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MMS 2003-031

Long-Term Monitoring at the East and West Flower Garden Banks National Marine Sanctuary, 1998-2001

Final Report

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Minerals Management Service
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Authors

Quenton R. Dokken
Ian R. MacDonald
John W. Tunnell, Jr.
Terry Wade
Kim Withers
Suzanne J. Dilworth
Thomas W. Bates
Carl R. Beaver
Christopher M. Rigaud

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Center for Coastal Studies
Texas A&M University, Corpus Christi
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Gulf of Mexico OCS Region
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NOTE TO READER

Information contained within this synthesis report takes precedence over all data reported in Dokken *et al.* 1996-1999. Advanced analysis and enhanced calculations make this data more robust and comprehensive.

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Project personnel and their major responsibilities:

1. Quenton R. Dokken — Project Manager, Co-Principal Investigator
2. Ian R. MacDonald — Scientist, Co-Principal Investigator
3. John W. Tunnell, Jr. — Scientist, Co-Principal Investigator
4. Terry Wade — Scientist/Data Analysis
5. Kim Withers — Scientist/Data Analysis
6. Suzanne J. Dilworth — Scientist/Logistics/Data Analysis/Field Management
7. Thomas W. Bates — Scientist/Data Analysis/Field Management
8. Carl R. Beaver — Scientist/Data Analysis/Field Management
9. Christopher M. Rigaud — Scientist/Data Analysis

Project Divers

Suzanne Dilworth	Thomas Bates	Quenton Dokken	Christopher Rigaud
Susan Childs	Carl Beaver	Jay Gardner	Chris Ledford
Ian MacDonald	Kerry DeHart	Omar Guerra	Noe Barrera
Mike Fredericks	Al Oswalt	David Hicks	Mark MacNamara
Amy Koltermann	Addie Frets	Jason Jones	Tomas Oberding
David Gray	Jennifer Davidson	Kyle Klootwyk	Jennifer Pearce
Tannika Engelhard	Rick Maxey		

Individual authors/contributors and the tasks they performed are listed below.

REPORT	Task/Analysis	Author/Contributor
LONG-TERM MONITORING AT THE EAST AND WEST FLOWER GARDEN BANKS, 1998-2001 (MMS/NOAA FUNDED PROJECT)	Project Management, Discussion, Conclusions, Recommendations, Editorial Management	Quenton R. Dokken Ian R. MacDonald John W. Tunnell, Jr.
	Introduction Study Site Methods	Suzanne J. Dilworth Quenton R. Dokken Kim Withers John W. Tunnell, Jr. Ian R. MacDonald
	Random Photographic Transects	Christopher Rigaud, Aimee Cunningham, and Kim Withers
	Encrusting Growth Stations	Thomas W. Bates and Kim Withers
	Repetitive Quadrats	Thomas W. Bates and Kim Withers
	Sclerochronology	Carl Beaver and Kim Withers
	Water Chemistry	Terry Wade
	Insolation	Ian R. MacDonald and Norman Guinasso
	Temperature	Thomas W. Bates and Suzanne J. Dilworth
	Urchin Surveys	Suzanne J. Dilworth
	Document Layout & Preparation	Suzanne J. Dilworth

EXECUTIVE SUMMARY

During the 1998 - 2001 monitoring period analysis of monitoring data indicated that the Flower Garden Banks (FGB) were healthy and productive. Relative to other coral reef systems of the Gulf of Mexico and Caribbean Sea, the FGB have low diversity of stony corals and high coral cover, generally ~ 50%. Located 193 and 172 km (East and West Flower Garden Bank, respectively), offshore from Galveston, Texas, the FGB are relatively isolated from terrestrial based impacts when compared to reef systems such as those of the Florida Keys and southern Gulf of Mexico. Although afforded a measure of protection from shore side development and watershed drainage impacts, within the FGB there is potential for habitat damage from industrial and recreational activities occurring in the near vicinity such as marine shipping, oil/gas production, and sport diving. Prior to designation as a National Marine Sanctuary in 1992, substantial anchor damage was observed. Some anchor damage has occurred since Sanctuary designation. No significant impact from oil/gas production activity has been documented after Sanctuary designation.

Based on the results of the random transect data, cover of the *Montastraea annularis* complex (*M. annularis*, *M. faveolata*, and *M. franksi*; Weil and Knowlton, 1994) at the EFGB increased. A concurrent loss of reef rock, *M. cavernosa* and *Diploria strigosa* was indicated, but the data is inconclusive and these results may be an artifact of methodology. Algal cover increased in 1999, but then declined. Reef rock was also negatively correlated with algal cover. It appeared that *M. annularis* complex and algae colonized more of the non-living surfaces of the bank. The significant positive correlation between algae and total coral suggested that algae were not expanding at the expense of coral cover.

Increases in the cover of the *M. annularis* complex at the WFGB was less than at the EFGB. The correlations between the *M. annularis* complex, *D. strigosa*, *M. cavernosa* and total coral cover were indicative of the fact that these three species are the predominant corals on the bank. The same negative correlation between reef rock and algae recorded at the EFGB was also seen at the WFGB. Consistent with the EFGB, algae primarily colonized non-living surfaces (i.e. reef rock). Unlike the EFGB, the *M. annularis* complex did not appear to be expanding into areas of non-living substrate. In addition, there were no significant correlations between the *M. annularis* complex and *D. strigosa* or *M. cavernosa* or algae and total cover as seen at the WFGB. The coral community at the WFGB remained stable throughout the monitoring period despite the increase in algal cover.

Random photographic transects were completed outside the boundaries of the designated 100 m^2 study area to test whether or not the study area remained representative of the reef habitat. No inconsistencies between the reef character outside the designated study area and the study area were evident (Appendix 1).

Variability of accretionary growth and encrusting growth was the rule. Annual accretionary growth of *Montastraea faveolata* at the East Flower Garden Bank (EFGB) averaged 7.5 mm/year (range = 6.12-8.23). At the West Flower Garden Bank (WFGB) annual accretionary growth ranged from 4.49 to 6.64 mm/year and averaged 5.37 mm/year. No significant long-term upward or downward trends in growth rates were evident, and no correlations of growth to environmental parameters could be ascertained. Rates of coral growth at the Flower Garden Banks were in the mid to upper range of growth rates of corals at various Caribbean Sea reefs. Encrusting growth, measured on colonies of *Diploria strigosa*, was also variable over time, but appeared balanced (i.e. gain versus loss of tissue). No significant long-term trends in encrusting growth were evident.

Habitat characters such as degree of bleaching and percent cover of algae and bare reef rock varied annually from 1998 to 2001. However, as with the growth data, no trends were evident and no change appeared to be long term. Disease was a minor component of the FGB ecosystem dynamics with no apparent significant impact.

Light intensity in the water column indicated that the water clarity of the Flower Garden Banks National Marine Sanctuary was between that of the clearest coastal waters and clearest oceanic waters. Periodic changes in water clarity reflected changes in cloud cover and concentrations of suspended particles and plankton. It was speculated that changing current patterns affected the transmissivity of the water column.

The temperature regime for 1998 and 2001 was consistent with historical patterns with temperatures staying within normal parameters. With the peak temperature less than 30^{o}C, bleaching was not a major event with the exception of the *Millepora alcicornis* colonies, which were particularly susceptible.

Ancillary efforts to the monitoring program by visiting scientists produced an expanded catalog of flora and fauna. Combined, Fredericq et al. (2001) (University of Louisiana at Lafayette) and Lehman and Albert (2001) (Center for Coastal Studies, Texas A&M University-Corpus Christi) produced a list of 72 species of algae, and Barrera and Tunnell (2001) (Center for Coastal Studies, Texas A&M University-Corpus Christi) added 100 new species to the catalog of molluscs found at the FGB. Dunton and Miller (2001) (University of Texas at Port Aransas) used stable nitrogen isotopes to describe a food web structure and macroalgal primary production. Nutrients at the Flower Garden Banks were derived primarily from local benthic cyanobacterial mats rather than from coastal zones. Nipper and Carr (2001) (Center for Coastal Studies, Texas A&M University-Corpus Christi and U.S. Geological Survey-Biological Resources Division Marine Ecotoxicology Research Station, respectively) tested the pore waters of the Flower Garden Banks substrates and described the pore water quality as good in all parameters.

The Minerals Management Service and Flower Garden Banks National Marine Sanctuary made substantial progress in implementing many of the recommendations of past reports. The *in situ* water quality monitoring instrumentation was upgraded; and the 2002 and 2003 monitoring program, as specified within the published RFP will include:

1) Expanded algal studies, nutrient flows, and nutrient concentration measurements;
2) More rigorous laboratory measurements of potential contaminants;
3) Continued analysis of population densities of the herbivore, *Diadema antillarium*;
4) Deep water stations will be established and monitored; and
5) Fish censuses will be conducted.

These actions will not only expand our knowledge and understanding of the Flower Garden Banks ecosystem, but will also improve the foundation from which management decisions are made.

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1.0 INTRODUCTION

1.1 OVERVIEW

The Flower Garden Banks National Marine Sanctuary (FGBNMS; designated 1992) includes deepwater coral habitats associated with two topographic high points located on the outer continental shelf in the northwestern Gulf of Mexico. The East Flower Garden Bank (EFGB) is located about 193 km southeast of Galveston, Texas (27^{o} 54.5' N, 93^{o} 36.0' W), and the West Flower Garden Bank (WFGB), about 20 km west of EFGB, is located about 172 km southeast of Galveston (27^{o} 52.4' N, 93^{o} 48.8' W; Figure 1.1.1.1). The Flower Garden Banks (FGB) are found in the most active offshore oil/gas exploration and production area in the world. Approximately 4,000 production platforms are located in the northern Gulf of Mexico and are concentrated in the northwestern quadrant where the FGB are located. Two kilometers east of the EFGB, a production platform has been producing natural gas since its installation in 1982. Currently, there are no data suggesting that oil and gas production in the vicinity has been detrimental to the coral communities of the FGB (Dokken *et al*. 1999, 2001). The purpose of the long-term monitoring efforts on the coral reefs of the FGB that began in 1989 (Gittings *et al*. 1992) is to provide relevant and timely environmental data to those charged with managing the resources of the FGBNMS and oil/gas exploration and production in the vicinity of the coral reefs. The objectives of the monitoring program are:

1. to document long-term changes in community composition of reef-building coral and associated communities;
2. to document long-term natural variation in reef growth;
3. to stimulate ancillary research efforts and coordinate monitoring activities by other agencies and institutions; and
4. to evaluate and synthesize monitoring data and other research in order to assess the impact of change and provide recommendations to managers.

1.1.1 Habitat Description

The FGB are part of a widely dispersed, discontinuous arc of reef environments along the outer continental shelf of the Gulf of Mexico (Rezak *et al*. 1985). The FGB are topographic features created when sedimentary rock was uplifted by underlying salt domes of Jurassic, Louann origin (Rezak 1981). The crests of these topographic highs extended into the intense photic zones of the surface waters providing the necessary habitat for overgrowth of scleractinian corals and other calcareous and sessile marine organisms. Environmental conditions on the northern Gulf's outer continental shelf are generally favorable for development of hermatypic scleractinian coral species. Salinities range from 34 to 36 ppt. Water temperatures range from a low of ~ 20^{o}C (mid-February) to a high of ~ 30^{o}C (August). Water clarity permits an average 75% per meter of water transmission of white light with 40% to 50% of surface light reaching to 37 m (McGrail *et al*. 1982).

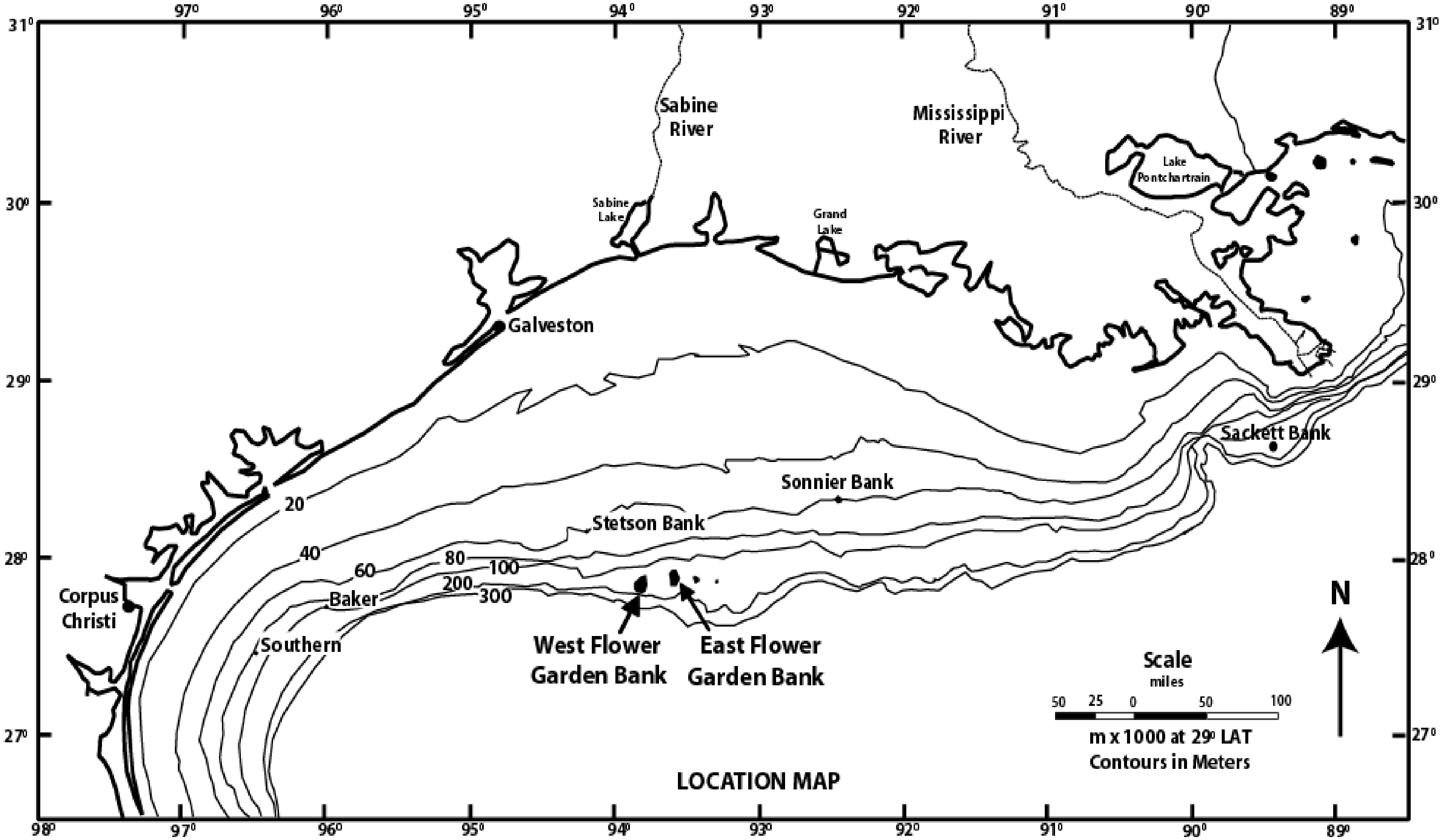


Figure 1.1.1.1. Location map of the East and West Flower Garden Banks in relation to the continental shelf and other topographic features of the northwestern Gulf of Mexico (from Gittings *et al.* 1992).

These coral banks are the largest charted calcareous banks in the northwestern Gulf of Mexico (Bright *et al*. 1985) and the northernmost coral reefs on the continental shelf of North America (Bright *et al*. 1984). Although non-coral communities exist on neighboring banks (e.g., Stetson Bank), the reefs at Cabo Rojo, about 100 km south of Tampico, Mexico, are the closest extensively developed coral reefs in the Gulf of Mexico.

The coral cap ranges in depth from approximately 18 to 44 m. The pear-shaped EFGB, encompassing about 67 km^2, slopes from the crest at roughly 20 m to a seabed plane of terrigenous muds at a depth of 100-120 m. The eastern and southern edges of the bank slope steeply whereas the area north and west of the coral cap slopes more gently. The WFGB is slightly more than twice as large (137 km^2) as the EFGB. Its major features are three crests aligned along an east-west axis. The middle crest rises from a depth of 100 – 150 m to within 18 m of the surface and supports coral reef habitat. Diversity of the coral community at both banks is depauperate with only 20 species of hermatypic corals (Bright *et al*. 1984), whereas up to 67 species can be found on some Caribbean reefs. Acroporid branching scleractinians (e.g., *Acropora palmata*) and shallow water gorgonians are absent from the FGB reefs.

Three biological zones have been delineated at the FGB (Rezak *et al*. 1985). In the shallowest areas of the banks (depths <36 m) is the *Montastraea-Diploria-Porites* Zone, with 16 coral species. The *Stephanocoenia-Millepora* Zone extends from 36 – 52 m and contains 13 coral species. Coral cover in both zones is interrupted by areas of bare reef rock and patches of biogenic sands. The Algal-Sponge Zone is found between ~ 46 – 88 m. Lower portions of this depth range are characterized by antipatharians that grade into a soft bottom composed of coarse carbonate sands below ~ 88 m.

The *Montastraea annularis* species complex (*Montastraea annularis, M. faveolata,* and *M. franksi*; Weil and Knowlton 1994) represents the dominant scleractinian taxa in the *Montastraea-Diploria-Porites* Zone, followed by *Diploria strigosa, M. cavernosa, Porites astreoides,* and *Colpophyllia natans*. Total live coral cover averages ~ 45–52% (Dokken *et al*. 1999, 2001). Nine genera of crustose coralline algae have been identified in this zone and calcareous green algae are also common. In addition, over 350 species of invertebrates, including more than 225 molluscan species (Bright and Pequenat 1974; Dokken *et al*. 2001) and 177 species of fishes (Pattengill 1998) have been recorded.

In the *Stephanocoenia-Millepora* Zone, along the narrow depth gradient between 36 and 46 m, the scleractinian *Stephanocoenia intersepta* and the hydrozoan *Millepora alcicornis* dominate. In addition, 11 other species of scleractinians are present including *Diploria strigosa*, *M. cavernosa*, *Colpophyllia natans* and *Agaricia* sp. (Bright and Pequenat 1974).

The EFGB study site was initially established in 1989 by Texas A&M University during early MMS-funded monitoring efforts (Gittings *et al*. 1992). The WFGB study site was originally established by Continental Shelf Associates (CSA) in 1988 and incorporated into the MMS monitoring efforts by Texas A&M University (Gittings *et al*. 1992). Both sites are located in the coral habitats of the *Diploria-Montastraea-Porites* Zone.

2.0 METHODS

2.1 FIELD LOGISTICS

Sampling cruises were conducted aboard the *M/V Fling* during 27 September - 1 October 1998, 12-16 September 1999, 17-22 September 2000, and 16-21 September 2001. Weather conditions were excellent during the 1998 cruise; however, conditions during the September 1999 cruise were marginal, forcing delay of one contracted task (core extraction). Core extraction was eventually performed in February 2000. For 2000 and 2001 cruises, weather and currents prevented ancillary deepwater studies, however, all other tasks were completed.

2.2 STUDY SITES

For all years, sampling was conducted within the previously established 100 x 100 m study sites on both the EFGB and WFGB. Subsurface buoys attached to stainless steel eyebolts cemented into the reef rock mark the four corners of each study site. During each sampling effort, graduated, color-coded polypropylene lines were extended between each corner eyebolt to mark the boundaries of the study sites and aid in diver navigation and location of individual monitoring stations. Boundary lines were removed at the end of each sampling effort. Each dive team was supplied with detailed underwater maps depicting relative positions of repetitive stations in relation to boundary lines and major topographical features (Figures 2.2.0.1 and 2.2.0.2). A master map on the surface was updated after each dive with the relative positions of new or renumbered stations. During spring, summer, and fall a large surface buoy is secured to a mooring line that is attached to a stainless steel u-bolt permanently cemented into the reef rock within each site. The buoys are owned by the FGBNMS and maintained by contract with Buoy Services, Inc. of Freeport, Texas. The buoys served as mooring sites for the research vessel during monitoring missions.

2.3 RANDOM TRANSECTS

The purpose of random transects was to determine reef community composition and structure. A minimum of 14 transects ~10 m long, that consisted of at least 17 non-overlapping photographs were performed within the boundaries of the study site on each bank during each monitoring cruise (Gittings *et al*. 1992; Hagman and Gittings 1992; Dokken *et al.* 1999, 2001). In addition, three transects consisting of 14 non-overlapping photographs were taken outside the boundaries of the study area at each bank during 1998-2001 cruises to determine if the coral community within the study area was representative of the banks as a whole (Appendix 1).

2.3.1 Field Methods and Data Capture

Divers were equipped with Nikonos V cameras with a 28 mm lens and dual Nikonos strobes mounted on a rectangular aluminum or stainless steel camera frame that holds the camera 1 m above the reef surface (Figure 2.3.0.1). The bottoms of the frames were wrapped in closed cell foam to protect the reef from damage. Cameras were loaded with Kodak Ektachrome 100, 36-exposure color slide film and set for *f*-11 and a distance of 0.8 m; strobes were set on TTL and slave. This system produces color positive images of reef substrate approximately 44 x 63 cm (0.2772 m^2).

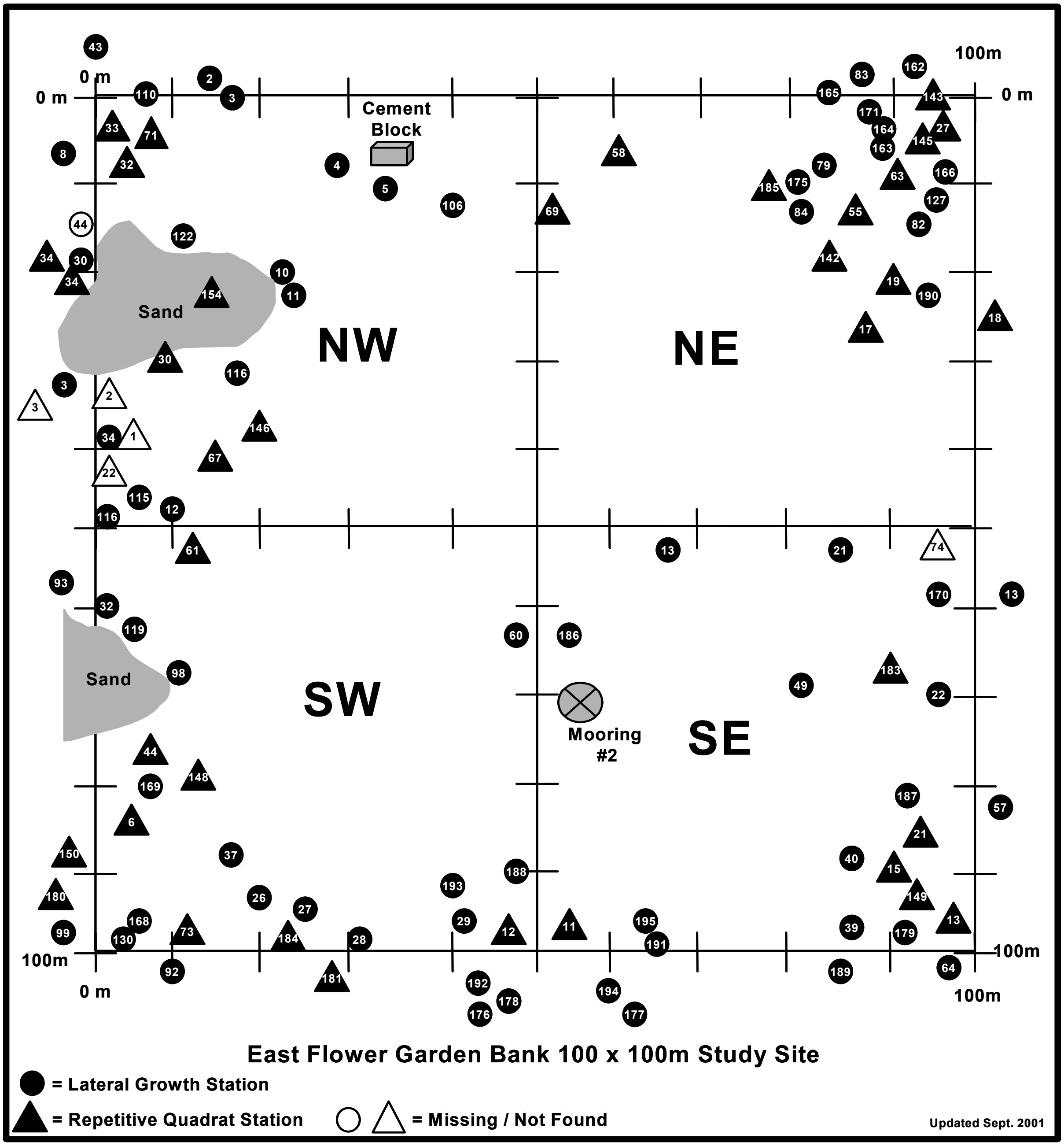


Figure 2.2.0.1. Map of East Flower Garden Bank 100 x 100 m study site showing relative positions of permanent stations, mooring bolt and other conspicuous features.

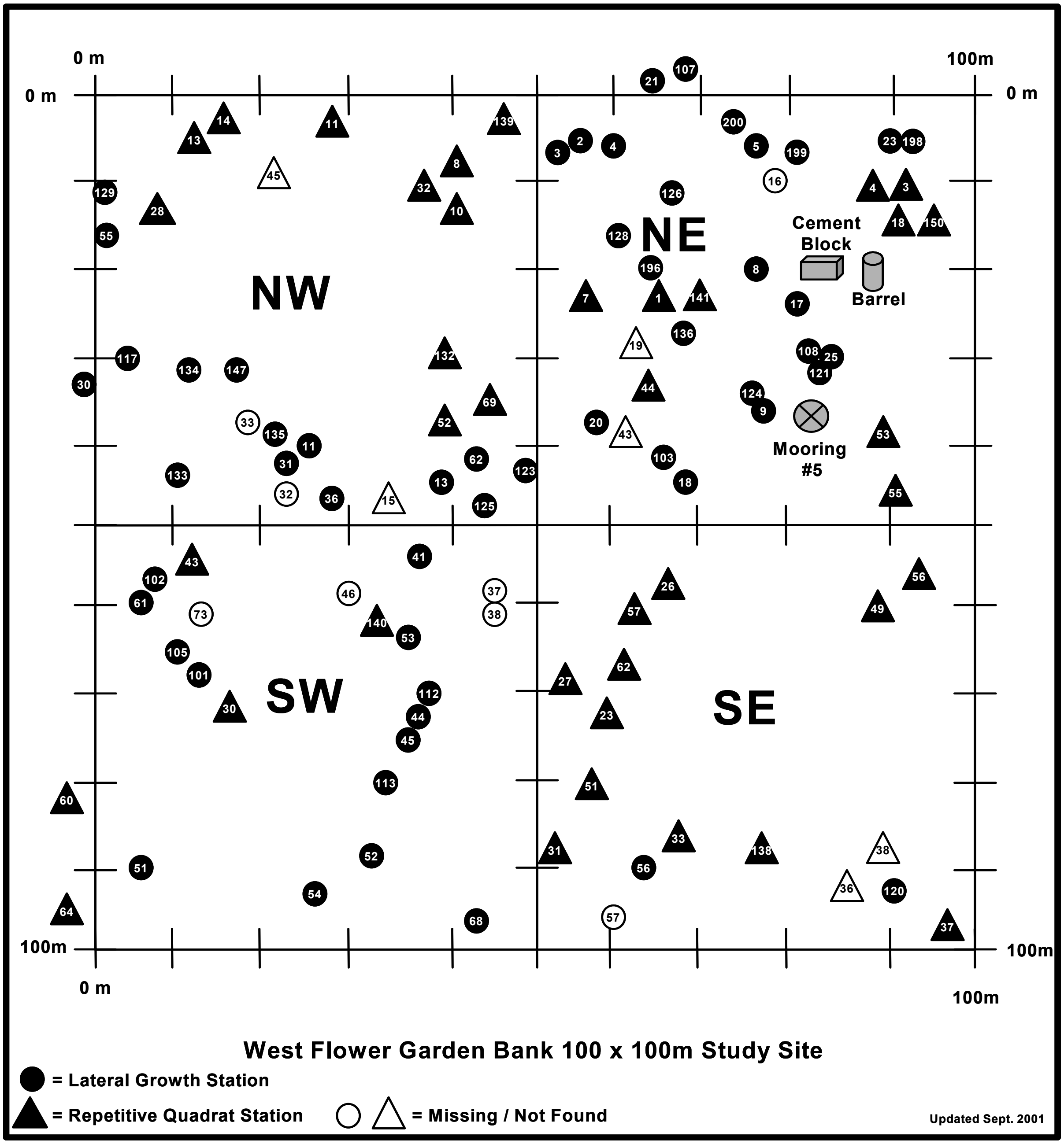


Figure 2.2.0.2. Map of West Flower Garden Bank 100 x 100 m study site showing relative positions of permanent stations, mooring bolt and other conspicuous features.

Figure 2.3.0.1. Diver with random transect camera framer.

Before entering the water, divers were assigned two sets of two random numbers. The first number of each set was a compass heading and the second was the number of fin kicks. Divers descended to the reef surface and proceeded to an assigned quadrant (i.e. northeast, northwest, southeast, southwest) to minimize the potential for transect overlap within the study area. At this point the diver swam in the designated compass heading for the specified number of fin kicks for transect beginning. Transects continued in the same direction until seventeen, non-overlapping photographs were taken. The diver then used the next set of random numbers to move to the starting point of the second transect. Each diver completed two transects (1 roll of film) during each dive. All quadrants of the study site were photographed at least once.

Slides were developed and digitally recorded on CD-ROM media. Areal coverage of coral species and other reef components was acquired using a Wacom serial graphics tablet and Jandel Scientific Sigma Scan Pro 4.0 software. The projection of the digitized images on the computer screen was calibrated to equal the actual area (cm^2) of the substrate represented by the slide. Coral colonies and other reef components were outlined using the serial graphics pen and areal coverage was automatically calculated. The following species or cover categories were used: coral species and total coral (1996-2001), filamentous algae (2000-

2001), crustose coralline algae (2000-2001), *Dictyota* sp. (2000-2001), total algae (1996-2001), total sponge (1996-2001), FA: Serpulidae (2000-2001), other (e.g., fish, disease; 2000-2001), reef rock (1998-2001), sand (1996-2001), artifacts (e.g., hand, SCUBA gauge; 2000-2001); and not identified (included all non-living categories except sand, other biological and the unidentifiable portions of slides 1996-1997; all non-living categories except sand and reef rock, other biological and the unidentifiable portions of slides 1998-1999; only the unidentifiable portions of slides in 2000-2001).

2.3.2 Data Presentation and Statistical Analysis

Mean percent cover and standard deviation for each year and bank were calculated for coral species and other cover categories. The areas of each species or category delineated in each slide taken along a transect were summed and divided by the sum of the areas of all slides taken along the transect (1 slide = 2,772 cm^2). The numbers of slides per transect varied slightly (minimum 17, maximum 22) as did the number of usable transects (minimum of 10 in 1996 on EFG; maximum of 19 on EFG in 2001). Data are presented separately for inside and outside transects.

For each bank and year, Shannon diversity (H', base 10), evenness (J'), and Berger-Parker dominance (d) were calculated for the coral community using mean percent cover of each coral species. Bray-Curtis cluster analysis of community similarity (complete link) was used to evaluate coral community similarity among years. Data are presented separately for inside and outside transects.

Using data from the study site transects only, one-way analysis of variance was used to determine significant differences ($p \leq 0.05$) in percent cover among years within each bank for the following: coral species (except rare *Agaricia fragilis*), total coral, total algae, total sponge and reef rock. Percent cover data for each species or category within each bank were tested for normality using the Kolmogorov-Smirnoff test and arcsine transformed if necessary. The general linear model was used since the design was unbalanced (numbers of transects per year varied). Where significant differences were found, Tukey's HSD was used to delineate homogenous subsets of years.

Using mean percent cover data for each species or category analyzed with analysis of variance (including data reported from previous monitoring by Gittings *et al.* (1992) and Continental Shelf Association (1996) in Dokken et al. (2001), as well as the data presented here), a non-parametric runs test was performed. Runs tests are used to determine whether or not events occur in a random sequence or whether the probability of a given event is a function of the outcome of a previous event. Additionally, this analysis is used for dichotomized data for which it tests the random sequence of a series of observations (Sokal and Rohlf, 1995). For the random transect data, runs tests were used to establish if data varied randomly or exhibited a systematic trend.

To determine if the study areas were representative of the remainder of the high diversity living coral reef at each bank, the Mann-Whitney U test (the non-parametric equivalent of a t-test) was used. Percent cover data for each shared coral species and cover category were tested for significant differences between inside and outside transects using mean cover for each year when both types of data were collected.

2.4 SCLEROCHRONOLOGY

Sclerochronology is the determination of annual growth rates through the measurement of the width of accretionary growth bands in coral core samples. In accordance with NOAA permit FGBNMS-11-99, one or two cores were extracted from *Montastraea faveolata* colonies at each bank only during the current contract period, when sea state and weather conditions allowed. Cores were extracted from EFGB during February 2000 and September 2001 and from WFGB during February 2000 and April 2002.

2.4.1 Field Methods and Data Capture

The *M. faveolata* colonies chosen for coring exhibited the following characteristics: upright growth with a non-scoured base, no evidence of abnormal growth patterns resulting from the colony toppling after the base had eroded, no obvious holes caused by boring organisms, and no overgrowth by algae or sponges. Cores were extracted using a pneumatic drill attached to a compressed air scuba cylinder. Coral heads were drilled perpendicularly to the water's surface on the top of the coral's head to obtain the most accurate and continuous growth information. Cores were 60 mm in diameter and were drilled to a depth of at least 100 mm to ensure at least 10 years of growth were represented. The hole left from core extraction was plugged with a preformed concrete plug inscribed with the date of core extraction.

Cores were longitudinally sectioned into 3-4 mm thick slabs using a dual-blade diamond impregnated rock saw. Coral slabs were arranged on Kodak brand Industrix 400 x-ray film and exposed to x-rays (100 mA, 20 KV for 1.25 seconds) to reveal annual density bands. A machined metal scale was included as a length standard in each x-ray image to insure precise measurement of growth bands. Measurement standards were included in each x-ray, so that when film negatives were scanned into a computer and enlarged for growth band analysis the image's scale was not compromised.

One annual growth increment is defined as the combination of one low-density band and its adjacent high-density band (Knutson *et al*. 1972). The area between the upper boundaries of two sequential high-density growth bands was considered an annual growth increment. Scanned images were enlarged by a factor of ten and the first complete set of high and low density bands were used as the starting point for growth analysis. An object-oriented drawing program was used to place measurement lines at three separate locations on each annual growth band parallel to the growth axis. The program automatically displayed each line length in millimeters after it was drawn. Measurement data was corrected using the scale included in each x-ray.

2.4.2 Data Presentation and Statistical Analysis

Overall mean growth rates with standard deviation were calculated for each bank and year (1985-2000) based on all available data. Data are presented for each year in tabular. Nonparametric runs tests were used to determine if growth rates varied systematically or randomly.

2.5 ENCRUSTING GROWTH

During previous studies (Continental Shelf Associates, 1996; Gittings *et al*., 1992), 60 colonies of *Diploria strigosa* on each bank were established as permanent stations to assess coral margin growth rates. Rates of coral advance (tissue gain) and retreat (tissue loss) were determined through photographic analysis of these stations.

2.5.1 Field Methods and Data Capture

Growth stations were set up on colonies of *D. strigosa* along a margin of live coral growth adjacent to bare reef rock. These stations were established by permanently embedding two pins in the reef rock in such a manner that the growth margin of the coral would bisect a repeatable close-up photograph of the station. A uniquely numbered plastic tag secured to one of the pins was used to identify each station.

Divers were equipped with a Nikonos V camera with a 28 mm lens, Nikonos close-up kit and strobe, and loaded with Kodak Ektachrome 100, 36-exposure slide film. The camera was set at *f*-22 and a distance of infinity, and the strobe was set to TTL. This setup produces 13.3 x 19.7 cm (262.01 cm^2) photographic images. To take the slide, the inside lower edge of the camera framer was placed against the two pins, producing a repeated image of the station (Figure 2.5.0.1). Each station was photographed and the station and frame number recorded on an underwater slate. The information was transferred to the permanent data log.

All images were digitized and stored on CD-ROM digital media. Images of each station taken during previous monitoring cruises were matched by ridge position of the corals. The area of the *D. strigosa* contained within slides was traced on a Wacom serial graphics tablet using Jandel Scientific SigmaScan Pro 4.0 to determine total coral tissue cover (cm^2) for each station.

2.5.2 Data Presentation and Statistical Analysis

Percent cover of tissue was calculated by subtracting the area measured for each station for the current year from the area measured during the previous year to determine advance, retreat, or no change. Percent cover changes were calculated by determining the amount of area gained or lost and dividing by the total photograph area (262.01 cm^2). At this time, these data are used for descriptive purposes only because the pins and markers denoting stations are constantly being lost, rendering the data unsuitable for repeated measures analysis of variance. In addition, at stations that are found, the loss of one pin often results in error due to problems orienting the camera exactly as it was the year before. We are working to find better methods for marking stations and ensuring correct camera orientation.

Figure 2.5.0.1. Diver photographing a permanent encrusting growth station.

2.6 REPETITIVE QUADRATS

Repetitive photographic stations were established to monitor the frequency and occurrence of tissue growth in the coral community as a whole as well as tissue loss due to bleaching, disease, replacement, and other causes.

2.6.1 Field Methods and Data Capture

Forty permanent, repetitive photographic stations were established on each bank and identified by securing a numbered plastic tag to a stainless steel post inserted into the reef rock (Figure 2.6.0.1). Each station was photographed during each cruise using an aluminum T-shaped camera frame mounted with a Nikonos V camera loaded with Kodak Ektachrome 100, 36-exposure slide film and a 15 mm lens (distance = 2 m, *f*-stop = 8). Two Ikelite 225 watt-second strobes were mounted on the ends of the horizontal bar and set on TTL and slave (Gittings *et al*. 1992). Consistent orientation of the camera was achieved by using a compass and bubble level mounted on the horizontal bar of the frame. Stations were photographed after placing the vertical bar of the frame against the steel post, orienting the compass to magnetic north and leveling the horizontal bar. This setup produces a slide that represents 8 m^2 of reef surface.

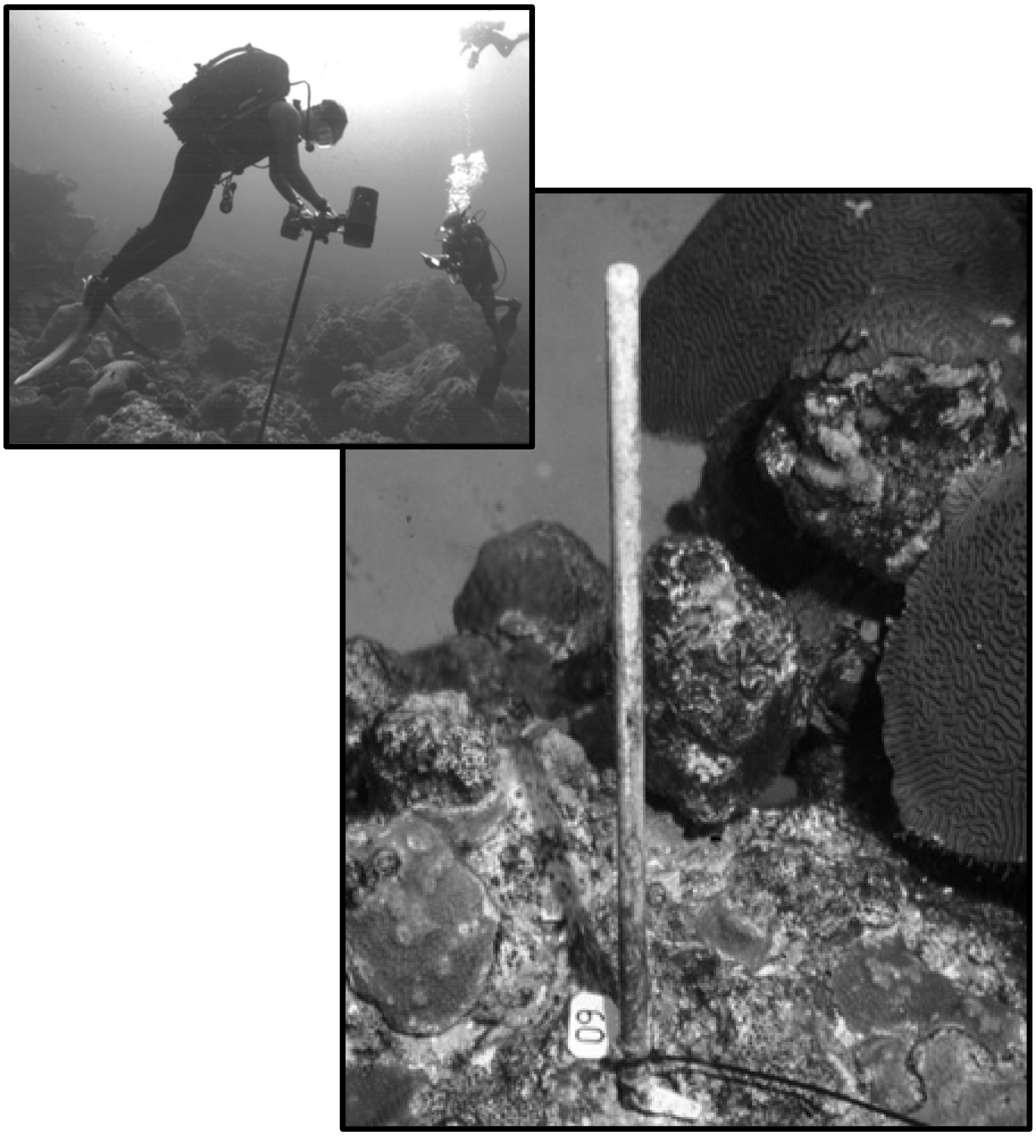


Figure 2.6.0.1. Diver photographing a permanent repetitive photographic station and example of station post.

Percent cover of coral species and extent of tissue loss or gain was estimated using point counts. Categories of tissue loss or gain were: paling (considerably lighter in color that than in previous years but has not yet reached a stark white color; a possible precursor of bleaching) (Kleppel et al. 1989), bleaching (with and without mortality), disease (with or without mortality and new), replacement (algae, sediment, or combination), other tissue loss (fish biting, competition, unexplained), and growth (infilling or marginal). Slides were projected onto a flat surface to produce an image 25.2 x 37.9 cm (955.09 cm^2) and each was overlain with three sets of 100 randomly positioned markers. Cover estimates were based on the total number of markers that intersected live coral tissue. This same procedure was used to estimate the extent of bleaching or tissue loss resulting from disease or other processes. The percentages calculated from each overlay were averaged to determine final percentages.

At stations where tissue growth and/or loss or replacement was observed, slides from the previous year were examined to attempt to determine the cause. In addition, the numbers of colonies of each species exhibiting bleaching were counted.

2.6.2 Data Presentation and Statistical Analysis

Overall mean percent cover and standard deviation of each species or cover category was determined for each bank and compared with random transect data to determine if repetitive photo stations reflect overall community composition at each bank. No statistical comparisons were made between data generated from random transects and data generated from repetitive quadrats since both the method (actual areal coverage vs point counts) and the scale/resolution of photos (0.28 m^2 vs 8 m^2) are different and any differences found could be artifacts of methods rather than true differences.

Mean percentage of points per station with standard deviation and maximum percentage of points for all stations at each bank and each year falling onto coral areas with growth and tissue loss processes were determined. Frequency of occurrence (number of photos containing corals exhibiting a category/total number of photos) was also determined for each category on each bank and for each year. Growth/retreat ratios were calculated for each year and each bank. At this time, no statistical analysis has been attempted on this data.

Percentage of colonies exhibiting bleaching or identifiable disease were determined from photos by counting the number of colonies of each species that were affected and dividing by the total number of colonies observed. Since disease data were only collected in this manner during 2000-01 and because this analysis returns an absolute value rather than a mean with standard deviation, statistical analysis is not possible at this time.

2.7 VIDEO TRANSECTS

Similar to the three previous studies (Gittings *et al*. 1992; Continental Shelf Associates 1996; Dokken *et al*. 1999), diver-held video transects were recorded to establish a permanent record of visual observations at the study sites. Two transects were performed on each bank using identical techniques as in previous studies. A Hi-8 video camcorder in an underwater housing was “flown” across the bottom by a diver at an angle of approximately 45°. A target height of 2 m above bottom was maintained by using a weighted, 2 m plumb-line attached to the camera housing. This resulted in a transect width of 3.5 m on the videotape when viewed at the center of the television monitor. Each 100 m transect represented a total area of 350 m^2. The transect areas videoed at the EFGB site were the northern boundary line (from west to east) and the eastern boundary line (from north to south). At the WFGB site the transect areas were the southern boundary line (from east to west) and the western boundary line (from south to north).

In addition to the two 100 m boundary line transects at each bank, a 360° circular-view video was performed at each of six corner markers (three on each bank marking the ends of two adjacent boundary lines). Using the corner markers as a center point, the video camera was held nearly horizontal and low to the reef (dependent upon topography of reef) and panned slowly in a full circle. This technique was useful for observing detail and gross changes to the areas of the reef around each corner marker. Prior to performing the video transects, the transect lines were pulled tight between anchor points, to insure the best chance of obtaining transect data that matched previous efforts. No data analyses were performed on video transects; they were simply archived for future reference.

2.8 WATER QUALITY/INSOLATION/TEMPERATURE

2.8.1 Water Quality

Semi-Permeable Membrane Devices (SPMD) were deployed on both banks to monitor the presence of hydrocarbons and other analytes in the water column. The SPMDs were installed in special housings and anchored to the sea floor near the surface and mooring bolt. The SPMDs were sent to Environmental Sampling Technologies in St. Joseph, Missouri for dialyses. The Geochemical and Environmental Research Group (GERG) at Texas A&M University, College Station, performed the purification and analyses. Three sample sets were analyzed.

All SPMDs were dialyzed, and diasylates for each site were combined and evaporated to 2 ml or less, sealed in an ampule, and shipped to GERG. At GERG, the samples and field blanks were purified using gel permeation chromatography (HPLC with Phenogel) to remove triolein. The sample extracts and field blanks, as well as laboratory quality control samples (procedural blank, spike blank, and spike blank duplicate), were analyzed for pesticides/PCB or PAH by standard GERG procedures.

2.8.2 Insolation

Li Cor Data Loggers - Two underwater Li Cor spherical light sensors were used to monitor irradiance in the optimum photosynthetic wave lengths (photosynthetically active radiation, PAR) at the EFGB and WFGB. Both sensors were deployed at 23.8 m depth. A reference sensor was also deployed on the HI-389 oil and gas production platform to monitor sea-surface irradiance. All instruments were configured to record hourly averages in units of $\mu M\ s^{-1}\ m^2$. From 1997 through November 2001, data from the sensors were recorded in Li-1000 data loggers.

YSI Data Sondes and OSP Installation - On September 12-13, 2001, two semi-permanent platforms were installed with new water quality monitoring instruments at National Marine Sanctuary sites in the EFGB and WFGB (Figure 2.8.2.1). The installations, known as Ocean Sentinel Platforms or OSPs, were designed to provide a secure attachment point for monitoring instruments. The design for the OSPs employs eight angle-iron struts welded to a galvanized train wheel. The frame for the datalogger is stainless steel and includes TBT anti-fouling collars to protect the sensors and the light diffuser from bioaccumulation. Although not part of this contract, a third OSP was installed at Stetson Bank in support of NOAA's monitoring objectives.

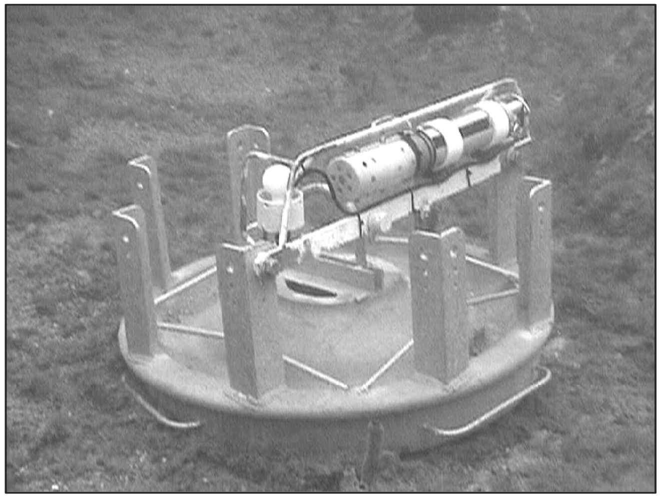


Figure 2.8.2.1. Ocean Sentinel Platform with YSI 6000 Data Sonde and light diffuser installed at the East and West Flower Garden Banks.

The first instrument installed was a YSI 6000 Data Sonde. The sonde logs data from sensors 30 minute intervals. The sensor suite installed in the sondes includes pressure (depth), temperature, salinity (conductivity), light in the range of PAR, dissolved oxygen, pH, and turbidity.

Estimating Light Attenuation - The attenuation coefficient for light transmission through water, *k*, is a parameter in the equation (1):

$$I_d = I_0\, e^{-kd} \quad (1)$$

where I_0 and I_d are light intensities at the surface and some depth, *d,* in meters (Parsons et al. 1984). Rearranging this equation (2),

$$ln(I_d/I_0)/-d = -k \quad (2)$$

it is possible to calculate the measured light attenuation in the water column at the two monitoring stations by comparing synoptic values to the reference sensor on the HI389 Platform. These estimates of -*k* were calculated from the accumulated daily irradiance at each sensor where full-day values were available for the reference and the underwater sensors.

The two underwater Li Cor sensors were set to record values during daylight hours by setting a minimum threshold value in the data logger configuration. All instruments were configured to record hourly averages in units of $\mu M\ s^{-1}m^{-2}$. Values were converted to $Mh^{1}m^{2}$. Data were recovered from the data loggers during the monitoring cruises in 1998 and 1999 (Appendix 2). Beginning in 1998, sensor units were fitted with TBT-impregnated collars to inhibit algae growth on sensor surfaces. Sensors units were recalibrated at least every year. Several sensors were found broken on recovery following a measurement interval, resulting in data loss and necessitated replacement with new sensors. Problems that resulted in data loss from the sensors are summarized in Appendix 2.

2.8.3 Temperature

Temperature readings were collected at each bank to detect relationships between temperature and biological changes at the FGB during the monitoring period. One HOBO-Temp recording thermograph (Onset Instruments, Pocasset, Massachusetts), sealed in a watertight container, was attached to a bottom structure near the light meters at each study site. Thermographs were set to record water temperature at 20-minute intervals. Temperature data was supplemented with Sea Surface Temperature (SST) data retrieved from data buoys (National Data Buoy Center No. 42019 located at 27^{o}92.0’ N, 95^{o} 35.0’ W).

2.9 SEA URCHIN SURVEYS

To monitor changes in sea urchin, *Diadema antillarium,* abundance, urchins were counted approximately 1.5 hours after sunset. Using the lines that marked the boundary of the study area as a belt transect, divers counted all sea urchins within 1 m of the lines. This resulted in 4 belt transects that encompassed an area of 100 m2 each. Because very few urchins were observed during any monitoring period, only descriptive data are presented.

3.0 RESULTS

3.1 RANDOM TRANSECTS

3.1.1 East Bank - Community Composition and Structure

Mean percent cover of the *Montastraea annularis* complex increased between 1996-2001 (Table 3.1.1.1). Total coral cover increased by 20% between the highest (2001) and lowest (1997) years. Some of the increases in mean estimates of both *Montastraea annularis* complex as well as total coral may be due to increasing numbers of transects, thus more of the coral cap within the study area was sampled. However when standard deviations (±1 SD) are examined there is a great deal of variability in cover estimates for *Montastraea annularis* complex (ranging from a low estimate of 7.1% in 1996 to a high estimate of 57.7% in 2001) as well as total coral cover. These increases also coincide with generally decreasing percentages of cover assigned to the unidentifiable category, suggesting that at least some of the increase may be due to better photographs that allowed for better and more reliable identification of *Montastraea annularis* complex in later years of the study. In fact, the increase in number of usable transects (transects were classified as unusable due to photographic insufficiencies such as under- or overexposure) through time reinforces this explanation.

Total algal cover was greatest in 1999 then fell in both 2000 and 2001. *Diploria strigosa* was also highest during 1999 and likewise declined in both 2000 and 2001. Although a minor component, cover of *Siderastrea* sp. was highest (1.8%) in 1996 and fell to less than 1% in all-successive years. Cover of the remaining coral species as well as sponges remained relatively stable throughout the monitoring period. Cover of reef rock was highest in 1998, the year before algal cover peaked, then declined.

Diversity and evenness declined from 1996-2001 as dominance increased reflecting increasing coverage by the *M. annularis* complex (Table 3.1.1.2). Although overall community similarity among years was approximately 70%, the rise in dominance by the *M. annularis* complex is seen in the dendrogram as the separate clustering of 2000-2001 (Figure 3.1.1.1).

3.1.2 East Bank – Comparisons Among Years

The ANOVA indicates there were significant differences among years for 5 of the 13 coral species as well as total coral, total algae and reef rock (Table 3.1.2.1). Three overlapping, homogenous subsets of years were delineated for the *M. annularis* complex. The primary difference was between the two years with highest cover, 2000 and 2001 and the two years with lowest cover, 1996 and 1997. Total coral, with four overlapping subsets, exhibits a similar pattern due to the dominance of the M. *annularis* complex in the community. Cover of other coral species tended to overlap greatly with primary differences between the years of highest and lowest cover. Algal cover in 1999 was significantly higher than all other years and cover in 2000-2001 was significantly greater than 1996-1998. Reef rock was significantly higher than other years in both 1998 and 1999.

Table 3.1.1.1.

Percent cover data[1] from 1996-2001 for the East Flower Garden Bank random transects.
Standard deviations are in parentheses.

Species	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Agaricia agaricites	0.4 (0.2)	0.5 (0.4)	0.4 (0.4)	0.2 (0.2)	0.2 (0.2)	0.4 (0.4)
Agaricia fragilis	0.005 (0.02)	0	0	0	0	0.1 (0.6)
Colpophyllia natans	0.8 (1.4)	0.8 (1.3)	2.1 (2.7)	3.6 (2.9)	2.6 (3.3)	2.6 (3.0)
Diploria strigosa	10.1 (7.1)	5.1 (4.4)	8.3 (3.7)	12.4 (6.0)	6.2 (2.8)	3.9 (4.1)
Montastraea annularis complex*	21.3 (14.2)	21.6 (8.1)	30.4 (11.1)	28.2 (11.7)	39.5 (9.6)	44.8 (12.9)
Montastraea cavernosa	3.7 (5.3)	4.7 (4.9)	3.5 (2.9)	2.4 (2.8)	4.8 (5.7)	3.6 (5.0)
Scolymia sp.	0.009 (0.01)	0.02 (0.02)	0.004 (0.008)	0.02 (0.02)	0.01 (0.02)	0.002 (0.009)
Stephanocoenia michilini	0.5 (0.9)	0.4 (0.6)	0.5 (0.9)	0.02 (0.09)	0.1 (0.2)	0.2 (0.5)
Mussa angulosa	0.1 (0.4)	0.02 (0.04)	0.1 (0.2)	0.08 (0.2)	0.2 (0.4)	0.06 (0.3)
Madracis sp.	0.4 (0.7)	0.8 (1.4)	0.6 (1.1)	0.3 (0.6)	0.8 (2.3)	0.2 (0.3)
Porites astreoides	3.6 (1.5)	5.3 (3.0)	4.2 (3.0)	3.4 (1.7)	2.6 (1.7)	4.6 (2.7)
Porites porites	0.005 (0.02)	0.1 (0.4)	0	0.005 (0.02)	0.04 (0.08)	0.03 (0.1)
Siderastrea sp.	1.8 (4.0)	0.2 (0.4)	0.2 (0.9)	0.6 (1.0)	0.03 (0.1)	0.2 (0.5)
Millepora sp.	0.9 (1.0)	1.9 (2.3)	1.3 (1.2)	1.6 (1.8)	1.3 (1.5)	0.9 (1.2)
Total Coral	**43.7 (12.0)**	**41.6 (8.3)**	**51.6 (8.3)**	**53.0(9.0)**	**58.3 (6.7)**	**61.8 (10.0)**
Filamentous algae					15.6 (4.9)	13.4 (5.8)
Crustose coralline algae					1.2 (0.8)	1.2 (0.5)
Dictyota sp.					0.5 (0.6)	0.2 (0.3)
Total Algae[2]	**6.1 (5.2)**	**0.5 (0.6)**	**3.2 (2.6)**	**24.7 (13.2)**	**17.3 (4.9)**	**14.9 (5.6)**
Total Sponge	**0.9 (1.0)**	**1.1 (1.7)**	**0.5 (0.9)**	**0.7 (0.9)**	**0.7 (0.8)**	**0.8 (1.0)**
Serpulidae					0.05 (0.04)	0.1 (0.09)
Other					0.03 (0.09)	0.09 (.2)
Reef rock[3]			**27.6 (5.9)**	**11.1 (8.2)**	**4.3 (1.7)**	**5.7 (3.6)**
Sand	**0.1 (0.2)**	**0.0**	**0.4 (1.0)**	**0.1 (0.3)**	**0.02 (0.07)**	**0.03 (0.1)**
Artifacts					1.4 (3.8)	0.3 (0.6)
No ID[3;4]	43.7 (12.0)	56.8 (8.2)	16.8 (2.8)	10.3 (12.3)	17.8 (4.6)	16.3 (3.9)
Number of transects	10	14	14	14	18	19

[*]*Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.
[1]Percent cover data for the synthesis report was calculated using total area sampled for each transect (see methods).
[2]Prior to 2000, algae were not separated into species or groups, so only total algal cover is available.
[3] In 1996 and 1997 only living coral was identified; this category contains reef rock, other, artifacts, serpulids and the unidentifiable portions of slides.
[4] In 1998 and 1999, serpulids, other, artifacts, and the unidentifiable portions of slides were grouped into this category.
[5]In 20002 and 2001, only the unidentifiable portions of slides (shadows, out of focus etc.) were grouped into this category.

Table 3.1.1.2.

Diversity (H', base 10), evenness (J'), dominance (Berger-Parker) of the coral community using average % cover by year on the East Flower Garden Bank.

	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Diversity	0.70	0.67	0.60	0.60	0.52	0.47
Evenness	0.65	0.61	0.58	0.55	0.46	0.42
Dominance	0.41	0.52	0.59	0.53	0.68	0.72

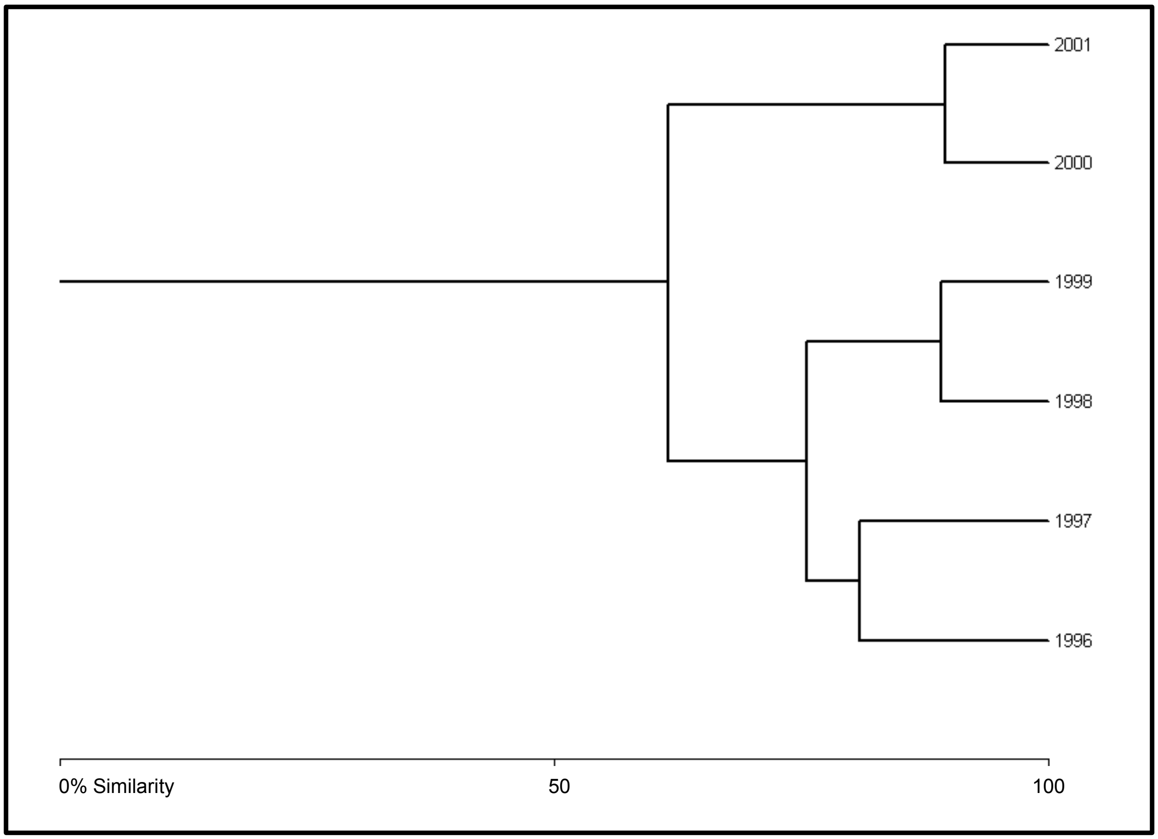


Figure 3.1.1.1. Bray-Curtis community similarity dendrogram for random transects from 1996-2001 for the East Flower Garden Bank.

Table 3.1.2.1.

Results of analysis of variance among years on reef components on the East Flower Garden Bank using % cover data. Data for all components except *Montastraea annularis* were arcsine transformed prior to analysis to normalize distribution.

Component	df	*F*	*p*	Homogenous Subsets
Montastraea annularis complex*	5, 83	10.949	0.0001	97 96 99 98 00 01
Agaricia agaricites	5, 83	3.148	0.0120	99 00 96 98 01 97
Colpophyllia natans	5, 83	2.306	0.0520	No homogenous subsets delineated
Diploria strigosa	5, 83	7.076	0.0001	01 97 00 98 96 99
Madracis sp.	5, 83	0.645	0.6660	No homogenous subsets delineated
Montastraea cavernosa	5, 83	0.538	0.7470	No homogenous subsets delineated
Millepora sp.	5, 83	0.795	0.5570	No homogenous subsets delineated
Mussa angulosa	5, 83	0.634	0.6750	No homogenous subsets delineated
Porites astreoides	5, 83	2.639	0.0290	00 99 96 98 01 97
Porites porites	5, 83	0.891	0.4910	No homogenous subsets delineated
Scolymia sp.	5, 83	2.653	0.0280	No homogenous subsets delineated
Siderastrea sp.	5, 83	2.526	0.0350	00 01 97 98 99 96
Sponge	5, 83	0.511	0.7670	No homogenous subsets delineated
Stephanocoenia mechelinii	5, 83	1.713	0.1410	No homogenous subsets delineated
Total coral	5, 83	11.415	0.0001	97 96 98 99 00 01
Total algae	5, 83	28.060	0.0001	97 98 96 01 00 99
Reef rock[1]	3, 61	64.760	0.0001	00 01 99 98

***Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.
[1] Was not a separate category until 1998.

There were significant negative correlations between cover of the *M. annularis* complex, reef rock and *D. strigosa* as well as between reef rock and total algal cover (Table 3.1.2.2). There were significant positive correlations between the *M. annularis* complex and total coral cover reflecting the increase of its cover and dominance in the coral community. In addition, there was a significant positive correlation between algal cover and total coral cover. Runs tests indicated no significant trends, only random variability in cover of any species or reef component (Table 3.1.2.3).

Table 3.1.2.2.

Non-parametric correlation (Spearman's rho, 2-tailed) between percent cover of major reef components of the East Flower Garden Bank. Ma = *Montastraea annularis* complex; Ds = *Diploria strigosa*; Mc = *Montastraea cavernosa*; TALG = total algae; RR = reef rock; TCOR = total coral. Bold indicates significant correlations.

		Ds	Mc	TALG	RR	TCOR
Ma	Correlation Coefficient	**-0.371**	**-0.209**	0.156	**-0.398**	**0.768**
	Sig. (2-tailed)	**0.0001**	**0.049**	0.1430	**0.0010**	**0.0001**
	N	**89**	**89**	89	**65**	**89**
Ds	Correlation Coefficient		0.053	0.050	0.196	0.016
	Sig. (2-tailed)		0.620	0.644	0.1180	0.881
	N		89	89	65	89
Mc	Correlation Coefficient			-0.038	0.007	0.083
	Sig. (2-tailed)			0.725	0.953	0.441
	N			89	89	89
TALG	Correlation Coefficient				**-0.291**	**0.227**
	Sig. (2-tailed)				**0.0180**	**0.032**
	N				**65**	**89**
RR	Correlation Coefficient					**-0.483**
	Sig. (2-tailed)					**0.0001**
	N					**65**

3.1.3 West Bank - Community Composition and Structure

Cover of the *Montastraea annularis* complex and total coral increased slightly between 1996-2001 (Table 3.1.3.1). Total algal cover increased dramatically between 1997 (lowest) and 2001 (highest). Although a minor component, cover of *Millepora* sp. was highest in 1997 and fell to less than 1% in each successive year. Also a minor component, *Siderastrea* sp. cover generally increased from 1996 to 2000 then dropped precipitously in 2001, the lowest value recorded. Cover of the remaining coral species as well as sponges remained relatively stable throughout the monitoring period. Cover of reef rock was highest in 1998 and 1999, declining by about 50% in each subsequent year.

Diversity was relatively stable between 1996 and 1999, increasing slightly in 2000 then decreasing to a low in 2001 (Table 3.1.3.2). Evenness and dominance were fairly stable throughout the study period. Overall community similarity was 85% (Figure 3.1.3.1). Year clusters corresponded to years of highest algal cover (1999-2001) and lowest algal cover (1996-1998).

Table 3.1.2.3.

Results of non-parametric runs test using median percent cover of coral species, total coral, algae, and sponge as the cutoff value for the East Flower Garden Bank.

Component	Cases	< mean	≥ mean	Runs	Z	Significance
Montastraea annularis complex*	9	4	5	4	-0.683	0.495
Agaricia agaricites	9	4	5	5	0.000	1.000
Colpophyllia natans	9	4	5	5	0.000	1.000
Diploria strigosa	9	4	5	5	0.000	1.000
Madracis sp.	9	4	5	6	0.040	0.968
Montastraea cavernosa	9	4	5	6	0.040	0.968
Millepora sp.	9	4	5	7	0.763	0.445
Mussa angulosa	9	3	6	6	0.408	0.683
Porites astreoides	9	4	5	5	0.000	1.000
Porites porites	9	4	5	4	-0.683	0.540
Scolymia sp.	9	4	5	3	-1.406	0.160
Siderastrea sp.	9	4	5	6	0.040	0.968
Sponge	9	4	5	8	1.486	0.137
Stephanocoenia mechelinii	9	4	5	4	-0.683	0.495
Total coral	9	4	5	4	-0.683	0.495
Total algae	9	4	5	5	0.000	1.000

[*] *Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

3.1.4 West Bank – Comparisons Among Years

Only one coral, *Madracis* sp. a minor component of the coral community, exhibited significant differences among years (Table 3.1.4.1). In 1999, the year when *Madracis* sp. cover was highest, was significantly higher than all other years except 2000. There were also significant differences among years in algae cover and reef rock with the delineated homogenous subsets representing the years of highest and lowest cover.

There were significant positive correlations between total coral cover and cover of the *M. annularis* complex, *D. strigosa*, and *M. cavernosa* (Table 3.1.4.2). Cover of reef rock was significantly negatively correlated with algal cover. Runs tests indicated no significant trends only random variation in deviations above or below median for any species or reef component (Table 3.1.4.3). Runs tests were not performed on reef rock since a minimum of five data points are necessary.

Table 3.1.3.1.

Percent cover data[1] from 1996-2001 for the West Flower Garden Bank random transects.
Standard deviations are in parentheses.

Species	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Agaricia agaricites	0.4 (0.9)	0.3 (0.3)	0.2 (0.2)	0.2 (0.2)	0.3 (0.2)	0.3 (0.2)
Agaricia fragilis	0	0	0	0	0.007 (0.03)	0.003 (0.01)
Colpophyllia natans	1.3 (1.8)	1.3 (1.6)	1.7 (2.7)	0.7 (1.7)	3.6 (4.3)	2.8 (2.7)
Diploria strigosa	7.9 (3.5)	9.1 (5.9)	9.6 (4.8)	10.9 (7.8)	8.1 (6.7	9.5 (5.8)
Montastraea annularis complex*	27.2 (8.3)	27.7 (9.9)	28.4 (11.9)	31.7 (8.6)	30.9 (11.6)	35.1 (12.0)
Montastraea cavernosa	1.5 (2.2)	4.3 (4.2)	2.6 (2.4)	2.4 (3.5)	5.8 (11.7)	2.1 (3.7)
Scolymia sp.	0.02 (0.03)	0.02 (0.02)	0.007 (0.02)	0.003 (0.02)	0.01 (0.02)	0.003 (0.009)
Stephanocoenia mechelinii	0.9 (2.1)	0.5 (1.3)	0.6 (1.1)	0.01 (0.04)	0.9 (0.9)	0.3 (0.6)
Mussa angulosa	0.06 (0.1)	0.1 (0.1)	0.07 (0.1)	0.2 (0.4)	0.3 (0.6)	0.07 (0.2)
Madracis sp.	0.08 (0.2)	0.1 (0.2)	0.03 (0.07)	0.5 (0.6)	0.2 (0.4)	0.06 (0.1)
Porites astreoides	2.5 (1.4)	2.7 (2.3)	2.4 (2.0)	2.7 (1.9)	2.5 (1.6)	2.0 (0.9)
Porites porites	0	0	0	0	0.1 (0.6)	0.003 (0.01)
Siderastrea sp.	0.1 (0.4)	0.2 (0.3)	1.7 (5.8)	1.4 (4.5)	2.0 (4.0)	0.002 (0.009)
Millepora sp.	1.9 (4.8)	1.5 (2.0)	0.7 (1.1)	0.8 (0.8)	0.7 (0.8)	0.7 (0.9)
Total Coral	**46.5 (12.3)**	**47.9 (13.9)**	**48.5 (12.7)**	**51.5 (8.1)**	**51.6 (13.7)**	**53.1 (11.4)**
Filamentous algae					16.4 (9.1)	22.4 (6.8)
Crustose Coralline algae					2.3 (0.8)	5.2 (2.9)
Dictyota sp.					0.09 (0.4)	0.02 (0.05)
Total Algae[2]	**4.5 (2.9)**	**0.1 (0.1)**	**2.3 (1.3)**	**18.8 (6.2)**	**22.6 (14.0)**	**25.4 (7.3)**
Total Sponge	**1.0 (1.0)**	**0.9 (1.3)**	**0.6 (0.6)**	**0.6 (0.7)**	**0.6 (0.8)**	**1.0 (1.1)**
Serpulidae					0.04 (0.06)	0.09 (0.3)
Other					0.009 (0.03)	0.3 (0.6)
Reef rock[3]			20.7 (11.2)	21.1 (9.8)	8.5 (3.7)	4.6 (2.9)
Sand	0.0	0.0	0.0	1.3 (3.3)	0.9 (2.1)	0.1 (0.2)
Artifacts					0.3 (0.6)	0.2 (0.5)
No ID[3; 4]	51.7 (9.5)	47.9 (13.9)	28.4 (15.9)	6.7 (1.8)	14.3 (4.7)	15.1 (3.5)
Number of transects	15	13	14	13	16	16

[*]Montastraea annularis complex is comprised of *M. annularis, faveolata*, and *franksi*.
[1]Percent Cover Data for the synthesis report was calculated using total area sampled for each transect (see methods).
[2]Prior to 2000, algae were not separated into species or groups, so only total algal cover is available.
[3] In 1996 and 1997 only living coral was identified; this category contains reef rock, other, artifacts, serpulids and the unidentifiable portions of slides.
[4]In 1998 and 1999, serpulids, other, artifacts, and the unidentifiable portions of slides were grouped into this category.
[5]In 20002 and 2001, only the unidentifiable portions of slides (shadows, out of focus etc.) were grouped into this category.

Table 3.1.3.2.

Diversity (H', base 10), evenness (J'), dominance (Berger-Parker) of the coral community using average % cover by year West Flower Garden Bank.

	1996	1997	1998	1999	2000	2001
Diversity	0.56	0.60	0.58	0.54	0.64	0.49
Evenness	0.52	0.55	0.53	0.50	0.56	0.49
Dominance	0.62	0.58	0.59	0.61	0.56	0.66

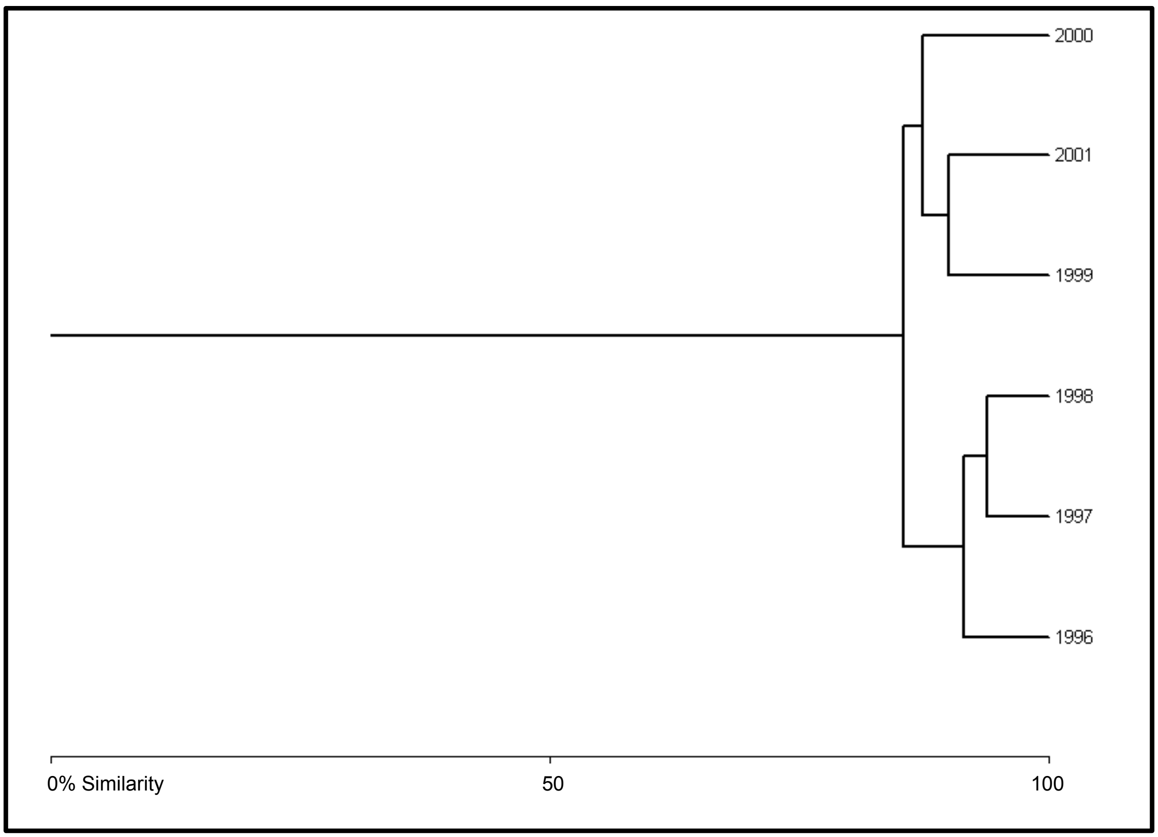


Figure 3.1.3.1. Bray-Curtis community similarity dendrogram for random transects from 1996-2001 for the West Flower Garden Bank.

Table 3.1.4.1.

Results of one-way analysis of variance and Tukey's HSD among years on reef components on the West Flower Garden Bank using % cover data. Data for all components except *Montastraea annularis*, *Diploria strigosa*, total coral and algae were arcsine transformed prior to analysis to normalize distributions.

Component	**df**	***F***	***p***	**Homogenous Subsets**
Montastraea annularis complex*	5, 81	1.222	0.7870	No homogenous subsets delineated
Agaricia agaricites	5, 81	0.748	0.5900	No homogenous subsets delineated
Colpophyllia natans	5, 81	2.356	0.0480	No homogenous subsets delineated
Diploria strigosa	5, 81	0.485	0.7870	No homogenous subsets delineated
Madracis sp.	5, 81	4.104	0.0030	98 01 96 97 00 99
Montastraea cavernosa	5, 81	1.165	0.3340	No homogenous subsets delineated
Millepora sp.	5, 81	0.825	0.5360	No homogenous subsets delineated
Mussa angulosa	5, 81	1.095	0.3700	No homogenous subsets delineated
Porites astreoides	5, 81	0.328	0.8950	No homogenous subsets delineated
Porites porites	5, 81	0.914	0.4770	No homogenous subsets delineated
Scolymia sp.	5, 81	1.872	0.1080	No homogenous subsets delineated
Siderastrea sp.	5, 81	1.025	0.4090	No homogenous subsets delineated
Sponge	5, 81	0.617	0.6870	No homogenous subsets delineated
Stephanocoenia mechelinii	5, 81	1.067	0.3850	No homogenous subsets delineated
Total coral	5, 81	0.666	0.6500	No homogenous subsets delineated
Total algae	5, 81	34.439	0.0001	97 98 96 99 00 01
Reef rock[1]	3, 55	18.300	0.0001	01 00 98 99

**Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.
[1]Was not a separate category until 1998.

Table 3.1.4.2.

Non-parametric correlation (Spearman's rho, 2-tailed) between % cover of major reef components of the West Flower Garden Bank. Ma = *Montastraea annularis* complex; Ds = *Diploria strigosa*; Mc = *Montastraea cavernosa*; TALG = total algae; RR = Reef rock; TCOR = total coral. Bold indicates significant correlations.

		Ds	Mc	TALG	RR	TCOR
Ma	Correlation Coefficient	-0.116	-0.121	0.067	-0.091	**0.677**
	Sig. (2-tailed)	0.2870	0.2650	0.5340	0.4930	**0.0001**
	N	87	87	87	59	**87**
Ds	Correlation Coefficient		-0.086	-0.032	-0.103	**0.304**
	Sig. (2-tailed)		0.4280	0.7660	0.4370	**0.0040**
	N		87	87	59	**87**
Mc	Correlation Coefficient			-0.133	0.035	**0.229**
	Sig. (2-tailed)			0.2190	0.7950	**0.0330**
	N			87	59	**87**
TALG	Correlation Coefficient				**-0.438**	0.044
	Sig. (2-tailed)				**0.0010**	0.6850
	N				**87**	87
RR	Correlation Coefficient					-0.217
	Sig. (2-tailed)					0.0980
	N					59

Table 3.1.4.3.

Results of non-parametric runs test using median percent cover of coral species, total coral, algae, sponge and reef rock as the cutoff value for the West Flower Garden Bank.

Component	Cases	> mean	≤ mean	Runs	Z[1]	Significance
Montastraea annularis complex*	9	4	5	4	-0.683	0.4950
Agaricia agaricites	9	4	5	3	-1.406	0.1600
Colpophyllia natans	9	4	5	4	0.000	1.000
Diploria strigosa	9	4	5	6	0.040	0.9680
Madracis sp.	9	4	5	4	-0.683	0.4950
Montastraea cavernosa	9	4	5	5	0.000	1.000
Millepora sp.	9	3	6	4	-0.408	0.6830
Mussa angulosa	9	3	6	6	0.408	0.6830
Porites astreoides	9	4	5	7	0.763	0.4450
Scolymia sp.	9	4	5	3	-1.406	0.1600
Siderastrea sp.	9	4	5	6	0.040	0.968
Sponge	9	4	5	5	0.000	1.0000
Stephanocoenia mechelinii	9	4	5	8	1.486	0.1370
Total coral	9	4	5	4	-0.683	0.4950
Total algae	9	4	5	5	0.000	1.0000

[1] Non-parametric equivalent of the F statistic, i.e. distribution of data along a bell curve
***Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

3.2 SCLEROCHRONOLOGY

3.2.1 East Bank

Two cores of *Montastraea faveolata* were taken from the EFGB in 2001 (Figure 3.2.1.1). Estimated growth (mm/year) of *M. faveolata* ranged from 5.05 – 11.19 mm, with an overall mean of 7.50 mm ±1.02 (1 SD). Lowest overall mean growth occurred in 1986 and highest occurred in 2000 (Table 3.2.1.1.). The nonparametric runs test on median annual growth was not significant (median = 7.45; n= 16; cases < median = 8; cases $\geq$ median = 8; runs = 8; Z = -0.259; asymptotic significance [2-tailed] = 0.796) indicating that there was no systematic or cyclic variability occurring in the values; variability in growth rates appears to be occurring randomly.

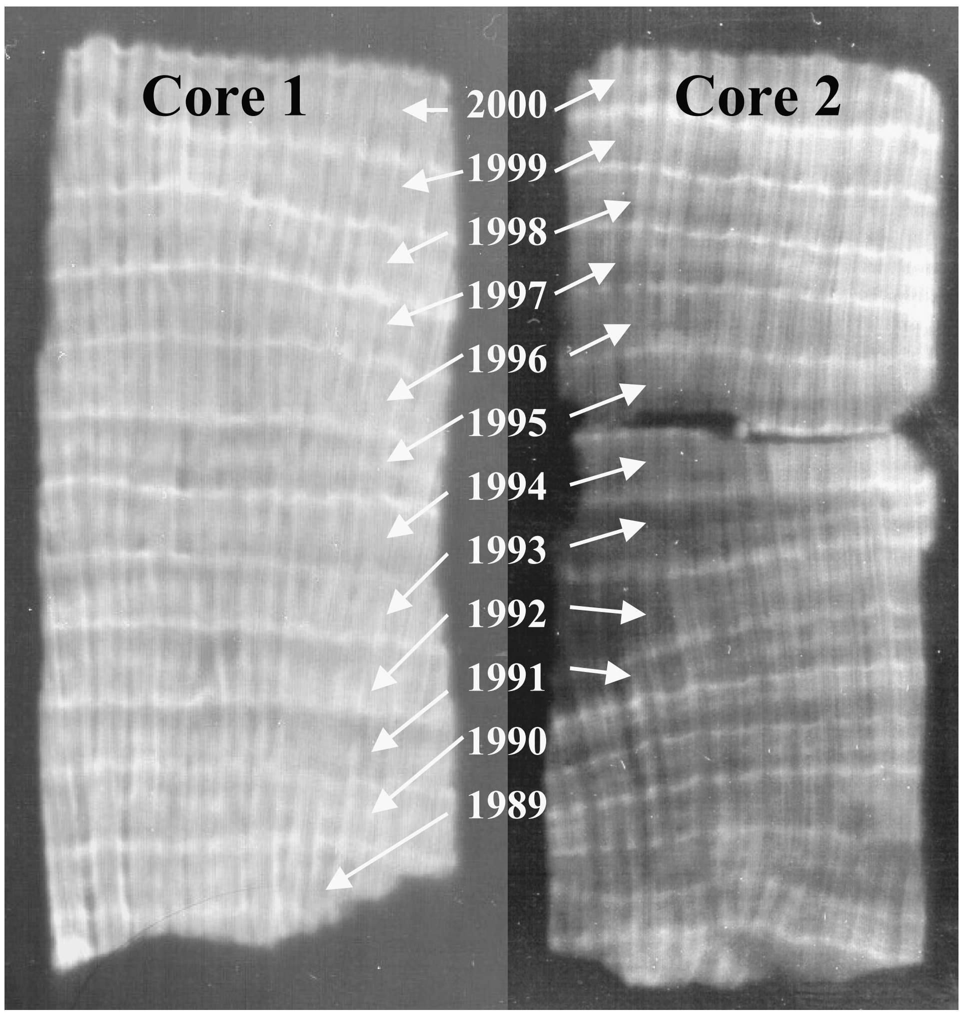


Figure 3.2.1.1. X-ray images of two coral cores taken at the East Flower Garden Bank, September 2001 (uppermost layer of core includes some growth from collection year).

Table 3.2.1.1.

Mean annual growth (mm) with standard deviation for 1985 to 2001 determined from measurements of accretionary growth bands in cores from *Montastraea faveolata*, East Flower Garden Bank. Mean and SD were calculated from three measurements of each set of high and low density bands in each core; overall growth rate was calculated from the means of all data.

Coral Core Years Marked on X-rays	**Years Coral Cores Taken**			**Overall**
	2001		**1999**	
	Core 1	**Core 2**	**Core 1**	
1985			6.25 (0.58)	6.25 (0.58)
1986			6.12 (0.61)	6.12 (0.61)
1987			7.40 (0.20)	7.40 (0.20)
1988			7.36 (0.67)	7.36 (0.67)
1989	7.56 (0.16)		7.84 (0.13)	7.70 (0.21)
1990	7.84 (0.86)		5.32 (0.23)	6.58 (1.49)
1991	7.67 (0.35)	7.97 (0.70)	7.00 (0.23)	7.55 (0.60)
1992	8.51 (0.42)	9.92 (1.13)	5.76 (0.28)	8.06 (1.93)
1993	7.44 (0.25)	8.13 (0.81)	7.58 (0.48)	7.72 (0.58)
1994	7.85 (0.67)	7.82 (0.41)	6.38 (0.40)	7.40 (0.85)
1995	7.55 (0.47)	8.90 (0.96)	7.54 (0.99)	8.05 (1.03)
1996	8.46 (0.39)	7.92 (0.47)	6.13 (0.68)	7.50 (1.14)
1997	7.84 (0.59)	6.95 (0.64)	6.64 (0.54)	7.14 (0.74)
1998	7.95 (0.70)	7.62 (0.23)	6.45 (0.41)	7.34 (0.80)
1999	7.78 (0.35)	7.31 (0.32)	8.20 (0.89)	7.76 (0.63)
2000	8.28 (0.98)	8.18 (0.44)		8.23 (0.68)

3.2.2 West Bank

The two cores taken at the WFGB during the 2001 monitoring cruise were unusable due to burrowing mollusc holes throughout both cores. In April 2002, another core was taken at the WFGB that was usable (Figure 3.2.2.1). Estimated growth (mm/year) of *Montastraea faveolata* ranged from 3.88 – 8.01 mm, with an overall mean of 5.37 mm ± 0.79 (1 SD). Lowest overall mean growth was in 1986 and highest was in 2000 (Table 3.2.2.1). The nonparametric runs test on median annual growth (mm) was not significant (median = 5.29; n= 15; cases < median = 7; cases ≥ median = 8; runs = 6; Z = -1.059; asymptotic significance [2-tailed] = 0.290) indicating that variability in growth rates is random with no systematic or cyclic pattern of variability.

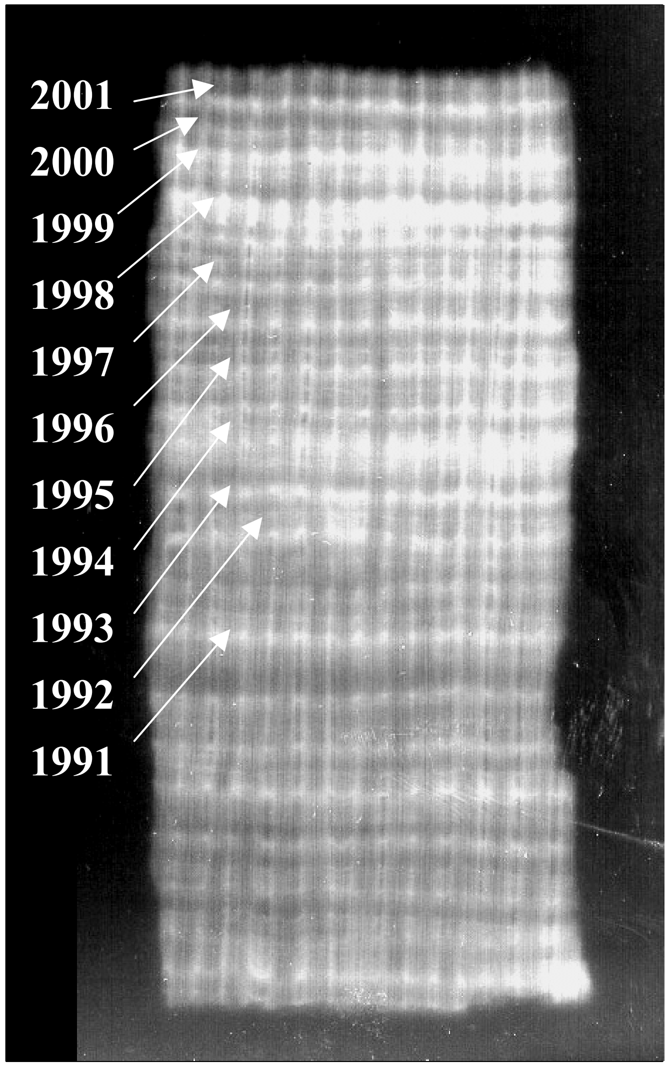


Figure 3.2.2.1. X-ray image of the coral core taken at the West Flower Garden Bank, April 2002 (uppermost layer of core includes some growth from collection year).

Table 3.2.2.1.

Mean annual growth (mm) with standard deviation for 1985 to 2001 determined from measurements of accretionary growth bands in cores from *Montastraea faveolata*, West Flower Garden Bank. Mean and SD were calculated from three measurements of each set of high and low density bands in each core; overall growth rate was calculated from the means of all data.

Coral Core Years Marked on X-rays	**Years Coral Cores Taken**		**Overall**
	Core 1	**Core 1**	
	1999	**2002**	
1985	5.43 (0.44)		5.43 (0.44)
1986	4.60 (0.28)		4.60 (0.28)
1987	5.37 (0.05)		5.37 (0.05)
1988	4.99 (0.20)		4.99 (0.20)
1989	4.80 (0.40)		4.80 (0.40)
1990	4.49 (0.75)		4.49 (0.75)
1991	5.94 (0.47)	5.68 (0.55)	5.80 (0.48)
1992	5.01 (0.24)	5.56 (0.43)	5.29 (0.43)
1993	5.56 (0.33)	4.83 (0.10)	5.19 (0.45)
1994	4.73 (0.75)	5.11 (0.51)	4.92 (0.61)
1995	4.89 (0.78)	5.34 (0.26)	5.11 (0.58)
1996	5.18 (0.54)	5.68 (0.26)	5.43 (0.47)
1997	5.98 (0.72)	4.77 (0.34)	5.37 (0.83)
1998	5.36 (0.42)	7.61 (0.43)	6.49 (1.29)
1999	4.63 (0.09)	6.41 (0.10)	5.52 (0.98)
2000		6.64 (0.17)	6.64 (0.17)
2001		4.94 (0.00)	4.94 (0.00)

3.3 ENCRUSTING GROWTH STATIONS

Throughout the 1998-2001 monitoring period, a large number of encrusting growth stations had become unsuitable for analysis either by loss of pins or advance or retreat of the coral margin beyond the area of the close-up camera frame. New stations were established to replace those no longer useable. Subsequently, this caused a reduced number of stations that could be compared from year to year for coral growth. This reduction is particularly noticeable in the 2000-2001 data, in which 13 (EFGB) and 25 (WFGB) stations are compared in 2000 and 29 (EFGB) and 24 (WFGB) stations are compared in 2001.

There was a high degree of variability between advance/retreat percentages among years for both the EFGB and WFGB (Table 3.3.0.1,). At EFGB, there appeared to be a net loss of *Diploria strigosa* from 1998-2000. Growth and loss were approximately equal during 2001. Net loss was also noted at EFGB during 1998-1999 but net gains were noted during 2000-2001 (Figure 3.3.0.1). Additionally, there was a net overall gain at WFGB (Figure 3.3.0.2). Although some of these changes accurately assess growth and retreat of coral tissue, a more likely explanation for the differences is camera positioning at each station from year to year. Due to pin loss, breakage, etc., some stations had only one pin for camera placement making it difficult to replicate the same picture year after year. However, the technique has become better over the years, which is reflected in the lower and more similar percentages of growth and retreat at each bank in 2000 and 2001. Appendix 2 shows the data for each station for each year and its respective coral coverage.

Table 3.3.0.1.

Number of encrusting growth stations of *Diploria strigosa* and average gain (+), loss (−), or no change (=) in percent cover of coral tissue at the East and West Flower Garden Banks, 1998-2001.

EFGB		**WFGB**	
# of Changes	**% cover**	**# of Changes**	**% cover**
1998		**1998**	
21	(+) 9.55%	19	(+) 14.07%
14	(−) 27.41%	14	(−) 18.42%
11	(=) 1.27%	6	(=) 0.26%
1999		**1999**	
27	(+) 13.59%	17	(+) 17.38%
12	(−) 29.51%	22	(−) 24.52%
11	(=) 0.85%	8	(=) 0.46%
2000		**2000**	
5	(+) 10.55%	9	(+) 5.49%
3	(−) 13.95%	10	(−) 1.89%
5	(=) 0.37%	6	(=) 0.35%
2001		**2001**	
6	(+) 7.72%	14	(+) 10.93%
11	(−) 7.78%	4	(−) 3.36%
12	(=) 0.25%	6	(=) 0.12%

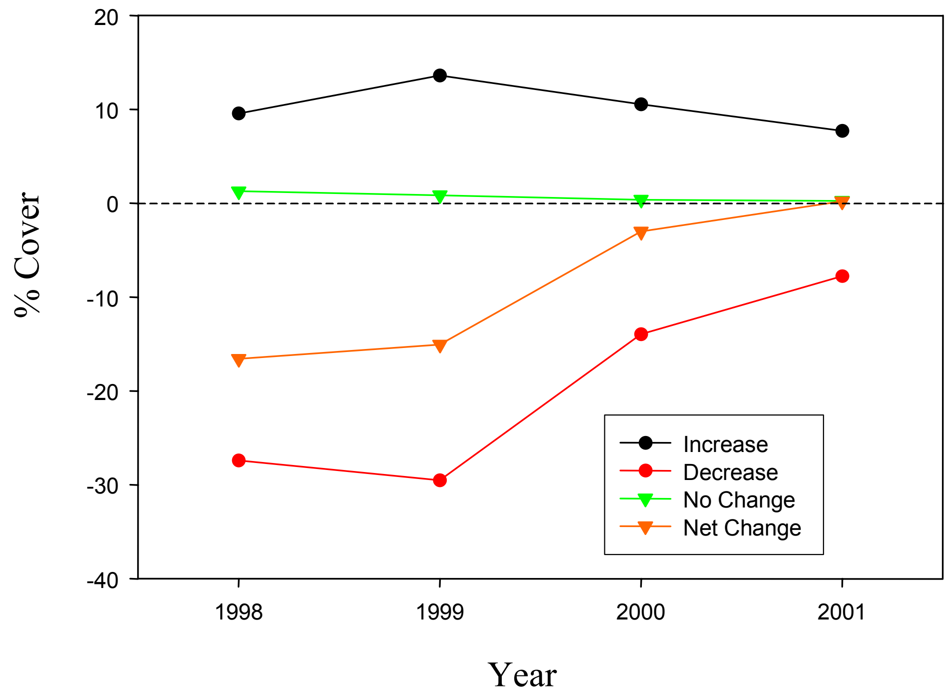


Figure 3.3.0.1. Encrusting growth station percent cover changes for the East Flower Garden Bank from 1998-2001.

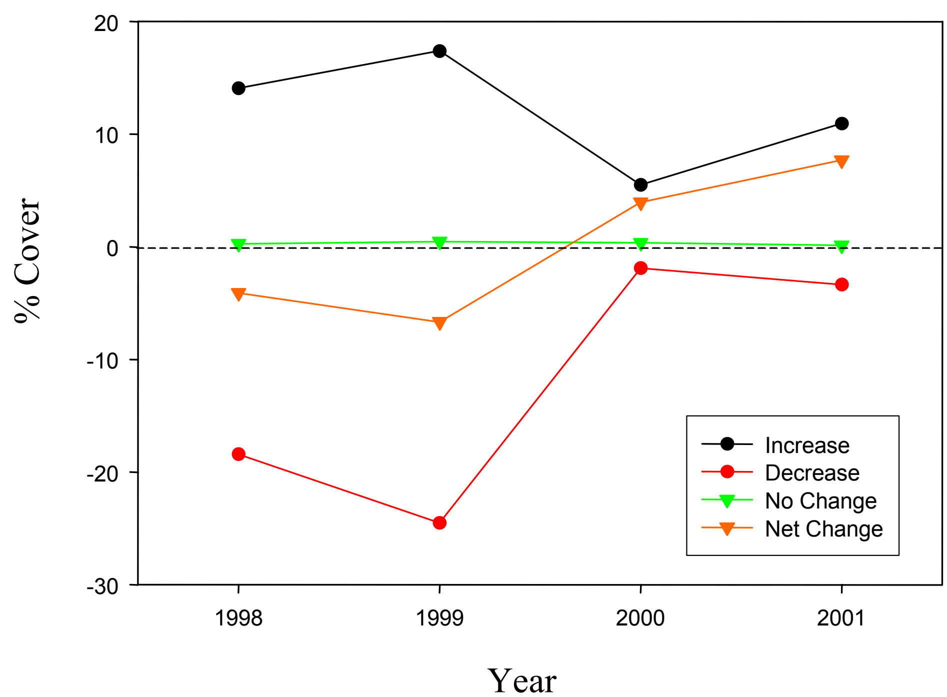


Figure 3.3.0.2. Encrusting growth station percent cover changes for the West Flower Garden Bank from 1998-2001.

3.4 REPETITIVE QUADRATS

3.4.1 East Bank – Species Composition and Cover

In general, the species composition and percent cover of the coral community in the 8 m^2 repetitive quadrats is similar to that found in the analysis of the random inside transects at EFGB (Table 3.4.1.1). Overall, mean coral cover was about 7% lower than the inside random transects in 2000 and 10% in 2001; mean cover of the *Montastraea annularis* complex was also 2-7% lower. *Diploria strigosa* mean cover was higher than the inside transects in both years. The mean cover of the remaining species was somewhat lower than that found in the inside transects, and four uncommon species, *Agaricia agaricites*, *A. fragilis*, *Scolymia* sp., and *Siderastrea* sp., were not found in the analysis of the 8 m^2 repetitive quadrats. These differences are likely due to the differences in photographic analysis techniques (point counts vs determination of actual areal coverage) and differences in photographic resolution (8 m^2 vs 0.28 m^2) rather than any substantial differences in the coral communities. All analyzed species fell within the same range of cover based on ± 1 SD. Because of the differences in photographic analysis methods and the fact that percent cover data for repetitive quadrats were only collected during 2000-2001, no statistical comparisons between cover estimates from repetitive quadrat data and random transects were made.

Table 3.4.1.1.

Mean percent cover of coral species and total coral with standard deviation in 8 m^2 repetitive quadrats at the East Flower Garden Bank, 2000-2001[1]. Twenty-six stations were photographed in 2000; 32 stations were photographed in 2001.

Species	2000	2001
Montastraea annularis complex*	37.5 (16.8)	37.0 (17.8)
Montastraea cavernosa	3.0 (4.7)	2.8 (5.0)
Diploria strigosa	7.3 (8.8)	6.3 (7.6)
Colpophyllia natans	1.9 (3.4)	2.9 (4.1)
Porites astreoides	2.2 (2.1)	1.7 (1.9)
Stephanocoenia mechelinii	0.04 (0.2)	0.03 (0.1)
Mussa angulosa	0.03 (0.1)	0.0
Millepora sp.	0.8 (1.5)	0.8 (1.0)
Madracis sp.	0.2 (0.6)	0.3 (1.0)
Porites porites	0.04 (0.1)	0.1 (0.4)
Total Coral	53.1 (13.2)	51.6 (15.3)

[1] Percent cover can only be calculated for 2000-2001 data.
**Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

Mean percentages of points falling on areas of paling (the possible precursor of bleaching; Kleppel *et al.* 1989), bleaching, disease, and retreat per station were essentially stable between 2000-2001 (Table 3.4.1.2). The maximum percentage of points falling on areas of bleaching without mortality was stable, but declined on areas of bleaching followed by mortality. Frequency of samples exhibiting paling increased slightly from 2000 to 2001; frequency of bleaching with or without mortality declined during the same period. The total percentage of colonies exhibiting bleaching increased from 2000 to 2001 (Table 3.4.1.3), and most species exhibited slightly increased percentages of bleached colonies. However, the majority of the overall increase appears to be due to bleaching of substantially greater numbers of *Millepora* sp. colonies.

Table 3.4.1.2.

Mean percentage of points falling on areas of bleaching, disease, etc. by station with standard deviation, maximum percentage for all stations and frequency (%) of occurrence for 8 m^2 repetitive quadrats at the East Flower Garden Bank. 2000 – based on 26 stations and 1551 colonies. 2001 – based on 32 stations and 1581 colonies.

Observation	**Mean percent/station (SD)**		**Maximum percent/any station**		**Frequency of occurrence**	
	2000	**2001**	**2000**	**2001**	**2000**	**2001**
Paling	1.2 (2.0)	1.3 (1.5)	31	42	61.5	68.7
Bleaching followed by mortality	1.2 (3.4)	0.3 (0.9)	31	10	34.6	21.9
Bleaching not followed by mortality	0.5 (1.0)	0.4 (0.8)	14	14	46.2	37.5
Disease followed by mortality	0.0	0.02 (0.1)	0	1	0	3.1
Disease not followed by mortality	0.0	0.0	0	0	0	0
Algal-replacement	1.4 (1.6)	1.2 (2.4)	36	40	80.8	68.7
Sediment-replacement	0.1 (0.3)	0.07 (0.2)	4	2	19.2	12.5
Algal/sediment- replacement	0.2 (0.4)	0.1 (0.3)	5	3	26.9	15.6
Tissue loss due to competition	0.0	0.0	0	0	0	0
Tissue loss due to fish biting	0.0	0.0	0	0	0	0
Unexplained tissue loss	0.7 (1.3)	0.9 (1.2)	20	30	65.4	68.7
Growth-infilling	0.2 (0.5)	0.2 (0.3)	6	6	23.1	31.2
Growth-marginal	0.7 (1.0)	1.0 (1.0)	18	31	69.2	81.2
New disease	0.05 (0.3)	0.05 (0.3)	1	2	3.8	3.1

Table 3.4.1.3.

Percentage of colonies exhibiting bleaching[1] by species at the East Flower Garden Bank for 2000-2001.

Species	**2000**	**2001**
Montastraea annularis complex*	1.1	1.5
Montastraea cavernosa	0.0	0.2
Diploria strigosa	0.8	1.1
Colpophyllia natans	0.06	0.2
Porites astreoides	0.06	0.2
Stephanocoenia mechelinii	0.0	0.06
Mussa	0.0	0.06
Millepora sp.	0.4	1.1
Madracis sp.	0.06	0.2
Total percent	2.6	4.4
Total colonies	1551	1581

[1] Data from which percentages could be calculated was only collected in 2000-2001.
[*] *Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

Very little disease was noted, and only one point fell on an area of mortality due to disease. Only 1 or 2 points fell on areas exhibiting new disease (Table 3.4.1.4). There was no loss of tissue due to competition or fish biting; however, the percentage of points falling on areas of unexplained tissue loss increased. The mean percentage of points falling on areas of algal replacement per station declined slightly whereas the maximum percentage increased by 4% from 2000 to 2001. However, frequency of algal-replacement declined substantially. Sediment-replacement and , algal/sediment-replacement both declined.

Table 3.4.1.4.

Overall percentage of points falling on areas of colonies exhibiting bleaching, disease, etc. at the East Flower Garden Banks, 1998-2001.

Observation	1998	1999	2000	2001
Paling[1]	N/A	N/A	1.2	1.3
Bleaching followed by mortality	0.0	0.1	1.2	0.3
Bleaching not followed by mortality	0.02	0.06	0.5	0.4
Disease followed by mortality	0.0	0.0	0.0	0.03
Disease not followed by mortality	0.0	0.03	0.0	0.0
Algal- replacement	2.3	1.4	1.4	1.2
Sediment- replacement	0.8	0.3	0.1	0.06
Algal/sediment- replacement	0.06	0.1	0.2	0.09
Tissue loss due to competition	0.03	0.0	0.0	0.0
Tissue loss due to fish biting	0.0	0.0	0.0	0.0
Unexplained tissue loss	0.3	0.7	0.8	0.9
Growth-infilling	0.3	0.5	0.2	0.2
Growth-marginal	4.5	2.3	0.7	1.0
New disease[1]	N/A	N/A	0.03	0.06
Overall growth	4.8	2.8	0.9	1.2
Overall retreat, mortality & tissue loss	3.5	2.6	3.7	2.6
Approximate Growth:Loss Ratio	5:3	1:1	1:4	1:3
Number of stations	33	33	26	32

[1] These categories were added in 2000.

Infilling growth was stable during the 2000-2001 monitoring period but marginal growth increased in 2001 (Table 3.4.1.4). The majority of stations contained corals that exhibited growth during this monitoring period. Overall, there were greater percentages of tissue loss or retreat than growth in both years of the most recent monitoring period (Table 3.4.1.4). During 1998-2001, the overall percentage of points falling on areas of tissue loss and/or retreat as well as rates of loss remained relatively stable, but the percentage of points falling on areas of growth declined. Growth/loss ratios suggest a slowing of growth processes from 1998 to 1999, and increase in loss processes in 2000. Loss appeared to slow in 2001, but was still greater than growth.

3.4.2 West Bank – Species Composition and Cover

The species composition and percent cover of the coral community in the 8 m^2 repetitive quadrats is generally the same as that found in analysis of random inside transects (Table 3.4.2.1). Although estimates of total coral cover and the cover of most species is lower than the random inside transects, these differences are likely due to differences in photographic analysis rather than substantial differences in the coral community. All analyzed species fell within the same range of cover based on ±1 SD. Four uncommon species, *Agaricia agaricites*, *A. fragilis*, *Porites porites,* and *Scolymia* sp., found in the inside random transects, were not found in the 8 m^2 quadrats. Because of the differences in photographic analysis methods and the fact that percent cover data for repetitive quadrats were only collected during 2000-2001, no statistical comparisons between cover estimates from repetitive quadrat data and random transects were done.

Table 3.4.2.1.

Mean percent cover of coral species and total coral with standard deviation in 8 m^2 repetitive quadrats at the West Flower Garden Bank, 2000-2001. Thirty-one stations were photographed in 2000; 36 stations were photographed in 2001.

Species	2000	2001
Montastraea annularis complex*	32.3 (13.2)	31.3 (13.0)
Montastraea cavernosa	3.9 (6.7)	3.8 (7.1)
Diploria strigosa	6.4 (5.8)	6.2 (5.7)
Colpophyllia natans	1.5 (2.2)	1.8 (3.0)
Porites astreoides	2.2 (2.1)	2.6 (2.0)
Stephanocoenia mechelinii	0.3 (1.0)	0.4 (1.1)
Mussa angulosa	0.06 (0.1)	0.1 (0.3)
Millepora sp.	0.8 (1.0)	1.1 (1.3)
Madracis sp.	0.1 (0.3)	0.1 (0.6)
Siderastrea siderea	1.0 (4.1)	0.9 (3.6)
Total Coral	50.0 (9.6)	48.3 (10.2)

[1] Data from which percent cover can be calculated was only collected in 2000-2001.
**Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

Mean percentages of points that fell on areas of bleaching followed by mortality, disease followed by mortality, algal-replacement retreat, sediment- replacement retreat, tissue loss due to competition, unexplained tissue loss, and new disease per station were essentially stable between 2000-2001 (Table 3.4.2.2). Mean percentage of points falling on areas of bleaching without mortality per station declined substantially as did the frequency at which it occurred. Percentage of points falling on areas of all the remaining categories increased, although only slightly for most. Frequency of bleaching followed by mortality, algal-replacement retreat, algal/sediment replacement retreat, and tissue loss due to competition increased substantially; frequency of unexplained tissue loss nearly doubled. Mean percentage of points falling on areas of paling as well as its frequency, increased fairly dramatically. The total percentage of colonies exhibiting bleaching doubled between 2000-2001, with all species except *Colpophyllia natans* and *Mussa angulosa* contributing to the increase (Table 3.4.2.3).

Very little disease was noted with only one point falling on an area of mortality due to disease in 2001 (Table 3.4.2.2). Although the mean percentage of points falling on areas of new disease was stable during the monitoring period, the frequency at which it occurred nearly doubled.

Infilling growth increased during the 2000-2001 monitoring period and marginal growth was stable (Table 3.4.2.2). Most stations contained corals that exhibited growth during the most recent monitoring period. However, tissue loss was still greater than growth in both years (Table 3.42.4). From 1998 to 2000, the overall percentage of points falling on areas of tissue loss and/or retreat declined, with a small increase in 2001; the percentage of points falling on areas of growth has declined substantially since 1998. Growth/loss ratios suggest a slowing of growth from 1998-1999, near equivalence of these processes during 1999 and 2000 and increasing loss processes in 2001.

Table 3.4.2.2.

Mean percentage of points falling on areas of bleaching, disease, etc. by station with standard deviation, maximum percentage for all stations and frequency (%) of occurrence for 8 m^2 repetitive quadrats at the West Flower Garden Bank. 2000 – based on 34 stations and 1627 colonies. 2001 – based on 33 stations and 1591 colonies

Observation	Mean percent/station (SD)		Maximum percent/ any station		Frequency of occurrence	
	2000	2001	2000	2001	2000	2001
Paling	0.3 (0.5)	0.8 (2.4)	2	13	32.3	39.4
Bleaching followed by mortality	0.05 (0.2)	0.07 (0.2)	1	1	2.9	12.1
Bleaching not followed by mortality	1.3 (2.2)	0.3 (0.6)	11	1	52.9	27.3
Disease followed by mortality	0.0	0.04 (0.2)	0	1	0	3.0
Disease not followed by mortality	0.02 (0.1)	0.0	1	0	2.9	0
Algal- replacement	0.5 (0.1)	0.8 (1.0)	3	3	55.9	66.7
Sediment- replacement	0.08 (0.3)	0.06 (0.2)	2	1	8.8	9.1
Algal/sediment- replacement	0.03 (0.2)	0.2 (0.6)	1	2	2.9	15.1
Tissue loss due to competition	0.03 (0.1)	0.05 (0.1)	1	1	5.9	12.1
Tissue loss due to fish biting	0.0	0.0	0	0	0	0
Unexplained tissue loss	0.3 (0.5)	0.4 (0.4)	2	1	26.5	54.5
Growth-infilling	0.06 (0.2)	0.2 (0.5)	1	2	11.8	24.2
Growth-marginal	0.6 (0.7)	0.6 (1.1)	3	4	55.9	45.4
New disease	0.4 (1.5)	0.3 (0.8)	8	4	8.8	15.1

Table 3.4.2.3.

Percentage of colonies exhibiting bleaching[1] by species at the West Flower Garden Bank for 2000-2001.

Species	2000	2001
Montastraea annularis complex*	0.2	0.6
Montastraea cavernosa	0.06	0.3
Diploria strigosa	0.4	0.6
Colpophyllia natans	0.06	0.0
Porites astreoides	0.06	0.3
Mussa angulosa	0.06	0.0
Millepora sp.	0.4	0.6
Total percent	1.2	2.4
Total colonies	1627	1591

[1] Data from which percentages could be calculated was only collected in 2000-2001.
**Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

Table 3.4.2.4.

Overall percentage of points falling on areas of colonies exhibiting bleaching, disease etc. at the East Flower Garden Banks, 1998-2001.

Observation	1998	1999	2000	2001
Paling[1]	N/A	N/A	0.3	0.8
Bleaching followed by mortality	0.2	0.1	0.05	0.06
Bleaching not followed by mortality	0.3	0.06	1.3	0.06
Disease followed by mortality	0.03	0	0	0.03
Disease not followed by mortality	1.2	0.03	0.03	0
Algal- replacement	1.7	1.4	0.5	0.9
Sediment- replacement	0.8	0.3	0.09	0.06
Algal/sediment- replacement	0.06	0.1	0.03	0.2
Tissue loss due to competition	0.03	0	0.03	0.06
Tissue loss due to fish biting	0	0	0	0
Unexplained tissue loss	0.3	0.7	0.3	0.4
Growth-infilling	0.3	0.5	0.06	0.2
Growth-marginal	4.3	2.1	0.6	0.6
New disease[1]	N/A	N/A	0.4	0.3
Overall growth	4.6	2.6	0.7	0.8
Overall retreat, mortality & tissue loss	3.1	2.6	1.0	1.7
Approximate Growth:Loss Ratio	5:3	1:1	1:1	1:2
Number of Stations	35	35	34	33

[1] These categories were added in 2000.

3.5 VIDEO TRANSECTS

Following the established protocol for video documentation, linear transects were recorded following the perimeter boundary lines at each bank. The images collected appear consistent with the results of the encrusting, quadrat, and random photographic samples. The most notable observations at the EFGB were an area of increased algal cover on the south transect approximately 03:31 (mm:ss) into taping and a few noted instances of what appeared to be bleaching on the west transect. On the WFGB, some bleaching was seen on the *Montastraea annularis* complex and *M. cavernosa*, as well as several areas of parrot fish biting/marks on the north transect. On all transects, *Millepora* sp. appeared to be bleaching in almost all instances.

3.6 WATER QUALITY/INSOLATION/TEMPERATURE

3.6.1 Water Quality

One SPMD was deployed at each bank during the 2000 and 2001 monitoring cruises (Table 3.6.1.1). Upon retrieval of the 2000 SPMD canisters, it was discovered that the membranes were torn and many postlarval crustaceans were residing within the metal housing. Therefore, the SPMDs could not be sent in for dialyzation. The 2001 SPMDs were also not analyzed because they could not be located.

Table 3.6.1.1.

Semi-Permeable Membrane Device (SPMD) sampling periods for the East and West Flower Garden Banks, 2000-2001.

	Deployment	Retrieval	Date Analyzed
2000			
EFGB	13-Sept-00	10-Nov-00	Not sent for analysis, membrane torn
WFGB	11-Sept-00	11-Nov-00	Not sent for analysis, membrane torn
2001			
EFGB	19-Sept-01	*	Not Found
WFGB	17-Sept-01	*	Not Found

* searched for SPMDs in November 2001

However, during the period of 12 June – 20 Sept 2001, SPMDs were deployed at EFGB to monitor for impacts from a nearby oil/gas drilling project. W&T Offshore Inc, New Orleans granted permission to report the data on concentrations of polycyclic aromatic hydrocarbons (PAH) collected (Table 3.6.1.2). Concentrations of PAH ranged from 0-135.6 ng (parts per trillion) during this period.

Table 3.6.1.2.

Semi-Permeable Membrane Device (SPMD) deployed at the East Flower Garden Bank during drilling activities on HI-389 (courtesy of W&T Offshore, Inc.), May-September 2001.

ESSI Label	Deployed	Retrieved	Status	Total PAH Level (ng)
EFGB 05/27/01	05/27/01	--	Lost in Field	--
EFGB 06/12/01	06/12/01	07/08/01	Analyzed	0
EFGB 07/09/01	07/09/01	07/19/01	Analyzed	0
EFGB 07/19/01	07/19/01	07/31/01	Analyzed	135.6
EFGB 07/31/01	07/31/01	09/06/01	Analyzed	11.1
EFGB 09/06/01	09/06/01	09/20/01	Analyzed	0
EFGB 09/20/01	09/20/01	--	Lost in Field	--

3.6.2 Insolation

This report presents all available data collected since February 1997. Portions of the 1997 data sets have been previously described in earlier reports (Dokken *et al.* 1999) and are summarized here for completeness. The mean PAR irradiance and corresponding values for -*k* were lower at the WFGB than at the EFGB during 1997-1999; however, it does not appear that these differences are statistically significant. Beginning in March 2000, and continuing through November 2001, the instruments in use at the HI-389 platform and the WFGB station became erratic. Accurate comparisons of irradiance between the EFGB and WFGB were not possible for that period. Lack of reference irradiance measurements made it impossible to estimate -*k*.

Seasonal variation in light levels was clearly evident in the plot of PAR values recorded at the HI-389 Platform (Figure 3.6.2.1). Higher frequency variability is caused by weather patterns that periodically increase cloud cover. During 1999, a transient problem with the instrument resulted in three data gaps (Figure 3.6.2.1). PAR levels were recorded during these gaps, but the levels were unacceptably low and were rejected as bad data. The cause of these events is under investigation, but may have been due to mechanical shading of the sensor during platform operations. The sensor was recalibrated, but failed to respond. Consequently, there were no reference data from which to calculate extinction rates.

Seasonal variation in PAR was present, but less coherent for values recorded by the instruments at the EFGB and WFGB (Figures 3.6.2.2 and 3.6.2.3). For example, PAR doses recorded at the EFGB instrument during summer of 1997 and 1999, show distinct decreases during month-long episodes that are not reflected in values recorded at HI-389. The cause of these deviations is presumably change in the transmission characteristics of the water at the site. Decreased transmissivity could result from presence of more turbid coastal water masses, increases in phytoplankton production over the site, or both. Direct comparison of PAR dosage and water column attenuation was made for the 405 days when synoptic values were available for both underwater sensors (Figure 3.6.2.4).

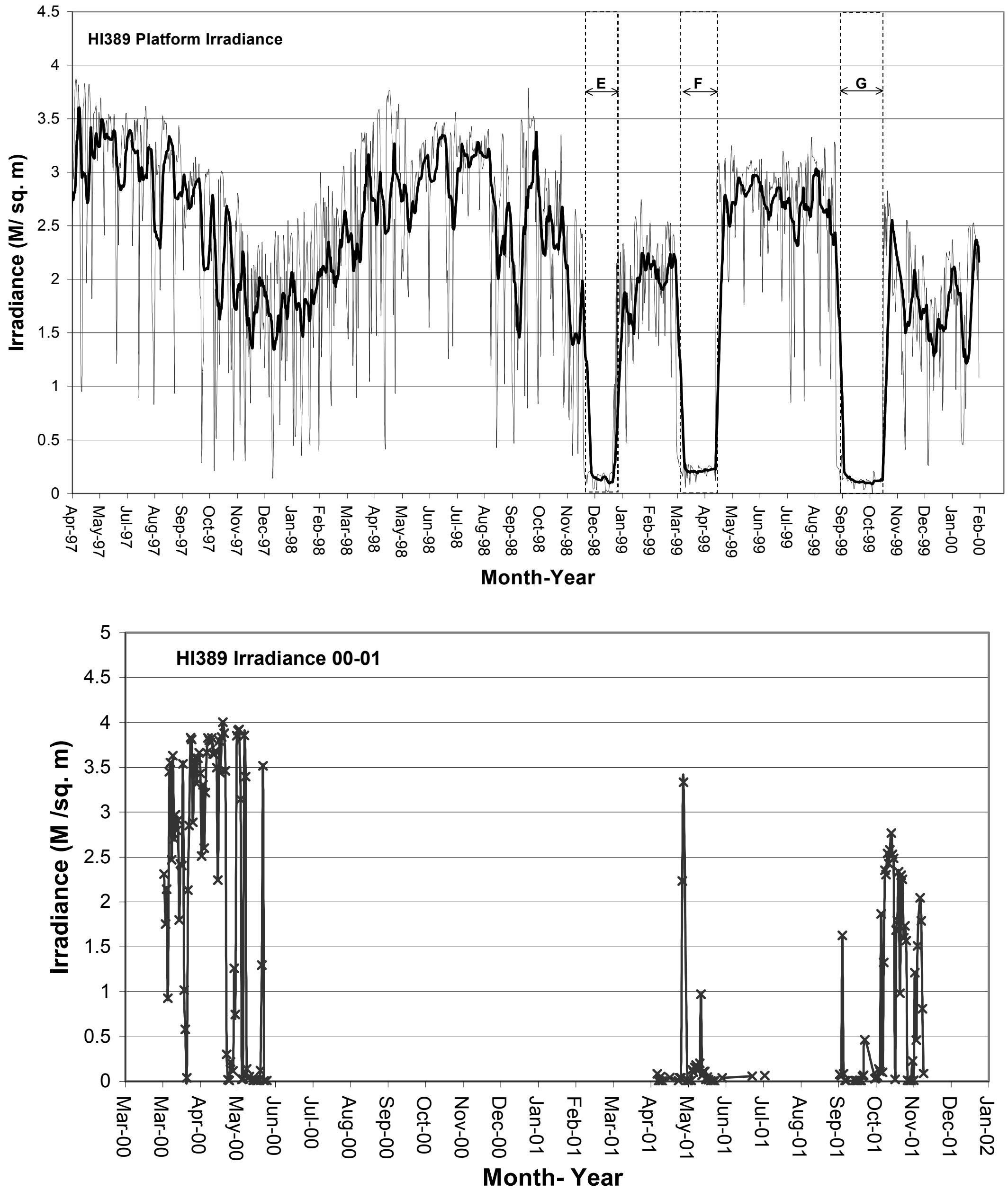


Figure 3.6.2.1. Irradiance at the HI389 platform: Upper panel shows mean hourly irradiance from April 1997 to February 2000. Lower panel shows mean hourly irradiance from March 2000 to November 2001; instrument was intermittent. Areas marked E, F, and G represent gaps in the data, see Appendix 2.

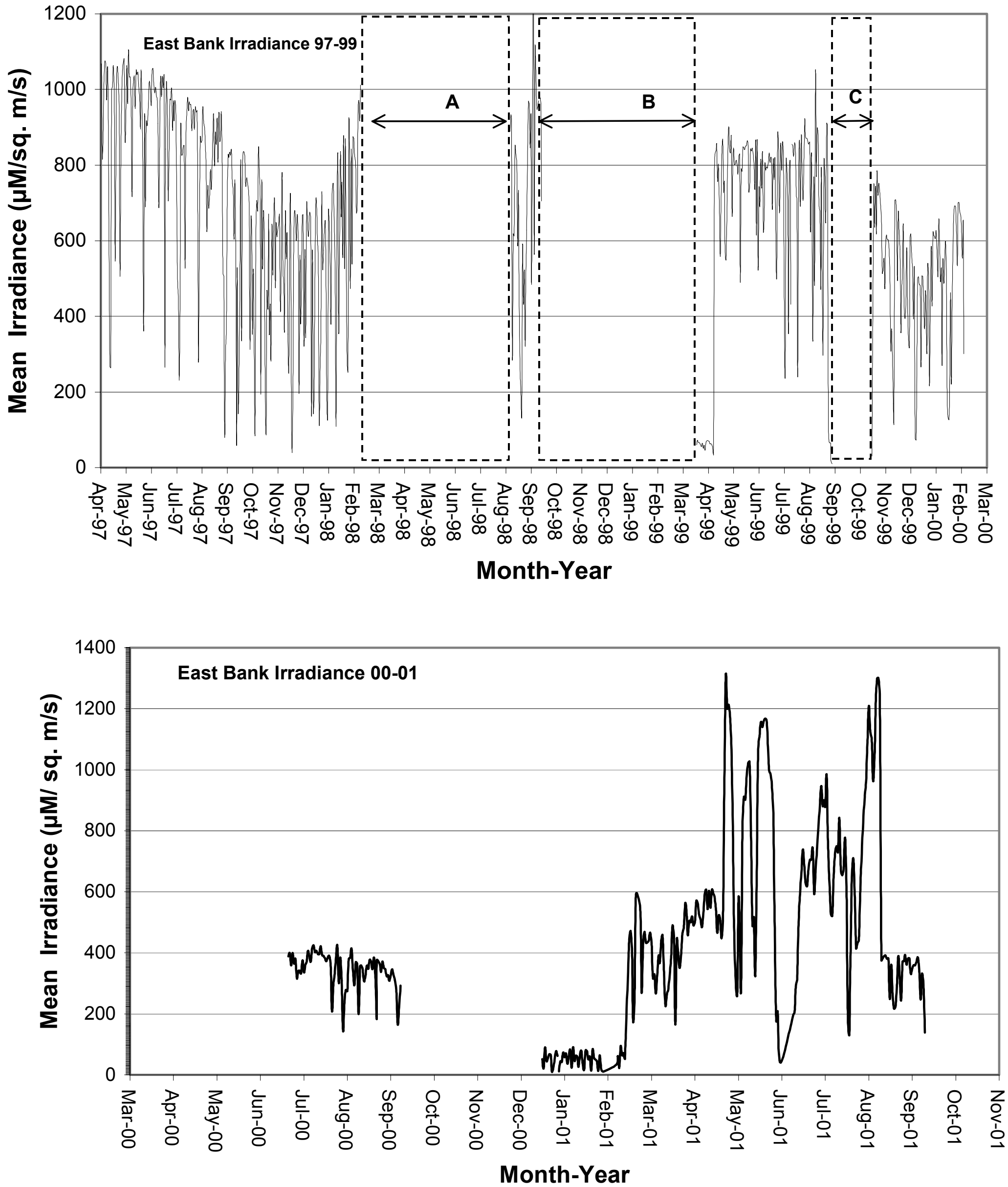


Figure 3.6.2.2. Irradiance at the East Flower Garden Bank: Upper panel shows mean hourly irradiance from April 1997 to February 2000. Lower panel shows mean hourly irradiance from March 2000 to November 2001; note scale change, instrument was intermittent. Areas marked A, B, and C represent gaps in the data, see Appendix 2.

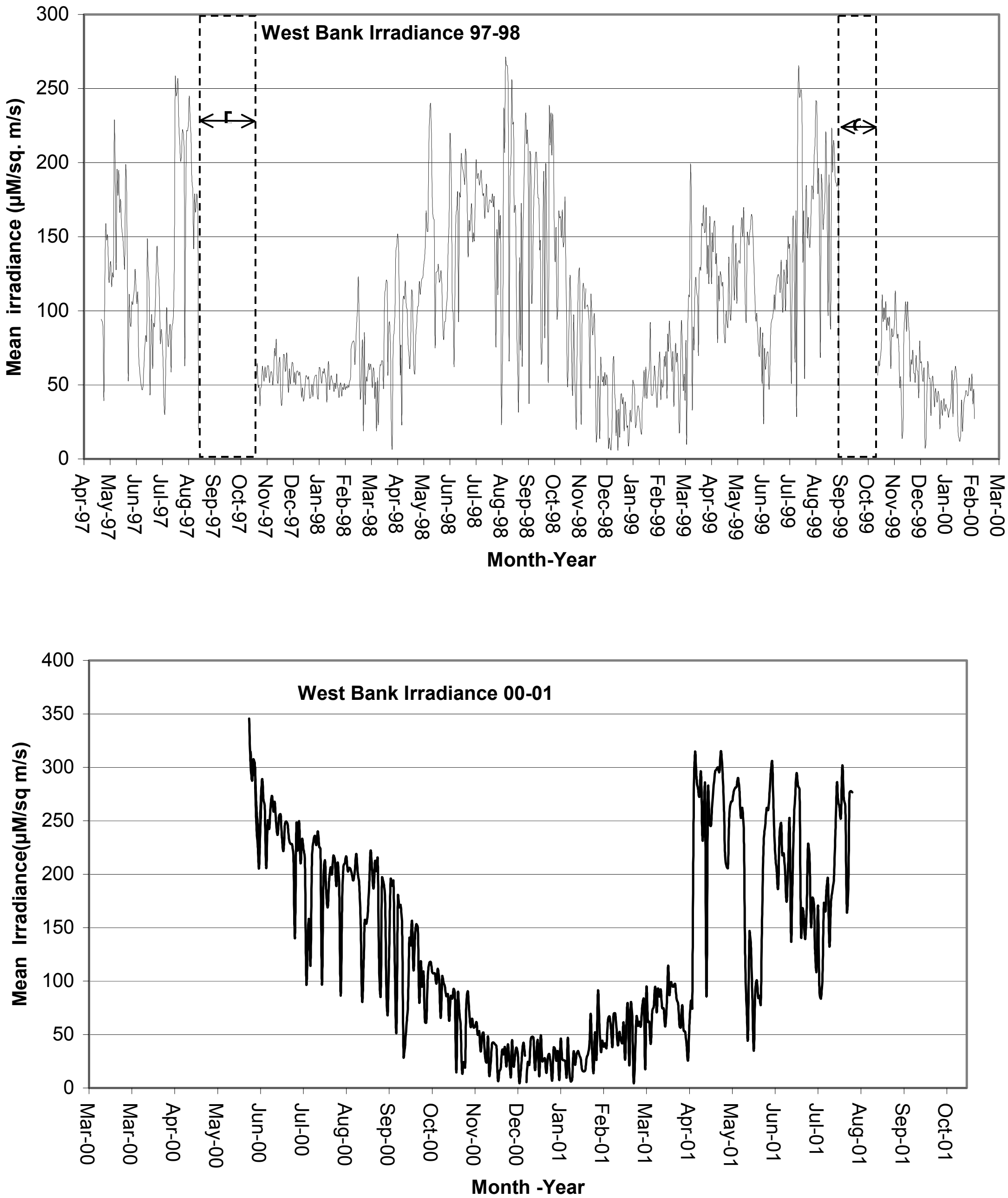
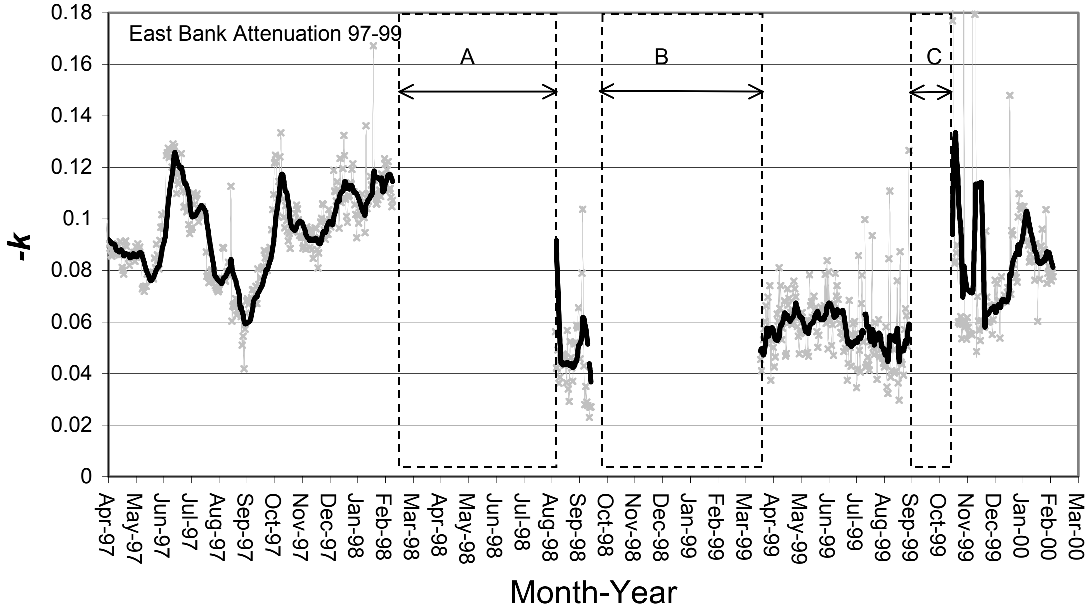


Figure 3.6.2.3. Irradiance at the West Flower Garden Bank: Upper panel shows mean hourly irradiance from April 1997 to February 2000. Lower panel shows mean hourly irradiance from June 2000 to August 2001. Areas marked “r” represent gaps in the data, see Appendix 2.



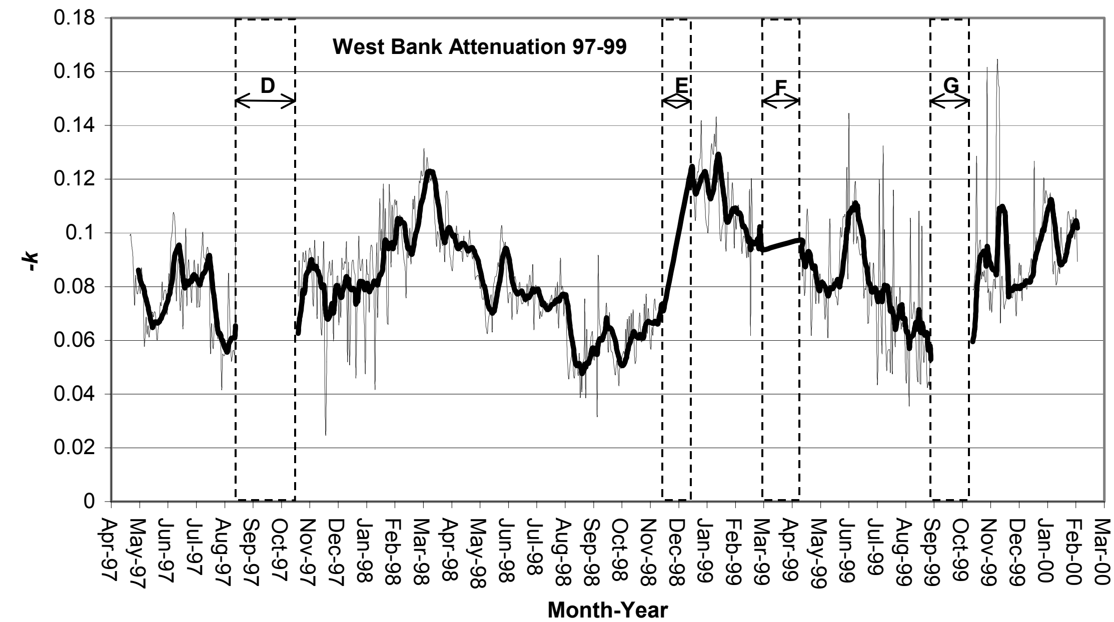


Figure 3.6.2.4 Total insolation at the East Flower Garden (upper) and at the West Flower Garden Bank (lower) monitoring stations (23.8 m water depth) April 1997 to March 2000. Areas marked A, B, C, D, E, F, and G represent gaps in the data, see Appendix 2.

Between 23 September 2001-8 February 2002, salinity, turbidity, dissolved oxygen and pH, in addition to temperature and PAR, were continuously measured. During this period, salinity at EFGB declined from 38 ppt to about 32 ppt; at WFGB salinity remained relatively stable at 35-36 ppt. Turbidity at both banks was relatively stable, but was greater at EFGB. There was a brief, but dramatic increase in turbidity during mid-October at WFGB and there were numerous short-lived turbidity spikes at EFGB. DO concentrations at EFGB were generally higher than at WFGB. Both DO and pH increased through the period as would be expected with observed seasonal decline in water temperature. The complete record for YSI data collected (salinity, depth, dissolved oxygen, pH, temperature, turbidity, and PAR) at the EFGB and WFGB seafloor stations is shown in Figures 3.6.2.5 and 3.6.2.6.

3.6.3 Temperature

Seawater temperatures obtained from the Hobo-Temp recording thermographs (Onset Instruments, Pocasset, Massachusetts) deployed near the mooring bolt. Data indicate an overall mean minimum temperature of 20.3^{o}C in February of 2001 and a mean maximum of 29.8^{o}C in August of 2001 (Figures 3.6.3.1). Due to equipment failure, no data was recorded from April 2000 to November 2000; instruments were replaced in November 2000.

3.7 SEA URCHIN SURVEYS

Sea urchin surveys for *Diadema antillarium* were conducted on both the 2000 and 2001 monitoring cruises. Results from those surveys are in Table 3.7.0.1.

Table 3.7.0.1.

Average number of *Diadema antillarium* per meter square on the East and West Flower Garden Banks from 1996-2001.

Year	EFGB	WFGB
1996	No counts made due to sea conditions	0.0033 m^2
1997	No counts made due to sea conditions	0.0038 m^2
1998	0.023 m^2	No counts made due to sea conditions
1999	No counts made due to sea conditions	No counts made due to sea conditions
2000	0.018 m^2	0.030 m^2
2001	0.005 m^2	0.050 m^2

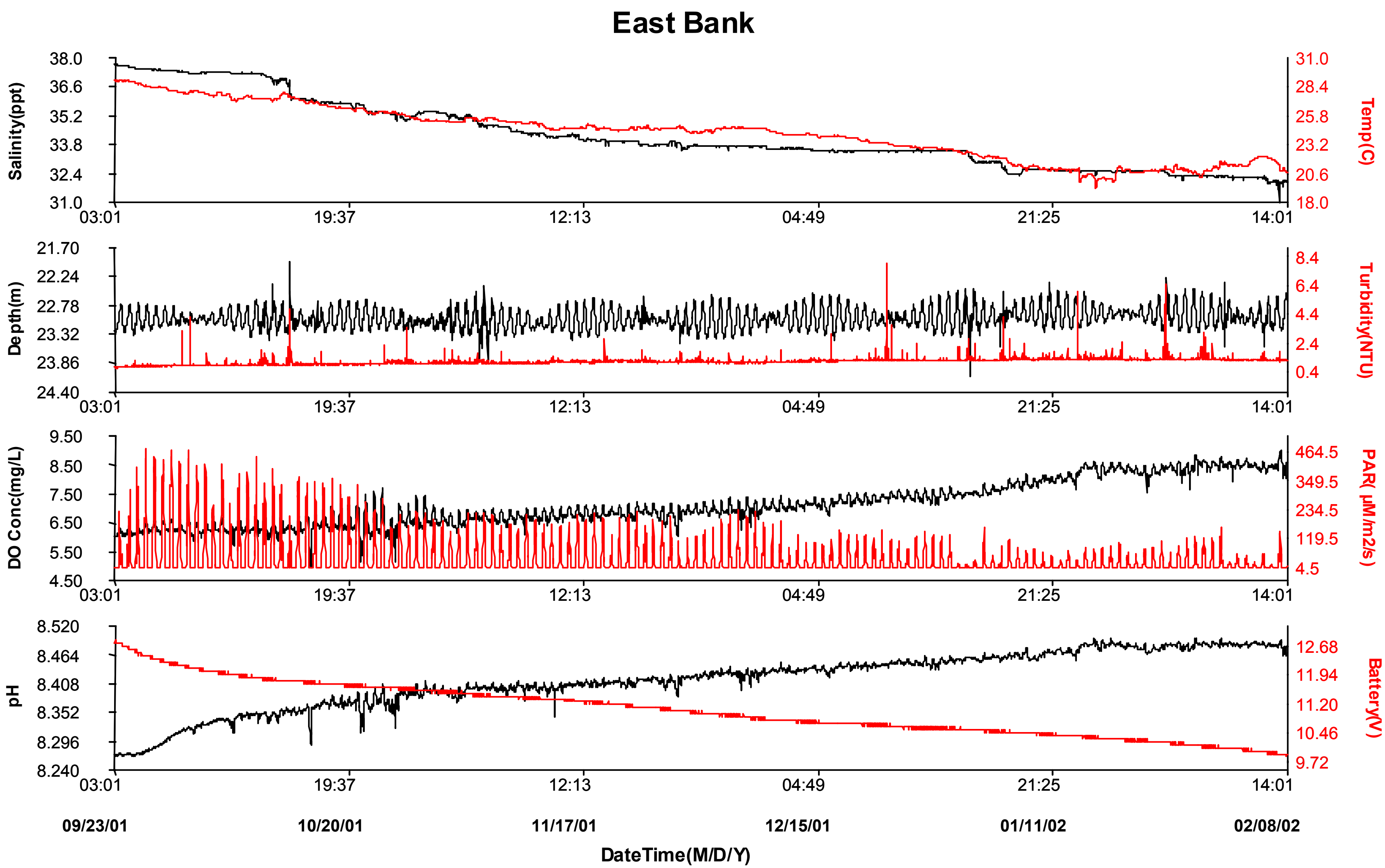


Figure 3.6.2.5. Complete data record of environmental parameters from YSI probe installed at East Flower Garden Bank seafloor station, September 2001-February 2002.

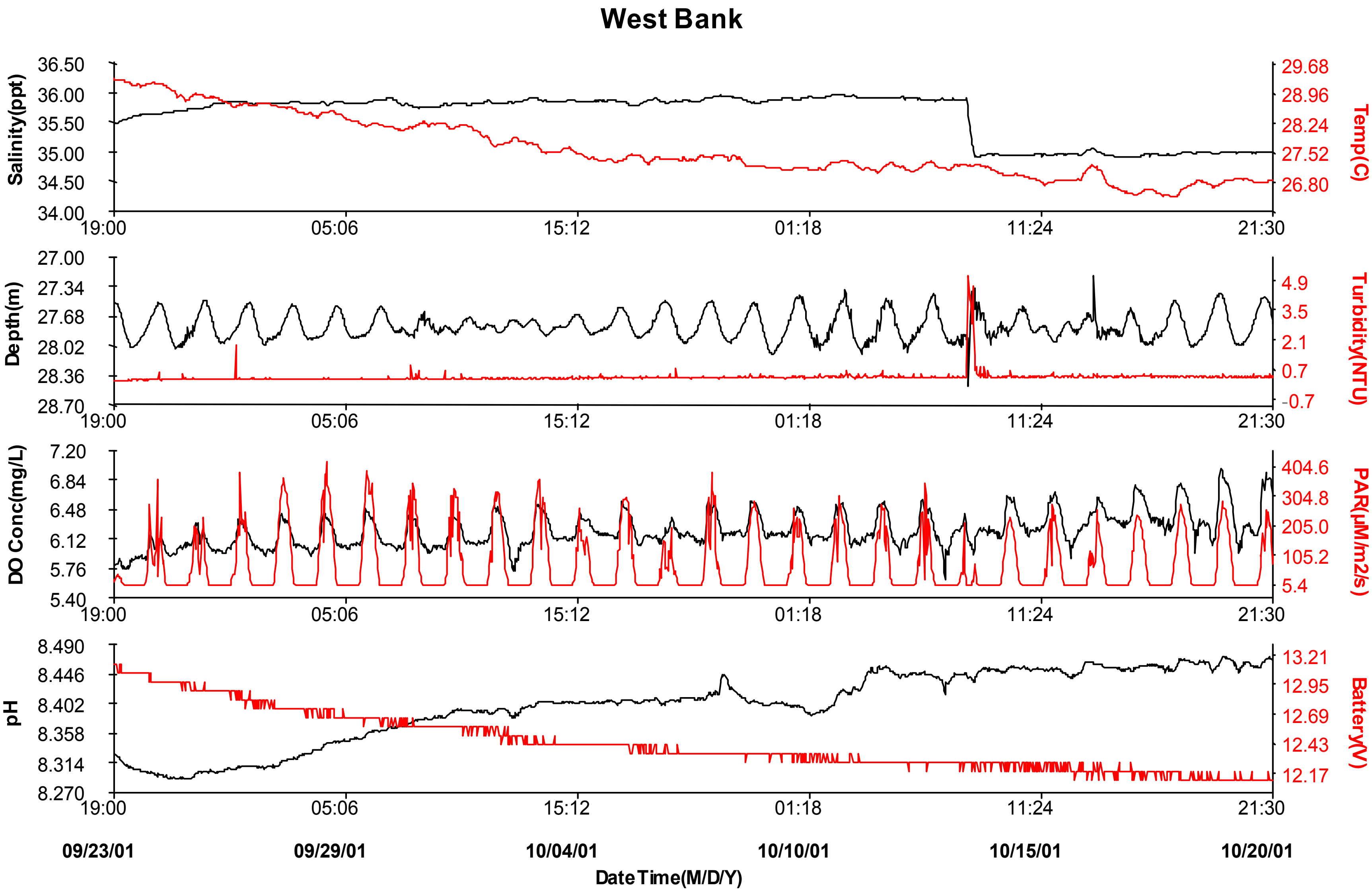
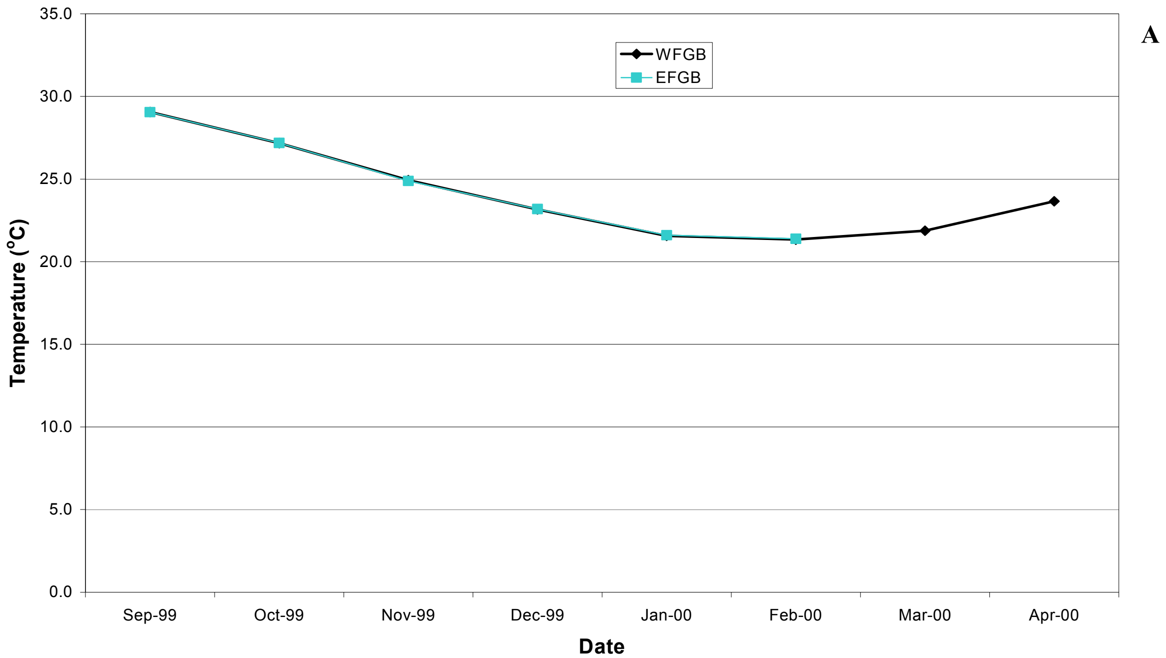


Figure 3.6.2.6. Complete data record of environmental parameters from YSI probe installed at West Flower Garden Bank seafloor station, September 2001-October 2002.



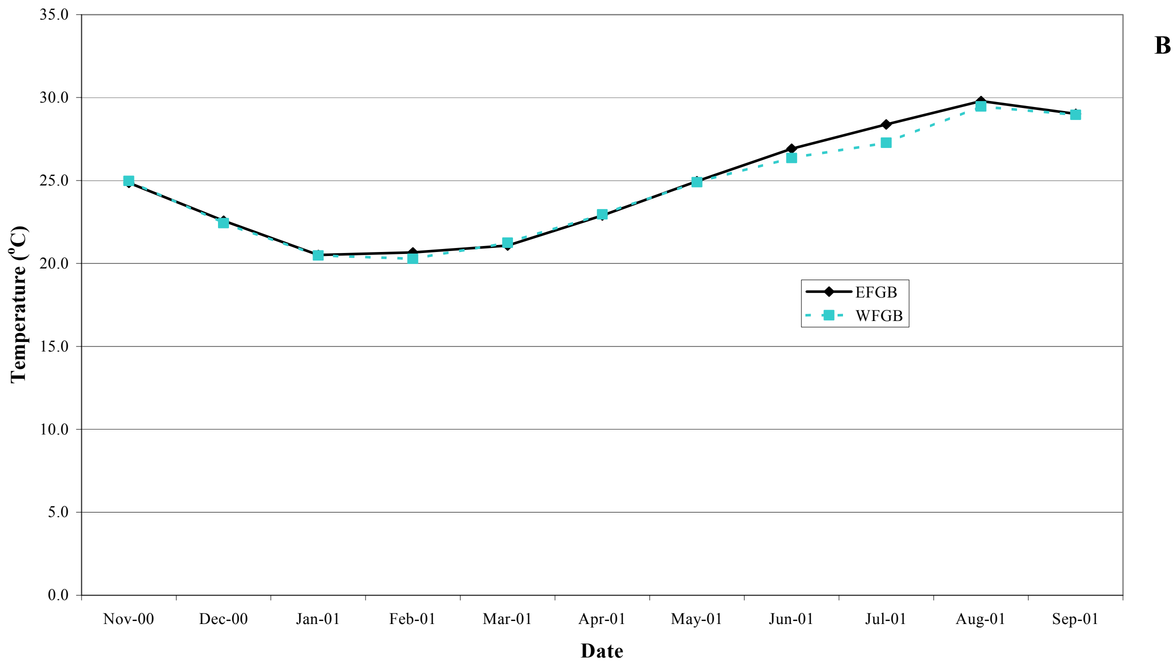


Figure 3.6.3.1. Mean seawater temperatures for the East and West Flower Garden Banks from September 1999 to April 2000 (A) and November 2000 to September 2001 (B).

4.0 DISCUSSION

4.1 GENERAL

Through the 2001 monitoring period, the Flower Garden Banks (FGB) appeared to be healthy and productive. Dokken et al. (1999) described the character of the FGB coral reefs with comparisons to other coral reef systems of the Gulf of Mexico and Caribbean Sea. Relative to these other coral reef systems, the FGB have low diversity of stony corals and high coral cover, generally ~ 50%. Located approximately 180 km from the nearest landmass, the FGB are relatively isolated from terrestrial based impacts when compared to reef systems such as those of the Florida Keys (FMRI 1997; Lapointe 1997; Porter et al. 2002), southern Gulf of Mexico (Tunnell 1992; Chavez and Tunnell 1993), Netherlands Antilles (Bak and Nieuwland 1995), and the Caribbean Sea of Central America (Cortés 1997).

Although afforded a measure of protection from shore side development and watershed drainage impacts, within the FGB there is potential for habitat damage from industrial and recreational activities occurring in the near vicinity such as anchoring and oil spills. Prior to designation as a National Marine Sanctuary in 1992, substantial anchor damage was observed. Since designation, no damage from these activities has been documented. No significant impact from oil/gas activity has been documented before or after Sanctuary designation. Lang et al. (2001) characterized the FGB as "…near excellent in the spectrum of possible reef conditions." The results reported herein are in general agreement.

Management of the FGB began in the early 1980's with the application for a drilling/ production permit in the High Island 389 lease block by Mobil Exploration and Production U.S. Inc. The proposed drill site was approximately 1.5 km east of the East Flower Garden Bank. The High Island A389 production platform was required to shunt all permitted discharges to within 10 m of the seabed (~120 m) and a monitoring program was established to track trends in the health of the coral reef. Management primarily focused on prevention of negative impacts from oil and gas operations in the area. In 1992, with the designation of the Flower Garden Banks as a national marine sanctuary, the potential for impacts from other human activities was recognized and additional management guidelines were instituted. Buffer zones were established around the banks that exclude oil and gas activity and the banks were deemed no anchoring zones. To eliminate anchor damage, mooring buoys were installed to allow access to the FGB by recreational divers and their support vessels. Fishing guidelines allowed for single hook and line fishing, but no spearfishing or multiple hook, traps, or net type commercial equipment. These guidelines are still in effect as of October 2002.

The number of recreational divers visiting the FGB annually is not known precisely, but it is believed that about 3,000 recreational divers make at least 9,000 dives on the FGB each year. The impact of this activity is not known, and the monitoring strategy does not produce data that would clearly distinguish and document the impact of recreational diving.

The FGB continue to be dominated by *Montastraea* spp. and *Diploria strigosa*, which according to the findings of Hughes and Jackson (1985), would indicate the relatively stable environment favored by the more robust and massive species of corals. Understanding of chronic versus catastrophic mortality (Bythell et al. 1993) at the FGB is virtually nil.

Hurricanes routinely pass through the area (e.g. Hurricane Andrew 1992, Hurricane Georges 1998), but no attributable impact has been recorded. In addition, tropical storms and winter high-pressure fronts force surface conditions above the FGB to sea states > 5 m several times each year. The depth of the FGB is likely the most important contributing factor to minimizing impact from storms. Chronic mortality from predation (Simpson 1979), disease (Bruckner and Bruckner 1998, 2000) and competition occurs continuously as indicated by the monitoring data, but it is balanced by growth. Bythell et al. (1993) postulated that due to inherent morphological and physical differences between *M. annularis* and *D. strigosa*, the population dynamics of *M. annularis* may be more controlled by chronic mortality events and *D. strigosa* more influenced by events of catastrophic mortality.

4.2 CORAL GROWTH AND CONDITION

Dokken et al. (1999; 2001) reported annual variability of accretionary growth within banks and between banks (Tables 3.3.1.1 and 3.3.2.1), which is consistent with the data reported herein for 2000 and 2001. No significant long-term upward or downward trends in growth rates were evident. These conclusions are consistent with the reports of Gittings et al. (1992) and Continental Shelf Associates (1996). Between 1985 and 2001, *Montastraea faveolata* growth at the EFGB ranged from 6.12 to 8.23 mm/yr. Accretionary growth at the WFGB ranged from 4.49 to 6.64 mm/yr. There is no clear explanation of why *M. faveolata* generally accretes faster at the EFGB. Random transect data also indicated that the *M. annularis* complex grew faster at the EFGB. Rates of coral growth at the Flower Garden Banks were in the mid to upper range of growth rates of corals at various Caribbean Sea reefs (Dokken et al. 2001).

Interpretation of repetitive quadrat data was problematic because rather than recording the numbers of colonies exhibiting the characteristic, the number of points contacted on the random point intercept mask was recorded, consistent with the historical methodology. The frequencies for the last two years at EFGB suggest that all causes of loss except unexplained tissue loss declined (Table 3.5.1.2). However, the percentage of colonies exhibiting bleaching increased (Table 3.5.1.3). Thus, at EFGB, the frequencies may not be providing a clear picture of the extent to which these processes are occurring or exist. On the other hand, at WFGB, frequencies of nearly all causes of loss increased between 2000-2001 (Table 3.5.2.2) and the percentage of colonies exhibiting bleaching also increased (Table 3.5.2.3). Data compilation of the last four years suggested that the overall percent cover of “new growth” declined fairly dramatically, however, since the same point mask was not used on the same photo every year, this may or may not be the case. However, since these are measures of “relative” growth and loss, then it is possible that the percent of area affected by loss processes, although it has fluctuated up and down by about 1% over the last four years, is relatively stable, whereas the percentage of the area exhibiting growth is declining. The growth:loss ratios suggested that the processes were essentially in equilibrium during 1998-1999, but that loss processes affected more area during 2000-2001, with the greatest loss occurring during 2000. Still, the long-term picture suggested stability.

Growth/loss ratios estimated from repetitive quadrat data at EFGB seem somewhat contradictory in light of the large apparent increases in *Montastraea annularis* and total coral cover seen in the random transects. However, the cover estimates from the random transect data are not directly comparable to the cover estimated for the 8 m quadrats due to differences in both slide scale and data capture technique. There was a very slight decline in percent cover of *M. annularis* complex, *Diploria strigosa*, and total coral in the repetitive quadrat stations (see Table 3.5.1.1) that seems in line with the growth/loss ratios. In addition, net loss of *D. strigosa* was noted at encrusting stations for 1998-2000; growth and loss were approximately equal during 2001. Frequencies of paling, bleaching and disease followed by mortality, replacement (all), tissue loss due to competition, unexplained tissue loss, and new disease increased between 2000-2001 as did infilling growth. Frequencies of bleaching without mortality, disease without mortality, and marginal growth declined. These changes indicate that, at least at repetitive quadrat stations, loss processes are outpacing growth processes and this is reflected in the growth/loss ratios.

At the WFGB, decreased growth was also seen between 1998-1999. Growth/loss were essentially equivalent in 1999-2000, then increased substantially in 2001. Again, the percent cover estimates generated from the random transect data is not directly comparable to those from the repetitive quadrats for the same reasons cited above. However, unlike the EFGB, only moderate increases in cover of *M. annularis* complex were seen at the WFGB, so the growth/loss ratios do not seem to be quite as contradictory. Like the EFGB, cover of the *M. annularis* complex and total coral cover declined slightly in the repetitive quadrats which is also in line with the increased loss seen in 2001. Frequencies of nearly all causes of loss increased from 2000 to 2001 whereas frequencies of both growth processes declined.

Habitat characters such as degree of bleaching and percent cover of algae and bare reef rock varied annually from 1996 - 2001. Although no significant trends were evident and no change appeared to be long term, there was a substantial increase in the *M. annularis* complex at the EFGB. Based on the results of the random transect data, cover of the *M. annularis* complex at the EFGB appeared to be increasing at the expense of reef rock, *M. cavernosa* and *D. strigosa* (correlations), but only more data will allow a definitive answer. Runs tests do not indicate trends, only natural or random variability. Algal cover increased in 1999, but this appeared to be a very short-term condition based on casual observations approximately four weeks after the monitoring cruise. Reef rock was also negatively correlated with algal cover. It appeared that the *M. annularis* complex and algae colonized more of the non-living surfaces of the bank. The significant positive correlation between algae and total coral suggested that algae were not expanding at the expense of coral cover.

In using random photographic methods to collect the data on which these correlations have been founded, there are two possible sources for error: 1) randomness of the photographic transects and 2) laboratory measurement and analysis of the data contained in the photographs. The potential for subjective error is minimized by increasing transect replicates and using the same personnel and technology to complete the laboratory analysis each year, but it cannot be eliminated all together. Although we are confident in the conclusion that the *M. annularis* complex did expand in area coverage, we are less confident in stating that the coverage of *M. annularis* doubled (110% increase) from 1996 to 2001 (Table 3.1.1.1). There are three key considerations in understanding how the data could indicate a 110% increase: 1) standard deviations, 14.2% in 1996 and 12.9% in 2001, show substantial overlap in the ranges, 2) the increase in number of transects, 10 in 1996 to 19 in 2001, and 3) the reduction in "No ID" category from > 43% in 1996 and 1997 to < 18% in 1998, 1999, 2000, and 2001. Also, in 1996 a transition was made to a computer-based technology for delineating the content of transect photographs and calculating relative percentages of each component.

Expansion of the *M. annularis* complex at the WFGB showed a more moderate increase (29%) from 1996 to 2001 (Table 3.1.3.1). As at the EFGB, standard deviations muted any statistical significance and the "NO ID" category declined from > 51% in 1996 to < 16% in 2001. In contrast the number of usable transects remained consistent with the number ranging from 13 to 16 transects.

The correlations between the *M. annularis* complex, *D. strigosa*, *M. cavernosa* and total coral cover were indicative of the fact that these three species are the predominant corals on the bank. The same negative correlation between reef rock and algae recorded at the EFGB was also seen at the WFGB. It appeared that like the EFGB, algae primarily colonized non-living surfaces (i.e. reef rock). Unlike the EFGB, the *M. annularis* complex did not appear to be expanding into areas of non-living substrate. In addition, there were no significant correlations between the *M. annularis* complex and *D. strigosa* or *M. cavernosa* or algae and total cover as seen at the EFGB. It appeared that the coral community at the WFGB remained relatively stable throughout the monitoring period.

Random photographic transects were completed outside the boundaries of the designated 100 m^2 study area to test whether or not the study area remained representative of the reef habitat. No inconsistencies between the reef character outside the designated study area and the study area were evident. The study area continued to be representative of the reef habitat at each bank.

Disease was a minor component of the FGB ecosystem dynamics with no apparent significant impact (Dokken et al. 2001; Oberding 2002). This was in contrast to near shore Gulf and Caribbean reefs such as the Florida Keys (Porter et al. 2001) where "dramatic" increases in the occurrence of disease (404% increase) and the number of coral species affected by diseases (218% increase) occurred in recent years. Garzón-Ferreira et al. (2001) reported on the increase in coral diseases on coral reefs of Colombia (i.e. southwestern Caribbean). Black band disease was common with corals of the *Montastraea* spp. and *Diploria* sp. commonly infected. Richardson et al. (2001) stated, "A second overwhelming threat, yet to be documented, is the role of coral diseases in initiating phase shifts on coral reefs." There is no evidence of a phase shift at the FGB, but research and monitoring programs should be alert to such an event should it occur.

Oberding reported black band disease, ridge mortality, yellow blotch, plaque disease, and neoplasia in the corals of the FGB with black band being the most common disease condition primarily affecting *M. annularis*, *D. strigosa*, and *M. caveronsa*. He also reported "conditions of unknown or undeterminable diseases." It must noted that Oberding's disease identifications were made strictly with the use of photographic guides. Staff members of the FGBNMS question his conclusions of "black band being the most common." Further investigations are needed to further clarify the identification of disease conditions at the FGB. To date there are no clear indications that disease conditions at the FGB have changed appreciably from historical conditions. This is not surprising since the increase of disease in near shore reef habitats has been in part attributed to anthropogenic stresses (Peters 1997; Green and Bruckner 2000; Acosta 2001); and the FGB are considered to be relatively free of land based anthropogenic stresses. As described by Bruckner and Bruckner (1998, 2000) there was evidence of coral loss to feeding patterns/habits of *Sparisoma viride*. A review of private archived photographs (Q. Dokken) provided evidence that this condition existed prior to 1996.

Bleaching at the FGB was observed most commonly in 1997-98 (Dokken et al. 1999, 2001) but not as a threatening event. The hydrocoral, *Millepora alcicornis*, and to a lesser extent the scleractinian coral, *Montastraea cavernosa*, were most susceptible to this condition. Consistent with the reports of Gittings et al. (1992) and Hagman and Gittings (1992), bleaching correlated strongly with temperature, most commonly occurring when seawater temperatures at the coral surface exceeded 30°C. Bleaching events were of short duration, but because of the sampling schedule dictated, one time per year, bleaching as an annual event is poorly understood at the Flower Garden Banks. But, to date bleaching does not appear to be a significant threat. However, bleaching events should be monitored with the understanding that bleaching stressed corals may be more susceptible to coral disease pathogens (Harvell et al. 2001).

In 1999 a bloom of filamentous algae was present during the time of monitoring cruise (Dokken et al. 2001). The bloom occupied bare reef rock, but based on subsequent anecdotal observations, was short lived. Over the duration of this monitoring program it was difficult to draw firm conclusions regarding fluctuations in algal densities. Although algal densities increased at the time of the annual monitoring expeditions, the absence of monitoring data throughout the year and of nutrient data to which to possibly correlate changes left questions of algal fluctuations unanswered. The grazing patterns and relative impacts of herbivorous fish and urchins have not been studied at the FGB with the exception of Gittings and Bright (1987). Urchin densities at the WFGB tended to be greater than at the EFGB (Table 3.8.0.1) and there was an increase from 1996 to 2001 at the WFGB, but based on a one time per year census conducted during the time of the September monitoring cruise *Diadema antillarum* populations have not made an appreciable recovery since the 1983-84 mass mortality event (Lessios 1988). It is also noted that anecdotal observations (Q. Dokken) suggest the possibility that urchin densities vary throughout the year and may be greater in the spring and summer months prior to September. Systematic quantitative surveys need to be conducted to determine the validity of this observation. Surveying 80 reef sites in the Florida Keys between August and December 1999, Chiappone et al. (2002) reported minimal recovery of *D. antillarum*. No urchins were recorded in 69 of the sampled sites, and all total, only 16 individuals were recorded from all 80 sites.

Dunton and Miller (2001 *in* Dokken et al. 2001) concluded that nutrients at the FGB are produced autochthonously by benthic cyanobacterial mats rather than transported into the system from coastal zones. Dodge and Lang (1983) demonstrated correlations of coral growth to flooding events in southern Louisiana suggesting that the FGB may not be as isolated from coastal zone impacts as one would assume. Subsequently, the reason for algal blooms is not clearly understood. In contrast, Lapointe (1997) described external sources of nitrogen as facilitating the habitat shift of coral dominance to algae dominance on the reefs of southern Florida. Lapointe's conclusions were challenged by Hughs et al. (1999) who maintained that a reduction in the herbivory was the primary cause of the coral to macroalgae shift. In the lagoon systems of Belize, McClanahan et al. (1999) point to a combination of factors, temperature, nutrients, and fishing, causing a phase shift from coral to macroalgae. Aronson and Precht (2000) suggest changes in the herbivore populations as the primary factor for the phase shift in Discovery Bay, Jamaica. Although population densities of *Diadema antillarum* were low during the monitoring sampling periods, no such phase shifts occurred at the FGB.

4.3 INSOLATION/TEMPERATURE/WATER QUALITY

Comparison of data from the underwater light sensors to the reference station clearly showed the effect of probable overcast conditions on light availability at depth. Although light levels were much lower at depth, the highs and lows of sunny and overcast days match closely through the records. Additionally, seasonal changes can also be discerned in the general trends of light level for the underwater and reference sensors. Abrupt shifts in the measured light intensity at depth, e.g. between 16 and 17 July 1996 (see Figure 3.7.2.1, lower), which are not mirrored by the reference values, indicated changes in the light transmission properties of the water column.

The estimates of the attenuation coefficient, k, provided information on the water column characteristics. Overall, the k values were in the range that Parsons et al. (1984) suggested falls between the clearest coastal water ($k = 0.15$) and the clearest oceanic waters ($k = 0.033$). The robust growth rates that have generally been reported for hermatypic corals at the Flower Garden Banks probably reflect these clear water column conditions. Monitoring light levels is therefore an important means for gauging the physical conditions that maintain coral health in this marine sanctuary. Previous reports of light intensity levels at the monitoring sites (CSA 1996), give only the daily averages in graphic form. The raw data from this study should be reviewed and re-processed to calculate attenuation values.

The temperature regime for 2000 and 2001 was unremarkable with temperatures staying within normal parameters. Seawater temperatures typically range from ~18°C in February to 30°C in August. From May through November temperatures generally stay at or above 25°C and only during the months of January, February and March do temperatures approach the lower limits. The months of April and December are transition months with temperatures rising and falling, respectively. During July and August 1997 temperatures exceeded 30°C and subsequently increased bleaching was observed during this time period.

The utilization of Semipermeable Membrane Devices (SPMD) to collect information on the chemical quality of the water column proved problematic. Specifically, the SPMD were suitable for short-term (i.e. < 30 days) deployment only. Beyond this deployment duration the SPMD "ribbons" became fouled with sessile growth and juvenile crustaceans took up residence in the housing and tore holes in the ribbons as they fed on the sessile growth. The water quality at the FGB was deemed good based on the SPMD data collected, a conclusion supported by the work of Nipper and Carr (2001 *in* Dokken et al. 2001) in their assessment of the toxicity of the interstitial water of the sediments on the reef cap. Concentrations of polycyclic aromatic hydrocarbons (PAH) were very low, < 1,150 ng (parts per trillion) and usually < 500 ng. Likely sources were condensate oil seepage and ship fuels. Along with PAH, pesticides and PCBs were detected at concentrations < 100 ng. At the miniscule concentrations recorded it was not possible to conclusively attribute impact by these compounds, but based on the growth and health measured, we would logically conclude that they had no influence on the corals.

4.4 BIODIVERSITY

Dokken et al. (1999) reported the lack of information on biodiversity as a gap in the knowledge and management foundation of the FGB. To initiate efforts to close this gap, Dokken et al. (2001) included as attachments reports by Fredericq et al., Lehman and Albert, and Barrera and Tunnell that clearly demonstrated the incompleteness of the knowledge of the biodiversity of the Flower Garden Banks. Combined, Fredericq et al. and Lehman and Albert produced a list of 72 species of algae and Barrera and Tunnell added 100 new species to the catalog of molluscs found at the FGB. Thomas (1996) stated, "*Coral reefs are undergoing unprecedented changes throughout the world. A major problem in understanding this change is the almost total lack of information on biodiversity from reef systems*." Further he stated, "*Long-term protection of coral reefs will be realized only with the understanding of where and how biodiversity levels are established and maintained*." Thomas advocated concentrated comprehensive efforts to catalog the biodiversity of important reef systems. Wells (1995) noted that not only should the basic knowledge of reef biodiversity be expanded, but also knowledge of adjacent habitats.

Generally, of the flora and fauna of the Flower Garden Banks, only the stony corals have been completely identified. Relatively little work has been undertaken to fully describe the crustaceans, sponges, and echinoderms. Almost all-taxonomic investigation has been restricted to the shallow habitats of the coral cap. The authors suggest that efforts to more fully describe the flora and fauna of the FGB are warranted. This would likely be outside the limits of a monitoring project, but it could prove insightful in assessing long-term change. To be fully comprehensive and instructive, this effort should include seasonal investigations of the planktonic communities as well.

5.0 RECOMMENDATIONS

Dokken et al. (1999) concluded their report with the following recommendations:

1) Eliminate growth spikes as a method for measuring accretionary growth. Use sclerochronology measurements to measure accretionary growth exclusively.
2) Continue and expand water chemistry analysis using SPMD technology. Record data no less than quarterly.
3) Expand water chemistry analysis to include nutrients (nitrogen and phosphorous) on a schedule no less than quarterly.
4) The protocol and technology applied to the measurement of light characteristics should be enhanced to allow diurnal collections, particularly during the late summer months before and after the annual spawning event.
5) Use random photographic transects outside the boundaries of the 100 m^2 study sites to test the representativeness of the designated study sites.
6) Continue analysis of sea urchin abundance on a quarterly basis.
7) Add qualitative and quantitative analysis of macroalgae.
8) Add fish census (stationary visual and/or roving diver census).
9) Add seasonal photographic transects to assess temporal occurrences, such as disease and bleaching.
10) Continue and expand monitoring and studies of the biogenic zones below the coral cap. Trophic structure analysis should be undertaken to describe biological energy linkages between the biogenic zones.
11) Measure seasonal and annual current patterns around and above the FGB.
12) Develop and apply dynamic ecosystem models to research and management decision making.

In 2001, Dokken et al. made the following recommendations:

1) The monitoring program be continued.
2) The monitoring program be expanded to include algal studies, nutrient flows in the trophic structure, nutrient concentrations in the water column, and pore water toxicity, and detailed studies of disease. If necessary, the budget should be adjusted to accommodate these studies.
3) The *in situ* water quality monitoring instrumentation be upgraded and the suite of parameters of water quality measured be expanded to include dissolved oxygen, salinity, pH, and turbidity, nitrites, nitrates, ammonium, and phosphates. If necessary, the budget should be adjusted to accommodate these upgrades.
4) Sample no less than four times per year those flora/faunal components and water quality parameters that can undergo short term fluctuations (i.e. algal biomass, bleaching, herbivore populations, and contaminant concentrations).
5) Expand monitoring program to include Stetson Bank to both monitor the health and sustainability of the Stetson Bank ecosystem and as a more terrestrially influenced habitat against which to compare and contrast the FGB.

The Minerals Management Service and FGBNMS have made substantial progress in implementing most of these recommendations. The 2002 and 2003 monitoring program, as specified within the RFP will include:

1) Expanded algal studies, nutrient flows, and nutrient concentrations will be conducted.
2) The *in situ* water quality monitoring instrumentation has been upgraded.
3) More rigorous measurements of potential contaminants will be conducted in the laboratory.
4) Population densities of the herbivore, *Diadema antillarum*, will be monitored.
5) Deep water stations below the coral cap will be monitored.
6) Fish census will be conducted.

These actions will not only expand our knowledge and understanding of the FGB ecosystem, but will also improve the foundation from which management decisions are made.

6.0 CONCLUSION

The results of the 1998 through 2001 monitoring efforts were consistent with those of Gittings *et al*. (1992), CSA (1996), and Dokken *et al.* (1999; 2001) in that variability was common. Growth rates, coral cover, algal cover, and bare rock exposure varied annually. Negative conditions such as bleaching and increased algal cover did occur, but were not permanent and did not significantly impact the stony corals. Disease, although present, was not a significant factor in the gain or loss of coral cover. Abundance of the herbivore, *Diadema antillarum*, was low, but there was no indication that the habitat was degraded by this condition.

Investigations of the algal community and micromolluscan fauna added substantially to the species list of the FGB. This advance underscored the need for additional investigations into the community diversity of the FGB. Other investigations described the trophic structure and nutrient flows of the FGB with comparison to Stetson Bank. Whereas preliminary indications were that the FBG are autogenous, Stetson Bank, closer to the Texas coast is allochthonous.

Water conditions, temperature and transmissivity, followed historical patterns staying within the limits required for coral growth and health. Preliminary measurements of salinity, pH, and turbidity indicated that water conditions are dynamic with both short and long-term changes and patterns occurring. Although contaminants such as PAH were recorded from the water column, the concentrations were very low (i.e. 0 to ~1,200 part per trillion) and had no measurable impact on the habitat. Investigations of benthic pore water quality indicated no contamination.

Within the boundaries of the study area there were no indications that commercial or recreational activity in the area had significant negative impact on the health of the coral community. The coral habitat was judged to be in balance relative to the health and growth of the stony corals.

7.0 LITERATURE CITED

Acosta, A. 2001. Disease in zooanthids: dynamics in space and time. Hydrobiologia 460:113-130.

Aronson, R.B. and W.F. Precht. 2000. Herbivory and algal dynamics on the coral reef at Discovery Bay, Jamaica. Limnol. Oceanogr. 45(1):251-255.

Bak, R.P.M. and G. Nieuwland. 1995. Long-term change in coral communities along depth gradients over leeward reefs in the Netherlands Antilles. Bull. Mar. Sci. 56(2):609-619.

Baker, P.A. and J.N. Weber. 1975. Skeletal growth variations in the reef coral, *Montastraea annularis*, with depth. Geol. Soc. Am., Abstracts 7:24.

Barrera, N. and J.W. Tunnell, Jr. 2001. Micromolluscan faunal survey of the East and West Flower Garden Banks. Pp. 99-108 *in* Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term monitoring of the East and West Flower Garden Banks, 1998-1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2001-101. 120 pp.

Bright, T. and L. Pequegant. 1974. Biota of the West Flower Garden Bank. Houston, Texas: Gulf Publishing Co.

Bright, T.J., D.W. McGrail, R. Rezak, G.S. Boland, and A.R. Trippet. 1985. The Flower Gardens: A compendium of information. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 85-0024. 103 pp.

Bright, T.J., G.P. Kraemer, G.A. Minnery, and T.S. Viada. 1984. Hermatypes of the Flower Garden Banks, northwestern Gulf of Mexico: a comparison to other western Atlantic reefs. Bull. Mar. Sci. 24(3):461-476.

Brower, J.E., J.H. Zar, and C.N. von Ende. 1998. Field and laboratory methods for general ecology. Boston, MA: WCB McGraw Hill. 273 pp.

Bruckner, A. and R.J. Bruckner. 1998. Rapid wasting syndrome or coral predation by stoplight parrotfish? Reef Encounter 7/23:18-22.

Bruckner, A. and R.J. Bruckner. 2000. Destruction of coral by *Sparisoma viride*. Coral Reefs. 17:350.

Bythell, J.C., E.H. Gladfelter, and M. Bythell. 1993. Chronic and catastrophic natural mortality of three common Caribbean reef corals. Coral Reefs. 12:143-152.

Chavez, E.A. and J.W. Tunnell. 1993. Needs for management and conservation of the southern Gulf of Mexico. Proc. 8th Symp Coastal and Ocean Management. Pp. 2,040-2,053.

Chiappone, M., D.W. Swanson, S.L. Miller, and S.G. Smith. 2002. Large-scale surveys on the Florida Reef Tract indicate poor recovery of the long-spined sea urchin *Diadema antillarum*. Coral Reefs 21:155-159.

Continental Shelf Association (CSA). 1996. Long-term monitoring at the East and West Flower Garden Banks. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 96-0046. 79 pp.

Cortés, J. 1997. Status of Caribbean reefs of Central America. Proc. 8th Coral Reef Sym 1:335-340.

Dodge, R.E. and J.C. Lang. 1983. Environmental correlates of hermatypic coral (*Montastraea annularis*) growth on the East Flower Garden Bank, Northwest Gulf of Mexico. Limnol. Oceanogr. 28(2):228-240.

Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, C.R. Beaver, G.S. Boland, and D.K. Hagman. 1999. Long-term monitoring of the East and West Flower Garden Banks 1996-1997. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study 99-0005. 101 pp.

Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term Monitoring of the East and West Flower Garden Banks, 1998-1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2001-101. 120 pp.

Dunton, K. and H. Miller. 2001. Food web structure and macroalgal primary production at the East and West Flower Garden Banks. pp. 89 -98 *In* Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term monitoring of the East and West Flower Garden Banks, 1998-1999. OCS Study MMS 2001-101. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. 120 pp.

FMRI. 1997. Florida Keys Marine Sanctuary water quality protection plan; Coral reef/hard bottom monitoring project; Annual report. Florida Marine Research Institute, St. Petersburg, FL. 160 pp.

Fredericq, S., N. Phillips, S. Lin, B. Gavio, and F. Gurgel. 2001. List of taxonomic macroalgae collected during the 1999 monitoring cruise at the East and West Flower Garden Banks September 15-20, 1999. Pp. 65-71 *in* Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term monitoring of the East and West Flower Garden Banks, 1998-1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2001-101. 120 pp.

Garzón-Ferreira, J., D.L. Gil-Agudelo, L.M. Barrios, and S. Zea. 2001. Stony coral diseases observed in southwestern Caribbean reefs. Hydrobiologia 460:65-69.

Gittings, S.R. and T.J. Bright. 1987. Mass mortality of *Diadema antillarum* at the Flower Garden Banks, Northwest Gulf of Mexico: effect on algae and coral cover. Abstract. Benthic Ecology Meetings, Raleigh, NC.

Gittings, S.R., G.S. Boland, K.J.P. Deslarzes, D.K. Hagman, and B.S. Holland. 1992. Long-term monitoring at the East and West Flower Garden Banks. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 92-0006. 206 pp.

Green, E.P. and A.W. Bruckner. 2000. The significance of coral disease epizootiology for coral reef conservation. Biol. Conserv. 96:347-361.

Hagman, D.K. and S.R. Gittings. 1992. Coral bleaching on high latitude reefs at the Flower Garden Banks, northwestern Gulf of Mexico. Proc. 7th Int. Coral Reef Symp., Guam 1:38-43.

Harvell, D., K. Kim, C. Quirolo, J.Weir, and G. Smith. 2001. Coral bleaching and disease: contributions to 1998 mass mortality in *Briareum asbestinum* (Octocorallia, Gorgonacea). Hydrobiologia 460:97-104.

Hudson, J.H. 1981. Growth rates in *Montastraea annularis*, a recond of environmental change in Key Largo coral reef marine sanctuary. FL Bul. Mar. Sci. 31:444-459.

Hudson, J.H. and D.M. Robin. 1980. Effects of drilling mud on the growth rate of the reef-building coral, *Montastraea annularis*. Pp. 455-470 *in* Geyer, R.A. (ed.). Marine Environmental Pollution, Vol. 1:Hydorcarbons. Elsevier Scientific Publishing Company. New York. 591 pp.

Hughes, T.P. and J.B.C. Jackson. 1985. Population dynamics and life histories of foliaceous corals. Ecol. Monogr. 55:141-166.

Hughes, T.P., A.M. Szmant, R. Steneck, R. Carpenter, and S. Miller. 1999. Algal blooms on coral reefs: What are the causes? Limnol. Oceanogr. 44(6):1583-1586.

Huston, M. 1985. Variation in coral growth rates with depth at Discovery Bay, Jamaica. Coral Reefs 4:19-25.

Kleppel G.S., R.E. Dodge , and C. J. Reese. 1989. Changes in pigmentation associated with the bleaching of stony corals. Limnol. Oceanogr 34:1331-1335.

Knutson, D.W., R.W. Buddemeier, and S.V. Smith. 1972. Coral chronometers: seasonal growth bands in reef corals. Science 177:270-272.

Lang, J.C., K.J.P. Deslarzes, and G.P. Schmahl. 2001. The Flower Garden Banks: remarkable reefs in the NW Gulf of Mexico. Coral Reefs 20:126.

Lapointe, B.E. 1997. Nutrient thresholds for bottom-up control of macroalgal blooms on coral reefs in Jamaica and southeast Florida. Limno. Oceanogr. 42(5, part 2):1119-1131.

Lehman, R.L. and E.M. Albert. 2001. Algal community structure of the East and West Flower Garden Banks, Nowthwestern Gulf of Mexico. Pp. 73-87 *in* Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term monitoring of the East and West Flower Garden Banks, 1998-1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2001-101. 120 pp.

Lessios, H.A. 1988. Mass mortality of *Diadema antillarum* in the Caribbean: What have we learned? Ann. Rev. Ecol. Syst. 19:371-93.

McClanahan, T.R., R.B. Aronson, W.F. Precht, and N.A. Muthiga. 1999. Fleshy algae dominate remote coral reefs of Belize. Coral Reefs 18:61-62.

McGrail, D.W., M. Carnes, D. Horne, T. Cecil, J. Hawkins, and F. Halper. 1982. Water and sediment dynamics at the Flower Garden Banks. Pp. 103-226 i*n* McGrail, D.W., R. Rezak, and T.J. Bright (eds.) Environmental studies at the Flower Gardens and selected banks. Final Report to MMS. Contract #AA851-CTO-25. NTIS Order No. PB83-101303.

Niper, M. and R.S. Carr. 2001. Toxicity testing of sediment pore water from the Flower Garden Banks, Gulf of Mexico. Pp. 109-119 *in* Dokken, Q.R., I.R. MacDonald, J.W. Tunnell, Jr., T. Wade, C.R. Beaver, S.A. Childs, K. Withers, and T.W. Bates. 2001. Long-term monitoring of the East and West Flower Garden Banks, 1998-1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2001-101. 120 pp.

Oberding, T. In preparation. An evaluation of coral diseases and disease-conditions in the Flower Garden Banks National Marine Sanctuary (Gulf of Mexico). M.S. Thesis. College of Science and Technology. Texas A&M University-Corpus Christi. Corpus Christi, TX.

Parsons, T. R., M. Takahashi, and B. Hargrave. 1984. Biological oceanographic processes. 3rd Edition. Pergamon Press. 330 pp.

Pattengill, C.V. 1998. The structure and persistence of reef fish assemblages of the Flower Garden Banks National Marine Sanctuary. Ph.D. Dissertation. Dept. Wildlife and Fisheries. Texas A&M University. College Station, TX. 163 pp.

Peters, E.C. 1997. Diseases of coral reef organisms. *In* C. Birkeland, ed. Life and Death of Coral Reefs. New York, NY: Chapman and Hal. Pp. 114-139.

Porter, J.W., P. Dustan, W.C. Jaap, K.L. Patterson, V. Kosmynin, O.W. Meier, M.E. Patterson, and M. Parsons. 2001. Patterns of spread of coral disease in the Florida Keys. Hydorbiologia 406:1-24.

Porter, J.W., V. Kosmynin, K.L. Patterson, K.G. Porter, W.C. Jaap, J.L. Wheaton, K. Hackett, M. Lybolt, C.P. Tsokos, G. Yanev, D.M. Marcinek, J. Dotten, D. Eaken, M. Patterson, O.W. Meier, M. Brill, and P. Dustan. 2002. Detection of coral reef change by the Florida Keys Coral Reef Monitoring Project. Chapter 27. Pp 749–769, Porter , J.W., and K.G. Porter (eds.). The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Source Book. New York, NY: CRC Press. 1,000 pp.

Rezak, R. 1981. Geology. Pp. 23-59 *in* Rezak, R. and T.J. Bright (eds.) Northern Gulf of Mexico topographic features study. Final Report to the U.S. Dept. of the Interior Bureau of Land Management. Contract #AA551-CT8-35. Vol. 1. NTIS Order No. PB81-248650.

Rezak, R., T.J. Bright, and D.W. McGrail. 1985. Reefs and banks of the northwestern Gulf of Mexico: Their geological, biological, and physical dynamics. New York, NY: John Wiley and Sons. 259 pp.

Richardson, L.L., G.W. Smith, K.B. Ritchie, and R.G. Carlton. 2001. Integrating microbiological, microsensor, molecular, and physiologic techniques in the study of coral disease pathogenesis. Hydrobiologia 460:71-89.

Simpson, G. 1979. Predation on live coral by the parrotfishes *Scarus vetula* and *Sparisoma viride*. In Ecological studies of Buck Island Reef National Monument. U.S. Dept. of the Interior, National Park Service Spec. Rep. Pp 7.1-7.11.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry, 3rd Edition. W.H. Freeman and Company. New York, New York. 887 pp.

Thomas, J.D. 1996. Using marine invertebrates to establish research and conservation priorities. Pp. 357-388 *in* Reaka-Kudla, M.L., D.E. Wilson, and E.O. Wilson (eds). Biodiversity II: Understanding and protecting our biological resources. National Academy Press. 551 pp.

Tunnell, J.W. 1992. Natural versus human impacts to southern Gulf of Mexico coral reef resources. Proc 7th Int. Coral Reef Symp. 1:300-306.

Weber, J.E. and E.W. White. 1977. Caribbean reef corals *Montastraea annularis* and *Montastraea cavernosa* – long-term growth data as determined by skeletal X-radiography. Pp. 171-179 *in* Frost S.H. et al. (eds), Reef and related carbonates – ecology and sedimentation. Am. Assoc. Pet. Geol. Stud. Geol. 4.

Weil, E. and N. Knowlton. 1994. A multi-character analysis of the Caribbean coral *Montastraea annularis* (Ellis & Solander, 1786) and its two sibling species, *M. faveolata* (Ellis & Solander, 1786) and *M. franksii* (Gregory, 1895). Bull. Mar. Sci. 55(1):151-175.

Wells, S.M. 1995. Science and management of coral reefs: problems and prospects. Coral Reefs 14:177-181.

8.0 APPENDIX 1 - OUTSIDE RANDOM TRANSECTS

8.1 East Bank – Community Composition, Structure and Trends

The *Montastraea annularis* complex in transects outside the study area increased to a peak in 2000 but slightly less cover was recorded in 2001 (Table 8.1.0.1). However, the same general pattern of increase in *M. annularis* complex, a peak in algal cover in 1999, and declining cover of reef rock was also evident outside the study area. Shannon diversity and evenness of the coral community were lowest in 2000 and dominance was highest, reflecting the greater coverage of the *M. annularis* complex recorded (Table 8.1.0.2). Diversity increased and dominance decreased in 2001 with the decreased coverage of the *M. annularis* complex recorded, but neither returned to pre-2000 levels. Bray-Curtis cluster analysis of community similarity indicates that overall similarity among the years is 66% with 2 clusters, generally reflecting the increased cover of the *M. annularis* complex during 2000-2001 (Figure 8.1.0.1). Using Mann-Whitney U, the non-parametric equivalent of a t-test, no significant differences were found between major reef components inside the study area versus outside the study area (Table 8.1.0.3). The community described outside of the study area is generally the same as that described inside the study area although it appears to be slightly more variable with regards to some of the less common species such as *Colpophyllia natans*.

8.2 West Bank – Community Composition, Structure and Trends

The outside transects at the WFGB exhibit an identical pattern for the *M. annularis* complex as was seen in the outside transects at the EFGB, with increasing cover of the *M. annularis* complex to a peak in 2000, then a slight decrease in the 2001 data (Table 8.2.0.1). The data collected outside the study area at the WFGB is in general agreement with that collected inside the study area with similar patterns of slightly increased *M. annularis* complex, a peak of algal cover in 1999. The declines in coral species diversity and evenness and the increase in dominance reflect an increase in the *M. annularis* complex cover recorded in 2000 and 2001 (Table 8.2.0.2). Although the *M. annularis* complex cover was slightly less in 2001, cover of several other species was either less or the species was absent in 2001 data collections. It is likely that, like the area outside of the study area on the EFGB, the area outside the study area on the WFGB is slightly more variable with regard to the non-dominant species. Like the EFGB, there were no significant differences between percent cover of major reef components inside the study area vs outside the study area (Table 8.2.0.3). Bray-Curtis cluster analysis of community similarity indicates that communities recorded for each year were about 80% similar (Figure 8.2.0.1). However, the same clusters of 1998-99 and 2000-01, as were delineated at the EFGB were also delineated at the WFGB, again reflecting the increased dominance of the *M. annularis* complex in 2000-02.

Table 8.1.0.1.

Mean cover (%) with standard deviation in parenthesis from outside random transects, East Flower Garden Bank.

	1998[1]	**1999[1]**	**2000**	**2001**
Agaricia agaricites	0.6	0.3	0.2 (0.2)	0.6 (0.6)
Agaricia fragilis	0.0	0.0	0.0	0.0
Colpophyllia natans	2.3	3.3	0.7 (1.1)	8.2 (7.4)
Diploria strigosa	9.7	8.7	5.4 (0.4)	4.0 (3.6)
Montastraea annularis complex*	29.0	33.6	56.8 (3.3)	52.9 (14.3)
Montastraea cavernosa	3.8	2.3	1.6 (2.3)	6.2 (8.3)
Scolymia sp.	0.1	0.0	0.0	0.02 (0.04)
Stephanocoenia michilini	0.6	0.4	0.0	1.1 (1.5)
Mussa angulosa	0.1	<0.1	0.3 (0.5)	0.4 (0.7)
Madracis sp.	0.3	2.4	0.0	0.0
Porites astreoides	4.7	4.1	2.6 (1.3)	3.1 (2.8)
Porites porites	0.1	<0.1	0.01 (0.02)	0.02 (0.04)
Siderastrea sp.	0.4	1.0	0.02 (0.05)	0.02 (0.04)
Millepora sp.	1.7	1.3	0.4 (0.3)	0.5 (0.4)
Total Coral	**53.1**	**58.2**	**67.9 (3.4)**	**73.0 (17.3)**
Filamentous algae	*	*	11.2 (3.0)	8.3 (7.4)
Crustose coralline algae	*	*	1.6 (0.9)	2.2 (1.2)
Dictyota sp.	*	*	0.2 (0.2)	0.2 (0.1)
Total Algae	**2.2**	**22.4**	**13.1 (3.4)**	**10.7 (8.4)**
Total Sponge	**1.4**	**0.0**	**0.3 (0.2)**	**0.4 (0.5)**
Serpulidae	*	*	0.06 (0.07)	0.2 (0.1)
Other	*	*	0.3 (0.6)	1.6 (2.8)
Reef rock	46.7	17.4	2.1 (0.9)	1.7 (2.2)
	1998[1]	**1999[1]**	**2000**	**2001**
Sand	0.0	1.0	0.0	0.07 (0.1)
Artifacts	*	*	0.6 (1.1)	0.3 (0.4)
Unidentifiable	*	*	15.7 (4.2)	11.9 (2.8)
Number of transects	N/A	N/A	4	3

[1] The original data were not available so new means and standard deviations could not be calculated. These data are presented as they appeared in the 1998-99 report; categories with a '*' were not used during these years
[*] *Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

Table 8.1.0.2.

Shannon diversity (H', base 10), evenness (J') and Berger-Parker dominance (d), outside study area at the East Flower Garden Bank.

	1998	1999	2000	2001
Diversity	0.65	0.63	0.30	0.50
Eveness	0.58	0.58	0.30	0.46
Dominance	0.54	0.58	0.83	0.69

Table 8.1.0.3.

Results of non-parametric Mann-Whitney U comparing inside transects to outside transects for major reef components, East Flower Garden Bank.

Component	N	U	Z	Significance
Montastraea annularis complex*	8	5.00	-0.866	0.486
Colpophyllia natans	8	8.00	0.000	1.000
Diploria strigosa	8	8.00	0.000	1.000
Madracis sp.	8	5.50	-0.730	0.486
Montastraea cavernosa	8	7.00	-0.289	0.886
Porites astreoides	8	7.50	-0.145	0.886
Siderastrea sp.	8	7.00	-0.292	0.886
Total algae	8	5.00	-0.866	0.486
Reef rock	8	7.00	-0.289	0.886

Montastraea annularis complex is comprised of *M. annularis, faveolata*, and *franksi*.

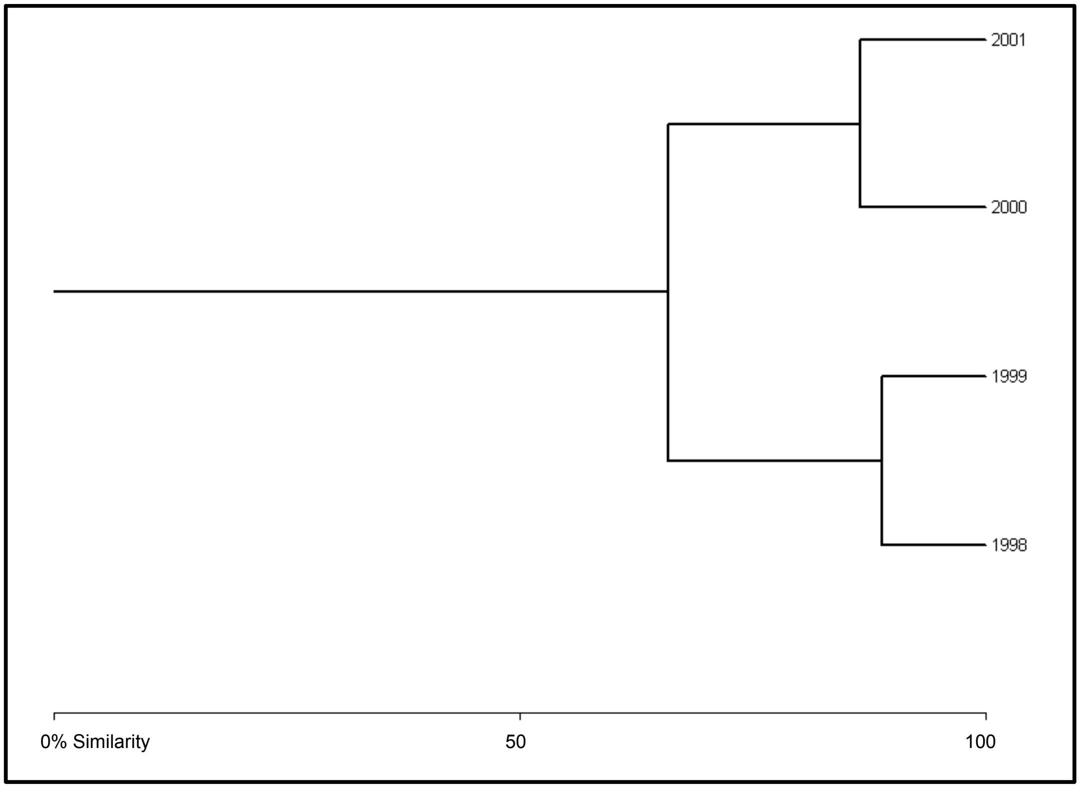


Figure 8.1.0.1. Bray-Curtis community similarity dendrogram for outside random transects from 1998-2001 for the East Flower Garden Bank.

Table 8.2.0.1.

Mean cover (%) with standard deviation in parenthesis from outside random transects, West Flower Garden Bank.

	1998	1999	2000	2001
Agaricia agaricites	0.4	0.3	0.3 (0.2)	0.4 (0.4)
Agaricia fragilis	0.0	0.0	0.008 (0.02)	0.0
Colpophyllia natans	2.0	2.0	1.3 (1.2)	2.6 (3.4)
Diploria strigosa	8.6	10.1	6.1 (2.0)	4.2 (1.4)
Montastraea annularis complex*	27.1	31.2	40.1 (4.9)	35.6 (7.3)
Montastraea cavernosa	2.9	3.7	3.2 (1.8)	1.1 (2.1)
Scolymia sp.	<0.1	0.1	0.0.	0.0
Stephanocoenia mechelinii	0.5	0.5	1.3 (1.8)	1.1 (1.2)
Mussa angulosa	0.1	<0.1	0.0	0.5 (0.8)
Madracis sp.	0.3	1.3	0.0	0.0
Porites astreoides	2.5	4.4	2.1 (1.8)	2.4 (1.0)
Porites porites	<0.1	<0.1	0.0	0.0
Siderastrea sp.	1.2	1.1	0.5 (1.0)	0.0
Millepora sp.	1.4	1.1	1.4 (1.6)	0.2 (0.2)
Total Coral	**47.0**	**55.7**	**56.8 (7.1)**	**48.0 (5.7)**
Filamentous algae	*	*	21.2 (5.3)	25.5 (3.4)
Crustose coralline algae	*	*	3.5 (0.9)	2.7 (1.5)
Dictyota sp.	*	*	0	0.007 (0.01)
Total Algae	**2.7**	**21.7**	**24.7 (5.8)**	**28.2 (4.7)**
Total Sponge	**1.0**	**0.0**	**0.9 (1.3)**	**0.8 (0.5)**
Serpulidae	*	*	0.04 (0.03)	0.02 (0.02)
Other	*	*	0.03 (0.07)	0.07 (0.1)
Reef rock	49.0	18.6	4.1 (1.6)	4.2 (1.8)
Sand	0.1	2.0	0.0	0.07 (0.1)
Artifacts	*	*	0.4 (0.5)	0.4 (0.8)
Unidentifiable	*	*	13.1 (2.0)	16.8 (3.2)
Number of transects	*	*	4	4

[*] *Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

[1] The original data were not available so new means and standard deviations could not be calculated. These data are presented as they appeared in the 1998-99 report; categories with a '*' were not used during these years.

Table 8.2.0.2.

Shannon diversity (H', base 10), evenness (J') and Berger-Parker dominance (d), outside West Flower Garden Bank.

	1998	1999	2000	2001
Diversity	0.63	0.64	0.48	0.45
Evenness	0.56	0.58	0.48	0.47
Dominance	0.57	0.56	0.71	0.74

Table 8.2.0.3.

Results of non-parametric Mann-Whitney U comparing inside transects to outside transects for major reef components, West Flower Garden Bank.

Component	N	U	Z	Significance
Montastraea annularis complex*	8	6.00	-0.577	0.686
Colpophyllia natans	8	7.00	-0.290	0.886
Diploria strigosa	8	4.00	-1.155	0.343
Madracis sp.	8	7.00	-0.290	0.886
Montastraea cavernosa	8	7.00	-0.289	0.886
Porites astreoides	8	7.00	-0.292	0.886
Siderastrea sp.	8	3.00	-1.443	0.200
Total algae	8	6.00	-0.577	0.686

**Montastraea annularis* complex is comprised of *M. annularis, faveolata*, and *franksi*.

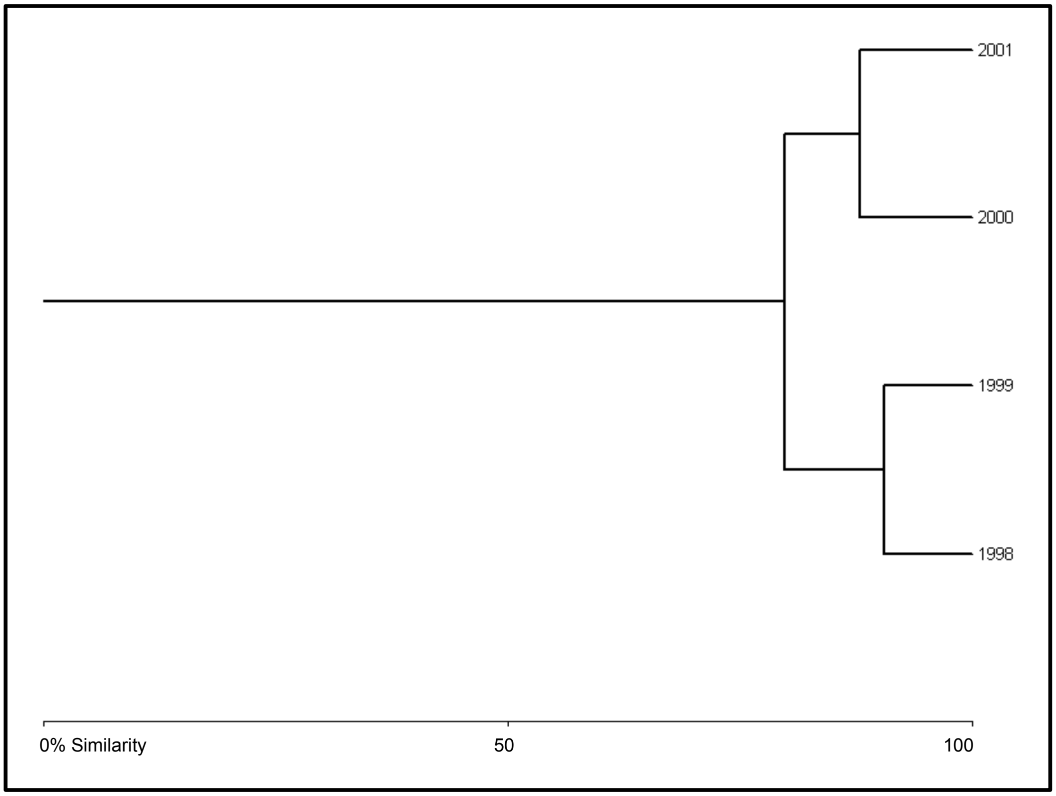


Figure 8.2.0.1. Bray-Curtis community similarity dendrogram for outside random transects from 1998-2001 for the West Flower Garden Bank.

9.0 APPENDIX 2

Dates of monitoring and other servicing cruise with summary of data collection intervals and quality description for East and West Flower Garden Banks and HI389 Platform reference sensor. Letters describing data gaps refer to notation in Figures 3.7.2.1 – 3.7.2.4.

Cruise start date	EFG data interval	WFG data interval	HI389 data interval
		9-Sep-97 to 8-Nov-97 (**D.** data logger overflow)	
8 Sep 97	10-Sep-97 to 3-Mar-98 (good data)	9-Nov-97 to 2 Mar 98 (good data)	9-Sep-97 to 3-Mar-98 (good data)
2 Mar 98	3-Mar-98 to 26-Aug-98 (**A.** sensor broken on deployment)	3-Mar-98 to 24-Aug-98 (good data)	4-Mar-98 to 26-Aug-98 (good data)
24 Aug 98	24-Aug-98 to 11-Oct-98 (good data)	24-Aug-98 to 14-Oct-98 (good data)	26-Aug-98 to 13-Oct-98 (good data)
14 Oct 98	14-Oct-98 to 23-Mar-99 (**B.** sensor broken on deployment)	14-Oct-98 to 23-Mar-99 (good data)	13-Oct-98 to 22-Mar-99 (acceptable data, **E.** transient error 25-Nov to 30 Dec-99)
23 Mar 99	22-Mar-99 to 5-Apr-99 (data logger overflow) 5-Apr-99 to 27-July-99 (good data)	23-Mar-99 to 26-Jul-99 (good data)	23-Mar-99 to 26-Jul-99 (acceptable data, **F.** transient error 12-Mar to 26-Apr-99)
26-Jul-99	27-Jul-99 to 13-Sep-99 (good data)	27-Jul-99 to 13-Sep-99 (good data)	26-Jul-99 to 13-Sep-99 (good data)
2- Sep 99	14-Sep-99 to 26-Oct-99 (**C.** data logger overflow)	14-Sep-99 to 26-Oct-99 (data logger overflow)	14-Sep-99 to 26-Oct-99 (**G.** data logger overflow)
25 Oct 99	26-Oct-99 to 16-Feb-00 (good data)	26-Oct-99 to 16-Feb-00 (good data)	26-Oct-99 to 16-Feb-00 (good data)
15 Feb 00	16-Feb-00 to 22-Jun-00 (battery failure; no data)	16-Feb-00 to 22-Jun-00 (housing flooded; no data)	16-Feb-00 to 22-Jun-00 (data intermittent)
22 Jun 00	22-Jun-00 to 11-Sep-00 (readings low—acceptable data)	22-Jun-00 to 11-Sep-00 (good data)	22-Jun-00 to 11-Sep-00 (sensor failure)
11 Sep 00	11-Sep-00 to 12-Dec-00 (sensor failure; no data)	11-Sep-00 to 12-Dec-00 (good data)	11-Sep-00 to 12-Dec-00 (sensor failure)
12 Dec 00	12-Dec-00 to 28-Apr-01 (readings low—acceptable data)	12-Dec-00 to 28-Apr-01 (good data)	12-Dec-00 to 28-Apr-01 (good data)
28 Apr 01	28-Apr-01 to 18-Aug-01 (acceptable data)	28-Apr-01 to 18-Aug-01 (good data)	28-Apr-01 to 18-Aug-01 (intermittent data)
18 Aug 01	18-Aug-01 to 17-Sep-01 (acceptable data)	18-Aug-01 to 17-Sep-01 (acceptable data)	18-Aug-01 to 17-Sep-01 (intermittent data)
28 Sep 01	28-Sep-01 to 08-Feb-02 (YSI sonde installed; good data)	28-Sep-01 to 08-Feb-02 (YSI sonde installed; good data)	28-Sep-01 to 08-Feb-02 (sensor failure)

10.0 APPENDIX 3

Encrusting growth stations of *Diploria strigosa* exhibiting net gain (+), loss (−), and no change (=) in percent cover of coral tissue at the East and West Flower Garden Banks, 1998-2001.

East Flower Garden Bank 1998

Station	Area of Coral Tissue (cm^2)	Difference from 1997 (cm^2)	Change in % Cover
	Tissue Gain (+)		
1	190.40	32.80	12.52
3	138.93	15.63	5.97
5	208.31	9.61	3.67
6	231.10	14.70	5.61
13	191.93	83.35	31.81
15	149.16	39.71	15.16
20	195.32	41.29	15.76
33	225.99	57.34	21.88
39	102.70	22.90	8.74
41	219.66	13.20	5.04
49	184.95	50.01	19.09
52	137.58	11.45	4.37
56	198.10	34.21	13.06
59	138.81	16.19	6.18
62	138.81	7.03	2.68
63	78.40	8.12	3.10
68	169.36	14.64	5.59
75	186.40	6.17	2.35
79	221.10	22.80	8.70
82	124.66	5.96	2.27
100	103.70	18.45	7.04
	Tissue Loss (-)		
2	0.00	-63.40	0.68
4	1.65	-143.74	0.15
7	117.33	-61.48	2.13
11	10.77	-147.68	1.94
12	0.00	-188.69	1.63
27	100.94	-33.55	1.63
28	115.36	-9.06	-0.16
31	35.38	-99.21	2.21
32	105.70	-40.15	1.10
35	79.15	-130.34	1.83
46	0.00	-114.59	-0.44
53	121.79	-22.95	0.68
54	154.17	54.60	0.15
55	159.58	-5.13	2.13

East Flower Garden Bank 1998, continued

Station	Area of Coral Tissue (cm^2)	Difference from 1997 (cm^2)	Change in % Cover
	No Change (=)		
10	210.45	1.78	-24.20
16	148.30	0.40	-54.86
25	141.19	5.57	-23.46
26	172.11	5.09	-56.36
42	128.70	4.28	-72.02
64	78.40	4.28	-12.80
70	177.54	-0.43	-3.46
83	99.55	5.80	-37.86
84	102.99	2.87	-15.32
85	124.47	4.80	-49.75
8	139.04	-1.16	-43.73

West Flower Garden Bank 1998

Station	Area of Coral Tissue (cm^2)	Difference from 1997 (cm^2)	Change in % Cover
	Tissue Gain (+)		
2	166.5	62.1	23.70
4	156.6	55.69	21.25
5	209.43	36.07	13.77
7	123.67	23.3	8.89
10	153.58	27.06	10.33
30	155.49	63.69	24.31
31	128.79	15.88	6.06
36	192.76	41.04	15.66
42	157.9	13.11	5.00
44	192.24	48.76	18.61
50	188.2	34.94	13.34
56	150.9	52.61	20.08
58	158.99	19.13	7.30
73	192.4	22.97	8.77
100	188.71	67.76	25.86
318	154.8	33.96	12.96
45a	191.24	47.19	18.01
67b	111.71	34.97	13.35
	Tissue Loss (-)		
3	99.65	-49.54	-18.91
6	73.56	-106.84	-40.78
9	139.63	-68.81	-26.26
11	179.28	-95.31	-36.38
34	133.83	-52.55	-20.06
35	116.87	-16.75	-6.39
37	66.47	-106.04	-40.47
38	180.91	-16.91	-6.45
43	104.34	-38.43	-14.67
53	100.28	-20.94	-7.99
54	75.49	-10.25	-3.91
59	129.39	-37.57	-14.34
60	70.17	-50.27	-19.19
101	120.41	-5.41	-2.06
	No Change (=)		
39	101.17	-0.63	-0.24
41	127.52	-2.96	-1.13
52	147.31	-3.65	-1.39
57	147.63	1.75	0.67
70	209.99	-0.75	-0.29
45b	228	2.21	0.84

East Flower Garden Bank 1999

Station	Area of Coral Tissue (cm^2)	Difference from 1998 (cm^2)	Change in % Cover
	Tissue Gain (+)		
3	138.93	16.48	6.29
5	208.31	43.99	16.79
6	231.10	54.98	20.98
7	117.33	19.91	7.60
10	228.00	17.55	6.70
11	40.70	29.93	11.42
15	165.68	16.52	6.30
16	178.32	30.02	11.46
21	24.75	10.80	4.12
31	155.10	119.72	45.69
32	120.74	15.03	5.74
35	199.73	120.58	46.02
37	188.10	48.07	18.35
39	142.37	39.67	15.14
42	154.32	25.62	9.78
49	199.12	14.17	5.41
52	163.22	25.64	9.79
54	176.31	22.14	8.45
56	227.40	29.30	11.18
62	158.42	14.62	5.58
64	112.54	25.12	9.59
68	187.55	18.19	6.94
75	212.61	26.21	10.00
79	245.47	24.36	9.30
83	140.17	40.62	15.50
84	189.78	86.79	33.12
100	129.31	25.61	9.77
	Tissue Loss (-)		
2	0.00	-39.74	-15.17
4	1.65	-65.49	-25.00
13	8.95	-182.98	-69.84
25	6.93	-134.26	-51.24
26	0.47	-171.50	-65.46
29	87.48	-37.70	-14.39
47	1.63	-175.18	-66.86
58	94.56	-7.24	-2.76
59	122.71	-16.10	-6.14
82	80.92	-43.74	-16.69
85	108.19	-16.28	-6.21

East Flower Garden Bank 1999, continued

Station	Area of Coral Tissue (cm^2)	Difference from 1997 (cm^2)	Change in % Cover
	No Change (=)		
1	197.53	7.13	2.72
8	107.78	-3.44	-1.31
27	107.30	6.36	2.43
28	119.83	4.47	1.71
33	229.45	3.46	1.32
36	107.75	6.63	2.53
41	228.60	8.94	3.41
53	118.60	-3.19	-1.22
55	166.13	6.55	2.50
63	77.98	-0.42	-0.16
70	169.71	-4.75	2.72

West Flower Garden Bank 1999

Station	Area of Coral Tissue (cm^2)	Difference from 1998 (cm^2)	Change in % Cover
	Tissue Gain (+)		
1	160.64	94.79	36.18
8	128.09	13.12	5.01
11	211.43	32.15	12.27
12	140.94	24.20	9.24
13	190.53	66.97	25.56
25	205.28	111.31	42.48
33	206.70	36.39	13.89
34	155.03	21.20	8.09
37	182.35	115.88	44.23
39	119.21	18.04	6.89
41	151.21	23.69	9.04
43	169.49	65.14	24.86
44	203.72	11.48	4.38
53	127.58	27.30	10.42
59	207.42	78.03	29.78
60	89.24	19.06	7.27
70	225.18	15.18	5.79
	Tissue Loss (-)		
2	75.94	-90.58	-34.57
3	54.28	-45.38	-17.32
4	103.34	-53.29	-20.34
5	156.19	-53.24	-20.32
9	0.00	-139.63	-53.29
15	148.86	-16.07	-6.13
19	109.78	-19.48	-7.43
23	68.09	-129.58	-49.46
24	6.99	-132.50	-50.57
26	1.16	-163.47	-62.39
29	89.26	-38.65	-14.75
31	36.85	-91.94	-35.09
32	117.37	-55.95	-21.35
35	101.80	-15.07	-5.75
36	117.71	-75.05	-28.65
38	156.26	-24.65	-9.41
40	36.50	-141.34	-53.94
45	138.68	-44.31	-16.91
55	123.54	-65.93	-25.16
56	139.08	-11.81	-4.51
57	121.91	-25.73	-9.82
58	92.14	-70.19	-26.79

West Flower Garden Bank 1999, continued

Station	Area of Coral Tissue (cm^2)	Difference from 1997 (cm^2)	Change in % Cover
No Change (=)			
6	73.57	0.00	0.00
10	149.54	-4.04	-1.54
14	176.12	3.44	1.31
21	24.54	-1.74	-0.66
22	180.76	5.83	2.23
28	121.14	7.75	2.96
30	164.14	8.64	3.30
42	151.07	-6.83	-2.61

East Flower Garden Bank 2000

Station	Area of Coral Tissue (cm^2)	Difference from 1999 (cm^2)	Change in % Cover
	Tissue Gain (+)		
15	133.65	30.25	11.55
28	110.64	36.17	13.80
35	107.02	16.11	6.15
37	171.69	40.06	15.29
79	215.45	15.68	5.99
	Tissue Loss (-)		
21	23.91	-23.91	-9.12
64	91.15	-77.50	-29.58
83	128.33	-8.25	-3.15
	No Change (=)		
12	124.22	-2.52	-0.96
31	8.93	-2.86	-1.09
32	113.12	-3.03	-1.16
46	0.00	0.00	0.00
49	184.14	3.58	1.37

West Flower Garden Bank 2000

Station	Area of Coral Tissue (cm^2)	Difference from 1999 (cm^2)	Change in % Cover
	Tissue Gain (+)		
29	131.41	10.10	3.86
32	173.91	13.15	5.02
47	221.96	27.23	10.39
50	206.72	22.99	8.78
51	140.04	15.90	6.07
68	163.92	27.97	10.68
U4	201.71	6.25	2.38
U5	190.39	9.28	3.54
U7	208.85	10.97	4.19
	Tissue Loss (-)		
02	169.43	-8.97	-3.43
04	167.91	-11.76	-4.49
05	149.81	-49.51	-18.90
31	135.99	-6.09	-2.32
42	154.96	-11.02	-4.21
56	121.32	-7.52	-2.87
61	4.87	-6.49	-2.48
70	206.39	-11.81	-4.51
U2	136.06	-16.81	-6.42
U6	144.36	-6.21	-2.37
	No Change (=)		
10	0.00	-3.37	-1.29
11	174.62	2.68	1.02
33	196.77	0.92	0.35
41	202.19	0.50	0.19
53	111.72	3.99	1.52
XXX	182.72	0.79	0.30

East Flower Garden Bank 2001

Station	Area of Coral Tissue (cm^2)	Difference from 2000 (cm^2)	Change in % Cover
	Tissue Gain (+)		
12	121.70	24.06	9.18
24(168)	175.22	38.19	14.58
56(187)	227.39	14.50	5.54
60	65.78	11.53	4.40
83(173)	120.08	31.14	11.88
92	147.11	17.04	6.50
	Tissue Loss (-)		
01(110)	37.00	-9.31	-3.55
08	236.46	-40.45	-15.44
13	214.95	-10.55	-4.03
15(119)	163.90	-27.65	-10.55
20(179)	210.81	-8.69	-3.32
37	211.74	-22.63	-8.64
43	198.59	-8.20	-3.13
54(192)	137.97	-31.13	-11.88
65(189)	182.07	-15.44	-5.89
79	231.14	-33.47	-12.77
82	130.06	-16.79	-6.41
	No Change (=)		
02	0.00	2.41	0.92
03(2)	229.70	5.18	1.98
05	190.54	2.42	0.93
21	0.00	0.00	0.00
22	0.00	0.00	0.00
28(193)	146.81	-4.06	-1.55
32	110.09	1.85	0.71
33(118)	161.27	-1.00	-0.38
39	69.28	-4.38	-1.67
53(176)	126.33	-4.30	-1.64
57	262.01	0.00	0.00
64	13.65	-0.03	-0.01

Station numbers followed by parentheses represent stations that have been retagged

West Flower Garden Bank 2001

Station	Area of Coral Tissue	Difference from 2000	Change in % Cover
Tissue Gain (+)			
02(104)	185.21	15.78	6.02
04	190.47	22.56	8.61
05	235.57	85.76	32.73
13	169.95	6.17	2.35
18	207.21	33.65	12.84
24(108)	136.65	29.13	11.12
25	94.43	19.55	7.46
26(121)	217.96	40.08	15.30
33(134)	229.04	32.27	12.32
41/41 DIG	181.51	41.29	15.76
47(102)	231.42	9.46	3.61
51(131)	155.96	15.91	6.07
68	190.01	26.08	9.96
XXX (147)	228.09	45.37	17.32
Tissue Loss (-)			
17(109)	107.92	-8.43	-3.22
19(103)	95.17	-26.39	-10.07
29(117)	115.23	-16.18	-6.18
50(101)	186.89	-19.83	-7.57
No Change (=)			
20	0.00	0.00	0.00
23	111.95	-1.15	-0.44
35(125)	117.41	-3.02	-1.15
56	84.39	2.84	1.08
61	3.15	-1.72	-0.66
70(113)	207.48	1.10	0.42

Station numbers followed by parentheses represent stations that have been retagged

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.