The State of Coral Reef Ecosystems of the Flower Garden Banks, Stetson Bank, and Other Banks in the Northwestern Gulf of Mexico

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INTRODUCTION AND SETTING

The East and West Flower Garden Banks (EFGB and WFGB) were designated as the Flower Garden Banks National Marine Sanctuary (FGBNMS) through the National Oceanic and Atmospheric Administration (NOAA) in January 1992. The two banks are prominent geological features located near the outer edge of the continental shelf in the northwestern Gulf of Mexico, approximately 192 km southeast of Galveston, Texas (Figure 7.1). These features, created by the uplift of underlying salt domes of Jurassic origin, rise from surrounding water depths of over 100 m to within 17 m of the surface. The northernmost thriving coral reef communities in North America cap the shallow portions of the EFGB and WFGB. They are relatively isolated from other coral reefs of the Caribbean and Gulf of Mexico, located over 690 km from the nearest reefs of the Campeche Bank off Mexico's Yucatan Peninsula, and over 1,200 km from the coral reefs of the Florida Keys. The area of the EFGB (27°54.5' N, 93°36.0' W) comprises about 65.8 km^2 of which about 1.02 km^2 is coral reef. Located 19.3 km to the west, the WFGB (27°52.5' N, 93°49.0' W) comprises about 77.2 km^2 of which about 0.4 km^2 is coral reef (Gardner et al., 1998).

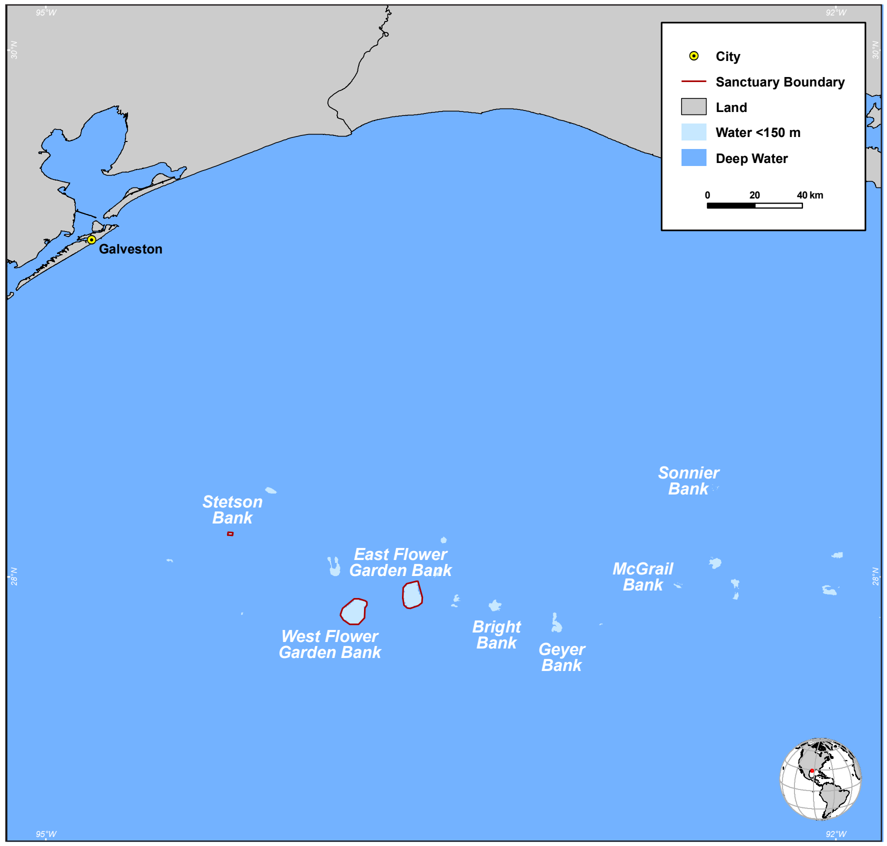

Figure 7.1. Map showing the locations of banks in the northwestern Gulf of Mexico. Map: K. Buja.

Structurally, the shallowest component of the Flower Garden Banks' (FGB) coral community is comprised of aggregations of large, closely spaced boulder and brain coral heads that grow to up to 3 m or more in diameter and height (Figure 7.2). Reef topography is relatively rugose, with many vertical and inclined surfaces. Between groups of coral heads, there are numerous sand patches and channels. Coral growth is relatively uniform over the entire top of both banks, occupying the bank crests down to about 50 m. As the reef slopes downward on the flanks of the bank tops, coral growth occurs in a more plate-like fashion to maximize exposure to available sunlight, and individual heads can cover large areas. Despite the low species numbers on the reef crest, the reefs exhibit extremely high coral cover, ranging on average between 45-52% down to 30 m depth, and up to 70% in areas down to at least 43 m depth.

Figure 7.2. Boulder and brain corals are typically found on the coral caps of the FGB. Photo: G.P. Schmahl.

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2. PBS&J
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There is a relatively low diversity (only about 21 species) of reef-building corals on the FGB likely due to its geographic isolation, annual range of water temperature and other factors. Interestingly, the coral reefs of the FFGB contain practically no elkhorn (*Acropora palmata*) or staghorn corals (*A. cervicornis*) and none of the shallow-water sea whips or sea fans (gorgonians) that are common elsewhere in the Caribbean. Deepwater surveys below 43 m, however, reveal a rich diversity of gorgonians and antipatharian corals.

Stetson Bank was added to the FGBNMS in 1996. It is located 48 km to the northwest of the WFGB and is also associated with an underlying salt dome. Stetson Bank is classified as a mid-shelf bank (Rezak et al., 1985) and is comprised of claystone/siltstone outcrops forming distinct pinnacles near its northern edge. Stetson Bank is not a true coral reef, but it does contain a low diversity coral community in addition to a prominent sponge fauna. Stetson Bank is dominated by fire coral (*Millepora alcicornis*) and in certain areas ten-ray star coral (*Madracis decactis*). These two species collectively make up about 32% of coral cover in the pinnacle region (Bernhardt, 2000). Stetson Bank is composed of claystone outcroppings that have been pushed within 17 m of the sea surface. Including the two dominant species, about 10 species of coral have been documented. The pinnacle region is the most conspicuous feature of the bank, which stretches along the northwest face of Stetson Bank for approximately 500 m. With the addition of Stetson Bank, the FGBNMS encompasses 145.8 km^2 and includes the entire bank areas of each of the three features.

In addition to the coral reefs within the FGBNMS, there are a number of other reefs and banks in the northwestern Gulf of Mexico that contain corals or coral communities. The FGB and Stetson Bank are part of a network of over one hundred continental shelf-edge features off the coasts of Texas and Louisiana. Many of these topographic features were the subjects of baseline scientific investigations in the late 1970s and early 1980s (Rezak et al., 1985). These studies first documented that a number of the banks contained coral reef resources. Additional surveys by FGBNMS staff and collaborators have provided further insight into the nature of these banks, of which at least four harbor substantial populations of scleractinian coral. They are: Bright Bank (11 species; Rezak et al., 1985; FGBNMS observations), Sonnier Bank (nine species; Rezak et al., 1985; Weaver et al., 2006), Geyer Bank (four species; Rezak et al., 1985, FGBNMS observations) and McGrail Bank (nine species; Rezak et al., 1985; Weaver et al., 2006; FGBNMS observations). The coral communities at McGrail Bank are of special interest. Recent surveys have revealed a community dominated by the blushing star coral (*Stephanocoenia intersepta*) which covers up to 30% of the seafloor in some areas at depths between 45 and 60 m (Schmahl and Hickerson, 2006; Figure 7.3).

*Figure 7.3. McGrail Bank contains colonies of the blushing star coral (*Stephanocoenia intersepta*). Photo: FGBNMS/NURC-UNCW.*

High resolution multibeam bathymetry of the reefs and banks and surrounding deepwater areas around the FGB has revealed structural connectivity previously not reported. This structural connectivity provides the basis for biological and ecological connectivity of many of the reefs and banks in the NW Gulf of Mexico, creating "habitat highways" which may support greater movement of species and individuals between locations. Recent manta ray (*Manta birostris*) tagging studies at the FGBNMS have verified multiple bank use by individual manta rays (R. Graham, pers. comm.), strengthening the connectivity concept in this region.

Many of the other banks in the northwestern Gulf of Mexico contain extensive communities of a variety of deeper water coral assemblages, characterized by antipatharians, gorgonians, solitary corals and species of branching corals such as *Oculina* spp. and *Madrepora* spp. These types of communities are typically observed in depths from 60 m to 150 m, and exhibit similar populations at similar depths and habitat types across the reefs and banks along the shelf edge. All of the reefs and banks in the vicinity provide hardbottom substrate that has been colonized by a high diversity of benthic invertebrates and serves as important habitat for a wide range of reef fish species (Dennis and Bright, 1988). These banks are currently unprotected, with the exception of regulation of direct impacts from oil and gas development. Further investigations are warranted to fully determine the extent of these living marine resources.

The FGBNMS sustained a number of disturbances in 2005, many of which are reported in more detail in this chapter. The first widespread FGBNMS coral disease event on record occurred during the early months of the year. This was followed by two major hurricanes passing through the region later in the season, one of which resulted in an enormous plume of discolored water originating from the Texas and Louisiana coast, moving rapidly out and over the FGBNMS. During this same time period, the onset of the most severe Caribbean coral bleaching event on record occurred.

In 2006, the FGBNMS created a Sanctuary Advisory Council and initiated a Management Plan Review (MPR), which is currently in progress. As with other Sanctuary MPR processes, a series of ongoing public scoping meetings provided an opportunity for user groups, such as recreational SCUBA divers, recreational and commercial fishers, and the oil and gas industry, to help identify issues of importance. The results of the meetings and additional input from regional experts provided guidance for development of working groups charged with addressing specific topics. Issues under scrutiny include fishing, visitor use, boundary expansion, pollutant discharge, enforcement and education.

ENVIRONMENTAL AND ANTHROPOGENIC STRESSORS

Climate Change and Coral Bleaching

It has long been suggested that the location and depth of coral reefs at Gulf of Mexico banks buffer them from the most acute short-term effects of global warming and climate change. Prior to 2005, the prevalence of coral bleaching was relatively low (less than 4% annually; Hagman and Gittings, 1992; Gittings et al., 1993; U.S. DOI-MMS, 1996; Dokken et al., 1999, 2003; Precht et al., 2008a). In 2005, elevated water temperatures were present on the reef cap for 50 days until September 23, 2005. By late August 2005, a bleaching event was underway at the FGBNMS. By October 2005, after the passage of two major hurricanes in the Gulf of Mexico, FGBNMS surveys reported that as much as 46% of the individual colonies exhibited some level of bleaching. Surveys conducted by FGBNMS in March 2006 showed that approximately 4-5% of the coral colonies still exhibited varying degrees of bleaching. More detailed information and data describing coral bleaching in the FGB can be found in the Benthic Habitats portion of this chapter.

Diseases

The incidence of disease has historically been very low at the EFGB and WFGB of the FGBNMS; however, in February 2005, the first widespread coral disease event was observed at both banks. This event affected multiple colonies and at least seven reef-building species. This plague-like disease, termed "white syndrome" (WS), has subsequently been surveyed and observed in 2006 and 2007. This disease (Figure 7.4) is more active during the winter months, which is quite different from typical plague-like coral diseases in the Caribbean. In 2007, 12-15% of the reef building corals were affected by the disease, and during winter surveys in 2007, partial mortality of affected corals at varying levels was recorded for the first time at the FGBNMS (A. Bruckner, pers. comm.) With the assistance of the Coral Disease and Health Consortium, a team of experts has been investigating the disease, including Andy Bruckner (NOAA Fisheries), Bob Jonas and Geoff Cooke (George Mason University). White band disease, which is common elsewhere in the tropical western Atlantic, has not been observed at the FGBNMS to date.

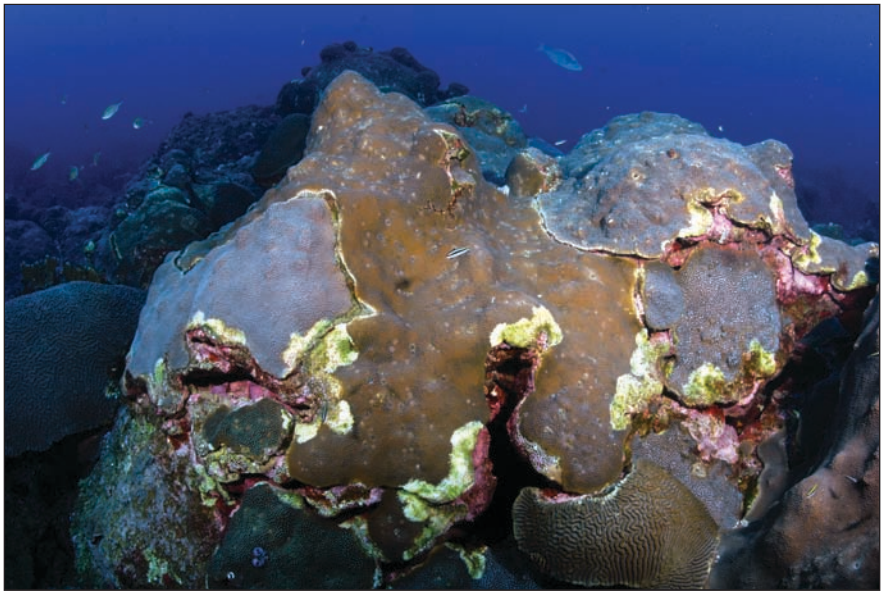


Figure 7.4. Winter plague-like coral disease at the FGBNMS. Photo: FGBNMS/ Schmahl.

Tropical Storms

Since 2000, four hurricanes have passed near the FGB (Figure 7.5). In August 2005, Hurricane Katrina (not shown on map), one of the most destructive storms in U.S. history, made landfall a few hundred miles northeast of the FGBNMS, near New Orleans, LA. Soon thereafter, on September 23, 2005, Hurricane Rita, a Category 3 storm (Saffir-Simpson Index), passed within 50 miles of the FGB before making landfall on the Texas coast. Although staff were not able to visit the FGBNMS between the hurricanes, staff members did assess damage at the banks soon after the passage of Hurricane Rita and reported significant damage to the reef including large (3–4 m diameter) dislodged coral heads (Figure 7.6), gouged and damaged corals from waterborne projectiles (Figure 7.6), displacement of sand and sediment, removal of and injury to large barrel sponges (Figure 7.6) and scouring in sand channels (Figure 7.7). The expansive *Madracis mirabilis* field on the east side of the EFGB also experienced catastrophic levels of breakage and toppling (Figure 7.7).

On November 13, 2005, a team from PBS&J, was assembled to conduct further hurricane impact surveys, focusing on the 100 x 100 m monitoring site at the EFGB. Approximately 1.5% of the coral colonies photographed at the EFGB quadrat stations in August 2005 were missing, apparently as a result of the hurricane (Precht et al., 2008b). At Stetson Bank, scouring of the claystone/siltstone valleys occurred.

Researchers working at the EFGB Brine Seep, reported impacts to experiment stations at 72 m – the deepest documented impact of the storms within the FGBNMS (K. Parsons-Hubbard, pers. comm.).

Water temperature at the EFGB increased slightly as Hurricane Katrina moved towards New Orleans, while the passage of Hurricane Rita resulted in a drop in water temperature. Salinity decreased at both EFGB and Stetson Bank during the passage of Hurricanes Katrina and Rita. More detail on temperature and salinity fluctuations during storms can be found in the the Water Quality section of this chapter.

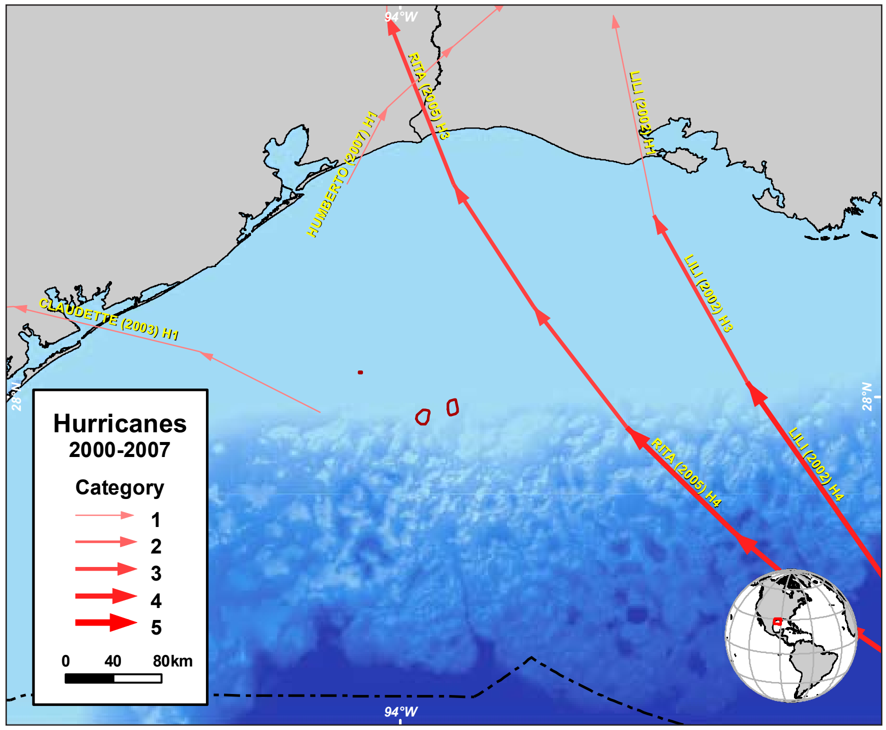


Figure 7.5. A map showing the paths and intensities of hurricanes passing near the FGBNMS, 2000-2007. Map. K. Buja. Source: http://maps.csc.noaa.gov/hurricanes/.

Figure 7.6. From left to right: a large Colpophyllia natans *colony was dislodged from the reef and tossed into a sand patch (left); another* Colpophyllia natans *sheared off during a storm (center); and storm damage to a barrel sponge (right). Left photo: FGBNMS/Hickerson; center and right photos: Joyce and Frank Burek.*

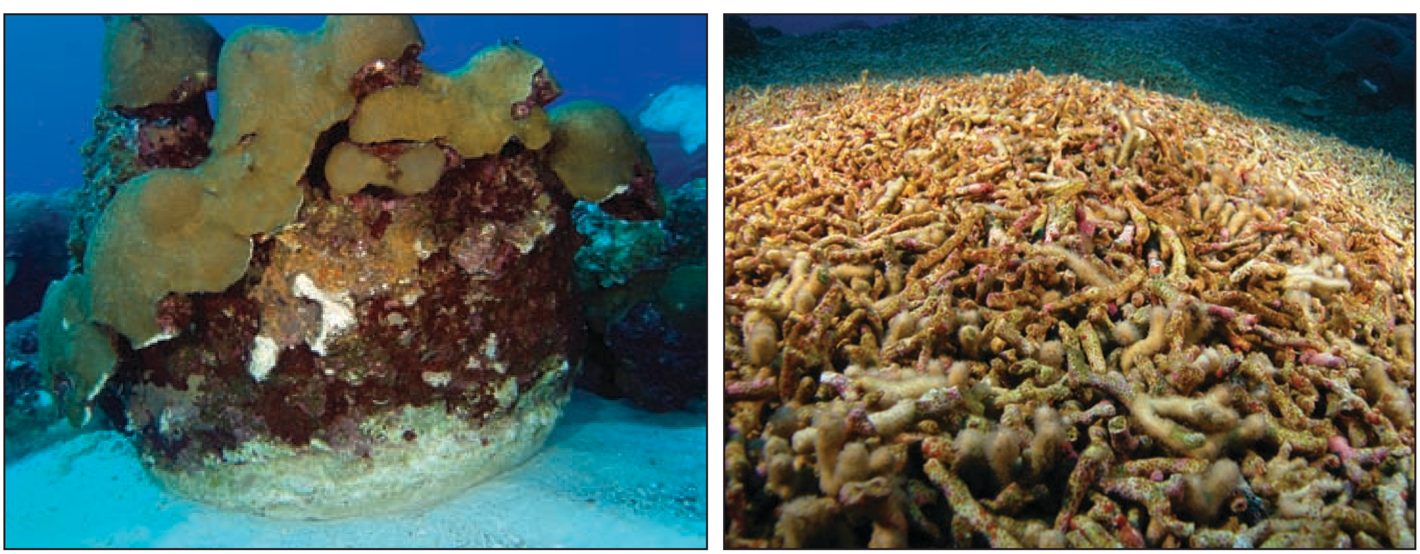


Figure 7.7. Coral outcropping showing souring of sand channel (left). Photo: Joyce and Frank Burek. Yellow pencil coral, Madracis mirabilis*, flattened during Hurricane Rita (right). Photo: TPWD/John Embesi.*

On September 12, 2007, Tropical Storm Humberto, the fastest developing storm on record, passed very near the FGBNMS before making landfall as a Category 1 hurricane on the Texas coast. The storm interrupted a monitoring cruise underway at the FGBNMS, forcing the scientists to abandon their mission and the ship to return to port. The effects, if any, from Hurricane Humberto on the FGBNMS will be included in the next report in this series.

Coastal Development and Runoff

The primary sources of degraded water quality include coastal runoff, river discharges and effluent discharges from offshore activities such as oil and gas development and marine transportation (Deslarzes, 1998). Oxygen-depleted (hypoxic) near-bottom waters have been found in a large area of the northern Gulf of Mexico. Often called the “dead zone” this area has included up to 16,500 km^2 of the continental shelf from the Mississippi Delta to the Texas coast. Although relatively far from the FGB, there is concern that this area could continue to grow and impact outer continental shelf areas.

General coastal runoff and degraded nearshore water quality can potentially impact the banks through cross-shelf transport processes which bring turbid, nutrient-rich water offshore. Deslarzes (2007) postulates the fluorescent bands observed in the carbonate skeletons of some corals come from the seasonal transport of nearshore water onto the FGBNMS, which may be tainted by urban, agricultural and biological contaminants.

Research using nitrogen isotopes suggests a pathway for direct primary nitrogen input from coastal river sources from a considerable distance. While nitrogen isotopes from the FGB have signatures of oceanic origin (K. Dunton, pers. comm.), benthic algae from Stetson Bank have a distinct nitrogen isotope signature similar to plants found in coastal estuarine systems. These findings suggest that recent coastal influences are reaching only as far as Stetson Bank.

Coastal Pollution

Hurricane Rita made landfall on the Texas-Louisiana border on September 24, 2005. The impact from the resultant rain and winds created a massive plume of discolored water originating from shore, and moving directly south. The plume reached the surface waters of the FGB by September 25 (Figure 7.8). Unfortunately the composition of this discolored water was not determined, and it is unknown at this time whether the water mass reached the coral caps. The discolored water persisted for at least one month after the hurricane event (NASA/GSFC; MODIS/NOAA CoastWatch; FGBNMS).

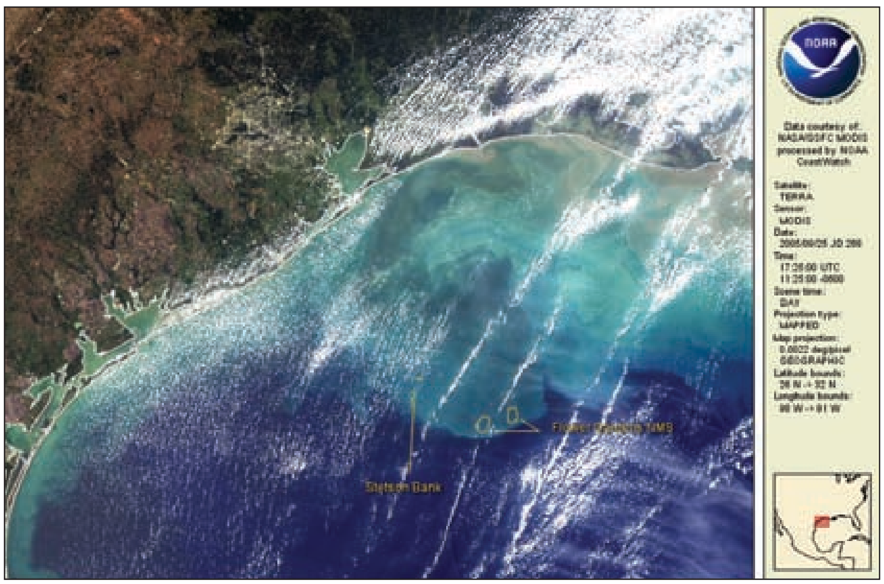


Figure 7.8. Satellite imagery showing plume of discolored water immediately after Hurricane Rita. Source: NASA/GSFC; MODIS/NOAA CoastWatch.

Tourism and Recreation

Recreational scuba diving is a popular activity at the FGB, and demand appears to be increasing. There are currently two live-aboard charter dive vessels that regularly visit the banks (Figure 7.9). The M/V *Spree* carries up to 24 divers, and the M/V *Fling* can carry up to 35 divers. A third vessel with a carrying capacity of 30-40 divers has indicated that they plan to offer dive charters to the FGBNMS in the near future. In 1997, a survey of charter dive operations revealed that an estimated 2,350 divers visited the FGB. These divers spent $870,000 in Texas, of which approximately $636,000 was spent in the local economy of Freeport, where it generated $1.1 million in sales/output, $477,000 in income, and 24 full-time and part-time jobs. An additional $234,000 was spent in other areas of Texas, with $559,000 in sales/output, $228,000 in income, and 11 jobs (Ditton and Thailing, 2001).

Figure 7.9. The M/V Spree*, one of two recreational dive charter vessels currently operating at the FGB, ties up to one of the FGBNMS’ 17 mooring buoys. Photo: R. Wilkins.*

Fishing

The impacts of fishing and associated activities are not well known. At this time, only traditional hook and line fishing is allowed in the FGBNMS. However, illegal fishing by both commercial long-liners and recreational spearfishers have been reported. Targeted fishing efforts, which are allowed under current regulations, could have a significant detrimental impact on snapper, mackerel and grouper populations. Anecdotal reports suggest that spawning aggregations are impacted from direct fishing pressure.

Lost and discarded fishing gear has been observed in the FGBNMS (Figure 7.10). Such objects can cause localized physical injury to coral reefs and have been known to entangle and injure sea turtles and other organisms. Illegally discarded fishing and shrimping bycatch has been reported by scuba divers.

Figure 7.10. Discarded shrimp net in deep water habitat at Stetson Bank. Photo: FGBNMS/ National Undersea Research Center-Univ. North Carolina, Wilmington.

Stetson Bank's proximity to the coast suggests greater use by recreational fishers than in other areas of FGBNMS. Due to the relatively soft nature of the substrate, Stetson Bank may be more prone to mechanical injury from fishing, which likely renders it more susceptible to disturbance from tropical storm and hurricane events. Evidence for this process comes from surveys conducted at Sonnier Bank, another mid-shelf bank similar in substrate and communities to Stetson Bank. Frequent visitors to Sonnier Bank have reported chronic incidents of anchor and fishing impacts. Post-Hurricane Rita surveys conducted by MMS, PBS&J and FGBNMS, revealed catastrophic impacts to the substrate there.

Trade in Coral and Live Reef Species

This activity is prohibited by Sanctuary regulations.

Ships, Boats and Groundings

Groundings do not occur at the FGBNMS due to the depth of the banks. However, anchors from large ships can have devastating local impacts to the living coral reef. Over the last 20 years there have been a number of incidences of significant impacts caused by the anchoring of large industry vessels, freighters and fishing vessels (Gittings et al., 1992). Foreign-flagged cargo vessels have occasionally anchored at the FGB without knowing of the anchoring restrictions. There have been at least three large vessel anchoring incidents since 1994. In 2002, the FGBNMS became the first international "no-anchor zone" through the development of new language integrated by the International Maritime Organization. Managers hope this designation will prevent future illegal anchoring incidents.

Marine Debris

Impacts to various habitats within the Sanctuary from marine debris have been documented through recent remotely operated vehicle (ROV) and SCUBA surveys. Seismic cables (Figure 7.11), defunct pipelines, longlines and shrimping nets have all been encountered in the FGBNMS. Stetson Bank is encompassed by a ring of higher relief outcroppings, making it especially prone to accumulation of marine debris, particularly nets and line. Although longlining and the use of nets for fishing or shrimping are not allowed within the Sanctuary, illegal nets have been observed covering delicate sponges and branching corals. Debris resulting from oil and gas extraction impacts seafloor habitats as well, and seismic cables have caused abrasions along the flanks of some areas of the coral reef caps.

It is suspected that debris will be found throughout the Sanctuary. Its abundance and spatial distribution is dependent upon several factors, including its origin/source, ocean currents, and physiographic characteristics. Understanding the amount, extent and types of debris in the FGBNMS is critical to the management of sanctuary resources and is a prerequisite to targeting cleanup, prevention and education efforts. Monitoring surveys undertaken by NOAA's Center for Coastal Monitoring and Assessment, Biogeography Branch (CCMA-BB) and the FGBNMS staff provided an initial characterization of the prevalence of marine debris at the FGBNMS, and initial results from those surveys can be found in the Benthic Habitat section of this chapter.

Aquatic Invasive Species

In August 2002, an invasive coral species from the Pacific Ocean, *Tubastraea coccinea*, was photographed at the EFGB on reef substrate at around 24 m depth (Figure 7.12). Prior to this discovery, no evidence of the coral had been reported on natural reef substrate in the Gulf of Mexico. However, it was known to inhabit the underwater structures of at least seven oil and gas platforms off the Texas coast. The first known sighting of *T. coccinea* on platforms in the Gulf occurred in 1991, and it was later documented on several other platforms (Fenner, 2001; Fenner and Banks, 2004). This coral species currently thrives on High Island A389A (HIA389A), a gas platform located within the EFGB boundaries. Since this initial discovery, at least two additional colonies have been documented at the EFGB. In September 2004, several dozen colonies of *T. coccinea* were also documented by the FGBNMS research team at Geyer Bank, located 52 km east-southeast of the EFGB. In May 2007, the FGBNMS documented over 100 colonies thriving at Geyer Bank. Several colonies were also documented at Sonnier Bank. This is further evidence of the threat to natural reef ecosystems by this invasive species.

A Pacific species of nudibranch (*Thecacera pacifica*) was first documented at Stetson Bank by Joyce Burek in 2006. The pair shown in Figure 7.12 was photographed during reproduction, so it is possible that this species may be proliferating. It is unknown how this invasive species will impact Stetson Bank ecosystem dynamics.

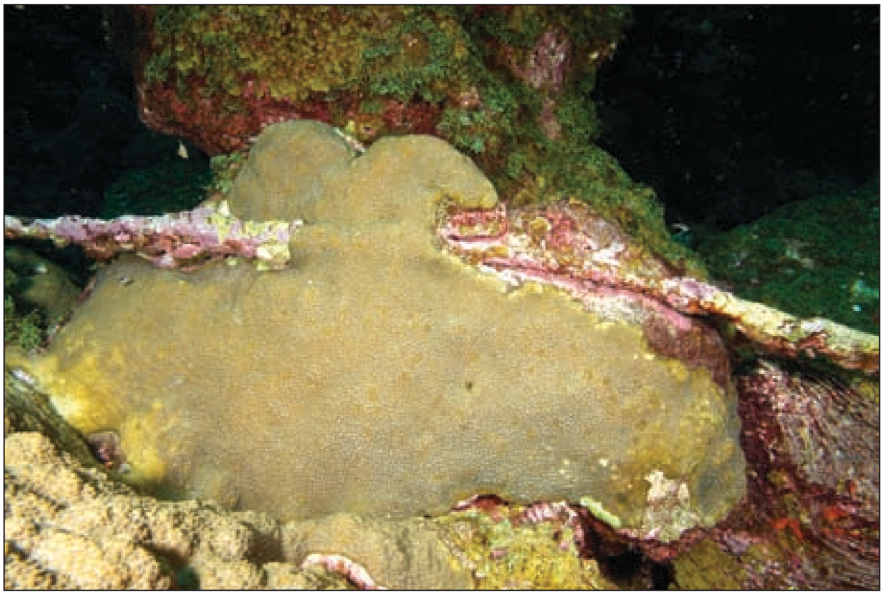


Figure 7.11. Seismic cable overgrown by coral on the crest of the reef. Photo: Joyce and Frank Burek.

Figure 7.12. Orange cup coral, Tubastraea coccinea*, is an invasive species from the Pacific and was found growing on the reef cap at the EFGB (left). A Pacific species of nudibranch,* Thecacera pacifica*, was photographed at Stetson Bank (right). Photos: Joyce and Frank Burek.*

Offshore Oil and Gas Exploration

The northern Gulf of Mexico is one of the most active areas for oil and gas exploration and development in the world. The Gulf of Mexico Outer Continental Shelf accounts for 25% of the oil and 14% of the natural gas produced in offshore U.S. waters (J. Sinclair, pers. comm.). By the end of 2007, 6,801 production platforms had been installed (of which approximately 2,910 were removed), about 47,969 wells had been drilled (including dry holes), and 63,400 km of pipeline installed (Figure 7.13).

Within the four-mile zones of both the EFGB and WFGB, which are regulated by the U.S. Department of the Interior, Minerals Management Service (MMS), there are currently 14 production platforms (six at the WFGB and eight at the EFGB, including one subsea station) and approximately 184.31 km of pipeline, 131.12 (71%) of which are dedicated gas pipelines. One platform and ap-

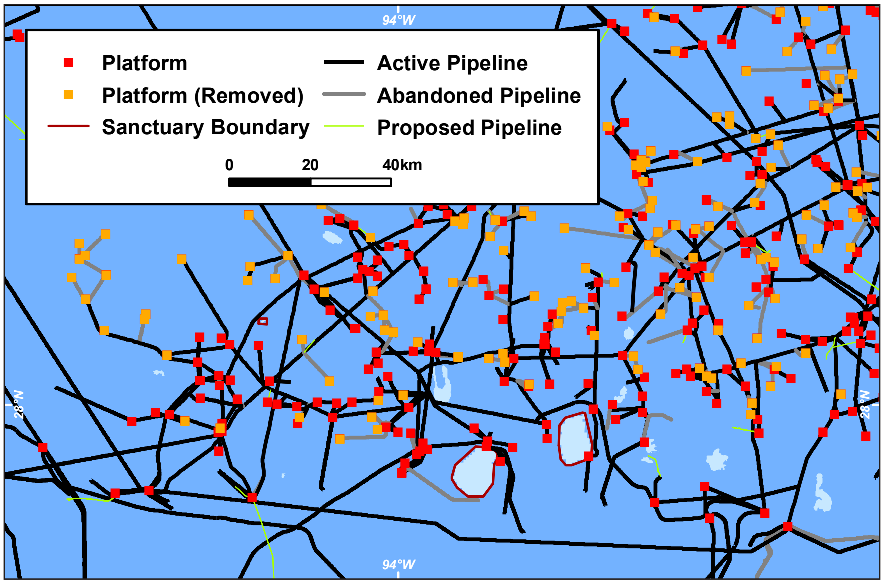


Figure 7.13. Oil and gas infrastructure in the vicinity of the FGBNMS. Map: K. Buja.

Flower Garden Banks

proximately 13.48 km of pipeline is located within a 6.5 km radius of Stetson Bank. Approximately fifteen decommissioned platforms have been converted to artificial reef sites in the vicinity of the FGBNMS.

There is one gas production platform (HIA389A) located within the EFGB boundary, less than 2 km from the coral cap (Figure 7.14). Recent exploration activities have been conducted by this platform. A pipeline has been constructed through the Sanctuary to link HIA389A to a subsea station outside Sanctuary boundaries. This pipeline will be used to transfer product from the subsea station to HIA389A for processing and shipment to shore.

Figure 7.14. An operational gas platform within the boundaries of the FGBNMS. Photo: FGBNMS/G.P. Schmahl.

Potential impacts from offshore oil and gas exploration and development include accidental spills, contamination by drilling, related effluents and discharge, anchoring of vessels involved in placing pipelines, drilling rigs and production platforms, seismic exploration, use of dispersants in oil spill mitigation and platform removal. In spite of the intense industrial activity, long-term monitoring studies indicate no significant detrimental impact to the coral reefs of the FGBNMS from nearby oil and gas development (Gittings, 1998). Fortunately, there have been no major oil spills or impacts from these activities.

While the structures of the platform appear to provide artificial substrate for both motile and sessile marine populations, there is growing concern that the oil and gas structures may act as vectors for the spread of invasive and exotic species. An example is the introduction and establishment of sergeant majors (*Abudefduf saxatilis*) at the FGBNMS in 1997 and the recent appearance of yellowtail snapper (*Ocyurus chrysurus*). Pattengill (1998) suggests that these resulted from "hopping" along platforms in the eastern Gulf, where they have been reported by recreational fishers. We suspect that this is also the vector used by the orange cup coral (*T. coccinea*) to colonize the EFGB.

CORAL REEF ECOSYSTEMS—DATA-GATHERING ACTIVITIES AND RESOURCE CONDITION

East and West Flower Garden Banks, Long-Term Monitoring Project

Since 1989, the coral caps of the East and West Banks of the FGBNMS have been monitored annually through a contract funded cooperatively by the FGBNMS and MMS. Since 2002, the contract has been held by a group led by PBS&J, Geo-Marine, Inc. and Dauphin Island Sea Lab. Monitoring of Stetson Bank is not included in the contract. Table 7.1 lists these activities, as well as the monitoring activities undertaken at the FGBNMS by other organizations.

Table 7.1. Table of assessment and monitoring activities. Source: E. Hickerson.

PROGRAM	OBJECTIVES	START DATE	FUNDING	PARTNERS
FGBNMS Long-Term Monitoring	Long-term monitoring of benthos, fish, lobster and *Diadema* at the East and West FGB	1988	FGBNMS, MMS	PBS&J, GeoMarine, Inc., Dauphin Island Marine Lab
Stetson Bank Long-Term Monitoring	Long-term monitoring of the coral pinnacle area at Stetson Bank	1993	FGBNMS	TAMUG, TPWD, various volunteer divers
Biogeographic Characterization of Fish Communities within the FGBNMS	Randomly selected benthic and fish transects on the reef cap and deep water habitats	2006	NCCOS, NOAA, FGBNMS	NCCOS, CCMA Biogeography Branch
REEF fish surveys	Roving diver surveys	1996	REEF, FGBNMS	REEF
AGRRA surveys	Conduct rapid assessment of the benthic community	1999	FGBNMS, AGRRA	AGGRA

AGRRA – Atlantic and Gulf Rapid Reef Assessments
CCMA – Center for Coastal Monitoring and Assessment
FGBNMS – Flower Garden Banks NMS
NCCOS – National Centers for Coastal Ocean Service
REEF – Reef Environment Education Foundation
TAMUG – Texas A&M University – Galveston
TPWD – Texas Parks and Wildlife

The FGBNMS Long-Term Monitoring (LTM) Project is conducted within one hectare (ha; 100 x 100 m area) study sites located on the coral caps at EFGB and WFGB (Figure 7.15). The study evaluates water quality (temperature, salinity, light attenuation, pH, turbidity, dissolved oxygen), reef diversity, coral growth rates, long-term changes in individual coral colonies, accretionary growth, general coral reef community health, and fish, lobster and *Diadema* populations. Water samples are analyzed for nitrogen, nitrate, nitrite, dissolved ammonia, soluble reactive phosphorus, total phosphorus and chlorophyll a. Though the study quantifies a number of important parameters, the one hectare study sites do not encompass all reef habitat types found in the FGBNMS, such as the *Madracis mirabilis* fields. This fact was highlighted as a weakness of the monitoring effort after it was discovered that the fields had been catastrophically impacted during the passage of Hurricane Rita, yet the decline was not detected by the LTM project results.

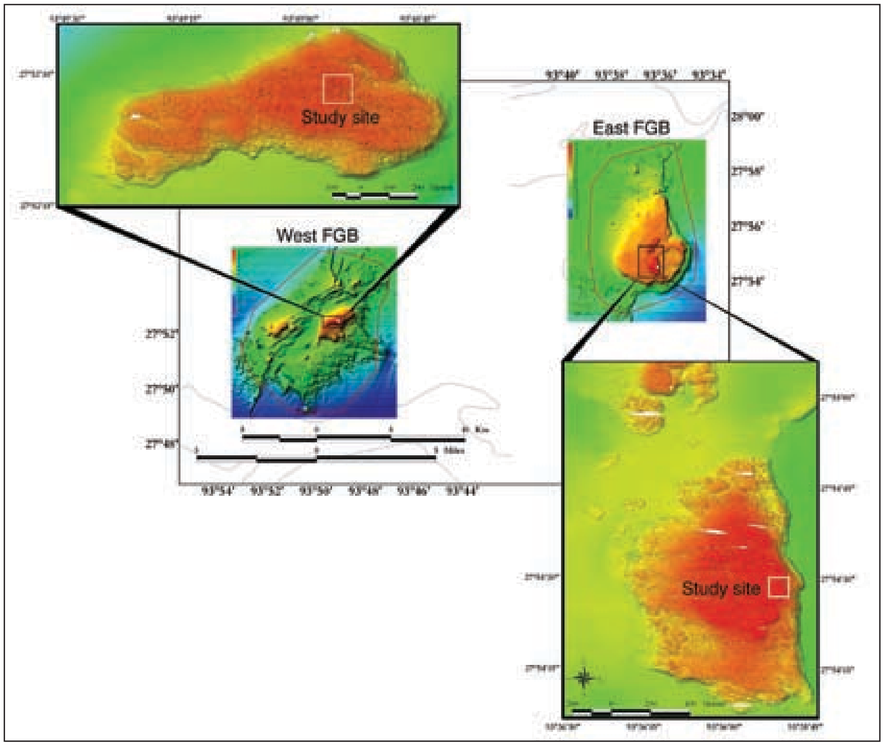


Figure 7.15. The location of study areas for the FGBNMS long-term monitoring project. Source: Gardner et al., 1998; D. Weaver.

Atlantic and Gulf Rapid Reef Assessment Surveys

Benthic and fish communities at one site on each of the EFGB and WFGB were assessed using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol in August 1999.

Reef Environmental Education Foundation Fish Surveys

The Reef Environmental Education Foundation (REEF) conducts fish surveys annually at the FGBNMS using roving diver surveys. The surveys do not quantify the abundance or biomass of the fish community, but all observations are entered into the REEF database. Methods and data are available at http://www.reef.org.

CCMA-BB Characterization of Fish and Benthic Communities at the FGBNMS

Since 1998, CCMA-BB has been working to characterize, monitor and assess tropical ecosystems throughout the U.S. Caribbean and Pacific. This work has resulted in the development of a wide range of products, including maps, peer-reviewed publications, integrated assessments, and a publicly accessible database and Web site. The ongoing collaboration with FGBNMS is closely related to these activities, providing some level of comparability among study sites.

Between September 13 and October 1, 2006, CCMA-BB and FGBNMS launched the collaboration with a research mission on board the NOAA ship R/V *Nancy Foster*. The purpose of this mission was threefold: 1) to provide the Sanctuary with a spatial characterization of fish and benthic communities; 2) to optimize a sampling design for use in future resource monitoring efforts; and 3) to provide a baseline assessment of resource status against which future change can be monitored. The sampling approach utilized by the project relies on stratified random sampling at bank top habitats shallower than 110 ft. Using strata based on location (EFGB and WFGB) and slope (flat and steep), a total of 73 random sites throughout both the EFGB and WFGB were selected for surveys (Figure 7.16). This approach complements the permanent sites surveyed as part of the FGBNMS LTM by providing a more spatially comprehensive examination of sanctuary resources. Subsequent analyses revealed that a more efficient design incorporating both depth and habitat complexity in addition to the bank strata will further optimize sampling. Information on fish species abundance, size and distribution was collected along with data describing benthic habitat composition, coral bleaching and marine debris. An additional 33 sites were surveyed during September 2007 and are currently being analyzed to further characterize the Sanctuary's coral cap community. More project details are available at http://ccma.nos.noaa.gov/ecosystems/sanctuaries/fgb_nms.html.

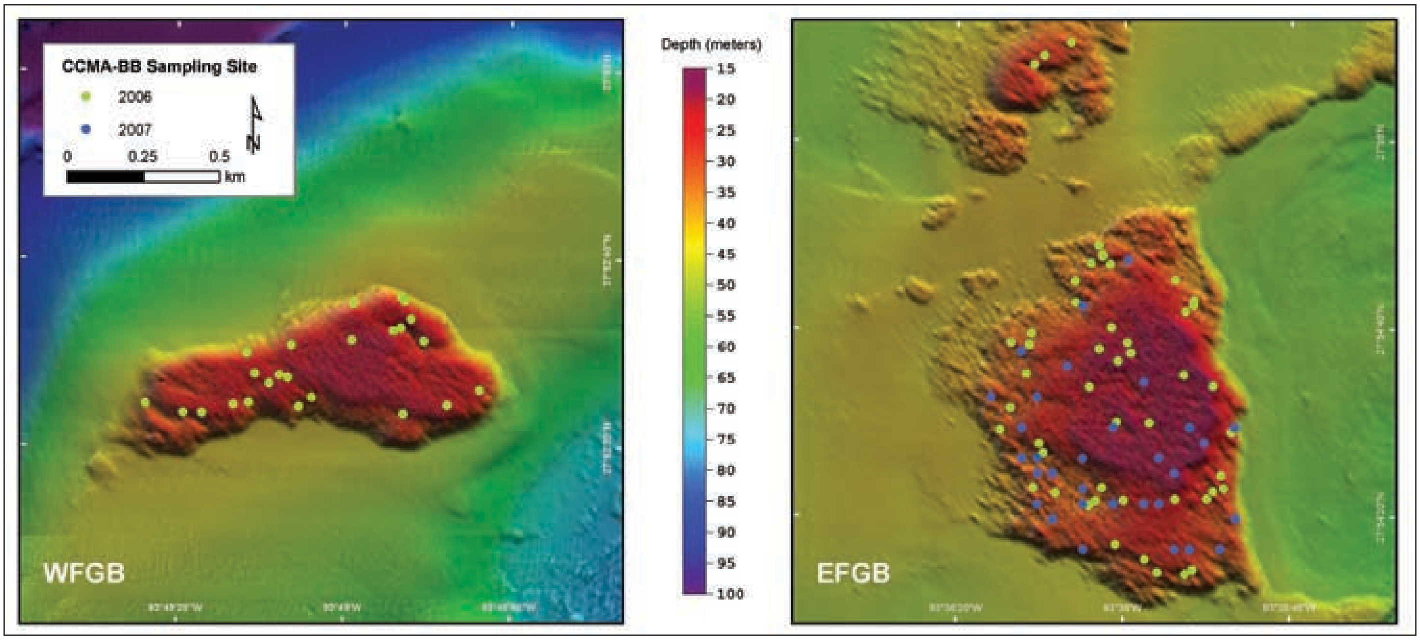


Figure 7.16. The location of stations surveyed by CCMA-BB in 2006 and 2007. Source: CCMA-BB; Map: B. Costa.

Other Sanctuary Activities

In addition to the programs which are summarized in Table 7.1, the FGBNMS supports (by providing shiptime on chartered or Sanctuary vessels) several researchers investigating a wide array of topics. A list of the research projects can be downloaded from: http://flowergarden.noaa.gov/document_library/sci_documents.html. In addition, the Sanctuary research team conducts an annual data collection cruise at Stetson Bank, but funding limitations have precluded data analysis to date. Sanctuary staff encourage recreational divers to submit observations of charismatic megafauna, such as sharks, rays and sea turtles, since observations are maintained in the Sanctuary's database.

The most recent data available from the FGBNMS LTM Project and CCMA-BB/FGBNMS surveys are presented below to characterize the status of benthic habitats and biological communities at the FGBNMS. The combination of these project results best describes the status of the resources, with limitations as noted below.

WATER QUALITY AND OCEANOGRAPHIC CONDITIONS

YSI 6600 Datasondes are deployed at the reef crests of all three banks of the FGBNMS. Sensors log the following measurements at 30 minute intervals: temperature, salinity, photosynthetically active radiation (PAR) irradiance, pH, turbidity and dissolved oxygen. Weather conditions and access to the site permit only quarterly servicing, however, due to fouling, limited memory capacity, etc., more regular servicing is recommended. Anomalies in the data sets prevent reporting of the data, with the exception of temperature. In addition to the deployment of the Datasondes, quarterly water sampling is conducted at the surface, midwater and near bottom. Additional temperature and salinity instruments were deployed on the reefs in the fall of 2007.

In 2005, water temperatures at the FGBNMS ranged from 21.46 to 30.93°C (mean =26.60°C ± 0.13% SE, n=349) at the EFGB and 21.11 to 30.45°C (mean=24.62°C ± 0.14 SE, n=304) at the WFGB. In June and July 2005, seawater temperature at the EFGB and WFGB oscillated between 25 and 28°C before increasing steadily to reach peak annual temperatures in August (Figure 7.17).

The temperature threshold for bleaching at the FGB is 30°C (Hagman and Gittings, 1992). Seawater temperature exceeded 30°C on the reef caps for extended periods at both banks in 2005. At the EFGB, average daily temperature was ≥ 29.5°C from July 29-September 19, 2005 (53 consecutive days). During that time, temperature exceeded 30°C during 29 days (including 16 consecutive days). At the WFGB, temperature on the reef cap was ≥ 29.5°C from July 26-August 22, 2005 (29 days) and temperature exceeded 30°C during seven days from August 6-21, 2005.

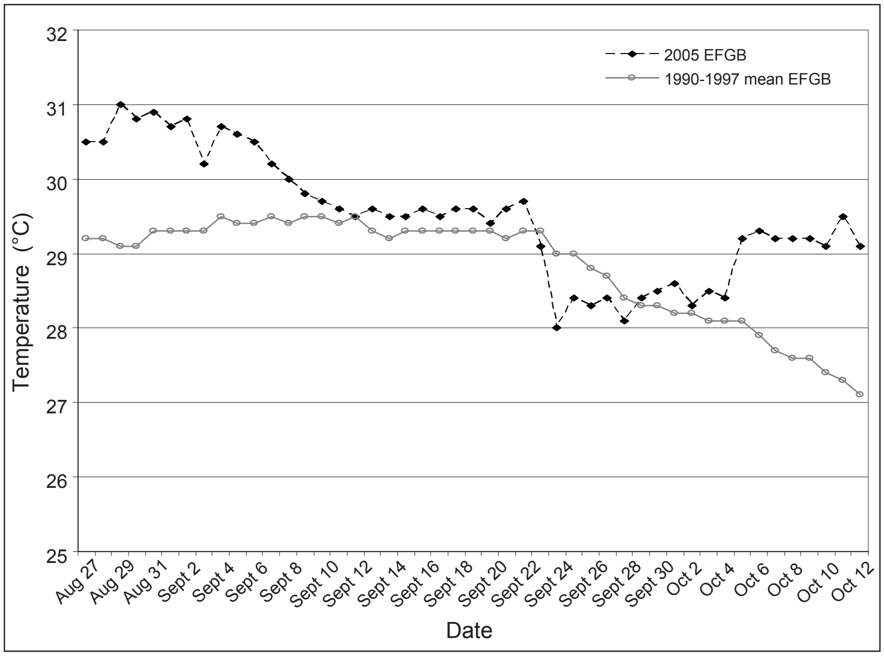


Figure 7.17. Temperature measurements at depth at the EFGB and Stetson Bank during the passage of Hurricanes Katrina and Rita in 2005. Source: FGBNMS/NASA/NOAA CoastWatch/PBS&J.

The temperature and salinity conditions that were experienced by the FGBNMS during Hurricanes Katrina and Rita events are worth noting. During the passage of Hurricane Katrina (August 28-29, 2005) temperature on the reef cap exceeded 30°C at the EFGB. HOBO temperatures indicated a slight increase in water temperature as Katrina passed through the region, but temperatures leveled off within a week. With the passage of Hurricane Rita in late September there was a sudden drop in temperature on the reef caps of the East Bank and West Bank. The temperature dropped from 29.6°C at 0033 hours to 27.4°C at 1933 hours. Temperature rose gradually after the passage of the hurricane. By 0733 hours on September 24, 2005 the temperature on the reef cap was up to 28.4°C

Salinity measurements for Stetson Bank and EFGB are compared in Figure 7.18. During both hurricane events, a drop in salinity is noted. The most dramatic drop was recorded at Stetson Bank after the passage of Hurricane Rita, from 35.4 parts per thousand (ppt) to 32.7 ppt over a period of 10 days. This can be first attributed to the immediate fresh water input into the system from the storm, and subsequent recovery, as seen in EFGB data. Stetson Bank, which is closer to shore, was most likely affected on a prolonged basis due to fresh water influences resulting from the water mass that moved offshore from the Texas/Louisiana coast through the FGBNMS.

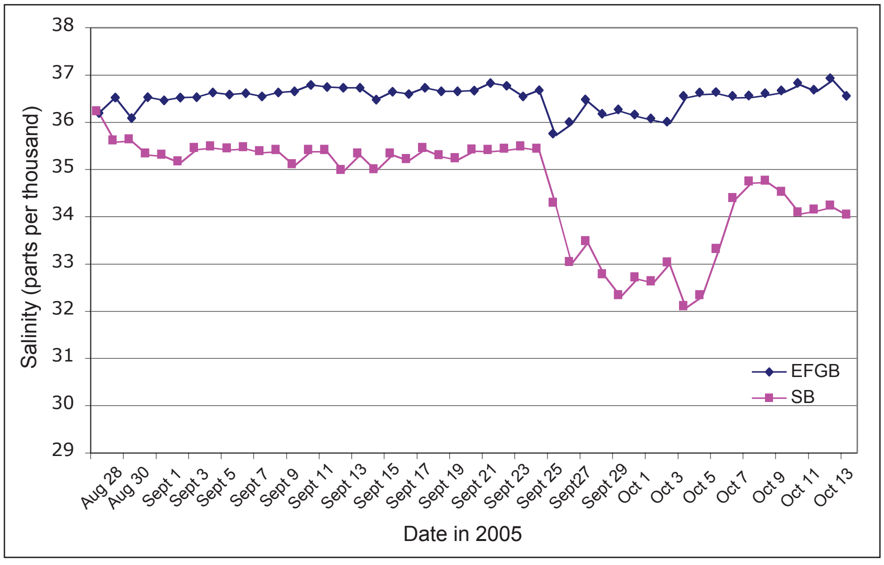


Figure 7.18. Salinity measurements at the EFGB and Stetson Bank (SB) during the passage of Hurricanes Katrina and Rita in 2005. Source: FGBNMS/NASA/NOAA CoastWatch/PBS&J.

BENTHIC HABITATS

East and West Flower Garden Banks, Long-Term Monitoring Project

One hectare study sites were established at both the EFGB and WFGB in 2002, and virtually all LTM monitoring occurs within these areas. The following is a description of the methods outlined in the statement of work for the contracted monitoring effort co-funded by FGBNMS and MMS (MMS Document: NSL-GM-04-06; GOMC4100, Section C). The monitoring includes several elements:

- **Random Photographic Transects:** 16 random photographic and/or digital video transects that are 10 m in length. Mean percent cover and standard deviation for each year and bank are calculated for coral species and other cover categories;
- **Permanent Growth Stations:** Photographs of 60 permanent stations for monitoring growth of the scleractinian coral *Diploria strigosa*;
- **Repetitive Quadrat Stations:** Forty repetitive photoquadrat stations to detect and evaluate long-term changes in individual coral colonies. In addition to the initial 40 stations, nine repetitive quadrat stations have been established at the EFGB in coral reef habitat at deeper depths (30-40 m);
- **Sclerochronology:** Cores of *Montastraea faveolata* coral colonies are taken biannually on each bank in odd numbered years to determine annual growth; and
- **Bleaching Incidence**: Percent cover of bleaching was calculated using random-dot analysis with CPCe® software. To obtain a percent cover value per bank in a particular year the total number of dots within a category (e.g., bleaching) was divided by the total number of dots analyzed for all repetitive quadrats minus the number of dots that fell on tape, wand and shadow.

Results and Discussion

The results presented here are from the FGBNMS long-term monitoring report covering the years 2002-2003 (Precht et al., 2005), 2004-2005 (Precht et al., 2008a) and data from 2006, which will be incorporated into the upcoming 2008 long-term monitoring report (Precht et al., unpub. data).

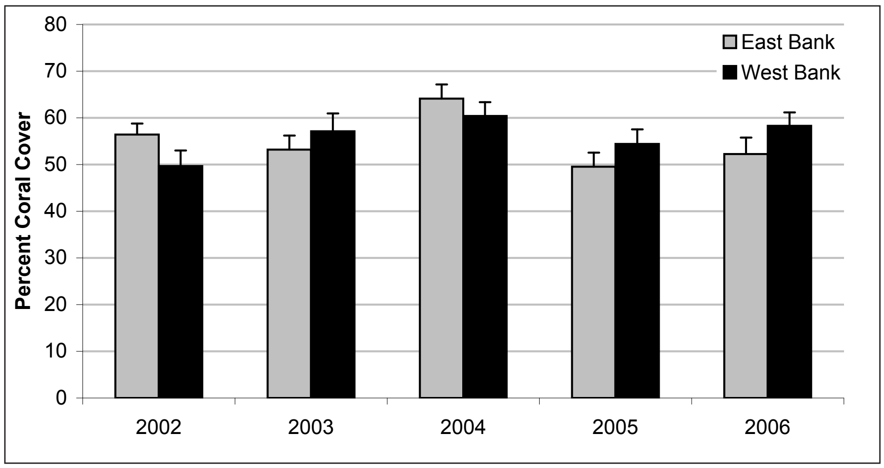


Figure 7.19. Mean percent coral cover at the FGB 2002-2006. Source: PBS&J, unpub. data.

Community Composition and Structure

Monitoring results for 2002-2006 highlighted the continued health of these reefs, expressed as consistently high coral cover, which ranged from 49.55%–64.13% (Figure 7.19). These results are consistent with past monitoring results as well (Figure 7.20). The *Montastraea annularis* complex persisted as the dominant species complex from 2002-2006 (26.8-40.12%), and *Diploria strigosa* (3.2-13.41%) continued to be the second most prevalent species at both banks. Other coral species are represented at the EFGB and WFGB, including *Porites astreoides* (3.39-8.19%) and *Montastraea cavernosa* (2.25-7.73%). After these top four coral species, ten additional species make up the remainder of coral cover within the random transects (Table 7.2).

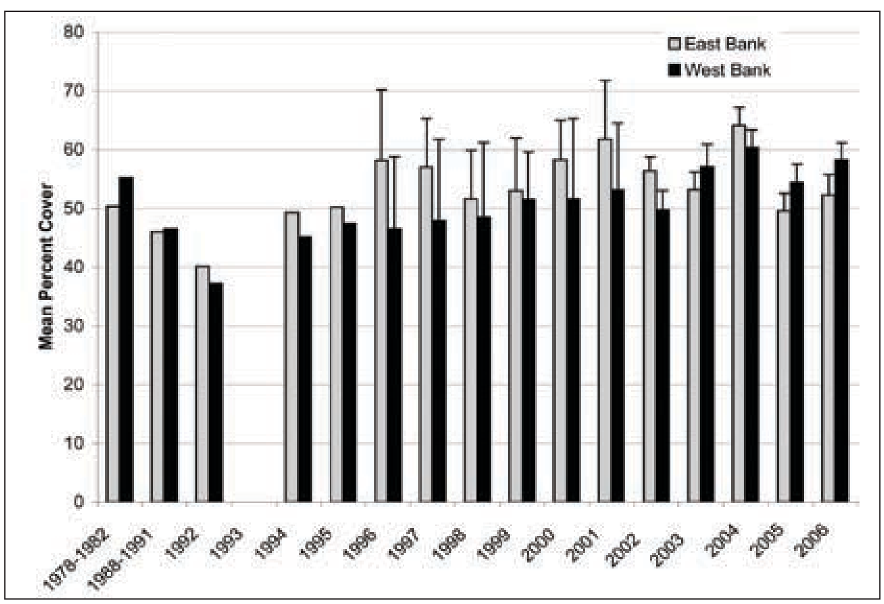


Figure 7.20. Mean percent coral cover at the FGB over time, showing the consistently high coral cover. No percent cover data were reported in 1993. Data sources by year: 1978-1982 from Gittings et al. (1992); 1988-1991 from Gittings et al., (1992); 1992-1995 from MMS (1996); 1996-2001 from Dokken et al. (2003); 2002-2003 from Precht et al., 2005; 2004-2005 from Precht et al. (in press).

Macroalgae cover ranged from 4.06%–34.03% from 2002-2006, with the highest value recorded at the East Bank in 2005. Seasonal variation in macroalgal populations is well documented, so it should be noted that in 2005 and 2006 monitoring took place in June instead of during the normal fall (September-November) sampling period. From 2002-2004 macroalgal cover ranged from 4.06-19.14% across both banks, while from 2005-2006 macroalgal cover ranged from 12.5% to 34.03%. When comparing macroalgae estimates between

Table 7.2. Random transect coral cover by species at the EFGB and WFGB between 2002 and 2006. Values are expressed as percent cover ± SE. Source: PBS&J, unpub. data.

COVER CATEGORY	EAST FLOWER GARDEN BANK					WEST FLOWER GARDEN BANK				
	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
Agaricia agaricites	0.53 ± 0.15	0.33 ± 0.11	0.3 ± 0.12	0.11 ± 0.07	0.08 ± 0.03	0.43 ± 0.11	0.24 ± 0.08	0.29 ± 0.11	0.24 ± 0.07	0.13 ± 0.06
Agaricia fragilis	0.00	0.01 ± 0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colpophyllia natans	0.57 ± 0.39	3.29 ± 1.40	2.81 ± 1.38	1.77 ± 1.08	1.73 ± 1.06	1.67 ± 1.21	2.17 ± 0.84	3.48 ± 1.56	1.4 ± 0.54	0.55 ± 0.28
Diploria strigosa	6.96 ± 1.69	6.19 ± 1.55	12.13 ± 3.05	5.95 ± 1.26	10.25 ± 1.52	3.2 ± 0.91	9.04 ± 2.68	13.41 ± 1.74	6.68 ± 1.29	10.14 ± 1.64
Madracis spp.	0.66 ± 0.41	0.82 ± 0.34	0.7 ± 0.34	0.88 ± 0.38	0.18 ± 0.08	0.7 ± 0.47	0.37 ± 0.29	0.54 ± 0.42	0.08 ± 0.04	0.15 ± 0.10
Millepora alcicornis	2.19 ± 0.56	2.23 ± 0.43	1.41 ± 0.53	1.63 ± 0.59	0.46 ± 0.20	2.16 ± 0.70	1.94 ± 0.54	1.05 ± 0.51	1.68 ± 0.47	0.65 ± 0.20
Montastraea annularis complex	33.59 ± 3.86	28.47 ± 2.98	30.14 ± 5.14	26.8 ± 4.09	31.45 ± 4.09	31.73 ± 3.57	33.8 ± 4.31	31.70 ± 2.70	36.20 ± 3.50	40.12 ± 3.29
Montastraea cavernosa	3.9 ± 1.08	4.24 ± 1.41	7.73 ±2.09	3.4 ± 1.14	2.48 ± 0.67	2.74 ± 1.16	2.67 ± 1.10	3.7 ± 1.02	2.43 ± 0.69	2.25 ± 0.84
Mussa angulosa	0.37 ± 0.16	0.00	0.03 ± 0.02	0.07 ± 0.05	0.05 ± 0.04	0.29 ± 0.16	0.07 ± 0.04	0.16 ± 0.07	0.13 ± 0.08	0.24 ± 0.16
Porites astreoides	6.79 ± 0.83	5.69 ± 0.98	8.19 ± 1.07	7.55 ± 1.19	4.91 ± 0.83	3.44 ± 0.74	3.77 ± 0.46	5.19 ± 0.62	4.04 ± 0.46	3.39 ± 0.57
Porites porites forma furcata	0.06 ± 0.04	0.00	0.00	0.00	0.00	0.01 ± 0.01	0.00	0.00	0.00	0.00
Scolymia cubensis	0.00	0.01 ± 0.01	0.00	0.01 ± 0.01	0.00 ± 0.00	0.00	0.04 ± 0.03	0.00	0.01 ± 0.01	0.01 ± 0.01
Siderastrea siderea	0.44 ± 0.25	0.00	0.27 ± 0.29	0.6 ± 0.38	0.20 ± 0.13	1.9 ± 1.08	2.04 ± 1.10	0.00	1.1 ± 0.73	0.00
Stephanocoenia intersepta	0.31 ± 0.13	0.76 ± 0.32	0.33 ± 0.26	0.47 ± 0.47	0.31 ± 0.16	1.39 ± 0.36	0.96 ± 0.45	0.59 ± 0.27	0.00	0.44 ± 0.21
TOTAL CORAL	**56.43 ± 2.36**	**53.20 ± 3.01**	**64.13 ± 3.03**	**49.55 ± 3.01**	**52.26 ± 3.50**	**49.67 ± 3.35**	**57.13 ± 3.81**	**60.41 ± 2.94**	**54.41 ± 3.13**	**58.28 ± 2.88**

banks, West Bank results were consistently lower than East Bank values from 2003, 2005 and 2006 (Figure 7.21).

Crustose coralline algae, turf algae and bare space (CTB) showed a reciprocal relationship with macroalgae in all years at both banks (Figure 7.22 and 7.23). Between 2002 and 2006, CTB ranged from 11.96-37.07%, with the lowest values occurring at the East Bank in 2005 and the highest at the East Bank in 2002. CTB was higher at the West Bank than at the East Bank from 2003-2006.

On September 23, 2005 Hurricane Rita passed 50 miles east of East Bank on its way to the Texas coast. Although transect data was not taken during a post-hurricane assessment data collection cruise in November 2005, it was collected in June 2006.

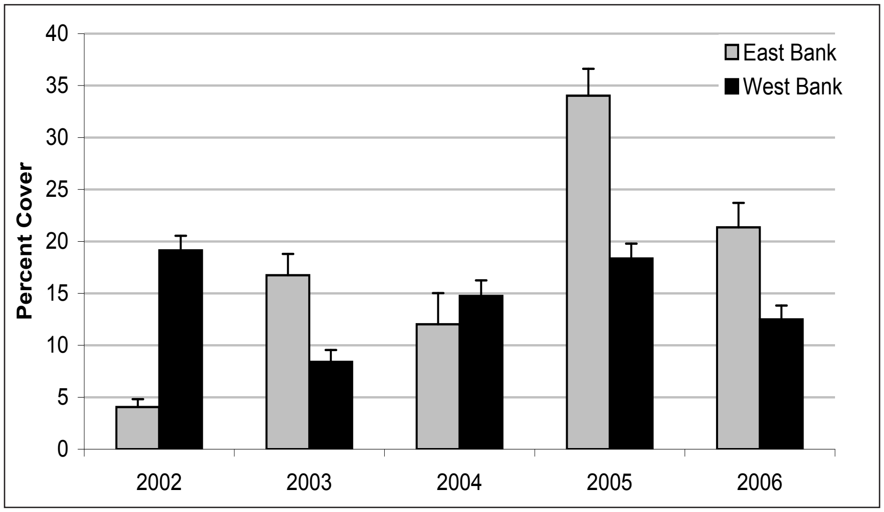


Figure 7.21. Mean percent macroalgae cover at the FGB 2002-2006. Source: PBS&J, unpub. data.

The June 2006 data revealed high CTB levels at East and West Bank (23.15% and 25.64%). Unexpectedly, macroalgae showed disparate patterns at East (21.36%) and West Bank (12.5%) in 2006.

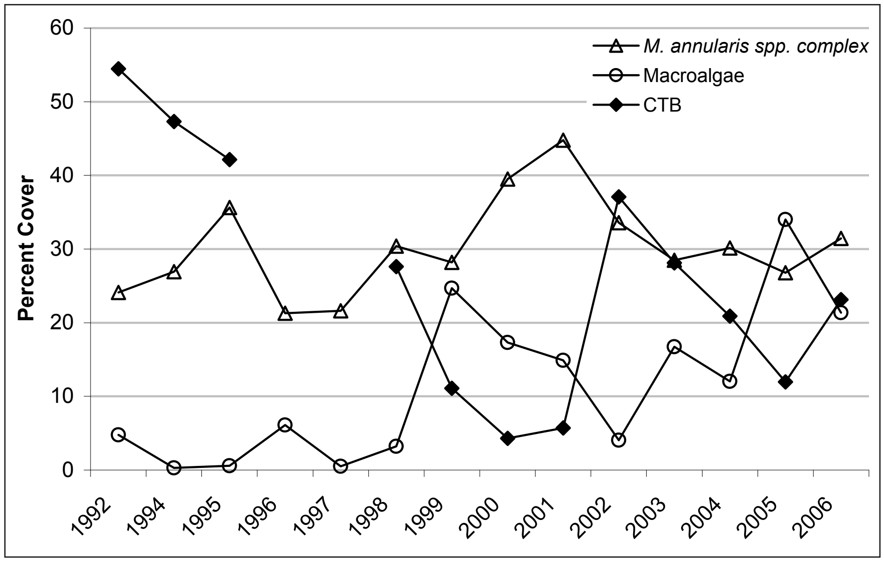


Figure 7.22. East Bank percent cover of Montastraea annularis *species complex, macroalgae and CTB 1992-2006. Source: PBS&J, unpub. data.*

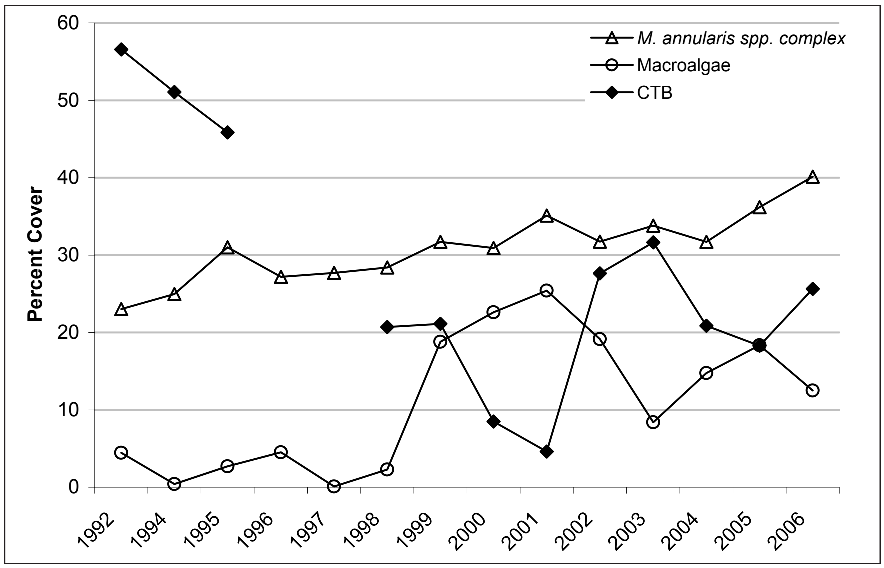


Figure 7.23. West Bank percent cover of Montastraea annularis *species complex, Macroalgae and CTB 1992-2006. Source: PBS&J, unpub. data.*

Coral cover and changes in community structure were measured in November 2005 using repetitive quadrat images and perimeter video at the East Bank long-term monitoring site. Hurricane waves were responsible for overturning large coral colonies, scouring, gouging and the removal of sand from sand flats, as well as bending stainless steel rods on the reef cap (65-75 ft). Although there were dramatic effects of the hurricane at the East Bank, coral cover was not appreciably affected according to repetitive quadrat results. Approximately 1.5% of coral colonies were missing in the 40 repetitive quadrat photographs taken on the coral cap (70-85 ft), while only 0.5% of colonies were missing at nine deep repetitive quadrat stations (105-131 ft). Levels of coral bleaching were relatively high for the FGB (about 6% on the coral caps), but bleaching had been observed before the hurricane (NOAA cruise August 23-27), and it is not known whether the hurricane exacerbated bleaching or whether it may have brought relief in the form of cooler water temperatures. Water quality data results showed that the passage of Hurricane Rita brought cooler water temperatures to the banks after 50 days of elevated temperatures.

Permanent Growth Stations (2002-2003): A total of eight analyses were completed for the East Bank, with four colonies advancing and four colonies retreating in lateral growth. At the West Bank there was a total of four analyses completed, two colonies grew laterally and two colonies showed lateral retraction. Due to the low sample size there was not enough data to draw conclusions about change in lateral growth of *Diploria strigosa* margins at the EFGB and WFGB.

Permanent Growth Stations (2004-2005): A total of 30 analyses were completed for the EFGB, with nine advances and 21 retreats recorded. A total of 25 analyses were completed for the WFGB, with 16 advances and nine retreats. Growth of *D. strigosa* margins was significantly greater on the West Bank than on the East Bank in 2004-2005 (ANOVA t=2.64, df=43, p=0.011). When pooling the data for the two banks, colony area increased 14% from 2004-2005.

Permanent Growth Stations (2005-2006): A total of 33 analyses were completed for the EFGB, with 22 advances and 11 retreats recorded. A total of 51 analyses were completed for the WFGB, with 34 advances and 17 retreats. Overall, this represents a positive growth trend of *D. strigosa* growth margins for the sampling period.

Repetitive Quadrat Stations (2002-2006): Photoquadrats encompassing 8 m^2 are used to monitor changes in coral reef community structure over time. Percent cover data as well as planimetry are used to track corals over time and include measurements of coral cover, bleaching, and disease as well as planimetry measurements of specific coral colonies. In general percent coral cover in the surveyed area is high and exhibits similar species dominance to random transect data. Planimetry is used to measure the margins of individual coral colonies annually to determine changes in marginal growth. Because the *M. annularis* complex is the dominant substratum occupant in repetitive quadrats we compared the cover of this taxon through time.

Over the 2002-2006 sampling period there was an overall extension of growth margins of *M. annularis* complex in repetitive quadrat images. Coral colonies are traced each year and their change in lateral growth is measured as area (cm^2). A proportion is created in relation to the previous years measurement and yields a proportional increase or decrease in the colony area. These proportional changes are averaged per bank and reported below.

Repetitive Quadrat Stations (2002-2003): Sixteen repetitive quadrats were paired and analyzed between 2002 and 2003 at the East Bank. Overall planimetry results showed a 15% growth or extension of margins of the *M. annularis* species complex at EFGB. At the West Bank, 27 images were paired and analyzed and showed an increase of 10% in *M. annularis* species complex.

Repetitive Quadrat Stations (2003-2004): Thirty-eight stations were paired and analyzed between 2003 and 2004 at the East Bank. *M. annularis* complex colonies at the East Bank showed a slight decline in marginal growth by 4%. West Bank showed a similar recession of growth margins (5%).

Repetitive Quadrat Stations (2004-2005): Thirty-six repetitive quadrat images were paired in 2004 and 2005 at the East Bank and the *M. annularis* complex colony margins showed expansion from 2004 to 2005 by 8%. At the West Bank, 20 photograph pairs were analyzed and showed a 3% extension of margins.

Repetitive Quadrat Stations (2005-2006): Thirty-seven repetitive quadrat pairs were compared at the East Bank from 2005-2006, and a 12% increase in *M. annularis* complex margins was measured. West Bank results showed a 17% increase in growth margins from 2005-2006 after analysis of 27 repetitive quadrat pairs.

Sclerochronology

Four coral cores are taken at each bank in odd years from *M. faveolata* colonies to monitor accretional growth of colonies over time. Estimated annual growth at the East Bank ranged from 3.19-14.54 mm/year from 1997-2005, with an average growth of 6.06 mm/year (Figure 7.24). At the West Bank growth rates ranged from 2.75-8.78 mm/year with an overall mean 5.53 mm/year. Mean annual growth rates were not significantly different between banks (t=0.96, df=19, p=0.35), however, a trend of lower growth rates occurs at the West Bank (Figure 7.24).

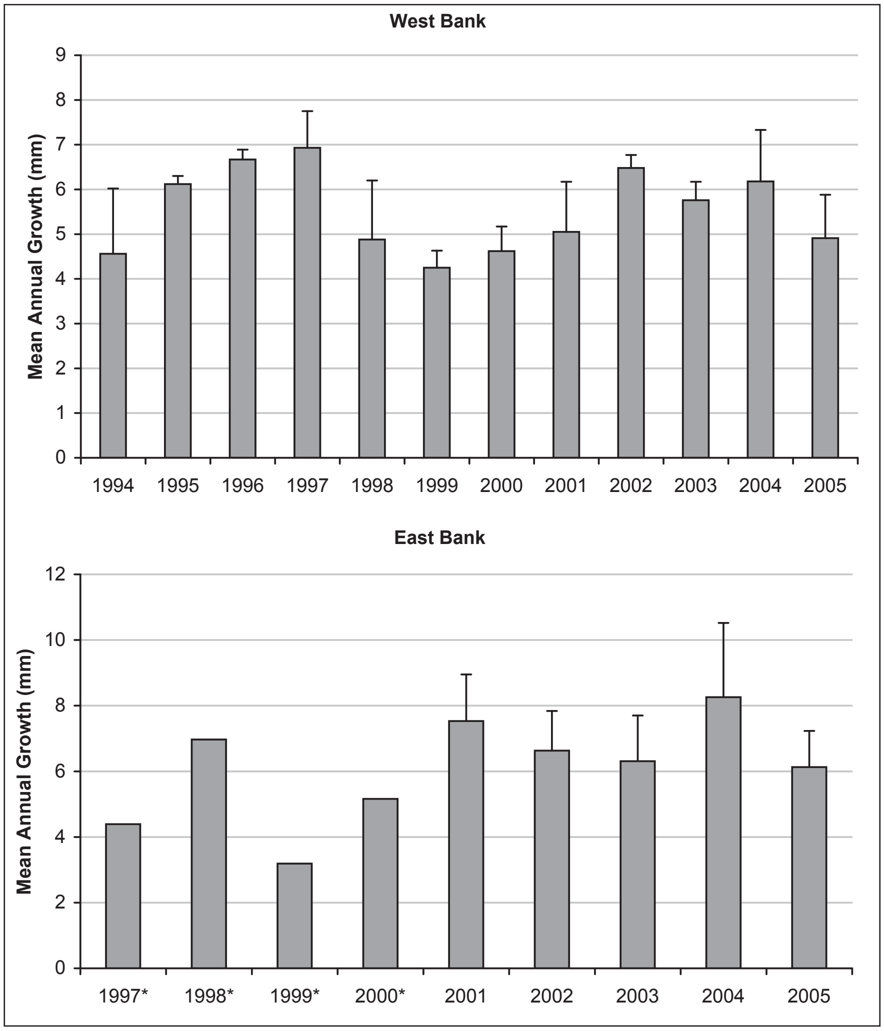


Figure 7.24. Mean annual growth in mm for Montastraea faveolata *colonies at WFGB (top) and EFGB (bottom). Asterisks indicate data estimated from a single measurement (n=1). Source: PBS&J, unpub. data.*

Bleaching Incidence

Information on coral bleaching is collected under the LTM program and via belt transects surveyed periodically by FGBNMS staff. The LTM data is collected once a year, and applies the methodology described above to determine the incidence of bleaching.

In addition, the FGBNMS research team conducts rapid assessment surveys to collect information in response to specific events such as hurricanes, coral disease outbreaks and coral bleaching events. After the passage of Hurricanes Katrina and Rita, the FGBNMS conducted surveys at both the EFGB and WFGB in October and November 2005, and again in January and March 2006, to document damage from the hurricanes and coral bleaching event.

At multiple mooring buoys in the FGBNMS, researchers laid out 15 x 1 m belt transects, counted every coral colony and scored it according to its bleaching condition (totally bleached, partially bleached or unbleached). Based on these surveys, an average of 42% of the colonies were either partially or fully bleached in October 2005 and 46% were partially or fully bleached in November 2005. In January 2006 (4.5%) and March 2006 (4.0%) observations were similar at the WFGB, and continued recovery was documented at the EFGB; January (10.3%) and March (4.0%). The bleaching appeared to be affecting 100% of the fire coral (*M. alcicornis*) and great star coral (*M. cavernosa*), and affecting at least eleven other species to varying degrees. Long-term monitoring results have shown loss of fire coral due to the bleaching event.

CCMA-BB Characterization of Fish and Benthic Communities at the FGBNMS

The partnership between CCMA-BB has provided an opportunity to characterize the Sanctuary's benthic habitats on a broader scale. This is in contrast to and complementary to the FGBNMS LTM contract that is primarily contained within a 100 x 100 m area on each of the EFGB and WFGB

Methods

A total of 73 stratified random sampling sites were surveyed within the FGBNMS in 2006, and in 2007, 33 additional sites were sampled before Tropical Storm Humberto forced the ship from the area. Data from 2007 was not incorporated into this summary. Detailed information on benthic habitat composition in 2006 was recorded within four 1 m^2 quadrats located along a series of transects. Data were also collected to quantify the level of coral bleaching within the quadrats and note the prevalence of marine debris along the transects. Detailed *in situ* data collection methodologies are available at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols_fgb.html.

Results and Discussion

Table 7.3 summarizes the benthic composition data. The overall coral cover for the East and West Bank were 53% and 59% respectively. These estimates are within 2% of those derived from the 2006 FGBNMS LTM effort. Percent cover of sponges falls within 0.15% of the FGBNMS LTM results while macroalgae estimates were greater during the FGBNMS LTM surveys by approximately 6% at EFGB and 14% at WFGB.

Table 7.3. Benthic habitat composition data summarized by strata and overall. Source: CCMA BB, unpub. data.

LOCATION	SLOPE	NUMBER OF SURVEYS	PERCENT CORAL		PERCENT MACROALGAE		PERCENT SPONGES	
			Mean	(+ SE)	Mean	(+ SE)	Mean	(+ SE)
East Bank	Flat	44	55	3.4	26	2.9	0.7	0.20
	Steep	5	34	9.4	41	11.1	0.6	0.42
	OVERALL	49	53	2.9	27	2.5	0.7	0.17
West Bank	Flat	19	61	4.3	25	3.7	0.4	0.14
	Steep	5	51	12.6	39	15.0	1.5	0.90
	OVERALL	24	60	3.4	27	3.0	0.6	0.12
All FGBNMS	Flat	63	57	2.0	26	1.7	0.6	0.11
	Steep	10	42	5.4	40	6.4	1.0	0.31
	OVERALL	73	55	1.7	27	1.5	0.7	0.09

CCMA-BB collects identical data at other locations within the U.S. Caribbean. As a point of comparison the data for 2006 are summarized in Table 7.4. Only sites at or below 60 ft are included in the summary to limit depth as a factor. The largest difference between the locations is percent coral cover, which at 55% is nearly seven times that seen in St. John, USVI, the next closest value. In contrast to the low values for percent coral cover, a large portion of area in the U.S. Caribbean locations is dominated by marine plants and algae. All locations surveyed in the U.S. Caribbean are significantly closer to land and therefore likely to be more heavily influenced by factors such as sedimentation, contaminants, or human use. These factors either alone or in combination may be responsible for the differences observed.

Table 7.4. Comparison of benthic habitat composition data between locations in the U.S. Caribbean and the FGBNMS. Source: CCMA-BB, unpub. data.

LOCATION	SURVEYS n=	PERCENT CORAL		PERCENT MACROALGAE		PERCENT SPONGES	
		Mean	SE	Mean	SE	Mean	SE
FGBNMS	73	55	1.7	28	19.9	0.7	0.09
St Croix, USVI	30	2	0.6	61	5.9	2.5	0.39
St John, USVI	51	8	1.0	51	3.0	7.2	0.78
La Parguera, PR	21	6	1.5	37	5.7	1.3	0.30

Atlantic and Gulf Rapid Reef Assessment (AGRRA)

This assessment was presented in the 2005 edition of this report.

ASSOCIATED BIOLOGICAL COMMUNITIES

East and West Flower Garden Banks Long-Term Monitoring Project

Fish counts were performed at both banks using stationary visual techniques for quantitatively assessing community structure of coral reef fishes (Bohnsack and Bannerot, 1986). A minimum of 24 surveys were performed at each bank to provide a statistically sound assessment of reef fish abundance and diversity. Survey sites were selected randomly from within the 1-hectare study locations at the EFGB and WFGB.

Results and Discussion

A mean of 21.5 diver surveys/samples (± 6.56 SD) were conducted during the 2004-2005 FGB survey efforts. Surveys were conducted during the day from 0700 hours through dusk. The 2004 data was gathered in September (East Bank) and November (West Bank). Data in 2005 was collected in June. The highest number of diver surveys/samples was conducted in 2004 at the West Bank, while the lowest occurred at the East Bank in 2004 (Table 7.5). Unfavorable weather conditions hampered survey efforts in 2004 and were the reason for the low number of fish surveys at the East Bank in 2004. An average of 38% of the 100 x 100 m study sites was visually surveyed during 2004-2005.

Table 7.5. Visual fish survey sampling statistics for the East and West Banks in 2004 and 2005. Each survey covers 177 m^2. Source: PBS&J.

	2004 EB	2004 WB	2005 EB	2005 WB
Number samples (n)	12	27	24	23
Percent area of study site sampled	21%	48%	42%	41%
Sampled area (m^2)	2,124	4,779	4,248	4,071
Total fish abundance	5,331	1,876	3,928	3,252

A mean of 57 fish species (± 6.0 SD) were observed during the 2004-2005 surveys. This is an increase from the 51 (± 3.5 SD) mean fish species recorded during the 2002-2003 surveys. A total of 85 fish species were recorded for all survey efforts combined at the FGB in 2004 and 2005 (Table 7.6). Comparison of species richness (number of species recorded per survey) between banks and years showed a similar pattern to fish abundance, with a significant difference between banks in 2004 but not in 2005, and a significant difference at East Bank, but not at West Bank, between 2004 and 2005. The highest mean richness recorded per diver survey was at East Bank in 2004 (mean richness=22 species/survey; Table 7.7).

Table 7.6. Species list of fishes recorded in stationary visual surveys conducted at East and West Banks in 2004 and 2005. Fish are presented in descending order of numerical abundance. Source: PBS&J.

FISH SPECIES	FISH COMMON NAMES	FAMILY NAME	TROPHIC GUILD	NUMBER
Chromis multilineata	Brown chromis	Pomacentridae	Carnivore	3599
Emmelichthyops atlanticus	Bonnetmouth	Inermiidae	Planktivore	3200
Clepticus parrae	Creole wrasse	Labridae	Carnivore	1442
Thalassoma bifasciatum	Bluehead	Labridae	Carnivore	711
Stegastes partitus	Bicolor damselfish	Pomacentridae	Herbivore	494
Stegastes planifrons	Threespot damselfish	Pomacentridae	Herbivore	439
Chromis cyanea	Blue chromis	Pomacentridae	Carnivore	326
Scarus vetula	Queen parrotfish	Scaridae	Herbivore	229
Halichoeres maculipinna	Clown wrasse	Labridae	Carnivore	207
Acanthurus coeruleus	Blue tang	Acanthuridae	Herbivore	195
Caranx ruber	Bar jack	Carangidae	Carnivore	189
Melichthys niger	Black durgon	Balistidae	Omnivore	160
Caranx hippos	Crevalle jack	Carangidae	Carnivore	159
Sparisoma viride	Stoplight parrotfish	Scaridae	Herbivore	149
Kyphosus sectator/incisor	Bermuda/Yellow chub	Kyphosidae	Omnivore	148
Scarus taeniopterus	Princess parrotfish	Scaridae	Herbivore	148
Canthidermis sufflamen	Ocean triggerfish	Balistidae	Omnivore	119
Inermia vittata	Boga	Inermiidae	Planktivore	101
Bodianus rufus	Spanish hogfish	Labridae	Carnivore	99
Elacatinus oceanops	Neon goby	Gobiidae	Omnivore	77
Mulloidichthys martinicus	Yellow goatfish	Mullidae	Carnivore	76
Acanthurus bahianus	Ocean surgeonfish	Acanthuridae	Herbivore	75
Scarus iseri	Striped parrotfish	Scaridae	Herbivore	71
Microspathodon chrysurus	Yellowtail damselfish	Pomacentridae	Herbivore	62

Table 7.6 (continued). Species list of fishes recorded in stationary visual surveys conducted at East and West Banks in 2004 and 2005.

FISH SPECIES	FISH COMMON NAMES	FAMILY NAME	TROPHIC GUILD	NUMBER
Sparisoma aurofrenatum	Redband parrotfish	Scaridae	Herbivore	62
Halichoeres garnoti	Yellowhead wrasse	Labridae	Carnivore	61
Stegastes variabilis	Cocoa damselfish	Pomacentridae	Herbivore	61
Chaetodon sedentarius	Reef butterflyfish	Chaetodontidae	Herbivore	57
Acanthurus chirurgus	Doctorfish	Acanthuridae	Herbivore	51
Mycteroperca tigris	Tiger grouper	Serranidae	Carnivore	48
Chaetodon ocellatus	Spotfin butterflyfish	Chaetodontidae	Herbivore	45
Bodianus pulchellus	Spotfin hogfish	Labridae	Carnivore	40
Abudefduf saxatilis	Sergeant major	Pomacentridae	Herbivore	30
Stegastes adustus	Dusky damselfish	Pomacentridae	Herbivore	29
Prognathodes aculeatus	Longsnout butterflyfish	Chaetodontidae	Herbivore	28
Ophioblennius atlanticus	Redlip blenny	Blenniidae	Omnivore	28
Caranx latus	Horse-eye jack	Carangidae	Carnivore	19
Holacanthus tricolor	Rock beauty	Pomacanthidae	Herbivore	19
Chaetodon striatus	Banded butterflyfish	Chaetodontidae	Herbivore	17
Stegastes leucostictus	Beaugregory	Pomacentridae	Herbivore	16
Lactophrys triqueter	Smooth trunkfish	Ostraciidae	Omnivore	14
Malacoctenus triangulatus	Saddled blenny	Blenniidae	Omnivore	13
Caranx lugubris	Black jack	Carangidae	Carnivore	12
Seriola dumerili	Amber jack	Carangidae	Carnivore	12
Holacanthus ciliaris	Queen angelfish	Pomacanthidae	Herbivore	11
Lutjanus jocu	Dog snapper	Lutjanidae	Carnivore	9
Elagatis bipinnulata	Rainbow runner	Carangidae	Carnivore	8
Holocentrus adscensionis	Squirrelfish	Holocentridae	Carnivore	8
Parablennius marmoreus	Seaweed blenny	Blenniidae	Omnivore	8
Amblycirrhitus pinos	Redspotted hawkfish	Cirrhitidae	Carnivore	7
Pomacanthus paru	French angelfish	Pomacanthidae	Herbivore	6
Halichoeres radiatus	Puddingwife	Labridae	Carnivore	5
Cantherhines macrocerus	Whitespotted filefish	Monocanthidae	Herbivore	4
Chromis insolata	Sunshinefish	Pomacentridae	Planktivore	4
Lutjanus griseus	Gray snapper	Lutjanidae	Carnivore	4
Acanthostracion polygonius	Honeycomb cowfish	Ostraciidae	Omnivore	3
Holocentrus rufus	Longspine squirrelfish	Holocentridae	Carnivore	3
Cantherhines pullus	Orangespotted filefish	Monocanthidae	Herbivore	2
Diodon hystrix	Porcupinefish	Diodontidae	Carnivore	2
Scarus coelestinus	Midnight parrotfish	Scaridae	Herbivore	2
Sparisoma chrysopterum	Redtail parrotfish	Scaridae	Herbivore	2
Stegastes diencaeus	Longfin damselfish	Pomacentridae	Herbivore	2
Aluterus schoepfi	Orange filefish	Monocanthidae	Herbivore	1
Equetus punctatus	Spotted drum	Sciaenidae	Carnivore	1
Gymnothorax moringa	Spotted moray	Muraenidae	Carnivore	1
Lactophrys bicaudalis	Spotted trunkfish	Ostraciidae	Omnivore	1
Sparisoma atomarium	Greenblotch parrotfish	Scaridae	Herbivore	1
Sparisoma rubripinne	Redfin parrotfish	Scaridae	Herbivore	1

Mean fish abundance per area ranged from a high at the East Bank in 2004 of 251.39/100 m^2 to a low at the West Bank in 2004 of 39.32/100 m^2 (Table 7.7). Mean density values in 2005 were 96.64 at EFGB and 80.01/100 m^2 at WFGB. In previous years, the mean density value for the East Bank has fluctuated from 82.78/100 m^2 in 2002 to 157.53/100 m^2 in 2003. Previous mean density values recorded in 2002 and 2003 at the West Bank were 73.29 and 84.62/100 m^2 respectively.

Table 7.7. Species and family richness and density values for the East and West Banks recorded during 2004 and 2005 survey efforts. Source: PBS&J.

	2004 EB	2004 WB	2005 EB	2005 WB
Total Species (Species Richness)	55	50	64	60
Total Families (Family Richness)	18	19	22	21
Mean Abundance/Survey	444.25	69.48	163.66	141.39
^SD	275.36	35.62	101.64	79.29
Mean Abundance/ m^2	2.51	0.39	0.97	0.8
Mean Species Richness/Survey	22	14.96	17.21	16.61
^SD:	4.22	6.15	2.75	3.07
Mean Spp Richness/ m^2	0.12	0.08	0.1	0.09
Mean Family Richness	11.5	8.71	9.79	9.74
^SD	2.11	2.88	1.91	1.79
Mean Family Richness/ m^2	0.07	0.049	0.06	0.06

Fish abundance (mean fish abundance recorded per survey) showed a significant difference ($t=7.056$, $df=37$, $p=2.38 \times 10^{-08}$) between the East and West Banks in 2004, but not in 2005. The East Bank showed a significant difference ($t=4.470$, $df=34$, $p=8.26 \times 10^{-05}$) in fish abundance between the years 2004 and 2005, but no significant interannual difference was found at the West Bank. The high density value for the East Bank in 2004 is attributed to the high numbers of the small schooling Inermiidae species, *Emmelichthyops atlanticus*. The mean observed abundance for *E. atlanticus* was 266.67 fish/survey (± 271.64 SD), corresponding to a mean density value of 150.9 fish/100 m^2. *Clepticus parrae*, *Chromis multilineata* and *Paranthias furcifer* were also observed in high densities at the East Bank in 2004 with mean density values of 20.37, 19.38 and 13.06/100 m^2 respectively. Density values of *C. multilineata* and *C. parrae*, which ranked as the top two most abundant species at the East Bank in 2005, were 37.87 and 9.41/100 m^2 respectively. Also ranked as the top two most abundant species at the West Bank in 2005, their density values there were 34.08 and 9.87/100 m^2.

C. multilineata and *C. parrae* were consistently the two most abundant species in 2004 and 2005, with the exception of 2004 when *E. atlanticus* was recorded in greater numbers than these fish the East Bank. Additionally, *P. furcifer*, *Thalassoma bifasciatum* and *Stegastes partitus* were regularly ranked among the top five most abundant species.

The sighting frequency of fish species varied between years and banks as they did during the 2002-2003 surveys. However, the species most frequently recorded per survey throughout the 2004-2005 surveys were *C. multilineata*, *Stegastes planifrons*, *S. partitus*, *Scarus vetula*, *T. bifasciatum*, *Acanthurus coeruleus* and *C. parrae*.

The number of fish families observed fell to an average of 20 fish families per bank, down from an average of 21 families observed during the 2002-2003 surveys. The most abundant families observed were the Labridae, Pomacentridae, Serranidae and Scaridae. Mean densities of fish in the family Labridae ranged from 8.80–31.60/100 m^2 at the West and East Banks, respectively, in 2004. Pomacentridae densities ranged from 15.50/100 m^2 at the West Bank in 2004 to 49.51/100 m^2 at the East Bank in 2005. Scaridae ranged in density from 2.73/100 m^2 at the West Bank in 2005 to 7.40/100 m^2 at the East Bank in 2004.

Families represented by the most species were the Pomacentridae, Labridae, Serranidae and Scaridae. The most species of Pomacentridae were recorded in 2005 at the East Bank with 12 representatives, while the fewest were recorded in 2004 with eight representative species. The greatest number of species of Serranidae were observed in 2005 at the West Bank with nine species. The number of Scaridae species was consistent, ranging from five recorded in 2004 at the West Bank to seven at the East Bank in 2005. The Labridae family was generally represented by seven species.

The Pomacentridae family was represented by a mean of 4.00 species/survey at the West Bank in 2005, while 4.58 species/survey were recorded at the East Bank in 2004. The most common representatives of the Pomacentridae family were *Chromis mulitilineata*, *C. cyanea*, *Stegastes partitus* and *S. planifrons*. The Labridae family was represented by a mean of 2.65 species/survey at the West Bank in 2005 and 3.67 species/survey at East Bank sites in 2004. The most common representatives of the Labridae family were *C. parrae*, *T. bifasciatum* and *Bodianus rufus*. Scaridae were represented by a mean of 1.78 species/survey at the West Bank in 2004 and a mean of 3.00 species /survey at the East Bank. The most common representatives of the Scaridae family were *Scarus vetula*, *S. taeniopterus, Sparisoma viride*, and *S. aurofrenatum*. The Serranidae family was represented by a mean of 0.63 species/survey at the West Bank in 2004 and 1.83 species/survey at the East Bank. *P. furcifer* was by far the most common representative of the Serranidae family; however, others included *Cephalopholis cruentata*, *Epinephelus adscensionis* and *Mycteroperca tigris*.

Fish in the family Acanthuridae are important herbivores on coral reefs and are represented at the FGB (and the rest of Florida, the Bahamas and the Caribbean) by three species: *Acanthurus bahianus*, *A. chirurgus* and *A. coeruleus*. Acanthuridae were represented by a mean of 0.93 species/survey at the West Bank in 2004 and 1.92 species/survey at the East Bank.

Shannon-Weiner diversity indices were similar between the East and West Banks in 2005 while indices in 2004 varied from each other and from those of 2005 (Table 7.8). The greatest diversity was calculated for the West Bank in 2004 and the lowest for the East Bank in 2004. Higher sampling effort (larger n) appears to have had a positive effect on diversity and evenness calculations.

Table 7.8. Fish diversity and evenness values calculated for fish communities surveyed. Source: PBS&J.

	2004 EB	2004 WB	2005 EB	2005 WB
Number of Samples (n)	12	27	24	23
Diversity (log10)	0.77	1.3	1.06	1.04
Evenness	0.44	0.76	0.58	0.58

Large (visually estimated fork lengths) fish present at the FGB included individuals from the Carangidae, Serranidae, Sphyraenidae and Lutjanidae families. Other families with large individuals included Scaridae, Ballistidae, Pomacanthidae and Kyphosidae. The weighted mean of recorded *Sphyraena barracuda* lengths ranged from 50 cm at the East Bank in 2005 to 88 cm at the West Bank in 2004. *Mycteroperca bonaci* (90 cm-weighted mean length), M. *tigris* (90 cm-weighted mean length), *Lutjanus jocu* (83 cm-weighted mean length) and *M. interstitialis* (50 cm-weighted mean length) were the largest species, aside from *S. barracuda*.

Species in the families Acanthuridae and Scaridae, as well as the Pomacentrid *Microspathodon chrysurus*, can be grouped in an herbivore category comprised of algae-scrapers and -denuders (Steneck, 1988; Pattengill-Semmens and Gittings, 2003). Three species of Acanthuridae and seven species of Scaridae were recorded in the surveys making a total of 11 species in this trophic guild. The mean number of herbivore species per survey ranged from 2.85 at the West Bank in 2004 to 5.07 at the East Bank in 2004. The mean number of herbivore species in 2005 was 3.75 at the East Bank and 3.35 at the West Bank. There was a significant difference (t=3.627, df=37, p=2.0262) in herbivore species richness between the East Bank and the West Bank in 2004, as well as between 2004 and 2005 at the East Bank (t=3.068, df=34, p=2.0322). Mean fish densities of the herbivore group ranged from 5.14 to 10.47/100 m^2 at the West Bank in 2005 and the East Bank in 2004, respectively. Densities at the East Bank in 2005 were 6.74/100 m^2, and at the West Bank in 2004 were 6.33/100 m^2. The only significant difference in mean densities of the herbivore group was found between the East and West Banks in 2004 (t=6.639, df=37, p=8.62 x 10^{-08}; Table 7.9). *S. vetula* and *A. coeruleus* were the most frequent species in the herbivore group.

Table 7.9. Mean densities of fishes (number of fish/100 m^2) recorded per survey at the FGB during 2004-2005. Source: PBS&J.

Category	2004		2005	
	East Bank	West Bank	East Bank	West Bank
Herbivores	10.47	6.33	6.74	5.14
Carnivores	0.57	0.46	0.38	0.66
Sphyraena barracuda	0.85	2.81	1.91	1.51
Kyophus sectator	1.84	1.45	0.31	0.54

The size-frequency distributions of herbivorous fishes are normal curves for all years at both banks. The curves for both banks in 2004 are shifted to the lower end of the size ranges and those of West Bank in 2004 shows a more exaggerated (less dispersed) pattern. The curves for 2005 are more evenly dispersed and are shifted more toward the larger sizes (Figure 7.25).

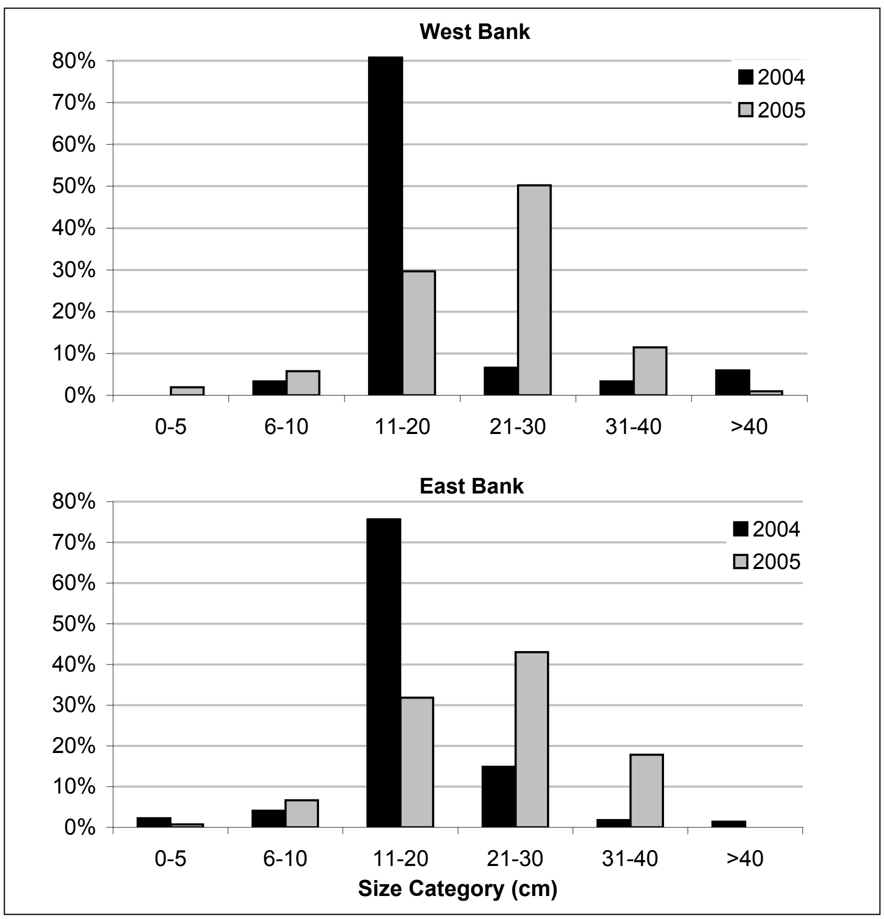


Figure 7.25. Herbivore size-frequency distributions at WFGB (top) and EFGB (bottom) recorded during 2004 and 2005. Source: Precht et al., in press.

Select species are grouped here as a carnivorous trophic category. These include serranids in the genera *Epinephelus*, *Cephalopholis*, *Mycteroperca* and *Dermatolepis,* as well as all species of lutjanids (Claro and Cantelar Ramos, 2003; Pattengill-Semmens and Gittings, 2003). A total of twelve species were observed in this group: two Lutjanidae and ten Serranidae (three more species than were observed in the 2002-2003 surveys). Although present in large numbers, the serranid *P. furcifer* is not included in the carnivore group. The mean carnivore species richness recorded per survey ranged from 0.63 at the East Bank in 2005 to 1.09 at the West Bank in 2005. Mean species richness recorded in 2004 was 0.74 at the West Bank and 0.83 at the East Bank. No significant differences were found in mean species richness between banks or years. Mean densities of the carnivore group ranged from 0.38/100 m^2 at the East Bank in 2005 to 0.66/100 m^2 at the West Bank in 2005. Mean densities recorded for 2004 were 0.46/100 m^2 at the West Bank and 0.57/100 m^2 at the East Bank (Table 7.10). No significant differences were found in mean carnivore densities per survey between years or banks. *M. tigris* and *L. jocu* were among the most frequently recorded species in the carnivore group.

Table 7.10. Weighted mean sizes (visual estimation of fork length) of the top five largest carnivore species at the East and West Banks in 2004 and 2005. Source: PBS&J.

2004 EAST BANK		**2004 WEST BANK**		**2005 EAST BANK**		**2005 WEST BANK**	
Fish Species	(cm)	Fish Species	(cm)	Fish Species	(cm)	Fish Species	(cm)
Sphyraena barracuda	56	*Mycteroperca tigris*	90	*Lutjanus jocu*	83	*Mycteroperca bonaci*	90
Mycteroperca interstitialis	50	*Serioloa lalandi*	90	*Caranx latus*	60	*Gymnothorax moringa*	80
Caranx lugubris	49	*Sphyraena barracuda*	88	*Caranx hippos*	52	*Caranx lugubris*	73
Canthidermis sufflamen	45	*Caranx latus*	70	*Sphyraena barracuda*	50	*Sphyraena barracuda*	66
Epinephelus adscensionis	40	*Lutjanus griseus*	55	*Diodon hystrix*	50	*Caranx latus*	65

The size-frequency distributions of the carnivorous fishes were generally non-normal in 2004-2005 and 2002-2003 surveys. The size distribution of carnivorous fish appeared with two peaks for each bank in both years, with the larger peak occurring in the smaller size range at the East Bank in 2004 and in the larger sizes for the other banks and years. The diminished size range was primarily that of the 31-40 cm range and to a lesser degree the 21-30 cm range. The exception was the West Bank in 2004 with the most fishes in the 31-40 cm range. No carnivorous fishes were recorded in the ranges of 0-5 or 6-10 cm at either bank in either year (Figure 7.26).

Analysis of selected species showed some differences in abundances between banks and years. A significant difference (t=2.213, df=48, p=0.03) in *S. barracuda* was found between 2004 and 2005 at the West Bank. The opposite was found during the 2002-2003 surveys, with significant differences occurring between banks but not years. A significant difference (t=2.422, df=34, p=0.02) was found for *Kyphosus sectator/incisor* between 2004 and 2005 at East Bank. During the 2002-2003 surveys, significant differences were found between banks but not between years.

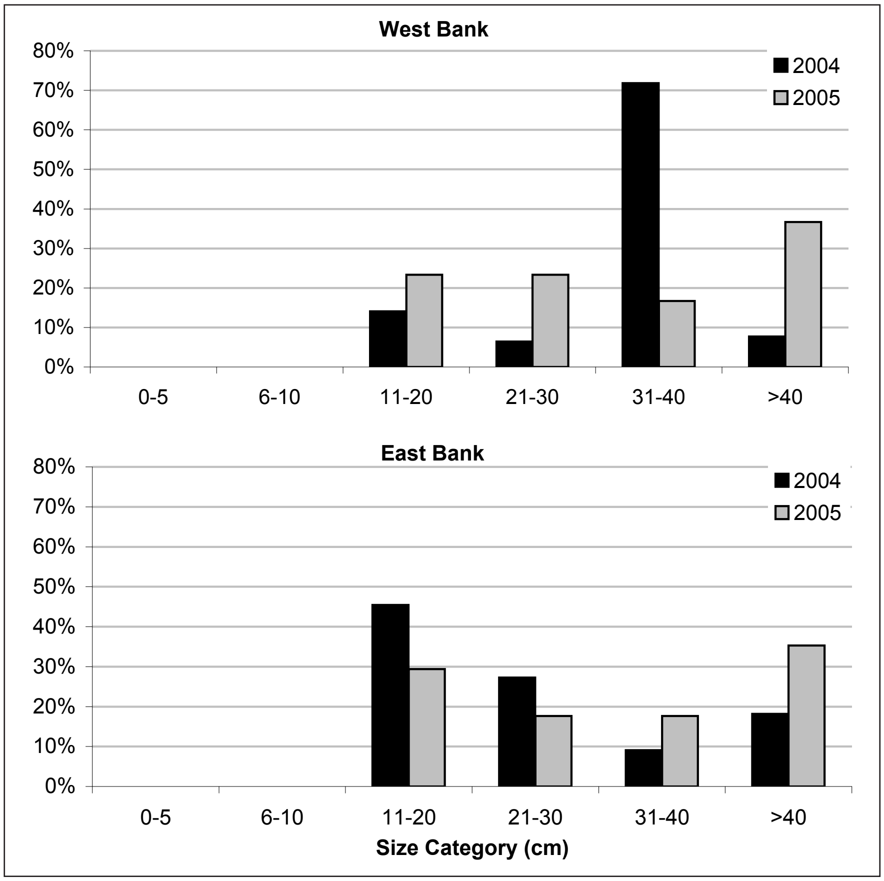


Figure 7.26. Carnivore size-frequency distributions at West (top) and East Banks (bottom) recorded during 2004 and 2005. Source: Precht et al., in press.

Sea Urchin And Lobster Surveys

Methods

Long spined sea urchin (*Diadema antillarum*) surveys were conducted to establish current population levels as a basis for comparison with future observations (Figure 7.27). Surveys were conducted approximately 1.5 hours after sunset using site boundaries as transect lines. Two transects, each 100 x 2 m (200 m^2) were surveyed using the same site boundary transect lines as those used for the video transects at each study site. Spiny lobster (*Panulirus argus*) and spotted lobster (*P. guttatus*) surveys were conducted in a similar manner.

Results and Discussion

In 2004 at the East Bank, 0.005 individuals/m² of *D. antillarum* and two *Echinometra lucunter* were documented along the northern and eastern perimeter lines. At the West Bank in 2004, the southern and western lines were monitored for urchins and lobsters, and 0.11 individuals/m² (44 individuals) of *D. antillarum* were documented. This is a dramatic increase from previous monitoring results. Before the 1984 demise of *D. antillarum* throughout the Caribbean, densities of sea urchins were reported as 0.54-1.63 individuals/m² (Gittings and Bright, 1987). Although there have been population recoveries in localized areas, population levels throughout the region are still depressed compared to pre-1984 levels (Edmunds and Carpenter, 2001). Two *P. argus* were also documented in 2004.

Figure 7.27. The long spined sea urchin, D. antillarum. *Photo: E. Hickerson.*

In 2005 at the East Bank, the northern and eastern perimeter lines were surveyed for urchin and lobster abundance. Urchin density at the East Bank in 2005 was 0.005 individuals/m². One *P. argus* was documented. At the West Bank, the southern and western lines revealed 0.013 individuals/m² of *D. antillarum* and one *E. lucunter*.

Similar to the rest of the western Atlantic, results at the FGB from sea urchin and lobster surveys continued to show low population densities at both banks in 2004 and 2005. The low densities reported here are similar to densities reported for the FGB in the past (Precht et al., 2005; Dokken et al., 2003). West Bank 2004 was an anomalous year with 44 individuals documented (0.11 individuals/m²), however the trend did not continue in 2005, when surveyed populations were again depressed (0.013 individuals/m²). Overall, these results do not differ from reports at coral reefs throughout the region.

CCMA-BB Characterization of Fish and Benthic Communities at the FGBNMS

Data on fish species abundance, size, and distribution were collected along a series of timed 25 x 4 m belt transects at 73 sites selected via a stratified random sampling approach based on slope categories of flat and steep. Detailed *in situ* data collection methodologies are accessible by visiting http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols_fgb.html.

Results and Discussion

Fish abundance, biomass, richness, and diversity (per 100 m²) are summarized in Table 7.11. The largest disparity between flat and steep strata was observed at the WFGB in both abundance and biomass metrics. In general, species richness, abundance and diversity were relatively similar between the two banks. Biomass was substantially higher on the WFGB.

*Table 7.11. Fish species data collected within timed 25 x 4 m belt transects summarized by strata and overall. * Shannon Diversity Index. Source: CCMA-BB, unpub. data.*

LOCATION	SLOPE	NUMBER OF SURVEYS	NUMBER OF INDIVIDUALS (per 100 m²)		BIOMASS (grams per 100 m²)		NUMBER OF SPECIES (per 100 m²)		MEAN DIVERSITY*	
			Mean	(±SE)	Mean	(±SE)	Mean	(±SE)	Mean	(±SE)
East Bank	Flat	44	323	26	18926	2904	25	0.5	2.1	0.05
	Steep	5	223	37	19445	7011	23	2.2	2.3	0.04
	OVERALL	49	315	22	18970	2484	25	0.5	2.1	0.05
West Bank	Flat	19	259	29	28657	9558	27	1.0	2.2	0.07
	Steep	5	497	184	39148	30584	27	2.1	2.1	0.19
	OVERALL	24	294	25	30195	7618	27	0.8	2.2	0.05
All FGBNMS	Flat	63	304	16	21857	2285	26	0.3	2.2	0.03
	Steep	10	345	48	28202	8205	25	1.1	2.2	0.05
	OVERALL	73	308	13	22518	1923	26	0.3	2.2	0.03

Two federally listed species were observed at FGBNMS in 2006. Nassau grouper (*Epinephelus striatus*) was documented at the FGBNMS for the first time during a scientific investigation, and Goliath grouper (*E. itajara*) was observed for the second time.

Groupers of the genera *Epinephelus*, *Cephalopholis* and *Mycteroperca* were recorded at 66 of the 73 sites surveyed with a total of 232 individuals observed. Furthermore, snapper of the genus *Lutjanus* were recorded at 28 sites with a total of 91 individuals observed. Of particular interest were large aggregations of dog snapper (*L. jocu*).

A large number of juvenile fish were observed among the fields of *Madracis* coral. It is possible that the structure of the *Madracis* coral is being utilized as a nursery area for some species as it offers refuge from predators.

CCMA-BB utilizes the same methodologies to collect fish data at other locations within the U.S. Caribbean. As a point of comparison these data are summarized in Table 7.12. Only sites at or below 60 ft are included in the summary to limit depth as a factor. Both fish density and richness were on the high end but within the range found in the U.S. Caribbean; however, biomass was two and a half times higher than the next closest value. This was due in large part to the presence of sizeable piscivores of the genera *Mycteroperca* and *Dermatolepis* present at FGBNMS.

Table 7.12. Comparison of fish data between locations in the U.S. Caribbean and the FGBNMS. All data collected within timed 25 x 4 m belt transects. Source: CCMA-BB, unpub. data.

LOCATION	NUMBER OF SURVEYS	NUMBER OF INDIVIDUALS (per 100 m^2)		BIOMASS (grams per 100 m^2)		NUMBER OF SPECIES (per 100 m^2)	
		Mean	±SE	Mean	±SE	Mean	±SE
FGNMS	73	311.55	22.16	28945.28	7371.55	25.67	0.46
St. Croix	66	158.74	9.56	5229.14	705.74	16.67	0.60
St. John	222	370.42	21.99	8527.49	585.29	24.76	0.43
Puerto Rico	61	117.07	10.52	3632.92	396.11	21.82	0.88

The survey effort to date has primarily focused on the shallower portions of the Sanctuary with little to no quantitative information on the deeper water environments or an understanding of how they are connected to the coral caps. Beginning in 2008, the FGBNMS in collaboration with NCCOS/CCMA-BB will begin to incorporate the deeper water regions into the overall survey design utilizing a combination of ROV and drop camera technologies.

Benthic Habitat Mapping

As reported in the 2005 report, the FGBNMS has been updating benthic characterization maps, through the use of high resolution bathymetric maps and ROV surveys. The first level biological characterization maps are presented in Figures 7.28, 7.29 and 7.30.

Rezak et al. (1985) developed a classification and characterization scheme for biological communities associated with the reefs and banks of the northwestern Gulf of Mexico. This classification structure was the culmination of a large body of work on the FGB (Bright and Pequegnat, 1974; Bright et al., 1985) and other reefs and banks in the area. Subsequent investigations have demonstrated the accuracy and usefulness of this classification framework. However, based on recent information, we propose some minor modifications to and reorganization of the classification scheme proposed by Rezak et al. (1985).

Coral reefs and coral communities form a mosaic of biological habitats at the FGB and other reefs and banks of the northwestern Gulf of Mexico. In addition to the

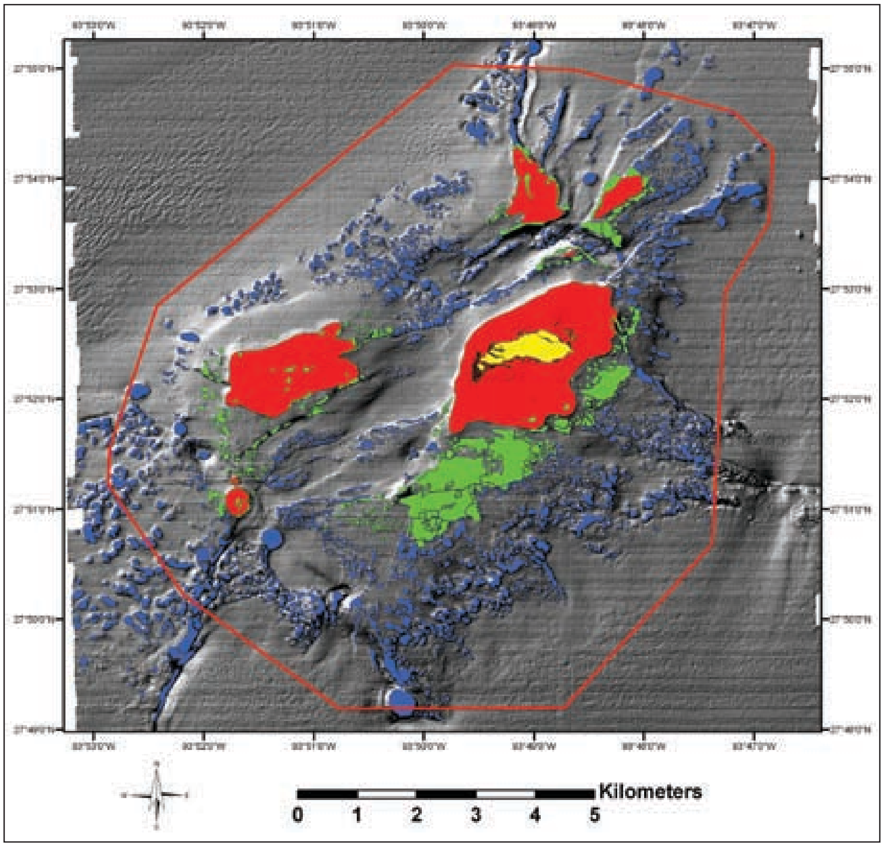
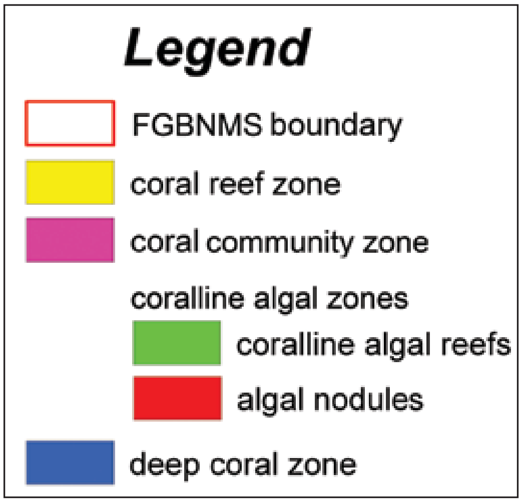


Figure 7.28. WFGB biological habitats. Please see the next page for this map's legend. Source: FGBNMS. Map: D. Weaver.



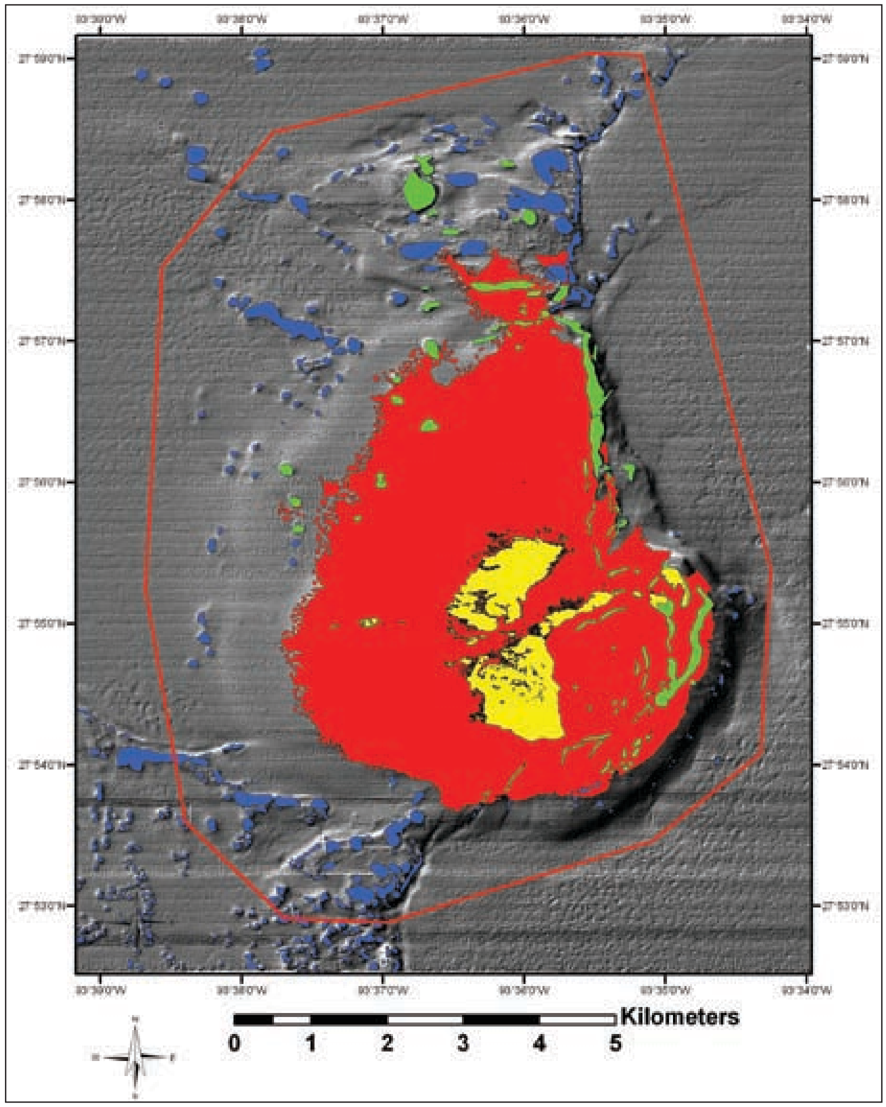


Figure 7.29. EFGB biological habitats. Source: FGBNMS. Map: D. Weaver.

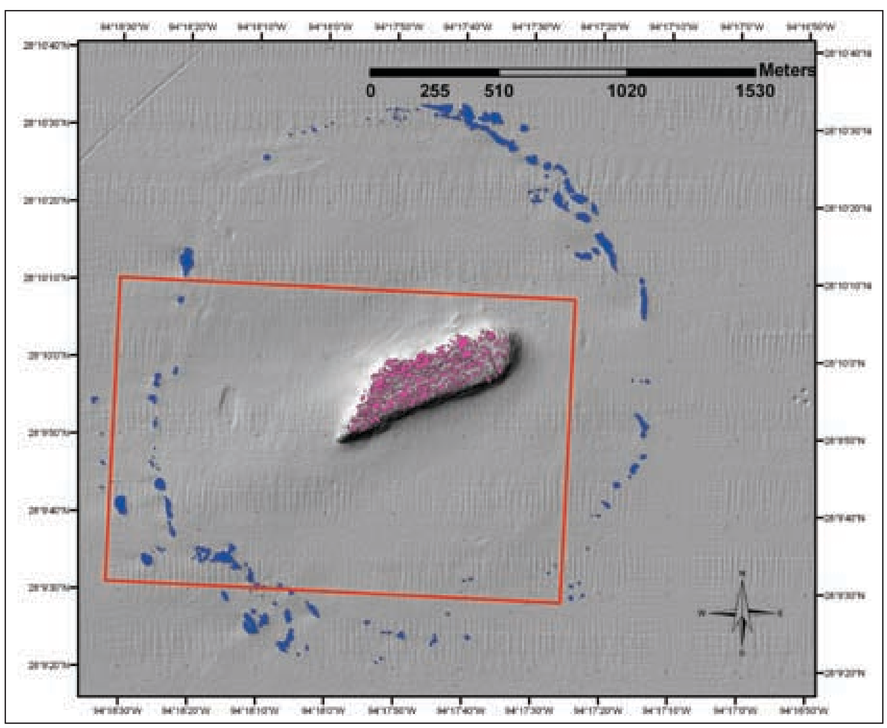


Figure 7.30. Stetson Bank biological habitats. Source: FGBNMS. Map: D. Weaver

well-developed hermatypic coral reefs that cap the shallowest portions of the EFGB and WFGB, there are a variety of other reef habitats that occur in association with many other topographic features in the area. All of these habitats could be considered as part of the coral reef ecosystem of the northern Gulf of Mexico and include coralline algal reefs and deep reef communities. We propose a classification hierarchy composed of biological zones. Within each zone there are multiple habitat types.

The first major biological zone is the "Coral Reef." The coral cap of the EFGB and WFGB exemplifies this zone. The Coral Reef Zone proposed here includes the "*Diploria-Montastraea-Porites*" zone, the "*Madracis* and Leafy Algae" zone and the "*Stephanocoenia-Millepora*" zones as described by Rezak et al. (1985). We propose that these classifications are sub-components of the coral reef zone. Major habitats within this zone are described by the dominant coral species that characterize the assemblage. The primary habitat of the coral reef zone of the FGB is the *Montastraea* habitat. Rezak et al. (1985) called this community the *Diploria-Montastraea-Porites* zone, but this is somewhat misleading in that the brain coral *Diploria* is not the dominant component of the species assemblage. Members of the genus *Montastraea* account for over 65% of the coral species encountered, while *Diploria* accounts for about 11%. Therefore it is more appropriate that the primary habitat within the coral reef zone be referred to as the *Montastraea* habitat. Other habitats within the coral reef zone include those typified by *Madracis* (*Madracis* and Leafy Algae zone of Rezak et al., 1985), *Stephanocoenia* (*Stephanocoenia-Millepora* of Rezak et al., 1985) and coral sand (composed of reef derived sediments). The *Montastraea* habitat is the primary hermatypic reef community of the FGB, and includes at least 23 species of stony corals. This habitat is interspersed by sand channels comprised of coral sand (coral debris with molluscan and algal components). The *Madracis* habitat occurs on the peripheral parts of the primary reef structure in depths ranging from 28 to 44 m, where large knolls characterized by almost monospecific stands of the small branching coral *Madracis mirabilis* occur. The *Stephanocoenia* habitat is a lower diversity coral community occurring in water depths primarily below 36 m. While dominated by the blushing star coral (*Stephanocoenia intersepta*), other species such as *Millepora alcicornis*, *Colpophyllia natans*, *Agaricia* spp., *Mussa angulosa* and *Scolymia* spp. are also encountered.

The second biological zone we call the "Coral Community Zone." This zone is comprised of areas that, while not considered to be "true" coral reefs, do contain hermatypic coral species at low densities, or are characterized by other coral reef associated organisms, such as the hydrozoan *Millepora* spp. (fire coral), sponges and macroalgae. Coral communities are found in depth ranges similar to those that contain coral reefs (18 to 50 m, but other environmental factors have not allowed full development of coral reefs to occur. The "Coral Community" includes the "*Millepora*-Sponge" zone described by Rezak et al. (1985), and also includes some other coral associated assemblages. The most distinctive habitat type in this zone is the *Millepora*-sponge community that characterizes the shallowest peaks of the mid-shelf reefs at Stetson and Sonnier Banks. The fire coral, *Millepora* spp., can account for up to 30% of the benthic cover on the pinnacles of Stetson Bank (Bernhardt, 2000). In addition to fire coral, sponges comprise up to an additional 30% of the substrate. The Coral Community Zone also includes habitats that are characterized by scattered occurrences of stony corals or fire coral at relatively low densities. This habitat, called the low-density coral habitat, also includes a mix of other components including leafy algae, coralline algae, sponges and anemones. Habitats within the Coral Community Zone can also be characterized by algae or sponges when they dominate a particular area.

The next primary area is the "Coralline Algae Zone" zone, characterized by crustose coralline algae that actively produce carbonate substrate, including rhodoliths, or algal nodules. The Coralline Algae Zone is consistent with that proposed as the "Algal-Sponge Zone" by Rezak et al. (1985), but includes additional habitat such as rocky outcrops. This zone is the largest reef-building zone area in the FGB extending from 45 to over 90 m in depth. Algal nodules, or rhodoliths, are formed by species of coralline algae that lay down successive, concentric layers of carbonate around an initial "nucleus" (such as a rock fragment) to form irregular spheres of 1–20 cm in size. Between 50-75 m, the nodules can cover 60-90% of the bottom (Minnery et al., 1985) and can often occupy 100% of the sea floor in some areas. Primary species include the coralline algae *Lithothamnium* sp., the squamariacean *Peyssonnelia* sp. and the encrusting foraminiferan *Gypsina plana*. Several species of hermatypic corals are scattered throughout the Algal Nodule Zone, and can be locally abundant, including saucer shaped specimens of *Agaricia* spp. and *Helioseris cucullata*. Leafy algae and sponges, most notably the toxic sponge *Neofibularia nolitangere*, are also common in this habitat. The Coralline Algae Zone also includes deepwater coralline algal reefs, which are typically low-relief (1-2 m high), flat-topped rocky outcrops, ridges and patch reefs. While coralline algae is the dominant benthic group on these reefs, the rocky outcrops provide habitat for a variety of gorgonians, antipatharians, sponges and other organisms. This zone corresponds with the area called "Partly Drowned Reefs" by Bright and Pequegnat (1974) and Bright et al. (1985). Since the concept of "drowned reef" implies certain geological origins and temporal history, this terminology is not used here in relation to present-day biological communities. In fact, Bright et al. (1985) defined "partly drowned reefs" as reef structures below the depths of hermatypic corals, but within a depth range favoring crustose coralline algae. This is consistent with the concept as used in the present classification.

The final reef-associated community is the "Deep Coral Zone". The deep coral zone is consistent with what Bright et al. (1985) called the "Drowned Reef Zone". This zone occurs in water depths below that which support active photosynthesis by coralline algae (90 m and greater). Solitary corals and deepwater branching corals, such as *Madrepora* and *Oculina* are also found in this zone. The Deep Coral Zone is characterized by a diverse assemblage of antipatharian and gorgonian corals, crinoids, bryozoans, sponges, azooxanthellate branching corals and small, solitary hard corals. It includes both low and high relief rock outcroppings of various origins. Rock outcrops are often highly eroded and lack coralline algal growth. Reef outcrops may be covered with a thin layer of silt in areas subject to frequent resuspension of sediments. The area of high sediment resuspension and turbid water was termed the "Nepheloid" zone by Bright et al. (1985) and Rezak et al. (1985). Since this terminology refers to a physical oceanographic condition and not a biological classification, it is not used here. Habitats within this zone include those characterized by dominant organisms of antipatharians, gorgonians, crinoids or coral, or mixtures of these component groups.

This effort is the first step in comprehensively characterizing the FGBNMS. Future efforts, in partnership with CCMA-BB, will focus on refining the level of characterization through further mapping, higher level bathymetric analysis, ROV and drop camera surveys. This project will be initiated in 2008.

Overall Condition and Summary of Analytical Results

The overall health of the reefs of the EFGB and WFGB continues to be described as stable, supporting over 50% live coral cover comprised of primarily robust and massive species. *Montastraea franksi*, as part of the *Montastraea annularis* species complex, dominates the community, with *Diploria strigosa* also providing substantial cover. The stability of the system is evidenced by the continued high coral cover, and the ability to recover following hurricanes and bleaching events. Algae appear to play a balanced role in the reef habitat and do not appear threatening to the coral component. Other than during hurricane events, water quality continues to be consistently good.

CURRENT CONSERVATION MANAGEMENT ACTIVITIES

Regulations governing the FGBNMS are authorized under the National Marine Sanctuaries Act, as amended, 16 U.S.C. 1431, and are contained within the Code of Federal Regulations 15 C.F.R. 922 (Subparts A, E, and L), available on the Internet at http://www.sanctuaries.nos.noaa.gov/oms/omsflower/omsflowerpubdoc.html. They are designed to protect the sensitive coral reef features of the Sanctuary. The regulations prohibit anchoring of any vessel within the Sanctuary; mooring of any vessel greater than 100 feet on a Sanctuary mooring buoy; oil and gas exploration and development within a designated no activity zone (almost the entire Sanctuary); injuring or taking coral and other marine organisms; using fishing gear other than traditional hook and line; discharging or depositing any substances or materials; altering the seabed; building or abandoning any structures; and using explosives or electrical charges.

In 2001, the International Maritime Organization designated the FGBNMS as the world's first international no-anchor zone. This designation enhances the protection and awareness of the site by providing guidance and regulations at an international level.

In 2005, the FGBNMS helped the Gulf of Mexico Fisheries Management Council (GOMFMC) recommend sites in the northwestern Gulf of Mexico as Habitat Areas of Particular Concern (HAPC). Although, in general, this designation does not carry any regulations that would protect the sites, a subgroup of the HAPC's were designated as Coral Essential Fish Habitat (EFH) Areas under the HAPC designation. This designation does carry regulations, including prohibiting anchoring, prohibiting trawling, bottom longlines, and trap/pot gear. EFGB and WFGB were already Coral EFH areas. The GOMFMC added Stetson Bank, McGrail Bank and a portion of Pulley's Ridge (Florida) under the Coral EFH designation.

The FGBNMS research team have developed regional identification posters for deepwater biota (50-180 m), including fishes, sponges, black corals, gorgonians, algae and invertebrates. These may be useful for researchers conducting projects in these depth ranges, and lessen the need to collect samples for identification. Copies of these posters can be downloaded from http://www.flowergarden.noaa.gov/document_library/sci_documents.html.

The FGBNMS is currently undergoing a management plan review. Issues that have been identified through a public scoping process conducted by the FGBNMS and the Sanctuary Advisory Committee include impacts from visitor use, harvesting impacts from fishing, boundary expansion needs, impacts of pollutant discharge, enforcement and education/outreach. Working groups have been created for each issue, and the groups are holding workshops to assist in information gathering and move the decision making process forward.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

The major deleterious impacts of 2005, including coral disease, major hurricanes, and coral bleaching clearly demonstrated that in spite of its remote location, the coral communities of the FGBNMS are susceptible to major environmental perturbations. There is no sign that these impacts will be any less severe in years to come. Importantly, small amounts of tissue are lost during each event, and while they may not be measurable from year to year, on a reef-wide scale, the cumulative effects may be detectable over time.

We may not currently have the tools or techniques to fight coral disease or bleaching or be able to divert the path of a major hurricane, but there are human activities that are manageable, and that's where the effort should be placed to attempt to slow down the negative forces that are wearing down the resilience of coral reefs and associated habitats.

The coral reef ecosystem at the FGB continues to thrive, despite its location in the middle of one of the largest oil and gas fields in the world. Each year, Sanctuary staff review dozens of new requests for pipeline or platform installation within the MMS four-mile regulatory zone. One unresolved concern associated with oil and gas activities is the large quantities of contaminated water, or "produced water" that is generated during offshore oil platform operations. The effects of produced water on coral reef ecosystems are unknown and represent a significant knowledge gap that needs to be addressed in response to the expansion of oil and gas activities in the region.

Other substantial knowledge gaps exist, in part due to the difficulty of accessing this relatively remote location. While distance from shore may lessen some of the impacts attributed to recreational use, it also hampers monitoring of human activities, research with respect to recreational use of the area by divers and fishers, and enforcement of Sanctuary regulations. While some data on visitor use can be attained by a variety of remote methods such as overflights, satellite imagery, and radar systems, the need for the Sanctuary to increase on-site observation, management, and enforcement has not been met. However, in response to this need the FGBNMS has constructed and implemented a vessel – an 83 ft catamaran, the R/V *Manta*, which will greatly enhance enforcement, management, research and education capabilities beginning in summer 2008.

The location and depth of the FGB also makes the logistics involved in monitoring activities difficult and expensive, which limits the frequency of sampling and the total area able to be surveyed during data collection. Under the current long-term monitoring methods, sampling points are limited to a 100 m^2 area in the shallowest part of the coral caps, which represents a fraction of the total area of the banks. Limitations in sampling frequency and spatial distribution of survey effort restrict scientists' analytical power to measure change with a sufficient level of confidence, especially when trying to account for adjacent reefs or banks. The addition of the CCMA-BB collaborative project has greatly enhanced our ability to assess the reef in its entirety because the approach used complements the fixed-site surveys. It is critical to continue this component of stratified random surveys throughout the coral cap and expand these efforts into the deeper waters of the Sanctuary. There is currently no funding to incorporate this project on a long-term basis.

Despite these limitations, both the LTM Project results and those of the joint FGBNMS and CCMA-BB study indicate that the EFGB and WFGB reefs are relatively pristine when compared to other Caribbean reef systems. Budget constraints have precluded the analysis of Stetson Bank monitoring data to date, but analysis of existing data is a priority for increasing management capability. Anecdotal and photographic observations made at Stetson Bank are noted (e.g., 2005 bleaching event), but cannot be acted upon without quantitative evidence.

The observations indicating that FGBNMS is an important spawning area for several species of grouper warrants further investigation and highlights the importance of considering a no-take marine reserve to protect the biodiversity of this region. It is clear that the reefs of the FGBNMS are biologically and ecologically connected with the numerous other reefs and banks found in the northwestern Gulf of Mexico that are unprotected. Both of these issues will be addressed during the FGBNMS Management Plan Review.

The coral reef ecosystem of the FGBNMS is in good or excellent condition. It is crucial that the status of this resource be maintained. In a world of declining coral reef health, this site can be used as a standard for comparison to other Caribbean coral reef systems and may function as a source of recruits for neighboring regions.

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