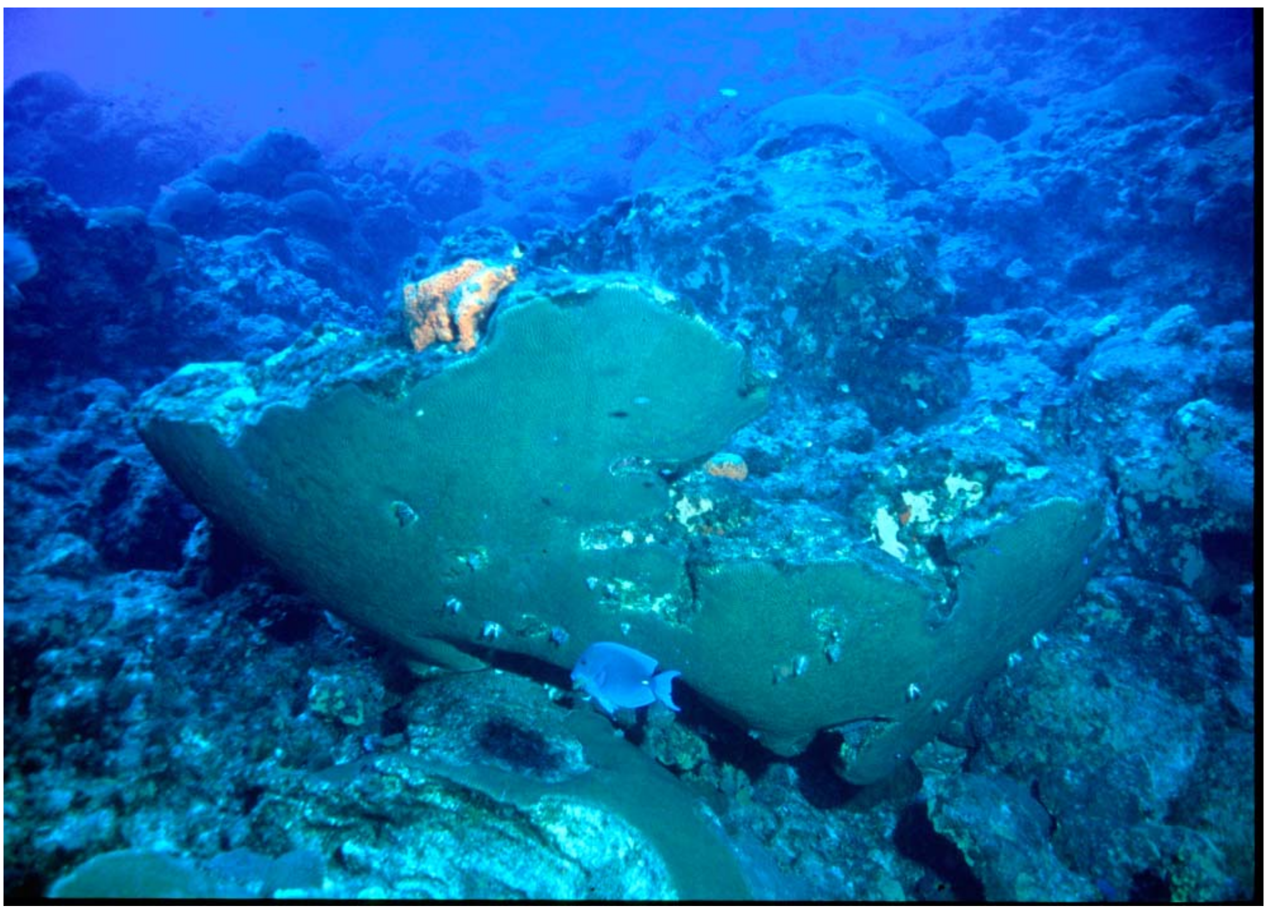
OCS Study
MMS 2008-019

Post-Hurricane Assessment at the East Flower Garden Bank Long-Term Monitoring Site: November 2005



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

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ABOUT THE COVER

The cover art depicts a toppled coral colony at the Flower Garden Banks, most likely a result of Hurricane Rita, which passed close to the Flower Garden Banks on 23 September 2005. Photograph courtesy of Gregory Boland (MMS).

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ACKNOWLEDGMENTS

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POST-HURRICANE ASSESSMENT AT THE EAST FLOWER GARDEN BANK LONG-TERM MONITORING SITE: NOVEMBER 2005 (MMS/NOAA FUNDED PROJECT)	Project Management, Discussion, Conclusions, Recommendations, Editorial Management	William F. Precht, Richard B. Aronson, Kenneth J.P. Deslarzes, Martha L. Robbart
	Executive Summary, Introduction, Study Site, Methods, Discussion	Martha L. Robbart, Kenneth J.P. Deslarzes
	Repetitive Quadrats	Martha L. Robbart, Richard B. Aronson, Karlisa Callwood, Ryan Moody
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EXECUTIVE SUMMARY

Hurricane Rita, a Category 3 storm on the Saffir-Simpson Index, passed within 50 miles (83 km) of the Flower Garden Banks on September 23, 2005. Soon after the hurricane, Flower Garden Banks National Marine Sanctuary (FGBNMS) staff rapidly assessed damage at the Flower Garden Banks and found large, dislodged coral heads; corals gouged and damaged from waterborne projectiles; displaced sand and sediment, scoured coral heads; and an ongoing coral-bleaching event.

On November 13, 2005, a team was assembled to assess hurricane damage to the 100 m by 100 m established monitoring site at the East Bank. During the summer of 2005, prior to Hurricane Rita, seawater temperatures were elevated at the Flower Garden Banks as well as throughout much of the Caribbean. Coral bleaching was observed during the summer at the Flower Garden Banks (NOAA coral spawning cruise August 23-27, 2005) and reported throughout the wider Caribbean. Results of both the hurricane damage and the thermal anomaly are reported from repetitive-quadrat, video-perimeter, and water-quality analyses.

Approximately 1.5% of coral colonies photographed at the East Bank repetitive quadrat stations were missing, apparently due to the effects of Hurricane Rita. *Diploria strigosa*, *Porites astreoides*, and *Montastraea* sp. comprised the majority of missing coral colonies with sizes ranging from 0.95 to 80.61 cm^2. Within the repetitive quadrats, ~10% of coral colonies photographed were bleached. This is the highest level of bleaching reported for the Flower Garden Banks since the bleaching event of 1990, when ~5% of corals at the East Bank were bleached. Bleaching was evident in all coral species, but it was most prevalent in the *Montastraea annularis* species complex, *M. cavernosa*, and *Millepora alcicornis*.

Two coral colonies were missing from the East Bank deep stations, apparently due to the hurricane (~0.5% of coral colonies photographed). Deep-site repetitive quadrats also exhibited bleaching, although to a lesser extent than the shallower sites (~3%). Adjacent to the deep stations, an expansive field of the delicate, branching coral *Madracis mirabilis* had experienced catastrophic levels of breakage and toppling. Unfortunately, to date, no quantitative surveys have been performed on this coral population.

Obvious signs of damage were documented in the perimeter videography and included dislodged and damaged coral colonies. Similar levels of bleaching were documented along perimeter lines as in the repetitive quadrats. Fish populations were comparable to fish populations recorded in past monitoring events.

Water quality results showed that the reef cap experienced elevated water temperatures for 50 days and that the passage of Hurricane Rita brought relief by lowering water temperatures on the reef. There was no evidence of damage from oil and gas production on the Flower Garden Banks.

1.0 INTRODUCTION

Tropical cyclones that enter the Gulf of Mexico have, on occasion, been hurricanes that traversed the Flower Garden Banks with varying intensity (Scholten and Deslarzes 1998). Severe hurricanes (categories 4 and 5) probably moved through the Flower Garden Banks region (within ~250 km) in 1900, 1909, 1915, 1957, 1961 (category 5), 1964, 1974, 1979, and 1980 (category 5). On August 8 and 9, 1980, Hurricane Allen, with a 5+ m surge and wind speeds of 96 km/hr, caused physical damages to the coral reefs of the Flower Garden Banks. A 2,000 kg coral head was displaced tens of meters across the reef cap on the East Bank (Combs, personal communication, 1989).

The 2005 hurricane season was the most active on record, fueled by record high sea-surface temperatures in the Atlantic (National Climatic Data Center 2005). Eleven tropical cyclones entered the Gulf of Mexico in 2005. One of these cyclones, Hurricane Rita, affected the Flower Garden Banks on September 23 as a category 3 hurricane (Figure 1.1.1). The other storms passed more than 500 km away from the Flower Garden Banks (Table 1.1.1).

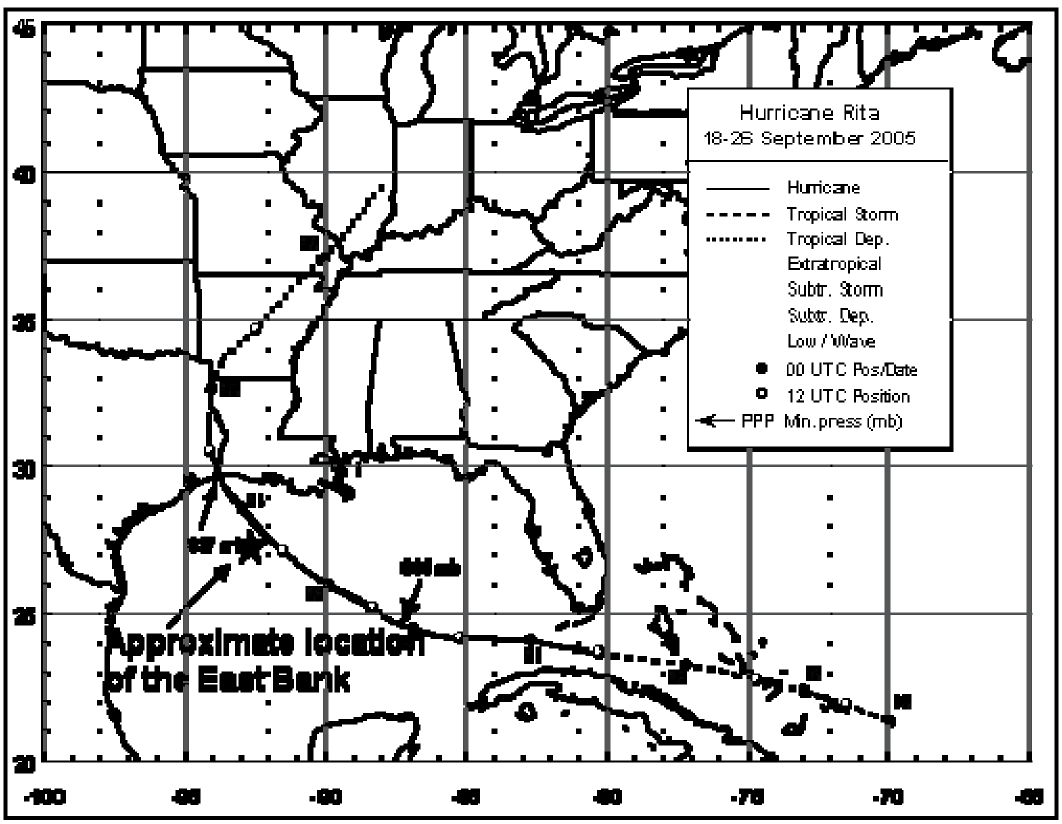


Figure 1.1.1. Track of Hurricane Rita, 18-26 September 2005 (National Hurricane Center 2006).

Table 1.1.1.

List of tropical cyclones that entered the Gulf of Mexico (GOM) in 2004 and 2005. The name and category of a given cyclone is listed according to its condition when it was closest to the Flower Garden Banks. Information on the cyclones was taken from The Weather Underground, Inc. (2005a; The Weather Underground 2005b).

Name/Category	Date	Wind Speed (mph) or Category	Trajectory
Tropical Storm Bonnie	8/10/04	50	Central GOM, ~600 km east of the Flower Garden Banks
Hurricane Charley	8/13/04	Cat 4	Passed over the Florida Straits, southwest Florida
Tropical Storm Frances	9/4/04	65	Northeast GOM, >1000 km east of the Flower Garden Banks
Hurricane Ivan	9/15/04	Cat 4	Passed ~550 km east of the Flower Garden Banks
Tropical Storm Matthew	10/09/04	40	Passed ~320 km east of the Flower Garden Banks
Tropical Storm Arlene	6/11/05	70	Central GOM, ~600 km east of the Flower Garden Banks
Tropical Storm Bret	6/25/05	40	Southwest GOM, >800 km south of the Flower Garden Banks
Tropical Storm Cindy	7/5/05	70	Central GOM, ~500 km east of the Flower Garden Banks
Hurricane Dennis	7/10/05	Cat 4	Central GOM, ~800 km east of the Flower Garden Banks
Hurricane Emily	7/19/05	Cat 1	Southwest GOM, ~600 km south of the Flower Garden Banks
Tropical Storm Gert	7/25/05	45	Southwest GOM, ~750 km south of the Flower Garden Banks
Tropical Storm Jose	8/23/05	50	Southwest GOM, ~800 km south of the Flower Garden Banks
Hurricane Katrina	8/28/05	Cat 5	Central GOM, ~500 km east of the Flower Garden Banks
Hurricane Rita	**9/23/05**	**Cat 3**	**Central GOM, over the Flower Garden Banks**
Tropical Storm Stan	10/3/05	40	Southwest GOM, ~850 km south of the Flower Garden Banks
Hurricane Wilma	10/24/05	Cat 3	Southeast GOM, ~900 km SE of the Flower Garden Banks

Preliminary assessments of the coral reefs at the Flower Garden Banks following Hurricane Rita included substantial mechanical impacts, evidence of fractured and displaced corals, sediment-scoured corals bordering sand flats (Figure 1.1.2), and corals scarred and indented by waterborne objects (Figure 1.1.3) (Hickerson and Schmahl, personal communication, 19 October 2005). As an example of physical damage, we measured one large coral head, 4 m across and 2 m high, that was dislodged from the reef cap (Figure 1.1.4). One meter of coarse sand was removed from large sand flats. Large barrel sponges, *Xestospongia muta*, were partially or fully removed from the reef, or were filled with sand (Hickerson and Schmahl, personal communication, 19 October 2005). The hurricane impacts were preceded and followed by other natural disturbances at the Flower Garden Banks: extreme warming of the water column from August through November 2005, which was associated with severe coral bleaching (Hickerson and Schmahl, personal communication, 19 October 2005) and near-shore runoff transported from the Texas-Louisiana coast to the shelf edge (NOAA CoastWatch 2005).

Figure 1.1.2. Sediment-scoured corals at the edge of a sand flat at the Flower Garden Banks in October 2005. The scouring and sand removal were likely caused by the passage of Hurricane Rita on 23 September 2005. Photo courtesy of Emma L. Hickerson, Flower Garden Banks National Marine Sanctuary.

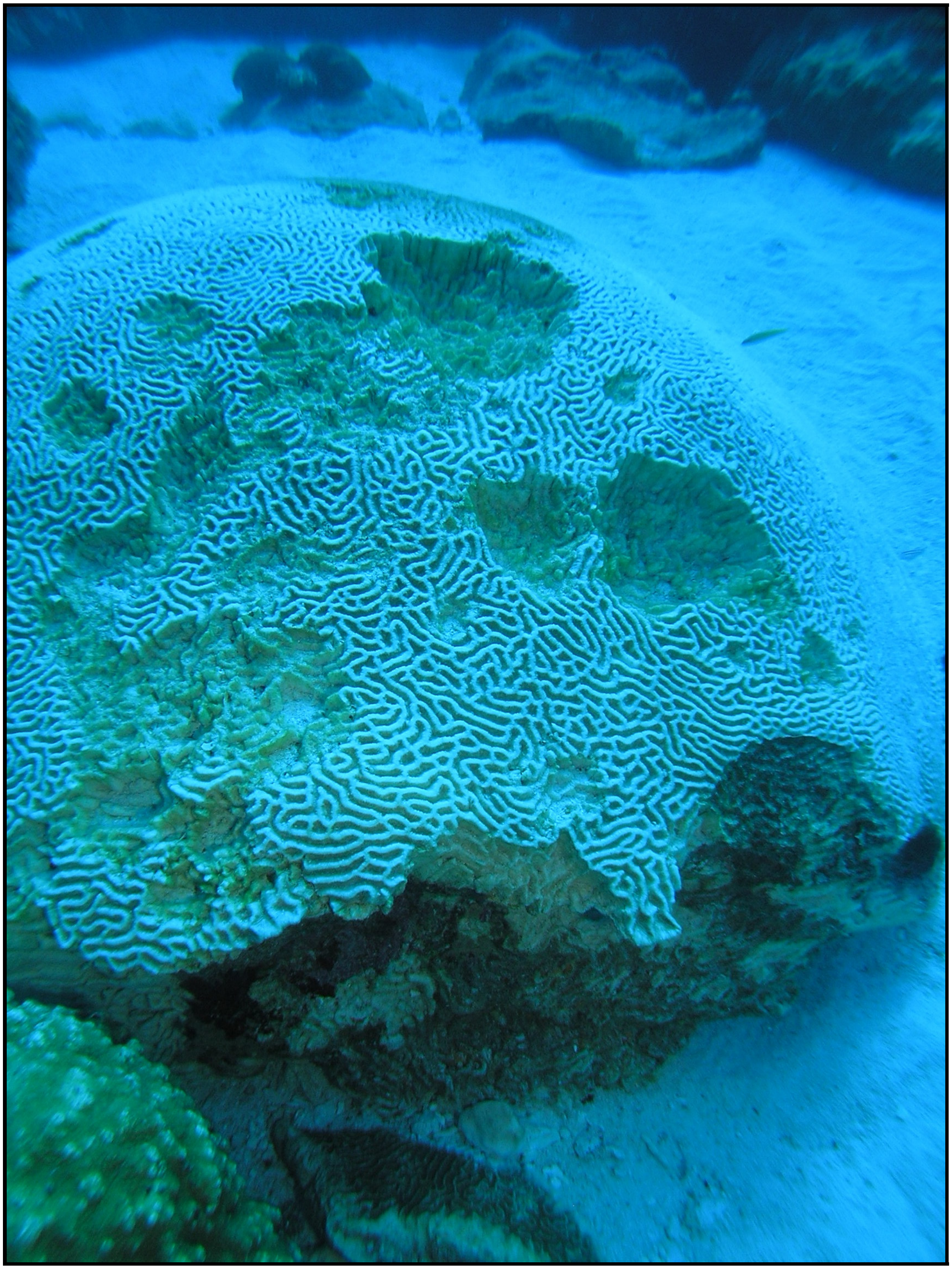


Figure 1.1.3. Coral colony indented by waterborne object(s). Damage likely occurred during the passage of Hurricane Rita on 23 September 2005. Photo courtesy of Emma L. Hickerson, Flower Garden Banks National Marine Sanctuary.

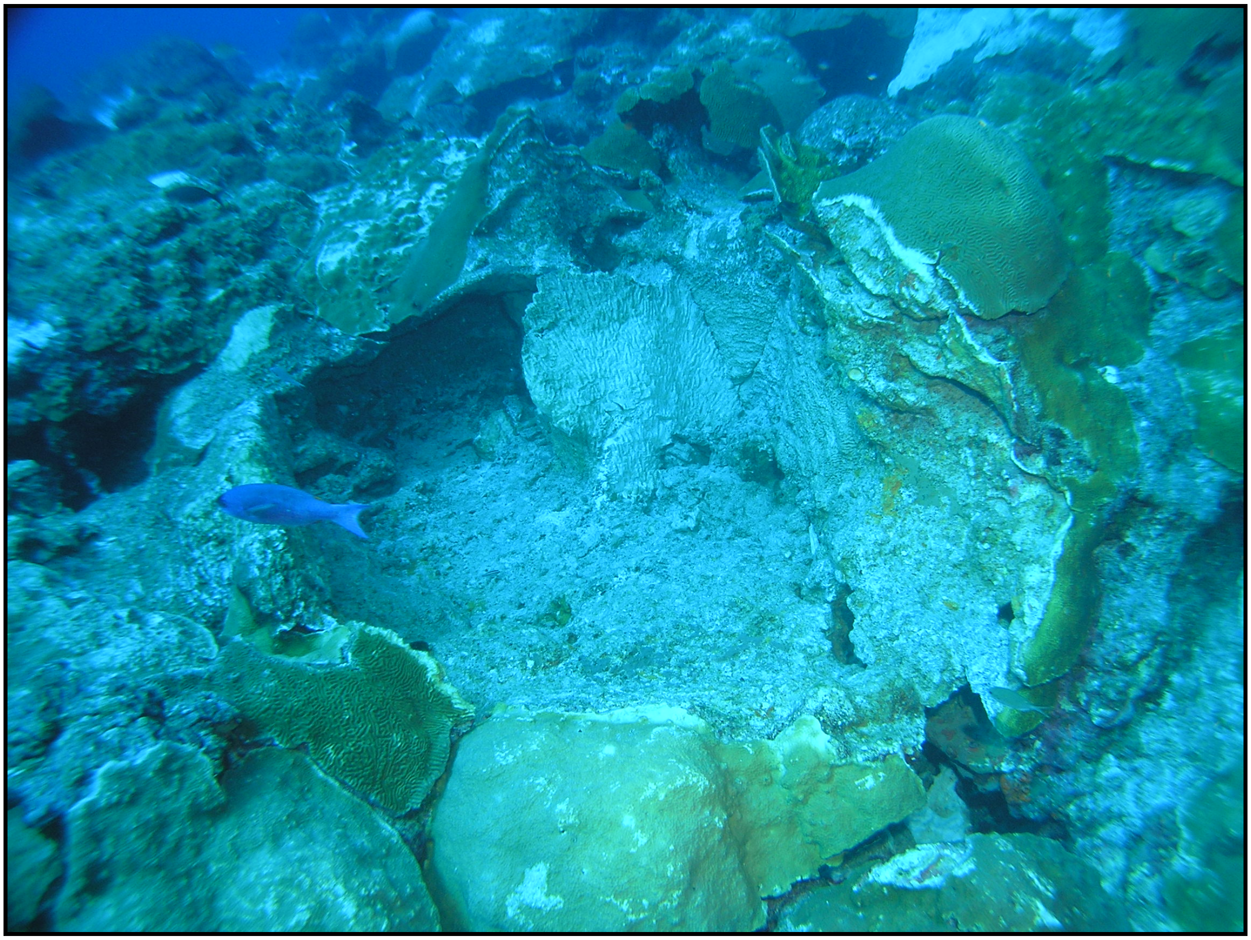


Figure 1.1.4. Footprint of a coral colony dislodged from the Flower Garden Banks reef cap observed after the passage of Hurricane Rita on 23 September 2005. Photo courtesy of Emma L. Hickerson, Flower Garden Banks National Marine Sanctuary.

In addition to hurricane impacts, the Flower Garden Banks experienced unusually warm summer water temperatures. Extensive coral bleaching, expressed as presence found along transects (48% of coral colonies were either partially or totally bleached), was documented in October 2005 by the FGBNMS. Many reefs throughout the greater Caribbean showed similarly high seawater temperatures during this period and subsequent bleaching of coral populations.

In order to assess the impacts of both Hurricane Rita and the thermal event on the benthic community at the East Bank, photography of repetitive quadrats and videography of perimeter lines were conducted, and the results were compared to earlier records. Water quality measurements are also presented for the water overlying the Flower Garden Banks during and after the passage of Hurricane Rita. The water parameters measured included physical (temperature, turbidity, circulation), biological (chlorophyll *a*), and chemical (salinity, dissolved oxygen, pH, nutrients, trace metals) characteristics.

2.0 METHODS

2.1 Repetitive Quadrats

2.1.1 Methodological Rationale

To monitor changes in the coral reef community structure due to Hurricane Rita, repetitive 8 m^2 quadrats were photographed. The photographs were analyzed in two ways. The first method involved using random-dot analysis to estimate the percent cover of benthic components in November 2005, including coral species and bleaching. The second approach used planimetry to analyze selected corals within repetitive quadrats between June 2005 and November 2005. The goal of this analysis was to determine whether specific coral colonies grew or lost tissue laterally. Dominant framework-building corals at the Flower Garden Banks (*Montastraea annularis* species complex, *Diploria strigosa*, and *Colpophyllia natans*) were selected for analysis based on their visible margins. These corals tended to be closer to the centers of the photographs.

2.1.2 Field Methods

In November 2005, following the passage of Hurricane Rita, 40 repetitive quadrats within the 100 m x 100 m study site at the East Bank were photographed. Nine deep-station repetitive quadrats were photographed, also at the East Bank. Stations were photographed using a Nikonos V camera and 15 mm lens. The camera was loaded with Kodak Ektachrome EliteChrome 200 ASA, 36-exposure slide film and standard settings were applied (distance = 2 m, f8). It was mounted in the center of a T-bar camera frame. Two Ikelite 75 watt-second strobes, placed 1.2 m apart, were mounted on the ends of the T-bar and set on TTL and slave (Gittings et al. 1992). The camera was positioned in a north-facing direction to ensure repetitive photographs from year to year. The consistent orientation of the camera was achieved with a compass and a bubble level.

2.1.3 Image Analysis of Repetitive Quadrats

Percent cover of corals by species; the cover of coral bleaching, paling, concentrated and isolated fish biting, and disease; and the cover of algae were determined by overlaying 300 random dots on each photograph using CPCe® point-count software with Excel extensions. Percent coverage was calculated from November 2005 images and compared to June 2005 repetitive-quadrat matches. Forty nine images were analyzed: 40 from within the 100 m x 100 m study site and 9 from the deep repetitive-quadrat stations (Appendix A).

Planimetry was used to measure tissue change between select coral colonies within quadrat matches between June 2005 and November 2005. Forty image pairs were analyzed from within the 100 m by 100 m study site and nine image pairs were analyzed from the deep repetitive quadrat stations. Four to six coral colonies were chosen within each repetitive quadrat. Area measurements were created using Sigma Scan Pro 5® planimetry software in each year for matched coral colonies (Appendix B).

2.1.4 Data Presentation and Statistical Analysis of Repetitive Quadrats

Percent cover of coral species, algae, bleaching, fish biting, and disease were 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 (i.e. coral) 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. Percent cover values were determined per quadrat and represent a range of estimates for each cover category, representative of each quadrat, but not necessarily the bank. The lateral extent of corals was compared between June 2005 and November 2005 by overlaying coral colonies and determining whether there was an increase or decrease between subsequent years.

Descriptive statistics were used to characterize the effects of Hurricane Rita within 8 m^2 repetitive quadrats.

2.2 Perimeter Videography

2.2.1 Methodological Rationale

Perimeter lines were videotaped for post-hurricane assessment in November 2005 in order to document change at known locations along the perimeter and within the study site. A general sense of coral condition and fish populations was obtained and compared between June and November 2005.

2.2.2 Field Methods

Divers videotaped two 100 m segments of the perimeter lines at the East Bank (north and east margins) in November 2005. Divers began at the northwest corner, completed a 360° videographic panorama, videotaped the north line to the northeast corner, completed another 360° videographic panorama, then videotaped the east line while swimming to the southeast corner, where they completed a third 360° videographic panorama. The videographer maintained ~2 m distance above the benthos using a weighted line attached to the video housing. The camera was aimed down at a 45° angle to capture the substratum.

2.2.3 Laboratory Methods

The video footage was reviewed to record the general condition of coral health and fish populations along the perimeter of the study sites. Individual coral heads displaying possible disease, bleaching, paling, and tissue loss due to fish biting were identified and recorded. Analysis categories were as follows: bleaching, paling, healthy colony, concentrated fish biting, isolated fish biting (damselfish territory), growth infilling (tissue regrowth), new incidence of fish biting, and unchanged. Concentrated fish biting (CFB) represents the concentrated biting which removes the coral polyps completely from an affected area and may be due to activity of the parrotfish *Sparisoma viride* (Bruckner and Bruckner 1998; Bruckner et al. 2000). Isolated fish biting describes less dense and smaller-scale fish biting, typically representative of damselfish territories. Affected coral colonies were compared between June 2005 and the post-hurricane video footage (November 2005), and changes in their condition were recorded. In addition to coral colony comparison, coral species composition and fish counts were assessed. These analyses were qualitative and therefore no statistical analyses were conducted.

2.3 Water Quality

2.3.1 YSI Datasondes

The YSI 6600 Series datasonde used in this study is a multiparameter, deployable monitoring system capable of measuring and recording temperature, depth, pH, dissolved oxygen, specific conductance, turbidity, and photosynthetically active radiation. The sondes typically have up to a 75-day battery life (at 15-minute sampling intervals) and store 150,000 individual parameter readings. The sondes are 51.8 cm (20.4 inches) long and have an 8.9 cm (3.5 in) diameter. The sondes are internally powered by 8 C-size, alkaline batteries.

One YSI datasonde was deployed at the East Bank (23 m water depth) and one at the West Bank (27 m water depth). Sand flats were used as deployment locations to accommodate the secure attachment of the datasondes to galvanized train wheels. Water quality data were gathered every 30 min to every 1.5 hr, depending on battery life.

The datasonde measurement methods were as follows:

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

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

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

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

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

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

Photosynthetically Active Radiation. Photosynthetically active radiation (PAR) is the portion of the light spectrum from 400-700 nm and is measured underwater using a PAR sensor that points upward. Units are micromoles per second per square meter, which are equivalent to microeinsteins per second per square meter. PAR sensors capable of field deployment typically have wipers or other devices associated with them to keep fouling communities from settling on the sensor. Any fouling of PAR sensors compromises the PAR data acquired.

2.3.2 HoboTemp Thermographs

HoboTemp recorders have an accuracy of ± 0.2°C and resolution is 0.02 °C at 25 °C. A HoboTemp thermograph was attached to each of the YSI instruments as a backup recorder of water temperature. The HoboTemp recorders were therefore deployed in 23 m water depth at the East Bank and in 27 m water depth at the West Bank. Temperature was recorded every hour.

3.0 RESULTS

3.1 REPETITIVE QUADRAT DATA

3.1.1 Study Site Repetitive Quadrat Percent Cover Data

Forty repetitive quadrats were photographed in November 2005 in the post-hurricane assessment effort. Coral cover within repetitive quadrats remained high at approximately 61%, and species relative abundance showed continued stability with *Montastraea annularis* species complex, *Diploria strigosa*, *P. astreoides*, and *M. cavernosa* as the four dominant species (Figure 3.1.1; Appendix A).

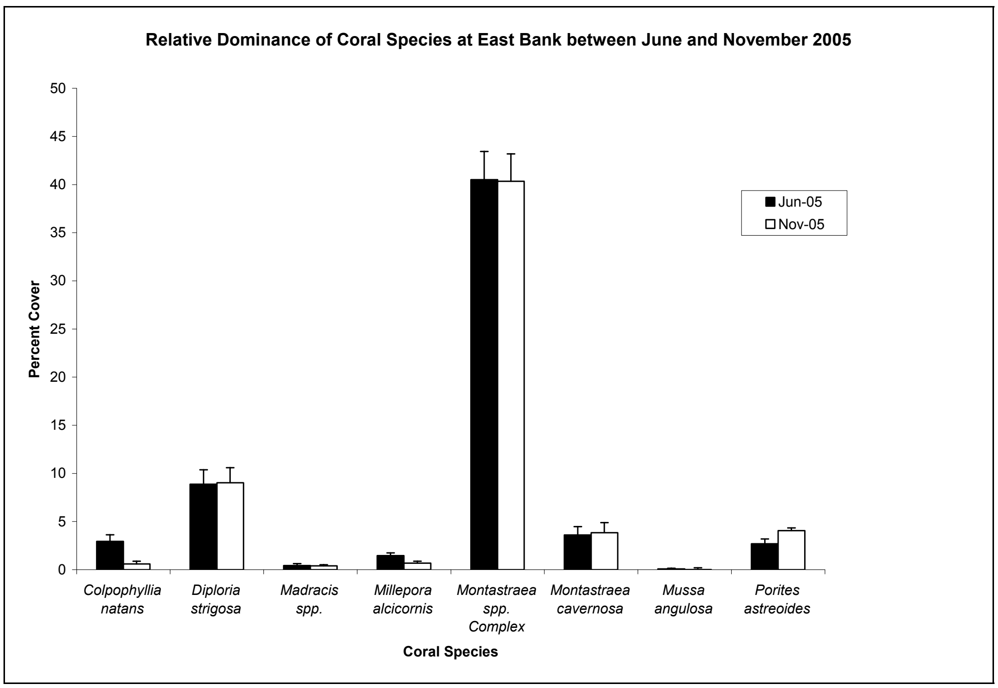


Figure 3.1.1. Relative dominance (+ SE) of predominant coral species in the East Bank study site repetitive quadrats in June and November 2005.

Approximately 1.5% of coral colonies within repetitive quadrats at the East Bank were missing, most likely due to the effects of Hurricane Rita. This did not noticeably affect coral-cover estimates, which did not vary substantially from June 2005 (Figure 3.1.1). *Diploria strigosa*, *Porites astreoides*, and *Montastraea* sp. comprised the majority of missing coral colonies with sizes ranging from 0.95 to 80.61 cm^2.

The most noticeable difference in the study site repetitive quadrats photographed at the East Bank in November 2005 was the level of bleaching: 9.74% (± 1.07SE). Most bleaching occurred on colonies of *Montastraea annularis* species complex, *M. cavernosa*, and *Millepora alcicornis* (Table 3.1.1). Paling and fish biting measurements were low at 1.48% or less, and disease was not observed (Table 3.1.2).

From June 2005 to November 2005 coral cover remained relatively constant (Table 3.1.3). In June 2005 macroalgae was high at 24%, while CTB was lower at 10%. After the hurricane, in November 2005 the inverse relationship between macroalgae and CTB was evident, with 24% CTB and 13% macroalgae. Macroalgae cover is seasonally influenced and with the passage of Hurricane Rita it is likely that macroalgae was removed from the substratum. The low levels of macroalgae in November 2005, more than a month after the storm's passage, is likely due to the seasonality of algal species.

Table 3.1.1.

Percent cover per coral species of isolated fish biting, concentrated fish biting, paling, and bleaching at the East Bank in November 2005, from random-dot analysis.

Coral Species	**East Bank November 2005**			
	IFB	**CFB**	**P**	**BL**
Colpophyllia natans	0.00	0.00	0.00	0.00
Diploria strigosa	0.00	0.00	0.13	0.17
Millepora alcicornis	0.00	0.00	0.00	1.13
Montastraea annularis complex	0.42	0.02	0.88	3.28
Montastraea annularis	0.00	0.00	0.00	0.02
Montastraea cavernosa	0.00	0.00	0.47	4.81
Montastraea faveolata	0.02	0.00	0.08	0.58
Montastraea franksi	0.41	0.02	0.80	2.69
Porites astreoides	0.00	0.00	0.00	0.08
Unidentifiable Coral	0.00	0.00	0.00	0.27
Total	**0.42**	**0.02**	**1.48**	**9.74**

Table 3.1.2.

Percent cover (± SE) of isolated fish biting, concentrated fish biting, paling, bleaching, and disease at the East Bank in November 2005, from random-dot analysis.

Observation	**East Bank November 2005**
Paling	1.48 ± 0.39
Bleaching	9.74 ± 1.07
Concentrated Fish Biting	0.02 ± 0.01
Isolated Biting	0.42 ± 0.09
Disease	0

Table 3.1.3.

Percent cover of coral, macroalgae, and CTB at the East Bank in June and November 2005.

	June 2005		November 2005	
	Percent Cover	**Standard Error**	**Percent Cover**	**Standard Error**
Coral	62.78	2.60	61.34	2.75
Macroalgae	23.78	2.13	13.04	1.02
CTB	10.38	1.16	23.81	1.73

3.1.2 Study Site Repetitive Quadrat Planimetry

Repetitive quadrat planimetry data showed stability in lateral growth measurements of the *Montastraea annularis* species complex in November 2005 (Appendix B).

Twenty one coral heads from the 40 quadrats photographed within the 100 m x 100 m study site were removed between June 2005 and November 2005; only 14 of these were part of the planimetry analysis. Measurements of all missing corals were made from the June 2005 photographs to obtain a total area of coral cover loss. A total of ~4 m^2 of coral cover was removed from the 40 quadrats between June 2005 and November 2005 (Table 3.1.4). This is equivalent to approximately 1.5% of coral cover on the East Bank shallow coral cap.

Table 3.1.4.

Area of coral colonies removed between June 2005 and November 2005 at the East Bank. (*) represents those coral colonies that were not used during the planimetry analysis.

Repetitive Quadrat Station #	**Coral Species**	**Area (cm^2)**
3	*Diploria strigosa*	32.43
4	*Diploria strigosa*	16.00
7	*Montastraea sp.*	7.03
	Porites astreoides	0.95
	Diploria strigosa	3.16
14b	*Diploria strigosa* *	80.61
	Diploria strigosa	7.23
18	*Madracis decactis* *	18.70
	Porites astreoides *	5.73
20b	*Montastraea sp*	16.57
21b	*Diploria strigosa* *	8.28
22	*Porites astreoides* *	3.05
	Porites astreoides *	1.41
26	*Diploria strigosa*	20.70
29	*Diploria strigosa*	44.37
	Diploria strigosa	16.58
29b	*Diploria strigosa*	13.67
30b	*Diploria strigosa*	71.70
	Diploria strigosa	4.92
UNK1	*Diploria strigosa*	21.16
UNK12	*Montastraea cavernosa**	2.72
	Total	**396.97**

3.1.3 Deep Station Repetitive Quadrat Percent Cover Data

Nine deep stations were photographed in November 2005 and 0.5% (2 colonies) of coral colonies within the deep station repetitive quadrats photographed were missing. Deep station analysis revealed less bleaching (3.05%) than in the shallower, study site quadrats. Coral cover remained high (74.5%), and the dominant corals were *Montastraea annularis* complex, *M. cavernosa*, *Colpophyllia natans*, and *Diploria strigosa* (Figure 3.1.2; Appendix A).

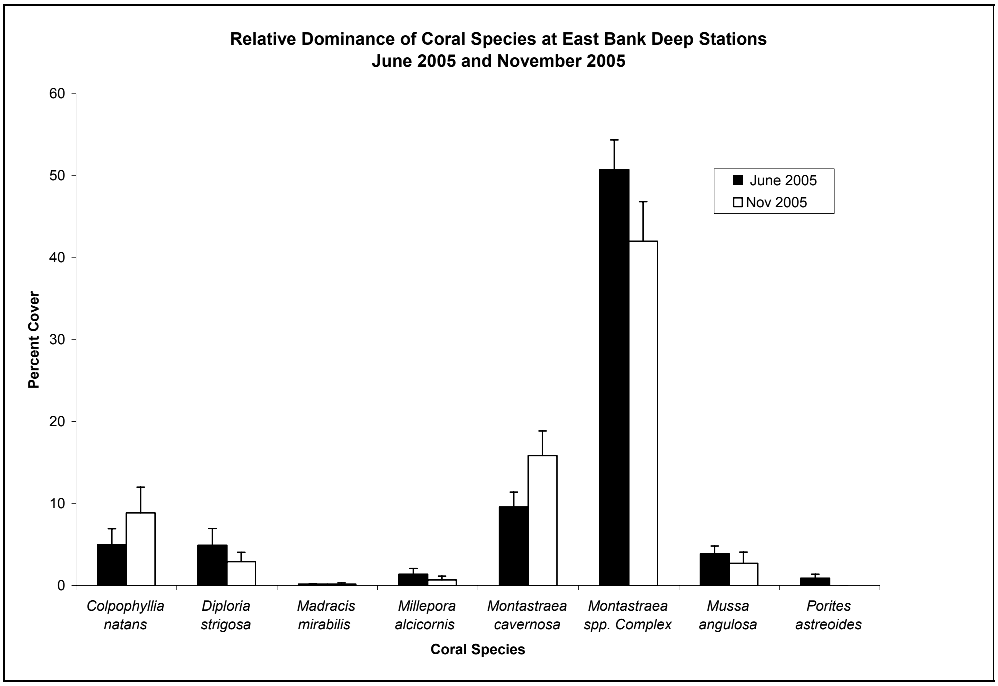


Figure 3.1.2. Relative dominance (+ SE) of predominant coral species in the East Bank deep station repetitive quadrats in June and November 2005.

3.1.4 Deep Station Repetitive Quadrat Planimetry

Deep station repetitive quadrat planimetry data showed an increase (5.74% ± 3.25 SE) in lateral growth measurements of the *Montastraea annularis* complex in November 2005 (Appendix B). Due to the high standard error associated with this increase it can be concluded that this value does not represent the actual change in margins from June 2005 to November 2005. Between June 2005 and November 2005, deep station repetitive quadrats lost a total of 2 colonies (*Diploria strigosa* and *M. cavernosa*). The total area lost was 0.24 m^2 or 0.5%.

3.2 East Bank Perimeter Videography

Corals along the perimeter lines (east and north) showed evidence of hurricane impacts, including the dislodgement, loss, or deposition of entire coral heads as well as breaking of corals, and abrasion on the reef. There was evidence of bleaching and fish biting, while fish population levels remained stable. Most distressed corals were affected by bleaching (6.4%), with slightly fewer incidences of fish biting (1.2%). No evidence of disease was observed in November 2005.

Perimeter video still images are provided here as evidence of hurricane damage. Due to the shifting of perimeter lines and associated video footage from sampling effort to sampling effort, images from year to year show different angles, positions and occur at varying depths along the perimeter lines.

3.2.1 Perimeter Lines

Physical damage was observed at several locations along the north perimeter line in November 2005, most likely due to Hurricane Rita. A partially bleached, dislodged colony of *Montastraea faveolata* was deposited along the perimeter line (Figure 3.2.1). Several colonies of *Diploria strigosa* were either shattered or completely dislodged (Figures 3.2.2-3.2.4).

Documented signs of coral stress in November 2005 included bleaching, isolated fish biting, concentrated fish biting, and paling (Table 3.2.1). As in June 2005, *Montastraea faveolata* and *M. franksi* were the most affected coral species. Brown and Blue chromis, Creole fish, and the Bluehead wrasse had the highest counts (Table 3.2.2).

Table 3.2.1.

Comparison of observations of the condition of coral colonies at the East Bank along perimeter lines and 360º panoramic views between June 2005 (n≈730) and November 2005 (n≈815). (CFB= Concentrated fish biting, IFB= Isolated fish biting, B= Bleaching, P= Paling, H= Healthy colony, ICFB= Increased tissue loss due to concentrated fish biting, IIFB= Increased tissue loss due to isolated fish biting, GI= Growth in filling [tissue regrowth], U= Unchanged condition).

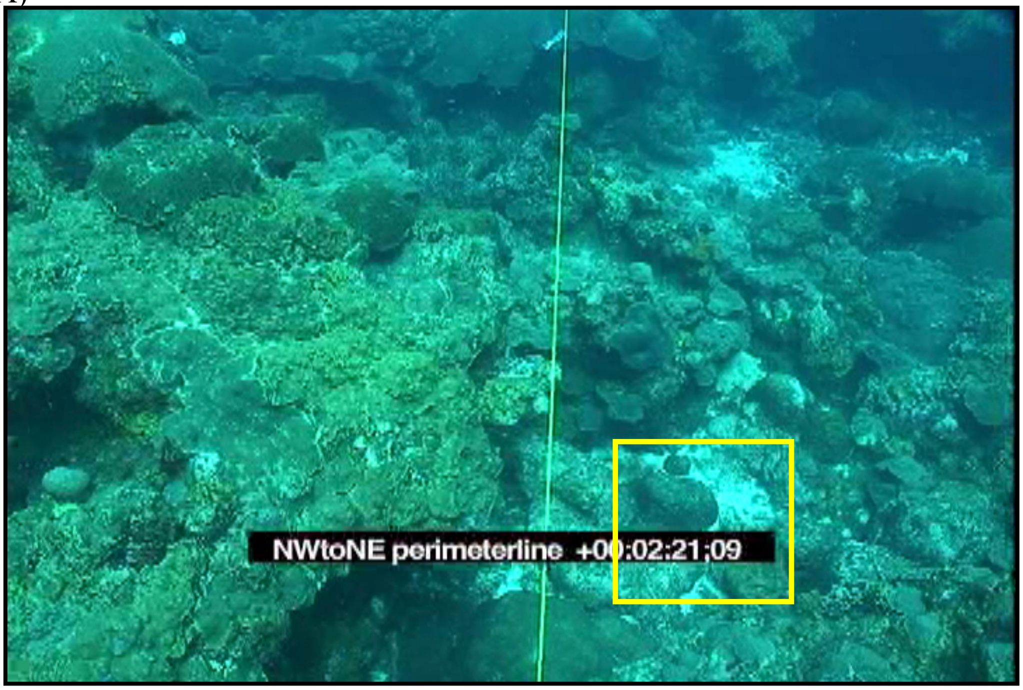
Number of Colonies	Coral Species	East Bank June 2005	East Bank November 2005
2	*Colpophyllia natans*	H	B
4	*Diploria strigosa*	H	B
1	*Madracis decactis*	B	U
7	*Millepora alcicornis*	H	B
1	*Millepora alcicornis*	B	U
1	*Montastraea annularis*	H	B
4	*Montastraea cavernosa*	H	B
2	*Montastraea faveolata*	IFB	IIFB
1	*Montastraea faveolata*	H	P
5	*Montastraea faveolata*	H	B
1	*Montastraea faveolata*	CFB	ICFB
1	*Montastraea faveolata*	IFB	B
4	*Montastraea franksi*	IFB	IIFB
14	*Montastraea franksi*	IFB	B
8	*Montastraea franksi*	H	B
1	*Montastraea franksi*	H	IFB
1	*Montastraea franksi*	H	B
1	*Montastraea franksi*	CFB	P
1	*Montastraea franksi*	H	CFB
1	*Montastraea franksi*	IFB	GI
1	*Porites astreoides*	H	B
2	*Porites astreoides*	B	GI
1	*Porites astreoides*	H	CFB
2	*Siderastrea siderea*	H	B

Table 3.2.2.

Fish species composition and individual counts for the East Bank in November 2005 along perimeter lines and 360º panoramic views at corner markers. (*) represents those individuals belonging to the Labridae, Pomacentridae, "Scaridae" (= Labridae: Scarinae), and Serranidae that could only be identified to the family level.

Species	Common Name	East Bank June 2005	East Bank November 2005
Acanthurus bahianus	Ocean surgeonfish	5	0
Acanthurus chirurgus	Doctorfish	0	5
Acanthurus coeruleus	Blue tang	7	5
Canthidermis sufflamen	Ocean triggerfish	3	1
Chaetodon aculeatus	Longsnout butterflyfish	0	1
Chaetodon sedentarius	Reef butterflyfish	4	2
Kyphosus sectatrix/incisor	Bermuda/Yellow chub	20	15
Labridae	**Wrasses ***	12	3
Bodianus rufus	Spanish hogfish	2	0
Clepticus parrae	Creole wrasse	14	2
Halichoeres garnoti	Yellowhead wrasse	0	3
Thalassoma bifasciatum	Bluehead wrasse	43	17
Lactophrys triqueter	Smooth trunkfish	0	0
Pomacentridae	**Damselfishes ***	24	14
Abudefduf saxatilis	Sergeant major	3	0
Chromis cyanea	Blue chromis	16	39
Chromis multilineata	Brown chromis	55	102
Microspathodon chrysurus	Yellowtail damselfish	1	1
Stegastes partitus	Bicolor damselfish	15	7
Stegastes planifrons	Threespot damselfish	7	5
Stegastes variabilis	Cocoa damselfish	5	0
"Scaridae"	**Parrotfishes ***	2	1
Scarus taeniopterus	Princess parrotfish	7	0
Scarus vetula	Queen parrotfish	11	7
Sparisoma viride	Stoplight parrotfish	5	0
Serranidae	**Sea Basses***	0	4
Mycteroperca tigris	Tiger grouper	2	0
Paranthias furcifer	Creole fish	15	98
Canthigaster rostrata	Sharpnose puffer	1	0
Total		**279**	**332**

(A)



(B)

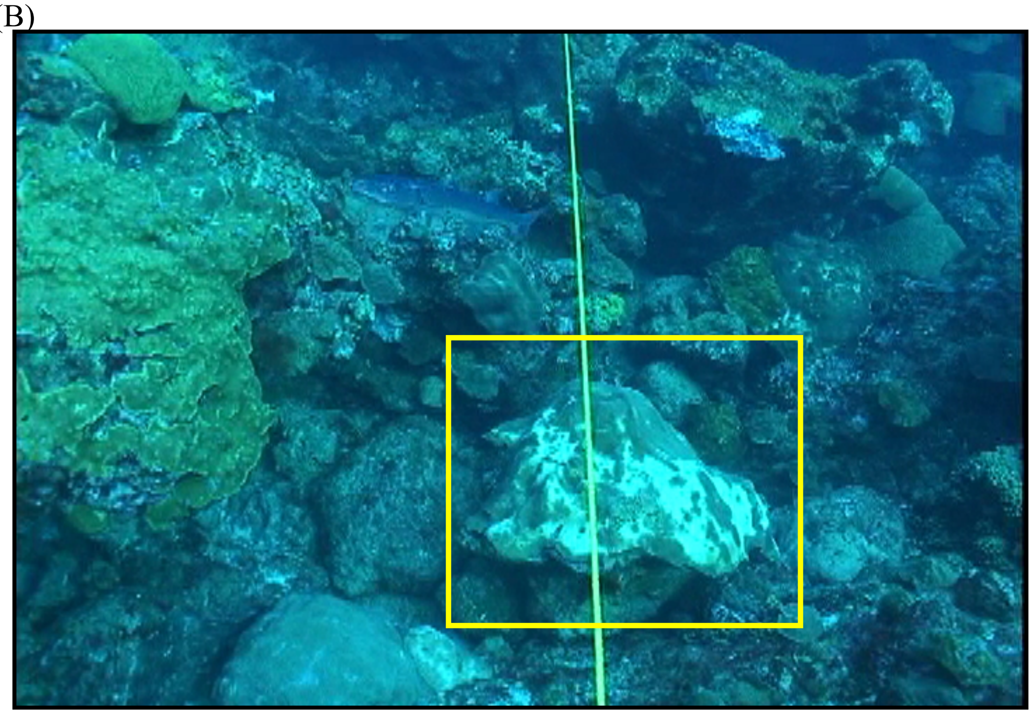
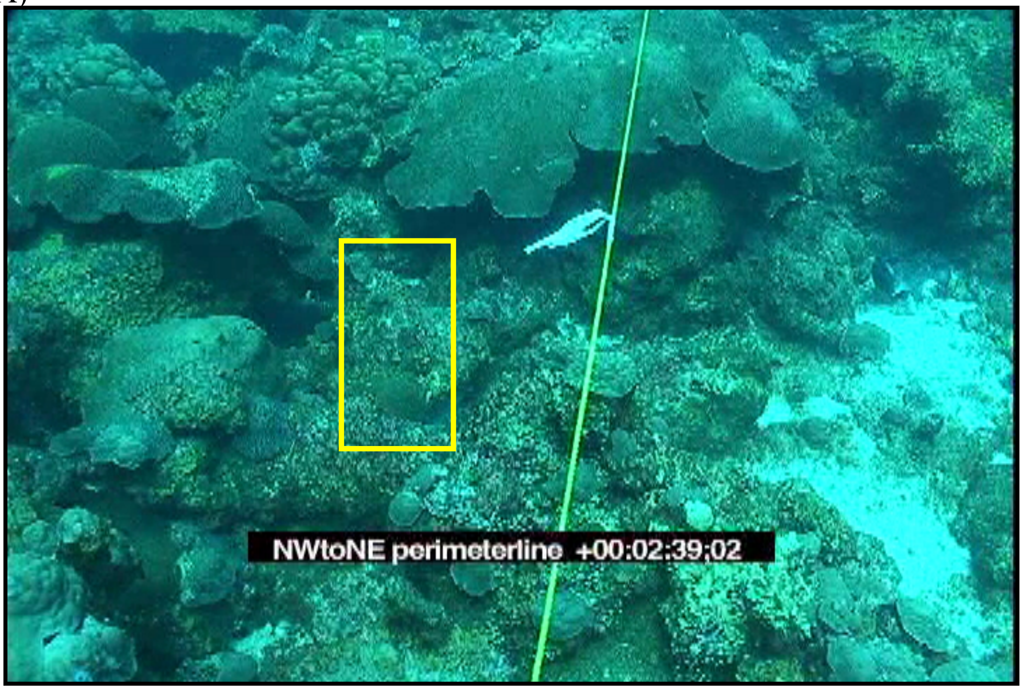


Figure 3.2.1. Photographs taken in June (A) and November (B) 2005 of a partially bleached colony of *Montastraea faveolata* deposited along the perimeter line. The yellow box highlights the approximate location of hurricane impact.

(A)



(B)

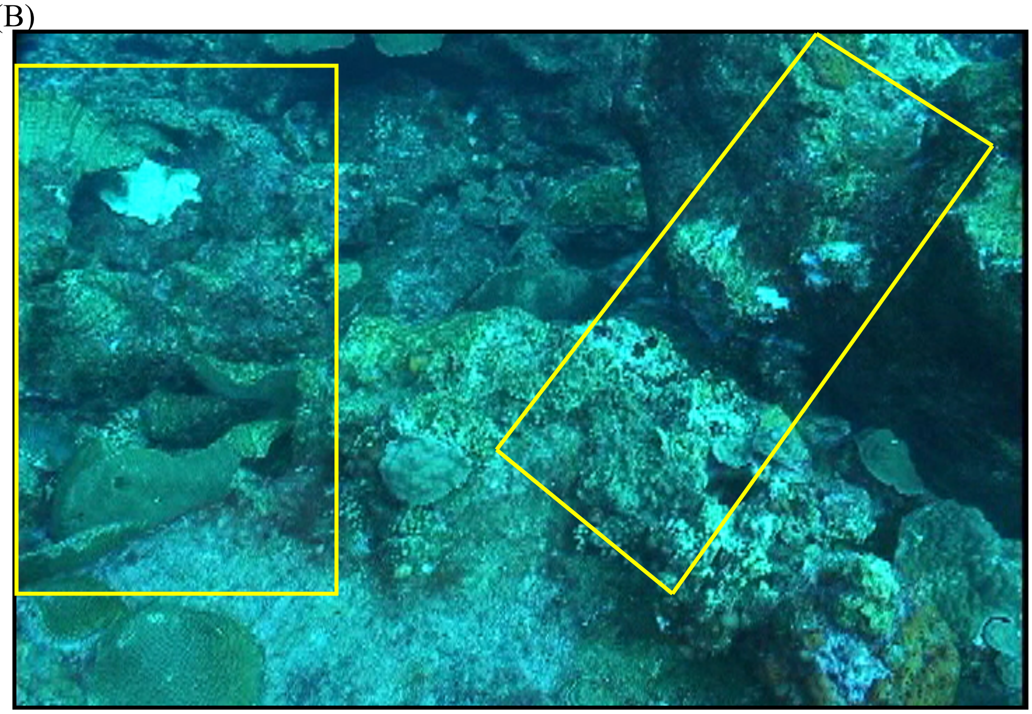
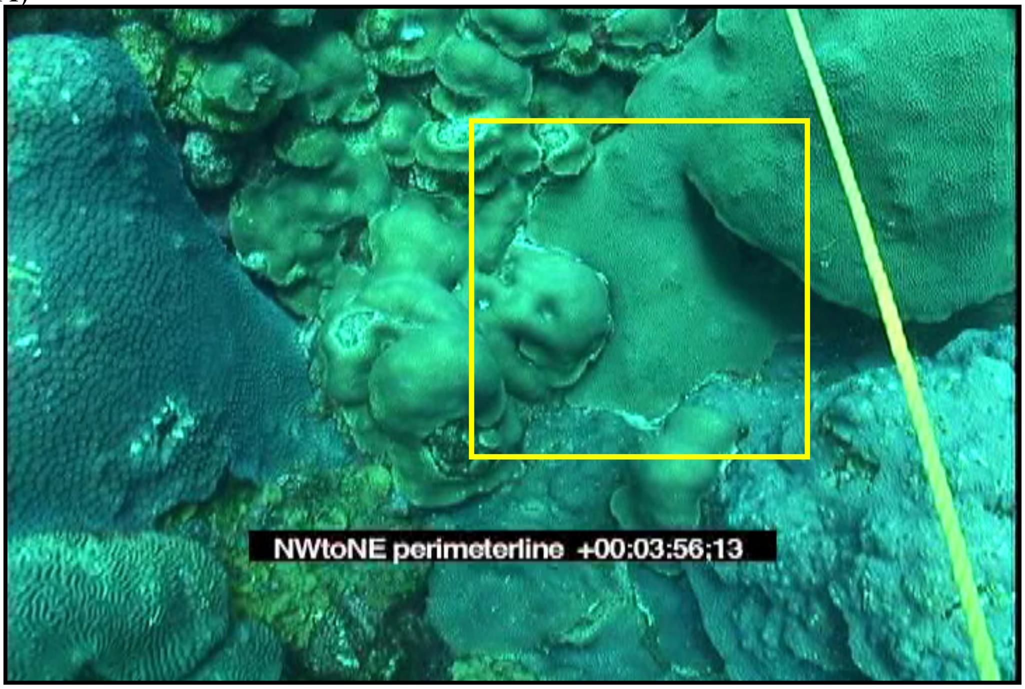


Figure 3.2.2. Photographs taken in June (A) and November (B) 2005 of a shattered colony of *Diploria strigosa* located on the left side of photograph B. The yellow boxes highlight the approximate location of hurricane impact.

(A)



(B)

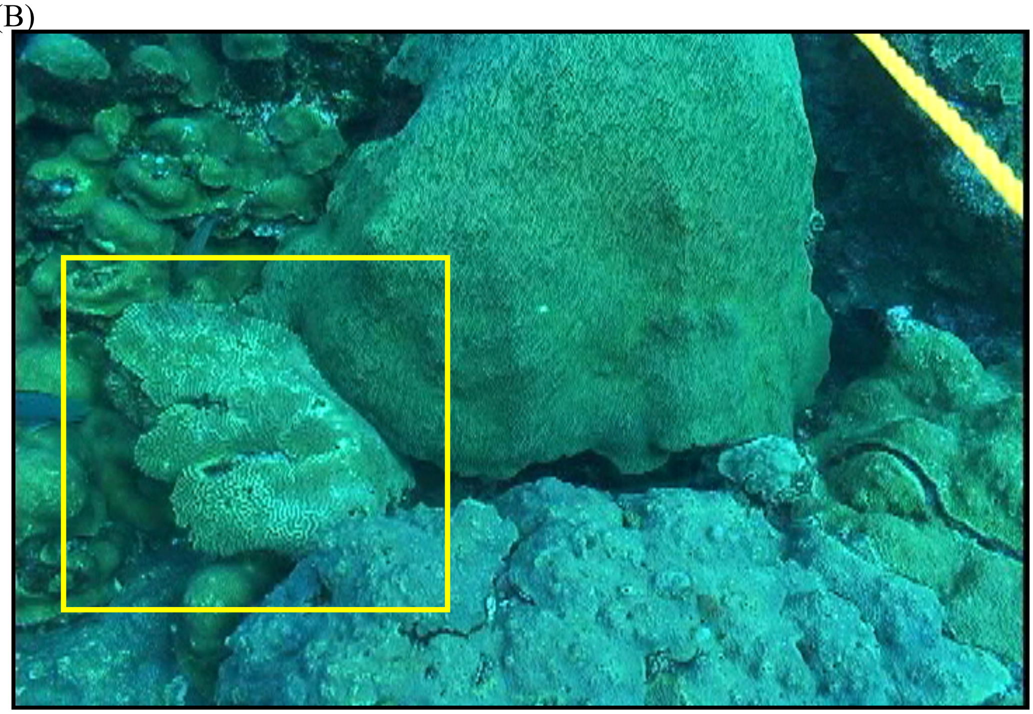


Figure 3.2.3. Photographs taken in June (A) and November (B) 2005 of a *Diploria strigosa* colony that appeared to be deposited in a new location. The yellow box highlights the approximate location of hurricane impact.

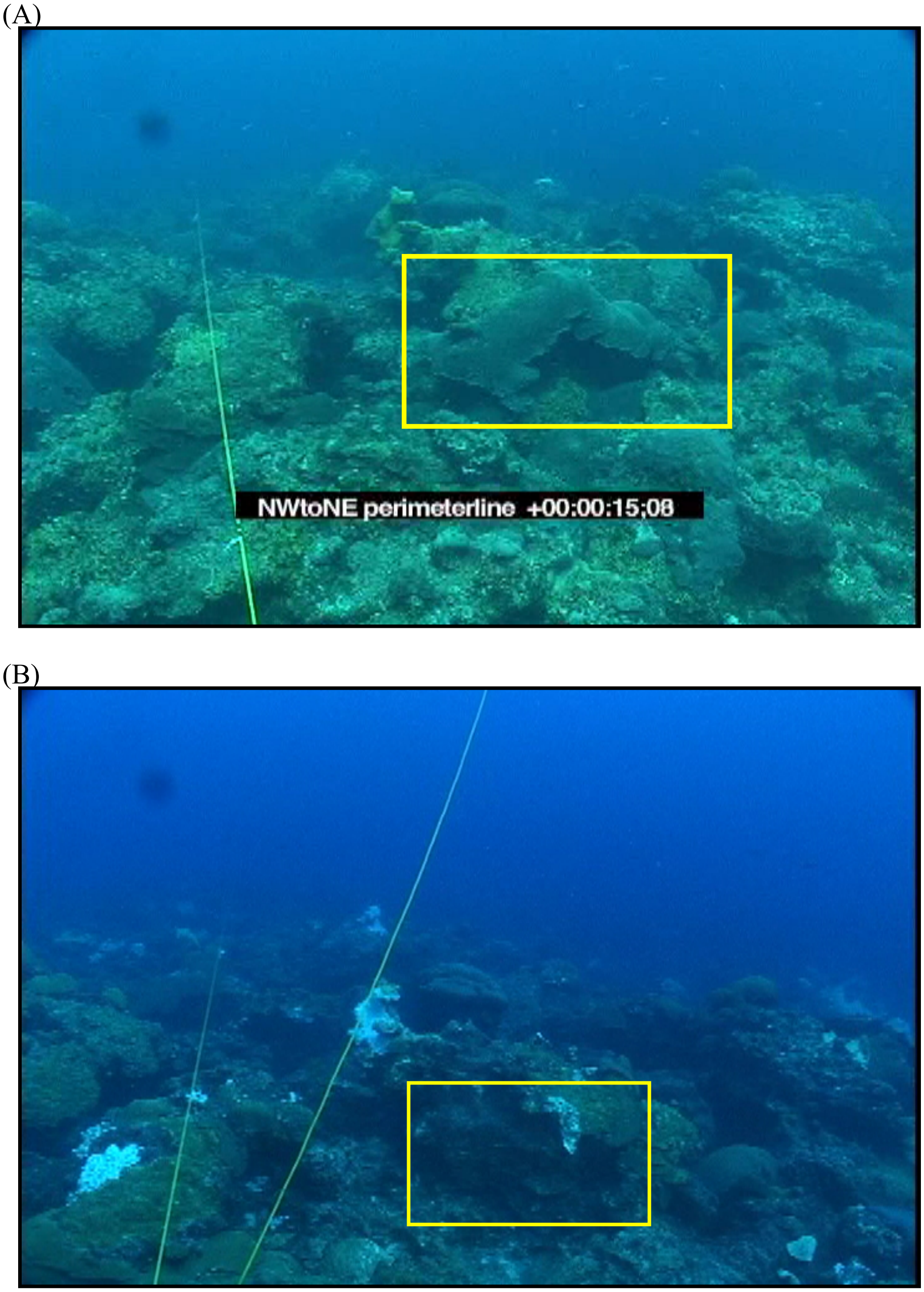


Figure 3.2.4. Photographs taken in June (A) and November (B) 2005 of a colony of *Diploria strigosa* that is missing from the center of photograph B. The yellow box highlights the approximate location of hurricane impact.

3.2.2 360° Panoramic Views

At the northwest corner during June 2005, there were very few incidences of bleaching and fish biting. In November 2005, several colonies of *Montastraea franksi* and *M. faveolata* were either partially or entirely bleached (Table 3.2.1). In both June and November, schools of Creole wrasse, Creole fish, and chromis appeared (Table 3.2.2).

At the northeast corner in June 2005, the presence of bleaching and fish biting was low and coral colonies appeared normal. In November 2005, colonies of *Montastraea franksi, M. faveolata* and *M. cavernosa* were bleached (Table 3.2.1). The fish assemblage consisted of schools of Creole fish and Creole wrasse in June, while in November the assemblage was dominated by Creole fish, Bluehead wrasse, and schools of chromis (Table 3.2.2).

At the southeast corner in June 2005, there were low levels of bleaching and fish biting. Fish populations consisted of Black durgon and Creole fish. In November 2005 there were several incidences of coral bleaching of *Diploria strigosa, Montastraea faveolata*, and *Millepora alcicornis* colonies (Table 3.2.1). Ocean triggerfish, Creole wrasses, Creole fish, and chromis were observed (Table 3.2.2).

3.3 Water Quality

The YSI datasondes and the HoboTemp thermistors recorded temperature, salinity, and dissolved oxygen during the passage of Hurricane Rita. However, no reliable pH, turbidity, or PAR data were collected. Upon retrieval of the East Bank YSI on 12 October 2005, it was found that the datasonde had undergone significant abrasion as evidenced by abundant scratches on the housing. The entire railroad wheel was covered with sediment, and only the angle-iron attachment arms remained exposed. PAR readings stopped at 1330 hours on 23 September 2005. Dissolved oxygen (DO) readings were also affected during the hurricane, as the DO membrane was torn and the DO electrolyte cavity was filled with sediment.

Temperature. With the passage of Hurricane Rita, there was a sudden drop in temperature on the reef caps of the East and West Flower Garden Banks (Figure 3.3.1). The temperature dropped from 29.6 °C at 0033 hours to 27.4 °C at 1933 hours on 23 September 2005. Temperature rose gradually after the passage of the hurricane. By 0733 hours on 9/24/05, the temperature on the reef cap had reached 28.4 °C.

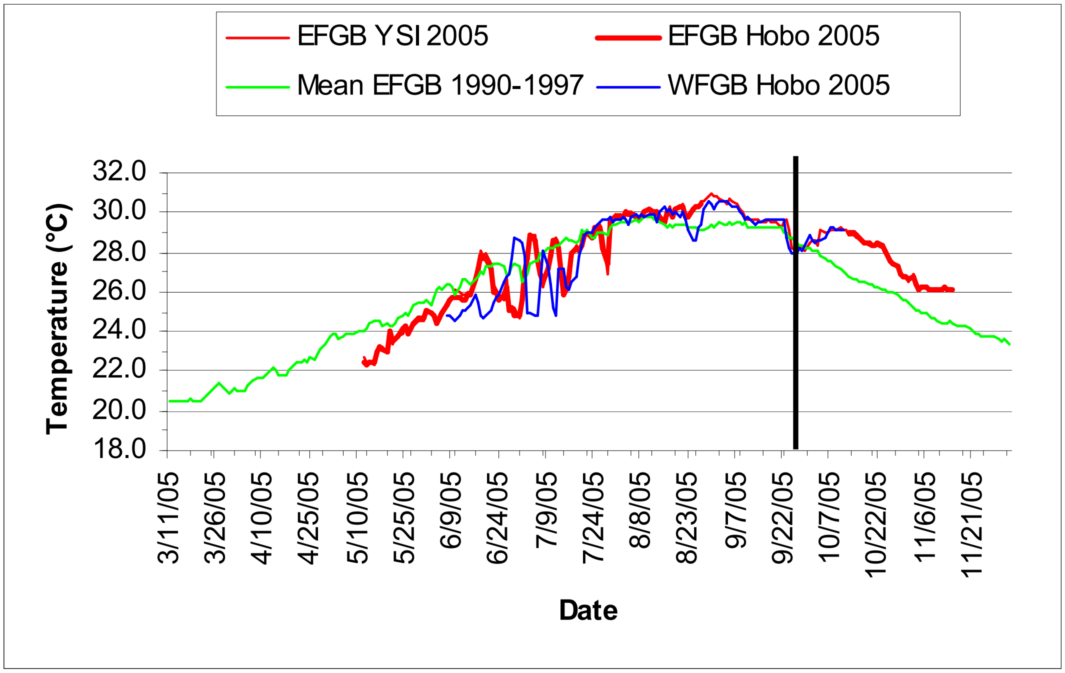


Figure 3.3.1. Water temperature at the East Bank in 2005 and mean temperature at the Flower Garden Banks from 1990 to 1997. A vertical line drawn through the temperature profiles shows the timing of the passage of Hurricane Rita near the Flower Garden Banks (23 September 2005). The 1990-1997 temperature data are from Gittings et al. (1992).

Salinity. No YSI water quality data are reported at the West Bank after 25 August 2005. During the passage of Hurricane Rita on 23 September 2005, mean daily salinity at the East Bank was 35.7 ppt.

Dissolved Oxygen. When Hurricane Rita passed over the Flower Garden Banks, the last measurements that were captured by the DO probe on 23 September 2005 averaged 4.7 mg/l. However, the 23 September data are questionable considering the damage the DO sensor incurred during the passage of the storm.

4.0 DISCUSSION

4.1 Hurricane and Thermal Anomaly Effects on the Benthic Community

Hurricane Rita. Hurricane Rita affected corals at the East Bank in a number of ways. Approximately 1.5% of coral colonies photographed at the East Bank were missing from repetitive quadrat stations. *Diploria strigosa*, *Porites astreoides*, and *Montastraea* sp. comprised the majority of missing coral colonies, with sizes ranging from 0.95 to 80.61 cm^2. Approximately 0.5% of coral colonies photographed at the deep stations were missing. These two colonies (*Diploria strigosa* and *Montastraea cavernosa*) measured 0.24 m^2, collectively. Coral cover measured from the repetitive quadrats, was not greatly affected by the loss of these corals.

The field of *Madracis mirabilis*, which occurs at a similar depth to the deep stations, suffered severe breakage and damage during Hurricane Rita. Corals within the deep repetitive quadrats are mainly plating morphologies and, therefore, may not be as susceptible to breakage as more fragile, branching morphologies, such as *M. mirabilis* (but see Aronson et al. 1994).

Bleaching Event. Coral reefs at locations throughout the region experienced low to high levels of bleaching in 2005, including Trinidad and Tobago, the British Virgin Islands, Florida, and the Flower Garden Banks (Table 4.1.1). Sea temperatures at the East Bank were elevated above 30 °C, the HotSpot bleaching threshold for the Flower Garden Banks, for 38 days from 30 July to 8 September 2005 (Figure 4.1.1). Although bleaching events are a natural occurrence, the increased frequency and severity of bleaching events is of concern because the likelihood of bleaching-associated mortality increases with exposure (Hoegh-Guldberg 1999). Additionally, higher temperatures have been linked to increased virulence of marine pathogens implicated in coral diseases (Harvell et al. 2002).

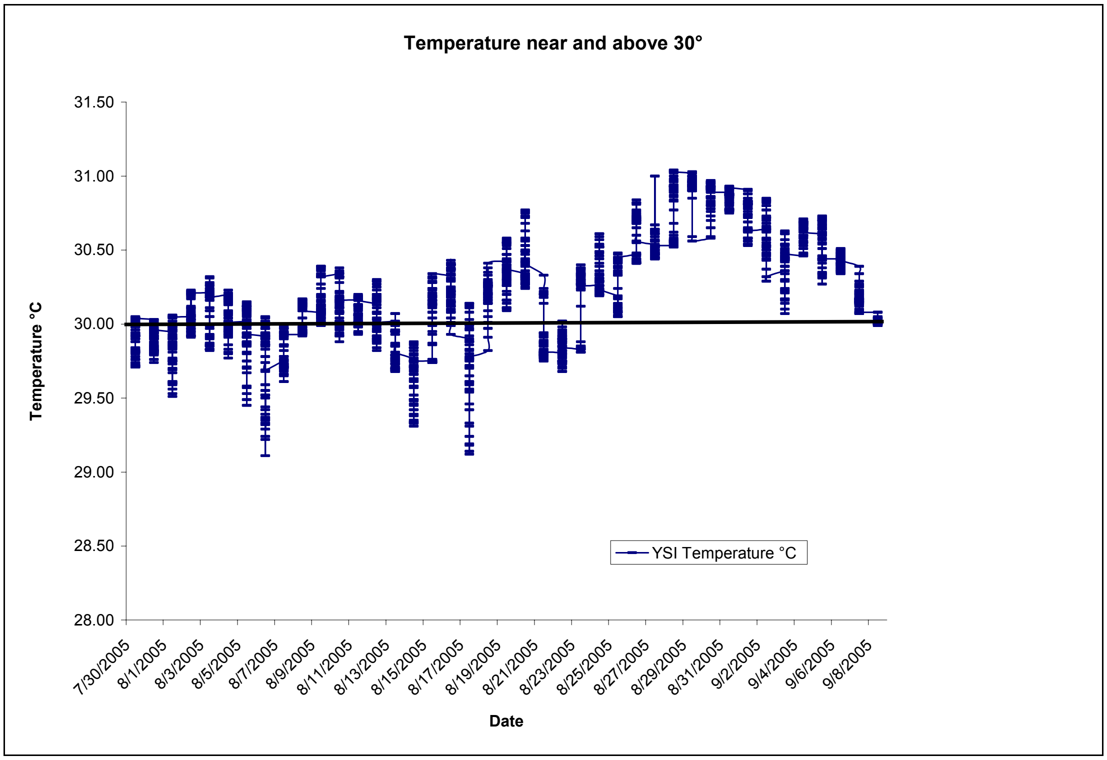


Figure 4.1.1. Temperature near, at, or above 30 °C from 30 July to 8 September 2005, as recorded by the YSI datasonde. Water quality data was gathered every 30 min to every 1.5 hours depending on battery life.

Table 4.1.1.

Bleaching of coral reefs throughout the western Atlantic during the fall of 2005. Compiled from ReefBase, NOAA Coral-list; available on NOAA website.

Location	Severity	Percent Affected
Bahamas	Low to High	75
Belize	Medium	20-80
British Virgin Islands	High	50-90
Colombia	Low	1-20
Cuba	Low to High	8-75
Flower Garden Banks	Medium	48
Jamaica	Medium	20-80
Mexico	Medium	40
Panama	Medium	70
Trinidad and Tobago	High	70-90

Unprecedented coral bleaching was documented at the East Bank in November 2005. Repetitive quadrats photographed at that time showed ~10% bleaching of the coral population, a marked increase from June 2005 (Figure 4.1.2). Video perimeter results showed similar bleaching rates and similar differences in relation to video perimeter data taken in June 2005 (Figure 4.1.3).

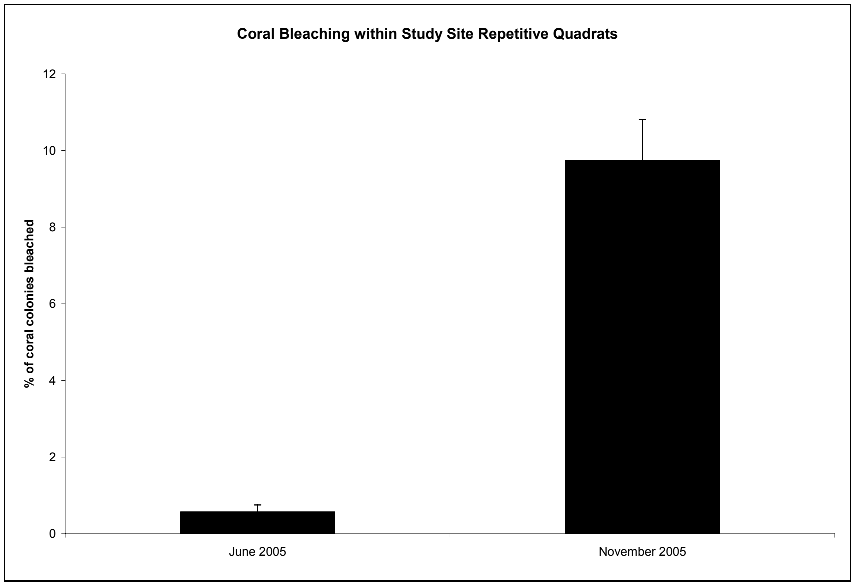


Figure 4.1.2. Percent of coral colonies bleached (+ SE) in the East Bank study site repetitive quadrats, June 2005 and November 2005.

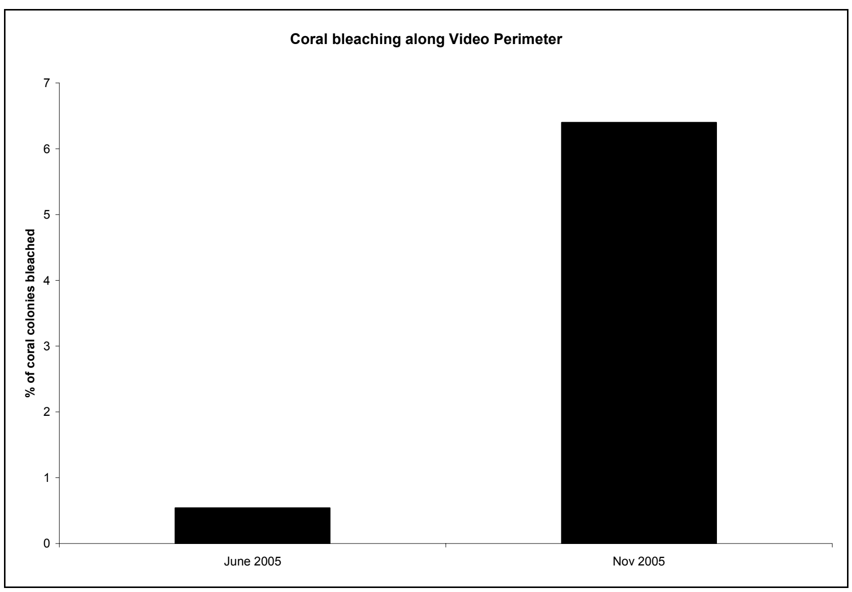


Figure 4.1.3. Percent of coral colonies bleached along the East Bank study site perimeter in June 2005 and in November 2005 after Hurricane Rita. Data are from perimeter videography.

Despite the loss of corals, coral cover remained high on the reef cap (61%) and at the deep stations (74.5%). A comparison of shallow study site quadrats with deep station quadrats showed different bleaching patterns related to depth (Figure 4.1.4). Shallow quadrats had higher levels of bleaching and experienced a loss of 1.5% of coral colonies. The deep quadrats had lower levels of coral bleaching and approximately 0.5% of coral colonies were missing.

Planimetry measurements showed that *Montastraea annularis* complex expanded their margins by 5.74% (± 3.25 SE) at deep station between June 2005 and November 2005. This is a huge increase in a very short period of time and likely does not represent a true increase in lateral growth. Considering the high error associated with these data more photographs may need to be taken in order to get a more accurate representation of the actual marginal growth or loss in these repetitive quadrat images.

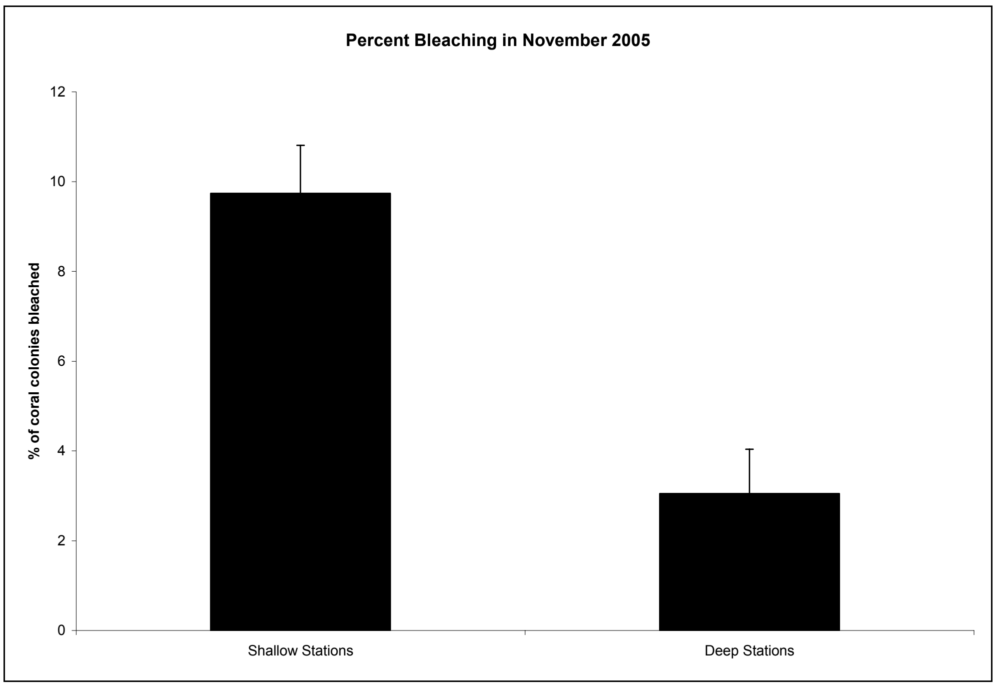


Figure 4.1.4. Percent of coral colonies bleached (+ SE) at the East Bank shallow stations and the East Bank deep stations in November 2005.

Transect data collected by FGBNMS staff in October 2005 showed that 48% of colonies monitored on the reef cap were partially or entirely bleached (Hickerson, personal communication, 9 November 2005). FGBNMS methodology involved counting and scoring every coral colony within four, 15 m belt transects (radiating from the mooring buoy) as totally bleached, partially bleached, or unbleached. Although some recovery may have taken place between October and November, it is unlikely that bleaching declined in one month from 48% to the 10% level we recorded. The discrepancy is mostly likely due to differences in sampling methods.

The 2005 bleaching event was the most severe ever documented at the Flower Garden Banks. In 1990, 4.8% bleaching was reported at the East Bank in association with high seawater temperatures (Hagman and Gittings 1992). Minor seasonal bleaching events were reported in 1992, 1994, 1995, and 1998 (Gittings et al. 1992; Continental Shelf Associates Inc. 1996; Dokken et al. 1999; Dokken et al. 2001). These episodes were followed by recovery.

4.2 Water Quality

Storm Intensity. The tracking of Hurricane Rita shows that it was a category 3 storm when it passed close to the Flower Garden Banks on 23 September 2005. Mean daily significant wave height at NOAA data buoy 42019 was 4.52 m during the hurricane (Figure 4.2.1.). Depth, measured by the YSI instrument at the East Bank, rose from 23 to 25 m from 0300 hours on 23 September to 0400 hours on 24 September. The highest point of the storm took place at 2000 hours on September 23 when maximum wave height reached 5.9 m at buoy 42019 (Figure 4.2.2). The intensity of Hurricane Rita at the Flower Garden Banks is clear from its physical effects, including the large amounts of sediment removed from sand flats, the dislodgment of corals, and the indentations on corals caused by waterborne reef material.

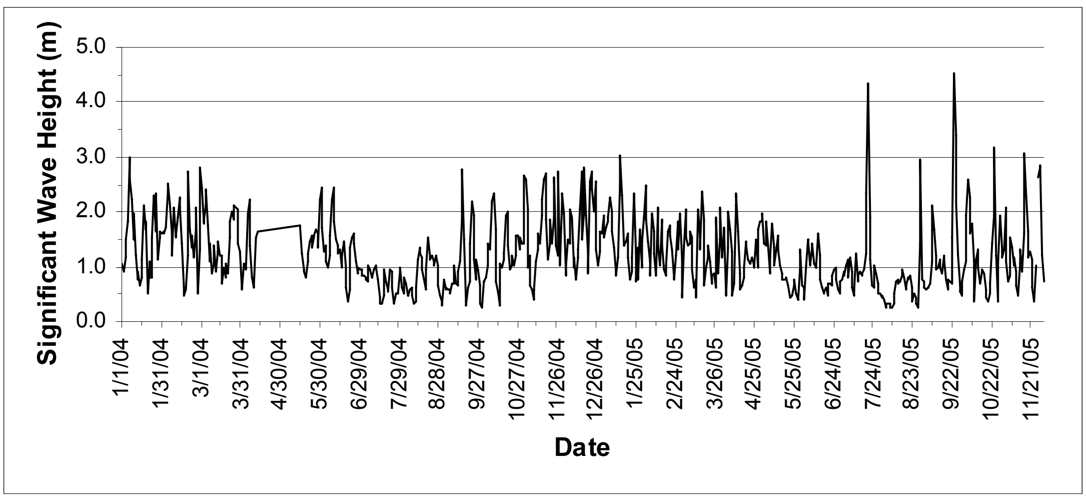


Figure 4.2.1. Significant wave height in 2004 and 2005 at NOAA data buoy 42019, located 172 km west of the East Bank (27°54.783’ N, 95°21.600’ W; (National Data Buoy Center 2005)). Significant wave height is calculated as the average of the highest one-third of all of the wave heights during the 20-minute sampling period.

Figure 4.2.2. Maximum wave height measured at buoy 42019 during the passage of Hurricane Rita.

Current velocity and direction, measured by current meters placed near the sea surface on Texas Automated Buoy System (TABS) "Buoy V" (27° 53.796'N, 93° 35.838'W), located near the East Bank, and "Buoy N" (27° 53.418'N, 94° 02.202'W), located near the West Bank, provide another way to estimate the power of the storm. Buoy N recorded data up until 0830 hours on 23 September; current velocity at that time was 58.09 cm/sec. Current velocity was 57.59 cm/sec at 1100 hours at "Buoy V" (Bender et al., personal communication, 1 December 2005). Summaries of current velocity and direction are depicted as stick plots. These plots show that at the East Bank, water was moving in a southeasterly and southerly direction at speeds ranging from 19.7 to 57.9 cm/sec from 23 to 24 September (Figure 4.2.3). The stick plot for the West Bank shows that from 22 to 23 September, current speed ranged from 10.2 cm/sec to 58.09 cm/sec and water was moving in a southeasterly direction (Figure 4.2.4). The current direction recorded at the TABS buoys corroborates our observations at the East Bank of permanent stainless-steel posts on the reef cap being bent in a southerly direction.

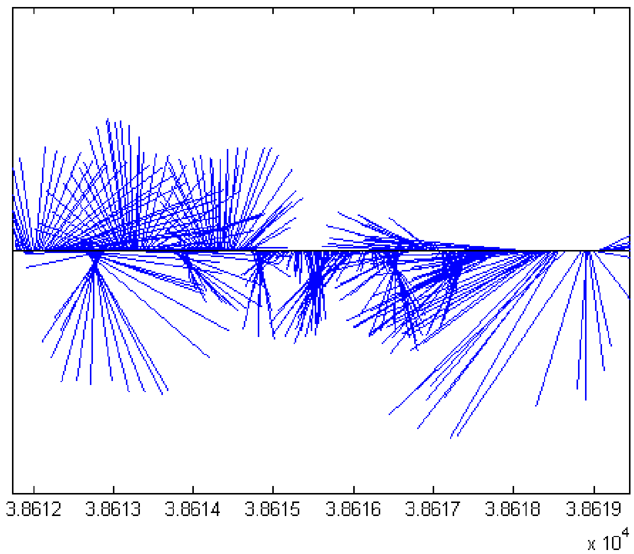


Figure 4.2.3. Stick plot of currents (speed (cm/sec)) and direction (north is top)) at Texas Automated Buoy System “Buoy V” (27°53.796' N, 93°35.838' W), located near the East Bank, from 9/16/05 to 9/24/05. Data courtesy of L.C. Bender III, L. L. Lee III, and N.L. Guinasso Jr., Geochemical and Environmental Research Group, Texas A&M University.

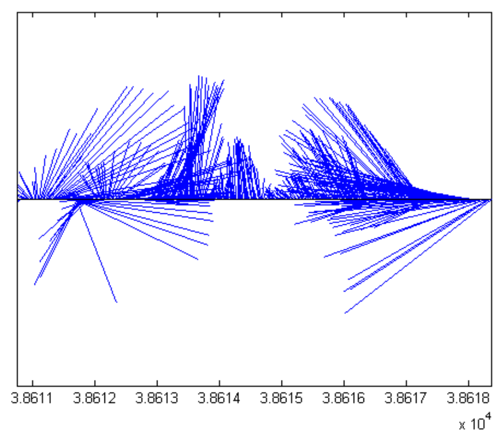


Figure 4.2.4. Stick plot of currents (speed (cm/sec)) and direction (north is top)) at Texas Automated Buoy System “Buoy N” (27°53.418' N, 94°02.202' W), located near the West Bank, from 9/15/05 to 9/23/05. Data courtesy of L.C. Bender III, L. L. Lee III, and N.L. Guinasso Jr., Geochemical and Environmental Research Group, Texas A&M University.

Temperature. In 2005, corals at the Flower Garden Banks were exposed to a prolonged period of thermal stress that was interrupted temporarily by the passage of Hurricane Rita (Figure 3.3.1). Thermal conditions on the reef cap were unquestionably more severe in 2005 than the average temperature at the Flower Garden Banks, including during 1990 when extensive bleaching occurred. The heating of the upper water column in 2005 probably caused more severe stress to sessile organisms on the reef cap than they experienced in 1990. Water temperatures at the reef cap cooled by approximately 1.5 °C (from 29.5 °C to 28 °C) after the passage of

Hurricane Rita, from 25 to 30 September 2005. This temporary cooling of the reef cap was likely the result of the mixing of cold deep water with the warm superficial water (the upper 50 m). At the foot of the Flower Garden Banks (~100 m), seawater temperatures average 19°C. Further down in the water column at 130 m, average water temperature is about 15°C (Nowlin et al. 1998).

Sediment Resuspension. The mixing of superficial water with the deeper water surrounding the Flower Garden Banks may also have temporarily exposed the reef cap to the nepheloid layer. Since the banks are large topographic prominences rising from a seafloor depth of 120 m to within 18 m of the sea surface, they obstruct and modify water transport passing through an area of the shelf edge that is otherwise relatively flat (McGrail 1985). However, despite the fact that such obstructions to water movement cause flow divergences and the deflection of water, the near-bottom water surrounding the base of the Flower Garden Banks typically does not flow over the banks (McGrail 1985; Lugo-Fernandez 1998). This near-bottom water, or bottom boundary layer, is characteristically turbid and known as the "nepheloid layer" (McGrail 1985).

The turbidity of the nepheloid layer is caused by the resuspension of terrigenous sediments (muddy sands, sandy mud, and mud (Rezak 1985)) at the base of the Flower Garden Banks. This turbid layer is confined near the bottom because the general water flow over the Flower Garden Banks is horizontal, even when extreme current velocities occur (e.g., 90 cm/sec; McGrail 1985). The maximum observed thickness of the nepheloid layer is 20 m. Hence, fine sediments resuspended at the base of the Flower Garden Banks typically cannot be transported onto the Flower Garden Banks reef cap by the local circulation (McGrail 1985). Under exceptional hurricane conditions such as those experienced on September 23, it is conceivable that sudden and intense vertical mixing caused the temporary resuspension of fine sediments from the base of the Flower Garden Banks into the water flowing over the reef cap. Such vertical mixing was probably not confined to the immediate vicinity of the Flower Garden Banks and may have caused the resuspension of fine sediments well within the 4-Mile Zone surrounding the Flower Garden Banks, including areas containing drilling discharges shunted to the seafloor.

During Hurricane Rita coarse sediments on the reef cap were likely resuspended over the reef cap and into deeper water surrounding the banks, judging from the transport of sediments from the sand flats, the scouring of corals, and the collision impacts on corals. Sediments on and immediately surrounding the living reef cap form the "coral debris facies" at 20-50 m water depth (Rezak 1985). The coral debris facies originate from the living reef and are composed of coarse coral sand and gravel, with inclusions of molluscan and coralline algal debris. The coral debris facies occur on and around the living reef and include large coral sand flats. Under typical conditions, gravity causes the sand to be transported to an apron of sand and gravel surrounding the living reef. Currents disperse the coarse sand and gravel into large ripples (with wavelengths up to 50 m) that are perpendicular and not parallel to the isobaths. This indicates that water typically moves around and not over the living reef (Rezak 1985).

Potential Exposure to Nearshore Pollutants. Following Hurricane Rita four to six inches of rainfall was recorded along the Mississippi and Atchafalaya rivers on September 24 2005. Other areas along the coast of Louisiana experienced up to 12 inches of rainfall on September 24 (Figure 4.2.5). Satellite imagery of total suspended matter in the northwestern Gulf of Mexico showed that nearshore water associated with the high levels of precipitation was driven across the shelf and onto the shelf edge, including the area of the Flower Garden Banks (Figure 4.2.6). The discolored water seen reaching the Flower Garden Banks could have contained pollutants delivered directly into the northern Gulf of Mexico from industrial sites. Such pollutants include >0.14 km^3/yr of sewage effluent from municipalities, and routine discharges from petroleum refineries and petrochemical plants (Weber et al. 1992) and materials contained in 610 km^3/yr of discharge from the Mississippi and Atchafalaya Rivers (Dai and Trenberth 2002). Coastal and river-borne pollutants probably include inorganic nutrients, organic carbon, insecticides and herbicides, and pathogens. FGBNMS staff (Emma Hickerson and G.P. Schmahl) collected coral tissue, sediment, and water samples for contaminant analysis.

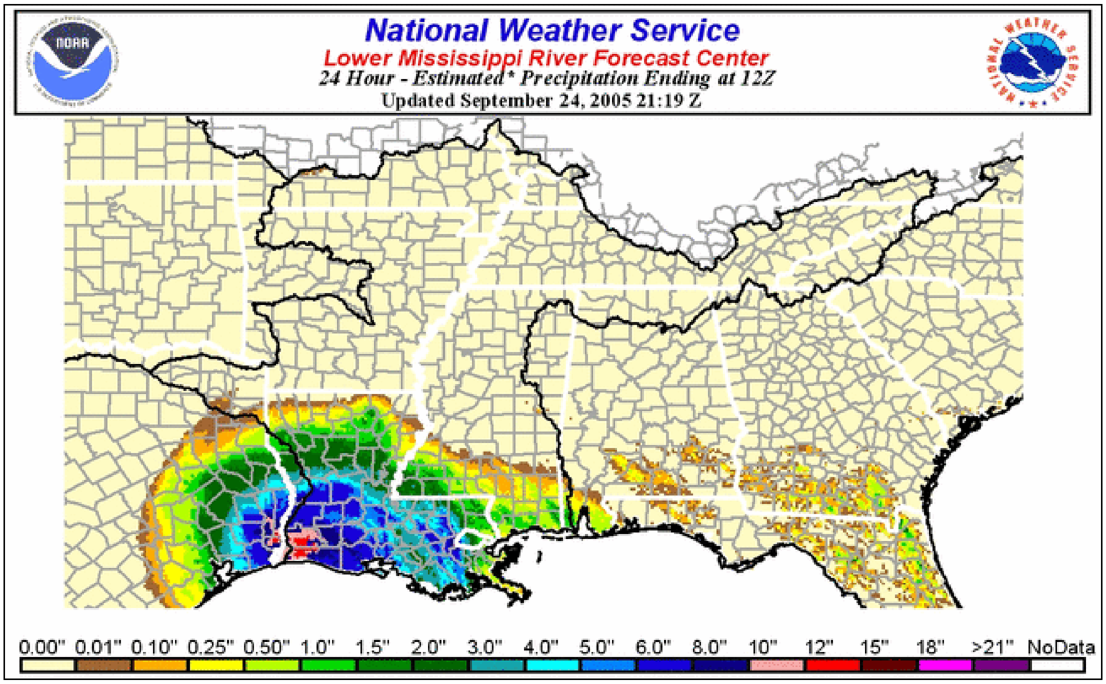


Figure 4.2.5. Rainfall data (inches) for the Gulf of Mexico region on September 24, 2005. Data provided by (NOAA National Weather Service 2005).

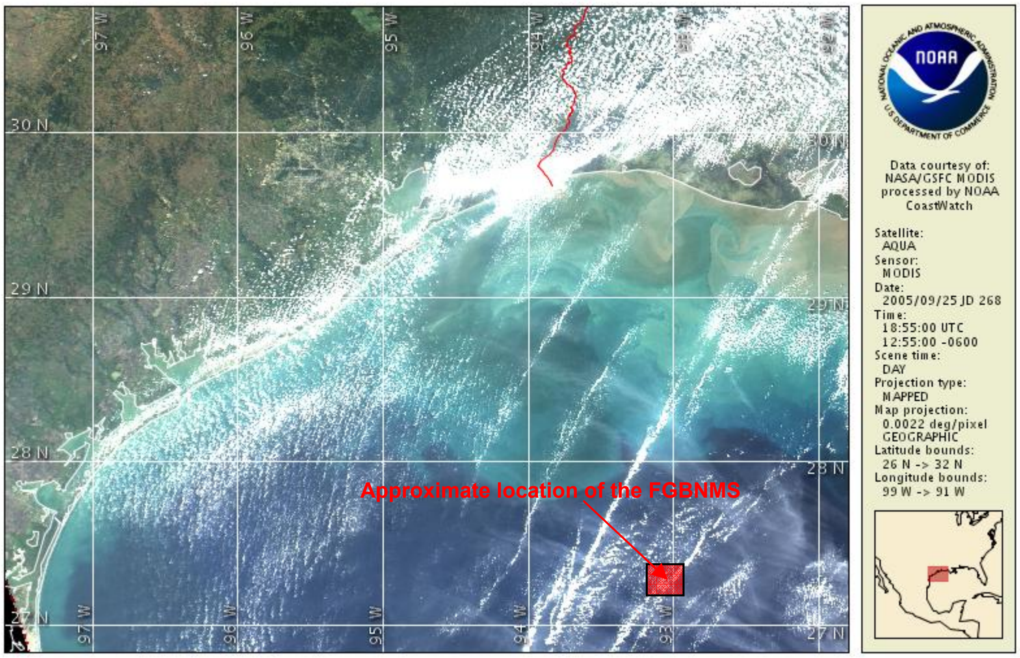


Figure 4.2.6. Dispersal of nearshore turbid water across the Louisiana-Texas (LATEX) shelf onto the shelf edge and the Flower Garden Banks on 25 September 2005. Image courtesy of NOAA CoastWatch.

5.0 CONCLUSIONS

The effects of Hurricane Rita which passed within 50 miles (83 km) of the Flower Garden Banks on September 23, 2005, were documented at the East Flower Garden Bank long-term monitoring site in November 2005, and in October 2005 by the Flower Garden Banks National Marine Sanctuary (FGBNMS). Documented damage associated with the storm included large, dislodged coral heads; corals gouged and damaged from waterborne projectiles; displaced sand and sediment, scoured coral heads; and an ongoing coral-bleaching event. No evidence of oil rigs, oil rig parts or rig discharges were documented at the East Bank.

Repetitive quadrat percent cover and planimetry data as well as perimeter video of the 100m by 100m permanent study site at the East Bank revealed higher than normal bleaching (10%) in November 2005. Bleaching had been observed in August 2005, before the passage of the hurricane and was associated with above normal sea surface temperatures recorded for the Flower Garden Banks. The repetitive quadrats revealed the removal of approximately $4m^2$ of coral from the 40 repetitive quadrats photographed. This area represented a 1.5% loss of all coral colonies photographed. Interestingly, missing corals consisted mainly of *Diploria strigosa*. Perimeter video along the north line revealed that several coral colonies were either shattered or missing. Most of the apparently missing or damaged colonies were *Diploria strigosa*. Interestingly, no missing, dislodged or broken corals were seen along the east perimeter line. Winds and waves moving in a southerly or southeasterly direction might explain this fact. Hurricane effects were different at depth. Deep station repetitive quadrats (32-40 m) showed a 0.5% decrease in coral colonies from nine repetitive quadrat stations photographed.

Water quality at the Flower Garden Banks was affected during the storm by suspension of sediments, which would have decreased available light and abraded corals. Water temperature decreased at the Banks as a result of the storm, which likely brought relief to bleaching corals. After the storm large volumes of freshwater run-off from the Mississippi and Atchafalaya Rivers as well as coastal Louisiana washed over the Banks and may have brought pollution out to the Flower Garden Banks, but these would not have been detected in November, two months after the storm.

Future work should include the detailed biological and geological characterization of banks closer to the path of Hurricane Rita (Sonnier, Geyer, McGrail Banks). In addition, no activity zones should be considered around unique banks other than the Flower Garden Banks given the prediction of increased hurricane activity in the upcoming decades.

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Appendix A

Appendix A

Percent Cover Data for Repetitive 8 m^2 Quadrats at East Flower Garden Bank

June 2005 and November 2005

Study Site Repetitive Quadrats				
	June 2005		November 2005	
	n = 41*		n = 40	
	Mean	Standard Error	Mean	Standard Error
Corals				
Colpophyllia natans	2.94	0.70	0.59	0.27
Unidentifiable coral	1.99	0.38	2.06	0.33
Diploria strigosa	8.88	1.49	9.02	1.55
Madracis decactis	0.33	0.16	0.40	0.15
Madracis mirabilis	0.11	0.11	0.00	0.00
Millepora alcicornis	1.47	0.28	0.68	0.16
Montastraea sp. complex	40.51	2.92	40.34	2.91
Montastraea cavernosa	3.60	0.87	3.85	0.88
Mussa angulosa	0.09	0.06	0.02	0.01
Porites astreoides	2.69	0.51	4.06	0.51
Siderastrea siderea	0.11	0.07	0.09	0.08
Stephanocoenia intersepta	0.08	0.04	0.24	0.11
Total Coral	**62.78**	**2.60**	**61.34**	**2.75**
Sponges				
Agelas clathrodes	0.00	0.00	0.17	0.08
Pseudoceratina crassa	0.01	0.01	0.07	0.03
Unidentifiable sponge	0.11	0.06	0.19	0.06
Xestospongia sp.	0.00	0.00	0.06	0.04
Total Sponge	**0.12**	**0.06**	**0.49**	**0.16**
Macroalgae				
Dictyota sp.	0.00	0.00	0.42	0.19
Lobophora sp.	23.72	2.12	0.00	0.00
Turf (greater than 3mm)	0.06	0.05	11.22	0.82
Unidentifiable macroalgae	0.00	0.00	1.40	0.35
Total Macroalgae	**23.78**	**2.13**	**13.04**	**1.02**
CTB				
Crustose coralline algae	1.59	0.42	3.29	0.57
CTB (including crustose coralline, fine turf, bare rock)	8.79	1.04	20.53	1.65
Total CTB	**10.39**	**1.16**	**23.81**	**1.73**
Other Live				
Ascidian	0.02	0.02	0.00	0.00
Other	0.10	0.03	0.12	0.05
Serpulidae	0.00	0.00	0.19	0.05
Rubble/Sand				
Rubble	0.04	0.04	0.00	0.00
Sand	0.42	0.26	0.79	0.44

Appendix A
Percent Cover Data for Repetitive 8 m^2 Quadrats at East Flower Garden Bank
June 2005 and November 2005

Study Site Repetitive Quadrats				
	June 2005		November 2005	
	n = 41*		n = 40	
	Mean	Standard Error	Mean	Standard Error
UNKNOWNS				
Unknown	2.37	0.40	0.21	0.06
TOTAL	**100.00**		**100.00**	

*41 study site repetitive quadrat stations analyzed (includes 40 recently established stations and old station number 185)

Appendix A
Percent Cover Data for Repetitive 8 m^2 Quadrats at East Flower Garden Bank
June 2005 and November 2005

Deep Station Repetitive Quadrats				
	June 2005		November 2005	
	n = 9		n = 9	
	Mean	Standard Error	Mean	Standard Error
Corals				
Colpophyllia natans	5.01	1.92	8.86	3.16
Unidentifiable coral	0.93	0.53	1.24	1.17
Diploria strigosa	4.93	2.03	2.91	1.15
Madracis decactis	0.00	0.00	0.08	0.08
Madracis mirabilis	0.16	0.05	0.16	0.16
Millepora alcicornis	1.41	0.76	0.68	0.46
Montastraea sp. complex	50.75	3.61	42.02	4.81
Montastraea cavernosa	9.57	1.82	15.84	3.02
Mussa angulosa	3.88	0.96	2.71	1.38
Porites astreoides	0.89	0.49	0.00	0.00
Total Coral	**77.51**	**3.77**	**74.50**	**4.44**
Sponges				
Unidentifiable Sponge	0.00	0.00	0.28	0.29
Total Sponge	**0.00**	**0.00**	**0.28**	**0.29**
Algae				
Lobophora	10.34	1.86	0.00	0.00
Turf (greater than 3mm)	0.48	0.17	8.98	4.18
Unidentifiable macroalgae	0.00	0.00	0.00	0.00
Total Macroalgae	**10.82**	**1.89**	**8.98**	**4.18**
CTB				
Crustose coralline algae	0.89	0.53	4.51	2.23
CTB (including crustose coralline, fine turf, bare rock)	7.95	1.39	7.74	2.50
Total CTB	**8.84**	**1.85**	**12.25**	**2.91**
Other Live				
Ascidian	0.04	0.04	0.00	0.00
Other	0.04	0.04	0.04	0.05
DEAD CORAL WITH ALGAE				
Dead coral with algae	0.00	0.00	0.36	0.23
Other				
Rubble	0.00	0.00	2.11	2.22
Sand	0.97	0.70	0.00	0.00
UNKNOWNS				
Unknown	1.78	0.86	1.48	1.46
TOTAL	**100.00**		**100.00**	

Appendix B

Appendix B

Repetitive 8 m^2 Quadrat Proportional Change for Selected Coral Heads at East Flower Garden Bank

June 2005 and November 2005

Study Site Repetitive Quadrats										
RQS # *	**Coral Head #**	**Species**	**Area of coral head in June 2005 (cm^2)**	**Area of coral head in Nov 2005 (cm^2)**	**Change in Area (cm^2)**	**% Change in Area**	**% change in coral colony area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change**
1	1	*Montastraea* sp.	17.73	17.28	-0.44	-0.05	-2.51	-5.22	-0.55	-0.03
	2	*Diploria strigosa*	4.83	4.94	0.11	0.01	2.24			0.02
	3	*Montastraea* sp.	6.71	4.89	-1.82	-0.19	-27.17			-0.27
	4	*Montastraea* sp.	9.67	7.39	-2.28	-0.24	-23.62			-0.24
	5	*Montastraea* sp.	6.47	5.69	-0.78	-0.08	-12.08			-0.12
2	1	*Montastraea* sp.	35.58	37.65	2.08	0.22	5.84	1.20	0.13	0.06
	2	*Montastraea* sp.	19.30	21.08	1.79	0.19	9.25			0.09
	3	*Montastraea* sp.	10.62	11.60	0.98	0.10	9.22			0.09
	4	*Montastraea* sp.	12.99	9.35	-3.64	-0.38	-28.02			-0.28
2b	1	*Diploria strigosa*	86.86	67.62	-19.24	-2.01	-22.15	-35.70	-3.74	-0.22
	2	*Montastraea* sp.	27.46	17.75	-9.71	-1.02	-35.37			-0.35
	3	*Diploria strigosa*	11.36	11.83	0.47	0.05	4.18			0.04
	4	*Montastraea* sp.	44.88	37.66	-7.22	-0.76	-16.09			-0.16
3	1	*Diploria strigosa*	14.22	16.28	2.05	0.21	14.43	-19.26	-2.02	0.14
	2	*Montastraea* sp.	46.66	59.23	12.57	1.32	26.94			0.27
	3	*Diploria strigosa*	7.74	10.49	2.75	0.29	35.60			0.36
	4	*Diploria strigosa*	32.43	0.00	-32.43	-3.40	-100.00			-1.00
	5	*Montastraea* sp.	33.67	29.47	-4.21	-0.44	-12.49			-0.12
4	1	*Montastraea* sp.	15.88	15.02	-0.86	-0.09	-5.44	-46.10	-4.83	-0.05
	2	*Montastraea* sp.	24.71	9.27	-15.44	-1.62	-62.48			-0.62
	3	*Diploria strigosa*	16.00	0.00	-16.00	-1.68	-100.00			-1.00
	4	*Montastraea* sp.	17.86	8.18	-9.67	-1.01	-54.18			-0.54
	5	*Montastraea* sp.	12.20	8.08	-4.12	-0.43	-33.78			-0.34
4b	1	*Montastraea* sp.	29.65	30.97	1.32	0.14	4.46	25.54	2.67	0.04
	2	*Montastraea* sp.	18.85	20.21	1.36	0.14	7.20			0.07
	3	*Montastraea* sp.	53.09	57.01	3.92	0.41	7.38			0.07
	4	*Diploria strigosa*	11.62	13.52	1.91	0.20	16.40			0.16
	5	*Montastraea* sp.	236.46	253.49	17.04	1.78	7.21			0.07
5	1	*Montastraea* sp.	19.55	24.35	4.81	0.50	24.58	12.45	1.30	0.25
	2	*Montastraea* sp.	29.20	36.77	7.57	0.79	25.94			0.26
	3	*Montastraea* sp.	11.95	12.90	0.95	0.10	7.93			0.08
	4	*Montastraea* sp.	47.37	46.25	-1.11	-0.12	-2.35			-0.02
	5	*Montastraea* sp.	5.95	6.19	0.24	0.03	4.06			0.04
7	1	*Montastraea* sp.	27.32	48.58	21.26	2.23	77.83	10.44	1.09	0.78
	2	*Montastraea* sp.	7.03	0.00	-7.03	-0.74	-100.00			-1.00
	3	*Porites astreoides*	0.95	0.00	-0.95	-0.10	-100.00			-1.00
	4	*Diploria strigosa*	3.16	0.00	-3.16	-0.33	-100.00			-1.00
	5	*Diploria strigosa*	4.32	4.63	0.31	0.03	7.17			0.07
9	1	*Montastraea* sp.	21.76	49.25	27.49	0.29	126.32	34.21	0.36	1.26
	2	*Montastraea* sp.	27.54	30.70	3.15	0.03	11.45			0.11
	3	*Montastraea* sp.	67.66	76.42	8.77	0.09	12.96			0.13
	4	*Montastraea* sp.	34.14	41.86	7.73	0.08	22.63			0.23
	5	*Montastraea* sp.	137.73	124.80	-12.93	-0.14	-9.39			-0.09
10	1	*Diploria strigosa*	17.67	13.12	-4.55	-0.48	-25.76	-32.08	-3.36	-0.26
	2	*Diploria strigosa*	11.21	16.93	5.73	0.60	51.13			0.51
	3	*Montastraea* sp.	110.87	79.94	-30.93	-3.24	-27.90			-0.28
	4	*Diploria strigosa*	19.52	17.19	-2.33	-0.24	-11.95			-0.12
11	1	*Diploria strigosa*	11.55	7.86	-3.69	-0.39	-31.98	-26.72	-2.80	-0.32
	2	*Montastraea* sp.	107.26	99.41	-7.85	-0.82	-7.32			-0.07
	3	*Montastraea* sp.	52.30	50.28	-2.02	-0.21	-3.86			-0.04
	4	*Montastraea* sp.	45.93	32.78	-13.16	-1.38	-28.64			-0.29
12	1	*Porites astreoides*	4.36	4.53	0.17	0.02	4.00	0.04	0.00	0.04
	2	*Porites astreoides*	3.57	3.91	0.34	0.04	9.59			0.10
	3	*Diploria strigosa*	5.27	6.07	0.80	0.08	15.14			0.15
	4	*Diploria strigosa*	3.41	4.12	0.71	0.07	20.98			0.21
	5	*Diploria strigosa*	15.87	13.88	-1.99	-0.21	-12.55			-0.13
12b	1	*Diploria strigosa*	46.10	47.49	1.39	0.15	3.02	-27.49	-2.88	0.03
	2	*Montastraea* sp.	2.75	3.45	0.70	0.07	25.40			0.25
	3	*Diploria strigosa*	84.50	82.50	-2.00	-0.21	-2.37			-0.02
	4	*Montastraea cavernosa*	28.74	1.16	-27.58	-2.89	-95.97			-0.96

* The RQS # is an identifier used during planimetry analysis
(not necessarily corresponding to the station number).

Appendix B

Repetitive 8 m^2 Quadrat Proportional Change for Selected Coral Heads at East Flower Garden Bank

June 2005 and November 2005

Study Site Repetitive Quadrats										
RQS # *	Coral Head #	Species	Area of coral head in June 2005 (cm^2)	Area of coral head in Nov 2005 (cm^2)	Change in Area (cm^2)	% Change in Area	% change in coral colony area	Total change in Area within Quadrat (cm^2)	Total % change in Area within Quadrat	Proportional Change
14	1	*Montastraea* sp.	13.40	20.64	7.24	0.76	54.06	-13.05	-1.37	0.54
	2	*Montastraea* sp.	24.30	18.72	-5.57	-0.58	-22.94			-0.23
	3	*Diploria strigosa*	2.37	2.30	-0.07	-0.01	-2.75			-0.03
	4	*Montastraea* sp.	22.62	25.11	2.49	0.26	10.99			0.11
	5	*Montastraea cavernosa*	17.73	0.59	-17.14	-1.79	-96.68			-0.97
14b	1	*Diploria strigosa*	8.58	9.74	1.16	0.12	13.57	-1.34	-0.14	0.14
	2	*Montastraea* sp.	1.81	2.83	-5.75	-0.60	-316.77			-3.17
	3	*Montastraea* sp.	14.02	19.59	17.77	1.86	126.82			1.27
	4	*Diploria strigosa*	8.63	6.72	-7.30	-0.76	-84.57			-0.85
	5	*Diploria strigosa*	7.23	0.00	-7.23	-0.76	-100.00			-1.00
15	1	*Montastraea* sp.	22.75	32.33	9.58	1.00	42.08	6.72	0.70	0.42
	2	*Montastraea* sp.	12.35	11.08	-1.27	-0.13	-10.31			-0.10
	3	*Montastraea* sp.	19.61	18.00	-1.61	-0.17	-8.20			-0.08
	4	*Montastraea* sp.	5.83	5.86	0.03	0.00	0.52			0.01
17	1	*Montastraea* sp.	32.86	33.67	0.81	0.08	2.45	14.84	1.55	0.02
	2	*Diploria strigosa*	20.86	20.61	-0.25	-0.03	-1.18			-0.01
	3	*Diploria strigosa*	30.35	34.95	4.60	0.48	15.17			0.15
	4	*Diploria strigosa*	66.91	77.25	10.34	1.08	15.46			0.15
	5	*Montastraea* sp.	13.85	13.19	-0.67	-0.07	-4.80			-0.05
18	1	*Montastraea* sp.	69.60	59.14	-10.46	-1.10	-15.03	-8.31	-0.87	-0.15
	2	*Montastraea* sp.	185.00	192.76	7.76	0.81	4.19			0.04
	3	*Diploria strigosa*	14.85	14.83	-0.02	0.00	-0.13			0.00
	4	*Diploria strigosa*	20.88	18.18	-2.71	-0.28	-12.96			-0.13
	5	*Montastraea* sp.	67.54	64.66	-2.88	-0.30	-4.26			-0.04
18b	1	*Montastraea* sp.	4.51	5.01	0.49	0.05	10.92	0.18	0.02	0.11
	2	*Diploria strigosa*	1.07	1.28	0.21	0.02	19.42			0.19
	3	*Montastraea* sp.	5.13	4.65	-0.47	-0.05	-9.22			-0.09
	4	*Diploria strigosa*	5.46	5.41	-0.05	0.00	-0.84			-0.01
20	1	*Montastraea* sp.	89.40	85.19	-4.21	-0.44	-4.71	-71.41	-7.48	-0.05
	2	*Montastraea cavernosa*	43.21	0.07	-43.14	-4.52	-99.84			-1.00
	3	*Diploria strigosa*	22.50	23.91	1.41	0.15	6.29			0.06
	4	*Montastraea cavernosa*	25.52	0.05	-25.47	-2.67	-99.81			-1.00
20b	1	*Montastraea* sp.	2.75	2.67	0.20	0.02	7.25	-12.96	-1.36	0.07
	2	*Diploria strigosa*	2.99	3.36	0.03	0.00	1.04			0.01
	3	*Diploria strigosa*	4.42	3.80	-0.50	-0.05	-11.21			-0.11
	4	*Montastraea* sp.	8.33	9.59	0.20	0.02	2.45			0.02
	5	*Montastraea* sp.	16.57	0.00	-12.90	-1.35	-77.89			-0.78
21	1	*Montastraea* sp.	22.38	17.82	-4.57	-0.48	-20.40	-49.71	-5.20	-0.20
	2	*Montastraea* sp.	15.50	6.09	-9.41	-0.99	-60.71			-0.61
	3	*Montastraea* sp.	22.26	23.81	1.55	0.16	6.98			0.07
	4	*Montastraea cavernosa*	52.87	0.36	-52.51	-5.50	-99.31			-0.99
	5	*Montastraea* sp.	53.20	68.43	15.23	1.59	28.63			0.29
21b	1	*Montastraea* sp.	83.30	44.85	-38.45	-4.03	-46.16	-31.61	-3.31	-0.46
	2	*Montastraea cavernosa*	13.55	12.17	-1.39	-0.15	-10.25			-0.10
	3	*Diploria strigosa*	46.30	54.58	8.29	0.87	17.90			0.18
	4	*Diploria strigosa*	46.36	49.96	3.61	0.38	7.78			0.08
	5	*Diploria strigosa*	21.78	18.12	-3.66	-0.38	-16.81			-0.17
22	1	*Montastraea* sp.	10.62	20.51	9.89	1.04	93.20	-26.26	-2.75	0.93
	2	*Diploria strigosa*	22.98	21.50	-1.47	-0.15	-6.42			-0.06
	3	*Colpophyllia natans*	11.47	0.06	-11.41	-1.20	-99.47			-0.99
	4	*Diploria strigosa*	34.89	31.59	-3.30	-0.35	-9.45			-0.09
	5	*Montastraea* sp.	53.94	33.97	-19.97	-2.09	-37.02			-0.37
23	1	*Montastraea* sp.	28.48	22.35	-6.13	-0.64	-21.53	-27.11	-2.84	-0.22
	2	*Montastraea* sp.	64.89	48.27	-16.62	-1.74	-25.61			-0.26
	3	*Montastraea* sp.	21.68	18.61	-3.08	-0.32	-14.18			-0.14
	4	*Diploria strigosa*	7.28	8.67	1.39	0.15	19.10			0.19
	5	*Diploria strigosa*	20.11	17.44	-2.68	-0.28	-13.31			-0.13
24	1	*Montastraea* sp.	23.02	16.58	-6.44	-0.67	-27.97	-7.39	-0.77	-0.28
	2	*Montastraea cavernosa*	20.62	0.01	-20.60	-2.16	-99.93			-1.00
	3	*Montastraea* sp.	48.33	43.81	-4.52	-0.47	-9.34			-0.09
	4	*Diploria strigosa*	9.37	11.01	1.64	0.17	17.53			0.18
	5	*Montastraea* sp.	62.26	84.79	22.53	2.36	36.19			0.36

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Appendix B

Repetitive 8 m^2 Quadrat Proportional Change for Selected Coral Heads at East Flower Garden Bank

June 2005 and November 2005

Study Site Repetitive Quadrats										
RQS # *	**Coral Head #**	**Species**	**Area of coral head in June 2005 (cm^2)**	**Area of coral head in Nov 2005 (cm^2)**	**Change in Area (cm^2)**	**% Change in Area**	**% change in coral colony area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change**
25	1	*Montastraea* sp.	1.49	1.60	0.11	0.01	7.14	2.79	0.29	0.07
	2	*Montastraea* sp.	7.82	9.66	1.84	0.19	23.49			0.23
	3	*Montastraea* sp.	1.91	2.40	0.49	0.05	25.64			0.26
	4	*Montastraea* sp.	3.69	4.05	0.36	0.04	9.78			0.10
26	1	*Diploria strigosa*	8.83	10.48	1.65	0.17	18.71	-27.29	-2.86	0.19
	2	*Diploria strigosa*	19.70	21.73	2.03	0.21	10.31			0.10
	3	*Diploria strigosa*	7.94	7.35	-0.59	-0.06	-7.49			-0.07
	4	*Diploria strigosa*	20.70	0.00	-20.70	-2.17	-100.00			-1.00
	5	*Diploria strigosa*	15.04	5.37	-9.67	-1.01	-64.29			-0.64
26b	1	*Montastraea* sp.	12.52	11.14	-1.38	-0.14	-11.03	-3.48	-0.36	-0.11
	2	*Montastraea* sp.	8.26	8.51	0.25	0.03	3.03			0.03
	3	*Diploria strigosa*	4.42	3.97	-0.45	-0.05	-10.23			-0.10
	4	*Diploria strigosa*	20.25	18.78	-1.47	-0.15	-7.28			-0.07
	5	*Diploria strigosa*	10.84	10.41	-0.43	-0.04	-3.93			-0.04
27	1	*Montastraea* sp.	4.60	5.11	-3.72	-0.39	-80.85	-45.73	-4.79	-0.81
	2	*Montastraea* sp.	16.68	22.18	2.48	0.26	14.90			0.15
	3	*Montastraea* sp.	11.01	12.17	4.23	0.44	38.38			0.38
	4	*Diploria strigosa*	15.16	18.64	-2.06	-0.22	-13.60			-0.14
	5	*Montastraea* sp.	241.20	184.83	169.79	17.78	70.39			0.70
29	1	*Diploria strigosa*	21.76	27.56	5.80	0.61	26.67	-56.97	-5.96	0.27
	2	*Diploria strigosa*	26.91	30.70	3.79	0.40	14.10			0.14
	3	*Diploria strigosa*	97.97	92.35	-5.62	-0.59	-5.73			-0.06
	4	*Diploria strigosa*	44.37	0.00	-44.37	-4.65	-100.00			-1.00
	5	*Diploria strigosa*	16.58	0.00	-16.58	-1.74	-100.00			-1.00
29b	1	*Diploria strigosa*	11.23	10.66	-0.57	-0.06	-5.09	-84.92	-8.89	-0.05
	2	*Montastraea* sp.	10.26	10.93	0.67	0.07	6.57			0.07
	3	*Montastraea cavernosa*	71.95	0.61	-71.34	-7.47	-99.16			-0.99
	4	*Diploria strigosa*	13.67	0.00	-13.67	-1.43	-100.00			-1.00
30	1	*Montastraea cavernosa*	53.02	1.26	-51.76	-5.42	-97.62	-185.24	-19.40	-0.98
	2	*Colpophyllia natans*	56.14	56.05	-0.09	-0.01	-0.16			0.00
	3	*Montastraea cavernosa*	82.55	0.48	-82.06	-8.59	-99.42			-0.99
	4	*Montastraea cavernosa*	32.05	3.02	-29.03	-3.04	-90.57			-0.91
	5	*Diploria strigosa*	49.65	27.35	-22.31	-2.34	-44.92			-0.45
30b	1	*Montastraea* sp.	16.46	8.48	-7.98	-0.84	-48.46	-83.58	-8.75	-0.48
	2	*Diploria strigosa*	71.70	0.00	-71.70	-7.51	-100.00			-1.00
	3	*Diploria strigosa*	4.92	0.00	-4.92	-0.52	-100.00			-1.00
	4	*Diploria strigosa*	7.62	7.58	-0.03	0.00	-0.42			0.00
	5	*Diploria strigosa*	9.59	10.63	1.04	0.11	10.84			0.11
31	1	*Montastraea* sp.	23.67	26.94	3.27	0.34	13.83	3.55	0.37	0.14
	2	*Montastraea* sp.	1.96	2.22	0.26	0.03	13.11			0.13
	3	*Montastraea* sp.	5.46	6.60	1.14	0.12	20.91			0.21
	4	*Montastraea* sp.	6.98	7.68	0.71	0.07	10.15			0.10
	5	*Montastraea* sp.	25.58	23.76	-1.83	-0.19	-7.14			-0.07
33	1	*Montastraea* sp.	10.58	10.38	-0.20	-0.02	-1.88	-24.48	-2.56	-0.02
	2	*Montastraea* sp.	15.47	11.89	-3.59	-0.38	-23.18			-0.23
	3	*Montastraea* sp.	55.16	55.49	0.33	0.03	0.60			0.01
	4	*Montastraea cavernosa*	21.42	0.40	-21.03	-2.20	-98.14			-0.98
36	1	*Montastraea* sp.	121.54	48.42	-73.12	-7.66	-60.16	-210.98	-22.09	-0.60
	2	*Montastraea* sp.	78.55	0.35	-78.20	-8.19	-99.55			-1.00
	3	*Montastraea* sp.	47.03	2.31	-44.73	-4.68	-95.10			-0.95
	4	*Montastraea* sp.	15.12	0.19	-14.93	-1.56	-98.77			-0.99
38	1	*Diploria strigosa*	74.52	62.14	-12.38	-1.30	-16.61	6.96	0.73	-0.17
	2	*Diploria strigosa*	15.18	15.00	-0.18	-0.02	-1.18			-0.01
	3	*Colpophyllia natans*	78.89	91.83	12.94	1.36	16.40			0.16
	4	*Diploria strigosa*	10.33	11.26	0.93	0.10	9.04			0.09
	5	*Diploria strigosa*	26.31	30.66	4.35	0.46	16.53			0.17
	6	*Diploria strigosa*	41.88	43.17	1.30	0.14	3.09			0.03
UNK1	1	*Montastraea* sp.	7.95	8.34	0.40	0.04	4.97	-19.97	-2.09	0.05
	2	*Diploria strigosa*	19.15	22.04	2.89	0.30	15.07			0.15
	3	*Montastraea* sp.	26.47	26.14	-0.33	-0.03	-1.25			-0.01
	4	*Diploria strigosa*	21.16	0.00	-21.16	-2.22	-100.00			-1.00
	5	*Montastraea* sp.	14.68	12.91	-1.76	-0.18	-12.01			-0.12

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Appendix B

Repetitive 8 m^2 Quadrat Proportional Change for Selected Coral Heads at East Flower Garden Bank

June 2005 and November 2005

Study Site Repetitive Quadrats										
RQS # *	**Coral Head #**	**Species**	**Area of coral head in June 2005 (cm^2)**	**Area of coral head in Nov 2005 (cm^2)**	**Change in Area (cm^2)**	**% Change in Area**	**% change in coral colony area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change**
UNK2	1	*Colpophyllia natans*	10.75	11.71	-0.23	-0.02	-2.12	4.61	0.48	-0.02
	2	*Diploria strigosa*	15.61	26.76	11.23	1.18	71.98			0.72
	3	*Montastraea* sp.	22.62	16.12	-9.13	-0.96	-40.38			-0.40
	4	*Diploria strigosa*	21.04	22.01	1.75	0.18	8.31			0.08
	5	*Montastraea* sp.	28.56	27.47	0.99	0.10	3.45			0.03

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Appendix B

Repetitive 8 m^2 Quadrat Proportional Change for Selected Coral Heads at East Flower Garden Bank

June 2005 and November 2005

Deep Station Repetitive Quadrats										
RQS # *	**Coral Head #**	**Species**	**Area of coral head in June 2005 (cm^2)**	**Area of coral head in November 2005 (cm^2)**	**Change in Area (cm^2)**	**% Change in Area**	**% change in coral colony area**	**Total change in Area within Quadrat (cm^2)**	**Total % change in Area within Quadrat**	**Proportional Change**
81	1	*Colpophyllia natans*	89.49	86.65	-2.84	-0.30	-3.17	-1.07	-0.11	-0.03
	2	*Colpophyllia natans*	4.11	5.06	0.95	0.10	22.99			0.23
	3	*Diploria strigosa*	68.85	55.06	-13.78	-1.44	-20.02			-0.20
	4	*Montastraea* sp.	62.28	76.90	14.61	1.53	23.46			0.23
82	1	*Montastraea cavernosa*	2.50	3.39	0.90	0.09	35.89	7.80	0.82	0.36
	2	*Montastraea cavernosa*	16.90	24.07	7.16	0.75	42.38			0.42
	3	*Colpophyllia natans*	15.51	15.24	-0.27	-0.03	-1.75			-0.02
	4	*Montastraea* sp.	29.71	29.72	0.01	0.00	0.04			0.00
83	1	*Montastraea* sp.	13.36	14.08	0.71	0.07	5.34	12.87	1.35	0.05
	2	*Montastraea cavernosa*	5.33	4.98	-0.35	-0.04	-6.55			-0.07
	3	*Montastraea* sp.	25.10	29.15	4.05	0.42	16.13			0.16
	4	*Montastraea cavernosa*	23.45	28.50	5.05	0.53	21.53			0.22
	5	*Montastraea* sp.	23.00	26.42	3.41	0.36	14.83			0.15
85	1	*Montastraea* sp.	1.97	2.23	0.26	0.03	13.44	0.12	0.01	0.13
	2	*Montastraea cavernosa*	0.63	1.09	0.46	0.05	72.46			0.72
	3	*Montastraea cavernosa*	39.87	37.30	-2.58	-0.27	-6.46			-0.06
	4	*Montastraea* sp.	13.55	16.34	2.78	0.29	20.53			0.21
	5	*Montastraea cavernosa*	17.00	16.19	-0.81	-0.08	-4.75			-0.05
86	1	*Colpophyllia natans*	159.85	183.68	23.83	2.50	14.91	31.00	3.25	0.15
	2	*Montastraea cavernosa*	49.02	68.44	19.42	2.03	39.62			0.40
	3	*Montastraea cavernosa*	25.29	27.52	2.22	0.23	8.79			0.09
	4	*Montastraea cavernosa*	43.83	29.35	-14.48	-1.52	-33.03			-0.33
87	1	*Montastraea* sp.	30.63	26.62	-4.02	-0.42	-13.12	-1.50	-0.16	-0.13
	2	*Montastraea* sp.	11.30	10.10	-1.20	-0.13	-10.66			-0.11
	3	*Montastraea* sp.	34.94	38.58	3.64	0.38	10.41			0.10
	4	*Montastraea* sp.	22.44	22.68	0.25	0.03	1.11			0.01
	5	*Diploria strigosa*	1.74	1.57	-0.17	-0.02	-9.58			-0.10
88	1	*Montastraea* sp.	15.48	15.72	0.24	0.03	1.56	4.35	0.46	0.02
	2	*Montastraea cavernosa*	31.38	31.39	0.01	0.00	0.04			0.00
	3	*Montastraea* sp.	12.74	15.60	2.86	0.30	22.44			0.22
	4	*Colpophyllia natans*	7.09	5.79	-1.30	-0.14	-18.32			-0.18
	5	*Montastraea* sp.	30.43	32.97	2.54	0.27	8.34			0.08
UNK8	1	*Montastraea cavernosa*	39.48	32.72	-6.76	-0.71	-17.12	-2.92	-0.31	-0.17
	2	*Montastraea cavernosa*	19.47	18.64	-0.82	-0.09	-4.23			-0.04
	3	*Colpophyllia natans*	11.22	11.43	0.21	0.02	1.91			0.02
	4	*Montastraea* sp.	22.78	25.74	2.96	0.31	13.01			0.13
	5	*Montastraea cavernosa*	6.03	7.51	1.48	0.16	24.64			0.25
UNK9	1	*Montastraea* sp.	11.11	10.62	-0.48	-0.05	-4.36	0.05	0.01	-0.04
	2	*Montastraea cavernosa*	4.26	3.66	-0.60	-0.06	-14.18			-0.14
	3	*Montastraea cavernosa*	42.11	41.38	-0.73	-0.08	-1.73			-0.02
	4	*Montastraea* sp.	4.87	3.66	-1.21	-0.13	-24.82			-0.25
	5	*Montastraea cavernosa*	10.20	13.27	3.08	0.32	30.16			0.30

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The Department of the Interior Mission

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

The Minerals Management Service Mission

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

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

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