COLLIER COUNTY BEACH RENOURISHMENT PROJECT
FDEP PERMIT NO. 0222355-001-JC
2007 YEAR ONE POST-CONSTRUCTION
ENVIRONMENTAL MONITORING REPORT

Prepared for:
Collier County, Florida
Florida Department of Environmental Protection

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1.0 INTRODUCTION

This year one post-construction environmental monitoring report was prepared in response to Collier County’s implementation of a comprehensive shore protection project between Florida Department of Environmental Protection (FDEP) survey control monuments R-22 to R-37, R-45 to R-55, and R-58A to R-79, along approximately 13.5 km (8.5 miles) of coastline, and ongoing inlet maintenance at Doctors Pass. From February 21, 2006 to May 23, 2006, approximately 667,562 cubic yards (cy) of beach compatible sand was placed within four construction reaches along Collier County’s beaches using an offshore sand source. The purpose of the 2007 year one post-construction environmental monitoring was to identify and report physical and/or biological effects on the natural nearshore habitat at least one year after construction of the Collier County Beach Renourishment and Doctors Pass Inlet Maintenance Dredging Projects. The following environmental report fulfills the FDEP monitoring requirements for both projects and meets the conditions mandated by the U.S. Army Corps of Engineers (USACE).

The principal area of the investigations was defined as the nearshore marine environment, a distance of approximately 300 meters offshore of the June 2003 mean high water line. The study area has been delineated and coordinated with the FDEP to investigate those marine resources located landward of the project’s proposed mixing zone. It should be noted that in recognition of the challenges associated with marine resource monitoring in southwest Florida, including the Collier County project area, the FDEP has approved a monitoring schedule that allows for summer (June through September) season documentation of the nearshore hardbottom. All post-construction biological monitoring events will be conducted between June and September of the appropriate year.

2.0 METHODS

The Coastal Oceanographic Hydrographic Data Collection and Processing (HYPACK® MAX 4.3a) program was the navigation and hydrographic surveying system used to process all differential global positioning system (DGPS) data. On-line screen graphic displays included the transect location in the form of targets, pre-plotted survey lines, an updated boat track across the survey area, adjustable left/right indicators, and other positioning information (e.g., boat speed, quality of fix, and line bearing). All data obtained was recorded onto the computer’s hard drive and transferred to a CD-Rom or external memory source at the end of each day, providing a backup of the raw survey data.
Coastal Planning & Engineering, Inc. (CPE) identified, through extensive coordination with representatives of Collier County and the FDEP, twenty-four (24), permanent, 150-meter long, cross-shore compliance monitoring transects. Transect establishment began at the diver verified pre-construction (2005) landward edge of the nearshore hardbottom formation and progressed offshore in generally shore perpendicular alignment. In addition, twelve (12) transects were established north and south of the construction fill segments as either transitional boundaries or control sites in order to provide comparative evaluation opportunities to assess project effects.

The Benthic Ecological Assessment for Marginal Reefs (BEAMR) surveying method was developed by CPE to evaluate nearshore marine habitats, and comparatively analyze the interrelationship between corals, algae, sediment, invertebrates, and fish species within nearshore reef systems. Due to the macroalgae dominated nature of the nearshore hardbottom communities throughout Florida, the BEAMR protocol allows researchers to incorporate macroalgal and other benthic functional groups into their analyses and characterization of larger transects established over hardbottom formations. Recently, the FDEP has specifically recommended using the BEAMR approach to characterize and assess potential affects to nearshore marine communities from beach nourishment projects in Collier County and other areas in the State of Florida. CPE and FDEP determined that considering the 150-meter length of the proposed shore-perpendicular transects it is not feasible to follow the standard benthic surveying protocol which calls for quadrat analysis every two (2) meters. Therefore, a 0.5-square meter (m²) quadrat was used with a sampling interval of every 7.5 meters, for a total of at least twenty (20) monitoring stations along each established transect. Within each 0.5-m² quadrat, planar percent cover of all sessile benthos was pooled to 11 major functional groups.

In addition, CPE marine biologists conducted a census of all scleractinian (hard coral) and octocoral (soft coral) colonies (≥ 5 cm) that fell within a 0.5-meter north and a 0.5-meter south belt, one meter in width, along the entire 150-m (east to west) transect. Belt-transect surveys recorded the species, size, location, and condition of each coral colony. Sand thickness was documented around each colony, and visual inspections assessed the condition of *Siderastrea* and *Solenastrea* colonies. If no individual colonies or groups of corals were found within the 1-m transect belt, the search area was expanded to a 6-m belt centered on the transect for the length (dependent upon visibility) of the permanent 150 m transect.

Video surveys were conducted by a marine biologist using a 4 mm Sony TRV-900 digital video camera in an Ikelite housing. The camera was set to fully automatic operation, “steadyshot”, and “progressive scan”, recording 15 frames per second at 640 x 480 resolution. The biologist swam, while filming each video transect, from east to west. Video of the seafloor beneath each 150-m transect line was maintained through a laser guidance system at a height of 40-cm after Porter et al. (2002). The visible width of imagery taken from this height was approximately 40-cm, thus the total area documented for each video transect was approximately 60 m².
3.0 FINDINGS

The 2007 post-construction environmental monitoring event documented the status of Collier County’s nearshore marine resources one year after completion of beach construction activities. While abiotic parameter testing documented a hardbottom substrate that is naturally affected by large scale sediment transport and accumulations, no measurements were significantly different from the pre-construction monitoring events. Over half (62.2 ±3.3%) of the nearshore hardbottom habitats within the Collier County study area recorded sediment cover at least one centimeter thick, an insignificant increase from both the 2005 pre-construction and 2006 immediate post-construction monitoring events. Nearshore accumulations of sediment along the monitoring transects measured an average thickness of 11.1 ±0.8 cm deep, which increased insignificantly from the pre-construction and immediate post-construction averages. Compliance transects adjacent to project construction also recorded insignificant increases in average sediment percent cover (61.2 ±3.6%) and average sediment thickness (11.9 ±1.1 cm). Likewise, control and transitional boundary transects recorded slight increases in sediment percent cover and sediment depth; however, all measurements were calculated to have no significant variation from the pre-construction levels. Of specific interest was the slight increase of fine mud recorded in all of the study project segments. However, considering that the approved sand source for the Collier County Beach Renourishment Project had a documented fine fraction of ~1.0%, it is unlikely that the mud accumulation documented during these investigations is the result of the beach project. The accumulations were first documented during the 2005 pre-construction monitoring event, and persisted through the 2006 and 2007 post-construction monitoring events. While all the segment increases in mud observations were calculated to be insignificant, an average increase of 5% cover was still recorded for those quadrats containing a portion of mud. Even though non-parametric trend analyses show an inclination towards increasing sedimentation, these measurements also demonstrate that the integrity of the nearshore hardbottom has not been compromised through sediment coverage. Overall, construction activities associated with the Collier County Beach Renourishment Project has not significantly altered the sediment distribution within the monitored nearshore hardbottom habitats of Collier County.

Monitoring of all thirty-six (36), 150-meter long transects within the nearshore study area of Collier County documented that benthic biota was not adversely affected by construction activities. Macroalgae was reported in relatively moderate abundance along the hardbottom resource. Overall, the County’s study area averaged 22.0 ±3.6% cover, which differed insignificantly from pre-construction and immediate post-construction averages. When analyzed separately, compliance transects, control station transects, and transitional boundary transects all documented non-significant differences in macroalgae percent cover from the pre-construction levels.

Scleractinian coral had limited documented diversity with only four species (Siderastrea siderea, Solenastrea hyades, Oculina robusta, and Phyllangia americana) identified along the nearshore hardbottom habitats of Collier County. As documented during the 2005 pre-construction and 2006 immediate post-construction monitoring events, coral
cover represents a very low percentage (~1.01%) of the nearshore reef habitat. Even so, along compliance transects, average hard coral cover has showed a marked increase between monitoring events, from 0.50% during the 2005 pre-construction monitoring, to 0.64% during 2006 immediate post-construction, to 0.86 ±0.16% in 2007. This increase proved to be statistically significant, and was most likely correlated to a 0.5 cm average increase in coral colony length measured throughout the compliance transects when compared to pre-construction values. A similar trend in hard coral colony growth, even though statistically insignificant, was documented at the control transects, where a 0.3% increase in coral cover was coupled with a 0.4 cm increase in average maximum length measurements of the coral colonies. This data suggests that the growth rates of scleractinian corals were not disturbed by the construction activities of the Collier County Beach Renourishment Project.

The nearshore zone of Collier County contains a habitat comprised of important benthic species and key substrate-building components. Collier County's comprehensive environmental monitoring program is specifically designed to monitor and assess habitat changes through the year 2011. While the 2007 year one post-construction monitoring event did not document significant adverse effects in the nearshore reef habitat of Collier County attributable to construction of the Collier County Beach Nourishment project, future monitoring events will be performed to comprehensively evaluate whether the project will have an affect on these marine resources. The year two post-construction monitoring event is scheduled for the summer of 2008, and the results of those investigations will be compared to the findings presented in the pre-construction and post-construction monitoring reports.
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COLLIER COUNTY BEACH RENOURISHMENT PROJECT  
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1.0 INTRODUCTION  

This year one post-construction environmental monitoring report was prepared in response to Collier County’s implementation of a comprehensive shore protection project between Florida Department of Environmental Protection (FDEP) survey control monuments R-22 to R-37, R-45 to R-55, and R-58A to R-79, along approximately 13.5 km (8.5 miles) of coastline (Figure 1), and ongoing inlet maintenance at Doctors Pass. From February 21, 2006 to May 23, 2006, approximately 667,562 cubic yards (cy) of approved beach compatible sediment was placed within four construction reaches along Collier County’s beaches. In addition, approximately 53,600 cy of dredged material was placed between R-60 and R-62 from the Doctors Pass Inlet Maintenance Dredging Project. The purpose of the 2007 year one post-construction environmental monitoring was to identify and document physical and/or biological effects on the natural nearshore habitat resulting from construction of the Collier County Beach Renourishment and Doctors Pass Inlet Maintenance Dredging Projects.

In February 2003, Coastal Planning & Engineering, Inc. (CPE) conducted a sidescan sonar survey of Collier County’s nearshore region study area (i.e., R-17 to R-81). The results of these investigations documented the presence of approximately 500 acres of nearshore hardbottom formations located 1,000 ft from the shoreline, or within the proposed mixing zone that could be affected by beach nourishment activities (Figures 2 through 5). During the summer of 2003, CPE’s marine biologists further documented and characterized these hardbottom resources adjacent to the beach nourishment project areas (Makowski and Lybolt, 2004). During the summer of 2005, a pre-construction environmental monitoring event was conducted to further document the physical and biological baseline characteristics of the natural nearshore habitat before construction of the Collier County Beach Renourishment and Doctors Pass Inlet Maintenance Dredging Projects commenced. The first post-construction assessment was carried out in 2006, immediately after beach restoration activities were completed.

This environmental report details the year one post-construction condition of hardbottom habitat functional groups, both biotic and abiotic, to assess any effects that may have resulted from sand placement within the approved project area. Direct and indirect effects, or the lack thereof, are evaluated through analysis of data collected as part of the County’s comprehensive in situ monitoring program. Of special interest was the possibility of cross-shore sand transport and its effect on nearshore hardbottom communities. The FDEP project permit (No. 0222355-001-JC) specifically states that the agency shall consider hardbottom coverage seaward of the initial (pre-construction) location of the nearshore edge of the hardbottom as directly attributable to the project. Should project related impact be determined, the results of these investigations will be used for the estimation of additional mitigation to compensate the loss of habitat and function as mandated in the FDEP permit. This report specifically applies to waters of
Figure 1. Project Location Map.
the Gulf of Mexico within the project area and fulfills the FDEP monitoring requirements which are supported by the U.S. Army Corps of Engineers (USACE) permit and Minerals Management Service (MMS) license.

The principal area of the immediate post-construction investigations was defined as the nearshore marine environment, a distance of approximately 300 meters offshore of the June 2003 mean high water line. The study area has been delineated and coordinated with the FDEP to investigate those marine resources located within and adjacent to the project’s proposed mixing zone. It should be noted that in recognition of the challenges associated with marine resource monitoring in southwest Florida, including the Collier County project area, the FDEP has approved a monitoring schedule that allows for summer (June through September) season documentation of the nearshore hardbottom. All post-construction biological monitoring events will be conducted between June and September of the appropriate year.

Hardbottom investigation monitoring segments (Figures 2 through 5) have been designated based on evaluation of the results of the February 2003 sidescan sonar survey and the 2003 Marine Resource Investigation Report (Makowski and Lybolt, 2004). They are focused on those areas within the County that have been defined by the FDEP as areas with significant potential to be affected by project construction, or appropriate to serve as control or transitional sites. Those areas not included in the defined study areas have been eliminated from the monitoring program due to the lack of evidence that marine resources are present, or they fall outside of the zone of probable effects from beach nourishment project activities. The study areas and specific monitoring transect locations have been accepted by the FDEP in the approved Collier County Mitigation and Biological Monitoring Program (Appendix A).

2.0 ENVIRONMENTAL MONITORING SEGMENTS

Marine field investigations within the four segments of beach were defined based on construction reaches associated with the Collier County Beach Renourishment Project sediment fill areas. The equipment and methods used during the 2006 immediate post-construction monitoring event were applicable to all study segment areas. The location and extent of the investigative sites delineated herein have been reviewed and approved by the FDEP, and are in compliance with the intent of the required monitoring conditions in the FDEP project permit (No. 0222355-001-JC) as delineated in the Collier County Mitigation and Biological Monitoring Program.

2.1 Vanderbilt Beach Segment (R-18 to R-31)

Evaluation of the February 2003 sidescan sonar survey results and the 2003 Marine Resource Investigation Report (Makowski and Lybolt, 2004) indicated that ten sites (approximately 1500 meters of transect documentation) were appropriate for investigation within Study Area 1, (FDEP survey monuments R-18 and R-31), which comprises the Vanderbilt Beach Segment of Collier County’s shoreline (Figure 2). Vanderbilt Beach was the first construction reach to be filled during the Collier County...
NOTES:
1. COORDINATES SHOWN ARE IN FEET BASED ON THE FLORIDA STATE PLANE COORDINATE SYSTEM, EAST ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. CPE SIDESCAN DATE: OCTOBER 25, 2007
4. CONSTRUCTION PROJECT AREA BETWEEN R021 TO R037; R043+500 TO R055; R057+750 TO R079.
5. THE PROPOSED ETOF IS BASED ON A METHODOLOGY SUGGESTED BY FDEP TO REPLACE THE ENGINEER’S ETOF ANALYSIS.
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MATCHLINE - FIGURE 3

MATCHLINE - FIGURE 5

U-55
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R-44
R-43
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F SHORE B
LV
D
HARBOUR DR
GULF
SHORE BLVD
INNER CLAM BAY
OUTER CLAM BAY
INNER DOCTORS BAY
PIPELINE CORRIDOR
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R055
R053+580
R050+250
R047+600
R046+725
R043+550
R051+275
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3. CPE SIDESCAN DATE: OCTOBER 25, 2007
4. CONSTRUCTION PROJECT AREA BETWEEN R021 TO R037; R043+500 TO R055; R57+750 TO R079.
5. THE PROPOSED ETOF IS BASED ON A METHODOLOGY SUGGESTED BY FDEP TO REPLACE THE ENGINEER'S ETOF ANALYSIS.
Beach Renourishment Project, as 121,487 cy of sand was placed on the beach between R-22 and R-31. After coordination with the FDEP, six permanent, cross-shore monitoring transects, three control transects, and one transitional boundary transect were selected and established as part of the County's long term biological monitoring program.

2.2 **Pelican Bay Segment (R-31 to R-41)**

Evaluation of the February 2003 sidescan sonar survey results and the 2003 Marine Resource Investigation Report (Makowski and Lybolt, 2004) indicated that nine sites (approximately 1350 meters of transect documentation) were appropriate for investigation within Study Area 2, (FDEP survey monuments R-31 and R-41), which comprises the Pelican Bay Segment of Collier County’s shoreline (Figure 3). Pelican Bay is adjacent to Vanderbilt Beach, and continued construction placed 56,955 cy of sand between monuments R-31 to R-37. After coordination with the FDEP, five permanent, cross-shore monitoring transects, three control transects, and one transitional boundary transect were selected and established as part of the County's long term biological monitoring program.

2.3 **Park Shore Segment (R-42 to R-57)**

Evaluation of the February 2003 sidescan sonar survey results and the 2003 Marine Resource Investigation Report (Makowski and Lybolt, 2004) indicated that ten sites (approximately 1500 meters of transect documentation) were appropriate for investigation within Study Area 3, (FDEP survey monuments R-42 and R-57), which comprises the Park Shore Segment of Collier County’s shoreline (Figure 4). Construction in Park Shore included fill of approximately 141,739 cy of sand between R-45 and R-55. After coordination with the FDEP, seven permanent, cross-shore monitoring transects, two control transects, and one transitional boundary transect were selected and established as part of the County's long term biological monitoring program.

2.4 **Naples Segment (R-57 to R-65)**

Evaluation of the February 2003 sidescan sonar survey results and the 2003 Marine Resource Investigation Report (Makowski and Lybolt, 2004) indicated that seven sites (approximately 1050 meters of transect documentation) were appropriate for investigation within Study Area 4, (FDEP survey monuments R-57 and R-65), which comprises the Naples Segment of Collier County’s shoreline (Figure 5). A total quantity of 347,381 cy of sand was placed within the Naples Segment between R-58A and R-79. In addition, approximately 53,600 cy of dredged material from Doctors Pass was placed between R-60 and R-62. After coordination with the FDEP, six permanent, cross-shore monitoring transects and one transitional boundary transect were selected and established as part of the County's long term biological monitoring program.
3.0 METHODS AND MATERIALS

CPE utilized a team of qualified professionals that included a field supervisor, marine biologists, and a boat operator/hydrographic surveyor. During the 2007 year one post-construction monitoring event, marine biologists used SCUBA equipment to visually inspect, conduct in situ benthic assessments, and document hardbottom benthic study areas. According to CPE’s dive safety program, all marine investigations require that at least two divers conduct all underwater activities, while a safety diver maintains watch at the surface. The boat operator/hydrographic surveyor were responsible for vessel positioning, equipment operation, and acquisition of survey coordinates specified by the divers.

3.1 Survey Vessel Navigation and Positioning

The navigation and positioning system used during the post-construction environmental monitoring evaluations was a Trimble AgGPS Differential Global Positioning System (DGPS) with Pro Beacon interfaced to the Coastal Oceanographic Hydrographic Data Collection and Processing program with correction from a U.S. Coast Guard Navigational Beacon. The Trimble Navigation system is designed for moderate precision static and dynamic processing applications. It provided real time and three dimension station coordinates and velocity measurements at once per second rate. The DGPS received the civilian signal from the Global Positioning System NAVSTAR satellites. The locator automatically acquired and simultaneously tracked GPS satellites while precisely measuring the code phase and Doppler phase shifts; it then computes position and velocity based on these changes. The DGPS automatically detected time, latitude, longitude, height, and velocity, at a once-per-second rate. Similarly, range rate corrections were computed every second, transmitted to the survey vessel via radio link, and were automatically applied to the onboard GPS receiver.

The Coastal Oceanographic Hydrographic Data Collection and Processing (HYPACK® MAX 4.3a) program was the navigation and hydrographic surveying system used to process all GPS position data. On-line screen graphic displays included the transect location in the form of targets, pre-plotted survey lines, an updated boat track across the survey area, adjustable left/right indicators, and other positioning information (e.g., boat speed, quality of fix, and line bearing). All data obtained was recorded onto the computer’s hard drive and transferred to a CD-Rom or external memory source at the end of each day, providing a backup of the raw survey data.

Navigational control was maintained on an IBM compatible PC running HYPACK® MAX software. The HYPACK® MAX software was configured to acquire data from the differential GPS receiver system, and was used to superimpose the survey plan on project area graphics generated in the Collier County Geographic Information System (GIS) database. The HYPACK® MAX software was also used to establish track lines and specific targets in each of the study segments, while providing relative course correction information to the helmsman as the vessel was maneuvered to specific locations.
3.2 Transect Establishment

CPE identified, through extensive coordination with representatives of Collier County and the FDEP, twenty-four (24), permanent, 150-meter long, cross-shore monitoring transects. Transect establishment began at the diver verified pre-construction (2005) landward edge of the nearshore hardbottom formation and progressed offshore in a generally shore-perpendicular alignment. In addition, twelve (12) transects were established north and south of the construction fill segments as transitional or control sites in order to provide comparative evaluation opportunities to assess project effects (Table 1). Monitoring transect site selection within the nearshore area was based on the following criteria:

1. Historic habitat characterization studies of Collier’s nearshore hardbottom resources, which aid in the evaluation of community persistence;

2. Proximity of hardbottom habitats to the beach renourishment project sites;

3. Characterization of specific biotic and abiotic communities documented in the 2003 Marine Resource Investigation Report; and

4. Presence of nearshore hardbottom habitats north and south of the beach renourishment project sites that may be indirectly affected by fill movement and equilibration from the project sites.

Environmental monitoring transects began at the eastern-most edge of the hardbottom and extended a maximum of 150 meters (492 ft) in a westerly direction perpendicular to shore. To aid in biological monitoring station permanence, stainless steel pins were installed at 5.0-m (16.4 ft) increments along each of the permanent transects, transitional boundary transects, and control station transects. If pins were located from the previous year’s establishment, then red flagging tape was tied to individual markers making relocation possible in low underwater visibility conditions. The spacing of the pins was determined based on CPE’s experience in monitoring west coast habitats with limited underwater visibility.

Along the previously defined shore-perpendicular transects, weighted buoys were dropped from the survey vessel at the approximate location of the eastern and western end points. Researchers then entered the water and adjusted the eastern-most point, if necessary, to a location coincident with the landward extent of the hardbottom biological community. Once the nearshore point was established, a diver swam offshore (west), using the permanent markers as a guide, a maximum of 150 meters with a metric scaled tape laid on the bottom which served as a guide for quadrat placement and habitat evaluation. Survey site locations were keyed to shoreline features (i.e., FDEP monuments) and State Plane coordinates (Florida State Plane Coordinate System, East Zone, NAD 83) were obtained for each study site.
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<tr>
<th>Vanderbilt Beach Segment</th>
<th>Northing</th>
<th>Easting</th>
</tr>
</thead>
<tbody>
<tr>
<td>R18+900</td>
<td>Control Station</td>
<td>709037.27</td>
</tr>
<tr>
<td>R19+400</td>
<td>Control Station</td>
<td>708484.17</td>
</tr>
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### 3.3 *In Situ* BEAMR Assessment Protocol

The Benthic Ecological Assessment for Marginal Reefs (BEAMR) surveying method was developed by CPE to evaluate nearshore marine habitats, and document the interrelationship between corals, algae, sediment, invertebrates, and fish species within nearshore reef systems (Lybolt and Baron, 2006). Due to the macroalgae dominated nature of the nearshore hardbottom communities throughout Florida, the BEAMR protocol allows researchers to incorporate macroalgal and other benthic functional groups into their analyses and characterization of larger transects established over hardbottom formations. Recently, the FDEP has specifically recommended using the BEAMR approach to characterize and assess potential affects to nearshore marine communities from beach nourishment projects in Collier County and other areas in the State of Florida.

The FDEP recognized that with the 150-meter length of the proposed shore-perpendicular transects it is not feasible to follow the standard benthic surveying protocol which calls for quadrat documentation and analysis every two (2) meters. Therefore, a 0.5 square meter ($m^2$) quadrat was used with a sampling interval of every 7.5 meters, to provide a minimum of twenty (20) monitoring stations along each established transect (Photograph 1). Within each 0.5-m$^2$ quadrat, planar percent cover of all sessile benthos was pooled to 11 major functional groups. Functional groups include: bare hard substrate, sediment, macroalgae, turf algae, crustose coralline algae, seagrass, sponge, hydroid, *Millepora* sp., octocoral, stony coral, anemone, zoanthid, wormrock, non-wormrock sessile annelid, bivalve, bryozoan, arthropod, and tunicate. Percent cover is visualized as though all contents were ‘pushed’ to one side of the quadrat. Every visible functional group within the quadrat is assigned a minimum value of 1% cover. Zero percent cover denotes functional groups which are absent. When sediment percent cover is positive, any combination of sediment type(s) are selected among the following: sand, shell, or mud. Sediment bound in a turf algae matrix is counted as turf algae. The crustose coralline algae functional group includes species from the Corallinaceae, Sporolithaceae, and Peyssonneliaceae families. Natural exposed substrate without turf cover and with or without a veneer of sediment less than one cm is counted as bare hard substrate. Unattached, floating, and/or motile organisms are disregarded, with the exception of Acropora cervicornis and Manicina areolata, and the diver must assess the area(s) under unattached organisms. The datasheet provides pre-assigned labels for the 10 most frequently encountered functional groups. Each of the remaining eight functional groups must be labeled in the “Other” section of the datasheet if present. The sum of all functional group percent cover estimated must equal 100%.

Maximum vertical relief of the hardbottom (not sand forms such as ripple marks, etc.) were measured from the lowest point in the quadrat to the highest point in the quadrat. Maximum standing sediment thickness over the hardbottom was documented by acquiring two random measurements and recording the higher of the two values. If no areas of loose unconsolidated sediment existed within the quadrat, then a value of zero
Photograph 1. An example of a 0.5 m² sampling quadrat along the R-23+285 monitoring transect. Both abiotic parameters and biotic functional groups are evaluated within the quadrat.

(cm) was recorded for the station. Sediment bound in a turf algae matrix and/or a dusting of sediment on bare substrate had to be at least one centimeter deep to be recorded as an accumulation of sediment. A 30 cm sediment depth was recorded when the maximum measurement was greater than or equal to 30 cm.

Each colony of octocoral and stony coral was identified and the maximum height or width was measured to the nearest centimeter. Octocoral individuals were identified to Genus. Stony coral individuals were identified to species whenever possible. The smallest size recorded was 1.0 cm, even for individuals less than 1.0 cm. Abnormal conditions of each colony were recorded e.g., bleaching, disease, stress. BEAMR specifically monitors stony corals and excludes fire corals (Millepora sp.) from this aspect of the benthic survey.

3.4 Quality Assurance/Quality Control (QA/QC)

BEAMR quality assurance/quality control (QA/QC) occurs in several stages. Qualified biologists are trained in the BEAMR Standard Operating Procedure (CPE, 2006). The standard BEAMR datasheet was used in the field and the datasheet prompted biologists to complete all fields. CPE developed an Access-based BEAMR data entry tool that is similar in appearance to the BEAMR datasheet. This data entry form has built-in QA
features such as standardized spellings, number format validation, and automatic summation of functional group percent cover (must be 100%). A standard QA protocol is applied once all data is entered where the electronic data are checked against the original datasheets. This database was developed to manage all biological data collected in the County. It eases QA/QC operations, data management, portability to GIS, and provides relatively secure data storage.

3.5 Limitations of BEAMR Results

3.5.1 Macroalgae

An artifact of the BEAMR genus-level macroalgae assessment method is the under-representation of macroalgae genera with less than 1% cover. Consequently the number of genera encountered is limited to the number of genera with at least 1% cover.

3.5.2 Coral

A principle of the BEAMR method is a non-invasive assessment. The topmost layers of sediment or epiphytes may obscure organisms living beneath. Small perturbations of the distribution of these topmost layers can bias assessments, especially of relatively scarce organisms such as corals; therefore, BEAMR likely under-represents the density of small corals.

3.6 Coral Census and Stress Index

CPE marine biologists conducted a census of all scleractinian (hard coral) and octocoral (soft coral) colonies (≥ 5 cm) that fell within a 1-m wide (0.5-meter north and a 0.5-meter south) belt, along the entire 150-m (east to west) transect. Belt-transect surveys recorded the species, size, location, and condition of each coral colony. In addition, sand thickness around each colony was recorded to document sediment depth. Visual inspections along the 150-m transects included an assigned stress index number (0-3) for colonies of *Siderastrea* and *Solenastrea* based on the observation and evaluation of the following stress indicators:

- Standing sediment on hard corals not removed by normal currents or wave actions;
- Frequency of observed bleaching (partial or complete), or signs of disease, within the hard coral colonies;
- Excessive mucus produced by hard corals to remove sediment from their surface; and/or
- Mottling of the color in scleractinian colonies,
- Stress level 0 equals no visible stress to the colony,
- Stress level 1 equates to 1-25% of the colony affected,
- Stress level 2 equates to 25-50% of the colony affected,
- And stress level 3 equals > 50% of the colony affected.
It should be noted that the stress index numbers utilized during these investigations were developed based on field and laboratory studies conducted by Nova Southeastern University (Vargas Angel et. al., 2005) for specific hard coral species found within the nearshore and offshore regions of southern Broward County, Florida. Use of the coral stress index as a hard coral monitoring method in Collier County has been incorporated as a subjective colony “health” measurement that has not been calibrated under laboratory conditions and therefore can not be used as a true measure of colony condition. Stress index numbers are assigned to individual coral colonies in this study by qualified marine biologists as part of the FDEP approved biological monitoring program as a relative hard coral colony health assessment tool. The stress index data collected and presented in this and subsequent reports for Collier County are not comparable to other geographically distinct coastal habitats.

3.7 Video Surveys

A metric-scaled survey tape was stretched the length of each 150 meter transect line (east to west), and the survey tape was used to delineate distance along the transect line during the video documentation of the hardbottom. The video surveys were conducted by a marine biologist using a 4 mm Sony TRV-900 digital video camera in an Ikelite housing. The camera was set to fully automatic operation, “steadyshot”, and “progressive scan”, recording 15 frames per second at 640 x 480 resolution. The biologist swam, while filming each video transect from east to west. Video of the seafloor beneath each 150 m transect line was obtained at a height of 40 cm after Porter et al. (2002). A convergent laser guidance system provided reference for the researcher when the camera was precisely 40 cm from the benthos (Figure 6). The visible width of imagery taken from this height was approximately 40 cm, thus the total area documented along each video transect was approximately 60 m². The survey tape was removed following the completion of each video transect.

3.8 Hardbottom Edge Mapping

Remote sensing techniques, including sidescan sonar imagery and aerial photography, was utilized by CPE to map the nearshore edge of hardbottom within the potential impact zone. After the remote sensing data was analyzed, diver documentation and groundtruthing was conducted at select sites where comparative analysis indicated change in the location of the shoreward hardbottom edge. The hardbottom/sand interface position was documented using DGPS and diver verified hardbottom edge locations were then incorporated into the Collier County GIS Database for comparison to the sidescan sonar imagery reduction. Additional information can be referenced in the CPE year-one post-construction monitoring report (Appendix B).
3.9 Artificial Reef Monitoring

In accordance with the FDEP project permit (No. 0222355-001-JC), environmental monitoring must be performed on the Collier County nearshore artificial reef to assess colonization performance upon the newly placed mitigation. During the 2007 nearshore artificial reef monitoring event, marine biologists used SCUBA equipment to visually inspect, conduct *in situ* benthic assessments, and document hardbottom benthic study areas. This monitoring report has been included as Appendix C.

3.10 Data Analyses & Deliverables

Analyses included descriptive statistics for both biotic and abiotic parameters. Overall Project Segment and County means are followed by standard errors, unless otherwise noted. Paired two-sample *t*-Tests were used to determine significant differences in abiotic parameters (e.g., sediment cover, sediment depth, vertical relief, bare hard substrate) between pre-construction and post-construction monitoring events. Analysis of Variance (ANOVA) tests were performed to determine if significant differences in biotic functional groups (e.g., macroalgae, coral, and sponge) occurred between pre-construction and post-construction assessments. All parametric statistical analyses were performed with SPSS® software. *P*-values less than 0.05 were considered significant. In addition, non-parametric trend analyses were performed using the software package PRIMER® (v6). Non-metric multi-dimensional scaling (MDS) was used to represent...
functional groups from different monitoring events by clustering dissimilarities from group to group. An Analysis of Similarity (ANOSIM) was carried out as an approximate analogue to the parametric ANOVA to test if no assemblage differences occur between monitoring events. Finally, a Similarity of Percentages analysis (SIMPER) was performed to specifically target dissimilarities among individual functional groups when comparing different monitoring events.

The Collier County Geographic Information System (GIS) was updated using ArcView 9.2 with all monitoring transect links and hardbottom edge locations, and has been included with this report on a supplemental DVD. In addition, digital video documentation of all 36 monitoring transects are included with this report on a series of supplemental DVDs.

4.0 RESULTS

4.1 Abiotic Parameters

The following abiotic results relate directly to the physical properties of Collier County’s nearshore habitat one year after construction completion. Four main parameters were recorded: sediment percent cover, sediment depth, vertical height (relief) of the hardbottom substrate, and percent cover of bare hard substrate. Table 2 summarizes all abiotic parameters according to segment.

4.1.1 Project Segment Sediment Cover and Bare Hard Substrate Comparative Analysis

In this section, sediment is differentiated between sand and mud. This differentiation was carried out during in situ monitoring and was based solely on visual and textural differences. No physical sampling and analysis of individual sand or mud samples are required under the FDEP approved biological monitoring program. Therefore, no mechanical sieve or geotechnical evaluation of sand or mud characteristics other than the visual and textural differentiation presented herein was conducted. This methodology has been subsequently confirmed with FDEP professionals during the 2007 year one post-construction monitoring event.

Sediment cover was recorded as the percentage of benthic substrate that consisted of at least one (1) cm of sand, and/or shell, and/or mud in each 0.5 m² monitoring quadrat. The Naples Segment contained the highest overall average of sediment cover percentage with 68.9 ±6.1% (Photograph 2). The range of average sediment percent cover over the seven monitoring transects in the Naples Segment showed a minimum of 44.7% at R-59+590 and a maximum of 89.3% at R-65. Percent cover of sediment in the Naples Segment slightly increased from the 2005 pre-construction survey, which recorded 67.9%, and the 2006 immediate post-construction survey, which recorded 68.1%; however, these increases proved to be insignificant (2007 v 2005, \( t \)-test, \( P=0.19 \); 2007 v 2006, \( t \)-test, \( P=0.36 \)). Quadrats recording 100% sediment cover and quadrats recording at least 50% sediment cover were the highest in the Naples Segment with a frequency of 0.32 and 0.77, respectively. The type of sediment recorded was analyzed using three sub-
categories: sand / shell / mud. The frequency of quadrats containing all three types of sediment was 0.68, while the frequency of quadrats containing no sediment totaled 0.01. Of particular interest was the high frequency of quadrats in the Naples Segment that contained a portion of fine mud, which calculated to 0.93. This total frequency was not significantly higher than the frequency of quadrats containing mud during the 2005 pre-construction survey (0.84, \( t \)-test, \( P=0.57 \)) or the 2006 immediate post-construction survey (0.91, \( t \)-test, \( P=0.86 \)). Conversely, bare hard substrate percent cover within the Segment (0.6 ±6.1%) decreased significantly from the pre-construction average of 7.4% and the immediate post-construction average of 4.2% (\( t \)-test, \( P<0.05 \)).

The Vanderbilt Beach Segment recorded the second highest overall average of sediment cover percentage with 66.8 ±5.1%, with a minimum cover of 38.9% at R-28+550 and a maximum cover of 84.9% at R-27+626 (Photograph 3). This increase from the 63.7% 2005 pre-construction average and the 66.1% 2006 immediate post-construction average were determined to be insignificant (2007 v 2005, \( t \)-test, \( P=0.23 \); 2007 v 2006, \( t \)-test, \( P=0.79 \)). Quadrats recording 100% sediment cover were the second highest in the Vanderbilt Beach Segment with a frequency of 0.24, while the frequency of quadrats containing less than 50% sediment cover was 0.27.
Table 2. 2007 Abiotic Parameter Summary.

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<th>SEGMENT NAME</th>
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<th>AVG SEDIMENT % COVER</th>
<th>AVG MAX SEDIMENT DEPTH (cm)</th>
<th>AVG MAX RELIEF (cm)</th>
<th>AVG BARE HARD SUBSTRATE % COVER</th>
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<td>0.9</td>
<td></td>
</tr>
<tr>
<td>TOTAL AVG</td>
<td>68.9</td>
<td>14.5</td>
<td>12.7</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>
Photograph 2. An example of a quadrat with 100% sediment cover along R-65. During the 2007 year one post-construction monitoring event, approximately 69% of the monitored habitat in Naples was documented as being comprised of sediment.

Further evaluation of the sediment types revealed that the frequency of quadrats containing all three types of sediment was 0.38, while the frequency of quadrats containing no sediment was only 0.02. Similar to the Naples Segment, Vanderbilt Beach recorded a high frequency of quadrats with a portion of mud, which totaled 0.79, and the highest recorded frequency of quadrats containing only mud at 0.33. These totals were insignificantly different from the 2005 and 2006 frequencies of quadrats with a portion of mud (2007 v 2005, $t$-test, $P=0.35$; 2007 v 2006, $t$-test, $P=0.66$) and 100% mud (2007 v 2005, $t$-test, $P=0.58$; 2007 v 2006, $t$-test, $P=0.93$).

Bare hard substrate within Vanderbilt Beach decreased in percent cover for a Segment average of 0.8 ±0.2%. This was significantly different from the 2005 pre-construction average (4.5%, $t$-test, $P<0.05$) and the 2006 immediate post-construction average (2.6%, $t$-test, $P<0.05$).
Photograph 3. Transect R-25+040, showing the low relief nature of the Vanderbilt Beach Segment. Vanderbilt Beach recorded the second highest sediment cover average and the lowest average vertical relief in Collier County.

CPE biologists documented that the Park Shore Segment had an overall average of 56.9 ±6.5% sediment cover over the ten monitoring transects in this study area, with a minimum of 35.0% at R-43+550 and a maximum of 89.1% at R-56+380. This increase in sediment coverage was insignificantly different from the 2005 pre-construction average of 55.0 (t-test, P=0.46) and the 2006 immediate post-construction average of 56.2% (t-test, P=0.81). Quadrats containing 100% sediment cover recorded a frequency of 0.25, while the frequency of quadrats containing less than 50% sediment cover was 0.38. Analysis of sediment types revealed that the frequency of quadrats containing all three types of sediment was 0.37, and the frequency of quadrats containing no sediment was 0.03. Quadrats observed with a portion of mud totaled 0.57, while quadrats containing a 100% mud was 0.11. These frequencies, even though slightly elevated from the 2005 pre-construction and 2006 post-construction totals, were analyzed to be insignificantly different (t-test, P>0.05). On the other hand, significant decreases were shown in bare hard substrate cover between the year one post-construction survey (0.5 ±1.6%) and both the pre-construction (4.4%, t-test, P<0.05) and immediate post-construction surveys (2.4%, t-test, P<0.05).

The Pelican Bay Segment contained the lowest overall average of sediment cover percentage with 56.5 ±2.9%, which was insignificantly different from the 2005 pre-construction sediment coverage of 54.7% (t-test, P=0.49) and the 2006 immediate post-construction sediment coverage of 55.7% (t-test, P=0.72). The 2007 average sediment
percent cover among the nine monitoring transects showed a minimum of 42.3% at R-37+700 and a maximum of 67.2% at R-39+250. Quadrats recording 100% sediment cover were the lowest in Pelican Bay with a frequency of 0.21, while the frequency of quadrats containing less than 50% sediment cover was 0.43. The frequency of quadrats containing all three sediment types was the lowest in Pelican Bay with 0.25, while the frequency of quadrats containing no sediment was highest among all the Segments with 0.13. Pelican Bay documented a high frequency (0.74) of quadrats containing a portion of mud, with approximately a quarter (0.26) of the quadrats containing only mud. This is an increase from the 2005 pre-construction and 2006 immediate post-construction frequency for quadrats containing a fraction of mud (2005, 0.69; 2006, 0.71) and quadrats containing only mud (2005, 0.21; 2006, 0.24); however, these increases are statistically insignificant (t-test, \( P > 0.05 \)). However, significant differences were calculated for bare substrate between the 2007 monitoring and the previous surveys. In 2007, bare hard substrate cover averaged 0.4 ±0.1%, a significant decrease from the 2005 pre-construction average of 7.2% (t-test, \( P < 0.05 \)) and the 2006 immediate post-construction average of 5.2% (t-test, \( P < 0.05 \)).

4.1.2 Sediment Cover and Bare Hard Substrate - Compliance, Control, and Transitional Transect Comparative Analysis

In this section, sediment is differentiated between sand and mud. This differentiation was carried out during in situ monitoring and was based solely on visual and textural differences. No physical sampling and analysis of individual sand or mud samples are required under the FDEP approved biological monitoring program. Therefore, no mechanical sieve or geotechnical evaluation of sand or mud characteristics other than the visual and textural differentiation presented herein was conducted. This methodology has been subsequently confirmed with FDEP professionals during the 2007 year one post-construction monitoring event.

Throughout the project area’s twenty-four compliance transects CPE’s marine biologists recorded an average sediment percent cover of 61.2 ±3.6%, with a minimum of 35.3% at R-50+250 and a maximum of 89.3% at R-65. These sediment cover percentages deviated insignificantly from the 2005 pre-construction and 2006 immediate post-construction survey total compliance averages of 50.7% (t-test, \( P = 0.29 \)) and 60.6% (t-test, \( P = 0.94 \)), respectively (Figure 7). Quadrats containing 100% sediment cover recorded a frequency of 0.27, and the frequency of quadrats containing less than 50% sediment cover was 0.31. Analysis of sediment types revealed that the frequency of quadrats containing all three types of sediment was 0.38, while 0.03 of the quads monitored contained no sediment coverage. Quadrats observed with a portion of mud had a frequency of 0.77 and quadrats containing only mud had a frequency of 0.19. This proved to be an insignificant increase from the 2005 pre-construction and 2006 immediate post-construction frequencies (t-test, \( P > 0.05 \)). Bare hard substrate cover differed significantly in 2007 (0.6 ±0.2%) from the pre-construction (5.3%, t-test, \( P < 0.05 \)) and immediate post-construction events (3.1%, t-test, \( P < 0.05 \)).
Figure 7. Comparative assessment of average sediment cover along compliance transects between the 2005 pre-construction and 2007 year one post-construction monitoring events.

Control station transects in all segments collectively recorded an overall average of 68.4 ±4.9% sediment cover, with a minimum of 43.6% at R-40 and a maximum of 89.1% at R-56+380. The 2005 pre-construction average (66.3%) and the 2006 immediate post-construction percent cover average (67.6%) did not significantly differ from the 2006 total averages (t-test, P>0.05). Quadrats containing 100% sediment cover recorded a frequency of 0.23; those quads containing less than 50% sediment cover was 0.27; and the frequency of quadrats with no sediment cover totaled 0.05. Analysis of sediment types revealed that the frequency of quadrats containing all three types of sediment was 0.30. Quadrats observed with a portion of mud totaled 0.72, while quadrats containing only mud were documented at a frequency of 0.29. All frequencies increased insignificantly from the 2005 and 2006 monitoring data (t-test, P>0.05). On the other hand, bare hard substrate cover (0.3 ±0.1%) decreased significantly from both the pre-construction average (5.4%, t-test, P<0.05) and the immediate post-construction average (3.7%, t-test, P=0.02).

Transitional boundary transects recorded an overall average of 52.9 ±6.1% sediment cover, which was not significantly different from the pre-construction average of 50.7% (t-test, P=0.63), nor the immediate post-construction average of 51.3% (t-test, P=0.74). Among the four boundary transects, the documented range included a minimum of 35.0% at R-43+550 and a maximum of 62.1% at R-21+080. Quadrats containing 100% sediment cover recorded a frequency of 0.24, while the frequency of quadrats containing less than 50% sediment cover was 0.46. The frequency of quadrats with no sediment
coverage totaled 0.04. Analysis of sediment types revealed that the frequency of quadrats containing all three types of sediment was 0.47. Quadrats documented with a portion of mud totaled 0.69, and of those, 0.05 were comprised entirely of mud. While these frequencies represent slight increases from the two previous monitoring events, the differences were calculated to be insignificant ($t$-test, $P > 0.05$). However, decreases in bare hard substrate were calculated to be significant between the year one post-construction event (0.9 ±0.4%) and the pre-construction (8.5%, $t$-test, $P=0.02$) and immediate post-construction averages (5.8%, $t$-test, $P=0.03$).

4.1.3 Project Segment Sediment Depth and Vertical Relief Comparative Analysis

The Naples Segment contained the highest overall average sediment depth with 14.5 ±2.2 cm, which did not deviate significantly from either the 2005 pre-construction (14.0 cm, $t$-test, $P=0.82$) nor the 2006 immediate post-construction sediment depth average (13.9 cm, $t$-test, $P=0.91$). The range of average sediment depth among the seven monitoring transects showed a minimum depth average of 8.0 cm at R-58-300 and a maximum depth average of 23.6 cm at R-59. A high frequency (0.87) was calculated for quadrats containing a sediment depth of at least 5 cm, and among those quadrats, Naples documented the highest frequency of samples containing a sediment depth of 30 cm (approximately one foot deep) or greater, with 0.21. Conversely, Naples recorded the second lowest vertical relief average among all the study area segments with 12.7 ±3.6 cm. Documented vertical relief was insignificantly different from the 2005 pre-construction average of 12.5 cm ($t$-test, $P=0.94$) and the 2006 immediate post-construction average of 13.1 cm ($t$-test, $P=0.79$). The range of average vertical relief in Naples showed a minimum of 3.6 cm at R-64+400 and a maximum height average of 31.1 cm at R-59+590. Even though this segment recorded the highest frequency of quadrats containing no vertical relief with 0.46, Naples also recorded one of the highest frequencies (0.29) for quadrats containing at least 30 cm of vertical relief. Further analysis of those quadrats showed a frequency of 0.09 for areas of at least 45 cm (~1.5 ft) and a frequency of 0.05 for areas of at least 60 cm (~2 ft) in height.

The Vanderbilt Beach Segment recorded the second highest sediment depth average with 12.7 ±1.6 cm, which was insignificantly different from the 2005 pre-construction sediment depth average of 10.5 cm ($t$-test, $P=0.38$) and the 2006 immediate post-construction sediment depth average of 11.7 cm ($t$-test, $P=0.69$). The range of average sediment depth among the ten monitoring transects recorded a minimum depth average of 5.2 cm at R-28+550 and a maximum of 23.1 cm at R-26+460. Similar to Naples, Vanderbilt Beach recorded a high frequency (0.68) of quadrats containing a sediment depth of at least 5 cm. Of those quadrats, a frequency of 0.19 was calculated for quadrats containing a sediment depth of 30 cm or higher. Consistent with the sediment depth results, Vanderbilt Beach recorded the lowest vertical relief average of all monitoring segments with 10.9 ±1.8 cm. That total average varied insignificantly from the 2005 pre-construction average of 12.0 cm ($t$-test, $P=0.67$) and the 2006 immediate post-construction average of 11.5 cm ($t$-test, $P=0.82$). The range of average vertical relief showed a minimum height of 1.8 cm at R-26+460 and a maximum height of 19.6 cm at R-23+285. Most of the quadrats (0.95) contained substrate that measured a vertical
height between 0 and 29 cm. Of the remaining quadrats, a frequency of 0.02 was calculated for vertical relief of at least 45 cm. No quadrats recorded vertical relief of 60 cm or greater within the Vanderbilt Beach Segment.

The Park Shore Segment recorded an average sediment depth measurement of 9.2 ±1.3 cm among the ten monitoring transects, with a minimum depth average of 3.5 cm at R-49 and a maximum of 15.1 cm at R-56+380 (Photograph 4). This was insignificantly different from the 2005 pre-construction average sediment depth of 7.7 cm (t-test, \( P=0.37 \)) and the 2006 immediate post-construction average sediment depth of 8.8 cm (t-test, \( P=0.81 \)). Quadrats containing a sediment depth of at least 5 cm recorded a frequency of 0.63, and of those quadrats, a frequency of 0.09 was calculated for sediment measurements of 30 cm or deeper.

Photograph 4. Park Shore Transect R-49. The Park Shore Segment recorded the second lowest sediment cover average and the second highest vertical relief average in Collier County.

Park Shore recorded an average vertical relief of 16.6 ±2.9 cm, with a minimum height average of 3.9 cm at R-56+380 and a maximum height average of 34.2 cm at R-43+550. These measurements were insignificantly different from the 2005 pre-construction average of 16.0 cm (t-test, \( P=0.87 \)) and 2006 post-construction average of 17.3 cm (t-test, \( P=0.89 \)). A frequency of 0.74 was recorded for quadrats with a vertical relief measuring between 0 and 29 cm. Of the remaining quadrats containing a vertical relief of at least 30
cm, a frequency of 0.10 was calculated for vertical relief measurements of 45 cm or higher.

The Pelican Bay Segment recorded the lowest average sediment depth measurement with 8.5 ±0.8 cm; an insignificant increase from both the 2005 pre-construction average of 7.0 cm (t-test, \(P=0.14\)) and the immediate post-construction average of 7.8 cm (t-test, \(P=0.51\)). The range of average sediment depths among the nine monitoring transects showed a minimum sediment depth average of 4.8 cm at R-41 and a maximum depth average of 12.2 cm at R-39+250. Even though a high frequency (0.69) was calculated for quadrats containing a sediment depth of at least 5 cm, only four quadrats in the entire segment recorded a sediment depth of 30 cm or deeper. The Pelican Bay Segment had the highest documented average vertical relief measurement in the County with 18.3 ±1.9 cm. This was an insignificant decrease from pre-construction and immediate post-construction monitoring from which the same measurement was recorded (19.3 cm, t-test, \(P>0.05\)). The range of average vertical relief showed a minimum height average of 12.7 cm at R-41 and a maximum height average of 32.2 cm at R-37+700. The highest frequency (0.77) of quadrats in the Pelican Bay Segment contained vertical relief measurements between 0 and 29 cm. In addition, Pelican Bay recorded the highest segment frequencies, 0.10 and 0.06, among quadrats containing vertical relief of 45 cm or higher and 60 cm or higher, respectively.

4.1.4 Sediment Depth and Vertical Relief - Compliance, Control, and Transitional Comparative Analysis

Throughout the project area, compliance transects recorded an average sediment depth measurement of 11.9 ±1.1 cm, which was insignificantly different from the 2005 pre-construction measurement of 10.6 cm (t-test, \(P=0.40\)) and the 2006 immediate post-construction measurement of 11.3 cm (t-test, \(P=0.71\)) (Figure 8). The range of average sediment depths among the twenty-four transects showed a minimum depth average of 3.5 cm at R-49 and a maximum depth average of 23.6 cm at R-59. Quadrats containing sediment depths less than 5 cm recorded a frequency of 0.29, while the frequency of quadrats with sediment depths in excess of 5 cm totaled 0.73. A frequency of 0.17 was calculated for quadrats containing sediment over 30 cm deep.
Compliance monitoring transects also recorded an average vertical relief height of 15.4 ±1.6 cm, which varied insignificantly from the pre-construction average measurement of 15.3 cm (t-test, *P*=0.98) and the immediate post-construction average measurement of 15.9 cm (t-test, *P*=0.81) (Figure 8). The range of average vertical relief showed a minimum height average of 1.8 cm at R-26+460 and a maximum height average of 32.2 cm at R-37+700. A frequency of 0.79 was calculated for quadrats with vertical relief measuring between 0 and 29 cm. Of the remaining quadrats containing a vertical relief of at least 30 cm, frequencies of 0.05 and 0.04 were calculated for vertical relief measurements of 45 cm or higher and 60 cm or higher, respectively.

Control station transects in all segments recorded a slight average depth increase of 10.1 ±1.3 cm for sediment thickness, compared to both the 2005 pre-construction measurement (8.2 cm) and the 2006 immediate post-construction measurement (9.6 cm). This increase however was calculated to be insignificant (2007 v 2005, *t*-test, *P*=0.27; 2007 v 2006, *t*-test, *P*=0.75). A minimum sediment depth average of 4.8 cm at R-41 and a maximum depth average of 15.1 cm at R-56+380 represented the range for control transects one year after project completion. Quadrats containing sediment of at least 5 cm thick recorded a frequency of 0.71, with only a small percentage (~5%) of those quadrats containing sediment over 30 cm deep. Average vertical relief height for the control transects was calculated as 10.5 ±1.7 cm, an insignificant decrease from both the 2005 pre-construction average of 11.1 cm (t-test, *P*=0.79) and the 2006 immediate post-construction average of 10.9 cm (t-test, *P*=0.84). A minimum height average of 3.9 cm
was calculated at R-56+380 and a maximum height average of 17.8 cm was calculated at R-39+250. The majority of quadrats contained a substrate relief height between 0 and 29 cm, with a frequency of 0.85. A frequency of 0.02 was calculated for quadrats containing vertical relief over 45 cm.

Monitoring of the transitional boundary transects recorded an average sediment depth measurement of 7.9 ±1.0 cm, which represents a statistically insignificant increase from the 2005 pre-construction average of 6.1 cm (t-test, \( P=0.30 \)) and the 2006 immediate post-construction average of 6.3 cm (t-test, \( P=0.23 \)). Among the four monitoring transects in transitional areas, a minimum depth average of 5.2 cm was measured at R-43+550 and a maximum depth average of 10.2 cm was recorded at R-21+080. Approximately half the quadrats (0.56) contained sediment that was 5 cm or greater in depth, and only one quadrat measured sediment thickness over 30 cm deep. Average vertical relief in transitional boundaries equaled 19.3 ±5.8 cm, which was insignificantly different from both the 2005 pre-construction measurement (21.0 cm, t-test, \( P=0.84 \)) and the 2006 immediate post-construction measurement (21.2 cm, t-test, \( P=0.83 \)) (Photograph 5). The range of average vertical relief showed a minimum height average of 8.5 cm at R-58-300 and a maximum height average of 34.2 cm at R-43+550. While the majority of quadrats contained vertical relief between 0 and 29 cm, relatively moderate frequencies were calculated for quadrats containing substrate relief of 45 cm or greater (0.15), and 60 cm or greater (0.06).
4.2 Biotic Parameters

The following results present the abundance and distribution of biotic functional groups within the nearshore environment of Collier County as documented during the study period. The four main parameters included: benthic flora (e.g. macroalgae), scleractinian (stony) coral, octocoral (soft coral), and other invertebrates (i.e. marine sponges, sessile worms, hydroids). Table 3 summarizes the benthic flora data, while Table 4 summarizes the percent cover data for coral and sponges.

4.2.1 Project Segment Benthic Floral Species Composition Comparative Analysis

The Park Shore Segment contained the highest overall average of macroalgae cover percentage with 27.4 ±4.0%, which marked an insignificant difference from the 2005 pre-construction average of 23.6% (ANOVA, \( P=0.50 \)) and the 2006 immediate post-construction average of 29.1% (ANOVA, \( P=0.79 \)). The range of measurements throughout the Segment consisted of a minimum average cover of 5.9% at R-56+380 and a maximum average cover of 45.4% at R-43+550. Of all the study area segments monitored during the 2006 post-construction event, Park Shore recorded the highest frequency of benthic red alga along its ten permanent transects. *Gracilaria* was recorded in the highest abundance with a frequency of 0.76 among the sampling quadrats. *Hypnea* and *Botryocladia* were also recorded in large numbers with frequencies of 0.70 and 0.41, respectively. Only three quadrats in the entire segment contained the red algae *Jania*. Observed green algae was restricted to one genera, *Caulerpa*, even though occurrence was recorded at the relatively high frequency of 0.63. *Sargassum* was the only brown algae documented, with a low frequency of 0.06. Other benthic flora documented along the sampling transects of Park Shore included turf algae/cyanobacteria with an average percent cover of 16.5 ±2.3%. This average varied from both the 2005 pre-construction segment average (13.5%) and the 2006 immediate post-construction segment average (17.9%), however both were determined to be insignificant differences (ANOVA, \( P>0.05 \)). Encrusting red algae recorded a minimal average percent cover of 0.05 ±0.02%.

The second highest overall average of macroalgae cover percentage (27.0 ±2.5%) was observed in the Pelican Bay Segment, with a minimum average cover of 13.0% at R-36 and a maximum average cover of 36.2% at R-38+380. This segment percentage was insignificantly different from the documented 2005 pre-construction macroalgae cover of 23.1% (ANOVA, \( P=0.29 \)) and the 2006 immediate post-construction cover of 27.3% (ANOVA, \( P=0.93 \)). Similar to the Park Shore Segment, the Pelican Bay Segment recorded high frequencies of red alga: 0.77 for *Gracilaria*, 0.58 for *Hypnea*, and 0.46 for *Botryocladia*. *Caulerpa* was again the only green algae recorded with a frequency of 0.55, and trace percentages of *Jania* and *Sargassum* were observed with a frequency of 0.02 and 0.07, respectively. Pelican Bay also recorded an average percent cover of 14.4 ±2.6% for turf algae/cyanobacteria and 0.05 ±0.02% for encrusting red algae; both were insignificantly different (ANOVA, \( P>0.05 \)) from the 2005 pre-construction totals (10.6% turf algae/cyanobacteria; 0.07% encrusting red algae) and the 2006 immediate post-construction totals (14.4% turf algae/cyanobacteria; 0.24% encrusting red algae).
Photograph 6. *Caulerpa* sp. was the only green alga identified in the study area and overall abundance was very high. Vanderbilt Beach recorded the highest average frequency for *Caulerpa* macroalgae percent cover with 0.68.

The Vanderbilt Beach Segment recorded an overall average macroalgae cover percentage of 22.0 ±3.3%, with a minimum average cover of 9.9% at R-29+700 and a maximum average cover of 39.2% at R-28+550. This was insignificantly different from the 2005 pre-construction segment average of 19.7% (ANOVA, \( P=0.24 \)) and the 2006 immediate post-construction segment average of 25.1% (ANOVA, \( P=0.61 \)). Again, *Gracilaria* recorded the highest red algae frequency with 0.72, followed by *Hypnea* (0.52) and *Botryocladia* (0.49). Even though *Caulerpa* was identified as the only green algae present, the alga was observed with the highest frequency (0.68) of all the project segments (Photograph 6). *Jania* and *Sargassum* were documented in sparse amounts with a frequency of 0.04 and 0.18, respectively. Turf algae/cyanobacteria and encrusting red algae recorded insignificant differences from the previous two monitoring events with average percent covers of 12.5 ±2.3% and 0.05 ±0.02%, respectively (ANOVA, \( P>0.05 \)).

During the 2007 monitoring event, the Naples Segment recorded the lowest overall average macroalgae percent cover with 11.7 ±2.9%, which equaled last year’s immediate post-construction average and was insignificantly different from the 2005 pre-construction average of 10.9 ±2.6% (ANOVA, \( P=0.82 \)). The range of average percent
cover varied from a minimum of 2.3% at R-58+860 to a maximum of 24.2% at R-58+580. *Gracilaria* was documented in the highest abundance, even though it was recorded in less than half of the sampling quadrats with a frequency of 0.46. The remainder of the red alga species identified in Naples was *Hypnea* (0.44) and *Botryocladia* (0.39); *Jania* was not documented in any of the sampling quadrats. Green algae within the Naples Segment consisted solely of *Caulerpa* with a frequency of 0.37. *Sargassum* was documented in only five quads in the entire Naples Segment. Other benthic flora included an average percent cover of 13.1 ±2.8% for turf algae/cyanobacteria (Photograph 7) and a trace occurrences of encrusting red algae with an average percent cover of 0.03 ±0.02%. Both measurements were insignificantly different (ANOVA, *P* >0.05) from the 2005 pre-construction averages (8.8% turf algae/cyanobacteria; 0.05% encrusting red algae) and 2006 immediate post-construction averages (13.9% turf algae/cyanobacteria; 0.10% encrusting red algae).

Photograph 7. Cyanobacteria growth amongst macroalgae within the Naples Segment.
Table 3. 2007 Benthic Flora Summary.

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<tr>
<th>SEGMENT NAME</th>
<th>TRANSECT NAME</th>
<th>AVG MACROALGAE % COVER</th>
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<th>AVG ENCRUSTING RED ALGAE % COVER</th>
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Table 4. 2007 Coral and Sponge Summary.

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4.2.2 *Benthic Floral Species Composition - Compliance, Control, and Transitional Transect Comparative Analysis*

Throughout the project area, compliance transects recorded an average macroalgae percent cover of 22.6 ±2.3%, which was an insignificant variation from both the 2005 pre-construction record of 19.6% (ANOVA, *P*=0.35) and the 2006 immediate post-construction average of 23.7% (ANOVA, *P*=0.76). The range of average percent cover for macroalgae among the twenty-four permanent transects showed a minimum of 2.3% at R-58+860 and a maximum of 43.0% at R-50+250 (Figure 9). *Gracilaria* was the most frequently observed (0.76) red algae, followed by *Hypnea* (0.54) and *Botryocladia* (0.52). Green algae was restricted to one genera, *Caulerpa*, and abundance was recorded in just over half (0.58) of the sampling quadrats. Sparse amounts of *Jania* and *Sargassum* recorded frequencies of 0.02 and 0.06, respectively. Turf algae/cyanobacteria was calculated to have an average percent cover of 15.5 ±1.5%; a insignificant difference (ANOVA, *P*>0.05) from both the 2005 pre-construction (11.8%) and 2006 immediate post-construction averages (16.1%). In 2007, encrusting red algae recorded a percent cover average of 0.03 ±0.01%, which was a significant decrease from the last year’s immediate post-construction average of 0.13% (ANOVA, *P*=0.04). However, the 2007 average did not differ significantly from the 2005 pre-construction average of 0.05 ±0.03% (ANOVA, *P*=0.56).

![Figure 9. Average macroalgae cover among compliance transects between the 2005 pre-construction, 2006 immediate post-construction, and 2007 year one post-construction monitoring events.](image-url)
During the year one post-construction monitoring event, control station transects in all segments recorded an overall average of 20.2 ±3.2% macroalgae cover, with a minimum of 5.9% at R-56+380 and a maximum of 34.0% at R-40. This difference was insignificant from the 2005 pre-construction average of 17.9% (ANOVA, $P=0.60$) and the 2006 immediate post-construction average of 22.6% (ANOVA, $P=0.61$). Red algae was observed in high abundance, with *Gracilaria* (0.68), *Hypnea* (0.51), and *Botryocladia* (0.39) being the most dominant (Photograph 8). *Caulerpa* was the only green alga documented with a frequency of 0.42. *Jania* (0.02) and *Sargassum* (0.05) were observed infrequently. An average turf algae/cyanobacteria percent cover of 10.2 ±1.8% was recorded, an insignificant difference from the pre-construction (7.5%) and immediate post-construction (12.6%) averages (ANOVA, $P>0.05$). Encrusting red algae recorded an insignificant change in average percent cover between previous monitoring events with a measurement of 0.10 ±0.02% (ANOVA, $P>0.05$).

Photograph 8. Red algae, such as *Gracilaria*, was recorded in high abundance along the nearshore reefs of Collier County.
Transitional boundary transects in all monitoring segments recorded an overall average of 28.9 ±7.4% macroalgae cover in 2007, with a minimum of 12.4% at R-58-300 and a maximum of 45.4% at R-43+550. These measurements varied insignificantly from the 2005 pre-construction average of 25.7% (ANOVA, P=0.76) and the 2006 immediate post-construction average of 29.9% (ANOVA, P=0.93). *Gracilaria* was documented in the highest abundance among the sampling quadrats with a frequency of 0.79. *Hypnea* and *Botryocladia* were also recorded in large numbers with frequencies of 0.53 and 0.48, respectively. Only two quadrats along the transitional boundary transects contained the red algae *Jania* in 2006. Green algae was restricted to only one documented genera, *Caulerpa*, and occurrence was recorded at a relatively high frequency of 0.68. *Sargassum* was the only brown algae documented, with a low frequency of 0.07. Turf algae/cyanobacteria along the transitional boundaries recorded an average percent cover of 14.3 ±4.7%; insignificantly different from both the 2005 pre-construction percent cover of 10.5% (ANOVA, P=0.55) and the 2006 immediate post-construction percent cover of 15.8% (ANOVA, P=0.84). The average percent cover of encrusting red algae among transitional boundary transects was 0.10 ±0.04%, an insignificant difference from both the pre-construction (0.05%) and immediate post-construction (0.20%) measurements (ANOVA, P>0.05).

### 4.2.3 Project Segment Coral Cover Comparative Analysis

The Pelican Bay Segment contained the highest overall average of scleractinian (hard stony coral) cover in 2007 with 1.91 ±0.30%; a significant increase from both the 2005 pre-construction average of 0.91% (ANOVA, P=0.01) and the 2006 immediate post-construction average of 1.10% (ANOVA, P=0.04). The range of measurements throughout the segment consisted of a minimum average cover of 0.69% at R-35+280 and a maximum average cover of 3.38% at R-38+380. *Siderastrea siderea* (Photograph 9) and *Solenastrea hyades* (Photograph 10) were the most dominant hard coral species with recorded frequencies of 0.69 and 0.17, respectively. Other scleractinian species included *Oculina robusta* at a frequency of 0.07 and *Phyllangia americana* at a frequency of 0.04. Octocoral average percent did not differ from either the 2005 pre-construction or 2006 immediate post-construction measurements with a total of less than 0.10% cover. *Leptogorgia virgulata* and *L. hebes* were the only octocoral species documented in the Pelican Bay study area.

The second highest overall average of hard coral cover percentage (1.21 ±0.29%) was observed in the Park Shore Segment, with a minimum average cover of 0.14% at R-56+210 and a maximum average cover of 3.23% at R-50+250. This percent increase was not significantly different from either the pre-construction average of 0.70% (ANOVA, P=0.07) nor the immediate post-construction average of 0.74% (ANOVA, P=0.16). *Siderastrea siderea* was the most abundant hard coral species observed; documented in over half of the sampling quadrats with a frequency of 0.56. *Solenastrea hyades*, *Phyllangia americana*, and *Oculina robusta* were all documented in low abundance during the 2007 investigations with recorded frequencies of 0.11, 0.07, and 0.02, respectively. Octocoral cover was very sparse, with *Leptogorgia* occurring in only seven sampled quadrats in the Park Shore Segment.

Photograph 10. A knobby star coral colony, *Solenastrea hyades*, recorded along transect R-35+280.
The Vanderbilt Beach Segment recorded an average scleractinian cover of 0.58 ±0.10%, with a minimum average cover of 0.28% at R-26+460 and a maximum average cover of 1.31% at R-21+080. No significant differences in hard coral cover were calculated when compared to both pre-construction and immediate post-construction measurements (ANOVA, \( P>0.05 \)). Over half of the sampling quadrats were documented to have *Siderastrea siderea* colonies with a frequency of 0.64. Other hard coral species included *Solenastrea hyades*, *Phyllangia americana*, and *Oculina robusta*, although none occurred with a frequency greater than 0.05. Octocoral was restricted to only one genera, *Leptogorgia*, with a low frequency of occurrence (0.06).

The Naples Segment recorded the lowest overall average hard coral cover in 2006 with 0.19 ±0.08%, a non-significant difference from both the 2005 pre-construction average (0.10%) and the 2006 immediate post-construction average (0.11%) (ANOVA, \( P>0.05 \)). The range of average percent cover included a minimum of 0.03% along R-59+590 and a maximum of 0.62% at R-58-300. Hard coral observations within the Naples Segment were low, as *Siderastrea siderea*, *Solenastrea hyades*, and *Phyllangia americana* all had documented frequencies less than 0.06. *Oculina robusta* was not observed in this segment. The octocoral *Leptogorgia* recorded its highest frequency of occurrence (0.06 ±0.03) within the Naples Segment.

4.2.4 Coral Cover - Compliance, Control, and Transitional Transect Comparative Analysis

Throughout the project area, compliance transects recorded an average scleractinian (hard coral) cover of 0.86 ±0.16%; a significant increase from the 2005 pre-construction average of 0.50% (ANOVA, \( P=0.03 \)), however an insignificant increase from last year’s immediate post-construction average of 0.64% (ANOVA, \( P=0.09 \)) (Figure 10). The range of average percent cover for hard coral had a minimum of 0.03% along R-59+590 and a maximum of 3.23% at R-50+250. *Siderastrea siderea* was observed in high abundance with a frequency of 0.53. Other hard coral species were observed with low frequency and included: *Solenastrea hyades* (0.11), *Phyllangia americana* (0.02), and *Oculina robusta* (0.02). *Leptogorgia* was the only octocoral identified with a frequency of 0.07.
Figure 10. Comparison of average hard coral cover among compliance transects showing a significant increase between the pre-construction to the post-construction monitoring events.

Control station transects in all segments recorded a hard coral cover average of 1.11 ±0.42%. This was an insignificant increase from both the 2005 pre-construction monitoring average of 0.73% hard coral cover (ANOVA, $P=0.33$) and the 2006 post-construction average of 0.71% (ANOVA, $P=0.27$) (Figure 11). A minimum of 0.14% was recorded along both R-56+210 and a maximum of 3.00% was recorded at R-40. *Siderastrea siderea* was again the most abundant scleractinian species observed at these sites, although a lower frequency of 0.39 was documented. *Solenastrea hyades*, *Phyllangia americana*, and *Oculina robusta* were all detected with frequencies below 0.10. Octocoral observations were restricted to the genera *Leptogorgia* and totaled a frequency of 0.05.

Transitional boundary transects recorded an overall average of 1.70 ±0.59% scleractinian cover, with a minimum of 0.62% at R-58-300 and a maximum of 3.38% at R-38+380 (Figure 12). This increase was statistically insignificant from the previous two monitoring events (ANOVA, $P>0.05$). *Siderastrea siderea* dominated all hard coral species and recorded a frequency of 0.82. Other species of hard coral included *Solenastrea hyades* and *Phyllangia americana* (Photograph 11) both with recorded frequencies below 0.12. *Oculina robusta* was observed in only one sampling quadrat along the transitional boundary transects during the 2006 investigations. Soft corals were solely represented by *Leptogorgia* with a low frequency of 0.09.
Figure 11. Comparison of average hard coral cover among control and transitional boundary transects between the 2005 pre-construction and post-construction monitoring events.

4.3 Coral Census and Stress Index Readings

The following section focuses on one major biotic functional group: coral colonies. Although corals made up a very low percentage (1.01%) of the reef habitat in Collier County, State agencies use them as an indicator of stress within the nearshore zone. Tabular presentations of coral colony data collected during these investigations are provided in Appendix D.

As noted previously, coral stress index numbers utilized during these investigations were developed based on field and laboratory studies conducted by Nova Southeastern University (Vargas Angel et al., 2005) for specific hard coral species found within the nearshore and offshore regions of southern Broward County, Florida. Use of the coral stress index as a hard coral monitoring method in Collier County has been incorporated as a subjective colony “health” measurement that has not been calibrated under laboratory conditions and therefore can not be used as a true measure of colony condition. Stress index numbers are assigned to individual coral colonies in this study by qualified marine biologists as part of the FDEP approved biological monitoring program as a relative hard coral colony health assessment tool. The stress index data collected and presented in this and subsequent reports for Collier County are not comparable to other geographically distinct coastal habitats.

4.3.1 Vanderbilt Beach Segment Coral Observations

Coral census belt-transect surveys documented a total of 98 separate colonies, greater than 5 cm in length, along the ten monitoring transects within the Vanderbilt Beach Segment during the 2007 monitoring event. Of the coral colonies observed, Siderastrea siderea was observed with the highest frequency (0.65) with an average colony length of 14.7 ±0.8 cm. This was insignificantly different from both the 2005 pre-construction (13.9 cm; ANOVA, \( P=0.33 \)) and 2006 immediate post-construction average length measurements for \( S. \) siderea (14.2 cm) (ANOVA, \( P=0.59 \)). Solenastrea hyades was the second most abundant species and showed no significant variations from previous data sets with a frequency of 0.33 and an average measurement across the colony of 25.9 ±1.4 cm (ANOVA, \( P>0.05 \)) (Photograph 12). Stress index numbers recorded in 2007 were consistent with those obtained during last year’s immediate post-construction assessments, with only one colony (a \( S. \) siderea at R-23+285) showing an increase from a #0 reading to a #1 reading. Further investigations recorded only one colony of Oculina robusta in the Vanderbilt Beach Segment belt census, and its maximum length measurement was 42 cm. Average sediment thickness around the base of the 98 colonies equaled 15.5 ±1.2 mm, which was insignificantly different from both the 2005 pre-construction measurement (14.2 mm) and the 2006 immediate post-construction measurement (15.0 mm) (ANOVA, \( P=0.63 \)).
4.3.2 Pelican Bay Segment Coral Observations

In 2007, one hundred nine (109) separate coral colonies were surveyed within the nine monitoring transects that comprise the Pelican Bay study area. The most abundant scleractinian coral observed was *Siderastrea siderea* with a frequency of 0.58 and an average maximum length of 15.7 ±0.6 cm. *S. siderea* colony measurements were not significantly different from pre-construction (15.0 cm) or immediate post-construction (15.3 cm) averages (ANOVA, *P*>0.05). Likewise, *Solenastrea hyades* colonies showed no significant differences from previous monitoring data with a frequency of 0.40 and an average length of 25.2 ±1.3 cm (ANOVA, *P*>0.05). Stress index numbers recorded during the 2006 investigations were consistent with readings collected during the 2005 pre-construction assessments for *S. siderea* and *S. hyades* colonies. Other coral identifications included only two colonies of *Oculina robusta*; their maximum lengths equaled 42 cm and 26 cm, respectively. Even though Pelican Bay recorded the second highest average sediment thickness around the base of the colonies in 2007 with 17.4 ±1.5 mm, this measurement was insignificantly different from both the 2005 pre-construction average (16.5 mm) and the 2006 post-construction average (16.9 mm) (ANOVA, *P*>0.05).

[Photograph 12. *Solenastrea hyades* were documented in relatively high abundance in all project segments. Specifically, in the Vanderbilt Beach and Pelican Bay Segments the average colony length measured just over 25.0 cm.]
4.3.3 Park Shore Segment Coral Observations

During the 2007 year one post-construction monitoring event, the Park Shore Segment recorded the highest number of corals of any project study area with 111 documented colonies. *Siderastrea siderea* recorded measurements consistent with the pre-construction and immediate post-construction totals for frequency (0.64) and average maximum length (12.4 ±0.7 cm) (ANOVA, *P*>0.05). *Solenastrea hyades* was observed with a frequency of 0.32 and an average maximum length of 25.1 ±1.4 cm; insignificantly different from the pre-construction and immediate post-construction measurements for *S. hyades* (ANOVA, *P*>0.05). The only other coral colony observed was an *Oculina robusta* with a maximum measurement of 17 cm. Average sediment thickness around the colony base equaled 14.6 ±1.5 mm, an insignificant difference from the pre-construction measurement of 13.5 mm (ANOVA, *P*=0.26) and the immediate post-construction measurement of 14.1 mm (ANOVA, *P*=0.80). Stress index numbers observed in 2007 were consistent with the pre-construction assessments (Photograph 13), with only one colony of *S. siderea* showing an increase from a #1 stress reading to a #2 stress reading at R-47+600.

![Photograph 13. Most Siderastrea siderea were documented with stress levels consistent with the pre-construction and the immediate post-construction levels.](image-url)
4.3.4 **Naples Segment Coral Observations**

The Naples Segment recorded the lowest number (39) of total coral colonies along the segment’s seven monitoring transects in 2007. *Solenastrea hyades* was documented with the highest frequency among hard corals in the segment with 0.41 and was measured to have an average maximum length of 23.2 ±2.1 cm. The 2007 observations were not significantly different from the pre-construction and immediate post-construction measurements for *S. hyades* (ANOVA, *P*>0.05). *Siderastrea siderea* recorded a frequency of 0.31 and an average maximum length of 15.9 ±1.3 cm, which were not significantly varied from either the 2005 pre-construction average of 15.1 cm (ANOVA, *P*=0.51) nor the 2006 immediate post-construction average of 15.3 cm (ANOVA, *P*=0.76). No colonies of *Oculina robusta* were observed. Stress index numbers recorded for hard coral colonies within the Naples Segment were consistent with all pre-construction assessments for *S. siderea* and *S. hyades* colonies.

Naples was the only segment in which octocorals were documented in relatively moderate abundance. *Leptogorgia* sp. was recorded with a frequency of 0.28 and an average maximum length of 24.9 ±2.1 cm (Photograph 14) during the 2006 immediate post-construction monitoring event. Even though the highest average for sediment thickness around the base of the coral colonies was recorded in the Naples Segment with a measurement of 18.8 ±3.5 mm, it was calculated to be insignificant from the pre-construction measurement of 17.3 mm (ANOVA, *P*=0.32) and the immediate post-construction average of 17.7 mm (ANOVA, *P*=0.68).

Photograph 14. *Leptogorgia* sp. was the only octocoral genera identified throughout the Collier County study area. The Naples Segment recorded the largest frequency of soft corals with 0.28.
4.3.5 Compliance, Control, and Transitional Transect Coral Observation Comparative Analysis

Throughout the project study area, 232 separate coral colonies were documented along twenty-four permanent compliance monitoring transects. *Siderastrea siderea* was the most abundant coral observed with a frequency of 0.58 with an average maximum length of 14.1 ±0.4 cm, which was insignificantly different from both the pre-construction average (13.3 cm) and the immediate post-construction average (13.9 cm) (ANOVA, \(P>0.05\)). During the 2007 investigations, *Solenastrea hyades* recorded the same frequency as pre-construction and immediate post-construction monitoring, 0.35, and was calculated to have an insignificantly different average maximum measurement of 24.8 ±0.9 cm (ANOVA, \(P>0.05\)). Only four colonies of *Oculina robusta* were documented in 2006, and their average maximum length was equal to the pre-construction average of 31.7 ±6.4 cm (Photograph 15). Along the compliance transects, average sediment thickness around the coral colony base measured 14.6 ±0.9 mm, a non-significant difference from the pre-construction measurement of 14.1 ±0.8 mm (ANOVA, \(P=0.86\)). Overall, stress index numbers recorded during the 2007 investigations were consistent with those documented during the previous year’s assessments, except for one colony (*S. siderea*) showing an increase from a #0 reading to a #1 reading at R-23+280 and another colony (*S. siderea*) showing a stress increase from a #1 reading to a #2 reading at R-47+700.

Among the eight control transects, 65 separate coral colonies were documented. The most frequently (0.59) identified coral colony was *Siderastrea siderea*, with an average maximum length of 13.7 ±0.6 cm. This was not significantly different from the pre-construction (12.6 cm) or immediate post-construction records (13.1 cm) (ANOVA, *P* > 0.05). *Solenastrea hyades* recorded a frequency of 0.36, the same as in 2005 pre-construction and 2006 immediate post-construction monitoring events, with an average maximum length (24.4 ±1.8 cm) that was insignificantly different from previous years (ANOVA, *P* > 0.05). No colonies of *Oculina robusta* were observed along the control transects. Sediment thickness at the colony base averaged 16.0 ±2.5 mm in 2007, not significantly different from the 14.6 mm pre-construction measurement (ANOVA, *P* = 0.24) or the 15.1 mm immediate post-construction average (ANOVA, *P* = 0.55). Stress index numbers recorded along the control transects in 2007 were consistent with all readings collected during the immediate post-construction assessments.

Investigations of the four transitional boundary transects yielded 60 separate coral colonies. *Siderastrea siderea* was the most common coral with a documented frequency of 0.62. The average maximum measurement of *Siderastrea* colonies was 16.5 ±1.0 cm, an insignificant increase from the pre-construction and immediate post-construction averages (ANOVA, *P* > 0.05). *Solenastrea hyades* was the second most abundant species with a frequency of 0.38 and an average maximum length of 26.5 ±1.6 cm, which did not differ significantly from the pre-construction or immediate post-construction measurements (ANOVA, *P* > 0.05). No *Oculina robusta* colonies were documented along the transitional boundary transects. Average sediment thickness around the base of the coral colonies measured 21.0 ±2.8 mm, an insignificant increase from the pre-construction measurement of 19.3 mm (ANOVA, *P* = 0.11) and the immediate post-construction average of 20.1 mm (ANOVA, *P* = 0.47). Stress index numbers recorded consistent readings to all pre-construction and immediate post-construction assessments for *S. siderea* and *S. hyades* colonies.

4.4  Other Invertebrates

Marine sponges were the most abundant benthic invertebrate observed on the hardbottom substrate in all the study segments in Collier County (Photograph 16) during the 2006 biological monitoring event. The Naples and Pelican Bay Segments recorded the highest averages for sponge cover with 4.5 ±1.6% and 4.6 ±1.1%, respectively. Park Shore documented an average of 3.2 ±0.7% sponge cover and Vanderbilt Beach reported an average sponge cover of 2.9 ±0.4%.

The other noteworthy invertebrates reported in Collier County included an average percent cover for hydroids (0.3 ±0.1%), tunicates (0.9 ±0.5%), bryozoans (0.7 ±0.2%), and sessile worms (0.2 ±0.1%). All other invertebrates (i.e., anemones, barnacles, *Millepora* sp., and zoanthids) reported percent covers of less than 0.1%. While most of these averages showed increases in percent cover, the year one post-construction data for identified invertebrates was not significantly different those documented during the 2005 pre-construction and 2006 immediate post-construction monitoring events (ANOVA, *P* > 0.05).
Photograph 16. Marine sponges, like this *Cliona delitrix*, were seen throughout the Collier County project area.

4.5 *Non-Parametric Trend Analysis*

Non-parametric trend analyses were carried out using the statistical package PRIMER-E® (v6). PRIMER software consists of a series of graphical and multivariate tools for analyzing arrays of species by sample data from community ecology (Clarke and Gorley, 2006). These analyses were performed to verify and validate the aforementioned results.

The data was first pre-treated with Log(x+1) transformations. This pre-treatment was applied to allow the intermediately abundant groups to contribute to the similarity. After pre-treating all the known functional groups, resemblance matrices were created using a Bray-Curtis Similarity measure. The resemblance matrix is the base for many of the operations performed by PRIMER’s graphical and statistical tools.

The first analysis conducted on the resemblance matrix was a multi-dimensional scaling (MDS) ordination. Figure 12 displays an MDS with possible clustering of data points; the data is defined by the factors *monitoring year event* (e.g., 2005, 2006, and 2007). The MDS plot interpretation is evident: points that are close together represent functional
groups, including sediment coverage, that are very similar in community composition; whereas points that are far apart correspond to different values within the data set. The stress level of the MDS is 0.17, which is low enough to give a good representation of the 2-dimensional data.

Figure 12. Non-parametric MDS plot defining the different monitoring year events through cluster representation. The different clusters show that there are varying trends, with different percents of similarity, among the functional groups from each of the monitoring events.

To gain greater resolution into the patterns within the different monitoring events, the variables in the original data matrix were averaged by specific categories. A resemblance matrix and a MDS plot were generated for this sub-dataset for the all monitored transects. Figure 13 shows an MDS 2-D Bubble plot of sediment coverage, where a divergence between monitoring events statistically reinforces the increase in sediment coverage from pre- to post-construction monitoring years. The biological treads are also shown, as Figure 14 shows how macroalgae benthic coverage first increased from pre- to immediate post-construction, and then decreased from immediate post-construction to year one post-construction.
Figure 13. Non-parametric MDS 2-D Bubble plot of sediment coverage, showing a divergence between monitoring event years. The legend on the right represents different sediment coverage percentages (e.g., 9%-90%) and the plot shows a trend of increasing sediment in Collier County between the monitoring years, 2005-2007.
Figure 14. County-wide macroalgae coverage trends represented through a non-parametric MDS 2-D Bubble plot. The legend on the right represents different macroalgae coverage percentages (e.g., 5%-50%) and the plot shows a trend of increasing, then decreasing, macroalgae in Collier County between the monitoring years, 2005-2007.
After the trends have been established, a two-way crossed (no-replicates) Analysis of Similarity (ANOSIM) was used to see if any of these trends had significant group differences at \( \alpha = 0.05 \). ANOSIM is an approximate analogue of the standard univariate 1- and 2-way analysis of variance test (Clarke and Gorley, 2006). The ANOSIM 2-way crossed layout permits the testing of the null hypothesis that there are no differences between site and time treatments. Figure 15 displays the histogram generated by the ANOSIM analysis along with the Global R and \( p \)-values. Significant differences were detected between the 2005 pre-construction monitoring event and the 2007 year one post-construction monitoring event (\( R = 0.471, p < 0.001 \)). Even though the \( p \)-value indicates statistically significant differences, the R value suggests the possibility of sample overlap between monitoring events and transect types. This means that although the communities may not be exactly alike, they are likely overlapping in community composition.

Based on analysis of the data it was determined that differences in functional groups have occurred between the 2005 pre-construction and the 2007 year one post-construction events, therefore, further analysis must be applied to define specific functional group variations. Using the PRIMER (v6) (Clark and Warwick, 2001), the Bray-Curtis similarity coefficient matrix was derived based on functional group percent cover from each quadrat; the similarity matrix was used to detect the extent of differences in the functional groups between the different sampling periods within each transect type. SIMPER (similarity percentage) analysis was used to identify the role of a specific functional group as it contributes to the separation between two groups of samples (i.e.,

![Year Test](image_url)

**Figure 15.** ANOSIM histogram comparing the 2005 pre-construction functional group data to the 2007 year one post-construction data sets.
2005 vs 2007, Figure 16). The SIMPER operates on the basis of dissimilarity percentages, thereby providing a more accurate interpretation of established group relationships not accurately depicted by the 2-d MDS Bubble plots.

**SIMPER ANALYSIS**

**Groups 2005 & 2007**

Average dissimilarity = 23.61

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>Avg Abund</th>
<th>Avg Abund</th>
<th>Avg Diss</th>
<th>Diss/SD</th>
<th>Contrib%</th>
<th>Cum.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Hard Substrate</td>
<td>1.79</td>
<td>0.03</td>
<td>6.6</td>
<td>3.56</td>
<td>27.96</td>
<td>27.96</td>
</tr>
<tr>
<td>Turf Algae</td>
<td>2.25</td>
<td>2.75</td>
<td>3.25</td>
<td>1.22</td>
<td>13.76</td>
<td>41.72</td>
</tr>
<tr>
<td>Macroalgae</td>
<td>2.62</td>
<td>2.89</td>
<td>2.7</td>
<td>1.25</td>
<td>11.43</td>
<td>53.15</td>
</tr>
<tr>
<td>Tunicate</td>
<td>0.12</td>
<td>0.75</td>
<td>2.51</td>
<td>1.36</td>
<td>10.61</td>
<td>63.76</td>
</tr>
<tr>
<td>Scleractinia</td>
<td>0.39</td>
<td>0.64</td>
<td>1.79</td>
<td>1.38</td>
<td>7.58</td>
<td>71.34</td>
</tr>
<tr>
<td>Sponge</td>
<td>1.21</td>
<td>1.43</td>
<td>1.66</td>
<td>1.42</td>
<td>7.02</td>
<td>78.37</td>
</tr>
<tr>
<td>Bryozoan</td>
<td>0.01</td>
<td>0.32</td>
<td>1.17</td>
<td>0.96</td>
<td>4.97</td>
<td>83.34</td>
</tr>
<tr>
<td>Hydroid</td>
<td>0.12</td>
<td>0.38</td>
<td>1.13</td>
<td>1.68</td>
<td>4.79</td>
<td>88.13</td>
</tr>
</tbody>
</table>

Figure 16. SIMPER analysis representing the dissimilarity among functional groups between the 2005 pre-construction and the 2007 post-construction monitoring events.

Through SIMPER analyses, it was shown that bare hard substrate contributed most to the dissimilarity between the 2005 pre-construction and the 2007 post-construction monitoring events, which was shown to be a statistically significant decrease through parametric $t$-tests (Section 4.1). Benthic flora dissociation are consistent with the summary tables, and even though parametric tests did not find significant differences, the increases in coverage are still accurately represented. Likewise, for benthic invertebrates (tunicates, scleractinia, sponges, bryozoans, hydroids), whom all have shown dissimilarity from the pre-construction to the year one post-construction through increases in overall coverage.

**5.0 DISCUSSION AND CONCLUSIONS**

**5.1 Abiotic Parameters**

**5.1.1 Sediment**

The 2007 post-construction environmental monitoring event documented the status of Collier County’s nearshore resources one year after beach construction activities had ceased. Abiotic parameter monitoring documented a hardbottom substrate that is characterized as one being naturally affected by large scale sediment accumulations; even so, none of the measurements for sediment coverage were significantly different from those documented during both the 2005 pre-construction and the 2006 immediate post-construction monitoring events ($t$-test, $P>0.05$). Over half (62.2 ±3.3%) of the nearshore benthic monitoring sites in the Collier County study area had documented sediment cover at least 1 cm thick, which represents an insignificant increase from the levels measured during the 2005 pre-construction (60.3%, $t$-test, $P>0.05$) and immediate post-construction
Nearshore accumulations of sediment documented during the 2007 investigations at the compliance, control, and transitional boundary sites had an average thickness measurement of 11.1 ±0.8 cm deep, which increased insignificantly (t-test, \( P>0.05 \)) from the pre-construction average of 9.8 cm and the immediate post-construction average of 10.4 cm. Compliance transects adjacent to the beach project fill sites recorded insignificant (t-test, \( P>0.05 \)) increases from pre-construction and immediate post-construction levels with an average sediment percent cover of 61.2 ±3.6% and an average sediment thickness of 11.9 ±1.1 cm. While control and transitional boundary transects also recorded slight increases in sediment percent cover and sediment depth during the 2007 monitoring event, all measurements were calculated to have no significant variation from the pre-construction totals (t-test, \( P>0.05 \)). Even though the parametric statistical analyses show that the increases in sediment coverage and sediment thickness are non-significant, non-parametric trend analyses show that an increasing abiotic divergence is evident between the pre-construction and post-construction monitoring events. Future monitoring of sediment coverage and depth will be necessary to help determine if these trends eventually lead to cause significant impact on the resource. However, current monitoring activities and data analysis provide evidence that the construction activities of the Collier County Beach Renourishment Project did not significantly add sediment coverage or depth to the nearshore hardbottom habitat region of Collier County.

Of specific interest was the slight increase of fine mud recorded in all of the study project segments (Photograph 17). Considering that the approved sand source for the Collier County Beach Renourishment Project had a documented fine fraction of \(~1.0\%\), it is unlikely that the mud accumulation documented during these investigations is the result of the beach project. The accumulations were first documented during the 2005 pre-construction monitoring event, and persisted through the 2006 and 2007 post-construction monitoring events. While all the segment increases in mud observations were calculated to be insignificant (t-test, \( P>0.05 \)), an average increase of 5% cover was still recorded for those quadrats containing a portion of mud. Overall, a frequency of 0.76 ±0.13 of all the quadrats assessed within the study area contained some portion of mud sediment. The mud may be a direct influence of recent severe storm events (i.e., Hurricane Charley, Hurricane Dennis, Hurricane Katrina, Hurricane Rita, Hurricane Wilma) that transported fine sediments inshore and deposited them along the reef. As the finer offshore sediments are transported to nearshore areas, they become trapped between and within hardbottom formations.

Theoretically, a layer of mud is persistently available for suspension and redistribution along the nearshore zone of Collier County. As such, another potential source of the fine material may be freshwater and upland stormwater that transport fine particles into the immediate nearshore zone through channeled passes. While the direct origin of the mud remains undetermined, it was concluded that the Collier County Beach Renourishment Project was not a potential source of the unconsolidated mud. This finding is supported by representatives of the FDEP (V. Kosmynin, pers. comm.). Future monitoring events will document whether these accumulations fluctuate or remain static over time.
Photograph 17. Example of fine mud sediment coverage within Collier County’s nearshore. These mud accumulations consist of unconsolidated clay-like materials that support a dark, top-layer of cyanobacteria growth.

Similar to the 2005 pre-construction and the 2006 immediate post-construction monitoring events, the Naples and Vanderbilt Beach Study Segments, which are in direct proximity to inland navigable passes, documented the highest sediment accumulations along Collier County. The Naples Segment, located south of Doctors Pass, recorded the highest average sediment cover with 68.9 ±6.1%, as well as the highest average sediment thickness of 14.5 ±2.2 cm. Likewise, the Vanderbilt Beach Segment, located south of Wiggins Pass, recorded an average sediment cover of 66.8 ±5.1%, with an average sediment depth of 12.7 ±1.6 cm (Photograph 18). This consistent accumulation of sediments within the Naples and Vanderbilt Beach Segments may be the cumulative effect of multiple stress factors targeting these specific regions (i.e., hydrological effects caused by proximity to the passes).
Photograph 18. Within the Vanderbilt Beach Segment, fine sediment coverage was commonly found. This Segment is located in close proximity to Wiggins Pass.

For example, Doctors Pass, located directly north of the Naples Segment at R-57, has been stabilized and maintained since 1960. The flow of freshwater from neighboring bays and canals channels agricultural and urban storm water runoff into this zone. Recent inlet maintenance included the Doctors Pass Maintenance Dredging Project (CEC, 1997), which integrated the dredging of a sediment basin within the ebb shoal and involved the placement of approximately 55,000 cubic yards (cy) of beach compatible material from that project area onto Naples Beach between R-59 and R-61. Between 2000 and 2002, Doctors Pass was dredged again by removing 39,800 cubic yards of sand and 9,070 cy of sand/rock (Staiger, 2003). The last dredging event took place in November 2005 and removed approximately 53,600 cy of material from Doctors Pass to a nearshore disposal site offshore of Lowdermilk Park (R-60 to R-61+816) (CPE, 2005).

Likewise, Wiggins Pass, located directly north of the Vanderbilt Beach Segment (between R-17 and R-18), is a natural inlet that has been relatively stable since 1927. Recent inlet maintenance described in the Wiggins Pass Inlet Management Plan (CPE, 1995) includes channel dredging and sediment bypassing. An average annual volume of 18,600 cubic yards has been dredged from the navigation channel since 1984, of which an estimated 14,000 cy per year has been placed on the beaches to the south of Wiggins Pass.
In addition to these hydrographic processes, a demographic influence may be a contributing factor to the observed sedimentation as well. The rapid population growth of Florida’s southwest coast, specifically in the Naples area, has been a suspected contributor to the environmental degradation of the nearshore hardbottom community. Often an increase in human population equates to an increase in nutrient runoff, which may directly affect the integrity of the coastal environment.

5.1.2 Vertical Relief

Vertical relief of the hardbottom substrate showed an inverse trend when compared to areas that experienced higher sedimentation (Figure 9). Even though vertical hardbottom relief showed a decreasing trend (14.6 ±1.7 cm) in response to higher sediment depths, no significant differences were calculated from either the 2005 pre-construction average (14.9 cm; t-test, \(P>0.05\)) or the 2006 immediate post-construction average (15.3 cm, t-test, \(P>0.05\)). The highest relief was measured in the study segments of Pelican Bay (18.3 ±1.9 cm) and Park Shore (16.6 ±2.9 cm). Monitoring transects R-37+700 (Pelican Bay Segment) and R-43+550 (Park Shore Segment) recorded the highest average hardbottom ledge height with measurements of 32.2 cm and 34.2 cm, respectively (Photograph 19).

Photograph 19. Vertical relief along the transitional boundary transect R-43+550. Relief of the hardbottom substrate adds to the complexity of the reef, and provides refuge for many species in Collier County.
Among the twenty-four compliance transects, average vertical relief decreased from 15.9 cm during immediate post-construction monitoring to 15.4 ±1.6 cm during year one post-construction monitoring; an insignificant difference ($t$-test, $P=0.81$). Control station transects and transitional boundaries both showed insignificant variations in vertical relief between pre-construction and post-construction monitoring events ($t$-test, $P>0.05$). While future monitoring will determine if the decrease in measured vertical relief is correlated to a trend of increased sedimentation, the current physical data shows that the vertical relief of Collier County’s nearshore reefs have not receded significantly following beach renourishment construction activities.

Vertical complexity plays an integral role in the nearshore reef system of Collier County, and provides suitable habitat to a wide array of fish and motile invertebrate species. Although fish counts were not required by the FDEP as part of the County's monitoring program, marine biologists identified several fish species that use the vertical relief of the substrate for refuge and predatory camouflage. Fish species observed by CPE marine biologists during in situ monitoring of the hardbottom resource include: gag grouper (Mycteroperca microlepsis), unidentified juvenile grunts (Haemulon sp.), common snook (Centropomus undecimalis), unidentified filefish (Family Monacanthidae), leopard searobin (Prionotus scitulus), gray snapper (Lutjanus griseus) (Photograph 20), yellowtail snapper (Ocyurus chrysurus), Atlantic spadefish (Chaetodipterus faber) (Photograph 21), black grouper (Mycteroperca bonaci), bridled goby (Coryphopterus glaucofraenum), goliath grouper (Epinephelus itajara), lookdowns (Selene vomer), sheepshead seabream (Archosargus probatocephalus), lizardfish (Synodus sp.), belted sandfish (Serranus subligarius), and polka-dot batfish (Ogcocephalus radiatus). In addition to essential fish habitat, vertical relief in hardbottom habitats serve as an important resource for nesting and juvenile marine turtles by supplying reef ledges as resting, sleeping, and foraging sites (Makowski et al., 2006).

Photograph 20. Gray snappers, Lutjanus griseus, documented near the permanent monitoring transect R-29+700.
5.2 Biotic Trends

5.2.1 Benthic Flora

Year one post-construction monitoring along the nearshore study area of Collier County documented that benthic biota has not been adversely affected by beach project construction activities. Macroalgae was reported in relatively moderate abundance along the hardbottom resource with an overall County average of 22.0 ±3.6% cover, an insignificant increase from the 2005 pre-construction average of 19.4% cover (ANOVA, \( P > 0.05 \)) and a insignificant decrease from the 2006 pre-construction average of 23.3%. This fluctuating trend was accurately represented through non-parametric multi-dimensional scaling. When analyzed separately, compliance, control station, and transitional boundary transects all showed slight decreases in macroalgae percent cover from the previous year, however the percent cover did not differ significantly from the pre-construction or immediate post-construction measurements (ANOVA, \( P > 0.05 \)).
In 2007, the macroalgal community was limited to only six identified genera, and was dominated by red algae. *Gracilaria* was documented with the highest frequency of all macroalgae (0.68 ±0.07) throughout the four study segments. This genus is known to occur from cold temperate regions along the eastern Atlantic coast of Nova Scotia to warm subtropical regions around the east and west coasts of Florida where it serves as a dietary item for marine turtles (Wershoven and Wershoven, 1992; Makowski et al., 2006). *Gracilaria* can grow vegetatively over an indefinite period of time and has been shown to have a high growth rate under non-limiting light and nutrient conditions (Peckol and Rivers, 1995). Temperature and light intensity are the critical factors that affect the seasonal variation of the flora’s proteins, carbohydrates, and R-Phycoerythrin to Chlorophyll *a* ratio (the ratio of red photopigments to the primary green photopigment). As long as nutrients are not limiting, protein and carbohydrate levels tend to show an inverse relationship to both temperature and light, decreasing as temperature and light increase. It is postulated that this unique ability may allow *Gracilaria* to proliferate in the highly turbid nearshore habitat of Collier County, where acclimation to reduced light intensity results in an increase in both pigment levels and photosynthetic ability (Lapointe and Duke, 1984).

The hypothesis that turbid, ephemeral habitats, such as the nearshore mixing zone of Collier County, tends to select for a heavy proliferation of Rhodophyta was also shown in the abundance of the another red macroalgae genera: *Hypnea*. *Hypnea*, which has been known for being a highly opportunistic alga that is commercially cultivated throughout the world for its kappa carrageenan (Littler and Mark, 2000), was recorded in over half of all the sampling quadrats with an overall County frequency of 0.56 ±0.05. An extremely invasive genera, *Hypnea* has the ability to epiphytize other algae and to easily fragment (Russell, 1992; Abbott, 1999). Similar to *Gracilaria*, an important feature of *Hypnea* has been its identification as a food source for the green sea turtle, *Chelonia mydas* (Wershoven and Wershoven, 1992; Makowski et al., 2006). *Hypnea* may comprise a significant part of the green sea turtles’ diet, sometimes representing 100 percent of the marine vegetation found in their stomachs (Russell and Balazs, 1994, 2000).

The third most abundant and only green macroalgae genera identified along Collier County’s nearshore was *Caulerpa*. With an overall County frequency of 0.55 ±0.07, *Caulerpa* can dominate hardbottom substrates and out compete other algal species under the right conditions. The genus utilizes an extremely thin filamentous rhizoid matrix, which mimics the root system of traditional vascular plants. This matrix attaches to hard surfaces and serves as a ‘conveyor belt’ by translocating inorganic and organic nutrients from the solid substrate (Meinesz, 1999). In addition, *Caulerpa* has a very low light compensation point (Littler and Mark, 2000), allowing it to grow in low light environments such as the turbid nearshore zone of Collier County.

Turf algae/cyanobacteria were recorded as part of the benthic flora assemblage and were measured to have decreases in average percent cover along all the study segments. Although the individual segment decreases in this functional group did not significantly differ from either the documented 2005 pre-construction or 2006 immediate post-construction measurements, an average decrease of 1.1% for turf algae/cyanobacteria
Turf algae/cyanobacteria mats consist of a multi-specific aggregation of diminutive, often filamentous, algae that attain a canopy height of only 1 to 10 mm (Steneck, 1988). These microalgal species have a high diversity (>100 species in western Atlantic), although only 30 to 50 species commonly occur at one time (Adey et al., 1987). There is a high turnover of individual turf algal species seasonally and only a few species are able to persist or remain abundant throughout the year; however, when observed as a functional group, turf algae percent cover remain relatively stable year round (Steneck and Dethier, 1994). These stable mats of turf/cyanobacteria growth, which have been seen growing on hard substrates as well as accumulations of fine mud, are inversely correlated to significant decreases in bare hard substrate averages throughout the County (Figure 17).

Along compliance transects, bare hard substrate presence decreased to 3.1 ±0.4% cover; which represents a significant decrease from the 2005 pre-construction total of 5.3 ±0.5% cover (ANOVA, $P<0.05$). Likewise, control station transects recorded a significant decrease in bare hard substrate percent cover between pre-construction (5.3 ±1.4%) and post-construction (3.7 ±1.2%) monitoring events (ANOVA, $P<0.05$). This negative correlation is not project related, but may be a result of increased abrasion of the substrate.
following major storm events in 2004 and 2005. Subsequently, turf algae/cyanobacteria mats are known to be opportunistic and are able to proliferate rapidly on an available bare substrate (Adey et al., 1987). These adaptations as rapid colonizers may have led to an increase in turf algae/cyanobacteria populations since the 2005 data collection event. In future monitoring events, turf algae percentage will be monitored thoroughly; turf algal mats are capable of trapping ambient sediment and have been known to kill corals through gradual, bioeroding encroachment (Adey et al., 1987).

![Figure 17](image.png)

Figure 17. Inverse relationship of turf algae cover versus bare hard substrate cover among compliance transects for pre-construction and post-construction monitoring events.

### 5.2.2 Coral

Scleractinian coral had limited documented diversity with only four species (*Siderastrea siderea*, *Solenastrea hyades*, *Oculina robusta*, and *Phyllangia americana*) identified along the nearshore hardbottom habitats of Collier County. As documented during the 2005 pre-construction monitoring event, coral cover represents a very low percentage (~1.01%) of the nearshore reef habitat. Even so, along compliance transects, average hard coral cover has showed a marked increase between monitoring events, from 0.50% during the 2005 pre-construction monitoring, to 0.64% during 2006 immediate post-construction, to 0.86 ±0.16% in 2007. This increase proved to be statistically significant (ANOVA, $P<0.05$), and was most likely correlated to a 0.5 cm average increase in coral
colony length measured throughout the compliance transects when compared to pre-construction values. A similar trend in hard coral colony growth, even though statistically insignificant (ANOVA, \( P>0.05 \)), was documented at the control transects, where a 0.3% increase in coral cover was coupled with a 0.4 cm increase in average maximum length measurements of the coral colonies. This data suggests that the growth rates of Scleractinian corals were not disturbed by the construction activities of the Collier County Beach Renourishment Project.

Among the scleractinian species identified, *Siderastrea siderea* was the most dominant hard coral observed with an overall County frequency of 0.49 ±0.15. Also known as the starlet coral, *S. siderea* has a brownish appearance and a rounded, stone-like growth form that can measure up to 30 cm across (Humann and Deloach, 2002). During the belt-transect coral census surveys, the County average maximum length for *Siderastrea siderea* was 15.8 ±0.7 cm. *Siderastrea siderea* has been demonstrated to exhibit a high toleration to the influx of terrigenous sediments (Torres and Morelock, 1999) (Photograph 23).

![Photograph 23. Example of fine mud sediment coverage around colonies of Siderastrea siderea. These mud accumulations often become trapped in the nearshore and are covered with a layer of cyanobacteria (Photo credit: V. Kosmynin; FDEP).](image)

The stress index assignments by CPE marine biologists noted that all but two *S. siderea* maintained the same stress level as pre-construction and immediate post-construction records. Of the two *S. siderea* that increased stress levels, both were recorded on compliance transects. At R-23+285, a 29 cm *S. siderea* increased from a #0 stress level to a #1 stress level; the primary stress noted was base sedimentation. The other coral was a 21 cm *S. siderea* at R-47+600, where sedimentation prompted a stress level increase
from a #1 to a #2. High sedimentation rates are one of the most important factors limiting coral cover and reef development (Rogers, 1990) (Photograph 24), however, studies have shown that *S. siderea* are among the most resilient coral species at sediment stressed sites (Torres and Morelock, 1999). This study shows that the majority of *S. siderea* monitored have not displayed multiple stress indictors after completion of the Collier County Beach Renourishment Project; however, future monitoring must be carried out to reveal if sediment stress is a long term effect within Collier’s nearshore habitat.

Photograph 24. An increase in sedimentation around the base of a coral colony (*S. siderea*) at control transect R-19+400. Increased sedimentation can lead to multiple stress indicators, such as bleaching (lower portion of the colony), that can affect the long-term success of the organism.

The second most abundant hard coral species documented County-wide in 2007 was the knobby star coral, *Solenastrea hyades*, with an overall frequency of 0.39 ±0.03. These reef building coral colonies form lobated heads with irregular bulges on the surface (Humann and Deloach, 2002). Usually displaying a yellow-brown pigment, *Solenastrea hyades* inhabit a wide range of high sedimentation marine environments, such as the coastal reefs of Collier County. The average size measurement of *Solenastrea* during the 2006 coral census surveys equaled 25.8 ±0.7 cm, and stress index readings were all consistent with those documented in the previous monitoring events.

The nearshore environment of Collier County is characterized as having higher relative natural turbidity, with a wider range of temperature and salinity than offshore habitats. Assuming that the colonies documented during these investigations have maintained a growth rate of 0.8 to 1.2 cm per year (Jaap, 1974), the *S. hyades* colonies along Collier
County’s nearshore reefs are estimated to be approximately 25 years old. This supports the theory that the hard corals associated with Collier reef system are capable of maintaining their viability given the stresses affecting the resource. Long term monitoring of the study area will be used to identify project related conditions that impact the stress thresholds, and ultimately the survivability of various benthic functional groups, such as hard corals.

5.3 Future Monitoring Events

The nearshore zone of Collier County contains a functionally important hardbottom habitat comprised of key species and essential substrate-building components (Photograph 25).

Photograph 25. Reef community health relies on a synergistic relationship between key marine species, and human influences should be avoided, minimized, or mitigated to protect the County’s natural resources.

Collier County's comprehensive environmental monitoring program is specifically designed to monitor and assess habitat conditions through the year 2011, with the specific intent of determining if documented effects resulted from construction of the Collier County Beach Renourishment project. While the 2007 year one post-construction monitoring event did not document any statistically significant adverse effects to the nearshore reef habitat of Collier County, subsequent monitoring of the study area habitats will be conducted according to State and Federal regulatory requirements. Collection of
the appropriate data will be necessary to determine if the placement of beach fill along the project area’s shorelines resulted in direct or indirect impacts to significant marine resources; or, if the project had no adverse effect at all. Future monitoring events shall be performed in compliance with the FDEP mandated monitoring plan, and the collected data will be evaluated and presented in subsequent monitoring reports. The two year post-construction monitoring event is scheduled for the summer of 2008, and will be compared to the findings presented in the 2005 pre-construction, 2006 immediate post-construction, and the 2007 year one post-construction monitoring reports.

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7.0 REFERENCES


