Nearshore Artificial Reef Monitoring Report

April 2005

Prepared for:
Palm Beach County Department of Environmental Resources Management
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West Palm Beach, Florida 33406

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Under Subcontract to:
Coastal Planning & Engineering, Inc.
2481 NW Boca Raton Boulevard
Boca Raton, Florida 33431

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Cover Photograph: Breakers Reef, Palm Beach, FL
by David Snyder.

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EXECUTIVE SUMMARY

This report updates the ongoing monitoring of epibiotal and fish assemblages on artificial mitigation reefs deployed along the coast of Palm Beach County, Florida. Since 2001, Continental Shelf Associates, Inc. has completed annual monitoring surveys consisting of three field sampling events per survey period. These three surveys may be described as follows:

- Survey 1 - August 2001, April 2002, and July 2002;
- Survey 2 - April 2003, October 2003, and December 2003; and
- Survey 3 - February 2004, July 2004, and August 2004.

The surveys were conducted at the following natural hard bottom and artificial reef locations:

Natural Locations

- Breakers Reef (Surveys 1 and 2);
- MacArthur Beach State Park (Survey 3); and
- Coral Cove Park (Surveys 1, 2, and 3).

Artificial Locations

- Juno Geogrid Mitigation (Surveys 1, 2, and 3);
- Jupiter Cloth Reef Rock Mitigation (Surveys 1, 2, and 3);
- Jupiter Concrete Mitigation (Survey 1);
- Jupiter Shallow Concrete Mitigation (Survey 1); and
- Coral Cove Rock Mitigation (Survey 3).

The overall goal of the mitigation reefs is to replicate as best as possible the assemblage structure of fishes and epibiota found on local nearshore hard bottom. As with the other surveys, specific research questions investigated were as follows:

- Do fish and invertebrate species inhabiting natural nearshore hard bottom habitats (<12 ft [<3.7 m]) represent distinct assemblages compared to artificial hard bottom habitats in deeper (12 to 24 ft [3.7 to 7.3 m]) National Geodetic Vertical Datum (NGVD)?
- Do natural hard bottom habitats in water depths <12 ft (<3.7 m) NGVD support disproportionate numbers of juvenile fishes as compared to artificial hard bottom habitats in water depths ranging from 12 to 24 ft (3.7 to 7.3 m) NGVD?
- What are the specific habitat preferences of newly settled fishes?

To address these questions, fish and epibiotal assemblages associated with artificial mitigation reefs were monitored and compared with natural hard bottom areas in slightly deeper water depths. Fish data were collected using visual census techniques, whereas epibiota found on the artificial and natural substrates were assessed with quantitative photographic sampling methods. The first question was addressed by examining basic assemblage attributes for fishes (relative abundance, frequency of occurrence, species richness, and species composition) and epibiota (percent cover and taxonomic composition) on mitigation and natural reefs. The second question was answered by examining abundance, frequency, and composition of species by life stage categories (adult, juvenile, and newly settled) on artificial and natural reefs. The third question was addressed by analyzing habitat use by newly settled fishes on mitigation and natural hard bottom. Microhabitats chosen by newly settled fishes were compared with sites selected at random on artificial reef and natural hard bottom sites.

Fish assemblages observed on natural nearshore hard bottom locations were distinct from those on artificial reefs in slightly deeper waters. The observed differences reflected individual species distribution patterns that were quantitative and qualitative in nature. Quantitative differences between samples were subtle, involving only variation in relative abundance of common species such as tomtate, porkfish, newly settled grunts, silver porgy, and cocoa damselfish. As for qualitative differences, some species such as striped croaker, pigfish, and pinfish were only observed on artificial reefs. Variation in observed fish assemblages is due not only to individual species movements, recruitment, and mortality, but also to sampling error inherent in visual censusing methods.

Epibiotal assemblages recorded on natural nearshore hard bottom locations were also distinct from those on artificial reefs in slightly deeper waters. These differences were most pronounced during Surveys 1 and 2, when sampling included the Breakers Reef. Breakers Reef supported a mature and diverse epibiotal assemblage, including hard corals, soft corals, sponges, and ascidians not found on nearshore hard bottom or artificial reefs. For this reason, Breakers Reef was dropped as a reference location, and MacArthur Beach was added—to have a reference location more representative of natural nearshore hard bottom. During Survey 3, the differences between artificial and natural samples were less pronounced than during the first two surveys, when Breakers Reef samples were included. Epibiota of natural hard bottom is very dynamic, showing considerable variation among surveys. Taxa, including macroalgae and worm rock, are ephemeral, reaching high values during certain seasons and being totally absent during others. This reflects the physically dynamic nature of the nearshore environment and the colonizing abilities of the epibiota. Here the difference in water depth between artificial reefs and natural hard bottom would affect the disturbance regime (burial and uncovery of hard bottom), light penetration, water motion, and other factors important to epibiotal growth and survival. Differences in these factors would be expected to influence the succesional trajectories and ultimately assemblage structure of the epibiota.

Visual census data of fish life stage abundances indicated that natural hard bottom habitats do not support disproportionate numbers of juvenile fishes as compared to artificial hard bottom habitats in slightly deeper water depths. Proportional abundance of fishes classified as juvenile and newly settled varied over time, but when combined into a single "early life stage" category were generally higher than proportional abundance of fishes classified as adults at both artificial reefs and natural hard bottom locations. Thus, within both habitat types, most individuals observed were early life stage (juvenile or newly settled). Often adult individuals such as jack crevalle, Spanish mackerel, and Atlantic bumper were present in large schools, thereby influencing the proportional abundances of adults when schooling species were among the censused species.

Newly settled grunts, porkfish, high-hat, and damselfishes utilized similar microhabitats on artificial and natural hard bottom. For the taxa considered in our analysis, microhabitat preference was less dependent on epibiotal composition and percent cover than it was on structural features of the reef or hard bottom. Newly settled grunts were most commonly observed at the base of natural or artificial features (at the sand-rock interface). Thus, it is possible that the presence of structures, either artificial or natural, triggered the settlement of the taxa we examined.

Monitoring results for fishes and epibiota were influenced by differences in water depth, relief, and sand burial rates at natural and artificial habitats. These important factors were confounded across sampling locations. Confounding of natural and artificial habitat types with water depth, relief, and sand burial restricts the generality of the monitoring results; all statements regarding the differences in fish and epibiotal assemblage structure, life stage proportions, and habitat use should not be extended beyond the study locations.

Although artificial reefs placed in slightly deeper water than nearshore hard bottom did not precisely replicate the nearshore hard bottom habitat or associated fish and epibiotal assemblages, they do serve as habitat for most local fishes and their life stages, including many species that also use natural nearshore habitat. The artificial reefs, with their fish and epibiotal components, certainly contribute to local ecosystem structure and function, and just as importantly, artificial reefs provide connections along the cross-shelf continuum for young fishes, which follow developmental pathways from inshore to offshore.

1.0 INTRODUCTION

This document presents the results of the third annual nearshore artificial reef monitoring project for Palm Beach County Department of Environmental Resources Management. Artificial reefs were deployed offshore of Palm Beach County to mitigate for direct losses of nearshore hard bottom and to provide recreational opportunities for county residents. This report updates the ongoing monitoring of the artificial reefs, with particular attention to the development of epibiotal and fish assemblages. Since 2001, Continental Shelf Associates, Inc. has completed annual monitoring surveys consisting of three field sampling events per survey period. These three surveys may be described as follows:

- Survey 1 - August 2001, April 2002, and July 2002;
- Survey 2 - April 2003, October 2003, and December 2003; and
- Survey 3 - February 2004, July 2004, and August 2004.

Comparing basic attributes of the biotic assemblages on artificial deployments with those same attributes on adjacent natural hard bottom areas assessed the biological efficacy of using artificial structures to mitigate for effects of burial on nearshore biota. Nearshore hard bottom consists of limestone outcrops that occur in water depths of 25 ft (7.8 m) or less. The nearshore environment is physically and biologically dynamic, and hard bottom habitats in this zone support diverse fish and epibiotal assemblages, which contribute important structural and functional components to regional coastal ecosystems. Early life stage (newly settled and juvenile) fishes use nearshore hard bottom as part of a larger scale cross-shelf gradient of habitats during developmental migrations. Although early life stage individuals are prevalent on nearshore hard bottom habitats of southeast Florida, specific habitat preferences are not known for most species.

Although the artificial reefs studied for this project were deployed primarily to mitigate for impacts to nearshore hard bottom in water depths of 12 ft (3.7 m) or less, it is difficult, if not impossible, to construct the reefs in comparable water depths of less than 12 ft (3.7 m). There are several reasons for this. First, large barges and tugboats used to transport and deploy the limestone boulder material cannot operate in water depths less than about 12 ft (3.7 m). Secondly, reefs (boulders) deployed in shallow water have a greater chance of being covered with sand or moved by high wave energy. Finally, placing artificial reefs in shallow water presents navigational and safety problems that lead to permitting difficulties. Thus, the tradeoff has been to place mitigation reefs in water depths as shallow as feasible.

The overall goal of the mitigation reefs is to replicate as best possible the assemblage structure of fishes and epibiota found on local nearshore hard bottom. Specific research questions investigated for nearshore waters of Palm Beach County, Florida were as follows:

- Do fish and invertebrate species inhabiting natural nearshore hard bottom habitats (<12 ft [<3.7 m]) represent distinct assemblages compared to artificial hard bottom habitats in deeper (12 to 24 ft [3.7 to 7.3 m]) National Geodetic Vertical Datum (NGVD)?

- Do natural hard bottom habitats in water depths <12 ft (<3.7 m) NGVD support disproportionate numbers of juvenile fishes as compared to artificial hard bottom habitats in water depths ranging from 12 to 24 ft (3.7 to 7.3 m) NGVD?
- What are the specific habitat preferences of newly settled fishes?

To address these questions, fish and epibiotal assemblages associated with artificial mitigation habitats deployed in water depths of 12 to 24 ft (3.7 to 7.3 m) were monitored and compared with natural hard bottom areas in water depths <12 ft (<3.7 m). Fish assemblage data were collected using visual census techniques, whereas epibiota found on the artificial and natural substrates were assessed by visual and photographic sampling methods. The first question was addressed by examining basic assemblage attributes for fishes (relative abundance, frequency of occurrence, species richness, and species composition) and epibiota (percent cover and taxonomic composition) on mitigation and natural reefs. The second question was answered by examining abundance, frequency, and composition of species by life stage categories (adult, juvenile, and newly settled) on artificial and natural reefs. These attributes provided the basis for comparison of the assemblages. The third question was addressed by analyzing habitat choice by newly settled fishes on mitigation and natural hard bottom. Microhabitats chosen by newly settled fishes were compared with sites selected at random (null sites) on artificial reef and natural hard bottom sites.

2.0 MATERIALS AND METHODS

2.1 DESCRIPTION OF SAMPLING LOCATIONS

2.1.1 Natural Hard Bottom

Three natural hard bottom areas have been used as reference locations during the course of the monitoring program (**Figure 1**). These sites were chosen to represent nearshore hard bottom of the type that has been buried or otherwise affected during dredge and fill projects on beaches of northern Palm Beach County. Because of the paucity of nearshore hard bottom in northern Palm Beach County, locations were initially selected based simply on availability, but specific site-selection criteria, including water depth, proximity to artificial reefs, structural complexity, and amount of emergent or exposed hard bottom, were used as much as possible. The three natural hard bottom areas chosen for study were

- Breakers Reef;
- MacArthur Beach State Park; and
- Coral Cove Park.

Positions of these locations are given in **Appendix A**, **Table A.1**, and brief descriptions are provided below. Breakers Reef was initially used as a reference area because it is the only hard bottom feature in water depths comparable to the artificial reefs deployed off Juno/Jupiter. However, after two monitoring surveys (Surveys 1 and 2), the epibiotal and fish assemblages at this location were not representative of the nearshore hard bottom assemblages found in shallower water (Continental Shelf Associates, Inc., 2003). Results from Breakers Reef are presented in this document for temporal comparisons, but for Survey 3, MacArthur Beach State Park was added in place of Breakers Reef to provide a more representative reference location.

2.1.1.1 Breakers Reef

Hard bottom at this location forms a continuous ledge that trends parallel to shore between Department of Natural Resources (DNR) Monuments R-096 and R-093 in about 20-ft (6-m) water depths. This location is about 3.9 mi (6.2 km) south of Lake Worth Inlet and occurs about 3.8 mi (6.1 km) from shore (**Figure 2**). Vertical relief of the ledge, which generally faces east, reaches 5 ft (1.5 m) in some areas. The hard bottom is colonized by dense epibiota consisting of algae, sponges, hard corals, octocorals, and tunicates.

2.1.1.2 MacArthur Beach State Park

At this location, emergent hard bottom occurs in shore-parallel patches of Anastasia formation from north of DNR Monument R-057 to about DNR Monument R-054 in water depths ranging from 0 to 13 ft (0 to 4 m). This location is about 3.8 mi (6.1 km) north of Lake Worth Inlet and 8.8 mi (14.2 km) south of Jupiter Inlet (**Figure 3**). The hard bottom here is generally low relief, but there are two single outcrops that reach 5 ft (1.5 m) and are exposed at low tide. Epibiota at this location consists of turf algae, macroalgae,

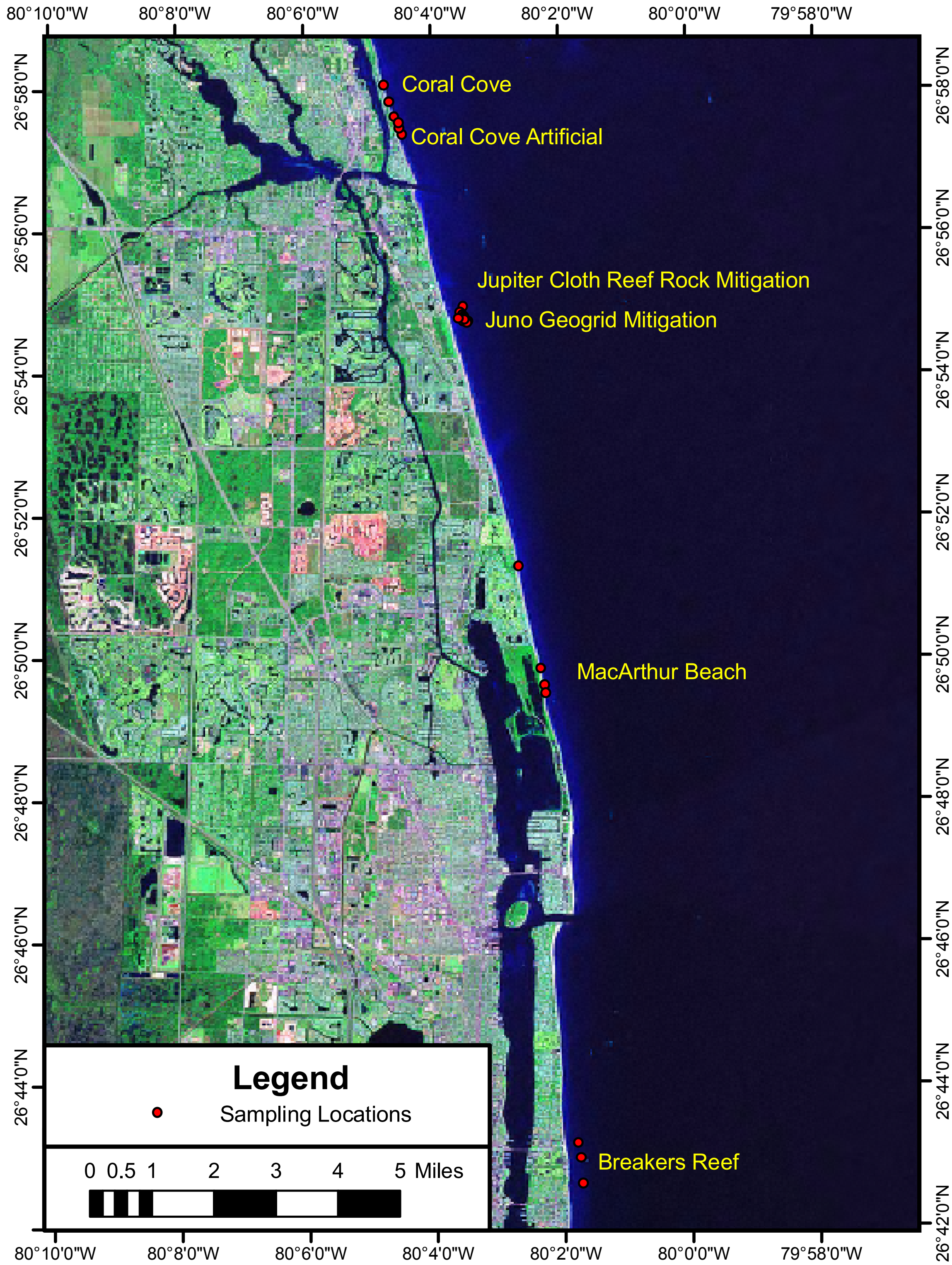

Figure 1. Artificial reef and natural hard bottom sampling locations relative to the Palm Beach County coastline.

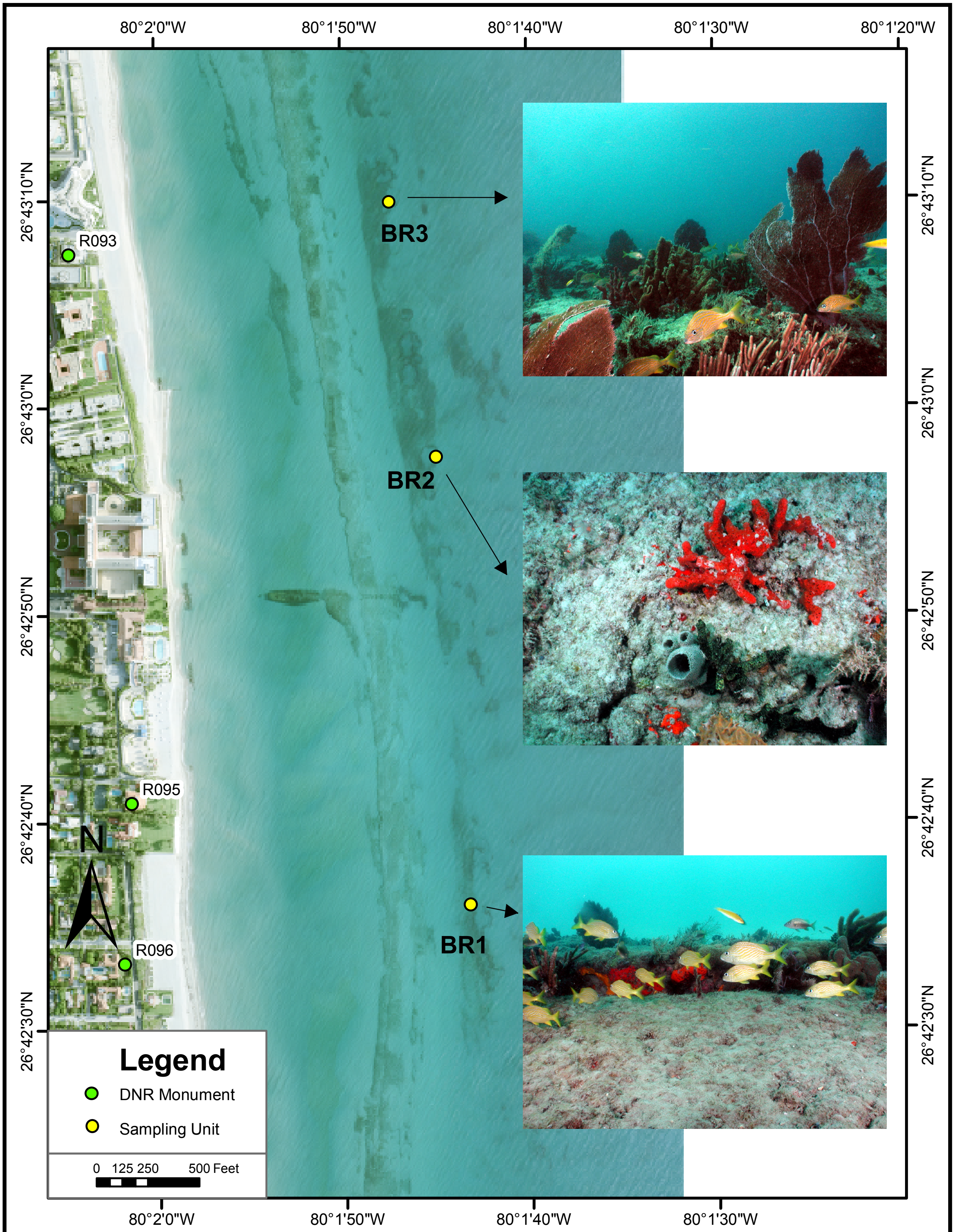

Figure 2. Breakers Reef (BR) location with representative images of hard bottom near the individual sampling units. Photos taken on 16 July 2004.

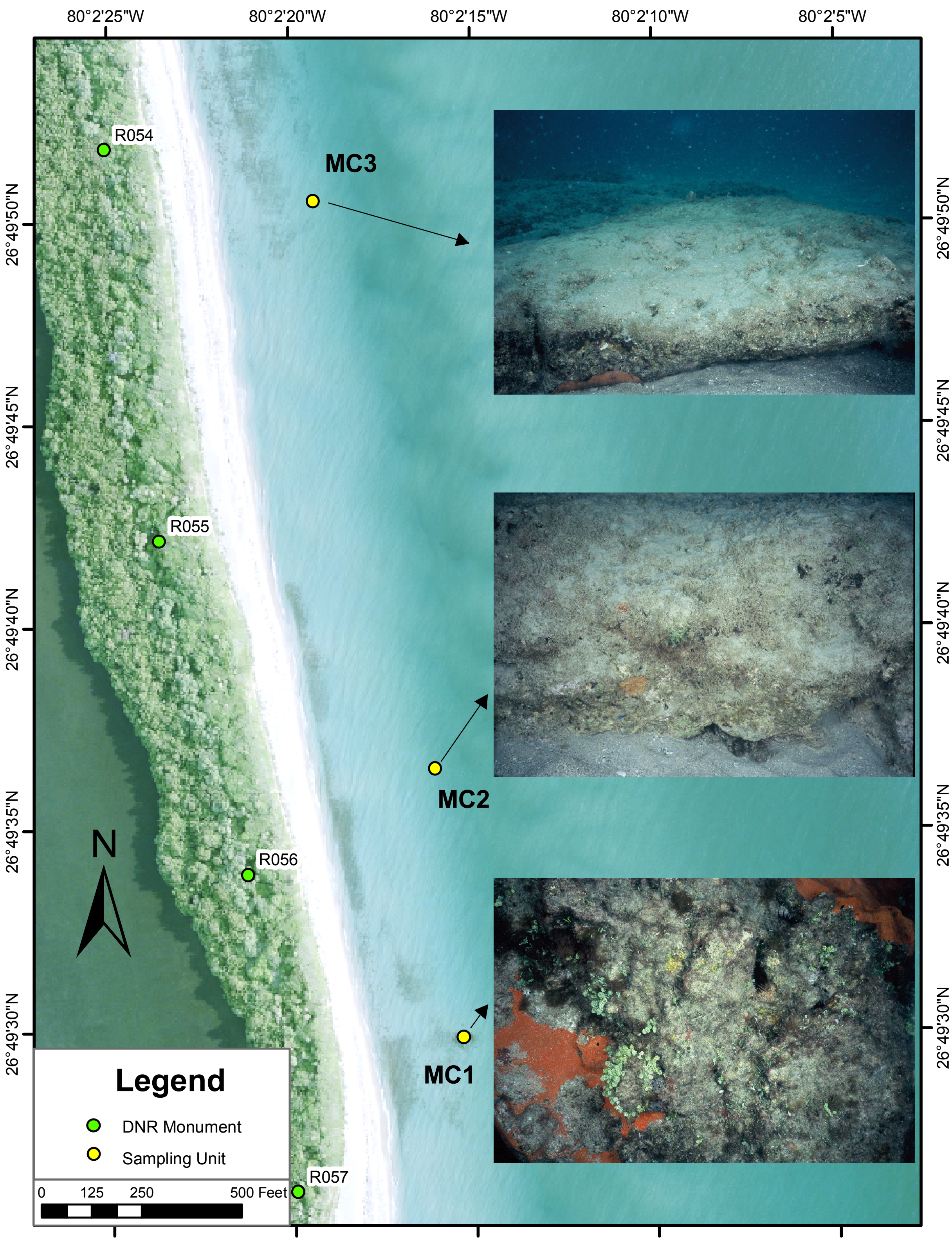

Figure 3. MacArthur Beach State Park (MC) location with representative images of hard bottom near the individual sampling units. Photos taken on 16 July 2004.

boring sponges, worm rock, small hard corals, and tunicates. No soft corals or large sponges are present.

2.1.1.3 Coral Cove Park

This location is characterized by another semi-continuous nearshore hard bottom trend that extends from about DNR Monument R-006 to about north of DNR Monument R-003 (**Figure 4**). The center of the location is about 8,000 ft (2,438 m) north of Jupiter Inlet in water depths of 0 to 13 ft (0 to 4 m). Relief at this site ranges from 0 to 3.3 ft (0 to 1 m), but most is less than 1.6 ft (0.5 m). Hard bottom complexity is high nearshore, where a rock trough exists about 82 ft (25 m) offshore. Movement of sand is very dynamic at this location and can vary following storms, ground swells, or even long periods of low wave energy. This location is the southern extension of the Anastasia formation, which forms large intertidal features in the Nature Conservancy's Blowing Rocks Preserve. Epibiotal assemblages here include turf and macroalgae, boring sponges, worm rock, small hard corals, and tunicates.

2.1.2 Artificial Reefs

Several artificial reefs have been deployed offshore of Palm Beach County since 1998 to mitigate for hard bottom losses due to the Jupiter and Juno Beach shore protection dredge and fill projects. This report focuses on artificial reefs sampled since August 2001, offshore of Juno/Jupiter in Palm Beach County. The individual reefs sampled during the first survey included

- Juno Geogrid Mitigation;
- Jupiter Cloth Reef Rock Mitigation;
- Jupiter Concrete Mitigation;
- Jupiter Shallow Concrete Mitigation; and
- Coral Cove Rock Mitigation.

Between the first and second field surveys, the Jupiter Concrete Mitigation and Jupiter Shallow Concrete Mitigation locations were buried by sand and are not discussed any further. In fall of 2003, another reef was constructed just south and offshore of the Coral Cove natural location described above. Here we discuss the Juno Geogrid Mitigation, Jupiter Cloth Reef Rock Mitigation, and Coral Cove Rock Mitigation reefs.

2.1.2.1 Juno Geogrid Mitigation

This reef consists of 3.3 ft (1-m) diameter limestone boulders deployed over Geogrid mattresses in 20 to 23 ft (6 to 7 m) water depths, about 1,700 ft (518 m) offshore of R-023 during 2000. Boulders were deployed over a footprint that is essentially a square framing a large sandy area (see **Figure 5**, GG3). Boulders were arranged in two tiers with Geogrid mattresses (large plastic mesh bags filled with rubble sized rocks) (see **Figure 5**) placed under and alongside rows of boulders to prevent scour and provide support. In 2001, two additional reefs were deployed using Geogrid and Armorflex, a concrete armoring material used for scour protection. These two features are as labeled GG1 and GG2 in **Figure 5**.

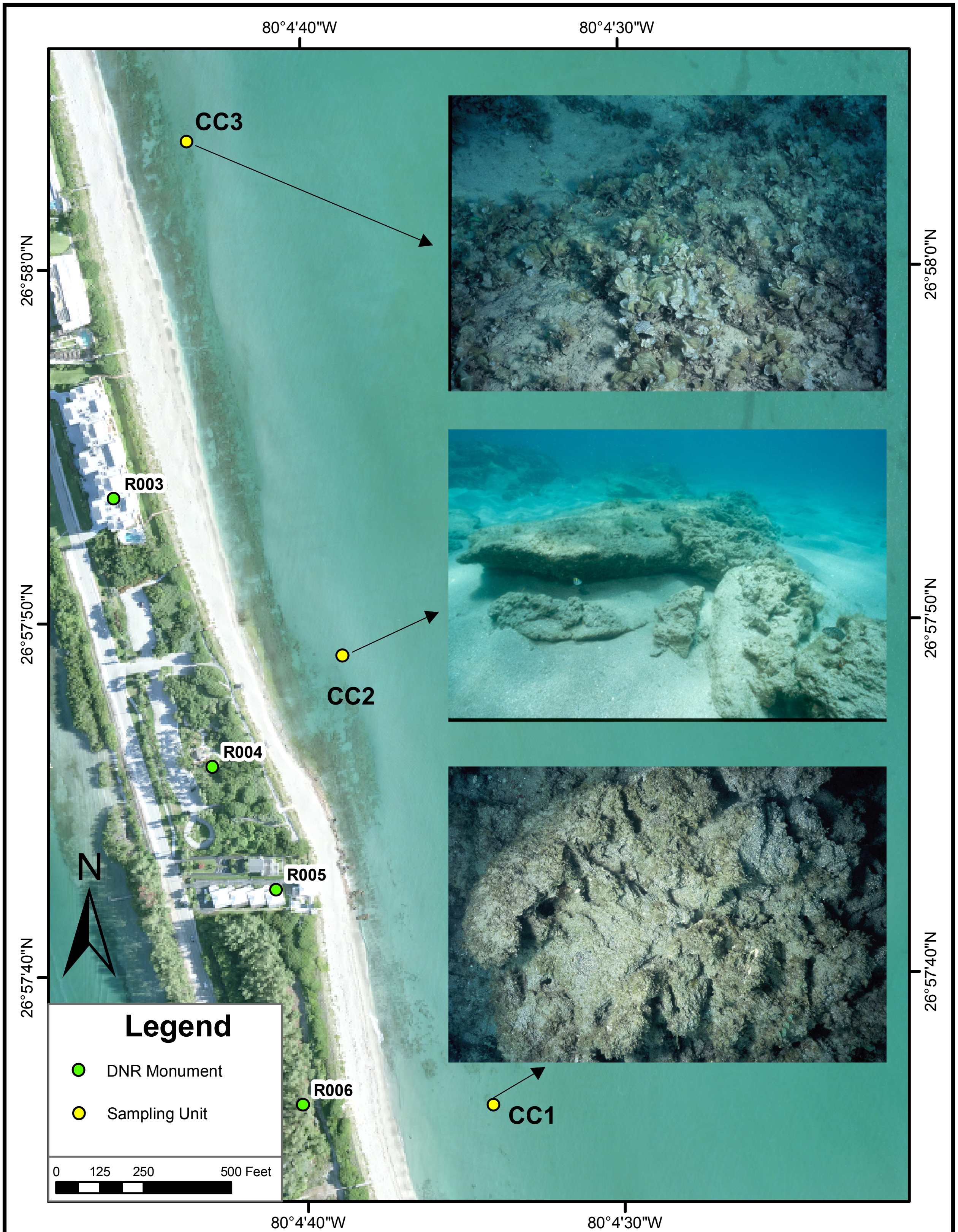

Figure 4. Coral Cove (CC) location with representative images of hard bottom near the individual sampling units. Photos taken on 16 July 2004.

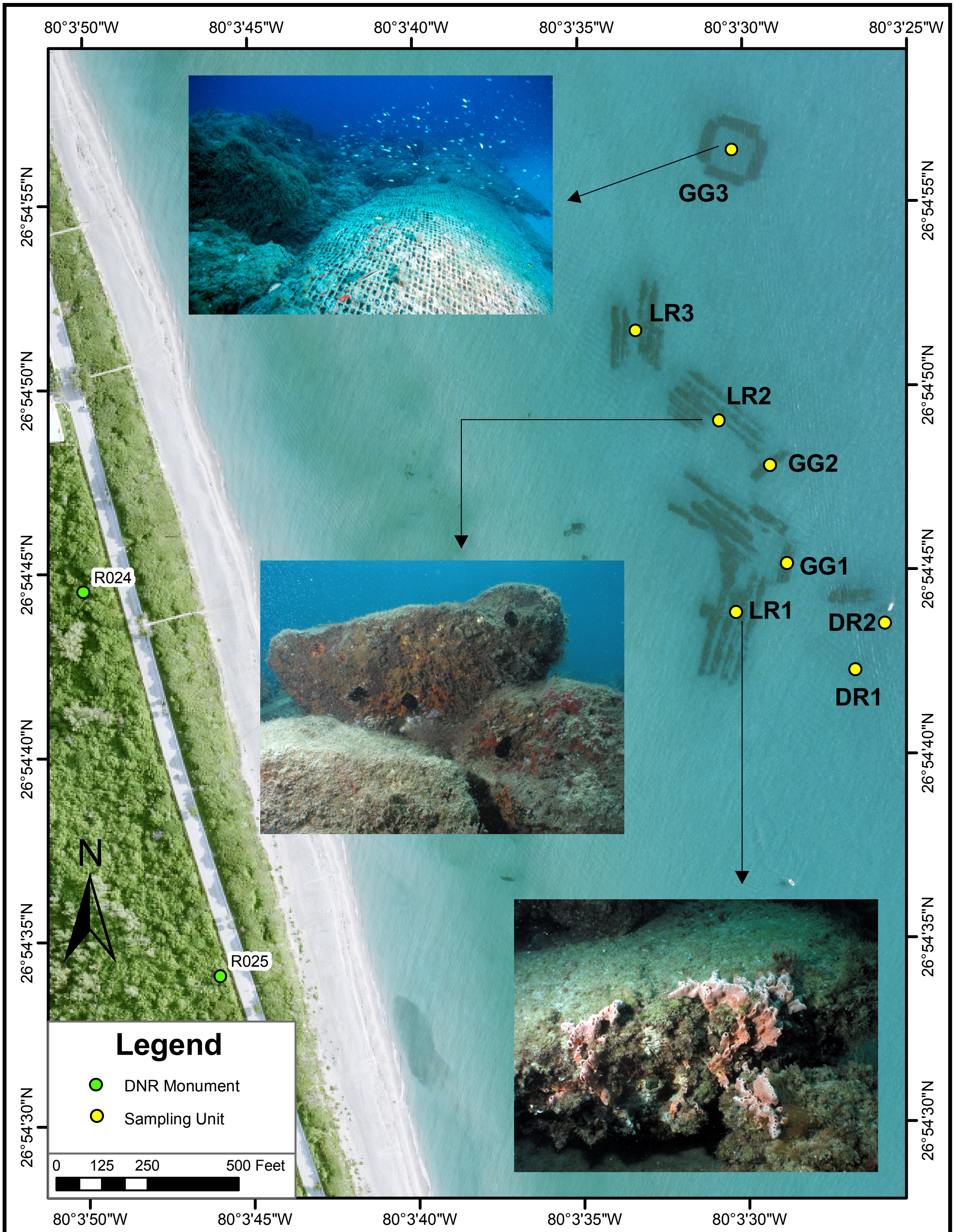

Figure 5. Geogrid (GG), cloth reef (LR), and concrete artificial reef (DR) locations. Photos taken on 16 July 2004.

2.1.2.2 Jupiter Cloth Reef Rock Mitigation

These reefs consist of linear rows of 3.3-ft (1-m) diameter limestone boulders deployed on filter cloth or fabric to prevent subsidence. There are three separate deployments of boulders on filter fabric. Boulders were deployed in water depths between 13 and 20 ft (4 and 6 m) in 1998 and 1999. These reefs are labeled as LR1, LR2, and LR3 in **Figure 5**.

2.1.2.3 Coral Cove Rock Mitigation

Offshore of Jupiter Island, about 0.95 mi (1.5 km) north of Jupiter Inlet in 6.6 to 13 ft (2 to 4 m) water depths, a series of mitigation reefs consisting of 3.3-ft (1-m) limestone boulders was deployed during fall of 2003 (**Figure 6**). The boulders are arranged in cells oriented roughly perpendicular to shore. The deployments are about 550 to 600 ft (168 to 183 m) from shore.

2.1.3 Sand Burial at Coral Cove Locations

During the course of monitoring efforts during Survey 2 and especially Survey 3, it was evident that appreciable amounts of sand were encroaching on the Coral Cove sampling locations. Also, during Survey 3, we observed considerable burial of the Coral Cove Rock Mitigation reef. Comparable aerial photographs illustrate the differences in the artificial structure between 2003 and 2004 (**Figure 7**). A similar pattern of sand burial is depicted for Coral Cove natural hard bottom between 2003 and 2004 (**Figure 8**). Burial of entire sampling sites affected the sampling at these sites during Survey 3; we have been unable to assess how the passage of two hurricanes have affected this situation.

The Coral Cove natural hard bottom has persisted historically against the natural dynamics of erosion and burial. It is possible that the current burial trend is due to the migration of sand from beach fill projects north of Coral Cove.

2.2 SAMPLING DESIGN

To answer the question posed in the introduction, a sampling program was designed to account for spatial and temporal variability within the limitations of the artificial reef deployment. Data used to characterize assemblage structure of fishes and epibiota, life stage patterns of fishes, and habitat preferences of newly settled fishes were gathered using visual census and photographic techniques. Collection of these samples from artificial reefs and natural hard bottom reference locations followed a nested design for the spatial component. Several hard bottom and artificial sampling locations were selected, each with non-overlapping, replicate, sampling units. Within these sampling locations and nested within sampling units were subsamples (censuses and photographs). The sites of sampling units within sampling locations were selected haphazardly; however, within the sampling units, sites were collected randomly for photographs and haphazardly for fishes. The temporal component included opportunistic sampling dates when weather, sea conditions, and water clarity were adequate for visual and photographic methods. The specific protocols followed for fish and epibiotal sampling are discussed below.

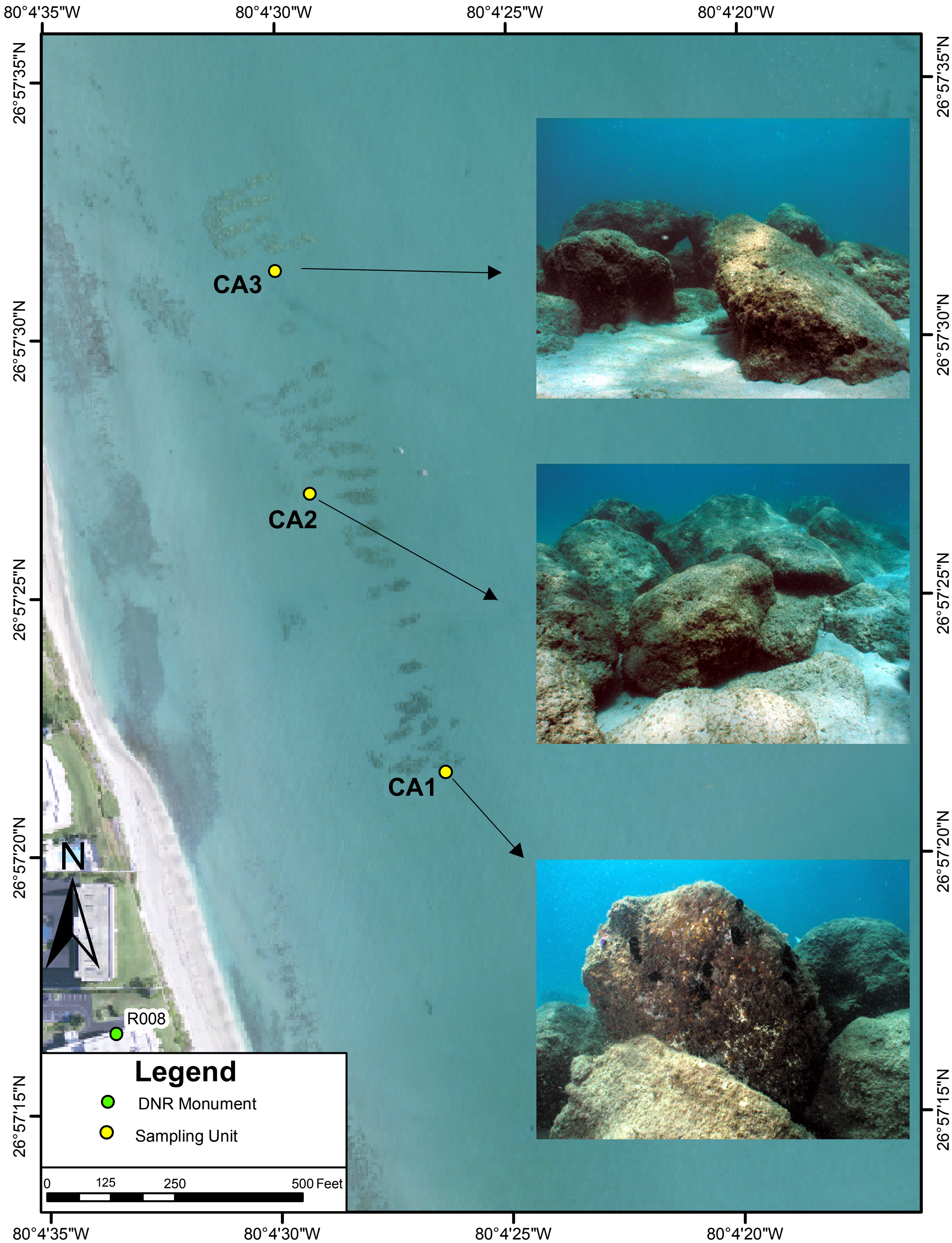

Figure 6. Coral Cove artificial (CA) reef location with representative images of the reef taken near individual sampling units. Photos taken on 16 July 2004.

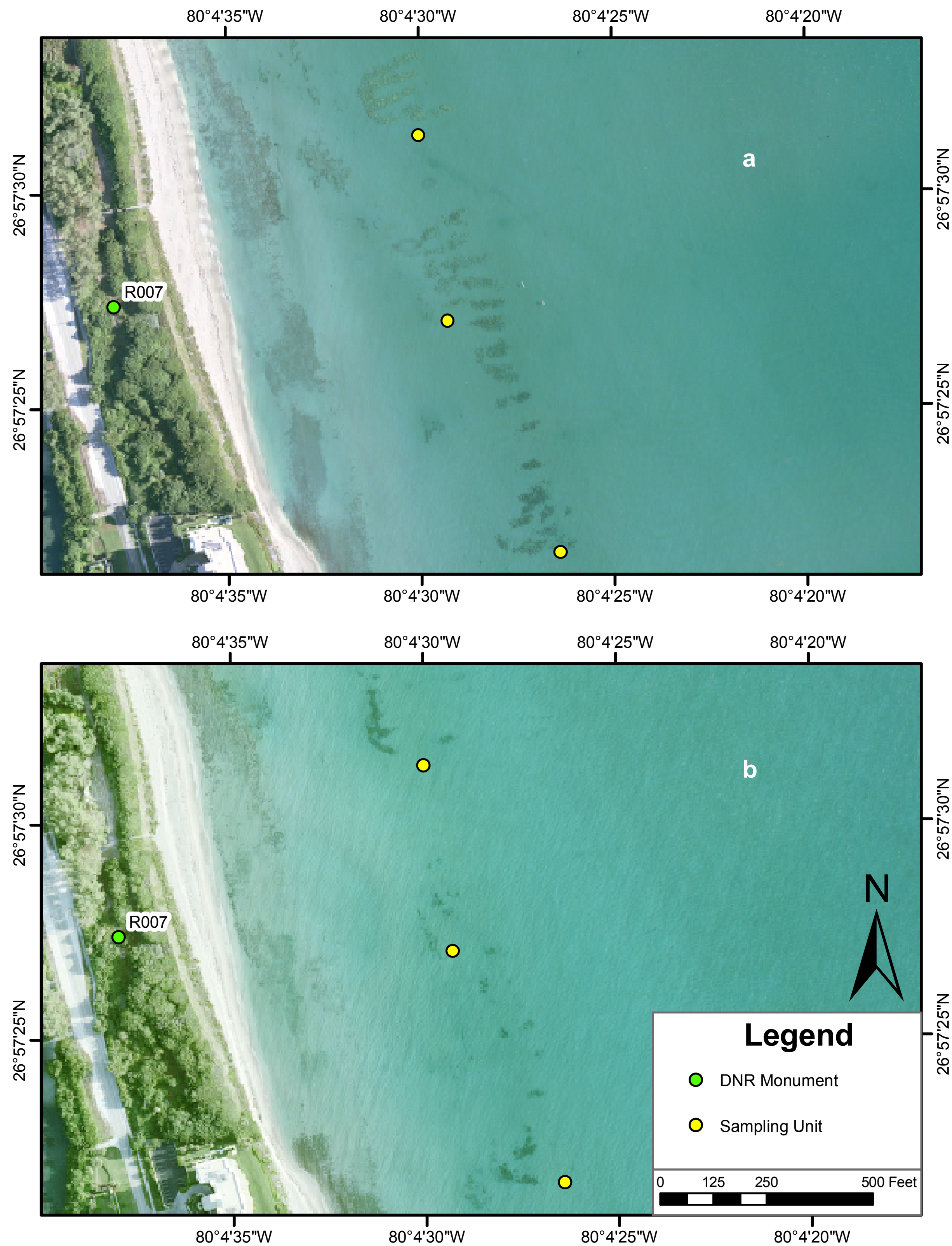

Figure 7. Aerial images of the Coral Cove artificial reef location taken on (a) 29 July 2003 and (b) 16 July 2004 showing the loss of artificial reef material.

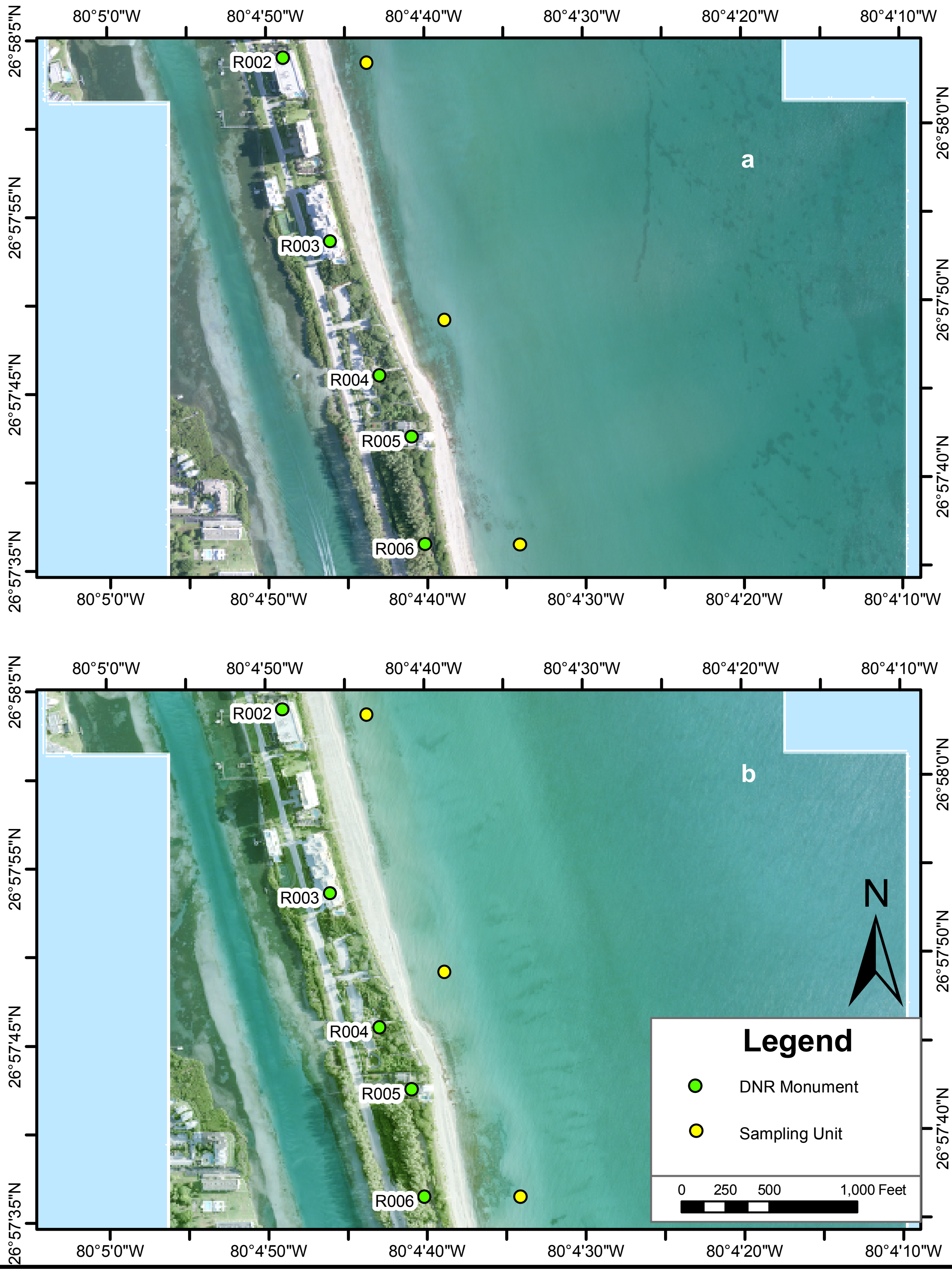

Figure 8. Aerial images of the Coral Cove hard bottom location taken on (a) 29 July 2003 and (b) 16 July 2004 showing the loss of natural hard bottom.

2.2.1 Fishes

2.2.1.1 Sampling

A visual census technique known as roving or timed swims provided the data needed to answer the first two research questions. Timed swims were conducted to ensure that representative samples of all visually conspicuous species and life stages present were collected. Timed swims provide relative abundance data, species lists, and life stage information. Although not strictly quantitative, these methods have proven reliable when compared with other censusing methods (Kimmel, 1985; Sale, 1997; Schmitt et al., 2002). The initial starting point for the timed swims was determined from random compass headings and swimming kicks, with the constraint that the swim paths were not overlapping in space. During a timed swim, all fishes within 10 ft (3 m) on either side of the diver were counted by life stage. The diver was free to look under ledges, in crevices, and overhead in the water column during the swim. Timed swims are effective, and it is best to replicate them at the level of the sampling unit (Sale, 1997). For this reason, three timed swims (subsamples) were made within each replicate sampling unit at each sampling location. Life stages adult, juvenile, and newly settled were assigned to fish during the census. These designations were generally based upon characteristics such as size and color pattern of a particular species.

To understand the effect of broad substrate categories on habitat selection by settling fishes, photoquadrats of areas with newly settled fish in the sampling locations were compared to null (random) photoquadrats collected within the same sampling locations. Areas around natural (Coral Cove and MacArthur Beach) and artificial (Geogrid and Cloth Reef) sampling locations were searched for newly settled fish by a diver swimming above the substrate and searching until one or more newly settled fish were sighted. A 3.12-ft^2 (0.29-m^2) photoquadrat was taken of the site occupied by the fish or group of fishes. These data were collected at two spatial scales: microhabitat and mesohabitat. The microscale is at the level of the quadrat, and the larger scale is meters to tens of meters. Microscale substrate categories were biotic and abiotic. Biotic characteristics were living substratum such as macroalgae, turf algae, sponges, hydroids, worm rock, and tunicates. Abiotic characteristics were exposed hard bottom, sand, sand-hard bottom interface, and dead worm rock. Position of the photoquadrat relative to the overall structure of the reef served as the mesoscale. Positions of each photoquadrat containing fish were scored as base, side, or top of the mitigation or natural reef structure. Random photoquadrats used for comparisons with the fish quadrats were collected at each sampling location for the epibiotal characterization. Details on collection of random photoquadrats and methods used for analyzing photographs are given in **Section 2.2.2**.

2.2.1.2 Data Analysis

Response variables used to compare fish assemblage structure between natural hard bottom and artificial reefs included mean numbers of species, mean number of individuals, and expected number of species. Mean numbers of species and individuals were calculated along with the standard deviations of the means (of subsamples) averaged across sampling units with study locations. Expected number of species was calculated using Hurlbert's (1971) formula scaled to 100 individuals. This measure allows comparisons of species richness based on a common number of individuals.

Multivariate analyses also were used to compare assemblages found on artificial and natural reefs. The approach taken employs non-parametric multivariate analyses as outlined by Clarke (1993). First, a sample similarity matrix was formed from the samples-by-species data matrix using the Bray Curtis Similarity Index. This similarity matrix was then analyzed using non-metric multidimensional scaling (MDS). MDS is an ordination technique that provides an image of inter-sample relationships in abstract space. Samples that are most similar in terms of species composition and abundance will cluster near one another in the ordination diagram. The species-by-samples data matrices included all species observed during timed swims. A single data matrix was analyzed for each survey by first, fourth-root transforming the raw numbers and then using the Bray Curtis Similarity Index (Bray and Curtis, 1957) to construct sample similarity matrices. Data transformation was done to lessen the impact of highly abundant species on the analysis. Sample similarity matrices also were analyzed with analysis of similarity (ANOSIM) tests (Clarke, 1993). ANOSIM works from the Bray Curtis Similarity Index by comparing the rank order of similarities among groups of samples from categorically different sampling locations (e.g., mitigation or natural). This comparison is achieved by computing a statistic, R, which reflects differences between locations contrasted with differences among replicates within locations. R is calculated as follows:

$$R = \frac{(\bar{r}_B - \bar{r}_W)}{1/2M}$$

where r_B is the average of rank similarities from all pairs of replicates between different locations and r_w is the average of rank similarities among replicates within locations and M=n(n-1)/2 and n is the total number of samples under consideration. R generally ranges from 1 (all replicates within a location are more similar to each other than to any replicates from different locations) to 0 (similarities between location and within locations are the same on average); however, negative values are possible (Chapman and Underwood, 1999; Clarke and Warwick, 2001). Statistical significance of ANOSIM tests was achieved by comparing the actual values with a distribution of R statistics generated from 999 permutations of the original data.

Another analysis of the similarity matrix, similarity percentages (SIMPER), was performed to determine which species were responsible for any observed differences among samples (sampling locations).

Life stage proportions between artificial and natural hard bottom were compared using Chi-Square (X^2) tests of heterogeneity (Sokal and Rohlf, 1995). The specific hypothesis tested was that there is no difference in proportional abundance of life stage category between artificial reefs and natural hard bottom. These tests were conducted for each survey using the overall abundance of each life stage category.

Habitat preference by newly settled taxa was examined using Canonical Correspondence Analysis (CCA). CCA is a combination of regression and ordination where the species scores are constrained as linear combinations of the environmental (in this case epibiotal and substrate cover) variables (ter Braak, 1986; Palmer, 1993). The analysis combines a species-by-samples matrix and an environment-by-samples matrix to produce ordinations that convey the influence of environmental variables on the species distribution. Here the species or taxa are null (random) sites, *Haemulon* spp. and *Equetus* spp. Environmental variables used in the analysis included percent cover of biotic and physical substrata. Biotic substrata were macroalgae, turf algae, sponge, hydroids, worm rock, and detached plant material. Physical substrates included sand, exposed hard bottom, sand over hard bottom, and shells (and shell fragments). At a larger scale, positions of photoquadrats were recorded as top, side, and base of the natural or artificial hard bottom feature. In CCA, percent cover estimates were input as continuous variables, and positions on the structures (top, side, or base) were input as nominal variables (e.g., 1's and 0's). All variables were subjected to a forward selection process that chooses variables that contribute most to the variance explained by the analysis. Each variable was evaluated statistically by permutation tests following a stepwise selection process. All tests employed 999 random permutations of the environmental data. Once a subset of meaningful environmental variables was selected, the CCA was re-run to produce ordinations of taxa scores and sample scores with environmental variables superimposed as arrows indicating the strength and direction of correlation with the ordination axes.

2.2.2 Epibiota

2.2.2.1 Sampling

To assess epibiotal assemblages on mitigation and natural reefs, nine replicate photographic quadrats of 3.12 ft^2 (0.29 m^2) were collected using a Nikonos camera (in previous reports [Continental Shelf Associates, Inc., 2002, 2003] photoquadrat size was reported as 0.25 m^2; this was incorrect as the actual photoquadrat dimensions were 1.5 ft x 2.1 ft (0.455 m x 0.635 m). This camera was equipped with two 150 watt-sec strobes and a 28-mm lens mounted on a stainless steel frame that encompassed the dimensions of the quadrat. Multiple small samples were used instead of few larger quadrats since higher numbers of smaller quadrats would provide a more representative account of epibiota, allowing for statistical testing and generalization. Fixed, repeatedly visited transects are effective for monitoring the growth and condition of individual colonies, but such transects may not be representative of the reef as a whole. Inferences can only be made at the level of the transect.

Placement of photoquadrats within sampling sites was randomized using a baseline running along the long axis of the sampling site. Random coordinates were predetermined and executed by number of swimming kicks along and then either left or right from the baseline.

2.2.2.2 Data Analysis

Quantitative images were analyzed by overlaying 25 random points (digitally using Point Count software) to estimate percent cover of epibiota (e.g., algae, sponges, corals, and tunicates) and substrata (e.g., sand, rock, etc.). Estimates from individual images were averaged over sampling units and locations for final analyses.

3.0 RESULTS

3.1 ASSEMBLAGE STRUCTURE

Mean number of individuals, species, and expected number of species varied among sampling locations and surveys. During Survey 1 (2001, 2002), mean numbers of individuals were consistently higher at artificial reef locations (**Figure 9**). Numbers of individuals increased for each sampling location (artificial and natural) over time within Survey 1. During Survey 2 (2003), the numbers of individuals observed also was higher in samples from artificial reef locations than natural hard bottom locations.

Mean number of species was generally higher in samples from artificial reefs across all surveys. During Survey 1, mean number of species was higher at all artificial reef locations, with the exception of Breakers Reef during July (**Figure 10**). Mean numbers of species observed during Survey 2 were higher at the artificial reef locations for all sampling times. The same pattern emerged during Survey 3 (2004), with the exception that the MacArthur Beach samples from May yielded higher values than the combined Cloth reef/Geogrid samples.

When the number of species was standardized to a common number of individuals (100) using Hurlbert's (1971) expected number of species index, the pattern of higher richness on the artificial reefs shifted. During Survey 1, Breakers Reef had the highest expected number of species for the first two sampling times, and Coral Cove had the highest expected value for the last sampling time (**Figure 11**). During Survey 2, Breakers Reef produced the highest expected number of species during the first sampling time, but the artificial reefs produced higher values for the next two sampling times. Survey 3 expected number of species estimates varied between artificial reefs and natural hard bottom.

Similarity analyses of the fish species composition and abundance at the sampling locations revealed several patterns within and among surveys. Artificial reefs (Cloth, Geogrid, and Concrete) and natural hard bottom reference sites (Breakers Reef and Coral Cove) formed separate clusters in the MDS plot (**Figure 12**). ANOSIM test for this survey was significant ($R= 0.533$, $p<0.1\%$).

Survey 2 samples from artificial and natural locations fell into discrete groups in MDS plots similar to that observed in Survey 1 (**Figure 12**). Samples from Breakers Reef, Coral Cove, and the artificial reefs were significantly different (ANOSIM, $R= 4.0465$, $p<0.1\%$).

Survey 3 samples were more variable in ordination space than the other two surveys. This is in part due to the dropping of the Breakers Reef location (**Figure 12**). There also was more overlap between artificial and natural groups of samples. Similarity among locations was higher than reported above for Surveys 1 and 2, but the ANOSIM was significant ($R= 0.353$, $p<0.1\%$).

Species responsible for the differences shown in sample similarity (and MDS ordination) with surveys were detected using SIMPER analyses. During Survey 1, the most abundant species contributing to the dissimilarity among locations were tomtate (*Haemulon*

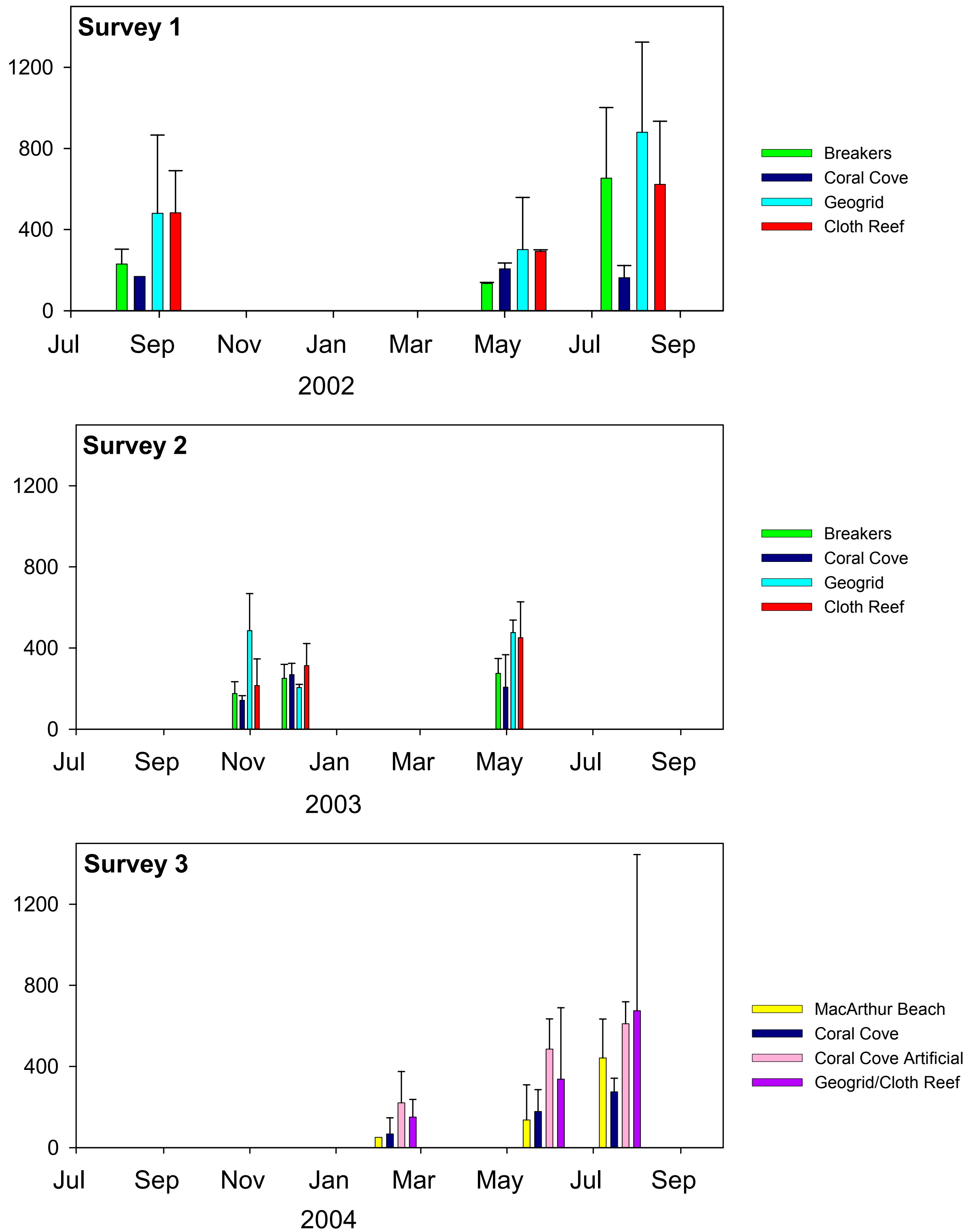

Figure 9. Mean numbers (error bars represent standard deviation) of individual fish observed at natural hard bottom and artificial reef locations during Surveys 1, 2, and 3.

CSA

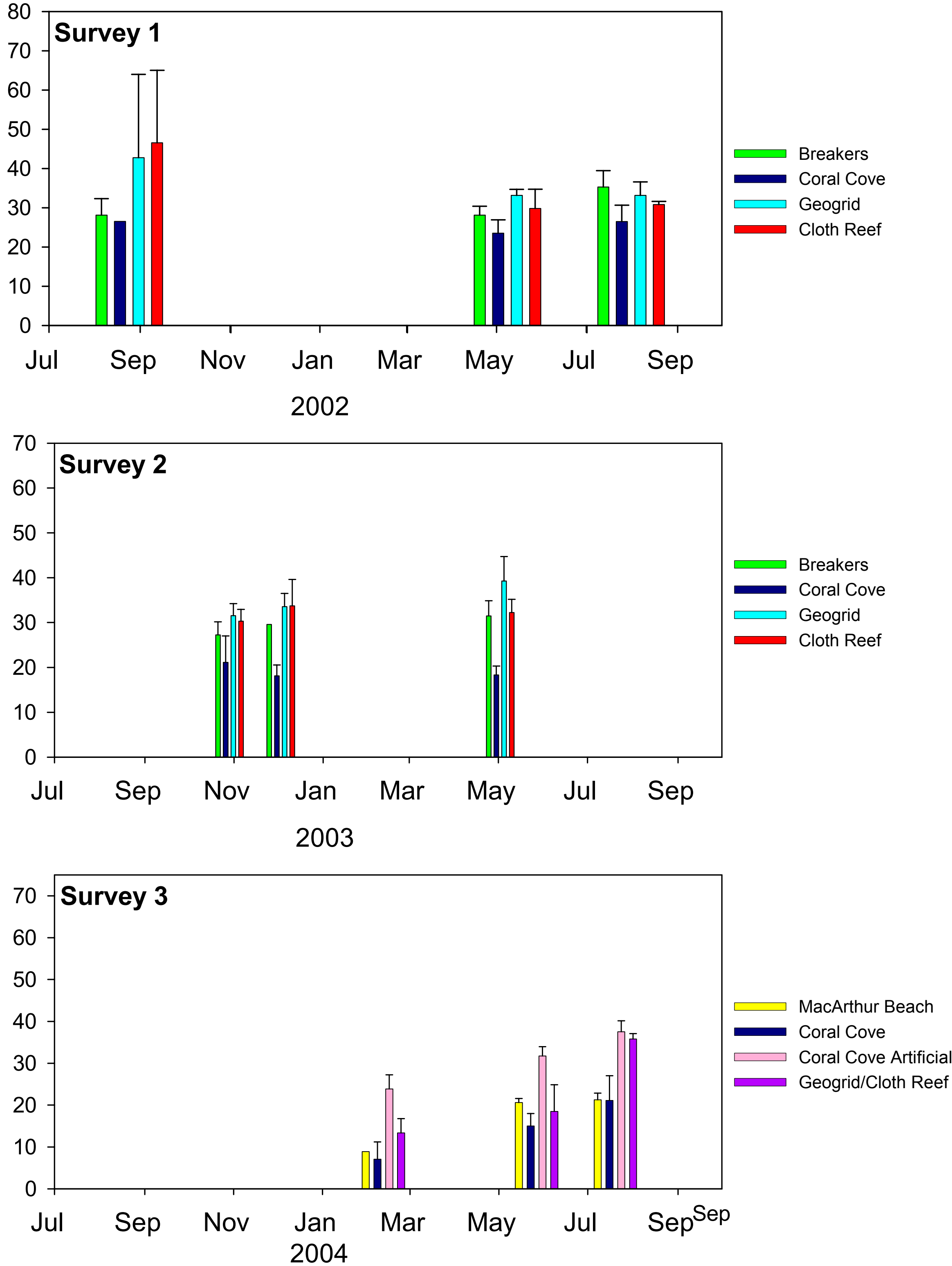

Figure 10. Mean numbers (error bars represent standard deviation) of fish species observed at natural hard bottom and artificial reef sampling locations during Surveys 1, 2, and 3.

CSA

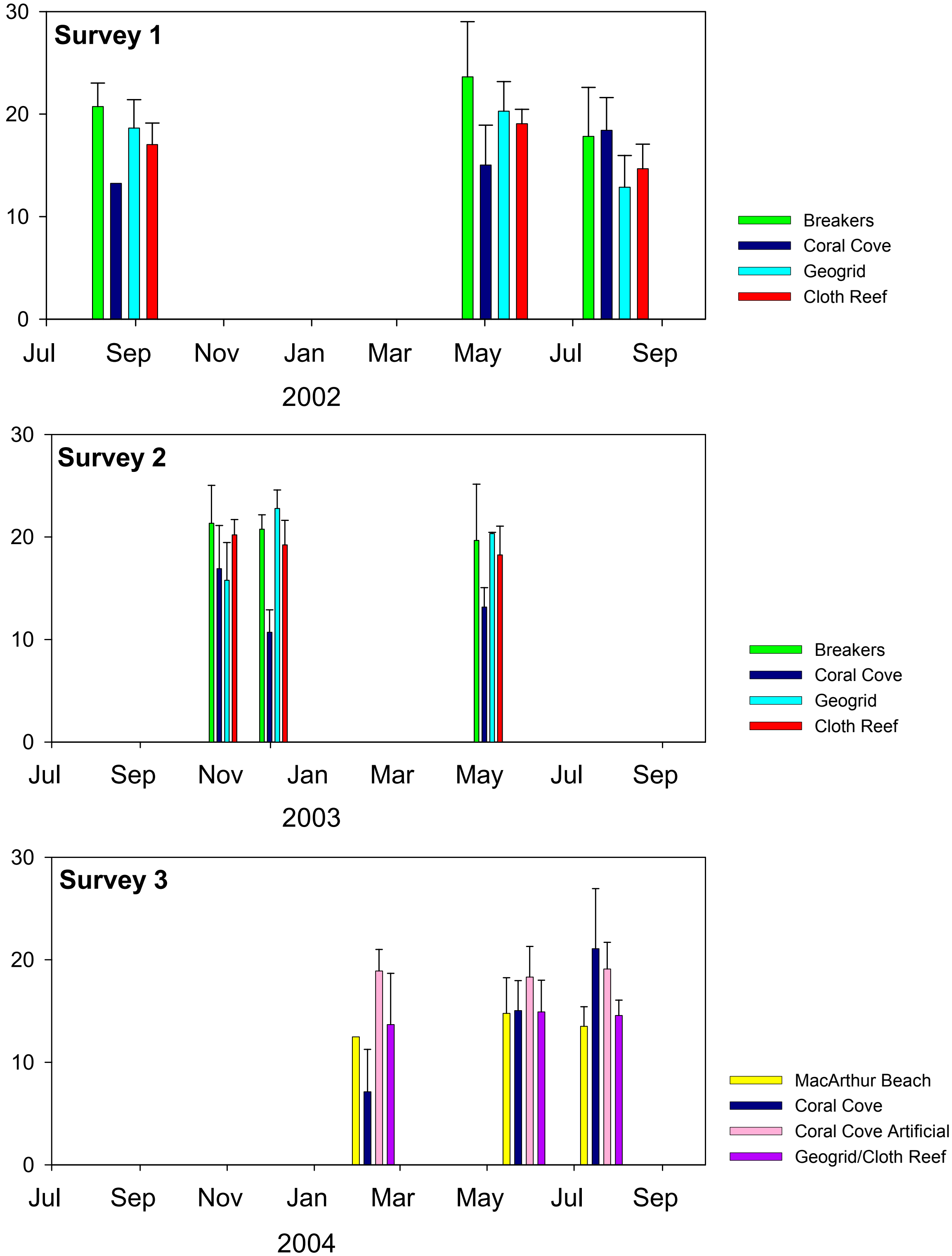

Figure 11. Expected number of fish species (per 100 individuals) for natural hard bottom and artificial reef sample locations during Surveys 1, 2, and 3. Error bars represent standard deviation.

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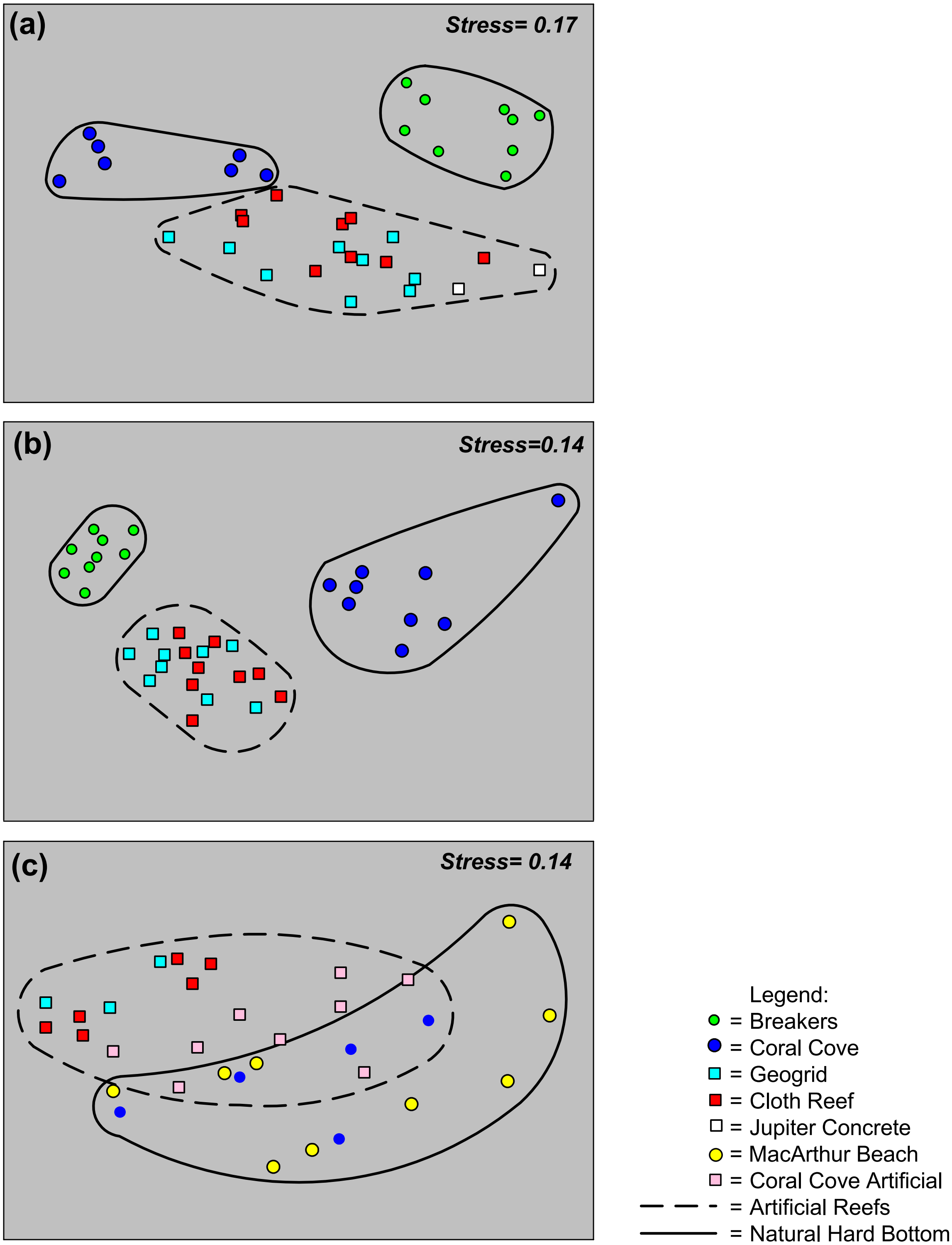

Figure 12. Multidimensional Scaling (MDS) plots of fish census data using all taxa and life stages collected during (a) Survey 1 (August 2001, April 2002, July 2002) (b) Survey 2 (April 2003, October 2003, and December 2003) and (c) Survey 3 (February 2004, July 2004, and August 2004) at artificial reefs and natural hard bottom.

aurolineatum), striped croaker (*Bairdiella sanctaluciae*), and French grunt (*Haemulon flavolineatum*) (**Table 1**). Each of these three species was most abundant on artificial reefs. Species that were more abundant on natural hard bottom included newly settled grunts (*Haemulon* spp.), smallmouth grunt (*H. chrysargyreum*), blue runner (*Caranx crysos*), and sailors choice (*H. parra*). Abundant species observed during this survey were mostly planktivores (tomtate, newly settled grunts, smallmouth grunt, and French grunts) or benthic omnivores (striped croaker and sailors choice). During Survey 2, there was a similar pattern of key species contributing to the observed differences in sample similarity between artificial reefs and natural hard bottom (**Table 2**). Tomtate, newly settled grunts, and striped croaker were more abundant in samples from artificial reefs than on natural hard bottom. French grunt, white grunt, and bluehead (*Thalassoma bifasciatum*) were more abundant in samples from natural hard bottom. Survey 3 censuses again ranked tomtate, newly settled grunts, and striped croaker as contributing most to the differences between fish assemblages on artificial reefs and natural hard bottom (**Table 3**). Other species such as cocoa damselfish (*Stegastes variabilis*) and silver porgy (*Diplodus argenteus*) were more abundant in samples from artificial reefs, whereas sergeant major (*Abudefduf saxatilis*), blue runner, and slippery dick (*Halichoeres bivittatus*) were more abundant in samples from natural hard bottom.

Epibiota

Percent cover for the major epibiotal taxa and non-living substrata for Survey 3 is given in **Table 4**. (Data are presented only from May and July sampling times as photographs from the February 2004 sampling time were grossly overexposed due to an unknown camera-strobe problem.) The predominant taxon is turf algae, followed by macroalgae on both artificial and natural hard bottom. Epibiota of the natural nearshore hard bottom habitat at Coral Cove and MacArthur Beach consisted of turf algae, macroalgae, sponges, hydrozoans, encrusting bryozoans, and ascidians. No stony corals or octocorals have been observed or recorded, at any of the natural or artificial sampling locations. Turf algae (defined as unidentified, fine, filamentous algae) contributed most of the biotic cover across all natural hard bottom sampling locations and times.

Coverage of turf algae on natural hard bottom sites averaged 34.9% at Coral Cove and 40.0% at MacArthur Beach. Macroalgae were represented by green algae (*Caulerpa* spp., *Codium* sp., *Halimeda* sp.) and brown algae (*Dictyota* sp. and *Padina* sp.). Only *Padina* sp. contributed appreciably to the overall cover estimates for Coral Cove in May. Sponges and hydroids were observed in samples from natural hard bottom sites, but these contributed little with respect to the overall percent cover. No stony corals were observed in photoquadrats taken at either of the natural hard bottom sites during this survey. Non-living substrata in photoquadrats were mostly sand over hard bottom or plain sand.

Cover of epibiota on artificial reefs also was dominated by turf algae, which accounted for 43.0% and 71.9% on Cloth Reef Mitigation/Geogrid and Coral Cove Artificial locations, respectively (**Table 4**). Unidentified green and brown macroalgae, as well as *Caulerpa* spp. were recorded on artificial reefs during Survey 3. Encrusting sponges were represented by several taxa and were recorded across all sampling locations. Cover by sponges was generally low and patchy throughout all artificial sampling locations. The algae hydroid (*Thyroscyphus* sp.) was frequently encountered in photoquadrats from artificial reefs and was the second most abundant taxon on the older Cloth Reef and Geogrid deployments, reaching 38.7% cover on the Geogrid location in May and 19.9% on the Cloth Reef in July. Though recorded during 2002 surveys, worm rock was not recorded at any artificial reefs during 2004. **Appendix B** (**Tables B.7** and **B.8**) contains the epibiotal tables from Surveys 1 and 2.

Table 1. Survey 1 percentage contribution of the top 20 species according to the Bray Curtis dissimilarity in species abundances (SIMPER analysis) between natural hard bottom sites and artificial reefs by broad trophic grouping. "+" denotes natural hard bottom abundance is greater than artificial reefs.

Species	+/-	Planktivore	Herbivore	Benthic Omnivore	Carnivore	Totals
Tomtate	-	3.86				3.86
Striped croaker	-			2.82		2.82
French grunt	-	2.65				2.65
grunts (ns)	+	2.61				2.61
Smallmouth grunt	+	2.24				2.24
Seaweed blenny	-			2.05		2.05
Pigfish	-			1.91		1.91
White grunt	-			1.88		1.88
Blue runner	+				1.87	1.87
Sailors choice	+			1.81		1.81
Round scad	-	1.8				1.8
Spadefish	-	1.77				1.77
Hairy blenny	+			1.72		1.72
Bluehead	+			1.61		1.61
Gray triggerfish	-				1.57	1.57
Bicolor damselfish	+	1.53				1.53
Bar jack	-				1.53	1.53
Lane snapper	-				1.49	1.49
Clown wrasse	+			1.46		1.46
Copper sweeper	-	1.43				1.43
Sergeant major	+	1.42				1.42
Total		19.31		15.26	6.46	

ns = newly settled.

Table 2. Survey 2 percentage contribution of the top 20 species according to the Bray Curtis dissimilarity in species abundances (SIMPER analysis) between natural hard bottom sites and artificial reefs by broad trophic grouping. "+" denotes natural hard bottom abundance is greater than artificial reefs.

Species	+/-	Planktivore	Herbivore	Benthic Omnivore	Carnivore	Total
Tomtate	-	4.48				4.48
Striped croaker	-			3.18		3.18
Grunts (ns)	-	2.97				2.97
French grunt	+	2.33				2.33
White grunt	+			2.31		2.31
Bluehead	+			2.23		2.23
Blue runner	-				2.02	2.02
Pigfish	-			1.94		1.94
Crevalle jack	-				1.88	1.88
Smallmouth grunt	+	1.87				1.87
Gray triggerfish	-				1.69	1.69
Seaweed blenny	-					1.61
Hairy blenny	+			1.61		1.6
Silver porgy	+			1.53		1.53
Bicolor damselfish	+	1.52				1.52
Beaugregory	-			1.5		1.5
Lane snapper	-				1.5	1.5
Blue tang	-		1.49			1.49
Spanish hogfish	+			1.48		1.48
Sergeant major	+	1.46				1.46
Total		14.63	1.49	15.78	7.09	

ns = newly settled.

Table 3. Survey 3 percentage contribution of the top 20 species according to the Bray Curtis dissimilarity in species abundances (SIMPER analysis) between natural hard bottom sites and artificial reefs by broad trophic grouping. "+" denotes natural hard bottom abundance is greater than artificial reefs.

Species	+/-	Planktivore	Herbivore	Benthic Omnivore	Carnivore	Total
Tomtate	-	4.54				4.54
Grunts (ns)	+	3.84				3.84
Striped croaker	-			3.11		3.11
Cocoa damselfish	-			3.06		3.06
Silver porgy	-			2.87		2.87
Sergeant major	+	2.67				2.67
Blue runner	+				2.61	2.61
Slippery dick	+			2.6		2.6
French grunt	-	2.46				2.46
Copper sweeper	-	2.46				2.46
Smallmouth grunt	-	2.31				2.31
Sailors choice	+			2.24		2.24
High-hat	-			2.24		2.24
White grunt	-			2.15		2.15
Black margate	-			2.13		2.13
Pigfish	-			2.08		2.08
Yellowtail parrotfish	-		2.02			2.02
Lane snapper	+				2	2
Doctorfish	+		1.84			1.84
Sheepshead	-				1.79	1.79
Total		18.28	3.86	22.48	6.4	

ns = newly settled.

Table 4. Percent cover of epibiota and substrata from photoquadrats collected at natural hard bottom and artificial reefs during Survey 3 (May 2004 and July 2004).

Species	Natural				Artificial					
	Coral Cove		MacArthur		Coral Cove		Geogrid		Cloth Reef	
	May	July	May	July	May	July	May	July	May	July
ALGAE										
Coralline algae			0.6							
Calcareous macroalgae										0.2
Caulerpa racemosa				0.9						
Caulerpa sertularoides										0.9
Caulerpa sp.		0.2	0.6			0.2				0.2
Codium sp.			0.3							0.3
Crustose coralline algae							0.4			
Dictyota sp.			0.7							1.9
Chlorophyta				0.3				2.7		14.9
Halimeda sp.		0.2		1.2						0.3
Padina sp.	40.0		0.4	0.4						
Phaeophyta		0.7		3.3	3.4	1.8		2.7		17.8
Turf algae	18.2	51.6	39.3	59.4	69.9	73.8	20.4	53.8	62.7	35.0
SPONGES										
Cliona sp.			0.7	3.0					0.4	
Holopsamma sp.						1.0				
Monanchora unguifera			0.1					0.4	0.2	
Porifera							0.4		0.9	
Sponge, encrusting										0.3
HYDROZOA										
Hydroid/Algae Mix								4.9		0.2
Hydroidea	0.9							0.9	0.4	
Thyroscyphus sp.			1.2	0.1	2.4	3.0	38.7	11.6	6.0	19.9
OTHER EPIBIOTA										
Ascidia nigra					0.1					
Bryozoa, encrusting					0.6				0.2	
Millepora sp.								0.9		
Zoanthidea			0.3	0.6	1.5	0.3				
ECHINODERMS										
Echinoidea			0.6	0.3						
SUBSTRATA										
Detached algae			0.1				0.9		0.2	0.7
Exposed hard substrate					1.0					0.5
Other material in field of view	3.1		3.7		4.3		2.7	6.2	5.1	
Rock			0.1				0.9		0.4	
Rubble			1.8	2.2			7.6	0.9		
Sand	4.0	4.4	8.6	15.3	5.2	9.4	5.8		6.0	4.6
Sediment covering				0.1						
Sediment on hard substrate	31.1	40.7	38.5	12.1	11.6	10.4	21.8	4.0	17.1	2.5
Shell hash			1.2	0.1		0.2	0.4		0.2	
Shells		0.2	0.1	0.6						
Worm Rock, Eroding (Dead)	2.7	2.0	0.9							

3.2 LIFE STAGE PATTERNS

Figure 13 shows the proportion of life stage categories for each natural hard bottom and artificial sampling location during each survey. Chi-Square tests comparing the proportional numbers of the three life stage categories between artificial reefs and natural hard bottom were significant for each survey. During Survey 1, life stage proportions were significantly different between artificial reefs and natural hard bottom (X^2 =59.742, p<0.000). On Breakers Reef natural hard bottom locations, adults contributed most to proportional abundances (**Figure 13**). At the other natural hard bottom site, Coral Cove, juvenile stage individuals contributed most across the locations and times. Artificial reef locations supported higher proportions of juvenile stage fish during all dates during Survey 1 (**Figure 13**).

Proportional life stage abundances of fishes differed significantly (between artificial reefs and natural hard bottom during Survey 2 (X^2 =69.949, p<0.000). Analyses indicated adults accounted for most of the individuals observed at the Breakers Reef location and during the November 2003 survey at the Coral Cove location (**Figure 13**). In samples from the artificial reefs, the proportion of juvenile stage individuals was higher in November and December 2003 at both Geogrid and Cloth Reef artificial locations. Newly settled fish were the predominant life stage in May 2003 at both artificial reef locations.

As with the other two surveys, Survey 3 proportional life stage abundances differed significantly (X^2 =88.656, p<0.000) between artificial reefs and natural hard bottom. In February 2004, adult stage fish contributed most to the proportional abundance at natural hard bottom locations (**Figure 13**). Newly settled fish were most important during the May and July sampling periods. Artificial reef locations differed from natural hard bottom locations in the high proportion of juveniles present across most sampling times (with the exception of February 2004). Newly settled fish contributed to higher proportions across all surveys.

3.3 HABITAT PREFERENCE BY NEWLY SETTLED FISH

Habitat preference by newly settled fish yielded results similar to those observed during the previous survey (Survey 2) (Continental Shelf Associates, Inc., 2003). Fish taxa observed commonly during the assessment of habitat preference included drums (*Equetus* spp.), grunts (*Haemulon* spp.), porkfish (*Anisotremus virginicus*), black margate (*A. surinamensis*), damselfishes (*Stegastes* spp.), copper sweeper (*Pempheris schomburgkii*), lane snapper (*Lutjanus synagris*), and yellowtail snapper (*Ocyurus chrylsurus*). Of these, grunts and drums occurred most frequently. **Figure 14** depicts the epibiotal and substrate categories most important to newly settled grunts and drums, as well as the null (random photoquadrats) from the natural hard bottom areas (Coral Cove and MacArthur Beach). The null sites were characterized by high percentages of turf algae and low to moderate amounts of macroalgae, sponges, and other epibiota. Both of the newly settled fish taxa (grunts and drums) were more varied in the epibiotal composition of their surroundings. Higher portions of sand were evident in the photoquadrats with newly settled fish of both taxa (**Figure 14**). Photoquadrats from the artificial reefs displayed similar patterns of epibiotal and substratum percentages in the null and fish taxa quadrats. **Figure 15** shows the differences in epibiotal and substratum characteristics between the two taxa and the null sites.

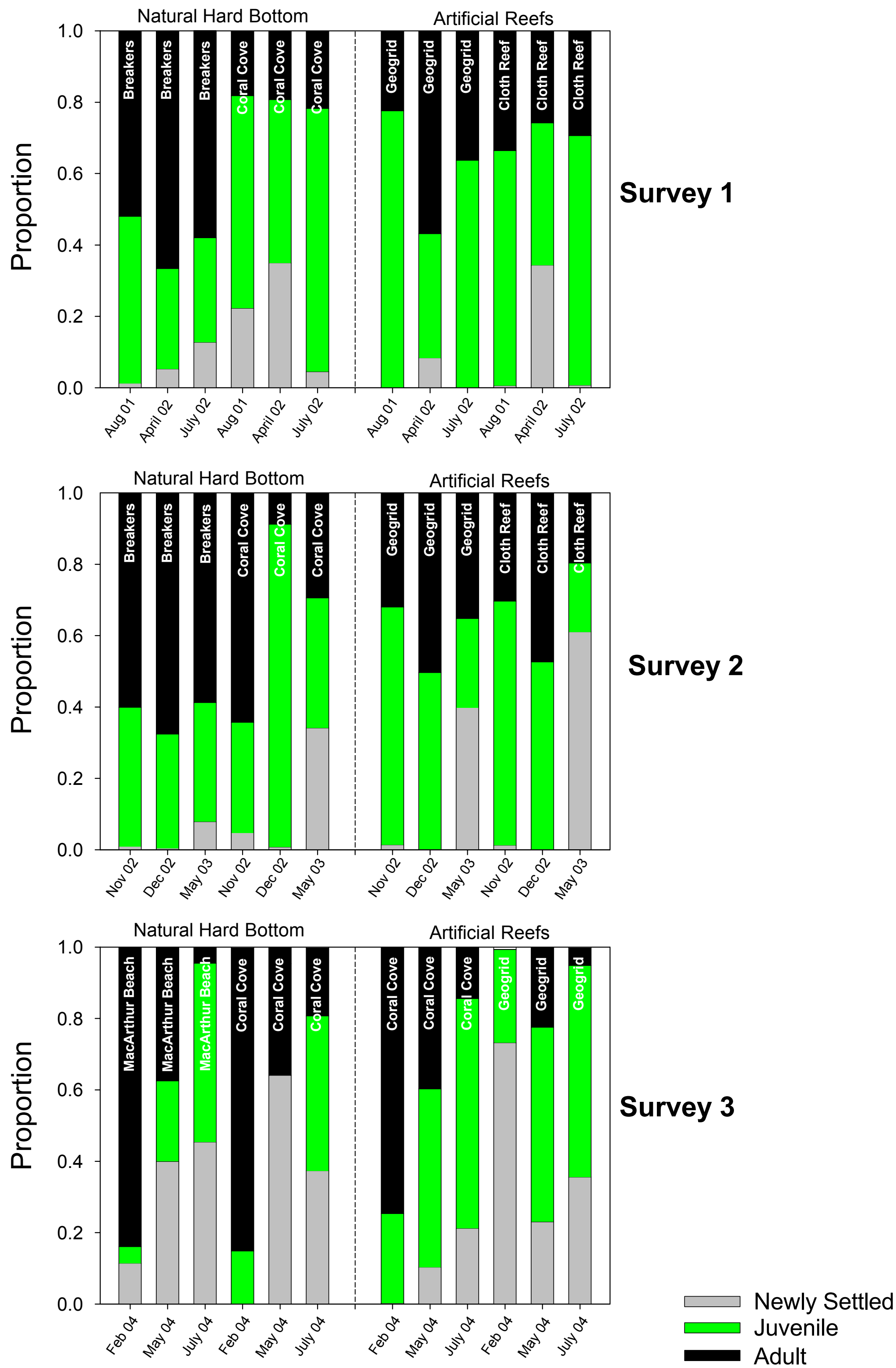

Figure 13. Proportion of fish life stage categories for natural hard bottom and artificial reefs observed during Surveys 1, 2, and 3.

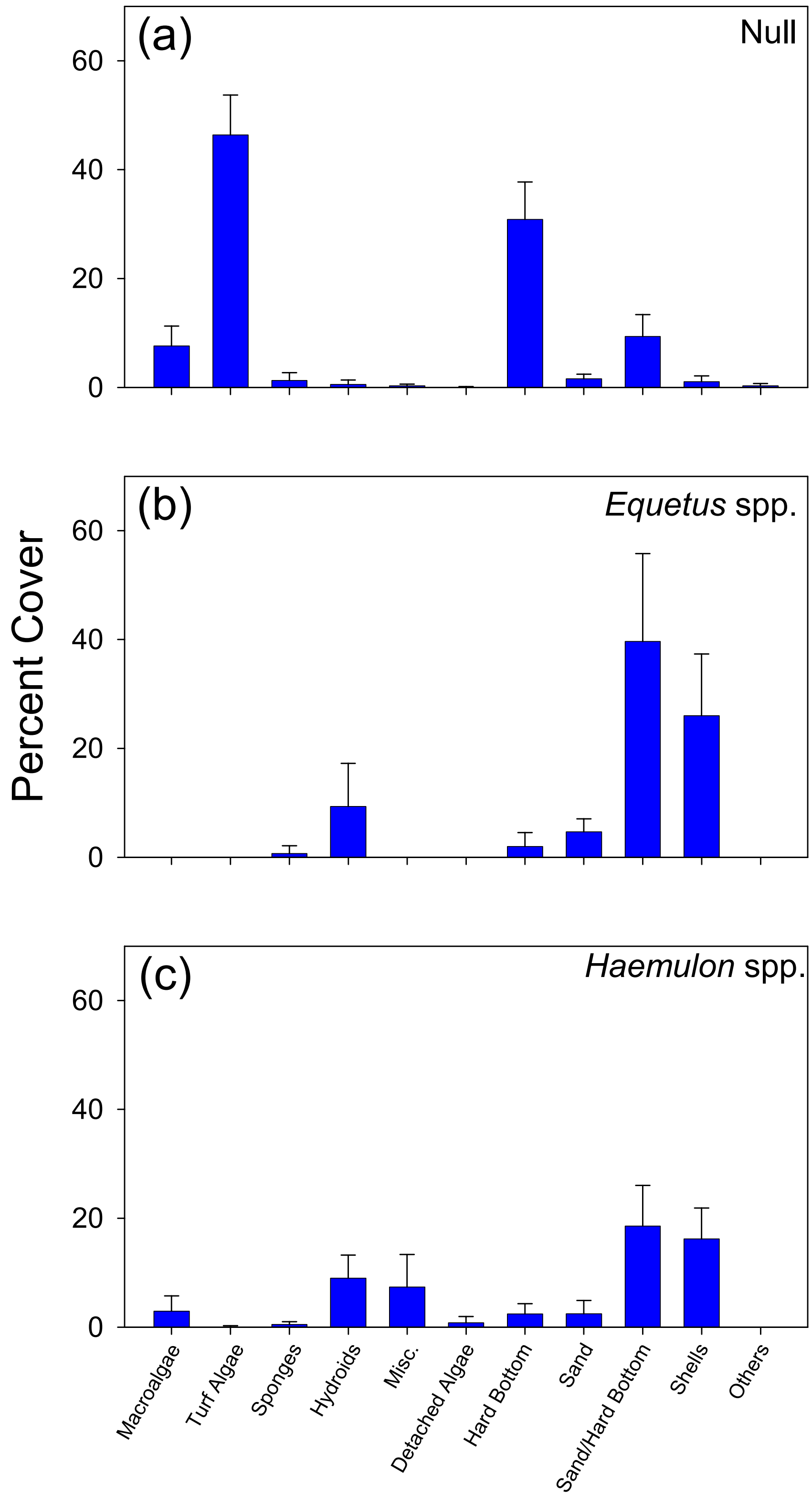

Figure 14. Mean values (error bars represent 95% confidence intervals) for major biotic and abiotic substrate characteristics in quadrats (a) randomly chosen (null), (b) chosen by newly settled drum (*Equetus* spp.), and (c) chosen by newly settled grunts (*Haemulon* spp.) at natural hard bottom locations.

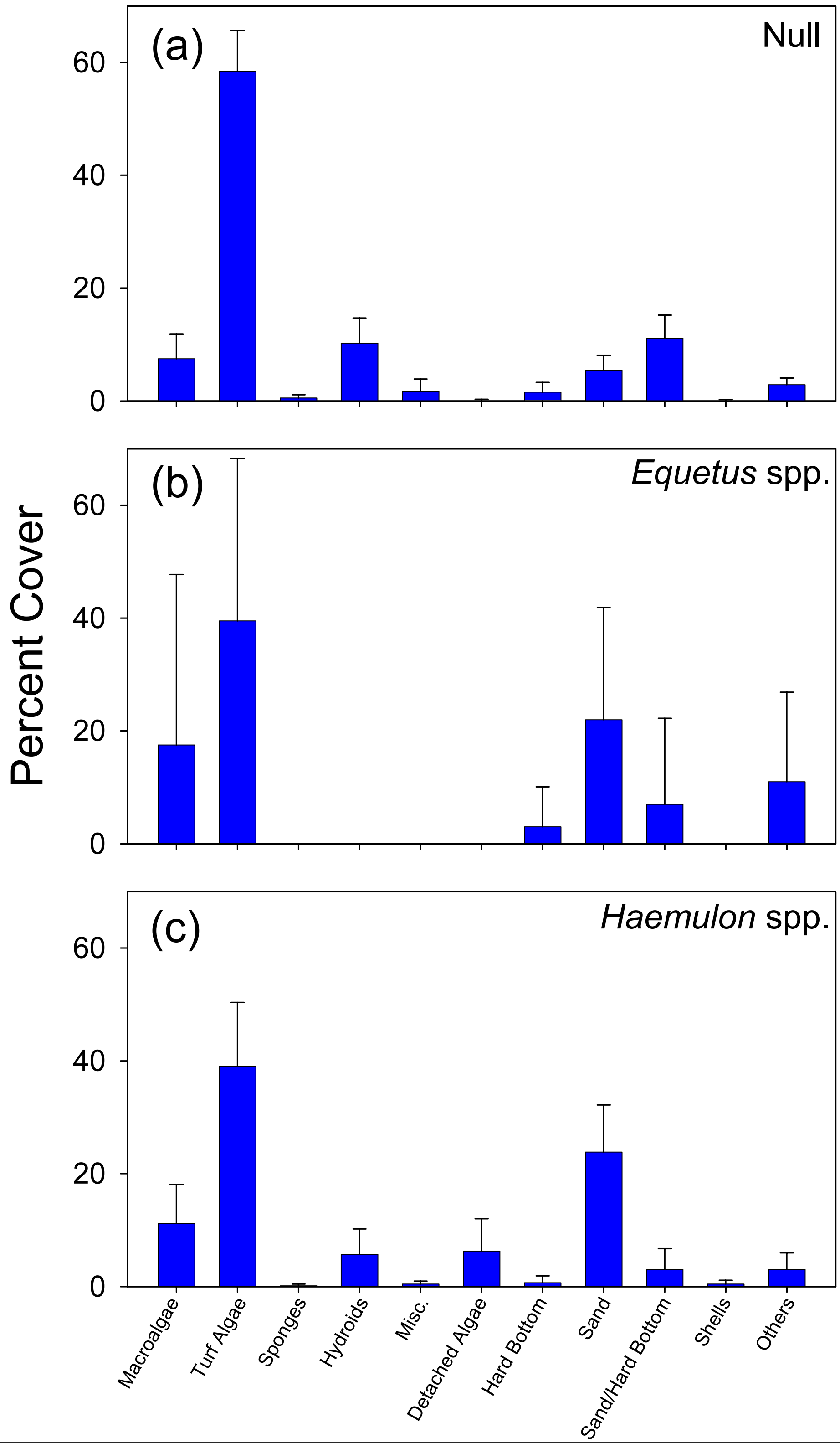

Figure 15. Mean values (error bars represent 95% confidence intervals) for major biotic and abiotic substrate characteristics in quadrats (a) randomly chosen (null), (b) chosen by newly settled *Equetus* spp., and (c) chosen by newly settled *Haemulon* spp. at artificial reef locations.

Biotic (fish and null taxa) and environmental (epibiota and substrata) sample matrices were compared using CCA (**Figure 16**). Samples from natural hard bottom and artificial reefs overlapped considerably. The first two CCA axes accounted for 49.2% of the variation in the sample patterns. Exposed hard bottom, sand, turf algae, and detached algae were most important in explaining the sample patterns in ordination space. The species biplot (**Figure 17**) showed that random quadrats were most commonly collected on the top or sides of the reef or hard bottom structures and that the most important epibiotal components contained within the quadrats were turf algae and sediment over hard bottom. Several of the taxa included in the analysis such as damselfishes, porkfish, black margate, lane snapper, and drums settled in sites with higher portions of macroalgae, sand, and exposed hard bottom. Newly settled grunts preferred areas that coincided with detached algae, sand, and exposed hard bottom at the base of the structures.

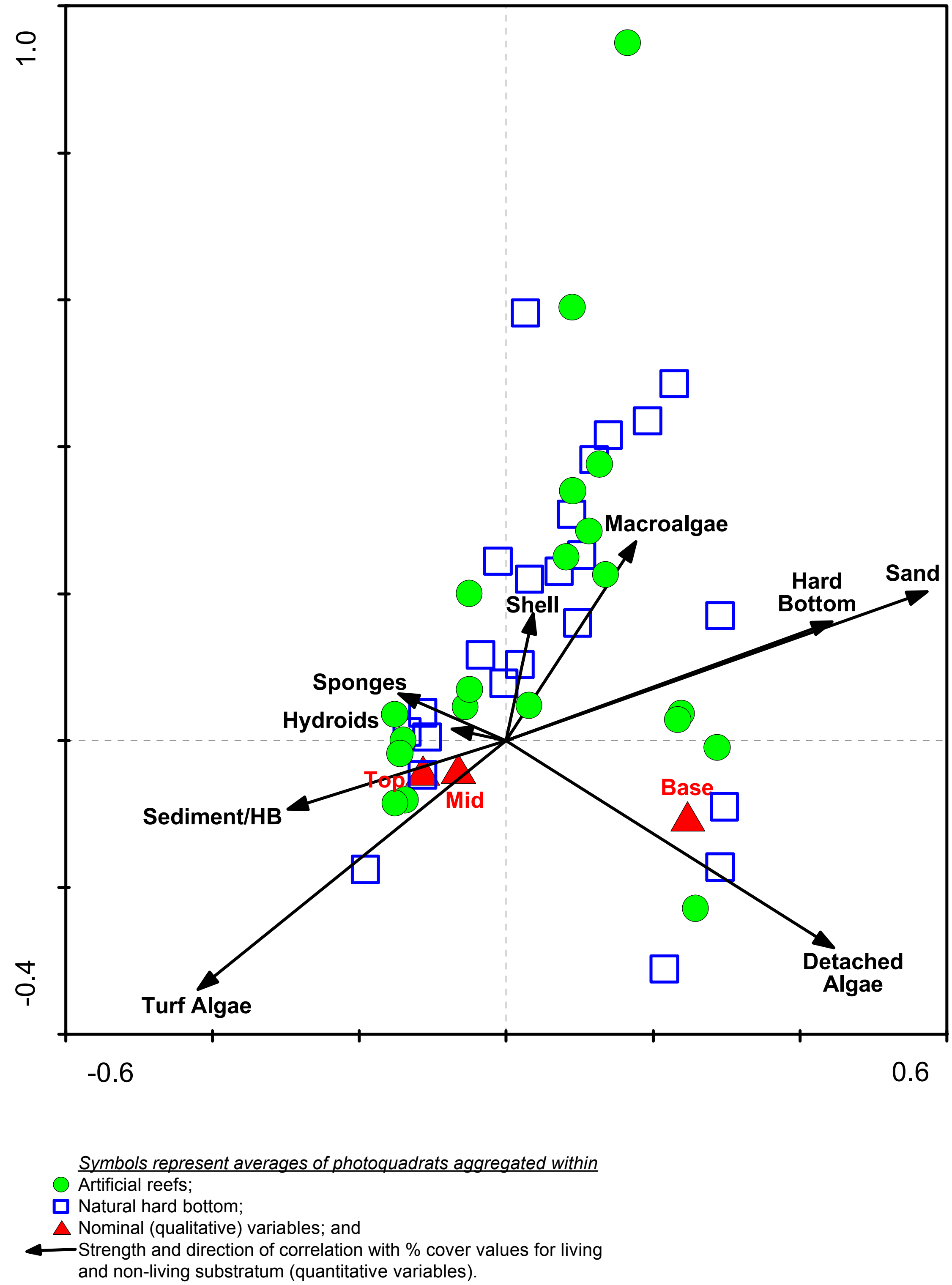

Figure 16. Samples biplot generated by canonical correspondence analysis of habitat choice by newly settled fishes on natural hard bottom and artificial reefs during May and July 2004.

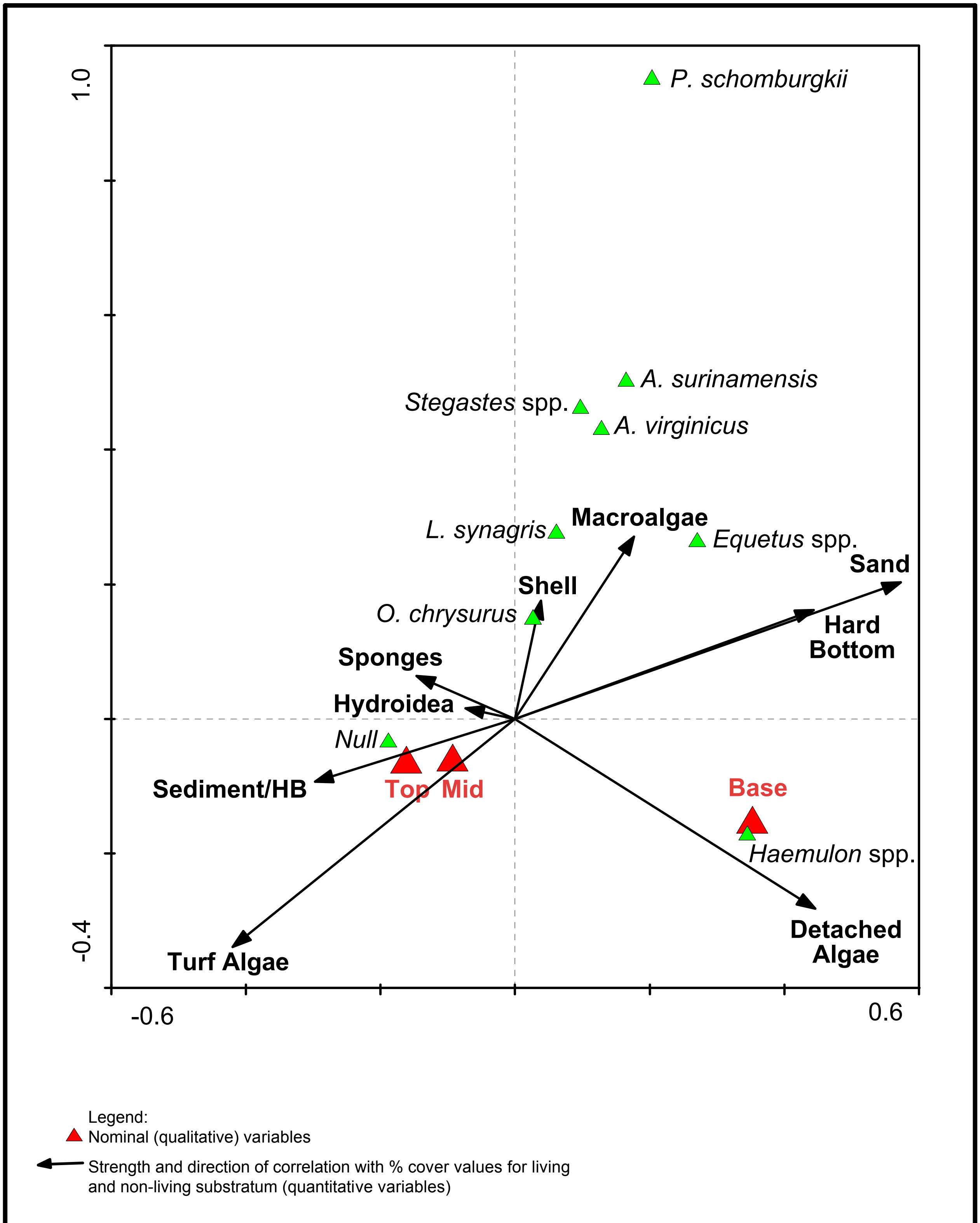

Figure 17. Species biplot generated by canonical correspondence analysis of habitat choice by newly settled fishes on natural and artificial reefs. Taxa evaluated were grunts (*Haemulon* spp.), porkfish *(Anisotremus virginicus)*, drums *(Equetus* spp.*)*, and damselfishes *(Stegastes* spp.). Randomly selected sites without fish are designated as null.

4.0 DISCUSSION

Fish assemblages observed on natural nearshore hard bottom locations in water depths <12 ft (<3.7 m) were distinct from those on artificial reefs in deeper waters (12 to 24 ft [3.7 to 7.3 m]) offshore of Palm Beach County. These differences were demonstrated by analysis of visual census data using summary measures (species and numbers of individuals) and multivariate approaches (using individual species by samples' similarity matrices). Summary measures showed that during most sampling periods, artificial reefs supported more species and individuals than natural nearshore hard bottom. The Breakers Reef natural location was a notable exception, exhibiting high numbers of species during Surveys 1 and 2. Although summary measures are often used to characterize assemblage structure, they are only collective numbers and do not account for individual species or life stage patterns.

Multivariate analyses proved very sensitive in exposing differences in species-specific distribution patterns that were quantitative (abundance) and qualitative (presence-absence). Quantitative differences between samples were subtle, involving only differences in relative abundance of species such as tomtate, porkfish, newly settled grunts, silver porgy, and cocoa damselfish, which are common to both artificial reefs and natural hard bottom. Some species such as striped croaker, pigfish, and pinfish were more characteristic of artificial reef assemblages. These kinds of species contributed to qualitative differences.

Epibiotal assemblages recorded on natural nearshore hard bottom locations in water depths <12 ft (<3.7 m) were distinct from those on artificial reefs in deeper waters (12 to 24 ft [3.7 to 7.3 m]) offshore of Palm Beach County. These differences were most pronounced during Surveys 1 and 2, when sampling included Breakers Reef. Breakers Reef supported a mature and diverse epibiotal assemblage, including hard corals, soft corals, sponges, and ascidians not found on nearshore hard bottom or artificial reefs. This was the reason Breakers Reef was dropped as a reference location and MacArthur Beach was added—to have a reference location more representative of natural nearshore hard bottom. During Survey 3, the differences between artificial and natural samples were less pronounced than during the first two surveys, when Breakers Reef samples were included. Although lower taxonomic resolution provided by the photoquadrats prevents a detailed species-level analysis such as that completed for the fishes, there were some basic differences that emerged during Survey 3. Most notable was the disproportionate cover of the algae hydroid (*Thyroscyphus* sp.) on artificial reefs. This taxon typically encrusts artificial surfaces. Epibiota of natural hard bottom is very dynamic. Taxa such as macroalgae and worm rock are ephemeral, reaching high values during certain seasons and being totally absent during others. This reflects the physically dynamic nature of the nearshore environment and the colonizing abilities of the epibiota. Here the difference in water depth between artificial reefs and natural hard bottom would affect the disturbance regime (burial and uncovery or hard bottom), light penetration, water motion, and other factors important to epibiotal growth and survival. Differences in these factors would be expected to influence the successional trajectories and ultimately assemblage structure of the epibiota. In addition to these factors, sampling error and the lack of epibiotal data for February 2004 certainly have contributed to the observed patterns.

Visual census data showed that fish assemblages differed between artificial reefs and natural hard bottom. These same data collated as life stage abundances indicated that natural hard bottom habitats in water depths <12 ft (<3.7 m) do not support disproportionate numbers of juvenile fishes as compared to artificial hard bottom habitats in water depths ranging from 12 to 24 ft (3.7 to 7.3 m) off Palm Beach County. Proportional abundance of fishes classified as juvenile and newly settled varied over time, but when combined into a single "early life stage" category were generally higher than proportional abundance of fishes classified as adults at both artificial reefs and natural hard bottom locations. Thus, within both habitat types, most individuals observed were early life stage (juvenile or newly settled). Often adult individuals such as jack crevalle, Spanish mackerel, and Atlantic bumper were present in large schools, thereby influencing the proportional abundances of adults when schooling species were among the censused species. As with the assemblage structure, individual species exhibited differing patterns of life stage abundance (and occurrence) between artificial reef and natural hard bottom locations. For example, juvenile black margate and sailors choice were more common on natural hard bottom, whereas juvenile tomtate, striped croaker, and smallmouth grunt were more common on artificial reefs.

Although fish assemblage and life stage patterns differed between artificial reefs and natural hard bottom, the investigation of habitat preferred by newly settled fishes suggests less differences between the two habitat types. For the species considered in our analysis, habitat preference was less dependent on epibiotal composition and percent cover than it was on structural features of the reef or hard bottom. Newly settled grunts (*Haemulon* spp.) were most commonly observed at the base of natural or artificial features (at the sand-rock interface). Macroalgae was important for settling members of other fish taxa, but it appears that structure alone is enough to promote settlement by the species we examined. Thus, it is possible that the presence of structures, either artificial or natural, triggered the settlement of the taxa we examined. This suggests that artificial reefs provide linkages for some species along cross-shelf developmental pathways that would be completely absent for the nearshore in cases where natural nearshore hard bottom is lost to beach renourishment.

The observed differences between fish and epibiotal assemblages, life stage proportions, and newly settled fish habitat preference on artificial and natural habitats in differing water depths must be considered in light of several factors. Water depth was a confounding factor in the design of this monitoring program. This is why the first question in the Introduction was posed the way it was. Because of logistics and other limitations, the study design could not account for the water depth gradient (as well as other factors that co-vary with water depth).

Another confounding factor is that artificial limestone boulder reefs have higher overall relief (but may not be more complex habitats) than natural nearshore hard bottom. Although limestone boulders are a viable and economically feasible means of creating artificial mitigation reefs, unique characteristics of the relatively low-lying natural nearshore hard bottom have not been replicated. High relief has been identified as an important factor in determining fish assemblage structure on artificial reefs. High relief can affect water motion and circulation, which can in turn influence habitat utilization by fishes of all life stages. For epibiota, higher relief equates with higher overall surface area, in particular, vertical surfaces. Additionally, high relief features are less likely to follow natural disturbance (burial) regimes of lower relief nearshore hard bottom, allowing for very different epibiotal successional trajectories to develop. Another important factor to keep in mind while interpreting the monitoring results is the problem of sand encroachment, or burial of natural hard bottom and artificial reefs, which has been going on for most of this project. The phenomenon of sand burial of both natural hard bottom, and artificial reefs at the Coral Cove location was highlighted between Surveys 2 and 3, when both were covered to some extent with sand. Although sand burial is part of the nearshore system dynamics, we were forced to sample adaptively and opportunistically as some sampling units at Coral Cove were partially or completely lost. Consequently, the total area of natural hard bottom in the study locations was reduced and not equivalent in all cases to the total area of artificial reefs sampled synoptically. As a result, simple species-area differences could affect the comparisons being made at the assemblage level.

The confounding of habitat types with water depth, relief, and sand burial restricts the generality of the monitoring results; all statements regarding the differences in fish and epibiotal assemblage structure, life stage proportions, and habitat preference should not be extended beyond the study locations.

Although artificial reefs placed in slightly deeper water cannot precisely replicate the nearshore hard bottom habitat or the fish and epibiotal assemblages, they do serve as important habitat for most local fishes and their life stages, which also use natural nearshore habitat. The spatial and temporal dynamics inherent in reef fish assemblages will likely prevent complete agreement in structure (proportional abundances, numbers of species, and individuals) between artificial and natural habitats offshore of Palm Beach County. Nevertheless, taxonomic and life stage compositions are broadly similar between the two; this similarity should increase during future surveys with the elimination of Breakers Reef as a reference site. The artificial reefs, with their fish and epibiotal components, certainly contribute to local ecosystem structure and function and just as importantly, artificial reefs provide connections along the cross-shelf continuum for young fishes that follow developmental pathways from inshore to offshore (Lindeman et al., 2000).

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APPENDICES

APPENDIX A

SAMPLE SUMMARY

Table A.1. Positions of artificial reefs and natural hard bottom locations sampled during the monitoring program.

Location	Material	Type	Latitude	Longitude	Northing (x)	Easting (y)
Coral Cove Artificial	Limestone boulders	Artificial	26.9560	-80.0740	957815.4701	954282.2588
Coral Cove Artificial	Limestone boulders	Artificial	26.9575	-80.0748	957550.8609	954825.6487
Coral Cove Artificial	Limestone boulders	Artificial	26.9587	-80.0750	957482.5145	955261.4107
Juno Geogrid Mitigation	Limestone boulders	Artificial	26.9157	-80.0584	963000.1840	939658.2413
Jupiter Cloth Reef Rock Mitigation	Limestone boulders	Artificial	26.9143	-80.0592	962737.2693	939161.6248
Jupiter Cloth Reef Rock Mitigation	Limestone boulders	Artificial	26.9136	-80.0585	962965.1287	938916.2378
Jupiter Cloth Reef Rock Mitigation	Limestone boulders	Artificial	26.9129	-80.0585	962976.8138	938635.7955
Jupiter Cloth Reef Rock Mitigation	Limestone boulders	Artificial	26.9122	-80.0584	963011.8691	938390.4085
Jupiter Concrete Mitigation	Concrete	Artificial	26.9121	-80.0572	963420.8474	938361.1958
Jupiter Concrete Mitigation	Concrete	Artificial	26.9117	-80.0574	963339.0517	938232.6597
Juno Armorflex Mitigation[1]	Limestone boulders	Artificial	26.9133	-80.0581	963105.3498	938793.5443
Juno Armorflex Mitigation[1]	Limestone boulders	Artificial	26.9129	-80.0581	963105.3498	938641.6381
Juno Armorflex Mitigation[1]	Limestone boulders	Artificial	26.9125	-80.0580	963152.0902	938524.7871
Jupiter Shallow Concrete Mitigation	Concrete	Artificial	26.9128	-80.0597	962585.3631	938612.4253
MacArthur Beach State Park	Natural	Natural	26.8268	-80.0378	969965.2262	907402.0958
MacArthur Beach State Park	Natural	Natural	26.8307	-80.0387	969660.9596	908817.6320
MacArthur Beach State Park	Natural	Natural	26.8547	-80.0443	967768.8959	917528.5259
MacArthur Beach State Park	Natural	Natural	26.8250	-80.0376	970036.2987	906732.5095
Coral Cove	Natural	Natural	26.9677	-80.0788	956228.6716	958512.1417
Coral Cove	Natural	Natural	26.9636	-80.0774	956673.7315	957045.1191
Coral Cove	Natural	Natural	26.9601	-80.0761	957105.2534	955761.7136
Breakers Reef	Natural	Natural	26.7100	-80.0287	973260.3150	864961.0355
Breakers Reef	Natural	Natural	26.7194	-80.0298	972863.4364	868378.4330
Breakers Reef	Natural	Natural	26.7160	-80.0292	973090.6570	867139.3235

[1] = In the text, these sites were lumped under Juno Geogrid Mitigation.

Table A.2. Sample summary.

Type	Location	Date	Units	Timed Swims	Photo Quadrats	Fish Quadrats
Survey 1						
Natural	Breakers Reef	24-Aug-2001	3	9	27	
		8-May-2002	3	9	27	
		31-Jul-2002	3	9	27	
	Coral Cove	23-Aug-2001	1	2	9	
		30-Apr-2002	3	8	27	
		26-Jul-2002	3	9	27	
Artificial	Juno Geogrid Mitigation	8-Aug-2001	1	2	9	
		22-Aug-2001	2	3	18	
		23-Aug-2001	2	5	18	
		30-Apr-2002	3	7	27	
		17-Jul-2002	3	8	27	
	Jupiter Cloth Reef Rock Mitigation	22-Aug-2001	3	7	27	
		6-May-2002	3	9	27	
		17-Jul-2002	1	3	9	
		18-Jul-2002	2	6	18	
	Jupiter Concrete Mitigation	8-Aug-2001	1	2	9	
		22-Aug-2001	2	3	18	
Totals			39	101	351	
Survey 2						
Natural	Breakers Reef	12-Nov-2002	3	9	27	
		12-Dec-2002	3	9	27	
		13-May-2003	3	8	27	
	Coral Cove	29-Oct-2002	3	9	27	
		3-Dec-2002	3	8	27	
		2-May-2003	3	8	27	26
		3-May-2003	1	1	9	
Artificial	Juno Geogrid Mitigation	29-Oct-2002	1	3	9	
		30-Oct-2002	2	4	18	29
		3-Dec-2002	3	8	27	
		15-Apr-2003	1	3	9	
		30-Apr-2003	2	5	18	
	Jupiter Cloth Reef Rock Mitigation	22-Oct-2002	1	1	9	
		30-Oct-2002	3	8	27	
		5-Dec-2002	3	9	27	
		30-Apr-2003	3	9	27	62
Totals			38	102	342	117

Table A.2. (Continued).

Type	Location	Date	Units	Timed Swims	Photo Quadrats	Fish Quadrats
Survey 3						
Natural	Coral Cove	12-Feb-2004	1	3	9	
		27-May-2004	2	5	18	8
		20-Jul-2004	2	4	18	19
	MacArthur Beach Park	12-Feb-2004	3	5	27	
		28-May-2004	3	6	27	19
		19-Jul-2004	3	8	27	27
Artificial	Coral Cove Artificial	12-Feb-2004	3	8	27	
		27-May-2004	2	5	18	7
		2-Jun-2004	2	4	18	22
		20-Jul-2004	3	6	27	16
	Juno Geogrid Mitigation	11-Feb-2004	1	3	9	
		28-May-2004	1	3	9	
		19-Jul-2004	1	3	9	9
	Jupiter Cloth Reef Rock Mitigation	11-Feb-2004	2	6	18	
		28-May-2004	2	4	18	5
		20-Jul-2004	1	3	9	16
		21-Jul-2004	1	3	9	
Totals			33	79	297	148

APPENDIX B

SUMMARY TABLES

Table B.1. Summary statistics for fishes observed at Breakers Reef natural hard bottom during Surveys 1 and 2.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Tomtate	*Haemulon aurolineatum*	15	3,004	166.8889	316.8410	100388.2222	0.19447
French Grunt	*Haemulon flavolineatum*	18	1,909	106.0556	102.0533	10414.8791	0.12358
Sergeant Major	*Abudefduf saxatilis*	18	1,777	98.7222	105.3743	11103.7418	0.11504
Smallmouth Grunt	*Haemulon chrysargyreum*	13	1,299	72.1667	84.5377	7146.6176	0.08409
Bluehead Wrasse	*Thalassoma bifasciatum*	18	1,120	62.2222	25.3065	640.4183	0.07251
Silver Porgy	*Diplodus argenteus*	18	757	42.0556	36.2564	1314.5261	0.04901
Blue Runner	*Caranx crysos*	8	723	40.1667	86.2358	7436.6176	0.04681
Grunts (Newly Settled)	*Haemulon* spp.	9	590	32.7778	78.9680	6235.9477	0.03820
Ocean Surgeon	*Acanthurus bahianus*	18	438	24.3333	12.3527	152.5882	0.02836
Porkfish	*Anisotremus virginicus*	18	353	19.6111	14.7932	218.8399	0.02285
Bicolor Damselfish	*Stegastes partitus*	18	327	18.1667	12.5710	158.0294	0.02117
Round Scad	*Decapterus punctatus*	1	300	16.6667	70.7107	5000.0000	0.01942
Sailor's Choice	*Haemulon parra*	18	269	14.9444	31.7592	1008.6438	0.01741
Cocoa Damselfish	*Stegastes variabilis*	17	244	13.5556	10.9985	120.9673	0.01580
Slippery Dick	*Halichoeres bivittatus*	15	217	12.0556	11.4248	130.5261	0.01405
Spanish Hogfish	*Bodianus rufus*	17	196	10.8889	5.8901	34.6928	0.01269
Clown Wrasse	*Halichoeres maculipinna*	17	158	8.7778	6.3018	39.7124	0.01023
Spotted Goatfish	*Pseudupeneus maculatus*	17	118	6.5556	6.6175	43.7908	0.00764
Sharpnose Puffer	*Canthigaster rostrata*	16	101	5.6111	3.9129	15.3105	0.00654
Redband Parrotfish	*Sparisoma aurofrenatum*	17	89	4.9444	3.7491	14.0556	0.00576
Caesar Grunt	*Haemulon carbonarium*	12	78	4.3333	6.6686	44.4706	0.00505
Yellow Goatfish	*Mulloidichthys martinicus*	4	70	3.8889	11.9356	142.4575	0.00453
Doctorfish	*Acanthurus chirurgus*	14	69	3.8333	3.4683	12.0294	0.00447
Stoplight Parrotfish	*Sparisoma viride*	13	65	3.6111	3.2924	10.8399	0.00421
Blue Tang	*Acanthurus coeruleus*	14	62	3.4444	3.6497	13.3203	0.00401
Puddingwife	*Halichoeres radiatus*	17	54	3.0000	2.1420	4.5882	0.00350
Glassy Sweeper	*Pempheris schomburgkii*	3	52	2.8889	8.2597	68.2222	0.00337
White Grunt	*Haemulon plumieri*	14	52	2.8889	3.2519	10.5752	0.00337
Black Margate	*Anisotremus surinamensis*	15	48	2.6667	3.0486	9.2941	0.00311

Table B.1. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Gray Snapper	*Lutjanus griseus*	12	46	2.5556	3.0141	9.0850	0.00298
Bluestriped Grunt	*Haemulon sciurus*	12	45	2.5000	3.9742	15.7941	0.00291
Seaweed Blenny	*Parablennius marmoreus*	7	43	2.3889	4.9603	24.6046	0.00278
Chub	*Kyphosus* spp.	9	42	2.3333	4.7154	22.2353	0.00272
Dusky Damselfish	*Stegastes adustus*	10	42	2.3333	2.9902	8.9412	0.00272
Trumpetfish	*Aulostomus maculatus*	10	39	2.1667	2.6402	6.9706	0.00252
Beaugregory	*Stegastes leucostictus*	10	36	2.0000	2.5205	6.3529	0.00233
Purple Reef-Fish	*Chromis scotti*	7	32	1.7778	4.1381	17.1242	0.00207
Mahogany Snapper	*Lutjanus mahogoni*	5	31	1.7222	4.2260	17.8595	0.00201
Atlantic Spadefish	*Chaetodipterus faber*	2	30	1.6667	5.9409	35.2941	0.00194
Spanish Grunt	*Haemulon macrostomum*	9	27	1.5000	2.4071	5.7941	0.00175
High-Hat	*Equetus acuminatus*	10	22	1.2222	1.5168	2.3007	0.00142
Bridled Goby	*Coryphopterus glaucofraenum*	6	20	1.1111	2.3736	5.6340	0.00129
Graysby	*Epinephelus cruentatus*	14	20	1.1111	1.1318	1.2810	0.00129
Porcupinefish	*Diodon hystrix*	9	19	1.0556	1.6260	2.6438	0.00123
Spotfin Butterflyfish	*Chaetodon ocellatus*	8	19	1.0556	1.3492	1.8203	0.00123
Harlequin Bass	*Serranus tigrinus*	7	18	1.0000	1.5339	2.3529	0.00117
Gray Triggerfish	*Balistes capriscus*	7	17	0.9444	1.4337	2.0556	0.00110
Redfin Parrotfish	*Sparisoma rubripinne*	9	17	0.9444	1.3048	1.7026	0.00110
Yellowtail Snapper	*Ocyurus chrysurus*	7	16	0.8889	1.6410	2.6928	0.00104
Bar Jack	*Caranx ruber*	1	15	0.8333	3.5355	12.5000	0.00097
Orange Filefish	*Cantherhines pullus*	10	15	0.8333	1.0432	1.0882	0.00097
Banded Butterflyfish	*Chaetodon striatus*	8	14	0.7778	0.9428	0.8889	0.00091
Schoolmaster	*Lutjanus apodus*	5	14	0.7778	1.7675	3.1242	0.00091
Striped Parrotfish	*Scarus croicensis*	3	14	0.7778	2.0452	4.1830	0.00091
Princess Parrotfish	*Scarus taeniopterus*	2	13	0.7222	2.2702	5.1536	0.00084
Yellowfin Mojarra	*Gerres cinereus*	9	13	0.7222	0.8948	0.8007	0.00084
Squirrelfish	*Holocentrus adscensionis*	2	12	0.6667	2.5896	6.7059	0.00078
Colon Goby	*Coryphopterus dicrus*	7	11	0.6111	0.9164	0.8399	0.00071
Cubbyu	*Equetus umbrosus*	3	11	0.6111	2.1182	4.4869	0.00071

Table B.1. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Neon Goby	*Gobiosoma oceanops*	4	11	0.6111	1.3779	1.8987	0.00071
Saddled Blenny	*Malacoctenus triangulatus*	6	11	0.6111	1.0922	1.1928	0.00071
Scrawled Cowfish	*Acanthostracion quadricornis*	7	9	0.5000	0.7071	0.5000	0.00058
Goldspot Goby	*Gnatholepis thompsoni*	3	8	0.4444	1.1490	1.3203	0.00052
Great Barracuda	*Sphyraena barracuda*	2	8	0.4444	1.6529	2.7320	0.00052
Gray Angelfish	*Pomacanthus arcuatus*	5	7	0.3889	0.6978	0.4869	0.00045
Greater Soapfish	*Rypticus saponaceus*	4	6	0.3333	0.6860	0.4706	0.00039
Sheepshead Porgy	*Calamus penna*	6	6	0.3333	0.4851	0.2353	0.00039
Smooth Trunkfish	*Lactophrys triqueter*	5	6	0.3333	0.5941	0.3529	0.00039
Blue Goby	*Ioglossus calliuris*	2	5	0.2778	0.9583	0.9183	0.00032
Bluespotted Cornetfish	*Fistularia tabacaria*	3	5	0.2778	0.7519	0.5654	0.00032
Yellowhead Wrasse	*Halichoeres garnoti*	4	5	0.2778	0.5745	0.3301	0.00032
Yellowtail Damselfish	*Microspathodon chrysurus*	4	5	0.2778	0.5745	0.3301	0.00032
Cottonwick	*Haemulon melanurum*	1	4	0.2222	0.9428	0.8889	0.00026
French Angelfish	*Pomacanthus paru*	3	4	0.2222	0.5483	0.3007	0.00026
Queen Angelfish	*Holacanthus ciliaris*	4	4	0.2222	0.4278	0.1830	0.00026
Rainbow Parrotfish	*Scarus guacamaia*	3	4	0.2222	0.5483	0.3007	0.00026
Redtail Parrotfish	*Sparisoma chrysopterum*	2	4	0.2222	0.7321	0.5359	0.00026
Reef Butterflyfish	*Chaetodon sedentarius*	4	4	0.2222	0.4278	0.1830	0.00026
Yellow Jack	*Caranx bartholomaei*	2	4	0.2222	0.7321	0.5359	0.00026
Blue Angelfish	*Holacanthus bermudensis*	3	3	0.1667	0.3835	0.1471	0.00019
Blue Chromis	*Chromis cyanea*	2	3	0.1667	0.5145	0.2647	0.00019
Chain Moray	*Echidna catenata*	3	3	0.1667	0.3835	0.1471	0.00019
Goldentail Moray	*Gymnothorax miliaris*	2	3	0.1667	0.5145	0.2647	0.00019
Ocean Triggerfish	*Canthidermis sufflamen*	2	3	0.1667	0.5145	0.2647	0.00019
Orangespotted Filefish	*Aluterus schoepfi*	2	3	0.1667	0.5145	0.2647	0.00019
Rock Beauty	*Holacanthus tricolor*	3	3	0.1667	0.3835	0.1471	0.00019
Scrawled Filefish	*Aluterus scriptus*	3	3	0.1667	0.3835	0.1471	0.00019
Sheepshead	*Archosargus probatocephalus*	1	3	0.1667	0.7071	0.5000	0.00019
Southern Stingray	*Dasyatis americana*	3	3	0.1667	0.3835	0.1471	0.00019

Table B.1. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Spotted Moray	*Gymnothorax moringa*	3	3	0.1667	0.3835	0.1471	0.00019
Spotted Scorpionfish	*Scorpaena plumieri*	3	3	0.1667	0.3835	0.1471	0.00019
Vermillion Snapper	*Rhomboplites aurorubens*	1	3	0.1667	0.7071	0.5000	0.00019
Yellowhead Jawfish	*Opistognathus aurifrons*	1	3	0.1667	0.7071	0.5000	0.00019
Balloonfish	*Diodon holocanthus*	2	2	0.1111	0.3234	0.1046	0.00013
Lane Snapper	*Lutjanus synagris*	2	2	0.1111	0.3234	0.1046	0.00013
Littlehead Porgy	*Calamus proridens*	2	2	0.1111	0.3234	0.1046	0.00013
Nurse Shark	*Ginglymostoma cirratum*	1	2	0.1111	0.4714	0.2222	0.00013
Pigfish	*Orthopristis chrysoptera*	2	2	0.1111	0.3234	0.1046	0.00013
Three Spot Damselfish	*Stegastes planifrons*	1	2	0.1111	0.4714	0.2222	0.00013
Whitespotted Filefish	*Cantherhines macrocerus*	2	2	0.1111	0.3234	0.1046	0.00013
Barred Blenny	*Hypleurochilus bermudensis*	2	2	0.1111	0.3234	0.1046	0.00013
Brown Chromis	*Chromis multilineata*	1	1	0.0556	0.2357	0.0556	0.00006
Butter Hamlet	*Hypoplectrus unicolor*	1	1	0.0556	0.2357	0.0556	0.00006
Coney	*Epinephelus fulvus*	1	1	0.0556	0.2357	0.0556	0.00006
Flamefish	*Apogon maculatus*	1	1	0.0556	0.2357	0.0556	0.00006
Gag Grouper	*Mycteroperca microlepis*	1	1	0.0556	0.2357	0.0556	0.00006
Glasseye Snapper	*Priacanthus cruentatus*	1	1	0.0556	0.2357	0.0556	0.00006
Honeycomb Cowfish	*Acanthostracion polygonia*	1	1	0.0556	0.2357	0.0556	0.00006
Midnight Parrotfish	*Scarus coelestinus*	1	1	0.0556	0.2357	0.0556	0.00006
Mutton Snapper	*Lutjanus analis*	1	1	0.0556	0.2357	0.0556	0.00006
Queen Triggerfish	*Balistes vetula*	1	1	0.0556	0.2357	0.0556	0.00006
Slender Filefish	*Monacanthus tuckeri*	1	1	0.0556	0.2357	0.0556	0.00006
Longlure Frogfish	*Antennarius multiocellatus*	1	1	0.0556	0.2357	0.0556	0.00006
Trunkfish	*Lactophrys trigonus*	3	5	0.2778	0.6691	0.4477	0.00032

Table B.2. Summary statistics for fishes observed at Coral Cove natural hard bottom during Surveys 1, 2, and 3.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Crevalle Jack	*Caranx hippos*	6	1,565	74.52381	188.45201	35514.16190	0.14047
Silver Porgy	*Diplodus argenteus*	19	1,393	66.33333	93.49296	8740.93333	0.12503
Grunts (Newly Settled)	*Haemulon* spp.	13	1,217	57.95238	108.53547	11779.94762	0.10924
Porkfish	*Anisotremus virginicus*	21	930	44.28571	48.26401	2329.41429	0.08348
Slippery Dick	*Halichoeres bivittatus*	20	714	34.00000	24.95596	622.80000	0.06409
Sailor's Choice	*Haemulon parra*	19	581	27.66667	35.49554	1259.93333	0.05215
Black Margate	*Anisotremus surinamensis*	20	498	23.71429	13.59096	184.71429	0.04470
Hairy Blenny	*Labrisomus nuchipinnis*	21	470	22.38095	13.12050	172.14762	0.04219
Sergeant Major	*Abudefduf saxatilis*	17	419	19.95238	26.78148	717.24762	0.03761
French Grunt	*Haemulon flavolineatum*	5	337	16.04762	47.68383	2273.74762	0.03025
Atlantic Bumper	*Chloroscombrus chrysurus*	3	305	14.52381	47.85146	2289.76190	0.02738
Cocoa Damselfish	*Stegastes variabilis*	17	282	13.42857	12.80848	164.05714	0.02531
Blue Runner	*Caranx crysos*	8	259	12.33333	23.81036	566.93333	0.02325
Tomtate	*Haemulon aurolineatum*	5	183	8.71429	23.05459	531.51429	0.01643
Doctorfish	*Acanthurus chirurgus*	18	178	8.47619	7.88428	62.16190	0.01598
Molly Miller	*Scartella cristata*	13	177	8.42857	10.71248	114.75714	0.01589
Seaweed Blenny	*Parablennius marmoreus*	15	169	8.04762	12.33887	152.24762	0.01517
Lane Snapper	*Lutjanus synagris*	12	152	7.23810	12.35680	152.69048	0.01364
Chub	*Kyphosus sectatrix/incisor*	6	144	6.85714	13.41002	179.82857	0.01293
Smallmouth Grunt	*Haemulon chrysargyreum*	5	135	6.42857	16.36940	267.95714	0.01212
High-Hat	*Equetus acuminatus*	16	126	6.00000	7.75242	60.10000	0.01131
Drum (Newly Settled)	Sciaenidae	2	101	4.80952	21.36263	456.36190	0.00907
Redfin Parrotfish	*Sparisoma rubripinne*	19	91	4.33333	4.16333	17.33333	0.00817
Ocean Surgeon	*Acanthurus bahianus*	15	89	4.23810	4.19410	17.59048	0.00799
Glassy Sweeper	*Pempheris schomburgkii*	4	59	2.80952	10.44806	109.16190	0.00530
Bar Jack	*Caranx ruber*	2	55	2.61905	11.55195	133.44762	0.00494
Beaugregory	*Stegastes leucostictus*	8	54	2.57143	4.11791	16.95714	0.00485

Table B.2. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Dusky Damselfish	*Stegastes adustus*	12	47	2.23810	2.82674	7.99048	0.00422
Sheepshead	*Archosargus probatocephalus*	8	37	1.76190	3.63187	13.19048	0.00332
Gray Snapper	*Lutjanus griseus*	7	33	1.57143	3.64104	13.25714	0.00296
Lookdown	*Selene vomer*	2	26	1.23810	5.44890	29.69048	0.00233
Mahogany Snapper	*Lutjanus mahogoni*	4	26	1.23810	3.67294	13.49048	0.00233
White Grunt	*Haemulon plumieri*	2	23	1.09524	4.79484	22.99048	0.00206
Spotfin Mojarra	*Eucinostomus argenteus*	1	20	0.95238	4.36436	19.04762	0.00180
Snook	*Centropomus undecimalis*	2	17	0.80952	2.92607	8.56190	0.00153
Bluehead Wrasse	*Thalassoma bifasciatum*	6	14	0.66667	1.31656	1.73333	0.00126
Caesar Grunt	*Haemulon carbonarium*	2	12	0.57143	2.20389	4.85714	0.00108
Clown Wrasse	*Halichoeres maculipinna*	3	11	0.52381	1.50396	2.26190	0.00099
Spanish Grunt	*Haemulon macrostomum*	5	10	0.47619	0.98077	0.96190	0.00090
Great Barracuda	*Sphyraena barracuda*	4	6	0.28571	0.64365	0.41429	0.00054
Puddingwife	*Halichoeres radiatus*	4	6	0.28571	0.71714	0.51429	0.00054
Spotted Goatfish	*Pseudupeneus maculatus*	1	6	0.28571	1.30931	1.71429	0.00054
Bicolor Damselfish	*Stegastes partitus*	4	5	0.23810	0.53896	0.29048	0.00045
Spotted Scorpionfish	*Scorpaena plumieri*	3	4	0.19048	0.51177	0.26190	0.00036
Yellowfin Mojarra	*Gerres cinereus*	3	4	0.19048	0.51177	0.26190	0.00036
Blue Tang	*Acanthurus coeruleus*	2	3	0.14286	0.47809	0.22857	0.00027
French Angelfish	*Pomacanthus paru*	2	3	0.14286	0.47809	0.22857	0.00027
Gag Grouper	*Mycteroperca microlepis*	2	3	0.14286	0.47809	0.22857	0.00027
Schoolmaster	*Lutjanus apodus*	3	3	0.14286	0.35857	0.12857	0.00027
Yellow Jack	*Caranx bartholomaei*	3	3	0.14286	0.35857	0.12857	0.00027
Blackear Wrasse	*Halichoeres poeyi*	2	2	0.09524	0.30079	0.09048	0.00018
Cottonwick	*Haemulon melanurum*	1	2	0.09524	0.43644	0.19048	0.00018
Gray Triggerfish	*Balistes capriscus*	1	2	0.09524	0.43644	0.19048	0.00018
Purplemouth Moray	*Gymnothorax vicinus*	1	2	0.09524	0.43644	0.19048	0.00018
Atlantic Spadefish	*Chaetodipterus faber*	1	1	0.04762	0.21822	0.04762	0.00009

Table B.2. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Banded Butterflyfish	*Chaetodon striatus*	1	1	0.04762	0.21822	0.04762	0.00009
Blue Angelfish	*Holacanthus bermudensis*	1	1	0.04762	0.21822	0.04762	0.00009
Dog Snapper	*Lutjanus jocu*	1	1	0.04762	0.21822	0.04762	0.00009
Flamefish	*Apogon maculatus*	1	1	0.04762	0.21822	0.04762	0.00009
Mutton Snapper	*Lutjanus analis*	1	1	0.04762	0.21822	0.04762	0.00009
Nurse Shark	*Ginglymostoma cirratum*	1	1	0.04762	0.21822	0.04762	0.00009
Orange Filefish	*Cantherhines pullus*	1	1	0.04762	0.21822	0.04762	0.00009
Pigfish	*Orthopristis chrysoptera*	1	1	0.04762	0.21822	0.04762	0.00009
Pinfish	*Lagodon rhomboides*	1	1	0.04762	0.21822	0.04762	0.00009
Redlip Blenny	*Ophioblennius atlanticus*	1	1	0.04762	0.21822	0.04762	0.00009
Saddled Blenny	*Malacoctenus triangulatus*	1	1	0.04762	0.21822	0.04762	0.00009
Sand Perch	*Diplectrum formosum*	1	1	0.04762	0.21822	0.04762	0.00009
Sharptail Eel	*Myrichthys breviceps*	1	1	0.04762	0.21822	0.04762	0.00009
Tarpon	*Megalops atlanticus*	1	1	0.04762	0.21822	0.04762	0.00009
Sharksucker	*Echeneis naucrates*	1	1	0.04762	0.21822	0.04762	0.00009

Table B.3. Summary statistics for fishes observed at Mac Arthur Beach natural hard bottom during Survey 3.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Grunt (Newly Settled)	*Haemulon* spp.	5	1,033	114.77778	131.25717	17228.44444	0.29472
Silver Porgy	*Diplodus argenteus*	6	331	36.77778	52.55420	2761.94444	0.09444
Porkfish	*Anisotremus virginicus*	8	302	33.55556	30.83874	951.02778	0.08616
Sailor's Choice	*Haemulon parra*	8	286	31.77778	33.89608	1148.94444	0.08160
Sergeant Major	*Abudefduf saxatilis*	6	286	31.77778	58.56786	3430.19444	0.08160
High-Hat	*Equetus acuminatus*	7	213	23.66667	33.54475	1125.25000	0.06077
Black Margate	*Anisotremus surinamensis*	7	197	21.88889	34.04572	1159.11111	0.05621
Slippery Dick	*Halichoeres bivittatus*	3	126	14.00000	27.36330	748.75000	0.03595
Cocoa Damselfish	*Stegastes variabilis*	3	121	13.44444	28.29802	800.77778	0.03452
Glassy Sweeper	*Pempheris schomburgkii*	3	110	12.22222	20.01111	400.44444	0.03138
French Grunt	*Haemulon flavolineatum*	3	96	10.66667	26.71610	713.75000	0.02739
Smallmouth Grunt	*Haemulon chrysargyreum*	3	87	9.66667	17.08801	292.00000	0.02482
Hairy Blenny	*Labrisomus nuchipinnis*	7	58	6.44444	4.87625	23.77778	0.01655
Doctorfish	*Acanthurus chirurgus*	5	53	5.88889	7.92850	62.86111	0.01512
Gray Snapper	*Lutjanus griseus*	5	30	3.33333	5.31507	28.25000	0.00856
Lane Snapper	*Lutjanus synagris*	3	28	3.11111	6.99007	48.86111	0.00799
Seaweed Blenny	*Parablennius marmoreus*	6	28	3.11111	4.22624	17.86111	0.00799
Ocean Surgeon	*Acanthurus bahianus*	4	15	1.66667	2.59808	6.75000	0.00428
Spotfin Mojarra	*Eucinostomus argenteus*	1	10	1.11111	3.33333	11.11111	0.00285
Sand Perch	*Diplectrum formosum*	2	9	1.00000	2.34521	5.50000	0.00257
White Grunt	*Haemulon plumieri*	2	9	1.00000	2.12132	4.50000	0.00257
Redfin Parrotfish	*Sparisoma rubripinne*	3	8	0.88889	1.96497	3.86111	0.00228
Tomtate	*Haemulon aurolineatum*	1	6	0.66667	2.00000	4.00000	0.00171
Chub	*Kyphosus sectatrix/incisor*	2	5	0.55556	1.13039	1.27778	0.00143
Molly Miller	*Scartella cristata*	4	5	0.55556	0.72648	0.52778	0.00143
Bicolor Damselfish	*Stegastes partitus*	1	4	0.44444	1.33333	1.77778	0.00114
Bluehead Wrasse	*Thalassoma bifasciatum*	3	4	0.44444	0.72648	0.52778	0.00114

Table B.3. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Cottonwick	*Haemulon melanurum*	1	4	0.44444	1.33333	1.77778	0.00114
Great Barracuda	*Sphyraena barracuda*	3	4	0.44444	0.72648	0.52778	0.00114
Sand Drum	*Umbrina coroides*	1	4	0.44444	1.33333	1.77778	0.00114
Yellowfin Mojarra	*Gerres cinereus*	3	4	0.44444	0.72648	0.52778	0.00114
French Angelfish	*Pomacanthus paru*	1	3	0.33333	1.00000	1.00000	0.00086
Schoolmaster	*Lutjanus apodus*	1	3	0.33333	1.00000	1.00000	0.00086
Bar Jack	*Caranx ruber*	1	2	0.22222	0.66667	0.44444	0.00057
Blue Runner	*Caranx crysos*	2	2	0.22222	0.44096	0.19444	0.00057
Bridled Goby	*Coryphopterus glaucofraenum*	1	2	0.22222	0.66667	0.44444	0.00057
Southern Stingray	*Dasyatis americana*	2	2	0.22222	0.44096	0.19444	0.00057
Spanish Grunt	*Haemulon macrostomum*	1	2	0.22222	0.66667	0.44444	0.00057
Atlantic Spadefish	*Chaetodipterus faber*	1	1	0.11111	0.33333	0.11111	0.00029
Banded Butterflyfish	*Chaetodon striatus*	1	1	0.11111	0.33333	0.11111	0.00029
Blackear Wrasse	*Halichoeres poeyi*	1	1	0.11111	0.33333	0.11111	0.00029
Blue Angelfish	*Holacanthus bermudensis*	1	1	0.11111	0.33333	0.11111	0.00029
Caesar Grunt	*Haemulon carbonarium*	1	1	0.11111	0.33333	0.11111	0.00029
Dusky Damselfish	*Stegastes adustus*	1	1	0.11111	0.33333	0.11111	0.00029
Goldspot Goby	*Gnatholepis thompsoni*	1	1	0.11111	0.33333	0.11111	0.00029
Greater Soapfish	*Rypticus saponaceus*	1	1	0.11111	0.33333	0.11111	0.00029
Goliath grouper	*Epinephelus itajara*	1	1	0.11111	0.33333	0.11111	0.00029
Puddingwife	*Halichoeres radiatus*	1	1	0.11111	0.33333	0.11111	0.00029
Purplemouth Moray	*Gymnothorax vicinus*	1	1	0.11111	0.33333	0.11111	0.00029
Sheepshead	*Archosargus probatocephalus*	1	1	0.11111	0.33333	0.11111	0.00029
Yellowtail Snapper	*Ocyurus chrysurus*	1	1	0.11111	0.33333	0.11111	0.00029

Table B.4. Summary statistics for fishes observed at Jupiter Cloth Reef (artificial) during Surveys 1, 2, and 3.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Tomtate	*Haemulon aurolineatum*	23	8,001	333.37500	319.98041	102387.46196	0.29544
Grunts (Newly Settled)	*Haemulon* spp.	14	3,656	152.33333	283.76133	80520.49275	0.13500
French Grunt	*Haemulon flavolineatum*	20	1,626	67.75000	137.13251	18805.32609	0.06004
Sardine	*Sardinella* sp.	1	1,000	41.66667	204.12415	41666.66667	0.03692
Silver Porgy	*Diplodus argenteus*	23	954	39.75000	27.59056	761.23913	0.03523
Round Scad	*Decapterus punctatus*	5	953	39.70833	163.85876	26849.69384	0.03519
Porkfish	*Anisotremus virginicus*	24	872	36.33333	28.36818	804.75362	0.03220
Striped Croaker	*Bairdiella sanctaeluciae*	19	835	34.79167	39.78418	1582.78080	0.03083
Slippery Dick	*Halichoeres bivittatus*	24	710	29.58333	14.88482	221.55797	0.02622
Cocoa Damselfish	*Stegastes variabilis*	24	701	29.20833	17.80811	317.12862	0.02588
White Grunt	*Haemulon plumieri*	24	595	24.79167	17.95884	322.51993	0.02197
Sergeant Major	*Abudefduf saxatilis*	19	526	21.91667	30.29840	917.99275	0.01942
Smallmouth Grunt	*Haemulon chrysargyreum*	14	458	19.08333	36.29579	1317.38406	0.01691
Glassy Sweeper	*Pempheris schomburgkii*	4	452	18.83333	45.79792	2097.44928	0.01669
Seaweed Blenny	*Parablennius marmoreus*	18	431	17.95833	23.56947	555.51993	0.01591
Permit	*Trachinotus falcatus*	1	430	17.91667	87.77338	7704.16667	0.01588
Bigeye Scad	*Selar crumenophthalmus*	2	425	17.70833	81.58723	6656.47645	0.01569
Crevalle Jack	*Caranx hippos*	2	402	16.75000	81.63293	6663.93478	0.01484
Pigfish	*Orthopristis chrysoptera*	21	330	13.75000	18.90997	357.58696	0.01219
Spanish Mackerel	*Scomberomorus maculatus*	3	318	13.25000	61.13083	3736.97826	0.01174
Doctorfish	*Acanthurus chirurgus*	24	298	12.41667	10.54974	111.29710	0.01100
Hairy Blenny	*Labrisomus nuchipinnis*	24	245	10.20833	5.56370	30.95471	0.00905
Drum (Newly Settled)	Sciaenidae	3	211	8.79167	29.74527	884.78080	0.00779
Ocean Surgeon	*Acanthurus bahianus*	18	204	8.50000	8.04876	64.78261	0.00753
Bluehead Wrasse	*Thalassoma bifasciatum*	22	178	7.41667	5.06408	25.64493	0.00657
Bar Jack	*Caranx ruber*	8	155	6.45833	15.20577	231.21558	0.00572
Redfin Parrotfish	*Sparisoma rubripinne*	22	153	6.37500	4.14742	17.20109	0.00565

Table B.4. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Beaugregory	*Stegastes leucostictus*	15	137	5.70833	10.05843	101.17210	0.00506
Lane Snapper	*Lutjanus synagris*	21	129	5.37500	4.20985	17.72283	0.00476
Sheepshead	*Archosargus probatocephalus*	9	120	5.00000	12.76885	163.04348	0.00443
High-Hat	*Equetus acuminatus*	21	102	4.25000	3.28700	10.80435	0.00377
Gray Triggerfish	*Balistes capriscus*	23	97	4.04167	2.77378	7.69384	0.00358
Black Margate	*Anisotremus surinamensis*	22	96	4.00000	3.98912	15.91304	0.00354
Spotted Goatfish	*Pseudupeneus maculatus*	13	74	3.08333	5.28259	27.90580	0.00273
Sailor's Choice	*Haemulon parra*	16	70	2.91667	3.95537	15.64493	0.00258
Blue Runner	*Caranx crysos*	5	66	2.75000	10.28401	105.76087	0.00244
Guachanche	*Sphyraena guachancho*	5	60	2.50000	6.52753	42.60870	0.00222
Gray Snapper	*Lutjanus griseus*	18	57	2.37500	2.94607	8.67935	0.00210
Blue Tang	*Acanthurus coeruleus*	16	54	2.25000	2.73861	7.50000	0.00199
Pinfish	*Lagodon rhomboides*	15	50	2.08333	2.74918	7.55797	0.00185
Spanish Grunt	*Haemulon macrostomum*	14	49	2.04167	3.04287	9.25906	0.00181
Cottonwick	*Haemulon melanurum*	4	49	2.04167	6.74685	45.51993	0.00181
Yellow Jack	*Caranx bartholomaei*	11	48	2.00000	2.63752	6.95652	0.00177
Atlantic Spadefish	*Chaetodipterus faber*	9	45	1.87500	3.46802	12.02717	0.00166
Spotfin Mojarra	*Eucinostomus argenteus*	9	44	1.83333	3.01686	9.10145	0.00162
Dusky Damselfish	*Stegastes adustus*	9	38	1.58333	3.24261	10.51449	0.00140
Spanish Hogfish	*Bodianus rufus*	16	37	1.54167	2.20630	4.86775	0.00137
Chub	*Kyphosus sectatrix/incisor*	9	34	1.41667	2.82715	7.99275	0.00126
Mahogany Snapper	*Lutjanus mahogoni*	11	27	1.12500	1.70198	2.89674	0.00100
Puddingwife	*Halichoeres radiatus*	12	26	1.08333	1.41165	1.99275	0.00096
Caesar Grunt	*Haemulon carbonarium*	9	25	1.04167	2.23566	4.99819	0.00092
Redband Parrotfish	*Sparisoma aurofrenatum*	9	24	1.00000	1.74456	3.04348	0.00089
French Angelfish	*Pomacanthus paru*	11	22	0.91667	1.24819	1.55797	0.00081
Orange Filefish	*Cantherhines pullus*	10	21	0.87500	1.51263	2.28804	0.00078
Bridled Goby	*Coryphopterus glaucofraenum*	4	21	0.87500	2.34637	5.50543	0.00078

Table B.4. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Bicolor Damselfish	*Stegastes partitus*	2	21	0.87500	4.07871	16.63587	0.00078
Saddled Blenny	*Malacoctenus triangulatus*	14	20	0.83333	1.23945	1.53623	0.00074
Stoplight Parrotfish	*Sparisoma viride*	8	20	0.83333	1.37261	1.88406	0.00074
Porcupinefish	*Diodon hystrix*	12	19	0.79167	0.93153	0.86775	0.00070
Reef Croaker	*Odontoscion dentex*	12	19	0.79167	1.02062	1.04167	0.00070
Southern Stingray	*Dasyatis americana*	5	18	0.75000	2.65805	7.06522	0.00066
Sand Drum	*Umbrina coroides*	6	15	0.62500	1.68916	2.85326	0.00055
Clown Wrasse	*Halichoeres maculipinna*	6	14	0.58333	1.44212	2.07971	0.00052
Belted Sandfish	*Serranus subligarius*	7	13	0.54167	1.17877	1.38949	0.00048
Striped Parrotfish	*Scarus croicensis*	3	11	0.45833	1.31807	1.73732	0.00041
Blue Angelfish	*Holacanthus bermudensis*	6	10	0.41667	1.05981	1.12319	0.00037
Sheepshead Porgy	*Calamus penna*	6	9	0.37500	0.87539	0.76630	0.00033
Flamefish	*Apogon maculatus*	2	7	0.29167	0.99909	0.99819	0.00026
Yellowtail Reef-Fish	*Chromis enchrysura*	2	7	0.29167	1.08264	1.17210	0.00026
Nurse Shark	*Ginglymostoma cirratum*	7	7	0.29167	0.46431	0.21558	0.00026
Scrawled Cowfish	*Acanthostracion quadricornis*	6	7	0.29167	0.55003	0.30254	0.00026
Mutton Snapper	*Lutjanus analis*	4	6	0.25000	0.60792	0.36957	0.00022
Yellow Goatfish	*Mulloidichthys martinicus*	2	6	0.25000	0.89685	0.80435	0.00022
Yellowtail Snapper	*Ocyurus chrysurus*	4	6	0.25000	0.60792	0.36957	0.00022
Whitespotted Soapfish	*Rypticus maculatus*	6	6	0.25000	0.44233	0.19565	0.00022
Yellowfin Mojarra	*Gerres cinereus*	3	5	0.20833	0.65801	0.43297	0.00018
Spotted Scorpionfish	*Scorpaena plumieri*	5	5	0.20833	0.41485	0.17210	0.00018
Sea Bream	*Archosargus rhomboidalis*	2	4	0.16667	0.63702	0.40580	0.00015
Trumpetfish	*Aulostomus maculatus*	4	4	0.16667	0.38069	0.14493	0.00015
Spotfin Butterflyfish	*Chaetodon ocellatus*	4	4	0.16667	0.38069	0.14493	0.00015
Neon Goby	*Gobiosoma oceanops*	3	4	0.16667	0.48154	0.23188	0.00015
Blackear Wrasse	*Halichoeres poeyi*	3	4	0.16667	0.48154	0.23188	0.00015
Hogfish	*Lachnolaimus maximus*	4	4	0.16667	0.38069	0.14493	0.00015

Table B.4. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Gag Grouper	*Mycteroperca microlepis*	4	4	0.16667	0.38069	0.14493	0.00015
Greater Soapfish	*Rypticus saponaceus*	3	4	0.16667	0.48154	0.23188	0.00015
Greater Amberjack	*Seriola dumerili*	2	4	0.16667	0.56466	0.31884	0.00015
Orangespotted Filefish	*Aluterus schoepfi*	1	3	0.12500	0.61237	0.37500	0.00011
Cubbyu	*Equetus umbrosus*	3	3	0.12500	0.33783	0.11413	0.00011
Butter Hamlet	*Hypoplectrus unicolor*	2	3	0.12500	0.44843	0.20109	0.00011
Smooth Trunkfish	*Lactophrys triqueter*	2	3	0.12500	0.44843	0.20109	0.00011
Bucktooth Parrotfish	*Sparisoma radians*	2	3	0.12500	0.44843	0.20109	0.00011
Scrawled Filefish	*Aluterus scriptus*	2	2	0.08333	0.28233	0.07971	0.00007
Twospot Cardinalfish	*Apogon pseudomaculatus*	1	2	0.08333	0.40825	0.16667	0.00007
Sharpnose Puffer	*Canthigaster rostrata*	1	2	0.08333	0.40825	0.16667	0.00007
Rock Hind	*Epinephelus adscensionis*	2	2	0.08333	0.28233	0.07971	0.00007
Purplemouth Moray	*Gymnothorax vicinus*	2	2	0.08333	0.28233	0.07971	0.00007
Longspine Squirrelfish	*Holocentrus rufus*	1	2	0.08333	0.40825	0.16667	0.00007
Schoolmaster	*Lutjanus apodus*	2	2	0.08333	0.28233	0.07971	0.00007
Molly Miller	*Scartella cristata*	1	2	0.08333	0.40825	0.16667	0.00007
Rainbow Parrotfish	*Scarus guacamaia*	1	2	0.08333	0.40825	0.16667	0.00007
Snook	*Centropomus undecimalis*	1	1	0.04167	0.20412	0.04167	0.00004
Whitenose Pipefish	*Cosmocampus albirostris*	1	1	0.04167	0.20412	0.04167	0.00004
Red Grouper	*Epinephelus morio*	1	1	0.04167	0.20412	0.04167	0.00004
Silver Jenny	*Eucinostomus gula*	1	1	0.04167	0.20412	0.04167	0.00004
Flagfin Mojarra	*Eucinostomus melanopterus*	1	1	0.04167	0.20412	0.04167	0.00004
Bluespotted Cornetfish	*Fistularia tabacaria*	1	1	0.04167	0.20412	0.04167	0.00004
Spotted Moray	*Gymnothorax moringa*	1	1	0.04167	0.20412	0.04167	0.00004
Bluestriped Grunt	*Haemulon sciurus*	1	1	0.04167	0.20412	0.04167	0.00004
Blue Hamlet	*Hypoplectrus gemma*	1	1	0.04167	0.20412	0.04167	0.00004
Honeycomb Cowfish	*Acanthostracion polygonia*	1	1	0.04167	0.20412	0.04167	0.00004
Rose Blenny	*Malacoctenus macropus*	1	1	0.04167	0.20412	0.04167	0.00004

Table B.4. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Planehead Filefish	*Monacanthus hispidus*	1	1	0.04167	0.20412	0.04167	0.00004
Black Grouper	*Mycteroperca bonaci*	1	1	0.04167	0.20412	0.04167	0.00004
Gray Angelfish	*Pomacanthus arcuatus*	1	1	0.04167	0.20412	0.04167	0.00004
Atlantic Guitarfish	*Rhinobatos lentiginosus*	1	1	0.04167	0.20412	0.04167	0.00004
Spotted Soapfish	*Rypticus subbifrenatus*	1	1	0.04167	0.20412	0.04167	0.00004
Parrotfish (Newly Settled)	Scaridae	1	1	0.04167	0.20412	0.04167	0.00004
Cero Mackerel	*Scomberomorus regalis*	1	1	0.04167	0.20412	0.04167	0.00004
Banded Rudderfish	*Seriola zonata*	1	1	0.04167	0.20412	0.04167	0.00004
Redtail Parrotfish	*Sparisoma chrysopterum*	1	1	0.04167	0.20412	0.04167	0.00004
Bandtail Puffer	*Sphoeroides spengleri*	1	1	0.04167	0.20412	0.04167	0.00004

Table B.5. Summary statistics for fishes observed at Jupiter Geogrid Mitigation Reef (artificial) during Surveys 1, 2, and 3.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Tomtate	*Haemulon aurolineatum*	21	11,147	530.80952	553.96070	306872.46190	0.42176
Round Scad	*Decapterus punctatus*	8	1,862	88.66667	241.14567	58151.23333	0.08057
Grunts (Newly Settled)	*Haemulon* spp.	9	1,389	66.14286	162.36542	26362.52857	0.04368
Striped Croaker	*Bairdiella sanctaeluciae*	18	1,371	65.28571	67.99863	4623.81429	0.04626
Sardine	*Sardinella* sp.	3	1,101	52.42857	218.20600	47613.85714	0.03462
Porkfish	*Anisotremus virginicus*	21	924	44.00000	43.09408	1857.10000	0.05626
Glassy Sweeper	*Pempheris schomburgkii*	11	770	36.66667	51.89733	2693.33333	0.02421
Cocoa Damselfish	*Stegastes variabilis*	21	744	35.42857	21.85537	477.65714	0.02387
French Grunt	*Haemulon flavolineatum*	15	725	34.52381	63.13685	3986.26190	0.02286
Slippery Dick	*Halichoeres bivittatus*	21	709	33.76190	21.33754	455.29048	0.02230
Sergeant Major	*Abudefduf saxatilis*	21	644	30.66667	32.07855	1029.03333	0.02066
Silver Porgy	*Diplodus argenteus*	19	569	27.09524	26.10920	681.69048	0.01843
Bigeye Scad	*Selar crumenophthalmus*	2	475	22.61905	71.54752	5119.04762	0.01494
Seaweed Blenny	*Parablennius marmoreus*	14	421	20.04762	27.09885	734.34762	0.01324
Blue Runner	*Caranx crysos*	11	403	19.19048	54.57895	2978.86190	0.01267
Bluehead Wrasse	*Thalassoma bifasciatum*	19	307	14.61905	12.63122	159.54762	0.01009
Hairy Blenny	*Labrisomus nuchipinnis*	20	253	12.04762	8.78337	77.14762	0.00855
Doctorfish	*Acanthurus chirurgus*	21	212	10.09524	7.42903	55.19048	0.00676
Smallmouth Grunt	*Haemulon chrysargyreum*	12	191	9.09524	16.19847	262.39048	0.00601
White Grunt	*Haemulon plumieri*	20	191	9.09524	8.23957	67.89048	0.00613
Gray Snapper	*Lutjanus griseus*	17	162	7.71429	14.53665	211.31429	0.00509
Ocean Surgeon	*Acanthurus bahianus*	16	155	7.38095	8.88525	78.94762	0.00509
Atlantic Spadefish	*Chaetodipterus faber*	10	150	7.14286	16.35019	267.32857	0.00472
Bar Jack	*Caranx ruber*	9	147	7.00000	21.72326	471.90000	0.00478
Beaugregory	*Stegastes leucostictus*	16	139	6.61905	8.35150	69.74762	0.00447
Black Margate	*Anisotremus surinamensis*	17	128	6.09524	6.75947	45.69048	0.01053
Redfin Parrotfish	*Sparisoma rubripinne*	19	119	5.66667	4.79931	23.03333	0.00381

Table B.5. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Lane Snapper	*Lutjanus synagris*	16	112	5.33333	7.57188	57.33333	0.00431
Gray Triggerfish	*Balistes capriscus*	17	109	5.19048	5.02612	25.26190	0.00343
Drum (Newly Settled)	Sciaenidae	2	105	5.00000	21.79449	475.00000	0.00330
Pigfish	*Orthopristis chrysoptera*	19	84	4.00000	4.44972	19.80000	0.00264
Spanish Hogfish	*Bodianus rufus*	17	80	3.80952	3.23449	10.46190	0.00264
Porcupinefish	*Diodon hystrix*	16	65	3.09524	4.25329	18.09048	0.00226
Blue Tang	*Acanthurus coeruleus*	14	64	3.04762	3.35375	11.24762	0.00201
High-Hat	*Equetus acuminatus*	17	64	3.04762	3.70778	13.74762	0.00204
Yellow Jack	*Caranx bartholomaei*	13	59	2.80952	4.35453	18.96190	0.00198
Pinfish	*Lagodon rhomboides*	12	56	2.66667	3.70585	13.73333	0.00208
Permit	*Trachinotus falcatus*	1	55	2.61905	12.00198	144.04762	0.00173
Spanish Grunt	*Haemulon macrostomum*	13	54	2.57143	3.77586	14.25714	0.00173
Crevalle Jack	*Caranx hippos*	2	52	2.47619	10.89779	118.76190	0.00164
Spotfin Mojarra	*Eucinostomus argenteus*	6	50	2.38095	5.58996	31.24762	0.00072
Chub	*Kyphosus sectatrix/incisor*	11	50	2.38095	3.07370	9.44762	0.00157
Guachanche	*Sphyraena guachancho*	2	48	2.28571	8.81557	77.71429	0.00151
Dusky Damselfish	*Stegastes adustus*	11	47	2.23810	3.85882	14.89048	0.00148
Bicolor Damselfish	*Stegastes partitus*	6	47	2.23810	7.66749	58.79048	0.00148
Sheepshead	*Archosargus probatocephalus*	5	45	2.14286	6.29512	39.62857	0.00142
Sailor's Choice	*Haemulon parra*	11	40	1.90476	3.14491	9.89048	0.00126
Caesar Grunt	*Haemulon carbonarium*	8	38	1.80952	3.65539	13.36190	0.00119
Striped Parrotfish	*Scarus croicensis*	1	37	1.76190	8.07406	65.19048	0.00116
Stoplight Parrotfish	*Sparisoma viride*	10	29	1.38095	2.06098	4.24762	0.00091
Mahogany Snapper	*Lutjanus mahogoni*	9	28	1.33333	3.27618	10.73333	0.00088
Cottonwick	*Haemulon melanurum*	2	27	1.28571	4.13694	17.11429	0.00088
French Angelfish	*Pomacanthus paru*	9	26	1.23810	1.84132	3.39048	0.00094
Snook	*Centropomus undecimalis*	6	24	1.14286	2.53546	6.42857	0.00075
Orange Filefish	*Cantherhines pullus*	11	23	1.09524	2.18872	4.79048	0.00079

Table B.5. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Puddingwife	*Halichoeres radiatus*	13	23	1.09524	1.09109	1.19048	0.00082
Reef Croaker	*Odontoscion dentex*	7	21	1.00000	2.36643	5.60000	0.00066
Saddled Blenny	*Malacoctenus triangulatus*	7	20	0.95238	2.24669	5.04762	0.00063
Yellow Goatfish	*Mulloidichthys martinicus*	5	19	0.90476	2.84438	8.09048	0.00060
Scrawled Cowfish	*Acanthostracion quadricornis*	12	18	0.85714	1.15264	1.32857	0.00057
Spanish Mackerel	*Scomberomorus maculatus*	3	18	0.85714	2.59395	6.72857	0.00057
Greater Amberjack	*Seriola dumerili*	4	17	0.80952	2.29388	5.26190	0.00072
Yellowtail Snapper	*Ocyurus chrysurus*	6	15	0.71429	1.34695	1.81429	0.00047
Colon Goby	*Coryphopterus dicrus*	1	14	0.66667	3.05505	9.33333	0.00044
Blue Angelfish	*Holacanthus bermudensis*	10	12	0.57143	0.67612	0.45714	0.00044
Princess Parrotfish	*Scarus taeniopterus*	3	11	0.52381	1.63153	2.66190	0.00035
Sharpnose Puffer	*Canthigaster rostrata*	1	10	0.47619	2.18218	4.76190	0.00031
Clown Wrasse	*Halichoeres maculipinna*	7	10	0.47619	0.74960	0.56190	0.00031
Bridled Goby	*Coryphopterus glaucofraenum*	1	9	0.42857	1.96396	3.85714	0.00028
Nurse Shark	*Ginglymostoma cirratum*	9	9	0.42857	0.50709	0.25714	0.00028
Spotted Goatfish	*Pseudupeneus maculatus*	6	9	0.42857	0.81064	0.65714	0.00028
Bucktooth Parrotfish	*Sparisoma radians*	4	9	0.42857	1.16496	1.35714	0.00028
Blackear Wrasse	*Halichoeres poeyi*	4	8	0.38095	0.86465	0.74762	0.00025
Mutton Snapper	*Lutjanus analis*	4	7	0.33333	0.79582	0.63333	0.00028
Gag Grouper	*Mycteroperca microlepis*	4	7	0.33333	0.73030	0.53333	0.00022
Molly Miller	*Scartella cristata*	1	7	0.33333	1.52753	2.33333	0.00022
Belted Sandfish	*Serranus subligarius*	2	7	0.33333	1.06458	1.13333	0.00022
Orangespotted Filefish	*Aluterus schoepfi*	2	6	0.28571	1.10195	1.21429	0.00019
Sheepshead Porgy	*Calamus penna*	3	6	0.28571	0.90238	0.81429	0.00019
Southern Stingray	*Dasyatis americana*	6	6	0.28571	0.46291	0.21429	0.00019
Butter Hamlet	*Hypoplectrus unicolor*	2	6	0.28571	1.10195	1.21429	0.00019
Spotted Scorpionfish	*Scorpaena plumieri*	5	6	0.28571	0.56061	0.31429	0.00019
Bluelip Parrotfish	*Cryptotomus roseus*	2	5	0.23810	0.76842	0.59048	0.00006

Table B.5. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Hogfish	*Lachnolaimus maximus*	2	5	0.23810	0.88909	0.79048	0.00016
Schoolmaster	*Lutjanus apodus*	5	5	0.23810	0.43644	0.19048	0.00016
Flamefish	*Apogon maculatus*	2	4	0.19048	0.67964	0.46190	0.00013
Neon Goby	*Gobiosoma oceanops*	2	4	0.19048	0.67964	0.46190	0.00013
Greater Soapfish	*Rypticus saponaceus*	3	4	0.19048	0.51177	0.26190	0.00016
Redband Parrotfish	*Sparisoma aurofrenatum*	3	4	0.19048	0.51177	0.26190	0.00016
Great Barracuda	*Sphyraena barracuda*	3	4	0.19048	0.51177	0.26190	0.00047
Black Sea Bass	*Centropristis striata*	1	3	0.14286	0.65465	0.42857	0.00009
Bluespotted Cornetfish	*Fistularia tabacaria*	2	3	0.14286	0.47809	0.22857	0.00009
Goldspot Goby	*Gnatholepis thompsoni*	3	3	0.14286	0.35857	0.12857	0.00009
Scrawled Filefish	*Aluterus scriptus*	1	2	0.09524	0.43644	0.19048	0.00006
Yellowtail Reef-Fish	*Chromis enchrysura*	2	2	0.09524	0.30079	0.09048	0.00006
Rock Hind	*Epinephelus adscensionis*	2	2	0.09524	0.30079	0.09048	0.00006
Red Grouper	*Epinephelus morio*	2	2	0.09524	0.30079	0.09048	0.00009
Silver Jenny	*Eucinostomus gula*	1	2	0.09524	0.43644	0.19048	0.00006
Purplemouth Moray	*Gymnothorax vicinus*	2	2	0.09524	0.30079	0.09048	0.00006
Rose Blenny	*Malacoctenus macropus*	1	2	0.09524	0.43644	0.19048	0.00006
Planehead Filefish	*Monacanthus hispidus*	1	2	0.09524	0.43644	0.19048	0.00006
Black Grouper	*Mycteroperca bonaci*	2	2	0.09524	0.30079	0.09048	0.00006
Parrotfish (Newly Settled)	Scaridae	2	2	0.09524	0.30079	0.09048	0.00006
Littlehead Porgy	*Calamus proridens*	1	1	0.04762	0.21822	0.04762	0.00003
Spotfin Butterflyfish	*Chaetodon ocellatus*	1	1	0.04762	0.21822	0.04762	0.00003
Reef Butterflyfish	*Chaetodon sedentarius*	1	1	0.04762	0.21822	0.04762	0.00003
Banded Butterflyfish	*Chaetodon striatus*	1	1	0.04762	0.21822	0.04762	0.00003
Sand Perch	*Diplectrum formosum*	1	1	0.04762	0.21822	0.04762	0.00003
Goliath Grouper	*Epinephelus itajara*	1	1	0.04762	0.21822	0.04762	0.00003
Bluestriped Grunt	*Haemulon sciurus*	1	1	0.04762	0.21822	0.04762	0.00003
Queen Angelfish	*Holacanthus ciliaris*	1	1	0.04762	0.21822	0.04762	0.00003

Table B.5. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Rock Beauty	*Holacanthus tricolor*	1	1	0.04762	0.21822	0.04762	0.00003
Gray Angelfish	*Pomacanthus arcuatus*	1	1	0.04762	0.21822	0.04762	0.00022
Vermillion Snapper	*Rhomboplites aurorubens*	1	1	0.04762	0.21822	0.04762	0.00509
Whitespotted Soapfish	*Rypticus maculatus*	1	1	0.04762	0.21822	0.04762	0.00003
Queen Parrotfish	*Scarus vetula*	1	1	0.04762	0.21822	0.04762	0.00013
Cero Mackerel	*Scomberomorus regalis*	1	1	0.04762	0.21822	0.04762	0.00003
Greenblotch Parrotfish	*Sparisoma atomarium*	1	1	0.04762	0.21822	0.04762	0.00003
Bandtail Puffer	*Sphoeroides spengleri*	1	1	0.04762	0.21822	0.04762	0.00003
Three Spot Damselfish	*Stegastes planifrons*	1	1	0.04762	0.21822	0.04762	0.00003

Table B.6. Summary statistics for fishes observed at Coral Cove Reef (artificial) during Survey 3.

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Tomtate	*Haemulon aurolineatum*	5	1,452	161.33333	427.84606	183052.25000	0.21340
Silver Porgy	*Diplodus argenteus*	9	935	103.88889	72.94081	5320.36111	0.13742
Black Margate	*Anisotremus surinamensis*	9	730	81.11111	107.89166	11640.61111	0.10729
Grunts (Newly Settled)	*Haemulon* spp.	6	728	80.88889	182.79937	33415.61111	0.10700
Porkfish	*Anisotremus virginicus*	9	481	53.44444	66.10240	4369.52778	0.07069
Sergeant Major	*Abudefduf saxatilis*	9	299	33.22222	40.64719	1652.19444	0.04394
Blue Runner	*Caranx crysos*	7	281	31.22222	35.22704	1240.94444	0.04130
Smallmouth Grunt	*Haemulon chrysargyreum*	3	263	29.22222	83.94459	7046.69444	0.03865
French Grunt	*Haemulon flavolineatum*	3	219	24.33333	50.59891	2560.25000	0.03219
Sailor's Choice	*Haemulon parra*	9	193	21.44444	23.88049	570.27778	0.02837
Hairy Blenny	*Labrisomus nuchipinnis*	9	183	20.33333	11.80042	139.25000	0.02690
Cocoa Damselfish	*Stegastes variabilis*	8	128	14.22222	21.98737	483.44444	0.01881
Slippery Dick	*Halichoeres bivittatus*	8	100	11.11111	18.22392	332.11111	0.01470
Sheepshead	*Archosargus probatocephalus*	5	85	9.44444	23.56964	555.52778	0.01249
Striped Croaker	*Bairdiella sanctaeluciae*	5	75	8.33333	14.46548	209.25000	0.01102
Glassy Sweeper	*Pempheris schomburgkii*	2	54	6.00000	12.00000	144.00000	0.00794
Atlantic Bumper	*Chloroscombrus chrysurus*	1	50	5.55556	16.66667	277.77778	0.00735
High-Hat	*Equetus acuminatus*	5	50	5.55556	6.48288	42.02778	0.00735
Lane Snapper	*Lutjanus synagris*	4	50	5.55556	8.24790	68.02778	0.00735
Redfin Parrotfish	*Sparisoma rubripinne*	6	50	5.55556	7.35036	54.02778	0.00735
Round Scad	*Decapterus punctatus*	2	45	5.00000	10.00000	100.00000	0.00661
Seaweed Blenny	*Parablennius marmoreus*	6	35	3.88889	3.95109	15.61111	0.00514
Gray Snapper	*Lutjanus griseus*	6	29	3.22222	6.72268	45.19444	0.00426
White Grunt	*Haemulon plumieri*	2	26	2.88889	7.28774	53.11111	0.00382
Spotfin Mojarra	*Eucinostomus argenteus*	1	25	2.77778	8.33333	69.44444	0.00367
Molly Miller	*Scartella cristata*	6	23	2.55556	2.83333	8.02778	0.00338
Sand Drum	*Umbrina coroides*	2	23	2.55556	5.07718	25.77778	0.00338

Table B.6. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Doctorfish	*Acanthurus chirurgus*	5	20	2.22222	2.81859	7.94444	0.00294
Spanish Grunt	*Haemulon macrostomum*	4	15	1.66667	2.73861	7.50000	0.00220
Pigfish	*Orthopristis chrysoptera*	3	14	1.55556	3.94053	15.52778	0.00206
Yellow Jack	*Caranx bartholomaei*	2	14	1.55556	3.97213	15.77778	0.00206
Chub	*Kyphosus sectatrix/incisor*	2	12	1.33333	3.31662	11.00000	0.00176
Porcupinefish	*Diodon hystrix*	4	10	1.11111	1.76383	3.11111	0.00147
Spotted Goatfish	*Pseudupeneus maculatus*	4	9	1.00000	1.22474	1.50000	0.00132
Bluehead Wrasse	*Thalassoma bifasciatum*	4	8	0.88889	1.61589	2.61111	0.00118
Blackear Wrasse	*Halichoeres poeyi*	1	7	0.77778	2.33333	5.44444	0.00103
Yellowfin Mojarra	*Gerres cinereus*	2	7	0.77778	1.98606	3.94444	0.00103
Bar Jack	*Caranx ruber*	3	6	0.66667	1.11803	1.25000	0.00088
Blue Tang	*Acanthurus coeruleus*	2	6	0.66667	1.41421	2.00000	0.00088
Caesar Grunt	*Haemulon carbonarium*	2	4	0.44444	1.01379	1.02778	0.00059
Ocean Surgeon	*Acanthurus bahianus*	4	4	0.44444	0.52705	0.27778	0.00059
Guachanche	*Sphyraena guachancho*	2	4	0.44444	0.88192	0.77778	0.00059
Beaugregory	*Stegastes leucostictus*	1	3	0.33333	1.00000	1.00000	0.00044
Bridled Goby	*Coryphopterus glaucofraenum*	1	3	0.33333	1.00000	1.00000	0.00044
Colon Goby	*Coryphopterus dicrus*	1	3	0.33333	1.00000	1.00000	0.00044
Dusky Damselfish	*Stegastes adustus*	3	3	0.33333	0.50000	0.25000	0.00044
Nurse Shark	*Ginglymostoma cirratum*	2	3	0.33333	0.70711	0.50000	0.00044
Spotted Scorpionfish	*Scorpaena plumieri*	2	3	0.33333	0.70711	0.50000	0.00044
Atlantic Spadefish	*Chaetodipterus faber*	2	2	0.22222	0.44096	0.19444	0.00029
Blue Angelfish	*Holacanthus bermudensis*	2	2	0.22222	0.44096	0.19444	0.00029
Crevalle Jack	*Caranx hippos*	1	2	0.22222	0.66667	0.44444	0.00029
Neon Goby	*Gobiosoma oceanops*	1	2	0.22222	0.66667	0.44444	0.00029
Reef Croaker	*Odontoscion dentex*	1	2	0.22222	0.66667	0.44444	0.00029
Spanish Mackerel	*Scomberomorus maculatus*	1	2	0.22222	0.66667	0.44444	0.00029
Vermillion Snapper	*Rhomboplites aurorubens*	1	2	0.22222	0.66667	0.44444	0.00029

Table B.6. (Continued).

Common Name	Scientific Name	Occurrences	Sum	Mean	Standard Deviation	Variance	Proportion
Bandtail Puffer	*Sphoeroides spengleri*	1	1	0.11111	0.33333	0.11111	0.00015
Bicolor Damselfish	*Stegastes partitus*	1	1	0.11111	0.33333	0.11111	0.00015
Flamefish	*Apogon maculatus*	1	1	0.11111	0.33333	0.11111	0.00015
Gray Triggerfish	*Balistes capriscus*	1	1	0.11111	0.33333	0.11111	0.00015
Great Barracuda	*Sphyraena barracuda*	1	1	0.11111	0.33333	0.11111	0.00015
Greater Amberjack	*Seriola dumerili*	1	1	0.11111	0.33333	0.11111	0.00015
Greater Soapfish	*Rypticus saponaceus*	1	1	0.11111	0.33333	0.11111	0.00015
Green Moray	*Gymnothorax funebris*	1	1	0.11111	0.33333	0.11111	0.00015
Goliath grouper	*Epinephelus itajara*	1	1	0.11111	0.33333	0.11111	0.00015
Mahogany Snapper	*Lutjanus mahogoni*	1	1	0.11111	0.33333	0.11111	0.00015
Orange Filefish	*Cantherhines pullus*	1	1	0.11111	0.33333	0.11111	0.00015
Parrotfish	Scaridae	1	1	0.11111	0.33333	0.11111	0.00015
Puddingwife	*Halichoeres radiatus*	1	1	0.11111	0.33333	0.11111	0.00015
Purplemouth Moray	*Gymnothorax vicinus*	1	1	0.11111	0.33333	0.11111	0.00015
Reef Butterflyfish	*Chaetodon sedentarius*	1	1	0.11111	0.33333	0.11111	0.00015
Rose Blenny	*Malacoctenus macropus*	1	1	0.11111	0.33333	0.11111	0.00015
Snook	*Centropomus undecimalis*	1	1	0.11111	0.33333	0.11111	0.00015
Southern Stingray	*Dasyatis americana*	1	1	0.11111	0.33333	0.11111	0.00015
Spotted Moray	*Gymnothorax moringa*	1	1	0.11111	0.33333	0.11111	0.00015
Stoplight Parrotfish	*Sparisoma viride*	1	1	0.11111	0.33333	0.11111	0.00015

Table B.7. Percent cover of major epibiotal taxa and substrate on mitigation and natural reefs.

Survey Area	Coral Cove		Breakers Reef		Jupiter Concrete Mitigation	Juno Shallow Mitigation	Jupiter Cloth Reef Rock Mitigation		Juno Geogrid Mitigation	
Survey Dates	Aug 2001	May 2002	Aug 2001	May 2002	Aug 2001	Aug 2001	Aug 2001	May 2002	Aug 2001	May 2002
ALGAE										
Crustose coralline algae			0.33				2.46		0.15	
Green algae – unidentified	5.19									
Padina sp. (white scroll alga)		0.15								
Turf algae	85.37	2.37	61.50	9.78	44.22	25.00	58.00	31.26	71.26	5.37
SPONGES										
?*Amphimedon compressa*			0.83							
Aplysina sp.			0.67							
?*Callyspongia* sp.			0.67	0.44						
?*Callyspongia vaginalis*			0.17							
Cliona delitrix				0.44						
?*Iotrochota birotulata*			1.00							
Spheciospongia vesparium			0.67							
Verongula sp.			0.50							
Orange encrusting sponge			0.33							
Red encrusting sponge			0.33							
Porifera – unidentified			2.00	9.19	1.56		0.46		1.37	2.81
HYDROIDS										
Hydroid/Algae mix	0.30	1.19	3.33	0.44	29.33		9.77	9.33	6.96	4.44
Hydroidea			1.17	1.48			7.77	17.93	8.44	26.96
OCTOCORALS										
Eunicea sp.			0.17	1.19						
Gorgonacea			0.67	0.44						
Muricea sp.			1.33	0.44						
Plexaura sp.			0.83							
Plexaurella sp.			0.33	0.15						

Table B.7. (Continued).

Survey Area	Coral Cove		Breakers Reef		Jupiter Concrete Mitigation	Juno Shallow Mitigation	Jupiter Cloth Reef Rock Mitigation		Juno Geogrid Mitigation	
Survey Dates	Aug 2001	May 2002	Aug 2001	May 2002	Aug 2001	Aug 2001	Aug 2001	May 2002	Aug 2001	May 2002
Pseudopterogorgia sp.			5.50	1.33						
Pterogorgia sp.				0.44						
Octocorallia – unidentified				1.78						
STONY CORALS										
Colpophyllia natans				0.30						
Dichocoenia stokesii				0.15						
Millepora sp.			0.83							
Montastraea cavernosa			0.33	0.15						
Oculina diffusa				0.15						
Porites sp.					0.22					
Siderastrea radians	0.15									
OTHER SESSILE EPIBENTHOS										
Encrusting bryozoa							5.54	0.15	4.15	0.89
Honeycomb tubeworm tubes	0.15								0.44	
Palythoa sp.				0.89						
Worm rock		82.96						31.26		54.52
Zoanthus sp.							0.15			
Ascidia nigra							0.15		0.15	
MOTILE EPIBENTHOS										
Arbacia punctulata	0.15									
SUBSTRATE CATEGORIES										
Exposed hard substrate	2.37	3.56	1.67		1.11		7.77	4.15	1.93	1.93
Rock				0.44						
Rubble				0.15			0.38		0.15	
Sand	1.93	1.19	0.17	0.44	0.67	9.00	0.77	0.44		
Sediment on hard substrate	4.30	8.30	13.50	68.44	19.78	64.00	8.62	4.44	5.37	2.52
Substrate			0.33							

Table B.8. Percent cover of epibiota and substrata from photoquadrats collected at natural hard bottom and artificial reefs during Survey 2.

Species	Breakers Reef					Coral Cove						Geogrid						Cloth Reef					
	Aug 2001	May 2002	Jul 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003
ALGAE																							
Caulerpa brachypus?															0.48								
Caulerpa cupressoides											1.11												
Caulerpa racemosa											0.33						0.43						0.30
Caulerpa sertularoides											1.56												
Caulerpa sertularoides farlowii																				0.30			
Caulerpa sp.									0.15		0.22												
Codium isthmocladum														0.74									
Crustose coralline algae	0.33										0.89	0.15				0.15		2.46				0.15	
Dictyopteris sp.											1.67												
Dictyota sp.											4.33			0.15	2.86	0.37	0.29				1.83		0.59
Green algae #1																							0.15
Green algae, unidentified					0.15	5.19			0.31						0.10	0.07					0.17	0.15	
Halimeda sp.																0.15							
Macroalgae			1.19		0.30			1.19		0.16	2.56			2.67	7.90	0.44				0.15	3.50	1.19	0.15
Padina sp. (white scroll alga)							0.15				3.89												
Phaeophyta sp. (unknown brown algae)										0.96	0.11												
Rhodophyta sp. (unidentified red algae)									1.08		1.00												0.30
Turf algae	61.50	9.78	65.04	76.57	22.07	85.04	2.37	19.85	46.00	46.08	17.33	71.26	5.04	32.74	46.00	62.96	48.43	58.00	31.26	43.41	55.83	60.44	61.63
SPONGES																							
?*Amphimedon compressa*	0.83																						
?*Callyspongia* sp.	0.67	0.44																					
?*Callyspongia vaginalis*	0.17																						
?*Iotrochota birotulata*	1.00		0.59																				
?*Tethya* sp.					0.15																		
Agelas sp.			0.44																				
Amphimedon compressa (erect rope sponge)				0.43																			
Anthosigmella sp. (brown encrusting sponge)				1.86	0.30																		
Aplysina sp.	0.67				0.15																		
Callyspongia sp.					0.30																		
Callyspongia vaginalis (branching vase sponge)				0.14																			
Cliona delitrix		0.44																					
Cliona sp.			0.15								0.78					0.07							
Holopsamma sp.				0.14												1.41						0.30	

Table B.8. (Continued).

Species	Breakers Reef					Coral Cove						Geogrid						Cloth Reef					
	Aug 2001	May 2002	Jul 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003
(lumpy overgrowing sponge)																							
Iotrochota birotulata				2.57	4.00																		
Niphates sp.					0.15																0.17		
Orange encrusting sponge	0.33																						
Orange encrusting sponge #1					0.44				0.15								0.29				0.17		0.30
Pink overgrowing sponge #1					3.56										0.76		1.71				2.17		1.33
Porifera	2.00	9.19	0.30	0.29	1.48			0.59			0.11	1.04	2.81		0.10	0.96	1.00	0.46		0.74	0.17	1.78	
Red encrusting sponge	0.33				2.37				1.23						0.67						0.33		0.15
Spheciospongia vesparium	0.67																						
Sponge, encrusting			2.67	1.43	1.93			0.15	1.85	1.92	0.11				1.62	3.19	2.00			0.15	1.67	0.89	3.56
Sponge, red spotty encrusting					0.15																		0.30
Sponge, rope			0.59	0.57																			
Verongula sp.	0.50																						
HYDROZOANS																							
Hydroid/Algae mix	3.33	0.44		0.14		0.30	1.19		10.92	0.16	1.56	6.96	4.44	7.11	4.76	7.04	7.29	9.08	9.33	7.70	7.83	20.44	3.56
Hydroidea	1.17	1.48	0.15	0.14					2.62	6.88	0.11	8.44	26.96	14.37	0.86	6.44	1.43	7.08	17.93	14.52	0.33	3.41	1.04
Millepora alcicornis			1.33	0.14	0.44																		
Millepora sp.	0.83																						
Thyroscyphus ramosus (algae hydroid)																0.07							
Thyroscyphus sp. (algae hydroid)					1.33				8.15						22.19	6.81	21.14				16.00	3.26	12.15
OCTOCORALS																							
Carijoa riisei (white telesto)										3.36													
Eunicea sp.	0.17	1.19		0.57	1.93																		
Gorgonacea	0.67	0.44																					
Muricea sp.	1.33	0.44		1.71	0.44																		
Octocorallia		1.78	5.04	1.00	1.33																		
Plexaura sp.	0.83																						
Plexaurella sp.	0.33	0.15		0.71	2.96																		
Pseudopterogorgia bipinnata					0.15																		
Pseudopterogorgia americana				2.71	0.59																		
Pseudopterogorgia sp.	5.17	1.33		0.57																			
Pseudopterogorgia spp.	0.33																						
Pterogorgia sp.		0.44	2.22		2.52																		
STONY CORALS																							
Colpophyllia natans		0.30																					
Dichocoenia stokesii		0.15																					
Diploria strigosa				0.29																			
Montastraea cavernosa	0.33	0.15																					
Oculina diffusa		0.15	0.30																				
Siderastrea radians						0.15																	
Siderastrea siderea				0.14																			

Table B.8. (Continued).

Species	Breakers Reef					Coral Cove						Geogrid						Cloth Reef					
	Aug 2001	May 2002	Jul 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003	Aug 2001	May 2002	Jul 2002	Oct 2002	Dec 2002	Apr 2003
Solenastrea bournoni			0.15		0.89																		
Stephanocoenia michelini				0.43																			
OTHER SESSILE EPIBIOTA																							
Ascidacea																					0.17		
Ascidia nigra									0.31			0.15			0.10	0.07	0.29	0.15		0.30		0.15	0.30
Bryozoa, encrusting												4.15	0.89		0.38	0.22	0.43	5.54	0.15			2.81	0.89
Honeycomb tubeworm tubes						0.15						0.44											
Palythoa sp.- zoanthids		0.89	2.22																				
Worm Rock			2.37				82.96	48.00		2.88	20.11		54.52	32.44					31.26	19.56			
Zoanthidea				0.14					0.46						0.48								0.15
Zoanthus																		0.15					
MOTILE EPIBENTHOS																							
Arbacia punctulata						0.15			0.15														
Echinoidea sp. (unknown sea urchin)																						0.15	
Holothuroidea sp.											0.11												
Lima scabra - rough fileclam																							0.15
Terebellidae sp. (spaghetti worm)																0.07							
SUBSTRATE CATEGORIES																							
Exposed hard substrate	1.67		1.04		0.89	2.37	3.56	3.70	0.46	0.16	18.67	1.93	1.93					7.08	4.15				0.30
Rocks		0.44			0.15			4.00															
Rubble		0.15	0.15					0.44			0.11	0.15			0.10			0.31		2.37			
Sand	0.17	0.44	0.74	0.43	42.67	1.93	1.19	7.11	0.31	10.56	9.78			1.33			4.29	0.77	0.44	0.59		1.48	0.30
Sediment covering					4.44				0.15		0.11				0.10		0.14						
Sediment on hard substrate	13.50	68.44	12.89	5.57	1.33	4.30	8.30	6.81	22.92	22.08	13.22	5.04	2.52	5.78	10.29	7.04	8.71	8.62	4.44	7.41	9.50	2.52	6.52
Shell hash			0.30	0.86	0.15											0.07	1.71					0.15	0.44
Shells				0.14					0.15		0.22				0.10	0.15	0.14				0.17	0.15	4.44
Substrate	0.33																						
Worm rock, eroding (dead)								8.15						2.22						1.63			0.30
OTHER																							
Detrital material - dead sea grass										0.96													
Detrital material - detached sea grass or other vegetation									0.15														
n/c		1.33	0.15	0.29	0.15					3.84				0.44		1.93			1.04	1.19		0.59	0.15
Other material in field of view	0.83				0.15	0.44	0.30		2.46			0.30	0.89		0.19	0.30	0.29	0.31					0.59