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Montastraea annularis	0.02	0.00	0.00	0.00	7.97	25.59	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Montastraea cavernosa	5.26	1.07	8.87	22.90	7.32	6.21	0.44	1.56	13.92	7.10	2.15	0.22	0.13	3.85
Montastaea faveolata	2.15	1.36	43.58	0.14	3.21	13.75	10.99	0.00	0.00	0.00	15.49	22.37	12.58	0.10
Montastraea franksi	15.39	25.38	0.48	0.02	17.24	2.79	19.23	18.33	21.12	14.94	26.74	17.10	44.50	10.44
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00
*Mycetophyllia lamarckiana **	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Porites astreoides	5.04	3.94	3.34	3.85	3.31	0.59	4.38	1.95	2.01	3.18	2.40	7.48	2.54	3.98
Porites porites forma *furcata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scolymia sp.	0.04	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.22	0.03	0.00	0.00	0.02
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Siderastrea siderea	5.88	6.23	0.26	0.00	20.44	0.00	0.00	0.00	0.00	0.01	0.00	8.13	0.00	0.00
Stephanocoenia intersepta	1.63	0.83	0.79	1.05	0.26	0.10	0.25	0.00	0.32	1.44	0.00	0.00	0.43	0.00
Bleached coral	0.10	0.10	0.04	0.02	0.04	0.00	0.00	0.00	0.09	0.01	0.00	0.00	0.00	0.00
Diseased coral	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTHER	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CBT	31.41	28.30	29.29	46.32	20.14	28.41	41.10	37.75	25.10	49.00	36.91	25.50	22.18	51.21
CCA	2.61	2.39	0.27	2.23	0.76	1.21	0.00	0.00	0.49	0.42	0.02	1.23	0.00	0.00
Crustose coralline red	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00
Dictyota sp.	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	3.36	0.04
Filamentous Algae	13.28	16.50	3.51	1.50	2.46	13.23	3.10	0.65	3.91	6.78	0.00	0.00	0.57	2.34
Filamentous Red Algae	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	3.30	2.57	0.00	0.00
Fish	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Fish bites	0.10	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Halimeda sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Lobophora sp.	0.00	0.00	1.10	5.04	0.64	0.00	0.74	0.97	0.00	0.11	3.25	2.76	1.48	6.90
Macroalgae (puffball)	0.64	0.53	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	1.99	0.64	0.00	0.11	0.00	0.00	0.87	0.00	0.00	1.30	0.00	0.00	2.42	0.00
Serpulids	0.03	0.03	0.12	0.05	0.18	0.03	0.01	0.01	0.03	0.00	0.01	0.03	0.08	0.00
Shell	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0.54	0.67	0.00	0.18	0.05	0.05	1.58	0.68	0.40	1.34	0.22	0.00	0.05	0.41
Sea Urchin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Undefined	3.17	4.24	2.75	3.61	0.44	1.06	6.12	0.55	5.54	0.25	2.88	4.23	1.48	5.46
Transect tag/line	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.16	0.00	0.00	0.08	0.14	0.09	0.09
Total Cover	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**99.96**	**100.00**	**100.00**	**100.00**	**100.00**	**100.14**	**100.00**	**100.00**	**100.41**
Total Coral	**46.22**	**46.60**	**62.93**	**40.80**	**75.18**	**55.96**	**46.17**	**59.17**	**64.44**	**40.20**	**53.46**	**63.54**	**68.30**	**33.92**
Total Algae	**48.05**	**47.81**	**34.19**	**55.25**	**24.11**	**42.84**	**44.95**	**39.36**	**29.58**	**56.91**	**43.49**	**32.07**	**27.59**	**60.49**

* First sighting of this species at the West Bank, laboratory verification needed.

Appendix 1b
Percent Cover Data for Random Transect Videography

	East Bank 2002													
Coral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Agaricia agaricites	0.80	0.00	0.80	2.00	0.00	0.20	0.20	0.00	0.40	0.60	1.00	0.00	0.40	1.00
Colpophyllia natans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	5.60	0.80	0.00
Coral	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diploria strigosa	9.40	3.20	16.20	12.00	15.60	1.40	6.40	1.00	11.00	4.40	16.60	0.00	0.20	0.00
Madracis decactis	0.00	0.00	5.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00	1.20	0.00
Millepora sp.	0.00	1.00	3.60	0.40	0.00	0.00	4.40	4.80	6.60	3.40	2.80	0.00	1.40	2.20
Montastraea annularis	30.40	55.00	15.20	12.00	24.60	38.40	18.60	53.40	35.60	41.60	21.20	52.00	44.40	27.80
Montastraea cavernosa	7.20	0.00	5.00	7.60	4.20	12.20	0.20	1.20	7.80	0.60	0.00	0.00	0.20	8.40
Mussa angulosa	0.00	0.40	1.60	1.00	0.40	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Porites astreoides	7.00	6.40	3.80	9.40	4.40	3.40	8.40	8.40	11.00	8.00	9.20	1.40	4.40	9.80
Porites porites forma *furcata*	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.20	0.20
Siderastrea siderea	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.00	0.00	0.40	0.40	0.00	0.00	0.00
Siderastrea sp.	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stephanocoenia intersepta	1.60	0.40	0.80	0.00	0.00	0.20	0.60	0.00	0.00	0.00	0.80	0.00	0.00	0.00
Total Coral	**56.60**	**66.60**	**55.60**	**44.60**	**49.20**	**57.60**	**41.40**	**68.80**	**72.40**	**60.60**	**55.00**	**59.00**	**53.20**	**49.40**
Calcareous Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.20	0.00	0.00	0.00	0.00	0.00
Filamentous Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.20
Macroalgae	2.20	0.20	0.20	0.60	0.00	0.20	0.20	2.00	1.20	2.60	0.00	2.40	5.40	4.60
Turf Algae	1.20	8.40	1.20	2.80	1.80	0.20	0.20	1.80	2.60	2.20	2.60	3.00	1.00	0.80
Total Algae	**3.40**	**8.60**	**1.40**	**3.40**	**1.80**	**0.40**	**0.40**	**4.60**	**4.00**	**4.80**	**2.60**	**5.40**	**6.40**	**9.60**
Gorgonians	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0.40	0.00	0.00	0.60	0.60	0.00	0.60	0.20	5.20	0.60	1.20	0.00	0.40	1.20
Zooanthid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fine Turf, Bare, Crustose Corallines	33.00	23.20	38.20	50.20	48.00	42.00	53.40	26.40	18.40	31.00	40.00	35.60	39.80	39.80
Other	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	6.60	0.80	4.80	1.20	0.40	0.00	4.00	0.00	0.00	3.00	1.20	0.00	0.00	0.00
Overall Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Appendix 1b
Percent Cover Data for Random Transect Videography

	East Bank 2003													
Coral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Agaricia agaricites	0.40	0.00	0.60	0.40	1.40	0.40	0.00	0.00	0.00	0.40	0.80	0.20	0.00	0.00
Colpophyllia natans	3.81	6.40	4.00	0.80	0.00	1.80	0.00	0.00	1.80	0.00	1.20	0.80	20.00	5.40
Diploria strigosa	9.02	6.40	6.80	3.20	7.40	0.00	1.40	5.40	3.20	1.60	5.20	24.20	7.40	5.40
Madracis decactis	3.01	0.00	0.00	0.00	0.00	3.20	0.00	0.40	0.00	0.20	2.60	2.20	0.00	0.00
Millepora alcicornis	1.80	0.80	5.00	0.20	2.60	1.00	0.20	4.20	1.80	2.20	5.40	2.40	0.20	3.40
Montastraea annularis sp	28.86	22.00	26.60	38.00	38.40	21.00	35.00	48.80	43.00	10.00	15.20	20.80	19.60	47.60
Montastraea cavernosa	1.00	15.20	0.60	3.60	2.60	9.40	8.00	0.00	13.80	0.00	0.40	0.40	4.40	0.00
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Porites astreoides	6.41	0.60	5.00	1.60	4.40	5.00	3.80	1.80	3.80	13.00	10.00	7.80	5.20	11.20
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Stephanocoenia intersepta	0.80	3.40	1.80	1.00	0.00	3.20	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Total Coral	**55.11**	**54.80**	**50.40**	**48.80**	**56.80**	**45.40**	**48.40**	**60.60**	**67.40**	**27.40**	**40.80**	**59.00**	**57.00**	**73.00**
Calcareous Algae	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filamentous Algae	0.00	0.60	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae	19.64	4.40	18.80	17.00	23.20	23.60	16.20	16.80	12.60	34.40	10.20	11.00	8.00	6.80
Turf Algae	0.80	0.80	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.40	6.00	1.20	0.40	0.20
Total Algae	20.44	5.80	18.80	17.00	23.80	23.60	16.20	17.60	12.60	34.80	16.20	12.20	8.40	7.00
Sponge	1.00	0.40	0.40	1.80	0.40	5.20	3.40	2.40	0.40	0.20	0.60	0.80	3.20	1.40
Fine Turf, Bare, Crustose Corallines	23.45	38.4	30.2	32.4	19	25.8	32	19.2	19.2	37.6	40.6	26.2	31.4	18.4
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Sand	0.00	0.60	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	1.80	0.00	0.20
Overall Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Appendix 1b

Percent Cover Data for Random Transect Videography

	West Bank 2002													
Coral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Agaricia agaricites	0.60	0.40	0.20	0.60	1.40	0.40	0.00	0.40	0.40	0.00	0.00	0.00	1.00	1.00
Colpophyllia natans	0.00	0.00	0.00	0.00	0.00	0.00	17.00	0.00	0.00	2.80	0.00	0.80	2.60	0.00
Coral	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diploria strigosa	2.40	5.40	0.80	0.80	0.20	7.40	4.00	2.40	1.00	0.40	3.00	12.20	0.20	0.00
Madracis decactis	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.40	6.60	0.00	0.00	1.60	0.00
Millepora sp.	0.20	0.00	5.60	7.60	0.20	0.00	3.40	5.60	0.00	1.20	4.40	0.60	0.20	2.20
Montastraea annularis species complex	28.40	48.00	20.00	26.00	19.80	50.00	41.20	18.40	31.20	49.20	38.80	19.80	9.60	27.80
Montastraea cavernosa	0.00	0.00	3.00	0.00	2.00	0.00	0.20	11.40	0.00	3.40	0.40	13.00	5.00	8.40
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	1.80	0.00	0.00	0.60	0.00
Porites astreoides	6.00	1.20	7.20	1.00	2.60	0.00	5.00	2.40	2.20	1.00	0.60	4.40	5.80	9.80
Porites porites forma *furcata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20
Siderastrea siderea	0.00	0.20	4.40	10.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.20	0.00
Stephanocoenia intersepta	0.00	2.40	0.40	0.00	3.40	1.00	1.80	0.00	1.20	0.20	3.60	2.40	3.00	0.00
Total Coral	**37.60**	**57.60**	**42.80**	**47.00**	**29.60**	**58.80**	**72.80**	**40.60**	**36.40**	**66.60**	**50.80**	**53.20**	**41.00**	**49.40**
Calcareous Algae	0.40	1.40	2.40	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.00	0.00
Filamentous Algae	16.20	3.80	3.00	8.40	6.40	2.20	5.00	3.00	4.00	0.60	5.60	4.80	9.60	4.20
Macroalgae	0.40	9.40	1.20	6.00	0.40	0.20	0.00	0.00	0.40	0.40	0.40	0.20	1.80	4.60
Turf Algae	9.20	12.60	12.20	13.20	9.40	11.40	8.60	14.60	13.40	13.40	13.20	17.20	10.00	0.80
Total Algae	**26.20**	**27.20**	**18.80**	**27.60**	**16.40**	**13.80**	**13.60**	**17.60**	**17.80**	**14.40**	**19.60**	**22.40**	**21.40**	**9.60**
Sponge	1.40	1.40	2.60	0.40	3.60	2.00	0.60	3.20	1.80	0.00	0.20	0.80	0.40	1.20
Fine Turf, Bare, Crustose Corallines	33.00	9.80	35.40	24.40	50.20	25.00	8.00	37.80	43.40	18.60	26.80	23.60	23.20	39.80
Other	0.00	0.00	0.00	0.00	0.20	0.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	1.80	4.00	0.40	0.60	0.00	0.00	4.80	0.80	0.60	0.40	2.60	0.00	14.00	0.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Appendix 1b

Percent Cover Data for Random Transect Videography

	West Bank 2003													
Coral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Agaricia agaricites	0.00	0.80	0.20	0.00	0.00	0.60	0.40	0.00	0.00	0.80	0.20	0.00	0.00	0.40
Colpophyllia natans	5.20	0.00	0.00	0.00	9.00	1.00	0.00	0.00	4.40	7.40	0.00	0.00	3.40	0.00
Diploria strigosa	2.20	4.20	7.80	12.07	0.40	0.20	7.60	39.40	16.60	8.40	1.60	12.00	4.00	10.20
Madracis decactis	0.00	4.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
Millepora sp.	1.60	2.80	0.60	0.20	4.40	3.00	0.00	0.00	0.00	2.80	5.80	5.00	1.00	0.00
Montastraea annularis	26.20	34.00	50.00	19.11	34.80	50.00	28.20	22.20	10.40	21.20	57.20	38.00	63.80	18.20
Montastraea cavernosa	2.40	5.20	3.20	0.00	8.80	3.60	0.20	0.20	13.60	0.20	0.00	0.00	0.00	0.00
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40	0.00	0.00	0.20	0.00
Porites astreoides	4.60	6.20	1.20	2.62	3.80	1.60	6.40	5.60	5.20	2.60	2.60	1.80	4.60	4.00
Scolymia cubensis	0.20	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderastrea siderea	6.00	4.00	0.00	0.00	14.40	0.00	0.00	0.00	0.00	0.00	0.00	4.20	0.00	0.00
Stephanocoenia intersepta	3.00	0.40	5.60	0.00	0.20	0.00	0.00	0.00	1.20	2.60	0.00	0.00	0.40	0.00
Total Coral	**51.40**	**61.60**	**69.00**	**34.00**	**75.80**	**60.40**	**43.80**	**67.40**	**51.40**	**46.60**	**67.40**	**61.00**	**77.40**	**32.80**
Calcareous Algae	0.00	0.00	0.00	2.62	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Filamentous Algae	0.00	1.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae	7.80	0.40	4.80	9.66	0.00	0.00	0.80	4.40	0.60	1.60	4.20	0.80	3.00	9.00
Turf Algae	4.00	0.20	0.80	4.83	0.40	2.60	7.60	3.00	11.20	8.40	5.80	16.80	0.40	0.40
Total Algae	**11.80**	**1.80**	**5.80**	**17.10**	**0.40**	**2.60**	**8.40**	**7.80**	**11.80**	**10.00**	**10.00**	**17.60**	**3.40**	**9.40**
Sponge	0.80	2.20	0.40	4.23	0.80	4.20	3.20	1.00	0.40	2.20	1.20	0.60	0.40	0.20
FBC	34.60	26.00	24.80	44.67	23.00	32.80	42.20	23.80	36.40	39.20	21.40	20.80	16.40	57.00
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	1.40	8.40	0.00	0.00	0.00	0.00	2.40	0.00	0.00	2.00	0.00	0.00	2.40	0.60
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Appendix 1c
Point Counts for LPI Data

	East Bank 2002													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
Agaricia agaricites	2	3	3	5	1	0	1	0	0	1	1	0	1	2
Colpophyllia natans	0	12	1	5	1	4	3	0	3	5	0	4	0	3
Diploria strigosa	14	4	19	12	6	14	6	5	9	4	5	1	6	6
Madracis decactis	1	0	4	1	1	0	0	0	0	4	0	0	0	0
Millepora alcicornis	0	4	0	1	1	2	0	4	0	2	2	2	1	1
Montastraea annularis	0	0	5	0	2	1	0	0	0	2	0	3	3	3
Montastraea cavernosa	3	11	0	5	7	3	0	0	8	3	6	7	9	4
Montastraea franksi	20	15	21	14	24	21	41	22	27	18	19	18	25	20
Montastraea faveolata	2	1	0	4	4	3	4	2	3	1	6	6	9	5
Mussa angulosa	2	0	0	0	0	0	0	1	0	0	1	0	0	0
Porites astreoides	12	6	6	5	7	5	4	9	9	5	8	10	3	6
Siderastrea siderea	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Stephanocoenia intersepta	0	0	0	0	0	0	0	1	2	0	1	1	0	0
Total Coral	**56**	**56**	**59**	**52**	**54**	**53**	**59**	**44**	**61**	**49**	**49**	**52**	**57**	**50**
Lobophora sp.	2	1	0	0	0	0	0	0	5	0	0	1	2	0
Sponge	0	0	0	0	0	0	0	0	0	0	2	2	0	0
Vase or Barrel Sponge	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	10	5	0	0	2	0	0	0	0
Dead Coral – rubble	0	0	2	0	0	2	0	0	0	0	0	0	0	0
CTB	42	43	39	46	46	34	36	56	34	49	49	45	41	50
Total Cover	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Appendix 1c
Point Counts for LPI Data

	East Bank 2003													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
Agaricia agaricites	3	0	0	0	1	0	0	1	0	0	2	0	0	0
Colpophyllia natans	2	4	0	0	0	3	3	0	0	0	0	14	3	0
Diploria strigosa	9	4	12	9	2	7	2	0	5	14	11	11	10	21
Millepora alcicornis	0	1	3	0	2	4	8	0	3	3	8	0	0	8
Millepora annularis	0	0	0	0	0	0	15	0	0	0	0	0	0	0
Montastraea cavernosa	0	13	15	3	3	0	5	0	15	0	0	7	9	1
Madracis decactis	3	0	0	0	0	0	2	5	0	0	2	1	2	0
Montastraea faveolata	7	17	0	20	11	15	5	13	19	13	22	0	26	15
Montastraea franski	12	25	11	7	27	20	21	29	16	11	12	6	5	13
Madracis mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porites astreoides	3	2	5	13	2	5	5	8	8	8	1	7	3	6
Porites porites forma *furcata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanocoenia intersepta	3	2	2	2	1	0	0	0	0	0	5	0	0	0
Total Coral	**42**	**68**	**48**	**54**	**49**	**54**	**66**	**56**	**66**	**49**	**63**	**46**	**58**	**64**
CTB	26	24	33	37	23	20	22	21	17	22	27	39	31	24
Macroalgae	22	2	19	9	26	24	12	23	17	29	5	15	11	11
Other	3	0	0	0	2	0	0	0	0	0	0	0	0	0
rubble	0	6	0	0	0	2	0	0	0	0	0	0	0	0
sediment	7	0	0	0	0	0	0	0	0	0	5	0	0	1
Total Cover	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Appendix 1c
Point Counts for LPI Data

	West Bank 2002													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
Agaricia agaricites	1	1	1	1	0	0	1	2	1	0	0	1	1	2
Colpophyllia natans	0	9	0	2	3	1	3	0	4	1	2	0	0	0
Diploria strigosa	7	4	12	2	8	3	13	0	6	3	13	17	7	0
Madracis decactis	0	1	0	1	1	0	0	1	0	2	0	0	1	0
Millepora alcicornis	1	0	0	3	0	0	3	0	0	2	2	0	0	1
Montastraea annularis	0	0	0	0	0	0	2	0	13	49	7	0	0	0
Montastraea cavernosa	0	0	4	0	0	6	3	0	12	0	0	17	4	0
Montastraea franksi	30	25	24	20	29	49	34	31	14	15	21	17	21	33
Montastraea faveolata	21	4	7	15	12	0	6	5	7	0	9	0	5	9
Porites porites forma *furcata*	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Porites astreoides	3	4	2	0	4	4	1	2	2	0	1	0	7	3
Siderastrea siderea	0	0	13	1	0	0	0	0	0	0	0	0	2	0
Stephanocoenia intersepta	0	1	0	1	0	0	1	1	0	0	1	1	0	0
Total Coral	**63**	**49**	**63**	**46**	**57**	**63**	**67**	**42**	**59**	**72**	**56**	**57**	**48**	**48**
Dictyota sp.	1	9	0	4	3	2	0	0	0	0	0	2	0	0
Lobophora sp.	1	0	0	0	0	2	0	0	0	0	0	0	1	0
Sand	0	0	0	0	2	0	2	0	0	0	1	3	9	0
CTB	35	41	37	50	38	33	31	58	41	28	43	38	42	52
Totals	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Appendix 1c
Point Counts for LPI Data

	West Bank 2003													
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**
Agaricia agaricites	0	1	0	0	0	0	2	0	1	3	0	1	0	1
Agaricia humilus	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Colpophyllia natans	0	0	2	0	6	7	0	0	1	1	0	0	5	4
Diploria strigosa	6	0	2	17	3	1	9	43	5	5	0	1	1	7
Millepora alcicornis	0	0	1	4	0	6	1	0	0	4	10	1	8	2
Mussa angulosa	0	1	0	0	0	0	0	0	0	0	2	0	0	3
Montastraea annularis	0	0	0	0	9	32	0	0	0	0	0	0	0	0
Montastraea cavernosa	0	5	0	0	1	0	5	1	32	1	0	0	16	0
Madracis decactis	0	0	0	0	0	0	1	0	0	0	0	1	2	0
Montastraea faveolata	13	24	22	6	0	13	13	3	19	6	20	19	12	9
Montastraea franski	32	12	25	0	9	7	17	24	5	24	30	27	17	23
Madracis mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Porites astreoides	1	4	3	5	0	0	1	2	2	4	3	3	3	3
Porites porites forma *furcata*	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Stephanocoenia intersepta	4	1	1	1	0	1	1	0	0	0	0	0	3	0
Siderastrea siderea	5	0	0	0	25	0	0	0	0	0	0	8	0	0
Total Coral	**61**	**50**	**56**	**33**	**53**	**67**	**50**	**73**	**66**	**73**	**65**	**61**	**67**	**52**
CTB	26	43	38	64	34	33	48	20	34	28	31	31	25	40
Macroalgae	12	0	6	3	14	0	2	2	0	3	4	8	4	8
Other	1	0	0	0	0	0	0	0	0	4	0	0	0	0
Rubble	0	0	0	0	0	0	0	5	0	8	0	0	2	0
Sediment	0	7	0	0	0	0	0	0	0	11	0	0	2	0
Total Cover	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Appendix 2

Sclerochronology

East and West Bank 1998-2003

(measurements in mm ± SE)

Year	East Bank 1	East Bank 2	East Bank 3	East Bank 4	West Bank 1	West Bank 2	West Bank 3	West Bank 4
1998	8.3 ± 0.3	NA	NA	NA	0.3	NA	NA	NA
1999	11.66 ± 1.3	7 ± 1.8	NA	NA	8.33 ± 1.3	NA	7.66 ± 1.9	NA
2000	11.33±1.3	6.66 ± 2.2	12.33 ± 1.3	12.33 ± 1.3	8 ±	10.33 ± 1.9	7.33 ± 1.3	8.33 ± 1.9
2001	10.66 ± 1.3	6.33 ± 2.2	9.66 ± 1.3	6.66 ± 1.3	8.33 ± 1.3	5.33 ± 1.3	7±	8.66 ± 1.3
2002	10 ±	13.33 ± 1.3	10.33 ± 1.3	6.66 ± 1.3	7.66 ± 1.3	7±	6.66 ± 1.3	10 ±
2003	4.83 ± 0.9	10.66 ± 1.3	9.66 ± 1.3	5.66 ± 1.3	7.33 ± 1.3	5 ±	6.66 ± 1.3	6.33 ± 1.3

Appendix 3
Diploria strigosa Lateral Growth

East Bank 2001-2002			
Station# (old)	**Area of Coral Tissue in 2002 (cm^2)**	**Difference from 2001(cm^2)**	**Change in % cover**
	Tissue Gain (+)		
old 3 E	167.57	6.50	4.03
old 5E	230.71	5.67	2.52
old 12E	179.02	19.13	11.96
old 34E	173.63	9.35	5.69
old 111E	197.33	11.13	5.98
old 122 E	114.76	11.90	11.56
old 130E	103.43	16.12	18.46
old 162E	116.52	7.51	6.89
old 189E	197.81	27.91	16.43
old 191E	81.61	12.45	18.01
old 195E	152.84	11.97	8.50
old 32E	108.82	1.99	1.86
old 40E	33.73	4.68	16.13
old 188E	139.02	2.66	1.95
	Tissue Loss (-)		
old 106	126.50	-9.43	-6.94
old 110	16.40	-3.25	-16.56
old 175	107.82	-1.17	-1.07
old 193	128.28	-0.81	-0.62

Appendix 3
Diploria strigosa Lateral Growth

East Bank 2002-2003			
Station # (new)	Area of Coral Tissue in 2003 (cm^2)	Difference from 2002(cm^2)	Change in % cover
	Tissue Gain (+)		
29	132.87	6.36	5.03
7	116.72	1.97	1.71
50	129.56	1.28	1.00
55	153.27	0.42	0.28
	Tissue Loss (-)		
47	174.00	-5.01	-2.80
14	193.37	-3.97	-2.01
17	107.82	-1.19	-1.11
3	108.83	-1.95	-1.76

Appendix 3

Diploria strigosa Lateral Growth

West Bank 2001-2002			
Station# (old)	Area of Coral Tissue in 2002 (cm^2)	Difference from 2001(cm^2)	Change in % cover
	Tissue Gain (+)		
old 25	83.61	5.38	6.88
old 101	137.25	9.01	7.02
old 108	131.37	13.64	11.59
old 126	141.54	5.47	4.02
old 199	135.95	13.30	10.85
old 13	97.02	2.45	2.59
old 103	117.54	4.70	4.17
old 113	30.46	1.62	5.61
	Tissue Loss (-)		
old 121	161.66	-11.70	-6.75
old 105	168.02	-0.65	-0.39
old 125	46.44	-3.31	-6.65

Appendix 3

Diploria strigosa Lateral Growth

West Bank 2002-2003			
Station # (new)	**Area of Coral Tissue in 2003 (cm^2)**	**Difference from 2002(cm^2)**	**Change in % cover**
	Tissue Gain (+)		
101	138.52	1.26	0.92
80	131.48	0.11	0.08
	Tissue Loss (-)		
113	18.64	-11.82	-38.82
121	114.50	-3.04	-2.59

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

East Bank 2001-2002										
RQS #	**Coral Head #**	**Species**	**Area of coral head in 2001 (cm^2)**	**Area of coral head in 2002 (cm^2)**	**Change in Area (cm^2)**	**% change in coral colony area**	**% Change in Area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change from 2001**
14	1	*Montastraea sp.*	15.04	18.24	3.20	21.30	0.34	27.05	2.83	0.213
	2	*Montastraea sp.*	18.06	24.86	6.80	37.68	0.71			0.377
	3	*Montastraea sp.*	21.91	35.86	13.95	63.66	1.46			0.637
	4	*Montastraea cavernosa*	17.61	20.71	3.10	17.60	0.32			0.176
17	1	*Montastraea sp.*	23.03	30.01	6.98	30.30	0.73	55.67	5.83	0.303
	2	*Diploria strigosa*	14.56	19.30	4.74	32.53	0.50			0.325
	3	*Diploria strigosa*	16.62	30.05	13.42	80.76	1.41			0.808
	4	*Diploria strigosa*	40.29	69.46	29.17	72.40	3.05			0.724
	5	*Montastraea sp.*	14.28	15.64	1.36	9.54	0.14			0.095
20	1	*Montastraea sp.*	73.17	78.57	5.40	7.38	0.57	16.50	1.73	0.074
	2	*Montastraea cavernosa*	26.40	29.25	2.85	10.80	0.30			0.108
	3	*Diploria strigosa*	20.31	23.35	3.04	14.95	0.32			0.149
	4	*Montastraea cavernosa*	26.91	28.05	1.14	4.23	0.12			0.042
	5	*Montastraea sp.*	10.33	14.41	4.08	39.53	0.43			0.395
21	1	*Montastraea sp.*	15.11	15.20	0.09	0.57	0.01	17.91	1.88	0.006
	2	*Montastraea sp.*	26.31	27.63	1.32	5.02	0.14			0.050
	3	*Montastraea sp.*	19.21	17.38	-1.83	-9.51	-0.19			-0.095
	4	*Montastraea cavernosa*	50.63	52.64	2.00	3.96	0.21			0.040
	5	*Montastraea sp.*	45.40	61.73	16.33	35.96	1.71			0.360
22	1	*Montastraea sp.*	11.19	17.18	5.99	53.48	0.63	35.33	3.70	0.535
	2	*Diploria strigosa*	30.71	16.07	-14.64	-47.66	-1.53			-0.477
	3	*Colpophyllia natans*	8.63	12.58	3.95	45.81	0.41			0.458
	4	*Diploria strigosa*	28.49	70.40	41.91	147.10	4.39			1.471
	5	*Montastraea sp.*	42.60	40.73	-1.87	-4.40	-0.20			-0.044
29	1	*Diploria strigosa*	19.95	22.60	2.64	13.25	0.28	5.22	0.55	0.132
	2	*Diploria strigosa*	27.16	27.00	-0.16	-0.61	-0.02			-0.006
	3	*Diploria strigosa*	93.93	95.56	1.63	1.74	0.17			0.017
	4	*Diploria strigosa*	40.81	45.29	4.48	10.98	0.47			0.110
	5	*Diploria strigosa*	16.47	13.10	-3.37	-20.47	-0.35			-0.205
30	1	*Montastraea sp.*	37.04	51.36	14.32	38.67	1.50	27.19	2.85	0.387
	2	*Colpophyllia natans*	44.07	52.26	8.19	18.59	0.86			0.186
	3	*Montastraea cavernosa*	31.00	43.00	12.00	38.70	1.26			0.387
	4	*Diploria strigosa*	41.10	33.77	-7.33	-17.83	-0.77			-0.178
36	1	*Montastraea sp.*	102.90	227.86	124.96	121.44	13.08	112.28	11.76	1.214
	2	*Montastraea sp.*	88.80	94.71	5.92	6.67	0.62			0.067
	3	*Montastraea sp.*	39.78	19.32	-20.46	-51.43	-2.14			-0.514
	4	*Montastraea sp.*	17.10	18.96	1.86	10.87	0.19			0.109
38	1	*Diploria strigosa*	60.67	74.54	13.87	22.86	1.45	49.67	5.20	0.229
	2	*Diploria strigosa*	12.88	16.82	3.94	30.56	0.41			0.306
	3	*Colpophyllia natans*	102.09	108.48	6.39	6.26	0.67			0.063
	4	*Diploria strigosa*	8.71	10.79	2.08	23.86	0.22			0.239
	5	*Diploria strigosa*	25.18	28.26	3.08	12.22	0.32			0.122
	6	*Diploria strigosa*	40.21	60.53	20.32	50.54	2.13			0.505

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

East Bank 2002-2003										
RQS#	Coral Head #	Coral Species Evaluated	Area in 2002 (cm^2)	Area in 2003 (cm^2)	Change in Area (cm^2)	% change in area	% change in coral	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change from 2002
2	1	*Montastraea sp.*	24.82	34.89	10.07	1.05	40.55	25.03	2.62	0.405
	2	*Montastraea sp.*	6.03	12.56	6.53	0.68	108.39			1.084
	3	*Montastraea sp.*	16.80	18.69	1.90	0.20	11.28			0.113
	4	*Montastraea sp.*	11.75	18.29	6.54	0.69	55.70			0.557
7	1	*Montastraea sp.*	29.33	35.07	5.74	0.60	19.57	13.62	1.43	0.196
	2	*Montastraea sp.*	6.11	8.48	2.38	0.25	38.93			0.389
	3	*Porites astreoides*	0.82	0.99	0.17	0.02	20.37			0.204
	4	*Diploria strigosa*	3.21	3.18	-0.02	0.00	-0.73			-0.007
	5	*Diploria strigosa*	2.63	8.00	5.36	0.56	203.57			2.036
9	1	*Montastraea sp.*	20.79	41.25	20.46	2.14	98.40	-7.69	-0.81	0.984
	2	*Montastraea sp.*	70.76	63.91	-6.85	-0.72	-9.68			-0.097
	3	*Montastraea sp.*	89.72	73.70	-16.02	-1.68	-17.85			-0.179
	4	*Montastraea sp.*	39.99	28.82	-11.16	-1.17	-27.92			-0.279
	5	*Montastraea sp.*	121.14	127.02	5.87	0.62	4.85			0.048
11	1	*Diploria strigosa*	10.43	14.65	4.22	0.44	40.44	25.59	2.68	0.404
	2	*Montastraea sp.*	92.82	115.29	22.47	2.35	24.21			0.242
	3	*Montastraea sp.*	41.74	43.58	1.84	0.19	4.41			0.044
	4	*Montastraea sp.*	40.37	37.43	-2.94	-0.31	-7.28			-0.073
12	1	*Porites astreoides*	3.58	3.46	-0.11	-0.01	-3.16	0.20	0.02	-0.032
	2	*Porites astreoides*	3.24	3.69	0.45	0.05	13.92			0.139
	3	*Porites astreoides*	4.77	5.54	0.77	0.08	16.13			0.161
	4	*Diploria strigosa*	2.97	2.90	-0.06	-0.01	-2.18			-0.022
	5	*Diploria strigosa*	14.64	13.80	-0.85	-0.09	-5.79			-0.058
14	1	*Montastraea sp.*	18.24	13.55	-4.69	-0.49	-25.69	-8.46	-0.89	-0.257
	2	*Montastraea sp.*	24.86	32.76	7.90	0.83	31.77			0.318
	3	*Diploria strigosa*	1.56	2.37	0.81	0.08	51.90			0.519
	4	*Montastraea sp.*	35.86	22.81	-13.05	-1.37	-36.40			-0.364
	5	*Montastraea cavernosa*	20.71	21.28	0.57	0.06	2.77			0.028
16	1	*Montastraea sp.*	26.85	33.45	6.60	0.69	24.59	5.04	0.53	0.246
	2	*Montastraea sp.*	25.42	30.93	5.51	0.58	21.65			0.217
	3	*Montastraea sp.*	28.73	23.49	-5.24	-0.55	-18.22			-0.182
	4	*Diploria strigosa*	7.39	5.56	-1.83	-0.19	-24.74			-0.247
17	1	*Montastraea sp.*	30.01	32.46	2.45	0.26	8.16	12.23	1.28	0.082
	2	*Diploria strigosa*	19.30	23.29	3.99	0.42	20.70			0.207
	3	*Diploria strigosa*	30.05	32.59	2.54	0.27	8.47			0.085
	4	*Diploria strigosa*	69.46	69.72	0.26	0.03	0.38			0.004
	5	*Montastraea sp.*	15.64	18.62	2.99	0.31	19.10			0.191
18	1	*Montastraea sp.*	23.42	35.02	11.60	1.21	49.54	13.62	1.43	0.495
	2	*Porites astreoides*	4.89	8.51	3.62	0.38	74.02			0.740
	3	*Porites astreoides*	1.77	2.81	1.04	0.11	58.82			0.588
	4	*Porites astreoides*	2.47	2.20	-0.27	-0.03	-10.76			-0.108
	5	*Montastraea sp.*	4.83	2.46	-2.37	-0.25	-49.08			-0.491
20	1	*Montastraea sp.*	78.57	83.13	4.56	0.48	5.80	18.00	1.88	0.058
	2	*Montastraea cavernosa*	29.25	32.61	3.36	0.35	11.50			0.115
	3	*Diploria strigosa*	23.35	28.95	5.60	0.59	23.98			0.240
	4	*Montastraea cavernosa*	28.05	30.49	2.44	0.26	8.70			0.087
	5	*Montastraea sp.*	14.41	16.44	2.03	0.21	14.11			0.141
21	1	*Montastraea sp.*	15.20	18.47	3.27	0.34	21.52	5.95	0.62	0.215
	2	*Montastraea sp.*	27.63	22.77	-4.86	-0.51	-17.58			-0.176
	3	*Montastraea sp.*	17.38	23.16	5.78	0.61	33.25			0.333
	4	*Montastraea cavernosa*	52.64	52.83	0.20	0.02	0.37			0.004
	5	*Montastraea sp.*	61.73	63.29	1.56	0.16	2.53			0.025
22	1	*Montastraea sp.*	17.18	20.16	2.51	0.26	14.60	35.80	3.75	0.146
	2	*Diploria strigosa*	16.07	12.27	42.32	4.43	263.31			2.633
	3	*Colpophyllia natans*	12.58	36.59	24.01	2.51	190.83			1.908
	4	*Diploria strigosa*	70.40	19.69	-50.71	-5.31	-72.03			-0.720
	5	*Montastraea sp.*	40.73	58.40	17.67	1.85	43.39			0.434

Appendix 4
Repetitive $8m^2$ Quadrat Proportional Change for Selected Coral Heads

East Bank 2002-2003										
RQS#	Coral Head #	Coral Species Evaluated	Area in 2002 (cm^2)	Area in 2003 (cm^2)	Change in Area (cm^2)	% change in area	% change in coral	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change from 2002
25	1	*Montastraea sp.*	195.55	256.45	60.90	6.38	31.14	65.85	6.89	0.311
	2	*Diploria strigosa*	1.46	1.94	0.48	0.05	33.16			0.332
	3	*Montastraea sp.*	0.47	0.60	0.13	0.01	27.21			0.272
	4	*Montastraea sp.*	16.31	20.65	4.34	0.45	26.58			0.266
26	1	*Diploria strigosa*	8.96	9.28	10.75	1.13	119.94	-1.12	-0.12	1.199
	2	*Diploria strigosa*	22.03	21.43	-10.10	-1.06	-45.85			-0.458
	3	*Diploria strigosa*	9.06	8.60	-0.46	-0.05	-5.08			-0.051
	4	*Diploria strigosa*	19.89	19.70	-0.19	-0.02	-0.96			-0.010
	5	*Diploria strigosa*	13.04	11.93	-1.11	-0.12	-8.53			-0.085
29	1	*Diploria strigosa*	22.60	23.47	0.88	0.09	3.87	10.50	1.10	0.039
	2	*Diploria strigosa*	27.00	27.37	0.37	0.04	1.37			0.014
	3	*Diploria strigosa*	95.56	98.37	2.81	0.29	2.94			0.029
	4	*Diploria strigosa*	45.29	48.02	2.74	0.29	6.04			0.060
	5	*Diploria strigosa*	13.10	16.80	3.71	0.39	28.32			0.283
30	1	*Montastraea sp.*	51.36	39.80	-11.56	-1.21	-22.51	-35.17	-3.68	-0.225
	2	*Colpophyllia natans*	52.26	54.66	2.40	0.25	4.58			0.046
	3	*Montastraea cavernosa*	125.86	92.50	-33.36	-3.49	-26.51			-0.265
	4	*Montastraea cavernosa*	43.00	37.97	-5.03	-0.53	-11.70			-0.117
	5	*Diploria strigosa*	33.77	46.15	12.38	1.30	36.67			0.367
31	1	*Montastraea sp.*	62.90	89.86	26.96	2.82	42.87	33.84	3.54	0.429
	2	*Diploria strigosa*	10.63	12.11	1.48	0.15	13.87			0.139
	3	*Montastraea sp.*	95.56	100.82	5.26	0.55	5.51			0.055
	4	*Diploria strigosa*	6.80	8.10	1.30	0.14	19.11			0.191
	5	*Diploria strigosa*	19.85	18.68	-1.16	-0.12	-5.87			-0.059
32	1	*Montastraea sp.*	10.84	11.95	1.11	0.12	10.23	30.97	3.24	0.102
	2	*Diploria strigosa*	14.89	20.41	5.52	0.58	37.09			0.371
	3	*Montastraea sp.*	2.16	2.47	0.31	0.03	14.46			0.145
	4	*Montastraea sp.*	214.12	238.14	24.02	2.51	11.22			0.112
36	1	*Montastraea sp.*	227.86	212.13	-15.73	-1.65	-6.90	0.59	0.06	-0.069
	2	*Montastraea sp.*	94.71	98.58	3.87	0.41	4.08			0.041
	3	*Montastraea sp.*	19.32	32.86	13.54	1.42	70.06			0.701
	4	*Montastraea sp.*	18.96	17.87	-1.09	-0.11	-5.74			-0.057
38	1	*Diploria strigosa*	74.54	65.91	-8.63	-0.90	-11.58	1.30	0.00	-0.116
	2	*Diploria strigosa*	16.82	16.04	-0.78	-0.08	-4.63			-0.046
	3	*Colpophyllia natans*	108.48	108.25	-0.24	-0.03	-0.22			-0.002
	4	*Diploria strigosa*	10.79	10.06	-0.73	-0.08	-6.73			-0.067
	5	*Diploria strigosa*	28.26	26.61	-1.65	-0.17	-5.82			-0.058
	6	*Diploria strigosa*	60.53	65.22	4.69	0.49	7.75			0.077

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

West Bank 2001-2002										
RQS #	Coral Head #	Species	Area of coral head in 2001 (cm^2)	Area of coral head in 2002 (cm^2)	Change in Area (cm^2)	% change in coral colony area	% Change in Area	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change from 2001
2	1	*Diploria strigosa*	11.52	12.99	1.48	12.81	0.15	16.00	1.68	0.128
	2	*Diploria strigosa*	19.10	21.80	2.70	14.16	0.28			0.142
	3	*Diploria strigosa*	7.50	7.07	-0.43	-5.78	-0.05			-0.058
	4	*Diploria strigosa*	15.92	14.65	-1.28	-8.02	-0.13			-0.080
	5	*Diploria strigosa*	13.67	9.91	-3.77	-27.55	-0.39			-0.275
	6	*Montastraea cavernosa*	21.28	38.57	17.30	81.30	1.81			0.813
4	1	*Diploria strigosa*	25.59	18.81	-6.78	-26.50	-0.71	-10.86	-1.14	-0.265
	2	*Diploria strigosa*	25.70	22.06	-3.64	-14.18	-0.38			-0.142
	3	*Diploria strigosa*	4.98	4.29	-0.68	-13.76	-0.07			-0.138
	4	*Diploria strigosa*	16.12	15.88	-0.24	-1.49	-0.03			-0.015
	5	*Montastraea sp.*	4.86	5.35	0.49	10.06	0.05			0.101
5	1	*Diploria strigosa*	4.59	5.52	0.93	20.23	0.10	39.63	4.15	0.202
	2	*Diploria strigosa*	22.73	24.53	1.80	7.92	0.19			0.079
	3	*Diploria strigosa*	22.95	20.74	-2.21	-9.63	-0.23			-0.096
	4	*Diploria strigosa*	27.47	31.16	3.68	13.41	0.39			0.134
	5	*Montastraea sp.*	18.32	53.74	35.42	193.41	3.71			1.934
6	1	*Montastraea sp.*	74.70	69.68	-5.02	-6.73	-0.53	18.83	1.97	-0.067
	2	*Montastraea sp.*	5.39	6.55	1.16	21.47	0.12			0.215
	3	*Montastraea sp.*	34.96	54.60	19.64	56.16	2.06			0.562
	4	*Diploria strigosa*	6.35	7.74	1.39	21.97	0.15			0.220
	5	*Diploria strigosa*	7.41	9.07	1.66	22.47	0.17			0.225
7	1	*Siderastrea siderea*	59.09	62.66	3.57	6.04	0.37	-6.43	-0.67	0.060
	2	*Diploria strigosa*	9.23	9.13	-0.09	-1.01	-0.01			-0.010
	3	*Siderastrea siderea*	4.63	4.40	-0.23	-5.03	-0.02			-0.050
	4	*Diploria strigosa*	72.05	68.46	-3.59	-4.98	-0.38			-0.050
	5	*Siderastrea siderea*	46.92	40.83	-6.09	-12.98	-0.64			-0.130
8	1	*Mussa angulosa*	3.50	3.35	-0.15	-4.30	-0.02	-11.20	-1.17	-0.043
	2	Montastraea sp. (dead)	2.39	1.95	-0.45	-18.62	-0.05			-0.186
	3	*Montastraea sp.*	2.17	1.18	-0.99	-45.74	-0.10			-0.457
	4	*Madracis decactis*	3.99	2.61	-1.38	-34.61	-0.14			-0.346
	5	*Montastraea sp.*	18.94	10.71	-8.23	-43.47	-0.86			-0.435
9	1	*Diploria strigosa*	7.19	4.39	-2.80	-38.98	-0.29	-25.42	-2.66	-0.390
	2	*Montastraea sp.*	213.91	193.12	-20.80	-9.72	-2.18			-0.097
	3	*Diploria strigosa*	4.48	6.59	2.11	47.17	0.22			0.472
	4	*Montastraea sp.*	39.41	37.21	-2.20	-5.59	-0.23			-0.056
	5	*Diploria strigosa*	7.20	5.46	-1.74	-24.10	-0.18			-0.241
11	1	*Porites astreoides*	3.99	3.49	-0.50	-12.52	-0.05	0.15	0.02	-0.125
	2	*Porites astreoides*	5.26	5.71	0.45	8.54	0.05			0.085
	3	*Porites astreoides*	3.06	3.00	-0.06	-2.00	-0.01			-0.020
	4	*Montastraea sp.*	3.43	3.79	0.36	10.61	0.04			0.106
	5	*Porites astreoides*	4.73	3.96	-0.77	-16.24	-0.08			-0.162
	6	*Porites astreoides*	3.32	3.99	0.67	20.17	0.07			0.202
12	1	*Diploria strigosa*	11.15	11.73	0.57	5.14	0.06	6.84	0.72	0.051
	2	*Colpophyllia natans*	30.12	33.87	3.76	12.47	0.39			0.125
	3	*Diploria strigosa*	34.45	32.07	-2.38	-6.92	-0.25			-0.069
	4	*Porites astreoides*	5.46	10.35	4.89	89.72	0.51			0.897
14	1	*Diploria strigosa*	45.62	47.45	1.82	4.00	0.19	38.17	4.00	0.040
	2	*Montastraea cavernosa*	47.12	54.76	7.64	16.21	0.80			0.162
	3	*Diploria strigosa*	5.26	6.30	1.04	19.88	0.11			0.199
	4	*Diploria strigosa*	3.81	4.53	0.73	19.05	0.08			0.191
	5	*Colpophyllia natans*	82.12	109.06	26.94	32.81	2.82			0.328
15	1	*Montastraea sp.*	66.19	80.94	14.75	22.28	1.54	16.80	1.76	0.223
	2	*Montastraea sp.*	6.75	6.50	-0.25	-3.75	-0.03			-0.038
	3	*Montastraea sp.*	12.99	12.53	-0.46	-3.55	-0.05			-0.036
	4	*Montastraea sp.*	22.41	25.10	2.69	11.99	0.28			0.120
	5	*Montastraea sp.*	52.95	53.03	0.08	0.16	0.01			0.002
16	1	*Montastraea sp.*	71.49	67.33	-4.16	-5.83	-0.44	-1.37	-0.14	-0.058
	2	*Diploria strigosa*	3.03	4.05	1.03	33.85	0.11			0.339
	3	*Montastraea sp.*	2.48	3.30	0.82	32.97	0.09			0.330
	4	*Montastraea cavernosa*	25.84	26.55	0.71	2.73	0.07			0.027
	5	*Porites astreoides*	3.90	4.15	0.25	6.36	0.03			0.064

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

West Bank 2001-2002										
RQS #	**Coral Head #**	**Species**	**Area of coral head in 2001 (cm^2)**	**Area of coral head in 2002 (cm^2)**	**Change in Area (cm^2)**	**% change in coral colony area**	**% Change in Area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change from 2001**
19	1	*Montastraea sp.*	52.38	52.14	-0.25	-0.47	-0.03	-0.19	-0.02	-0.005
	2	*Montastraea sp.*	2.28	2.18	-0.10	-4.34	-0.01			-0.043
	3	*Diploria strigosa*	7.34	8.67	1.33	18.07	0.14			0.181
	4	*Diploria strigosa*	28.92	27.74	-1.17	-4.06	-0.12			-0.041

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

West Bank 2002-2003										
RQS#	Coral Head #	Coral Species Evaluated	Area in 2002 (cm^2)	Area in 2003 (cm^2)	Change in Area (cm^2)	% change in area	% change in coral	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change from 2002
2	1	*Diploria strigosa*	12.99	11.90	-1.09	-0.11	-8.40	2.88	0.30	-0.084
	2	*Diploria strigosa*	21.80	22.03	0.22	0.02	1.03			0.010
	3	*Diploria strigosa*	7.07	8.06	0.99	0.10	14.07			0.141
	4	*Diploria strigosa*	14.65	19.50	4.86	0.51	33.16			0.332
	5	*Diploria strigosa*	9.91	13.60	3.69	0.39	37.27			0.373
	6	*Montastraea cavernosa*	38.57	32.78	-5.79	-0.61	-15.02			-0.150
4	1	*Diploria strigosa*	18.81	22.73	3.92	0.41	20.84	10.01	1.05	0.208
	2	*Diploria strigosa*	22.06	25.55	3.49	0.37	15.83			0.158
	3	*Diploria strigosa*	4.29	4.57	0.28	0.03	6.54			0.065
	4	*Diploria strigosa*	15.88	17.72	1.84	0.19	11.61			0.116
	5	*Montastraea sp.*	5.35	5.82	0.47	0.05	8.88			0.089
5	1	*Diploria strigosa*	5.52	5.27	-0.26	2.65	-4.64	-10.43	10.83	-0.046
	2	*Diploria strigosa*	24.53	25.31	0.78	2.49	3.17			0.032
	3	*Diploria strigosa*	20.74	23.76	3.02	3.53	14.56			0.146
	4	*Diploria strigosa*	31.16	33.75	2.59	3.89	8.30			0.083
	5	*Montastraea sp.*	53.74	37.18	-16.56	-1.73	-30.81			-0.308
6	1	*Montastraea sp.*	69.68	71.53	1.85	0.19	2.66	-5.35	-0.56	0.027
	2	*Montastraea sp.*	6.55	7.71	1.16	0.12	17.70			0.177
	3	*Montastraea sp.*	54.60	47.61	-6.99	-0.73	-12.80			-0.128
	4	*Diploria strigosa*	7.74	8.12	0.37	0.04	4.81			0.048
	5	*Diploria strigosa*	9.07	7.32	-1.75	-0.18	-19.27			-0.193
7	1	*Siderastrea siderea*	62.66	65.85	3.19	0.33	5.10	26.87	2.81	0.051
	2	*Diploria strigosa*	9.13	9.88	0.74	0.08	8.15			0.082
	3	*Siderastrea siderea*	4.40	5.42	1.02	0.11	23.26			0.233
	4	*Diploria strigosa*	68.46	81.66	13.20	1.38	19.28			0.193
	5	*Siderastrea siderea*	40.83	49.54	8.71	0.91	21.33			0.213
8	1	*Mussa angulosa*	3.35	8.92	5.57	0.58	166.11	21.52	2.25	1.661
	2	*Montastraea sp.(dead)*	1.95	2.32	0.37	0.04	19.16			0.192
	3	*Montastraea sp.*	1.18	2.55	1.37	0.14	116.91			1.169
	4	*Madracis decactis*	2.61	5.06	2.45	0.26	94.14			0.941
	5	*Montastraea sp.*	10.71	22.45	11.74	1.23	109.68			1.097
9	1	*Diploria strigosa*	4.39	4.07	-0.32	-0.03	-7.23	25.47	2.67	-0.072
	2	*Montastraea sp.*	193.12	206.63	13.51	1.41	7.00			0.070
	3	*Diploria strigosa*	6.59	6.03	-0.56	-0.06	-8.47			-0.085
	4	*Montastraea sp.*	37.21	47.28	10.07	1.05	27.07			0.271
	5	*Diploria strigosa*	5.46	8.22	2.76	0.29	50.52			0.505
11	1	*Porites astreoides*	3.49	4.61	1.12	0.12	31.99	3.69	0.39	0.320
	2	*Porites astreoides*	5.71	6.44	0.73	0.08	12.70			0.127
	3	*Porites astreoides*	3.00	3.78	0.78	0.08	25.94			0.259
	4	*Montastraea sp.*	3.79	4.30	0.51	0.05	13.41			0.134
	5	*Porites astreoides*	3.96	4.14	0.18	0.02	4.59			0.046
	6	*Porites astreoides*	3.99	4.37	0.38	0.04	9.60			0.096
12	1	*Diploria strigosa*	11.73	11.71	-0.01	0.00	-0.11	3.28	0.34	-0.001
	2	*Colpophyllia natans*	33.87	32.05	-1.82	-0.19	-5.37			-0.054
	3	*Diploria strigosa*	32.07	37.69	5.62	0.59	17.54			0.175
	4	*Porites astreoides*	10.35	9.84	-0.51	-0.05	-4.91			-0.049
14	1	*Montastraea sp.*	73.52	71.76	-1.76	-0.18	-2.40	9.99	1.05	-0.024
	2	*Colpophyllia natans*	54.93	52.26	-2.66	-0.28	-4.85			-0.048
	3	*Montastraea sp.*	8.05	20.45	12.39	1.30	153.88			1.539
	4	*Diploria strigosa*	9.73	10.29	0.55	0.06	5.70			0.057
	5	*Montastraea sp.*	42.50	43.97	1.47	0.15	3.46			0.035
14	1	*Diploria strigosa*	47.45	50.96	3.52	0.37	7.41	-2.85	-0.30	0.074
	2	*Montastraea cavernosa*	54.76	50.14	-4.62	-0.48	-8.44			-0.084
	3	*Diploria strigosa*	6.30	6.52	0.22	0.02	3.46			0.035
	4	*Diploria strigosa*	4.53	4.38	-0.15	-0.02	-3.37			-0.034
	5	*Colpophyllia natans*	109.06	97.98	-11.09	-1.16	-10.17			-0.102
	6	*Diploria strigosa*	30.69	39.96	9.27	0.97	30.22			0.302
15	1	*Montastraea sp.*	80.94	66.48	-14.46	-1.51	-17.87	-5.14	-0.54	-0.179
	2	*Montastraea sp.*	6.50	6.74	0.24	0.03	3.77			0.038
	3	*Montastraea sp.*	12.53	14.52	1.99	0.21	15.91			0.159
	4	*Montastraea sp.*	25.10	29.15	4.05	0.42	16.13			0.161
	5	*Montastraea sp.*	53.03	56.06	3.03	0.32	5.72			0.057

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

West Bank 2002-2003										
RQS#	Coral Head #	Coral Species Evaluated	Area in 2002 (cm^2)	Area in 2003 (cm^2)	Change in Area (cm^2)	% change in area	% change in coral	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change from 2002
16	1	*Montastraea sp.*	67.33	74.08	6.75	0.71	10.03	7.77	0.27	0.100
	2	*Diploria strigosa*	4.05	4.06	0.01	0.00	0.23			0.002
	3	*Montastraea sp.*	3.30	3.48	0.18	0.02	5.58			0.056
	4	*Montastraea cavernosa*	26.55	27.15	0.60	0.06	2.28			0.023
	5	*Porites astreoides*	4.15	4.38	0.22	0.02	5.38			0.054
17	1	*Montastraea sp.*	29.54	24.34	-5.20	-0.54	-17.60	-10.07	-1.05	-0.176
	2	*Diploria strigosa*	38.22	37.62	-0.60	-0.06	-1.57			-0.016
	3	*Porites astreoides*	61.99	63.31	1.32	0.14	2.13			0.021
	4	*Porites astreoides*	36.69	29.57	-7.12	-0.75	-19.40			-0.194
	5	*Porites astreoides*	6.60	8.12	1.52	0.16	22.98			0.230
	6	*Porites astreoides*	4.72	4.73	0.01	0.00	0.16			0.002
18	1	*Porites astreoides*	3.44	4.55	1.11	0.12	32.16	-8.06	-0.84	0.322
	2	*Diploria strigosa*	8.69	12.43	3.74	0.39	43.08			0.431
	3	*Porites astreoides*	24.87	12.04	-12.83	-1.34	-51.61			-0.516
	4	*Porites astreoides*	3.98	3.90	-0.07	-0.01	-1.85			-0.018
19	1	*Montastraea sp.*	52.14	55.14	3.00	0.31	5.76	7.35	0.77	0.058
	2	*Montastraea sp.*	2.18	2.35	0.17	0.02	7.87			0.079
	3	*Diploria strigosa*	8.67	9.40	0.73	0.08	8.43			0.084
	4	*Diploria strigosa*	27.74	31.18	3.44	0.36	12.41			0.124
20	1	*Montastraea sp.*	18.36	19.39	1.03	0.11	5.61	16.29	1.71	0.056
	2	*Montastraea sp.*	14.56	12.24	-2.32	-0.24	-15.91			-0.159
	3	*Diploria strigosa*	11.16	19.66	8.51	0.89	76.22			0.762
	4	*Diploria strigosa*	18.70	25.61	6.91	0.72	36.96			0.370
	5	*Montastraea sp.*	5.66	7.82	2.16	0.23	38.10			0.381
22	1	*Diploria strigosa*	3.45	3.18	-0.27	-0.03	-7.85	21.33	2.23	-0.079
	2	*Montastraea sp.*	11.89	12.54	0.65	0.07	5.49			0.055
	3	*Diploria strigosa*	8.09	10.90	2.81	0.29	34.72			0.347
	4	*Montastraea sp.*	67.30	84.34	17.04	1.78	25.32			0.253
	5	*Diploria strigosa*	2.08	3.18	1.10	0.11	52.63			0.526
23	1	*Montastraea sp.*	12.37	10.18	-2.19	-0.23	-17.74	-19.95	-2.09	-0.177
	2	*Montastraea sp.*	76.78	61.27	-15.51	-1.62	-20.20			-0.202
	3	*Diploria strigosa*	3.75	3.59	-0.16	-0.02	-4.27			-0.043
	4	*Diploria strigosa*	12.99	10.90	-2.08	-0.22	-16.04			-0.160
24	1	*Montastraea cavernosa*	143.58	149.29	5.71	0.60	3.98	5.13	0.54	0.040
	2	*Montastraea sp.*	21.94	20.54	-1.40	-0.15	-6.39			-0.064
	3	*Diploria strigosa*	14.23	13.42	-0.82	-0.09	-5.75			-0.057
	4	*Montastraea sp.*	16.45	17.12	0.67	0.07	4.05			0.041
	5	*Montastraea cavernosa*	24.62	25.60	0.98	0.10	3.97			0.040
25	1	*Montastraea cavernosa*	26.53	31.06	4.53	0.47	17.09	15.54	1.63	0.171
	2	*Diploria strigosa*	95.20	104.58	9.38	0.98	9.86			0.099
	3	*Montastraea sp.*	33.70	34.68	0.98	0.10	2.91			0.029
	4	*Porites astreoides*	3.17	3.30	0.13	0.01	4.20			0.042
	5	*Montastraea sp.*	14.02	14.52	0.50	0.05	3.60			0.036
26	1	*Diploria strigosa*	31.45	14.99	-16.46	-1.72	-52.33	-23.22	-2.43	-0.523
	2	*Montastraea sp.*	46.44	45.21	-1.23	-0.13	-2.64			-0.026
	3	*Montastraea sp.*	51.04	42.38	-8.66	-0.91	-16.96			-0.170
	4	*Montastraea sp.*	9.44	9.74	0.30	0.03	3.20			0.032
	5	*Diploria strigosa*	20.92	23.74	2.82	0.30	13.48			0.135
28	1	*Colpophyllia natans*	21.19	20.47	-0.73	-0.08	-3.42	6.46	0.68	-0.034
	2	*Diploria strigosa*	5.24	5.32	0.09	0.01	1.64			0.016
	3	*Colpophyllia natans*	14.53	14.77	0.24	0.03	1.66			0.017
	4	*Montastraea sp.*	39.82	47.39	7.57	0.79	19.01			0.190
	5	*Diploria strigosa*	7.10	6.39	-0.71	-0.07	-9.96			-0.100
29	1	*Diploria strigosa*	6.87	7.41	0.54	0.06	7.89	0.03	0.00	0.079
	2	*Montastraea sp.*	73.96	72.64	-1.31	-0.14	-1.78			-0.018
	3	*Diploria strigosa*	4.07	4.87	0.80	0.08	19.66			0.197
	4	*Diploria strigosa*	4.80	4.80	0.01	0.00	0.11			0.001
	5	*Diploria strigosa*	12.09	12.08	0.00	0.00	-0.02			0.000
31	1	*Montastraea sp.*	12.95	16.08	3.13	0.33	24.16	6.60	0.69	0.242
	2	*Diploria strigosa*	7.96	8.03	0.06	0.01	0.79			0.008
	3	*Montastraea sp.*	40.26	39.82	-0.44	-0.05	-1.09			-0.011
	4	*Montastraea sp.*	36.66	38.88	2.21	0.23	6.04			0.060
	5	*Montastraea sp.*	13.02	14.65	1.63	0.17	12.52			0.125

Appendix 4

Repetitive 8m^2 Quadrat Proportional Change for Selected Coral Heads

West Bank 2002-2003										
RQS#	**Coral Head #**	**Coral Species Evaluated**	**Area in 2002 (cm^2)**	**Area in 2003 (cm^2)**	**Change in Area (cm^2)**	**% change in area**	**% change in coral**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change from 2002**
36	1	*Montastraea sp.*	29.35	31.40	2.04	0.21	6.96	37.18	3.89	0.070
	2	*Montastraea sp.*	149.72	177.56	27.84	2.92	18.60			0.186
	3	*Madracis decactis*	5.92	6.54	0.62	0.07	10.51			0.105
	4	*Diploria strigosa*	64.61	63.35	-1.25	-0.13	-1.94			-0.019
	5	*Diploria strigosa*	12.36	20.29	7.93	0.83	64.14			0.641
37	1	*Colpophyllia natans*	47.03	49.39	2.36	0.25	5.01	-16.83	-1.76	0.050
	2	*Montastraea sp.*	37.10	30.23	-6.86	-0.72	-18.50			-0.185
	3	*Diploria strigosa*	42.89	34.09	-8.80	-0.92	-20.52			-0.205
	4	*Colpophyllia natans*	18.07	14.55	-3.52	-0.37	-19.47			-0.195
64	1	*Montastraea sp.*	90.14	65.14	-25.00	-2.62	-27.74	-22.93	-2.40	-0.277
	2	*Diploria strigosa*	33.12	33.03	-0.09	-0.01	-0.28			-0.003
	3	*Montastraea sp.*	25.88	26.02	0.15	0.02	0.56			0.006
	4	*Diploria strigosa*	20.96	18.48	-2.48	-0.26	-11.82			-0.118
	5	*Diploria strigosa*	2.71	7.21	4.50	0.47	165.85			1.659
64	1	*Montastraea sp.*	23.20	29.84	6.63	0.69	28.59	10.12	1.06	0.286
	2	*Diploria strigosa*	24.97	26.92	1.95	0.20	7.81			0.078
	3	*Diploria strigosa*	6.47	6.44	-0.03	0.00	-0.50			-0.005
	4	*Diploria strigosa*	4.46	5.76	1.30	0.14	29.19			0.292
	5	*Diploria strigosa*	1.09	1.35	0.26	0.03	24.32			0.243
92	1	*Diploria strigosa*	9.24	13.73	4.49	0.47	48.57	7.14	0.75	0.486
	2	*Diploria strigosa*	28.20	39.38	11.18	1.17	39.66			0.397
	3	*Montastraea sp.*	52.75	43.44	-9.31	-0.97	-17.65			-0.177
	4	*Montastraea sp.*	13.52	14.30	0.78	0.08	5.78			0.058
UNK1	1	*Montastraea sp.*	17.92	21.46	3.54	0.37	19.76	9.68	1.01	0.198
	2	*Montastraea sp.*	41.09	45.37	4.29	0.45	10.43			0.104
	3	*Montastraea sp.*	13.05	13.21	0.16	0.02	1.24			0.012
	4	*Montastraea sp.*	76.47	79.40	2.93	0.31	3.83			0.038
	5	*Diploria strigosa*	5.92	4.69	-1.24	-0.13	-20.90			-0.209
UNK2	1	*Montastraea sp.*	3.02	3.19	0.17	0.02	5.69	1.39	0.15	0.057
	2	*Diploria strigosa*	14.08	15.24	1.16	0.12	8.23			0.082
	3	*Diploria strigosa*	9.33	8.21	-1.12	-0.12	-11.98			-0.120
	4	*Diploria strigosa*	9.05	10.22	1.17	0.12	12.97			0.130
UNK3	1	*Montastraea cavernosa*	86.69	88.76	2.06	0.22	2.38	21.39	2.24	0.024
	2	*Diploria strigosa*	1.54	2.01	0.47	0.05	30.67			0.307
	3	*Montastraea cavernosa*	63.41	81.36	17.95	1.88	28.31			0.283
	4	*Diploria strigosa*	9.46	10.36	0.90	0.09	9.50			0.095

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Statistic	Depth (m)	Temp (℃)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	min	22.96	18.94	35.46	8.26	6.13	0.03	2.73
EFGB	max	23.89	31.18	35.89	8.27	7.32	79.02	72.44
EFGB	mean	23.23	23.64	35.76	8.26	6.64	11.39	26.36
EFGB	SE	0.01	0.21	0.03	0.00	0.05	0.94	1.55
EFGB	n	219	219	16	2	32	218	149

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (℃)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	10/29/2002	23.12	26.29	35.66	8.27	6.63	6.20	4.80
EFGB	10/30/2002	23.28	26.31	35.80	8.26	6.13	5.36	72.44
EFGB	10/31/2002	23.29	26.19	35.83		6.43	5.07	61.09
EFGB	11/1/2002	23.30	25.96	35.78		6.44	5.02	40.14
EFGB	11/2/2002	23.30	25.87	35.89		6.43	5.03	36.12
EFGB	11/3/2002	23.31	25.88	35.78		6.37	5.01	29.99
EFGB	11/4/2002	23.24	26.00	35.71		6.25	5.01	48.06
EFGB	11/5/2002	23.28	26.09	35.73		6.40	4.99	22.76
EFGB	11/6/2002	23.19	25.86	35.78		6.75	5.02	70.50
EFGB	11/7/2002	23.22	25.87	35.73		6.88	5.00	70.26
EFGB	11/8/2002	23.23	25.73	35.84		6.83	5.04	40.48
EFGB	11/9/2002	23.22	25.61	35.86		6.87	5.10	62.93
EFGB	11/10/2002	23.22	25.68	35.82		6.81	5.13	55.74
EFGB	11/11/2002	23.22	25.89	35.73		6.74	5.11	40.12
EFGB	11/12/2002	23.20	26.48	35.46		6.57	5.13	56.74
EFGB	11/13/2002	23.25	26.53	35.85		6.83	5.14	60.78
EFGB	11/14/2002	23.22	26.17			6.73	5.23	43.11
EFGB	11/15/2002	23.21	25.58			6.43	5.29	12.17
EFGB	11/16/2002	23.18	25.19			6.72	5.19	45.90
EFGB	11/17/2002	23.17	25.02			7.03	5.25	47.58
EFGB	11/18/2002	23.20	25.13			6.76	5.40	41.23
EFGB	11/19/2002	23.14	25.33			6.51	5.26	16.43
EFGB	11/20/2002	23.14	25.31			6.55	5.29	18.94
EFGB	11/21/2002	23.10	25.02			7.12	5.37	48.44
EFGB	11/22/2002	23.13	24.87			7.12	5.68	48.83
EFGB	11/23/2002	23.10	24.43			7.32	6.03	45.48
EFGB	11/24/2002	23.13	24.59			6.86	6.84	41.74
EFGB	11/25/2002	23.15	25.23			6.66	7.20	51.55
EFGB	11/26/2002	23.16	25.19			6.50	7.67	34.98
EFGB	11/27/2002	23.19	25.41			6.19	12.52	8.30
EFGB	11/28/2002	23.18	25.80			6.40	5.48	22.81
EFGB	11/29/2002	23.19	25.03			6.13	6.00	34.47
EFGB	11/30/2002	23.22	25.13				6.02	10.35
EFGB	12/1/2002	23.16	25.11				6.15	35.62
EFGB	12/2/2002	23.15	24.82				5.58	19.38
EFGB	12/3/2002	23.13	23.98				5.53	14.79
EFGB	12/4/2002	23.15	24.31				5.54	20.37

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	12/5/2002	23.10	24.30				5.45	4.88
EFGB	12/6/2002	23.15	24.39				5.45	29.49
EFGB	12/7/2002	23.16	24.28				5.44	16.33
EFGB	12/8/2002	23.16	25.00				5.55	17.73
EFGB	12/9/2002	23.19	24.83				5.56	6.53
EFGB	12/10/2002	23.19	23.13				5.38	3.88
EFGB	12/11/2002	23.20	24.38				5.36	18.24
EFGB	12/12/2002	23.23	27.88				5.48	7.87
EFGB	12/13/2002	23.34	31.18				5.60	22.43
EFGB	12/14/2002	23.16	25.22				5.49	16.86
EFGB	12/15/2002	23.17	24.42				5.60	12.74
EFGB	12/16/2002	23.16	24.90				5.72	12.44
EFGB	12/17/2002	23.15	24.97				5.68	18.41
EFGB	12/18/2002	23.17	25.69				5.62	20.77
EFGB	12/19/2002	23.16	24.22				5.46	17.04
EFGB	12/20/2002	23.12	23.78				5.39	26.56
EFGB	12/21/2002	23.14	23.46				5.44	10.54
EFGB	12/22/2002	23.16	24.75				5.61	21.44
EFGB	12/23/2002	23.14	24.14				6.44	10.51
EFGB	12/24/2002	23.16	22.90				5.53	8.71
EFGB	12/25/2002	23.12	22.58				5.63	10.47
EFGB	12/26/2002	23.16	22.70				5.58	7.86
EFGB	12/27/2002	23.17	22.42				5.61	5.19
EFGB	12/28/2002	23.17	21.53				5.66	11.17
EFGB	12/29/2002	23.17	21.49				5.67	13.43
EFGB	12/30/2002	23.22	22.99				5.75	8.96
EFGB	12/31/2002	23.17	22.47				5.82	10.68
EFGB	1/1/2003	23.12	22.48				5.56	17.22
EFGB	1/2/2003	23.10	20.39				5.64	14.23
EFGB	1/3/2003	23.11	21.01				5.63	14.64
EFGB	1/4/2003	23.12	20.76				5.72	14.76
EFGB	1/5/2003	23.10	20.36				5.71	13.26
EFGB	1/6/2003	23.13	20.79				5.49	17.38
EFGB	1/7/2003	23.11	20.39				5.54	18.86
EFGB	1/8/2003	23.10	20.19				5.47	19.27
EFGB	1/9/2003	23.13	20.03				5.45	11.46
EFGB	1/10/2003	23.11	20.00				5.44	17.54
EFGB	1/11/2003	23.13	19.91				5.47	4.54
EFGB	1/12/2003	23.12	19.38				5.94	3.34
EFGB	1/13/2003	23.25	19.35				5.55	13.40
EFGB	1/14/2003	23.11	19.64				5.53	4.99
EFGB	1/15/2003	23.17	19.95				5.58	7.54
EFGB	1/16/2003	23.13	19.63				5.59	16.29
EFGB	1/17/2003	23.18	19.61				5.55	11.45
EFGB	1/18/2003	23.15	19.49				5.53	20.45
EFGB	1/19/2003	23.11	19.49				5.54	20.62
EFGB	1/20/2003	23.10	19.52				5.50	15.37
EFGB	1/21/2003	23.09	19.68				5.51	11.86

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	1/22/2003	23.14	20.96				5.55	8.12
EFGB	1/23/2003	23.20	21.43				5.97	8.65
EFGB	1/24/2003	23.13	19.90				5.55	10.62
EFGB	1/25/2003	23.16	20.13				5.60	10.66
EFGB	1/26/2003	23.15	19.92				5.70	3.89
EFGB	1/27/2003	23.13	20.58				5.60	6.59
EFGB	1/28/2003	23.16	20.23				5.60	13.75
EFGB	1/29/2003	23.12	19.67				5.56	24.23
EFGB	1/30/2003	23.09	19.59				5.42	8.45
EFGB	1/31/2003	23.08	19.63				5.36	15.74
EFGB	2/1/2003	23.10	19.66				5.37	19.90
EFGB	2/2/2003	23.12	19.66				6.47	17.76
EFGB	2/3/2003	23.18	20.12				5.41	13.27
EFGB	2/4/2003	23.17	20.15				5.41	21.99
EFGB	2/5/2003	23.14	19.43				5.42	13.60
EFGB	2/6/2003	23.15	19.46				5.42	9.92
EFGB	2/7/2003	23.15	19.42				6.51	2.73
EFGB	2/8/2003	23.16	21.28				12.44	3.70
EFGB	2/9/2003	23.16	20.06				31.21	10.16
EFGB	2/10/2003	23.12	19.97				29.10	30.32
EFGB	2/11/2003	23.10	19.90				29.78	31.79
EFGB	2/12/2003	23.17	20.05				22.48	18.88
EFGB	2/13/2003	23.17	20.03				5.75	23.93
EFGB	2/14/2003	23.11	19.95				5.95	34.64
EFGB	2/15/2003	23.14	19.88				5.62	6.30
EFGB	2/16/2003	23.12	19.62				5.64	5.48
EFGB	2/17/2003	23.08	19.01				5.70	37.23
EFGB	2/18/2003	23.18	18.94				6.29	28.09
EFGB	2/19/2003	23.14	19.88				8.92	46.13
EFGB	2/20/2003	23.08	19.94				8.79	30.98
EFGB	2/21/2003	23.10	19.97				8.80	17.25
EFGB	2/22/2003	23.19	20.19				8.78	50.03
EFGB	2/23/2003	23.17	19.81				8.69	69.41
EFGB	2/24/2003	23.17	19.84				8.79	59.11
EFGB	2/25/2003	23.11	19.76				8.64	24.04
EFGB	2/26/2003	23.02	19.74				8.72	24.34
EFGB	2/27/2003	22.99	19.53				9.23	11.28
EFGB	2/28/2003	22.96	19.46				8.70	13.43
EFGB	3/1/2003	23.14	19.57				8.69	19.34
EFGB	3/2/2003	23.18	19.73				8.76	21.50
EFGB	3/3/2003	23.19	20.05				8.71	7.41
EFGB	3/4/2003	23.15	20.00				8.68	39.10
EFGB	3/5/2003	23.13	19.91				8.71	37.24
EFGB	3/6/2003	23.13	19.89				8.70	10.65
EFGB	3/7/2003	23.15	20.06				8.70	18.76
EFGB	3/8/2003	23.14	19.93				8.74	19.39
EFGB	3/9/2003	23.17	20.45				8.66	42.28
EFGB	3/10/2003	23.19	20.50				8.68	42.05

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	3/11/2003	23.17	20.37				8.67	22.55
EFGB	3/12/2003	23.18	20.44				8.64	41.14
EFGB	3/13/2003	23.11	20.50				8.62	50.72
EFGB	3/14/2003	23.09	20.57				8.61	67.23
EFGB	3/15/2003	23.09	20.65				8.61	38.98
EFGB	3/16/2003	23.14	20.78				8.78	32.85
EFGB	3/17/2003	23.11	20.78				8.61	70.55
EFGB	3/18/2003	23.07	20.94				8.61	67.55
EFGB	3/19/2003	23.18	20.36				8.69	56.67
EFGB	3/20/2003	23.13	20.95				8.73	55.89
EFGB	3/21/2003	23.11	20.68				8.98	65.83
EFGB	3/22/2003	23.12	20.60				8.91	67.15
EFGB	3/23/2003	23.07	20.55				8.97	57.05
EFGB	3/24/2003	23.10	20.51				8.84	58.41
EFGB	3/25/2003	23.06	20.59				8.79	19.17
EFGB	3/26/2003	23.05	20.43				8.74	16.05
EFGB	3/27/2003							
EFGB	3/28/2003							
EFGB	3/29/2003							
EFGB	3/30/2003							
EFGB	3/31/2003							
EFGB	4/1/2003							
EFGB	4/2/2003							
EFGB	4/3/2003							
EFGB	4/4/2003							
EFGB	4/5/2003							
EFGB	4/6/2003							
EFGB	4/7/2003							
EFGB	4/8/2003							
EFGB	4/9/2003							
EFGB	4/10/2003							
EFGB	4/11/2003							
EFGB	4/12/2003							
EFGB	4/13/2003							
EFGB	4/14/2003							
EFGB	4/15/2003							
EFGB	4/16/2003							
EFGB	4/17/2003							
EFGB	4/18/2003							
EFGB	4/19/2003							
EFGB	4/20/2003							
EFGB	4/21/2003							
EFGB	4/22/2003							
EFGB	4/23/2003							
EFGB	4/24/2003							
EFGB	4/25/2003							
EFGB	4/26/2003							
EFGB	4/27/2003							

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (℃)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	4/28/2003							
EFGB	4/29/2003							
EFGB	4/30/2003							
EFGB	5/1/2003							
EFGB	5/2/2003							
EFGB	5/3/2003							
EFGB	5/4/2003							
EFGB	5/5/2003							
EFGB	5/6/2003							
EFGB	5/7/2003							
EFGB	5/8/2003							
EFGB	5/9/2003							
EFGB	5/10/2003							
EFGB	5/11/2003							
EFGB	5/12/2003							
EFGB	5/13/2003							
EFGB	5/14/2003							
EFGB	5/15/2003							
EFGB	5/16/2003							
EFGB	5/17/2003							
EFGB	5/18/2003							
EFGB	5/19/2003							
EFGB	5/20/2003							
EFGB	5/21/2003							
EFGB	5/22/2003							
EFGB	5/23/2003							
EFGB	5/24/2003							
EFGB	5/25/2003							
EFGB	5/26/2003							
EFGB	5/27/2003							
EFGB	5/28/2003							
EFGB	5/29/2003							
EFGB	5/30/2003							
EFGB	5/31/2003							
EFGB	6/1/2003							
EFGB	6/2/2003							
EFGB	6/3/2003							
EFGB	6/4/2003							
EFGB	6/5/2003							
EFGB	6/6/2003							
EFGB	6/7/2003							
EFGB	6/8/2003							
EFGB	6/9/2003							
EFGB	6/10/2003							
EFGB	6/11/2003							
EFGB	6/12/2003							
EFGB	6/13/2003							
EFGB	6/14/2003							

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	6/15/2003							
EFGB	6/16/2003							
EFGB	6/17/2003							
EFGB	6/18/2003							
EFGB	6/19/2003							
EFGB	6/20/2003							
EFGB	6/21/2003							
EFGB	6/22/2003							
EFGB	6/23/2003							
EFGB	6/24/2003							
EFGB	6/25/2003							
EFGB	6/26/2003							
EFGB	6/27/2003							
EFGB	6/28/2003							
EFGB	6/29/2003							
EFGB	6/30/2003							
EFGB	7/1/2003							
EFGB	7/2/2003							
EFGB	7/3/2003							
EFGB	7/4/2003							
EFGB	7/5/2003							
EFGB	7/6/2003							
EFGB	7/7/2003							
EFGB	7/8/2003							
EFGB	7/9/2003							
EFGB	7/10/2003							
EFGB	7/11/2003							
EFGB	7/12/2003							
EFGB	7/13/2003							
EFGB	7/14/2003							
EFGB	7/15/2003							
EFGB	7/16/2003							
EFGB	7/17/2003							
EFGB	7/18/2003							
EFGB	7/19/2003							
EFGB	7/20/2003							
EFGB	7/21/2003							
EFGB	7/22/2003							
EFGB	7/23/2003							
EFGB	7/24/2003							
EFGB	7/25/2003							
EFGB	7/26/2003							
EFGB	7/27/2003							
EFGB	7/28/2003							
EFGB	7/29/2003							
EFGB	7/30/2003							
EFGB	7/31/2003							
EFGB	8/1/2003							

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	8/2/2003							
EFGB	8/3/2003							
EFGB	8/4/2003							
EFGB	8/5/2003							
EFGB	8/6/2003							
EFGB	8/7/2003							
EFGB	8/8/2003							
EFGB	8/9/2003							
EFGB	8/10/2003							
EFGB	8/11/2003							
EFGB	8/12/2003							
EFGB	8/13/2003							
EFGB	8/14/2003							
EFGB	8/15/2003							
EFGB	8/16/2003							
EFGB	8/17/2003							
EFGB	8/18/2003							
EFGB	8/19/2003							
EFGB	8/20/2003							
EFGB	8/21/2003							
EFGB	8/22/2003							
EFGB	8/23/2003							
EFGB	8/24/2003							
EFGB	8/25/2003							
EFGB	8/26/2003	22.98	28.51				4.16	
EFGB	8/27/2003	23.23	28.46				3.92	
EFGB	8/28/2003	23.21	28.27				3.93	
EFGB	8/29/2003	23.25	28.17				3.90	
EFGB	8/30/2003	23.22	28.29				4.19	
EFGB	8/31/2003	23.22	28.46				4.93	
EFGB	9/1/2003	23.21	28.31				3.71	
EFGB	9/2/2003	23.20	27.94				3.71	
EFGB	9/3/2003	23.21	28.12				3.64	
EFGB	9/4/2003	23.22	28.17				3.50	
EFGB	9/5/2003	23.26	28.32				3.25	
EFGB	9/6/2003	23.26	28.29				2.68	
EFGB	9/7/2003	23.25	28.21				2.10	
EFGB	9/8/2003	23.28	28.29				1.48	
EFGB	9/9/2003	23.30	28.15				0.48	
EFGB	9/10/2003	23.29	28.10				0.03	
EFGB	9/11/2003	23.29	28.19				0.06	
EFGB	9/12/2003	23.31	27.95				0.71	
EFGB	9/13/2003	23.34	27.89				0.25	
EFGB	9/14/2003	23.34	27.90				0.57	
EFGB	9/15/2003	23.34	27.88				1.42	
EFGB	9/16/2003	23.37	27.80				55.75	
EFGB	9/17/2003	23.38	27.76				19.87	
EFGB	9/18/2003	23.39	27.70				63.28	

Appendix 5
Water Quality Data

East Flower Garden Bank								
October 29, 2002 to November 3, 2003								
Site	Date	Depth (m)	Temp (°C)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
EFGB	9/19/2003	23.42	27.69				34.25	
EFGB	9/20/2003	23.40	27.55				33.51	
EFGB	9/21/2003	23.37	27.32				41.93	
EFGB	9/22/2003	23.35	27.40				48.44	
EFGB	9/23/2003	23.60	27.44				1.59	
EFGB	9/24/2003	23.58	27.13				2.84	
EFGB	9/25/2003	23.43	27.09				12.87	
EFGB	9/26/2003	23.35	27.17				20.86	
EFGB	9/27/2003	23.32	27.01				21.85	
EFGB	9/28/2003	23.32	27.01				46.33	
EFGB	9/29/2003	23.35	26.63				25.96	
EFGB	9/30/2003	23.33	26.36				20.65	
EFGB	10/1/2003	23.38	26.24				18.51	
EFGB	10/2/2003	23.33	25.96				18.16	
EFGB	10/3/2003	23.37	25.91				18.04	
EFGB	10/4/2003	23.34	25.91				7.76	
EFGB	10/5/2003	23.28	25.82				4.12	
EFGB	10/6/2003	23.29	25.73				3.52	
EFGB	10/7/2003	23.32	25.65				5.22	
EFGB	10/8/2003	23.31	25.95				10.87	
EFGB	10/9/2003	23.32	25.87				18.20	
EFGB	10/10/2003	23.31	26.12				73.88	
EFGB	10/11/2003	23.32	26.24				57.92	
EFGB	10/12/2003	23.69	26.18				29.23	
EFGB	10/13/2003	23.37	25.79				33.39	
EFGB	10/14/2003	23.27	25.78					
EFGB	10/15/2003	23.31	25.55				34.85	
EFGB	10/16/2003	23.32	25.53				19.34	
EFGB	10/17/2003	23.28	25.64				27.85	
EFGB	10/18/2003	23.29	25.47				37.63	
EFGB	10/19/2003	23.34	25.51				55.32	
EFGB	10/20/2003	23.38	25.41				44.80	
EFGB	10/21/2003	23.36	25.18				47.85	
EFGB	10/22/2003	23.31	25.11				46.27	
EFGB	10/23/2003	23.35	25.18				34.94	
EFGB	10/24/2003	23.35	25.24				28.15	
EFGB	10/25/2003	23.67	25.60				33.92	
EFGB	10/26/2003	23.74	25.42				36.99	
EFGB	10/27/2003	23.76	25.24				79.02	
EFGB	10/28/2003	23.80	25.09				70.41	
EFGB	10/29/2003	23.84	24.86				24.36	
EFGB	10/30/2003	23.89	25.07				3.37	
EFGB	10/31/2003	23.86	25.52				2.22	
EFGB	11/1/2003	23.87	25.55				1.34	
EFGB	11/2/2003	23.64	25.37				1.35	
EFGB	11/3/2003	23.76	25.26				1.43	
	371.00							

Appendix 5
Water Quality Data

East Flower Garden Bank Hobo Data October 29, 2002 - March 11, 2004		
Site	Statistic	EFG Daily Mean Temp Hobo
EFG	min	19.30
EFG	max	29.97
EFG	mean	23.05
EFG	SE	0.15
EFG	n	397

East Flower Garden Bank Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	10/29/2002	26.70
EFG	10/30/2002	26.83
EFG	10/31/2002	26.65
EFG	11/1/2002	26.43
EFG	11/2/2002	26.34
EFG	11/3/2002	26.22
EFG	11/4/2002	26.32
EFG	11/5/2002	26.50
EFG	11/6/2002	26.26
EFG	11/7/2002	26.23
EFG	11/8/2002	26.16
EFG	11/9/2002	25.99
EFG	11/10/2002	25.95
EFG	11/11/2002	26.00
EFG	11/12/2002	26.13
EFG	11/13/2002	25.93
EFG	11/14/2002	25.78
EFG	11/15/2002	25.51
EFG	11/16/2002	25.27
EFG	11/17/2002	24.83
EFG	11/18/2002	25.02
EFG	11/19/2002	25.13
EFG	11/20/2002	25.10
EFG	11/21/2002	24.74
EFG	11/22/2002	24.59
EFG	11/23/2002	24.16
EFG	11/24/2002	24.29
EFG	11/25/2002	24.66
EFG	11/26/2002	24.20
EFG	11/27/2002	24.31
EFG	11/28/2002	24.20
EFG	11/29/2002	24.01
EFG	11/30/2002	24.06
EFG	12/1/2002	24.01
EFG	12/2/2002	23.95
EFG	12/3/2002	23.48
EFG	12/4/2002	23.67

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (°C)
EFG	12/5/2002	23.74
EFG	12/6/2002	23.12
EFG	12/7/2002	22.68
EFG	12/8/2002	22.88
EFG	12/9/2002	22.45
EFG	12/10/2002	22.49
EFG	12/11/2002	22.23
EFG	12/12/2002	22.03
EFG	12/13/2002	22.21
EFG	12/14/2002	21.75
EFG	12/15/2002	21.67
EFG	12/16/2002	21.64
EFG	12/17/2002	22.14
EFG	12/18/2002	22.35
EFG	12/19/2002	22.77
EFG	12/20/2002	22.51
EFG	12/21/2002	21.64
EFG	12/22/2002	21.31
EFG	12/23/2002	22.15
EFG	12/24/2002	21.68
EFG	12/25/2002	21.44
EFG	12/26/2002	21.55
EFG	12/27/2002	21.45
EFG	12/28/2002	20.57
EFG	12/29/2002	21.09
EFG	12/30/2002	21.40
EFG	12/31/2002	21.31
EFG	1/1/2003	21.37
EFG	1/2/2003	20.35
EFG	1/3/2003	20.51
EFG	1/4/2003	20.45
EFG	1/5/2003	20.51
EFG	1/6/2003	20.88
EFG	1/7/2003	20.68
EFG	1/8/2003	20.32
EFG	1/9/2003	20.40
EFG	1/10/2003	20.16
EFG	1/11/2003	19.82
EFG	1/12/2003	19.61
EFG	1/13/2003	19.66
EFG	1/14/2003	19.79
EFG	1/15/2003	19.59
EFG	1/16/2003	19.75
EFG	1/17/2003	19.64
EFG	1/18/2003	19.55
EFG	1/19/2003	19.61
EFG	1/20/2003	20.17

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	1/21/2003	20.24
EFG	1/22/2003	19.94
EFG	1/23/2003	19.53
EFG	1/24/2003	19.30
EFG	1/25/2003	19.42
EFG	1/26/2003	19.64
EFG	1/27/2003	19.89
EFG	1/28/2003	20.11
EFG	1/29/2003	20.33
EFG	1/30/2003	20.30
EFG	1/31/2003	20.35
EFG	2/1/2003	20.32
EFG	2/2/2003	20.31
EFG	2/3/2003	20.28
EFG	2/4/2003	20.12
EFG	2/5/2003	19.94
EFG	2/6/2003	20.09
EFG	2/7/2003	19.90
EFG	2/8/2003	20.30
EFG	2/9/2003	20.62
EFG	2/10/2003	20.62
EFG	2/11/2003	20.55
EFG	2/12/2003	20.70
EFG	2/13/2003	20.76
EFG	2/14/2003	20.69
EFG	2/15/2003	20.55
EFG	2/16/2003	20.15
EFG	2/17/2003	19.67
EFG	2/18/2003	19.59
EFG	2/19/2003	19.86
EFG	2/20/2003	19.88
EFG	2/21/2003	19.99
EFG	2/22/2003	20.01
EFG	2/23/2003	19.79
EFG	2/24/2003	19.75
EFG	2/25/2003	19.68
EFG	2/26/2003	19.66
EFG	2/27/2003	19.39
EFG	2/28/2003	19.34
EFG	3/1/2003	19.69
EFG	3/2/2003	19.58
EFG	3/3/2003	20.01
EFG	3/4/2003	19.92
EFG	3/5/2003	19.81
EFG	3/6/2003	19.87
EFG	3/7/2003	19.93
EFG	3/8/2003	20.04

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	3/9/2003	20.42
EFG	3/10/2003	20.41
EFG	3/11/2003	20.32
EFG	3/12/2003	20.38
EFG	3/13/2003	20.48
EFG	3/14/2003	20.57
EFG	3/15/2003	20.60
EFG	3/16/2003	20.79
EFG	3/17/2003	20.83
EFG	3/18/2003	20.77
EFG	3/19/2003	20.44
EFG	3/20/2003	20.84
EFG	3/21/2003	20.60
EFG	3/22/2003	20.57
EFG	3/23/2003	20.50
EFG	3/24/2003	20.48
EFG	3/25/2003	20.44
EFG	3/26/2003	20.36
EFG	3/27/2003	20.46
EFG	3/28/2003	20.63
EFG	3/29/2003	20.24
EFG	3/30/2003	19.93
EFG	3/31/2003	19.93
EFG	4/1/2003	20.06
EFG	4/2/2003	20.25
EFG	4/3/2003	20.39
EFG	4/4/2003	20.48
EFG	4/5/2003	20.45
EFG	4/6/2003	20.51
EFG	4/7/2003	21.00
EFG	4/8/2003	20.87
EFG	4/9/2003	20.78
EFG	4/10/2003	20.67
EFG	4/11/2003	20.62
EFG	4/12/2003	20.62
EFG	4/13/2003	20.29
EFG	4/14/2003	20.10
EFG	4/15/2003	20.12
EFG	4/16/2003	20.54
EFG	4/17/2003	20.15
EFG	4/18/2003	20.13
EFG	4/19/2003	20.69
EFG	4/20/2003	20.70
EFG	4/21/2003	20.94
EFG	4/22/2003	21.30
EFG	4/23/2003	21.24
EFG	4/24/2003	21.58

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	4/25/2003	21.87
EFG	4/26/2003	22.24
EFG	4/27/2003	22.46
EFG	4/28/2003	22.60
EFG	4/29/2003	22.72
EFG	4/30/2003	22.80
EFG	5/1/2003	22.72
EFG	5/2/2003	22.61
EFG	5/3/2003	22.67
EFG	5/4/2003	22.67
EFG	5/5/2003	22.66
EFG	5/6/2003	22.58
EFG	5/7/2003	22.76
EFG	5/8/2003	23.10
EFG	5/9/2003	23.62
EFG	5/10/2003	23.78
EFG	5/11/2003	23.54
EFG	5/12/2003	23.56
EFG	5/13/2003	23.31
EFG	5/14/2003	23.40
EFG	5/15/2003	
EFG	5/16/2003	
EFG	5/17/2003	
EFG	5/18/2003	
EFG	5/19/2003	
EFG	5/20/2003	
EFG	5/21/2003	
EFG	5/22/2003	
EFG	5/23/2003	
EFG	5/24/2003	
EFG	5/25/2003	
EFG	5/26/2003	
EFG	5/27/2003	
EFG	5/28/2003	
EFG	5/29/2003	
EFG	5/30/2003	
EFG	5/31/2003	
EFG	6/1/2003	
EFG	6/2/2003	
EFG	6/3/2003	
EFG	6/4/2003	
EFG	6/5/2003	
EFG	6/6/2003	
EFG	6/7/2003	
EFG	6/8/2003	
EFG	6/9/2003	
EFG	6/10/2003	

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	6/11/2003	
EFG	6/12/2003	
EFG	6/13/2003	
EFG	6/14/2003	
EFG	6/15/2003	
EFG	6/16/2003	
EFG	6/17/2003	
EFG	6/18/2003	
EFG	6/19/2003	
EFG	6/20/2003	
EFG	6/21/2003	
EFG	6/22/2003	
EFG	6/23/2003	
EFG	6/24/2003	
EFG	6/25/2003	
EFG	6/26/2003	
EFG	6/27/2003	
EFG	6/28/2003	
EFG	6/29/2003	
EFG	6/30/2003	
EFG	7/1/2003	
EFG	7/2/2003	
EFG	7/3/2003	
EFG	7/4/2003	
EFG	7/5/2003	
EFG	7/6/2003	
EFG	7/7/2003	
EFG	7/8/2003	
EFG	7/9/2003	
EFG	7/10/2003	
EFG	7/11/2003	
EFG	7/12/2003	
EFG	7/13/2003	
EFG	7/14/2003	
EFG	7/15/2003	
EFG	7/16/2003	
EFG	7/17/2003	
EFG	7/18/2003	
EFG	7/19/2003	
EFG	7/20/2003	
EFG	7/21/2003	
EFG	7/22/2003	
EFG	7/23/2003	
EFG	7/24/2003	
EFG	7/25/2003	
EFG	7/26/2003	
EFG	7/27/2003	

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	7/28/2003	
EFG	7/29/2003	
EFG	7/30/2003	
EFG	7/31/2003	
EFG	8/1/2003	
EFG	8/2/2003	
EFG	8/3/2003	
EFG	8/4/2003	
EFG	8/5/2003	
EFG	8/6/2003	
EFG	8/7/2003	
EFG	8/8/2003	
EFG	8/9/2003	
EFG	8/10/2003	
EFG	8/11/2003	
EFG	8/12/2003	
EFG	8/13/2003	
EFG	8/14/2003	
EFG	8/15/2003	
EFG	8/16/2003	
EFG	8/17/2003	
EFG	8/18/2003	
EFG	8/19/2003	
EFG	8/20/2003	
EFG	8/21/2003	
EFG	8/22/2003	
EFG	8/23/2003	
EFG	8/24/2003	
EFG	8/25/2003	
EFG	8/26/2003	29.97
EFG	8/27/2003	29.91
EFG	8/28/2003	29.66
EFG	8/29/2003	29.69
EFG	8/30/2003	29.84
EFG	8/31/2003	29.79
EFG	9/1/2003	29.72
EFG	9/2/2003	29.42
EFG	9/3/2003	29.70
EFG	9/4/2003	29.73
EFG	9/5/2003	29.84
EFG	9/6/2003	29.79
EFG	9/7/2003	29.75
EFG	9/8/2003	29.85
EFG	9/9/2003	29.55
EFG	9/10/2003	29.68
EFG	9/11/2003	29.67
EFG	9/12/2003	29.43

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Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	9/13/2003	29.39
EFG	9/14/2003	29.42
EFG	9/15/2003	29.35
EFG	9/16/2003	29.32
EFG	9/17/2003	29.28
EFG	9/18/2003	29.17
EFG	9/19/2003	29.15
EFG	9/20/2003	28.92
EFG	9/21/2003	28.77
EFG	9/22/2003	28.95
EFG	9/23/2003	28.85
EFG	9/24/2003	28.57
EFG	9/25/2003	28.63
EFG	9/26/2003	28.64
EFG	9/27/2003	28.51
EFG	9/28/2003	28.47
EFG	9/29/2003	28.00
EFG	9/30/2003	27.80
EFG	10/1/2003	27.65
EFG	10/2/2003	27.38
EFG	10/3/2003	27.34
EFG	10/4/2003	27.36
EFG	10/5/2003	27.26
EFG	10/6/2003	27.12
EFG	10/7/2003	27.16
EFG	10/8/2003	27.31
EFG	10/9/2003	27.15
EFG	10/10/2003	27.41
EFG	10/11/2003	27.54
EFG	10/12/2003	27.48
EFG	10/13/2003	27.24
EFG	10/14/2003	27.16
EFG	10/15/2003	26.94
EFG	10/16/2003	26.99
EFG	10/17/2003	27.05
EFG	10/18/2003	26.97
EFG	10/19/2003	26.95
EFG	10/20/2003	26.82
EFG	10/21/2003	26.62
EFG	10/22/2003	26.61
EFG	10/23/2003	26.65
EFG	10/24/2003	26.73
EFG	10/25/2003	26.75
EFG	10/26/2003	26.65
EFG	10/27/2003	26.41
EFG	10/28/2003	26.27
EFG	10/29/2003	26.20

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (°C)
EFG	10/30/2003	26.48
EFG	10/31/2003	26.82
EFG	11/1/2003	26.86
EFG	11/2/2003	26.66
EFG	11/3/2003	26.63
EFG	11/4/2003	26.75
EFG	11/5/2003	26.92
EFG	11/6/2003	26.91
EFG	11/7/2003	26.87
EFG	11/8/2003	26.80
EFG	11/9/2003	26.71
EFG	11/10/2003	26.63
EFG	11/11/2003	26.60
EFG	11/12/2003	26.56
EFG	11/13/2003	26.47
EFG	11/14/2003	26.22
EFG	11/15/2003	25.91
EFG	11/16/2003	25.86
EFG	11/17/2003	25.93
EFG	11/18/2003	25.81
EFG	11/19/2003	25.35
EFG	11/20/2003	25.14
EFG	11/21/2003	24.82
EFG	11/22/2003	24.75
EFG	11/23/2003	24.70
EFG	11/24/2003	24.37
EFG	11/25/2003	24.12
EFG	11/26/2003	24.25
EFG	11/27/2003	24.14
EFG	11/28/2003	24.04
EFG	11/29/2003	24.09
EFG	11/30/2003	24.05
EFG	12/1/2003	24.07
EFG	12/2/2003	24.09
EFG	12/3/2003	24.27
EFG	12/4/2003	24.37
EFG	12/5/2003	24.18
EFG	12/6/2003	23.93
EFG	12/7/2003	23.70
EFG	12/8/2003	23.67
EFG	12/9/2003	23.58
EFG	12/10/2003	23.11
EFG	12/11/2003	22.86
EFG	12/12/2003	22.57
EFG	12/13/2003	22.47
EFG	12/14/2003	22.32
EFG	12/15/2003	22.66

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	12/16/2003	22.47
EFG	12/17/2003	22.03
EFG	12/18/2003	22.09
EFG	12/19/2003	22.11
EFG	12/20/2003	22.26
EFG	12/21/2003	22.38
EFG	12/22/2003	22.30
EFG	12/23/2003	22.20
EFG	12/24/2003	22.06
EFG	12/25/2003	21.97
EFG	12/26/2003	21.89
EFG	12/27/2003	21.88
EFG	12/28/2003	21.86
EFG	12/29/2003	21.76
EFG	12/30/2003	21.50
EFG	12/31/2003	21.58
EFG	1/1/2004	21.81
EFG	1/2/2004	21.77
EFG	1/3/2004	21.75
EFG	1/4/2004	21.61
EFG	1/5/2004	21.76
EFG	1/6/2004	21.48
EFG	1/7/2004	21.22
EFG	1/8/2004	21.55
EFG	1/9/2004	21.51
EFG	1/10/2004	21.27
EFG	1/11/2004	21.16
EFG	1/12/2004	21.40
EFG	1/13/2004	21.42
EFG	1/14/2004	21.42
EFG	1/15/2004	21.22
EFG	1/16/2004	21.20
EFG	1/17/2004	21.49
EFG	1/18/2004	21.36
EFG	1/19/2004	21.10
EFG	1/20/2004	21.02
EFG	1/21/2004	21.14
EFG	1/22/2004	21.68
EFG	1/23/2004	20.88
EFG	1/24/2004	20.97
EFG	1/25/2004	21.25
EFG	1/26/2004	21.17
EFG	1/27/2004	21.29
EFG	1/28/2004	21.69
EFG	1/29/2004	21.55
EFG	1/30/2004	21.39
EFG	1/31/2004	21.22

Appendix 5
Water Quality Data

East Flower Garden Bank		
Hobo Data October 29, 2002 - March 11, 2004		
Site	Date	Temperature (℃)
EFG	2/1/2004	21.05
EFG	2/2/2004	21.18
EFG	2/3/2004	21.17
EFG	2/4/2004	21.13
EFG	2/5/2004	21.17
EFG	2/6/2004	21.24
EFG	2/7/2004	21.04
EFG	2/8/2004	20.84
EFG	2/9/2004	20.57
EFG	2/10/2004	20.52
EFG	2/11/2004	20.51
EFG	2/12/2004	20.43
EFG	2/13/2004	20.17
EFG	2/14/2004	20.33
EFG	2/15/2004	20.27
EFG	2/16/2004	20.12
EFG	2/17/2004	20.09
EFG	2/18/2004	19.91
EFG	2/19/2004	20.96
EFG	2/20/2004	21.14
EFG	2/21/2004	20.78
EFG	2/22/2004	21.20
EFG	2/23/2004	21.69
EFG	2/24/2004	21.34
EFG	2/25/2004	21.05
EFG	2/26/2004	20.01
EFG	2/27/2004	20.39
EFG	2/28/2004	20.52
EFG	2/29/2004	20.43
EFG	3/1/2004	20.40
EFG	3/2/2004	20.38
EFG	3/3/2004	20.89
EFG	3/4/2004	20.67
EFG	3/5/2004	20.85
EFG	3/6/2004	20.84
EFG	3/7/2004	20.79
EFG	3/8/2004	20.73
EFG	3/9/2004	20.57
EFG	3/10/2004	20.25
EFG	3/11/2004	20.54

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Statistic	Depth (m)	Temp (℃)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	min	25.29	19.24	35.02	7.92	0.78	3.79	1.06
WFGB	max	28.43	29.94	37.01	8.30	8.94	39.98	185.03
WFGB	mean	27.36	23.43	36.48	8.24	6.18	7.29	20.14
WFGB	SE	0.03	0.15	0.04	0.01	0.14	0.20	1.07
WFGB	n	396	395	134	107	157	290	290

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	10/30/2002	27.62	27.046	35.579	7.918	3.183	8.387	57.851
WFGB	10/31/2002	27.898	26.842	35.544	8.027	3.713	8.592	41.398
WFGB	11/1/2002	27.9	26.7	35.609		4.191	8.679	23.863
WFGB	11/2/2002	27.894	26.485	35.615		4.397	8.64	20.253
WFGB	11/3/2002	27.902	26.456	35.56		3.079	8.598	21.044
WFGB	11/4/2002	27.839	26.611	35.475		2.416	8.469	36.718
WFGB	11/5/2002	27.877	26.673	35.574		2.723	8.383	14.871
WFGB	11/6/2002	27.785	26.233	35.67		2.985	8.329	43.231
WFGB	11/7/2002	27.802	25.923	35.727		3.312	8.321	48.084
WFGB	11/8/2002	27.821	26.024	35.695		3.168	8.248	28.827
WFGB	11/9/2002	27.824	26.029	35.742		3.188	8.242	39.391
WFGB	11/10/2002	27.85	26.186	35.721		3.164	8.229	38.577
WFGB	11/11/2002	27.821	26.316	35.815		2.427	8.221	35.404
WFGB	11/12/2002	27.78	26.241	35.855		2.796	8.212	43.975
WFGB	11/13/2002	27.819	25.86	35.927		3.06	8.296	41.214
WFGB	11/14/2002	27.799	25.714	35.962		2.701	8.335	30.115
WFGB	11/15/2002	27.814	25.346	35.93		0.779	8.377	7.13
WFGB	11/16/2002	27.792	25.488	35.874		2.124	8.296	25.026
WFGB	11/17/2002	27.763	25.365	35.968		3.468	8.306	33.197
WFGB	11/18/2002	27.785	25.412	36.141		3.326	8.367	29.549
WFGB	11/19/2002	27.732	25.171	36.078		3.58	8.456	11.308
WFGB	11/20/2002	27.723	25.042	36.087		3.827	8.448	16.776
WFGB	11/21/2002	27.689	25.034	36.18		3.253	8.527	32.529
WFGB	11/22/2002	27.718	24.418	35.962		4.355	9.298	28.501
WFGB	11/23/2002	27.693	24.465	36.094		5.325	9.527	32.269
WFGB	11/24/2002	27.719	24.682	36.243		4.569	12.371	34.342
WFGB	11/25/2002	27.736	24.635	36.262		4.68	10.477	34.074
WFGB	11/26/2002	27.744	24.531	36.194		4.605	9.506	28.314
WFGB	11/27/2002	27.746	24.559	36.291		4.206	9.312	5.076
WFGB	11/28/2002	27.743	24.352	36.237		4.399	9.485	16.986
WFGB	11/29/2002	27.756	24.208	36.266		4.883	8.952	25.495
WFGB	11/30/2002	27.776	24.214	36.306		4.876	8.056	8.146
WFGB	12/1/2002	27.724	23.925	36.201		5.456	7.81	19.779
WFGB	12/2/2002	27.708	23.551	36.052		5.449	8.215	11.188
WFGB	12/3/2002	27.713	23.882	36.209		5.444	14.283	12.979
WFGB	12/4/2002	27.712	24.023	36.257		5.048	22.594	10.986
WFGB	12/5/2002	27.668	23.167	35.81		5.144	33.335	1.422
WFGB	12/6/2002	27.729	22.867	35.714		4.999	39.981	13.454

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	12/7/2002	27.713	22.673	35.831		5.104	10.833	9.262
WFGB	12/8/2002	27.689	22.532	35.861		5.215	11.956	9.421
WFGB	12/9/2002	27.727	22.725	35.983		5.323	9.39	4.852
WFGB	12/10/2002	27.742	22.399	35.919		5.814	11.017	1.699
WFGB	12/11/2002	27.728	22.332			5.127	9.233	12.294
WFGB	12/12/2002	27.677	22.692			3.893	8.465	4.516
WFGB	12/13/2002	27.683	23.91			4.746	8.173	13.365
WFGB	12/14/2002	27.644	24.617			3.978	8.181	12.222
WFGB	12/15/2002	27.67	25.215			3.131	8.048	13.82
WFGB	12/16/2002	27.652	24.716			4.002	8.11	11.997
WFGB	12/17/2002	27.686	25.182			4.331	8.054	17.47
WFGB	12/18/2002	27.727	25.517			4.735	8.052	17.316
WFGB	12/19/2002	27.75	25.132			5.622	8.26	10.529
WFGB	12/20/2002	27.733	24.43			5.729	8.475	16.416
WFGB	12/21/2002	27.754	24.853				8.875	13.424
WFGB	12/22/2002	27.722	25.173				8.143	18.27
WFGB	12/23/2002	27.738	24.962				8.152	6.34
WFGB	12/24/2002	27.76	24.027				8.235	5.198
WFGB	12/25/2002	27.76	24.011				8.248	6.688
WFGB	12/26/2002	27.777	23.697				8.273	4.197
WFGB	12/27/2002	27.804	24.035				8.427	3.932
WFGB	12/28/2002	27.778	24.746				8.217	10.251
WFGB	12/29/2002	27.779	24.654				8.269	9.734
WFGB	12/30/2002	27.795	24.847				8.298	5.719
WFGB	12/31/2002	27.798	24.847				8.504	7.405
WFGB	1/1/2003	27.713	24.299				8.665	7.757
WFGB	1/2/2003	27.721	24.622				10.713	8.665
WFGB	1/3/2003	27.723	23.921				10.546	6.493
WFGB	1/4/2003	27.754	23.633				10.51	5.983
WFGB	1/5/2003	27.742	23.526				10.073	3.515
WFGB	1/6/2003	27.762	23.783				10.123	6.194
WFGB	1/7/2003	27.751	23.623				10.202	7.823
WFGB	1/8/2003	27.738	23.468				9.702	7.618
WFGB	1/9/2003	27.763	22.989				10.652	5.892
WFGB	1/10/2003	27.774	22.99				9.823	7.111
WFGB	1/11/2003	27.766	23.57				8.74	1.681
WFGB	1/12/2003	27.739	23.594				8.698	1.055
WFGB	1/13/2003	27.684	22.947				8.408	5.126
WFGB	1/14/2003	27.466	22.491				8.379	1.688
WFGB	1/15/2003	27.504	22.255				8.344	3.521
WFGB	1/16/2003	27.479	22.495				8.306	7.947
WFGB	1/17/2003	27.37	22.07				8.229	6.21
WFGB	1/18/2003	27.457	21.635				8.223	9.544
WFGB	1/19/2003	27.409	21.523				8.227	8.954
WFGB	1/20/2003	27.416	21.28				8.256	5.942
WFGB	1/21/2003	27.391	21.553				8.242	6.076
WFGB	1/22/2003	27.373	21.519				8.279	3.627
WFGB	1/23/2003	27.334	21.606				8.45	5.245

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	1/24/2003	27.368	22.674				17.787	5.79
WFGB	1/25/2003	27.35	22.782				24.292	7.716
WFGB	1/26/2003	27.35	23.636				20.781	3.234
WFGB	1/27/2003	27.147	24.169				8.173	4.02
WFGB	1/28/2003	26.95	23.978				8.706	15
WFGB	1/29/2003	26.77	23.416				8.29	18.027
WFGB	1/30/2003	27.174	23.197				8.308	9.067
WFGB	1/31/2003	27.198	22.706				8.162	11.897
WFGB	2/1/2003	27.321	22.292		8.13	7.162	8.075	7.032
WFGB	2/2/2003	27.642	20.036		8.129	6.965	6.631	14.569
WFGB	2/3/2003	27.693	20.088		8.134	6.957	6.669	11.203
WFGB	2/4/2003	27.698	20.111		8.143	7.032	6.706	19.1
WFGB	2/5/2003	27.668	19.993		8.144	7.001	6.7	13.183
WFGB	2/6/2003	27.693	20.098		8.144	6.954	6.706	12.226
WFGB	2/7/2003	27.72	20.086		8.155	6.822	6.694	2.567
WFGB	2/8/2003	27.655	19.898		8.159	6.799	6.669	4.093
WFGB	2/9/2003	27.7	19.784		8.159	6.858	6.694	14.386
WFGB	2/10/2003	27.668	19.814		8.157	6.932	6.763	32.741
WFGB	2/11/2003	27.639	19.831		8.161	6.949	6.694	33.166
WFGB	2/12/2003	28.345	20.025		8.055	4.096	7.4	14.388
WFGB	2/13/2003	28.429			8.038	3.511	7.431	14.568
WFGB	2/14/2003	27.873	20.158	36.742	8.133	5.754	6.963	16.596
WFGB	2/15/2003	27.683	19.886	36.773	8.169	6.779	6.738	1.569
WFGB	2/16/2003	27.672	19.995	36.841	8.174	6.868	6.775	3.599
WFGB	2/17/2003	27.643	19.767	36.836	8.177	7.137	6.787	25.716
WFGB	2/18/2003	27.682	19.776	36.86	8.181	7.199	6.825	22.812
WFGB	2/19/2003	27.725	19.919	36.889	8.184	7.144	6.781	15.35
WFGB	2/20/2003	27.682	19.874	36.877	8.183	7.088	6.781	9.793
WFGB	2/21/2003	27.645	19.664	36.834	8.179	6.876	6.812	6.42
WFGB	2/22/2003	27.646	19.622	36.814	8.196	7.199	6.862	14.769
WFGB	2/23/2003	27.633	19.243	36.657	8.202	7.408	6.819	13.256
WFGB	2/24/2003	27.661	19.665	36.772	8.21	7.731	6.787	18.852
WFGB	2/25/2003	27.633	19.451	36.638	8.214	7.014	6.794	2.714
WFGB	2/26/2003	27.63	19.857	36.778	8.217	7.041	6.769	5.014
WFGB	2/27/2003	27.663	19.618	36.744	8.224	7.216	6.8	3.911
WFGB	2/28/2003	27.637	19.764	36.789	8.234	7.312	6.8	4.726
WFGB	3/1/2003	27.69	20.026	36.859	8.239	7.133	6.794	4.243
WFGB	3/2/2003	27.667	20.121	36.881	8.247	7.243	6.862	5.244
WFGB	3/3/2003	27.679	20.089	36.883	8.247	6.916	6.769	2.664
WFGB	3/4/2003	27.682	19.784	36.848	8.259	7.489	6.806	11.124
WFGB	3/5/2003	27.66	19.677	36.826	8.259	7.416	6.812	8.201
WFGB	3/6/2003	27.628	19.653	36.801	8.266	7.132	6.812	4.496
WFGB	3/7/2003	27.632	20.176	36.862	8.276	7.245	6.794	6.217
WFGB	3/8/2003	27.609	20.091	36.843	8.279	7.352	6.837	8.983
WFGB	3/9/2003	27.639	19.994	36.61	8.275	7.381	6.8	11.69
WFGB	3/10/2003	27.644	19.637	36.732	8.275	7.357	6.844	9.826
WFGB	3/11/2003	27.638	19.99	36.659	8.282	7.191	6.812	5.419
WFGB	3/12/2003	27.657	20.003	36.833	8.286	7.276	6.856	12.349

Appendix 5

Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	3/13/2003	27.603	20.359	36.86	8.286	7.352	6.869	16.848
WFGB	3/14/2003	27.613	20.159	36.841	8.285	7.327	6.906	15.718
WFGB	3/15/2003	27.655	20.351	36.855	8.277	7.275	6.856	9.863
WFGB	3/16/2003	27.663	20.509	36.863	8.283	7.321	6.812	9.953
WFGB	3/17/2003	27.657	20.789	36.76	8.285	7.442	6.831	15.865
WFGB	3/18/2003	27.651	21.199	36.852	8.284	7.455	6.944	14.761
WFGB	3/19/2003	27.753	21.377	36.854	8.286	7.577	7.025	15.907
WFGB	3/20/2003	27.698	21.35	36.831	8.289	7.551	6.85	16.248
WFGB	3/21/2003	27.701	21.321	36.807	8.289	7.611	6.894	13.341
WFGB	3/22/2003	27.689	20.603	36.731	8.281	7.405	9.275	14.104
WFGB	3/23/2003	27.644	20.562	36.639	8.29	7.612	7.931	17.68
WFGB	3/24/2003	27.684	20.781	36.603	8.291	7.623	6.75	18.934
WFGB	3/25/2003	27.642	21.067	36.6	8.282	6.838	6.856	5.759
WFGB	3/26/2003	27.618	21.438	36.616	8.288	7.195	6.7	12.923
WFGB	3/27/2003	27.657	21.398	36.653	8.296	7.499	6.669	19.618
WFGB	3/28/2003	27.646	21.488	36.746	8.289	7.336	6.612	18.211
WFGB	3/29/2003	27.641	21.291	36.824	8.288	7.213	6.7	6.501
WFGB	3/30/2003	27.654	20.881	36.869	8.297	7.541	6.688	18.22
WFGB	3/31/2003	27.648	20.636	36.842	8.3	7.98	6.669	16.444
WFGB	4/1/2003	27.693	20.63	36.864	8.287	7.649	6.656	13.128
WFGB	4/2/2003	27.679	20.636	36.862	8.282	7.686	6.663	13.046
WFGB	4/3/2003	27.631	20.644	36.8	8.267	7.456	6.75	14.456
WFGB	4/4/2003	27.641	20.722	36.78	8.264	7.284	6.838	11.374
WFGB	4/5/2003	27.672	20.674	36.771	8.264	7.276	7.056	8.904
WFGB	4/6/2003	27.666	20.584	36.723	8.257	7.216	6.781	7.663
WFGB	4/7/2003	27.66	20.769	36.743	8.268	7.346	6.956	9.197
WFGB	4/8/2003	27.633	20.695	36.735	8.261	7.068	7.231	5.011
WFGB	4/9/2003	27.62	20.524	36.669	8.274	7.439	6.775	17.108
WFGB	4/10/2003	27.624	20.051	36.442	8.269	8.481	7	21.425
WFGB	4/11/2003	27.653	19.875	36.606	8.266	8.006	6.8	9.433
WFGB	4/12/2003	27.661	20.095	36.315	8.275	8.943	6.806	20.762
WFGB	4/13/2003	27.697	20.004	36.68	8.272	8.391	6.881	23.958
WFGB	4/14/2003	27.676	20.063	36.705	8.274	8.027	6.85	24.996
WFGB	4/15/2003	27.666	20.028	36.472	8.269	7.753	6.988	26.849
WFGB	4/16/2003	27.69	20.116	36.725	8.271	7.411	6.462	20.363
WFGB	4/17/2003	27.7	20.329	36.768	8.279	7.625	6.331	21.854
WFGB	4/18/2003	27.691	20.326	36.758	8.282	7.997	6.531	23.326
WFGB	4/19/2003	27.687	20.276	36.544	8.268	7.14	7.431	17.381
WFGB	4/20/2003	27.647	21.368	36.555	8.277	7.146	8.806	14.509
WFGB	4/21/2003	27.639	21.051	36.681	8.273	7.456	6.407	16.645
WFGB	4/22/2003	27.65	21.239	36.823	8.26	7.447	7.025	20.798
WFGB	4/23/2003	27.641	21.607	36.815	8.268	7.139	6.406	14.957
WFGB	4/24/2003	27.69	21.618	36.577	8.268	6.946	6.744	10.723
WFGB	4/25/2003	27.654	21.99	36.884	8.285	7.295	6.906	25.003
WFGB	4/26/2003	27.679	22.052	36.914	8.283	7.319	7.875	28.989
WFGB	4/27/2003	27.699	22.034	36.879	8.283	7.696	7.3	29.181
WFGB	4/28/2003	27.702	22.087	36.924	8.28	7.504	6.775	23.563
WFGB	4/29/2003	27.704	22.057	36.946	8.275	7.229	6.85	16.686

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	4/30/2003	27.774	22.084	35.022	8.28	7.467	8.625	24.098
WFGB	5/1/2003	27.751	22.154	37.014	8.274	7.232	7.631	15.276
WFGB	5/2/2003	27.706	22.235	36.806	8.282	7.69	11.256	25.601
WFGB	5/3/2003	27.722	21.955	36.931	8.276	7.336	9.269	19.483
WFGB	5/4/2003	27.692	21.668	36.894	8.275	7.293	7.633	18.979
WFGB	5/5/2003	27.728	21.727	36.814	8.274	7.077	6.62	21.336
WFGB	5/6/2003	27.68	21.753	36.827	8.281	7.396	6.069	18.238
WFGB	5/7/2003	27.664	21.869	36.459	8.277	7.204	5.644	16.13
WFGB	5/8/2003	27.669	21.955	36.739	8.281	7.211	5.619	14.49
WFGB	5/9/2003	27.651	21.845	36.798	8.279	7.194	5.606	12.451
WFGB	5/10/2003	27.666	21.741	36.485	8.271	7.056	5.606	9.952
WFGB	5/11/2003	27.677	21.793	36.649	8.277	7.122	5.631	9.412
WFGB	5/12/2003	27.665	21.451	36.671	8.275	7.071	5.613	12.034
WFGB	5/13/2003	27.677	21.351	36.271	8.278	7.209	5.819	17.57
WFGB	5/14/2003	27.693	21.34	36.624	8.265	7.124	5.506	15.328
WFGB	5/15/2003	27.716	21.801	36.638	8.254	6.759	6.025	15.256
WFGB	5/16/2003	27.649	21.601	36.543	8.262	6.942	6.25	1.962
WFGB	5/17/2003							
WFGB	5/18/2003							
WFGB	5/19/2003							
WFGB	5/20/2003							
WFGB	5/21/2003							
WFGB	5/22/2003							
WFGB	5/23/2003							
WFGB	5/24/2003							
WFGB	5/25/2003							
WFGB	5/26/2003							
WFGB	5/27/2003							
WFGB	5/28/2003							
WFGB	5/29/2003							
WFGB	5/30/2003							
WFGB	5/31/2003							
WFGB	6/1/2003							
WFGB	6/2/2003							
WFGB	6/3/2003							
WFGB	6/4/2003							
WFGB	6/5/2003							
WFGB	6/6/2003							
WFGB	6/7/2003							
WFGB	6/8/2003							
WFGB	6/9/2003							
WFGB	6/10/2003							
WFGB	6/11/2003							
WFGB	6/12/2003							
WFGB	6/13/2003							
WFGB	6/14/2003							
WFGB	6/15/2003							
WFGB	6/16/2003							

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	6/17/2003							
WFGB	6/18/2003							
WFGB	6/19/2003							
WFGB	6/20/2003							
WFGB	6/21/2003							
WFGB	6/22/2003							
WFGB	6/23/2003							
WFGB	6/24/2003							
WFGB	6/25/2003							
WFGB	6/26/2003							
WFGB	6/27/2003							
WFGB	6/28/2003							
WFGB	6/29/2003							
WFGB	6/30/2003							
WFGB	7/1/2003							
WFGB	7/2/2003							
WFGB	7/3/2003							
WFGB	7/4/2003							
WFGB	7/5/2003							
WFGB	7/6/2003							
WFGB	7/7/2003							
WFGB	7/8/2003							
WFGB	7/9/2003							
WFGB	7/10/2003							
WFGB	7/11/2003							
WFGB	7/12/2003							
WFGB	7/13/2003							
WFGB	7/14/2003							
WFGB	7/15/2003							
WFGB	7/16/2003							
WFGB	7/17/2003							
WFGB	7/18/2003							
WFGB	7/19/2003							
WFGB	7/20/2003							
WFGB	7/21/2003							
WFGB	7/22/2003							
WFGB	7/23/2003							
WFGB	7/24/2003							
WFGB	7/25/2003							
WFGB	7/26/2003							
WFGB	7/27/2003							
WFGB	7/28/2003							
WFGB	7/29/2003							
WFGB	7/30/2003							
WFGB	7/31/2003							
WFGB	8/1/2003							
WFGB	8/2/2003							
WFGB	8/3/2003							

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	8/4/2003							
WFGB	8/5/2003							
WFGB	8/6/2003							
WFGB	8/7/2003							
WFGB	8/8/2003							
WFGB	8/9/2003							
WFGB	8/10/2003							
WFGB	8/11/2003							
WFGB	8/12/2003							
WFGB	8/13/2003							
WFGB	8/14/2003							
WFGB	8/15/2003							
WFGB	8/16/2003							
WFGB	8/17/2003							
WFGB	8/18/2003							
WFGB	8/19/2003							
WFGB	8/20/2003							
WFGB	8/21/2003							
WFGB	8/22/2003							
WFGB	8/23/2003							
WFGB	8/24/2003							
WFGB	8/25/2003							
WFGB	8/26/2003							
WFGB	8/27/2003							
WFGB	8/28/2003	27.962	29.538				5.287	185.031
WFGB	8/29/2003	27.955	29.754				5.298	63.335
WFGB	8/30/2003	27.634	29.935				5.6	6.846
WFGB	8/31/2003	27.318	29.696				6.302	22.977
WFGB	9/1/2003	27.387	29.206				5.342	44.615
WFGB	9/2/2003	27.44	29.372				5.319	74.11
WFGB	9/3/2003	27.501	29.544				5.302	79.333
WFGB	9/4/2003	27.531	29.764				5.273	61.521
WFGB	9/5/2003	27.562	29.742				5.302	48.512
WFGB	9/6/2003	27.566	29.841				5.321	70.737
WFGB	9/7/2003	27.528	29.687				5.315	76.8
WFGB	9/8/2003	27.564	29.528				5.373	61.198
WFGB	9/9/2003	27.6	29.61				5.304	54.202
WFGB	9/10/2003	27.611	29.423				5.342	68.708
WFGB	9/11/2003	27.664	29.424				5.381	63.592
WFGB	9/12/2003	27.723	29.427				5.41	42.396
WFGB	9/13/2003	27.742	29.36				5.648	65.515
WFGB	9/14/2003	27.754	29.285				5.473	60.644
WFGB	9/15/2003	27.765	29.227				5.471	35.273
WFGB	9/16/2003	27.798	29.29				5.51	63.481
WFGB	9/17/2003	27.814	29.237				5.535	62.667
WFGB	9/18/2003	27.833	28.911				5.571	27.356
WFGB	9/19/2003	27.862	29.164				5.617	20.054
WFGB	9/20/2003	27.826	29.125				5.677	14.479

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	9/21/2003	27.887	28.83				5.719	11.556
WFGB	9/22/2003	27.905	28.851				5.796	23.369
WFGB	9/23/2003	27.861	29.008				5.752	37.425
WFGB	9/24/2003	27.891	28.91				5.681	42.621
WFGB	9/25/2003	27.875	28.853				5.623	47.775
WFGB	9/26/2003	27.897	28.974				5.585	44.598
WFGB	9/27/2003	27.876	29.067				5.298	49.729
WFGB	9/28/2003	27.858	29.221				4.906	51.602
WFGB	9/29/2003	27.912	29.026				6.144	52.669
WFGB	9/30/2003	27.897	28.498				5.667	30.758
WFGB	10/1/2003	27.863	28.128				5.552	41.229
WFGB	10/2/2003	27.916	27.912				5.454	34.452
WFGB	10/3/2003	27.892	27.683				5.031	31.431
WFGB	10/4/2003	27.898	27.863				4.506	36.523
WFGB	10/5/2003	27.842	27.998				4.544	35.887
WFGB	10/6/2003	27.85	27.884				4.771	15.94
WFGB	10/7/2003	27.879	28.136				4.585	29.95
WFGB	10/8/2003	27.864	28.174				4.569	34.635
WFGB	10/9/2003	27.864	27.896				4.16	11.994
WFGB	10/10/2003	27.856	27.736				4.742	6.163
WFGB	10/11/2003	27.828	27.527				4.517	22.91
WFGB	10/12/2003	27.848	27.585				4.331	17.66
WFGB	10/13/2003	27.646	27.811				4.623	26.862
WFGB	10/14/2003	27.559	27.762				4.342	8.06
WFGB	10/15/2003	27.578	27.52				4.367	15.875
WFGB	10/16/2003	27.586	27.198				4.319	12.425
WFGB	10/17/2003	27.548	27.409				4.329	19.629
WFGB	10/18/2003	27.549	27.101				4.44	17.052
WFGB	10/19/2003	27.593	26.79				4.485	19.856
WFGB	10/20/2003	27.626	26.895				4.396	23.167
WFGB	10/21/2003	27.621	26.95				4.656	24.898
WFGB	10/22/2003	27.576	27.076				4.679	28.6
WFGB	10/23/2003	27.626	27.022				4.925	28.367
WFGB	10/24/2003	27.63	26.983				4.6	23.615
WFGB	10/25/2003	27.611	26.951				4.171	9.946
WFGB	10/26/2003	27.569	26.859				4.185	5.621
WFGB	10/27/2003	27.551	27.017				4.079	4.933
WFGB	10/28/2003	27.549	27.05				4.267	25.708
WFGB	10/29/2003	27.558	26.785				4.985	23.002
WFGB	10/30/2003	27.589	26.912				4.694	26.065
WFGB	10/31/2003	27.559	26.928				4.138	28.248
WFGB	11/1/2003	27.613	26.942				4.221	26.871
WFGB	11/2/2003	27.609	26.947				4.319	23.852
WFGB	11/3/2003	27.596	26.93				4.777	24.14
WFGB	11/4/2003	27.599	26.944				5.154	25.608
WFGB	11/5/2003	27.587	26.894				4.054	23.875
WFGB	11/6/2003	27.587	26.921				4.094	22.498
WFGB	11/7/2003	27.56	26.92				3.925	11.071

Appendix 5
Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	11/8/2003	27.553	26.748				3.792	13.094
WFGB	11/9/2003	27.545	26.497				4.292	17.608
WFGB	11/10/2003	27.567	26.676				4.423	21.948
WFGB	11/11/2003	27.575	26.849				4.088	22.973
WFGB	11/12/2003	27.558	26.65				4.529	22.008
WFGB	11/13/2003	27.531	26.573				4.223	14.544
WFGB	11/14/2003	27.525	26.468				4.253	18.402
WFGB	11/15/2003	27.513	26.313				4.248	15.279
WFGB	11/16/2003	27.542	26.333				4.404	15.252
WFGB	11/17/2003	27.495	26.288				4.131	14.806
WFGB	11/18/2003	27.545	26.296				5.185	13.44
WFGB	11/19/2003	27.498	25.98				5.543	15.254
WFGB	11/20/2003	27.477	25.698				6.075	11.965
WFGB	11/21/2003	27.502	25.344				5.512	7.429
WFGB	11/22/2003	27.414	25.249				5.235	11.185
WFGB	11/23/2003	27.402	25.151				5.025	8.879
WFGB	11/24/2003	27.363	24.896				8.265	8.227
WFGB	11/25/2003	27.37	24.559				4.929	6.125
WFGB	11/26/2003	27.372	24.482				5.311	6.806
WFGB	11/27/2003	27.415	24.389					
WFGB	11/28/2003	27.31	24.07					
WFGB	11/29/2003	27.451	23.687					
WFGB	11/30/2003	27.453	23.895					
WFGB	12/1/2003	27.378	24.321					
WFGB	12/2/2003	27.357	24.456					
WFGB	12/3/2003	27.423	24.501					
WFGB	12/4/2003	27.359	24.546					
WFGB	12/5/2003	27.321	24.392					
WFGB	12/6/2003	27.265	24.072					
WFGB	12/7/2003	27.221	23.905					
WFGB	12/8/2003	27.272	23.849					
WFGB	12/9/2003	27.391	23.693					
WFGB	12/10/2003	27.473	23.298					
WFGB	12/11/2003	27.508	23.081					
WFGB	12/12/2003	27.538	23.039					
WFGB	12/13/2003	27.542	23.012					
WFGB	12/14/2003	27.58	22.836					
WFGB	12/15/2003	27.558	22.631					
WFGB	12/16/2003	27.562	22.609					
WFGB	12/17/2003	27.515	22.651					
WFGB	12/18/2003	27.549	22.656					
WFGB	12/19/2003	27.497	22.548					
WFGB	12/20/2003	27.512	22.514					
WFGB	12/21/2003	27.508	22.496					
WFGB	12/22/2003	27.462	22.182					
WFGB	12/23/2003	27.391	22.005					
WFGB	12/24/2003	27.356	21.961					
WFGB	12/25/2003	27.404	21.813					

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Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	12/26/2003	27.364	21.941					
WFGB	12/27/2003	27.381	21.862					
WFGB	12/28/2003	27.392	21.794					
WFGB	12/29/2003	27.368	21.762					
WFGB	12/30/2003	27.423	21.508					
WFGB	12/31/2003	27.473	21.594					
WFGB	1/1/2004	27.432	21.552					
WFGB	1/2/2004	27.43	21.977					
WFGB	1/3/2004	27.386	22.185					
WFGB	1/4/2004	27.348	22.23					
WFGB	1/5/2004	27.316	22.291					
WFGB	1/6/2004	27.332	22.091					
WFGB	1/7/2004	27.346	21.671					
WFGB	1/8/2004	27.208	21.461					
WFGB	1/9/2004	27.17	21.508					
WFGB	1/10/2004	26.969	21.407					
WFGB	1/11/2004	27.057	21.516					
WFGB	1/12/2004	27.091	21.29					
WFGB	1/13/2004	27.067	20.769					
WFGB	1/14/2004	26.961	20.953					
WFGB	1/15/2004	26.803	21.321					
WFGB	1/16/2004	26.623	21.259					
WFGB	1/17/2004	26.545	21.523					
WFGB	1/18/2004	26.435	21.517					
WFGB	1/19/2004	26.332	21.374					
WFGB	1/20/2004	26.403	21.718					
WFGB	1/21/2004	26.38	21.35					
WFGB	1/22/2004	26.247	20.104					
WFGB	1/23/2004	25.864	21.113					
WFGB	1/24/2004	25.724	21.925					
WFGB	1/25/2004	25.566	22.249					
WFGB	1/26/2004	25.482	22.479					
WFGB	1/27/2004	25.4	22.146					
WFGB	1/28/2004	25.379	22.037					
WFGB	1/29/2004	25.33	21.64					
WFGB	1/30/2004	25.359	21.511					
WFGB	1/31/2004	25.334	21.595					
WFGB	2/1/2004	25.368	21.729					
WFGB	2/2/2004	25.291	21.621					
WFGB	2/3/2004	25.426	21.754					
WFGB	2/4/2004	25.531	21.656					
WFGB	2/5/2004	25.673	21.496					
WFGB	2/6/2004	25.785	21.513					
WFGB	2/7/2004	26.089	21.213					
WFGB	2/8/2004	26.026	20.656					
WFGB	2/9/2004	25.961	20.402					
WFGB	2/10/2004	25.824	20.268					
WFGB	2/11/2004	25.877	20.13					

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Water Quality Data

West Flower Garden Bank								
October 30, 2002 to March 11, 2004								
Site	Date	Depth (m)	Temp (ºC)	Sal (ppt)	pH	DO (mg/l)	Turb (NTU)	PAR (einst s-1m-2)
WFGB	2/12/2004	25.736	20.645					
WFGB	2/13/2004	25.768	21.066					
WFGB	2/14/2004	25.808	21.295					
WFGB	2/15/2004	25.721	20.279					
WFGB	2/16/2004	25.702	19.712					
WFGB	2/17/2004	25.749	20.24					
WFGB	2/18/2004	25.642	20.644					
WFGB	2/19/2004	25.505	21.608					
WFGB	2/20/2004	25.386	20.665					
WFGB	2/21/2004	25.445	21.101					
WFGB	2/22/2004	25.608	19.979					
WFGB	2/23/2004	25.516	20.165					
WFGB	2/24/2004	25.711	20.225					
WFGB	2/25/2004	25.572	20.581					
WFGB	2/26/2004	25.556	19.623					
WFGB	2/27/2004	25.633	19.562					
WFGB	2/28/2004	25.615	19.558					
WFGB	2/29/2004	25.801	20.139					
WFGB	3/1/2004	25.883	20.047					
WFGB	3/2/2004	25.836	20					
WFGB	3/3/2004	25.845	20.096					
WFGB	3/4/2004	25.914	20.482					
WFGB	3/5/2004	25.661	20.882					
WFGB	3/6/2004	25.713	20.89					
WFGB	3/7/2004	25.512	20.965					
WFGB	3/8/2004	25.456	21.201					
WFGB	3/9/2004	25.417	21.153					
WFGB	3/10/2004	25.562	21.229					
WFGB	3/11/2004	25.513	21.427					

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Statistic	WFG Daily Mean Temp Hobo
WFG	min	19.34
WFG	max	29.86
WFG	mean	23.82
WFG	SE	0.17
WFG	n	405

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	2/1/2003	20.177
WFG	2/2/2003	20.091
WFG	2/3/2003	20.202
WFG	2/4/2003	20.152
WFG	2/5/2003	20.097
WFG	2/6/2003	20.19
WFG	2/7/2003	20.093
WFG	2/8/2003	19.936
WFG	2/9/2003	19.859
WFG	2/10/2003	19.91
WFG	2/11/2003	19.936
WFG	2/12/2003	19.924
WFG	2/13/2003	20.023
WFG	2/14/2003	20.121
WFG	2/15/2003	19.996
WFG	2/16/2003	20.059
WFG	2/17/2003	19.851
WFG	2/18/2003	19.926
WFG	2/19/2003	20.023
WFG	2/20/2003	19.988
WFG	2/21/2003	19.762
WFG	2/22/2003	19.714
WFG	2/23/2003	19.345
WFG	2/24/2003	19.902
WFG	2/25/2003	19.577
WFG	2/26/2003	19.94
WFG	2/27/2003	19.849
WFG	2/28/2003	20.042
WFG	3/1/2003	20.158
WFG	3/2/2003	20.253
WFG	3/3/2003	20.117
WFG	3/4/2003	20.017
WFG	3/5/2003	19.692
WFG	3/6/2003	19.952
WFG	3/7/2003	20.404
WFG	3/8/2003	20.184
WFG	3/9/2003	19.994

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	3/10/2003	19.958
WFG	3/11/2003	20.134
WFG	3/12/2003	20.351
WFG	3/13/2003	20.529
WFG	3/14/2003	20.378
WFG	3/15/2003	20.535
WFG	3/16/2003	20.823
WFG	3/17/2003	21.127
WFG	3/18/2003	21.262
WFG	3/19/2003	21.754
WFG	3/20/2003	21.453
WFG	3/21/2003	21.261
WFG	3/22/2003	20.736
WFG	3/23/2003	20.821
WFG	3/24/2003	21.171
WFG	3/25/2003	21.408
WFG	3/26/2003	21.676
WFG	3/27/2003	21.65
WFG	3/28/2003	21.724
WFG	3/29/2003	21.429
WFG	3/30/2003	21.034
WFG	3/31/2003	20.907
WFG	4/1/2003	20.885
WFG	4/2/2003	20.803
WFG	4/3/2003	20.923
WFG	4/4/2003	20.901
WFG	4/5/2003	20.865
WFG	4/6/2003	20.837
WFG	4/7/2003	20.897
WFG	4/8/2003	20.992
WFG	4/9/2003	20.617
WFG	4/10/2003	20.19
WFG	4/11/2003	20.117
WFG	4/12/2003	20.408
WFG	4/13/2003	20.331
WFG	4/14/2003	20.369
WFG	4/15/2003	20.363
WFG	4/16/2003	20.474
WFG	4/17/2003	20.69
WFG	4/18/2003	20.575
WFG	4/19/2003	20.921
WFG	4/20/2003	21.527
WFG	4/21/2003	21.662
WFG	4/22/2003	21.77
WFG	4/23/2003	21.982
WFG	4/24/2003	22.234
WFG	4/25/2003	22.493

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	4/26/2003	22.547
WFG	4/27/2003	22.533
WFG	4/28/2003	22.593
WFG	4/29/2003	22.609
WFG	4/30/2003	22.625
WFG	5/1/2003	22.806
WFG	5/2/2003	22.822
WFG	5/3/2003	22.437
WFG	5/4/2003	22.29
WFG	5/5/2003	22.481
WFG	5/6/2003	22.497
WFG	5/7/2003	22.497
WFG	5/8/2003	22.757
WFG	5/9/2003	22.453
WFG	5/10/2003	22.385
WFG	5/11/2003	22.493
WFG	5/12/2003	22.108
WFG	5/13/2003	22.098
WFG	5/14/2003	22.318
WFG	5/15/2003	22.567
WFG	5/16/2003	22.683
WFG	5/17/2003	23.59
WFG	5/18/2003	22.491
WFG	5/19/2003	22.801
WFG	5/20/2003	22.965
WFG	5/21/2003	22.835
WFG	5/22/2003	22.796
WFG	5/23/2003	22.399
WFG	5/24/2003	21.999
WFG	5/25/2003	22.238
WFG	5/26/2003	22.224
WFG	5/27/2003	21.951
WFG	5/28/2003	21.537
WFG	5/29/2003	22.067
WFG	5/30/2003	23.196
WFG	5/31/2003	25.423
WFG	6/1/2003	23.197
WFG	6/2/2003	21.847
WFG	6/3/2003	21.495
WFG	6/4/2003	21.376
WFG	6/5/2003	21.306
WFG	6/6/2003	21.356
WFG	6/7/2003	21.213
WFG	6/8/2003	21.167
WFG	6/9/2003	21.278
WFG	6/10/2003	21.3
WFG	6/11/2003	21.36

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	6/12/2003	21.505
WFG	6/13/2003	21.61
WFG	6/14/2003	21.698
WFG	6/15/2003	22.432
WFG	6/16/2003	22.244
WFG	6/17/2003	21.662
WFG	6/18/2003	21.859
WFG	6/19/2003	22.541
WFG	6/20/2003	22.559
WFG	6/21/2003	22.387
WFG	6/22/2003	23.307
WFG	6/23/2003	25.13
WFG	6/24/2003	24.708
WFG	6/25/2003	24.346
WFG	6/26/2003	25.842
WFG	6/27/2003	27.27
WFG	6/28/2003	26.859
WFG	6/29/2003	27.073
WFG	6/30/2003	27.332
WFG	7/1/2003	27.68
WFG	7/2/2003	28.238
WFG	7/3/2003	28.462
WFG	7/4/2003	27.958
WFG	7/5/2003	27.127
WFG	7/6/2003	27.907
WFG	7/7/2003	28.694
WFG	7/8/2003	28.124
WFG	7/9/2003	28.599
WFG	7/10/2003	28.694
WFG	7/11/2003	28.703
WFG	7/12/2003	29.415
WFG	7/13/2003	29.371
WFG	7/14/2003	29.061
WFG	7/15/2003	26.117
WFG	7/16/2003	25.883
WFG	7/17/2003	25.529
WFG	7/18/2003	25.207
WFG	7/19/2003	25.623
WFG	7/20/2003	25.886
WFG	7/21/2003	27.082
WFG	7/22/2003	27.671
WFG	7/23/2003	28.392
WFG	7/24/2003	28.593
WFG	7/25/2003	28.042
WFG	7/26/2003	27.497
WFG	7/27/2003	27.37
WFG	7/28/2003	27.579

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	7/29/2003	27.385
WFG	7/30/2003	27.479
WFG	7/31/2003	27.582
WFG	8/1/2003	27.892
WFG	8/2/2003	28.447
WFG	8/3/2003	28.642
WFG	8/4/2003	29.771
WFG	8/5/2003	29.707
WFG	8/6/2003	29.317
WFG	8/7/2003	29.161
WFG	8/8/2003	28.928
WFG	8/9/2003	28.541
WFG	8/10/2003	29.028
WFG	8/11/2003	28.016
WFG	8/12/2003	28.186
WFG	8/13/2003	28.744
WFG	8/14/2003	29.307
WFG	8/15/2003	28.8
WFG	8/16/2003	28.945
WFG	8/17/2003	29.101
WFG	8/18/2003	29.028
WFG	8/19/2003	28.579
WFG	8/20/2003	28.329
WFG	8/21/2003	28.122
WFG	8/22/2003	28.995
WFG	8/23/2003	29.068
WFG	8/24/2003	29.363
WFG	8/25/2003	29.427
WFG	8/26/2003	29.54
WFG	8/27/2003	29.58
WFG	8/28/2003	29.529
WFG	8/29/2003	29.759
WFG	8/30/2003	29.863
WFG	8/31/2003	29.467
WFG	9/1/2003	29.117
WFG	9/2/2003	29.298
WFG	9/3/2003	29.504
WFG	9/4/2003	29.667
WFG	9/5/2003	29.738
WFG	9/6/2003	29.769
WFG	9/7/2003	29.525
WFG	9/8/2003	29.471
WFG	9/9/2003	29.563
WFG	9/10/2003	29.319
WFG	9/11/2003	29.377
WFG	9/12/2003	29.348
WFG	9/13/2003	29.28

Appendix 5
Water Quality Data

West Flower Garden Bank

Hobo Data February 1, 2003 - March 11, 2004

Site	Date	Temperature (ºC)
WFG	9/14/2003	29.227
WFG	9/15/2003	29.13
WFG	9/16/2003	29.127
WFG	9/17/2003	29.063
WFG	9/18/2003	28.752
WFG	9/19/2003	28.767
WFG	9/20/2003	28.773
WFG	9/21/2003	28.38
WFG	9/22/2003	28.537
WFG	9/23/2003	28.591
WFG	9/24/2003	28.429
WFG	9/25/2003	28.423
WFG	9/26/2003	28.603
WFG	9/27/2003	28.684
WFG	9/28/2003	28.768
WFG	9/29/2003	28.52
WFG	9/30/2003	27.961
WFG	10/1/2003	27.634
WFG	10/2/2003	27.415
WFG	10/3/2003	27.245
WFG	10/4/2003	27.444
WFG	10/5/2003	27.528
WFG	10/6/2003	27.44
WFG	10/7/2003	27.663
WFG	10/8/2003	27.706
WFG	10/9/2003	27.294
WFG	10/10/2003	27.204
WFG	10/11/2003	27.042
WFG	10/12/2003	27.093
WFG	10/13/2003	27.366
WFG	10/14/2003	27.331
WFG	10/15/2003	27.02
WFG	10/16/2003	26.889
WFG	10/17/2003	27.093
WFG	10/18/2003	26.755
WFG	10/19/2003	26.518
WFG	10/20/2003	26.561
WFG	10/21/2003	26.647
WFG	10/22/2003	26.763
WFG	10/23/2003	26.695
WFG	10/24/2003	26.677
WFG	10/25/2003	26.632
WFG	10/26/2003	26.568
WFG	10/27/2003	26.828
WFG	10/28/2003	26.718
WFG	10/29/2003	26.457
WFG	10/30/2003	26.724

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	10/31/2003	26.612
WFG	11/1/2003	26.701
WFG	11/2/2003	26.687
WFG	11/3/2003	26.691
WFG	11/4/2003	26.701
WFG	11/5/2003	26.679
WFG	11/6/2003	26.695
WFG	11/7/2003	26.648
WFG	11/8/2003	26.431
WFG	11/9/2003	26.252
WFG	11/10/2003	26.567
WFG	11/11/2003	26.587
WFG	11/12/2003	26.366
WFG	11/13/2003	26.308
WFG	11/14/2003	26.195
WFG	11/15/2003	26.034
WFG	11/16/2003	26.099
WFG	11/17/2003	26.024
WFG	11/18/2003	26.008
WFG	11/19/2003	25.669
WFG	11/20/2003	25.404
WFG	11/21/2003	25.018
WFG	11/22/2003	24.994
WFG	11/23/2003	24.909
WFG	11/24/2003	24.523
WFG	11/25/2003	24.327
WFG	11/26/2003	24.15
WFG	11/27/2003	24.05
WFG	11/28/2003	23.635
WFG	11/29/2003	23.44
WFG	11/30/2003	23.691
WFG	12/1/2003	24.09
WFG	12/2/2003	24.223
WFG	12/3/2003	24.311
WFG	12/4/2003	24.307
WFG	12/5/2003	24.09
WFG	12/6/2003	23.803
WFG	12/7/2003	23.667
WFG	12/8/2003	23.635
WFG	12/9/2003	23.426
WFG	12/10/2003	22.956
WFG	12/11/2003	22.82
WFG	12/12/2003	22.848
WFG	12/13/2003	22.782
WFG	12/14/2003	22.617
WFG	12/15/2003	22.345
WFG	12/16/2003	22.475

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	12/17/2003	22.485
WFG	12/18/2003	22.459
WFG	12/19/2003	22.351
WFG	12/20/2003	22.349
WFG	12/21/2003	22.263
WFG	12/22/2003	21.937
WFG	12/23/2003	21.817
WFG	12/24/2003	21.782
WFG	12/25/2003	21.682
WFG	12/26/2003	21.756
WFG	12/27/2003	21.672
WFG	12/28/2003	21.618
WFG	12/29/2003	21.497
WFG	12/30/2003	21.381
WFG	12/31/2003	21.409
WFG	1/1/2004	21.461
WFG	1/2/2004	21.891
WFG	1/3/2004	22.064
WFG	1/4/2004	22.064
WFG	1/5/2004	22.1
WFG	1/6/2004	21.833
WFG	1/7/2004	21.406
WFG	1/8/2004	21.26
WFG	1/9/2004	21.332
WFG	1/10/2004	21.246
WFG	1/11/2004	21.338
WFG	1/12/2004	20.93
WFG	1/13/2004	20.553
WFG	1/14/2004	20.93
WFG	1/15/2004	21.209
WFG	1/16/2004	21.004
WFG	1/17/2004	21.403
WFG	1/18/2004	21.424
WFG	1/19/2004	21.101
WFG	1/20/2004	21.734
WFG	1/21/2004	20.682
WFG	1/22/2004	19.97
WFG	1/23/2004	21.213
WFG	1/24/2004	21.72
WFG	1/25/2004	22.166
WFG	1/26/2004	22.228
WFG	1/27/2004	21.807
WFG	1/28/2004	21.65
WFG	1/29/2004	21.251
WFG	1/30/2004	21.252
WFG	1/31/2004	21.364
WFG	2/1/2004	21.346

Appendix 5
Water Quality Data

West Flower Garden Bank		
Hobo Data February 1, 2003 - March 11, 2004		
Site	Date	Temperature (ºC)
WFG	2/2/2004	21.336
WFG	2/3/2004	21.529
WFG	2/4/2004	21.27
WFG	2/5/2004	21.235
WFG	2/6/2004	21.127
WFG	2/7/2004	20.778
WFG	2/8/2004	20.261
WFG	2/9/2004	20.095
WFG	2/10/2004	19.799
WFG	2/11/2004	20.234
WFG	2/12/2004	20.349
WFG	2/13/2004	20.976
WFG	2/14/2004	20.992
WFG	2/15/2004	19.77
WFG	2/16/2004	19.645
WFG	2/17/2004	19.97
WFG	2/18/2004	20.917
WFG	2/19/2004	21.131
WFG	2/20/2004	20.395
WFG	2/21/2004	20.994
WFG	2/22/2004	19.557
WFG	2/23/2004	19.805
WFG	2/24/2004	20.339
WFG	2/25/2004	20.166
WFG	2/26/2004	19.353
WFG	2/27/2004	19.339
WFG	2/28/2004	19.542
WFG	2/29/2004	19.91
WFG	3/1/2004	19.835
WFG	3/2/2004	19.809
WFG	3/3/2004	19.916
WFG	3/4/2004	20.434
WFG	3/5/2004	20.605
WFG	3/6/2004	20.623
WFG	3/7/2004	20.678
WFG	3/8/2004	20.891
WFG	3/9/2004	20.895
WFG	3/10/2004	20.948
WFG	3/11/2004	21.175

Appendix 6
Fish Survey
East and West Flower Garden Banks 2002 and 2003

East Bank 2002		
Family	**Spp**	**Abundance***
Acanthuridae	Doctorfish	27
Acanthuridae	Blue tang	21
Acanthuridae	Surgeon fish	7
Atherinidae	Silverside	100
Aulostomidae	Trumpetfish	1
Balistidae	Black durgeon	22
Balistidae	Ocean triggerfish	1
Blenniidae	Red lipped blenny	1
Carangidae	Bar jack	10
Carangidae	Black jack	3
Carangidae	Horse-eye jack	1
Carangidae	Rainbow runner	1
Chaetodontidae	Reef butterfly fish	30
Chaetodontidae	Banded butterflyfish	4
Gobiidae	Neon goby	5
Holocentridae	Squirrelfish	2
Holocentridae	Longspine squirrelfish	1
Inermiidae	Boga* >200	200
Kyphosidae	Chub	106
Labridae	Bluehead	479
Labridae	Creole wrasse	464
Labridae	Clown wrasse	24
Labridae	Spanish hogfish	13
Labridae	Puddingwife	1
Lutjanidae	Dog snapper	4
Monocanthidae	Whitespotted filefish	3
Monocanthidae	Orangespotted filefish	2
Mullidae	Yellow goatfish	3
Ostraciidae	Smooth trunkfish	3
Ostraciidae	Spotted trunkfish	3
Pomacanthidae	Rock beauty	5
Pomacanthidae	French angelfish	2
Pomacanthidae	Queen angelfish	2
Pomacentridae	Blue chromis	334
Pomacentridae	Brown chromis	175
Pomacentridae	3 Spot damselfish	149
Pomacentridae	Bicolor damselfish	96
Pomacentridae	Cocoa damsel	12
Pomacentridae	Sergeant major	9
Pomacentridae	Yellowtail damsel	6
Pomacentridae	Beaugregory	1
Scaridae	Queen parrotfish	33
Scaridae	Stoplight parrotfish	24
Scaridae	Striped parrotfish	5
Scaridae	Princess parrotfish	4
Serranidae	Creole fish	202
Serranidae	Rock hind	5
Serranidae	Yellowmouth grouper	4
Serranidae	Graysby	3
Serranidae	Tiger grouper	3
Serranidae	Yellowfin grouper	2
Serranidae	Marbled grouper	1
Sphyraenidae	Barracuda	15
Tetraodontidae	Sharpnose puffer	11
Total		**2645**

West Bank 2002		
Family	**Spp**	**Abundance***
Acanthuridae	Blue tang	29
Acanthuridae	Doctorfish	10
Aulostomidae	Trumpetfish	1
Balistidae	Black durgeon	19
Blenniidae	Saddled blenny	1
Carangidae	Blue runner	6
Carangidae	Bar jack	2
Chaetodontidae	Reef butterfly fish	22
Chaetodontidae	Longsnout butterfly fish	2
Chaetodontidae	Spotfin butterfly fish	2
gobiidae	Neon goby	1
Holocentridae	Squirrelfish	2
Holocentridae	Longspined squirrelfish	1
Kyphosidae	Chub	36
Labridae	Bluehead	366
Labridae	Creole wrasse	255
Labridae	Clown wrasse	64
Labridae	Yellowhead wrasse	24
Labridae	Spanish hogfish	23
Labridae	Puddingwife	1
Lutjanidae	Dog snapper	1
Lutjanidae	Gray snapper	1
Monocanthidae	Orangespotted filefish	2
Monocanthidae	Whitespotted filefish	1
Mullidae	Yellow goatfish	10
Muraenidae	Spotted moray	1
Ostraciidae	Smooth trunkfish	5
Ostraciidae	Spotted trunkfish	2
Ostraciidae	Honeycomb cowfish	1
Pomacanthidae	Queen angelfish	9
Pomacanthidae	French angelfish	8
Pomacanthidae	Rock beauty	8
Pomacentridae	Brown chromis	239
Pomacentridae	3 Spot damselfish	121
Pomacentridae	Blue chromis	80
Pomacentridae	Bicolor damselfish	63
Pomacentridae	Cocoa damsel	26
Pomacentridae	Yellowtail damsel	20
Pomacentridae	Sergeant major	6
Pomacentridae	Spotfin damsel	6
Pomacentridae	Long-fin damsel	1
Scaridae	Queen parrotfish	33
Scaridae	Stoplight parrotfish	30
Scaridae	Princess parrotfish	5
Scaridae	Redband parrotfish	2
Serranidae	Creole fish	459
Serranidae	Rock hind	4
Serranidae	Graysby	2
Serranidae	Yellowtail grouper	2
Serranidae	Red hind	1
Serranidae	Tiger grouper	1
Sphyraenidae	Barracuda	34
Tetraodontidae	Sharpnose puffer	21
Total		**2072**

* Number of fish sited in the 100m x 100m study site in an average of sixteen surveys conducted at each bank

Appendix 6
Fish Survey
East and West Flower Garden Banks 2002 and 2003

East Bank 2003		
Family	**Spp**	**Abundance***
Acanthuridae	Blue tang	20
Acanthuridae	Doctorfish	18
Acanthuridae	Ocean surgeonfish	5
Aulostomidae	Trumpetfish	2
Balistidae	Black durgeon	22
Blenniidae	Redlip blenny	4
Carangidae	Bar jack	17
Carangidae	Crevalle jack	12
Carangidae	Horseye jack	16
Chaetodontidae	Reef butterflyfish	11
Chaetodontidae	Spotfin butterflyfish	6
Diodontidae	Balloonfish	1
Gobiidae	Neon goby	21
Holocentridae	Longspine squirrelfish	2
Holocentridae	Squirrelfish	1
Kyphosidae	Bermuda chub	122
Labridae	Bluehead	149
Labridae	Creole wrasse	1575
Labridae	Puddingwife	1
Labridae	Spanish hogfish	25
Monocanthidae	Whitespotted filefish	7
Mullidae	Yellow goatfish	3
Ostraciidae	Honeycomb cowfish	2
Ostraciidae	Smooth trunkfish	3
Ostraciidae	Spotted trunkfish	1
Pomacanthidae	Queen angelfish	2
Pomacanthidae	Rock beauty	3
Pomacentridae	Bicolor damselfish	125
Pomacentridae	Blue chromis	327
Pomacentridae	Brown chromis	815
Pomacentridae	Cocoa damselfish	8
Pomacentridae	Purple reeffish	1
Pomacentridae	Sergeant major	4
Pomacentridae	Threespot damselfish	138
Pomacentridae	Yellowtail damselfish	6
Scaridae	Princess parrotfish	27
Scaridae	Queen parrotfish	38
Scaridae	Redband parrotfish	3
Scaridae	Stoplight parrotfish	18
Serranidae	Coney	1
Serranidae	Creole fish	350
Serranidae	Rock hind	2
Serranidae	Tiger grouper	3
Serranidae	Yellowmouth grouper	1
Sphyraenidae	Barracuda	14
Tetraodontidae	Sharpnose puffer	15
Total		**3947**

West Bank 2003		
Family	**Spp**	**Abundance***
Acanthuridae	Blue tang	48
Acanthuridae	Doctorfish	3
Acanthuridae	Ocean surgeonfish	3
Balistidae	Black durgeon	33
Balistidae	Ocean triggerfish	16
Blenniidae	Redlip blenny	4
Carangidae	Bar jack	27
Chaetodontidae	Reef butterflyfish	28
Chaetodontidae	Longsnout butterflyfish	5
Chaetodontidae	Spotfin butterflyfish	5
Cirrhitidae	Redspotted hawkfish	2
Diodontidae	Balloonfish	1
Diodontidae	Porcupinefish	1
Gobiidae	Neon goby	43
Gobiidae	Goldspot goby	1
Holocentridae	Longspine squirrelfish	4
Holocentridae	Blackbar soldierfish	1
Holocentridae	Squirrelfish	1
Inermiidae	Boga	220
Kyphosidae	Bermuda chub	11
Labridae	Bluehead	304
Labridae	Creole wrasse	216
Labridae	Spanish hogfish	27
Labridae	Yellowhead wrasse	5
Lutjanidae	Dog snapper	3
Mullidae	Yellow goatfish	17
Ostraciidae	Smooth trunkfish	8
Ostraciidae	Spotted moray	2
Pomacanthidae	Rock beauty	8
Pomacanthidae	Queen angelfish	3
Pomacentridae	Brown chromis	431
Pomacentridae	Blue chromis	184
Pomacentridae	Threespot damselfish	167
Pomacentridae	Bicolor damselfish	137
Pomacentridae	Cocoa damselfish	21
Pomacentridae	Yellowtail damselfish	12
Pomacentridae	Dusky damselfish	5
Pomacentridae	Sergeant major	4
Pomacentridae	Purple reeffish	1
Pomacentridae	Sunshinefish	1
Scaridae	Queen parrotfish	41
Scaridae	Stoplight parrotfish	19
Scaridae	Princess parrotfish	16
Scaridae	Redband parrotfish	5
Serranidae	Creole fish	381
Serranidae	Coney	2
Serranidae	Graysby	2
Serranidae	Rock hind	2
Serranidae	Tattler bass	2
Serranidae	Marbled grouper	1
Sphyraenidae	Barracuda	36
Tetraodontidae	Sharpnose puffer	20
Total		**2540**

* Number of fish sited in the 100m x 100m study site in an average of sixteen surveys conducted at each bank

Appendix 7
Coral Disease

Figure 1. Plague-like syndrome on *Diploria strigosa* observed during the 2002 monitoring cruise.

Figure 2. Plague-like syndrome on *Diploria strigosa* observed during the 2002 monitoring cruise.

Appendix 7
Coral Disease

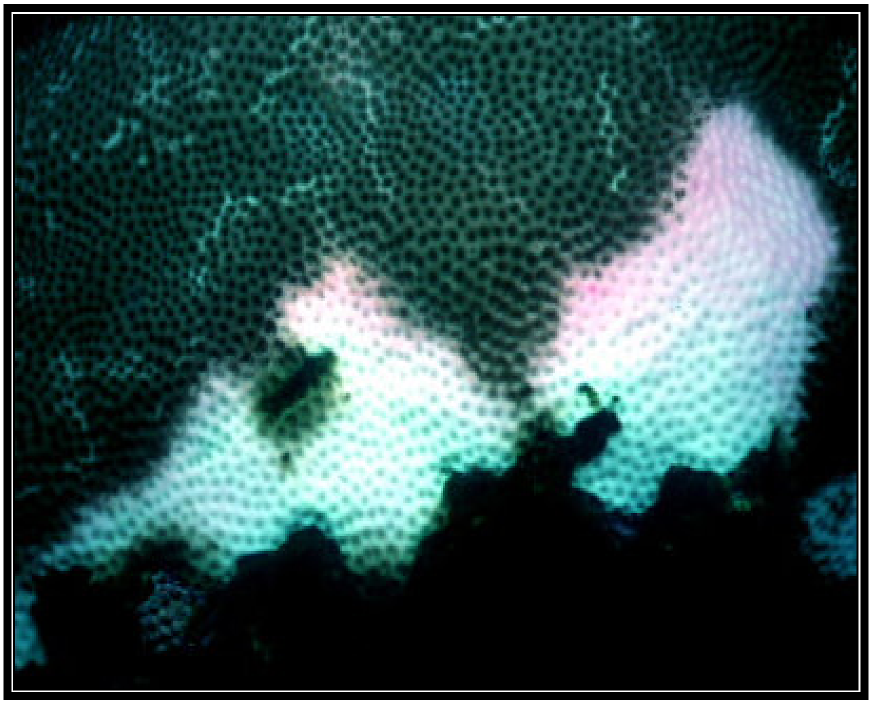

Figure 3. Plague-like syndrome on *Siderastrea siderea* observed during the 2003 monitoring cruise.

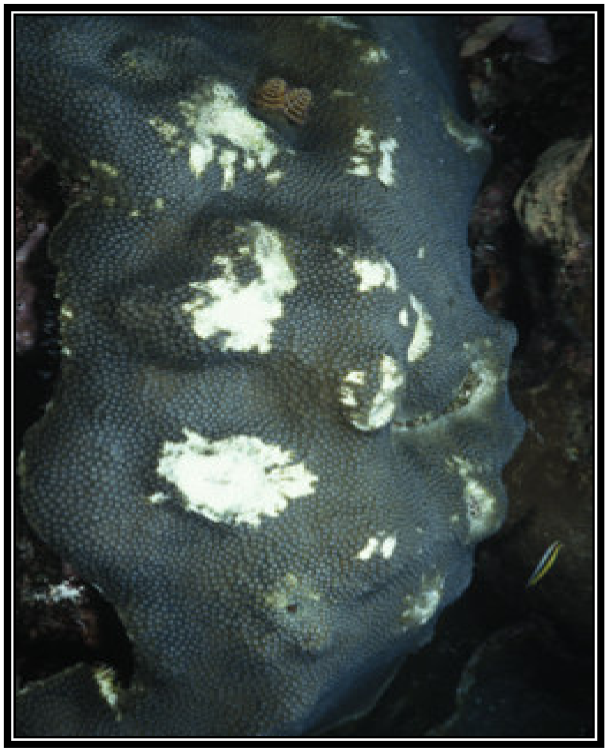

Figure 4. Concentrated parrotfish biting on *Montastraea faveolata* observed during the 2002 monitoring cruise.

Appendix 7
Coral Disease

Figure 5. Concentrated parrotfish biting on *Colpophyllia natans* observed during the 2002 monitoring cruise.

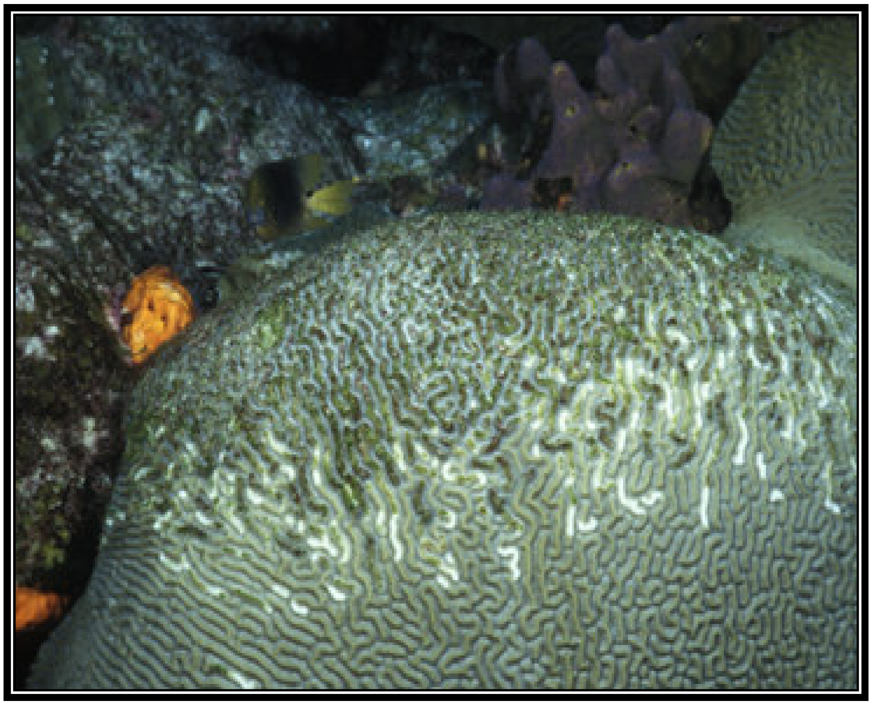

Figure 6. Ridge mortality caused by *Stegastes planifrons* territories on *Diploria strigosa* observed during the 2002 monitoring cruise.

Appendix 7
Coral Disease

Figure 7. Interspecific coral competition observed during the 2002 monitoring cruise.

MARCH 3, 1849

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.