Southeast Florida Coral Reef Evaluation and Monitoring Project

Southeast Florida Coral Reef Evaluation and Monitoring Project

2014 Year 12 Final Report

Prepared By:

David S. Gilliam and Charles J. Walton
Nova Southeastern University Oceanographic Center
8000 N. Ocean Dr.
Dania Beach FL 33004

And

Vanessa Brinkhuis, Robert Ruzicka and Michael Colella
Florida Fish and Wildlife Institute
100 8th Ave
St. Petersburg, FL 33701

September 2015

Completed in Fulfillment of Contract RM085 for

Florida Department of Environmental Protection
Coral Reef Conservation Program 1277 N.E. 79th Street Causeway
Miami, FL 33138

Project 4
Former Southeast Florida Coral Reef Initiative
Land-Based Sources of Pollution
Local Action Strategy Project 12

This report should be cited as follows:
Gilliam, D.S., Walton, C.J, Brinkhuis, V., Ruzicka, R., and M. Colella. 2015. Southeast Florida Coral Reef Evaluation and Monitoring Project 2014 Year 12 Final Report. Florida DEP Report #RM085. Miami Beach, FL. pp. 43.

This is a report of the Florida Fish and Wildlife Conservation Commission and Nova Southeastern University pursuant to FDEP Grant No. RM085 to FWC. Though funded in part by a grant agreement from the Florida Department of Environmental Protection (FDEP) through National Oceanic and Atmospheric Administration (NOAA) Award No. NA08NOS4260327 to FDEP, the views, statement, findings, conclusions, and recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the State of Florida or NOAA or any of their sub agencies**.**

TABLE OF CONTENTS

LIST OF ACRONYMS

CRCP ……………………………..………. (FDEP) Coral Reef Conservation Program
CREMP ……………………………..…. Coral Reef Evaluation and Monitoring Program
FDEP …………………………..…… Florida Department of Environmental Protection
FKNMS ……………………………………... Florida Keys National Marine Sanctuary
FWC ………………………………. Florida Fish and Wildlife Conservation Commission
FWRI ……………………………………………………... Wildlife Research Institute
SECREMP ……………………. Southeast Coral Reef Evaluation and Monitoring Project

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The purpose of the Southeast Coral Reef Evaluation and Monitoring Project (SECREMP) is to monitor the status and trends in the southeast Florida (Miami-Dade, Broward, Palm Beach, and Martin counties) reef system. Annual SECREMP assessments have been conducted at fixed sites since 2003 providing local, state, and federal resource managers with information on the temporal changes in benthic cover and population demographics of stony corals, octocorals, and barrel sponges (*Xestospongia muta*).

Protocol changes were made to the program in 2012 (Gilliam et al. 2013). In 2014, the protocol included one 22 m digital still image transect and one 1 m x 22 m belt transect survey at each station. In the belt transect, stony coral species (colonies ≥ 4 cm diameter), octocoral (first 10 m of the belt), and barrel sponge (*Xestospongia muta*) abundance, size, and condition are recorded. Octocorals generally have greater species richness than stony corals, and they are much more difficult to identify in the field. Five target species were added to the belt transect protocol in order to describe and document changes within the octocoral community. Five species (*Eunicea calyculata*, *Antillogorgia americana*, *Eunicea flexuosa*, *Pseudoplexaura porosa*, and *Gorgonia ventalina*) were selected based on their abundance across a range of habitats, depths and ease of field identification using morphological characteristics. These data permit a meaningful evaluation of the status and trends in the coral reef communities of southeast Florida and are consistent with the Coral Reef Evaluation and Monitoring Project (CREMP) in Florida Keys National Marine Sanctuary and Dry Tortugas National Park. Stony coral and octocoral species density, size class distribution, and condition can be tracked and evaluated through time. The core method of using image-transects to estimate benthic percent cover has not changed. Project year 12 (2014) signifies the third year for collecting demographic data. Annual site differences (between 2013 and 2014) in the percent cover of major benthic taxa (stony corals, octocorals, sponges, and macroalgae) and stony coral, octocoral, and barrel sponge densities are presented, as well as a regional long-term trend analysis of the major benthic taxa dating back to 2003.

Mean (±SD) region-wide (n = 22 sites) stony coral density was 1.26 ± 0.89 colonies (≥ 4 cm)/m² and ranged from 0.27 ± 0.35 colonies/m² (PB1) to 3.75 ± 0.43 colonies/m² (BC4). In 2014, 28 stony coral species were identified with a region-wide mean (±SD) of 7.97 ± 2.89 species per site and a range of 3.50 ± 0.58 (BCA) to 13.25 ± 1.50 (BC4) species within a site. Six species (*Porites astreoides*, *Montastraea cavernosa*, *Siderastrea siderea*, *Stephanocoenia intersepta*, *Agaricia agaricites*, and *Meandrina meandrites*) were very common region-wide and contributed more than 80% to total colony abundance in each county. Within the region stony coral colonies with what appeared to be active disease were recorded affecting 28 total colonies within 10 of the 22 sites in 2014. Nine species were recorded and the disease conditions included black band disease (two colonies), yellow band (two colonies), 'white disease' (14 colonies), and dark spot (10 colonies). A white syndrome referred to as rapid tissue loss was identified on *Acropora cervicornis* colonies in site BCA and DC1.

Region-wide (n = 22 sites) mean (±SD) octocoral density was 9.97 ± 7.93 colonies/m², and ranged from a high of 27.02 ± 9.22 colonies/m² at site PB5 to 0.00 ± 0.00 colonies/m² at site MC1. The five target species (*E. calyculata*, *A. americana*, *E. flexuosa*, *P. porosa*,

and *G. ventalina*) were identified in all counties, except Martin, and at 19 sites. *Antillogorgia americana*, *E. flexuosa,* and *E. calyculata* were present at most of the sites and were the most abundant of the target species.

Barrel sponges (*X. muta*) are large, conspicuous, important components of the Florida reef community. Barrel sponges were identified in all counties, except Martin, and at 17 of the 22 sites. No barrel sponges were identified at DC8, BCA, PB1, MC1, and MC2. At sites which had barrel sponges present, densities ranged from a high of 0.74 ± 0.17 sponges/m² at site PB5 to a low of 0.01 ± 0.02 sponges/m² at site DC6.

Region-wide (n = 22 sites) mean (±SD) stony cover in 2014 (2.8 ± 3.8%) was not significantly different than in 2013 (2.5 ± 3.4%) (p = 0.1194). There were also no sites which had significantly different cover in 2014 than in 2013. The long-term analysis did not find a region-wide significant long-term trend for stony coral cover (p = 0.445). At the site level, BCA has experienced a significant trend (decreasing) in cover since 2003 (p < 0.001). No other sites have any significant trends since 2003.

There was no year-to-year significant difference in mean (±SD) octocoral cover region-wide (n = 22 sites) between 2013 (9.9 ± 6.8%) and 2014 (9.6 ± 6.4%). At the site level, BC3 (p < 0.001) had significantly less octocoral cover in 2014 than in 2013, while BC2 (p < 0.001) and DC1 (p = 0.005) significantly greater octocoral cover in 2014 than in 2013. For the long-term analysis (2003-2014) there was a region-wide significant decreasing trend identified for octocoral cover (p = 0.003), and at the site level, PB3 and PB1 experienced a significant decreasing trend (p = 0.006 and p < 0.001, respectively) while DC1 experienced an increasing trend (p = 0. 003).

At the region-wide level, all sites (n = 22 sites) pooled, mean (±SD) sponge cover was significantly greater in 2014 (5.5 ± 3.6%) than in 2013 (5.2 ± 3.4%) (p = 0.046). At the individual site level, BCA (p < 0.001) had significantly lower cover in 2014 than in 2013 while PB1 (p < 0.001) had significantly greater cover. When evaluating region-wide trends since 2003, sponge cover has shown a significant increasing trend (p < 0.001). Even though the region has experienced an increasing trend in sponge cover, no individual sites have had a significant increasing trend. One site (PB1, p < 0.001) did have a decreasing trend in cover.

Region-wide mean (±SD) macroalgae cover in 2014 (10.3 ± 9.6%) was significantly greater than in 2013 (9.1 ± 12.0%) (p < 0.001). DC5 (p < 0.001), DC3 (p = 0.002), and BC3 (p < 0.001) had significantly greater macroalgae cover in 2014 than in 2013. Only one site (DC1) was significantly lower in 2014 (p < 0.001). Annual macroalgae cover has fluctuated greatly over the last 10 years ranging from less than 5% in 2003 to nearly 20% in 2006. The highly variable nature both temporally and spatially (even at the station level) of macroalgae cover makes identifying long-term trends difficult, and a trend was not identified for macroalgae cover region-wide.

After 12 years of monitoring, the status (as defined by percent cover of stony corals, octocorals, sponges, and macroalgae) of the southeast Florida reef system has demonstrated some changes from 2003 to 2014. For example, a region-wide decrease in octocoral cover and region-wide increase in sponge cover has occurred. However, the long-term trend analysis completed for years 2003 through 2014 did not indicate consistent trends within major functional groups among counties or sites. This result indicates that local (site level) factors may be exerting more influence than regionalized factors. Identifying and separating these spatially and temporally variable stressors is a challenge.

The chronic nature of disturbances and the significant economic value of southeast Florida reefs require comprehensive, long-term monitoring to define and quantify change and to help identify threats to the ecosystem. The information generated by SECREMP provides scientifically valid status and trends data designed to help local resource managers understand the implications of actions occurring in terrestrial and adjacent marine habitats. However, SECREMP was established to be a monitoring project independent of coastal development projects and un-permitted incidents (e.g., ship groundings), and as such, most localized impacts from these activities are not specifically targeted by SECREMP. There is a need for more comprehensive, longer-term, and site-specific project and incident monitoring. Both continual region-wide monitoring (SECREMP) and improved incident-specific monitoring are necessary if resource managers are to develop sound management plans for coral reefs that permit sustainable use, and realization of the economic value, of these fragile marine ecosystems.

Introduction

The coral reef ecosystem in Florida extends approximately 577 km from the Dry Tortugas in the south, to the St. Lucie Inlet in the north. However, until 2003, the primary focus for long-term coral reef monitoring was limited to the Florida Keys and Dry Tortugas in Monroe County, with only limited attention directed towards the reefs off Miami-Dade, Broward, Palm Beach, and Martin counties. Coral reef monitoring efforts in the Keys grew with the establishment of the Florida Keys National Marine Sanctuary (FKNMS) in 1990. Since 1996, the Coral Reef Evaluation and Monitoring Project (CREMP) has documented changes in reef resources along the Florida Reef Tract, from Key West to Carysfort (Ruzicka et al. 2010; Ruzicka et al. 2013). In 1999, the project was expanded to include sites in the Dry Tortugas.

In 2003, CREMP was further expanded to include 10 sites offshore of southeast Florida in Miami-Dade, Broward, and Palm Beach counties. The project has since been expanded three times. In 2006, three sites in Martin County offshore of the St. Lucie Inlet Preserve State Park were established; in 2010, two new sites in Palm Beach County and two new sites in Miami-Dade County were established; and in 2012 three new sites in Broward County and Miami-Dade County were established (one site in Martin County was discontinued). This CREMP expansion, named the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP), is filling gaps in coverage of knowledge and monitoring of coral reef ecosystems in Florida and nationwide through annual sampling of 22 sites.

Off the mainland coast of southeast Florida, the northern extension of Florida's coral reef ecosystem extends beyond the Florida Keys, approximately 170 km from Miami-Dade County into Martin County. From Cape Florida (Miami-Dade County), north to central Palm Beach County, in particular offshore of Broward County, the reef system is described as a series of linear reef complexes (referred to as reefs, reef tracts, or reef terraces) running parallel to shore (Moyer et al. 2003; Banks et al. 2007; Walker et al. 2008) (Figure 1). The Inner Reef (also referred to as the "First Reef") crests in 3 to 7 m depths. The Middle Reef ("Second Reef") crests in 12 to 14 m depths. A large sand area separates the Outer and Middle Reef complexes. The Outer Reef ("Third Reef") crests in 15 to 21 m depths. The Outer Reef is the most continuous reef complex, extending from Cape Florida to northern Palm Beach County. Inshore of these reef complexes, there are extensive nearshore ridges and colonized pavement areas. From Palm Beach County to Martin County, the reef system is comprised of limestone ridges and terraces colonized by reef biota (Walker and Gilliam 2013).

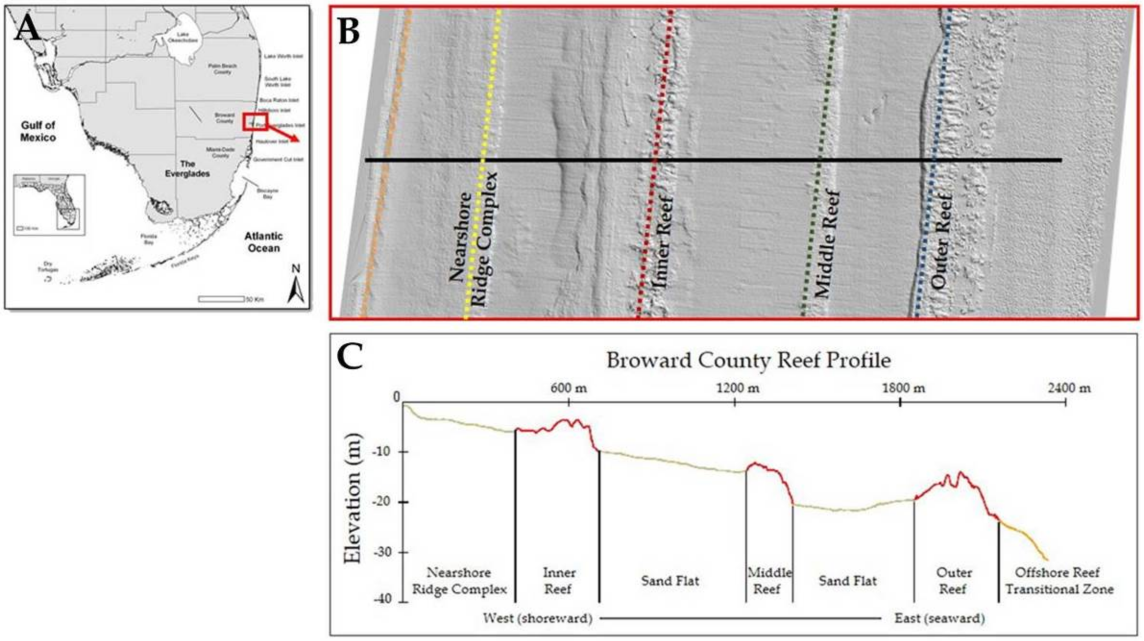

Figure 1. Panel A is a view of southern Florida showing an area off Broward County in red that corresponds to Panel B which is sea floor bathymetry from LIDAR (Light Detection and Ranging) data. The black line in Panel B shows the location of a bathymetric profile illustrated in Panel C.

Most previous and current monitoring efforts (e.g., Gilliam et al. 2015) along the mainland southeast coast originated as impact and mitigation studies from environmental impacts to specific sites (dredge impacts, ship groundings, pipeline and cable deployments, and beach renourishment). The temporal duration of monitoring efforts associated with marine construction activities are generally limited, defined by the activity permit, and focused on monitoring for project effects to the specific reference areas.

In 2003, the Florida Department of Environmental Protection (FDEP) proposed and was awarded funding for the inception of coral reef monitoring along the southeast Florida coast. To ensure that this monitoring is of the highest scientific quality, and consistent with CREMP monitoring in the Dry Tortugas and the FKNMS, the FDEP contracted this work to the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI) who in turn subcontracts Nova Southeastern University Oceanographic Center.

The southeast Florida reef system exists within 3 km of the mainland Atlantic coast, offshore of a highly urbanized area influenced by numerous impacts from commercial and recreational fishing and diving, major shipping ports, sewer outfalls, canal discharges, ship groundings, and marine construction activities. These reefs are important economic assets with an estimated $3.4 billion in sales and income generated from the natural reefs offshore southeast Florida (Johns et al. 2003, 2004). The goal of SECREMP is to provide local, state, and federal resource managers an annual report on the status and condition of the southeast Florida (Miami-Dade, Broward, Palm Beach, and Martin counties) reef system. These reports also provide resource managers with information on temporal changes in resource condition. SECREMP is also important for resource managers because, unlike previous southeast Florida monitoring efforts, the reef status and trend information is collected at a broad spatial scale and independently of marine construction activities, thereby providing results that are not directly tied to event response monitoring of these activities.

The current SECREMP effort includes 22 sites. Figures 2a and 2b show the location of the 22 sites along the southeast Florida coast. Project sampling is scheduled annually between May and August. Table 1 provides reef type, depths locations, and sample date of each of the SECREMP sites.

In 2011, CREMP made changes to the standard sampling methods, switching from video capturing to digital still image photography and replacing the standard Station Species Inventory (SSI) with demographic surveys of stony corals, octocorals, and the barrel sponge, *Xestospongia muta*. These changes were also adopted by the SECREMP program in 2012 (Gilliam et al. 2013).

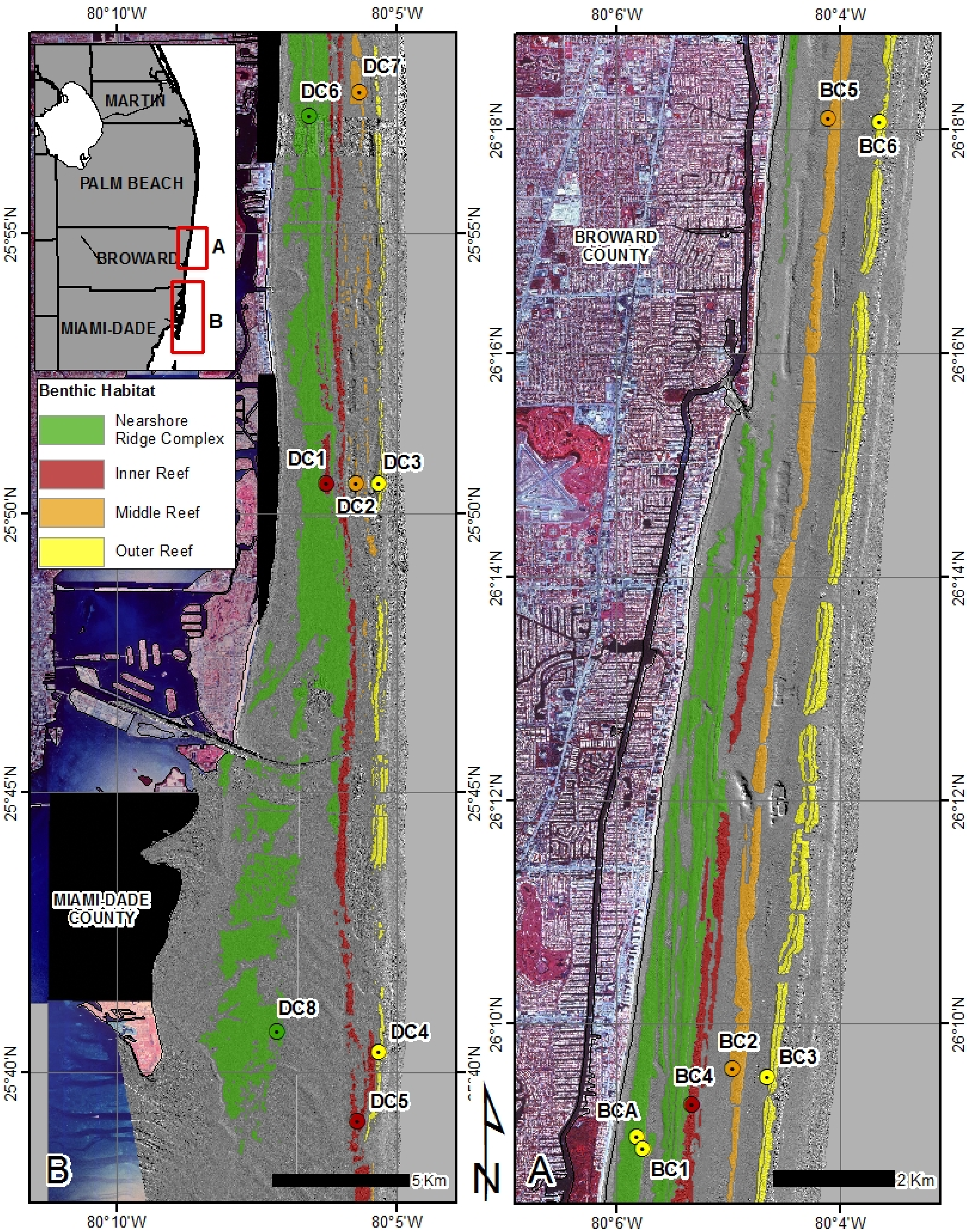

Figure 2a. Location and habitat map of Broward (panel A) and Miami-Dade (panels B and C) counties SECREMP sites.

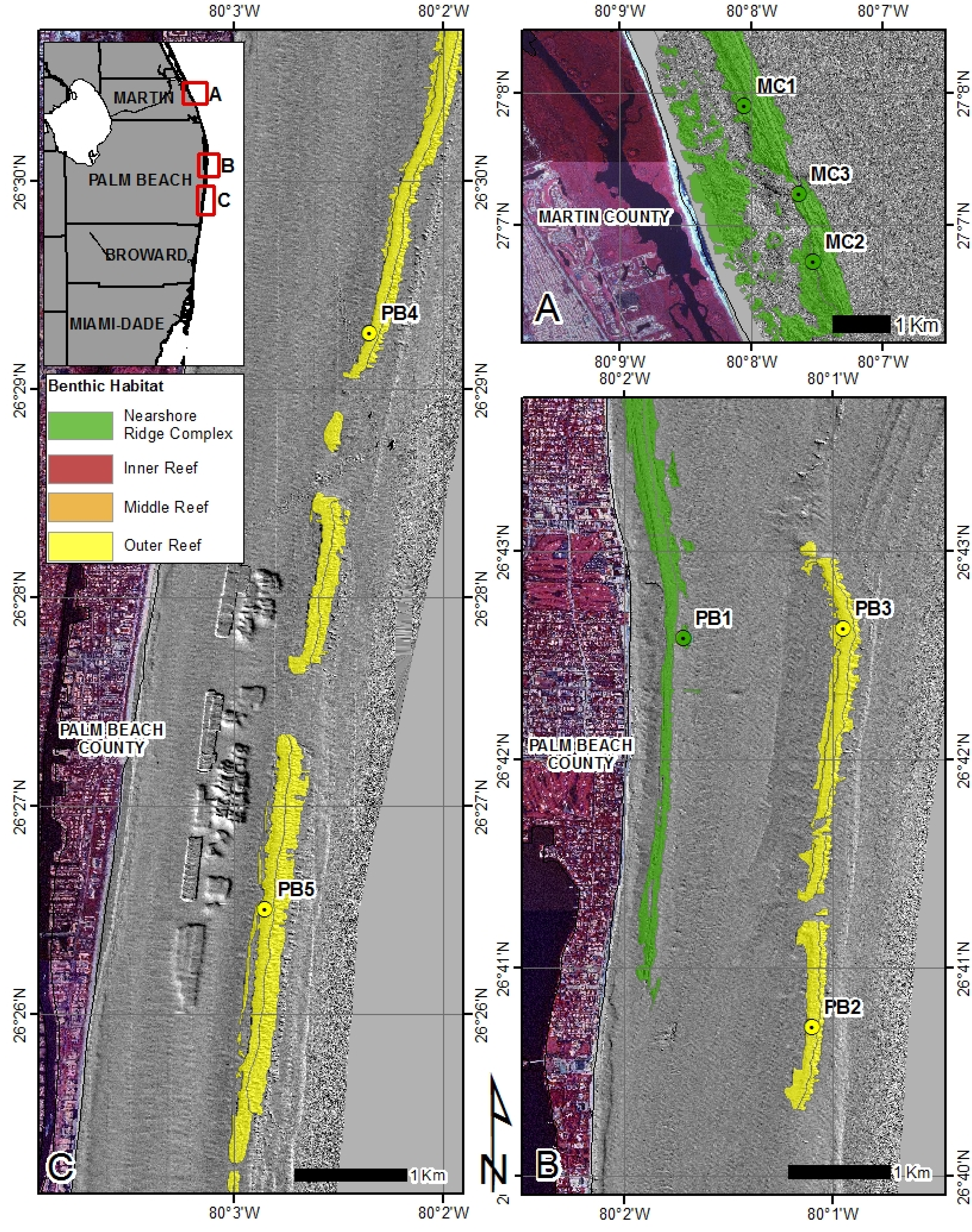

Figure 2b. Location and habitat map of Martin (panel A) and Palm Beach (panels B and C) counties SECREMP sites.

Table 1. Monitoring site reef type, depth (ft), location, and 2014 sample date (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County) (NRC = Nearshore Ridge Complex).

Site Code	Reef Type	Depth	Latitude (N)	Longitude (W)	Sample Date
DC1	Inner	25	25° 50.530’	80° 06.242’	18 June
DC2	Middle	45	25° 50.520’	80° 05.704’	24 June
DC3	Outer	55	25° 50.526’	80° 05.286’	18 June
DC4	Outer	41	25° 40.357’	80° 05.301’	30 June
DC5	Inner	24	25° 39.112’	80° 05.676’	30 June
DC6	NRC	15	25° 57.099’	80° 06.534’	20 June
DC7	Middle	55	25° 57.530’	80° 05.639’	20 June
DC8	NRC	15	25° 40.707’	80° 07.111’	8 Aug
BCA	NRC	25	26° 08.985’	80° 05.810’	9 June
BC1	NRC	25	26° 08.872’	80° 05.758’	12 June
BC2	Middle	40	26° 09.597’	80° 04.950’	9 June
BC3	Outer	55	26° 09.518’	80° 04.641’	12 June
BC4	Inner	30	26° 08.963’	80° 05.364’	12 June
BC5	Middle	45	26° 18.100’	80° 04.095’	20 Aug
BC6	Outer	55	26° 18.067’	80° 03.634’	20 Aug
PB1	NRC	25	26° 42.583’	80° 01.714’	16 July
PB2	Outer	55	26° 40.710’	80° 01.095’	17 July
PB3	Outer	55	26° 42.626’	80° 00.949’	16 July
PB4	Outer	55	26° 29.268’	80° 02.345’	18 July & 19 Aug
PB5	Outer	55	26° 26.504’	80° 02.854’	15 July
MC1	NRC	15	27° 07.900’	80° 08.042’	29 May
MC2	NRC	15	27° 06.722’	80° 07.525’	29 May

Methods

Each site consists of four monitoring stations delineated by permanent stainless steel markers. Stations are 2 m x 22 m. The SECREMP stations have a north-south orientation, which is generally parallel to the reef tracts of southeast Florida. Within each station, field sampling consists of one photo-image transect along the center 300 transect and one 1 m x 22 m belt-transect (Figure 3). Prior to 2014 all three transects (100, 300, and 500, as illustrated in Figure 3) were imaged (Gilliam et al. 2013). Following discussions with DEP and FWC partners, it was determined that documenting potential changes in percent functional group benthic cover was just as effective by just imaging the 300 transect. This image-transect reduction follows a similar effort by CREMP. The exception is site BCA where all three transects (100, 300, and 500) are still imaged to capture changes in the cover of *Acropora cervicornis*, a threatened species listed under the United States Endangered Species Act.

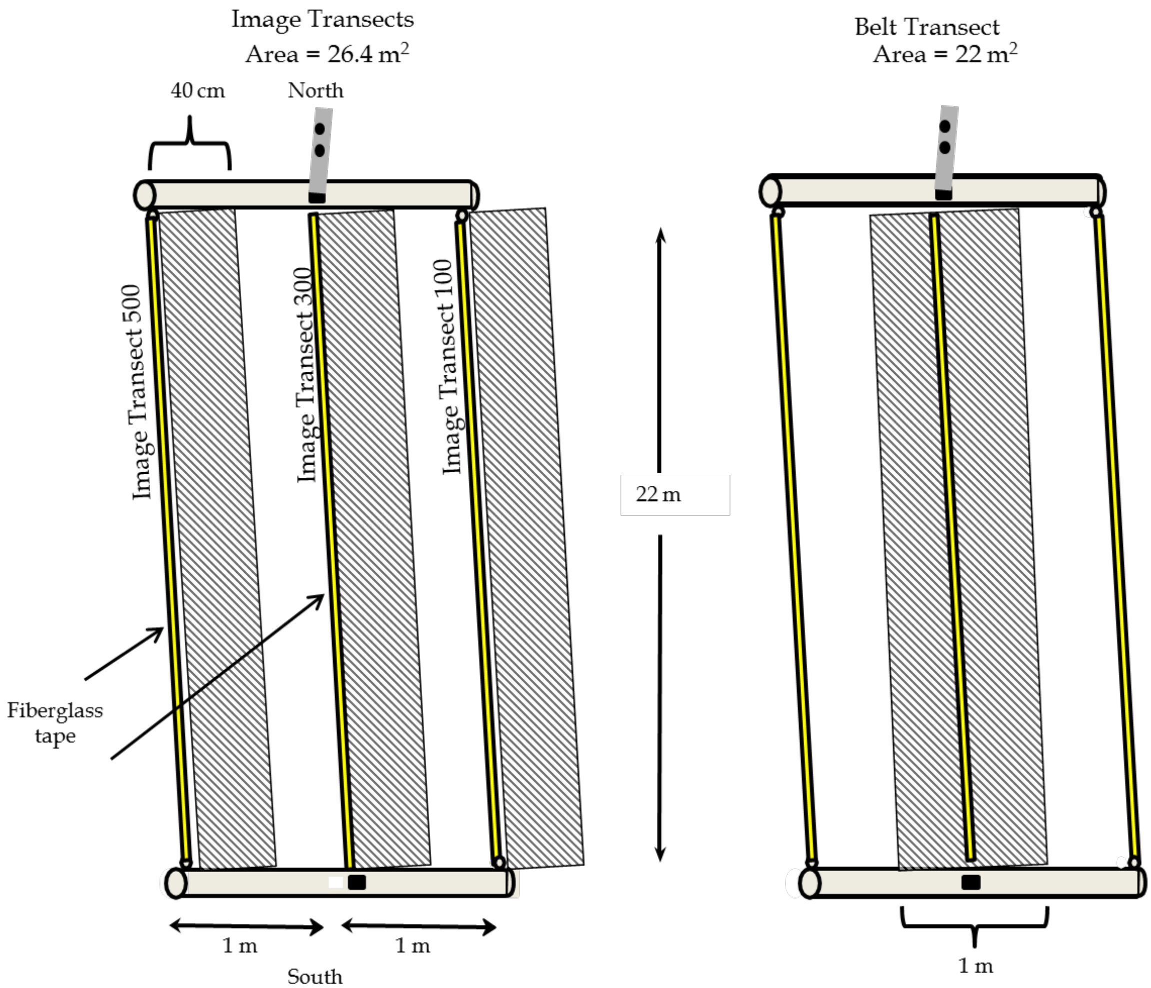

Figure 3. Layout of each SECREMP station showing the areas (hatch areas) within which the image and belt transect data were collected (note the gorgonian belt area is 1 m x 10 m). The 300 transect within each station was the only image transect in all sites except BCA which included all (100, 300, and 500) image transects.

Image Transects

All transect images, delineated with fiberglass tapes, were taken with a Canon PowerShot S95 digital camera. All transect images were taken on the east side of the transect tapes and were captured at a distance of 40 cm above the reef to yield an approximately 40 cm wide image. An aluminum bar aids in maintaining a constant height above the substrate. Prior to starting each transect, the camera operator photographed a clapperboard that provides information on the date and location of each transect. To ensure minimal overlap between images, benthic features seen in the top border of the camera viewfinder and the fiberglass tape were visual reference points used to proceed along the transect.

In the lab, images were formatted for PointCount '99 image analysis software. Fifteen random points were overlaid on each image. Underneath each point, select benthic taxa were identified to species (e.g. stony corals, *Gorgonia ventalina*, *Xestospongia muta*), genus (e.g. *Dictyota* spp., *Halimeda* spp., and *Lobophora* spp), or higher taxonomic levels (e.g. encrusting or branching octocoral, crustose coralline algae, zoanthid, sponge, and macroalgae). Un-colonized substrate was identified as sand or substrate (consolidated pavement or rubble). The software uses a "point and click" feature that enters the identification data into a spreadsheet. After all images were analyzed, the data were checked for quality assurance and entered into the Microsoft Access database.

Stony Coral Demographic Survey

In 2011, CREMP protocol was modified to collect colony density and size class information in addition to species richness. This modification allowed for an expanded assessment of the prevalence of disease, bleaching, or malignant conditions that adversely affect corals. The revised demographic survey protocol is similar to those used along the entire Florida Reef Tract by the Florida Reef Resilience Program (FRRP) (Wagner et al. 2010) and locally, by the Broward County annual reef monitoring project (Gilliam et al. 2015). These modifications were adopted by SECREMP in 2012 (Gilliam et al 2013). At all stations, divers conducted a 1 m x 22 m belt transect from north to south along the "300" transect (Figure 3) (note: CREMP surveys a 1 m x 10 m transect). Every stony coral species present was recorded and all colonies ≥ 4 cm diameter were measured to the nearest cm with a ruler affixed to the 0.5 m PVC stick. The maximum diameter and height taken along growth plane, the presence of disease, clionaids and bleaching, the percentage of estimated tissue mortality, and the cause of the mortality, if known, were recorded for each colony. Mortality was considered ''recent'' if the corallite structure can be clearly distinguished, and there is minimal overgrowth by algae or other fouling organisms. Otherwise, mortality was classified as ''old''. *Millepora alcicornis* (fire coral) colony presence or absence only was recorded. For summary analyses colony sizes were grouped into five (diameter) classes: small (4–10 cm), medium (10-30 cm), medium-large (31-50 cm), large (51-100 cm), and extra-large (> 100 cm).

Octocoral Demographic Survey

An octocoral demographic survey was added to the SECREMP methods in 2012 (Gilliam et al. 2013). As before, these methods follow those adopted by CREMP. At all stations, divers conducted a 1 m x 10 m octocoral survey along the 300 transect (Figure 3). The survey was completed in two stages. First, all octocoral colonies within the belt transect were counted, regardless of species, to provide a measurement of overall octocoral density. Second, for five target species of octocorals, *Eunicea calyculata*, *Antillogorgia americana* (formerly *Pseudopterogorgia americana*), *Eunicea flexuosa* (formerly *Plexaura flexuosa*), *Pseudoplexaura porosa*, and *Gorgonia ventalina*, all colonies within the belt transect were recorded and measured. These species were selected because they can be distinguished in the field, and they are relatively abundant in their preferred reef habitat along the Florida Reef Tract. For each colony recorded, maximum height and maximum width were recorded for *G. ventalina* and maximum height only for the other five species. Colonies were measured to the nearest centimeter with a ruler affixed to the 0.5 m PVC stick. The presence of disease, syndromes, or bleaching was recorded for each species in addition to any condition leading to compromised health of the colony (e.g., predation, overgrowth). For summary analyses octocoral sizes (height) were grouped into four size classes: recruit (≤ 5 cm), small (5–25 cm), medium (25-50 cm), and large (> 50 cm).

Barrel Sponge Demographic Survey

A barrel sponge (*Xestospongia muta*) survey was also added to the SECREMP methods in 2012. Barrel sponge density is determined by counting all sponges within the belt transect (1 m x 22 m) (Figure 3). Maximum sponge diameter, base diameter, and height were recorded. The percent of the sponge affected by injury, disease, and/or bleaching were also recorded. For summary analyses barrel sponge sizes (maximum sponge diameter) were grouped into four size classes: recruit (≤ 5 cm), small (5–20 cm), medium (21-50 cm), and large (> 50 cm).

Monitoring Site Temperature Record

In 2007, the deployment of Onset (www.onsetcomp.com) temperature loggers was added to the SECREMP sampling protocol. Throughout the course of the project three models of temperature loggers have been deployed, StowAway TidbiT™, Hobo Pendant Temperature Data Logger, and Hobo Water Temp Pro v2. Two temperature recorders were deployed at each site and were replaced during each annual sampling event. The loggers were programmed to record data at a sampling interval of two hours. Two loggers were deployed at each site in order to provide backup data in case one logger fails or is lost due to loggers remaining on site for a year. The two loggers were attached approximately 10 cm off the substrate to the 'northern' stake identifying Stations 1 and 2. Data from both loggers were downloaded. If data from both loggers were successfully downloaded, the data from the logger attached to Station 1 was reported.

Statistical Analyses

Differences in stony coral, octocoral, and barrel sponge density (colonies/m^2) between years 2013 and 2014 were tested region-wide (22 sites) using Student's t-Test in the publicly available software R (version 3.2.0).

Differences in stony coral, macroalgae, octocoral, and sponge percent cover between 2013 and 2014 at each site were tested using a two-way mixed model ANOVA, with year and site (stations nested within site) as fixed effects. Station data were pooled and square-root transformed. Significant differences within sites between years were identified using a Bonferroni adjusted ($p \leq 0.002$) post-hoc Tukey-Kramer test. All analyses were completed using a generalized linear mixed model (GLIMMIX) with SAS/STAT® v 9.2 software.

Long-term trends in benthic cover (stony coral, macroalgae, octocoral, and sponge) were examined using a generalized mixed model regression in SAS v 9.2. Trend analyses followed those completed for the CREMP analyses (Ruzicka et al. 2013). Trends were examined at the site level with stations as replicates (n = four stations per site) and region-wide with the data averaged for 12 sites. County-wide summaries were not analyzed statistically because of design constraints and limited within county replication. Benthic percent cover variables for each station at each of the 10 sites sampled from

2003-2014 (BCA, BC1, BC2, BC3, DC1, DC2, DC3, PB1, PB2, PB3) and two from 2006-2014 (Martin County Sites MC1 and MC2) were pooled and square root-transformed. Stations were nested within sites to provide long-term trend information at the site and region level. A 2-sided *t*-test was used to determine whether the slope of the regression was significantly different from zero. Model residual met all assumptions for normality and homogenous variance. For trend analysis of sites (not region), a post hoc Bonferroni adjustment ($p < 0.0042$) was used to determine significance in order to reduce the possibility of Type I error due to the repeated testing of the same response variable. Lower statistical power and the Bonferroni correction limited the number of sites for which a significant trend in cover was identified.

Year 12 (2014) Results

Stony Coral Demographic Survey

For the region (n = 22 sites) mean (±SD) stony colony density (colonies/m²) was 1.26 ± 0.90. Mean (±SD) stony coral density (colonies ≥ 4 cm/m²) for each site is shown in Table 2. Density ranged from a high of 3.75 ± 0.43 colonies/m² at site BC4 to a low of 0.27 ± 0.35 colonies/m² at site PB1. BCA density does not include *Acropora cervicornis* because the colony density at this site does not permit counting individual colonies. Region-wide there was no significant difference determined for stony coral density between 2013 and 2014 (t-test, $p > 0.05$).

Figure 4 illustrates the stony coral size (colony diameter) distribution by size class for the region. The stony coral community in the region is dominated by small (4–10cm) and medium (10-30 cm) sized colonies. Region-wide mean (±SD) stony colony size was 15.92 ± 16.47 cm. PB1 had the smallest mean colony size (6.83 ± 1.93 cm) compared to BC1 which had the largest (37.43 ± 27.05 cm).

Table 2. Mean stony coral site density (colonies ≥ 4 cm/m²) (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County).

Site	Density ± SD	Site	Density ± SD
DC1	2.10 ± 0.32	BC4	3.75 ± 0.43
DC2	1.08 ± 0.27	BC5	1.09 ± 0.51
DC3	0.33 ± 0.07	BC6	0.59 ± 0.15
DC4	0.75 ± 0.23	BCA	0.58 ± 0.33
DC5	2.55 ± 0.29	PB1	0.27 ± 0.35
DC6	1.42 ± 0.50	PB2	1.24 ± 0.17
DC7	1.02 ± 0.23	PB3	1.18 ± 0.67
DC8	0.82 ± 0.13	PB4	1.62 ± 0.63
BC1	2.16 ± 0.66	PB5	2.20 ± 0.58
BC2	0.78 ± 0.24	MC1	1.06 ± 0.22
BC3	0.76 ± 0.43	MC2	0.40 ± 0.10

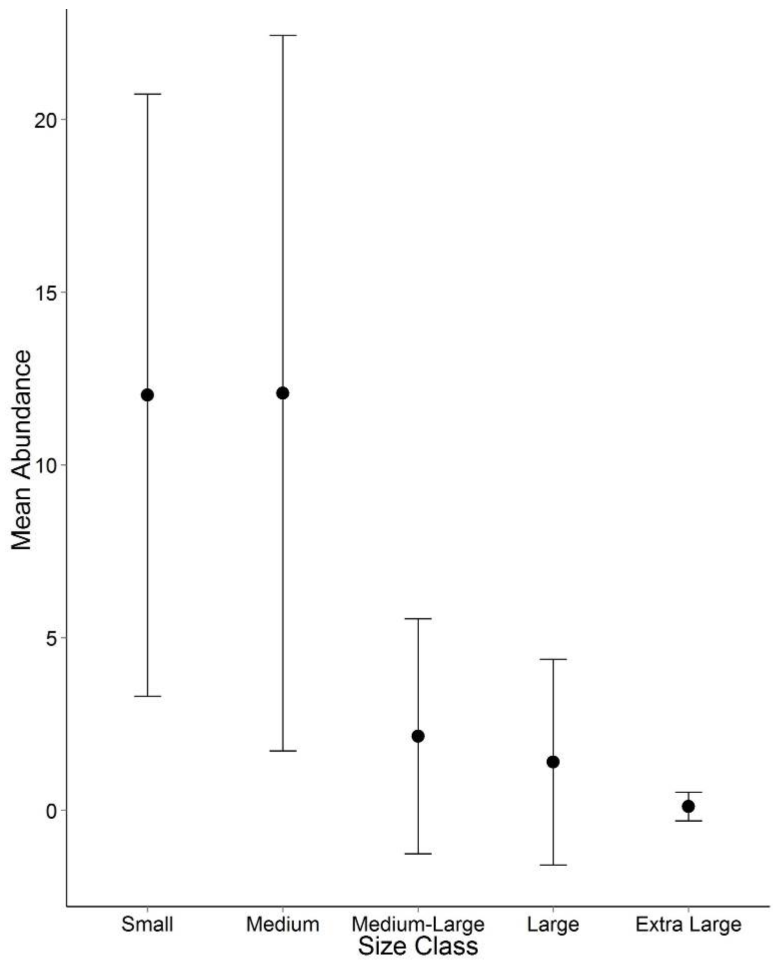

Figure 4. Mean (± SD) region-wide stony coral site abundance (number of colonies) by colony size class (small = 4–10cm, medium =10-30 cm, medium-large = 31-50 cm, large = 51-100 cm, and extra-large = >100 cm).

A total of 28 stony coral species were identified in the 22 sites and 26 were included in the demographic survey (colonies ≥ 4 cm). *Millipora alcicornis* was only recorded as presence/absence, and *Acropora cervicornis* was not included in the demographic survey because individual colonies could not be measured at site BCA which is dominated by *A. cervicornis*. A region-wide mean (±SD) of 7.97 ± 2.89 species per site and a range of 3.50 ± 0.58 (BCA) to 13.25 ± 1.50 (BC4) species within a site was documented. Six species (*Porites astreoides*, *Montastraea cavernosa*, *Siderastrea siderea*, *Stephanocoenia intersepta*, *Agaricia agaricites*, and *Meandrina meandrites*) were very common region-wide and contributed more than 80% to total colony abundance in each county. Twenty-six species were identified in the Miami-Dade sites, 22 in the Broward sites, 19 in the Palm Beach sites, and nine in Martin sites. Appendix 1 lists all the species identified and presence/absence for each site. The order of species in Appendix 1 represents the project (n = 22 sites) most to least abundant species (top to bottom).

Within the region stony coral colonies with the appearance of active disease were recorded within 10 of the 22 sites affecting 28 total colonies. These 28 colonies represent a region-wide disease prevalence of 1.2%. Nine species were recorded and the disease conditions included black band disease (two colonies), yellow band (two colonies), ‘white disease’ (14 colonies), and dark spot (10 colonies). Of the 28 total colonies, 10 were *S. siderea* colonies with dark spot syndrome. A white syndrome referred to as rapid tissue loss was identified on *Acropora cervicornis* colonies in site BCA and DC1.

Octocoral Demographic Survey

Mean (±SD) octocoral colony density (colonies/m²) for the project (n = 22 sites) was 9.97 ± 7.93. Mean (±1SD) octocoral density for each site is shown in Table 3. Density ranged from a high of 27.02 ± 9.22 colonies/m² at site PB5 to a low of 0.00 ± 0.00 colonies/m² at site MC1. Region-wide no significant difference was determined for octocoral density between 2013 and 2014 (t-test, $p > 0.05$).

No target octocoral species were identified in site PB1 or the Martin County sites (MC1 and MC2). The five target species (*E. calyculata, A. americana, E. flexuosa, P. porosa*, and *G. ventalina*) were identified in all counties (except Martin). *Antillogorgia americana* and *E. flexuosa* were identified in 19 sites. Table 3 presents the mean (±SD) density (colonies/m²) for the target species for each site. Region-wide there was no significant difference determined for target octocoral species density between 2013 and 2014 (t-test, $p > 0.05$). In the region, A*ntillogorgia americana* density was the greatest of the six species followed by *E. flexuosa, E. calyculata, G. ventalina*, and *P. porosa.*

Figure 5 illustrates the octocoral size (colony height) distribution by size class for the region. These data are based on the five target species. Small (5–25cm) colonies contribute most to the octocoral community while the recruit (≤5 cm) size class contributed the least. Region-wide mean (±SD) octocoral size was 26.82 ± 20.53 cm. BC5 had the smallest mean colony size (19.44 ± 14.30 cm) compared to PB4 which had the largest (37.15 ± 24.15 cm).

Table 3. Mean (±SD) octocoral density (colonies/m²) for each site (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County).

Site	Total Density ± SD	Target Density ± SD	Site	Total Density ± SD	Target Density ± SD
DC1	8.18 ± 1.48	2.80 ± 0.70	BC4	3.95 ± 1.93	2.23 ± 0.05
DC2	14.25 ± 3.60	4.8 ± 1.51	BC5	7.45 ± 1.12	3.90 ± 1.07
DC3	7.22 ± 2.45	2.67 ± 1.09	BC6	19.27 ± 3.83	5.17 ± 0.72
DC4	12.43 ± 6.36	3.70 ± 0.00	BCA	0.85 ± 0.79	1.12 ± 1.24
DC5	7.15 ± 1.61	5.40 ± 1.84	PB1	0.18 ± 0.17	0.00 ± 0.00
DC6	8.12 ± 1.95	3.20 ± 0.72	PB2	20.55 ± 10.63	5.03 ± 1.60
DC7	3.83 ± 0.28	2.20 ± 0.00	PB3	12.45 ± 5.12	4.97 ± 1.12
DC8	16.28 ± 3.39	3.27 ± 0.84	PB4	17.65 ± 2.17	3.55 ± 0.62
BC1	11.15 ± 1.97	2.02 ± 0.62	PB5	27.02 ± 9.22	5.85 ± 0.66
BC2	8.65 ± 2.60	3.40 ± 1.18	MC1	0.00 ± 0.00	0.00 ± 0.00
BC3	12.75 ± 2.59	2.75 ± 0.64	MC2	0.02 ± 0.05	0.00 ± 0.00

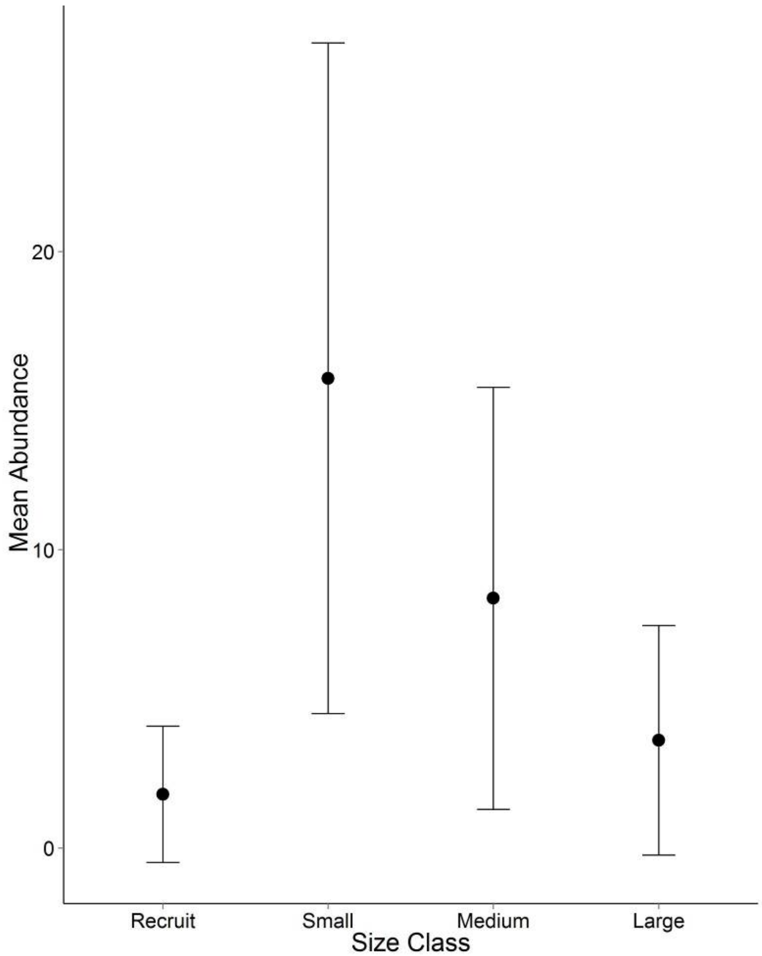

Figure 5. Mean (± SD) region-wide site abundance (number of colonies) of octocorals by colony size class (recruit = ≤5 cm, small = 5 – 25 cm, medium = 25-50 cm, and large = > 50 cm.

Barrel Sponge Demographic Survey

Mean (±SD) barrel sponge density (colonies/m²) for the project (n = 22 sites) was 0.30 ± 0.27. Table 4 summarizes the mean (±SD) barrel sponges (*Xestospongia muta*) densities (sponges/m²) for each site. *Xestospongia muta* were identified in all counties except Martin and in 18 of the 22 sites. No *X. muta* were identified in sites BCA, PB1, MC1, and MC2 (Table 4). In sites which had *X. muta* present, densities ranged from a high of 0.74 ± 0.17 sponges/m² at site PB5 to a low of 0.02 ± 0.05 sponges/m² at site DC1.

Figure 6 illustrates the barrel sponge size (max diameter) distribution by size class for the region. The small (5–20cm) and medium (21-50 cm) size classes contribute more to the barrel sponge community than the recruit (≤ 5 cm) or large classes (> 50 cm). Region-wide mean (±SD) octocoral size was 26.82 ± 20.53 cm. DC1 had the smallest mean colony size (4.00 ± 3.46 cm) compared to DC5 which had the largest (31.89 ± 18.72 cm).

Table 4. Mean barrel sponge (*Xestospongia muta*) density (sponges/m²) for each site (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County).

Site	Density ± SD	Site	Density ± SD
DC1	0.02 ± 0.05	BC4	0.27 ± 0.06
DC2	0.41 ± 0.00	BC5	0.49 ± 0.27
DC3	0.30 ± 0.16	BC6	0.42 ± 0.22
DC4	0.61 ± 0.09	BCA	0.00 ± 0.00
DC5	0.10 ± 0.07	PB1	0.00 ± 0.00
DC6	0.01 ± 0.02	PB2	0.18 ± 0.06
DC7	0.34 ± 0.06	PB3	0.66 ± 0.15
DC8	0.00 ± 0.00	PB4	0.70 ± 0.14
BC1	0.17 ± 0.13	PB5	0.74 ± 0.17
BC2	0.50 ± 0.10	MC1	0.00 ± 0.00
BC3	0.62 ± 0.16	MC2	0.00 ± 0.00

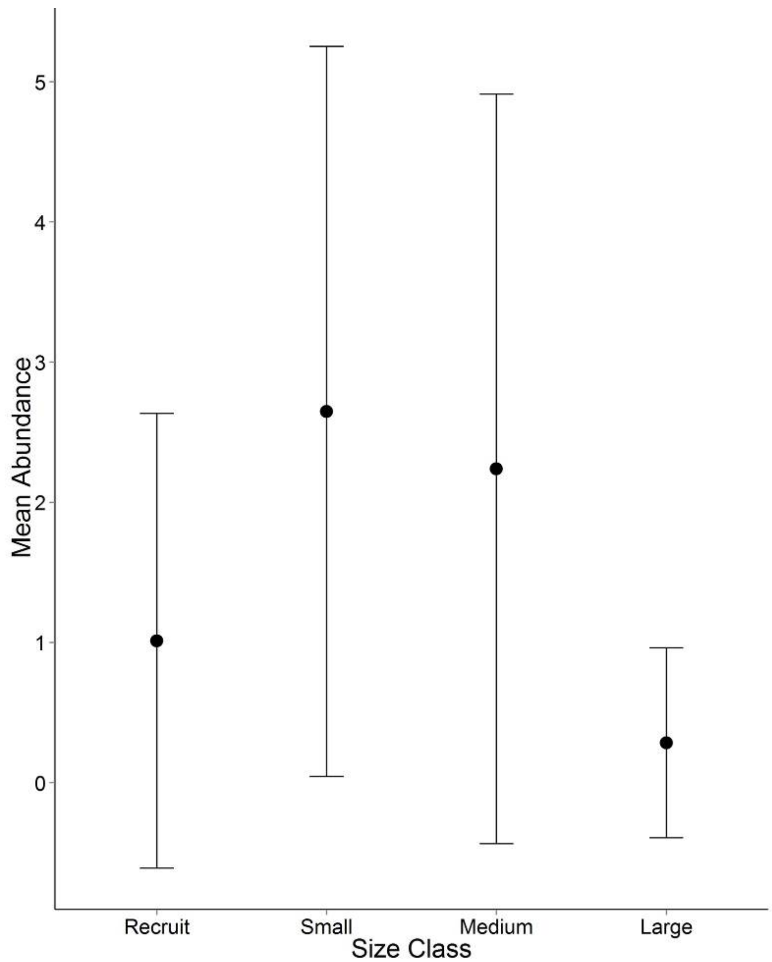

Figure 6. Mean (± SD) region-wide site abundance (number of sponges) of barrel sponges by sponge size class.

Benthic Functional Group Percent Cover Year-to-Year Analysis: 2013 vs. 2014

Region-wide (n = 22 sites) mean (±SD) stony cover in 2013 (2.8 ± 0.04%) was not significantly different than the mean in 2014 (2.6 ± 0.04%) (Table 5). There was no significant differences determined region-wide or at the site level for stony coral cover from 2013 to 2014 (Table 5). In 2014, stony coral cover was less than 3% at all sites except sites DC1, BCA, BC1, BC4, and MC1. Site BCA had the greatest cover (14%) and is dominated by an *A. cervicornis* patch, and BC1 (12%) is in an area of increased abundance of larger (1 m diameter) *M. cavernosa* stony coral colonies.

There was no significant difference determined in mean (±SD) octocoral cover region-wide (n = 22 sites) in 2013 (9.9 ± 6.8%) compared to 2014 (9.6± 6.4%) (Table 5). However, two sites (BC2 and DC1) were determined to have significantly greater octocoral cover in 2014 than in 2013 (Table 5), while one site (BC3) was determined to have significantly less octocoral cover in 2014 than in 2013. Of the four major functional groups examined for year-to-year comparisons, octocorals contribute most to benthic cover ranging from a low of less than 0.1% in the Martin County sites (MC1 and MC2) to a high of over 15% in four sites (BC6, PB2, PB4, and PB5) (Table 5).

Mean (±SD) sponge cover significantly increased in 2014 (5.5 ± 3.6%) from 2013 (5.2 ± 3.3%) region-wide (Table 5). One site was determined to have significantly greater sponge cover in 2014 (PB1), and one site (BCA) was determined to have significantly less sponge cover in 2014. In 2014, sponge cover was greater than 3% at 18 of the 22 sites (exceptions were sites BCA, DC1, DC6, and MC1). Two sites (PB3 and PB4) had cover greater than 10% (Table 5).

Region-wide mean (±SD) macroalgae cover in 2014 (10.3 ± 9.6%) was significantly greater than the mean in 2013 (9.2 ± 12.0%) (Table 5). Three sites BC3, DC3, and DC5) were determined to have significantly greater cover in 2014 than in 2013 (Table 5).

One site (DC1) was determined to have significantly less cover in 2014 (Table 5). Because macroalgae cover is both temporally and spatially (even at the station level) variable, the cover estimates within the sites ranged from a low of 1% (PB2) to a high of 39% (MC2). Five sites (BC4, DC5, PB5, MC1, and MC2) had cover greater than 15% (Table 5).

Table 5. Mean (±SD) stony coral, octocoral, sponge, and macroalgae percent cover in 2013 and 2014 (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County). A 2-way mixed model ANOVA was used to detect difference between years (NS = not significant).

	Stony coral					**Octocoral**				
	2013		**2014**			**2013**		**2014**		
Site	**Mean**	**SD**	**Mean**	**SD**	**p**	**Mean**	**SD**	**Mean**	**SD**	**p**
DC1	4.24	1.84	5.44	3.30	NS	8.34	0.98	12.08	2.98	<0.001
DC2	0.95	0.97	1.55	0.81	NS	11.37	0.94	12.04	1.71	NS
DC3	0.24	0.13	0.40	0.34	NS	8.38	1.88	7.97	2.83	NS
DC4	1.52	1.00	1.36	1.12	NS	14.58	2.72	12.15	2.22	NS
DC5	1.59	0.55	2.94	2.15	NS	16.74	4.53	12.93	2.85	NS
DC6	2.50	0.96	2.86	1.59	NS	9.37	2.93	7.04	1.86	NS
DC7	0.51	0.17	0.50	0.33	NS	8.09	3.28	7.73	0.65	NS
DC8	1.51	1.10	1.51	0.68	NS	15.82	3.67	14.11	4.06	NS
BCA	10.93	3.35	13.85	3.38	NS	2.96	1.31	2.85	0.81	NS
BC1	12.67	3.86	12.27	3.47	NS	7.36	0.86	7.10	1.12	NS
BC2	0.73	0.86	0.78	0.41	NS	4.69	1.74	7.98	1.92	<0.001
BC3	0.69	0.65	0.61	0.45	NS	13.12	0.96	8.65	3.36	<0.001
BC4	4.04	1.84	4.23	1.76	NS	4.28	1.15	4.20	1.36	NS
BC5	1.49	0.61	1.08	0.78	NS	6.76	1.90	8.41	1.52	NS
BC6	0.76	0.38	0.58	0.46	NS	16.44	2.79	16.79	1.60	NS
PB1	0.11	0.12	0.03	0.05	NS	0.00	0.00	0.03	0.00	NS
PB2	1.68	0.75	2.09	1.33	NS	17.12	10.25	0.00	8.44	NS
PB3	1.49	0.90	1.27	0.85	NS	12.99	3.79	18.45	3.43	NS
PB4	1.70	0.84	1.73	0.85	NS	18.93	4.21	11.91	4.21	NS
PB5	1.94	1.16	2.35	0.75	NS	19.81	2.54	22.03	0.49	NS
MC1	2.97	2.94	3.60	3.91	NS	0.12	0.25	14.11	0.05	NS
MC2	1.52	1.26	1.12	0.77	NS	0.00	0.00	0.02	0.06	NS
Mean	2.54	3.41	2.83	3.84	NS	9.88	6.77	9.60	6.42	NS

Table 5. Continued.

	Sponge					Macroalgae				
	2013		2014			2013		2014		
Site	**Mean**	**SD**	**Mean**	**SD**	**p**	**Mean**	**SD**	**Mean**	**SD**	**p**
DC1	2.64	0.96	2.66	0.65	NS	15.26	6.83	3.60	1.24	<0.001
DC2	4.93	0.70	4.97	1.04	NS	5.73	5.41	5.59	3.68	NS
DC3	5.47	1.82	3.59	1.81	NS	1.13	0.74	6.49	1.87	0.002
DC4	7.50	3.08	7.34	2.89	NS	2.22	1.35	8.38	4.04	NS
DC5	3.50	1.13	4.22	1.89	NS	7.06	5.63	25.18	4.96	<0.001
DC6	2.28	0.76	2.14	0.75	NS	10.02	1.60	9.80	1.48	NS
DC7	7.52	2.21	7.47	2.96	NS	2.53	1.70	6.44	2.82	NS
DC8	2.58	0.56	3.19	0.85	NS	6.28	1.82	7.79	4.87	NS
BCA	3.58	3.19	0.72	0.70	<0.001	2.69	3.41	6.66	8.74	NS
BC1	3.25	0.59	3.72	1.15	NS	7.04	2.74	7.81	2.15	<0.001
BC2	5.22	1.00	5.67	1.26	NS	3.21	0.90	6.13	3.22	NS
BC3	6.42	1.00	5.09	1.10	NS	1.88	6.41	12.20	5.19	NS
BC4	3.01	0.71	3.93	0.95	NS	26.08	6.73	18.87	4.24	NS
BC5	6.92	1.02	7.11	2.29	NS	10.92	2.43	7.31	1.17	NS
BC6	3.80	1.41	5.92	2.67	NS	4.36	3.41	4.39	1.10	NS
PB1	1.82	2.04	3.47	3.75	<0.001	0.28	0.31	1.75	2.91	NS
PB2	7.44	0.90	8.47	1.42	NS	0.60	0.62	1.19	0.76	NS
PB3	10.65	1.76	12.26	3.19	NS	5.12	1.79	7.21	2.59	NS
PB4	12.69	5.58	13.34	4.34	NS	3.22	1.29	2.22	0.94	NS
PB5	8.60	2.56	9.79	1.50	NS	11.91	3.60	15.19	2.76	NS
MC1	1.54	0.67	2.72	0.86	0.009	23.38	13.04	23.05	5.53	NS
MC2	2.56	1.29	3.72	1.49	0.031	50.38	6.14	38.72	9.26	NS
Mean	5.18	3.40	5.52	3.65	0.047	9.15	12.0	10.27	9.56	<0.001

Long-Term Trends

Annual trends (2003-2014) for the region (pooled for 12 sites) in stony coral, octocoral, sponge, and macroalgae cover are presented in Figure 7. Annual trends for each county (sites within a county pooled) are presented in Figures 8-11 and are included to provide more detail for each county.

Region-wide there was no significant trend identified for stony coral cover (see Appendix 2 for the region-wide and site level statistical p-values). Mean stony coral cover has dropped within the 10 sites below 5% since 2005 (Figure 7) but much of this loss in cover is attributed to site BCA which is the only site to have experienced a significant trend of decreasing cover since 2003 (Appendix 2). BCA is a site dominated by *Acropora cervicornis* and cover in this site has dropped from a high of 40% in 2005 to a low of 14% in 2011. BCA cover did significantly increase to 14% in 2014 (Table 5). One site (DC1) has experienced a significant trend of increasing cover since 2003 (Appendix 2).

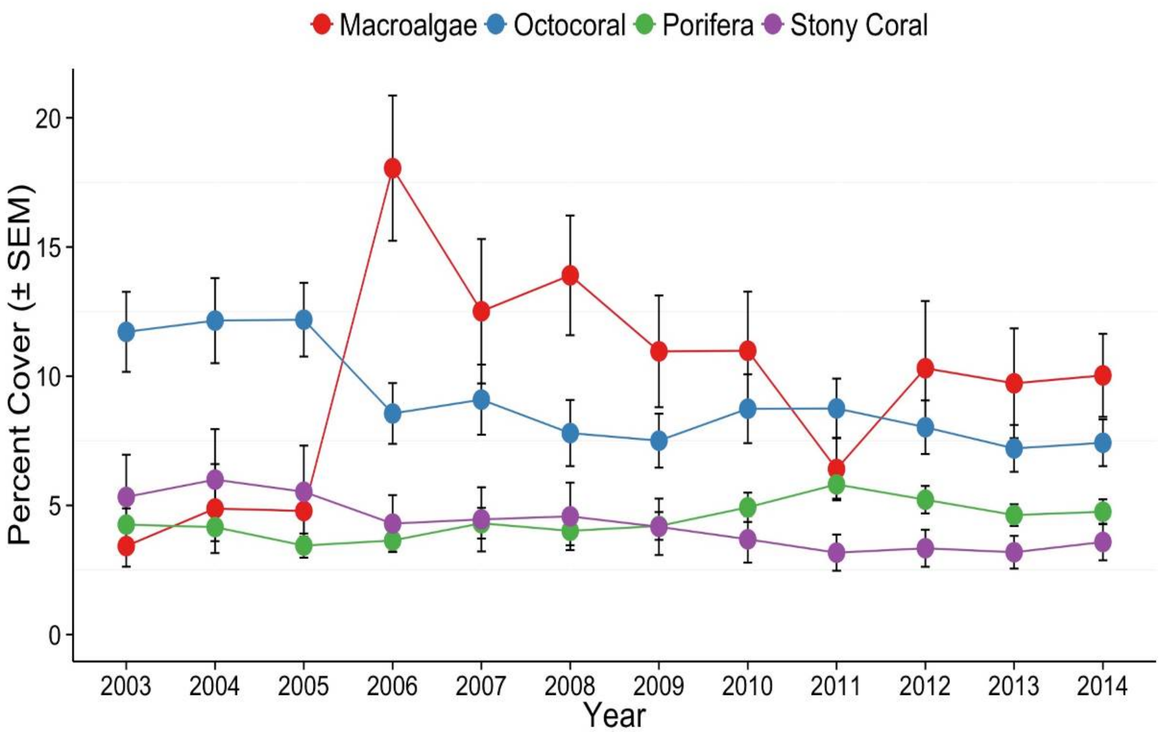

Figure 7. Mean region-wide (n = 10 sites 2003-2006 and 12 sites 2006-2014) annual stony coral, octocoral, sponge and macroalgae percent cover. No trend (mixed model regression; see Appendix 2 for statistical values) was identified for stony coral ($p > 0.44$) or macroalgae ($p > 0.35$) cover but a decreasing trend was identified for octocoral ($p < 0.01$) and an increasing trend for sponge ($p < 0.01$) cover.

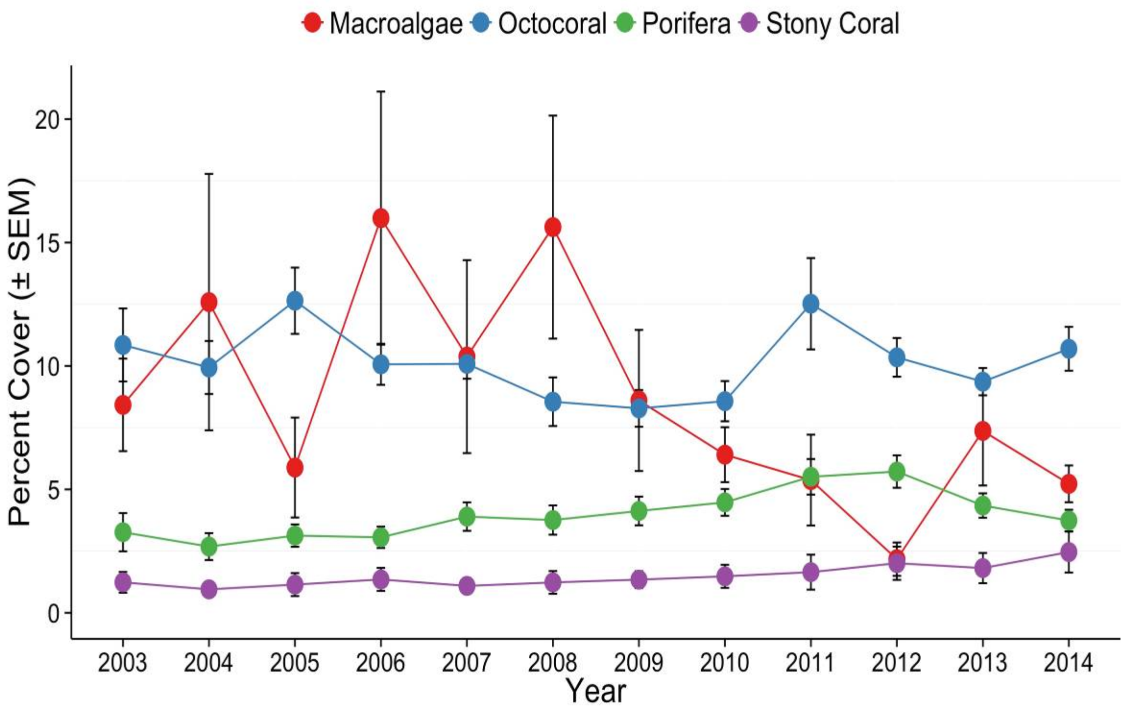

Figure 8. Mean Miami-Dade County (n = 3 sites) annual stony coral, octocoral, sponge, and macroalgae percent cover.

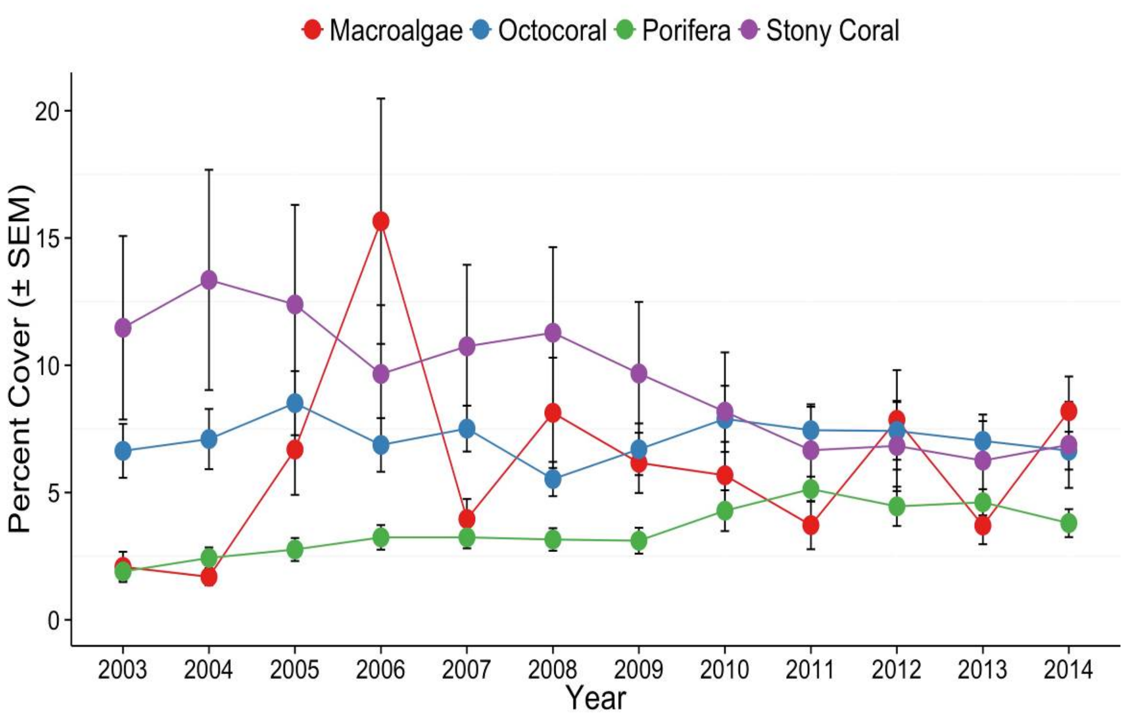

Figure 9. Mean Broward County (n = 4 sites) annual stony coral, octocoral, sponge, and macroalgae percent cover.

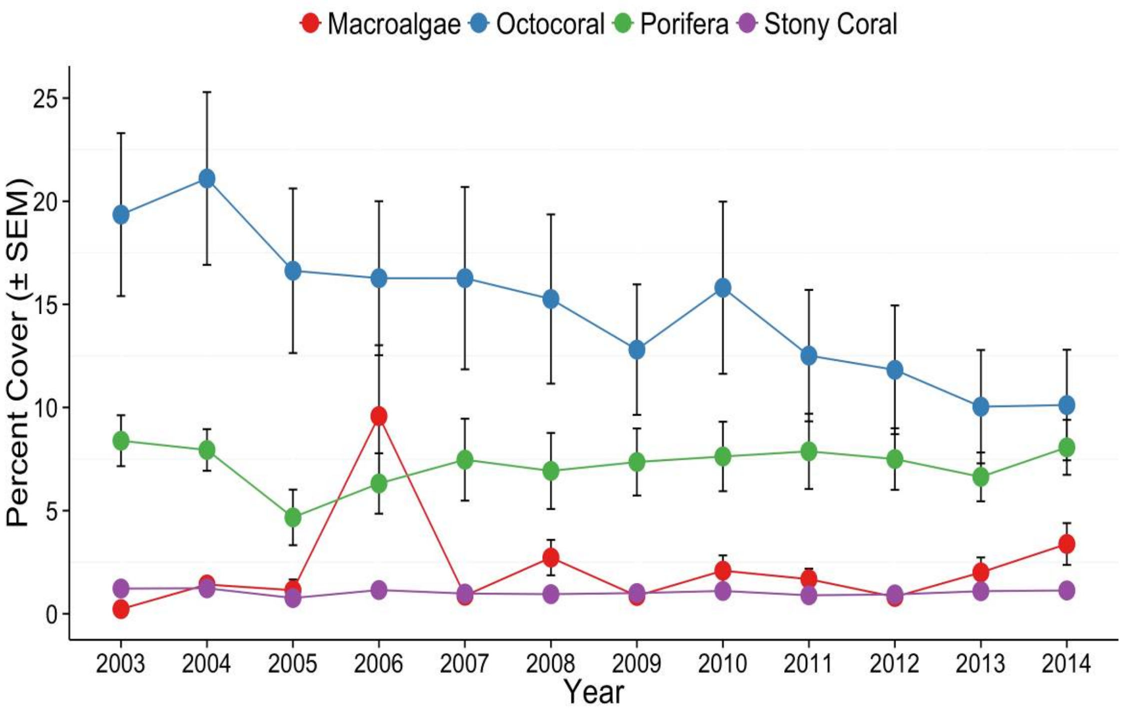

Figure 10. Mean Palm Beach County (n = 3 sites) annual stony coral, octocoral, sponge, and macroalgae percent cover.

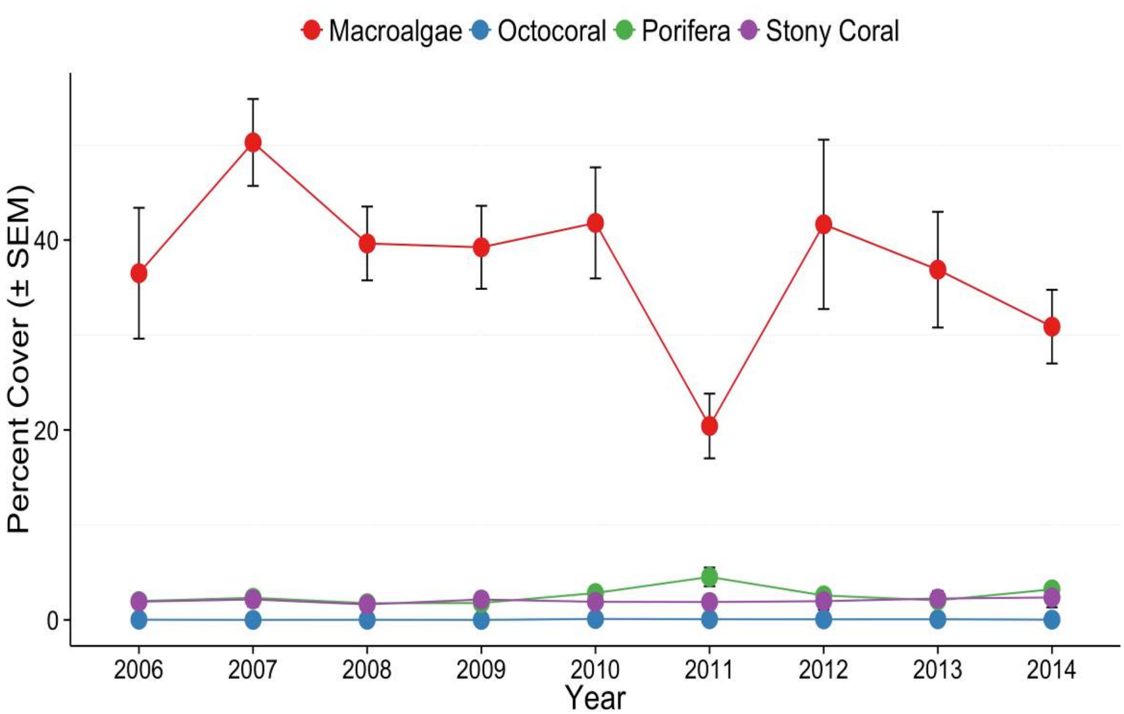

Figure 11. Mean Martin County (n = 2 sites) annual stony coral, octocoral, sponge, and macroalgae percent cover.

Region-wide there has been a significant decreasing trend identified for octocoral cover (Figure 7) (Appendix 2). Two sites (PB3 and PB1) were determined to have significant decreasing trends in octocoral cover since 2003. Site PB3 has decreased from 30% in 2004 to a low of 15% in 2012. Octocoral cover in PB1 has always been low but since 2006 has been less than 0.15%. One site (DC1) was determined to have a significant increasing trend in octocoral cover since 2003. DC1 has increased from 5% in 2003 to 12% in 2014.

Sponge cover has shown a significant increasing trend region-wide since 2003 (Figure 7) (Appendix 2). Most sites (Figures 8-11) show an increasing slope in sponge cover but no individual site has increased significantly. One (PB1) site was, however, determined to have a decreasing trend in sponge cover with a range of cover from 11% in 2004 to 1% in 2010.

As would be expected, macroalgae cover has fluctuated greatly over the last 12 years from less than 5% in 2003 to nearly 20% in 2006 and then back near to 10% in 2014 (Figure 7). The highly variable nature of macroalgae cover makes identifying long-term trends difficult, and no trend was identified for macroalgae cover region-wide (Appendix 2). One site showed a significant increasing trend (BC1) while one site showed a significant decreasing trend (DC1).

Site Temperature Record

Temperature loggers were deployed in 2007 at the 10 sites established in 2003. Loggers have also been deployed at all new sites (n = 12 and are collected and replaced during each sampling event. During the 2014 sites visits, temperature data were successfully downloaded at all 22 sites.

The 2014 sample dates shown in Table 2 are the same dates that temperature loggers were redeployed or deployed at each of the 22 sites. Table 6 presents the dates and maximum and minimum temperatures (°C) for each site from late winter 2007 into summer 2014. Figures 12-15 show the annual temperatures for the 22 sites by county. These figures illustrate the general warming trend (as expected) at all sites from February to August/September. Figure 15 also shows that the three Martin County sites tend to have lower winter temperatures (as low as 14°C in winter 2010) while much of the remaining year is similar to the southern counties.

Table 6. Maximum and minimum temperatures (°C) and dates for the 22 sites with temperature loggers winter 2007 through spring 2014.

	Maximum		**Minimum**	
Site	**Temp**	**Date**	**Temp**	**Date**
DC1	31.4	4 Aug 11	19.7	23 Jan 09
DC2	30.7	5 Aug 11	20.1	4 Mar 10
DC3	30.6	25 Aug 11	20.4	1 Feb 11
DC4	30.5	25 Aug 11	20.3	31 Jan 11
DC5	30.9	24 Aug 11	20.3	31 Jan 11
DC6	29.2	8 Oct 13	21.9	24 Jan 14
DC7	29.0	2 Oct 13	22.3	12 Mar 14
DC8	30.4	15 Aug 13	21.4	20 Jan 14
BCA	30.9	12 Aug 09	19.0	6 Feb 09
BC1	31.1	24 Aug 11	19.6	5 Mar 10
BC2	30.6	24 Aug 11	20.4	5 Mar 10
BC3	30.7	25 Aug 11	20.0	22 Feb 11
BC4	29.6	23 Aug 13	22.4	23 Mar 14
BC5	29.2	1 Oct 13	22.3	23 Mar 14
BC6	29.0	1 Oct 13	22.1	23 Mar 14
PB1	30.9	22 Aug 11	19.5	6 Mar 10
PB2	30.6	22 Aug 11	18.5	5 Apr 11
PB3	30.5	22 Aug 11	19.7	7 Mar 10
PB4	30.8	22 Aug 11	19.6	5 Apr 11
PB5	30.8	25 Aug 11	19.7	22 Feb 11
MC1	30.6	12 Aug 09	13.4	11 Jan 10
MC2	30.7	11 Aug 09	13.8	11 Jan 10

For the 16 sites (except PB3) established prior to 2013 during some period when temperatures have been recorded, the maximum temperature recorded was over 30.5°C (Table 7). These warm temperatures were generally recorded during the later summer months (August-September) of 2007, 2009, and 2011. No sites in 2013 experienced water temperatures over 30.5°C. The coolest temperatures were recorded during the winter months (January-March) of 2009, 2010, and 2011.

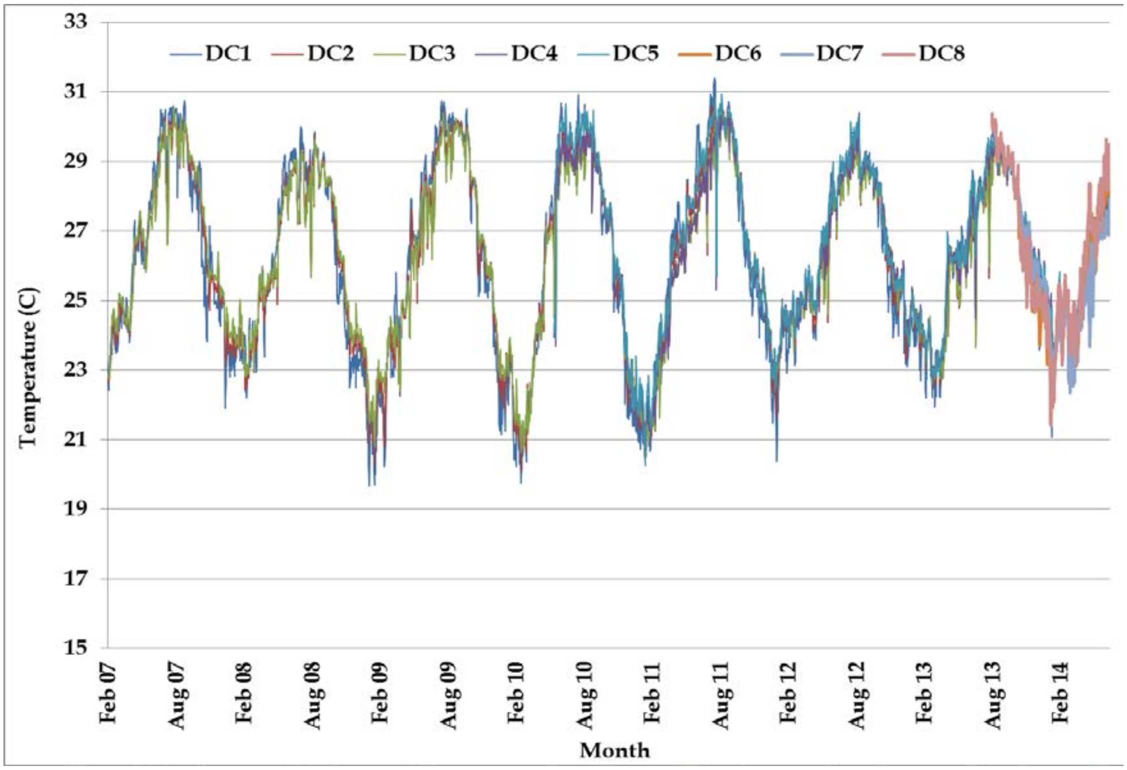

Figure 12. Mean daily temperatures (°C) for the five Miami-Dade County sites, February 2007 – June 2014

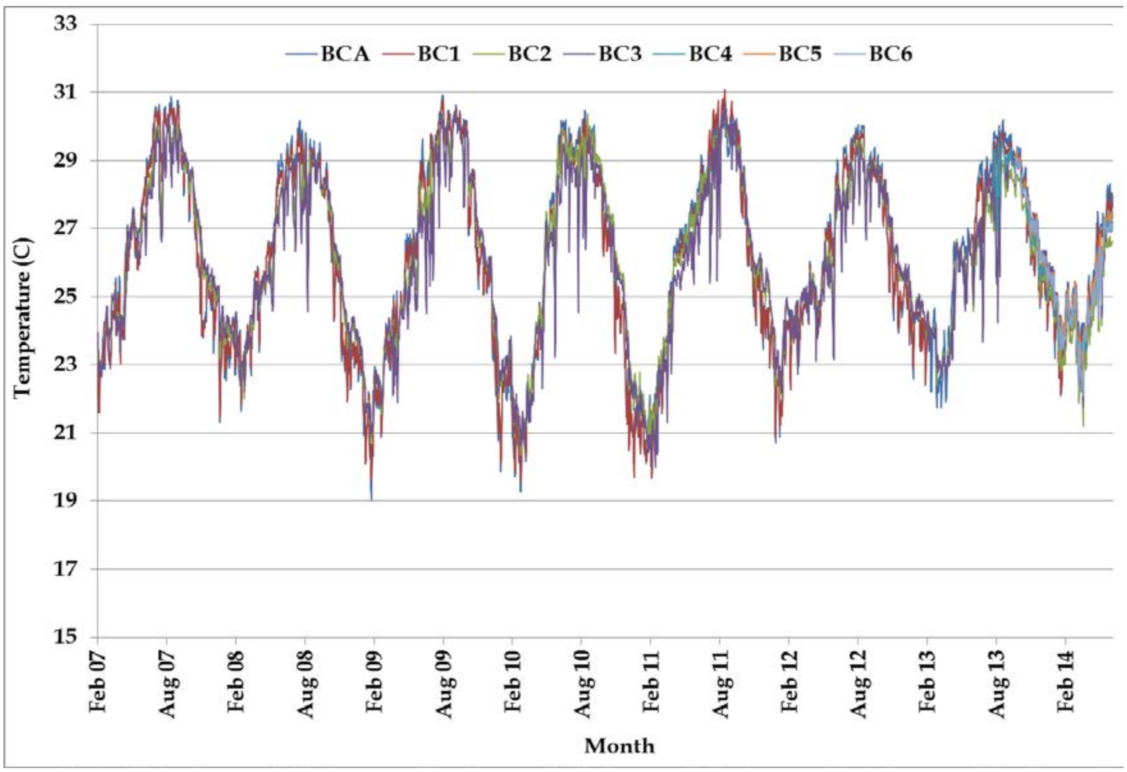

Figure 13. Mean daily temperatures (°C) for the four Broward County sites, February 2007 – June 2014**.**

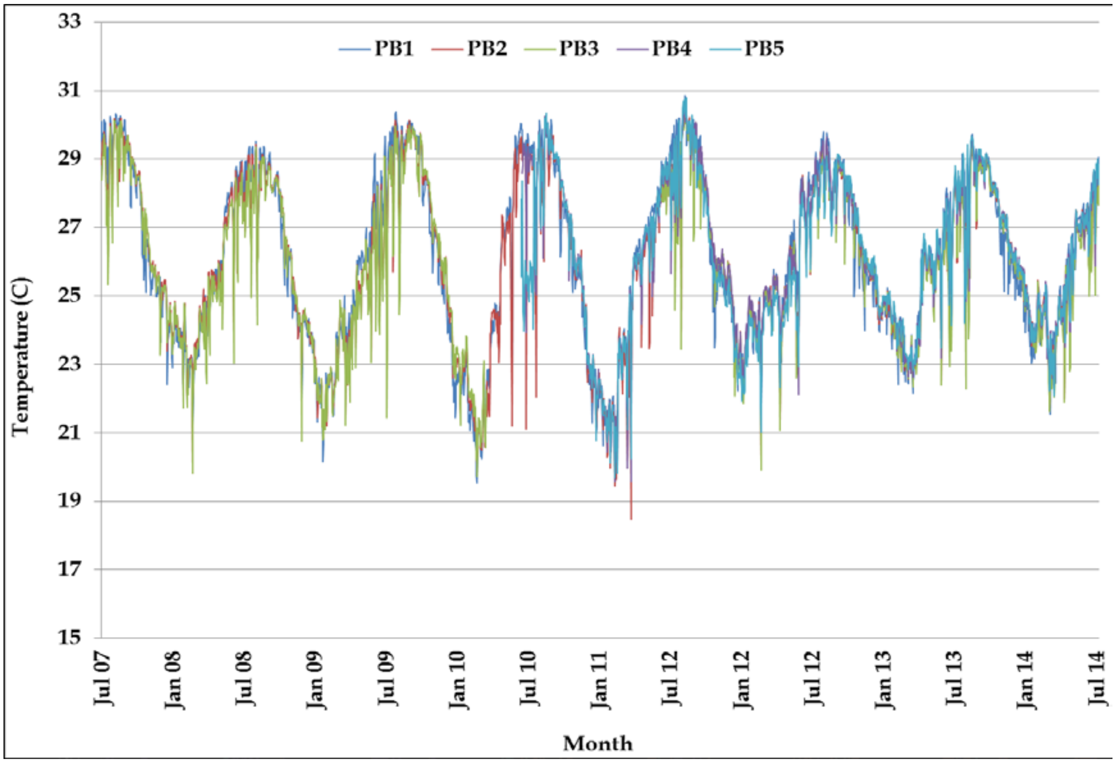

Figure 14. Mean daily temperatures (°C) for the five Palm Beach County sites, July 2007 – July 2014.

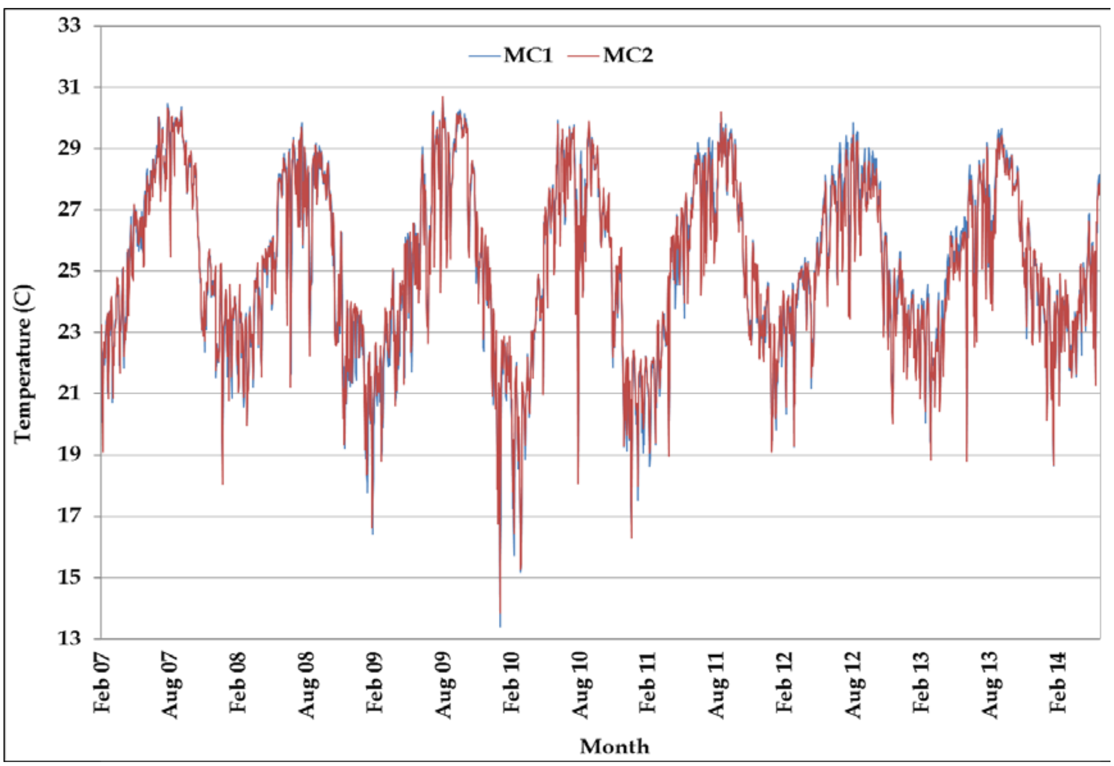

Figure 15. Mean daily temperatures (°C) for the three Martin County sites, February 2007 – May 2014.

Table 7. Number of days per year ≥ 30.5°C for the 22 sites with temperature loggers, winter 2007 through 2013 (NA = sites not established) (2014 is not included because a full year of temperature data was not collected at the time each site was sampled).

Site	2007	2008	2009	2010	2011	2012	2013	Total
DC1	11	0	7	5	18	0	0	41
DC2	0	0	0	0	6	0	0	6
DC3	1	0	0	0	1	0	0	2
DC4	0	0	0	0	1	0	0	1
DC5	0	0	0	2	8	0	0	10
DC6	NA	NA	NA	NA	NA	NA	0	0
DC7	NA	NA	NA	NA	NA	NA	0	0
DC8	NA	NA	NA	NA	NA	NA	0	0
BCA	21	0	7	0	0	0	0	28
BC1	8	0	6	0	13	0	0	27
BC2	0	0	0	0	1	0	0	1
BC3	0	0	0	0	2	0	0	2
BC4	NA	NA	NA	NA	NA	NA	0	0
BC5	NA	NA	NA	NA	NA	NA	0	0
BC6	NA	NA	NA	NA	NA	NA	0	0
PB1	0	0	0	0	0	6	0	6
PB2	0	0	0	0	0	2	0	2
PB3	0	0	0	0	0	0	0	0
PB4	0	0	0	0	0	5	0	5
PB5	0	0	0	0	0	7	0	7
MC1	0	0	1	0	0	0	0	1
MC2	0	0	2	0	0	0	0	2
Total	41	0	23	7	50	20	0	141

Discussion

The coral reef ecosystem off of southeast Florida is the northern extension of the Florida Reef Tract and as such, is a high-latitude system near the environmental threshold for significant coral reef growth. Southeast Florida reefs generally have similar stony coral species richness but reduced stony coral cover, compared to the southern portions of the Florida Reef Tract in the Dry Tortugas and Florida Keys (Ruzicka et al. 2010; Ruzicka et al. 2012). Benthic cover by octocorals and macroalgae is more similar throughout the Florida Reef Tract, while sponges appear to contribute more to cover in southeast Florida than in the Florida Keys or Dry Tortugas (Ruzicka et al. 2010; Ruzicka et al. 2012; Ruzicka et al. 2013).

Protocol changes were made to the project in 2012, replacing the standard species richness survey with targeted demographic surveys for stony corals, octocorals, and barrel sponges (Gilliam et al. 2013). Mean (±SD) region-wide (n = 22 sites) stony coral density was 1.26 ± 0.90 colonies (≥ 4 cm)/m² and ranged from 0.27 ± 0.35 colonies/m² (PB1) to 3.75 ± 0.43 colonies /m² (BC4) (Table 2). Region-wide there were no significant differences determined for stony coral density between 2013 and 2014. Region-wide mean (±SD) stony colony size was 15.92 ± 16.47 cm. Site PB1 had the smallest mean colony size (6.83 ± 1.93 cm) compared to BC1 which had the largest (37.43 ± 27.05 cm). The stony coral community in the region is dominated by small (≤4–10cm) and medium (10-30 cm) sized colonies (Figure 4).

In 2014, 28 stony coral species were identified with a region-wide mean (±SD) of 7.97 ± 2.89 species per site and a range of 18 (DC5) to 5 (BCA and MC1) species within a site (Appendix 1). Six species (*Montastraea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Stephanocoenia intersepta*, *Agaricia agaricites*, and *Meandrina meandrites*) were very common region-wide and contributed more than 80% in total colony abundance. Interestingly, three of these species (*M. cavernosa*, *S. siderea*, and *P. astreoides*) were also identified as being three of the most common species in the Florida Keys (Ruzicka et al. 2013) and in the Dry Tortugas (Ruzicka et al. 2012).

Within the region diseased stony coral colonies were recorded within 10 of the 22 sites affecting 28 total colonies. These 28 colonies represent a region-wide disease prevalence of 1.1% and were the most recorded since 2009 when 31 diseased colonies were recorded (Gilliam 2012). The 2014 effort was also unique in the presence of yellow band on two *M. faveolata* colonies in Miami-Dade County (DC4 and DC5), 'white disease' (14 colonies), and dark spot (10 colonies). Of the 28 total colonies, 10 were *S. siderea* colonies with dark spot syndrome. A white syndrome referred to as rapid tissue loss was identified on *Acropora cervicornis* colonies in site BCA and DC1.

Octocorals have previously been documented as a dominant benthic group in terms of density offshore of Broward County (Gilliam et al. 2012), but prior to 2012 there had been no program which documented octocoral density throughout the southeast Florida region. Region-wide there were no significant differences determined for octocoral density between 2013 and 2014. In 2014, region-wide (n = 22 sites) mean (±SD) octocoral density was 9.97 ± 7.93 colonies / m², and ranged from a high of 27.02 ± 9.22 colonies/m² at site PB5 to a low of 0.00 ± 0.00 colonies/m² at site MC1 (Table 3). The Miami-Dade and Broward county site mean densities estimated in this program were similar to the densities estimated in Gilliam et al. (2012) while the Palm Beach sites tended to have greater octocoral densities. The five target species were added to the protocol in order to increase our ability to describe and document changes in the octocoral community. These five species were added because they are common along the entire Florida Reef Tract (V. Brinkhuis personal communication). The choice of these five species appears to be appropriate for southeast Florida with the five target species (*E. calyculata, A. americana, E. flexuosa, P. porosa*, and *G. ventalina*) identified in all counties except Martin (no target species were present) (Table 3) and in 19 sites. *Antillogorgia americana, E. flexuosa,* and *E. calyculata* were present in most of the sites and were also the most abundant of the target species.

Barrel sponges (*X. muta*) are large, conspicuous, and important components of the Florida reef community. Prior to 2012 there had been no southeast Florida region-wide monitoring of barrel sponge abundance or condition. Barrel sponges were identified in 17 sites. No barrel sponges were identified in the nearshore sites DC8, BCA, PB1, MC1, and MC2 (Table 4). In sites which had barrel sponges present, mean (±SD) densities ranged from a high of 0.74 ± 0.17 sponges/m² at site PB5 to a low of 0.02 ± 0.01 sponges/m² at site DC1. Region-wide there were no significant differences determined for barrel sponge density between 2013 and 2014. The small (5–20cm) and medium (21-50 cm) size classes contribute more to the barrel sponge community than the recruit (≤5 cm) or large classes (>50 cm) (Figure 6). Region-wide mean (±SD) octocoral size was 26.82 ± 20.53 cm. Site DC1 had the smallest mean colony size (4.00 ± 3.46 cm) compared to DC5 which had the largest (31.89 ± 18.72 cm).

Region-wide mean (±SD) stony cover in 2014 (2.8 ± 3.8%) and was not significantly greater than the mean in 2013 (2.5 ± 3.4%) (Table 5) and additionally no individual site had a significant change in 2014 (Table 5). Sites BCA (13.8 ± 3.4%) and BC1 (12.3 ± 3.5%), which did not significantly change, are the sites which have the greatest stony coral cover in the project. Both sites are on the nearshore ridge complex offshore of Broward County. Site BCA is dominated by an *A. cervicornis* patch, and BC1 is in an area of increased abundance of larger (1 m diameter) *Montastraea cavernosa* stony coral colonies. Although the long-term trend analysis did not determine a region-wide significant trend for stony coral cover (Figure 7) (Appendix 2), one site, BCA, has experienced a significant trend (decreasing) in cover since 2003 (Appendix 2). This decreasing trend is due to year-to-year significant loss in cover which has been determined in the past (Gilliam et al. 2013). However, in 2014 *A. cervicornis* cover did not significantly change.

Site BCA was included in the project to monitor one of the few, remaining large stands of *A. cervicornis* in southeast Florida. *A. cervicornis* was listed as Threatened under the U.S. Endangered Species Act in 2006 (see Federal Register 71 FR 26852, May 9, 2006). Due to the status of Acroporid corals, the results from BCA deserve additional recognition. *Acropora cervicornis* cover decreased from a high of 39% in 2004 and 2005 to a low of 10% in 2013. However, in 2014 *A. cervicornis* cover was 13.6% which is an increase (not significant with the Bonferroni adjustment) from 2013. Sampling has been conducted at the same time each year (June in 2004-2014, Gilliam et al. 2013). The passing of Hurricane Wilma over the area in October 2005 may have contributed to some of the decline in 2006. A severe cyanobacteria bloom of *Lyngbya* spp. occurred in 2004 and may have resulted in direct mortality to *A. cervicornis.* The abundance of *Lyngbya* spp. at BCA appears to have diminished after 2004 (D. Gilliam, personal observation). Data collected by a separate monitoring effort, which includes the site BCA *A. cervicornis* patch and a second *A. cervicornis* patch to the north, has suggested that disease and predation by the fireworm, *Hermodice carunculata*, may be the primary causes of tissue loss (Gilliam, unpublished data). Stony coral cover within the *A. cervicornis* patch has also been record as declining by two additional projects (Walker et al. 2012; Gilliam et al. 2015). SECREMP is an annual monitoring project designed with the use of permanent transects. This annual permanent transect design may not provide all the data appropriate for determining the changes in condition of a large *A. cervicornis* patch where notable changes could occur very quickly. Since asexual reproduction is an important mechanism structuring *A. cervicornis* populations, these larger patches may be in a dynamic state with changing boundaries and relative cover within the patch (Walker et al. 2012). A large survey effort conducted between Broward County's Port Everglades and Hillsboro Inlets (includes the area containing BCA) found numerous areas of high *A. cervicornis* abundance (D'Antonio 2013) illustrating that the changes in annual condition within BCA may not be indicative of the *A. cervicornis* population offshore southeast Florida in general.

Even though there was no year-to-year significant difference determined in mean (±SD) octocoral cover region-wide (n = 22 sites) in 2014 (9.6 ± 6.4%) compared to 2013 (9.9 ± 6.8%), two sites (DC1 and BC2) were determined to have significantly greater octocoral cover in 2014 than in 2013 (Table 5), and one site (BC3) was also determined to have significantly less octocoral cover in 2014 than in 2013. For the long-term analysis (2003-2014), a region-wide significant decreasing trend was identified for octocoral cover (Figure 7) (Appendix 2), and at the site level PB3 and PB1 followed this significant decreasing trend (Appendix 2). No physical damage has been identified at BC3 or PB3, and other potential causes driving the loss of octocoral cover at these sites is difficult to identify with only annual visits.

A decreasing trend in octocoral cover for the SECREMP region is a very interesting result when compared to trends identified in octocoral cover in the Florida Keys (1999-2009). Octocoral cover was determined to have significantly increased Keys-wide and in all three habitats included in the study (Ruzicka et al 2013). Although both regions are part of the larger Florida Reef Tract, there are regional differences in sources and severity of stressors which may lead to different shifts in reef community structure.

Mean (±SD) sponge cover was determined to have significantly increased in 2014 (5.5 ± 3.6%) from 2013 (5.2 ± 3.4%) region-wide (Table 5). At the site level, one site was determined to have significantly greater sponge cover in 2014 (PB1), and one site (BCA) was determined to have significantly less sponge cover in 2014. Similarly to this most recent year-to-year comparison, sponge cover has shown a significant increasing trend region-wide since 2003 (Figure 7) (Appendix 2), but at the site level only site, PB1, was determined to have a significant trend and it was decreasing (Appendix 2). As noted above concerning octocoral cover, potential causes driving changes in cover within the region is difficult to identify with only annual visits.

Region-wide mean (±SD) macroalgae cover in 2014 (10.3 ± 9.6%) was significantly greater than the mean in 2013 (9.2 ± 12.0%) (Table 5). Three sites (BC3, DC5, and DC3) were determined to be significantly greater cover in 2014 than in 2013 (Table 5). One site (DC1) was determined to be significantly less cover in 2014 (Table 5). Macroalgae cover is both temporally and spatially (even at the station level) variable which likely lead to the significant differences determined between the sites (Table 5). As would be expected, macroalgae cover has fluctuated greatly over the last 10 years from less than 5% in 2003 to nearly 20% in 2006 and then back near to 10% since 2012 (Figure 7). The highly variable nature of macroalgae cover make identifying long-term trends difficult, and no trend was identified for macroalgae cover region-wide (Appendix 2).

In 2005, site PB1 was greatly affected by sand movement. Stations 2 and 4 were completely covered with sand several centimeters in depth. Stations 1 and 3 were also impacted, but to a lesser degree than Stations 2 and 4. In 2006, Stations 2 and 4 remained buried in sand. From 2007 to 2014, Stations 2 and 4 have very slowly started to become uncovered; but both stations remain dominated by sand. From 2006 to 2012, stony coral, octocoral, and sponge cover were very low (essentially zero) in these stations, but hard substrate is becoming exposed and functional group cover is increasing. The cause of this sand movement is unknown, although past beach nourishment activities and the 2004 hurricanes, Jeanne and Frances, may have contributed to this significant sand movement. The variable sand cover at this site greatly influenced summary data for site PB1, and therefore, the long term trend analyses. The loss of reef habitat at these two stations reduced the number of coral species identified in Palm Beach, and is responsible for the declining trends observed for octocoral and sponge cover at this site (Table 5 and Appendix 2).

Temperature loggers have been deployed at the 10 original sites since 2007 and have been deployed continuously at the 12 additional sites. With more than seven years of temperature data recorded, some trends in water temperatures are becoming evident. All sites (Figures 12-15) show the expected pattern of cooler water temperatures in the winter months (December – March) and warmer temperature in the summer months (June – September). For all sites, August and September are the warmest months and SECREMP now has eight summer period data records (2007-2014). It is also becoming clear that there is inter-annual variability in seasonal water temperatures and this variability may not be consistent among all counties. Temperatures greater than 30.5°C is a temperature above which bleaching has been recorded in the Florida Keys (Manzello et al. 2007). Table 7 lists the number of days temperatures above 30.5°C have been recorded for all sites. In 2013, no sites had temperatures recorded above 30.5°C. The number of sites with temperatures recorded above 30.5°C in 2013 was the fewest since 2008 which also had no records above 30.5°C. The SECREMP sampling period is generally conducted between late May and early August prior to the warmest recorded temperatures and when warm water stony coral bleaching is observed. The effect of these high temperatures on the stony coral communities at the SECREMP sites is not entirely known, but with stony coral cover not significantly changing at the sites (except for site BCA), a measurable negative effect associated with high water temperatures was not evident. In winter (December–February) 2010, much of the Florida Reef Tract experienced extreme cold water temperatures, with some areas below 10°C and many areas with prolonged periods below 16°C. This 2010 cold-water event resulted in unprecedented stony coral mortality in many areas of the Florida Reef Tract south of the Biscayne region (Colella et al. 2012, Lirman et al. 2011). Temperature data from the 13 SECREMP sites with loggers in winter 2010, indicated southeast Florida water temperatures did not fall as low as temperatures recorded in the Florida Keys region (only Martin County had temperatures lower than 16°C). Percent cover data from 2010 to 2012 supports the observation that the cold-water event did not measurably impact the southeast region of the Florida Reef Tract.

The coral reefs of southeast Florida represent a significant economic resource to the region. Between June 2000 and May 2001, visitors spent 28 million person-days enjoying artificial and natural reefs in southeast Florida. During the same period, reef-related expenditures and income amounted to over 5.7 billion dollars and supported over 61,300 jobs in Miami-Dade, Broward, Palm Beach, and Martin Counties (Johns et al. 2003, 2004). Notably, Johns et al. (2003) indicate southeast Florida reefs generate six times the sales, income, and jobs compared to reefs in the Florida Keys.

These important economic and recreational benefits are threatened because the coral reef environments of southeast Florida are under varied and chronic stressors. This area is highly urbanized along the coast. Dredging for beach nourishment, inlet and port channel deepening, and maintenance can have significant direct impacts on reef substrate, as well as impacts on water quality. Chronic turbidity and deposition of silt can smother sessile invertebrates and result in barren areas. Nearshore reef areas are at risk from the diversion of millions of gallons of fresh water and treated wastewater into the ocean, and the resultant reduction in salinity. Additional risks include the introduction of agricultural and industrial chemical contamination, and excess nutrients.

Impacts from boating and fishing activities are a significant threat to reef areas as damage from fishing gear and anchoring can be severe. Adverse impacts from SCUBA divers can also occur. Traffic from large ports (Miami, Port Everglades, and Palm Beach), including cruise and container ships, military vessels, and oil tankers, can conflict with reef resources. Fiber optic cables deployed across the reefs (Jaap 2000) and ships grounding and anchoring on reefs causing extensive and often long-lasting damage (Gilliam and Moulding 2012).

The chronic nature of disturbances to, and the significant economic value of, southeast Florida reefs require comprehensive, long-term monitoring to be conducted to define and quantify change and to help identify threats to the ecosystem. The region-wide information generated during the annual SECREMP site visits provide scientifically valid status and trends data designed to help local resource managers understand the implications of actions occurring in terrestrial and adjacent marine habitats. However, SECREMP was established to be a monitoring project independent of coastal development projects and un-permitted incidents (e.g., ship groundings), and as such most localized impacts from these activities are not captured by SECREMP. There is a need for more comprehensive, longer-term, and site-specific project/incident monitoring. Both continual region-wide monitoring (SECREMP) and improved incident-specific monitoring are necessary if resource managers are to develop sound management plans for coral reefs that allow continued use, and realization of the economic value, of these fragile marine ecosystems.

The expansion of the CREMP to include sites in Broward, Miami-Dade, Palm Beach, and Martin Counties, through SECREMP, and the recent addition of stony coral, octocoral, and barrel sponge demographic efforts has insured that this suite of parameters is being monitored for the full extent of the Florida coral reef ecosystem. While a true effects study designed to assist resource managers in gauging potential effects from past or future impacts (e.g., beach nourishment, pipelines, etc.) is not possible with our limited sample size, local resource managers (county) were directly involved in choosing the sample sites and were present during the site selection field work. Site BCA (*A. cervicornis* patch) is an example of a site specifically chosen by state and county resource managers in order to monitor potential changes to this unique area.

As a monitoring project under the NOAA Coral Reef Conservation Program Cooperative Agreement for the southeast Florida coast, SECREMP will continue characterization of ecosystem condition, inventory/mapping of biotic resources, and database development, providing resource managers with the critical information required to manage this valuable, yet increasingly threatened, natural resource**.**

Acknowledgements

The following additional Fish & Wildlife Research Institute personnel assisted with 2014 project planning and management: Jeff Beal.

The following Florida Department of Environmental Protection personnel assisted with 2014 project planning and management: Jenny Baez, Joanna Walczak, and Jamie Monty.

The following Nova Southeastern University Oceanographic Center personnel assisted with 2014 project planning, management, data collection, analysis, and report writing: Kathryn Correia, Nicole D'Antonio, Daniel Fahy, Ari Halperin, Lystina Kabay, Elizabeth Larson, Mauricio Lopez-Padierna.

Literature Cited

Banks, K., Riegl, B., Piller, W., Dodge, R.E., and Shinn, E.A. 2007. Geomorphology of the southeast Florida continental reef tract (Dade, Broward and Palm Beach Counties, USA). Coral Reefs 26: 617-640.

Colella, M., Ruzicka, R., Kidney, J., Morrison, J., and Brinkhuis, V. 2012. Cold-water event of January 2010 results in catastrophic benthic mortality on patch reefs in the Florida Keys. Coral Reefs 31(2): 621-632.

D'Antonio, N.L. 2013. Effects of habitat characteristics on population dynamics of Acropora cervicornis in the near-shore environment of southeast Florida. Master's Thesis. Nova Southeastern University Oceanographic Center. 133 pp.

Lirman, D., Schopmeyer, S., Manzello, D., Gramer, L. J., Precht, W. F., Muller-Karger, F., Banks, K., Barnes, B., Bartels, E., Bourque, A., Byrne, J., Donahue, S., Duquesnel, J., Fisher, L., Gilliam, D., Hendee, J., Johnson, M., Maxwell, K., McDevitt, E., Monty, J., Rueda, D., Ruzicka, R. and Thanner S. 2011. Severe 2010 cold-water event caused unprecedented mortality to corals of the Florida Reef Tract and reversed previous survivorship patterns. PloS ONE 6(8). Doi:10.1371/journal.pone.0023047.

Gilliam, D.S. 2012. Southeast Florida Coral Reef Evaluation and Monitoring Project 2011 Year 9 Final Report. Florida DEP Report #RM085. Miami Beach, FL. pp. 49.

Gilliam, D.S. and Moulding, A.L. 2012. A Study to Evaluate Reef Recovery Following Injury and Mitigation Structures Offshore Southeast Florida: Phase I. Nova Southeastern University Oceanographic Center. Dania Beach, Florida. 60 pp.

Gilliam, D.S., Brinkhuis, V., Ruzicka, R., and Walton, C.J. 2013. Southeast Florida Coral Reef Evaluation and Monitoring Project 2012 Year 10 Final Report. Florida DEP Report #RM085. Miami Beach, FL. pp. 53.

Gilliam, D.S, Dodge, RE., Spieler, RE., AA. Halperin, Walton, C.J., Kilfoyle, K., and Miller, C. 2015. Marine biological monitoring in Broward County, Florida: Year 14 Annual Report. Prepared for the BC Board of County Commissioners, BC Natural Resources Planning and Management Division, 127 pp.

Jaap, W.C. 2000. Coral reef restoration. Ecological Engineering 15:345-364.

Johns, G.M., Leeworthy, V.R., Bell, F.W., and Bonn, M.A. 2001. Socioeconomic study of reefs in southeast Florida. Final Report. Hazen and Sawyer Environmental Engineers & Scientists. 348 pp.

Johns, G.M, Milon, J.W., and Sayers, D. 2004. Socioeconomic study of reefs in Martin County, FL. Final Report Hazen and Sawyer Environmental Engineers & Scientists. 120 pp.

Kohler, K.E. and Gill, S.M. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geo. 32 (9): 1259-1269.

Manzello, D.P., Berkelmans, R., and Hendee, J.C. 2007. Coral bleaching indices and thresholds for the Florida Reef Tract, Bahamas, and St. Croix, US Virgin Islands. Marine Pollution Bulletin 54: 1923–1931.

Morrison, J.M., Ruzicka, R., Colella, M.A., Brinkhuis, V.I., Lunz, K.S., Kidney, J.A., Meyers, M.K., and Porter, J.W. 2012. Comparison of Image-Acquisition Technologies Used for Benthic Habitat Monitoring. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9-13 July 2012.

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

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ruzicka, R., Colella, M., Semon, K., Brinkhuis, V., Morrison, J., Kidney, J., Porter, J., Meyers, M., Christman, M., and Colee, J. 2010. CREMP 2009 Final Report. Fish & Wildlife Research Institute/Florida Fish & Wildlife Conservation Commission. Saint Petersburg, FL. 110 pp.

Ruzicka, R.R, Colella, M.A., Porter, J.W., Morrison, J.M, Kidney, J.A., Brinkhuis, V., Morrison, Lunz, K.S., Macaulay, K.A, Bartlett, L.A., Meyers, M.K., Colee, J. 2013. Temporal changes in benthic assemblages on Florida Keys reefs 11 years after the 1997/1998 El Nino. Mar Ecol Prog Ser 489:125-141.

Ruzicka, R., Brinkhuis, V., Colella, M., Kidney, J., Lunz, K., Ward, G., Macaulay, K., Porter, J., Meyers, M. 2012. Long-term Monitoring & Assessment of Selected Coral Reef Sites in the Dry Tortugas National Park. 2009-2010 Final Report. Fish & Wildlife Research Institute/Florida Fish & Wildlife Conservation Commission. Saint Petersburg, FL. 53 pp.

Walker, B.K. and Gilliam, D.S. 2013. Determining the extent and characterizing coral reef habitats of the northern latitudes of the Florida Reef Tract (Martin County). PLoS ONE 8(11): e80439. doi:10.1371/journal.pone.0080439.

Wagner, D.E., Kramer, P., van Woesik, R. 2010. Species composition, habitat, and water quality influence coral bleaching in southern Florida. Mar Ecol Prog Ser 408:65-78.

Walker, B.K., Riegl, B., and Dodge, R.E. 2008. Mapping coral reefs in suboptimal water clarity: southeast Florida, USA. Journal of Coastal Research 24: 1138-1150.

Walker, B.K., Larson, E.A., Moulding, A.L., and Gilliam, D.S. 2012. Small-scale mapping of indeterminate arborescent acroporid coral (*Acropora cervicornis*)

patches. Coral Reefs: DOI 10.1007/s00338-012-0910-3.

Appendix

Appendix 1. Stony coral species presence (P) and absence (A) for each site (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; and MC = Martin County).

Species	DC1	DC2	DC3	DC4	DC5	DC6	DC7	DC8
Porites astreoides	P	P	P	P	P	P	P	P
Montastraea cavernosa	P	P	P	P	P	P	P	P
Siderastrea siderea	P	P	P	P	P	P	P	P
Stephanocoenia intersepta	P	P	P	P	P	P	P	P
Agaricia agaricites complex	P	A	A	P	P	P	A	A
Meandrina meandrites	P	P	P	P	P	P	P	P
Porites porites	P	A	A	P	P	P	A	A
Dichocoenia stokesii	P	P	P	P	P	P	P	P
Solenastrea bournoni	P	P	A	P	P	P	P	P
Madracis decactis	A	A	P	A	P	A	P	A
Madracis mirabilis	A	A	A	A	A	A	A	A
Diploria clivosa	A	A	A	A	A	P	A	P
Acropora cervicornis	P	A	A	A	A	P	A	A
Orbicella faveolata	P	A	A	P	P	A	P	A
Diploria strigosa	A	A	A	A	P	A	P	A
Agaricia fragilis	A	A	P	A	P	A	A	A
Colpophyllia natans	P	A	A	A	P	A	A	P
Oculina diffusa	A	A	A	A	A	A	A	P
Eusmilia fastigiata	A	P	A	P	A	A	A	A
Agaricia lamarcki	A	A	A	P	A	A	A	A
Mycetophyllia aliciae	A	A	P	A	P	A	P	A
Siderastrea radians	P	A	A	A	A	A	A	A
Orbicella annularis	A	P	A	A	A	P	P	A
Diploria labyrinthiformis	A	A	A	A	P	A	A	A
Isophyllia sinuosa	A	A	A	A	A	A	A	A
Orbicella franksi	A	A	A	A	P	A	A	A
Scolymia cubensis	A	P	A	P	A	A	P	A
Millepora alcicornis	P	P	P	P	P	P	P	P
Total Species Richness	**14**	**11**	**10**	**14**	**18**	**13**	**14**	**11**

Appendix 1 Continued. Stony coral species presence (P) and absence (A) for each site (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; and MC = Martin County).

Species	BC1	BC2	BC3	BC4	BC5	BC6	BCA
Porites astreoides	P	P	P	P	P	P	P
Montastraea cavernosa	P	P	P	P	P	P	A
Siderastrea siderea	P	P	P	P	P	P	P
Stephanocoenia intersepta	P	P	P	P	P	P	A
Agaricia agaricites complex	P	P	A	P	A	A	P
Meandrina meandrites	P	P	P	P	P	P	A
Porites porites	A	P	A	P	P	A	A
Dichocoenia stokesii	P	P	P	P	P	P	A
Solenastrea bournoni	P	P	P	P	P	A	A
Madracis decactis	P	A	P	P	P	A	A
Madracis mirabilis	P	A	A	A	A	A	A
Diploria clivosa	A	A	A	P	A	A	A
Acropora cervicornis	A	A	A	P	A	A	A
Orbicella faveolata	P	P	A	P	A	A	A
Diploria strigosa	A	A	P	P	A	A	A
Agaricia fragilis	P	A	A	P	A	A	P
Colpophyllia natans	P	A	A	A	A	A	A
Oculina diffusa	A	A	A	A	A	A	A
Eusmilia fastigiata	P	A	A	A	A	A	A
Agaricia lamarcki	A	P	P	A	A	A	A
Mycetophyllia aliciae	A	A	A	A	A	A	A
Siderastrea radians	A	A	A	P	A	A	A
Orbicella annularis	A	A	A	A	A	A	A
Diploria labyrinthiformis	P	A	A	A	A	A	A
Isophyllia sinuosa	A	A	A	A	A	A	A
Orbicella franksi	A	A	A	A	A	A	A
Scolymia cubensis	A	A	A	A	A	A	A
Millepora alcicornis	P	P	P	P	P	P	P
Total Species Richness	16	12	11	17	10	7	5

Appendix 1 Continued. Stony coral species presence (P) and absence (A) for each site (DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; and MC = Martin County).

Species	**PB1**	**PB2**	**PB3**	**PB4**	**PB5**	**MC1**	**MC2**
Montastraea cavernosa	P	P	P	P	P	A	A
Porites astreoides	A	P	P	P	P	P	A
Montastraea cavernosa	P	P	P	P	P	P	A
Siderastrea siderea	A	P	P	P	P	P	P
Stephanocoenia intersepta	A	P	P	P	P	A	A
Agaricia agaricites complex	A	A	P	P	P	A	A
Meandrina meandrites	P	P	P	P	P	A	A
Porites porites	A	A	A	A	P	A	A
Dichocoenia stokesii	A	P	P	P	P	A	A
Solenastrea bournoni	P	A	A	A	P	A	P
Madracis decactis	A	P	P	P	P	A	A
Madracis mirabilis	A	P	A	A	A	A	A
Diploria clivosa	A	A	A	A	P	P	P
Acropora cervicornis	A	A	A	A	A	A	A
Orbicella faveolata	A	A	A	P	P	A	A
Diploria strigosa	P	A	P	P	P	A	A
Agaricia fragilis	A	A	A	A	A	A	A
Colpophyllia natans	A	A	A	A	P	A	A
Oculina diffusa	P	A	A	A	A	P	P
Eusmilia fastigiata	A	P	A	A	A	A	A
Agaricia lamarcki	A	A	A	A	P	A	A
Mycetophyllia aliciae	A	A	A	A	A	A	A
Siderastrea radians	A	A	A	A	A	A	A
Orbicella annularis	A	A	A	A	A	A	A
Diploria labyrinthiformis	A	A	A	A	A	A	A
Isophyllia sinuosa	A	A	A	A	A	P	A
Orbicella franksi	A	A	A	A	A	A	A
Scolymia cubensis	A	A	A	A	A	P	A
Millepora alcicornis	P	P	P	P	P	P	P
Total Species Richness	6	10	10	11	16	8	5

Appendix 2. Model estimation of change in stony coral, octocoral, sponge, and macroalgae percent cover per year (±1SE) by site from 2003 to 2014. Linear trends correspond to the time series presented in Figure 7. Significant trends in cover– increasing (↑), decreasing (↓), or unchanged (↔) - are bolded (R= region-wide comparison; BC = Broward County; DC = Miami-Dade County; PB = Palm Beach County; MC = Martin County).

Variable	Level	Est.	SE	DF	t	p	Trend	Max (Yr)	Min (Yr)
Stony Coral	R	-0.003	0.001	162.100	-0.77	0.445	↔	5.9 (04)	3.1 (11)
	DC1	0.006	0.003	147.700	2.146	0.034	↑	5.44 (14)	2.13 (04)
	DC2	0.003	0.003	147.700	1.141	0.256	↑	1.55 (14)	0.45 (05)
	DC3	0.002	0.003	147.700	0.526	0.599	↑	0.50 (12)	0.10 (08)
	BC1	0.001	0.003	147.700	0.389	0.698	↑	12.70 (08)	10.45 (10)
	BC2	0.002	0.003	147.700	0.845	0.400	↑	0.81 (11)	0.36 (03)
	BC3	0.020	0.003	147.700	0.692	0.490	↑	0.91 (06)	0.22 (09)
	BCA	**-0.023**	**0.003**	**147.700**	**-7.789**	**0.000**	↓	41.09 (04)	10.93 (13)
	PB1	-0.005	0.003	156.233	-1.592	0.114	↓	0.80 (04)	0.00 (11)
	PB2	0.000	0.003	147.700	-0.015	0.988	↓	2.16 (03)	1.49 (11)
	PB3	0.002	0.003	147.700	0.779	0.437	↑	1.49 (13)	0.67 (06)
	MC1	0.005	0.004	205.400	1.234	0.219	↑	3.60 (14)	1.77 (06)
	MC2	-0.005	0.004	205.400	-1.218	0.225	↓	2.07 (06)	0.80 (12)
Octocoral	**R**	**-0.004**	**0.001**	**170.5**	**-3.05**	**0.003**	↓	12.6 (05)	7.8 (09)
	DC1	**0.009**	**0.003**	**157.805**	**3.012**	**0.003**	↑	12.08 (14)	4.61 (03)
	DC2	-0.001	0.003	157.805	-0.370	0.712	↓	19.58 (11)	10.93 (07)
	DC3	-0.009	0.003	157.805	-2.826	0.005	↓	15.49 (05)	5.70 (09)
	BC1	0.002	0.003	157.805	0.645	0.003	↑	8.56 (10)	5.33 (08)
	BC2	-0.002	0.003	157.805	-0.262	0.794	↓	9.87 (05)	4.69 (13)
	BC3	-0.002	0.003	157.805	-0.777	0.439	↓	15.28 (10)	8.65 (14)
	BCA	0.003	0.003	157.805	0.987	0.325	↑	3.00 (07)	1.53 (06)
	PB1	**-0.013**	**0.003**	**164.068**	**-4.037**	**0.000**	↓	3.05 (04)	0.0 (11)
	PB2	-0.009	0.003	157.805	-2.736	0.069	↓	30.08 (04)	17.12 (13)
	PB3	**-0.017**	**0.003**	**157.805**	**-5.558**	**0.000**	↓	30.17 (04)	11.91 (14)
	MC1	0.002	0.005	204.818	0.644	0.340	↑	0.14 (11)	0.00 (09)
	MC2	0.000	0.005	204.818	-0.013	0.989	↓	0.08 (10)	0.00 (13)

Appendix 2 Continued.

Variable	Level	Est.	SE	DF	t	p	Trend	Max (Yr)	Min (Yr)
Sponge	**R**	**0.004**	**0.001**	**161.9**	**4.08**	**0.000**	↑	5.8 (11)	3.3 (05)
	DC1	0.008	0.003	150.386	2.750	0.007	↑	4.32 (11)	0.57 (03)
	DC2	0.002	0.003	150.386	0.750	0.454	↑	7.34 (12)	4.08 (04)
	DC3	0.003	0.003	150.386	0.970	0.334	↑	6.09 (12)	2.66 (08)
	BC1	0.004	0.003	150.386	1.480	0.141	↑	4.90 (11)	2.15 (04)
	BC2	0.007	0.003	150.386	2.200	0.029	↑	6.21 (11)	2.75 (03)
	BC3	0.007	0.003	150.386	2.420	0.017	↑	8.15 (12)	2.39 (03)
	BCA	0.005	0.003	150.386	1.630	0.105	↑	3.58 (13)	0.31 (03)
	PB1	**-0.012**	**0.003**	**155.685**	**3.920**	**0.000**	↓	**10.68 (04)**	**0.00 (14)**
	PB2	0.002	0.005	229.331	0.380	0.704	↑	8.47 (14)	3.44 (05)
	PB3	0.009	0.005	229.331	1.770	0.078	↑	15.29 (07)	8.66 (04)
	MC1	-0.018	0.008	257.762	2.330	0.021	↓	3.17 (11)	1.02 (09)
	MC2	0.003	0.003	150.386	1.120	0.263	↑	5.87 (11)	2.41 (08)
Macroalgae	R	-0.001	0.002	238.4	-0.93	0.352	↔	19.3 (06)	3.4 (03)
	DC1	**-0.017**	**0.005**	**229.331**	**3.450**	**0.001**	↓	31.89 (04)	3.60 (14)
	DC2	-0.006	0.005	229.331	1.140	0.256	↓	20.48 (06)	0.46 (09)
	DC3	-0.003	0.005	229.331	0.510	0.608	↓	17.77 (09)	0.35 (12)
	BC1	**0.016**	**0.005**	**229.331**	**3.270**	**0.001**	↑	17.37 (12)	0.32 (03)
	BC2	0.004	0.005	229.331	0.710	0.479	↓	10.84 (06)	1.80 (08)
	BC3	-0.006	0.005	229.331	1.270	0.206	↓	37.18 (06)	1.88 (04)
	BCA	0.009	0.005	229.331	1.810	0.072	↑	6.66 (14)	0.04 (03)
	PB1	-0.003	0.005	232.357	0.550	0.585	↓	10.94 (06)	0.03 (07)
	PB2	0.002	0.005	229.331	0.380	0.704	↑	11.16 (06)	0.0 (03)
	PB3	0.009	0.005	229.331	1.770	0.078	↑	15.29 (07)	0.49 (03)
	MC1	-0.018	0.008	257.762	2.330	0.021	↓	42.40 (04)	21.84 (11)
	MC2	-0.005	0.008	257.762	0.640	0.521	↓	58.18 (07)	19.00 (11)