Miami Harbor
Baseline Hardbottom Study

FINAL

March 2011

Prepared for:
U.S. Army Corps of Engineers
Jacksonville District
701 San Marco Boulevard
Jacksonville, FL 32207

Prepared by:
Dial Cordy and Associates Inc.
490 Osceola Avenue
Jacksonville Beach, FL 32250

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EXECUTIVE SUMMARY

The Miami Harbor Deepening Project was designed to widen and deepen the outer entrance channel to increase access to the Port of Miami by larger vessels, including post-Panamax vessels. In order to accommodate these larger vessels, the outer entrance channel is proposed to be widened at the outer reef and deepened to 52 (±1) feet. In order to fulfill navigational and safety requirements for the Port of Miami, 4.4 acres of the third (outermost) reef will be directly affected. Avoidance and minimization of impacts to natural resources (hardbottom and seagrasses) was conducted through the NEPA process and a Record of Decision was signed on May 22, 2006.

The environmental characterization presented in this report is intended to assess the nearshore hardbottom, second and third reef biological communities in the vicinity of the deepening and widening project, both in direct-effect areas (4.4 acres) and in indirect-effect areas (up to 500 m away from the channel). The indirect-effect area in this study is further from the channel than the area deemed the "indirect-effect area" which, under NEPA, the Corps is responsible for monitoring, during and after construction. The larger indirect-effect baseline survey area satisfies agency comments and requests. Benthic organisms (scleractinians, octocorals, and sponges) found within representative sampling sites of the anticipated footprint of the improved entrance channel (R3DN and R3DS) and of the area adjacent to the improved entrance channel (HBNC, HBN, HBS, HBSC, R2N, R2S, R3N, R3S1, R3S2, R3S3) were sampled in August 2010 (Figure 3). The statistical approaches used in the nearshore hardbottom sites (ANOVA) and on the second and third reefs (regression) were designed to test for an effect of dredging on these benthic populations, in comparison with post-construction surveys.

Baseline results reveal that nearshore hardbottom, second and third reef sites, which are within 500 m of the Miami entrance channel, are colonized by sponges, octocorals and scleractinian corals, in decreasing order of abundance. Macroalgae were present, but were not quantified in this study. The majority of scleractinians were smaller than 10 cm, and octocorals were generally smaller than 25 cm. Octocorals are more dominant in nearshore hardbottom and second reef areas, whereas sponges are similarly abundant on the second and third reefs. Sponge data were not collected for nearshore hardbottom sites, so their dominance at these sites is not known. Scleractinians are low in abundance across nearshore hardbottom, second and third reefs. These reefs have little relief or rugosity; and the areas of highest relief lie adjacent to the channel or occur in isolated patches. Typical subtropical macroalgae, including *Dictyota*, cyanobacteria, and turf algae were common, although not quantified during this study. *Diadema antillarum* were extremely rare, with only two individuals counted across 90 transects at the second and third reef sites.

Comparisons with other studies in the region show that these reefs are similarly depauperate in terms of scleractinian coral cover (Moyer et al. 2003; Gilliam et al. 2006). The dominance of sponges and octocorals is a common feature of the reefs of southeast Florida (Gililam et al. 2006; Moyer et al. 2003).

ANOVA results for nearshore hardbottom sites showed that scleractinian and octocoral density were significantly lower at HBS compared to HBSC, HBN, and HBNC. There were no significant differences in the densities of organisms between any other sites.

Linear regression results for second and third reef octocoral, scleractinian and sponge density per square meter were mixed, although most relationships were positive, with density increasing with distance from the channel. Half the regressions performed were significantly positive in relation to distance from the channel. Regressions of scleractinian colony condition with distance were only significant for fish bites and bleaching at a single site. Together, the ANOVA and regression data may be used for comparison purposes with post-construction surveys to document an effect of dredging on these benthic biological communities.

1.0 INTRODUCTION

1.1 Study Context and Objectives

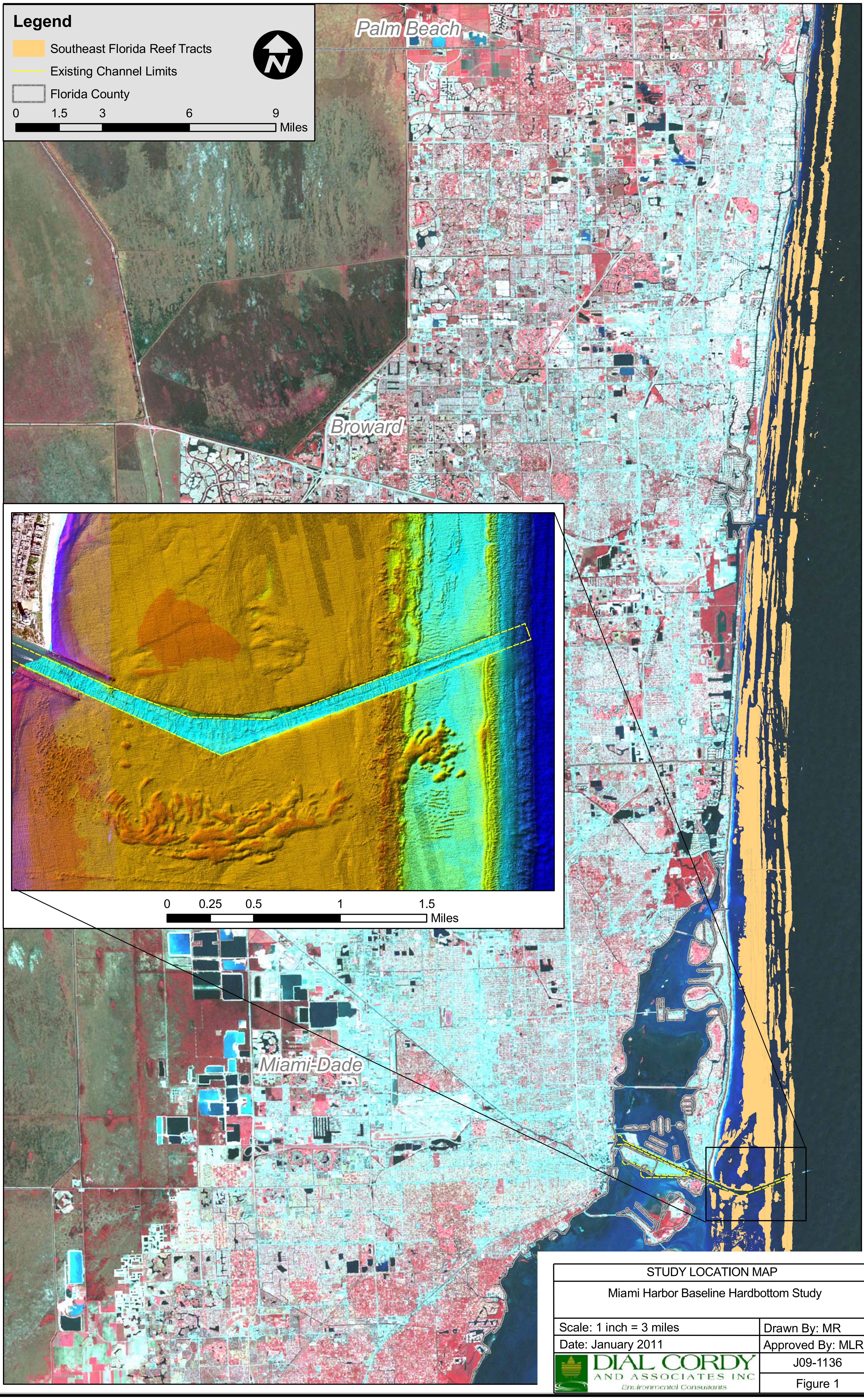
The Miami Harbor Deepening Project was designed to widen and deepen the outer entrance channel to increase access to the Port of Miami by larger vessels, including post-Panamax vessels. To accommodate these larger vessels, the outer entrance channel is proposed to be widened at the outer reef and deepened to 52 (±1) feet (15.6 ± 0.3 m). In order to fulfill navigational and safety requirements for the Port of Miami, 4.4 acres (1.78 hectares) of the third (outermost) reef will be directly affected. Avoidance and minimization of impacts to natural resources (hardbottom and seagrasses) was conducted through the NEPA process and a Record of Decision was signed on May 22, 2006.

Dial Cordy and Associates Inc. was contracted by the Jacksonville District, U.S. Army Corps of Engineers to: (1) conduct a Pilot Study of the nearshore hardbottom and second and third reefs adjacent to the entrance channel, (2) prepare a Quantitative Study plan based on Pilot Study results, and (3) conduct the Quantitative Study of the hardbottom habitat adjacent to Government Cut that may be affected by the proposed Miami Harbor Deepening Project. This study characterizes the benthic communities within the directly-affected and indirectly-affected areas of the nearshore hardbottom and second and third reefs. In addition to serving as a baseline characterization of these areas, the study was designed so that pre- and post-construction results may be compared to detect effects of dredging on the hardbottom resources.

1.2 Study Area

The study area is located in central Miami–Dade County, along reefs east of the Port of Miami entrance channel (Figure 1). The relict reefs of southeast Florida extend from Miami–Dade to Palm Beach County and were accretional reefs during the early Holocene Epoch, approximately 10,000 years ago (Banks et al. 2007). Today, nearshore hardbottom areas (patch reefs) and parallel ridges or reefs lie offshore in a shore-parallel position, and are dominated by macroalgae, octocorals, sponges, and to a lesser extent hard corals (Moyer et al. 2003, Gilliam 2007). Throughout this report, these reef areas will be referred to as nearshore hardbottom or hardbottom, second or middle reef, and third or outer reef (after Moyer et al. 2003).

The reefs in Miami–Dade County run almost continuously in a generally north-to-south direction along the coast to approximately 55th Street, Miami Beach. A break in the reef ridges occurs from 55th Street south for approximately 2 kilometers (km), where a historic river inlet, Bocas Ratones, was mapped in 1770 and naturally closed before 1887 (Cantillo et al. 2000). South of the historic river inlet, only two reefs resume running parallel to the coast and are commonly referred to as the second (middle) and third (outer) reefs, with patchy nearshore hardbottom areas lying west of the second reef tract (Figure 1).



STUDY LOCATION MAP

Miami Harbor Baseline Hardbottom Study

Scale: 1 inch = 3 miles	Drawn By: MR
Date: January 2011	Approved By: MLR
DIAL CORDY AND ASSOCIATES INC Environmental Consultants	J09-1136
	Figure 1

1.2.1 Pilot Study

A Pilot Study was conducted in October 2009 to define hardbottom habitat types within the study area, based on landscape and biological characteristics, so that statistically valid comparisons could be drawn between the habitat types in the Quantitative Study (see Dial Cordy and Associates 2010). The results of the Pilot Study guided the design for the full Quantitative Study plan to assess the distribution and abundance of benthic organisms adjacent to the channel. The study area included hardbottom, second, and third reef sites within 150 meters (m) of the existing outer entrance channel, and also included north and south reference or control sites located on hardbottom, second, and third reefs at comparable depths (Figure 2).

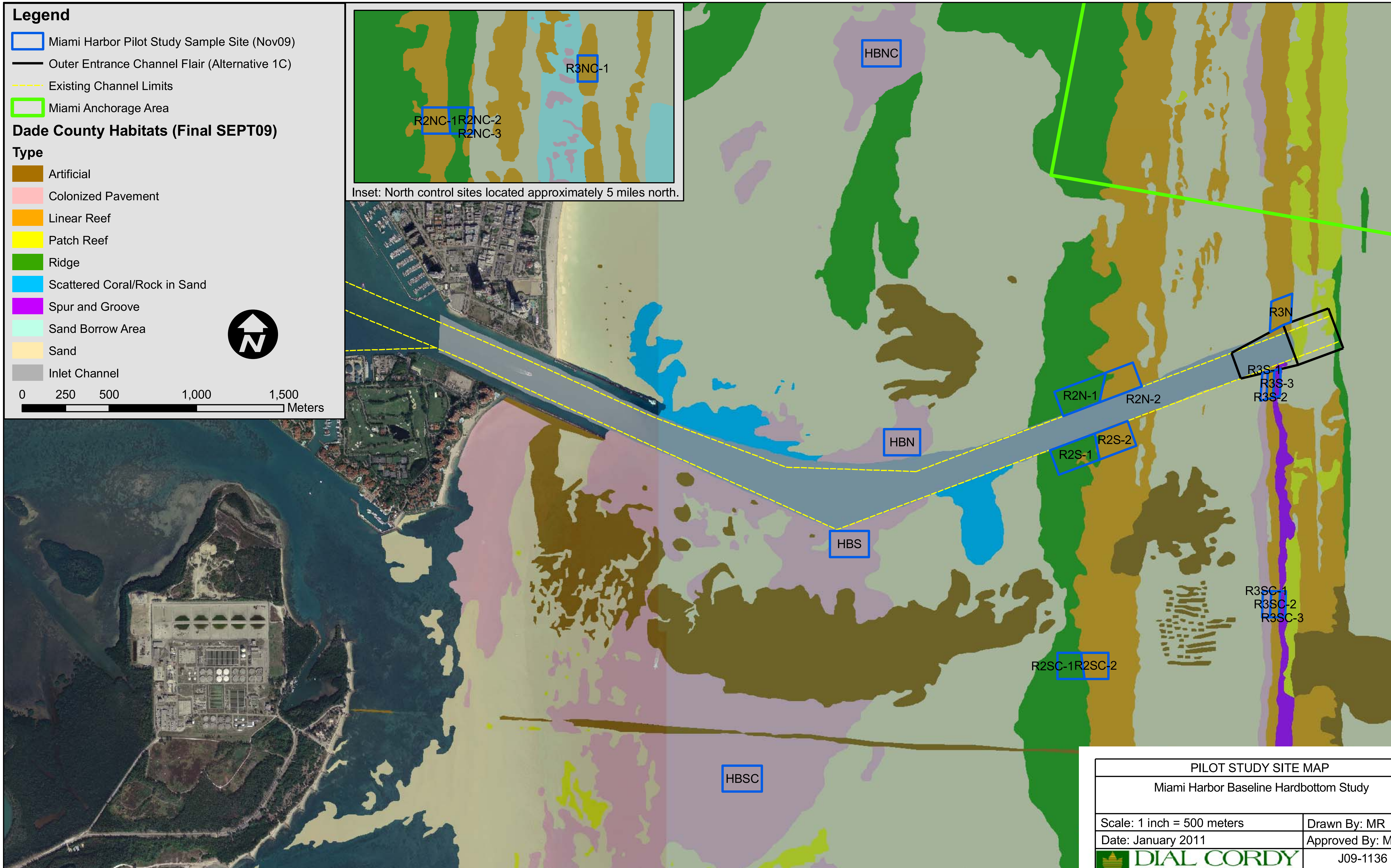
In situ and videographic benthic community data were collected to ascertain sample size adequacy and a sampling design for the full quantitative reef assessment. The Pilot Study included initial mapping of the reef community zones: (1) adjacent to the channel on the second reef tract (middle reef), (2) adjacent to the channel on the third reef (outer reef), (3) adjacent to the channel inshore of the first reef where nearshore hardbottom occurs, and (4) at control sites for the hardbottom, second, and third reefs located at least 0.8 km (0.5 miles) north and south of the Federal Channel.

Habitat types within reefs (hardbottom, second, and third) were delineated based upon the classification of Walker (2009), using a combination of geomorphological and biological features. Similar methods were used in previous studies to characterize reefs off Broward and Palm Beach counties (Walker et al. 2008). To determine a representative sample sizes for each habitat type, sampling was performed to assess the variances associated with the parameters to be evaluated in the quantitative assessment (e.g., coral colony density and species richness). These variances were used in power analyses to determine the optimal sample sizes required to be able to answer the study questions.

> <u>What are the pre-disturbance population levels of benthic organisms along a distance gradient (450 m north and up to 1000 m south) from the Miami Harbor entrance channel on the second and third reefs?</u>
>
> <u>What are the pre-disturbance population levels of benthic organisms in indirect-effect areas of nearshore hardbottom habitat and associated reference sites?</u>
>
> <u>What are the pre-disturbance biological characteristics of the benthic populations on Reef 3 within the direct-effect area?</u>

1.2.2 Pilot Study Site Selection

Sites were selected to determine the appropriate sample size (amount of area) characterizing the pre- and post-construction population levels of benthic organisms in indirect-effect and reference sites. Twenty sites were chosen: ten indirect-effect (“treatment”) sites along the north and south edges of the channel and ten unaffected reference (“control”) sites paired with the treatment sites. The control sites were located at least 0.8 km (0.5 miles) north and south of the indirect-effect sites, far enough away to prevent confounding effects from background channel turbidity, sedimentation, and anchorage influences (Figure 2). Ten randomly directed transects were selected to sample within each site.



PILOT STUDY SITE MAP	
Miami Harbor Baseline Hardbottom Study	
Scale: 1 inch = 500 meters	Drawn By: MR
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	Figure 2

In situ data were collected along a 1-m wide swath of each 10-m transect, for a total of 100 m^2 of *in situ* data per site. For more details on site selection for the Pilot Study, see Dial Cordy and Associates (2010).

1.2.3 Pilot Study Transect Sampling Methodology

Along each transect, both in situ and videographic methods were employed to collect taxonomic richness and cover data. *In situ* data collected for the Pilot Study included species richness of scleractinian corals and generic richness of octocorals within 10 transects, or 100 m^2 per site. Since these habitat types are dominated by octocorals, it was considered important to include them as a parameter in the Pilot Study. Species- and genus-richness curves were created from these data.

Videographic data were collected along a 40-centimeter (cm) swath of each transect for a total of 40 m^2 per site. The underwater video camera was positioned perpendicular to the bottom and 40 cm above the benthos using a scale bar, which was visible in the video. The diver swam at approximately 2–3 m per minute to ensure good-quality still captures from the videos for analysis. Percent cover data for scleractinians species, octocorals to the lowest possible taxonomic level, sponges, sand, rubble, macroalgae, algal turf, and other benthic components were analyzed using CPCe® (Kohler and Gill 2006). The number of scleractinian coral colonies and the number of octocoral holdfasts were also analyzed for a selection of sites.

1.2.4 Pilot Study Statistical Analysis

The primary goals of the analysis were to estimate differences among treatments and test their significance using an ANOVA-based approach, and to use the variability within samples to estimate minimum detectable differences. The minimum detectable differences are indicators of the prospects for detecting significant differences in a full study of comparable design at the conventional type I and type II error rates of 5% and 20%, respectively. Prior to ANOVA, the data were tested for conformity to the assumptions of parametric statistics and transformed as necessary.

1.2.5 Pilot Study Results

Indirect-effect sites and reference sites sampled during the Pilot Study were similar to other reef areas in southeastern Florida that have been characterized by Gilliam (2007), Moyer et al. (2003), and others. In general, these areas are dominated by macroalgae (45–82% cover across sites), with lower cover of other biological groups, including corals (scleractinians and *Millepora*; 0.05–4.62% cover), sponges (0.54–6% cover), and octocorals (1 to 15% cover). The rubble, sand, and pavement group (4–71% cover) was the second most dominant cover type after macroalgae.

1.2.6 Statistical Results

Living hard-coral cover was <5% in all cases. Few significant or marginally non-significant differences were detected. In the majority of cases, the minimum detectable difference calculated from the error variances obtained in the ANOVA was larger than the differences between group means, explaining the preponderance of non-significant results. The minimum detectable differences, δ, were greater than the corresponding group means in all four cases tested (macroalgae, octocorals, corals, and sponges), suggesting that a drop from current values to zero would not be detectable with statistical significance (Dial Cordy and Associates 2010).

The sample sizes required to detect a 5% change in macroalgal cover at $P = 0.05$ with a power of 0.80 ranged from 275–450 transects per site. Octocoral variances were also high. The sample sizes required to detect a 5% change at $P = 0.05$ with a power of 0.80 for octocorals would start at 2,200 transects per site. These results showed that an ANOVA approach is not practical for sampling in this variable and patchy environment.

1.2.7 Conclusions of Pilot Study Statistical Analysis and Recommendations for Quantitative Study Plan

Due to the low cover and high patchiness of hard corals and octocorals at the Pilot Study sites, a regression-based approach on the second and third reefs, beginning adjacent to the channel, was recommended for the Quantitative Study Plan. For nearshore hardbottom communities west of the second reef, a stratified random approach was recommended, based upon octocoral and scleractinian colony density within treatment and control sites identified during the Pilot Study. It was also recommended that all areas be sampled using colony counts rather than estimates of cover, due to the low cover of benthic organisms.

By following this recommended design, post-construction surveys conducted after the dredging operation will allow comparison with the pre-dredging data. Effects of the dredging operation on the second and third reefs, should they occur, would be detectable as a significant difference between the pre- and post-dredging states in the relationship between distance from the channel and the magnitude of change. Effects on hardbottom sites would be detectable as significant interaction terms of ANOVA between time (before *versus* after dredging) and treatment (indirect-effect *versus* reference).

2.0 METHODS

2.1 Quantitative Study Benthic Sampling

Based on the results of the Pilot Study, the baseline quantitative study protocol was designed to assess benthic populations at nearshore hardbottom, second, and third reef sites in the vicinity of the Port of Miami entrance channel (Figure 3). The abundance and density of octocoral and scleractinian colonies were assessed within nearshore hardbottom sites. The abundance, size, density and colony condition of reef benthic populations, including scleractinians, octocorals and sponges, were assessed at indirect-effect sites at the second and third reefs, and at third reef direct-effect areas. These surveys provide baseline data for pre-construction conditions of benthic reef invertebrates at hardbottom, second and third reef sites adjacent to the Port of Miami entrance channel. The indirect-effect area in this study is further from the channel than the area deemed the "indirect-effect area" which, under NEPA, the Corps is responsible for monitoring, during and after construction. The larger indirect-effect baseline survey area satisfies agency comments and requests.

Hardbottom areas west of the second reef were assessed using an ANOVA approach. Benthic populations on the second and third reef within the indirect-effect areas were sampled using a regression-based approach. Sampling methods were designed to detect changes in organism abundance, density, and colony condition (for scleractinians) when compared to post-construction surveys using the same methods.

2.1.1 Nearshore Hardbottom Site Selection

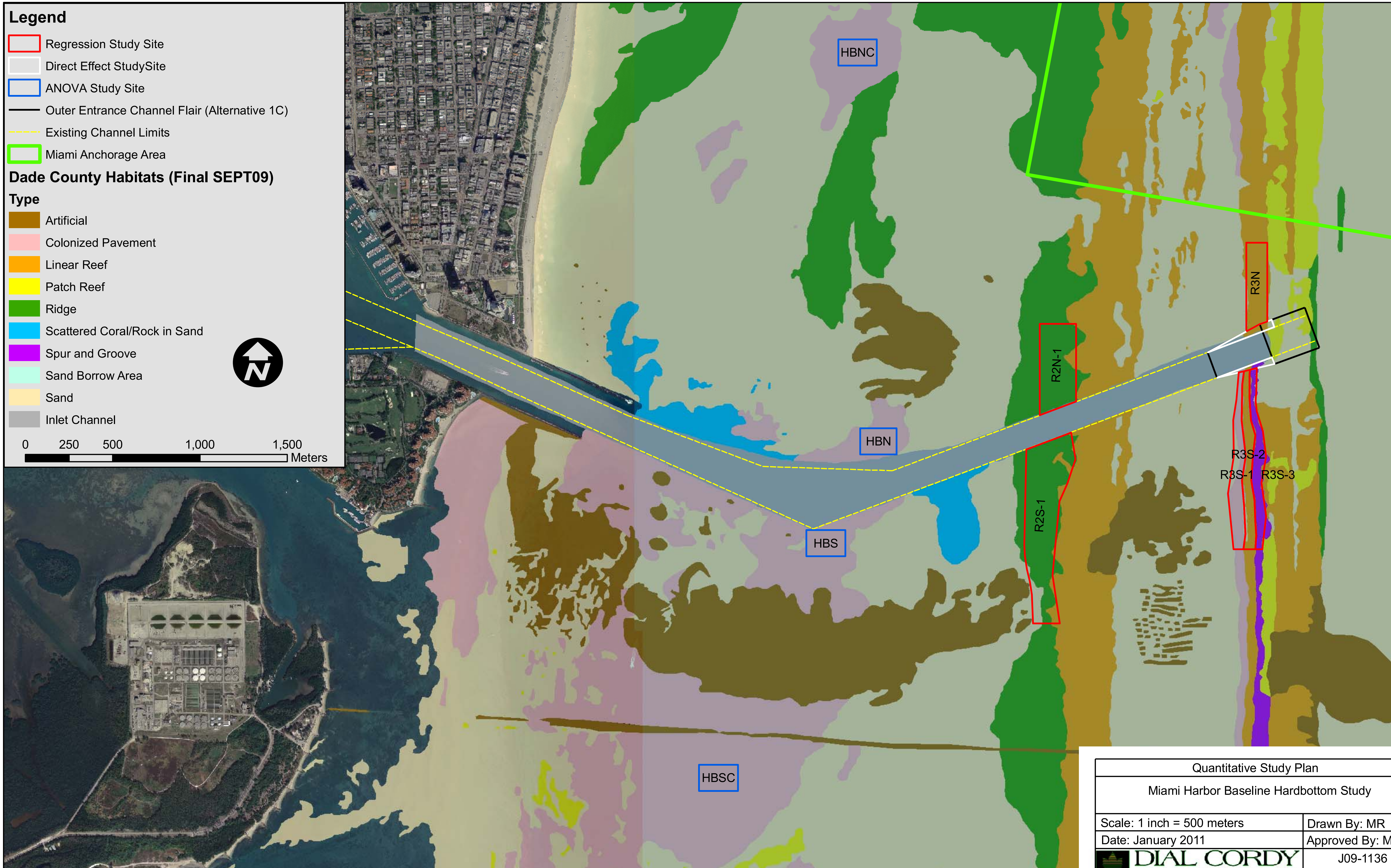
Nearshore hardbottom areas to the west of the second reef lie adjacent to the existing channel (treatment sites), and discontinuous areas of hardbottom (control sites) lie to the north and south of these areas (Figure 3a). Four sites, hardbottom north (HBN), hardbottom north control (HBNC), hardbottom south (HBS), and hardbottom south control (HBSC) were surveyed within the nearshore hardbottom habitat west of the second reef (Figure 3a).

2.1.1.1 Transect Placement

Within a hardbottom site, four 20 x 20 m blocks were randomly established in ArcView GIS to provide four block-center locations that were greater than 20m from the hardbottom site edge and greater than 40 m from any other block-center location. From each block center, a 20 x 20 m (400-m^2) square was created. For each 20x20 block, six transect-start locations were randomly established using ArcView GIS, with each start location being greater than 2 m from the block edge and greater than 3 m from any other transect-start location. From these random start locations, 10-m transects were placed using random bearings that did not allow any portion of a transect to be closer than 2 m from any other transect and did not allow a transect to cross another transect (Figure 3b).

2.1.1.2 Sampling Methods

In situ data collected along transects included the abundance of benthic octocorals and scleractinians. Specifically, the following information was documented along each 10 x 1 m transect: (1) species-specific scleractinian colony counts; and (2) genus-specific octocoral colony counts. Video transect data for all transects (10 x 0.4 m per transect) were collected for archival purposes. A total of 24 transects, or 240 m^2, were sampled per site.



Quantitative Study Plan

Miami Harbor Baseline Hardbottom Study

Scale: 1 inch = 500 meters	Drawn By: MR
Date: January 2011	Approved By: MLR
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	Figure 3a

Legend
Nearshore Hardbottom Transect Line
INTERVAL
TRANSECT
Nearshore Hardbottom Transect Start
ORIGIN
START
END
Random Survey Block (20x20 meters)
Miami Pilot Study Sample Site
Existing Channel Limits
Dade County Habitats (Final SEPT09)
Type
Artificial
Colonized Pavement
Linear Reef
Patch Reef
Ridge
Scattered Coral/Rock in Sand
Spur and Groove
Sand Borrow Area
Sand
Inlet Channel
0 50 100 200 300
Meters
N
HBNC
North control sites located approximately 2.2 km north.
HBN
HBS
HBSC
South control sites located approximately 1.5 km south.
Nearshore Hardbottom Sites
Miami Harbor Baseline Hardbottom Study
Scale: 1 inch = 100 meters
Drawn By: MR
Date: January 2011
Approved By: MLR
DIAL CORDY AND ASSOCIATES INC
Environmental Consultants
J09-1136
Figure 3b

2.1.1.3 Statistical Analysis

The four nearshore hardbottom sites—HBN, HBNC, HBS, and HBSC—were compared using a one-way analysis of variance (ANOVA). Because sites were unreplicated within treatments, a one-way design was used, in which the sites were groups and blocks were nested within sites. Four randomly placed blocks were established within each site, and six transects were sampled randomly within each block (Table 1). The data were tested for the assumptions of parametric statistics using the Anderson–Darling test for normality and Levene's test for homogeneity of variances (Levene's test is used for non-normal data). Data were transformed as necessary.

Table 1. Nested ANOVA design for transect placement within nearshore hardbottom habitat sites

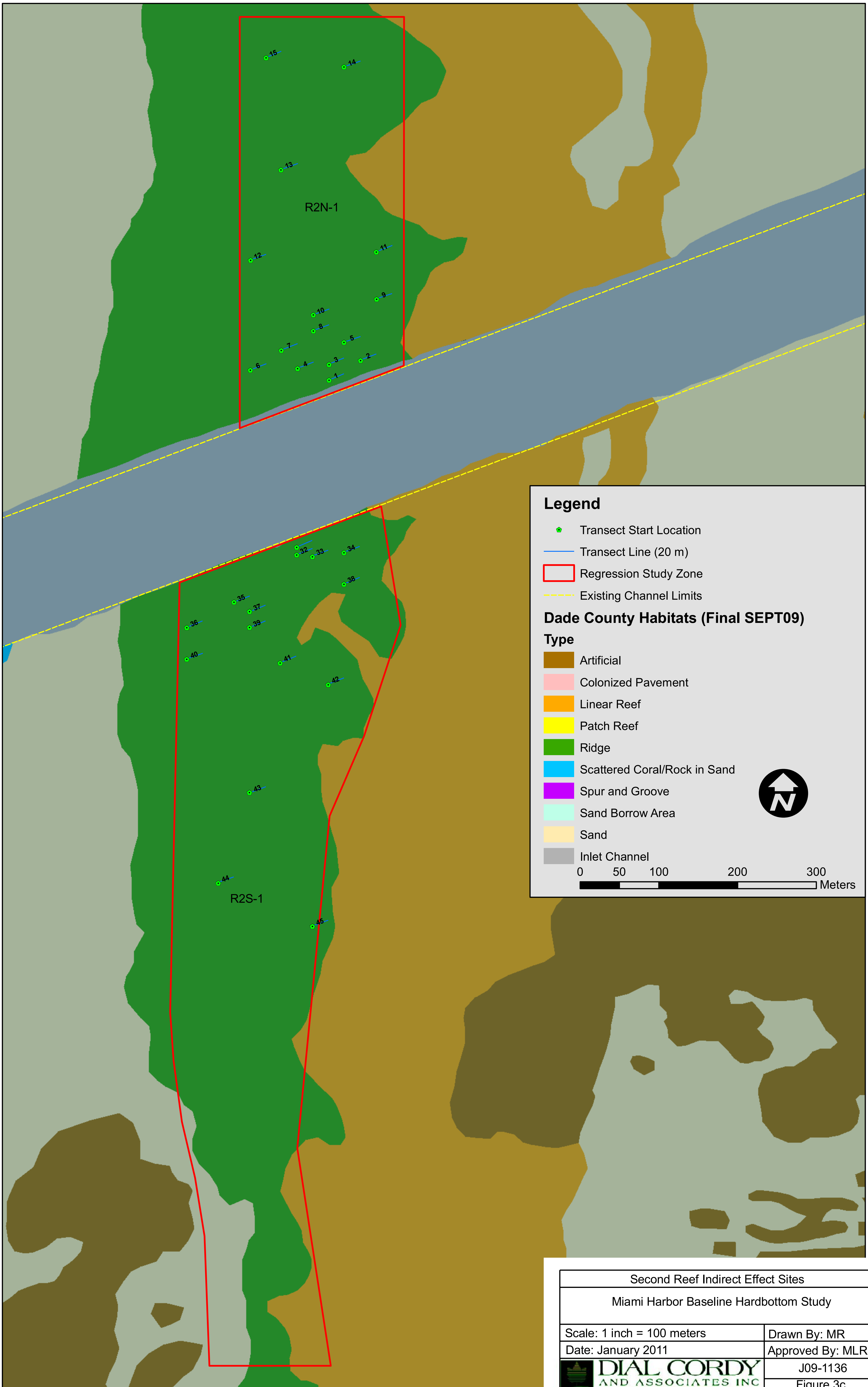
Sites	HBN	HBNC	HBS	HBSC
Blocks per Site	4	4	4	4
Transects per block	6	6	6	6
Transects per site	24	24	24	24

2.1.2 Indirect-Effect Site Selection

Areas of hardbottom habitat on the second and third reefs adjacent to the entrance channel, but not within the dredging footprint, were selected as indirect-effect sampling sites. Six sites on the second and third reefs were chosen based on habitat types described in Walker et al. (2009). Sampling originated 10 m from the channel-edge and progressed in both directions perpendicular to the channel, with transects oriented east-west (Figure 3c, 3d, Table 2). Transects were placed at regular intervals at all six sites. Transects were 10 m in length and *in situ* data were collected within a meter swath of the transect line, for a total of 10 m^2 per transect and 150 m^2 per site. Video transect data were collected along a 0.4 m swath, for a total of 4 m^2 per transect and 60 m^2 per site. Video transects were collected for archival purposes and not analyzed in this study. Video and *in situ* transect data were obtained at regular intervals to the north and south within the second and third reef sites (15 transects per site; Table 2).

2.1.2.1 Sampling Methods

In situ data collected along transects (10 x 1 m) included the composition, density, size, and condition of benthic invertebrate organisms. Specifically, the following information was documented along each transect: 1) scleractinian colonies, identified to species (maximum diameter measured in cm); 2) octocoral colonies, identified to genus (maximum diameter or height measured in cm, for upright colonies the maximum height would be measured and for flat or encrusting colonies, the maximum diameter would be measured); 3) sponge morphotypes (maximum diameter or height measured in cm); 4) zoanthids (maximum diameter measured in cm); and 5) macroalgae identified to the lowest taxonomic level. Occurrences of sea urchins, including *Diadema antillarum*, were recorded by transect. Rugosity data were collected along each transect, and calculated as (1–d/l), where d = the geometric distance of a transect measured using a weighted line and l = the length of the transect. The Florida Resilience Relief Program (FRRP) bleaching assessment protocol was used to characterize scleractinian colony condition. Disease data were collected using accepted guidelines (Bruckner 2001). Video-transect data for all transects were collected for archival purposes, as discussed above.



Second Reef Indirect Effect Sites	
Miami Harbor Baseline Hardbottom Study	
Scale: 1 inch = 100 meters	Drawn By: MR
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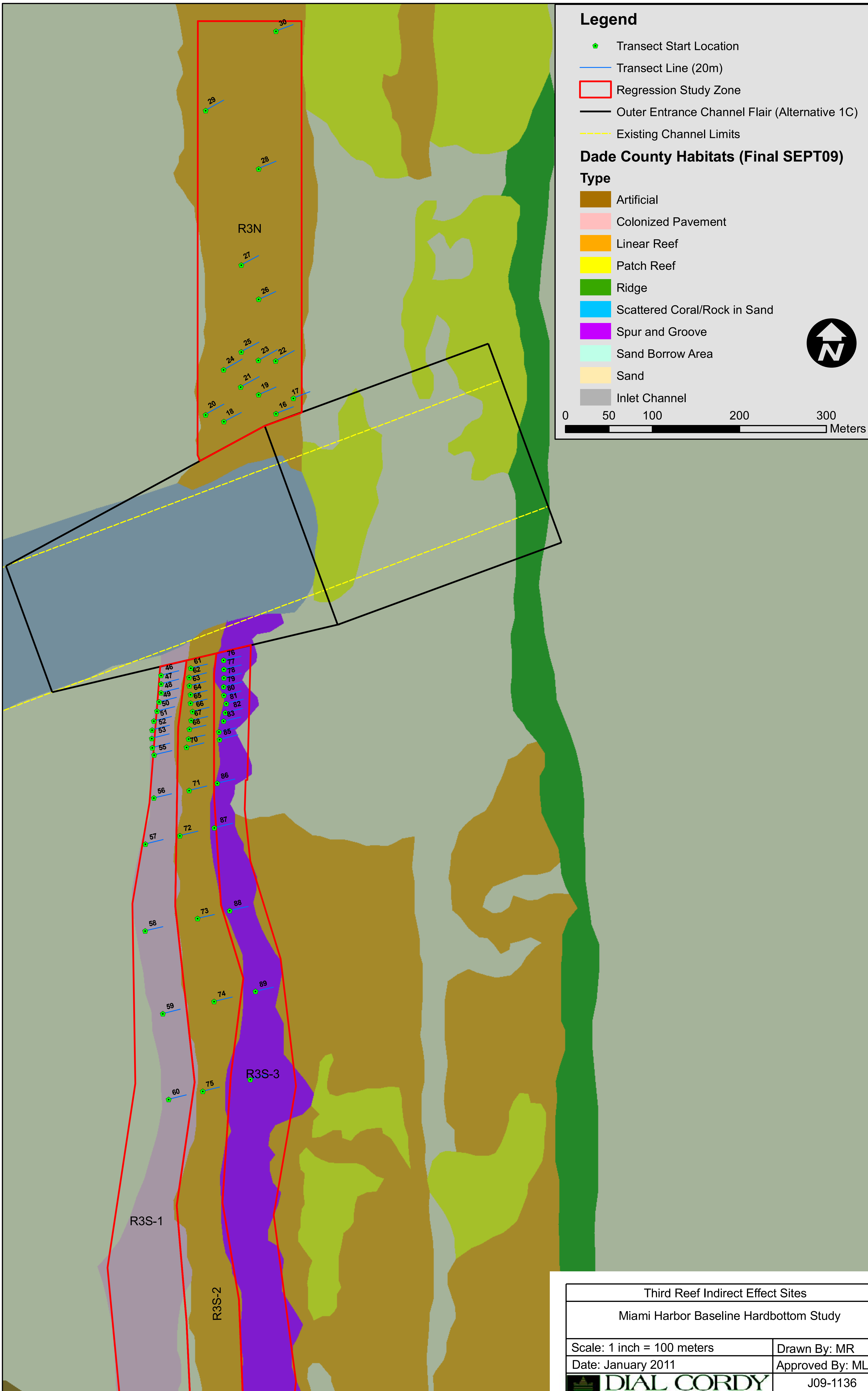
	Figure 3c



Third Reef Indirect Effect Sites	
Miami Harbor Baseline Hardbottom Study	
Scale: 1 inch = 100 meters	Drawn By: MR
Date: January 2011	Approved By: MLR
DIAL CORDY AND ASSOCIATES INC Environmental Consultants	J09-1136
	Figure 3d

Table 2. Transect distance from the channel at second and third reef sites.

Distance from channel (m)	Site					
	R2N	R2S	R3N	R3S-1	R3S-2	R3S-3
10	●	●	●	●	●	●
20	●	●	●	●	●	●
30	●	●	●	●	●	●
40	●	●	●	●	●	●
50	●	●	●	●	●	●
60	●	●	●	●	●	●
70	●	●	●	●	●	●
80	●	●	●	●	●	●
90	●	●	●	●	●	●
100	●	●	●	●	●	●
150	●	●	●	●	●	●
200	●	●	●	●	●	●
300	●	●	●	●	●	●
400	●	●	●	●	●	●
450	●		●			
500		●		●	●	●

2.1.2.2 Statistical Analysis

Regression analyses were performed to explore the relationships between distance from the channel and the mean number of colonies per square meter for the following categories: hard corals, octocorals, and sponges. Linear regressions were tested using six models, and the best-fit model is reported. The models tested are as follows, with *x* representing distance from the channel (the independent variable) and *y* representing the response (dependent) variable.

- linear model: $y = b_0 + b_1x$
- exponential model: $\log(y) = b_0 + b_1x$
- logarithmic model: $y = b_0 + b_1\log(x)$
- power model: $\log(y) = b_0 + b_1\log(x)$
- reciprocal model: $y^{-1} = b_0 + b_1x$
- quadratic model: $y^{0.5} = b_0 + b_1x$

The best-fit relationships are reported. Significance of the slope of the best-fit line was assessed initially at $\alpha = 0.05$. A second assessment of significance was carried out using the Bonferroni adjustment of $\alpha_{adj} = 0.0028$ to preserve an experiment-wise error rate of 0.05 over the 18 regressions calculated in the set. The response variables were normally distributed in all best-fit models, with normality tested using the Anderson–Darling method ($P > 0.05$ in all cases).

2.1.3 Direct-Effect Site Selection

Direct-effect areas lie along the north and south edges of the existing channel on the outermost reef (Figure 3e). The northern direct-effect site (R3DN) is approximately 11,000 m^2, whereas the south site, R3DS, is 7,000 m^2. In order to determine the pre-disturbance biological characteristics of the benthic populations within R3DN and R3DS, fifteen 20 x 1 m transects were surveyed, for a total area of 300 m^2 surveyed in each site.

Transect origins were randomly located within the direct-effect sites no closer than 5 m from another origin and no closer than 1 m from the edge of a site, using ArcView GIS. A random bearing was selected from a range of random bearings for each transect individually so that no transect was overlapping and so that no transect went beyond the boundaries of a site.

2.1.3.1 Sampling Methods

In situ data collected along transects (20 x 1 m) included the composition, density, size, and condition of benthic invertebrate organisms. Specifically, the following information was documented along each transect: (1) scleractinian colonies, identified to species (with maximum diameter measured in cm); (2) octocoral colonies, identified to genus (with maximum diameter or height measured in cm; for upright colonies the maximum height was measured, and for flat or encrusting colonies the maximum diameter was measured); (3) sponge morphotypes (with maximum diameter or height measured in cm); (4) zoanthids (with maximum diameter measured in cm); and (5) macroalgae, identified to the lowest taxonomic level.Occurrences of sea urchins, including *Diadema antillarum*, were recorded by transect. Rugosity data were collected along each transect, and calculated as (1–d/l), where d = the geometric distance of a transect measured using a weighted line and l = the length of the transect. The Florida Reslience Relief Program (FRRP) bleaching assessment protocol was used to characterize scleractinian colony condition. Disease data were collected using accepted guidelines (Bruckner 2001). Video data for all transects (20 x 0.4 m per transect) were collected for archival purposes. Fifteen transects were sampled at each site for a total of 300 m^2 per site.

2.1.3.2 Statistical Analysis

Descriptive statistics on the abundance, density, size, and condition of scleractinians, octocorals, and sponges were calculated for direct-effect sites R3DN and R3DS.

Third Reef Direct Effect Sites	
Miami Harbor Baseline Hardbottom Study	
Scale: 1 inch = 50 meters	Drawn By: MR
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	Figure 3e

3.0 RESULTS

3.1 Quantitative Benthic Sampling

Quantitative Study results are presented for nearshore hardbottom, second and third reef indirect-effect sites and third reef direct-effect sites. Parametric and non-parametric statistics were used to analyze the abundance, density, and size-class distribution of scleracitnians, octocorals, and sponges. Additionally, the condition of scleractinians was analyzed for second and third reef sites. See Sections 2.1.1.3 and 2.1.2.2 for more details. Raw data are presented in table form in Appendix A.

All sampling was conducted in areas of hardbottom habitat in 6–15 m (21–50 feet) of water. Hard substrate was typically interspersed with small sand pockets (Table 3). Artificial substrates were rare and low in cover and included metallic cables, fishing line and weights, wood, rope, iron angle, and other metallic objects (Table 3). Maximum vertical relief at nearshore hardbottom sites was 70 cm (Table 3). Second and third reef indirect-effect sites had little rugosity, whereas higher relief was documented at direct-effect sites, directly adjacent to the channel on the third reef (Table 3). Direct-effect sites were the only sites that included boulders, rocks and rubble. Sedimentation was documented at all sites but R3N and coincided with an outgoing tide. Photographs representative of the biological benthic communities at each site are presented in Appendix B.

Sample Size Adequacy

The emphasis of the Quantitative Study was to quantify the scleractinian and octocoral populations. Scleractinian species richness and species diversity were assessed using colony counts. Previous studies of the second and third reefs in Miami–Dade and Broward County used 30 m^2 as an adequate sample size to document scleractinian species richness, density, and percent cover (Gilliam et al. 2004). The optimal amount of sampling area was attained when the cumulative number of scleractinian species reached its asymptote on a species-area rarefaction curve.

For nearshore hardbottom sites, as few as 9 or as many as 18 transects were needed to create rarefaction curves that leveled off (Figure 4). Fewer transects were needed to adequately sample the diversity of octocoral genera, which are the dominant sessile invertebrates of these hardbottom areas (Figure 5). Within second and third reef sites, 4–13 transects were necessary to adequately sample the diversity of scleractinian species, whereas 3–11 transects were adequate for octocorals (Figure 6 and 7).

3.2.2 Neashore Hardbottom Sites

Nearshore hardbottom sites included treatment sites HBN, HBS and control sites HBNC, and HBSC. Four blocks were sampled within each site, and 6 transects were surveyed within each block, for a total of 24 transects covering 240 m^2 within a single site. Data on scleractinian abundance by species and octocoral abundance by genus were collected from all transects.

Nearshore hardbottom sites were topographically low in relief, generally less than 10 cm and never greater than 70 cm. Rubble was present at two sites, HBNC and HBS, but only occurred at 3 and 7 transects respectively. During data collection visibility was 10–20 feet (3–6 m) and field notes documented a veneer of fine sediment at all nearshore hardbottom sites. Qualitative assessment suggested there was more sediment present at the northern sites.

Table 3. Abiotic data for all sites.

	Sites											
Characteristics	**HBN**	**HBNC**	**HBS**	**HBSC**	**R2N**	**R2S**	**R3N**	**R3S-1**	**R3S-2**	**R3S-3**	**R3DN**	**R3DS**
Hardbottom	•	•	•	•	•	•	•	•	•	•	•	•
Boulders											•	•
Rocks					•	•		•		•	•	•
Rubble		•	•					•			•	•
Shell Hash							•					
Sand	•	•	•	•	•		•	•	•	•	•	•
Artificial substrate								•		•		
Sedimentation	•	•	•	•	•	•		•	•	•	•	•
Rugosity (1-d/l)	NA	NA	NA	NA	0.05	0.05	0.06	0.07	0.07	0.06	0.11	0.11
Maximum Relief (cm)	30	20	No data	70	NA	NA	NA	NA	NA	NA	NA	NA
Depth Range (m)	7–9	8–9	7–9	6–7	8–9	6–9	12–14	11–12	10–11	10-12	12–14	12–15

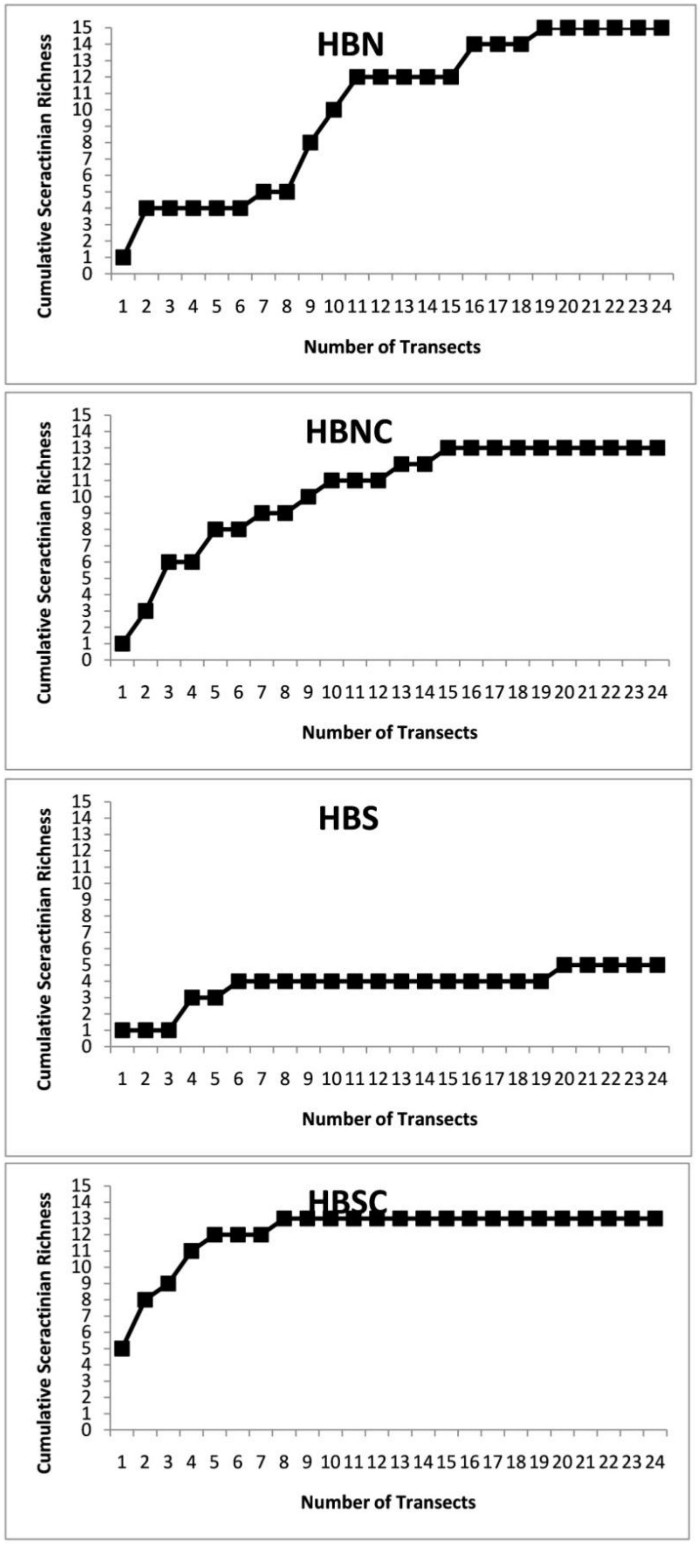

Figure 4 Scleractinian species rarefaction curves for all nearshore hardbottom sites.

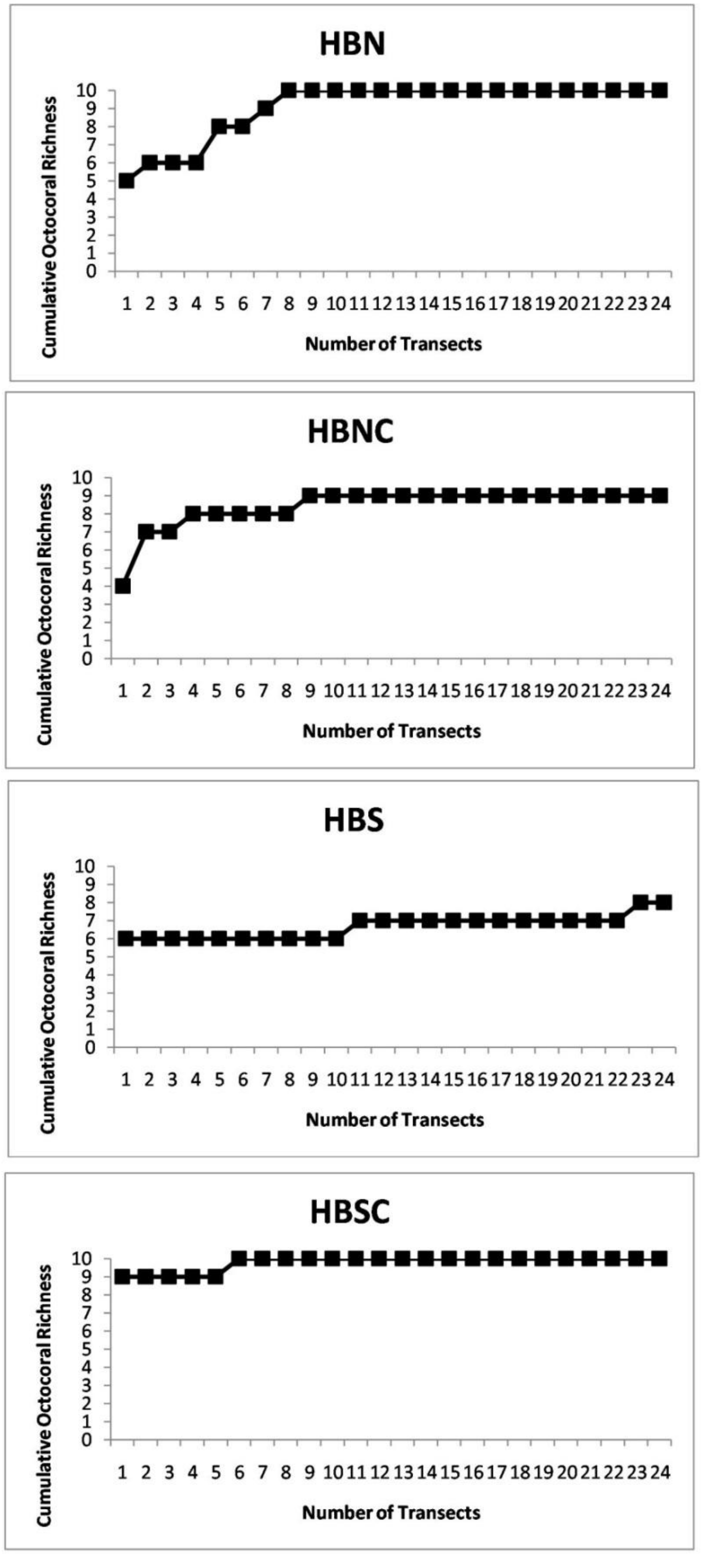

Figure 5 Octocoral genera rarefaction curves for all nearshore hardbottom sites.

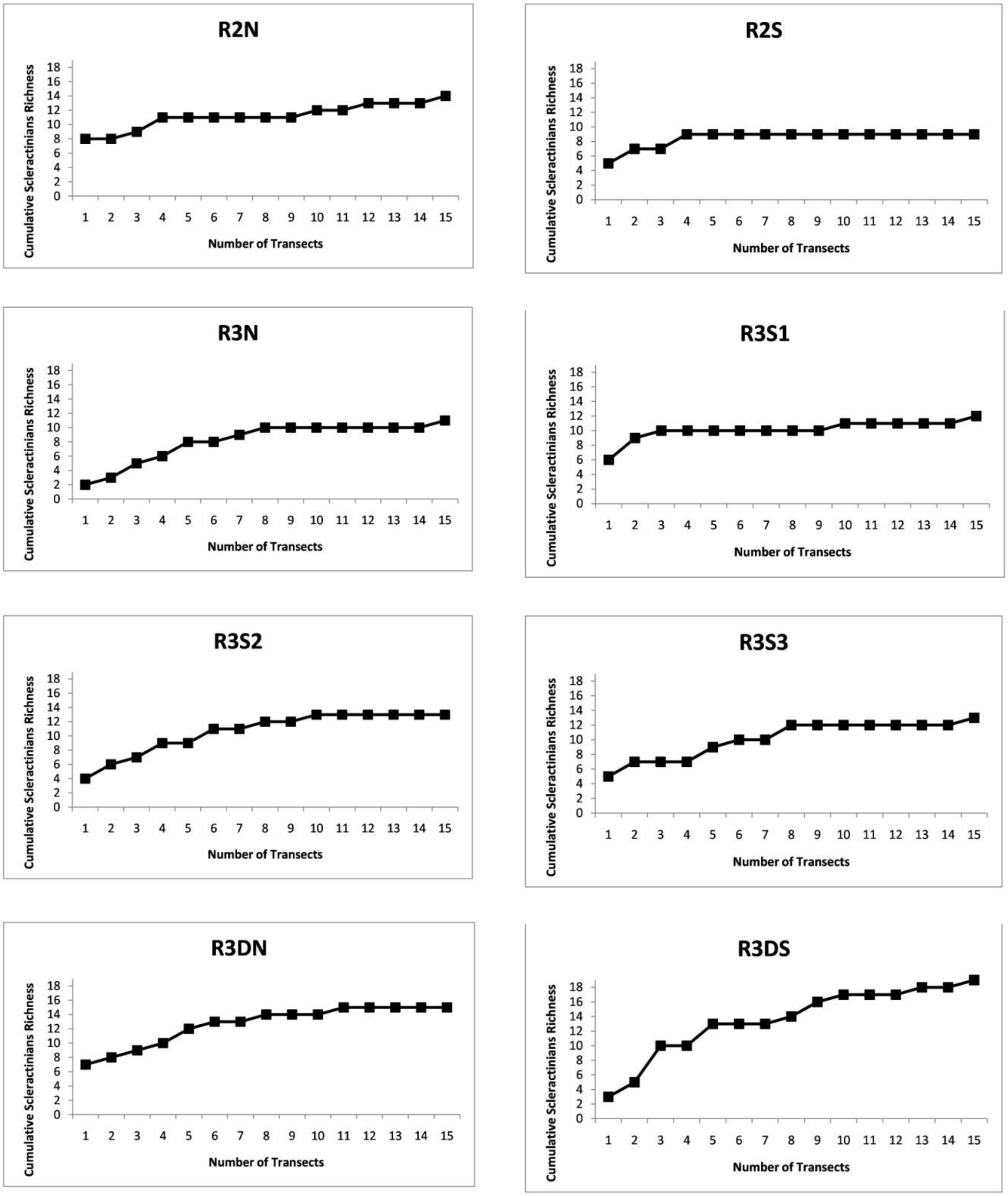

Figure 6 Scleractinian species rarefaction curves for all second and third reef sites.

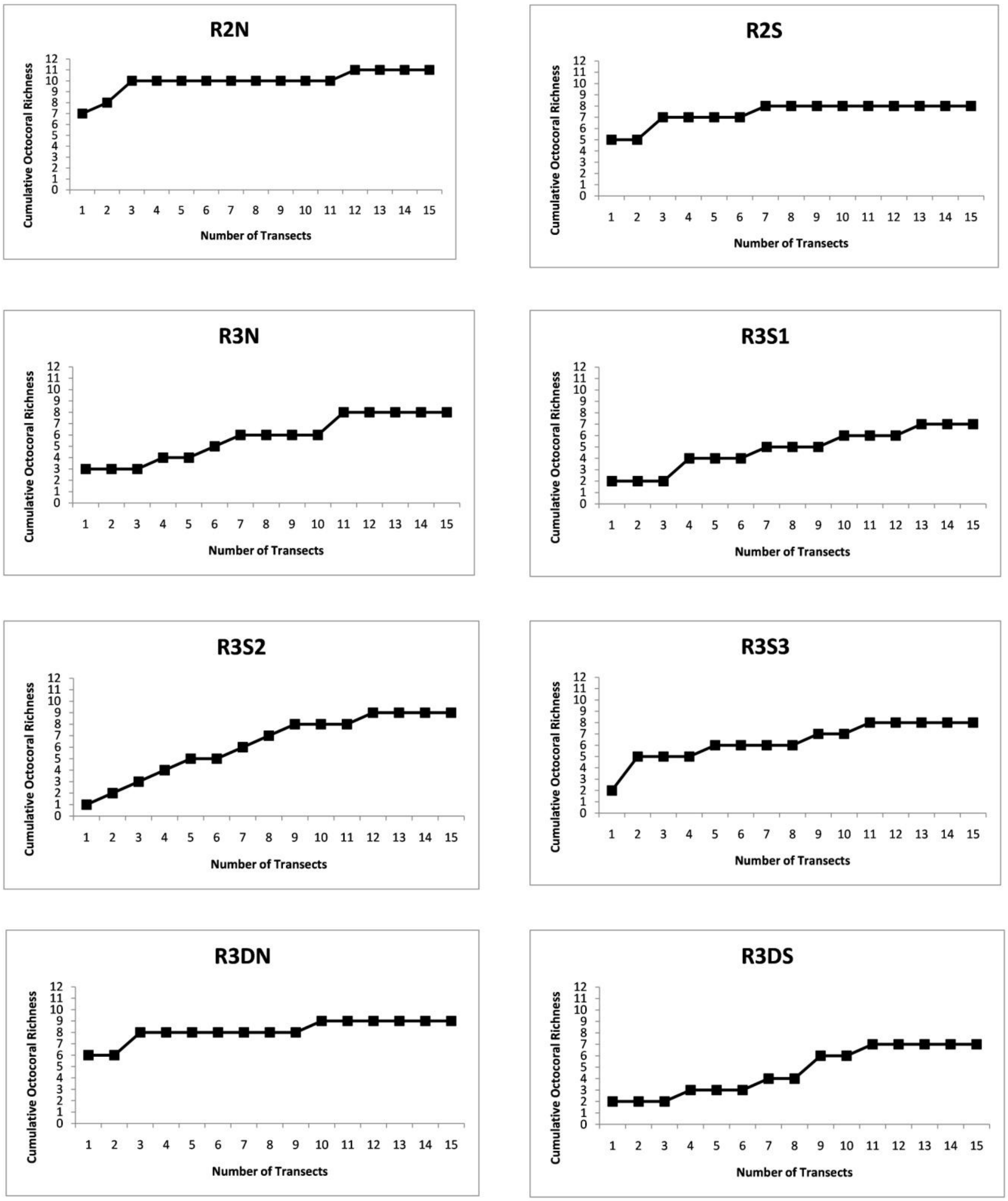

Figure 7 Octocoral genera rarefaction curves for all second and third reef sites.

Scleractinian Species Richness

Eighteen scleractinian coral species were documented across all nearshore hardbottom sites (Table 4). Three sites (HBN, HBNC and HBSC) included 11–14 species, whereas HBS contained 5 species (Table 4). Abundance ranged from 46–549 colonies across nearshore hardbottom sites (Table 5).

Table 4. Scleractinian species present at each nearshore hardbottom sites.

Scleractinian Species	HBN	HBNC	HBS	HBSC
Agaricia agaricites	●			
Cladocora arbuscula		●		
Dichocoenia stokesii	●	●		●
Diploria clivosa				●
Diploria strigosa	●	●		●
Favia fragum	●			●
Madracis decactis	●			●
Meandrina meandrites				●
Montastraea cavernosa	●			●
Oculina diffusa	●	●	●	●
Porites astreoides	●	●	●	●
Porites porites	●	●		
Scolymia sp.	●	●		
Siderastrea radians	●	●	●	●
Siderastrea siderea	●	●		●
Solenastrea bournoni	●	●	●	●
Solenastrea hyades		●		
Stephanocoenia intersepta	●	●	●	●

Table 5. Number of scleractinian colonies, species richness, and density of scleractinian colonies at nearshore hardbottom sites.

Site	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
HBN	252	14	1.1	0.5	24
HBNC	549	11	2.3	1.1	24
HBS	46	5	0.2	1.1	24
HBSC	253	13	1.1	0.6	24

A small proportion of scleractinian species made up the majoirty of scleractinian colonies at nearshore hardbottom sites. Across all sites, three species predominated: *Siderastrea radians, Stephanoecoenia intersepta* and *Solenastrea bournoni*. Four other species, *Porites astreoides*, *Oculina diffusa*, *Favia fragum* and *Dichocoenia stokesii*, contributed to the five most abundant species at one or more sites. The top-five scleractinians in abundance across all nearshore hardbottom sites are presented graphically. The five most abundant scleractinians at nearshore hardbottom sites constituted 82% of colonies documented at HBN, and 97% of colonies at HBNC (Figures 8). The five most abundant scleractinians made up 100% of those documented at HBS and over 62% of colonies documented at HBSC. *Siderastrea radians* was the dominant scleractinian coral at all nearshore hardbottom sites (Figure 9).

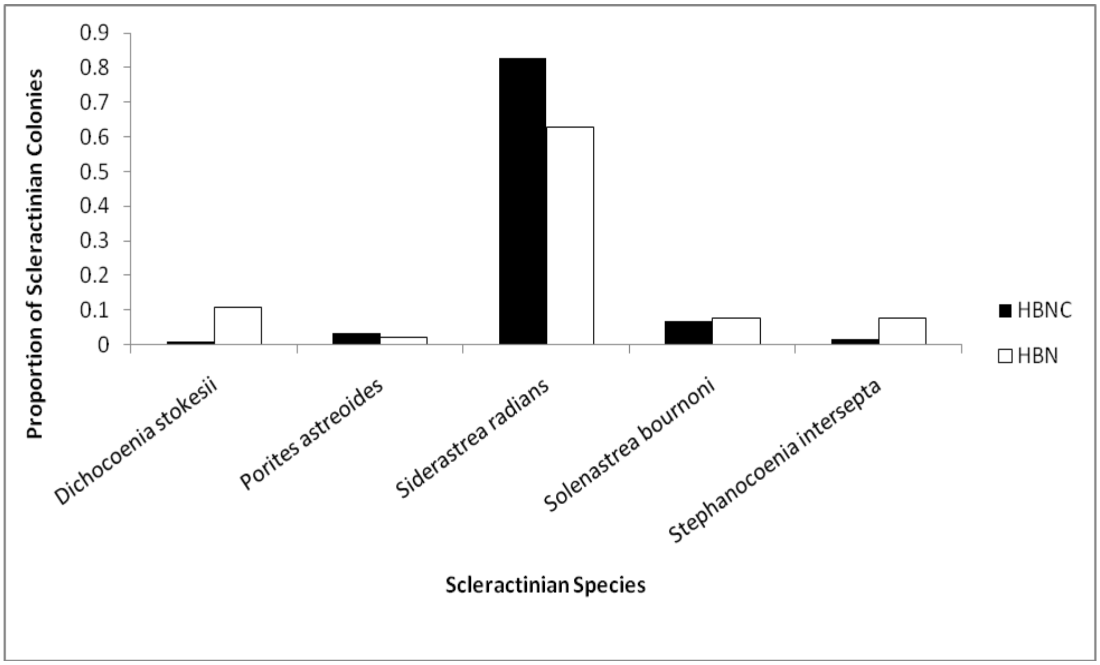

Figure 8 Proportional abundance of the five most abundant scleractinian corals at the northern nearshore hardbottom sites.

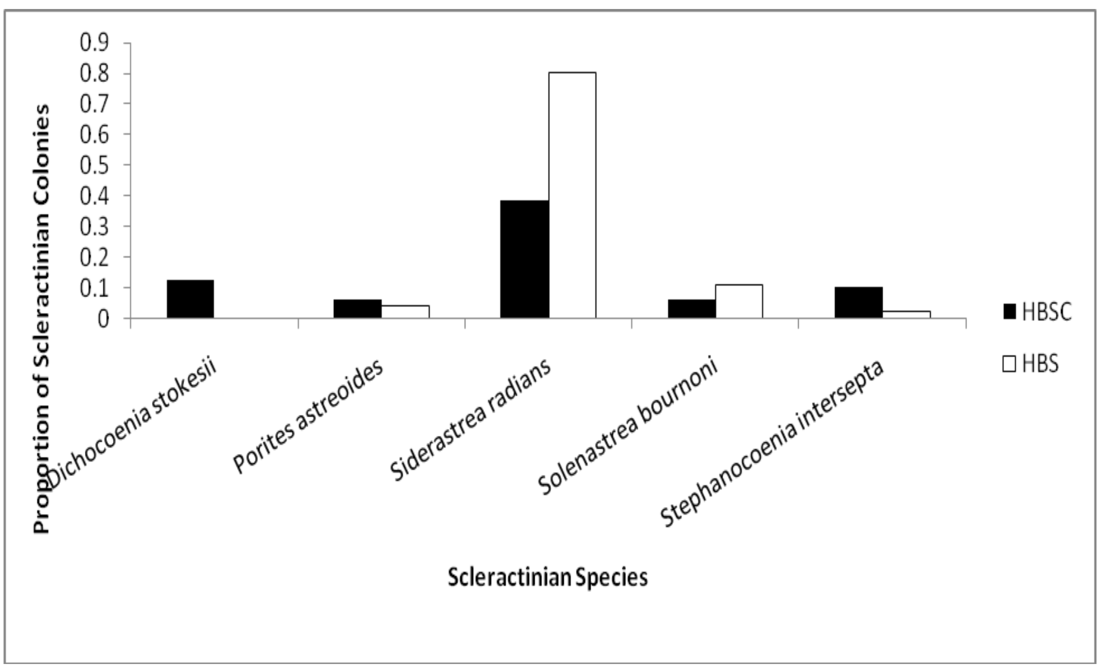

Figure 9 Proportional abundance of the five most abundant scleractinian corals at the southern nearshore hardbottom sites.

Scleractinian Species Diversity

The Shannon–Wiener diversity Index (H') was used to calculate species diversity. Diversity (H') values ranged from 0.7–2.1 across the four sites. HBNC and HBS diversity values were low when compared to HBN and HBSC (Table 6). Evenness (J') ranged from 0.3–0.8 across nearshore hardbottom sites and was lowest at HBNC and HBS (Table 6).

Table 6. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for scleractinian species at nearshore hardbottom sites.

Index	HBN	HBNC	HBS	HBSC
Diversity (H')	1.4	0.8	0.7	2.1
Evenness (J')	0.5	0.3	0.4	0.8

Scleractinian Density

Scleractinian density ranged from 0–4.4 individuals per square meter across all transects within hardbottom sites. Mean scleractinian density was lowest at HBS (0.2 ind/m^2) and highest at HBNC (2.3 ind/m^2) (Figure 10).

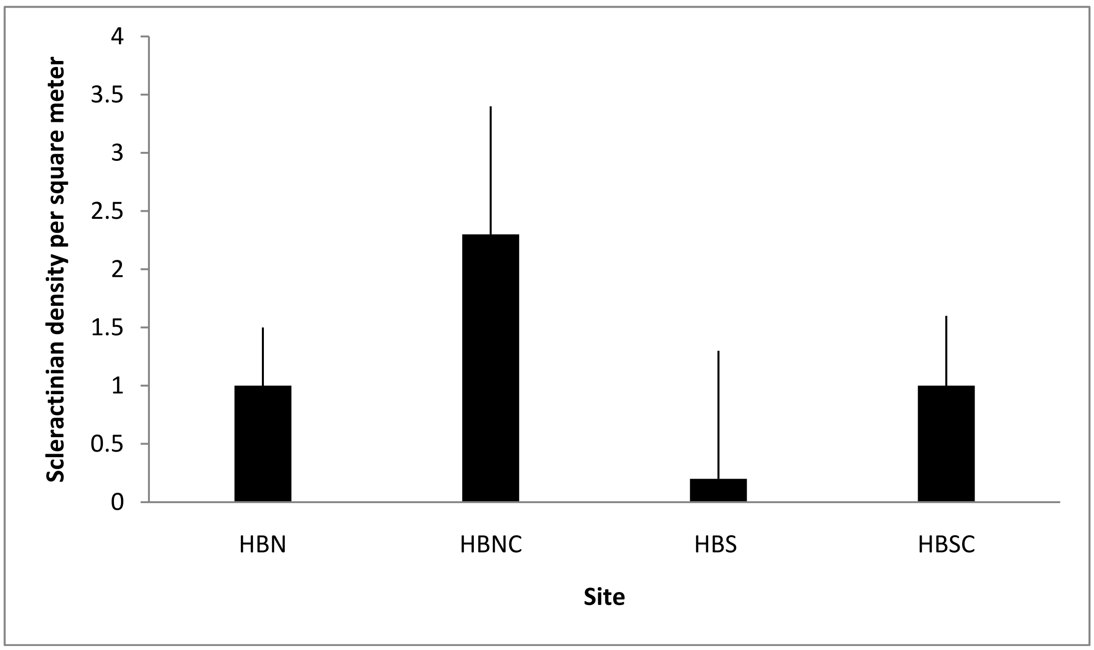

Figure 10 Mean density of scleractinian colonies at nearshore hardbottom sites. Error bars represent one SD.

Hard coral data, expressed as numbers of colonies per square meter, were generally non-normal within blocks (Anderson–Darling tests, $P < 0.05$ in most cases) and the variances were heterogeneous among blocks (Levene's test, $P < 0.001$). Homogeneity of variances was only achieved by: (1) transforming the data to [$1/y^2$]; and (2) eliminating the four blocks within the HBS site. The data from HBS were all close to zero (very few coral colonies), and this exerted a strong influence on the distribution of variances (Figure 10). These two procedures homogenized the variances (Levene's test, $P = 0.395$). Despite transformation, the data remained non-normal (Anderson–Darling tests, $P < 0.05$ in most cases). Because ANOVA is robust to violations of the normality assumption, the test was performed despite the normality problem. Significant effects of site and block nested within site were detected ($P < 0.001$ in both cases; Table 7). *A posteriori* pairwise comparisons were made by computing the ANOVAs pairwise between sites. These six comparisons (Bonferroni α_{adj} = 0.0083 for 6 tests) revealed that the density of colonies in HBS was significantly lower than at the other three sites ($P \leq 0.002$), and that the three other sites were not significantly different from each other ($P \geq 0.064$).

Table 7. ANOVA results (blocks nested within sites) testing the difference in scleractinian colony density

Source of variation	df	MS	*F*	*P*-value
Site	3	1.87	22.84	<0.001
Block(Site)	12	0.08	3.50	<0.001
Error	80	0.02		

Hydrocoral Density

Hydrocorals were represented by *Millepora alcicornis* at nearshore hardbottom sites. Density ranged from 0–1.3 colonies/m^2 across all transects within nearshore hardbottom sites. Density of *M. alcicornis* colonies was highest at HBNC (0.55) and lowest at HBS (0.01) (Figure 11).

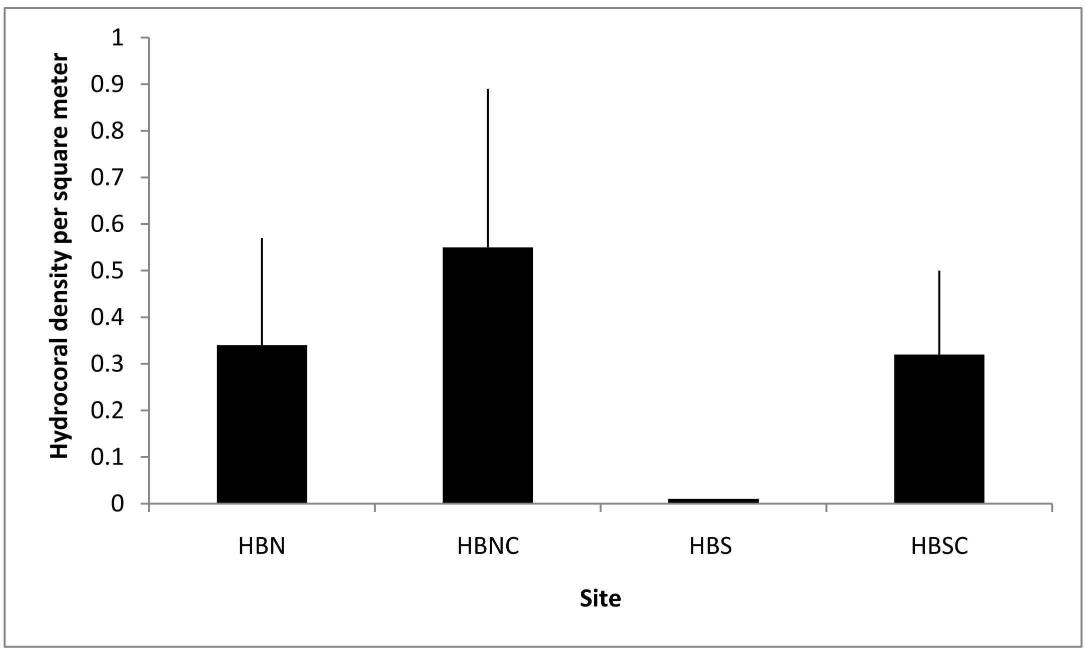

Figure 11 Mean density of the hydrocoral *Millepora alcicornis* at nearshore hardbottom sites. Error bars represent one SD.

Octocoral Generic Richness

Nearshore hardbottom sites included 8–10 octocoral genera (Table 8). HBN and HBSC had the highest number of genera, whereas HBS had the fewest (Table 9). Patterns of generic dominance varied across sites, except that *Eunicia* and *Pseudopterogorgia* were the predominant octocoral genera at across second and third reefs sites (Figures 12 and 13). *Briareum* and *Erythropodium* were absent at HBS, whereas *Gorgonia* were absent only at HBNC.

Table 8. List of octocoral genera present at each site.

Octocoral Genus	HBN	HBNC	HBS	HBSC
Briaerium	●	●		●
Erythropodium	●	●		●
Eunicea	●	●	●	●
Gorgonia	●		●	●
Muricea	●	●	●	●
Plexaura	●	●	●	●
Plexaurella	●	●	●	●
Pseudoplexaura	●	●	●	●
Pseudopterogorgia	●	●	●	●
Pterogorgia	●	●	●	●

Table 9. Number of octocoral colonies, species richness, and density of octocoral colonies by hardbottom area as encountered in visual belt transects off Miami, FL. (SD = standard deviation; *N* = number of belt transects)

Site	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
HBN	1572	10	6.6	2.3	24
HBNC	3346	9	13.9	6.0	24
HBS	418	8	1.7	1.4	24
HBSC	1945	10	8.1	2.4	24

Eunicia, *Muricea* and *Pseudopterogorgia* were the predominant octocoral genera nearshore hardbottom indirect-effect sites (Figures 12 and 13). *Briareum* and *Erythropodium* were not graphed because their proportional abundance was extremely low. *Briareum* and *Erythropodium* were absent from HBS. *Gorgonia* were not present at HBNC.

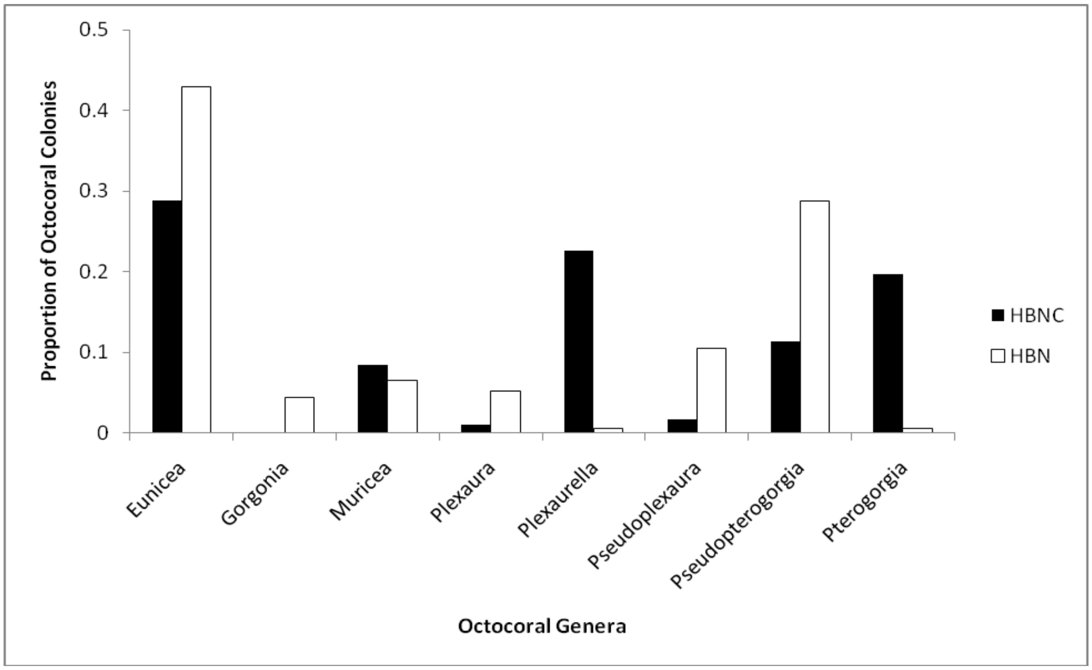

Figure 12 Proportional abundance of octocorals at the northern nearshore hardbottom sites.

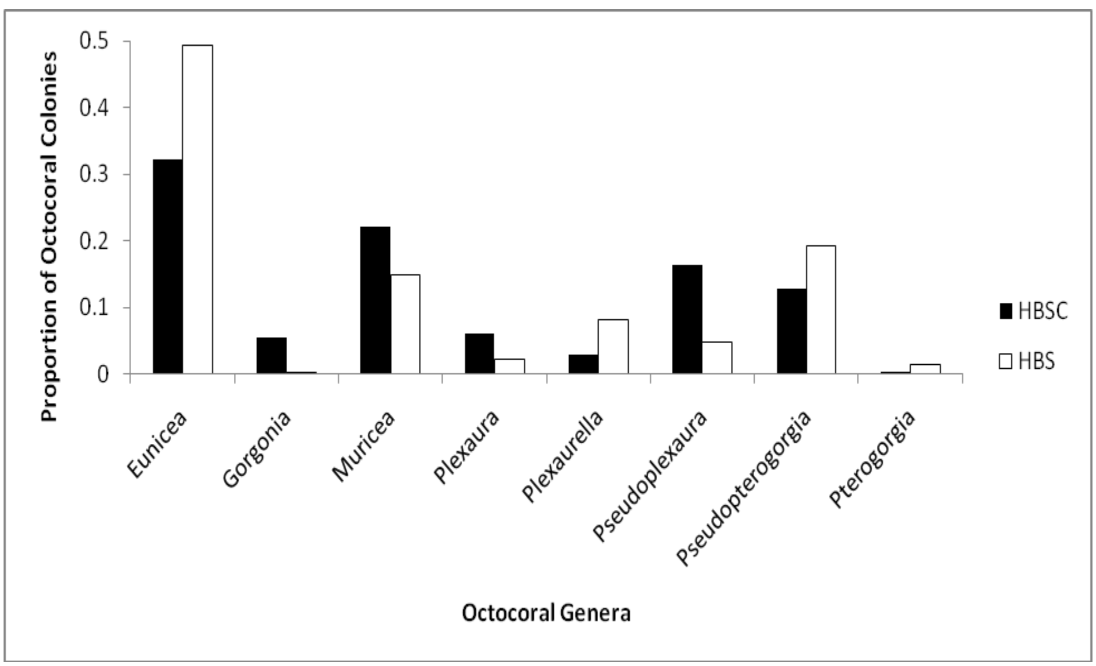

Figure 13 Proportional abundance of octocorals at the southern nearshore hardbottom sites.

Octocoral Diversity

Octocoral generic diversity (H') ranged from 1.5–1.8 across nearshore hardbottom sites. HBN and HBS were low compared to HBNC and HBSC (Table 10). Evenness (J') ranged from 0.7–0.8 across nearshore hardbottom sites and was lowest for HBN and HBS (Table 10).

Table 10. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for octocoral genera at nearshore hardbottom sites.

Index	HBN	HBNC	HBS	HBSC
Diversity (H')	1.5	1.8	1.5	1.8
Evenness (J')	0.7	0.8	0.7	0.8

Octocoral Density

Octocoral density ranged from 0.2–29.2 individuals/m^2 across all transects at nearshore hardbottom sites. Site mean octocoral density was lowest at HBS (1.7 ind/m^2) and highest at HBNC (14.5 ind/m^2) (Figure 14).

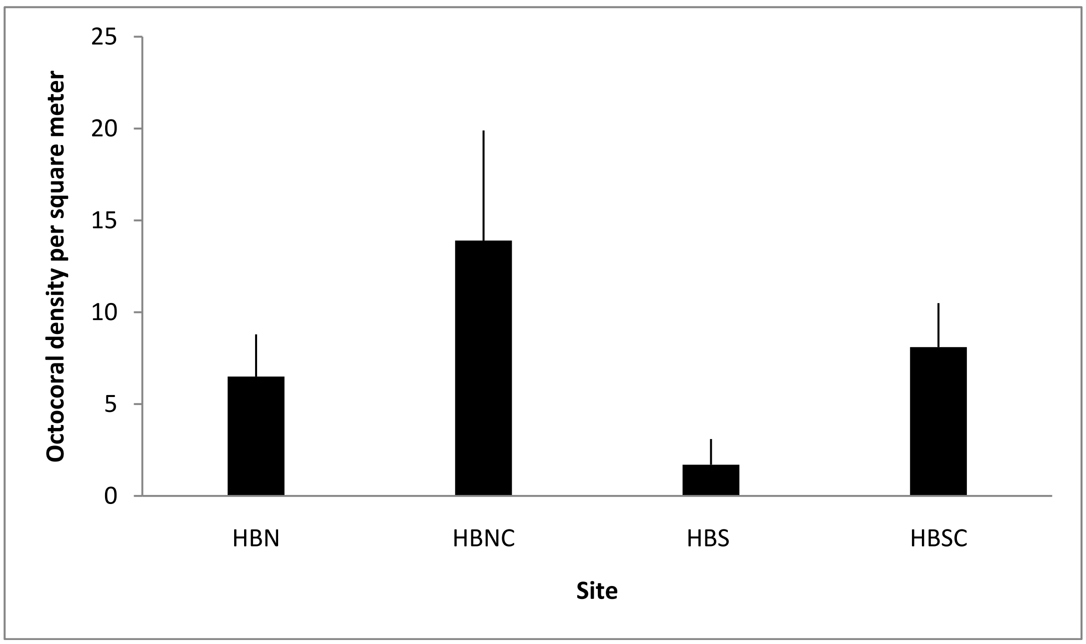

Figure 14 Mean density of octocoral colonies at nearshore hardbottom sites. Error bars represent one SD.

ANOVA Analysis

Octocoral data, expressed as numbers of colonies per square meter, were non-normal within blocks (Anderson–Darling tests, $P < 0.05$ in most cases), and the variances were heterogeneous (Levene's test, $P < 0.001$). Homogeneity of variances was achieved by fourth-root transformation (Levene's test, $P = 0.297$); however, the data remained non-normal (Anderson–Darling test, $P < 0.05$ in most cases). Because ANOVA is robust to violations of the normality assumption, the test was performed despite the normality problem. Significant effects of site and block (nested within site) were detected ($P < 0.001$ in both cases; Table 11). *A post-hoc* pairwise comparisons (Bonferroni $\alpha_{adj} = 0.0083$ for 6 tests) revealed that the density of colonies in HBS was significantly lower than at the other three sites ($P \leq 0.006$), and that the three other sites were not significantly different from each other ($P \geq 0.066$).

Examination of the mean values (Figure 14) shows that, as for hard corals, the density of octocorals was substantially lower in HBS.

Table 11. ANOVA results (blocks nested within site) testing the difference in octocoral colony density.

Source of variation	df	MS	*F*	*P*-value
Site	3	2.92	15.18	<0.001
Block(Site)	12	0.19	8.59	<0.001
Error	80	0.02		

3.2.1 Second and Third Reef Indirect-Effect Sites

The second and third reef indirect-effect sites included R2N, R2S, R3N, R3S1, R3S2, and R3S3. They represented four habitat types as described by Walker et al. (2009). A linear regression approach was used to assess benthic communities in relation to distance from the existing channel (see 2.1.2.1 for more details). Each site included 15 transects, placed at regular intervals, starting at 10 m distance from the channel. The southern sites, R2S, R3S1, R3S2, and R3S3 ended at 500 m distance from the channel, whereas the northern sites, R2N and R3N, extended to 450 m from the channel. Due to the proximity of the anchorage to the north, the sites were intentionally designed to stop south of it, in order to avoid possible confounding effects.

Second and third reef indirect-effect sites were surveyed in 6.3–12 m (21–40 ft) of water. Turbidity was noted during data collection at all sites, except for R3N. Visibility ranged from 6–9 m (20–30 ft) during data collection surveys. Second and third reef indirect-effect sites were topographically low in relief, with rugosity values ranging from 0.05 to 0.07. Rubble and rocks were present at four out of six sites. Sand occurred at all sites, with shell hash occurring only at R3N. Algae were present at all sites and included typical genera found in subtropical reefs in addition to turf and cyanobacteria (Table 12). One *Diadema antillarum* was counted at R2N and one at R3S3.

Table 12. Occurrence of algae at second and third reef indirect-effect sites.

	Site							
Algae	**R2N**	**R2S**	**R3DN**	**R3DS**	**R3N**	**R3S1**	**R3S2**	**R3S3**
Caulerpa			●					
Codium		●						
Cyanobacteria		●	●	●	●	●	●	●
Dictyota		●	●	●	●	●	●	●
Halimeda	●	●	●	●	●	●	●	●
Lobophora		●			●			
Sargassum		●						
Schizothrix	●	●	●	●	●	●	●	●
Turf	●		●	●	●	●	●	●
Udotea		●						
Valonia		●						

Scleractinian Species Richness

Twenty-seven species of scleractinian corals were present at the second and third reef indirect- effect sites (Table 13). The number of species ranged from 9–14 across sites, and was highest at R2N. Abundance ranged from 98–327 colonies surveyed across second and third reef indirect-effect sites (Table 14).

Table 13. List of scleractinian species present across indirect-effect sites.

	Site					
Scleractinian Species	**R2N**	**R2S**	**R3N**	**R3S1**	**R3S2**	**R3S3**
Acropora cervicornis	●					
Agaricia agaricites	●		●	●	●	
Agaricia lamarkiana			●			
Colpophyllia natans	●	●			●	
Dichocoenia stokesii	●	●	●	●	●	●
Diploria clivosa	●					
Diploria strigosa	●	●	●	●	●	●
Eusmilia fastigiata						
Favia fragum	●	●				
Isophyllia sinuosa						●
Madracis decactis				●	●	●
Meandrina meandrites	●	●	●	●	●	●
Montastraea annularis			●			
Montastraea cavernosa	●	●	●	●	●	●
Montastraea faveolata					●	
Oculina diffusa	●					
Porites astreoides	●	●	●	●	●	●
Porites porites	●		●	●	●	●
Scolymia sp.				●		
Siderastrea radians	●	●	●	●	●	●
Solenastrea bournoni				●	●	●
Solenastrea hyades						●
Stephanocoenia intersepta	●	●	●	●	●	●

Table 14. Number of scleractinian colonies, species richness, and density of scleractinian colonies by indirect-effect site as encountered in visual belt transects within the second and third reef indirect-effect sites. (SD = standard deviation; *N* = number of belt transects.)

Site	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
R2N	327	14	2.2	1.2	15
R2S	213	9	1.4	1.1	15
R3N	98	11	0.7	0.3	15
R3S1	272	12	1.8	0.8	15
R3S2	250	13	1.7	0.7	15
R3S3	311	13	2.1	0.9	15

A small proportion of species made up the majoirty of scleractinian colonies at second and third reef indirect-effect sites. Across all second reef sites, the top five scleractinian corals were consistent. Across all third reef sites, the top five scleractinians were consistent and the same as second reef sites, with the exception of *Madracis decactis*, which replaced *Dichocoenia stokesii*. The five most abundant scleractinians made up more than 95% of the colonies documented at the second reef sites and more than 85% at the third reef sites (Figures 15 and 16). *Siderastrea radians* was the dominant scleractinian coral at the second reef sites (Figure 15), whereas *Porites astreoides* was the dominant species at third reefs sites, followed by *S. radians* (Figure 16).

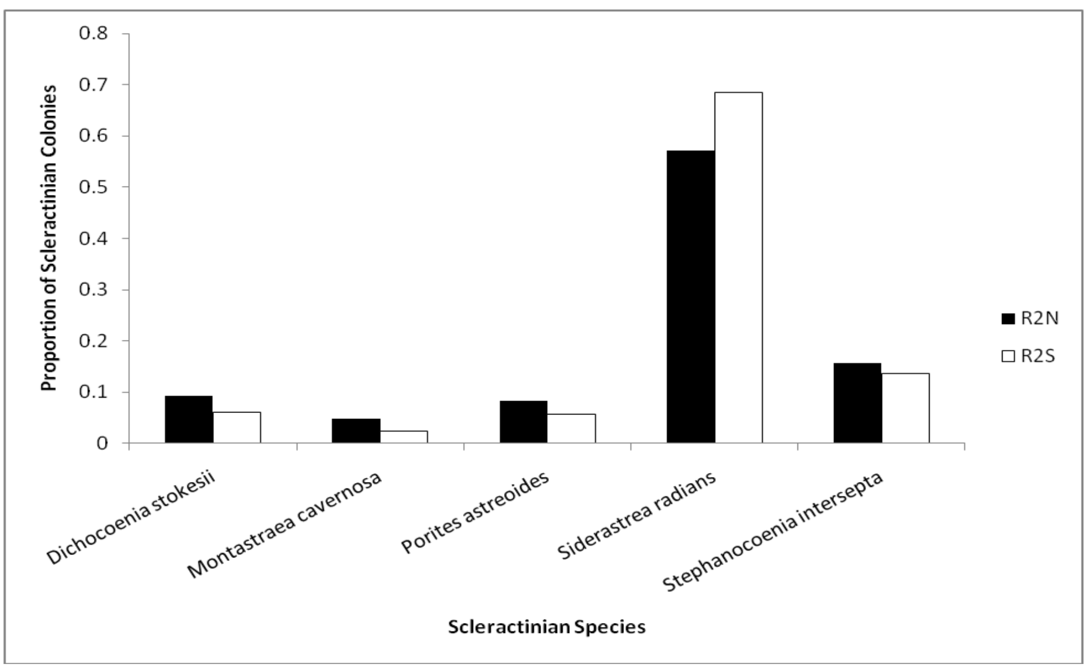

Figure 15 Proportional abundance of the five most abundant scleractinian corals at the second reef indirect-effect sites.

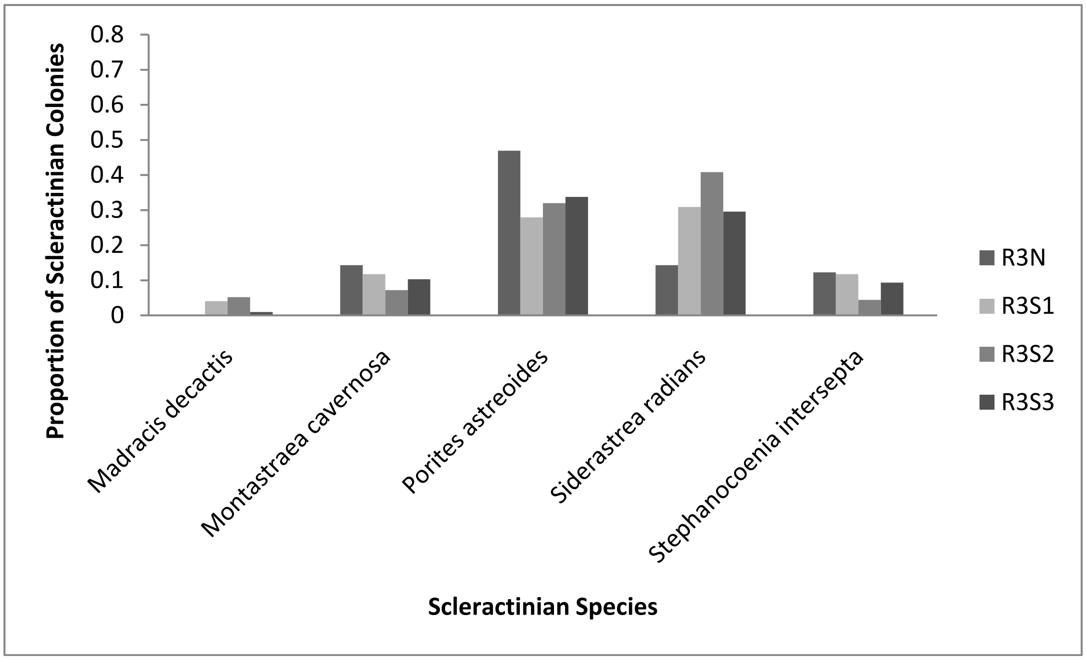

Figure 16 Proportional abundance of the five most abundant scleractinian corals at the third reef indirect-effect sites.

Scleractinian Diversity

Diversity (H') values ranged from 1.11–1.85 across second and third reef indirect-effect sites. H' and evenness (J') values were higher at third reef sites than second reef sites (Table 15).

Table 15. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for scleractinian species at indirect-effect reef sites.

Index	R2N	R2S	R3N	R3S1	R3S2	R3S3
Diversity (H')	1.43	1.11	1.65	1.85	1.64	1.80
Evenness (J')	0.54	0.50	0.69	0.75	0.64	0.70

Scleractinian Density

Scleractinian density ranged from 0.2–4.7 ind/m^2 across all transects at the second and third reef indirect-effect sites. Mean scleractinian density was lowest at R3N and highest at R2N (Table 14 and Figure 17).

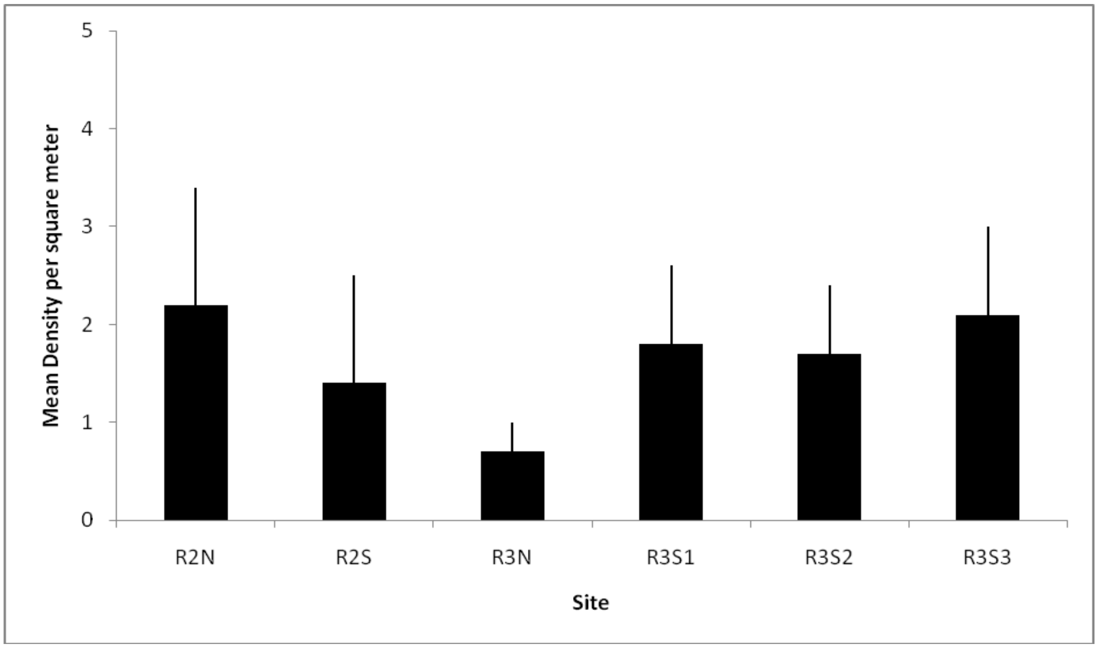

Figure 17 Mean density of scleractinian colonies at second and third reef indirect-effect sites. Error bars represent one SD.

Regression Results

Scleractinian colony density in relation to distance from the channel was different for each indirect-effect site. The response variables were normally distributed in all best-fit models, with normality tested using the Anderson–Darling method ($P > 0.05$ in all cases). Significance of the slope of the best-fit line was assessed initially at $\alpha = 0.05$. Four out of six sites showed a significant relationship with distance, with three (R2S, R3S1, and R3S2) displaying negative relationships and one (R3N) displaying a positive relationship ($P < 0.05$; Figure 18). Two sites, R2N and R3S3, showed non-significant negative relationships between colony density and distance from the channel. A second assessment of significance was carried out using the Bonferroni adjustment of $\alpha_{adj} = 0.0083$ to preserve an experimentwise error rate of 0.05 over the 6 regressions calculated in the set. By this criterion, only R3S1 displayed a significantly positive relationship between the density of colonies and distance from the channel.

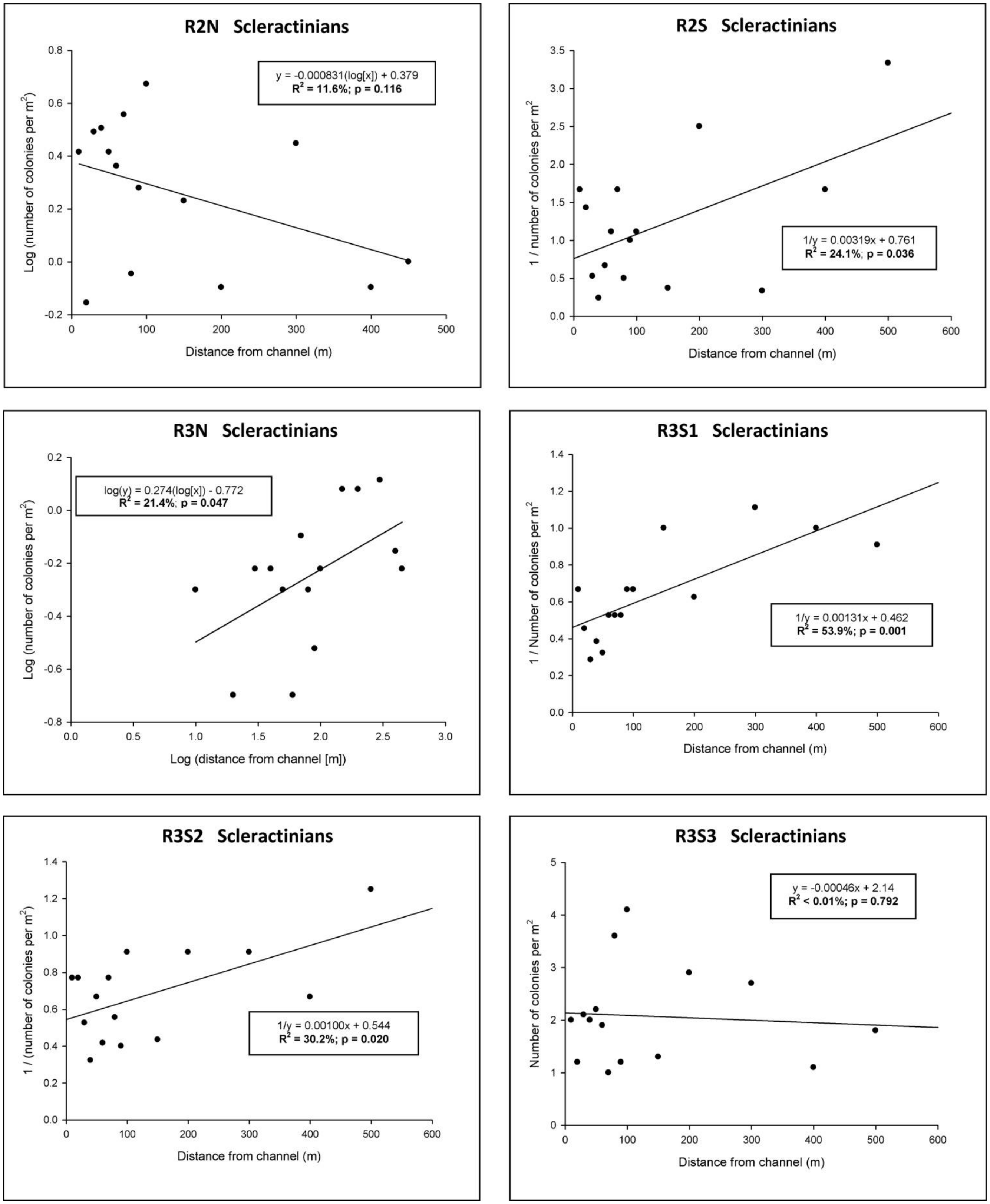

Figure 18 Linear regression results for scleractinian colony density per m^2 at the second and third reef indirect-effect sites.

Scleractinian density displayed a non-significant negative relationships to distance at R2N (Figure 18). For R2S, the inverse of hard corals displayed a significant positive relationship to distance at the 0.05 level, suggesting that the density of colonies was negatively related to distance. This relationship, however, was not significant at the Bonferroni-adjusted α_{adj}. The regression between the reciprocal of the density of hard corals and distance explained 24.1% of the variance. For R3N, the best-fit model yielded a significant and positive relationship between scleractinians and distance from the channel at the 0.05 level. The best-fit regression explained 21.4% of the variance. For R3S1, hard corals were significantly and inversely (i.e., negatively) related to distance, with the regression explaining 53.9% of the variance. This regression was significant not only at α = 0.05, but also at the Bonferroni-adjusted α_{adj}. For R3S2, hard corals were significantly and inversely related to distance at α = 0.05, with the regression explaining 30.2% of the variance; this relationship was not significant at the Bonferroni-adjusted α_{adj}. For R3S3, hard corals displayed a non-significant negative relationship to distance from the channel.

Scleractinian Colony Size

Maximum diameter data were collected for all scleractinian colonies along all transects within the indirect-effect sites on the second and third reefs. Scleractinian corals ranged in size from <1 cm to 60 cm in maximum diameter. Size-class data were tabulated from maximum colony diameters and are presented in Table 16. Coral colony size-class data, presented as proportion of total number of colonies per site, revealed that 87% of coral colonies across the indirect-effect sites were 10 cm or smaller (Figure 19).

Table 16. Scleractinian colonies grouped according to size-class category in the indirect-effect sites.

	Size Class				
Site	**0-5cm**	**6-10cm**	**11-25cm**	**>26cm**	**Total**
R2N	248	45	26	8	**327**
R2S	165	34	11	3	**213**
R3N	32	40	21	5	**98**
R3S1	175	61	33	3	**272**
R3S2	157	60	29	4	**250**
R3S3	183	81	47		**311**
Total	**960**	**321**	**167**	**23**	**1471**

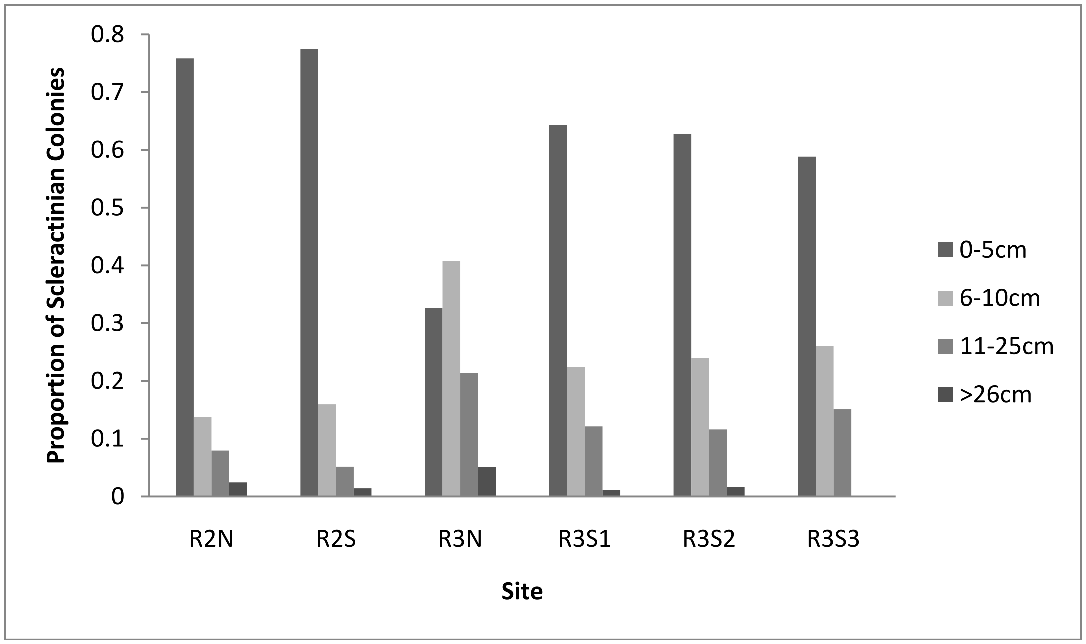

Figure 19 Proportion of scleractinian coral colonies by size class and site.

Scleractinian Condition

Colony-condition data were collected along all transects at the second and third reef indirect-effect sites. Condition categories included bleaching, fish bite-marks, partial mortality, and disease. No disease was observed along any of the transects surveyed. An average of 10% of scleractinians surveyed across the indirect-effect sites exhibited one or more conditions. Table 17 shows the percentage of coral colonies affected by one or more conditions, and the percentages of colonies affected by specific conditions. Single colonies may have been affected by more than one condition (Table 17).

Table 17. Percentage of coral colonies with at least one condition and percentages of colonies affected by specific conditions at the second and third reef indirect-effect sites. Values for the specific conditions may sum to more than the total percentage of colonies exhibiting a condition because some colonies were affected by more than one condition.

	Sites					
	R2N	**R2S**	**R3N**	**R3S-1**	**R3S-2**	**R3S-3**
N	325	213	98	272	250	309
Colonies exhibiting condition	5.5%	1.9%	19.4%	16.9%	11.2%	14.6%
Bleaching	2.5%	-	4.1%	1.8%	2.0%	1.9%
Fish Bites	-	-	1.0%	8.5%	2.4%	6.1%
Partial Mortality	3.1%	1.9%	14.3%	8.8%	6.8%	6.1%

Regression Results

Linear regressions were performed on the following response variables: proportion of scleractinian colonies with one or more conditions, proportion of colonies with signs of bleaching, proportion of colonies bearing fish bite-marks, and proportion of colonies exhibiting partial mortality. Analyses were performed on data sets from the R2 and R3 sites containing two or more observations of a particular condition. Data transformations did not improve regression fits and, therefore, were not used.

The proportion of colonies with one or more conditions did not vary significantly with distance from the channel at R2N, R2S, R3N, R3S1, or R3S2. At R3S3, there was a significantly positive relationship between distance and the proportion of colonies with at least one condition.

The proportion of colonies with signs of bleaching did not vary significantly with distance at R2N, R3S1, and R3S2. At R3S3, there was a significantly positive relationship between bleaching and distance ($y = 0.0064+0.000537x$; $P < 0.0001$; $R^2 = 76.5\%$). No colonies were observed with signs of bleaching at R2S, and only one bleached colony was observed at R3N.

The proportion of colonies with fish bite-marks did not vary significantly with distance at R3S1 or R3S3, but there was a significantly positive relationship with distance at R3S2 ($y = 0.0009 + 0.000154x$; $P = 0.038$; $R^2 = 23.6\%$). There were no colonies with fish bite-marks at R2N or R2S, and only two colonies showed evidence of fish bites at R3N.

The proportion of colonies exhibiting partial mortality did not vary significantly with distance at R2N, R2S, R3N, R3S1, R3S2, or R3S3.

Generic Richness of Octocorals

Eleven octocoral genera were represented across the second and third reef indirect-effect sites (Table 18). Second and third reef indirect-effect sites included 7–11 octocoral genera (Table 19). R2N and R3S2 had the highest number of genera, whereas R3S1 had the fewest. Abundance ranged from 150 individuals recorded in the transects at R3N to 1510 at R2N (Table 19).

Table 18. List of octocoral genera present across indirect-effect sites.

	Sites					
Octocoral Genus	**R2N**	**R2S**	**R3N**	**R3S1**	**R3S2**	**R3S3**
Briareum	●	●	●	●	●	●
Erythropodium	●	●	●	●	●	●
Eunicea	●	●	●	●	●	●
Gorgonia	●	●	●	●	●	●
Iciligorgia	●					
Muricea	●	●	●	●	●	●
Plexaura	●	●	●	●	●	●
Plexaurella	●				●	●
Pseudoplexaura	●	●	●	●	●	●
Pseudopterogorgia	●	●	●	●	●	●
Pterogorgia	●	●	●		●	

Table 19. Number of octocoral colonies, generic richness, and density of octocoral encountered within the visual belt transects second and third reef indirect-effect sites. (SD = standard deviation; *N* = number of belt transects).

Site	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
R2N	1510	11	10.1	3.6	15
R2S	609	8	4.1	2.3	15
R3N	150	8	1.0	0.5	15
R3S1	196	7	1.3	1.3	15
R3S2	455	9	3.0	1.7	15
R3S3	454	8	3.0	0.6	15

Eunicia and *Pseudopterogorgia* were the predominant octocoral genera across the second and third reef indirect-effect sites (Figures 20 and 21). With increasing distance from shore (from west to east) *Eunicia* abundance declined and *Pseudopterogorgia* abundance increased (Figure 20 and 21).

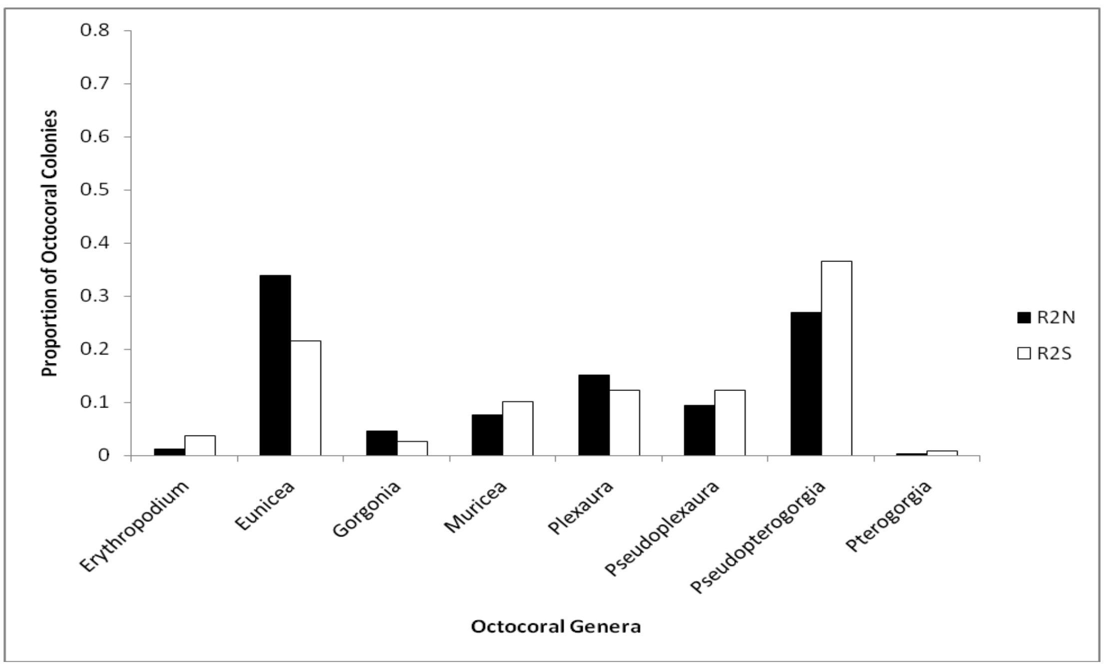

Figure 20 Proportional abundance of octocorals at the second reef indirect-effect sites.

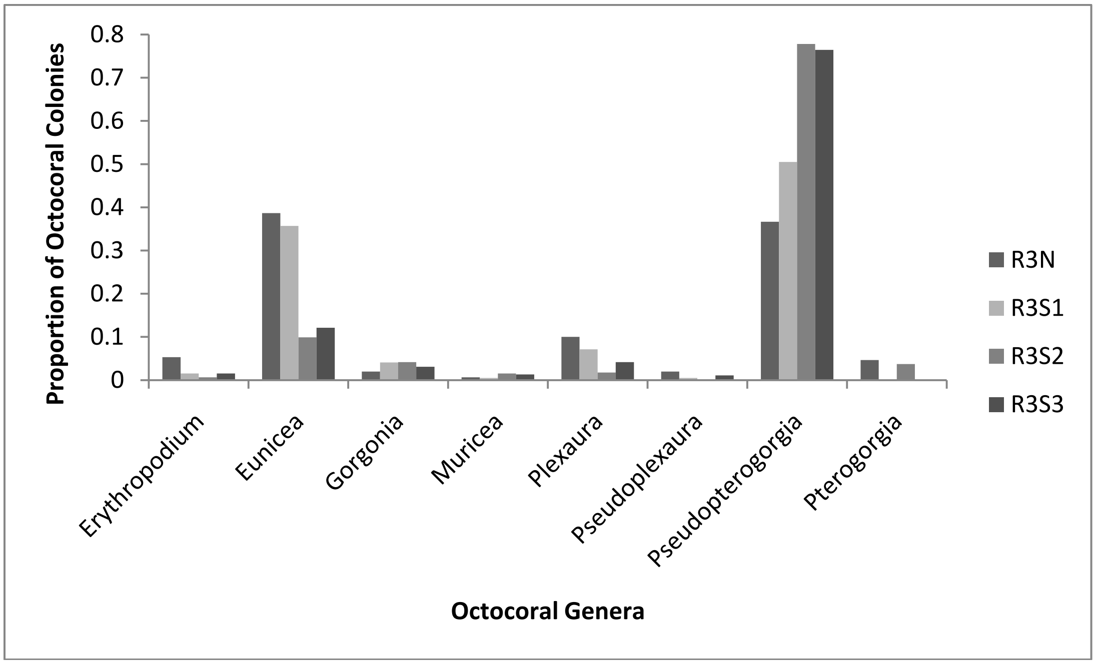

Figure 21 Proportional abundance of octocorals at the third reef indirect-effect sites.

Octocoral Diversity

The Shannon–Wiener diversity Index (H') was used to calculate generic diversity for octocorals. Diversity (H') values ranged from 0.87–1.70 across the second and third reef indirect-effect sites. Diversity and evenness (J') declined from the second to the third reef. This trend continued on the third reef, where H' and J' values declined in a west-to-east direction (Table 20).

Table 20. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for octocoral genera at indirect-effect reef sites.

	Site					
Index	**R2N**	**R2S**	**R3N**	**R3S1**	**R3S2**	**R3S3**
Diversity (H')	1.70	1.58	1.45	1.15	0.87	0.89
Evenness (J')	0.70	0.81	0.70	0.59	0.40	0.43

Octocoral Density

Octocoral colony density in relation to distance from the channel varied across sites (Figure 22). The response variables were normally distributed in all best-fit models, with normality tested using the Anderson–Darling method (*P* > 0.05 in all cases). Significance of the slope of the best-fit line was assessed initially at $\alpha = 0.05$. A second assessment of significance was carried out using the Bonferroni adjustment of $\alpha_{adj} = 0.0083$ to preserve an experimentwise error rate of 0.05 over the 6 regressions calculated in the set. Four of the six sites showed a positive relationship with distance, but only two of these (R3N and R3S1) were statistically significant at the 0.05 level. Two sites (R3S2 and R3S3) showed slightly negative relationships between colony density and distance from the channel, which were not significant at the 0.05 level.

Octocorals at R2N and R2S displayed non-significant positive relationships to distance (Figure 22). For R3N, the best-fit model yielded a significant positive relationship between octocorals and distance at the 0.05 level The best-fit regression explained 51.5% of the variance and was significant at the Bonferroni-adjusted α_{adj}. For R3S1, octocorals also exhibited a significantly positive relationships to distance at the 0.05 level. The regression explained 82.2% of the variance and was significant at the Bonferroni-adjusted α_{adj}. For R3S2 and R33, octocorals were non-significantly and negatively related to distance.

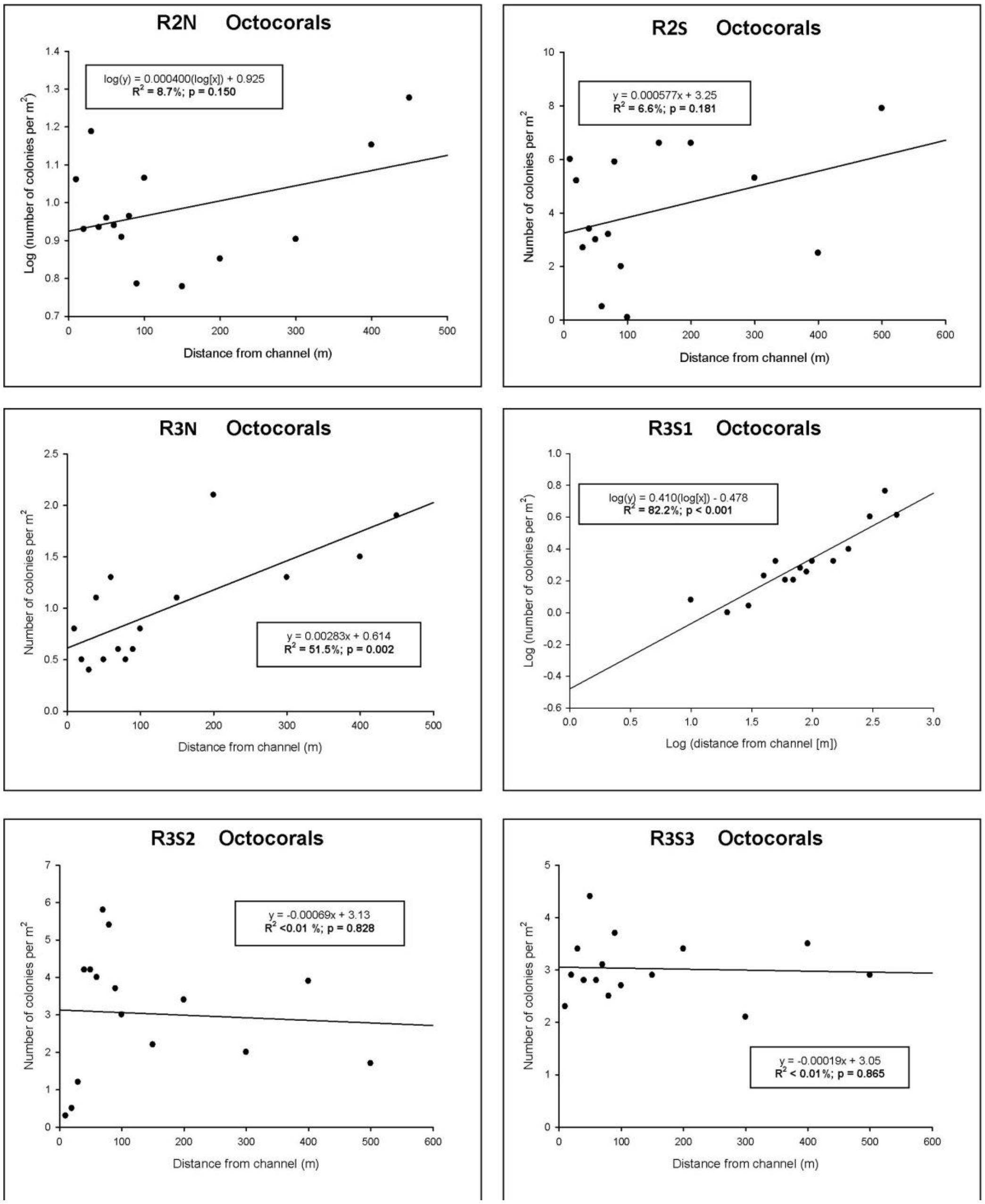

Figure 22 Linear regression results for octocoral colony density at the second and third reef indirect-effect sites.

Octocoral Colony Size

Maximum diameter data were collected for all octocorals along all transects within the indirect-effect sites on the second and third reefs. Maximum diameter was defined as the maximum linear extent of a colony (cm): height for erect or branching varieties, or diameter for encrusting varieties. Octocoral sizes ranged from 1–140 cm in maximum diameter across all indirect second and third reef sites. Octocoral size-class data reveal that 61% of colonies across the indirect-effect sites were 1–25 cm in maximum diameter (Table 21; Figure 23).

Table 21. Octocoral colonies grouped according to size class category for indirect-effect sites.

	Size Class				
Site	**0-5cm**	**6-10cm**	**11-25cm**	**>26cm**	**Total**
R2N	28	193	702	587	**1510**
R2S	52	128	283	146	**609**
R3N	3	25	61	61	**150**
R3S1	10	43	96	47	**196**
R3S2	19	46	155	235	**455**
R3S3	20	40	162	232	**454**
Total	**132**	**475**	**1459**	**1308**	**3374**

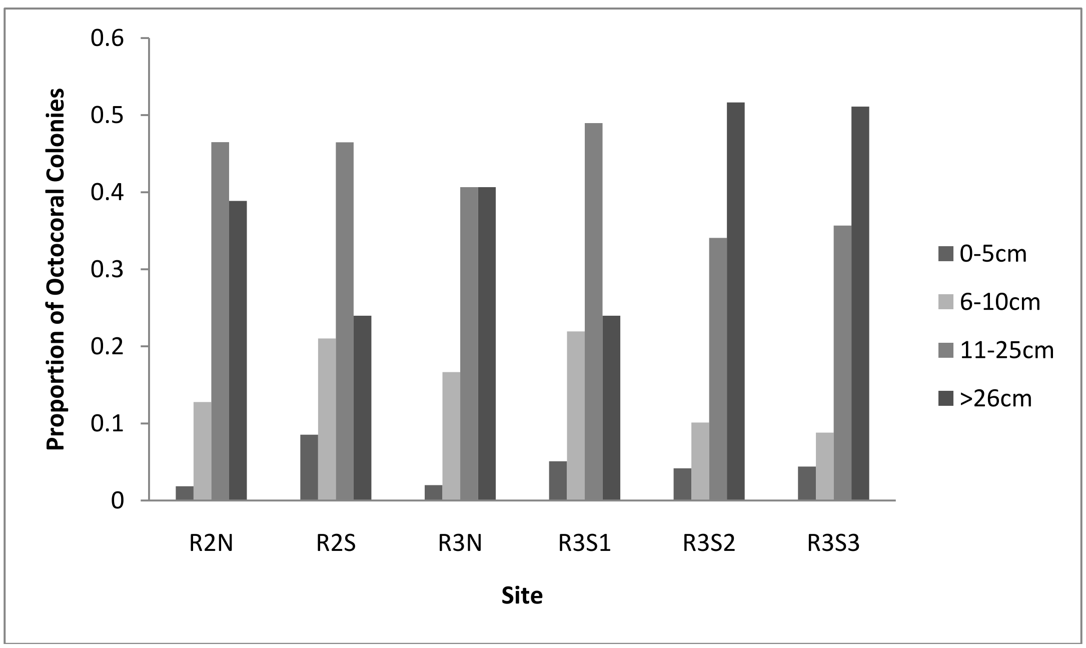

Figure 23 Proportion of octocoral colonies by size class and site.

Morphological Richness of Sponges

Sponge data were collected at all transects, including the abundance and size of each colony. Sponge data were grouped by morphotype—ball, barrel, vase, encrusting, boring, tube, and finger—rather than taxonomically, due to the difficulty of accurately identifying sponges in the field (Table 22).

All morphotypes occurred at each indirect-effect site except for R2N, where barrel sponges were absent (Table 22). Abundance ranged from 721–1588 sponges across sites and was lowest at R2S and highest at R3S1 (Table 23). Encrusting and finger sponges were the predominant morphotypes across all sites (Figure 24). Barrel sponges (which were *Xestospongia muta*) and boring sponges (not displayed on the graph) were lowest in abundance (Figure 24).

Table 22. List of sponge morphotypes present at each indirect-effect site.

	Sites					
Sponge Morphotype	**R2N**	**R2S**	**R3N**	**R3S1**	**R3S2**	**R3S3**
Ball	•	•	•	•	•	•
Barrel		•	•	•	•	•
Boring	•	•	•	•	•	•
Encrusting	•	•	•	•	•	•
Finger	•	•	•	•	•	•
Tube	•	•	•	•	•	•
Vase	•	•	•	•	•	•

Table 23. Number of sponge colonies, morphotype richness, and density of sponge colonies encountered within the visual belt transects second and third reef indirect-effect sites. (SD = standard deviation; *N* = number of belt transects).

Site	Colonies	Morphotype	Mean Density (colonies/m^2)	SD	*N*
R2N	1554	6	10.4	3	15
R2S	721	7	4.8	1.9	15
R3N	1117	7	7.4	3.6	15
R3S1	1588	7	10.6	3.9	15
R3S2	1338	7	8.9	2.8	15
R3S3	1194	7	8.0	2.1	15

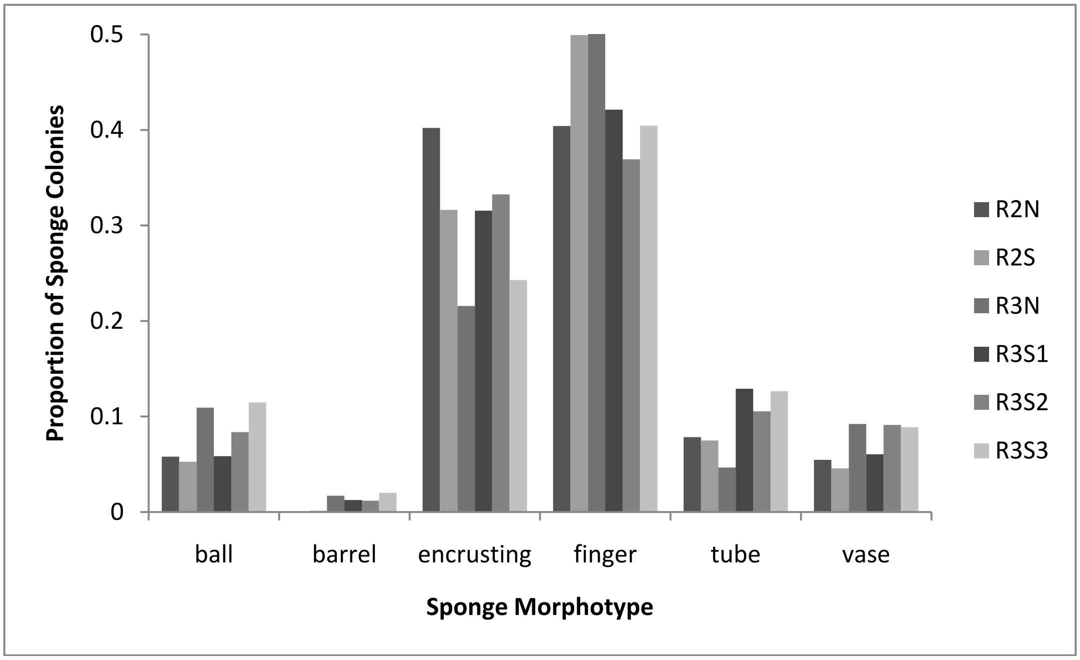

Figure 24 Proportional sponge abundance by morphotype and site.

Sponge Density

Mean sponge density ranged from 5–11 colonies/m^2 across the indirect-effect sites (Figure 25). Sponge density in relation to distance from the channel varied across sites (Figure 26). The response variables were normally distributed in all best-fit models, with normality tested using the Anderson–Darling method ($P > 0.05$ in all cases). Significance of the slope of the best-fit line was assessed initially at $\alpha = 0.05$. A second assessment of significance was carried out using the Bonferroni adjustment of $\alpha_{adj} = 0.0083$ to preserve an experimentwise error rate of 0.05 over the 6 regressions calculated in the set. Five out of six sites showed a positive relationship with distance, but only two of these (R3N and R3S1) were statistically significant at the 0.05 level. Sponges at R2N displayed a negative relationship with distance from the channel, but this relationship was not significant at the 0.05 level.

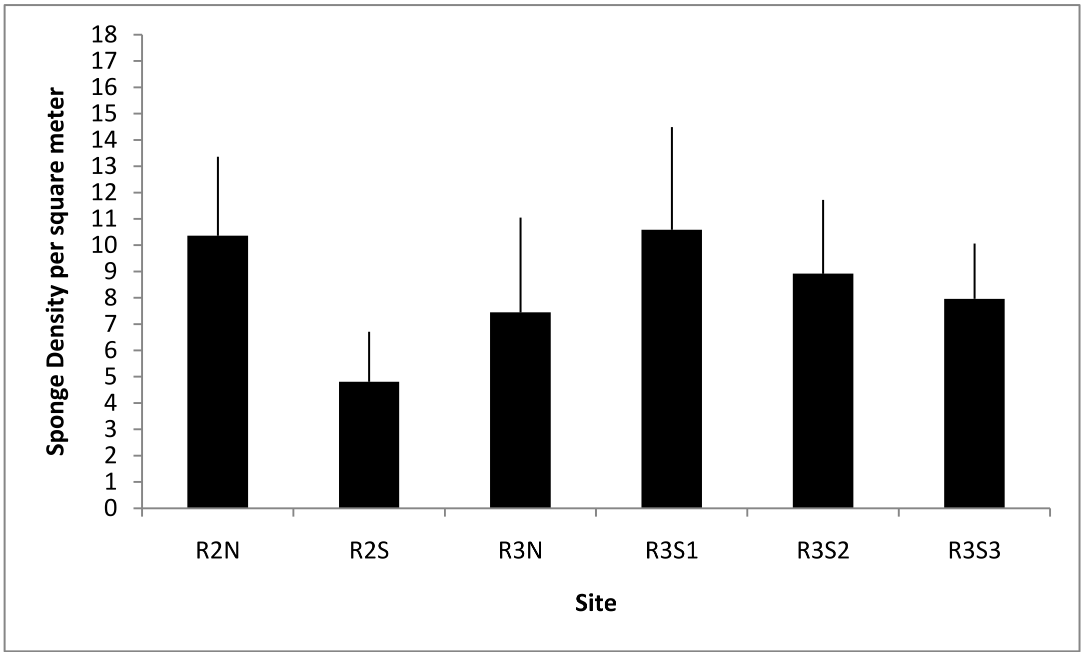

Figure 25 Mean sponge colony density per square meter at the second and third reef indirect-effect sites. Error bars represent one SD.

For R2N sponges displayed a non-significant negative relationship to distance (Figure 26). For R2S sponges displayed a non-significant positive relationship to distance. For R3N, the best-fit model yielded a significant and positive relationship between sponges and distance at the 0.05 level. The best-fit regression explained 25.1% of the variance for sponges, but this was not significant at the Bonferroni-adjusted α_{adj}. For R3S1, sponges also exhibited a significantly positive relationship to distance at the 0.05 level, with the regression explaining 25.1% of the variance; however, this relationship was not significant at the Bonferroni-adjusted α_{adj}. For R3S2 and R3S3, sponges were non-significantly and positively related to distance.

Sponge Size

The data on maximum diameters of sponges were grouped into size classes for comparison purposes. Sixty-six percent of sponges were 10 cm or smaller and 94% of colonies were smaller than 25 cm (Table 24; Figure 27).

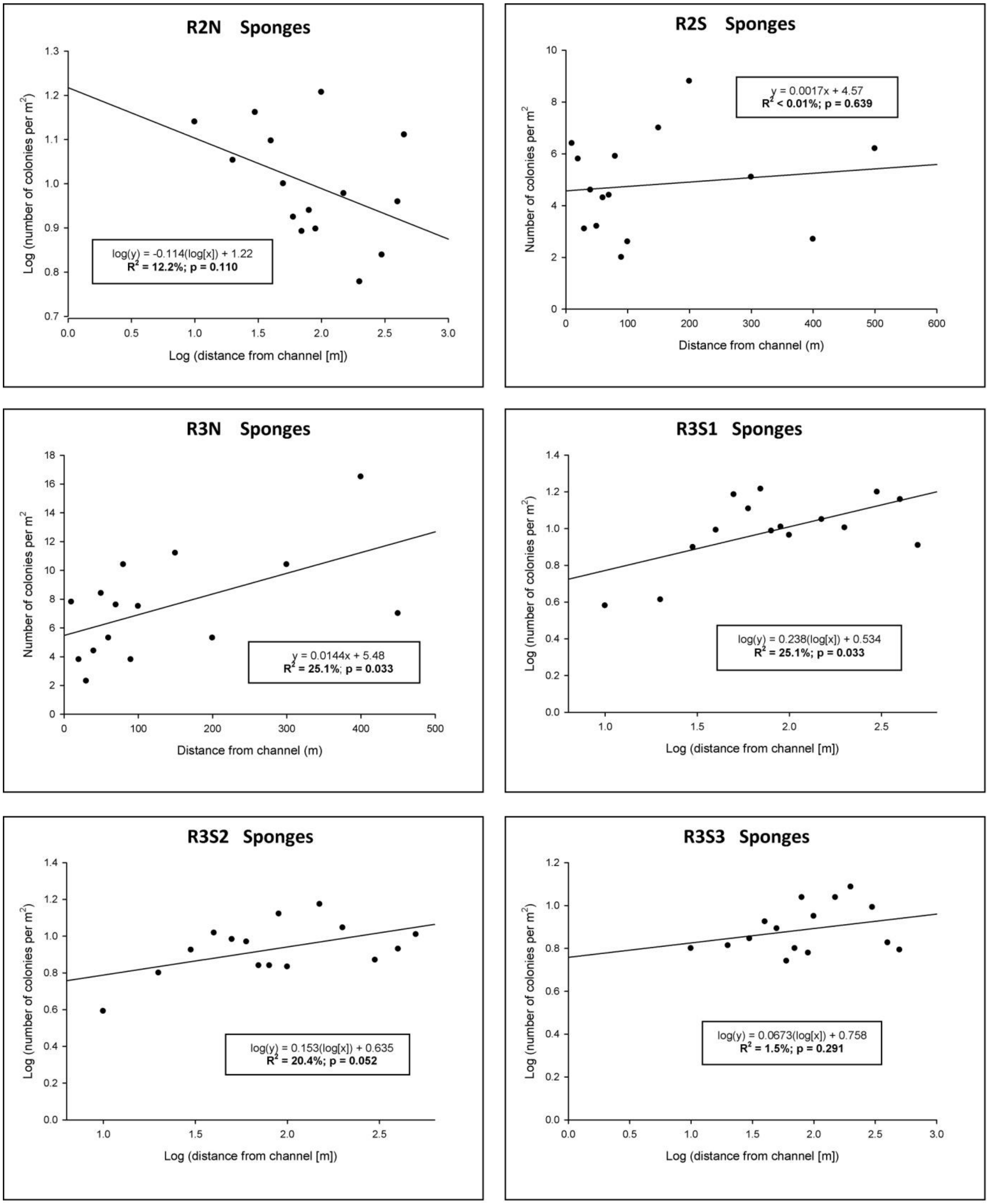

Figure 26 Linear regression results for sponge colony density at the indirect-effect sites.

Table 24. Sponge colonies grouped according to size-class category for the indirect-effect sites.

Size Class					
Site	**0-5cm**	**6-10cm**	**11-25cm**	**>26cm**	**Total**
R2N	598	485	399	72	**1554**
R2S	246	233	220	22	**721**
R3N	336	309	365	107	**1117**
R3S1	574	488	428	98	**1588**
R3S2	520	442	321	55	**1338**
R3S3	361	389	360	84	**1194**
Total	**2635**	**2346**	**2093**	**438**	**7512**

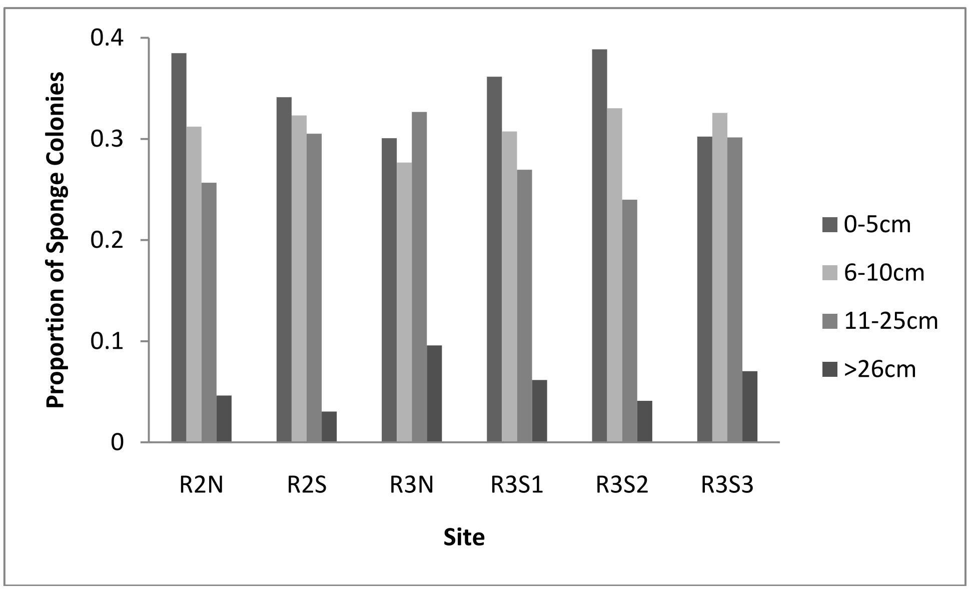

Figure 27 Proportion of sponge colonies by size class and site.

Third Reef Direct-Effect Sites

Third reef direct-effect sites lie on the north and south edges of the existing channel. The northern direct-effect site (R3DN) and the southern site (R3DS) were surveyed using fifteen 20 x 1m randomly placed transects, for a total of 300 m^2 surveyed per site. Descriptive results are provided here for direct-effect sites. Further statistical treatments were not conducted since these areas will be removed as a result of construction activities (see Section 2.1.3 for more on Methods).

Third reef direct-effect sites were surveyed in 11.9–15.2 m (39–50 ft) of water. Turbidity was noted during data collection, and visibility ranged from 6–9 m (20–30 ft) during data collection surveys. Direct-effect sites were topographically low in relief, with rugosity values of 0.11 for each site. Rubble, rocks, and boulders were present at both sites. Sand occurred at both sites, but no shell hash occured at either site. Algae included typical genera found in subtropical reefs in addition to turf and cyanobacteria (Table 25). No *Diadema antillarum* were found at direct-effect sites.

Table 25. Algae at second and third reef direct-effect sites.

	Site	
Algae	**R3DN**	**R3DS**
Caulerpa	●	
Cyanobacteria	●	●
Dictyota	●	●
Halimeda	●	●
Schixothrix	●	●
Turf	●	●

Scleractinian Richness

Nineteen species of scleractinian corals were present at the direct-effect sites (Table 26). The number of species ranged from 15 to 19, with the highest number of species occurring at R3DS (Table 27). Abundance ranged from 306 colonies surveyed at R3DN to 403 colonies at R3DS.

Table 26. Scleractinian species present at each direct-effect site.

Scleractinian Species	R3DN	R3DS
Agaricia agaricites	•	•
Dendrogyra cylindrus		•
Dichocoenia stokesii	•	•
Diploria labyrinthiformis		•
Diploria strigosa	•	•
Eusmilia fastigiata	•	•
Favia fragum		•
Madracis decactis	•	•
Meandrina meandrites	•	•
Montastraea cavernosa	•	•
Montastraea faveolata		•
Mycetophyllia aliciae	•	
Porites astreoides	•	•
Porites porites	•	•
Scolymia	•	•
Siderastrea radians	•	•
Siderastrea siderea	•	•
Solenastrea bournoni	•	•
Solenastrea hyades		•
Stephanocoenia intersepta	•	•

Table 27. Number of scleractinian colonies, species richness, and density of scleractinians encountered with in the visual belt transects at third reef direct-effect sites. (SD = standard deviation; *N* = number of belt transects).

Site	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
R3DN	306	15	2.0	0.4	15
R3DS	403	19	2.7	0.8	15

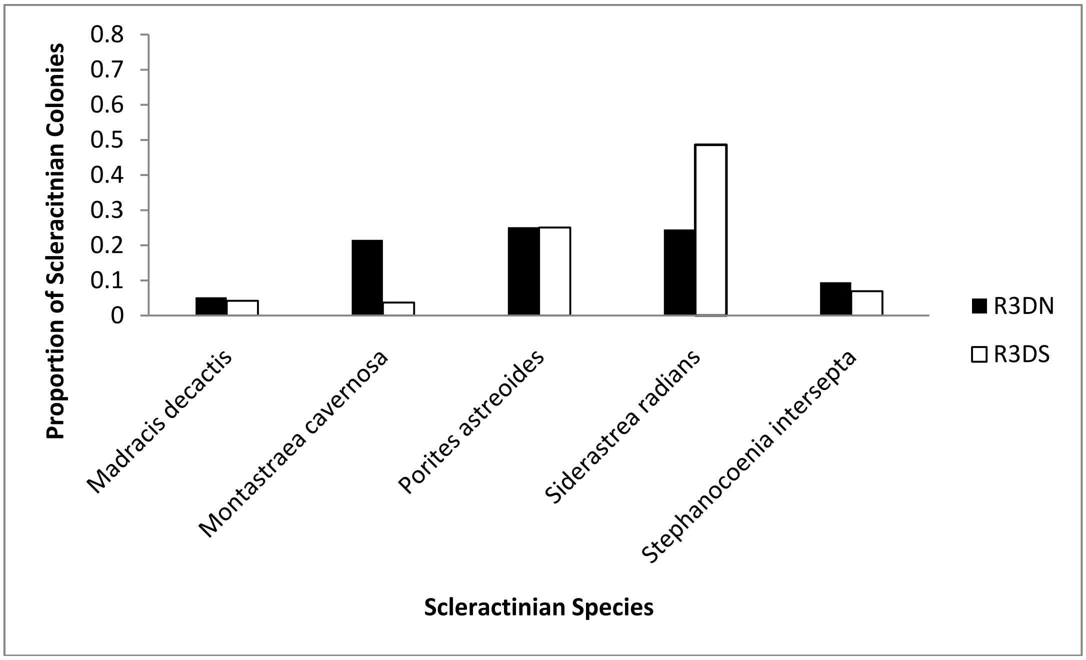

Figure 28 Proportional abundance of scleractinians at the third reef direct-effect sites.

The most common scleractinian species at R3DN was *Porites astreoides* and the most common scleractinian species at R3DS was *Siderastrea radians (*Figure 28*)*. The top five scleractinians at R3DN and R3DS constituted 85 and 88% of all scleractinians documented at these sites (Figure 28).

Scleractinian Diversity

H' and evenness (J') values were higher at R3DN than R3DS (Table 28).

Table 28. Shannon–Wiener Diversity Index (H') and Evenness (J') calculated for scleractinian species at direct-effect sites.

Index	R3DN	R3DS
Diversity (H')	1.97	1.65
Evenness (J')	0.73	0.56

Scleractinian Density

Scleractinian density ranged from 0.2 to 2.8 ind/m^2 across all transects at the direct-effect sites. Mean scleractinian density was lower at R3DN and higher at R3DS (Table 27; Figure 29).

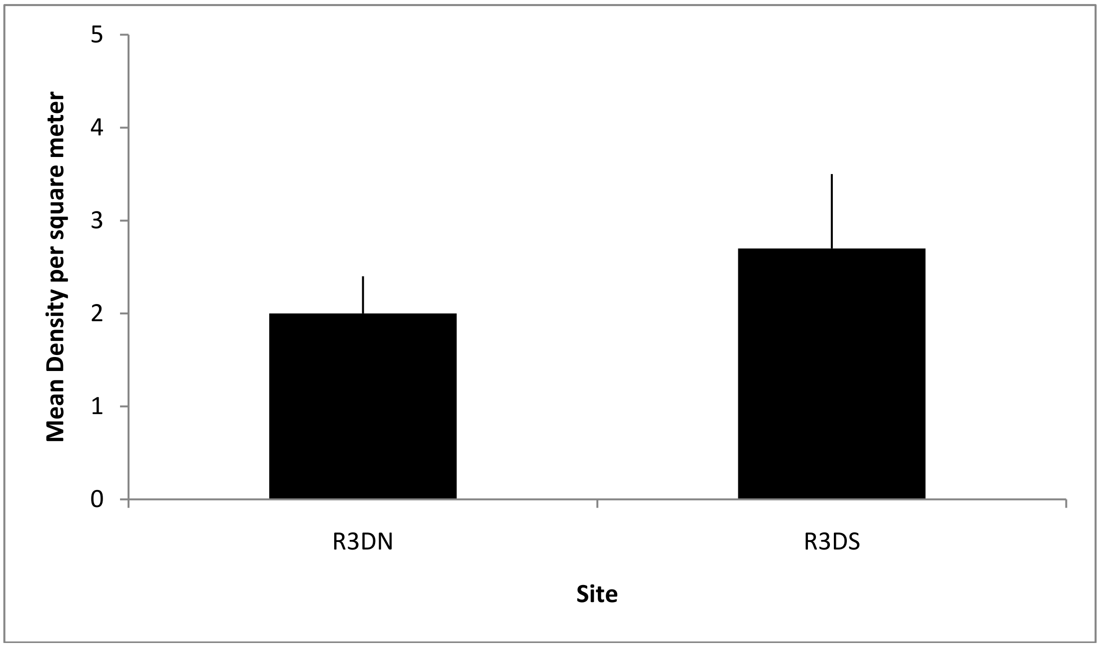

Figure 29 Mean density of scleractinian colonies at indirect-effect sites. Error bars represent one SD.

Scleractinian Colony Size

Maximum diameter data were collected for all scleractinian colonies along all transects within the direct-effect sites. Scleractinian corals ranged in size from <1 cm to 46 cm in maximum diameter. Size-class data were tabulated from maximum colony diameters and are presented in Table 29. Coral colony size-class data, presented as proportion of total number of colonies per site, revealed that 87% of coral colonies at both direct-effect sites were 10 cm or smaller (Figure 30).

Table 29. Scleractinian colonies grouped according to size-class category in the direct-effect sites.

Site	0-5cm	6-10cm	11-25cm	>26cm	Total
R3DN	155	110	38	3	**306**
R3DS	275	77	47	4	**403**
Total	**430**	**187**	**85**	**7**	**709**

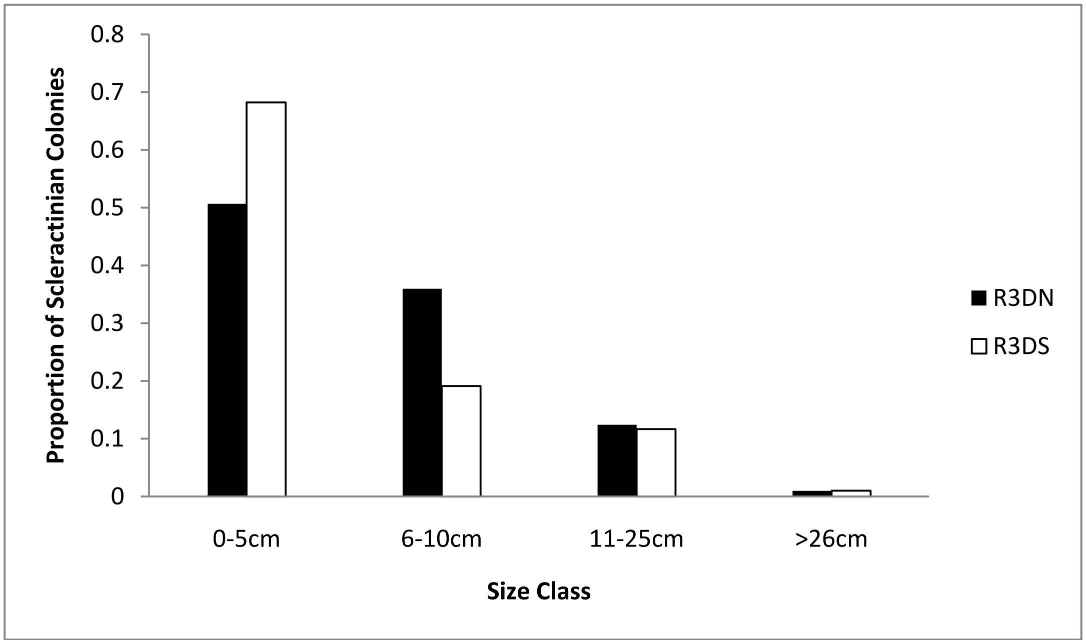

Figure 30 Proportion of scleractinian colony size class data at direct-effect sites.

Scleractinian Condition

Data collection included information on the condition of each scleractinian colony. Coral bleaching, fish bites, and mortality data were collected for affected colonies. An average of 6% of scleractinian colonies surveyed at direct-effect sites were affected by a condition, which included bleaching, fish bites, and/or partial mortality. Some colonies exhibited more than one condition (i.e. partial mortality and fish bites) (Table 30).

Table 30. Percent of scleractinian corals with a given condition at third reef direct-effect sites. Values may add to higher than the total percentage of corals affected by a condition because some colonies were affected by more than one condition.

	R3DN	R3DS
N	304	403
Percent of colonies exhibiting a condition	6.6%	6.2%
Bleaching	0.3%	2.0%
Fish Bites	3.3%	2.2%
Partial Mortality	4.6%	2.7%

Generic Octocoral Richness

Nine octocoral genera were represented at direct-effect sites (Table 31). R3DN had the higher number of octocoral genera compared to R3DS. Abundance ranged from 127 individuals recorded in the transects at R3DN to 293 at R3DS (Table 32).

Table 31. List of Octocoral genera present at direct-effect sites.

Octocoral Genus	R3DN	R3DS
Briarieum	●	
Erythropodium	●	
Eunicea	●	●
Gorgonia	●	●
Muricea	●	●
Plexaura	●	●
Pseudoplexaura	●	●
Pseudopterogorgia	●	●
Pterogorgia	●	●

Table 32. Number of octocoral colonies, species richness, and density of octocoral colonies by hardbottom area as encountered in visual belt transects off Miami, FL. (SD = standard deviation; *N* = number of belt transects)

Hardbottom Area	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
R3DN	293	9	2.0	0.5	15
R3DS	127	7	0.8	0.7	15

Eunicia and *Pseudopterogorgia* were the predominant octocoral genera at third reef direct-effect sites (Figure 31). *Briareum* and *Erythropodium* were absent at R3DS.

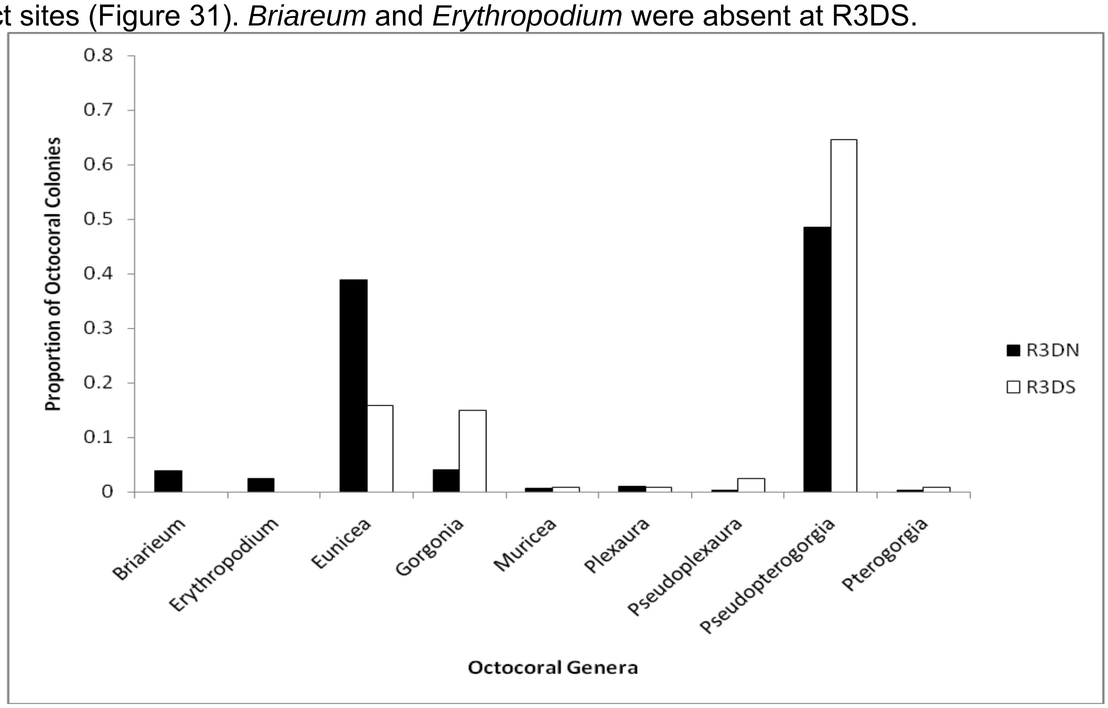

Figure 31 Proportional abundance of octocorals at the third reef direct-effect sites.

Octocoral Diversity

Diversity (H’) values ranged from 1.06–1.18 at R3DS and R3DN, respectively. Diversity and evenness (J’) were the same at both sites (Table 33).

Table 33. Shannon–Wiener Diversity Index (H') and Evenness (J’) calculated for octocoral genera at direct-effect reef sites.

Index	R3DN	R3DS
Diversity (H')	1.18	1.06
Evenness (J)	0.54	0.54

Octocoral Density

Octocoral density ranged from 0.35–2.85 ind/m^2 across all transects at the direct-effect sites. Mean octocoral density was lower at R3DN when compared to R3DS (Table 32; Figure 32).

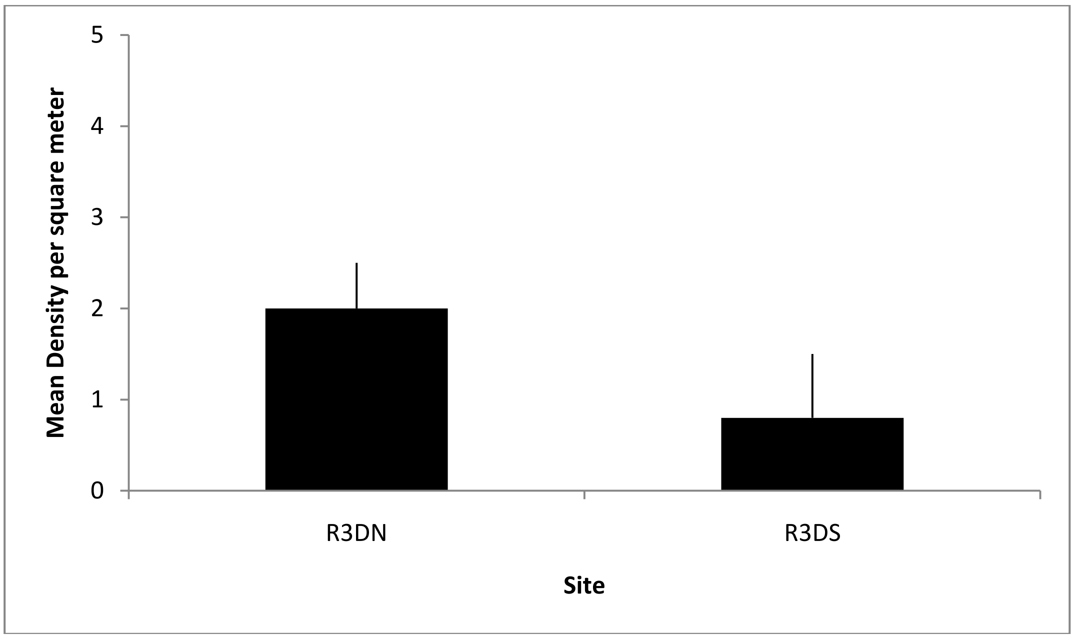

Figure 32 Density of octocoral colonies at direct-effect sites. Error bars represent one SD.

Octocoral Size

Octocoral size-class distribution was different between direct-effect sites. At R3DN, on the north side of the channel, octocorals in the 11–25 cm size class predominated, while at R3DS, smaller octocorals (0–5 cm) were proportionally greater in abundance (Table 34; Figure 33).

Table 34. Octocoral colonies grouped according to size class category for direct-effect sites.

Site	0-5cm	6-10cm	11-25cm	>26cm	Total
R3DN	27	40	131	95	**293**
R3DS	19	19	32	57	**127**
Total	**46**	**59**	**163**	**152**	**420**

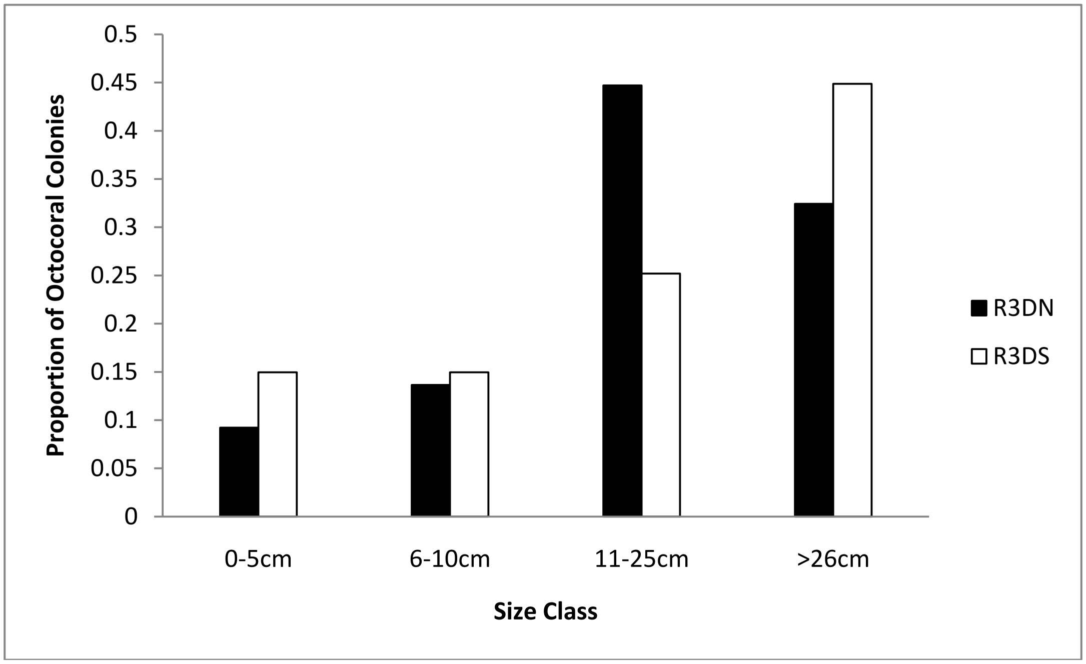

Figure 33 Proportion of octocoral colonies by size class and site.

Sponge Richness

Sponge data were collected from all transects, including abundance and size of individual colonies. Sponge data were grouped by morphotype—ball, barrel, vase, encrusting, boring, tube, and finger—rather than taxonomically, due to the difficulty of accurately identifying sponges in the field (Table 35).

All morphotypes occurred at each direct-effect site, except for R3DS, where barrel sponges were absent (Table 35). Abundance ranged from 967–2178 sponges at R3DS and R3DN, with more than twice as many sponges occurring on the north side of the channel, compared to the south side. (Table 36). Encrusting and finger sponges were the predominant morphotypes at both sites (Figure 34). Barrel sponges (*Xestospongia muta*) were lowest in proportional abundance and were not displayed graphically (Figure 34).

Table 35. List of sponge morphotypes present at each direct-effect site.

Sponge Morphotype	R3DN	R3DS
ball	●	●
barrel	●	
boring	●	●
encrusting	●	●
finger	●	●
tube	●	●
vase	●	●

Table 36. Number of sponge colonies, species richness, and density of sponge colonies encountered within the visual belt transects at third reef direct-effect sites. (SD = standard deviation; *N* = number of belt transects)

Hardbottom Area	Colonies	Species	Mean Density (colonies/m^2)	SD	*N*
R3DN	2178	7	14.5	3	15
R3DS	967	6	6.4	1.7	15

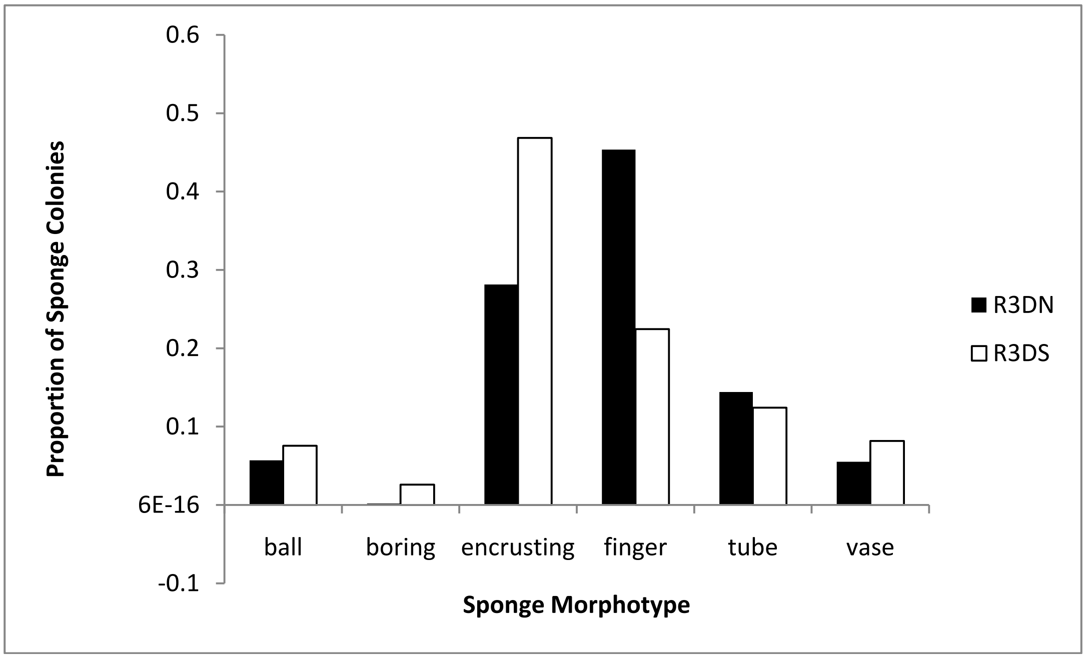

Figure 34 Proportional sponge abundance by morphotype and site.

Sponge Density

Mean sponge density was different, depending upon site. Mean sponge densities were 6 and 14 colonies/m^2 at R3DS and R3DN, respectively (Figure 35).

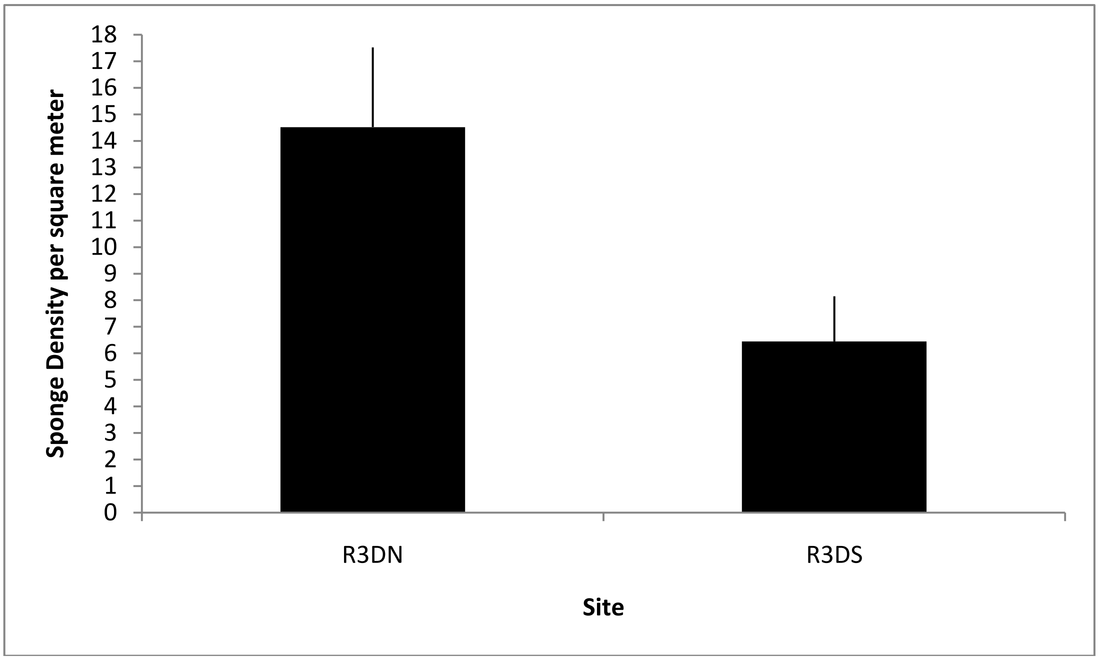

Figure 35 Mean density of sponge colonies at third reef direct-effect sites. Error bars represent one SD.

Sponge Size

The data on maximum diameters of sponges were grouped into size classes for comparison purposes. More than half (58%) of sponges were 10 cm or smaller and 93% of colonies were smaller than 25 cm (Table 37; Figure 36).

Table 37. Sponge colonies grouped according to size-class category for the direct-effect sites.

Site	0-5cm	6-10cm	11-25cm	>26cm	Total
R3DN	484	668	854	172	**2178**
R3DS	328	351	266	22	**967**
Total	**812**	**1019**	**1120**	**194**	**3145**

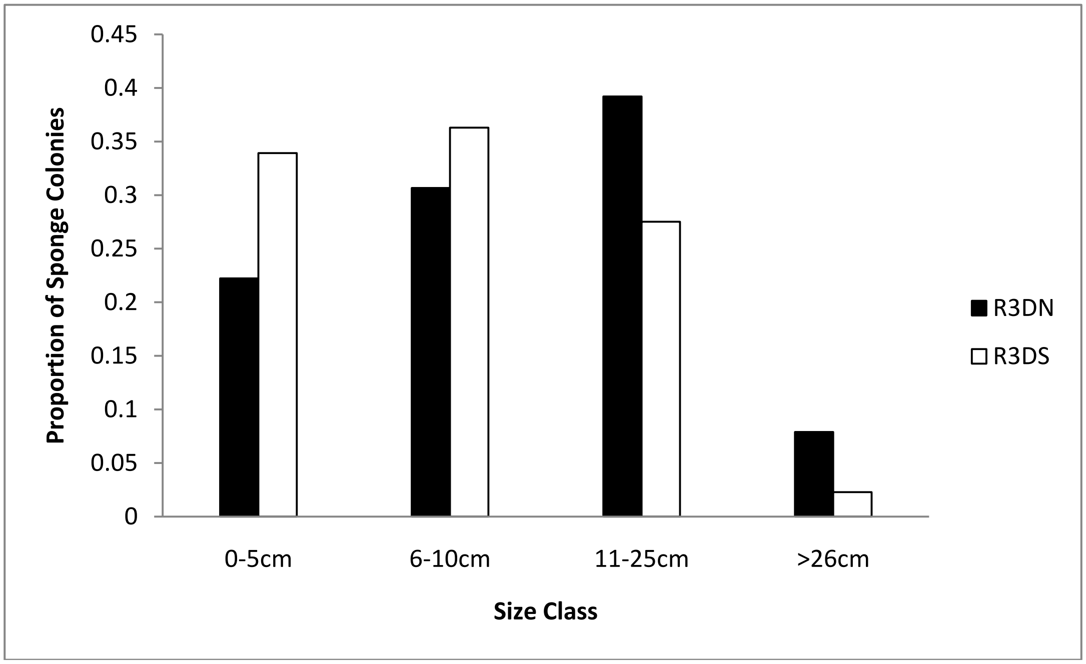

Figure 36 Proportion of sponge colonies by size class and site.

4.0 DISCUSSION

The environmental characterization presented in this report was intended to assess the nearshore hardbottom, second and third reef biological communities in the vicinity of the deepening and widening project, both in direct-effect areas (4.4 acres) and in indirect-effect areas (up to 500 m away from the channel). Benthic organisms (scleractinians, octocorals, and sponges) found within representative sampling sites of the anticipated footprint of the improved entrance channel (R3DN and R3DS) and of the area adjacent to the improved entrance channel (HBNC, HBN, HBS, HBSC, R2N, R2S, R3N, R3S1, R3S2, R3S3) were sampled in August 2010. The statistical approaches used in the nearshore hardbottom sites (ANOVA) and on the second and third reefs (regression) were designed in order to test for an effect of dredging on these benthic populations, in comparison with post-construction surveys.

The reef tracts of southeast Florida (Miami–Dade, Broward, and Palm Beach Counties) are high-latitude reefs, existing near the northern limit of reef growth in the continental United States (e.g., Goldberg 1973). The southeast reef complex found offshore is highly variable in terms of spatial distribution of its biological communities (Moyer et al. 2003) and does not conform to the classic reef zonation described for tropical and subtropical reef systems (Goreau 1959; Stoddart 1969; Loya 1972; Goldberg 1973). Numerous factors, such as seasonally cold ocean water, tidal-inlet discharge, groundwater seepage, freshwater input and high variability of substratum complexity and composition have been proposed to explain why benthic communities of high-latitude reefs off Florida differ from typical reefs of the western Atlantic region (Goldberg 1973). These reefs do, however, generally conform to the reef zonation found in the Florida Keys (Banks et al. 2007).

Although some aspects of the geology of these reefs are well understood (Walker et al. 2009; Banks et al. 2007), the biological communities associated with these reefs are less well documented. Some peer-reviewed articles and studies for government entities related to infrastructure projects describe benthic biological communities in Broward and Palm Beach counties (Moyer et al. 2003; Gilliam et al. 2006; Dial Cordy 2009). In Miami–Dade County a single study of the benthic communities is ongoing, under the auspices of the Coral Reef Evaluation and Monitoring Project (CREMP) (Gilliam et al. 2010). The Southeast CREMP (SECREMP) data and the results of the Broward County Shore Protection Program environmental monitoring project (Gilliam et al. 2006), which monitored sites associated with beach sand placement in Broward County, were used for regional comparison purposes (Table 38).

Table 38. Comparison of scleractinian coral, octocoral, and sponge density at sites closest to Port of Miami. R2N and R3N data are from this study; JUL 7 and JUL8 data are taken from Gilliam et al. (2006). R3N* and R3S* are averaged values from direct and indirect sites on the north and south sides of the channel (R3N and R3DN) and (R3S1, R3S2, R3S3 and R3DS).

	Second Reef			Third Reef		
	R2N	**R2S**	**Jul 7**	**R3N***	**R3S***	**Jul 8**
Depth (m)	8-9	6-9	10	12-14	10-15	15
Coral Density (colonies/m^2)	2.2	1.4	1.3	1.4	2.1	2.0
Octocorals (colonies/m^2)	10.1	4.1	0.4	1.5	2.0	2.5
Sponges (colonies/m^2)	10.4	4.8	7.2	11	8.5	6.8

A regional comparison reveals that all sites, regardless of reef, are dominated by sponges, octocorals, and to a lesser extent scleractinian corals (Table 38; Moyer et al. 2003). Second reef sites in this study had higher densities of octocorals when compared to third reef sites; however this pattern may be localized as the Broward County JUL sites show the opposite pattern (Table 38). When comparing species richness, this study identified 26 species, compared to SECREMP species richness of 21 (Table 39). SECREMP data were taken from 3 sites, on the first, second and third reefs, approximately 5 miles north of the sites in this study. A smaller area was sampled at SECREMP sites, when compared to the current study, which explain the lower species richness values for the SECREMP data.

Table 39. Hard coral species presence/absence for Miami–Dade SECREMP sites and this study. Adapted from Gilliam et al. (2010).

Species List	SECREMP Miami–Dade Sites	This Study
Acropora cervicornis	•	•
Agaricia agaricites	•	•
Agaricia fragilis	•	
Agaricia lamarcki	•	•
Cladocora arbuscula		•
Colpophyllia natans		•
Dichocoenia stokesii	•	•
Diploria clivosa		•
Diploria labyrinthiformis	•	•
Diploria strigosa	•	•
Eusmilia fastigiata	•	•
Madracis decactis	•	•
Isophyllia sinuosa		•
Meandrina meandrites	•	•
Millepora alcicornis	•	•
Montastraea annularis complex	•	•
Montastraea cavernosa	•	•
Mycetophyllia aliciae	•	•
Oculina diffusa		•
Phyllangia americana	•	
Porites astreoides	•	•
Porites porites	•	•

Species List	SECREMP Miami–Dade Sites	This Study
Scolymia cubensis	●	●
Siderastrea radians		●
Siderastrea siderea	●	●
Solenastrea bournoni	●	●
Stephanocoenia intersepta	●	●

Nearshore Hardbottom Comparisons
Nearshore hardbottom sites included a total of 14 species of scleractinian corals, typical of nearshore habitats. A total of 10 octocoral genera were documented within the nearshore hardbottom sites. These sites were dominated by octocorals (6.6–13.9 ind/m^2), with a much smaller contribution to benthic cover by scleractinian corals (0.2–2.3 ind/m^2). ANOVA detected a significantly lower density of scleractinians and octocorals (ind/m^2) at HBS compared to densities at the three other sites (HBSC, HBN, HBNC). ANOVA results also indicated that the three other sites were not significantly different from each other.

A veneer of fine sediment was noted at all sites within the nearshore hardbottom and visibility was lower 3–6 m (10–20 feet) when compared to the second and third reefs 6–9 m (20–30 feet). The deposition of fine sediments was noted to be higher at the northern sites than at the southern sites. Littoral transport moves water and sediments north to south along the east coast of Florida; the lower amount of deposited sediment noted at southern sites may be due to flushing provided by the existing channel, which would move sediments out of the nearshore area before they can be deposited on the substratum on the south side of the channel. Higher turbidity was associated with an outgoing tide, and no north–south difference in turbidity was noted.

Second Reef Comparisons
Second reef indirect-effect sites had a maximum richness of 14 scleractinian species and 11 octocoral genera. Second reef indirect-effect sites were dominated by comparable densities of sponges and octocorals (4–10 ind/m^2 for both groups) and a much lower density scleractinian coral population (1.4–2.2 ind/m^2). In this way, second reef sites were similar to nearshore hardbottom sites, although sponges were not surveyed at nearshore hardbottom sites. The five most abundant scleractinians at second reef sites were the same as nearshore hardbottom sites, with the exception of *Montastrea cavernosa*. *Siderastrea radians* was by far the dominant coral at these sites (60% of all scleractinians at R2N and 70% of all scleractinians at R2S). Size-class data comparisons revealed that most scleractinian colonies were smaller than 10 cm.

Colony density regression results for second reef sites showed differing patterns for north and south sites. R2N showed a decrease in scleractinian and sponge density with distance from the channel, although neither change was significant at the 0.05 level. At R2S scleractinian density increased with distance from the channel, and this relationship was significant (P = 0.036); sponge and octocoral relationships were non-significant, but generally increased with distance from the channel.

Scleractinians affected by one or more conditions (e.g. bleaching, fish bites, and partial mortality) were 2–5% of the total colonies at second reef sites, which was lower than the percentage of colonies affected at third reef sites (11–19%). Regression results revealed no significant relationship between colonies affected by a condition and distance from the channel at second reef sites.

Third Reef Comparisons

Third reef sites had a maximum richness of 19 scleractinian species, and 9 octocoral genera. Sponge density ranged from 4.8–4.5 ind/m^2 across third reefs sites, similar to density ranges at second reef sites. Scleractinians and octocorals were lower in density, (0.7–2.7 ind/m^2 and 0.8–3 ind/m^2) when compared to second reef sites. Scleractinians were similarly low across nearshore hardbottom, second and third reef sites. Size-class data comparisons revealed that most scleractinian colonies were smaller than 10 cm.

Third reef colony density regression results showed variable patterns across indirect sites. Direct-effect sites were not included in regression analysis. Generally, scleractinian colony density increased with distance from the channel, these results were significant ($P < 0.05$) at 3 out of 4 sites. Octocoral and sponge density also increased or did not change with distance from the channel; these results were significant ($P < 0.05$) for 5 out of 8 regressions.

Scleractinians affected by one or more conditions (e.g. bleaching, fish bites, and partial mortality) ranged between 11 and 19% at third reef indirect-effect sites, higher than those found at second reef indirect-effect sites. Six percent of scleractinian colonies were affected by a condition at third reef direct-effect sites. Partial mortality was the predominant condition documented across sites. Few regression results were significant for condition related to distance from the channel. At R3S3 a significant positive relationship ($P < 0.05$) existed between condition and distance from the channel, this was due to the bleaching results at this site, which were also significantly and positively related to distance from the channel ($P < 0.05$). R3S2 also had significantly positive relationship with distance from the channel in the fish bite category, but this was not documented at any other site.

Third reef direct-effect sites were characterized by similar densities of scleractinians, octocorals and sponges as other third reef sites. Size-class data comparisons revealed that most scleractinian colonies were smaller than 10 cm. Habitat relief, while still relatively low, was higher at direct-effect sites compared to indirect-effect sites (0.11 versus 0.07). The increased relief at direct-effect sites may be a result of previous dredging efforts. Interestingly, third reef direct-effect sites had a higher number of scleractinian species than other third reef sites (19 compared to 13), which may be explained by the greater sampling area.

Summary

In summary, nearshore hardbottom, second and third reef sites, which are within 500 meters of the Miami entrance channel, are colonized by sponges, octocorals and scleractinian corals, in decreasing order of abundance. Octocorals are more predominant in nearshore hardbottom and second reef areas, whereas sponges are similarly abundant on second and third reefs. Sponge data were not collected for nearshore hardbottom sites, so their dominance at these sites is not known. Scleractinians are low in abundance across nearshore hardbottom, second and third reefs. These reefs have little relief or rugosity; and the areas of highest relief lie adjacent to the channel or occur in isolated pockets. Typical subtropical macroalgae, including *Dictyota*, cyanobacteria, and turf algae, were common, although not quantified during this study. *Diadema antillarum* were extremely rare, with only two individuals counted across 90 transects at second and third reef sites.

ANOVA results for nearshore hardbottom sites showed that scleractinian and octocoral density were significantly lower at HBS compared to HBSC, HBN, and HBNC. There were no significant differences between any of the other sites.

Linear regression results for second and third reef octocoral, scleractinian and sponge density per square meter were mixed, although most relationships were positive, with density increasing with distance from the channel. Half the regressions performed were significantly positive in relation to distance from the channel. Regressions of scleractinian colony condition with distance were only significant for fish bites and bleaching at a single site.

Together, the ANOVA and regression analyses of octocorals, scleractinian and sponge data serve as a statistically quantified baseline for nearshore hardbottom, second and third reef areas adjacent to the Port of Miami entrance channel project. These data may be used for comparison purposes with post-construction surveys to document any impacts of dredging on these communities.

5.0 LITERATURE CITED

Banks, K.W., B.M. Riegl, E.A. Shinn, W.E. Piller, and R.E. Dodge. 2007. Geomorphology of the southeast Florida continental reef tract (Miami–Dade, Broward, and Palm Beach Counties, USA). Coral Reefs (2007) 26:617-633.

Bruckner, A.W. 2001. Coral health and mortality: Recognizing signs of coral diseases and predators. In: Humann and Deloach (eds.), Reef Coral Identification. Jacksonville, FL: Florida Caribbean Bahamas New World Publications, Inc. pp. 240-271.

Cantillo, A. Y., Hale, K., Collins, E., Pikula, L. and Caballero, R. 2000. Biscayne Bay: Environmental History and Annotated Bibliography. NOAA Technical Memorandum NOS NCCOS CCMA 145. Silver Spring, Maryland, Pp. 128.

Dial Cordy and Associates, Inc. 2010. Miami Harbor Hardbottom Assessment Pilot Study and Quantitative Study Plan, Technical Memorandum. U.S. Army Corps of Engineers, Jacksonville District. Pp.15.

Dial Cordy and Associates, Inc. 2009. Benthic and Fish Community Assessment at Port Everglades Harbor Entrance Channel. U.S. Army Corps of Engineers, Jacksonville District. Pp. 65.

Gilliam, D.S. 2010. Southeast Florida Coral Reef Evaluation and Monitoring Project 2009 Year 7 Final Report. Florida DEP report #RM085. Miami Beach, FL. Pp. 42.

Gilliam, D.S. 2007. Southeast Florida Coral Reef Evaluation and Monitoring Project 2006 Year 4 Final Report. Prepared for: Florida Fish and Wildlife Conservation Commission, Fish & Wildlife Research Institute, Florida Department of Environmental Protection. Pp. 31.

Gilliam, D.S., R.E. Dodge, R.E. Spieler, L.K.B. Jordan, and J.C. Walczak. 2006. Marine Biological Monitoring in Broward County, Florida: Year 6 Annual Report. Technical Report DPEP 04-01. Ft. Lauderdale, Florida: Broward County, Board of County Commissioners.

Gilliam, D.S., R.E. Dodge, R.E. Spieler, L.K.B. Jordan, and J.A. Monty. 2004. Marine Biological Monitoring in Broward County, Florida: Year 4 Annual Report. Technical Report DPEP 04-01. Ft. Lauderdale, Florida: Broward County, Board of County Commissioners.

Kohler, K.E. and S.M Gill. 2006. Coral point count with excel extensions (CPCe): A visual basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32: 1259-1269.

Moyer, R.P., B. Riegl, K. Banks, and R.E. Dodge. 2003. Spatial patterns and ecology of benthic communities on a high-latitude South Florida (Broward County, USA) reef system. Coral Reefs 22(4):447-464.

Port of Miami website. www.**miami**dade.gov/**portofmiami**/ Accessed February 10, 2011.

Walker, B.K. 2009. Benthic Habitat Mapping of Miami–Dade County: Visual Interpretation of LADS Bathymetry and Aerial Photography. Florida DEP Report #RM069. Miami Beach, FL. Pp. 47.

Walker, B.K., B. Riegl, and R.E. Dodge. 2008. Mapping coral reef habitats in southeast Florida using a combined technique approach. Journal of Coastal Research 24**:** 1138-1150.

APPENDIX A

Raw Data

(on attached CD)

APPENDIX B

Photographs

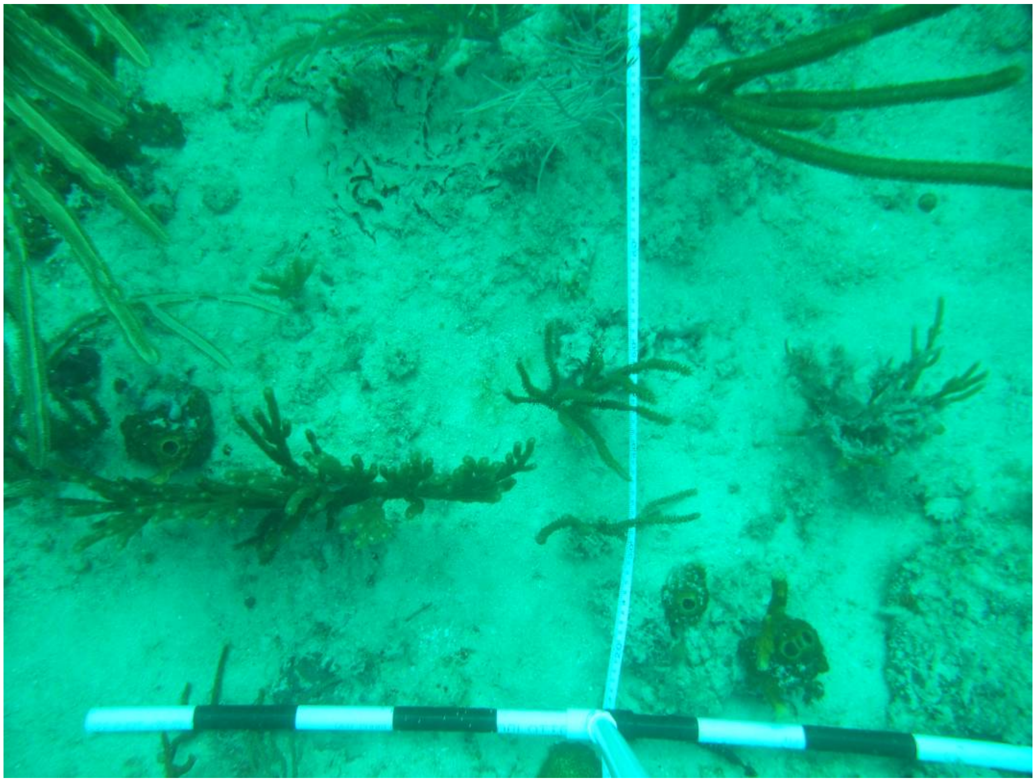

Photo 1. Representative photo of octocorals and sponges at HBNC, Transect 4.

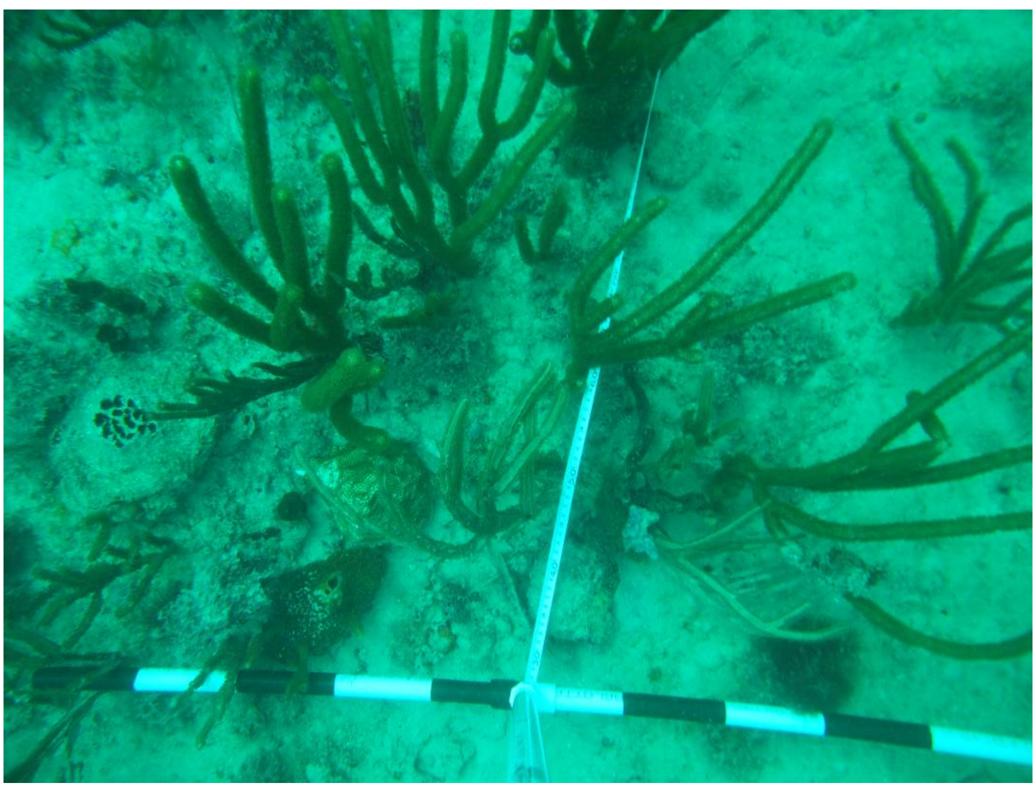

Photo 2. Representative photo of octocorals at HBNC, Transect 6.

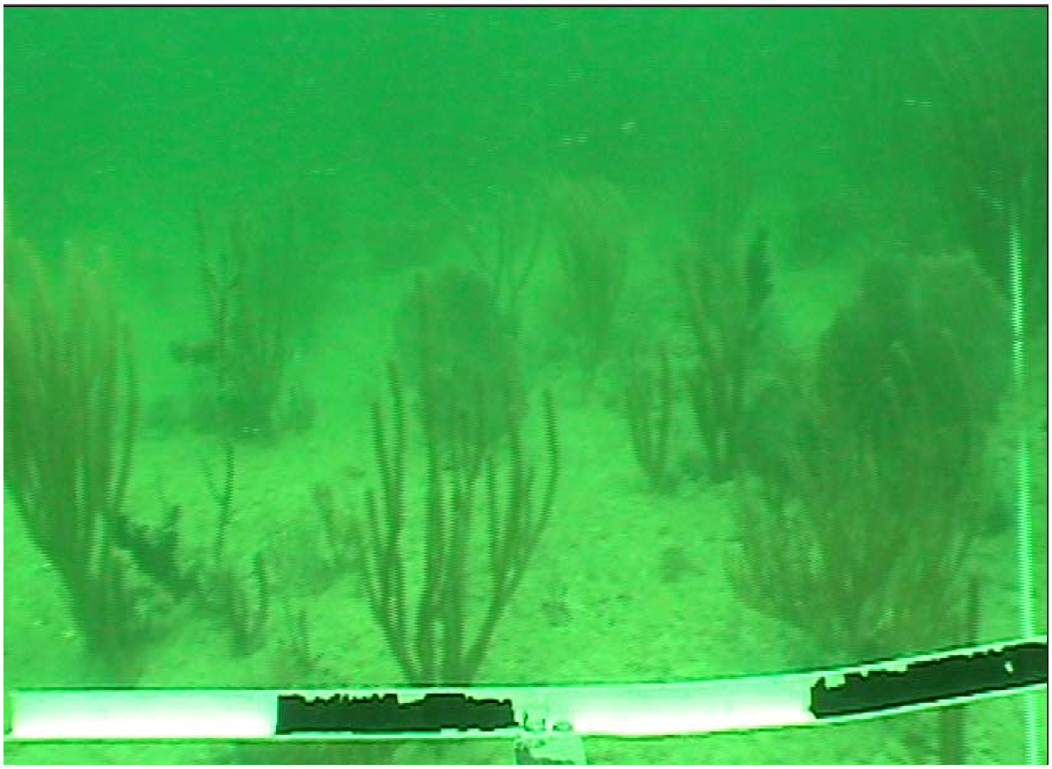

Photo 3. Representative landscape photo at HBN, Transect 4.

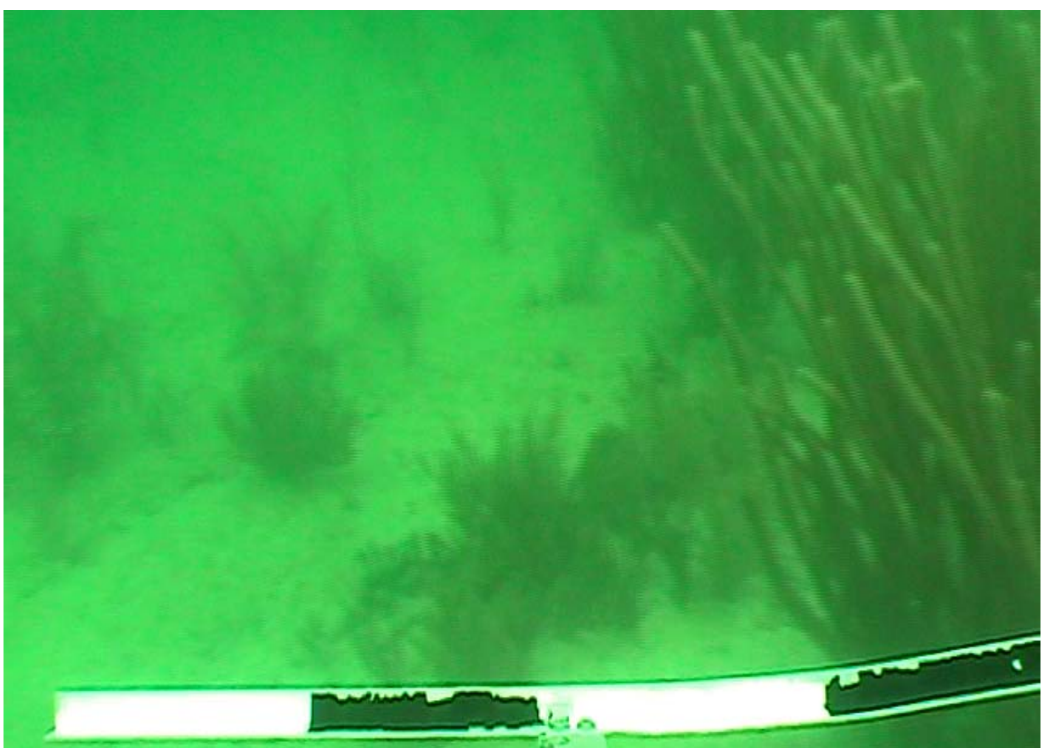

Photo 4. Representative photo at HBN, Transect 18.

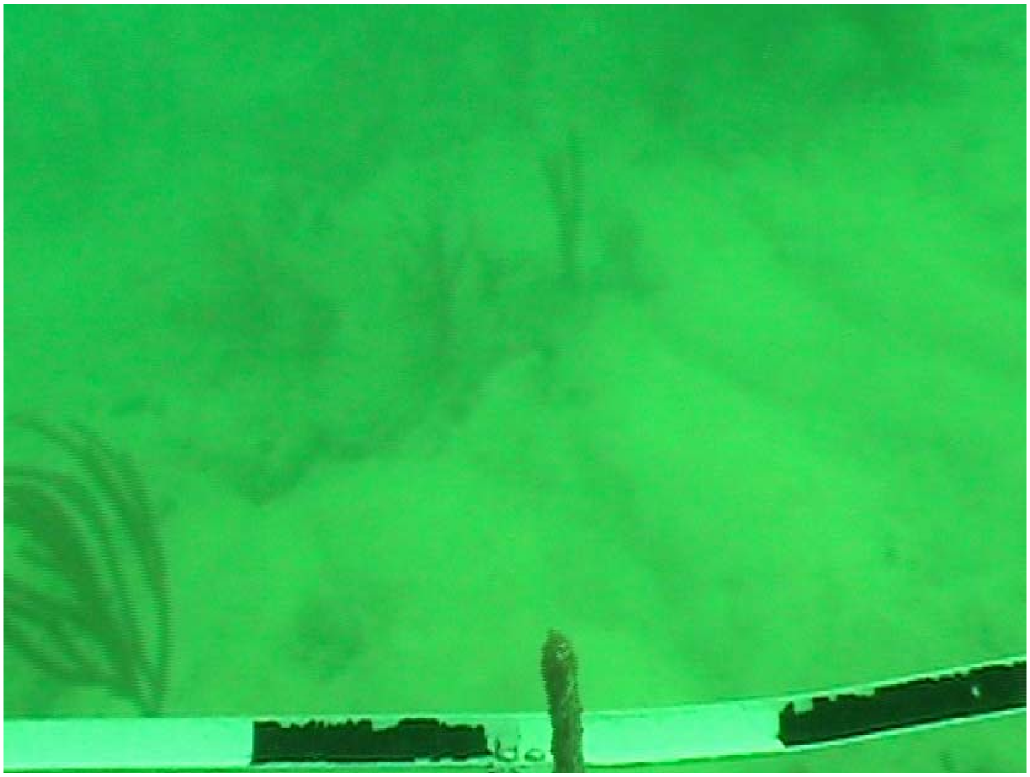

Photo 5. Representative photo at HBS, Transect 2.

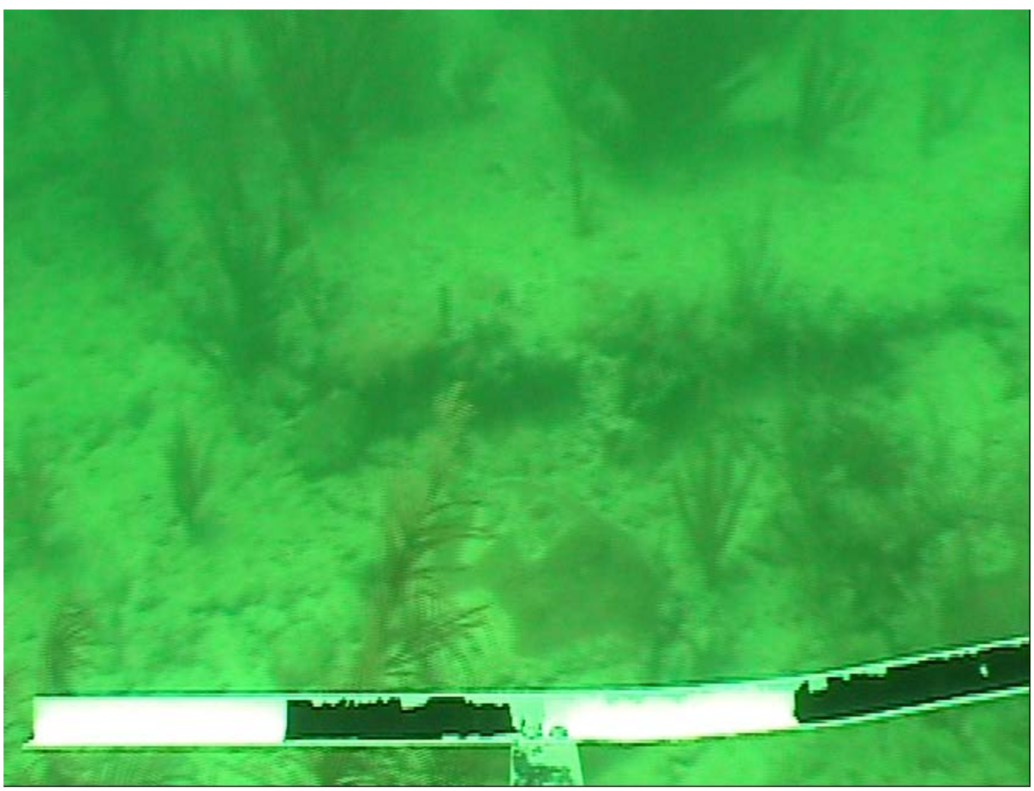

Photo 6. Representative photo at HBS, Transect 12.

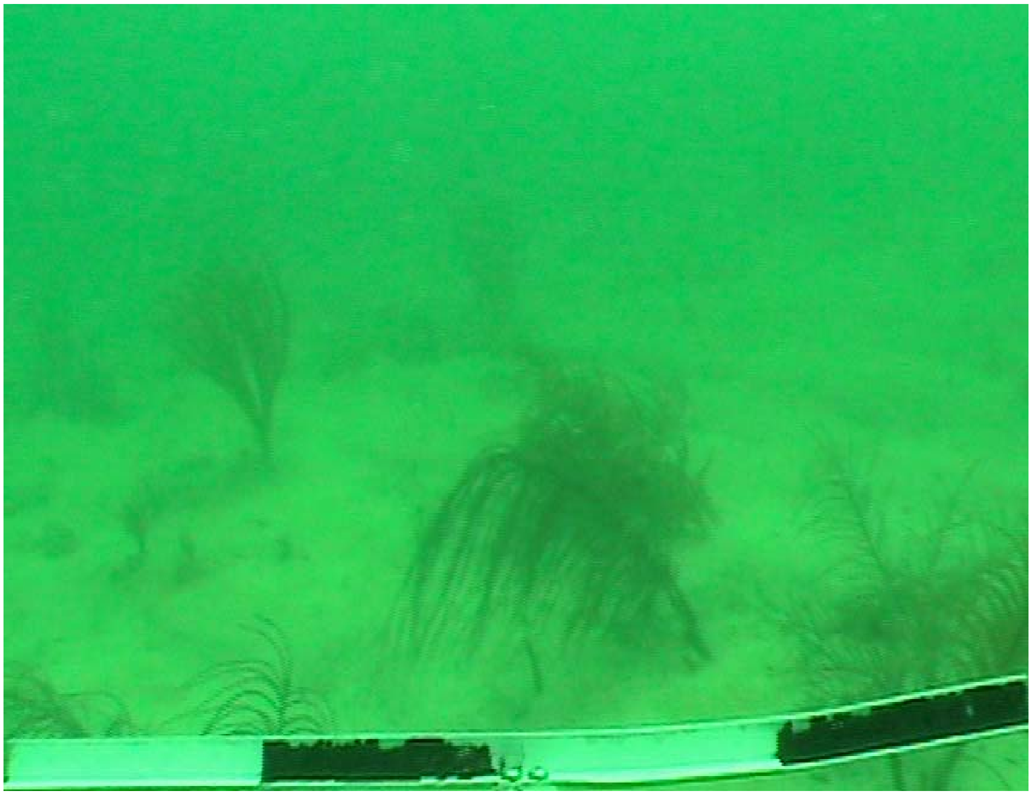

Photo 7. Representative photo at HBSC, Transect 1.

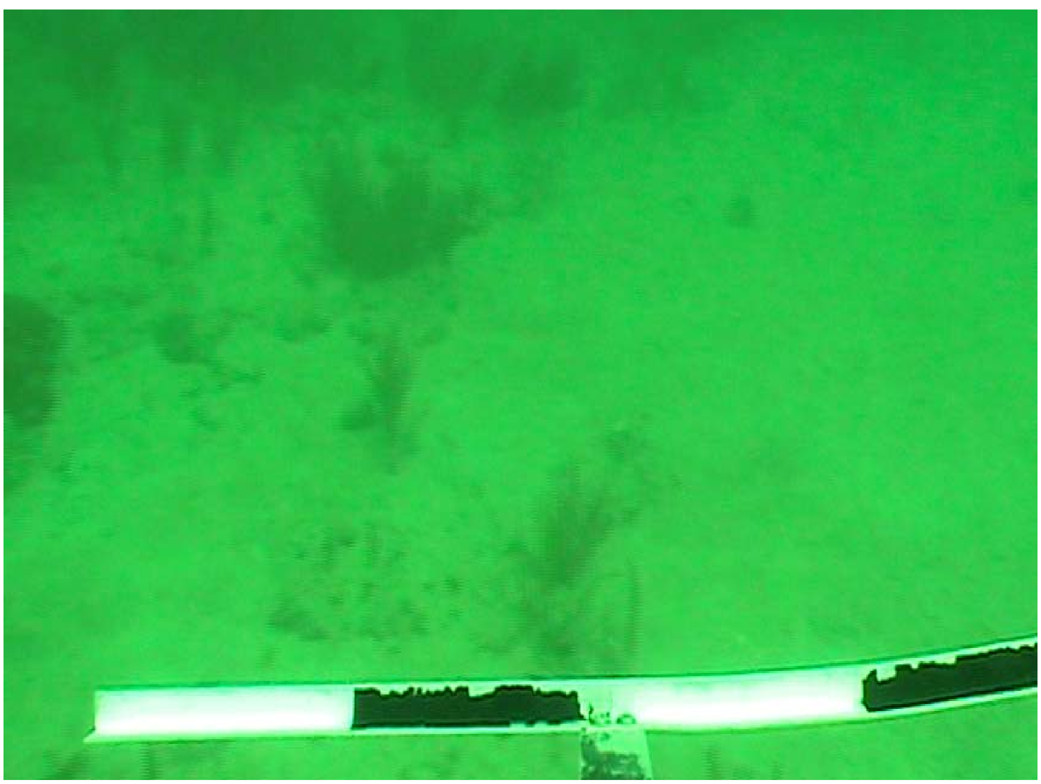

Photo 8. Representative photo at HBSC, Transect 14.

Photo 9. Representative landscape photo at R2N, Transect 10.

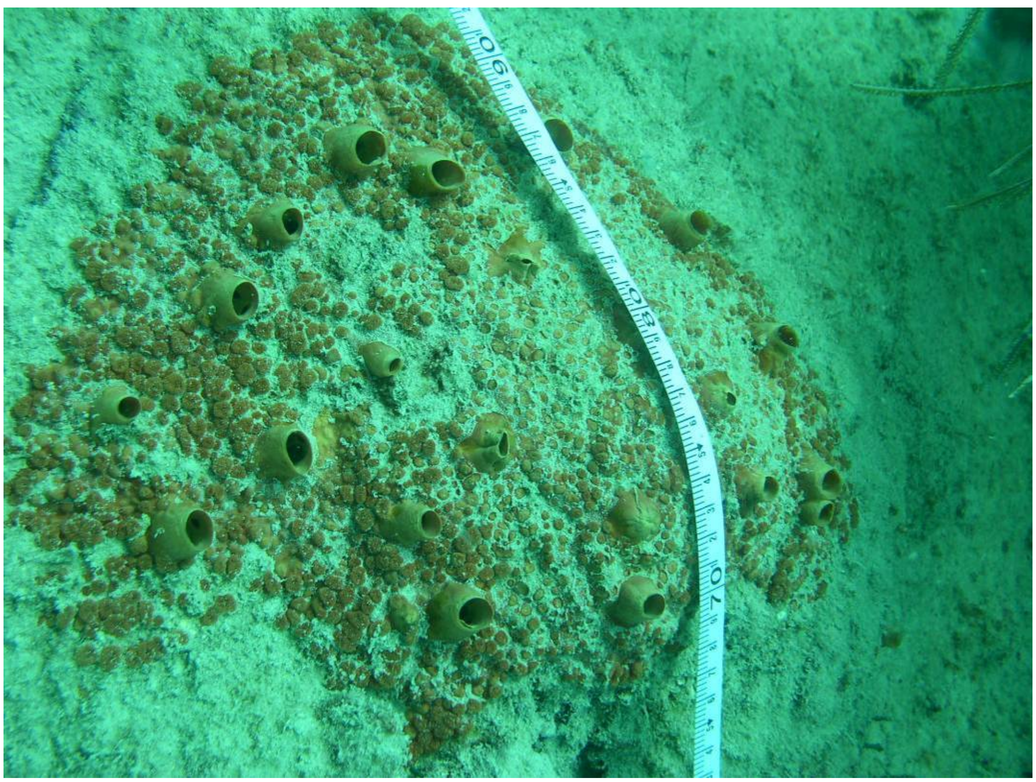

Photo 10. Representative photo *Cliona delitrix* (boring sponge) at R2N, Transect-20.

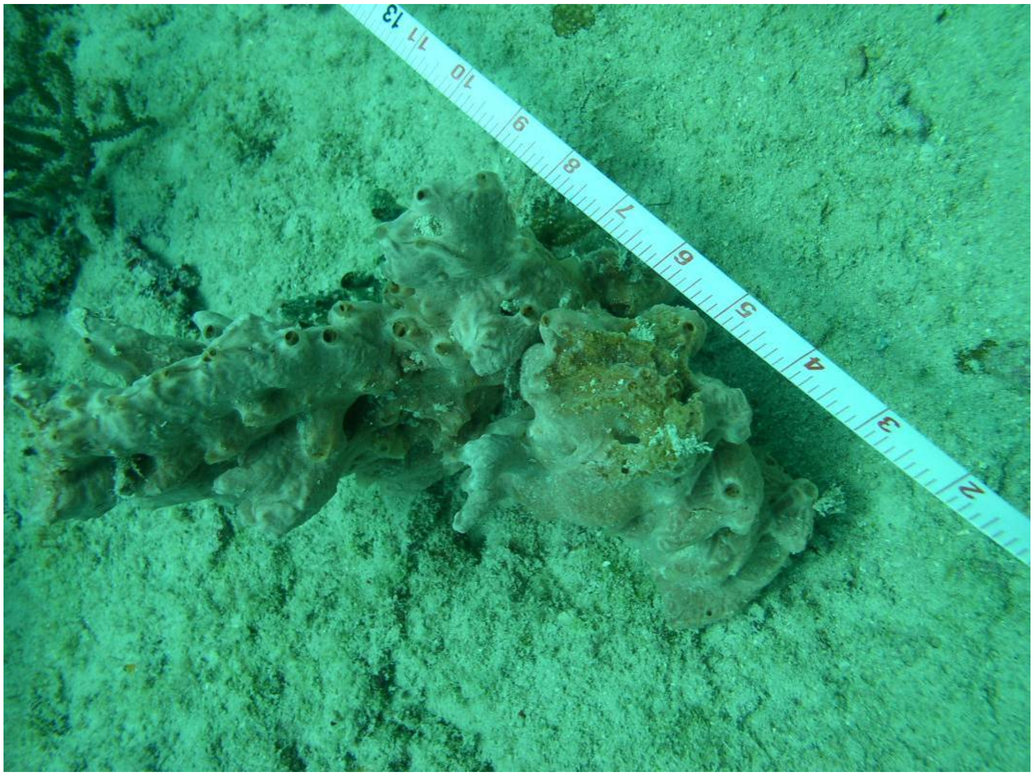

Photo 11. Representative photo of sponge at R2N, Transect-40.

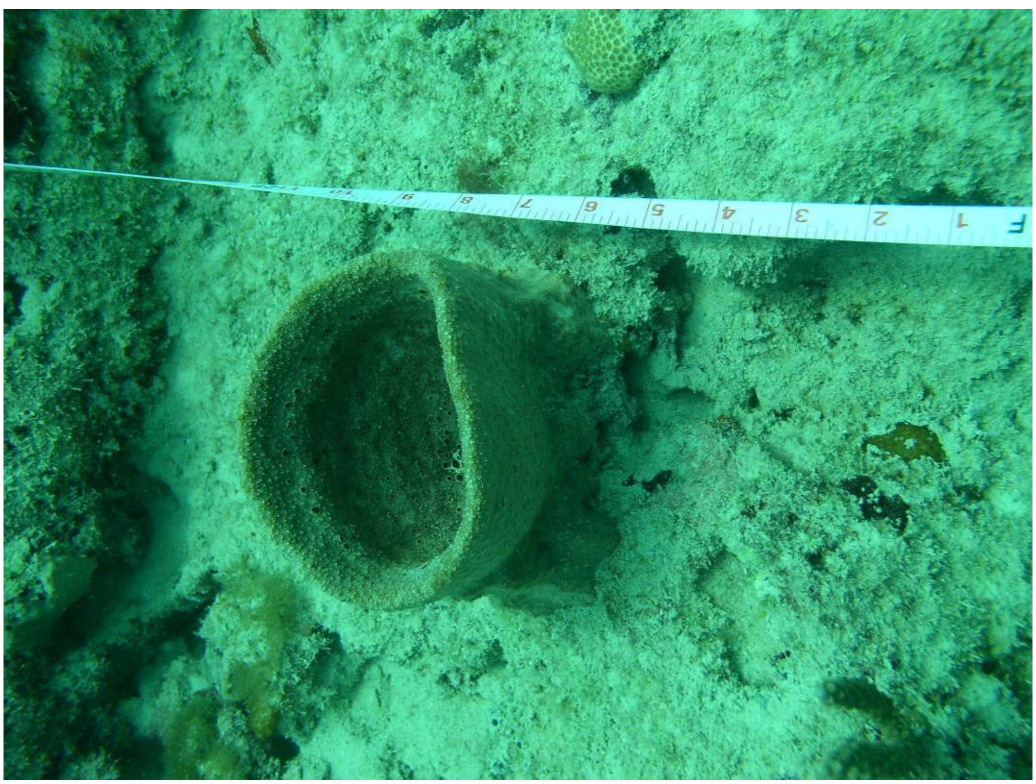

Photo 12. Representative photo of vase sponge at R2N, Transect-50.

Photo 13. Representative photo of *Montastraea cavernosa* at R2S, Transect-30.

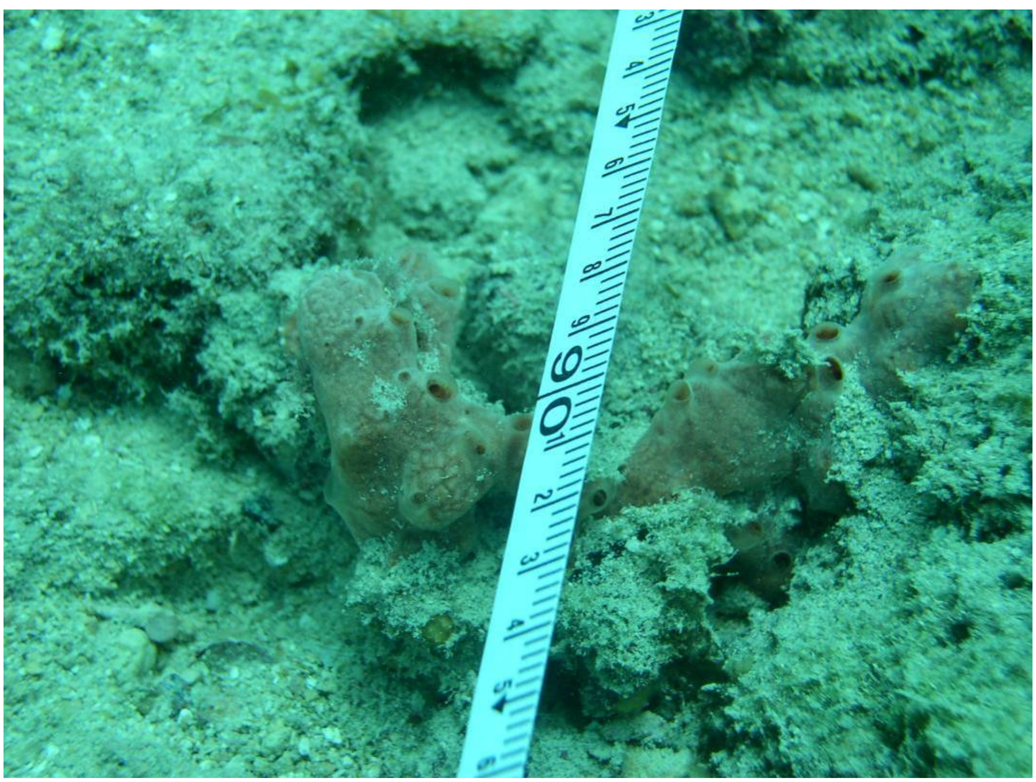

Photo 14. Representative photo of encrusting sponge at R2S, Transect-40.

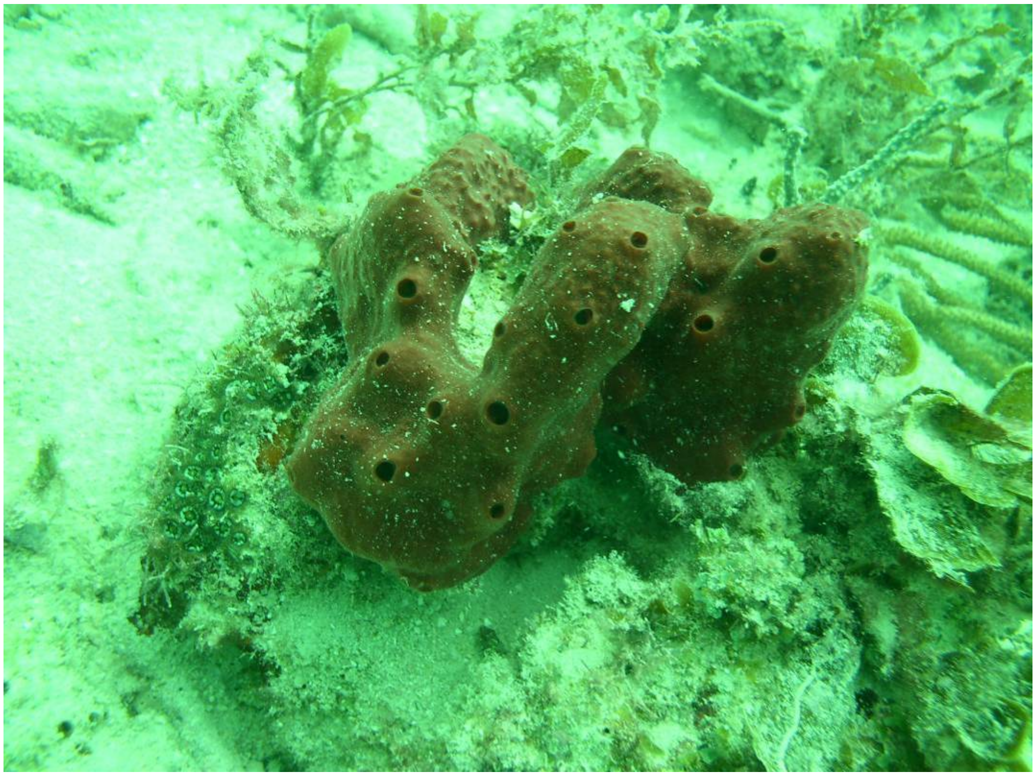

Photo 15. Representative photo of encrusting sponge at R2S, Transect 100.

Photo 16. Representative landscape photo at R2S, Transect 300.

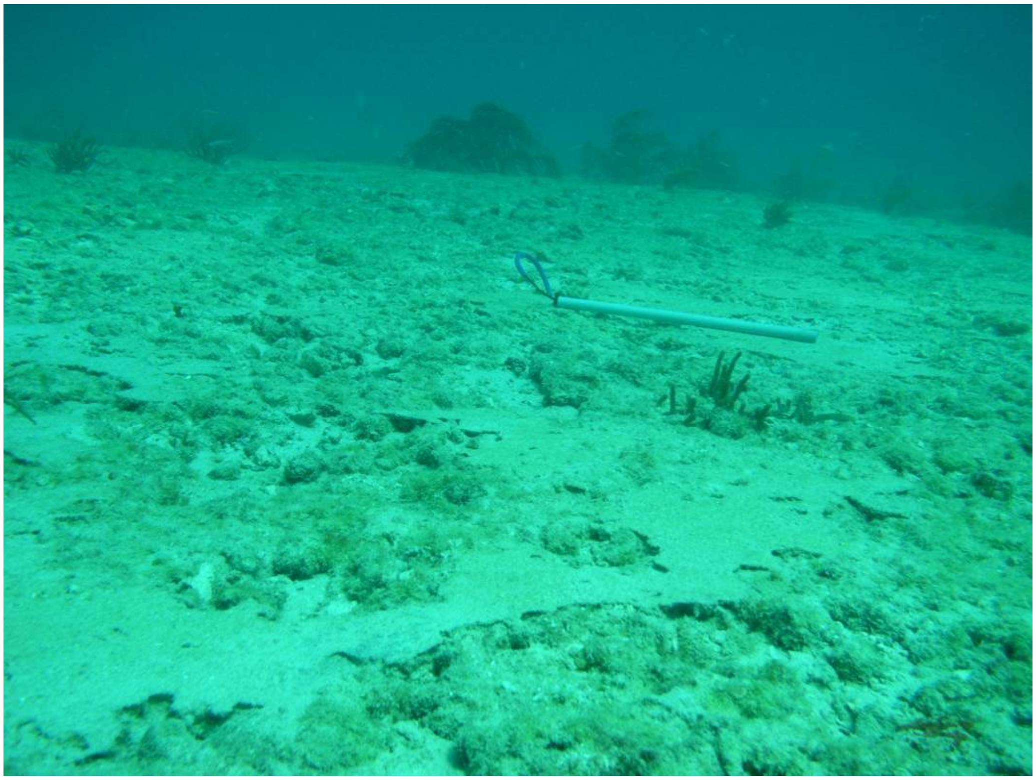

Photo 17. Representative landscape photo at R3N, Transect 20.

Photo 18. Representative landscape photo at R3N, Transect 80.

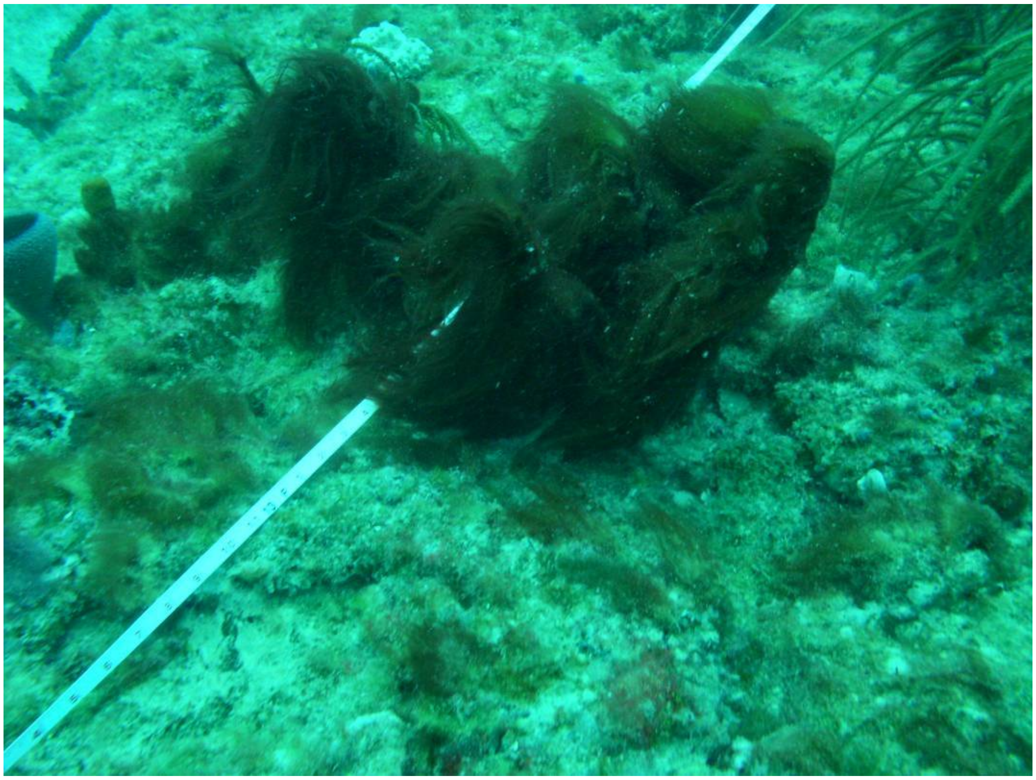

Photo 19. Representative photo of cyanobacteria (*Lyngbya*) at R3N, Transect 300.

Photo 20. Representative photo of *Montastrea cavernosa* at R3N, Transect 300.

Photo 21. Representative landscape photo at R3S1, Transect 60.

Photo 22. Representative landscape photo at R3S1, Transect 100.

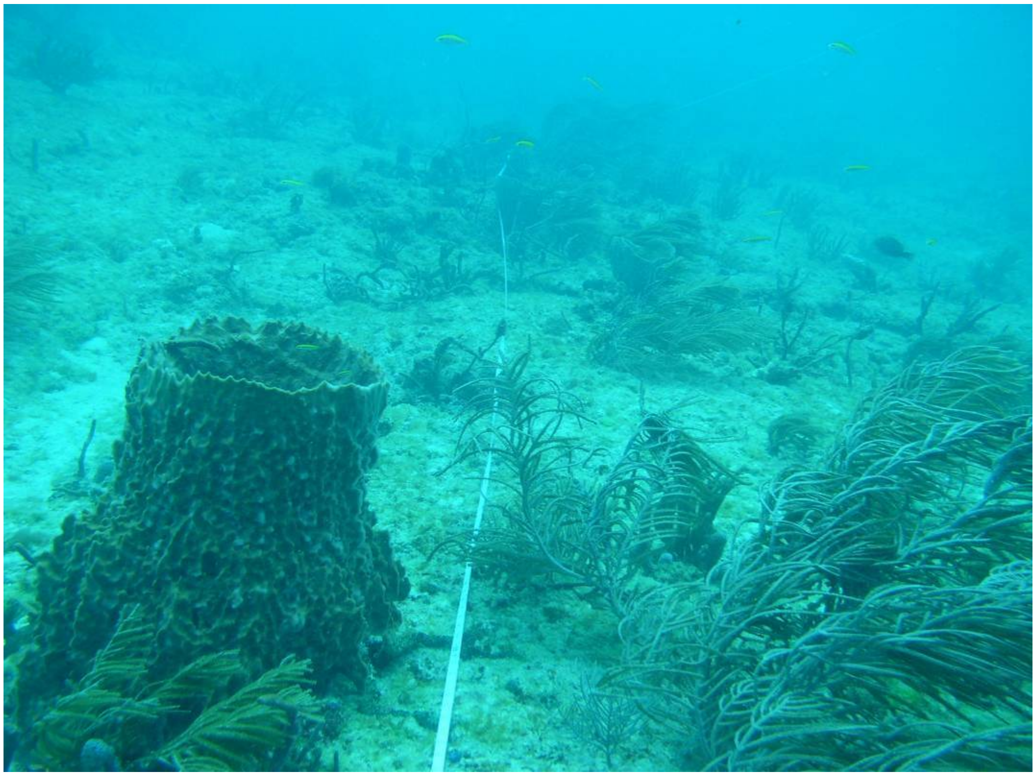

Photo 23. Representative landscape photo at R3S1, Transect 300.

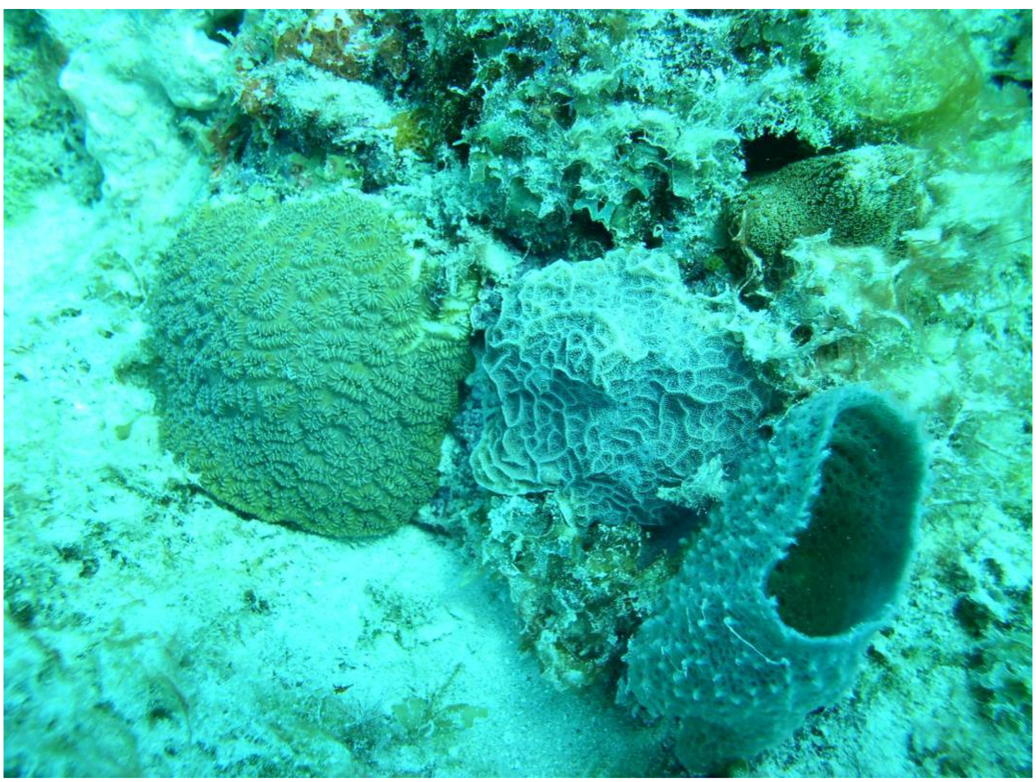

Photo 24. Representative photo of hard coral and sponge assemblage at R3S1, Transect 400.

Photo 25. Representative photo of substrate at R3S2, Transect 30.

Photo 26. Representative landscape photo at R3S2, Transect 50.

Photo 27. Representative landscape photo at R3S2, Transect 150.

Photo 28. Representative photo of tube sponge at R3S2, Transect 300.

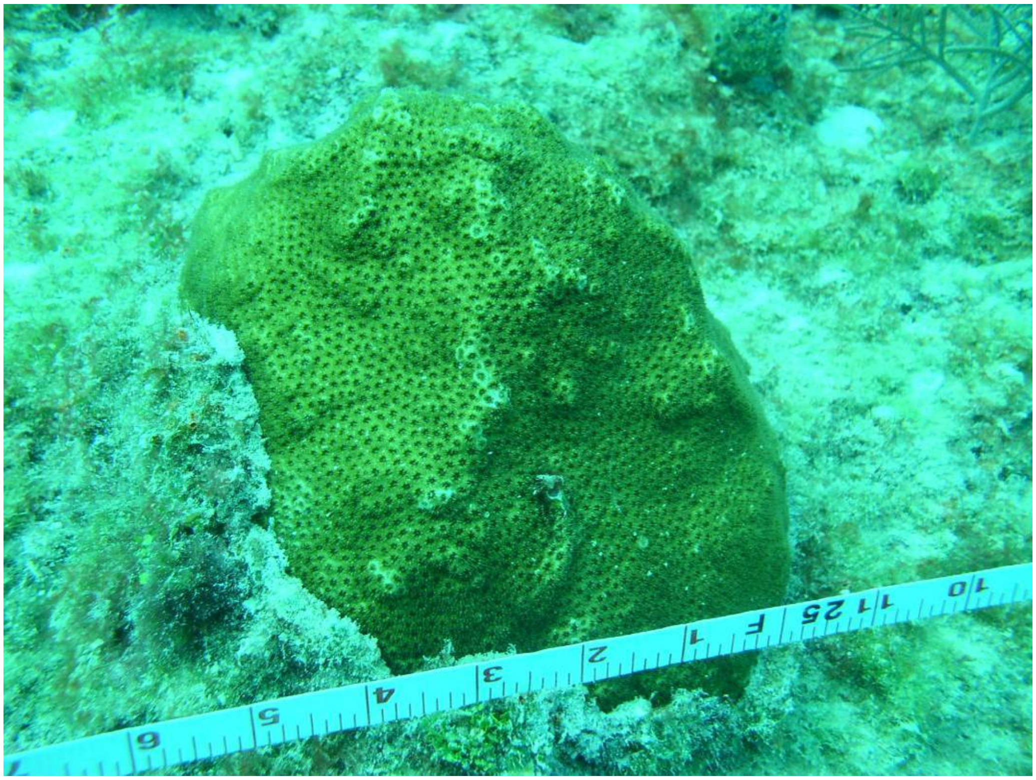

Photo 29. Representative photo of *Solenastrea bournoni* at R3S3, Transect 20.

Photo 30. Representative landscape photo at R3S3, Transect 30.

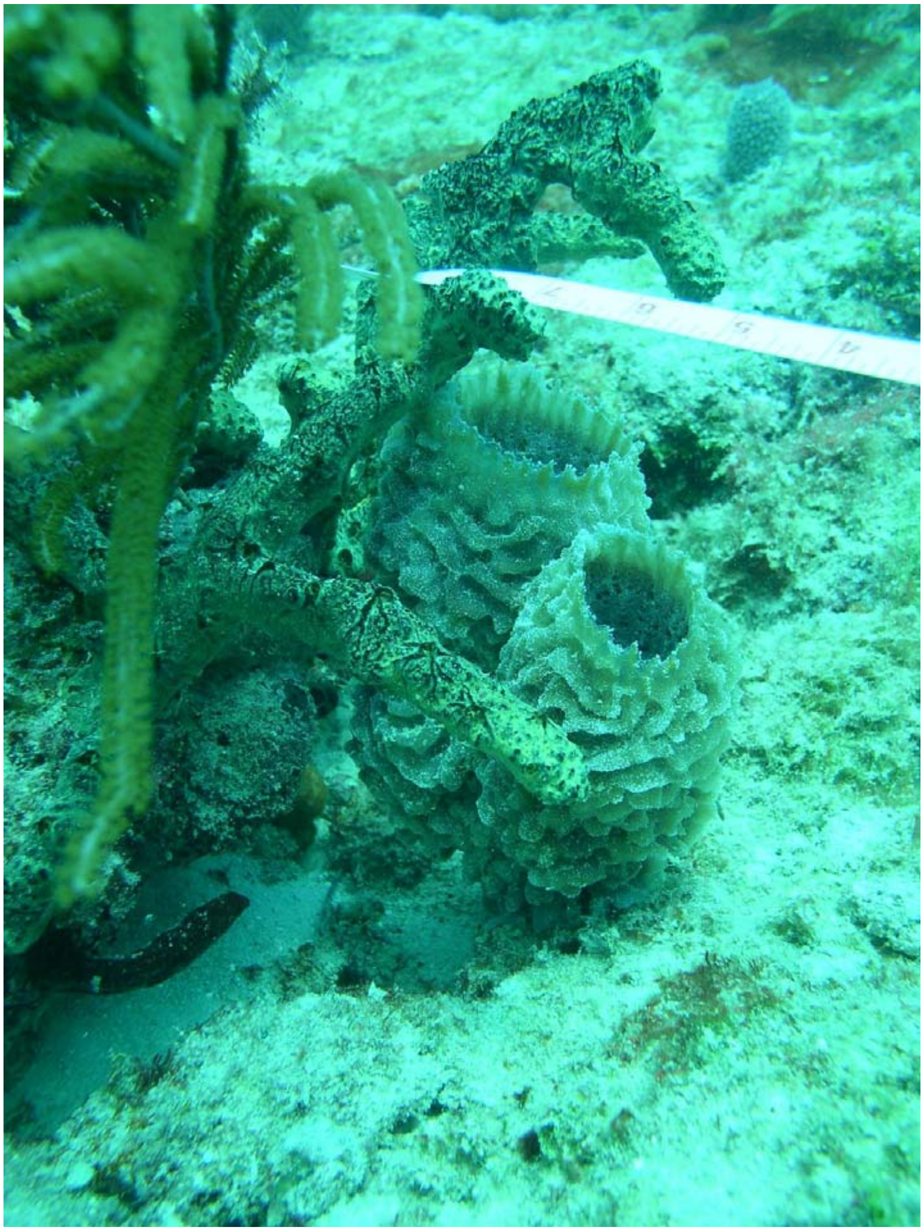

Photo 31. Representative photo of sponges at R3S3, Transect 90.

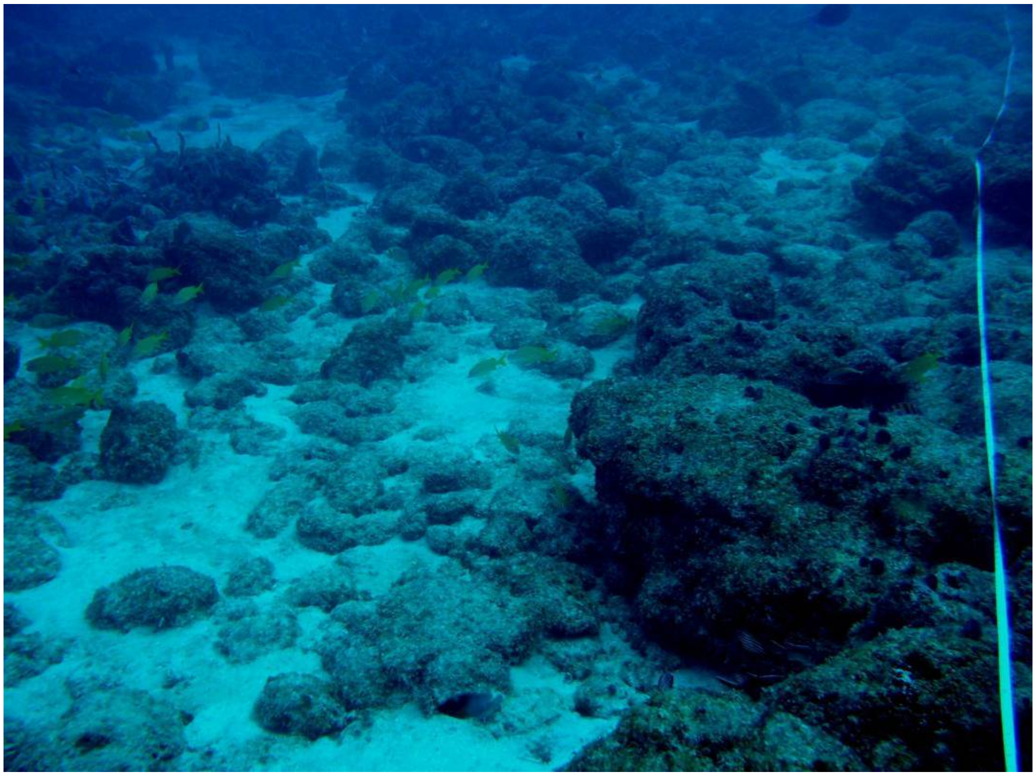

Photo 32. Representative landscape photo at R3DS, Transect 1.

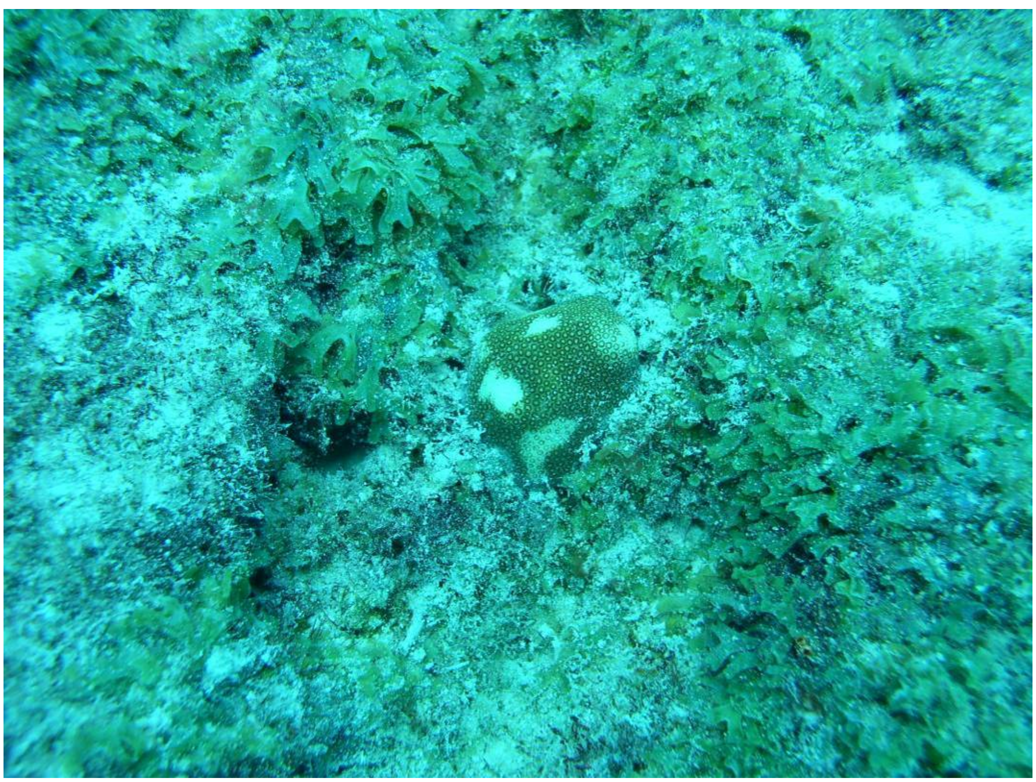

Photo 33. Representative photo of coral with fish bites at R3DS, Transect 4.

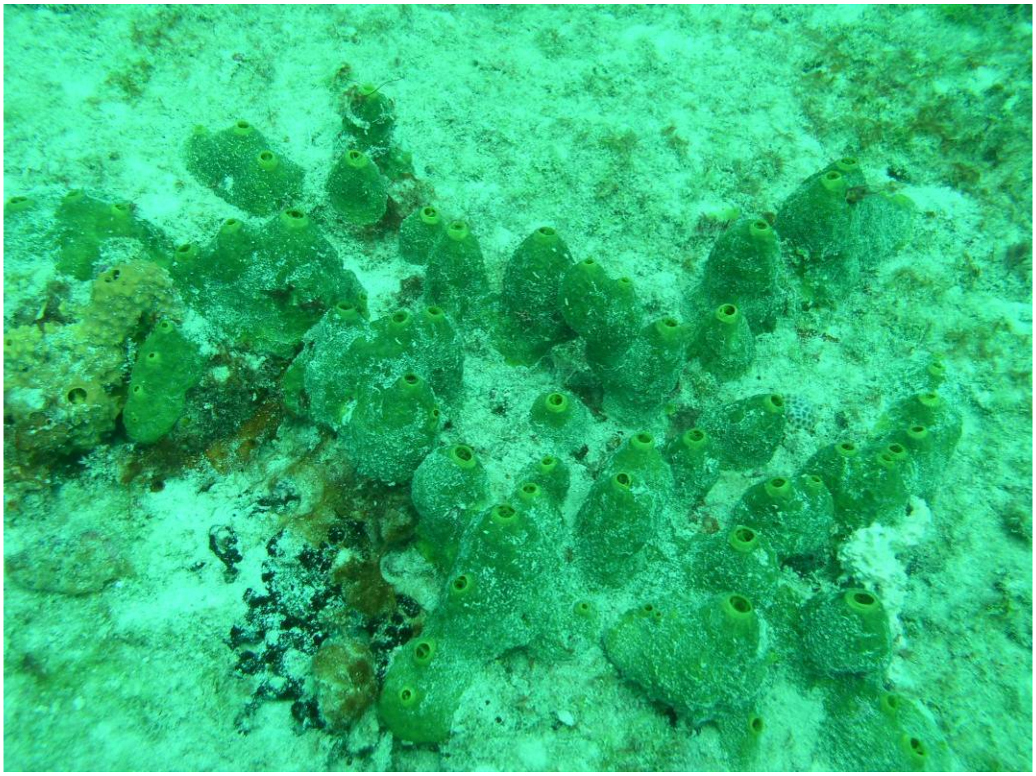

Photo 34. Representative photo of tube sponge at R3DS, Transect 10.

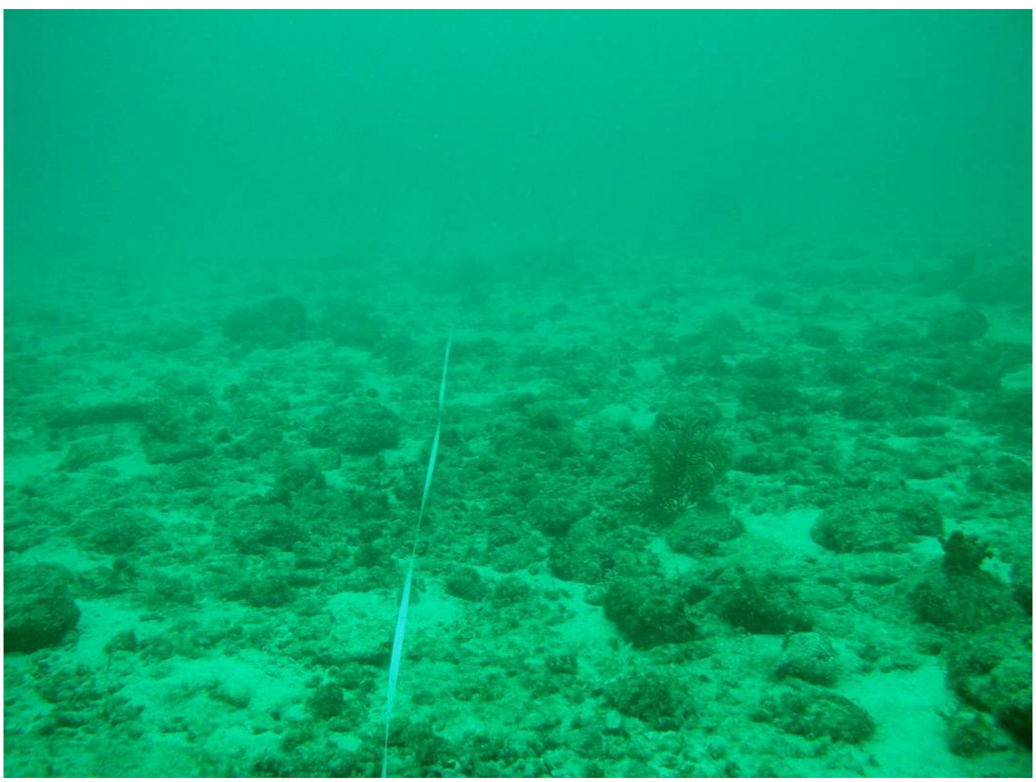

Photo 35. Representative landscape photo at R3DS, Transect 11.

Photo 36. Representative photo of substrate at R3DN, Transect 4.

Photo 37. Representative photo of substrate at R3DN, Transect 7.

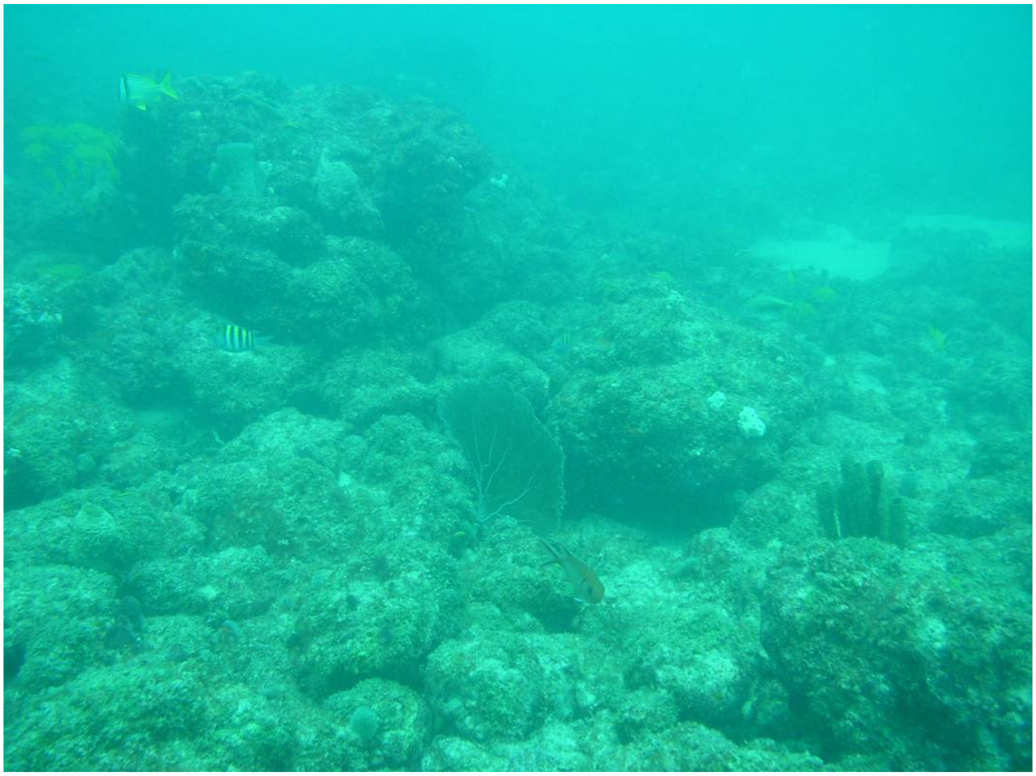

Photo 38. Representative landscape photo at R3DN, Transect 11.

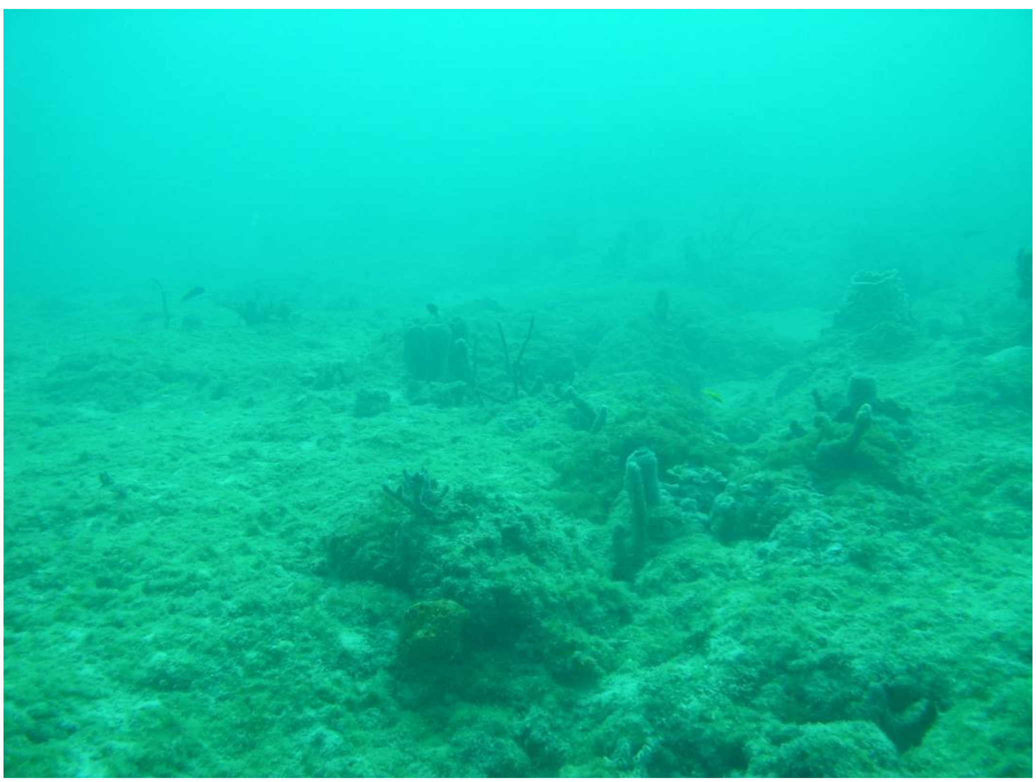

Photo 39. Representative landscape photo at R3DN, Transect 14.