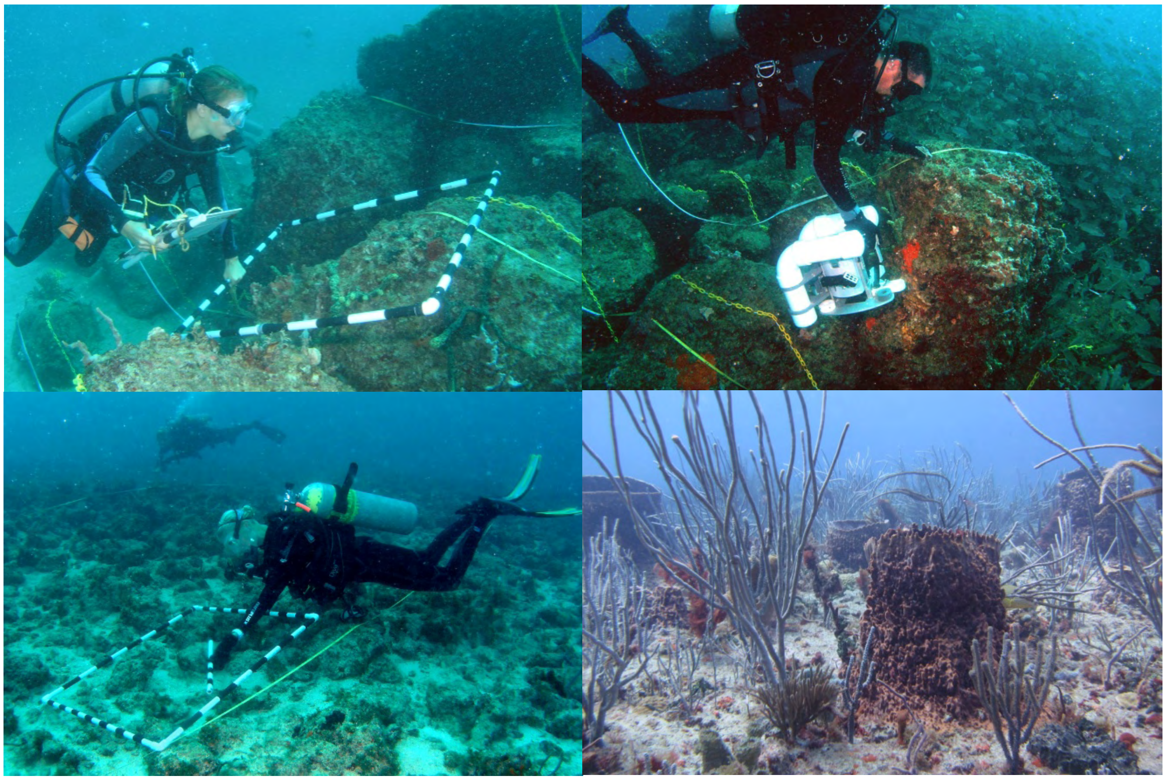
A Study to Evaluate Reef Recovery Following Injury and Mitigation Structures Offshore Southeast Florida: Phase II



Southeast Florida Coral Reef Initiative
Maritime Industry and Coastal Construction Impacts (MICCI)
Local Action Strategy Project 14, 15, and 16

Southeast Florida Coral Reef Initiative

Acting above to protect what's below.

A Study to Evaluate Reef Recovery Following Injury and Mitigation Structures Offshore Southeast Florida: Phase II

Final Report

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SUMMARY

Ecological, economic, and aesthetic resource services are lost when a reef injury event occurs on the coral reefs and hard bottom habitats of the southeast Florida region. These lost services need to be compensated either through recovery of the injured resource or from services gained from some type of mitigation. Restoration actions are imperative to preserving and protecting coral reef services on these high latitude reefs which are subjected to multiple natural and anthropogenic stressors due to their location along a heavily populated coast.

The ultimate goal of this two-phased project was to evaluate recovery of injured reef resource and development of deployed 'mitigation' reef communities to assist resource managers in determining appropriate compensatory mitigation and restoration for coral reef injury. Recovery was defined as the complete recovery of the injured reef's biotic community, structure, and physical environment (substrate types and complexity), or the development of a community on mitigation reefs which equal the services of the pre-injured reef.

Phase I of this project examined unpermitted injury areas by comparing natural linear reef control sites to sites that had been injured by ship groundings in Broward and Miami-Dade counties (Gilliam and Moulding, 2012). Phase II (this report) evaluated the development of benthic communities on artificial structures (boulders) in Miami-Dade, Broward, and Palm Beach counties compared to control sites. Boulder artificial reefs were selected because boulders have been deployed for compensatory mitigation of coral reef injuries and continue to be discussed as potential mitigation structures for coral reef impacts. Phase II also included an assessment of the current condition of sites associated with the Port of Miami entrance channel. This assessment included boulder reefs which were deployed as mitigation for past Port dredging, the channel floor in dredged Inner Reef, Middle Reef, and Outer Reefs areas, the Inner Reef channel wall, and samples on adjacent Inner Reef.

During both project phases, biological communities were surveyed using a population approach (density and size class) for scleractinian (stony corals), gorgonian corals, and barrel sponges (*Xestospongia muta*). Other benthic communities such as sponges, zoanthids, algae, etc., were evaluated using percent cover estimates. Stony corals, gorgonian corals, and barrel sponges are often used as reef indicator taxa on southeast Florida reefs. Stony corals are most often selected as primary reef condition indicators; however, due to their relatively low density on southeast Florida reefs, gorgonian corals are often used as ecological indicators of coral reef community and anthropogenic impacts. The giant barrel sponge is an ideal reef indicator species on southeast Florida reefs

due to its large size, long lifespan, and important filtering and essential fish habitat functions.

During Phase II, reef community characteristics of the control areas adjacent to each boulder reef were used to define the natural (full services) state against which the community on the boulder reefs is compared. The similarity of the boulder reef community to the natural reef control provides some indication of the services gained by the boulder reefs, and therefore, recovered in the system. The nine boulder reefs assessed during Phase II ranged in deployment years from 1994 to 2009.

Both the population dynamics approach, in terms of stony corals, and the multivariate community analysis approach used in this study indicated some trend in each of the counties towards greater similarity to the natural reefs as the boulder reefs age. Although stony coral species richness was similar, there were important differences in species contributions to the communities: the contribution of smaller, 'weedier' species on boulder reefs was greater than that on adjacent natural reefs; while larger, reef-structure forming species contributed greater to the natural reef community.

Reef community development on the Port of Miami channel floor has been very limited since the last dredging event in 1993, nearly 20 years ago. Dredged Inner and Outer Reef portions still appear very much like dredged reef. Complete channel floor recovery is not likely to occur because of the altered substrate.

It is evident that reef communities on the boulder reefs are still developing. With one exception, boulders reefs do not appear to be developing gorgonian communities similar to adjacent natural reefs. This is not simply due to the reef age since gorgonian recruitment and growth rates of many species are such that most of the boulder reefs should have a more developed community. Barrel sponges were not identified on any boulder reef.

The data generated through both phases of this project assists with evaluating appropriate restoration and mitigation efforts for future physical impacts to coral reefs. When reef impacts occur, lost resource services include more than just those provided by stony corals. Defining and measuring the services many reef community components provide can be difficult. However, it is understood that gorgonians and barrel sponges provide many services and are very important components of the southeast Florida reef community. Their limited development on boulder reefs needs to be considered before boulders are deployed as mitigation. With boulder reef stony coral colony size distribution dominated by smaller size classes, and limited gorgonian and barrel sponge populations, it is reasonable to extrapolate that boulder reefs would take decades to mitigate for a total loss of services, if at all. The length of time boulder reefs require to mitigate lost reef resources, assuming a total loss of the impacted community from events such as ship groundings or dredging, is longer than 17 years (the age of the oldest boulder reef assessed in this study).

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INTRODUCTION

The high latitude reefs of southeast Florida are subjected to multiple natural and anthropogenic stressors due to their location along a heavily populated coast. Multiple coastal construction projects, including beach nourishment, channel dredging, and cable installation, have occurred offshore southeast Florida within, or in close proximity to, coral reef habitats. These permitted coastal construction projects impact reef resources and are expected to continue in the future.

In addition to these events, within a period 13 years, 1994-2007, there were numerous ship groundings and anchor events associated with the Port Everglades commercial anchorages which injured reef resources in Broward County. During this same time period, such events (documented and undocumented) also occurred offshore Miami-Dade and Palm Beach counties.

Physical impacts from ship groundings and other injury events generally requires emergency stabilization, primary restoration activities, and mitigation (compensatory restoration), which offsets lost ecological services from the time of injury to a recovery state. Federally authorized coastal construction projects require sequential mitigation: first, avoidance of impacts; second, minimization of impacts; third, compensatory mitigation for unavoidable impacts (Clean Water Act 40 CFR Part 230; US Army Corps of Engineers Regulatory Guidance Letter 02-02; Marine Sanctuaries Act 50 CFR 600.920). Resource trustees require compensatory mitigation to offset lost ecological services to coral reefs and other reef resources from authorized (e.g., channel dredging) and unauthorized impacts (e.g., vessel grounding events). Methods to determine the amount of compensatory restoration required following an injury event or a permitted project include Habitat Equivalency Analysis (HEA) and Resource Equivalency Analysis (REA), both of which rely on input parameters to determine the amount of compensatory restoration (mitigation) needed to compensate for interim ecological services lost from the injury (Kohler and Dodge, 2006; Viehman et al., 2009). Permitted projects in the State of Florida resulting in injury to resources may use the Uniform Mitigation Assessment Method (Chapter 62-345, Florida Administrative Code) to determine required compensatory mitigation. All of these assessment methods require data on the losses from the injury and recovery values for the compensatory action. However, data on reef resource recovery rates to support these parameters are limited, particularly for southeast Florida.

The goal of this two phase project was to evaluate injured reef resource recovery and deployed 'mitigation' reef community development to assist resource managers with the process of determining appropriate compensatory restoration and mitigation for coral reef injury. The initial approach was to examine identified unpermitted injury areas (Phase I) (Gilliam and Moulding, 2012) and deployed permitted mitigation structures (Phase II) and to evaluate both the benthic biological communities present and the physical characteristics of the sites that may influence recovery. During both phases biological communities were surveyed using a population approach (density and size class) for scleractinian (stony corals), gorgonian corals, and barrel sponges (*Xestospongia muta*). In addition to percent cover for stony corals and gorgonians, other benthic communities such as sponges, zoanthids, algae, etc., were evaluated using percent cover estimates since individuals or colonies are often difficult to quantify. Physical characteristics included substrate type (consolidated pavement, unconsolidated rubble, and sand) cover and topographic complexity. This examination of the current condition of injury sites and deployed structures is directly applicable to management of coral reefs by local, state, and federal agencies. The data generated through both phases of the project assists with evaluating appropriate restoration and mitigation efforts for future physical impacts to coral reefs. Restoration actions are imperative to preserving and protecting coral reef services into the future considering a possible continued decline from natural and anthropogenic impacts (Mumby and Steneck, 2008).

This project had two phases. Phase I compared natural linear reef control sites to sites that have been injured by ship groundings in Broward and Miami-Dade counties to determine differences in: 1) benthic community structure, 2) density and size of corals, gorgonians, and barrel sponges, and 3) physical characteristics such as rugosity and amount of unconsolidated substrate such as rubble and sand (Gilliam and Moulding, 2012). Phase II evaluated the development of benthic communities on artificial structures (boulders) in Miami-Dade, Broward, and Palm Beach counties compared to control sites. Boulder artificial reefs were chosen primarily because, as a substrate, boulders have been deployed for mitigation and continue to be discussed as potential mitigation structures. This report addresses the results of Phase II.

The southeast Florida reef system is large in area and extends along the coast from Miami-Dade County into Martin County (~75 km). It is also diverse in habitats (Walker et al., 2008; Banks et al., 2007) and biological communities both within and among habitats (Moyer et al., 2003; Gilliam et al., 2011; Sathe et al., 2009; Gilliam, 2011). The geographic scale and biological diversity of the southeast Florida reef system precluded controlled and consistent examination of structures specifically deployed as mitigation along the entire system. In order to accommodate a study which examines structures along the much of the system (Miami-Dade, Broward, and Palm Beach counties), the sampled artificial reefs needed to be similar among counties in terms of construction material, proximity to offshore linear reefs, and deployment substrate. The initial proposal was to sample structures specifically deployed as mitigation in each of the three counties. There are not sufficient structures offshore all three counties to meet all of the above proposed criteria. To examine and compare benthic communities on artificial structures in all three counties, similarity in material, deployment habitat, and deployment substrate is more important than whether a structure was specifically deployed as mitigation. All three counties had at least three artificial reefs constructed of the same material (boulders), deployed adjacent to one of the linear reef (Inner, Middle, or Outer), and deployed on sand substrate.

Three artificial structures were sampled offshore each of the three counties, and compared to sampled control areas located on adjacent natural reef. All nine artificial structures were constructed of boulders (boulder reefs) and deployed on sand habitat either between the Inner and Middle Reefs or between the Middle and Outer Reefs. The boulder reefs sampled in Miami-Dade County included the Anchorage boulders (AB), the Bal Harbor/Sunny Isles boulders (BAL), and the Golden Beach boulders (GBB). In Broward County the reefs included the Hallandale Beach boulders (HDB), the Dania Beach (sometimes called Mt. Dania) boulders (DBB), and the Dogpile boulders (DPB), and in Palm Beach County the Tycom (also referred to as the Boca corridors) boulders (TB), the Silpe boulders (SB), and the Cross Current boulders (XCB). In Miami-Dade the AB and GBB reefs were deployed as part of the county's artificial reef program while the BAL reef was deployed as mitigation for injuries associated with a beach nourishment project (Thanner et al., 2006). The HDB and DPB reefs were deployed as part of Broward County's artificial reef program, and the DBB boulder reef was deployed using funds from the USS Memphis grounding settlement (Banks et al., 1998). Similarly, two reefs, SB and XCB, were deployed as part of Palm Beach County's artificial reef program, and the third reef, TB, was deployed as mitigation for damages from a cable deployment project (CPE, 2003).

In addition to examining boulder reefs in each county, Phase II included an effort to provide benthic community data in areas associated with the permitted Port of Miami expansion project. The cut through the Outer Reef will be widened, resulting in the removal of all organisms that have colonized the channel walls at the Outer Reef since the original cut was made in the 1960s. The data gathered for this part of the Phase II project may assist resource managers in evaluating other proposed harbor expansion projects located in southeast Florida, including Port Everglades and Palm Beach Harbor.

Port of Miami entrance channel, Inner, Middle, and Outer Reef dredge area sites on the channel floor, and Inner Reef sites along the channel wall were sampled. The mitigation boulders reefs (PMB) associated with the 1993 permitted entrance channel maintenance dredging (USACE, 2011) were examined and natural (control) reef sites were examined on the Inner Reef adjacent to the Port channel (PMB CTL).).

METHODS

Site selection

All boulder reef site locations were either obtained from each county's artificial reef website or from discussions with county artificial reef program personnel. Table 1 lists the nine boulder reefs with their abbreviations used throughout the report, county location, and deployment year. Table 2 provides deployment habitat (adjacent to or between which linear reefs) and location. Figures 1 and 2 show the locations of each of the nine boulder reefs.

Table 1. Boulder reef name, abbreviation, county, and deployment year.

Boulder Reef	Abbr.	County	Year
Anchorage Boulder	AB	Miami-Dade	1994
Bal Harbor Boulder	BAL	Miami-Dade	1999
Golden Beach Boulder	GBB	Miami-Dade	2005
Hallandale Boulder	HDB	Broward	2003
Dania Beach Boulder	DBB	Broward	2001
Dog Pile Boulder	DOG	Broward	1999
Tycom Boulder	TB	Palm Beach	2001
Silpe Boulder	SB	Palm Beach	2009
Cross Current Boulder	XCB	Palm Beach	1999

Table 2. Boulder reef habitat and location. The habitat refers to the sand area between the named linear reefs (see Table 1 for site abbreviations).

Boulder Reef	Location	Latitude (N)	Longitude (W)
AB	Middle - Outer	25° 48.672′	- 80° 05.462′
BAL	Middle - Outer	25° 54.131′	-80° 05.384′
GBB	Inner-Middle	25° 57.753′	-80° 05.867′
HDB	Inner-Middle	25° 59.183′	-80° 06.096′
DBB	Middle - Outer	26° 03.154′	-80° 05.804′
DOG	Middle - Outer	26° 08.539′	-80° 04.850′
TB	Middle - Outer	26° 19.304′	-80° 03.541′
SB	Middle - Outer	26° 31.887′	-80° 01.940′
XCB	Middle - Outer	26° 45.706′	-80° 01.264′

Three control, or reference, sites were selected for comparison with each boulder reef (Tables 3 and 4). The control sites needed to be located on natural reef adjacent to each boulder reef and representative of a natural state, free of any visually obvious past documented or unidentified anthropogenic injury.

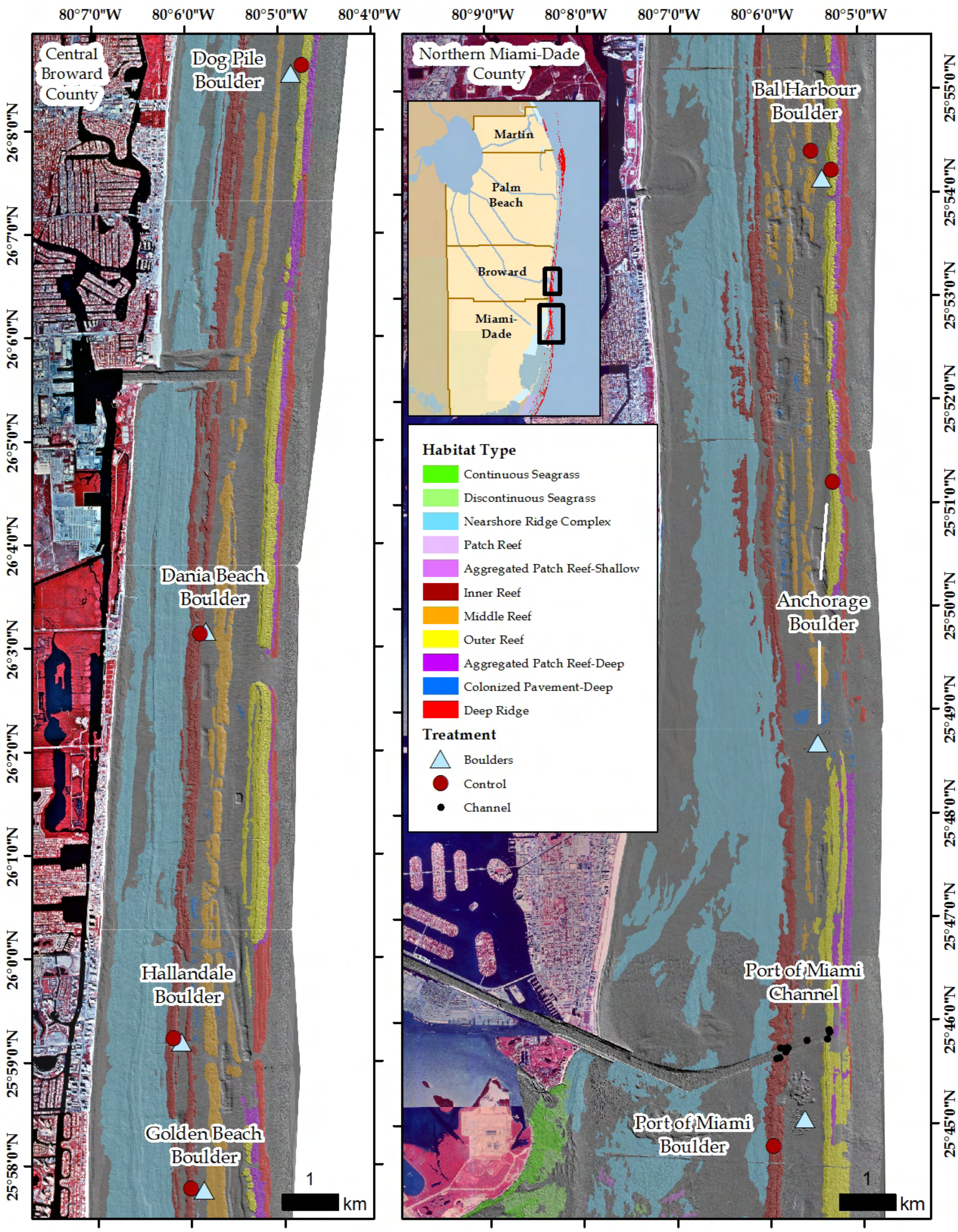

Figure 1. Map of the study area and the study site locations in Miami-Dade and Broward Counties. Locations of boulder and control groups are indicated by red circles and blue triangles, respectively.

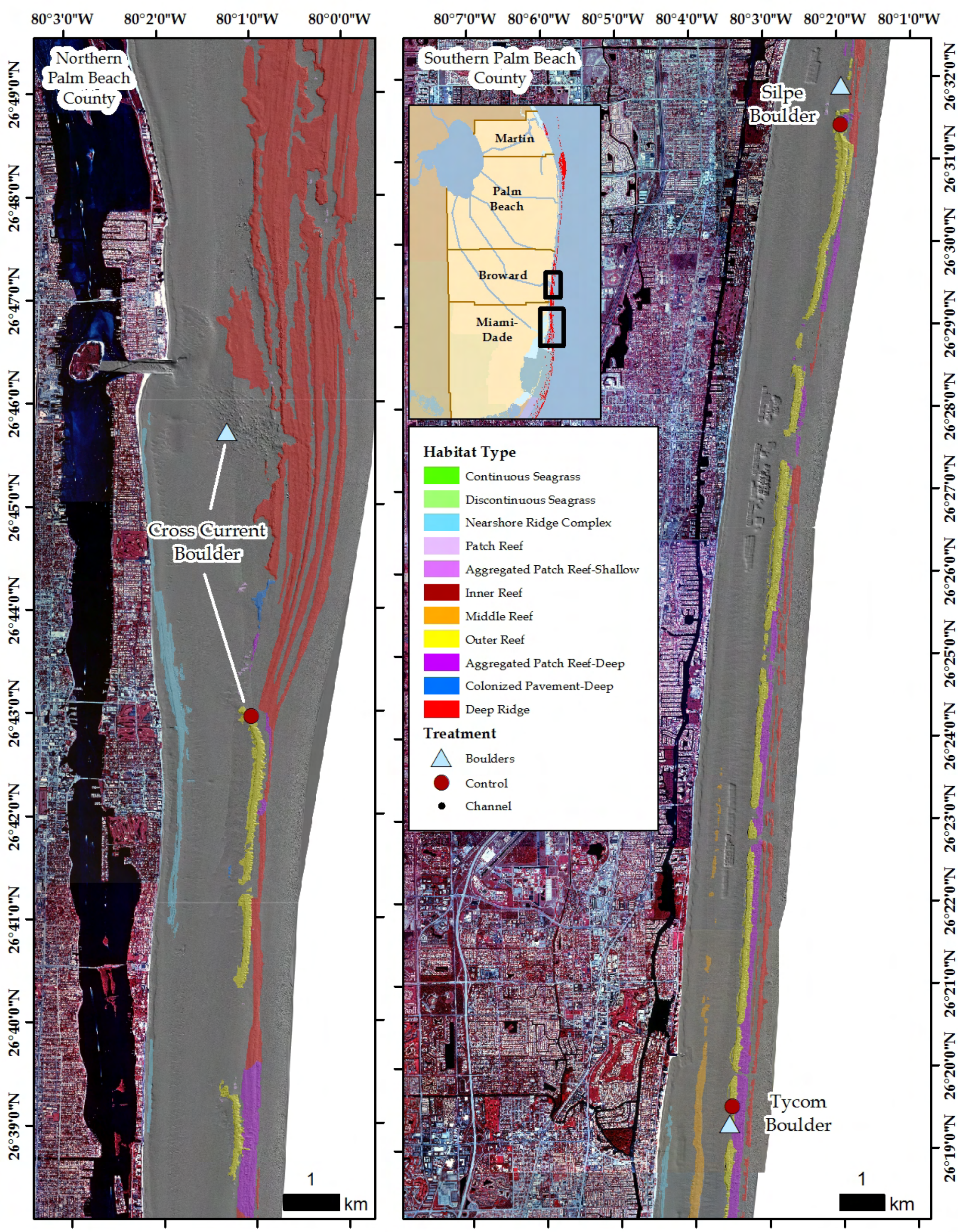

Figure 2. Map of the study area and the study site locations in Palm Beach County. Locations of boulder and control groups are indicated by red circles and blue triangles, respectively.

Then GIS techniques were used to randomly choose sites within each area, separated by at least 40 meters (m) to avoid overlap between samples), on the natural reefs. Figures 1 and 2 show the control sample areas for each of the boulder reefs.

Table 3. Each control area site name and abbreviation.

Control Site	Abbreviation
Anchorage Boulder Control 1	AB CTL 1
Anchorage Boulder Control 2	AB CTL 2
Anchorage Boulder Control 3	AB CTL 3
Bal Harbor Boulders Middle Reef Control 1	BAL MID CTL 1
Bal Harbor Boulders Middle Reef Control 2	BAL MID CTL 2
Bal Harbor Boulders Middle Reef Control 3	BAL MID CTL 3
Bal Harbor Boulders Outer Reef Control 1	BAL OUT CTL 1
Bal Harbor Boulders Outer Reef Control 2	BAL OUT CTL 2
Bal Harbor Boulders Outer Reef Control 3	BAL OUT CTL 3
Golden Beach Boulder Control 1	GBB CTL 1
Golden Beach Boulder Control 2	GBB CTL 2
Golden Beach Boulder Control 3	GBB CTL 3
Hallandale Boulder Control 1	HDB CTL 1
Hallandale Boulder Control 2	HDB CTL 2
Hallandale Boulder Control 3	HDB CTL 3
Dania Beach Boulder Control 1	DBB CTL 1
Dania Beach Boulder Control 2	DBB CTL 2
Dania Beach Boulder Control 3	DBB CTL 3
Dog Pile Boulder Control 1	DPB CTL 1
Dog Pile Boulder Control 2	DPB CTL 2
Dog Pile Boulder Control 3	DPB CTL 3
Tycom Boulder Control 1	TB CTL 1
Tycom Boulder Control 2	TB CTL 2
Tycom Boulder Control 3	TB CTL 3
Silpe Boulder Control 1	SB CTL 1
Silpe Boulder Control 2	SB CTL 2
Silpe Boulder Control 3	SB CTL 3
Cross Current Boulder Control 1	XCB CTL 1
Cross Current Boulder Control 2	XCB CTL 2
Cross Current Boulder Control 3	XCB CTL 3

Table 4. Control site county, reef, and location (see Table 3 for site abbreviations).

Control Site	County	Reef	Latitude (N)	Longitude (W)
AB CTL 1	Miami-Dade	Outer	25° 51.194'	-80° 05.294'
AB CTL 2	Miami	Outer	25° 51.217'	-80° 05.288'
AB CTL 3	Miami	Outer	25° 51.236'	-80° 05.301'
BAL MID CTL 1	Miami	Middle	25° 54.212'	-80° 05.289'
BAL MID CTL 2	Miami	Middle	25° 54.178'	-80° 05.303'
BAL MID CTL 3	Miami	Middle	25° 54.159'	-80° 05.280'
BAL OUT CTL 1	Miami	Outer	25° 54.395'	-80° 05.507'
BAL OUT CTL 2	Miami	Outer	25° 54.364'	-80° 05.500'
BAL OUT CTL 3	Miami	Outer	25° 54.322'	-80° 05.514'
GBB CTL 1	Miami	Inner	25° 57.767'	-80° 06.012'
GBB CTL 2	Miami	Inner	25° 57.715'	-80° 06.003'
GBB CTL 3	Miami	Inner	25° 57.788'	-80° 05.975'
HDB CTL 1	Broward	Inner	25° 59.218'	-80° 06.182'
HDB CTL 2	Broward	Inner	25° 59.204'	-80° 06.201'
HDB CTL 3	Broward	Inner	25° 59.256'	-80° 06.160'
DBB CTL 1	Broward	Inner	26° 03.132'	-80° 05.869'
DBB CTL 2	Broward	Inner	26° 03.188'	-80° 05.836'
DBB CTL 3	Broward	Inner	26° 03.158'	-80° 05.851'
DPB CTL 1	Broward	Outer	26° 08.617'	-80° 04.738'
DPB CTL 2	Broward	Outer	26° 08.552'	-80° 04.735'
DPB CTL 3	Broward	Outer	26° 08.516'	-80° 04.750'
TB CTL 1	Palm Beach	Outer	26° 19.516'	-80° 03.512'
TB CTL 2	Palm Beach	Outer	26° 19.508'	-80° 03.537'
TB CTL 3	Palm Beach	Outer	26° 19.532'	-80° 03.535'
SB CTL 1	Palm Beach	Outer	26° 31.406'	-80° 01.949'
SB CTL 2	Palm Beach	Outer	26° 31.405'	-80° 01.930'
SB CTL 3	Palm Beach	Outer	26° 31.422'	-80° 01.900'
XCB CTL 1	Palm Beach	Outer	26° 42.944'	-80° 01.021'
XCB CTL 2	Palm Beach	Outer	26° 42.959'	-80° 01.040'
XCB CTL 3	Palm Beach	Outer	26° 42.917'	-80° 01.032'

Three of the 1993 permitted Port of Miami expansion project mitigation boulders were randomly chosen to be sampled. The boulder reef was constructed between 1996-1997. GIS techniques were used to randomly choose all the sample sites in the Port of Miami entrance channel and within the natural Inner Reef south of the entrance channel. Three samples were completed within the entrance channel on the dredged Inner Reef and Outer Reef floor and Inner Reef wall. One Middle Reef sample was completed on the entrance channel floor. Table 5 provides the site abbreviations, Table 6 the location information, and Figure 3 shows the locations for all the sites associated with the Port of Miami effort.

Table 5. Port of Miami (POM) site abbreviations.

Site	Abbreviation
POM Boulder 1	PMB 1
POM Boulder 2	PMB 2
POM Boulder 3	PMB 3
POM Boulder Control 1	PMB CTL 1
POM Boulder Control 2	PMB CTL 2
POM Boulder Control 3	PMB CTL 3
POM Inner Reef Channel 1	PMC IR 1
POM Inner Reef Channel 2	PMC IR 2
POM Inner Reef Channel 3	PMC IR 3
POM Inner Reef Channel Wall 1	PMCW IR 1
POM Inner Reef Channel Wall 2	PMCW IR 2
POM Inner Reef Channel Wall 3	PMCW IR 3
POM Middle Reef Channel 1	PMC MR 1
POM Outer Reef Channel 1	PMC OR 1
POM Outer Reef Channel 2	PMC OR 2
POM Outer Reef Channel 3	PMC OR 3

Data collection

Benthic biological communities at all sites were evaluated in two ways. A population approach was used to evaluate stony and gorgonian corals along belt transects. Species distribution, density, and size class were measured. Secondly, a percent cover estimate was calculated for benthic communities, including stony corals, gorgonians, sponges, zoanthids, algae, etc. These values were calculated from digital video images analyzed with Coral Point Count with Excel (CPCe) software developed by the National Coral Reef Institute (NCRI) (Kohler and Gill, 2006).

Table 6. Port of Miami sites habitat and location.

Site	Habitat	Latitude (N)	Longitude (W)
PMB 1	Inner-Outer	25° 45.038'	-80° 05.634'
PMB 2	Inner-Outer	25° 44.976'	-80° 05.691'
PMB 3	Inner-Outer	25° 44.991'	-80° 05.774'
PMB CTL 1	Inner	25° 44.779'	-80° 05.974'
PMB CTL 2	Inner	25° 44.761'	-80° 05.922'
PMB CTL 3	Inner	25° 44.808'	-80° 05.896'
PMC IR 1	Inner	25° 45.727'	-80° 05.810'
PMC IR 2	Inner	25° 45.721'	-80° 05.851'
PMC IR 3	Inner	25° 45.695'	-80° 05.841'
PMCW IR 1	Inner	25° 45.638'	-80° 05.905'
PMCW IR 2	Inner	25° 45.626'	-80° 05.937'
PMCW IR 3	Inner	25° 45.732'	-80° 05.896'
PMC MR 1	Middle	25° 45.804'	-80° 05.611'
PMC OR 1	Outer	25° 45.817'	-80° 05.389'
PMC OR 2	Outer	25° 45.902'	-80° 05.373'
PMC OR 3	Outer	25° 45.884'	-80° 05.364'

A sample consisted of three parallel transects along which data were collected. Each replicate sample included a belt-quadrat transect and three video transects (Figure 4). At the boulder reef sites, the direction of the belt transects was dictated by the orientation of the boulder reef to keep the entire sample within the boulder area. At the control sites, random compass bearings were used to orient the transects. Three replicates were sampled within each boulder reef (three transects at each of three replicate points within a boulder reef) except for the Hallandale Beach (HDB) and Silpe (SB) reefs which only had two samples each because these reefs were not large enough in area for three replicates. Three replicates were sampled within control reef areas (three transects at each of nine replicate control reef sites) associated with each boulder reef. All Port of Miami sample locations included three replicates. Random compass bearings were used to orient the transects at the channel floor, mitigation boulder, and control sites. The channel wall sites ran approximately east-west along the wall. Most replicate samples (as defined by the length of the transects) were 20m in length and 4 to 5m in width. One HDB sample (sample 2) and one DBB sample (sample 3) were shortened to 17 m in length to ensure that the entire transect was within the boulder area.

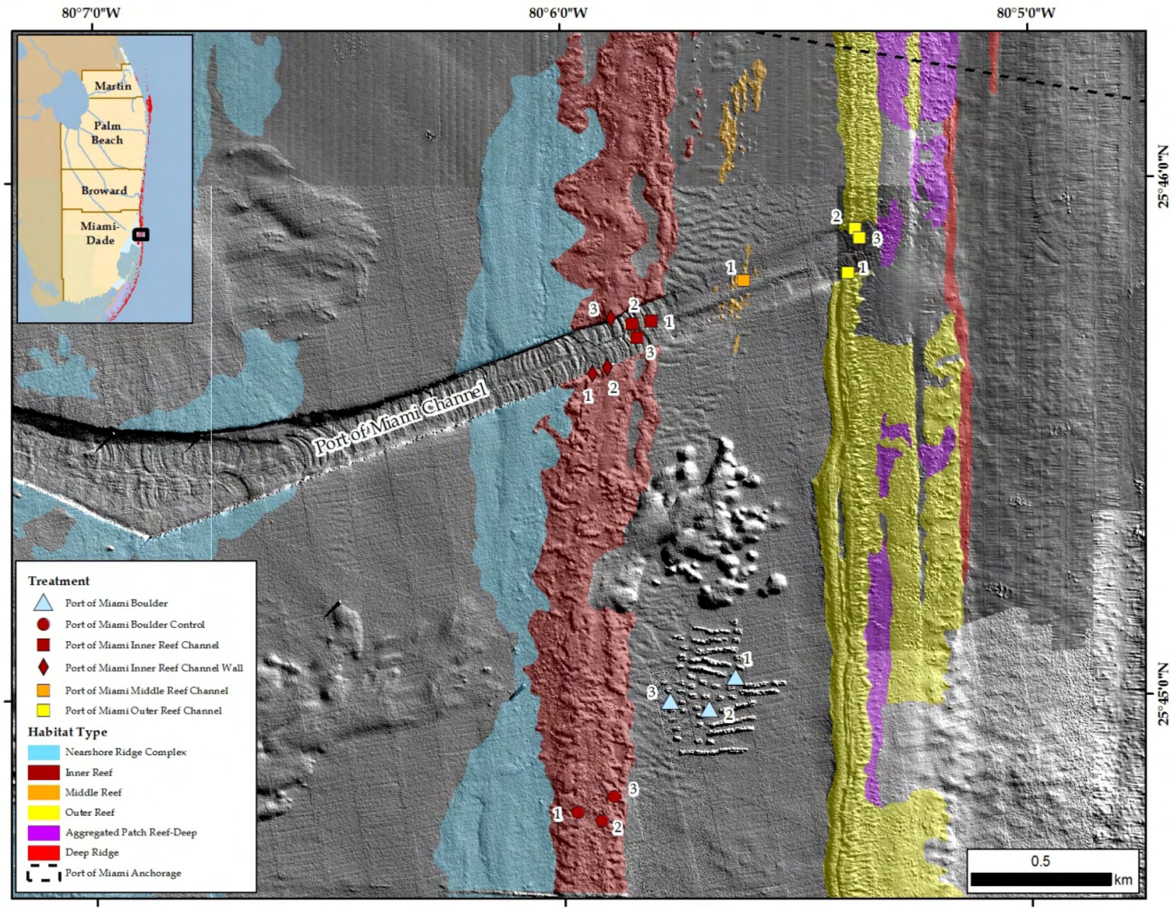

Figure 3. Map of the Port of Miami study area and the study site locations.

Surveying a 0.75 square meter (m^2) quadrat (1m x 0.75m) at each meter mark along both sides of a 20m belt-transect provided $30m^2$ total area per belt transect (40m x 0.75m). In each quadrat, stony corals, gorgonians, and barrel sponges (*Xestospongia muta*) were identified and measured. For stony corals ≥5 centimeters (cm) diameter, colony diameter and colony live tissue area (colony live tissue length x width) were measured. Stony coral species percent cover was calculated by dividing the sum of stony coral live tissue area by the total sample area. For gorgonian corals ≥2cm in height, colony height was measured and assigned to one of five size classes (2-5cm, 6-10cm, 11-25cm, 26-50cm, and >50cm). Barrel sponge height and base width were measured. This belt-quadrat transect method is directly comparable to the on-going Broward County Yearly Monitoring Reef Program (Gilliam et al., 2011) and was also used during the Phase I effort (Gilliam and Moulding, 2012).

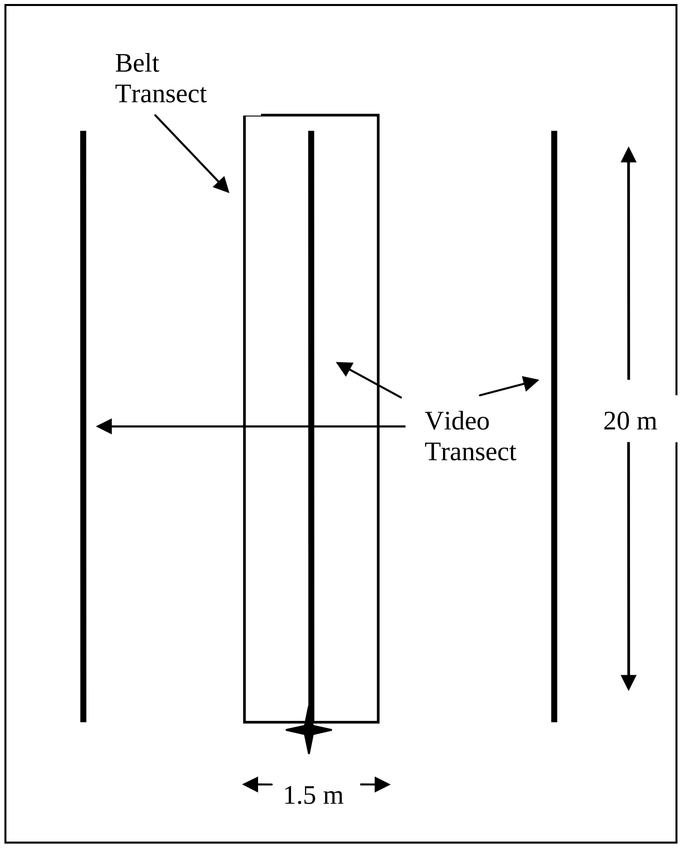

Figure 4. Diagram of the sampling method. Samples consisted of three video transects and one belt transect.

Due to the time-consuming nature of locating small colonies, juvenile stony corals <5cm in diameter and juvenile gorgonians <2 cm in height were counted and measured in smaller 0.25m^2 quadrats. For most samples, 40 quadrats were assessed for an area of 10m^2. Thirty quadrats were sampled at the three BAL sites, 26 quadrats were sampled at HDB sample 2, and 22 quadrats were sampled at DBB sample 3.

All three transects within a replicate sample were videotaped for percent cover estimates (Figure 4). Each video transect was 0.4m x 20m for a sample area of 8 m^2 per transect and 24m^2 per sample. Image software (RAVEN View by Observa, Inc.) was used to grab individual video frames (images). Each image was processed via CPCe, and 25 points were examined per image to determine percentage of functional group cover. The functional groups included biotic taxa (stony coral, gorgonian, sponge, coralline algae, macroalgae, zoanthid, and turf algae) and substrate type (consolidated reef pavement, unconsolidated rubble, and sand). This video transect method is directly comparable to the on-going

Southeast Florida Coral Reef Evaluation and Monitoring Program (Gilliam, 2011) and was also used during the Phase I effort (Gilliam and Moulding, 2012).

Prior to initiating the image analysis, a data quality assurance procedure was completed. All researchers completing the point counts analyzed the same transect to evaluate differences among the group. A Port of Miami boulder and a Port of Miami control site (Inner Reef) site were selected based on visual observations that it contained many of the functional groups represented throughout the project area. A Bray-Curtis similarity index (Primer™ v6 multivariate statistical software package, Clarke and Warwick, 2001) procedure was used to examine similarity among data sets and to drive discussions to increase consistency among point counters.

Several physical characteristics that may affect community composition were also evaluated. For the Port of Miami sites the video images were used to provide information on cover of substrate types including sand, rubble, and pavement (consolidated substrate). For all sites a small scale measure of rugosity was assessed using a chain link method (Rogers et al., 1982). For each belt transect, a chain 20m length, with links approximately 2cm in size, was draped along the contours of the substrate including all the holes, crevices, and raised surfaces. A measuring tape was stretched along the same transect to determine the ratio of the chain length (20m) to tape length to get an index of rugosity (length of tape/length of chain). An index value of 1.0 is flat, and the higher the index value, the more complex (rugose) the area.

<u>Data analysis</u>

The purpose of this study was to examine differences between boulder reefs and natural reef control sites and among the Port of Miami sites in population characteristics, community composition, and physical characteristics. The null hypotheses tested were as follows:

- H1: There is no difference in percent cover or density of stony corals, gorgonians, or barrel sponges (density only) among boulder reef and their adjacent control sites or among the Port of Miami sites.
- H2: There is no difference in mean colony size or size class distribution of stony corals and gorgonians, among boulder reef and control sites or among the Port of Miami sites.
- H3: There is no difference in cover of pavement, sand, or unconsolidated substrate (rubble) among the Port of Miami sites.

- H4: There is no difference in rugosity among boulder reef and control sites or among the Port of Miami sites.
- H5: There is no difference in benthic community composition (functional group percent cover and coral species percent cover) among boulder reef and control sites or among the Port of Miami sites.

The community data were analyzed in two ways. Univariate (Statistica 6.0 [Statsoft]) statistics were used to analyze the stony and gorgonian population data collected along the belt transects (H1 and H2). The percent cover estimates for substrate types (pavement, rubble, and sand) along the video transects (H3) and the rugosity data (H4) were also included in the univariate analysis.

For the comparisons, parametric analysis of variance techniques (ANOVA) were used, and when significant differences were found, Newman-Keuls post hoc test was used for pair-wise comparisons. Data were transformed where needed in an attempt to meet the parametric assumptions of normally distributed data and equal variance among groups (sites). The percent data (substrate type and stony and gorgonian coral) were arc sin transformed, and the density data were log transformed ($\log_{10}[x+1]$) prior to statistical analyses. Stony coral colonies and barrel sponges were pooled within each site for comparison of mean colony sizes among sites.

Multivariate (PrimerE, Clarke and Warwick, 2001) statistical analysis was performed on the video transect cover estimates of major functional groups to examine similarities between benthic communities among boulder reef and control sites, or among the Port of Miami channel wall, floor, boulders and controls sites (H5). A matrix of Bray-Curtis Similarity coefficients were generated from a matrix of stony coral species and major functional group cover data. The similarity coefficients were used to create non-metric multi-dimensional scaling (MDS) plots. The MDS plots provide a visual representation or map of the similarity (or dissimilarity) between sites such that the distance between sites in these plots is a measure of the relative dissimilarity in species composition or community composition (Clarke and Gorley, 2001). These plots are a convenient way of representing a large amount of data in a two dimensional space. The MDS plot generates a stress value, which indicates the level of difficulty in representing the similarity for all samples into a two-dimensional space. A stress value ≤0.05 indicates a plot with excellent representation and minimal chance of misinterpretation. Values from 0.05 to 0.10 represent a good ordination with slight chance of misinterpretation. Stress values from 0.10 to 0.20 indicate a useful plot but have a chance of misinterpretation, and values between 0.20 and 0.30 are considered acceptable, although conclusions should be cross-checked with other statistical measures (Clarke and Gorley, 2001). ANOSIM (analysis of similarities) tests were used to examine differences between sites. An ANOSIM produces p values and global (all samples) and pair-wise (comparing sites) R values of each comparison from the same Bray-Curtis similarity matrix. An R values of 1.00 indicate that within boulder reef replicate samples or replicate control areas are more similar to each other than any of the other samples, while R values of 0 indicate that within boulder reef replicate samples or replicate control areas are as similar to each other as they are within a group. Pair-wise R values were also examined. Note that for an ANOSIM test with only three replicates for each boulder reef or control area a significance level greater than 10% is not possible. Calculated R values greater than 0.75 indicate that treatments are well separated. An R value between 0.45 and 0.75 indicates that treatments were clearly different but overlapping. An R value between 0.45 and 0.25 indicates treatments were not clearly different, and less than 0.25 indicated the treatments were barely separable (Clarke and Gorley, 2001).

A SIMPER (similarity percentage) analysis was used to evaluate functional groups driving the differences between sites. A SIMPER analysis determines average dissimilarities between treatments as well as percent contribution of each functional group to the dissimilarity. An average dissimilarity of 100 means two sites are completely different while an average dissimilarity of 0 means two sites are exactly the same. A functional group with high percent contribution were considered good discriminating species (or species responsible for driving the difference between the two samples) between the sites (Clarke and Warwick, 2001).

RESULTS

Separate data analyses were completed for each of the two Phase II project studies: the boulder reefs and controls study, and the Port of Miami study. For clarity, results for each of these analyses are presented separately.

<u>Boulder Reefs and Controls</u>

Three replicate samples were surveyed for seven of the nine boulder reefs. The Hallandale Beach (HDB) and Silpe (SB) boulder reefs were only large enough for two replicate samples. Three replicate samples were surveyed on natural reef adjacent to eight of the boulder reef. Because an additional sampling opportunity became available, six control samples (three on the Middle Reef and three on the Outer Reef) were sampled adjacent to the Bal Harbor boulder reef (BAL). In total 25 boulder reef and 30 control reef samples were surveyed. Tables 1 and 2 provide information for the sampled boulder reefs, and Tables 3 and 4 provide information for the sampled control reef areas. Figures 1 and 2 shows the locations of each sampled boulder reef and control sample area.

For stony coral colonies ≥5cm diameter, there was no consistent pattern in percent cover (belt transect data) between boulder reefs and their natural reef controls in relation to deployment county or habitat (sand areas between linear reefs) (Table 7 and Figure 5) (see Table 2 for deployment county and habitat). Five boulders reefs, with representatives from all three counties, (AB, BAL, DBB, DPB, and TB) had greater mean percent cover than their adjacent natural reef controls, but only two (AB and DPB) were significant (ANOVA, $p<0.05$) (Figure 5). Two boulder reefs (HDB and SB) had significantly (ANOVA, $p<0.05$) less cover than their controls. As would be expected, the age of the boulder reef (years since deployment) appears to be influencing percent cover with the oldest boulder reefs (AB deployed in 1994 and BAL and DPB deployed in 1999) having significantly greater (ANOVA, $p<0.05$) percent cover than the youngest boulder reefs (GB deployed in 2005 and SB in 2009) (Figure 5). This is also illustrated by SB and HDB, both younger reefs, having less cover than their controls, and by the oldest reefs in each county having greater cover than the youngest reef. The encrusting coral, *Madracis decactis,* is a dominant coral on the AB, which had the greatest mean percent stony coral cover (6.6%), and contributes greatly to percent cover on BAL and DPB. When this species is removed the mean cover lowers to 2.3% on the AB, 3.6% on the DPB, and 3.2% on the BAL which are still greater than their adjacent controls but no longer much greater than the other boulder reefs or controls.

The relationship among boulder reefs and controls for colony density (colonies/m^2) of stony coral colonies ≥5cm diameter was similar to that seen with percent cover (Table 7 and Figure 6). Eight boulder reefs had greater mean density than their adjacent natural reef controls with only SB having less density. Of these eight, the mean density determined for five boulder reefs (AB, BAL, DBB, DPB, and TB) was greater (ANOVA, $p<0.05$) than their controls (Figure 6). Although not as strongly as determined for percent cover, age of the reefs again appears to be playing an important role in colony density with the older reefs (AB, BAL, and DPB) having greater densities than the younger reefs (HDB and SB).

Although not significant, all of the boulder reefs had smaller mean colonies sizes (diameter cm) than their control areas (Table 7). In addition to the smaller mean size of the stony corals in the boulder reef sites, the size of the largest colony identified within all of the boulder reefs was smaller than in their adjacent control areas (Table 8).

Table 7. Mean (standard error [SE]) stony coral percent cover, density (colonies/m²), colony size (diameter cm), and species richness (number of species) for each of the 9 boulder reefs and 10 control sites (see Tables 1 and 3 for site abbreviations).

	Cover		Density		Colony Size		Richness	
Site	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
AB	6.57	1.07	4.07	0.38	10.49	3.12	14.00	0.58
AB CTL	1.00	0.16	0.87	0.20	10.99	4.59	7.33	0.67
BAL	3.62	0.20	4.68	0.08	9.51	2.81	16.67	0.33
BAL MID CTL	1.70	0.76	0.70	0.15	15.67	7.94	8.00	1.00
BAL OUT CTL	1.76	0.53	0.96	0.06	11.74	5.70	7.67	1.20
GBB	0.54	0.04	1.33	0.15	6.92	1.30	8.00	1.00
GBB CTL	1.53	0.37	0.94	0.06	11.80	4.49	10.33	0.33
HDB	0.46	0.14	1.11	0.27	6.81	1.23	7.50	0.50
HDB CTL	3.40	0.63	1.06	0.04	16.42	7.64	8.67	1.20
DBB	1.63	0.43	2.85	0.66	7.20	1.55	11.00	0.58
DBB CTL	1.47	0.71	0.77	0.10	13.83	5.75	7.67	0.67
DPB	4.45	0.18	7.29	0.15	8.40	2.65	17.00	1.00
DPB CTL	0.49	0.18	0.56	0.08	10.96	3.68	5.33	0.67
TB	1.88	0.21	3.57	0.08	7.81	1.68	12.67	1.45
TB CTL	0.73	0.06	0.66	0.05	11.06	4.25	5.33	0.88
SB	0.02	0.00	0.07	0.00	6.00	1.15	1.50	0.50
SB CTL	4.60	0.71	2.27	0.31	17.98	7.36	7.00	0.58
XCB	0.86	0.17	1.20	0.32	8.55	2.53	9.00	0.58
XCB CTL	1.50	0.41	0.71	0.17	13.71	5.99	5.00	0.58

With the encrusting species, *M. decactis*, removed, no boulder reef had a stony coral colony greater than 30cm diameter, while all ten control areas had colonies greater than 30cm, and five control areas had colonies greater than 50cm. The oldest boulder reefs (AB, BAL, DPB, TB, and XCB) had colonies greater than 20cm while the youngest reef (HDB, GBB, and SB) did not. The largest colony in five of the nine boulder reefs was *Porites astreoides* while *Montastraea cavernosa* was the largest species identified in seven of the ten control areas.

Colony size (≥5cm diameter) distribution was examined by assigning all colonies to size (diameter) classes (5-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm, and >50cm). *M. decactis* was removed because it is difficult to accurately estimate size since it is an encrusting coral often growing into crevices.

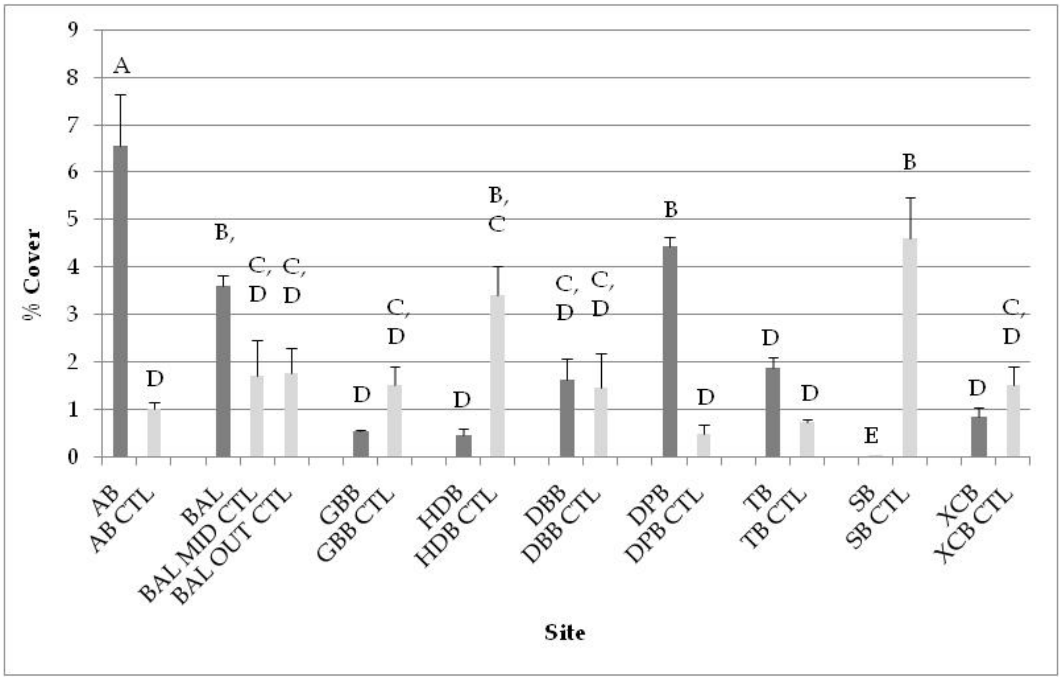

Figure 5. Mean (SE) percent stony coral cover (belt transect data) for each of the sites (see Tables 1 and 3 for site abbreviations). Letters above site bars denote significance groups (ANOVA, arc sin transformed, $p < 0.05$).

The boulder reef colony size distribution was more heavily right-skewed towards the smallest size class than the control sites (Tables 9 and 10). As mentioned, no boulder reefs had colonies greater than 30cm. For all boulder reefs the smallest size class (5-10cm) contributed over 60% to the assemblage and in four boulder reefs (GBB, HDB, DBB, and SB) this size class contributed over 90%. In contracts, in the control areas only four had a greater than 60% contribution from the 5-10cm size class and none were over 70%. Age again is a factor which appears to be influencing size class distribution with the older boulder reefs having a greater contribution from the 10-20cm and 21-30cm size classes (Tables 9 and 10).

Five boulder reefs (AB, BAL, DPB, and TB) sites had significantly greater species richness (colonies ≥5cm diameter) (ANOVA, $p<0.05$) than their adjacent control areas (Table 7 and Figure 7). Only boulder reef SB had significantly fewer species than its control area. Species richness is much more similar among the boulder reefs and the control reefs than percent cover or density. Many of the older boulder reefs did have more stony coral species, but the influence of age on the number of species does not appear to be as evident as with percent cover or density. There were ten species common to all boulder reefs and control areas (see Appendix Tables 1-3).

Table 8. The mean (standard error [SE]) size (diameter cm) of the largest colonies identified each site, and the species and size (diameter cm) of that largest colony within the entire site (see Table 1 for site abbreviations).

	Largest Colonies		Largest Colony	
Site	**Mean**	**SE**	**Species**	**Diameter (cm)**
AB	25.33	7.51	*Colpophyllia natans*	25
AB CTL	33.00	1.73	*Montastrea cavernosa*	35
BAL	26.67	4.16	*Porites astreoides*	30
BAL MID CTL	54.33	30.02	*Montastrea faveolata*	85
BAL OUT CTL	40.00	11.14	*Montastrea cavernosa*	52
GBB	13.33	0.58	*Porites astreoides*	14
GBB CTL	35.33	8.08	*Agaricia agaricites*	40
HDB	12.00	1.41	*Agaricia fragilis*	13
HDB CTL	62.67	14.19	*Meandrina meandrites*	78
DBB	16.00	3.00	*Porites astreoides*	19
DBB CTL	36.67	12.58	*Montastrea cavernosa*	50
DPB	20.33	4.51	*Porites astreoides*	25
DPB CTL	29.67	15.53	*Montastrea cavernosa*	47
TB	17.67	4.16	*Montastrea faveolata*	21
TB CTL	32.67	10.26	*Montastrea cavernosa*	44
SB	7.00	2.83	*Porites astreoides*	9
SB CTL	75.00	13.00	*Montastrea cavernosa*	83
XCB	21.67	2.08	*Mycetophyllia aliciae*	24
XCB CTL	45.00	13.23	*Montastrea cavernosa*	60

Porites astreoides and *Siderastrea siderea* were common to all boulder reefs. Important, larger, reef structure forming species (e.g. *Colpophyllia natans*, *Diploria* spp., and *Montastrea* spp.) contributed much more to the species assemblage in the control areas than to any of the boulder reefs (see Appendix Tables 1-3).

Stony coral recruits were defined as colonies <5cm diameter. Figure 8 shows the mean (SE) recruit density for each site. Eight of the boulder reefs had significantly greater (ANOVA, $p<0.05$) mean recruit density (colonies/m^2) than their adjacent control area (Table 11 and Figure 8). Only boulder reef SB had lower recruit density, and this difference was significant (ANOVA, $p>0.05$). Recruit species richness followed this same pattern except that the reduced SB richness was not significant (Figure 9).

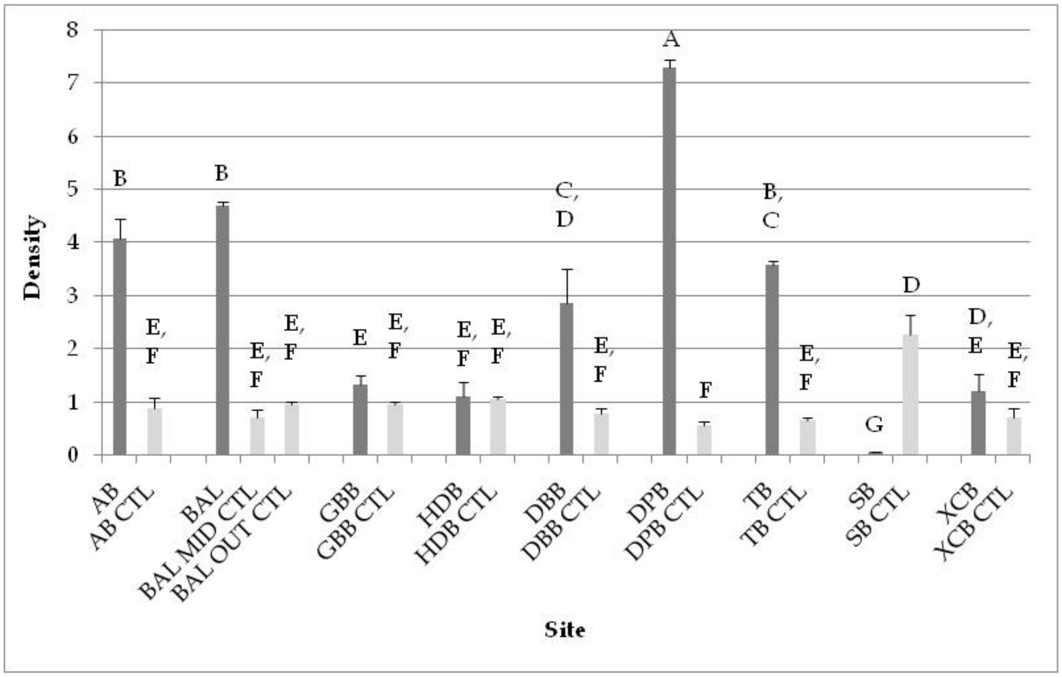

Figure 6. Mean (SE) stony coral density (colonies/m²) for each of the sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

Although most of the boulder reefs had significantly more recruits and species than their controls, the difference among boulders reefs and among the control reefs was much less than what was seen for non-recruit percent cover, density, or species richness. *Siderastrea siderea* was the most abundant recruit in 44 of the 55 samples (boulder and control combined). Other common recruits included *Porites astreoides*, *Stephanocoenia intersepta*, and *Montastrea cavernosa*.

Mean percent gorgonian cover was significantly greater in all of the control areas compared to the boulder reefs (Table 12 and Figure 10) (ANOVA, $p<0.05$). Gorgonian percent cover was less than 2% at eight of the nine boulder reefs, and the boulder reef with the greatest cover (DPB at 5.5%) was equal to the cover of the lowest control area (DBB CTL). In contrast, all 10 control areas had cover greater than 5% and five of the ten had cover greater than 10%. Because gorgonian cover was so low on the boulder reefs, age or county or habitat trends are difficult to interpret.

Similar to the comparison with percent cover, mean gorgonian density (colonies/m²) was significantly greater in all of the control areas compared to the boulder reefs (Table 12 and Figure 11) (ANOVA, $p<0.05$).

Table 9. Mean stony coral (standard error [SE]) percent size (diameter cm) class (5-10cm, 11-20cm, and 21-30cm) distribution (see Table 1 and 3 for site abbreviations).

Site	5-10cm		11-20cm		21-30cm	
	Mean	SE	Mean	SE	Mean	SE
AB	61.4%	1.0%	26.7%	0.2%	11.9%	1.0%
AB CTL	62.2%	7.2%	23.6%	3.9%	6.9%	1.8%
BAL	73.3%	1.3%	22.8%	1.1%	4.0%	0.2%
BAL MID CTL	48.3%	7.1%	30.5%	4.1%	13.3%	4.7%
BAL OUT CTL	62.4%	3.9%	25.8%	1.8%	3.8%	2.1%
GBB	91.3%	3.8%	8.7%	3.8%	0.0%	0.0%
GBB CTL	65.9%	1.8%	22.8%	4.0%	6.6%	3.6%
HDB	92.8%	3.2%	7.2%	3.2%	0.0%	0.0%
HDB CTL	51.9%	5.8%	23.1%	5.2%	11.5%	2.6%
DBB	90.7%	2.3%	8.7%	2.3%	0.5%	0.5%
DBB CTL	53.2%	3.0%	27.1%	2.1%	12.9%	1.2%
DPB	82.5%	1.5%	15.9%	1.6%	1.7%	0.4%
DPB CTL	57.6%	8.4%	36.3%	8.8%	4.4%	2.4%
TB	84.7%	3.2%	14.7%	2.8%	0.6%	0.3%
TB CTL	62.0%	4.6%	27.5%	4.4%	6.5%	4.4%
SB	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SB CTL	34.7%	5.2%	41.5%	2.7%	10.8%	3.5%
XCB	77.0%	2.0%	18.6%	2.0%	4.5%	3.6%
XCB CTL	45.6%	5.6%	36.8%	1.8%	10.0%	3.8%

Gorgonian density was less than 2 colonies/m^2 at all boulder reefs, and all boulder reefs had densities less than the density of the lowest control area (GBB CTL). In contrast, seven control areas had densities greater than 5 colonies/m^2 and four had densities greater than 10 colonies/m^2. No gorgonian colonies were identified in the HDB transects. Though not significant, the older reefs deployed before 2000 (except AB) did have mean densities greater than the younger reefs deployed after 2001.

Size (height) class distribution of gorgonians was not similar between the boulder reefs and the control areas (Tables 13 and 14). The control areas size classes were normally distributed with the majority of gorgonians in all areas being in the middle 11-25cm class. The boulder reefs distribution was not nearly as normally distributed with many reefs having more equal contributions from several size classes. All control areas had gorgonian colonies greater than 50cm as compared to the boulder reefs with only four reefs having colonies greater than 50cm.

Table 10. Mean stony coral (standard error [SE]) percent size (diameter cm) class (31-40cm, 41-50cm, and >50cm) contribution (see Table 1 for site abbreviations).

	31-40cm		41-50cm		>50cm	
Site	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
AB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AB CTL	7.4%	3.5%	1.0%	0.6%	1.9%	0.3%
BAL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BAL MID CTL	2.6%	1.3%	1.3%	1.3%	3.9%	2.3%
BAL OUT CTL	4.4%	2.7%	2.5%	2.5%	1.2%	1.2%
GBB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GBB CTL	4.6%	2.4%	0.0%	0.0%	0.0%	0.0%
HDB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
HDB CTL	7.1%	4.3%	4.3%	2.8%	2.1%	1.0%
DBB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DBB CTL	3.3%	1.7%	3.5%	3.5%	0.0%	0.0%
DPB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DPB CTL	0.0%	0.0%	1.7%	1.7%	0.0%	0.0%
TB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TB CTL	2.0%	2.0%	2.0%	2.0%	0.0%	0.0%
SB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SB CTL	6.2%	1.5%	4.1%	1.2%	2.7%	0.8%
XCB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
XCB CTL	6.2%	3.2%	0.0%	0.0%	1.4%	1.4%

As with percent cover and density, the mean number of gorgonian species identified in the control areas was greater than identified in any of their corresponding boulder reefs (Table 12 and Figure 12), and for five reefs (AB, GBB, XCB, SB, TB) this difference was significant (ANOVA, $p<0.05$). There were no significant differences determined among any of the control areas. There were some differences in the dominant species identified in the boulder reefs and control areas. *Eunicea* spp. (*Eunicea* species can be difficult to identify in the field and were all pooled together) appeared to contribute more to the gorgonian assemblage in the control areas in all three counties (Appendix Tables 4, 5, and 6), while *Gorgonia ventalina* appeared to contribute more to the boulder reef assemblage. In Palm Beach county *Iciligorgia schrammi* was a common species at the boulder reefs.

No barrel sponges, *Xestospongia muta*, were identified in any of the boulder reef sites. In contrast, all of the control areas had barrel sponges (Table 15).

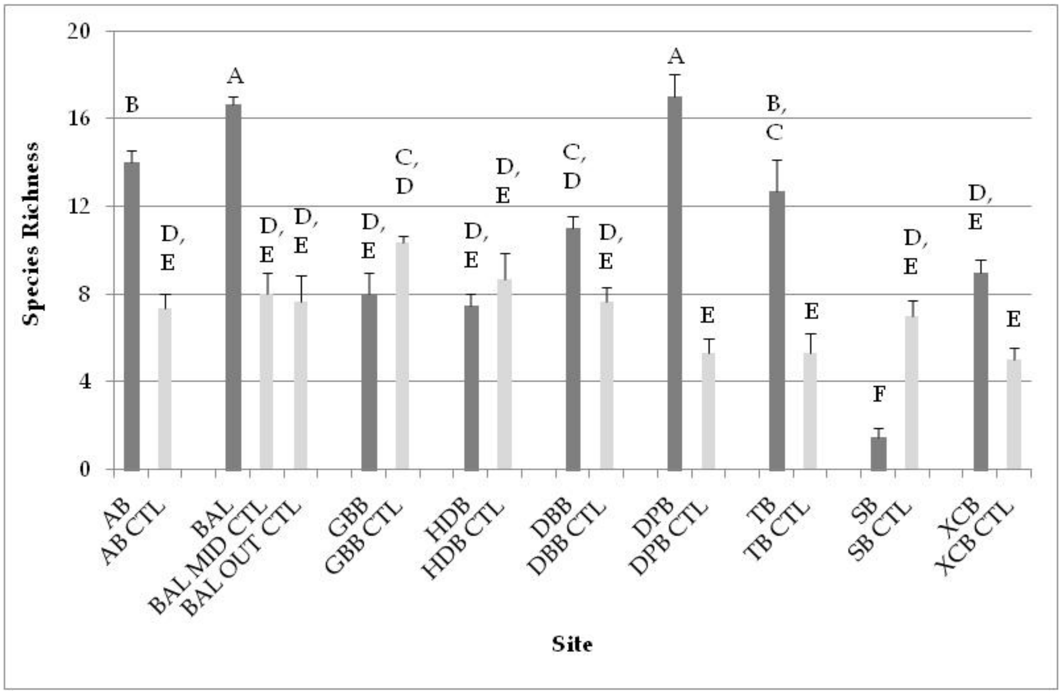

Figure 7. Mean (SE) stony coral species richness. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

Table 16 lists the mean rugosity measures for all sites. As expected, all boulder reefs were more rugose than their adjacent natural reef controls. The rugosity of the controls was much more constant throughout all counties than the boulders with only the BAL MID CTL area rugosity being significantly (ANOVA $p < 0.05$) greater than the DPB CTL area. All other control areas were not significantly different.

Functional group percent cover was estimated from the video transects. Figure 13 is the MDS ordination plot of percent functional group cover for all boulder reefs and control samples. This plot shows a distinct separation of all the boulder reef sites from the control area sites. A significant difference was determined among sites (ANOSIM, Global $R = 0.924$, $p = 0.1\%$). Pair-wise comparisons indicated that significant differences were determined between each grounding site and the control sites (For reefs AB, HDB, DBB, DPB, TB, SB, and XCB: R = 1, p = 10%; BAL: R = 0.835, p = 0.4%; and GBB: R = 0.93, p = 10%). Significant groupings (SIMPROF [similarity profiles] procedure on Bray Curtis similarity indices) are superimposed over the sites in the MDS plot (Figure 13). All control areas group in the 75% similarity and each of the boulder reefs group in the 80% similarity except HDB at 75% similarity.

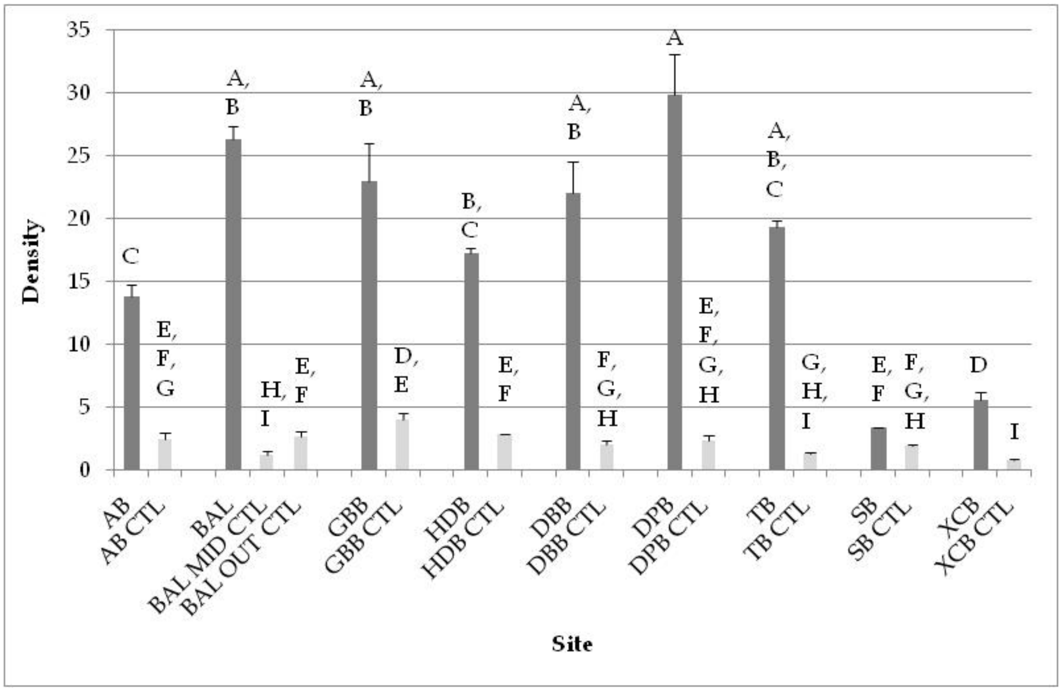

Figure 8. Mean (SE) stony coral recruit density (colonies/m²) for each of the sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

A SIMPER analysis was run to examine which functional groups contributed the most to the dissimilarity among sites. For each pair-wise comparison (boulder reef to adjacent control area) gorgonian, sponge, and the stony coral species, *M. cavernosa* and *P. astreoides*, percent cover were listed as functional groups contributing to the dissimilarity between each pair. Figure 14 is the same MDS plot as shown in Figure 13, but the relative contributions of gorgonian (Figure 14), sponge (Figure 15), *M. cavernosa* (Figure 16), and *P. astreoides* (Figure 17) are shown as bubbles superimposed over the sample name. The larger the bubble, the greater the percent cover of that group at that sample, and the more that functional group contributes to the dissimilarity between sites.

Figures 18, 19, and 20 are the same MDS plot as Figure 13 but with deployment habitat, county, and deployment year symbols shown. Boulder reefs and control areas group more clearly and are best explained by habitat (sand area between linear reefs for boulder reefs) (Figure 18) than by county (Figure 19). Figure 20 plots the deployment years for each of the boulder reefs.

Table 11. Mean (standard error [SE]) stony coral recruit density (colonies/m^2) and species richness (number of species) for each of the nine boulder reefs and 10 control sites (see Table 1 for site abbreviations).

	Density		Richness	
Site	**Mean**	**SE**	**Mean**	**SE**
AB	13.83	0.92	11.33	0.88
AB CTL	2.43	0.52	4.67	0.67
BAL	26.31	1.11	12.00	0.58
BAL MID CTL	1.20	0.29	4.33	1.20
BAL OUT CTL	2.57	0.44	6.00	1.00
GBB	22.93	3.13	14.00	1.00
GBB CTL	4.00	0.50	8.67	0.88
HDB	17.20	0.49	8.50	1.50
HDB CTL	2.83	0.03	5.67	0.67
DBB	22.05	2.56	13.33	0.88
DBB CTL	1.94	0.38	5.33	0.33
DPB	29.83	3.30	13.00	2.00
DPB CTL	2.27	0.41	4.67	0.67
TB	19.30	0.59	12.00	0.58
TB CTL	1.27	0.09	4.00	0.58
SB	3.35	0.04	7.50	0.41
SB CTL	1.87	0.08	6.00	1.41
XCB	5.50	0.70	5.33	1.33
XCB CTL	0.70	0.17	3.33	0.88

There is some indication that the older reefs deployed in 1999 and 2001 are more similar to the controls than the younger reefs deployed in 2003 and 2005 with the exception of AB. This relationship between the age of the boulder reefs and similarity to their adjacent natural reef controls is further illustrated in Table 17. Table 17 lists the average Bray-Curtis similarity index (percent) for each of the pair wise boulder reef-adjacent natural reef control comparisons.

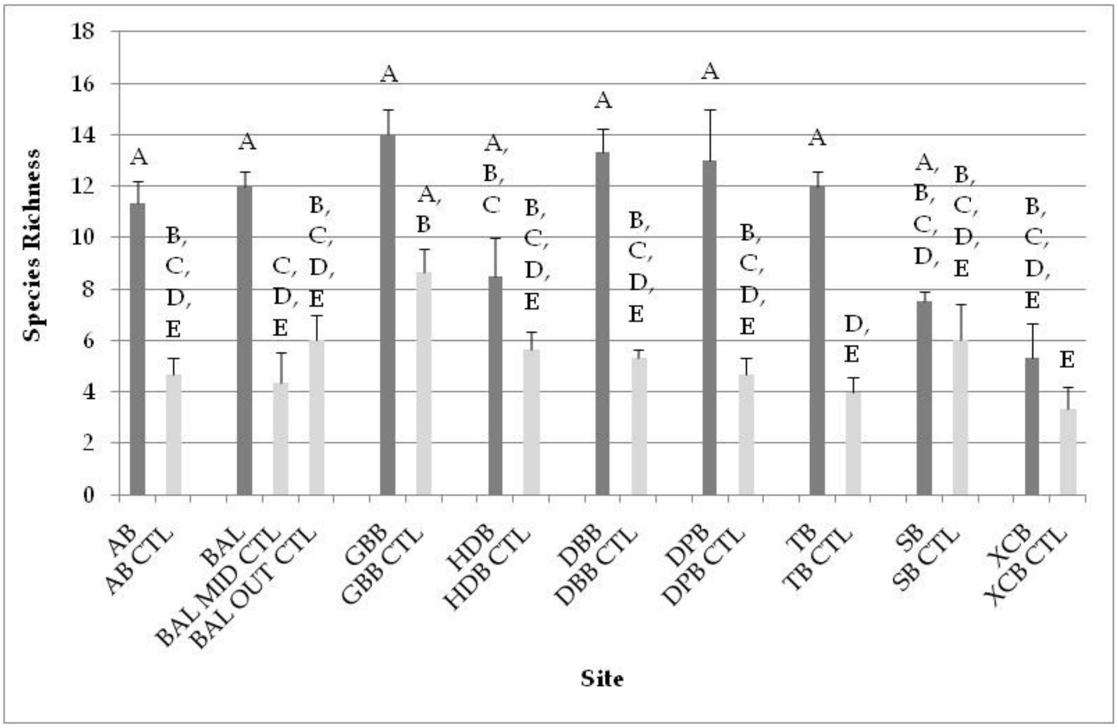

Figure 9. Mean (SE) stony coral recruit species richness. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

Table 12. The mean gorgonian (standard error [SE]) percent cover, density (colonies/m²), and species richness. (see Tables 1 and 3 for site abbreviations).

	Cover		Density		Richness	
Site	Mean	SE	Mean	SE	Mean	SE
AB	0.32	0	0.15	0.12	2.67	1.67
AB CTL	11.07	1.47	7.49	1.83	12.33	1.45
BAL	1.89	0.81	0.97	0.13	7.67	0.67
BAL MID CTL	4.55	0.52	3.72	0.71	8.67	1.33
BAL OUT CTL	8.29	1.05	5.03	0.38	11.67	0.88
GBB	0.22	0.11	0.24	0.18	3.00	1.73
GBB CTL	5.39	0.31	2.24	0.63	7.00	0.00
HDB	0.12	0.04	0.00	0.00	0.00	0.00
HDB CTL	5.99	0.39	6.90	1.37	6.67	0.33
DBB	1.59	0.13	1.84	0.74	8.00	1.00
DBB CTL	5.48	0.77	4.77	0.53	9.00	0.58
DPB	5.48	0.73	1.22	0.17	10.67	0.33
DPB CTL	12.84	1.35	15.00	0.90	14.67	0.33
TB	1.41	0.22	0.92	0.11	7.00	0.58
TB CTL	21.59	1.00	22.38	3.54	16.00	0.58
SB	0.13	0.09	0.45	0.15	7.50	1.22
SB CTL	19.28	2.48	25.02	6.02	17.67	1.20
XCB	1.37	0.45	1.12	0.42	3.00	1.15
XCB CTL	14.62	3.85	14.63	3.14	19.67	1.67

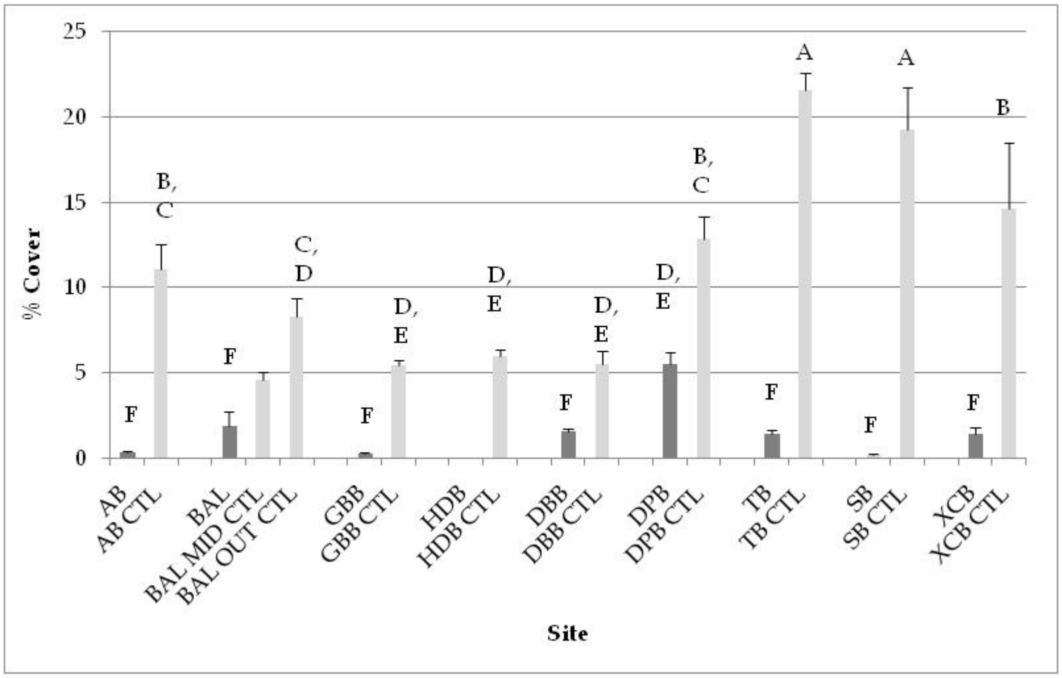

Figure 10. Mean (SE) percent gorgonian cover for each of the sites (see Tables 1 and 3 for site abbreviations). Letters above site bars denote significance groups (ANOVA, arc sin transformed, $p < 0.05$).

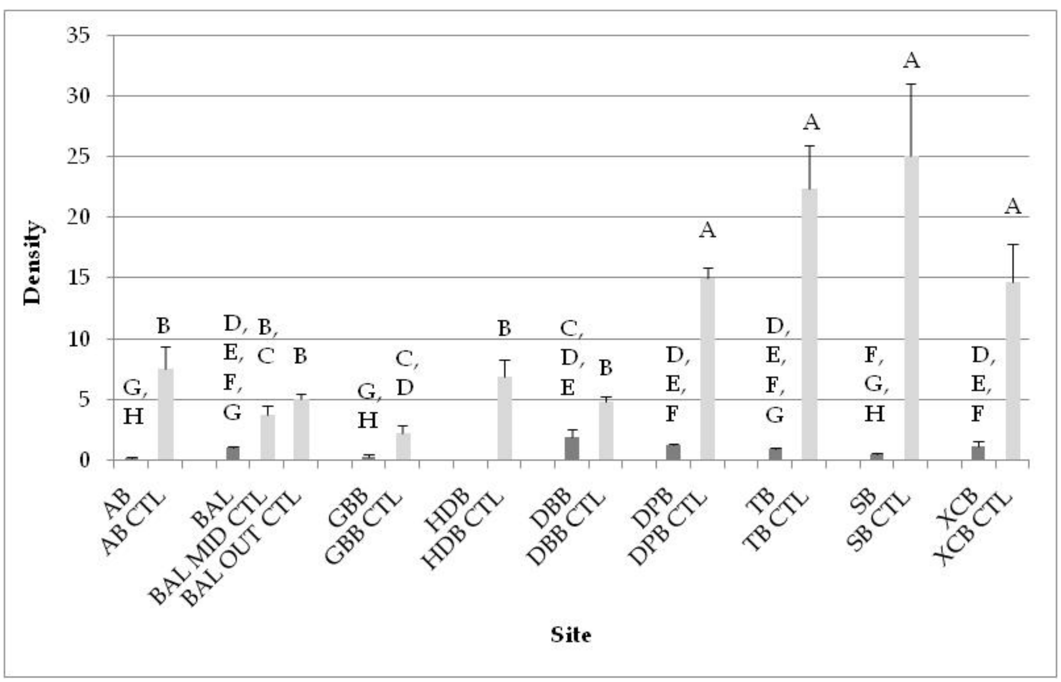

Figure 11. Mean (SE) gorgonian density (colonies/m^2) for each of the sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

Table 13. Mean (standard error [SE]) gorgonian percent size (height cm) class (2-5cm, 6-10cm, and 11-25cm) distribution (see Tables 1 and 3 for site abbreviations).

Site	2-5cm		6-10cm		11-25cm	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
AB	0.00%	0.00%	0.00%	0.00%	52.67%	28.99%
AB CTL	10.33%	1.20%	22.67%	2.96%	42.33%	1.76%
BAL	13.33%	5.78%	23.33%	2.03%	45.00%	4.93%
BAL MID CTL	4.67%	1.20%	26.00%	1.15%	46.33%	8.17%
BAL OUT CTL	5.00%	0.58%	19.00%	2.65%	56.33%	2.03%
GBB	17.67%	8.88%	29.67%	15.17%	11.00%	11.00%
GBB CTL	10.67%	5.78%	24.33%	2.96%	43.00%	8.08%
HDB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HDB CTL	4.67%	0.88%	21.67%	2.91%	52.00%	1.73%
DBB	11.67%	3.84%	26.33%	6.17%	38.00%	2.52%
DBB CTL	4.00%	1.53%	21.33%	3.48%	53.67%	0.88%
DPB	0.00%	0.00%	12.33%	1.76%	40.67%	2.73%
DPB CTL	6.33%	0.88%	27.67%	4.26%	53.00%	4.04%
TB	4.33%	2.60%	22.33%	3.71%	35.00%	7.81%
TB CTL	9.33%	2.33%	17.33%	3.84%	59.33%	2.40%
SB	56.50%	6.50%	0.00%	0.00%	41.00%	9.00%
SB CTL	13.33%	2.73%	22.67%	0.33%	39.00%	5.51%
XCB	0.00%	0.00%	2.67%	1.45%	22.33%	4.63%
XCB CTL	8.00%	2.08%	21.00%	1.00%	41.33%	3.18%

Table 14. Mean (standard error [SE]) gorgonian percent size (height cm) class (26-50cm and >50cm) distribution (see Tables 1 and 3 for site abbreviations).

	26-50cm		>50cm	
Site	Mean	SE	Mean	SE
AB	44.33%	29.42%	2.67%	2.67%
AB CTL	23.00%	5.13%	2.00%	0.58%
BAL	18.00%	2.65%	0.00%	0.00%
BAL MID CTL	20.00%	4.51%	2.67%	1.67%
BAL OUT CTL	14.67%	1.33%	5.33%	0.67%
GBB	8.33%	8.33%	0.00%	0.00%
GBB CTL	14.00%	4.51%	7.67%	4.70%
HDB	0.00%	0.00%	0.00%	0.00%
HDB CTL	20.33%	2.03%	1.00%	0.00%
DBB	22.67%	6.94%	1.00%	1.00%
DBB CTL	18.33%	4.37%	2.67%	0.88%
DPB	32.67%	8.41%	15.00%	7.64%
DPB CTL	10.00%	1.15%	3.00%	0.58%
TB	27.67%	2.33%	10.00%	5.29%
TB CTL	10.33%	1.20%	3.33%	0.33%
SB	2.50%	2.50%	0.00%	0.00%
SB CTL	20.00%	1.53%	5.00%	1.53%
XCB	38.67%	3.53%	36.67%	3.38%
XCB CTL	26.33%	2.33%	3.67%	0.88%

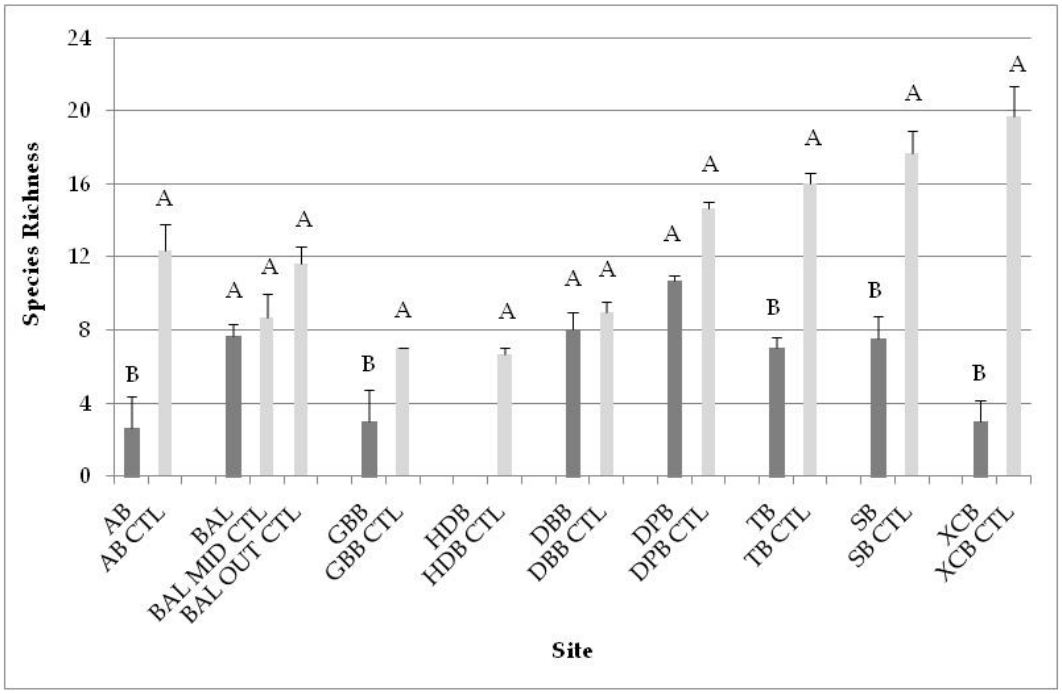

Figure 12. Mean (SE) gorgonian species richness. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Tables 1 and 3 for site abbreviations).

Table 15. Mean barrel sponge (standard error [SE]) density (sponges/m²) for all sites (see Tables 1 and 3 for site abbreviations).

Site	Density Mean	Density SE	Site	Density Mean	Density SE
AB	0.00	0.00	DBB	0.00	0.00
AB CTL	0.37	0.09	DBB CTL	0.20	0.05
BAL	0.00	0.00	DPB	0.00	0.00
BAL MID CTL	0.35	0.02	DPB CTL	0.42	0.12
BAL OUT CTL	0.44	0.14	TB	0.00	0.00
GBB	0.00	0.00	TB CTL	0.32	0.08
GBB CTL	0.25	0.02	SB	0.00	0.00
HDB	0.00	0.00	SB CTL	0.48	0.08
HDB CTL	0.17	0.10	XCB	0.00	0.00
			XCB CTL	0.20	0.00

Table 16. Mean (standard error [SE]) rugosity for all sites (see Tables 1 and 3 for site abbreviations).

Site	Rugosity	
	Mean	SE
AB	1.70	0.10
AB CTL	1.13	0.02
BAL	1.90	0.14
BAL MID CTL	1.32	0.01
BAL OUT CTL	1.12	0.01
GBB	1.75	0.05
GBB CTL	1.19	0.02
HDB	1.63	0.13
HDB CTL	1.18	0.02

Site	Rugosity	
	Mean	SE
DBB	2.05	0.14
DBB CTL	1.16	0.01
DPB	1.89	0.15
DPB CTL	1.02	0.00
TB	2.44	0.20
TB CTL	1.09	0.02
SB	1.78	0.00
SB CTL	1.15	0.00
XCB	1.52	0.04
XCB CTL	1.12	0.03

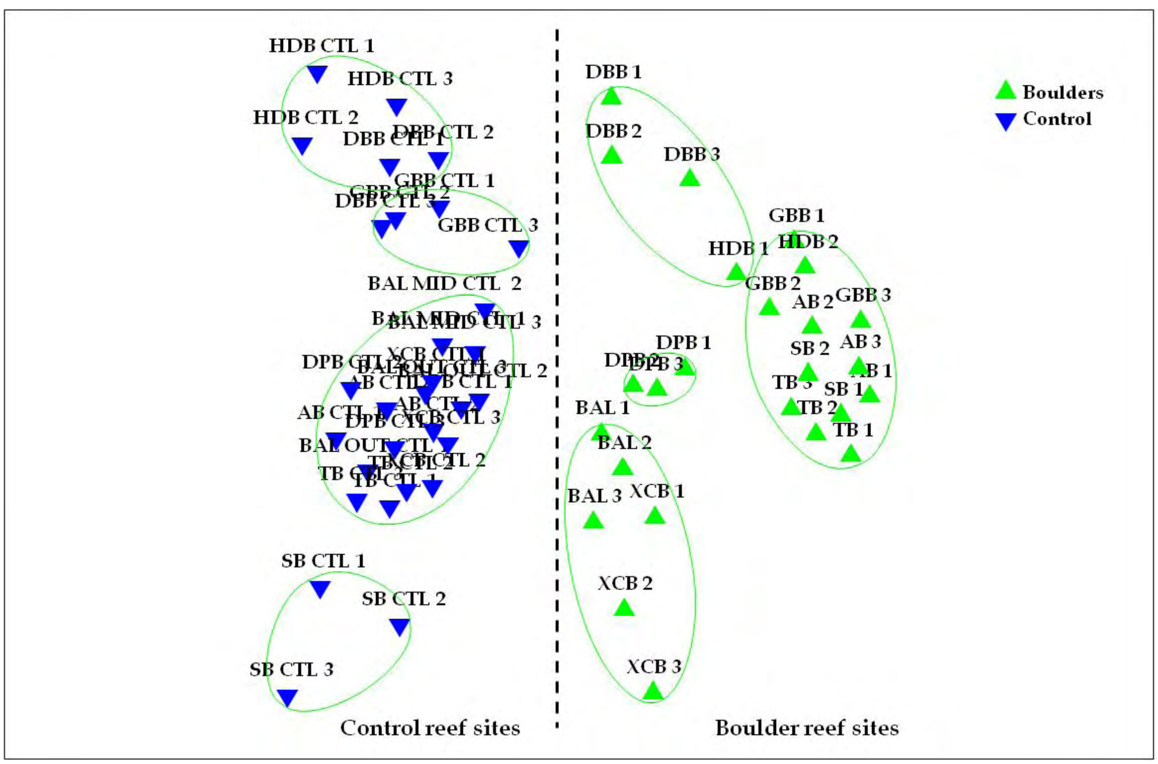

Figure 13. MDS plot of boulder reef and control area sites from video transect percent cover data (stress = 0.15) (see Tables 1 and 3 for site abbreviations). The green solid line represents Bray-Curtis similarity at 80%.

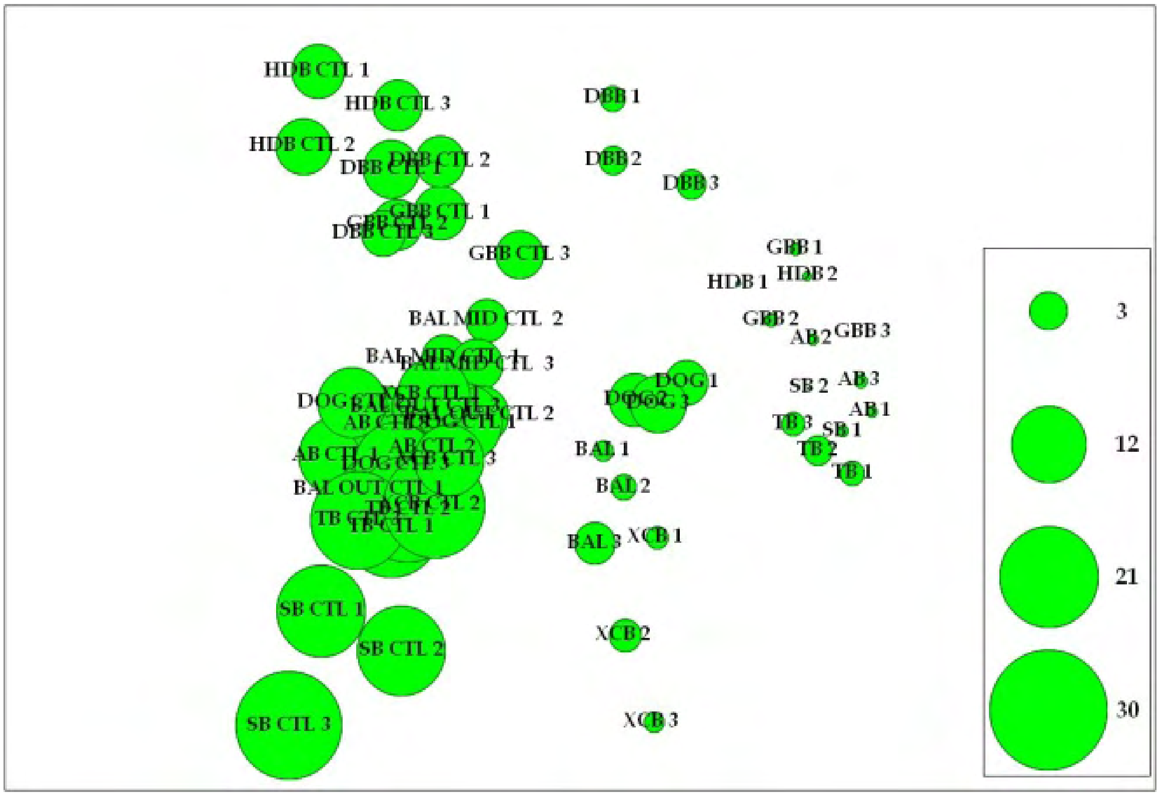

Figure 14. The same MDS plot as shown in Figure 13 with superimposed bubbles over each sample (stress 0.15). Each bubble represents gorgonian percent cover in each sample. The scale box in each plot represents the approximate cover for each size bubble.

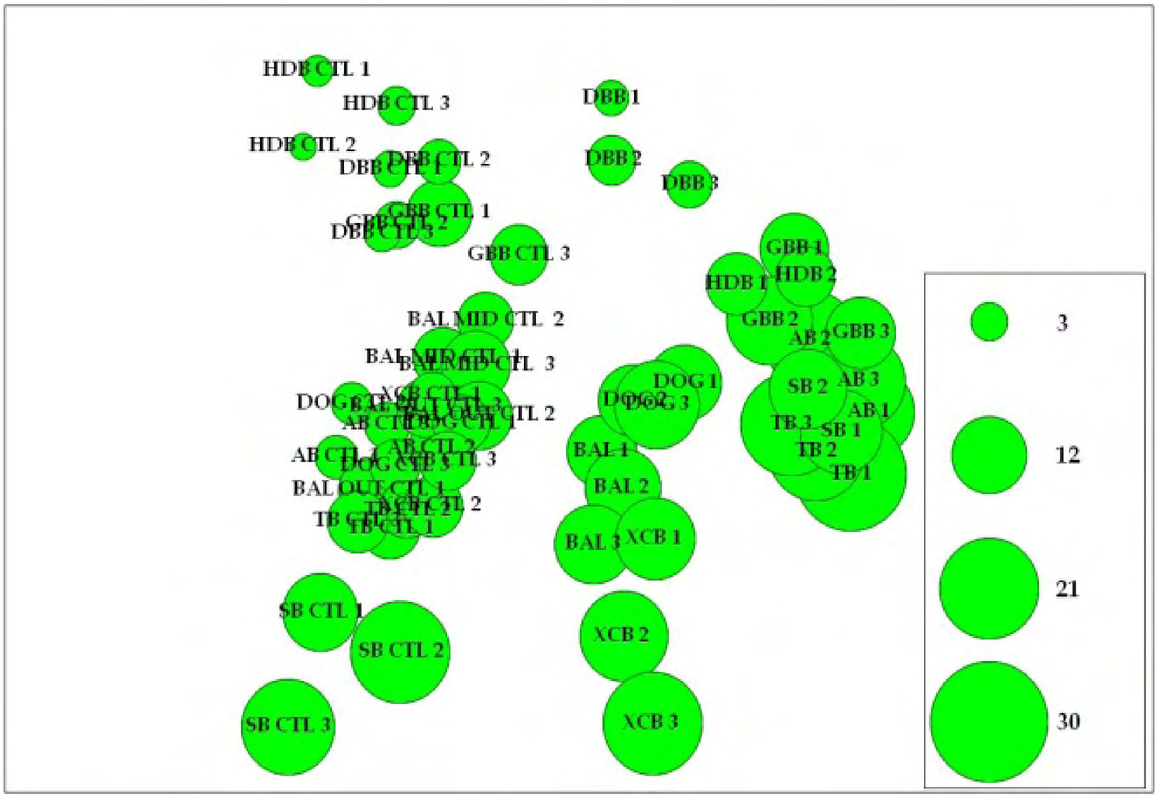

Figure 15. The same MDS plot as shown in Figure 13 with superimposed bubbles over each sample (stress 0.15). Each bubble represents the sponge percent cover in each sample. The scale box in each plot represents the approximate cover for each size bubble.

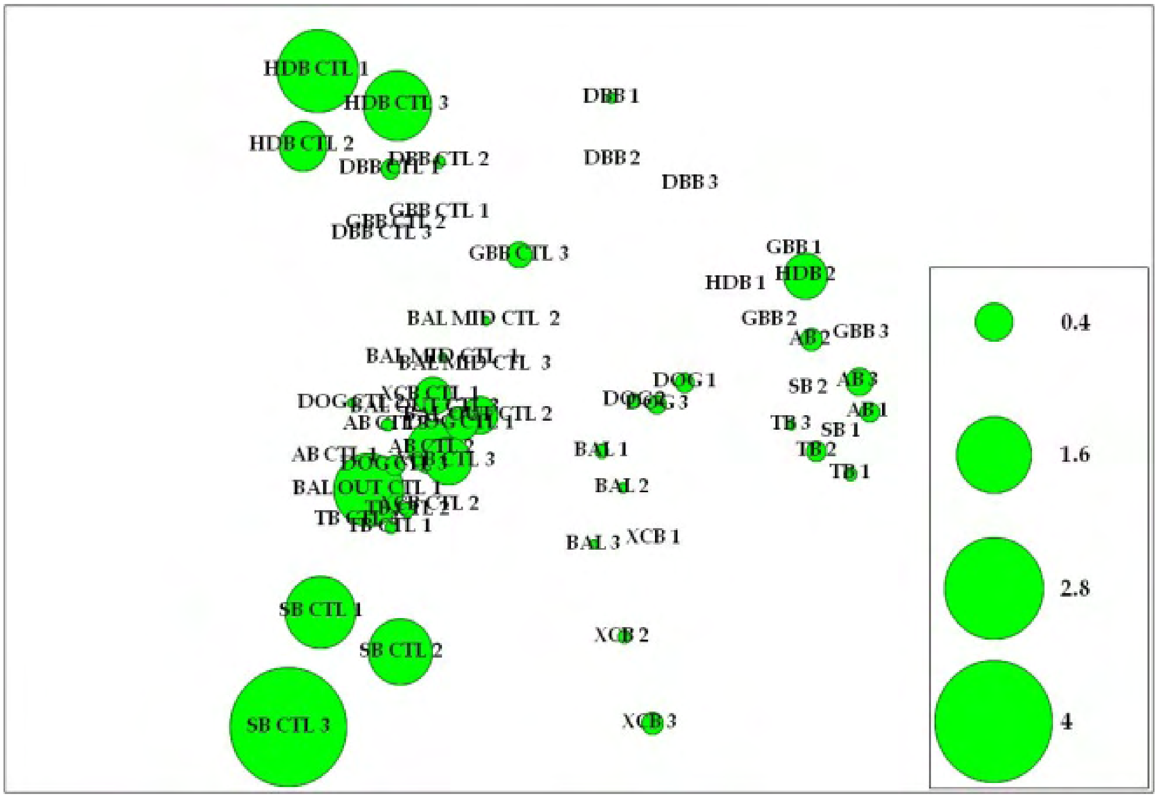

Figure 16. The same MDS plot as shown in Figure 13 with superimposed bubbles over each sample (stress 0.15). Each bubble represents the *M. cavernosa* percent cover in each sample. The scale box in each plot represents the approximate cover for each size bubble.

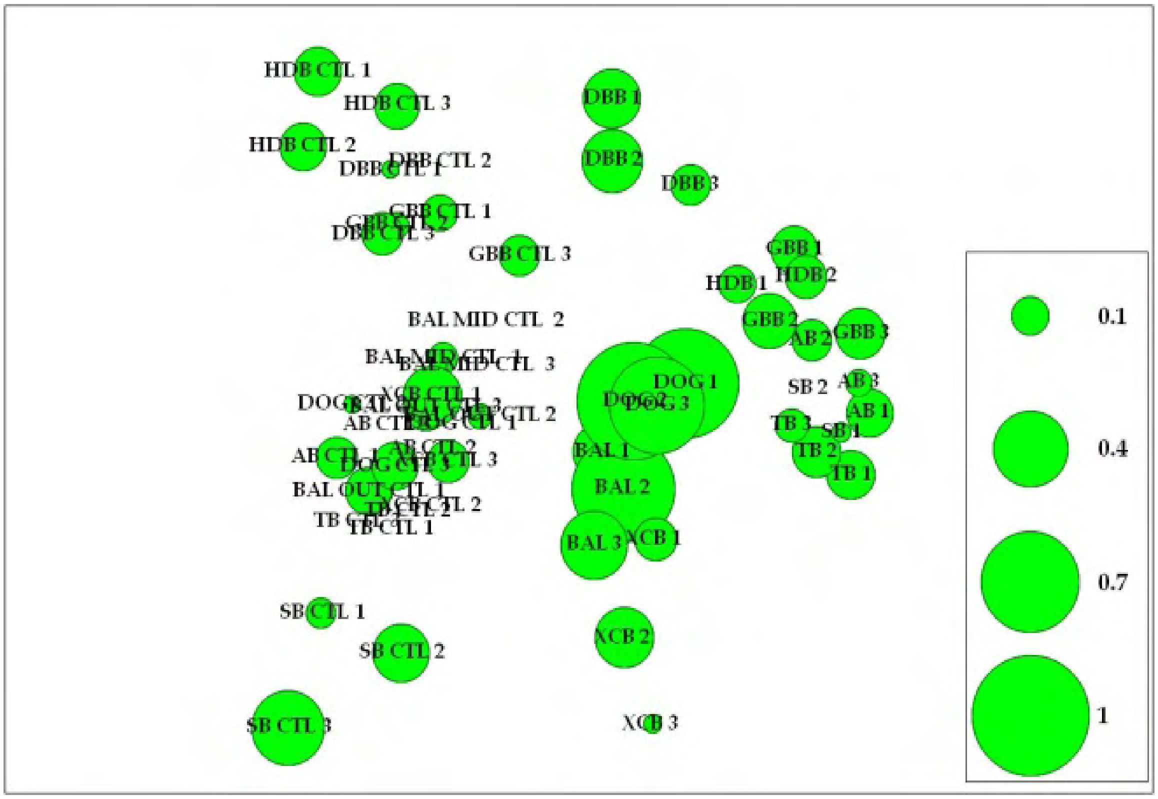

Figure 17. The same MDS plot as shown in Figure 13 with superimposed bubbles over each sample (stress 0.15). Each bubble represents the *P. astreoides* percent cover of in each sample. The scale box in each plot represents the approximate cover for each size bubble.

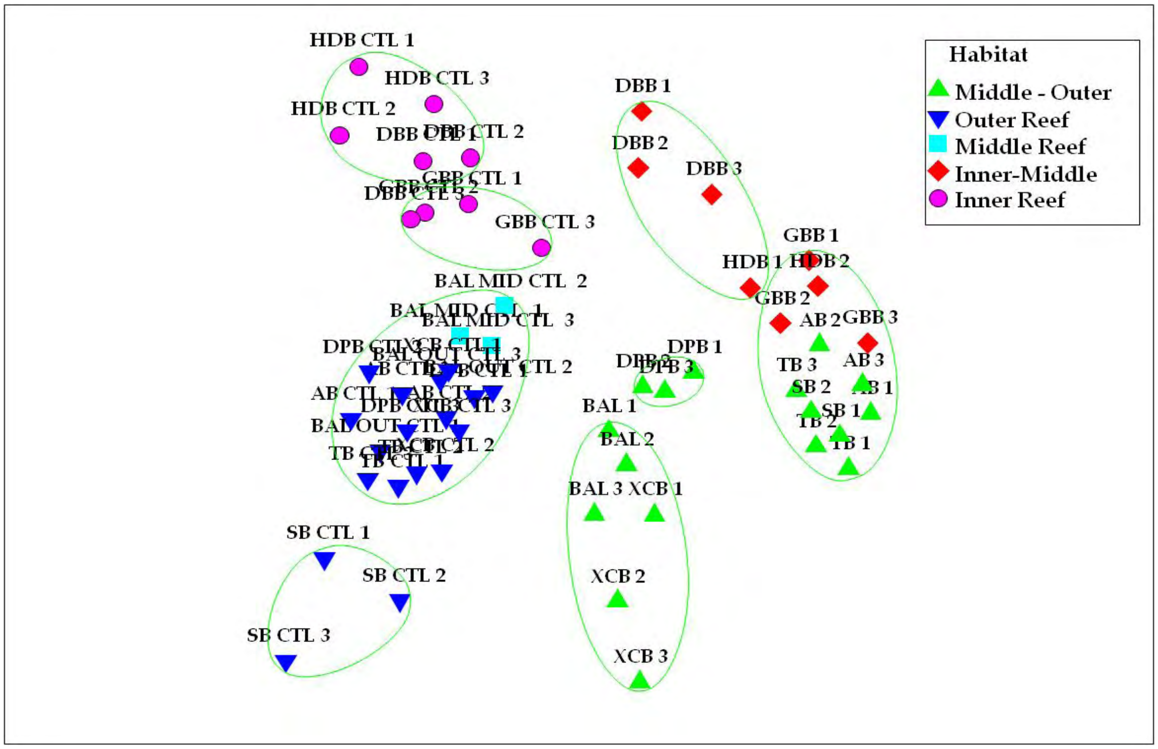

Figure 18. The same MDS as shown in Figure 13 with the habitat shown for each site (stress = 0.15) (see Tables 1 and 3 for site abbreviations). For the boulder reefs the habitat is the sand area between linear reefs on which they were deployed. The green solid line represents Bray-Curtis similarity at 80%.

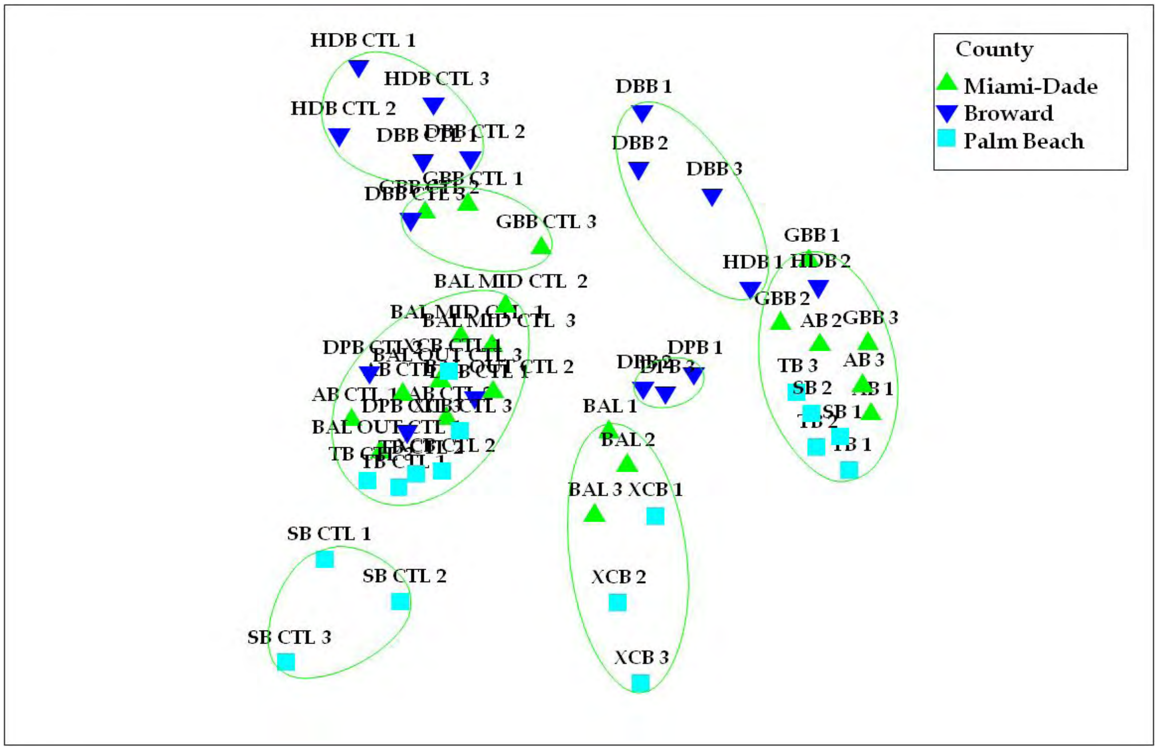

Figure 19. The same MDS as shown in Figure 13 with county shown for each site (stress = 0.15) (see Tables 1 and 3 for site abbreviations). The green solid line represents Bray-Curtis similarity at 80%.

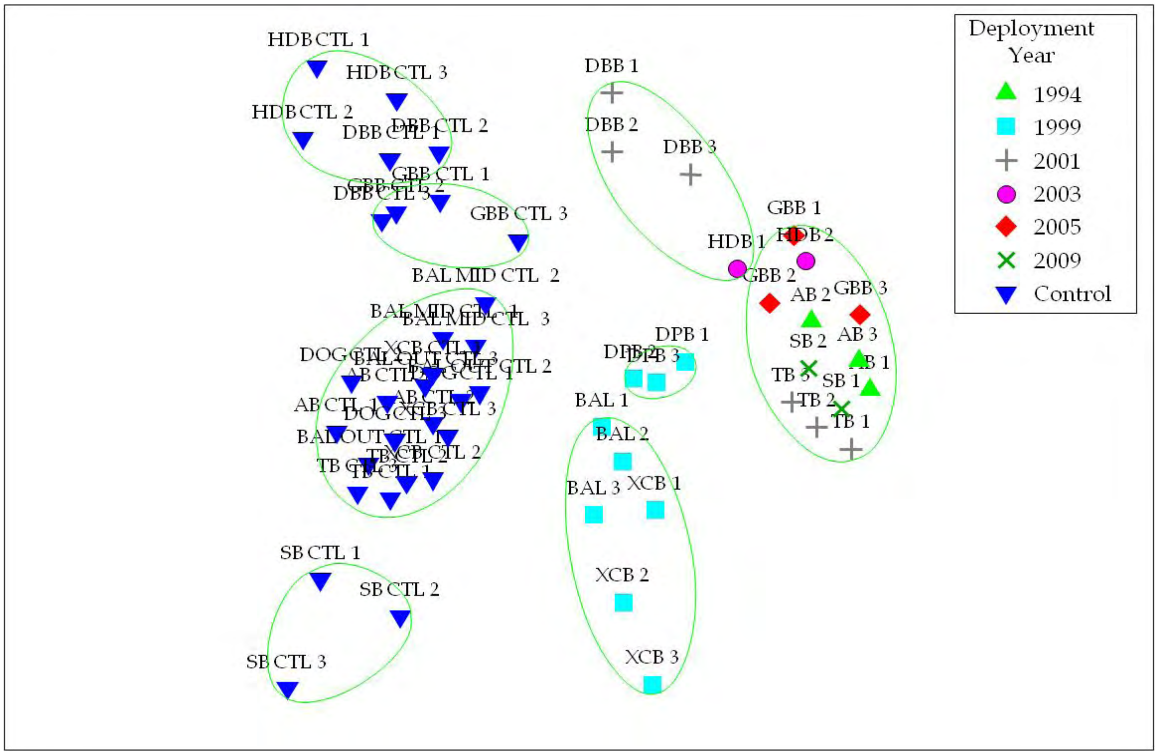

Figure 20. The same MDS as shown in Figure 13 with the boulder ref deployment year shown for each site (stress = 0.15) (see Tables 1 and 3 for site abbreviations). The green solid line represents Bray-Curtis similarity at 80%.

Table 17. Bray-Curtis similarity index (percent) sites from the average video transect percent cover data for each boulder reef compared to its adjacent control (see Tables 1 and 3 for site abbreviations).

Comparison	Deployment Year	Similarity
SB vs SB CTL	2009	61.3
AB vs AB CTL	1994	65.3
HDB vs HDB CTL	2003	65.5
TB vs TB CTL	2001	67.3
GBB vs GBB CTL	2005	73.6
XCB vs XCB CTL	1999	75.1
DPB vs DPB CTL	1999	76.2
DBB vs DBB CTL	2001	76.5
BAL vs BAL Out CTL	1999	79.1
BAL vs BAL Mid CTL	1999	83.3

Port of Miami

In the Port of Miami entrance channel, three replicate samples were surveyed along the dredged Inner Reef (PMC IR) and Outer Reef (PMC OR) channel floor, and along the Inner Reef channel wall (PMCW IR). One sample was completed in the entrance channel along the Middle Reef channel floor (PMC MR). In addition to the entrance channel samples, three mitigation boulders (PMB) samples, and three natural control Inner Reef (PMB CTL) samples were surveyed. The Anchorage Boulder control samples (AB CTL) were also included in this analysis as an Outer Reef natural control. Tables 4 and 5 provide information for the Port samples. Figure 3 shows the locations of each sample area.

For stony coral colonies ≥5 cm diameter, the Port of Miami boulders (PMB) had significantly greater (ANOVA, $p>0.05$) mean percent cover (belt transect data) than the other Port sites other than the Inner Reef channel wall (PMCW IR) (Table 18 and Figure 21). The stony coral cover on PMCW IR was greatly dominated by the encrusting coral, *Madracis decactis*. When this species is removed from the wall site analysis, mean percent cover drops from 5.5% to 0.5% which is less than the other sites except for the Inner Reef channel floor (PMC IR) and Outer Reef channel floor sites (PMC OR). PMB also had greater (ANOVA, $p>0.05$) stony coral density (colonies/m²), largest mean colony size (diameter cm), and greater stony coral species richness than most of the other sites (Table 18 and Figures 21-23). The channel floor sites (PMC IR, PMC MR, and PMC OR) had the lowest stony coral cover, density, colony size, and species richness.

Table 18. Mean (standard error [SE]) stony coral percent cover, density (colonies/m^2), colony size (diameter cm), and species richness (number of species) for each of the Port of Miami sites. There is no variance term (SE) for the PMC MR sites since only one sample was surveyed (see Table 5 for site abbreviations).

Site	Cover		Density		Colony Size		Species Richness	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
PMB	5.80	0.22	7.30	0.29	9.31	3.16	17.33	0.33
PMB CTL	2.21	0.46	1.50	0.47	13.74	7.47	11.00	2.00
PMC IR	0.25	0.10	0.60	0.22	7.22	2.82	5.67	2.33
PMCW IR	5.54	2.96	1.16	0.29	21.22	12.27	6.00	1.00
PMC MR	0.67	---	0.80	---	9.13	3.79	5.00	---
PMC OR	0.31	0.08	0.58	0.16	12.91	6.12	6.67	1.67
AB CTL	1.00	0.02	0.87	0.20	10.49	3.12	16.67	0.33

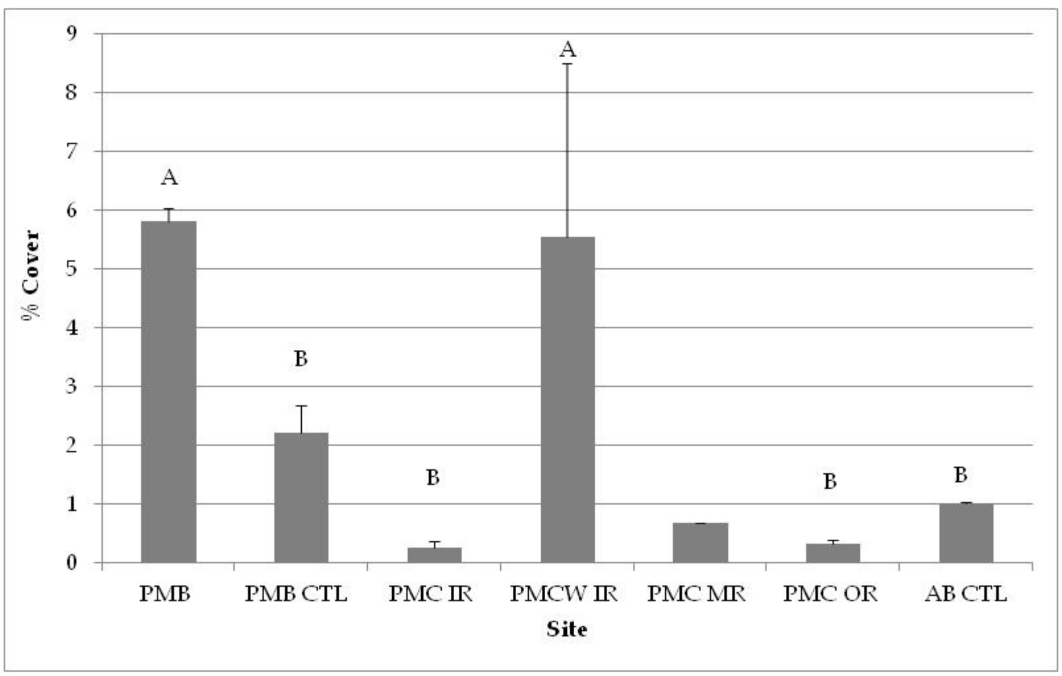

Figure 21. Mean (SE) percent stony coral cover (belt transect data) for each of the Port of Miami sites (see Table 5 for site abbreviations). Letters above site bars denote significance groups (ANOVA, arc sin transformed, $p < 0.05$) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

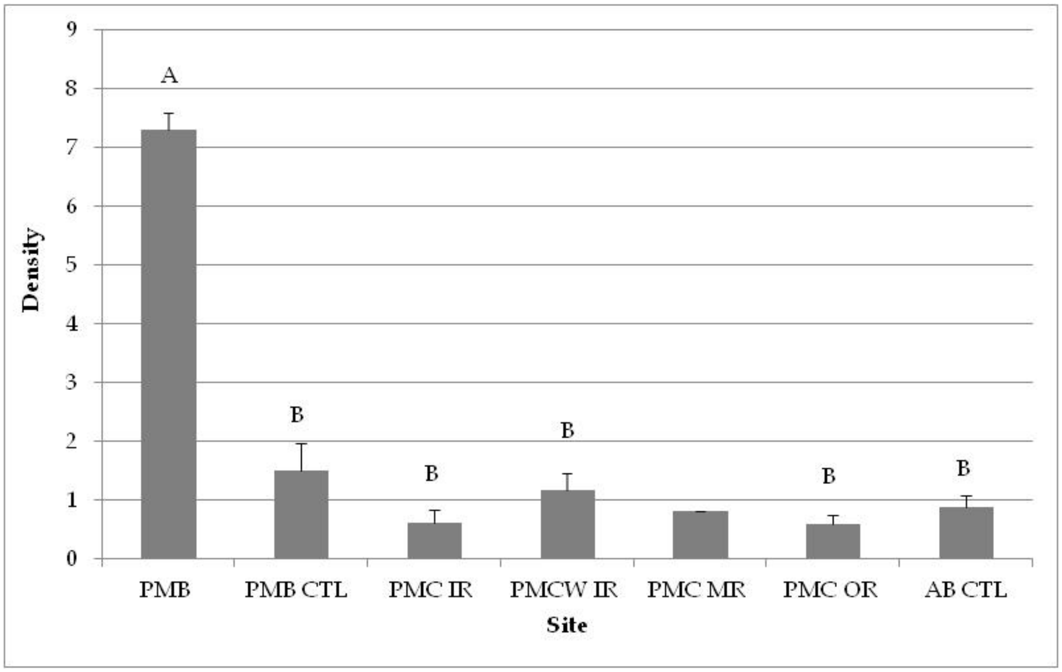

Figure 22. Mean (SE) stony coral recruit density (colonies/m²) for each of the Port of Miami sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis) (see Table 5 for site abbreviations).

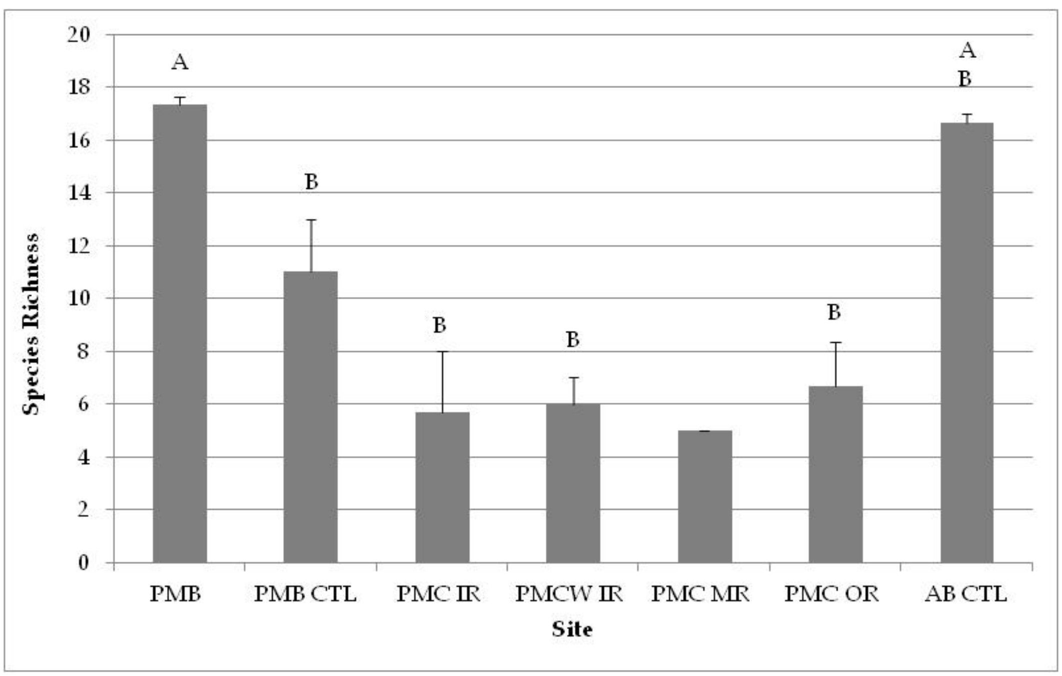

Figure 23. Mean (SE) stony coral species richness for each of the sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis) (see Table 5 for site abbreviations).

Table 19 list the largest (diameter cm) stony coral colony and species identified in each of the Port sites. The mean size of the largest colony identified in the Port channel sites (PMC IR, PMC MR, PMC OR, and PMCW IR) with *M. decactis* removed was smaller than all the other sites. With *M. decactis* included the Inner Reef wall site (PMCW IR) actually had the largest colonies.

Table 19. The mean (standard error [SE]) size (diameter cm) of the largest colony within the replicates at each site, and the species and size (diameter cm) of the largest colony within the site. Note the difference in largest colony and species in the PMCW IR sites when *M. decactis* is removed (see Table 5 for site abbreviations).

	Largest Colonies		Largest Colony	
Site	**Mean**	**SE**	**Species**	**Diameter (cm)**
PMB	32.00	3.06	*Porites astreoides*	45
PMB CTL	56.00	5.57	*Meandrina meandrites*	100
PMC IR	20.00	10.15	*Porites astreoides*	40
PMCW IR	73.33	25.87	*Agaricia lamarcki*	23
PMC MR	20.00	---	*Porites astreoides*	20
PMC OR	10.33	1.20	*Stephanocoenia intersepta*	12
AB CTL	33.00	1.73	*Montastrea cavernosa*	35

Colony size distribution was examined by assigning colony size (diameter) to classes (5-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm, and >50cm) (Table 20). The channel floor sites (PMC IR, PMC MR, and PMC OR) had no colonies greater than 30cm diameter contributing to the assemblage, and when *M. decactis* was removed from the analysis, the channel wall sites (PMCW IR) also had few large colonies (>30cm). As expected the boulder reef (PMB) had reduced contribution of colonies in the larger size classes (41-50cm and >50cm) as compared to the Inner Reef control (PMB CTL) or Outer Reef (AB CTL) control areas.

Porites astreoides, *Siderastrea siderea,* and *Stephanocoenia intersepta* were common to all the channel sites (PMC IR, PMC MR and PMC OR) (Appendix Table 7). *Porites astreoides* was a common on the PMB. The stony coral assemblage on the Inner Reef channel wall (PMCW IR) was greatly characterized by the encrusting coral, *Madracis decactis*.

Stony coral recruits were defined as colonies <5cm diameter. The PMB had significantly greater density (colonies/m^2) and species of stony coral recruits (ANOVA $p<0.05$) (Table 21 and Figure 24 and 25). Although not significant, the channel floor sites (PMC IR and PMC OR) had greater recruit densities and species richness than the Inner Reef (PMB CTL) and Outer Reef controls (AB CTL).

Table 20. Mean stony coral (standard error [SE]) percent size (diameter cm) class distribution (see Table 5 for site abbreviations).

Site	5-10cm		11-20cm		21-30cm	
	Mean	SE	Mean	SE	Mean	SE
PMB	75.64%	3.85%	20.67%	3.59%	2.48%	0.94%
PMB CTL	58.63%	2.04%	23.65%	0.75%	12.35%	2.34%
PMC IR	94.70%	3.36%	4.01%	2.23%	0.00%	0.00%
PMCW IR	41.37%	3.53%	21.70%	1.42%	21.78%	6.45%
PMC MR	62.50%	---	37.50%	---	0.00%	---
PMC OR	89.67%	5.60%	10.33%	5.60%	0.00%	0.00%
AB CTL	62.20%	7.20%	23.60%	3.90%	6.90%	1.80%

Site	31-40cm		41-50cm		>50cm	
	Mean	SE	Mean	SE	Mean	SE
PMB	0.91%	0.54%	0.14%	0.14%	0.16%	0.16%
PMB CTL	0.57%	0.57%	1.11%	1.11%	3.68%	1.85%
PMC IR	1.28%	1.28%	0.00%	0.00%	0.00%	0.00%
PMCW IR	6.27%	3.77%	4.39%	1.44%	4.49%	4.49%
PMC MR	0.00%	---	0.00%	---	0.00%	---
PMC OR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AB CTL	7.40%	3.50%	1.00%	0.60%	1.90%	0.30%

Table 21. Mean (standard error [SE]) stony coral recruit density (colonies/m^2) and species richness (number of species) for each Port of Miami sites (see Table 5 for site abbreviations).

Site	Density		Species Richness	
	Mean	SE	Mean	SE
PMB 3	33.70	4.99	13.67	0.33
PMB CTL 3	3.90	0.61	6.00	1.15
PMC IR 3	7.53	0.92	7.33	1.67
PMCW IR 3	2.63	0.84	6.00	1.15
PMC MR 1	1.90	---	5.00	---
PMC OR 3	7.27	2.11	9.00	1.15
AB CTL	2.43	0.52	4.67	0.67

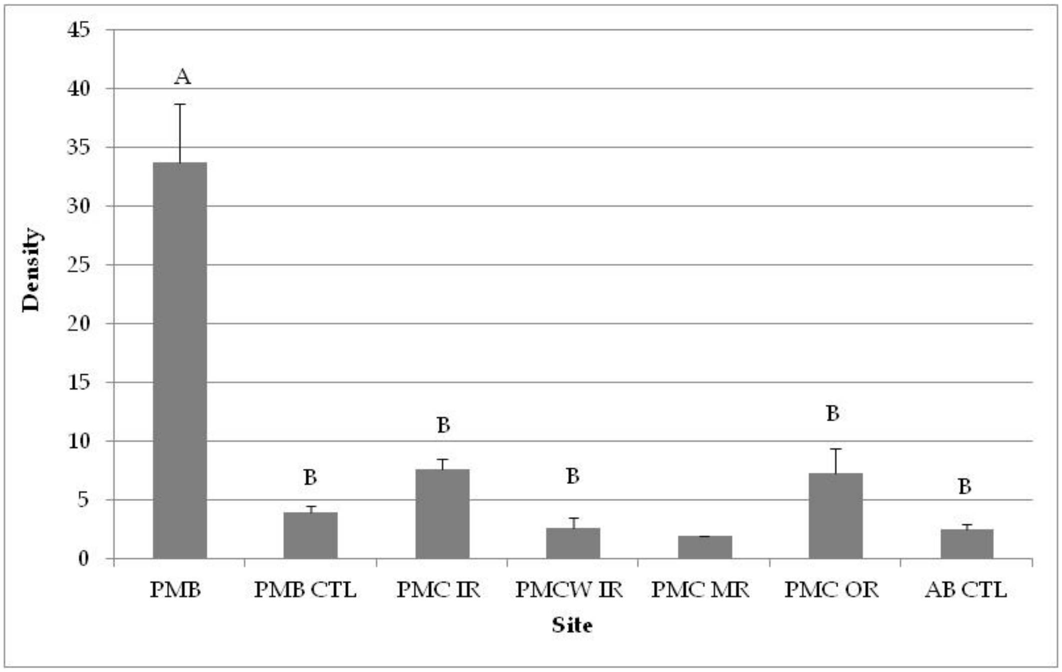

Figure 24. Mean (SE) stony coral recruit density (colonies/m²) for of the Port of Miami sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Table 5 for site abbreviations) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

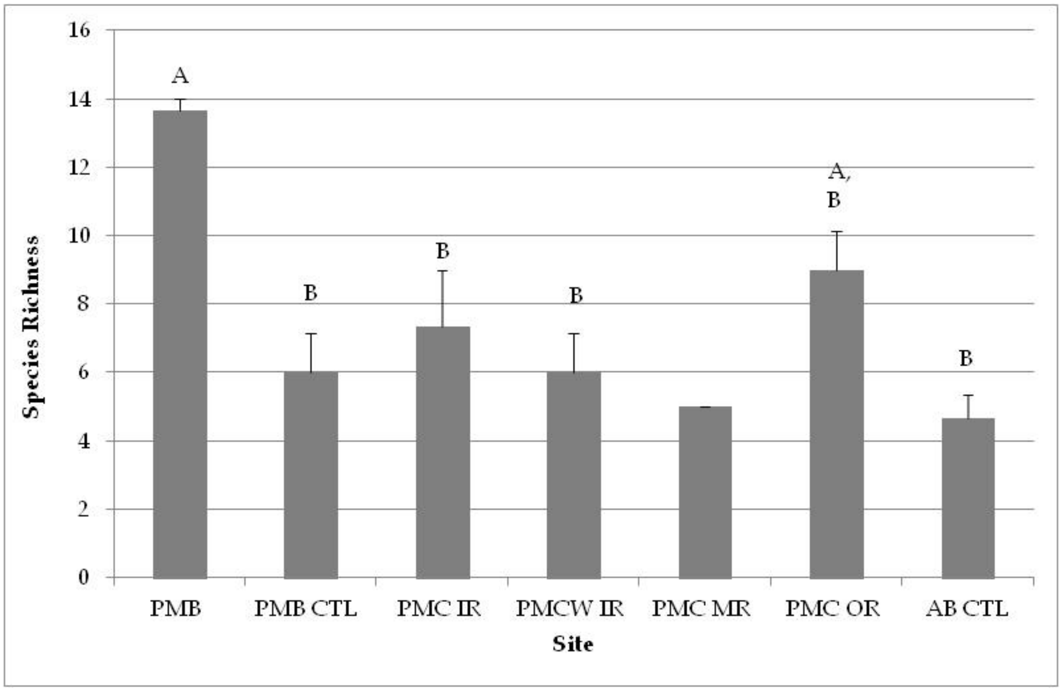

Figure 25. Mean (SE) stony coral recruit species richness. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Table 5 for site abbreviations) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

Gorgonians were not abundant in the Port channel. The Port channel sites (PMC IR, PMC MR, PMC OR, and PMCW IR) had significantly (ANOVA, $p<0.05$) less mean percent cover, density, and species richness than the PMB, AB CTL, and PMB CTL sites (Table 22 and Figure 26-28). None of the channel floor sites had greater than eight species while the PMB, AB CTL, and PMB CTL sites had more than 20 species. With such low abundance, the channel floor assemblages were fairly well distributed amongst a few species (*Gorgonia ventalina*, *Pseudopterogorgia americana*, and several *Eunicea* species (Appendix Table 8). *Eunicea* species as well as *Pseudoplexaura porosa* were common in the PMB.

No barrel sponges, *Xestospongia muta*, were identified in PMB or channel floor samples (PMC IR, PMC MR, or PMC OR) (Table 23). A few barrel sponges were identified along the Inner Reef channel wall (PMCW IR) but density was less than that identified in the Inner Reef control (PMB CTL) or Outer Reef control (AB CTL).

Table 22. The mean gorgonian (standard error [SE]) percent cover, density (colonies/m²), and species richness (see Table 5 for site abbreviations).

	Cover		**Density**		**Species Richness**	
Site	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
PMB	13.89	1.54	8.66	0.91	17.33	1.20
PMB CTL	9.29	1.04	8.19	2.10	18.67	0.88
PMC IR	0.08	0.08	0.11	0.02	2.33	0.33
PMCW IR	0.76	0.15	1.49	0.62	9.33	1.76
PMC MR	0.32	---	0.43	---	6.00	---
PMC OR	0.19	0.09	0.39	0.06	4.33	0.88
AB CTL	11.07	1.47	7.49	1.83	12.33	1.45

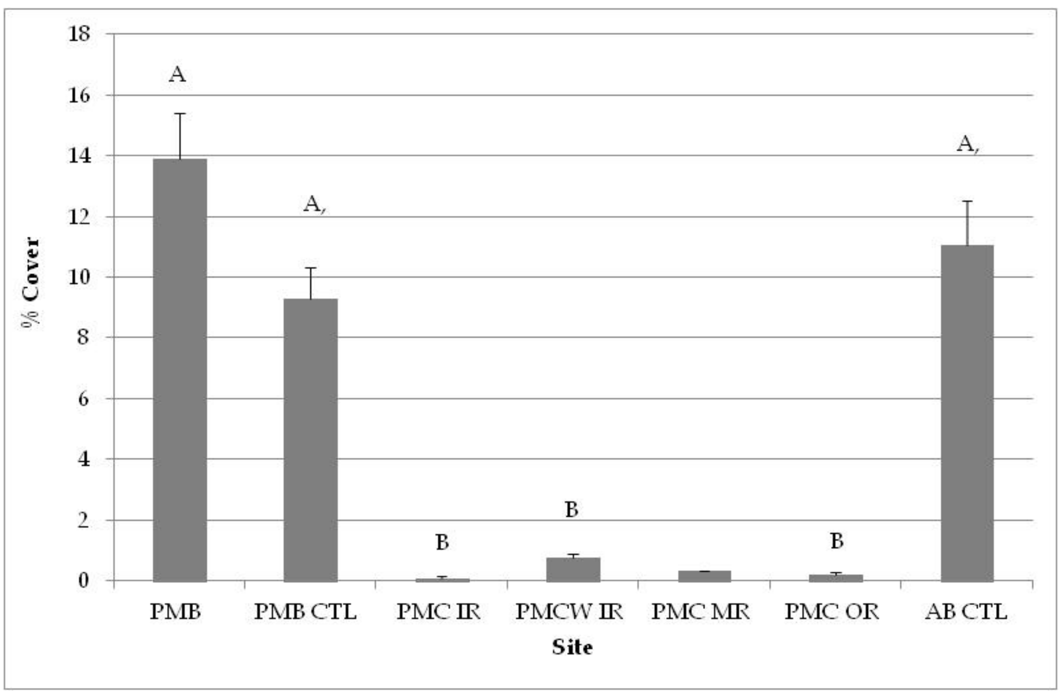

Figure 26. Mean (SE) percent gorgonian cover for each of the Port of Miami sites (see Table 5 for site abbreviations). Letters above site bars denote significance groups (ANOVA, arc sin transformed, $p < 0.05$) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

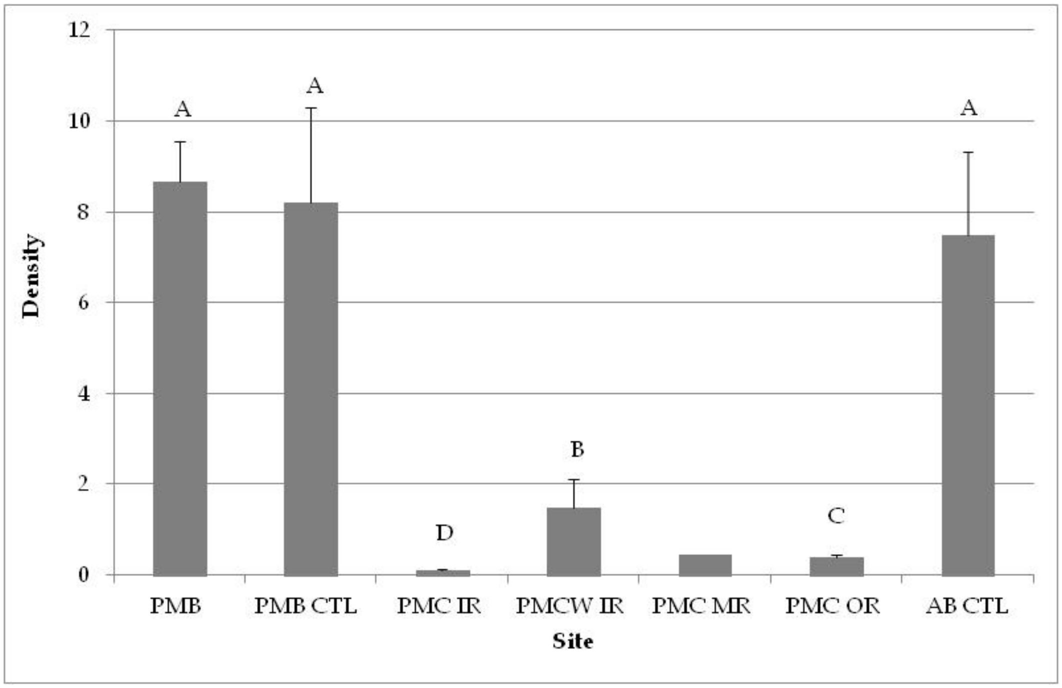

Figure 27. Mean (SE) gorgonian density (colonies/m²) for each of the sites. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Table 5 for site abbreviations) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

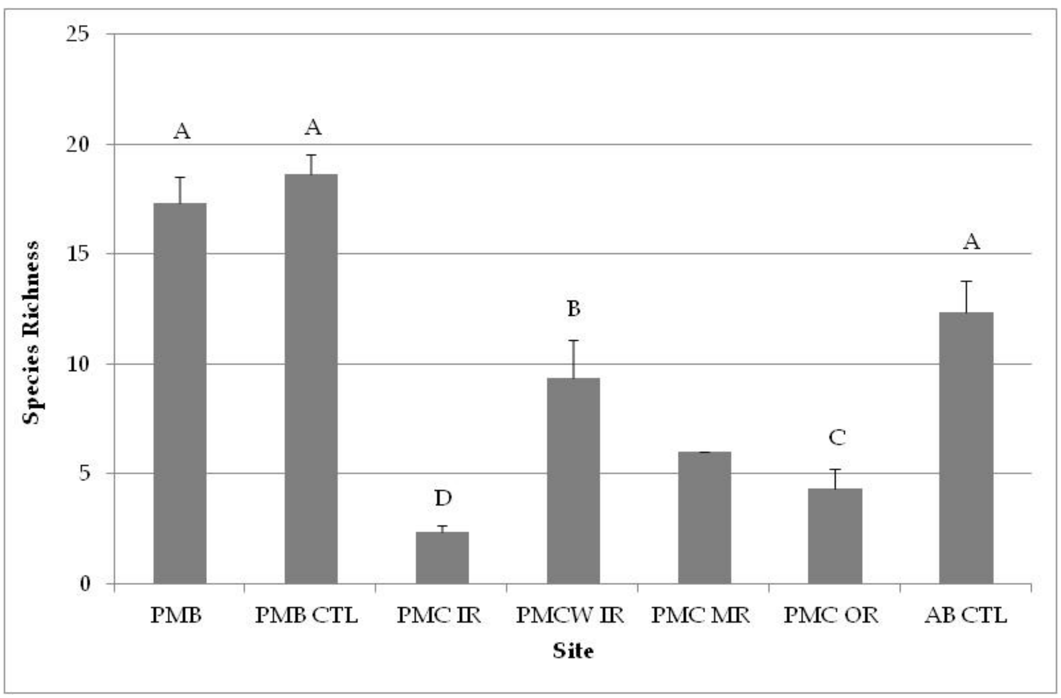

Figure 28. Mean (SE) gorgonian species richness. Letters above site bars denote significance groups (ANOVA, log [x+1] transformed, $p < 0.05$) (see Table 5 for site abbreviations) (only 1 PMC MR sample; therefore, no SE and not included in statistical analysis).

Table 23. Mean barrel sponge (standard error [SE]) density (sponges/m²) for all sites (see Table 5 for site abbreviations).

Site	Density	
	Mean	SE
PMB	0.00	0.00
PMB CTL	0.12	0.10
PMC IR	0.00	0.00
PMCW IR	0.02	0.02
PMC MR	0.00	---
PMC OR	0.00	0.00
AB CTL	0.37	0.1

Percent cover of substrate type (pavement, rubble, and sand) within each site was estimated from the transect videos (Table 24). Percent coverage of pavement (consolidated substrate) was greater than 90% in the PMB, PMB CTL, AB CTL, and PMCW IR sites. The channel floor sites (PMC IR, PMC MR, and PMC OR) had much greater cover of unconsolidated substrates (sand and rubble). The percent cover of rubble in the PMC IR and PMC OR site was significantly greater (ANOVA, $p<0.05$) than in the other sites. The PMC MR sites had the greatest cover of sand.

Table 24. Mean substrate (standard error [SE]) percent cover for all sites (see Table 5 for site abbreviations).

Site	Pavement		Sand		Rubble	
	Mean	SE	Mean	SE	Mean	SE
PMB	95.68	1.25	4.17	1.21	0.14	0.14
PMB CTL	92.32	0.75	5.30	0.52	2.38	0.88
PMC IR	39.87	12.11	0.58	0.24	59.54	12.33
PMCW IR	99.72	0.14	0.14	0.14	0.14	0.14
PMC MR	45.19	---	53.49	---	1.32	---
PMC OR	31.37	8.12	7.51	4.39	61.13	9.32
AB CTL	97.24	1.38	2.75	1.38	0.01	0.01

PMB had significantly greater (ANOVA, $p<0.05$) mean rugosity than all of the other sites (Table 25). The channel floor sites had mean rugosity values similar to the natural reef controls (PMB CTL and AB CLT).

Table 25. Mean rugosity (standard error [SE]) for seven of sites. Rugosity was not able to be measured for the channel wall (see Table 5 for site abbreviations).

	Rugosity	
Site	**Mean**	**SE**
PMB	2.27	0.11
PMB CTL	1.31	0.08
PMC IR	1.20	0.04
PMCW IR	---	---
PMC MR	1.07	---
PMC OR	1.26	0.09
AB CTL	1.13	0.02

The functional group percent cover was estimated from the video transects. A significant difference was determined among sites (ANOSIM, Global R = 0.949, p = 0.10%). Pair wise comparisons between the channel floor samples and the appropriate natural reef controls (PMB CTL for PMC IR and AB CTL for PMC OR) were also significant, as well as the comparison between the Inner Reef channel wall (PMCW IR) and PMB CTL. The ANOSIM procedure also determined that PMB was different from each of the natural reef controls (AB CTL and PMB CTL). Figure 29 is the MDS ordination plot of percent functional group cover for all the Port of Miami samples. Significant groupings at 80% (SIMPROF procedure on Bray Curtis similarity indices) for PMB, PMB CTL, and AB CTL sites and 75% for the channel floor sites are shown on the MDS plot (Figure 29).

A SIMPER analysis was run to examine which functional groups contributed to the dissimilarity between the Port of Miami sites. Increased percent cover of rubble (Figure 30) contributed to the separation of the channel floor (PMC IR and PMC OR) sites. The much greater contribution of *M. decactis* cover (Figure 31) in the Inner Reef channel wall sites (PMCW IR) contributed to its dissimilarity. Figure 32 illustrates the contribution barrel sponges, *Xestospongia muta*, to the natural reef control sites (PMB CTL and AB CTL) while the stony coral, *Porites astreoides,* contributed to the separation of the boulder sites (PMB) (Figure 33).

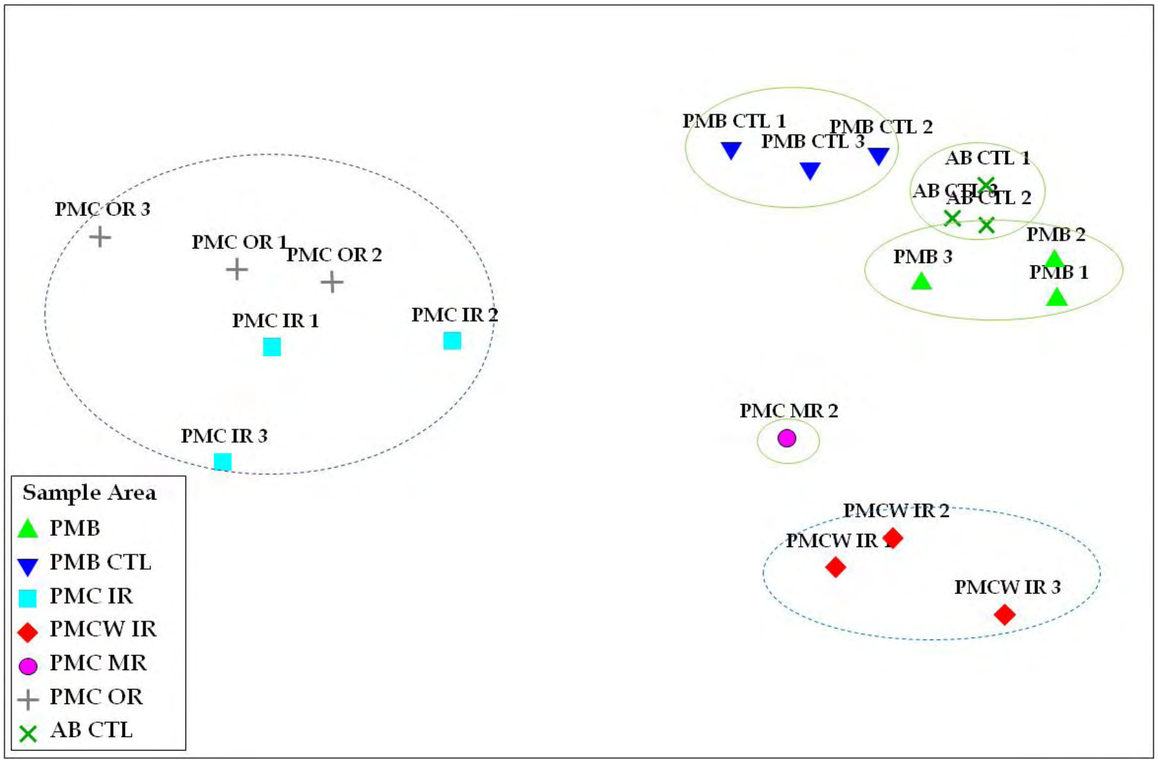

Figure 29. MDS plot of the Port of Miami sites from video transect percent cover data (stress = 0.09) (see Table 5 for site abbreviations). The green solid lines represent Bray-Curtis similarity at 80% and the blue dashed at 75%.

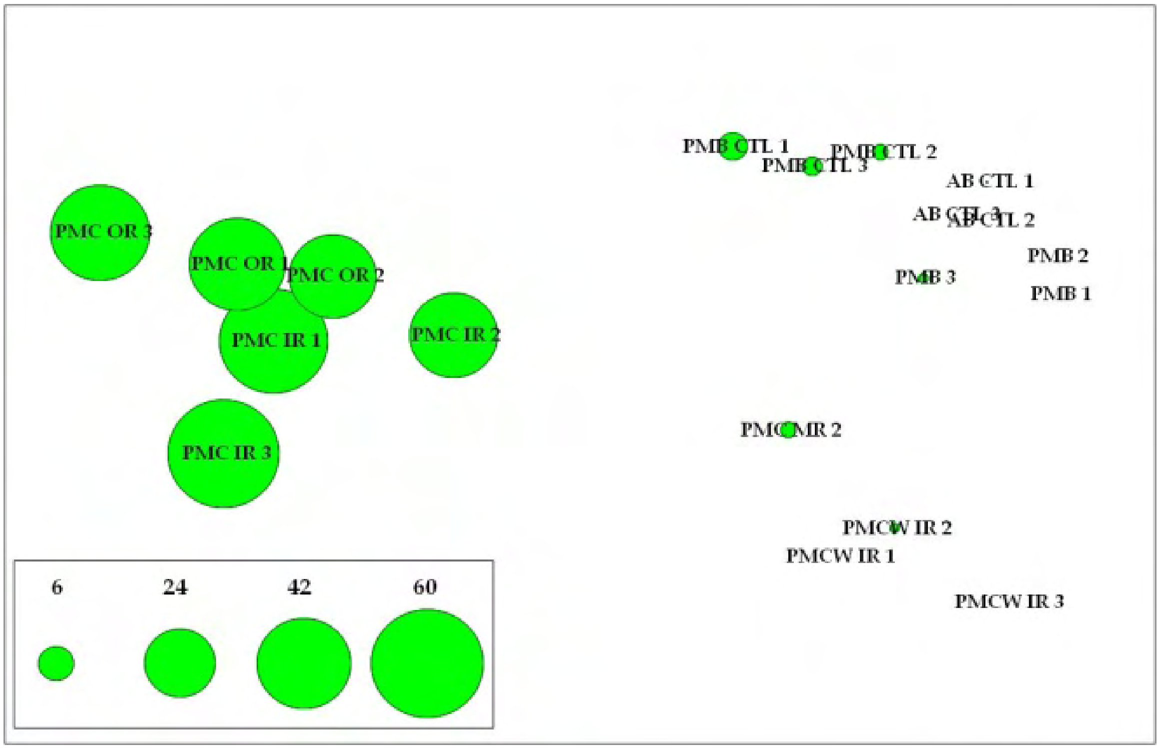

Figure 30. The same MDS as shown in Figure 29 with superimposed bubbles over each sample (stress 0.09). Each bubble represents the rubble percent cover of in each sample. The bubble scale box in each plot represents the approximate cover for each size bubble.

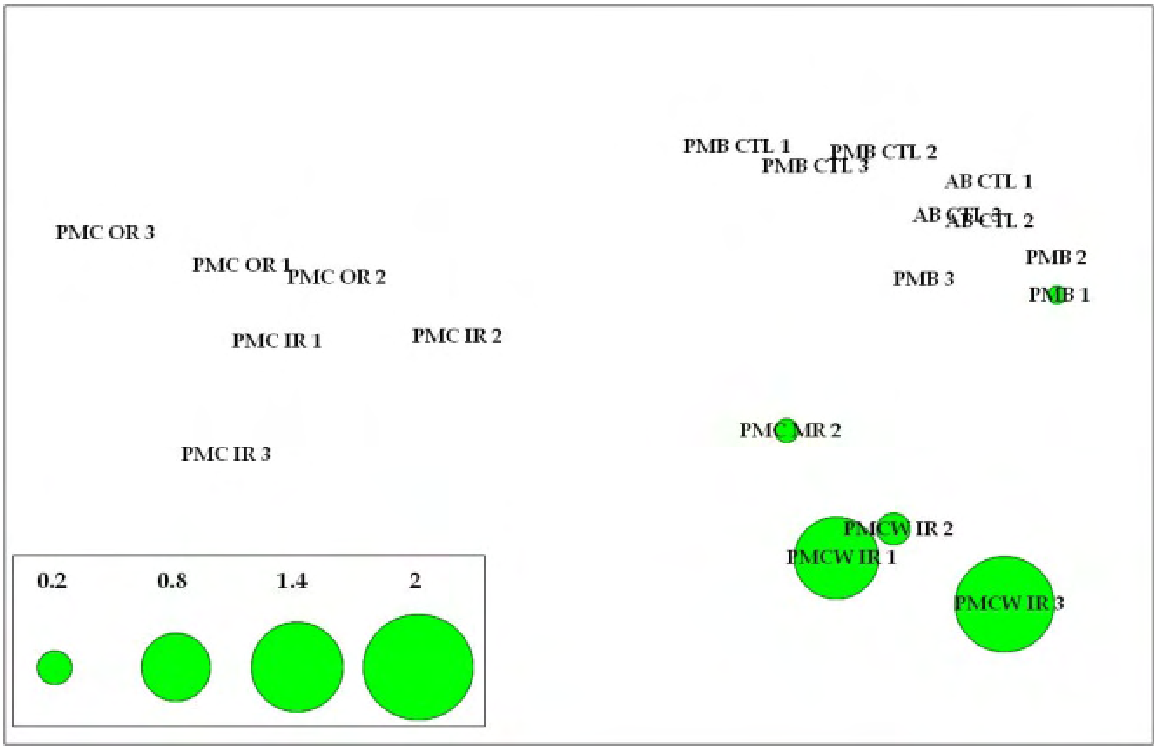

Figure 31. The same MDS as shown in Figure 29 with superimposed bubbles over each sample (stress 0.09). Each bubble represents the *M. decactis* percent in each sample. The bubble scale box in each plot represents the approximate cover for each size bubble.

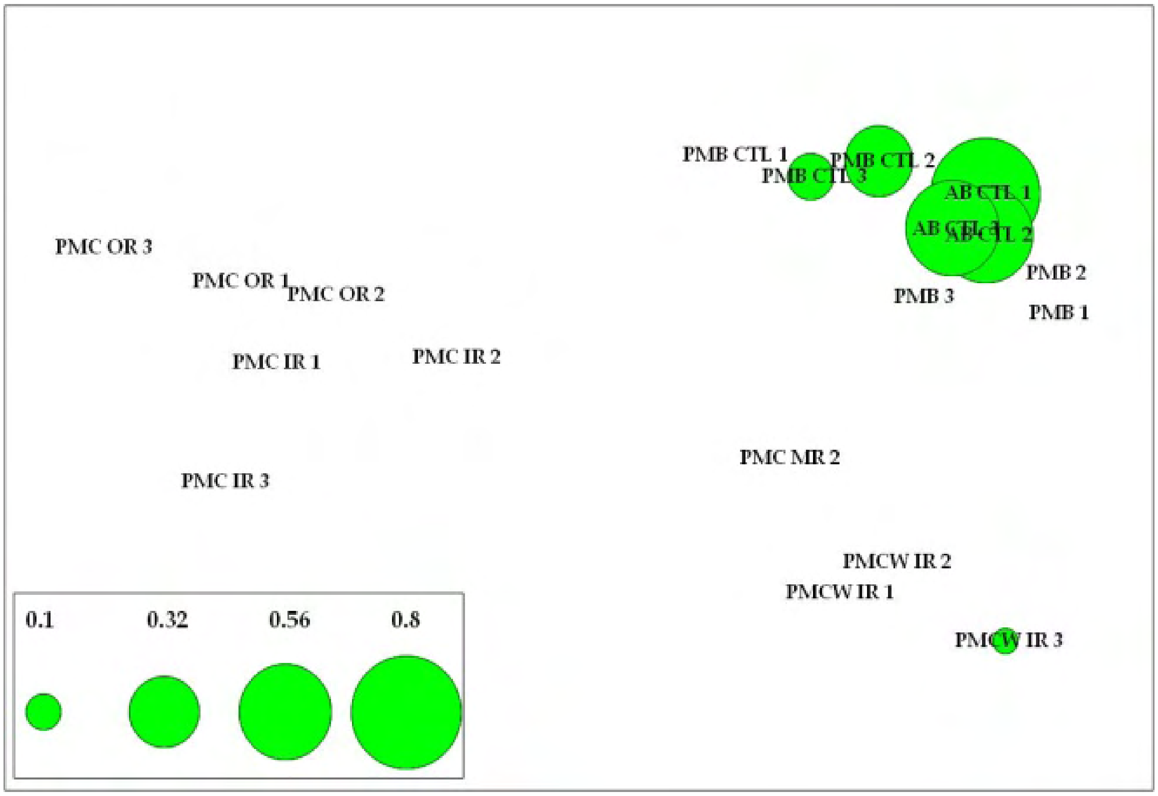

Figure 32. The same MDS as shown in Figure 29 with superimposed bubbles over each sample (stress 0.09). Each bubble represents the barrel sponge percent in each sample. The bubble scale box in each plot represents the approximate cover for each size bubble.

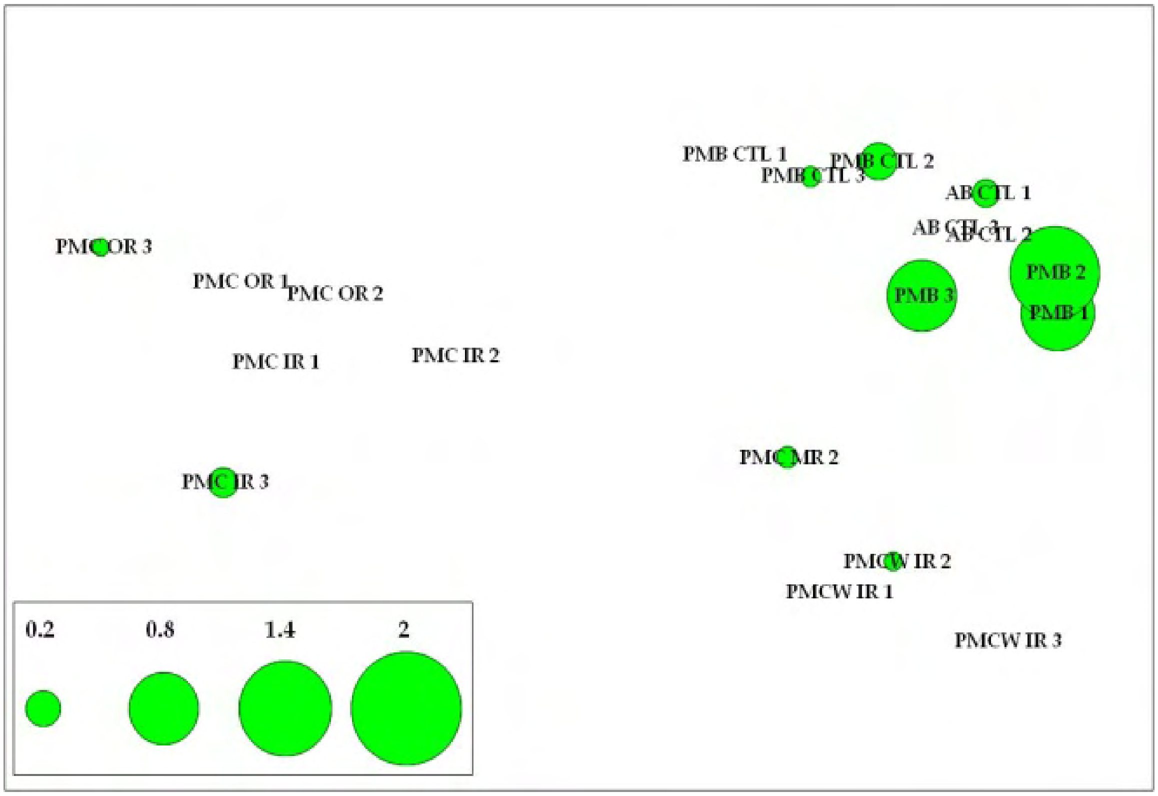

Figure 33. The same MDS as shown in Figure 29 with superimposed bubbles over each sample (stress 0.09). Each bubble represents the *P. astreoides* percent in each sample. The bubble scale box in each plot represents the approximate cover for each size bubble.

DISCUSSION

Phase II of the Maritime Industry and Coastal Construction Impacts (MICCI) Combined Project 14, 15, and 16 was designed to compare the current condition of boulder reef sites to adjacent natural control reef areas in Miami-Dade, Broward, and Palm Beach counties. These comparisons were used to determine differences in: 1) benthic community structure, 2) density and size of corals, gorgonians, and barrel sponges, and 3) physical characteristics such as rugosity. Phase II also included an assessment of the current condition of sites associated with the Port of Miami entrance channel. This assessment included boulder reefs which were deployed as mitigation for past Port dredging, the channel floor in dredged Inner Reef, Middle Reef, and Outer Reefs areas, the Inner Reef channel wall, and samples on adjacent Inner Reef. In addition to the comparisons stated above, percent cover of substrate types was compared among Port sites. The basic null hypotheses tested were as follows:

- H1: There is no difference in percent cover and/or density of stony corals, gorgonians, or barrel sponges (density only) among boulder reef and their adjacent control sites or among the Port of Miami sites.
- H2: There is no difference in mean colony size or size class distribution of stony corals and gorgonians, among boulder reef and control sites or among the Port of Miami sites.
- H3: There is no difference in cover of pavement, sand, or unconsolidated substrate (rubble) among the Port of Miami sites.
- H4: There is no difference in rugosity among boulder reef and control sites or among the Port of Miami sites.
- H5: There is no difference in benthic community composition (functional group percent cover and coral species percent cover) among boulder reef and control sites or among the Port of Miami sites.

Boulder Reefs and Controls

When reef injury occurs ecological, economic, and aesthetic resource services are lost. These lost services need to be recovered either through recovery of the injured resource or from services gained some type of mitigation (compensatory mitigation). Even if the injured reef has the potential for recovery, mitigation is often required to compensate for lost services from the time of injury to the time of full recovery (Viehman et al., 2009). For this project, recovery is defined as the complete return of ecological services back to the pre-injured condition (Edwards and Gomez, 2007). This condition includes a complete recovery of the reef biotic community, structure, and physical environment (substrate types and complexity) of the injured reef or the development of a community on mitigation reefs which equal the services of the pre-injured reef.

Limestone boulders have been deployed as mitigation for reef injuries which have occurred during permitted offshore construction activities, and remain a proposed type of mitigation for future activities (Lindberg and Seaman, 2011). The hypothesis is that limestone boulders provide stable substrate which closely mimics natural reef substrate, and therefore, will provide an appropriate environment for reef community development. As this community develops it will provide compensation for lost ecological services. This is extremely difficult to test due to the challenges in defining ecological services and in comparing reef communities among reefs (both artificial and natural) which are inherently very variable in biotic and physical structure both in time and space.

The originally goal of this project was to compare deployed mitigation reefs to natural reefs in three counties (Miami-Dade, Broward, and Palm Beach). The reef community development on these mitigation reefs as compared to adjacent natural reefs would provide information on the ability of mitigation reefs to return lost services for all three counties. There were a number of challenges which made this type of among county comparison difficult. To evaluate and compare communities and services gained, there needs to be sufficient replication (number of reefs) and consistency in reef material, deployment habitat, and deployment year (essentially age of the mitigation reef). There were not sufficient mitigation reefs in the three counties to meet all the needs described above. There were, however, boulder reefs deployed in each of the three counties which could be assessed and provide very meaningful data on community development. Although most of the assessed reefs were not deployed as mitigation, the assessed reefs were all constructed of boulders thus providing a consistent substrate, and all were deployed on sand substrate adjacent to one of the linear reefs providing similar habitat. This approach did have the advantage of keeping with the desire to collect reef, boulder, and natural community data within all three counties providing information along much of the southeast Florida reef system.

The reef community characteristics of the reef control areas adjacent to each boulder reef were used to define the natural (full services) state against which the community on the boulder reefs is compared. The similarity of the boulder reef community to the natural reef control provides some indication of the services gained by the boulder reefs, and therefore, recovered in the system. The nine boulder reefs assessed ranged in deployment years from 1994 (Anchorage boulders [AB] in Miami-Dade county) to 2009 (Silpe boulders [SB] in Palm Beach county) (Table 26). Comparing reef community similarities between each boulder reef and adjacent control along this 15 year time period does permit some discussion of the temporal scale involved with community development on the boulder reefs, and therefore, assisting with evaluating 'recovery' time for lost services.

Table 26. The deployment county, year, and age of the boulder reefs sampled. Age is the number of years from the deployment year to the current assessment.

Boulder Reef	County	Deployment	Age (Years)
Anchorage (AB)	Miami-Dade	1994	17
Bal Harbor (BAL)	Miami-Dade	1999	12
Golden Beach (GBB)	Miami-Dade	2005	6
Hallandale Beach (HDB)	Broward	2003	8
Dania Beach (DBB)	Broward	2001	10
Dogpile	Broward	1999	12
Tycom	Palm Beach	2001	10
Silpe	Palm Beach	2009	2
Cross Current	Palm Beach	1999	12

The boulder reefs appear to be slowly developing a stony coral assemblage similar to the natural linear reefs; however there were some statistical differences determined among the comparisons (rejection of null hypothesis 1). Five of the boulder reefs (AB, BAL, HDB, and DBB) had greater stony coral (colonies ≥5cm diameter) percent cover, density (colonies/m^2), and species richness than their adjacent controls (Table 7 and Figures 5-7). An additional two boulder reefs (TB and XCB) had greater species richness. There appears to be a relationship between these metrics and the age of the reefs. Those five reefs which exceed the control values are the five oldest reefs (Table 26). All boulder reefs, except SB which was the youngest reef, also had greater stony coral recruit (colonies <5cm diameter) densities than their controls. The establishment of a stony coral community, in terms of overall cover and density, on the boulder reefs is neither unexpected nor surprising. Other studies have documented high stony coral recruitment and colony densities on artificial reefs (Perkol-Finkel and Benayahu, 2005; Thanner et al., 2006). Boulder reefs provide stable substrate of a material (limestone) which is similar to natural reef substrate. Both of these conditions promote stony coral recruitment and potential survival. The stony coral community offshore southeast Florida is characterized by low densities (less than 2 colonies/m^2) and percent cover (generally less than 3%) (Gilliam, 2011 and Gilliam et al., 2011). With appropriate available substrate, which deployed structures present, developing similar cover and densities within 10-15 years would be expected.

Stony coral colony size (diameter) distribution was different between the boulder reefs and the controls (rejection of null hypothesis 2). Excluding *Madracis decactis* because of its encrusting growth form, the mean colony size of all nine boulder reefs was smaller than their adjacent controls (Table 7), and the largest colony identified in all of the controls was larger than identified on any of the boulders (Table 8). No boulder reef had colonies greater than 30cm while all ten control areas had colonies greater than 40cm. Stony corals are slow growing with many of the common southeast Florida species growing less than 1cm/year (linear extension) (Gladfelter et al., 1978; Bak and Engel, 1979; Dodge, 1981; Highsmith et al., 1983; Rogers et al., 1984; Hughes and Jackson, 1985; van Moorsel, 1988; Edmunds, 2000). The lack of larger colonies is expected since the age of even the oldest boulder reef (17 years) is not old enough for larger colonies to exist on these reefs.

There were important differences in the common species recorded within the boulder reefs and control areas. Species such as *Siderastrea siderea*, *Stephanocoenia intersepta*, and *Porites astreoides* that tend to contribute greatly to colony abundance but also tend to be smaller in size (Gilliam et al., 2011) and dense recruiters were common in the boulder reefs and are most likely driving similarity towards the control reefs. Complete similarity, and therefore return of services, to the natural reefs will require the presence of important, larger, reef structure forming species (e.g. *Colpophyllia natans*, *Diploria* spp., and *Montastrea* spp.). These species contribute much less to the species assemblage in the boulder reefs than in the control areas (see Appendix Tables 1-3).

In contrast to the stony coral community, the gorgonian community on the boulder reefs is not nearly as developed. All of the boulder reefs had lower gorgonian cover, density, and species richness than their adjacent control areas (Table 12 and Figures 10 -12) (rejection of null hypothesis 1). This result was unexpected. In the Phase I study (Gilliam and Moulding, 2012) gorgonian density and species richness were not different among the ship grounding sites and the control sites, and the difference in cover was much less. Gorgonians have been recorded as early colonizers in disturbed habitats and tend to have higher recruitment rates and growth rates (Lasker et al., 2003; Gutierrez-Rodriguez and Lasker, 2004) than most stony corals. Although boulder reefs may not be considered disturbed habitat, the open substrate available on deployed reefs should be conducive to gorgonian settlement and growth. The very low gorgonian abundance on the boulder reefs limits any interpretation as to whether a community may become more established as a boulder reef ages. Limited colonization of artificial reefs on southeast Florida and in the Bal Harbor mitigation reefs in particular have been documented (Thanner et al., 2006.)

Barrel sponges, *Xestospongia muta*, are large, long-lived conspicuous sponges along the Florida Reef tract (McMurray et al., 2008 and Bertin and Callahan, 2008). These sponges were specifically included in this assessment because of the ecological services (e.g. habitat, structure, food, living space) they contribute to the reef community. Although barrel sponges were identified in every control area, no barrel sponges were identified on any of the boulder reefs (rejection of hypothesis 1). This is perhaps the most unexpected study result, and with the limited gorgonian populations on the boulders illustrates the limitations artificial reefs, even boulders, have towards replacing the services lost from reef injury.

As expected all of the boulder reefs were much more complex (greater rugosity index, Table 16) than any of the natural reef control areas (rejection of null hypothesis 4). The effect of this greater complexity on reef community development was not examined as part of this study, but it illustrates the visual observation that boulder reefs look very different than natural reefs.

The multivariate analyses compared the community among the boulder reefs and control areas. The MDS plot (Figure 13) clearly illustrates that the replicate sites for each boulder reef are more similar to themselves than they are to their adjacent control sites (rejection of null hypothesis 5). This greater within reef similarity was also supported by the ANISOM results. The Bray-Curtis similarity indices (Table 17) do indicate that there may be a trend towards greater community similarity as a boulder reef ages. However, this trend is confounded by the fact that the oldest reef (AB deployed in 1994) has one of the lowest percent similarities.

This multivariate approach through the SIMPER analysis was able to support some of the population results. Gorgonian cover was determined to be a group driving the dissimilarity between the boulder reefs and control areas (Figure 14). The SIMPER analysis also determined that the greater cover of the large, reef structure forming stony coral species, *M. cavernosa*, on the control sites and the greater cover of the smaller, *P. astreoides*, on the boulder sites were both contributing to the dissimilarity among the boulder and control sites (Figure 16 and 17).

For resource managers to determine the amount of compensatory mitigation required following a reef injury event or a permitted project which impacts reef resources, they must have some information on whether a proposed mitigation action is capable of completely compensating for the lost services, and the time period required for proposed mitigation action to replace the lost services. Relating the results of this study to those two important points of information is a difficult task. Both the population dynamics approach, in terms of stony corals, and the multivariate community analysis approach did indicate some trend in each of the counties towards greater similarity to the natural reefs as the boulder reefs age. Seven of the nine boulder reefs were at least ten years old, but all still remain very different than the natural reefs especially in terms of the limited gorgonian populations and lack of barrel sponges on the boulder reefs. It is also evident that the reef communities on the boulder reefs are still developing. A determination of the rate of community development and final community equilibrium state (if one is reached) will require an evaluation of boulder reefs older than the oldest boulder reef in this study.

There are a number of possible processes and conditions which are limiting reef development on the boulder reefs, and therefore the potential for compensating lost services. The difference in the physical structure between the boulder reefs and natural reefs may be influencing the differences in communities. The boulder reefs are more complex, higher profile, and are essentially islands of hard substrate within a sand habitat. The natural variability in the southeast Florida coral reef community (Gilliam et al., 2011; Moyer et al., 2003) also contributes to the difficulty in comparing the communities. The MDS plots show that that although most of the boulder samples grouped together and most of the control samples group together there was still dissimilarity within each site.

<u>Port of Miami</u>

The Inner Reef channel floor sites (PMC IR) and the Outer Reef channel floor sites each had much lower stony coral cover, density, mean colony size (diameter), and species richness than their corresponding controls (Inner Reef control area [PMB CTL] and Outer Reef control area [AB CTL] (Table 18 and Figures 21-23) (rejection of null hypothesis 1). In contrast, both channel areas had greater stony coral recruit density and species richness than their natural reef controls (Table and Figures 24 and 25). The channel floor sites were very similar to each other in all the stony coral metrics.

Gorgonians were not abundant in the Port channel. Both the Inner Reef channel sites (PMC IR) and the Outer Reef channel sites (PMC OR) had mean percent cover less than 1% and density was less than 1 colony/m^2. These values are much lower compared to PMB CTL which had gorgonian cover of nearly 10% and colony density of 8 colonies/m^2 (Table 22 and Figures 26-28) (rejection of null hypothesis 1).

The Inner Reef and Outer Reef channel floor communities appears to be very similar to the grounding sites assessed in the Phase I of this project (Gilliam and Moulding, 2012). The channel floor sites were last impacted during a deepening project (dredged) in 1993-1994, and these sites still appear as injury sites. Similar to the ship grounding sites, the channel floor sites were dominated by rubble substrate (Table 24) which, in addition to being inside of a major port channel, is limiting community development.

Only one site was sampled on the Middle Reef in the entrance channel. Unlike the Inner Reef and Outer Reef channel floor sites which still had very visible signs of physical impacts, there were no indications of direct physical impacts from dredging at the Middle Reef site. The reef community, however, was still very similar to the Inner Reef and Outer Reef channel sites. The Middle Reef site was dominated by sand (Table 24) instead of rubble, but the affect on the community by limiting reef development is similar.

The channel wall was assessed along the dredged portion of the Inner Reef (PMCW IR). PMCW IR had greater stony coral cover and density than the channel floor sites (Table 18 and Figures 21-23). Mean stony coral cover and mean colony size on PMCW IR was comparable to that on PMB CTL, but when the encrusting stony coral, *Madracis decactis*, was removed from analysis cover dropped dramatically as well as mean colony size. The contribution of *M. decactis* to the reef community along the wall is also illustrated by the MDS plot (Figure 31). Gilliam and Walker (2008) completed an assessment in the Port Everglades entrance channel along the Nearshore Ridge Complex, and although the Port Everglades samples were closer to the Port entrance, *M. decactis* was also identified as an important species contributing to stony coral density and percent cover. The PMCW IR had greater gorgonian percent cover, density, and species richness that PMC IR but less than PMB CTL (rejection of null hypothesis 1). The channel wall had substrate cover dominated by consolidated pavement similar to PBM CTL. The stable pavement substrate is likely contributing to the greater reef develop along the wall compared to the channel floor, but the influence of the channel itself is likely contributing to the differences seen compared to the control. The last direct impacts to the channel wall are stated to have been during the 1968 channel deepening project (USACE, 2011). This much greater injury age, 43 years between the depending event and this project sampling, is also very likely to be contributing to the greater reef community development.

The Port of Miami mitigation boulder reefs (PMB) had greater stony coral cover and species richness but lower colony density and smaller mean colony size (diameter) than the Inner Reef control (PMB CTL) and Outer Reef control (AB CTL) (Table 18 and Figures 21-23) (rejection of null hypotheses 1 and 2). Stony coral recruit density was also greater on PMB (Table 21). These are similar stony coral assemblage relationships as those identified with the other boulder and control area comparisons made previously.

The gorgonian population on PMB does differentiate it from the other assessed boulder reefs. Unlike the other boulder reefs, PMB had greater gorgonian cover, density, and species richness than PMB CTL and AB CTL (Table 22 and Figures 26-28). The PMB had a much more developed gorgonian community than any of the other boulder reefs.

Barrel sponges were not identified on PMB or in the channel floor sites (PMC IR and PMC OR). These sponges were identified along the channel wall (PMCW IR) but in very low densities (Table 23).

The multivariate analysis (MDS plot, Figure 29) illustrated that the reef communities inside the entrance channel on the floor (PMC IR and PMC OR) and the wall (PMCW IR) were much more similar to themselves than to the natural reef control or the boulder reefs. There are reef resources present within the channel, but the disturbed physical characteristics of the channel sites, increase rubble for the floor sites (Figure 30), and the vertical nature of the wall sites, will continue to limit reef community development and recovery back to pre-disturbed conditions.

The Port of Miami boulders had greater stony coral cover, density, and species richness and much greater gorgonian cover, density, and species richness than the other assessed boulder reefs. The PMB reef was deployed in 1996 making it the second oldest boulder reef (AB was deployed in 1994), and it had the second highest rugosity determined among the boulder reefs. The age of PMB is likely driving increased stony coral and gorgonian community development but is also not likely the sole factor influencing its development. It is interesting that like all the boulder reefs, no barrel sponges were identified.

Conclusions

1. The sample data did provide evidence that the boulder reefs were developing a stony coral community that was similar to adjacent natural reef communities in terms of stony coral cover, density, and species richness. Stony coral colony sizes (diameter) are still generally smaller on the boulder reefs than on the natural reefs, but this is not unexpected since even the oldest reef has only been in the water for 17 years. The age of the reefs (years since deployment) does appear to be influencing stony coral development. Although species richness was similar, there were important differences in species contributions to the communities. The contribution of smaller, 'weedier' species on the boulder reefs was greater than that on adjacent natural reefs while larger, reef structure forming species contributed greater to the natural reef community.

2. Boulders reefs do not appear to be developing gorgonian communities similar to adjacent natural reefs (with the exception of PMB). This is not simply due to the ages of the boulder reefs since gorgonian recruitment and growth rates of

many species are such that most of the boulder reefs should have a more developed community.

3. Barrel sponges, *Xestospongia muta*, were not identified on any boulder reef. The reasons for this were not evident from and were not examined during this study. It is likely that there is some type of habitat associated characteristic that is not conducive to barrel sponge recruitment and/or survival.

4. When reef impacts occur, lost resource services include more than just those provided by stony corals. Defining and measuring the services many reef community components provide can be difficult. This is not necessarily the case for gorgonians and barrel sponges both of which are very important components of the southeast Florida reef community, and their limited development on boulder reefs needs to be considered before boulders are deployed as mitigation.

5. The length of time boulder reefs require to mitigate lost reef resources, assuming a total loss of the impacted community from events such as ship groundings or dredging, is longer than 17 years (the age of the oldest boulder reef assessed). With the stony coral colony size distribution dominated by smaller size classes and limited gorgonian and barrel sponge populations, it is reasonable to extrapolate that boulder reefs would take decades to mitigate for a total loss of services (if at all).

6. Regardless of the age of the reef, boulder reefs look like boulder reefs. This may be more than just a comment on aesthetics. It is not unreasonable to assume that deployed reefs that appear different, and are going to appear different for a long time, and provide services different than natural reef.

7. All the boulder reefs were deployed on sand habitat between linear reefs. The value and services that these sand habitats provide to the marine community are not well understood and are understudied. The affects to these habitats and potential loss of their services by deploying structures on them was not evaluated as part of this study but should be evaluated prior to any future proposed large scale mitigation reef deployments.

8. Port of Miami channel floor reef community development has been very limited since the last dredging event (1993) nearly 20 years ago. Dredged Inner and Outer Reef portions still appear very much like dredged reef. Complete channel floor recovery is not likely to occur because of the altered substrate. There are, however, reef resources present which should be considered prior to additional dredging activities.

9. The Port of Miami channel wall along the Inner Reef was recorded as last being directly impacted in 1968. The reef community on the channel wall has had over 40 years to develop (recover), and appears to be more similar to the Inner Reef than the channel floor is to the Inner Reef. This is to be expected since the recovery time for the channel wall has been twice as long, and the wall substrate is not dominated by rubble. The reef community is still, however, different than the natural reef implying that even after 40 years the communities on the wall have not recovered from the last direct impact event. As identified on the channel floor, there are reef resources present which should be considered prior to additional dredging activities.

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APPENDIX

Appendix Table 1. Mean (standard error [SE]) percent stony coral species contribution for Miami-Dade sites (see Tables 1 and 3 for site abbreviations).

Species	AB		AB CTL		BAL		BAL MID CTL		BAL OUT CTL		GBB		GBB CTL	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Agaricia agaricites	3.41%	2.54%	0.00%	0.00%	5.94%	0.42%	0.00%	0.00%	4.94%	5.66%	3.94%	3.42%	3.23%	3.47%
Agaricia fragilis	0.71%	1.23%	0.00%	0.00%	2.36%	2.28%	5.06%	4.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia lamarcki	0.00%	0.00%	1.59%	2.75%	0.97%	1.13%	1.28%	2.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia spp.	0.00%	0.00%	0.00%	0.00%	0.25%	0.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.30%	3.98%
Cladocora arbuscula	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.04%	3.54%	0.00%	0.00%
Colpophyllia natans	3.82%	1.62%	0.00%	0.00%	2.11%	2.13%	1.28%	2.22%	0.00%	0.00%	2.31%	0.42%	1.23%	2.14%
Dichocoenia stokesii	1.81%	0.94%	1.59%	2.75%	1.68%	1.15%	0.00%	0.00%	2.28%	1.99%	0.00%	0.00%	4.48%	3.88%
Diploria clivosa	0.54%	0.94%	1.59%	2.75%	0.71%	0.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.15%	1.99%
Diploria labyrinthiformis	0.24%	0.41%	0.00%	0.00%	1.89%	0.77%	0.00%	0.00%	0.00%	0.00%	2.71%	4.69%	0.00%	0.00%
Diploria strigosa	0.27%	0.47%	0.00%	0.00%	0.24%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.17%	1.93%
Eusmilia fastigiata	1.51%	1.83%	3.51%	6.08%	5.47%	1.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.15%	1.99%
Helioceris cucullata	0.00%	0.00%	0.00%	0.00%	0.23%	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Madracis decactis	25.86%	6.86%	3.51%	6.08%	5.94%	1.47%	25.26%	2.33%	3.51%	3.72%	0.00%	0.00%	0.00%	0.00%
Meandrina meandrites	3.45%	1.34%	11.31%	5.80%	4.99%	0.66%	8.64%	8.75%	7.15%	0.80%	2.06%	3.58%	15.25%	7.62%
Montastrea annularis	0.27%	0.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montastrea cavernosa	6.22%	0.76%	12.90%	3.16%	1.23%	2.12%	12.49%	4.61%	23.02%	7.78%	0.00%	0.00%	4.56%	1.72%
Montastrea faveolata	0.00%	0.00%	0.00%	0.00%	0.95%	0.41%	1.20%	2.09%	1.23%	2.14%	0.00%	0.00%	1.23%	2.14%
Mycetophyllia aliciae	0.47%	0.82%	2.54%	2.64%	0.94%	1.06%	3.70%	3.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia lamarckiana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia sp.	0.56%	0.51%	0.00%	0.00%	0.71%	1.23%	1.28%	2.22%	0.00%	0.00%	3.50%	3.17%	1.15%	1.99%
Oculina diffusa	0.92%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.43%	1.41%	0.00%	0.00%
Phyllangia americana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.28%	2.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Porites astreoides	27.74%	2.30%	29.75%	5.27%	31.60%	0.98%	1.28%	2.22%	19.51%	7.51%	28.56%	1.93%	9.16%	7.14%
Porites porites	0.87%	0.82%	0.00%	0.00%	1.69%	1.72%	0.00%	0.00%	0.00%	0.00%	23.69%	9.77%	2.17%	1.93%
Scolymia spp.	0.00%	0.00%	0.00%	0.00%	0.46%	0.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Siderastrea siderea	12.66%	0.93%	19.15%	12.28%	15.64%	2.14%	12.85%	4.63%	19.64%	4.18%	26.83%	9.73%	14.14%	13.73%
Solenastrea bournoni	0.24%	0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	2.14%	1.50%	1.36%	3.42%	3.28%
Stephanocoenia intersepta	8.41%	3.96%	12.57%	6.93%	14.01%	0.56%	24.37%	7.60%	17.48%	2.31%	1.43%	2.48%	33.20%	14.17%
Tubastrea coccinea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix Table 2. Mean (standard error [SE]) percent stony coral species contribution for Broward sites (see Table 1 for site abbreviations).

	HDB		HDB CTL		DBB		DBB CTL		DPB		DPB CTL	
Species	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Agaricia agaricites	1.15%	1.99%	1.47%	2.08%	4.41%	3.82%	3.34%	2.90%	13.12%	1.86%	0.00%	0.00%
Agaricia fragilis	2.35%	2.04%	1.47%	2.08%	0.00%	0.00%	0.00%	0.00%	0.60%	0.30%	0.00%	0.00%
Agaricia lamarcki	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.54%	0.00%	0.00%
Agaricia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cladocora arbuscula	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Colpophyllia natans	1.20%	2.09%	0.00%	0.00%	3.25%	2.82%	0.00%	0.00%	1.37%	0.41%	0.00%	0.00%
Dichocoenia stokesii	0.00%	0.00%	4.41%	6.24%	0.56%	0.98%	3.89%	3.53%	0.29%	0.26%	3.34%	2.95%
Diploria clivosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.15%	1.99%	1.35%	2.00%	0.00%	0.00%
Diploria labyrinthiformis	0.00%	0.00%	0.00%	0.00%	12.64%	2.47%	0.00%	0.00%	0.61%	0.74%	0.00%	0.00%
Diploria strigosa	1.08%	1.86%	3.14%	0.28%	1.08%	0.94%	1.15%	1.99%	1.08%	0.76%	0.00%	0.00%
Eusmilia fastigiata	1.15%	1.99%	0.00%	0.00%	1.94%	1.75%	0.00%	0.00%	0.95%	0.95%	0.00%	0.00%
Helioceris cucullata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Madracis decactis	0.00%	0.00%	0.00%	0.00%	1.65%	0.04%	0.00%	0.00%	8.71%	0.52%	0.00%	0.00%
Meandrina meandrites	2.15%	3.72%	5.88%	8.32%	3.02%	3.10%	4.05%	3.60%	1.64%	2.09%	5.33%	5.23%
Montastrea annularis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.51%	6.08%	0.00%	0.00%	0.00%	0.00%
Montastrea cavernosa	7.53%	13.04%	13.82%	5.41%	0.00%	0.00%	7.50%	10.15%	6.86%	2.26%	28.04%	12.60%
Montastrea faveolata	1.08%	1.86%	0.00%	0.00%	1.13%	1.96%	0.00%	0.00%	0.61%	0.30%	0.00%	0.00%
Mycetophyllia aliciae	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.14%	0.23%	0.00%	0.00%
Mycetophyllia lamarckiana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.14%	0.23%	0.00%	0.00%
Oculina diffusa	7.46%	6.52%	0.00%	0.00%	0.55%	0.95%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Phyllangia americana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Porites astreoides	17.65%	13.02%	27.75%	26.76%	25.67%	12.11%	21.41%	2.56%	22.32%	4.59%	34.08%	14.51%
Porites porites	28.50%	21.37%	9.22%	3.60%	24.90%	6.41%	1.15%	1.99%	2.43%	0.59%	0.00%	0.00%
Scolymia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%	0.55%	0.00%	0.00%
Siderastrea siderea	21.38%	2.45%	15.69%	1.39%	16.74%	13.97%	19.39%	9.15%	20.81%	2.63%	19.87%	11.37%
Solenastrea bournoni	4.02%	6.96%	4.61%	1.80%	0.27%	0.47%	10.03%	8.71%	3.04%	1.73%	0.00%	0.00%
Stephanocoenia intersepta	3.30%	3.23%	12.55%	1.11%	2.20%	0.94%	23.44%	4.45%	13.30%	3.36%	9.33%	4.94%
Tubastrea coccinea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix Table 3. Mean (standard error [SE]) percent stony coral species contribution for Pam Beach sites (see Table 1 for site abbreviations).

Species	TB		TB CTL		SB		SB CTL		XCB		XCB CTL	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Agaricia agaricites	10.64%	2.82%	1.37%	2.37%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia fragilis	0.98%	1.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia lamarcki	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cladocora arbuscula	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Colpophyllia natans	1.51%	1.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dichocoenia stokesii	0.57%	0.49%	1.67%	2.89%	0.00%	0.00%	2.01%	1.08%	0.61%	1.05%	9.74%	6.63%
Diploria clivosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Diploria labyrinthiformis	0.90%	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.84%	1.85%	0.00%	0.00%
Diploria strigosa	1.94%	0.12%	0.00%	0.00%	0.00%	0.00%	0.35%	0.60%	0.00%	0.00%	0.00%	0.00%
Eusmilia fastigiata	2.49%	0.96%	1.96%	3.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Helioceris cucullata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Madracis decactis	8.08%	4.94%	1.67%	2.89%	0.00%	0.00%	2.27%	1.98%	6.18%	2.02%	0.00%	0.00%
Meandrina meandrites	3.74%	2.97%	6.37%	7.75%	0.00%	0.00%	6.46%	2.89%	6.97%	7.35%	9.00%	8.41%
Montastrea annularis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montastrea cavernosa	4.73%	1.12%	18.29%	14.72%	0.00%	0.00%	50.67%	12.96%	19.27%	12.58%	50.75%	8.54%
Montastrea faveolata	0.29%	0.51%	0.00%	0.00%	0.00%	0.00%	0.53%	0.92%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia aliciae	0.61%	1.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.12%	1.13%	0.00%	0.00%
Mycetophyllia lamarckiana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia spp.	0.30%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Oculina diffusa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.89%	1.92%	0.00%	0.00%
Phyllangia americana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Porites astreoides	17.13%	0.32%	1.67%	2.89%	75.00%	35.36%	27.30%	9.53%	15.52%	0.78%	12.52%	11.01%
Porites porites	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scolymia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Siderastrea siderea	31.10%	2.55%	25.45%	8.75%	0.00%	0.00%	7.12%	1.72%	29.74%	14.44%	14.06%	9.58%
Solenastrea bournoni	0.29%	0.51%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Stephanocoenia intersepta	14.70%	3.41%	41.56%	20.43%	25.00%	35.36%	3.28%	3.18%	13.59%	5.48%	3.93%	4.19%
Tubastrea coccinea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.28%	2.22%	0.00%	0.00%

Appendix Table 4. Mean (standard error [SE]) percent gorgonian species contribution for Miami-Dade sites (see Tables 1 and 3 for site abbreviations).

	AB		AB CTL		BAL		BAL MID CTL		BAL OUT CTL		GBB		GBB CTL	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Diodogorgia nodulifera	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea calyculata	0.00%	0.00%	1.62%	0.48%	8.83%	3.17%	4.00%	1.84%	4.36%	2.51%	0.00%	0.00%	15.57%	12.82%
Eunicea flexuosa	0.00%	0.00%	5.54%	1.16%	1.52%	1.52%	12.04%	3.46%	10.85%	0.65%	1.85%	1.85%	7.02%	1.28%
Eunicea fusca	11.11%	11.11%	32.38%	10.87%	10.98%	4.29%	59.49%	3.98%	63.71%	1.50%	1.85%	1.85%	25.86%	13.19%
Eunicea knightii	0.00%	0.00%	1.76%	0.79%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea laciniata	0.00%	0.00%	0.10%	0.10%	0.00%	0.00%	0.25%	0.25%	1.15%	0.88%	0.00%	0.00%	0.00%	0.00%
Eunicea laxispica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea mammosa	0.00%	0.00%	0.10%	0.10%	3.81%	3.81%	0.00%	0.00%	0.24%	0.24%	0.00%	0.00%	0.00%	0.00%
Eunicea pinta	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea spp.	36.11%	32.03%	0.22%	0.22%	2.47%	1.33%	0.00%	0.00%	0.43%	0.22%	1.85%	1.85%	5.14%	4.18%
Eunicea succinea	0.00%	0.00%	0.10%	0.10%	0.00%	0.00%	0.48%	0.48%	0.00%	0.00%	0.00%	0.00%	0.50%	0.50%
Eunicea tournefortii	0.00%	0.00%	0.30%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Iciligorgia schrammi	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gorgonia ventalina	5.56%	5.56%	0.62%	0.39%	30.76%	4.02%	1.49%	0.41%	1.53%	0.42%	21.07%	14.16%	7.51%	0.79%
Muricea atlantica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.90%	1.90%
Muricea elongata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea laxa	0.00%	0.00%	0.10%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea muricata	0.00%	0.00%	1.34%	0.70%	4.37%	2.48%	2.20%	1.26%	0.24%	0.24%	0.00%	0.00%	0.00%	0.00%
Muricea spp.	0.00%	0.00%	0.00%	0.00%	3.33%	3.33%	0.25%	0.25%	1.43%	0.82%	12.04%	7.23%	0.00%	0.00%
Plexaura homomalla	0.00%	0.00%	0.22%	0.22%	0.00%	0.00%	0.00%	0.00%	0.24%	0.24%	0.00%	0.00%	0.00%	0.00%
Plexaura spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.67%	0.42%	0.00%	0.00%	0.00%	0.00%
Plexaurella nutans	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaurella spp.	2.78%	2.78%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura crucis	0.00%	0.00%	0.52%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura porosa	0.00%	0.00%	1.57%	0.81%	2.06%	1.04%	4.42%	1.85%	0.81%	0.50%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura spp.	36.11%	32.03%	1.01%	0.58%	1.11%	1.11%	0.00%	0.00%	0.96%	0.96%	0.00%	0.00%	3.40%	1.24%
Pseudopterogorgia acerosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudopterogorgia americana	0.00%	0.00%	50.97%	10.24%	29.80%	8.47%	13.68%	3.53%	9.56%	2.10%	0.00%	0.00%	0.00%	0.00%
Pseudopterogorgia rigida	0.00%	0.00%	0.37%	0.19%	0.00%	0.00%	1.21%	0.87%	1.91%	0.96%	0.00%	0.00%	0.33%	0.33%
Pseudopterogorgia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%	0.24%	25.00%	14.43%	32.76%	2.17%
Pterogorgia citrina	8.33%	8.33%	1.15%	0.70%	0.95%	0.95%	0.00%	0.00%	1.68%	0.63%	0.00%	0.00%	0.00%	0.00%
Unknown spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix Table 5. Mean (standard error [SE]) percent gorgonian species contribution for Broward sites (see Tables 1 and 3 for site abbreviations).

	HDB		HDB CTL		DBB		DBB CTL		DPB		DPB CTL	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Diodogorgia nodulifera	0.00%	0.00%	0.00%	0.00%	0.74%	0.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea calyculata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.66%	0.66%	3.51%	1.97%	3.44%	0.33%
Eunicea flexuosa	0.00%	0.00%	3.07%	0.47%	1.36%	1.36%	8.77%	1.98%	5.22%	3.23%	6.98%	0.34%
Eunicea fusca	0.00%	0.00%	12.22%	1.18%	8.58%	0.22%	3.95%	3.95%	9.13%	6.05%	66.67%	1.87%
Eunicea knightii	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.86%	0.86%	0.00%	0.00%
Eunicea laciniata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%	0.24%
Eunicea laxispica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea mammosa	0.00%	0.00%	0.00%	0.00%	12.22%	6.95%	0.60%	0.60%	2.09%	1.10%	0.36%	0.12%
Eunicea pinta	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea spp.	0.00%	0.00%	5.47%	0.25%	7.53%	2.76%	13.43%	2.18%	0.77%	0.77%	5.34%	1.63%
Eunicea succinea	0.00%	0.00%	0.00%	0.00%	1.02%	1.02%	2.72%	0.64%	2.95%	1.53%	0.82%	0.60%
Eunicea tournefortii	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	0.20%
Icilogorgia schrammi	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15.29%	12.81%	0.00%	0.00%
Gorgonia ventalina	0.00%	0.00%	4.99%	1.54%	31.82%	8.20%	3.75%	0.98%	2.47%	1.49%	0.54%	0.17%
Muricea atlantica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	10.46%	6.34%	0.24%	0.14%
Muricea elongata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea laxa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea muricata	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.07%
Muricea spp.	0.00%	0.00%	0.74%	0.43%	3.83%	2.08%	0.90%	0.52%	9.09%	9.09%	0.14%	0.07%
Plexaura homomalla	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaura spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.03%	3.03%	0.00%	0.00%
Plexaurella nutans	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.44%	0.44%	0.00%	0.00%	0.00%	0.00%
Plexaurella spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.71%	1.71%	0.00%	0.00%
Pseudoplexaura crucis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura porosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.22%	1.93%	1.61%	0.19%
Pseudoplexaura spp.	0.00%	0.00%	6.46%	1.43%	9.73%	5.34%	8.85%	1.00%	1.99%	1.08%	0.23%	0.13%
Pseudopterogorgia acerosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	1.23%	0.65%	0.22%
Pseudopterogorgia americana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.70%	0.87%	11.27%	1.54%
Pseudopterogorgia rigida	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%	0.30%	2.27%	2.27%	0.98%	0.36%
Pseudopterogorgia spp.	0.00%	0.00%	67.05%	2.21%	22.82%	4.94%	49.10%	4.92%	0.00%	0.00%	0.16%	0.08%
Pterogorgia citrina	0.00%	0.00%	0.00%	0.00%	0.34%	0.34%	5.66%	5.66%	0.00%	0.00%	0.08%	0.08%
Unknown spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Appendix Table 6. Mean (standard error [SE]) percent gorgonian species contribution for Palm Beach sites (see Table 5 for site abbreviations).

	TB		TB CTL		SB		SB CTL		XCB		XCB CTL	
Species	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Diodogorgia nodulifera	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.54%	3.63%
Eunicea calyculata	7.25%	1.84%	4.26%	0.95%	4.10%	3.31%	7.93%	1.25%	1.52%	1.52%	5.40%	0.50%
Eunicea flexuosa	0.00%	0.00%	7.11%	1.47%	2.62%	1.54%	34.67%	3.06%	0.00%	0.00%	18.44%	0.30%
Eunicea fusca	8.77%	2.91%	53.68%	5.85%	7.55%	3.83%	32.10%	5.58%	1.52%	1.52%	18.53%	4.94%
Eunicea knightii	0.00%	0.00%	6.51%	1.67%	0.96%	0.96%	0.43%	0.20%	0.00%	0.00%	0.27%	0.19%
Eunicea laciniata	0.00%	0.00%	0.57%	0.08%	0.05%	0.05%	1.07%	0.26%	0.00%	0.00%	1.31%	0.55%
Eunicea laxispica	0.00%	0.00%	0.16%	0.16%	0.09%	0.09%	0.13%	0.13%	0.00%	0.00%	0.00%	0.00%
Eunicea mammosa	0.00%	0.00%	0.93%	0.79%	2.23%	1.59%	0.70%	0.08%	0.00%	0.00%	0.98%	0.45%
Eunicea pinta	0.00%	0.00%	5.92%	4.18%	2.41%	2.41%	0.15%	0.08%	0.00%	0.00%	0.00%	0.00%
Eunicea spp.	0.00%	0.00%	0.75%	0.49%	0.28%	0.28%	0.83%	0.42%	0.00%	0.00%	0.33%	0.23%
Eunicea succinea	0.00%	0.00%	0.28%	0.28%	0.16%	0.16%	1.45%	0.88%	0.00%	0.00%	1.23%	0.41%
Eunicea tournefortii	1.52%	1.52%	0.24%	0.12%	0.07%	0.07%	0.00%	0.00%	0.00%	0.00%	0.65%	0.28%
Icilogorgia schrammi	1.01%	1.01%	0.00%	0.00%	13.65%	7.31%	5.38%	1.32%	89.24%	6.59%	4.12%	3.16%
Gorgonia ventalina	16.20%	7.92%	0.18%	0.09%	0.05%	0.05%	0.79%	0.34%	3.19%	1.60%	1.23%	1.13%
Muricea atlantica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea elongata	11.11%	5.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea laxa	0.00%	0.00%	1.05%	0.52%	4.47%	4.02%	2.12%	1.06%	3.03%	3.03%	14.87%	0.84%
Muricea muricata	0.00%	0.00%	0.53%	0.16%	0.09%	0.09%	1.29%	0.20%	0.00%	0.00%	2.36%	0.56%
Muricea spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaura homomalla	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaura spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaurella nutans	0.00%	0.00%	0.08%	0.08%	0.05%	0.05%	0.24%	0.16%	0.00%	0.00%	0.20%	0.11%
Plexaurella spp.	0.00%	0.00%	0.00%	0.00%	1.77%	1.77%	0.00%	0.00%	0.00%	0.00%	0.58%	0.12%
Pseudoplexaura crucis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura porosa	18.94%	3.30%	3.77%	1.24%	0.72%	0.72%	2.32%	1.19%	0.00%	0.00%	0.53%	0.37%
Pseudoplexaura spp.	0.00%	0.00%	3.69%	1.95%	5.30%	3.73%	0.24%	0.03%	0.00%	0.00%	1.21%	0.63%
Pseudopterogorgia acerosa	0.00%	0.00%	0.14%	0.14%	0.08%	0.08%	0.00%	0.00%	0.00%	0.00%	0.30%	0.20%
Pseudopterogorgia americana	25.22%	8.78%	8.83%	1.33%	16.19%	7.03%	2.47%	0.56%	0.00%	0.00%	20.21%	4.38%
Pseudopterogorgia rigida	9.99%	5.26%	0.00%	0.00%	7.71%	3.89%	0.00%	0.00%	0.00%	0.00%	1.16%	0.41%
Pseudopterogorgia spp.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pterogorgia citrina	0.00%	0.00%	1.25%	0.26%	0.15%	0.15%	5.64%	1.77%	0.00%	0.00%	1.48%	0.76%
Unknown spp.	0.00%	0.00%	0.08%	0.08%	8.56%	8.49%	0.06%	0.06%	1.51%	1.51%	0.06%	0.06%

Appendix Table 7. Mean (standard error [SE]) percent stony coral species contribution for the Port of Miami sites (see Table 5 for site abbreviations).

Species	PMB		PMB CTL		PMC IR		PMCW IR		PMC MR	PMC OR	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		Mean	SE
Agaricia agaricites	4.45%	1.28%	1.67%	1.67%	16.05%	8.91%	2.56%	2.56%	0.00%	2.56%	2.56%
Agaricia fragilis	2.02%	0.70%	0.57%	0.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agaricia lamarcki	0.16%	0.16%	0.00%	0.00%	0.00%	0.00%	3.45%	3.45%	0.00%	1.28%	1.28%
Colpophyllia natans	1.85%	0.33%	0.56%	0.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dichocoenia stokesi	3.44%	1.18%	10.66%	6.45%	0.00%	0.00%	2.73%	1.37%	8.33%	0.00%	0.00%
Diploria strigosa	0.89%	0.49%	1.70%	1.00%	1.28%	1.28%	0.00%	0.00%	0.00%	0.00%	0.00%
Diploria labyrinthiformis	0.30%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eusmilia fastigiata	3.95%	0.34%	1.69%	0.96%	1.28%	1.28%	0.00%	0.00%	0.00%	2.56%	2.56%
Madracis decactis	4.30%	1.47%	3.67%	1.22%	0.00%	0.00%	53.22%	6.03%	0.00%	5.13%	5.13%
Meandrina meandrites	3.20%	0.98%	4.26%	2.15%	4.18%	2.52%	0.00%	0.00%	0.00%	6.49%	3.45%
Montastrea cavernosa	2.72%	0.67%	3.93%	2.42%	2.56%	2.56%	5.80%	1.92%	0.00%	11.25%	6.42%
Montastrea faveolata	0.63%	0.32%	0.56%	0.56%	0.00%	0.00%	0.64%	0.64%	0.00%	0.00%	0.00%
Mycetophyllia aliciae	0.44%	0.25%	0.00%	0.00%	1.28%	1.28%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia lamarckiana	0.32%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mycetophyllia sp.	0.42%	0.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Oculina diffusa	0.16%	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Porites astreoides	39.30%	2.58%	23.65%	0.75%	12.21%	6.13%	1.92%	1.92%	54.17%	18.88%	7.23%
Porites porites	8.71%	1.50%	7.31%	2.23%	1.28%	1.28%	0.00%	0.00%	4.17%	9.51%	1.82%
Scolymia spp.	0.31%	0.31%	0.57%	0.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Siderastrea siderea	11.36%	2.65%	16.61%	0.62%	17.76%	3.15%	6.61%	1.61%	12.50%	29.50%	8.82%
Solenastrea bournoni	1.05%	0.29%	5.63%	3.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Stephanocoenia intersepta	10.01%	2.24%	16.97%	8.57%	42.11%	20.10%	23.06%	5.71%	20.83%	12.83%	5.75%

Appendix Table 8. Mean (standard error [SE]) percent gorgonian species contribution for the Port of Miami sites (see Table 5 for site abbreviations).

Species	PMB		PMB CTL		PMC IR		PMCW IR		PMC MR	PMC OR	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		Mean	SE
Eunicea calyculata	1.95%	0.42%	3.55%	1.36%	25.00%	14.43%	12.04%	3.03%	23.08%	2.22%	2.22%
Eunicea flexuosa	0.11%	0.11%	6.42%	0.75%	0.00%	0.00%	2.68%	1.34%	7.69%	11.85%	6.46%
Eunicea fusca	21.88%	1.88%	21.91%	6.07%	25.00%	25.00%	18.76%	10.42%	0.00%	3.03%	3.03%
Eunicea laciniata	0.69%	0.39%	0.37%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea mammosa	0.84%	0.32%	0.91%	0.46%	0.00%	0.00%	0.45%	0.45%	30.77%	0.00%	0.00%
Eunicea palmieri	0.00%	0.00%	1.27%	1.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea sp	1.50%	0.79%	4.44%	1.99%	16.67%	16.67%	0.45%	0.45%	7.69%	0.00%	0.00%
Eunicea succinea	0.52%	0.12%	0.55%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eunicea tourneforti	0.00%	0.00%	2.87%	1.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gorgonia ventalina	20.33%	2.09%	6.71%	1.01%	25.00%	14.43%	11.39%	6.36%	0.00%	28.48%	11.46%
Muricea atlantica	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.00%	6.11%	7.69%	2.22%	2.22%
Muricea elongata	0.00%	0.00%	0.09%	0.09%	0.00%	0.00%	0.67%	0.67%	0.00%	0.00%	0.00%
Muricea laxa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	27.96%	12.99%	0.00%	0.00%	0.00%
Muricea muricata	4.39%	1.06%	4.08%	0.87%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muricea sp	5.50%	0.11%	1.11%	0.67%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Muriceopsis flavida	0.12%	0.12%	0.32%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	2.22%	2.22%
Plexaura homomalla	1.32%	0.35%	0.55%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaura sp.	0.12%	0.12%	0.87%	0.44%	0.00%	0.00%	0.45%	0.45%	0.00%	0.00%	0.00%
Plexaurella nutans	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Plexaurella sp.	0.00%	0.00%	0.41%	0.29%	0.00%	0.00%	0.45%	0.45%	0.00%	0.00%	0.00%
Pseudoplexaura crucis	0.00%	0.00%	0.36%	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudoplexaura porosa	9.58%	1.47%	0.82%	0.82%	0.00%	0.00%	1.57%	0.81%	0.00%	3.03%	3.03%
Pseudoplexaura sp.	1.53%	0.76%	1.03%	0.52%	0.00%	0.00%	3.33%	3.33%	0.00%	0.00%	0.00%
Pseudopterogorgia acerosa	1.11%	0.40%	0.32%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudopterogorgia americana	20.94%	1.64%	34.11%	4.02%	8.33%	8.33%	4.02%	2.31%	23.08%	46.94%	6.94%
Pseudopterogorgia kallos	0.11%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudopterogorgia rigida	4.02%	1.39%	0.76%	0.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pseudopterogorgia sp	0.00%	0.00%	4.98%	2.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pterogorgia anceps	1.70%	0.87%	0.00%	0.00%	0.00%	0.00%	3.33%	3.33%	0.00%	0.00%	0.00%
Pterogorgia citrina	1.74%	1.07%	1.17%	0.74%	0.00%	0.00%	4.00%	3.06%	0.00%	0.00%	0.00%
Pterogorgia guadalupensis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.45%	0.00%	0.00%	0.00%