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Southeast Florida Coral Reef Evaluation and Monitoring Project

NSU
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FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

Florida Department of Environmental Protection

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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NOAA
CORAL REEF
CONSERVATION PROGRAM

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2016 Year 14 Final Report

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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 ………………………………………………...Fish and Wildlife Research Institute
SECREMP ……………………. Southeast Coral Reef Evaluation and Monitoring Project

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Executive Summary

The Southeast Coral Reef Evaluation and Monitoring Project (SECREMP) was established to provide local, state, and federal resource managers with an annual report on the status of the southeast Florida (Martin, Palm Beach, Broward, and Miami-Dade counties) reef system. Surveys have been conducted at fixed sites (22 in 2016) annually since 2003 documenting temporal changes in benthic cover and, since 2013, stony coral, octocoral, and barrel sponge (*Xestospongia muta*) population demographics. These annual surveys permit a meaningful regional evaluation and are consistent with the methods of the Coral Reef Evaluation and Monitoring Project (CREMP) in the Florida Keys National Marine Sanctuary (FKNMS) and Dry Tortugas National Park.

The 2016 data revealed an unprecedented decline in the stony coral community along the entire northern region of the Florida Reef Tract (southeast Florida reefs). This decline was very likely driven by an observed multi-year stony coral disease event initially reported in late 2014 and continuing through 2016. SECREMP disease prevalence in 2016 (4.4% regional) was the highest recorded during all years demographic data has been collected. Regionally from 2015 to 2016 there was a decline of 40% in stony coral benthic cover and 43% in live tissue area (LTA). At the site level five sites lost more than 50% cover and over 60% LTA. Total colony density also significantly declined regionally from 2015-2016 with 18 sites experiencing a decline. Several species were examined in more detail. *Montastraea cavernosa* and *Siderastrea siderea* exhibited regional and site level declines in LTA and density from 2015 – 2016, while *Meandrina meandrites* (94% decline in density) and *Dichocoenia stokesii* (83% decline) were nearly completely lost from the SECREMP sites.

While there were unprecedented declines in the stony coral communities there was no similar pattern evident in the octocoral or sponge communities. Regionally, octocoral cover exhibited a significant decreasing long-term trend while sponge cover significantly increased. Octocoral regional density has been increasing since 2013, and *X. muta* density has remained relatively stable from 2014 through 2016. From 2015 to 2016 regional macroalgae cover more than doubled and at the site level significant increases in macroalgae covered were associated with declines in at least one stony coral metric.

The southeast Florida reef system has been and continues to be impacted by varied and chronic stress associated with a highly urbanized coast coupled with commercial and recreational use. The high economic value of southeast Florida reefs supports the need for comprehensive, long-term monitoring to define and quantify change and to help identify threats to the ecosystem. The value of a long-term region-wide monitoring program is highlighted by the information, albeit concerning, presented in this report. SECREMP was able to capture significant impacts to the stony coral community associated with a severe stony coral disease outbreak. While SECREMP provides important, event independent monitoring data there is a need for more comprehensive, longer-term, and site-specific project and incident monitoring. Both continued 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 ecosystems.

Introduction

The coral reef ecosystem in Florida is an important aesthetic and economic resource that extends approximately 577 km from the Dry Tortugas in the south to the St. Lucie Inlet in the north. The primary focus on reefs in Florida has historically been limited to the Florida Keys and Dry Tortugas in Monroe County, although the reef system continues throughout southeast Florida. The southeast Florida reef system exists within 3 km off the mainland Atlantic coast of Florida and extends approximately 170 km from Miami-Dade County in the south to Martin County in the north. These reefs support diverse benthic organisms and fish communities. Additionally, the southeast Florida reef habitats are an important economic asset with an estimated $3.4 billion in sales and income generated from the natural reefs alone (Johns et al. 2001, 2004).

While the southeast Florida reefs are clearly an important resource they are located offshore of a highly urbanized area (population > 6 million) that is influenced by numerous impacts including commercial and recreational fishing and diving, major shipping ports, sewer outfalls, canal discharges, ship groundings, and marine construction activities. Prior to 2003, most monitoring efforts (e.g. Gilliam et al. 2015) along the mainland southeast coast were associated with impact and mitigation studies (dredge impacts, ship groundings, pipeline and cable deployments, and beach renourishment). The temporal duration and spatial extent of these monitoring efforts were limited, being defined by an activity permit and focused on monitoring for effects specific to a given impact. In 2003, the Florida Department of Environmental Protection (FDEP) was awarded funding for the inception of a long-term coral reef monitoring program along the southeast Florida coast. Prior to this the primary focus for long-term coral reef monitoring was limited to the Florida Keys and Dry Tortugas in Monroe County. 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 Keys portion of the Florida Reef Tract (FRT) from Key West to Carysfort Reef (Ruzicka et al 2010; Ruzicka et al. 2013). In 1999 the project was expanded to include sites in the Dry Tortugas. In order to provide continuity in monitoring efforts along the FRT from the Keys through southeast Florida, FDEP established the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP) as an expansion of CREMP. The goal of SECREMP has been 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 as well as information on temporal changes in resource condition.

Survey Sites

Off the mainland coast of southeast Florida from Cape Florida (Miami-Dade County) north to central Palm Beach County, in particular offshore 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). Since the inception of SECREMP sites have been spread across these four habitats.

SECREMP began monitoring in 2003 at 10 sites, three each in Palm Beach and Miami-Dade counties and four in Broward County, including a nearshore monotypic stand of *Acropora cervicornis*. In 2006, two sites were added in Martin County extending efforts to the northernmost area of the FRT. Four additional sites were added in 2010, two each in Palm Beach County and Miami-Dade County. Finally, in 2013 six sites were added, three each in Broward and Miami-Dade counties. Currently SECREMP monitors 22 sites from Miami-Dade County to Martin County distributed across all four described habitats. Figures 2 and 3 show the location of the 22 current sites along the southeast Florida coast. Project sampling occurs annually between May and August. Table 1 provides reef type, depths, locations, and the 2016 sample date of each of the SECREMP sites.

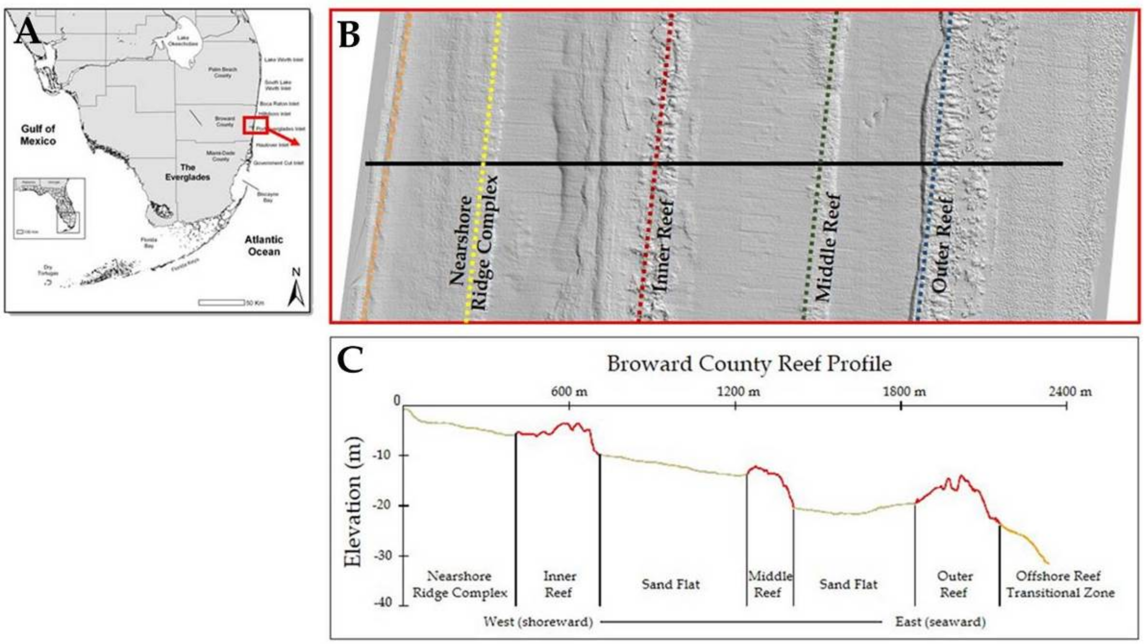

Figure 1. View of the southeast Florida coastline. Panel A is a view of southern Florida showing an area off Broward County in red that corresponds to Panel B which is sea floor bathymetry from LIDAR (Light Detection and Ranging) data. The black line in Panel B shows the location of a bathymetric profile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

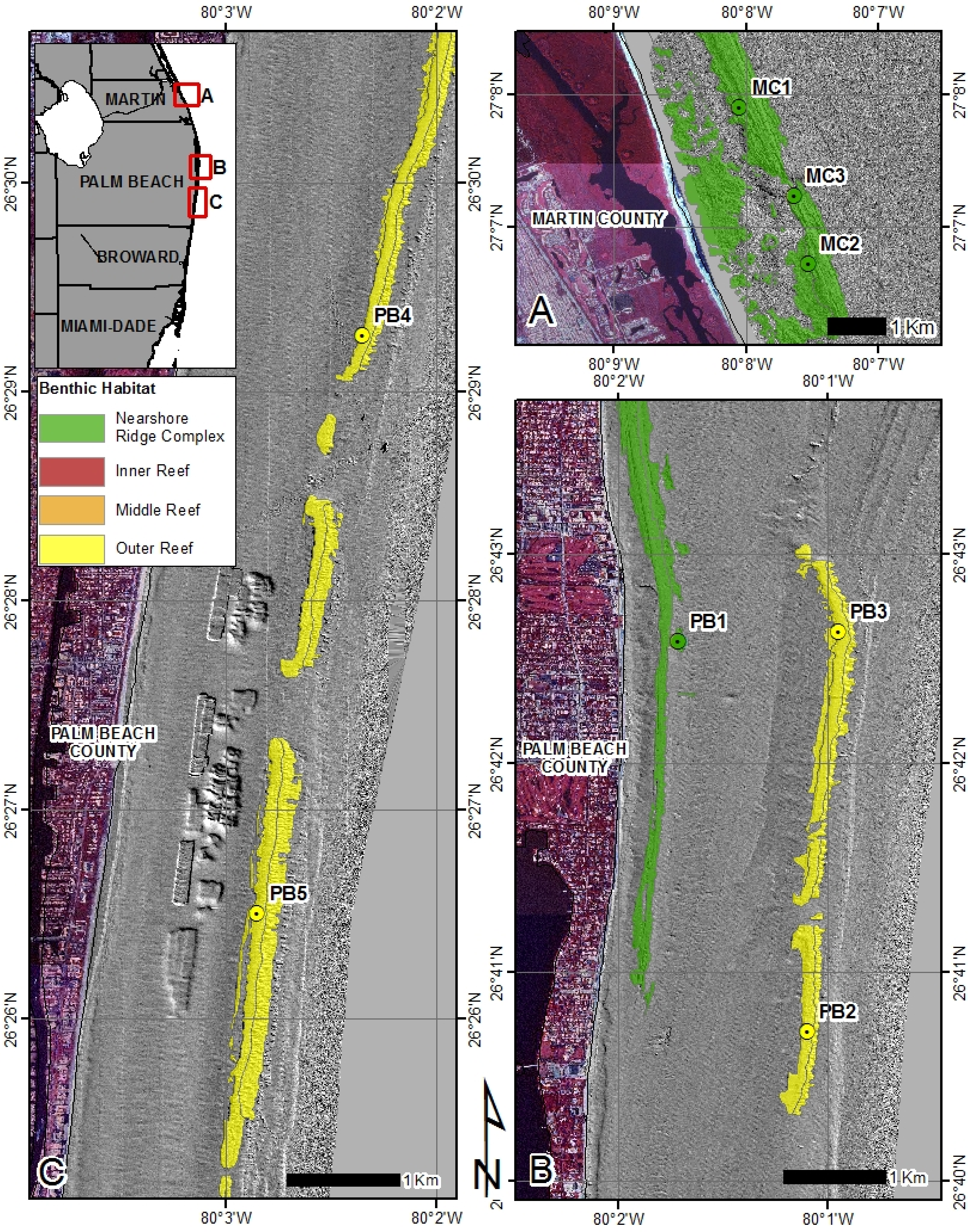

Figure 2. Site location and habitat map of Martin (Panel A) and Palm Beach (Panels B and C) counties.

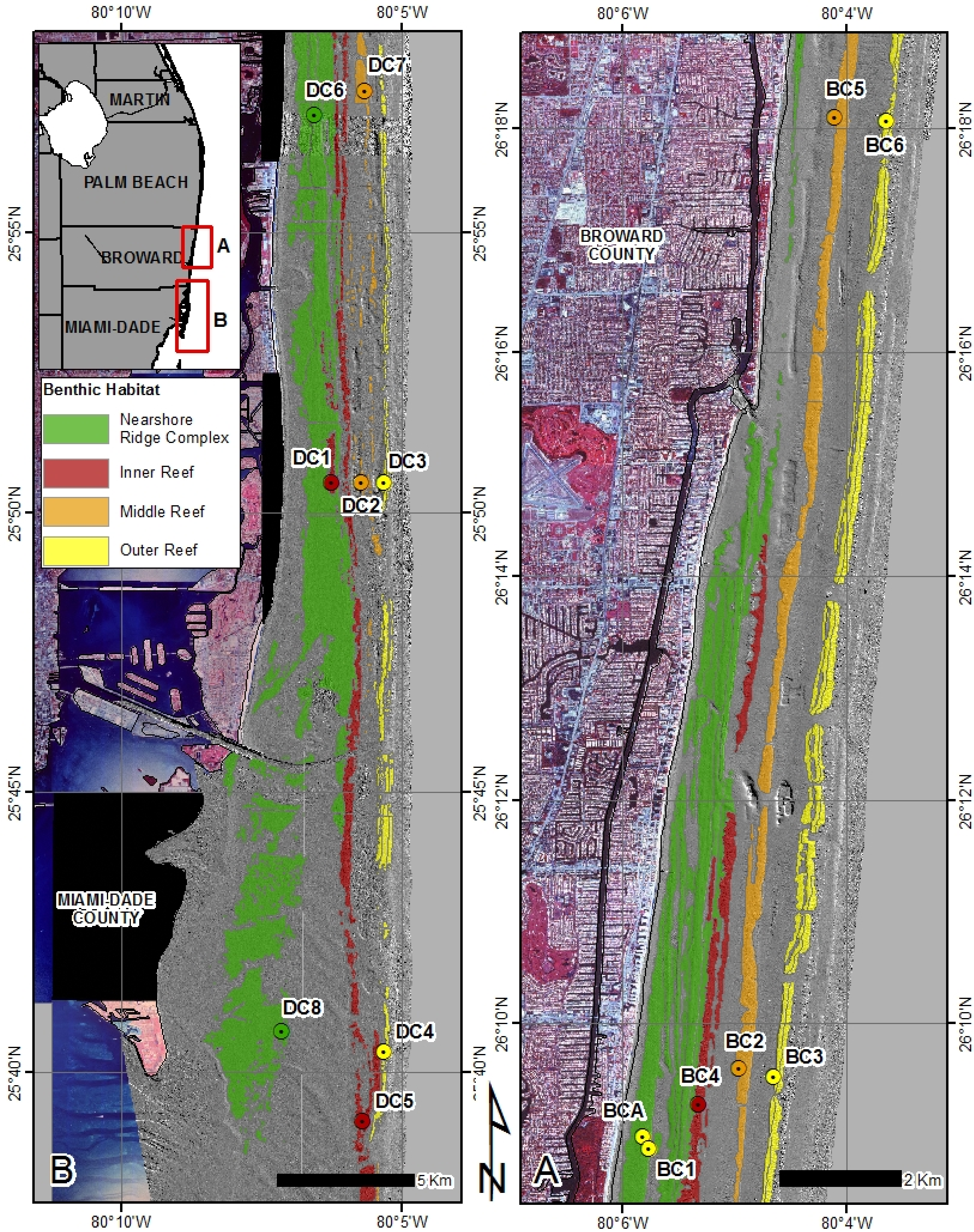

Figure 3. Site location and habitat map of Miami-Dade (Panel B) and Broward (Panel A) counties.

Table 1. Monitoring site reef types, depth (ft), location, and 2016 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’	14-July
DC2	Middle	45	25° 50.520’	80° 05.704’	9-Aug
DC3	Outer	55	25° 50.526’	80° 05.286’	9-Aug
DC4	Outer	41	25° 40.357’	80° 05.301’	19-Aug
DC5	Inner	24	25° 39.112’	80° 05.676’	25-Aug
DC6	NRC	15	25° 57.099’	80° 06.534’	13-July
DC7	Middle	55	25° 57.530’	80° 05.639’	13-July
DC8	NRC	15	25° 40.707’	80° 07.111’	19-Aug & 25-Aug
BCA	NRC	25	26° 08.985’	80° 05.810’	14-June
BC1	NRC	25	26° 08.872’	80° 05.758’	13-June
BC2	Middle	40	26° 09.597’	80° 04.950’	14-June
BC3	Outer	55	26° 09.518’	80° 04.641’	1-June & 13-June
BC4	Inner	30	26° 08.963’	80° 05.364’	1-June
BC5	Middle	45	26° 18.100’	80° 04.095’	8-Aug
BC6	Outer	55	26° 18.067’	80° 03.634’	23-Aug
PB1	NRC	25	26° 42.583’	80° 01.714’	21-July
PB2	Outer	55	26° 40.710’	80° 01.095’	20-July
PB3	Outer	55	26° 42.626’	80° 00.949’	19-July
PB4	Outer	55	26° 29.268’	80° 02.345’	22-July & 29-July
PB5	Outer	55	26° 26.504’	80° 02.854’	29-July & 8-Aug
MC1	NRC	15	27° 07.900’	80° 08.042’	24-May
MC2	NRC	15	27° 06.722’	80° 07.525’	24-May

Methods

Each site consists of four monitoring stations demarcated by stainless steel stakes that are permanently placed in the substrate. Each station is 22 meters in length and has a north-south orientation, which is generally parallel to the reef tracts of southeast Florida. Stations are surveyed annually in the summer from May to August. Survey transects are delineated by a fiber glass tape stretched between the stainless steel stakes at either end of a station. At each station, in situ sampling consists of a photo transect, a stony coral population survey, an octocoral population survey, and a *Xestospongia muta* population survey, all conducted along the same transect covering a similar area on the substrate (Figure 4).

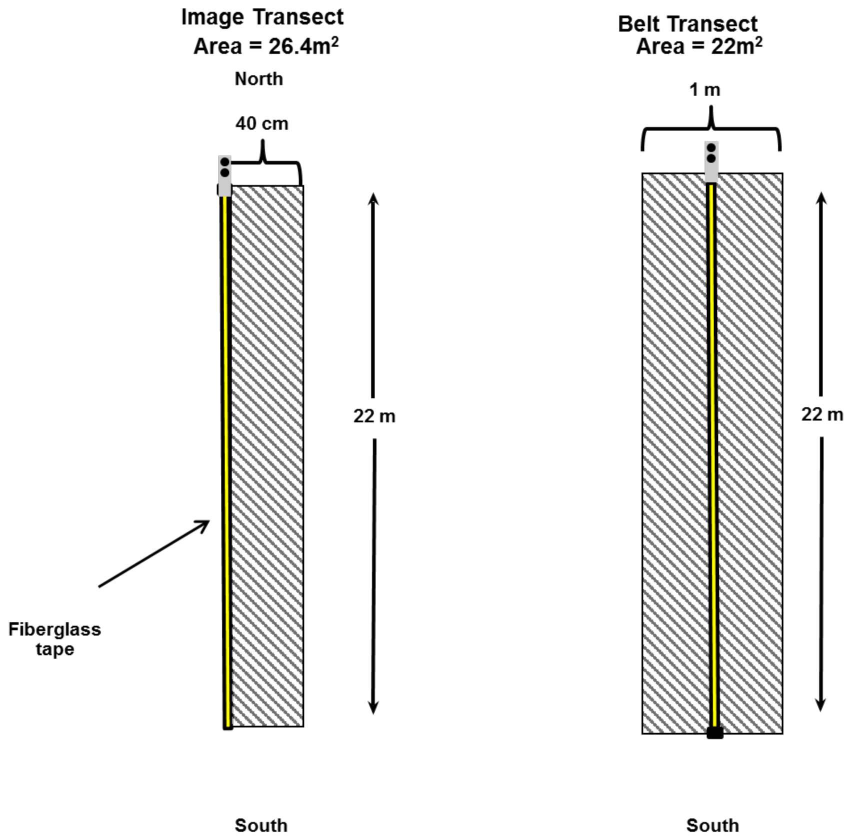

Figure 4. Layout of each SECREMP station showing the areas (hatch areas) within which the image and belt transect data were collected (note the gorgonian belt area is 1 m x 10 m).

Image Transects

All transect images were taken to the east of the fiberglass tape delineating a transect using a Canon PowerShot S95 digital camera. Each image was captured at a distance of ~40 cm above the reef substrate to yield images approximately 40 cm wide by 30 cm in height. A constant distance above the substrate was maintained using an aluminum bar affixed to the bottom of the camera. Benthic features seen in the top border of the camera viewfinder and the fiberglass tape were used as visual reference points to take abutting images with minimal overlap. This results in an image transect consisting of about 60 images and covering an area of approximately 0.4 m x 22 m.

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). After all images were analyzed, the data were checked for quality assurance and entered into the Microsoft Access database.

Stony Coral Demographic Survey

Stony coral population surveys were performed at all stations. Divers conducted a 1 m x 22 m belt transect from north to south along the transect tape (Figure 4) in which every stony coral colony ≥ 4 cm in diameter was identified to species and the maximum diameter and the maximum height, perpendicular to the plane of growth, were measured. Each colony was then visually assessed for the presence of diseases, bleaching and other conditions (i.e. predation, damsel fish, Clionaids etc.) Where these conditions resulted in partial mortality the percentage was visually estimated. Diseases include those with conditions that resulted in tissue mortality (i.e. white plague-like diseases or blackband disease) as well as conditions that may not visually result in tissue mortality (i.e. dark spot syndrome and tissue growth anomalies). Mortality was considered ‘‘recent’’ if the corallite structure was clearly distinguishable and there was minimal overgrowth by algae or other fouling organisms. Otherwise, mortality was classified as ‘‘old’’. For *Millepora alcicornis* (fire coral) only colony presence or absence was recorded.

Octocoral Demographic Survey

Octocoral population surveys were also conducted at all stations but covered a reduced survey area. Divers conducted a 1 m x 10 m belt transect starting at the northernmost stake for each station. Octocoral surveys were completed in two parts. 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, *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, the maximum height was measured and the colony was visually assessed for the presence of disease, bleaching and/or various other conditions (e.g., predation, overgrowths, etc.). Additionally, for *G. ventalina* the maximum width was also recorded. These species were selected because they are readily distinguishable in the field and are relatively abundant in their preferred reef habitat along the Florida Reef Tract. While colony conditions were assessed the condition data are not presented in this report.

Barrel Sponge Demographic Survey

A barrel sponge (*Xestospongia muta*) population survey was also conducted at each station. *Xestospongia muta* density was determined by counting all sponges within the 1 m x 22 m belt centered under the transect tape (Figure 4). For each sponge the maximum diameter, maximum base diameter, and maximum height were measured and the sponge was visually assessed for the presence of disease, bleaching and other conditions (i.e. damage/injury, predation). The percent of the sponge affected by injury, disease, and/or bleaching was also recorded. Similar to octocorals, sponge conditions are not presented in this report.

Monitoring Site Temperature Record

The deployment of Onset (www.onsetcomp.com) temperature loggers has been part of the SECREMP sampling protocol since 2007. Temperature loggers were deployed at all existing sites annually and at new sites as they were established. 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.

Two loggers were deployed at each site in order to provide redundancy in case one logger failed or was lost. The loggers were programmed to record data at a sampling interval of two hours. The two loggers were attached approximately 10 cm off the substrate to the 'northern' stakes identifying Stations 1 and 2 at each site. 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.

Analyses

To provide an additional metric to evaluate changes to the stony coral community, stony colony width, height and percent mortality (sum of old and recent) were used to calculate total live tissue area (LTA) for each site for 2013-2016. Region-wide LTAs were also calculated for select stony coral species (*Montastraea cavernosa*, *Meandrina meandrites*, *Dichocoenia stokesii*, and *Siderastrea siderea*) for 2013-2016. The LTA for each colony was calculated using the following equation:

$$SA = 2\pi\left(\frac{a^p\left(\frac{1}{2}b\right)^p + a^p\left(\frac{1}{2}b\right)^p + \left(\frac{1}{2}b\right)^p\left(\frac{1}{2}b\right)^p}{3}\right)^{\frac{1}{p}}$$

This equation was modified from Knud Thomsen's formula for the estimated surface area (SA) of an ellipsoid. The original SA equation was multiplied by ½ to estimate the surface area of a coral as the equivalent of the top half of an ellipsoid. In this modified version a = maximum height of the colony, b = the maximum diameter of the colony, and p ≈ 1.6075, a constant yielding a relative error of at most 1.061%. Following calculation of the SA, the value was converted to LTA via the following formula:

$$LTA = SA\left(1 - \left(\frac{\%\ Old\ Mortality + \%\ Recent\ Mortality}{100}\right)\right)$$

Mortality was divided by 100 to convert to a proportion. Additionally, LTA was calculated in cm^2 and then converted to m^2.

Region-wide stony coral density and LTA, octocoral density, and barrel sponge density were tested for differences between years 2013 – 2016. Additionally, select stony coral species (*M. cavernosa*, *M. meandrites*, *D. stokesii*, and *S. siderea*) were examined for changes in density and LTA between years. Similar to stony corals, the five octocoral target species were tested for differences in density and mean height between years. For metrics meeting the assumptions of a repeated measures analysis of variance (ANOVA), the ANOVA was performed using the linear mixed-effects model (lme) and anova functions in the nlme (Pinheiro et al. 2017) and base R packages, respectively, in R (version 3.3.3 (2017-03-06)) (R Core Team 2017). The lme equation was "metric" ~ year with site as the repeated measure within Year. Following the lme function, the anova function was used to perform the ANOVA on the lme model. Data that failed to meet the assumptions for a repeated measures ANOVA were transformed (square root for density and $\log_e(x)$ or $\log_e(x+1)$ for LTA and height). Transformed data that met the ANOVA assumptions were tested using the previously described lme and anova functions. Metrics failing to meet the assumptions of a repeated measure ANOVA following the transformation were tested using a Friedman's rank sum test on the non-transformed data. Significant differences between years for all metrics were identified by $p \leq 0.05$. For metrics analyzed via the lme and anova test and identified as significant, a general linear hypothesis (glht) and multiple comparisons "post-hoc" were performed to determine which years were significantly different. The "post-hoc" was performed using the glht function in the multcomp package (Hothorn et al. 2008) in R. Significant differences between years were identified by multiple comparison adjusted (Tukey single-step method) p-values ($p \leq 0.05$).

While not tested statistically, prevalence of disease for stony corals were calculated for the region for 2013 – 2016. Regional prevalence was calculated by taking the total number of diseased stony corals for the region and dividing it by the total number of all stony corals and multiplying by 100 to get prevalence as a percent. Site level prevalence values were calculated by dividing the total number of diseased colonies within a site it by the total number of colonies and multiplying by 100 to get prevalence as a percent.

Differences in stony coral, macroalgae, octocoral, and sponge percent cover between 2015 and 2016 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 (GLM) regression in SAS v 9.2 following 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. Benthic percent cover variables for each station at each of the 10 sites sampled from 2003-2016 (BCA, BC1, BC2, BC3, DC1, DC2, DC3, PB1, PB2, PB3) and two from 2006-2016 (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 residuals 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 14 (2016) Results

Stony Coral

The long-term stony coral benthic cover trend (2003-2016) for the region is presented in Figure 5. Region-wide there was a significant decreasing trend in stony coral cover (see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values). At the site level only BCA had a significant decreasing long-term trend. Annual trends for each site (presented by county starting in 2010 for clarity and to provide background data for demographic data that started in 2013) are presented in Figure 6. From 2015 to 2016, regional (22 sites) mean (±SEM) cover decreased from 2.54 ± 0.54% to 1.52 ± 0.32%. When the 2015 stony coral benthic cover was compared to 2016, seven sites had a significant decrease in cover in 2016 (see Appendix 1 for site level mean cover values and Appendix 2 for site level statistical p-values). Three sites with a significant decrease in cover from 2015 to 2016 were identified in Palm Beach County (PB2: 2015 – 2.04 ± 0.42%, 2016 - 0.87 ± 0.23%; PB4: 2015 – 1.56 ± 0.54%, 2016 - 0.40 ± 0.12%; PB5: 2015 – 2.04 ± 0.45%, 2016 – 0.79 ± 0.24%). Three sites in Broward County (BCA: 2015 – 9.88 ± 2.06 %, 2016 – 4.75 ± 1.06%; BC1:2015 – 12.35 ± 1.17%, 2016 – 7.28 ± 1.38%; BC5: 2015 – 1.43 ± 0.20%, 2016 – 0.16 ± 0.03%), and one site in Miami-Dade County (DC1: 2015 – 5.33 ± 2.54%, 2016 – 2.70 ± 0.76%) were also identified as having significant declines in cover from 2015 to 2016. Five sites (BCA: 51.9%, BC5: 88.8%, PB2: 57.4%, PB4: 74.4%, PB5:61.3%) had a greater than 50% decrease in stony coral cover, and two sites (BC1:41.1% and DC1:49.3%) had more than a 40% decrease (see Appendix 3 for year to year site level statistical p-values).

Region-wide colony live tissue area (LTA) for all species combined also showed a significant decrease in 2016 (Figure 7; repeated measures ANOVA: $p < 0.05$; see for region-wide and site mean values and Appendix 5 for regional statistical p-values). For the period from 2013-2016, 15 of 22 sites, representing all four counties, had the lowest LTA calculated in 2016. Additionally there was an average LTA loss from 2015 to 2016 of 35% (2015: 6.48 ± 2.36 m^2, 2016: 4.20 ± 1.50 m^2). Four sites had LTA losses from 2015 greater than 60%: PB5 (2015: 1.52 ± 0.27 m^2, 2016: 0.61 ± 0.21 m^2), PB4 (2015: 1.27 ± 0.15 m^2, 2016: 0.35 ± 0.12 m^2), BC6 (2015: 0.50 ± 0.22 m^2, 2016: 0.20 ± 0.03 m^2), and BC5 (2015: 0.91 ± 0.26 m^2, 2016: 0.19 ± 0.02 m^2). There was significant region-wide loss of *M. cavernosa*, *M. meandrites*, and *D. stokesii* LTA between the years 2013-2016 (repeated measures ANOVA: $p < 0.05$ for *M. cavernosa* and Friedman's test: $p < 0.05$ for *M. meandrites* and *D. stokesii*; see Appendix 5 for region-wide mean values and Appendix 6 for regional statistical p-values). From 2015 to 2016 *M. cavernosa*, *M. meandrites*, and *D. stokesii* lost (region-wide) 41% (2015: 3.43 ± 2.07 m^2, 2016: 2.03 ± 1.35 m^2), 99% (2015: 0.30 ± 0.10 m^2, 2016: 0.002 ± 0.001 m^2) and 80% (2015: 0.05 ± 0.02 m^2, 2016: 0.01 ± 0.00 m^2) LTA, respectively. Although not significant, *S. siderea* did experience an estimated 20% (2015: 0.30 ± 0.09 m^2, 2016: 0.24 ± 0.07 m^2) LTA region-wide loss (Friedman's test: $p > 0.05$; see Appendix 5 for region-wide mean values and Appendix 6 for regional statistical p-values).

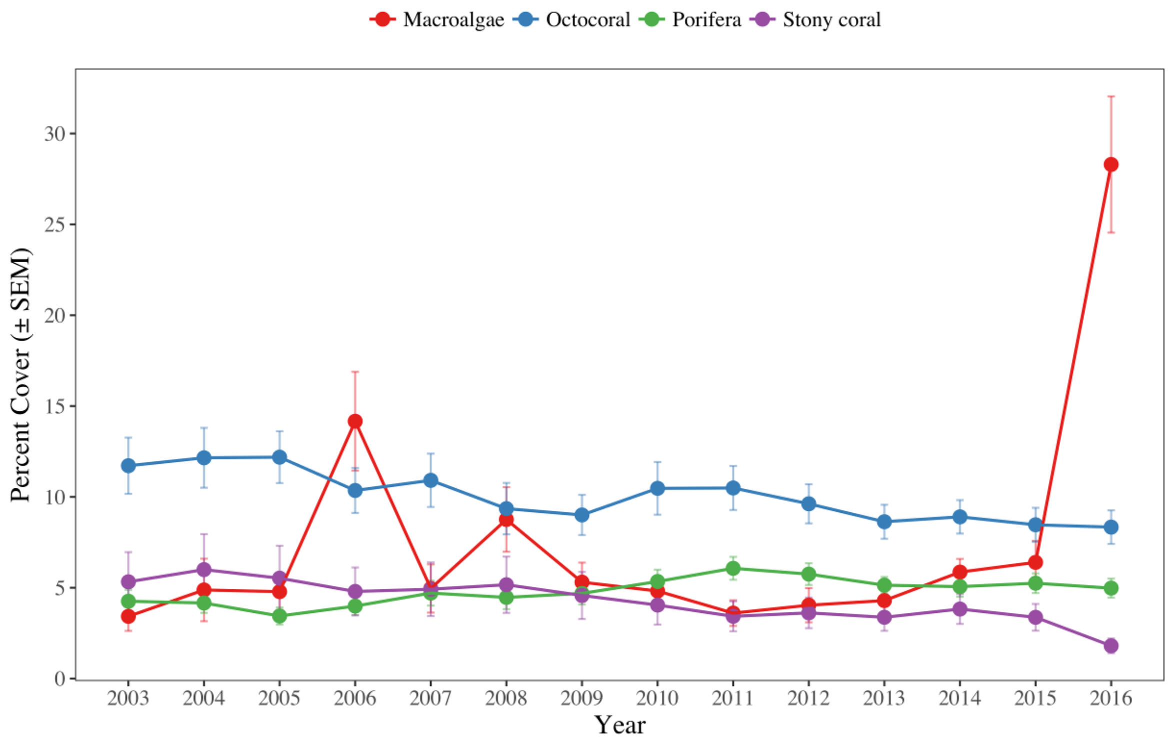

Figure 5. Mean region-wide annual percent cover of stony coral, octocoral, sponge, and macroalgae (n = 10 sites sampled since 2003). A significant decreasing trend (mixed model regression; see Appendix 2 for statistical values for all the sites evaluated) was identified for stony coral and octocoral cover, while significant increasing trends were identified for sponge and macroalgae cover.

Figure 6. Site mean stony coral percent cover (±SEM) for Martin, Palm Beach, Broward, and Miami-Dade Counties from 2010 to 2016.

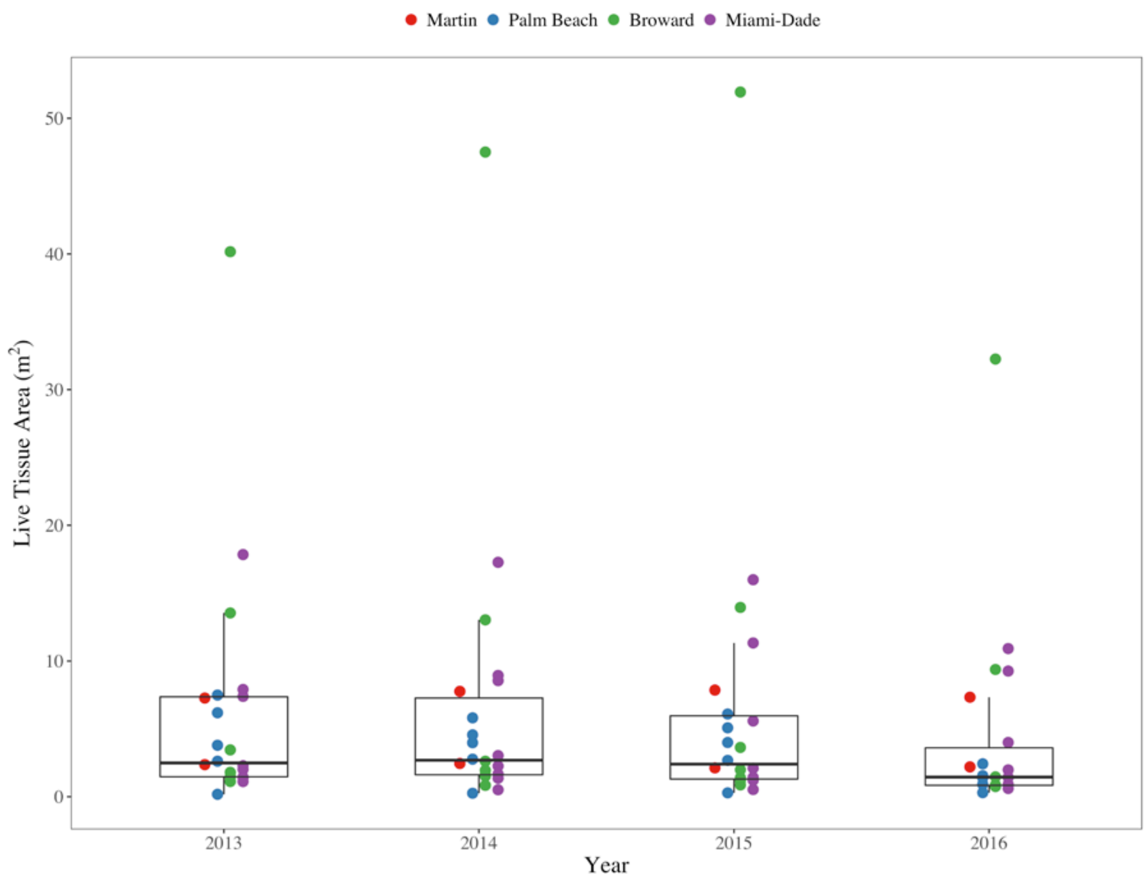

Figure 7. Distribution of live tissue area (LTA) for all stony corals summed by site from 2013 – 2016. Each point is the LTA at a site colored by county. The middle bar in the boxplot is the median LTA for the region, the areas above and below the median, hinges, represent the 1st and 3rd quartiles, respectively. The whiskers, upper and lower, extend from the hinge to the largest value no greater than 1.5*IQR, where IQR is the inter-quartile range (distance between 1st and 3rd quartiles). Points lying beyond the whiskers are considered outliers. There was a significant LTA decrease in 2016 (repeated measures ANOVA: $p < 0.05$; see Appendix 4 for region-wide and site mean values and Appendix 5 for regional statistical p-values).

Figure 8 illustrates the site distribution of colony densities across the region for 2013-2016 (22 sites). The 2016 regional mean (±SEM) stony colony density was 1.1 ± 0.17 colonies/m² which was significantly lower than in 2013 (1.2 ± 0.16 colonies/m²), 2014 (1.3 ± 0.18 colonies/m²), and 2015 (1.3 ± 0.19 colonies/m²) (repeated measure ANOVA: $p < 0.5$; see Appendix 7 for region and sites mean density values and Appendix 8 for statistical values). Density in 2016 ranged from a high of 3.4 ± 0.12 colonies/m² at site BC4 to a low of 0.27 ± 0.49 colonies/m² at site MC2 (see Appendix 7Appendix 6). Fourteen sites, representing three counties, had their lowest colony densities in 2016 (Appendix 7).

For all four select stony coral species, significant changes in colony density were found between years (*M. cavernosa* and *S. siderea* repeated measures ANOVA: $p < 0.05$; *D. stokesii* and *M. meandrites* Friedman's test: $p < 0.05$). For *M. cavernosa* (Figure 9) and *S. siderea* (Figure 10) densities in 2016 (0.13 ± 0.04 colonies/m^2 and 0.17 ± 0.03 colonies/m^2) were significantly lower than in 2013 (0.24 ± 0.06 colonies/m^2 and 0.23 ± 0.04 colonies/m^2), 2014 (0.26 ± 0.07 colonies/m^2 and 0.22 ± 0.04 colonies/m^2), and 2015 (0.25 ± 0.07 colonies/m^2 and 0.21 ± 0.03 colonies/m^2) (glth Tukey post-hoc: $p < 0.05$; see Appendix 9 for species mean density values and Appendix 10 for statistical values). From 2015 to 2016, declines in density of 48% (2015: 0.25 ± 0.07 colonies/m², 2016: 0.13 ± 0.04 colonies/m²) for *M. cavernosa* and 20% (2015: 0.21 ± 0.03 colonies/m², 2016 0.17 ± 0.03 colonies/m²) of *S. siderea* were observed. Significant declines in density were also identified for *M. meandrites* (2015: 0.05 ± 0.01 colonies/m^2, 2016: 0.003 ± 0.002 colonies/m^2) and *D. stokesii* (2015: 0.04 ± 0.01 colonies/m^2, 2016: 0.005 ± 0.003 colonies/m^2) from 2015 to 2016 (see Figure 11 and Figure 12, respectively). These two species experienced even greater declines in density compared to *M. cavernosa* and *S. siderea*, with a 94% loss for *M. meandrites* and 86% for *D. stokesii*.

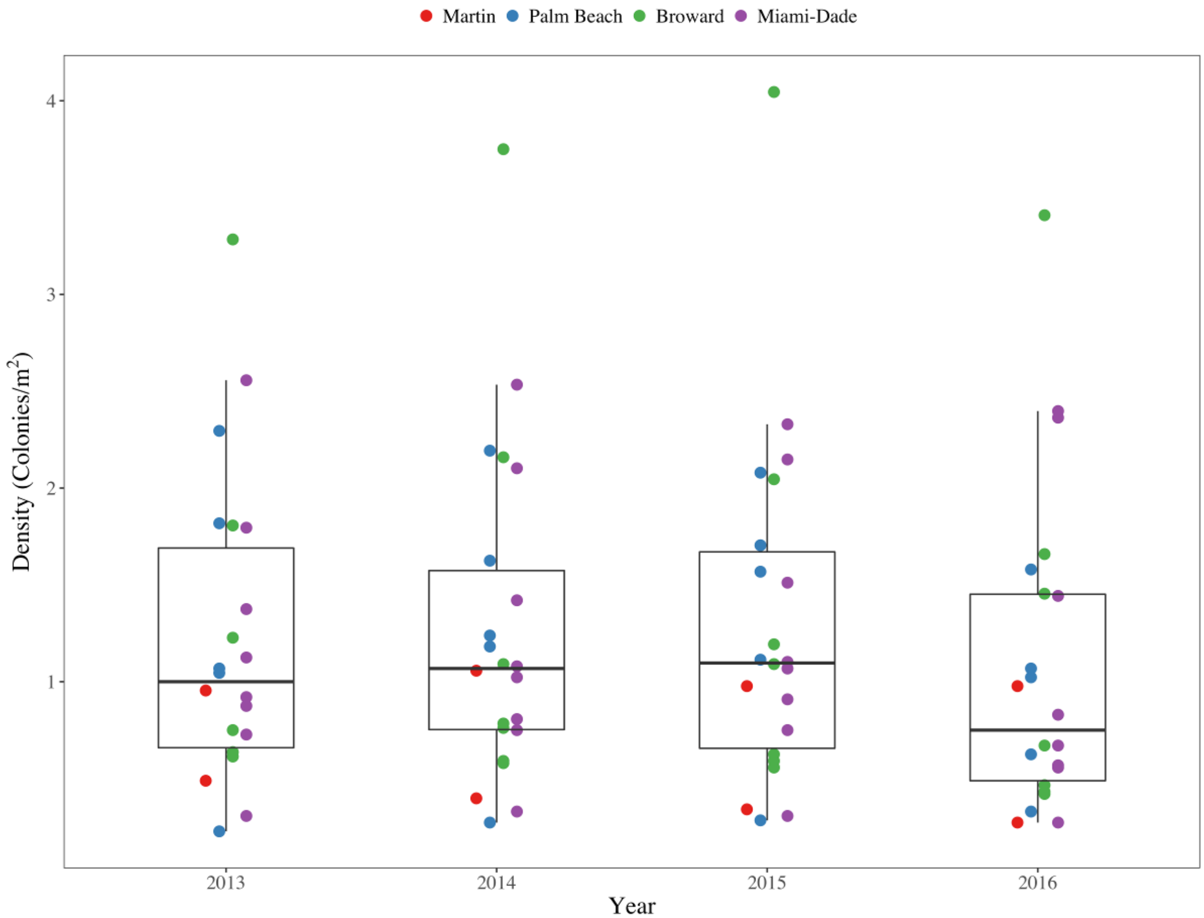

Figure 8. Distribution of region-wide stony coral density (colonies ≥4cm) summed by site from 2013 – 2016. Each point is the density at a site colored by county. See the caption for Figure 7 for explanation of the box and whisker components. Density in 2016 was significantly lower than 2013 (repeated measure ANOVA: $p < 0.5$; see Appendix 7 for region and sites mean density values and Appendix 8 for statistical values).

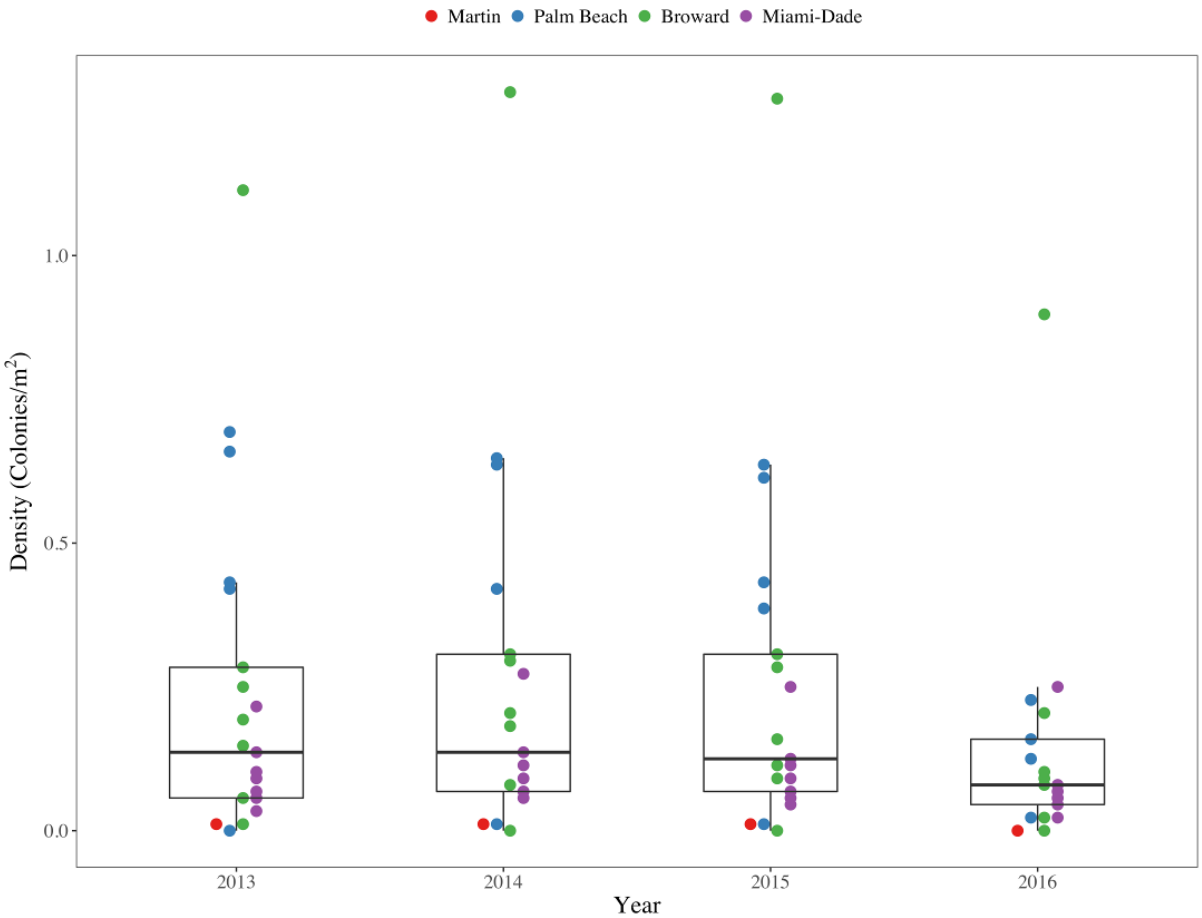

Figure 9. *Montastraea cavernosa* regional density distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. Density in 2016 was significantly lower than in 2013, 2014, and 2015 (glth Tukey post-hoc: $p < 0.05$; see Appendix 9 for species mean density values and Appendix 10 for statistical values).

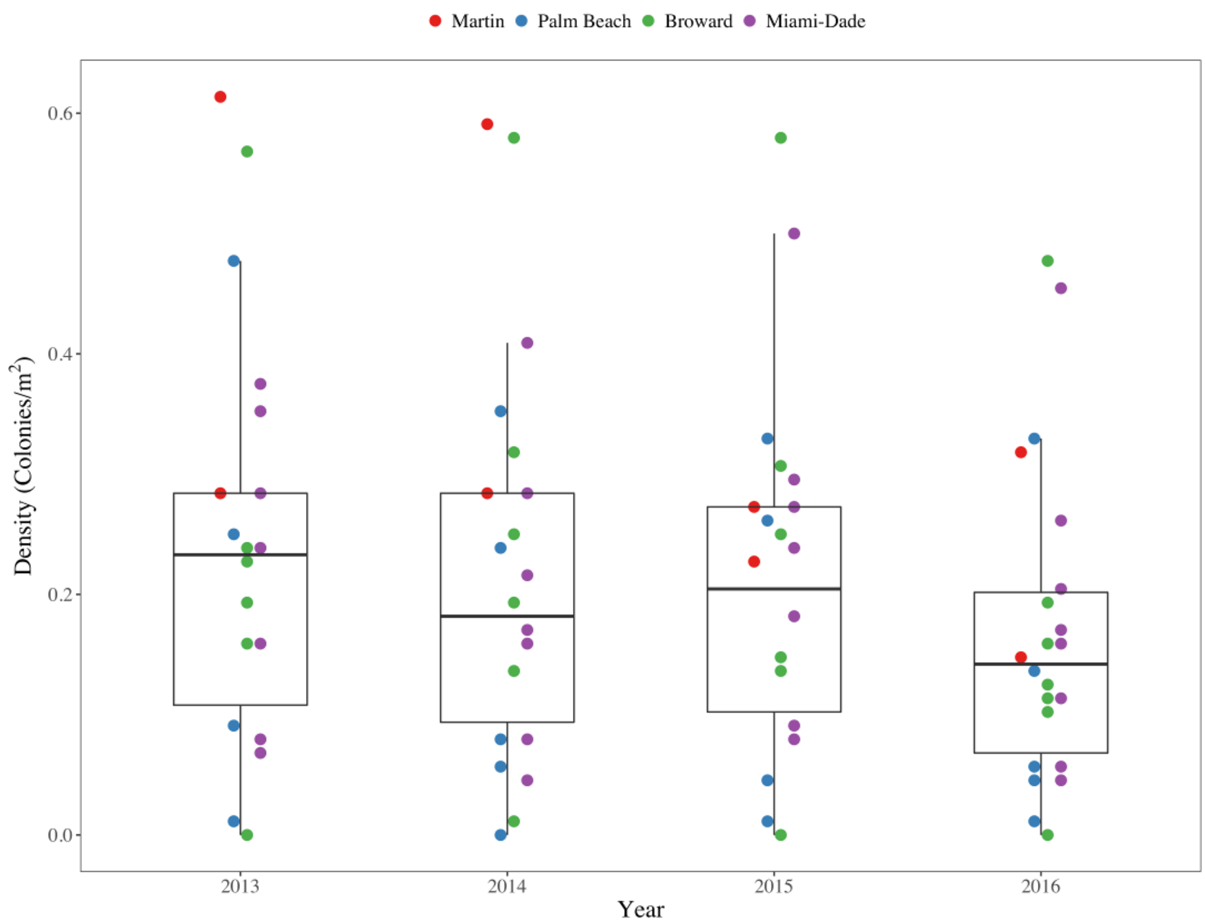

Figure 10. *Siderastrea siderea* regional density distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. Density in 2016 was significantly lower than in 2013, 2014, and 2015 (glth Tukey post-hoc: $p < 0.05$; see Appendix 9 for species mean density values and Appendix 10 for statistical values).

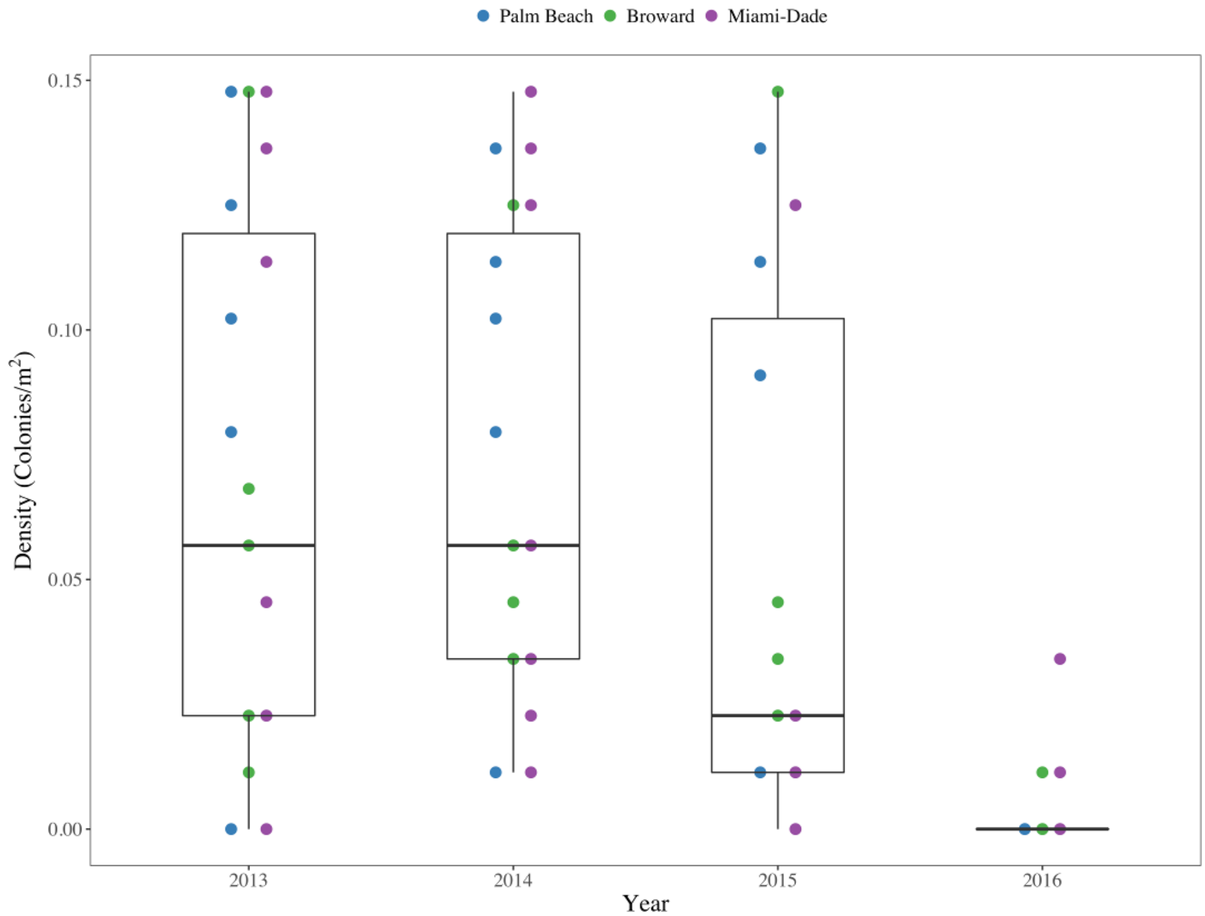

Figure 11. *Meandrina meandrites* regional density distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. Significant changes were identified between years (Friedman's test: $p < 0.05$ see Appendix 9 for species mean density values and Appendix 10 for statistical values).

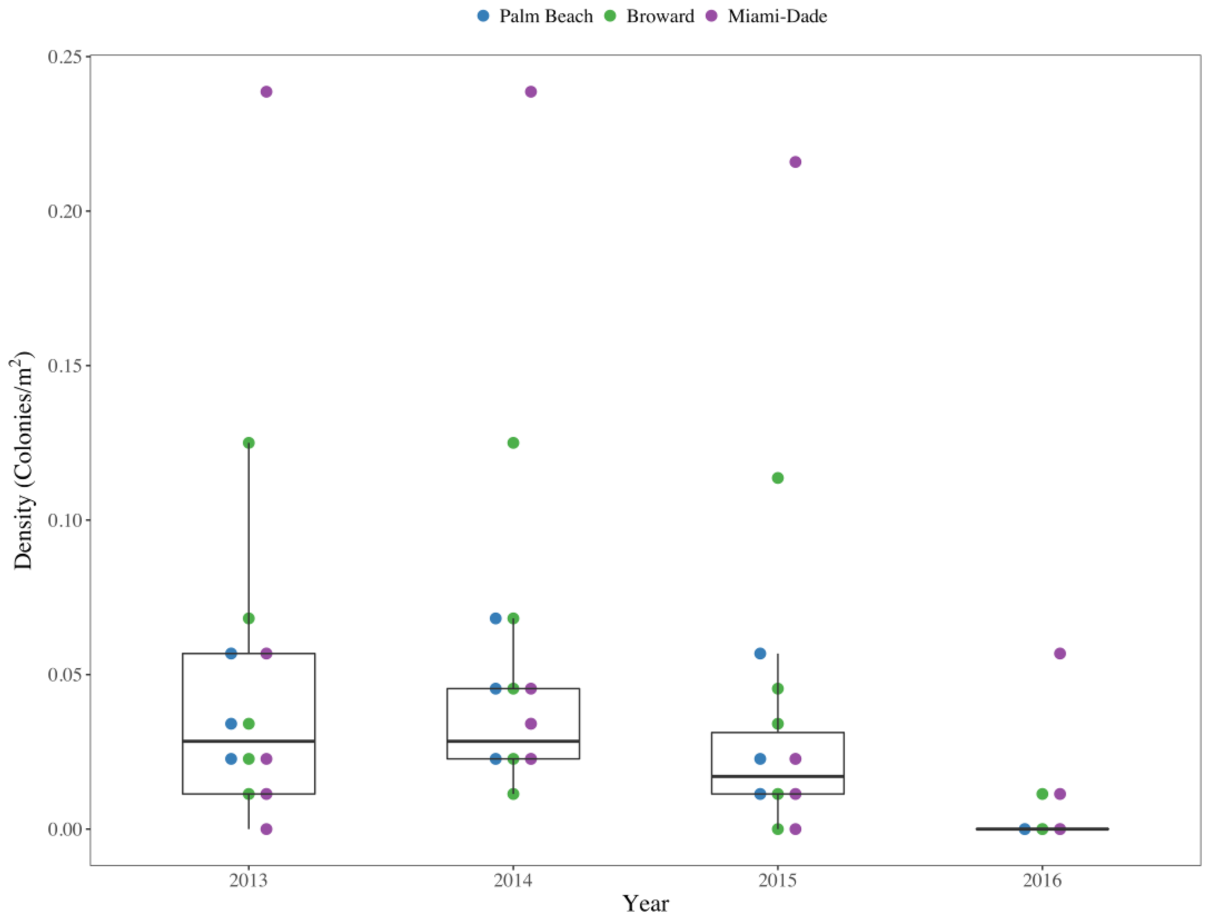

Figure 12. *Dichocoenia stokesii* regional density distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. Significant changes were identified between years (Friedman's test: $p < 0.05$ see Appendix 9 for species mean density values and Appendix 10 for statistical values).

Table 2. Stony coral disease prevalence (%). Values are the percent of total colonies identified with disease in each site and for the region values are the total number of diseased colonies for all sites combined divided by the total number of coral colonies for all sites combined.

Site	**2013 (%)**	**2014 (%)**	**2015 (%)**	**2016 (%)**
DC1	0.0	1.1	4.3	9.6
DC2	0.0	0.0	1.1	12.3
DC3	0.0	0.0	0.0	4.2
DC4	0.0	4.5	6.1	0.0
DC5	0.0	2.7	3.4	1.9
DC6	0.0	3.2	0.8	5.5
DC7	0.0	0.0	0.0	1.7
DC8	1.2	0.0	11.4	0.0
BCA	2.5	1.1	0.6	13.7
BC1	0.0	0.0	0.0	0.0
BC2	3.0	3.0	0.0	2.7
BC3	3.5	1.8	0.8	1.7
BC4	1.9	4.2	0.0	0.0
BC5	0.0	16.0	0.0	13.2
BC6	0.0	0.0	0.0	0.0
PB1	0.0	0.0	0.0	6.9
PB2	0.0	0.0	0.0	1.1
PB3	0.0	0.0	1.0	1.8
PB4	0.0	0.0	0.7	3.3
PB5	0.0	0.5	0.0	7.9
MC1	0.0	0.0	9.3	0.0
MC2	9.3	0.0	3.3	0.0
Region	1.0	1.6	1.8	4.4

Region-wide disease prevalence has increased every year since 2013 (Table 2). Prevalence increased from 1.8% in 2015 to 4.4% in 2016. At the site level, 12 sites had their highest recorded prevalence in 2016, while four sites had their highest in 2015. Throughout the four years of surveys collecting disease data, BC2 was the only site to never have a diseased colony identified. In 2013, dark spot syndrome, mostly on *S. siderea* colonies, was the primary contributor to disease prevalence. In contrast, in 2015 and 2016 white plague-like disease was the main contributor to disease prevalence and was the primary driver of the disease event.

Octocoral

The long-term octocoral benthic cover trend (2003-2016) for the region is presented in Figure 5. Similar to stony coral, region-wide there was a significant decreasing trend in octocoral cover (see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values). Five sites (DC3, PB1, PB2, PB3, and PB5) had significant decreasing long-term trends in cover, while DC1 had a significant increasing trend (see Appendix 1 for site mean cover values and Appendix 2 for site statistical p-values). Site annual trends are presented in Figure 13. From 2015 to 2016, regional (22 sites) mean (±SEM) cover, while not significant, decreased from 9.1 ± 1.2% to 8.8 ± 1.2% (see Appendix 3 for year to year site level statistical p-values). Octocoral cover significantly decreased from 2015 to 2016 at sites DC2 (0.12 ± 0.01% to 0.08 ± 0.00%) and DC7 (0.12 ± 0.02% to 0.05 ± 0.01%). Site PB3 octocoral cover was significantly higher in 2016 (0.17 ± 0.01%) than in 2015 (0.12 ± 0.01%) (see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values).

The 2016 regional mean (±SEM) octocoral colony density was 11.85 ± 1.83 colonies/m^2 (Figure 14). Density in 2016 ranged from a high of 29.33 ± 3.83 colonies/m^2 at site PB5 to a low of 0 colonies/m^2 at site MC1. A region-wide significant change in octocoral colony density was identified between years (repeated measures ANOVA: $p < 0.05$; see Appendix 7 for region and site mean values and Appendix 8 for region and site statistical p-values). Following the repeated measures ANOVA, pairwise comparisons indicated there was no significant change between 2015 (11.51 ± 1.76 colonies/m^2) and 2016 (11.85 ± 1.83 colonies/m^2), but both years were significantly higher than 2013 (8.68 ± 1.34 colonies/m^2) and 2014 (9.97 ± 1.55 colonies/m^2); which were not significantly different from each other (glht Tukey post-hoc: $p < 0.05$; see Appendix 8 for statistical p-values).

None of the five octocoral target species (*E. calyculata*, *A. americana*, *E. flexuosa*, *P. porosa*, and *G. ventalina*) were identified at site PB1 or either of the Martin County sites (MC1 and MC2). In 2016 the regional *Antillogorgia americana* density (2.07 ± 0.31 colonies/m^2) was the greatest of the five species followed by *E. flexuosa* (0.91 ± 0.26 colonies/m^2), *E. calyculata* (0.38 ± 0.08 colonies/m^2), *G. ventalina* (0.34 ± 0.07 colonies/m^2), and *P. porosa* (0.18 ± 0.04 colonies/m^2) (Appendix 11). There were no significant differences between any of the year to year comparisons (2013-2016) in region-wide colony densities for *P. porosa* (Figure 15) or *E. flexuosa* (Figure 16) (Friedman's test: $p > 0.05$; see Appendix 12 for statistical p-values). *Eunicea calyculata* had significantly lower colony densities in 2016 (0.38 ± 0.08 colonies/m^2) than in 2014 (0.58 ± 0.10 colonies/m^2), which did not significantly differ from 2013 (0.60 ± 0.13 colonies/m^2) or 2015 (0.53 ± 0.09 colonies/m^2) (Figure 17; repeated measures ANOVA: $p < 0.05$, glht Tukey post-hoc: $p < 0.05$). *Gorgonia ventalina* (Figure 18) and *A. americana* (Figure 19) had significantly higher colony densities in 2015 (0.35 ± 0.09 colonies/m^2 and 1.98 ± 0.28 colonies/m^2) and 2016 (0.34 ± 0.07 colonies/m^2 and 2.07 ± 0.31 colonies/m^2) than in 2013 (0.25 ± 0.06 colonies/m^2 and 1.57 ± 0.24 colonies/m^2), which was not significantly different from 2014 (0.28 ± 0.05 colonies/m^2 and 1.61 ± 0.26 colonies/m^2) for either species (repeated measures ANOVA & glht Tukey post-hoc: $p < 0.05$; see Appendix 11 for octocoral mean density values and Appendix 12 statistical p-values).

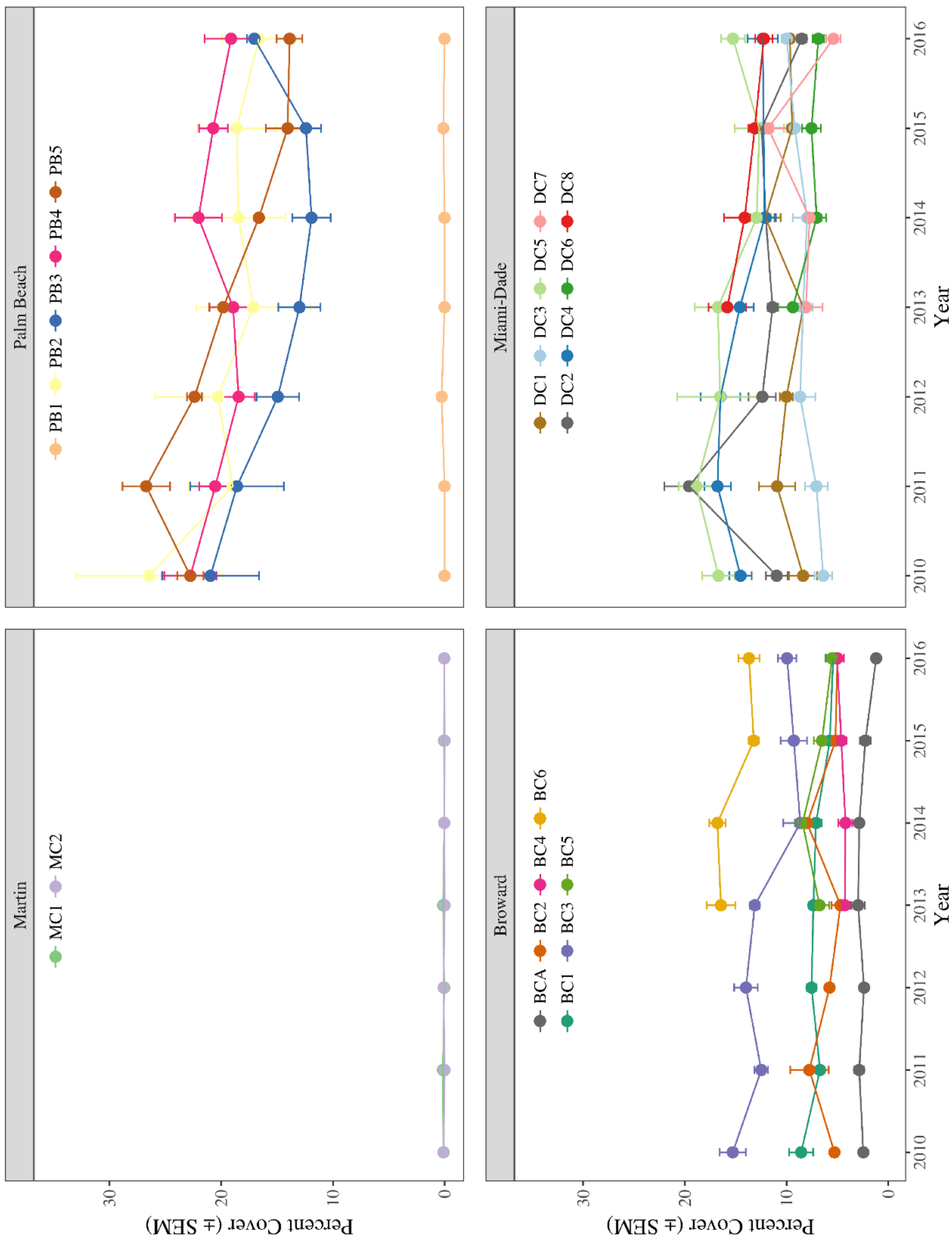

Figure 13. Mean octocoral percent cover (±SEM) for Martin, Palm Beach, Broward and Miami-Dade Counties from 2010 to 2016.

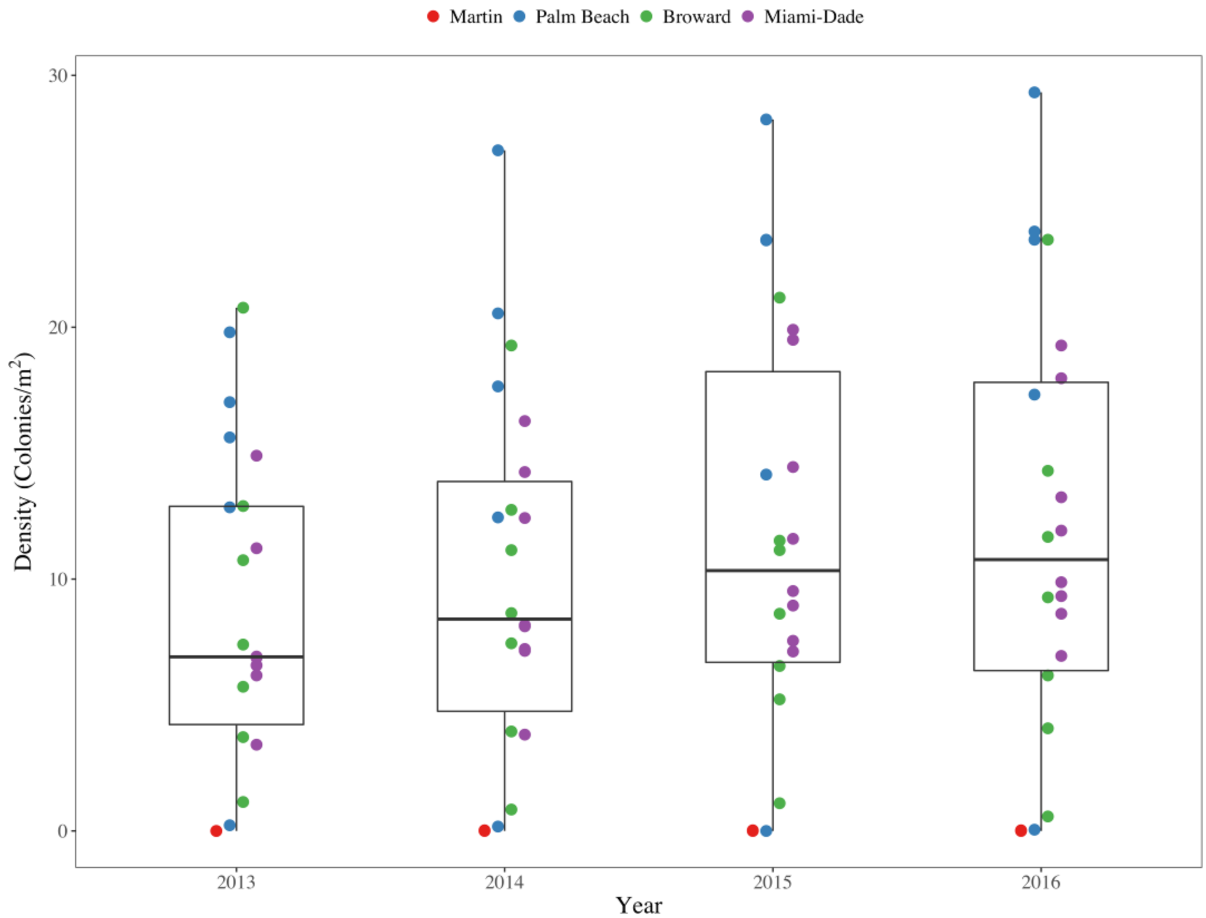

Figure 14. Region wide octocoral density (colonies/m²) distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. No significant differences were identified between 2015 and 2016, but both years were significantly greater than 2013 and 2014, which were not significantly different from each other (glht Tukey post-hoc: $p < 0.05$; see Appendix 8 for statistical p-values).

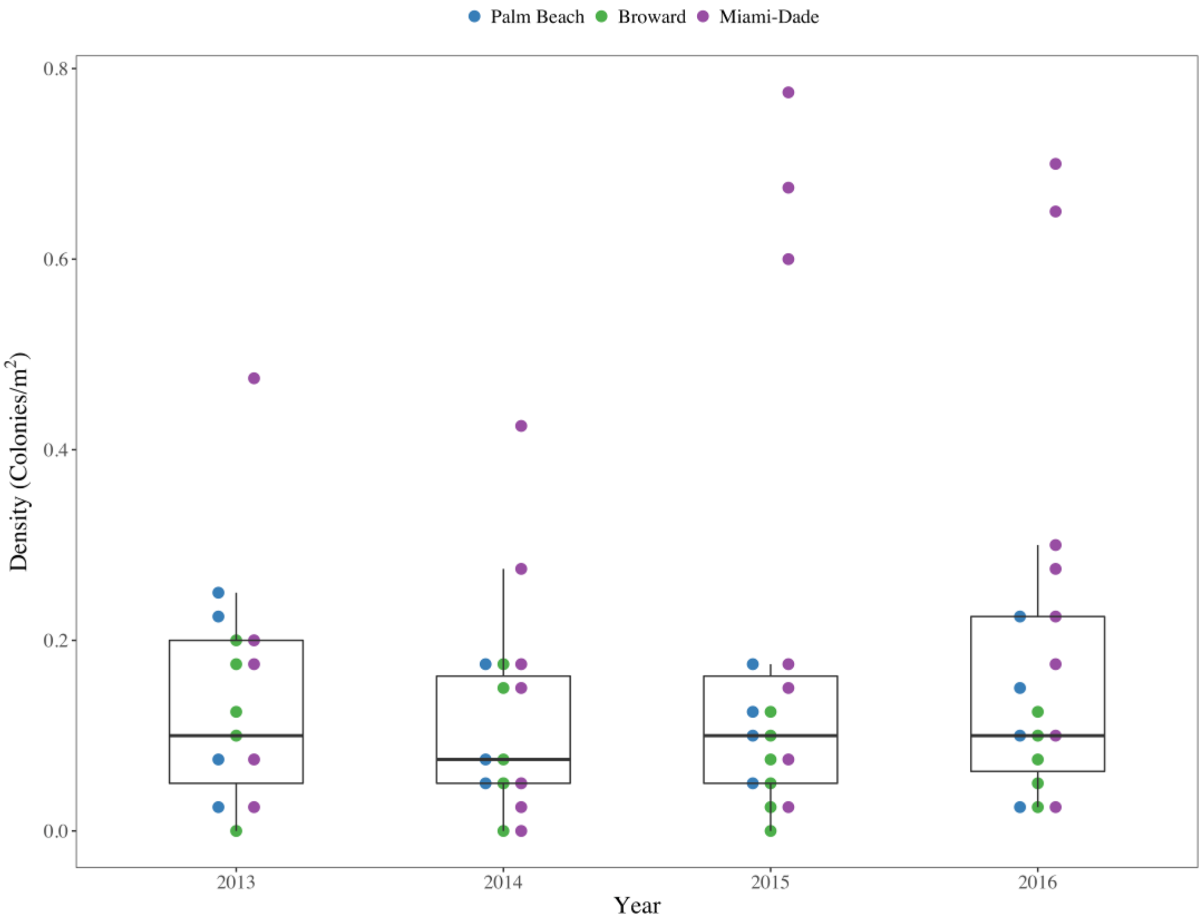

Figure 15. *Pseudoplexaura porosa* regional density (colonies/m^2) distribution 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. There was no significant difference between years (Friedman's test: $p > 0.05$; see Appendix 12 for statistical p-values).

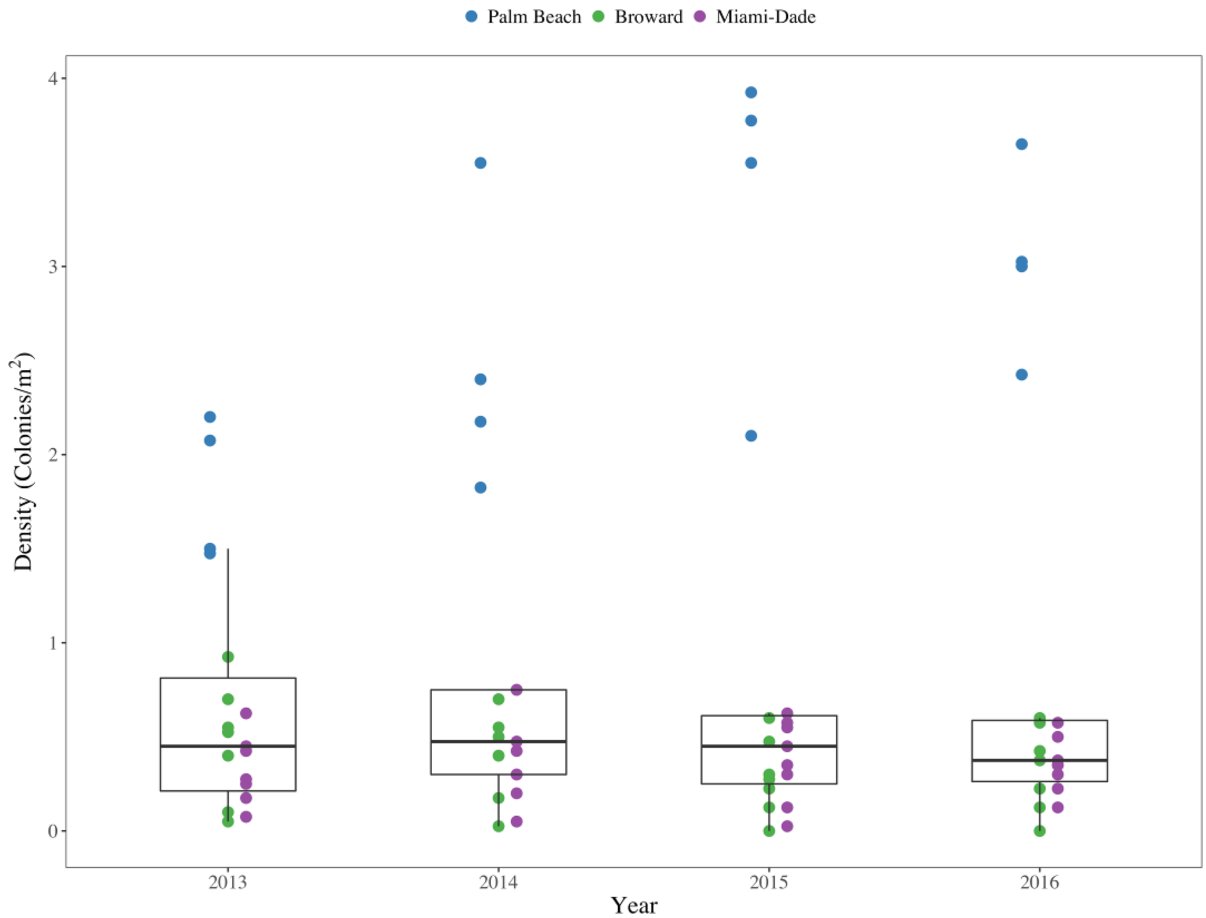

Figure 16. *Eunicea flexuosa* regional density (colonies/m2) distribution from 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. There was no significant difference between years (Friedman's test: $p > 0.05$; see Appendix 12 for statistical p-values).

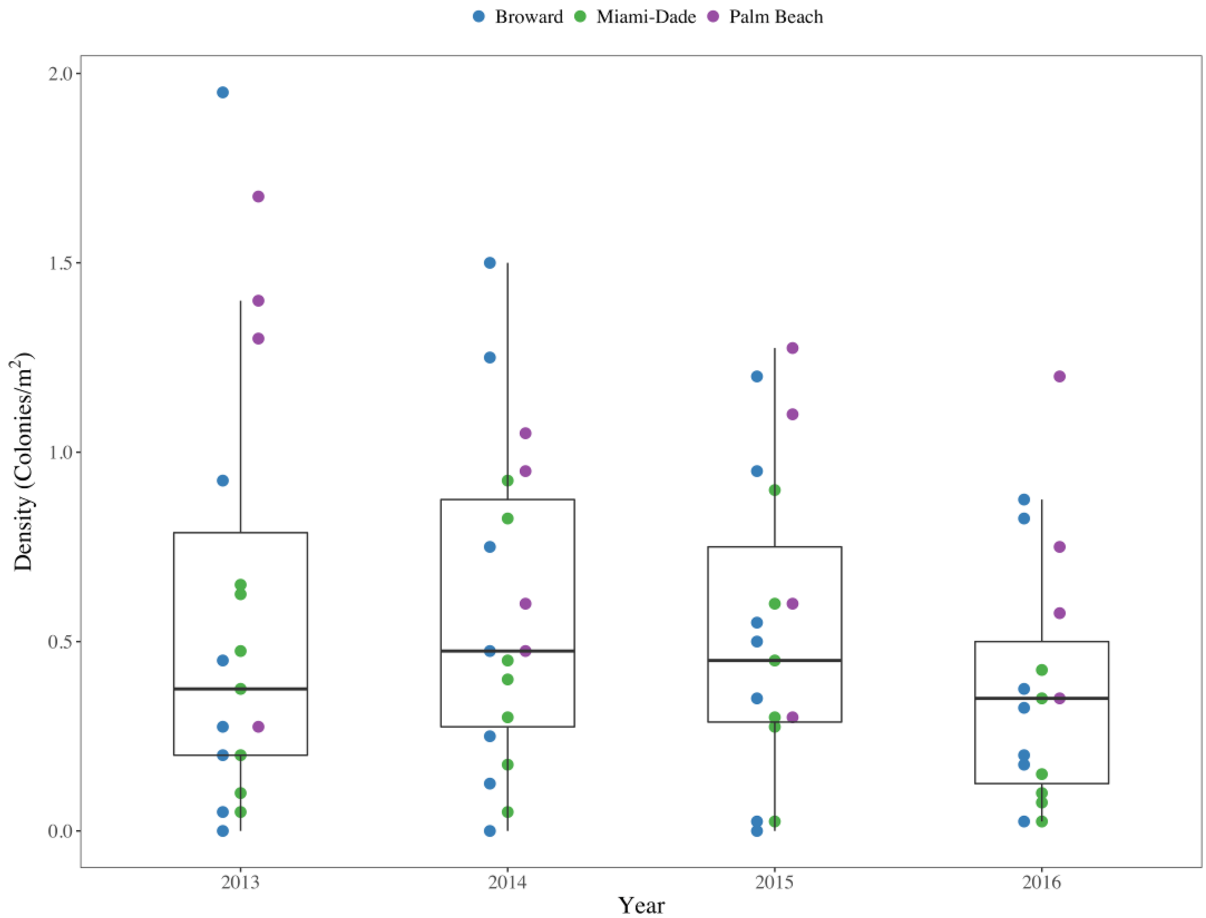

Figure 17. *Eunicea calyculata* regional density (colonies/m^2) distribution 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. 2016 was significantly lower than 2014, which did not significantly differ from 2015 or 2013 (repeated measures ANOVA: $p < 0.05$, glht Tukey post-hoc: $p < 0.05$; see Appendix 12 for statistical p-values).

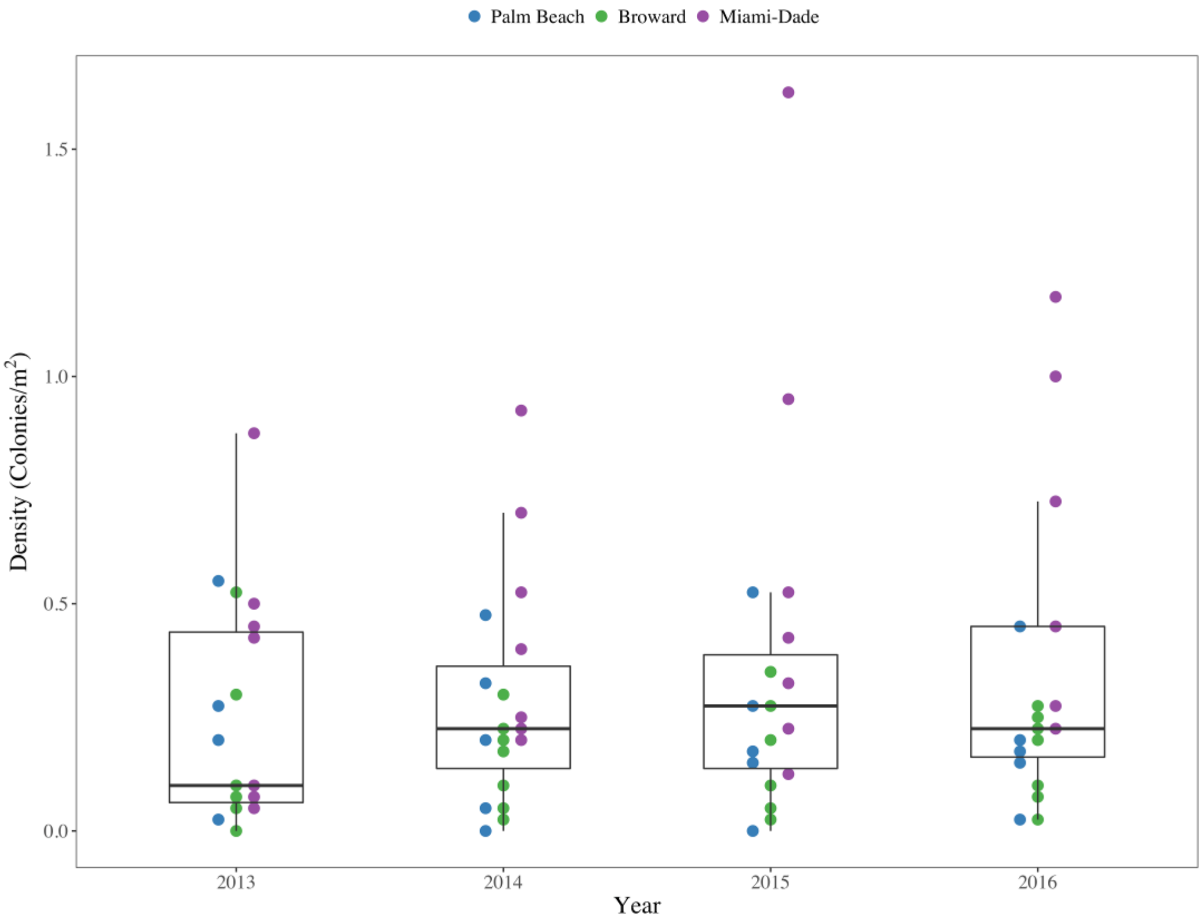

Figure 18. *Gorgonia ventalina* regional density (colonies/m^2) distribution 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. Only sites that have had the species were included. Densities were significantly higher 2015 and 2016 than in 2013 (repeated measures ANOVA & glht Tukey post-hoc: $p < 0.05$; see Appendix 12 for statistical p-values).

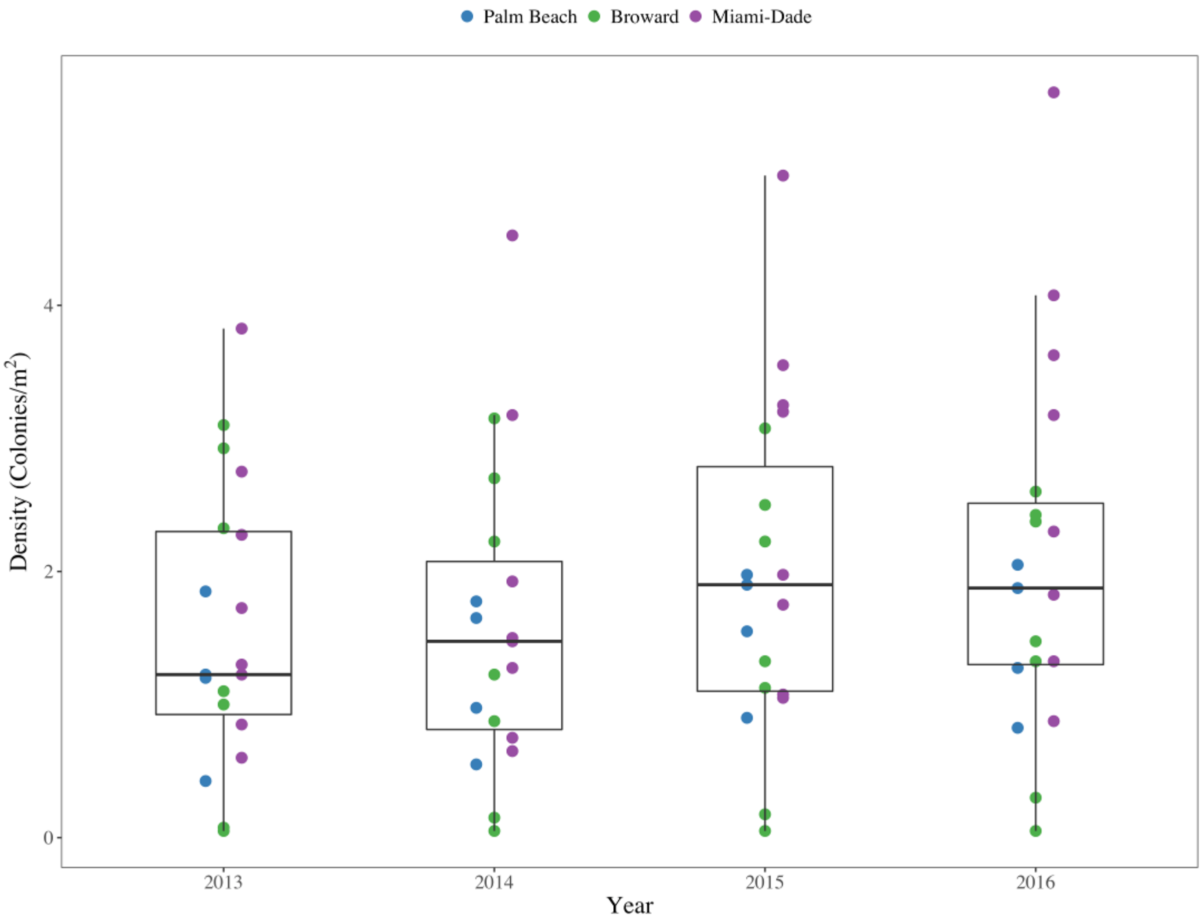

Figure 19. *Antillogorgia americana* regional density (colonies/m^2) distribution 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components please see the caption for Figure 7. Only sites that have had the species were included. Densities were significantly higher 2015 and 2016 than in 2013 (repeated measures ANOVA & glht Tukey post-hoc: $p < 0.05$; see Appendix 12 for statistical p-values).

No significant differences in average colony height were identified between years for *E. calyculata*, *G. ventalina*, and *E. flexuosa* (Figure 20; Friedman's test: $p < 0.05$; see Appendix 13 for target species mean heights and Appendix 14 for statistical p-values). Mean *P. porosa* colony height was significantly lower in 2016 (25.75 ± 2.23 cm) compared to 2013 (39.97 ± 3.07 cm), 2014 (33.72 ± 3.51 cm), and 2015 (27.72 ± 2.56 cm) (Figure 20; repeated measure ANOVA & glht Tukey post-hoc: $p < 0.05$; see Appendix 13 for octocoral mean heights and Appendix 14 for statistical p-values). *Antillogorgia americana* mean colony height was significantly different between years with the maximum colony height in 2013 (27.15 ± 0.52 cm) (Figure 20; Friedman's test: $p < 0.05$; see Appendix 13 for octocoral mean heights and Appendix 14 for statistical p-values).

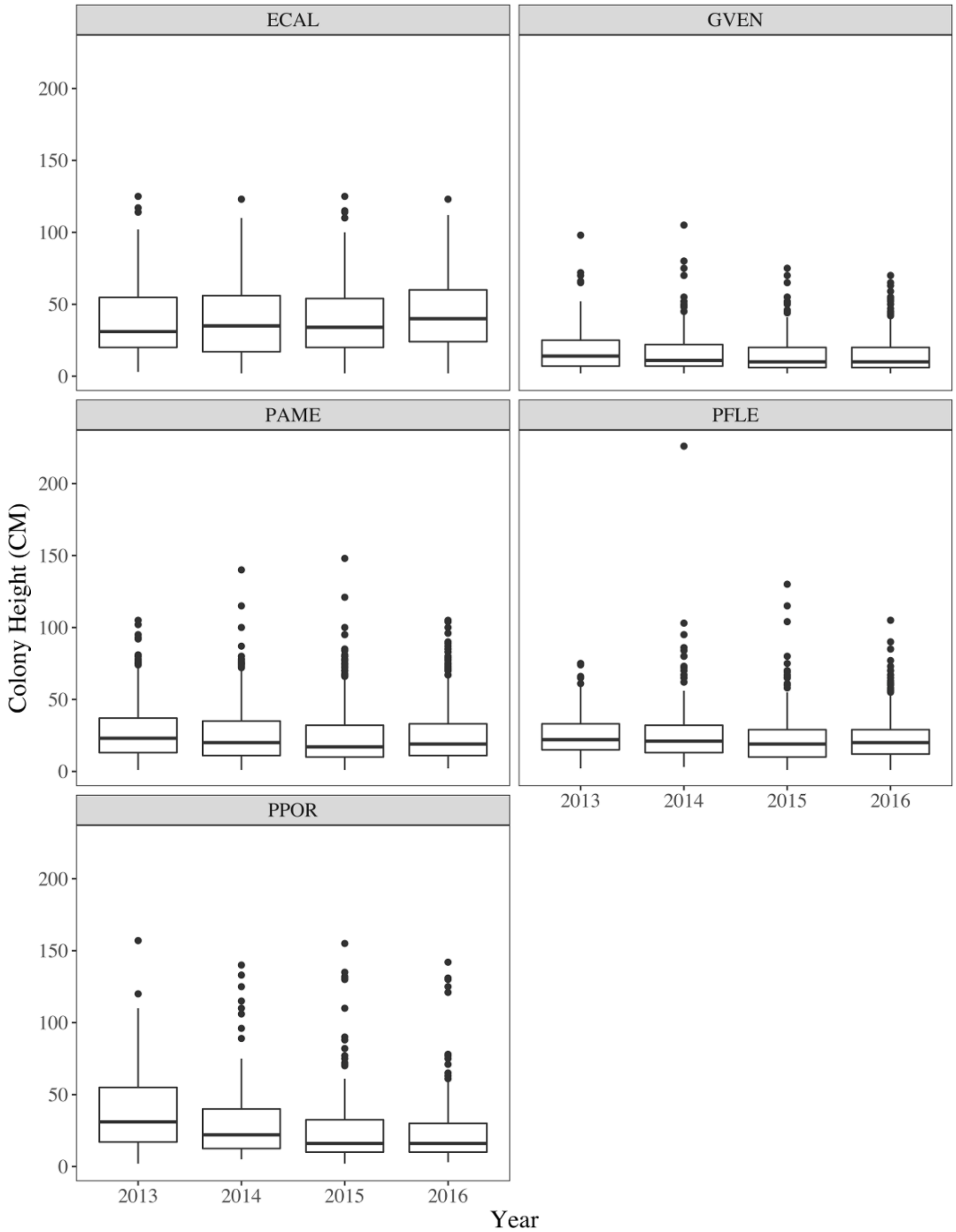

Figure 20. Octocoral target species colony height distribution 2013 to 2016. The middle bar in the boxplot is the median height for the region, the areas above and below the median, hinges, represent the 1st and 3rd quartiles, respectively. The whiskers, upper and lower, extend from the hinge to the largest value no greater than 1.5*IQR, where IQR in the inter-quartile range (distance between 1st and 3rd quartiles). Points lying beyond the whiskers are considered outliers. No significant difference between years were indentified for *E. calyculata* (ECAL), *G. ventalina* (GVEN), and *E. flexuosa* (PFLE) (Friedman's test: $p < 0.05$; see Appendix 14 for statistical p-values). *Pseudoplexaura porosa* (PPOR) was significantly lower in 2016 than 2015, 2014, and 2013; *A. americana* (PAME) was highest in 2016 (repeated measures ANOVA & glht Tukey post-hoc: $p < 0.05$; see Appendix 14 for statistical p-values).

Barrel Sponge (Xestospongia muta)

A significant region-wide change in *X. muta* density (Figure 21) was identified with 2013 (0.11 ± 0.01 sponges/m²) having the highest mean density followed by 2016 (0.08 ± 0.01 sponges/m²), 2015 (0.07 ± 0.01 sponges/m²), and 2014 (0.07 ± 0.01 sponges/m²) (Friedman's test: $p < 0.05$; see Appendix 7 for region mean values and Appendix 8 for statistical p-values). *Xestospongia muta* were identified at all sites except those on the nearshore ridge complex habitat; MC1, MC2, PB1, BCA, and DC8. The three sites with the highest densities in 2016 were all Palm Beach sites (PB3: 0.17 ± 0.03 colonies/m²; PB4: 0.18 ± 0.02 colonies/m²; and PB5: 0.22 ± 0.031 colonies/m²) with greater than 0.16 sponges/m² (see Appendix 7 for site mean values).

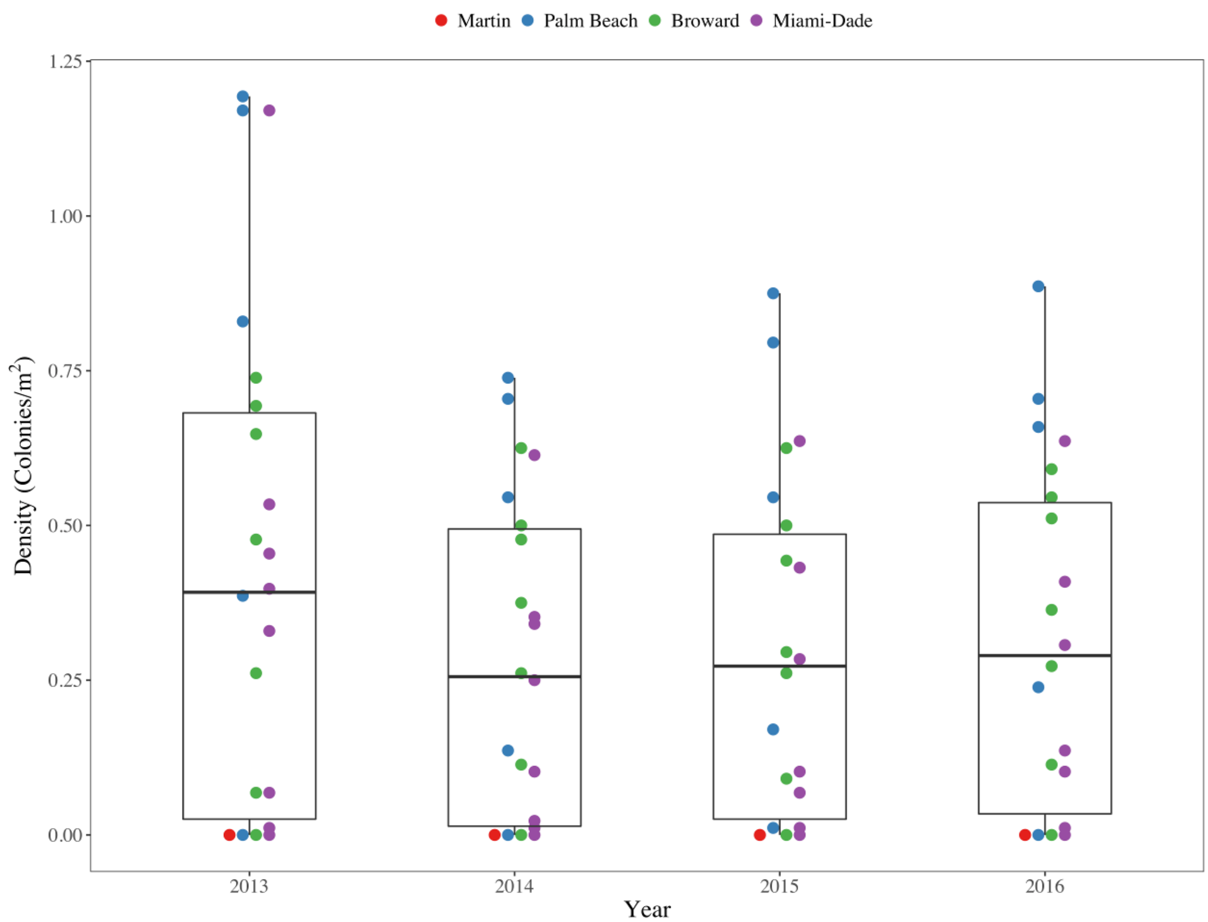

Figure 21. *Xestospongia muta* regional density (sponges/m²) distribution 2013 to 2016. Each point is the density at a site colored by county. For an explanation of the box and whisker components see the caption for Figure 7. A significant change between years was detected (Friedman's test: $p < 0.05$; see Appendix 7 for region mean values and Appendix 8 for statistical p-values).

Sponge and Macroalgae Percent Cover

Region-wide there was a significant increasing trend in sponge cover (Figure 5; see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values). At the site level, DC1 and PB5 had significant increasing long-term trends in cover, while PB1 had a significant decreasing trend (see Appendix 1 for site mean cover values and Appendix 2 for site statistical p-values). Regional (22 sites) mean (±SEM) cover was similar in 2015 (5.75 ± 0.61%) and 2016 (5.43 ± 0.54%) (Figure 5). At BC2 and DC3 sponge cover significantly increased from 2015 (6.55 ± 0.90%; 3.19 ± 0.84%) to 2016 (4.45 ± 0.58%; 4.86 ± 1.45%), and PB5 significantly decreased from 2015 (9.78 ± 1.40%) to 2016 (7.49 ± 0.86%) (Figure 22; see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values).

Region-wide there was a significant increasing trend in macroalgae cover (Figure 5; see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values). Ten sites (PB2, PB3, PB5, BCA, BC1, BC2, DC2, DC3, DC4, and DC5) had significant increasing long-term trends in cover, while three sites (MC1, MC2, and DC1) had significant decreasing trends (see Appendix 1 for site mean cover values and Appendix 2 for site statistical p-values). Regional (22 sites) mean (±SEM) cover increased from 11.16 ± 1.65% in 2015 to 26.90 ± 3.02% in 2016 (Figure 23). Macroalgae cover significantly increased from 2015 to 2016 at 10 sites (PB5, DC1, DC2, DC3, DC4, DC6, DC7, BC1, BC2, and BC3) (Figure 23). Only MC1 had a significant decrease in cover from 2015 (26.35 ± 8.89%) to 2016 (12.21 ± 7.54%) (Figure 23; see Appendix 1 for region-wide mean cover values and Appendix 2 for region-wide statistical p-values).

Site Benthic Temperature

During the 2016 sites visits, all temperature loggers were successfully recovered and data were downloaded for all 22 sites. The 2016 sample dates shown in Table 1 were the same dates that temperature loggers were collected and redeployed at each of the 22 sites. Figures 24-27 display the mean daily temperatures for the 22 sites by county (Martin: Figure 24; Palm Beach:
Figure 25; Broward: Figure 26; Miami-Dade: Figure 27). These figures illustrate the general warming trend (as expected) at all sites from February to August/September. Figure 24 also shows that the two 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 3 presents the dates and maximum and minimum temperatures (°C) for each site from late winter 2007 into summer 2016. For 18 sites, the maximum temperature was recorded in August 2014 (all ≥ 30.9°C) with one additional site in September 2014 (MC1: 30.6°C) (Table 3; also see Figures 24-27). All sites (22) in 2014 and 16 sites in 2015 had temperatures recorded over 30.5°C for multiple days (Table 4; 2016 was not included because a full year of temperature data was not collected at the time each site was sampled). A total of 43 days in 2014 and 77 days in 2015 had at least one site with recorded temperatures greater than 30.5°C. Prior to 2014, 2007 and 2011 were the years with the most days over 30.5°C recorded, each with 28 days.

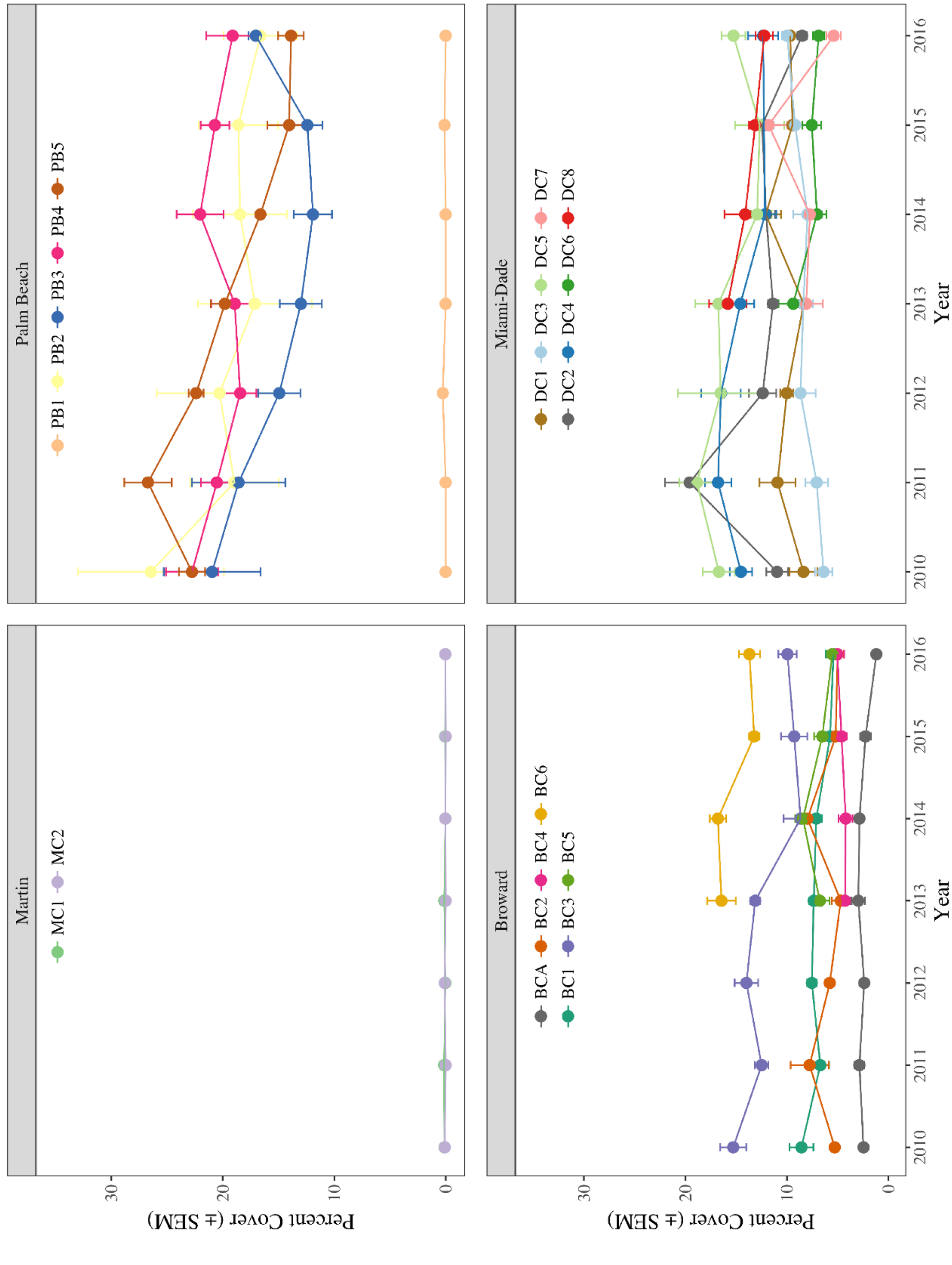

Figure 22. Mean sponge percent cover (±SEM) for Martin, Palm Beach, Broward and Miami-Dade Counties from 2010 to 2016.

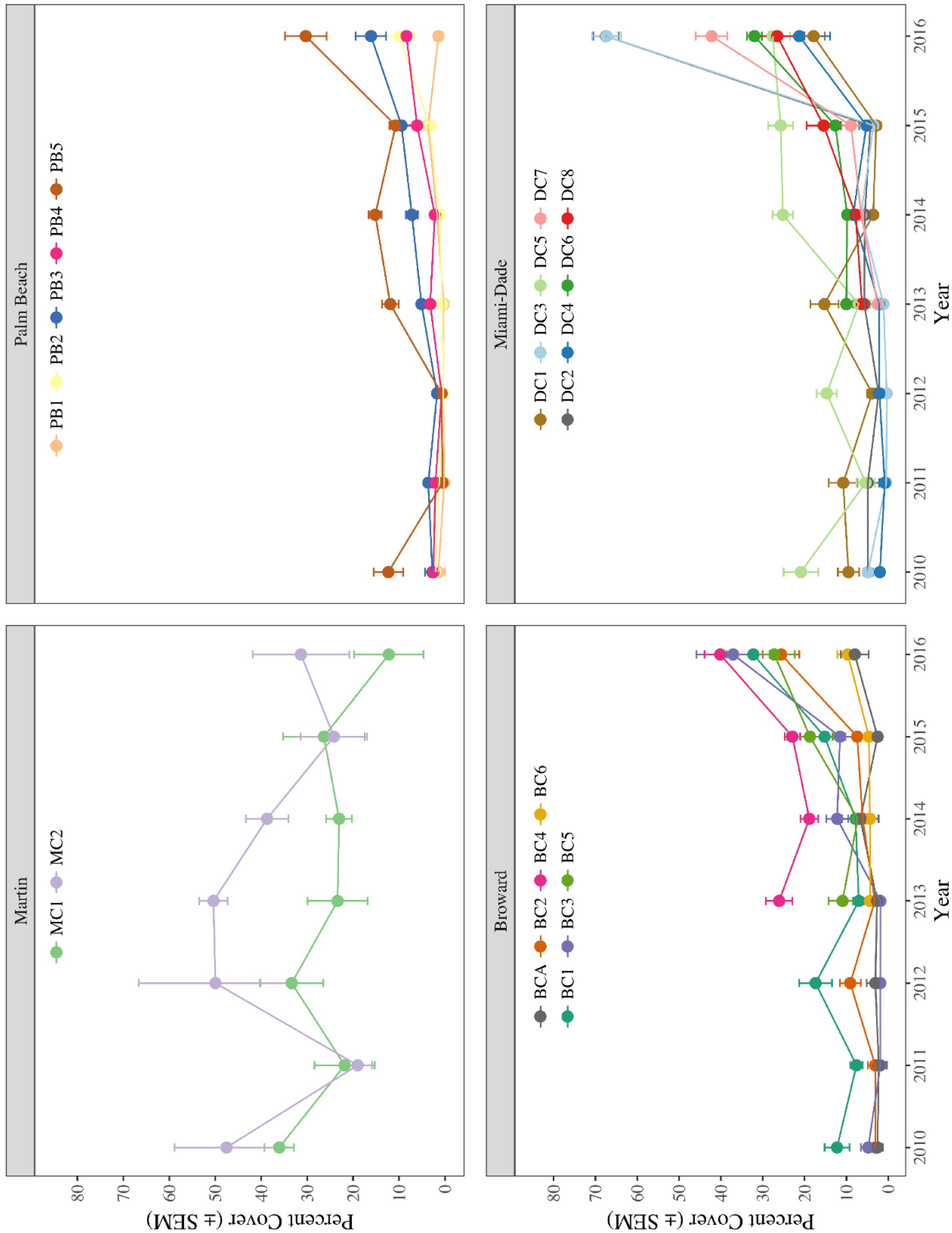

Figure 23. Mean macroalgae percent cover (±SEM) for Martin, Palm Beach, Broward and Miami-Dade Counties from 2010 to 2016.

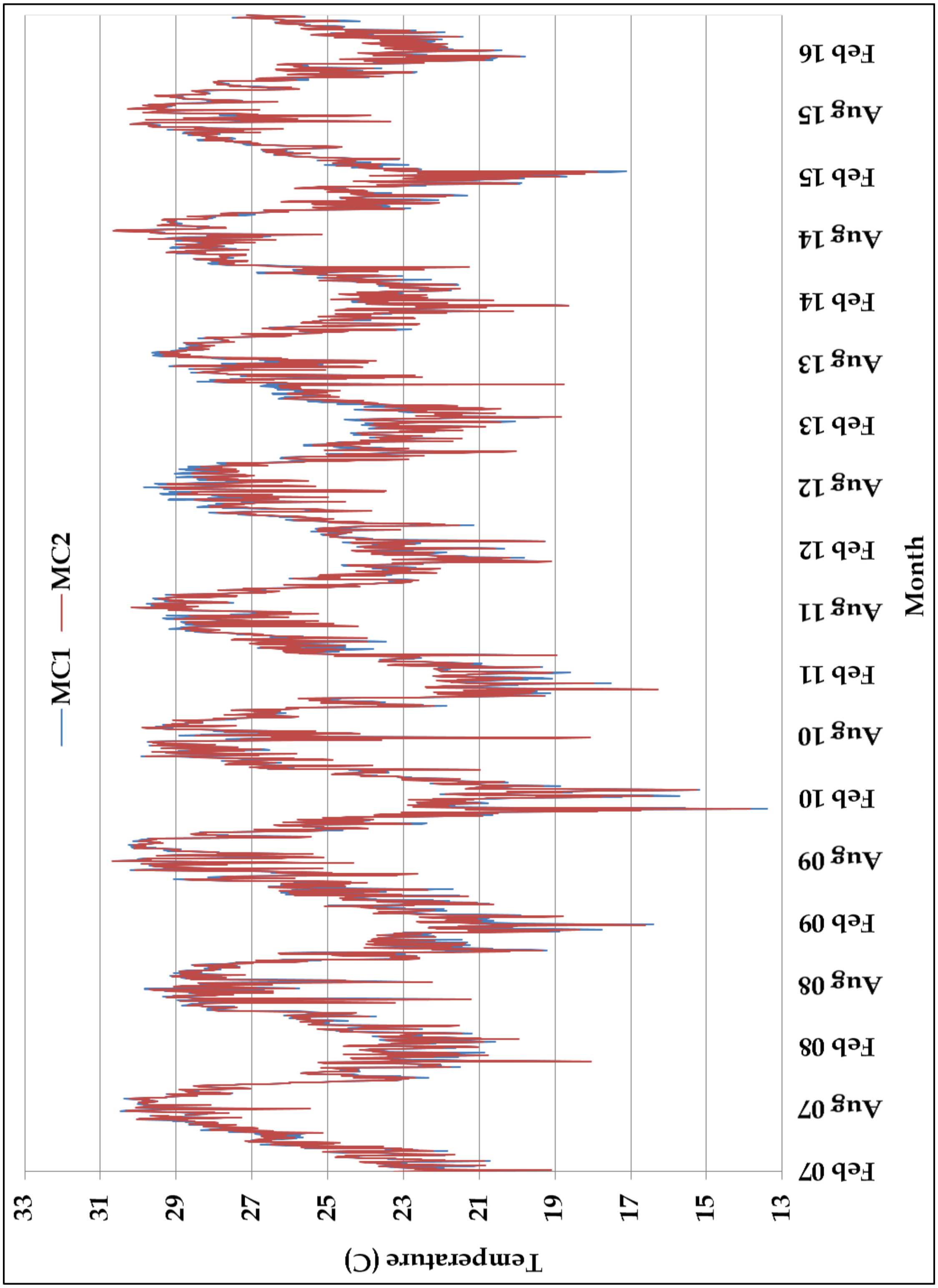

Figure 24. Mean daily temperatures for Martin County sites (°C), February 2007 – May 2016.

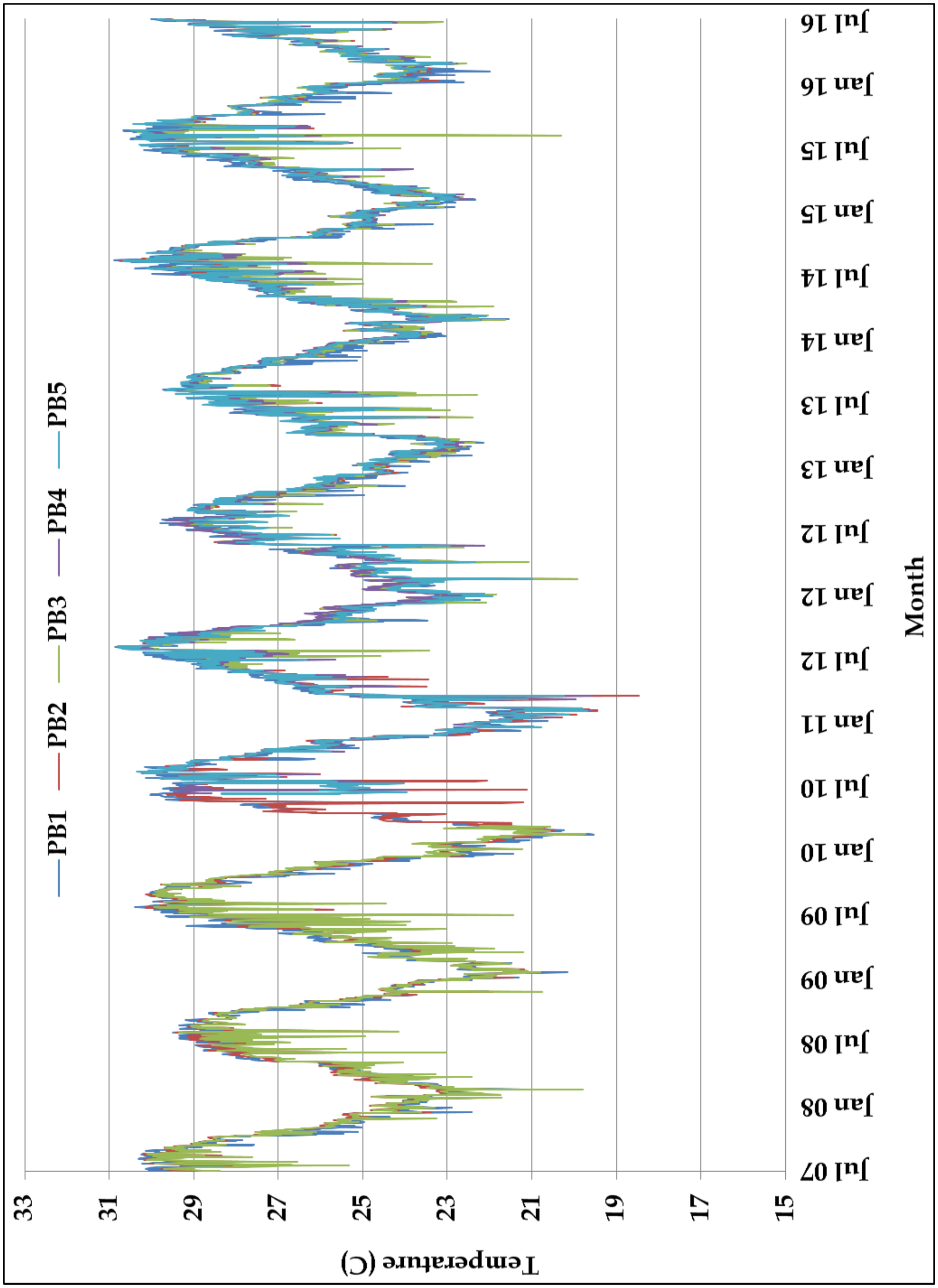

Figure 25. Mean daily temperatures for the Palm Beach County sites (°C), July 2007 – July 2016.

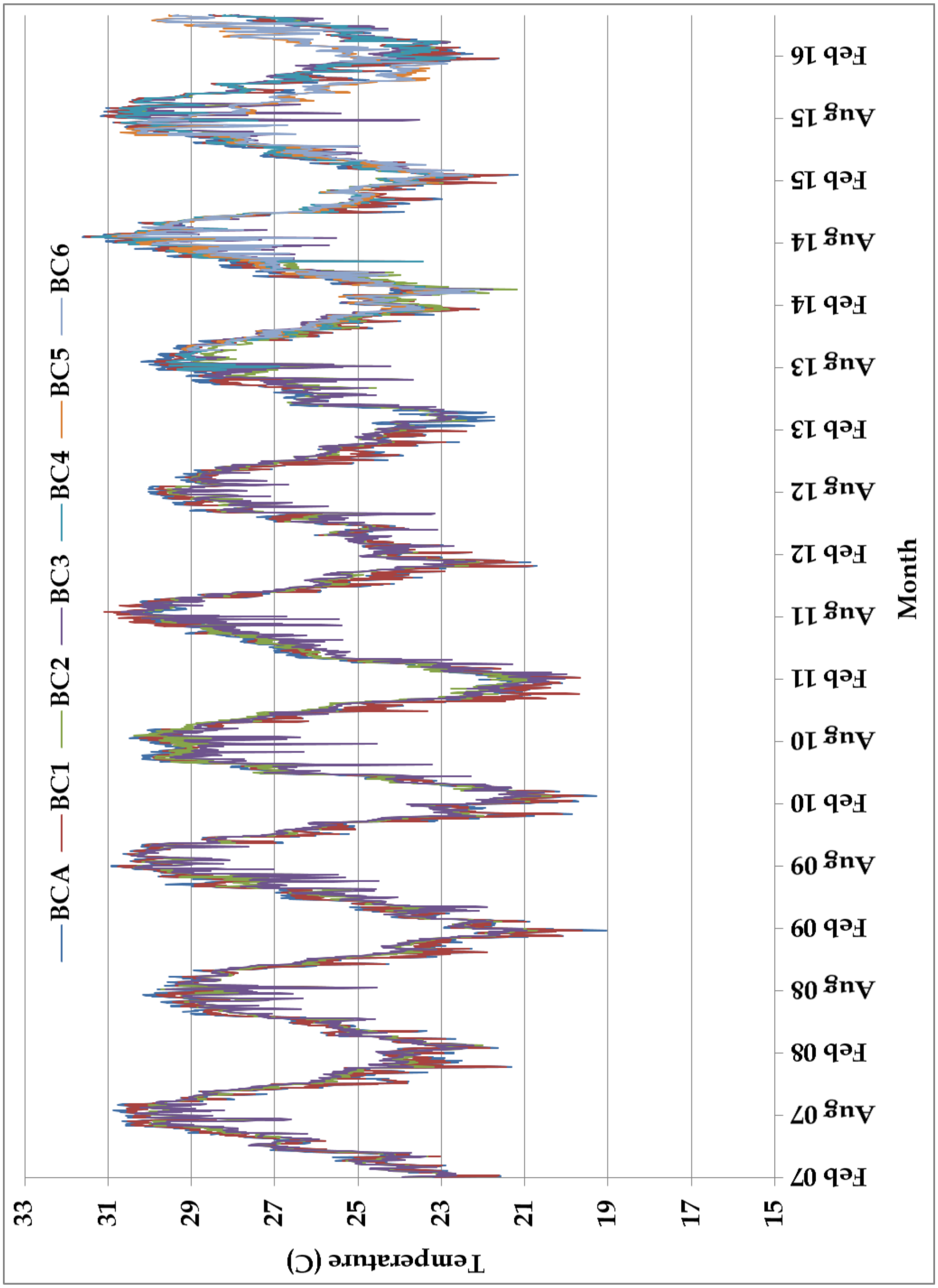

Figure 26. Mean daily temperatures for the Broward County sites (°C), February 2007 – June 2016.

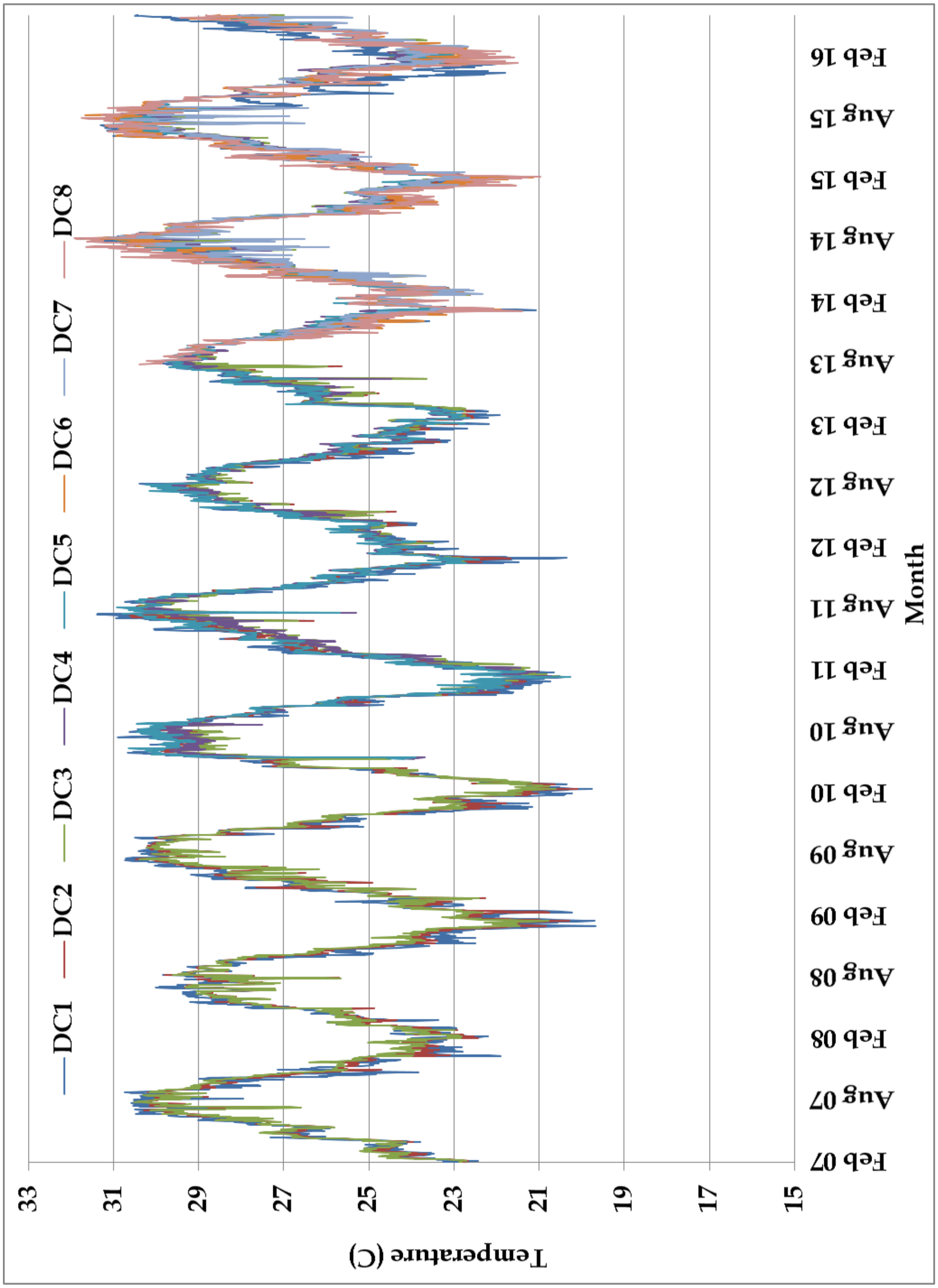

Figure 27. Mean daily temperatures for the Miami-Dade County sites (°C), February 2007 - June 2014.

Table 3. Maximum and minimum water temperatures (°C) and dates for the 22 sites with temperature loggers recording winter 2007 through December 2015.

	Maximum		**Minimum**	
Site	**Temp**	**Date**	**Temp**	**Date**
DC1	31.9	21 Aug 14	19.7	23 Jan 09
DC2	31.2	25 Aug 14	20.1	4 Mar 10
DC3	31.3	24 Aug 14	20.4	1 Feb 11
DC4	31.2	24 Aug 14	20.3	31 Jan 11
DC5	31.4	24 Aug 14	20.3	31 Jan 11
DC6	31.7	22 Aug 14	21.1	20 Feb 15
DC7	31.2	25 Aug 14	22.3	12 Mar 14
DC8	31.9	23 Aug 14	21.0	22 Feb 15
BCA	31.6	24 Aug 14	19.0	6 Feb 09
BC1	31.6	25 Aug 14	19.6	5 Mar 10
BC2	31.2	25 Aug 14	20.4	5 Mar 10
BC3	30.9	25 Aug 14	20.0	22 Feb 11
BC4	31.4	24 Aug 14	22.3	19 Feb 14
BC5	30.9	25 Aug 14	22.3	23 Mar 14
BC6	30.8	26 Aug 14	22.1	23 Mar 14
PB1	30.9	30 Aug 14	19.5	6 Mar 10
PB2	30.8	29 Aug 14	18.5	5 Apr 11
PB3	30.6	29 Aug 14	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	1 Sept 14	13.4	11 Jan 10
MC2	30.7	11 Aug 09	13.8	11 Jan 10

Table 4. Number of days per year with water temperature ≥ 30.5°C for the 22 sites with temperature loggers recording winter 2007 through 2015 (NA = sites not established) (2016 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	2014	2015
DC1	11	0	7	5	18	0	0	29	33
DC2	0	0	0	0	6	0	0	8	20
DC3	1	0	0	0	1	0	0	7	5
DC4	0	0	0	0	1	0	0	9	12
DC5	0	0	0	2	8	0	0	18	15
DC6	NA	NA	NA	NA	NA	NA	0	18	49
DC7	NA	NA	NA	NA	NA	NA	0	6	5
DC8	NA	NA	NA	NA	NA	NA	0	41	64
BCA	21	0	7	0	0	0	0	22	36
BC1	8	0	6	0	13	0	0	19	30
BC2	0	0	0	0	1	0	0	7	3
BC3	0	0	0	0	2	0	0	4	1
BC4	NA	NA	NA	NA	NA	NA	0	12	13
BC5	NA	NA	NA	NA	NA	NA	0	6	3
BC6	NA	NA	NA	NA	NA	NA	0	4	0
PB1	0	0	0	0	0	6	0	4	3
PB2	0	0	0	0	0	2	0	3	0
PB3	0	0	0	0	0	0	0	1	0
PB4	0	0	0	0	0	5	0	1	0
PB5	0	0	0	0	0	7	0	4	1
MC1	0	0	1	0	0	0	0	3	0
MC2	0	0	2	0	0	0	0	3	0

Discussion

The coral reef ecosystem offshore southeast Florida is the northern extension of the Florida Reef Tract (FRT) and 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 Florida Keys and Dry Tortugas (southern portions of the Florida Reef Tract) (Ruzicka et al. 2010; Ruzicka et al. 2012). Benthic cover by octocorals and macroalgae is similar throughout the FRT, 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).

During the 2016 sampling year, the northern portion of the FRT (southeast Florida reefs) experienced unprecedented stony coral community declines. Significant declines were detected for all stony coral metrics examined (cover, LTA, and density) at the regional and site levels. A stony coral disease event had been reported offshore southeast Florida starting in late 2014 and continued through 2016 (Kabay 2016, Precht et al 2016, personal and expert observations by numerous groups). This disease event was very likely the greatest contributing factor to the significant loss of stony coral colonies and live tissue identified within the SECREMP sites in 2016. In 2013 stony coral demographic surveys revealed disease prevalence for the region was 1.0% with only five of the 22 sites having diseased colonies recorded. In 2014, region-wide prevalence increased to 1.8% with 11 sites having diseased colonies recorded and in 2016 prevalence increased to 4.4% with 15 of the 22 sites having diseased colonies recorded.

A significant decreasing long-term trend in stony coral cover was determined region-wide, but at the site level only one site, BCA, had a significant decreasing trend. It is likely that additional sites after the 2017 sampling event will also have significant decreasing trends. When comparing 2015 to 2016 there was an estimated 33% loss in mean region-wide cover. Seven sites had a significant loss in cover and an additional 10 sites exhibited declines from 2015 to 2016, although not statistically significant. Stony coral live tissue areas (LTA) were estimated to provide an additional and perhaps more sensitive metric for describing changes to the amount of live tissue in the region. Region-wide (all sites and colonies pooled) there was a significant 43% loss in LTA from 2015 to 2016. For 16 sites, 2016 had the lowest estimated LTA and for five of those sites the loss was greater than 60% (Appendix 4). A significant decrease in region-wide stony coral density was also determined with an estimated 17% decrease in colony density from 2015 to 2016. Similar to benthic cover, at the site level 17 sites experienced a density decline in 2016 with an average loss of 27%.

Loss of *Montastraea cavernosa* and *S. siderea* is of particular concern because both species contribute greatly to stony coral benthic cover and density and are present in all four southeast Florida counties and reef habitats. *Montastraea cavernosa* is also one of the more common large (~>50cm diameter) colony forming species, and *S. siderea* has commonly been described as a ‘robust’ species capable of surviving in variable habitats and conditions. *Meandrina meandrites* and *D. stokesii* were also examined in detail. Although commonly in much lower densities than the previous two species, *M. Meadrites* and *D. stokesii* are frequently found throughout southeast Florida. *Meandrina meandrites* and *D. stokesii* were also two initial species reported as dramatically impacted by the disease event (personal and expert observations by numerous groups). The 2016 sampling event documented dramatic declines in colony density and LTA for all four species. An example highlighting these losses in terms of abundance, in 2013 114 *M. meandrites* colonies and 75 *D. stokesii* were identified within the 22 SECREMP sites by 2016 their abundances dropped to five and eight colonies, respectively.

Declines in the stony coral community were not confined to any one area and this regional scale loss is of great concern. Stony coral cover, density and LTA declines were observed in Martin, Palm Beach, Broward and Miami-Dade counties. These losses were also observed in all habitats, which range in depth from 3 to 21 meters. The rate of decline is also of concern as significant losses have been observed over relatively short time periods. Stony coral disease prevalence has increased every year since 2013. There were notable losses of *M. cavernosa*, *S. siderea*, *M. meandrites* and *D. stokesii* observed in 2015 (Gilliam et al 2016), but the declines from 2015 to 2016 were more extreme.

There is no clear relationship between the changes documented in the stony coral community and the octocoral or sponge communities. There remains a significant region-wide decreasing long-term trend in octocoral cover, but mean cover has been similar since 2014. Region-wide octocoral density has increased since 2013 and three of the five target species have increased significantly in density since 2013. *Eunicea flexuosa* and *P. porosa* densities have not changed significantly over this time period.

There was a non-significant increase (2015-2016) in *X. muta* density region-wide and at 15 of the 22 sites. A significant region-wide increasing long-term trend in sponge cover was identified, but similar to octocorals, there has been little change in mean regional sponge cover since 2013. The conditions driving the changes to the stony coral community do not appear to be, at the current level of examination, impacting the octocoral or sponge communities.

There continues to be a significant region-wide increasing long-term trend in macroalgae cover. Macroalgae mean cover in 2016 was the highest ever recorded and more than twice that measured in 2015. For all sites that had a significant increase in macroalgae cover in 2016 there was also a decrease in at least one stony coral metric (benthic cover, colony LTA and/or density). It is likely these significant macroalgae cover increases were driven by some of the same environmental conditions that contributed to the stony coral community declines. Macroalgae also likely occupied newly available benthic space resulting from the loss of stony corals.

SECREMP is an annual monitoring program and annual programs are designed to provide current status and long-term trend information. Capturing the processes that contribute to the changes in conditions and long-term trends is a challenge for annual sampling. However, there are compelling data and observations that supports that the significant stony coral declines from 2014 through 2016 have been driven by the on-going disease event. An increase in stony coral disease prevalence was identified in the SECREMP region in 2016. This increase was driven by what visually appears as a white plague-like disease. Diseased colonies were also noted outside of the sample area at many sites. It is notable and troublesome that this event has spread south into the Keys (expert observations by numerous groups) and increases in stony coral disease prevalence were also reported for the Keys in 2014 and 2015 (Van Woesik and McCaffrey 2017; expert observations and personal communication with CREMP personnel). Additionally, the loss of almost all known (>90%) pillar corals, *Dendrogyra cylindrus*, offshore southeast Florida is another example of the dramatic and significant impact this event has had on the stony coral community (Kabay 2016).

Diseased individuals are a normal part of all populations, but unfortunately, disease outbreaks appear to be becoming a greater and more common threat. There have been a number of environmental factors reported as potentially increasing the risk of disease and mortality above normal levels, including elevated water temperatures, various water quality parameters, and increased sedimentation and turbidity. Over the course of the SECREMP monitoring effort the maximum water temperatures were recorded in August 2014 for 19 of 22 sites. Additionally, more days with water temperatures above 30.5°C, a temperature above which bleaching has been recorded in the Florida Keys (Manzello et al. 2007), were reported in summer 2015 and 2016 than all previous years. Elevated water temperatures for two consecutive summers most certainly affected southeast Florida reefs as they have been suggested to affect reefs in the Keys (Van Woesik and McCaffrey 2017). Southeast Florida reefs are also offshore of a highly urbanized area driving increased nutrient loading from urban runoff and defining the ever increasing need for marine construction projects (beach nourishment, port dredging, etc.). Coastal nutrient loading has been shown to contribute to increased levels of disease and mortality (Vega Thurber et al. 2014) as well as increased marine construction project related sediments (Pollack et al 2014, Miller et al 2016). All the factors and/or conditions that may be potentially contributing to the reported disease outbreak cannot be defined or evaluated. A combination of factors is most likely driving the disease event. Additionally, not all coral mortality documented in this report was caused by disease; other stressors, environmental and biological, most certainly contributed to some mortality across the region and/or at specific sites.

The southeast Florida reefs 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 and supported over 61,300 jobs in Miami-Dade, Broward, Palm Beach, and Martin Counties (Johns et al. 2001, 2004). Notably, Johns et al. (2001) indicated 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 as evident from the data presented. This coastal area is highly urbanized, which combined with dredging for beach nourishment, inlet and port channel deepening, and maintenance 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 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 cause 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 requires 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 trend data designed to assist local resource managers in understanding the condition of the resources and possible 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 value for a long-term region-wide monitoring program is highlighted by the information, albeit concerning, presented in this report. Relying on project-related monitoring efforts would not have provided the regional scale picture of the dramatic stony coral community losses or have been able to put current conditions in context with long-term trends.

The expansion of CREMP to include sites in Broward, Miami-Dade, Palm Beach, and Martin Counties through SECREMP, has insured that a suite of parameters is being monitored for much of the FRT. As a monitoring project under the NOAA Coral Reef Conservation Program Cooperative Agreement for the southeast Florida coast, SECREMP will continue to provide valuable southeast Florida coral reef status and long-term trend data. SECREMP provides resource managers with the critical information required to manage this valuable, yet increasingly threatened, natural resource. The data presented in this report clearly demonstrate that the northern extension of the FRT is threatened more than ever and requires an elevated level of concern and action to identify and reduce stressors.

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Appendices

Appendix 1. Mean cover by site (R= region-wide comparison; BC = Broward County; DC = Miami-Dade County; PB = Palm Beach County; MC = Martin County). Region-wide values are calculated as an average of the sum of each site. Site level values are calculated as an average of the stations. For cover data for years prior to 2010 see Gilliam et al. (2013)

		2010	2011	2012	2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Stony Coral	R (n=10)	4.05 ± 1.07	3.43 ± 0.82	3.62 ± 0.84	3.37 ± 0.74	3.83 ± 0.82	3.37 ± 0.74	1.80 ± 0.40
	R (n=16,22)	3.15 ± 0.87	2.72 ± 0.68	2.95 ± 0.69	2.54 ± 0.54	2.83 ± 0.61	2.54 ± 0.54	1.52 ± 0.32
	DC1	3.24 ± 0.86	3.64 ± 1.82	4.57 ± 1.27	4.24 ± 0.92	5.44 ± 1.65	5.33 ± 2.54	2.70 ± 0.76
	DC2	0.93 ± 0.20	1.15 ± 0.22	0.95 ± 0.20	0.95 ± 0.48	1.55 ± 0.40	1.22 ± 0.29	0.76 ± 0.20
	DC3	0.27 ± 0.06	0.15 ± 0.09	0.50 ± 0.17	0.24 ± 0.07	0.40 ± 0.17	0.19 ± 0.09	0.22 ± 0.11
	DC4	1.18 ± 0.42	1.00 ± 0.34	1.76 ± 0.32	1.52 ± 0.50	1.36 ± 0.56	1.32 ± 0.37	1.09 ± 0.12
	DC5	2.29 ± 0.24	1.49 ± 0.24	1.73 ± 0.46	1.59 ± 0.28	2.94 ± 1.08	1.16 ± 0.29	0.70 ± 0.06
	DC6	NA ± NA	NA ± NA	NA ± NA	2.50 ± 0.48	2.86 ± 0.80	3.24 ± 0.84	2.72 ± 0.69
	DC7	NA ± NA	NA ± NA	NA ± NA	0.51 ± 0.09	0.50 ± 0.17	0.42 ± 0.04	0.16 ± 0.07
	DC8	NA ± NA	NA ± NA	NA ± NA	1.51 ± 0.55	1.51 ± 0.34	1.18 ± 0.24	1.36 ± 0.51
	BC1	10.45 ± 1.67	10.99 ± 2.08	10.80 ± 1.39	12.67 ± 1.93	12.27 ± 1.73	12.35 ± 1.17	7.28 ± 1.38
	BC2	0.64 ± 0.31	0.81 ± 0.32	0.66 ± 0.39	0.73 ± 0.43	0.78 ± 0.21	0.89 ± 0.47	0.38 ± 0.10
	BC3	0.23 ± 0.10	0.34 ± 0.06	0.74 ± 0.15	0.69 ± 0.32	0.61 ± 0.22	0.69 ± 0.32	0.41 ± 0.31
	BC4	NA ± NA	NA ± NA	NA ± NA	4.04 ± 0.92	4.23 ± 0.88	4.38 ± 1.13	3.49 ± 0.67
	BC5	NA ± NA	NA ± NA	NA ± NA	1.49 ± 0.30	1.08 ± 0.39	1.43 ± 0.20	0.16 ± 0.03
	BC6	NA ± NA	NA ± NA	NA ± NA	0.76 ± 0.19	0.58 ± 0.23	0.60 ± 0.22	0.31 ± 0.09
	BCA	21.38 ± 2.41	14.51 ± 1.52	15.13 ± 2.75	10.93 ± 1.67	13.85 ± 1.69	9.88 ± 2.06	4.75 ± 1.06
	PB1	0.15 ± 0.09	0.00 ± 0.00	0.07 ± 0.05	0.11 ± 0.06	0.03 ± 0.03	0.10 ± 0.07	0.10 ± 0.07
	PB2	1.94 ± 0.42	1.49 ± 0.48	1.54 ± 0.41	1.68 ± 0.38	2.09 ± 0.66	2.04 ± 0.42	0.87 ± 0.23
	PB3	1.23 ± 0.16	1.19 ± 0.22	1.20 ± 0.39	1.49 ± 0.45	1.27 ± 0.43	1.04 ± 0.12	0.57 ± 0.10
	PB4	1.12 ± 0.29	1.32 ± 0.41	1.65 ± 0.52	1.70 ± 0.42	1.73 ± 0.42	1.56 ± 0.54	0.40 ± 0.12
	PB5	1.55 ± 0.18	1.68 ± 0.32	1.93 ± 0.27	1.94 ± 0.58	2.35 ± 0.37	2.04 ± 0.45	0.79 ± 0.24
	MC1	2.35 ± 1.23	2.94 ± 1.33	3.14 ± 1.66	2.97 ± 1.47	3.60 ± 1.96	3.60 ± 1.67	2.98 ± 1.32
	MC2	1.46 ± 0.50	0.82 ± 0.24	0.80 ± 0.30	1.52 ± 0.63	1.12 ± 0.39	1.31 ± 0.38	1.23 ± 0.56

Appendix 1. Continued

		2010	2011	2012	2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Octocoral	R (n=10)	10.47 ± 1.45	10.49 ± 1.21	9.62 ± 1.08	8.63 ± 0.94	8.90 ± 0.92	8.46 ± 0.94	8.34 ± 0.93
	R (n=16,22)	11.35 ± 1.50	11.75 ± 1.42	10.63 ± 1.28	9.88 ± 1.07	9.60 ± 1.02	9.14 ± 0.97	8.76 ± 0.95
	DC1	8.37 ± 1.37	10.92 ± 1.77	10.00 ± 0.64	8.34 ± 0.49	12.08 ± 1.49	9.45 ± 1.95	9.67 ± 0.72
	DC2	10.97 ± 1.06	19.58 ± 2.42	12.38 ± 1.34	11.37 ± 0.47	12.04 ± 0.86	12.44 ± 0.79	8.49 ± 0.47
	DC3	6.38 ± 0.87	7.07 ± 1.12	8.66 ± 1.48	8.38 ± 0.94	7.97 ± 1.42	9.19 ± 2.11	9.98 ± 0.48
	DC4	14.52 ± 1.10	16.78 ± 1.29	16.49 ± 1.95	14.58 ± 1.36	12.15 ± 1.11	12.26 ± 0.78	12.34 ± 1.48
	DC5	16.70 ± 1.60	18.86 ± 1.76	16.53 ± 4.20	16.74 ± 2.27	12.93 ± 1.42	12.67 ± 2.41	15.26 ± 1.17
	DC6	NA ± NA	NA ± NA	NA ± NA	9.37 ± 1.47	7.04 ± 0.93	7.55 ± 0.92	6.87 ± 0.56
	DC7	NA ± NA	NA ± NA	NA ± NA	8.09 ± 1.64	7.73 ± 0.33	11.79 ± 1.82	5.39 ± 0.70
	DC8	NA ± NA	NA ± NA	NA ± NA	15.82 ± 1.84	14.11 ± 2.03	13.12 ± 0.62	12.23 ± 0.85
	BC1	8.56 ± 1.18	6.71 ± 0.87	7.54 ± 0.46	7.36 ± 0.43	7.10 ± 0.56	5.74 ± 1.00	5.42 ± 0.74
	BC2	5.28 ± 0.37	7.75 ± 1.88	5.77 ± 0.44	4.69 ± 0.87	7.98 ± 0.96	5.18 ± 0.45	5.01 ± 0.63
	BC3	15.28 ± 1.29	12.49 ± 0.68	13.99 ± 1.16	13.12 ± 0.48	8.65 ± 1.68	9.28 ± 1.29	9.95 ± 0.90
	BC4	NA ± NA	NA ± NA	NA ± NA	4.28 ± 0.58	4.20 ± 0.68	4.61 ± 0.51	5.03 ± 0.68
	BC5	NA ± NA	NA ± NA	NA ± NA	6.76 ± 0.95	8.41 ± 0.76	6.51 ± 0.79	5.52 ± 0.48
	BC6	NA ± NA	NA ± NA	NA ± NA	16.44 ± 1.40	16.79 ± 0.80	13.22 ± 0.49	13.69 ± 1.04
	BCA	2.45 ± 0.38	2.85 ± 0.47	2.37 ± 0.37	2.96 ± 0.65	2.85 ± 0.40	2.25 ± 0.53	1.19 ± 0.23
	PB1	0.00 ± 0.00	0.00 ± 0.00	0.26 ± 0.16	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.07	0.00 ± 0.00
	PB2	26.45 ± 6.56	18.96 ± 3.97	20.29 ± 5.63	17.12 ± 5.12	18.45 ± 4.22	18.61 ± 3.56	16.63 ± 3.29
	PB3	20.96 ± 4.33	18.58 ± 4.20	14.93 ± 1.88	12.99 ± 1.89	11.91 ± 1.72	12.41 ± 1.36	17.03 ± 0.63
	PB4	22.76 ± 2.33	20.53 ± 1.44	18.44 ± 1.47	18.93 ± 2.10	22.03 ± 2.11	20.71 ± 1.29	19.12 ± 2.36
	PB5	22.77 ± 1.18	26.71 ± 2.13	22.38 ± 0.67	19.81 ± 1.27	16.62 ± 0.25	14.05 ± 1.95	13.88 ± 1.14
	MC1	0.11 ± 0.08	0.14 ± 0.14	0.03 ± 0.03	0.12 ± 0.12	0.02 ± 0.02	0.05 ± 0.03	0.03 ± 0.03
	MC2	0.08 ± 0.08	0.00 ± 0.00	0.08 ± 0.08	0.00 ± 0.00	0.03 ± 0.03	0.00 ± 0.00	0.03 ± 0.03

Appendix 1. Continued

		2010	2011	2012	2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Sponge	R (n=10)	5.34 ± 0.65	6.07 ± 0.63	5.75 ± 0.60	5.14 ± 0.45	5.06 ± 0.56	5.25 ± 0.54	4.98 ± 0.52
	R (n=16,22)	5.83 ± 0.67	6.91 ± 0.73	6.25 ± 0.67	5.18 ± 0.54	5.52 ± 0.58	5.75 ± 0.61	5.43 ± 0.54
	DC1	3.70 ± 1.03	4.32 ± 0.84	3.74 ± 0.72	2.64 ± 0.48	2.66 ± 0.33	3.34 ± 0.38	3.17 ± 0.18
	DC2	5.19 ± 0.78	7.26 ± 1.44	7.34 ± 1.20	4.93 ± 0.35	4.97 ± 0.52	5.69 ± 0.33	5.88 ± 0.70
	DC3	4.54 ± 1.09	4.95 ± 1.15	6.09 ± 0.73	5.47 ± 0.91	3.59 ± 0.90	3.19 ± 0.84	4.86 ± 1.45
	DC4	7.75 ± 1.30	5.89 ± 0.97	6.78 ± 0.64	7.50 ± 1.54	7.34 ± 1.44	8.64 ± 1.39	7.74 ± 1.57
	DC5	4.26 ± 0.84	6.46 ± 1.06	5.25 ± 0.84	3.50 ± 0.57	4.22 ± 0.95	5.72 ± 1.08	5.02 ± 1.38
	DC6	NA ± NA	NA ± NA	NA ± NA	2.28 ± 0.38	2.14 ± 0.37	1.75 ± 0.24	2.42 ± 0.19
	DC7	NA ± NA	NA ± NA	NA ± NA	7.52 ± 1.10	7.47 ± 1.48	8.60 ± 0.60	7.82 ± 0.66
	DC8	NA ± NA	NA ± NA	NA ± NA	2.58 ± 0.28	3.19 ± 0.43	3.60 ± 0.27	3.78 ± 0.70
	BC1	3.52 ± 0.51	4.90 ± 0.80	3.78 ± 0.38	3.25 ± 0.30	3.72 ± 0.57	3.70 ± 0.82	3.17 ± 0.73
	BC2	5.25 ± 0.86	6.21 ± 0.33	4.46 ± 0.19	5.22 ± 0.50	5.67 ± 0.63	6.55 ± 0.90	4.45 ± 0.58
	BC3	7.34 ± 2.15	6.21 ± 0.75	8.15 ± 1.88	6.42 ± 0.50	5.09 ± 0.55	5.84 ± 0.39	4.48 ± 0.51
	BC4	NA ± NA	NA ± NA	NA ± NA	3.01 ± 0.35	3.93 ± 0.48	3.90 ± 0.93	3.52 ± 0.53
	BC5	NA ± NA	NA ± NA	NA ± NA	6.92 ± 0.51	7.11 ± 1.14	7.30 ± 1.05	7.00 ± 0.86
	BC6	NA ± NA	NA ± NA	NA ± NA	3.80 ± 0.70	5.92 ± 1.34	4.96 ± 0.89	5.53 ± 0.42
	BCA	1.03 ± 0.28	3.23 ± 1.22	1.43 ± 0.66	3.58 ± 1.59	0.72 ± 0.35	0.87 ± 0.17	0.75 ± 0.29
	PB1	0.98 ± 0.69	1.36 ± 0.55	1.57 ± 0.96	1.82 ± 1.02	3.47 ± 1.87	3.01 ± 1.29	3.98 ± 2.10
	PB2	8.20 ± 1.46	7.28 ± 1.05	7.76 ± 0.22	7.44 ± 0.45	8.47 ± 0.71	7.92 ± 0.87	7.24 ± 0.48
	PB3	13.68 ± 1.22	14.98 ± 2.03	13.17 ± 1.02	10.65 ± 0.88	12.26 ± 1.59	12.39 ± 1.22	11.80 ± 0.93
	PB4	11.79 ± 2.39	13.99 ± 2.90	13.84 ± 1.78	12.69 ± 2.79	13.34 ± 2.17	14.76 ± 2.44	13.24 ± 1.88
	PB5	10.41 ± 1.62	14.43 ± 1.79	11.53 ± 1.95	8.60 ± 1.28	9.79 ± 0.75	9.78 ± 1.40	7.49 ± 0.86
	MC1	2.41 ± 0.97	3.17 ± 0.95	2.06 ± 0.40	1.54 ± 0.33	2.72 ± 0.43	1.88 ± 0.47	2.72 ± 0.17
	MC2	3.24 ± 0.98	5.87 ± 1.55	3.09 ± 0.95	2.56 ± 0.64	3.72 ± 0.75	3.01 ± 0.48	3.36 ± 0.87

Appendix 1. Continued

		2010	2011	2012	2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Macroalgae	R (n=10)	4.82 ± 0.71	3.60 ± 0.71	4.04 ± 0.94	4.29 ± 0.81	5.86 ± 0.73	6.40 ± 1.18	28.30 ± 3.75
	R (n=16,22)	10.60 ± 2.28	5.36 ± 1.20	8.88 ± 2.54	9.15 ± 1.89	10.27 ± 1.51	11.16 ± 1.65	26.90 ± 3.02
	DC1	9.51 ± 2.52	10.76 ± 3.45	3.86 ± 1.17	15.26 ± 3.42	3.60 ± 0.62	2.88 ± 1.09	17.85 ± 2.70
	DC2	4.85 ± 1.16	4.90 ± 2.71	2.31 ± 1.25	5.73 ± 2.70	5.59 ± 1.84	4.28 ± 1.60	67.44 ± 3.03
	DC3	4.85 ± 1.05	0.47 ± 0.47	0.35 ± 0.10	1.13 ± 0.37	6.49 ± 0.94	3.57 ± 0.61	67.34 ± 3.52
	DC4	2.01 ± 0.79	0.84 ± 0.53	2.10 ± 0.73	2.22 ± 0.68	8.38 ± 2.02	5.21 ± 1.76	21.26 ± 7.35
	DC5	20.87 ± 4.12	5.42 ± 2.19	14.69 ± 2.44	7.06 ± 2.81	25.18 ± 2.48	25.72 ± 2.95	27.62 ± 4.12
	DC6	NA ± NA	NA ± NA	NA ± NA	10.02 ± 0.80	9.80 ± 0.74	12.66 ± 2.70	31.97 ± 1.76
	DC7	NA ± NA	NA ± NA	NA ± NA	2.53 ± 0.85	6.44 ± 1.41	8.91 ± 2.96	42.23 ± 3.74
	DC8	NA ± NA	NA ± NA	NA ± NA	6.28 ± 0.91	7.79 ± 2.43	15.44 ± 4.11	26.53 ± 6.43
	BC1	12.23 ± 2.99	7.60 ± 1.52	17.37 ± 3.92	7.04 ± 1.37	7.81 ± 1.07	15.21 ± 3.76	32.24 ± 6.36
	BC2	3.10 ± 0.84	3.12 ± 1.72	9.09 ± 2.49	3.21 ± 0.80	6.13 ± 1.61	7.42 ± 2.80	25.62 ± 4.39
	BC3	4.79 ± 1.80	1.89 ± 1.55	1.89 ± 0.52	1.88 ± 0.45	12.20 ± 2.59	11.55 ± 9.45	37.08 ± 8.75
	BC4	NA ± NA	NA ± NA	NA ± NA	26.08 ± 3.20	18.87 ± 2.12	22.91 ± 1.84	40.16 ± 3.74
	BC5	NA ± NA	NA ± NA	NA ± NA	10.92 ± 3.37	7.31 ± 0.58	18.71 ± 5.42	27.21 ± 4.90
	BC6	NA ± NA	NA ± NA	NA ± NA	4.36 ± 1.21	4.39 ± 0.55	4.63 ± 0.70	9.67 ± 2.53
	BCA	2.59 ± 1.31	2.27 ± 1.82	3.07 ± 2.09	2.69 ± 1.70	6.66 ± 4.37	2.54 ± 0.51	8.01 ± 3.32
	PB1	1.46 ± 1.46	0.16 ± 0.10	0.40 ± 0.34	0.28 ± 0.16	1.75 ± 1.45	3.66 ± 0.94	1.43 ± 0.89
	PB2	2.05 ± 0.98	1.25 ± 0.42	0.31 ± 0.20	0.60 ± 0.31	1.19 ± 0.38	3.38 ± 1.38	9.87 ± 3.19
	PB3	2.76 ± 1.62	3.63 ± 0.75	1.73 ± 0.64	5.12 ± 0.89	7.21 ± 1.30	9.46 ± 2.56	16.10 ± 3.32
	PB4	2.54 ± 0.43	2.08 ± 0.67	0.74 ± 0.38	3.22 ± 0.65	2.22 ± 0.47	6.07 ± 3.16	8.39 ± 0.83
	PB5	12.34 ± 3.22	0.55 ± 0.31	0.76 ± 0.27	11.91 ± 1.80	15.19 ± 1.38	10.72 ± 1.41	30.30 ± 4.52
	MC1	36.06 ± 3.21	21.84 ± 6.57	33.36 ± 6.87	23.38 ± 6.52	23.05 ± 2.77	26.35 ± 8.89	12.21 ± 7.54
	MC2	47.55 ± 11.29	19.00 ± 3.11	49.96 ± 16.68	50.38 ± 3.07	38.72 ± 4.63	24.18 ± 7.20	31.35 ± 10.52

Appendix 2. Long term model estimation of change in stony coral, octocoral, sponge, and macroalgae percent cover per year (±SEM) region-wide and by site from 2003 to 2016 (10 sites), 2006 to 2016 (12 sites), and 2010 – 2016 (16 sites). Significant trends in cover are bolded and indicated as increasing (↑), decreasing (↓), or no significant change (-) in the Trend column (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
Stony Coral	**R**	**-0.0030**	**0.0008**	**252.4**	**-3.68**	**0.0003**	↓
	DC1	0.0023	0.0024	177.6	0.97	0.3321	-
	DC2	0.0012	0.0024	177.6	0.52	0.6025	-
	DC3	0.0006	0.0024	177.6	0.27	0.7895	-
	DC4	0.0001	0.0052	387.7	0.01	0.9902	-
	DC5	-0.0100	0.0052	387.7	-1.92	0.056	-
	BC1	-0.0031	0.0024	177.6	-1.33	0.1862	-
	BC2	0.0008	0.0024	177.6	0.34	0.7321	-
	BC3	0.0002	0.0024	177.6	0.08	0.9397	-
	BCA	**-0.0287**	**0.0024**	**177.6**	**-12.1**	**<.0001**	↓
	PB1	-0.0030	0.0024	185.9	-1.28	0.202	-
	PB2	-0.0022	0.0024	177.6	-0.92	0.3576	-
	PB3	0.0000	0.0024	177.6	0	0.997	-
	PB4	-0.0061	0.0052	387.7	-1.16	0.2478	-
	PB5	-0.0053	0.0052	387.7	-1.02	0.3072	-
	MC1	0.0038	0.0032	226.8	1.21	0.2262	-
	MC2	-0.0041	0.0032	226.8	-1.29	0.1976	-
Octocoral	**R**	**-0.0037**	**0.0009**	**266.3**	**-4.15**	**<.0001**	↓
	DC1	**0.0064**	**0.0024**	**195.1**	**2.63**	**0.0091**	↑
	DC2	-0.0035	0.0024	195.1	-1.43	0.1534	-
	DC3	**-0.0049**	**0.0024**	**195.1**	**-2.02**	**0.0449**	↓
	DC4	-0.0073	0.0059	368.1	-1.23	0.2185	-
	DC5	-0.0059	0.0059	368.1	-1	0.3192	-
	BC1	-0.0005	0.0024	195.1	-0.2	0.8429	-
	BC2	-0.0031	0.0024	195.1	-1.26	0.2096	-
	BC3	-0.0025	0.0024	195.1	-1.04	0.3015	-
	BCA	-0.0003	0.0024	195.1	-0.12	0.9043	-
	PB1	**-0.0098**	**0.0025**	**201.5**	**-4.01**	**<.0001**	↓
	PB2	**-0.0083**	**0.0024**	**195.1**	**-3.42**	**0.0008**	↓
	PB3	**-0.0125**	**0.0024**	**195.1**	**-5.11**	**<.0001**	↓
	PB4	-0.0049	0.0059	368.1	-0.82	0.411	-
	PB5	**-0.0206**	**0.0059**	**368.1**	**-3.49**	**0.0005**	↓
	MC1	0.0011	0.0033	235.3	0.34	0.7341	-
	MC2	-0.0001	0.0033	235.3	-0.03	0.9745	-

Appendix 2. Continued

Variable	Level	Est.	SE	DF	t	p	Trend
Sponge	**R**	**0.0028**	**0.0009**	**250**	**3.05**	**0.0025**	↑
	DC1	**0.0072**	**0.0026**	**180.9**	**2.82**	**0.0054**	↑
	DC2	0.0024	0.0026	180.9	0.92	0.3579	-
	DC3	0.0024	0.0026	180.9	0.92	0.3593	-
	DC4	0.0016	0.0062	353.1	0.26	0.7952	-
	DC5	0.0011	0.0062	353.1	0.18	0.8568	-
	BC1	0.0028	0.0026	180.9	1.09	0.2762	-
	BC2	0.0048	0.0026	180.9	1.88	0.0617	-
	BC3	0.0049	0.0026	180.9	1.91	0.058	-
	BCA	0.0032	0.0026	180.9	1.23	0.2198	-
	PB1	**-0.0065**	**0.0026**	**187.1**	**-2.52**	**0.0127**	↓
	PB2	**0.0063**	**0.0026**	**180.9**	**2.45**	**0.0153**	↑
	PB3	0.0021	0.0026	180.9	0.82	0.4148	-
	PB4	0.0035	0.0062	353.1	0.56	0.5751	-
	PB5	-0.0093	0.0062	353.1	-1.5	0.1338	-
	MC1	0.0052	0.0035	220.3	1.47	0.1426	-
	MC2	0.0019	0.0035	220.3	0.54	0.5873	-
Macroalgae	**R**	**0.0097**	**0.0018**	**294.1**	**5.26**	**<.0001**	↑
	DC1	**-0.0128**	**0.0047**	**239.3**	**-2.73**	**0.0067**	↓
	DC2	**0.0133**	**0.0047**	**239.3**	**2.84**	**0.0048**	↑
	DC3	**0.0171**	**0.0047**	**239.3**	**3.66**	**0.0003**	↑
	DC4	**0.0482**	**0.0133**	**344.8**	**3.62**	**0.0003**	↑
	DC5	**0.0323**	**0.0133**	**344.8**	**2.43**	**0.0157**	↑
	BC1	**0.0213**	**0.0047**	**239.3**	**4.56**	**<.0001**	↑
	BC2	**0.0124**	**0.0047**	**239.3**	**2.66**	**0.0083**	↑
	BC3	0.0071	0.0047	239.3	1.52	0.1287	-
	BCA	**0.0103**	**0.0047**	**239.3**	**2.2**	**0.0287**	↑
	PB1	0.0023	0.0047	242.7	0.48	0.6291	-
	PB2	**0.0093**	**0.0047**	**239.3**	**1.98**	**0.049**	↑
	PB3	**0.0157**	**0.0047**	**239.3**	**3.35**	**0.0009**	↑
	PB4	0.0231	0.0133	344.8	1.73	0.0838	-
	PB5	**0.0517**	**0.0133**	**344.8**	**3.88**	**0.0001**	↑
	MC1	**-0.0251**	**0.0067**	**263.8**	**-3.74**	**0.0002**	↓
	MC2	**-0.0157**	**0.0067**	**263.8**	**-2.33**	**0.0203**	↓

Appendix 3. Year to year model estimation of change in stony coral, octocoral, sponge, and macroalgae percent cover per year (±SEM) by region and by site from 2015 to 2016. (R= region-wide comparison; DC = Miami-Dade County; BC = Broward County; PB = Palm Beach County; MC = Martin County).

Variable	**Level**	**DF**	**t**	**p**	**Significant Change**
Stony Coral	**R**	**66**	**8.46**	**<.0001**	↓
	DC1	**66**	**8.96**	**0.0039**	↓
	DC2	66	1.46	0.2307	-
	DC3	66	0.16	0.6937	-
	DC4	66	0.14	0.7075	-
	DC5	66	1.34	0.2521	-
	DC6	66	0.62	0.4357	-
	DC7	66	3.02	0.0869	-
	DC8	66	0.01	0.9302	-
	BC1	**66**	**21.37**	**<.0001**	↓
	BC2	66	1.74	0.1912	-
	BC3	66	3.43	0.0685	-
	BC4	66	1.25	0.2675	-
	BC5	**66**	**19.12**	**<.0001**	↓
	BC6	66	1.25	0.267	-
	BCA	**66**	**27.66**	**<.0001**	↓
	PB1	66	0	0.9994	-
	PB2	**66**	**7.32**	**0.0087**	↓
	PB3	66	2.22	0.1411	-
	PB4	**66**	**10.19**	**0.0022**	↓
	PB5	**66**	**8.97**	**0.0039**	↓
	MC1	66	1.05	0.3087	-
	MC2	66	0.73	0.3972	-
Octocoral	R	66	1.66	0.1015	-
	DC1	66	0.13	0.7181	-
	DC2	**66**	**7.42**	**0.0083**	↑
	DC3	66	0.65	0.4216	-
	DC4	66	0	0.9923	-
	DC5	66	2.96	0.0898	-
	DC6	66	0.27	0.6034	-
	DC7	**66**	**24**	**<.0001**	↑
	DC8	66	0.32	0.5707	-
	BC1	66	0.07	0.794	-
	BC2	66	0.04	0.8357	-
	BC3	66	0.31	0.5802	-
	BC4	66	0.17	0.6828	-
	BC5	66	0.74	0.3942	-
	BC6	66	0.07	0.7958	-
	BCA	66	3.03	0.0866	-
	PB1	66	0.96	0.3308	-
	PB2	66	1.06	0.3062	-
	PB3	**66**	**7.65**	**0.0074**	↓
	PB4	66	0.77	0.3824	-
	PB5	66	0	0.9843	-
	MC1	66	0.12	0.7254	-
	MC2	66	0.14	0.7054	-

Appendix 3. Continued

Variable	Level	DF	t	p	Significant Change
Sponge	R	66	1.36	0.1778	-
	DC1	66	0.07	0.7919	-
	DC2	66	0.04	0.8431	-
	DC3	**66**	**5.74**	**0.0194**	↓
	DC4	66	1.21	0.2749	-
	DC5	66	1.31	0.2562	-
	DC6	66	2.28	0.1358	-
	DC7	66	0.75	0.3885	-
	DC8	66	0.02	0.8925	-
	BC1	66	0.87	0.3552	-
	BC2	**66**	**7.85**	**0.0067**	↑
	BC3	66	3.75	0.0572	-
	BC4	66	0.24	0.6248	-
	BC5	66	0.1	0.7534	-
	BC6	66	0.86	0.3573	-
	BCA	66	0.4	0.5308	-
	PB1	66	1.97	0.1654	-
	PB2	66	0.51	0.4777	-
	PB3	66	0.26	0.612	-
	PB4	66	1.48	0.2274	-
	PB5	**66**	**5.64**	**0.0205**	↑
	MC1	66	3.63	0.0611	-
	MC2	66	0.19	0.6624	-
Variable	**Level**	**DF**	**t**	**p**	
Macroalgae	**R**	**66**	**-10.44**	**<.0001**	↓
	DC1	**66**	**10.32**	**0.002**	↓
	DC2	**66**	**61.4**	**<.0001**	↓
	DC3	**66**	**62.86**	**<.0001**	↓
	DC4	**66**	**7.37**	**0.0085**	↓
	DC5	66	0.04	0.8411	-
	DC6	**66**	**7.26**	**0.0089**	↓
	DC7	**66**	**20.34**	**<.0001**	↓
	DC8	66	2.42	0.1247	-
	BC1	**66**	**4.93**	**0.0299**	↓
	BC2	**66**	**9.06**	**0.0037**	↓
	BC3	**66**	**17**	**0.0001**	↓
	BC4	66	3.73	0.0577	-
	BC5	66	1.48	0.2282	-
	BC6	66	1.3	0.2576	-
	BCA	66	1.59	0.2123	-
	PB1	66	1.09	0.2995	-
	PB2	66	2.47	0.1205	-
	PB3	66	1.44	0.2352	-
	PB4	66	0.65	0.4233	-
	PB5	**66**	**7.58**	**0.0076**	↓
	MC1	**66**	**4.54**	**0.0368**	↑
	MC2	66	0.07	0.7952	-

Appendix 4. Stony coral live tissue area (m^2) by region and site. For region-wide values the live tissue area of all colonies within a site were summed and the average of all sites taken. Site values are the sum of the live tissue area of all colonies within a station and the average of the stations.

	2013			**2014**			**2015**			**2016**		
Level	Mean ± SE (m^2)			Mean ± SE (m^2)			Mean ± SE (m^2)			Mean ± SE (m^2)		
R	6.11	±	1.87	6.38	±	2.16	6.48	±	2.36	4.20	±	1.50
DC1	4.46	±	0.97	4.32	±	0.85	4.00	±	1.01	2.73	±	0.58
DC2	0.35	±	0.09	0.42	±	0.03	0.36	±	0.07	0.36	±	0.09
DC3	0.28	±	0.10	0.13	±	0.03	0.13	±	0.05	0.15	±	0.05
DC4	0.50	±	0.11	0.57	±	0.14	0.30	±	0.08	0.23	±	0.07
DC5	1.98	±	0.63	2.23	±	0.70	1.40	±	0.21	1.00	±	0.28
DC6	1.85	±	0.36	2.14	±	0.58	2.83	±	0.95	2.32	±	0.91
DC7	0.36	±	0.07	0.34	±	0.08	0.32	±	0.05	0.21	±	0.05
DC8	0.57	±	0.15	0.76	±	0.23	0.53	±	0.18	0.50	±	0.17
BC1	10.04	±	1.65	11.88	±	1.41	12.98	±	2.06	8.06	±	1.57
BC2	0.28	±	0.10	0.40	±	0.17	0.35	±	0.15	0.22	±	0.05
BC3	0.37	±	0.07	0.38	±	0.12	0.29	±	0.05	0.21	±	0.05
BC4	3.39	±	0.49	3.26	±	0.55	3.49	±	0.35	2.34	±	0.44
BC5	0.86	±	0.29	0.65	±	0.19	0.91	±	0.26	0.19	±	0.02
BC6	0.45	±	0.18	0.49	±	0.17	0.50	±	0.22	0.20	±	0.03
BCA	0.37	±	0.09	0.21	±	0.07	0.22	±	0.09	0.37	±	0.07
PB1	0.09	±	0.04	0.13	±	0.06	0.10	±	0.05	0.08	±	0.04
PB2	0.95	±	0.25	1.00	±	0.22	1.00	±	0.22	0.39	±	0.07
PB3	0.65	±	0.12	0.69	±	0.16	0.67	±	0.13	0.23	±	0.08
PB4	1.87	±	0.72	1.14	±	0.21	1.27	±	0.15	0.35	±	0.12
PB5	1.55	±	0.27	1.45	±	0.29	1.52	±	0.27	0.61	±	0.21
MC1	1.82	±	0.72	1.94	±	0.78	1.97	±	0.80	1.83	±	0.60
MC2	0.59	±	0.14	0.61	±	0.14	0.53	±	0.12	0.55	±	0.13

Appendix 5. Regional stony coral live tissue area of select species. Live tissue area was summed at each site and the regional live tissue area is the average of all sites.

	2013	2014	2015	2016
Species	Mean ± SE (m^2)	Mean ± SE (m^2)	Mean ± SE (m^2)	Mean ± SE (m^2)
D. stokesii	0.12 ± 0.05	0.08 ± 0.02	0.05 ± 0.02	0.01 ± 0.00
M. cavernosa	3.03 ± 1.62	3.41 ± 1.99	3.43 ± 2.07	2.03 ± 1.35
M. meandrites	0.55 ± 0.19	0.53 ± 0.18	0.30 ± 0.10	0.00 ± 0.00
S. siderea	0.32 ± 0.10	0.26 ± 0.08	0.30 ± 0.09	0.24 ± 0.07

Appendix 6. Stony coral live tissue area statistics.

ANOVA results.

Variable	Level	Intercept	Year
Region	DF	1	3
	F	113.953	9.460
	P	<.0001	<.0001
M. cavernosa	DF	1	3
	F	45.848	6.616
	P	<.0001	0.001

Friedman's test results.

Variable	Level	Value
M. meandrites	Chi-squared	34.097
	DF	3
	P	<.0001
D. stokesii	Chi-squared	34.854
	DF	3
	P	<.0001
S. siderea	Chi-squared	7.389
	DF	3
	P	0.0605

ANOVA post hoc Tukey Test.

Variable	Years	Est.	SE	z	P > |z|
Region	2014 - 2013	-0.0759	0.1506	-0.5040	0.9582
	2015 - 2013	-0.1580	0.1506	-1.0490	0.7207
	2016 - 2013	-0.7204	0.1506	-4.7820	< 0.001
	2015 - 2014	-0.0821	0.1506	-0.5450	0.9479
	2016 - 2014	-0.6445	0.1506	-4.2780	< 0.001
	2016 - 2015	-0.5624	0.1506	-3.7330	0.0010
M. cavernosa	2014 - 2013	-0.0298	0.1756	-0.1700	0.9983
	2015 - 2013	-0.0306	0.1756	-0.1740	0.9981
	2016 - 2013	-0.6583	0.1756	-3.7490	0.0010
	2015 - 2014	-0.0008	0.1756	-0.0050	1.0000
	2016 - 2014	-0.6285	0.1756	-3.5790	0.0019
	2016 - 2015	-0.6277	0.1756	-3.5740	0.0019

Appendix 7. Stony coral, octocoral and *Xestospongia muta* density data region and by site. Regional density was calculated as an average of all sites, where site is the sum of all four stations. Site level values were calculated as an average of the four stations.

		2013			**2014**			**2015**			**2016**		
Variable	**Level**	Mean ± SE			Mean ± SE			Mean ± SE			Mean ± SE		
Stony Coral	R	1.21	±	0.16	1.26	±	0.18	1.29	±	0.19	1.07	±	0.17
	DC1	1.80	±	0.15	2.10	±	0.16	2.15	±	0.03	2.36	±	0.06
	DC2	0.88	±	0.09	1.08	±	0.14	1.07	±	0.11	0.83	±	0.09
	DC3	0.31	±	0.09	0.33	±	0.03	0.31	±	0.06	0.27	±	0.07
	DC4	0.73	±	0.11	0.75	±	0.12	0.75	±	0.20	0.57	±	0.14
	DC5	2.56	±	0.24	2.53	±	0.14	2.33	±	0.26	2.40	±	0.26
	DC6	1.38	±	0.26	1.42	±	0.25	1.51	±	0.25	1.44	±	0.33
	DC7	1.13	±	0.05	1.02	±	0.12	1.10	±	0.14	0.67	±	0.09
	DC8	0.92	±	0.09	0.81	±	0.06	0.91	±	0.15	0.56	±	0.07
	BC1	1.81	±	0.35	2.16	±	0.33	2.05	±	0.34	1.66	±	0.30
	BC2	0.64	±	0.12	0.78	±	0.12	0.63	±	0.12	0.47	±	0.10
	BC3	0.75	±	0.11	0.76	±	0.22	0.59	±	0.08	0.42	±	0.03
	BC4	3.28	±	0.32	3.75	±	0.22	4.05	±	0.31	3.41	±	0.12
	BC5	1.23	±	0.19	1.09	±	0.25	1.19	±	0.22	0.67	±	0.08
	BC6	0.64	±	0.11	0.59	±	0.07	0.56	±	0.06	0.43	±	0.05
	BCA	0.61	±	0.18	0.58	±	0.17	1.09	±	0.40	1.46	±	0.17
	PB1	0.23	±	0.15	0.27	±	0.17	0.28	±	0.15	0.33	±	0.14
	PB2	1.07	±	0.15	1.24	±	0.09	1.57	±	0.31	1.07	±	0.33
	PB3	1.05	±	0.31	1.18	±	0.34	1.11	±	0.29	0.63	±	0.22
	PB4	1.82	±	0.38	1.63	±	0.31	1.71	±	0.29	1.02	±	0.27
	PB5	2.30	±	0.31	2.19	±	0.29	2.08	±	0.29	1.58	±	0.25
	MC1	0.96	±	0.09	1.06	±	0.11	0.98	±	0.18	0.98	±	0.31
	MC2	0.49	±	0.05	0.40	±	0.05	0.34	±	0.09	0.27	±	0.05

Appendix 7. Continued.

		2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Octocoral	R	8.68 ± 1.34	9.97 ± 1.55	11.51 ± 1.77	11.85 ± 1.83
	DC1	6.93 ± 1.42	8.18 ± 0.74	11.60 ± 1.52	13.25 ± 1.28
	DC2	9.17 ± 0.23	14.25 ± 1.80	19.50 ± 2.07	17.98 ± 1.44
	DC3	6.18 ± 1.43	7.23 ± 1.23	7.55 ± 1.36	9.33 ± 0.44
	DC4	11.23 ± 2.52	12.43 ± 3.18	14.45 ± 2.60	11.93 ± 1.00
	DC5	6.58 ± 1.19	7.15 ± 0.80	8.95 ± 0.91	8.63 ± 0.96
	DC6	6.90 ± 0.75	8.13 ± 0.97	9.53 ± 1.83	9.88 ± 1.65
	DC7	3.43 ± 0.26	3.83 ± 0.14	7.13 ± 0.47	6.95 ± 0.41
	DC8	14.90 ± 1.45	16.28 ± 1.70	19.90 ± 1.91	19.28 ± 1.41
	BC1	10.75 ± 0.79	11.15 ± 0.99	11.15 ± 0.96	11.68 ± 0.88
	BC2	7.40 ± 1.11	8.65 ± 1.30	8.63 ± 1.65	9.28 ± 1.99
	BC3	12.90 ± 1.06	12.75 ± 1.30	11.53 ± 1.40	14.30 ± 1.89
	BC4	3.73 ± 0.61	3.95 ± 0.97	5.23 ± 0.58	4.08 ± 0.68
	BC5	5.73 ± 0.53	7.45 ± 0.56	6.55 ± 0.63	6.18 ± 0.71
	BC6	20.78 ± 3.78	19.28 ± 1.91	21.18 ± 2.13	23.48 ± 0.88
	BCA	1.15 ± 0.51	0.85 ± 0.39	1.10 ± 0.54	0.58 ± 0.28
	PB1	0.23 ± 0.14	0.18 ± 0.09	0.00 ± 0.00	0.05 ± 0.03
	PB2	17.03 ± 3.85	20.55 ± 5.32	23.45 ± 5.59	23.48 ± 4.99
	PB3	12.85 ± 3.19	12.45 ± 2.56	14.15 ± 2.39	17.33 ± 3.14
	PB4	15.63 ± 2.32	17.65 ± 1.09	23.48 ± 2.48	23.80 ± 4.01
	PB5	19.80 ± 2.36	27.03 ± 4.61	28.25 ± 4.98	29.33 ± 3.83
	MC1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	MC2	0.00 ± 0.00	0.03 ± 0.03	0.03 ± 0.03	0.03 ± 0.03

Appendix 7. Continued

		2013	2014	2015	2016
Variable	**Level**	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
X. muta	R	0.11 ± 0.01	0.07 ± 0.01	0.08 ± 0.01	0.08 ± 0.01
	DC1	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.03 ± 0.01
	DC2	0.11 ± 0.02	0.09 ± 0.01	0.11 ± 0.01	0.10 ± 0.01
	DC3	0.10 ± 0.02	0.06 ± 0.02	0.07 ± 0.02	0.08 ± 0.03
	DC4	0.29 ± 0.03	0.15 ± 0.01	0.16 ± 0.01	0.16 ± 0.01
	DC5	0.08 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.02
	DC6	0.003 ± 0.003	0.003 ± 0.003	0.003 ± 0.003	0.003 ± 0.003
	DC7	0.13 ± 0.02	0.09 ± 0.01	0.11 ± 0.01	0.10 ± 0.02
	DC8	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	BC1	0.02 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.03 ± 0.01
	BC2	0.12 ± 0.03	0.13 ± 0.01	0.13 ± 0.02	0.13 ± 0.02
	BC3	0.17 ± 0.01	0.16 ± 0.02	0.16 ± 0.03	0.14 ± 0.03
	BC4	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.02
	BC5	0.19 ± 0.04	0.12 ± 0.03	0.11 ± 0.03	0.15 ± 0.02
	BC6	0.16 ± 0.04	0.09 ± 0.03	0.07 ± 0.03	0.09 ± 0.03
	BCA	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	PB1	0.00 ± 0.00	0.00 ± 0.00	0.003 ± 0.003	0.00 ± 0.00
	PB2	0.10 ± 0.05	0.03 ± 0.01	0.04 ± 0.01	0.06 ± 0.01
	PB3	0.21 ± 0.03	0.14 ± 0.03	0.18 ± 0.03	0.17 ± 0.03
	PB4	0.29 ± 0.07	0.18 ± 0.02	0.16 ± 0.03	0.18 ± 0.02
	PB5	0.30 ± 0.06	0.19 ± 0.02	0.22 ± 0.02	0.22 ± 0.02
	MC1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	MC2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Appendix 8. Stony coral, octocoral and *Xestospongia muta* density statistics.

ANOVA results.

Variable	Level	Intercept	Year
Stony Coral	DF	1	3
	F	199.845	6.782
	P	<0.0001	0.001
Octocoral	DF	1	3
	F	43.210	15.172
	P	<0.0001	<0.0001

Friedman's test results

Variable	Level	Value
X. muta	Chi-squared	16.149
	DF	3.000
	P	0.001

ANOVA post hoc Tukey Test.

Variable	Years	Est.	SE	z	P > |z|
Stony Coral	2014 - 2013	0.0194	0.0263	0.737	0.882
	2015 - 2013	0.0297	0.0263	1.127	0.67268
	2016 - 2013	-0.0769	0.0263	-2.919	0.01846
	2015 - 2014	0.0103	0.0263	0.39	0.9799
	2016 - 2014	-0.0963	0.0263	-3.656	0.00144
	2016 - 2015	-0.1066	0.0263	-4.046	< 0.001
Octocoral	2014 - 2013	1.2932	0.5323	2.429	0.07166
	2015 - 2013	2.8341	0.5323	5.324	< 0.001
	2016 - 2013	3.1727	0.5323	5.96	< 0.001
	2015 - 2014	1.5409	0.5323	2.895	0.01977
	2016 - 2014	1.8795	0.5323	3.531	0.00236
	2016 - 2015	0.3386	0.5323	0.636	0.92035

Appendix 9. Stony coral species of interest density by region.

	2013	2014	2015	2016
Species	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
D. stokesii	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.01 ± 0.003
M. cavernosa	0.24 ± 0.06	0.26 ± 0.07	0.25 ± 0.07	0.13 ± 0.04
M. meandrites	0.07 ± 0.01	0.07 ± 0.01	0.05 ± 0.01	0.003 ± 0.002
S. siderea	0.23 ± 0.04	0.22 ± 0.04	0.21 ± 0.03	0.17 ± 0.03

Appendix 10. Stony coral species of interest statistics

ANOVA results

Variable	Level	Intercept	Year
M. cavernosa	DF	1	3
	F	53.364	16.803
	P	<.0001	<.0001
S. siderea	DF	1	3
	F	116.652	5.650
	P	<.0001	0.002

Friedman's test results

Variable	Level	Value
D. stokesii	Chi-squared	38.177
	DF	3
	P	<.0001
M. meandrites	Chi-squared	33.16
	DF	3
	P	<.0001

ANOVA post hoc Tukey Test

Variable	Years	Est.	SE	z	P > |z|
M. cavernosa	2014 - 2013	0.0133	0.0199	0.666	0.91
	2015 - 2013	0.0062	0.0199	0.309	0.99
	2016 - 2013	-0.1085	0.0199	-5.447	<1e-06
	2015 - 2014	-0.0071	0.0199	-0.356	0.984
	2016 - 2014	-0.1217	0.0199	-6.112	<1e-06
	2016 - 2015	-0.1146	0.0199	-5.756	<1e-06
S. siderea	2014 - 2013	-0.0145	0.0170	-0.855	0.828
	2015 - 2013	-0.0186	0.0170	-1.093	0.6937
	2016 - 2013	-0.0659	0.0170	-3.877	<0.001
	2015 - 2014	-0.0040	0.0170	-0.238	0.9952
	2016 - 2014	-0.0513	0.0170	-3.022	0.0134
	2016 - 2015	-0.0473	0.0170	-2.784	0.0273

Appendix 11. Octocoral target species mean density.

	2013			2014			2015			2016		
	Mean ± SE			Mean ± SE			Mean ± SE			Mean ± SE		
E. calyculata	0.60	±	0.13	0.58	±	0.10	0.53	±	0.09	0.38	±	0.08
G. ventalina	0.25	±	0.06	0.28	±	0.05	0.35	±	0.09	0.34	±	0.07
A. americana	1.57	±	0.24	1.61	±	0.26	1.98	±	0.28	2.07	±	0.31
E. flexuosa	0.68	±	0.15	0.84	±	0.22	0.97	±	0.30	0.91	±	0.26
P. porosa	0.13	±	0.03	0.11	±	0.02	0.18	±	0.05	0.18	±	0.04

Appendix 12. Octocoral density statistics.

ANOVA results

Variable	Level	Intercept	Year
E. calyculata	DF	1	3
	F	92.817	3.1069
	P	<.0001	0.0339
G. ventalina	DF	1	3
	F	75.752	4.9452
	P	<.0001	0.0042
A. americana	DF	1	3
	F	46.731	7.9769
	P	<.0001	0.0002

Friendman's Test results

Variable	Level	Value
E. flexuosa	Chi-squared	2.9006
	DF	3
	P	0.407
P. porosa	Chi-squared	4.8837
	DF	3
	P	0.181

ANOVA post hoc Tukey Test results

Variable	Years	Est.	SE	z	P > |z|
E. calyculata	2014 - 2013	0.0202	0.0522	0.388	0.9802
	2015 - 2013	-0.0145	0.0522	-0.278	0.9925
	2016 - 2013	-0.1250	0.0522	-2.396	0.078
	2015 - 2014	-0.0347	0.0522	-0.666	0.9099
	2016 - 2014	-0.1452	0.0522	-2.783	0.0275
	2016 - 2015	-0.1105	0.0522	-2.117	0.1476
G. ventalina	2014 - 2013	0.0464	0.0286	1.623	0.3657
	2015 - 2013	0.0906	0.0286	3.166	0.00799
	2016 - 2013	0.0969	0.0286	3.387	0.0038
	2015 - 2014	0.0441	0.0286	1.543	0.41177
	2016 - 2014	0.0505	0.0286	1.765	0.29055
	2016 - 2015	0.0063	0.0286	0.222	0.99616
A. americana	2014 - 2013	0.0408	0.1278	0.319	0.98875
	2015 - 2013	0.4105	0.1278	3.213	0.00732
	2016 - 2013	0.5026	0.1278	3.934	< 0.001
	2015 - 2014	0.3697	0.1278	2.894	0.02008
	2016 - 2014	0.4618	0.1278	3.615	0.00156
	2016 - 2015	0.0921	0.1278	0.721	0.88882

Appendix 13. Octocoral target species mean height.

	2013			2014			2015			2016		
	Mean ± SE			Mean ± SE			Mean ± SE			Mean ± SE		
E. calyculata	37.8	±	1.1	38.8	±	1.2	38.7	±	1.2	43.7	±	1.5
G. ventalina	18.3	±	1.1	16.5	±	1.0	14.8	±	0.8	15.2	±	0.8
A. americana	27.1	±	0.5	25.1	±	0.5	23.2	±	0.5	23.8	±	0.4
E. flexuosa	24.9	±	0.6	24.4	±	0.7	21.5	±	0.6	22.3	±	0.5
P. porosa	40.0	±	3.1	33.7	±	3.5	27.8	±	2.6	25.7	±	2.2

Appendix 14.Octocoral height statistics

ANOVA results

Variable	**Level**	**Intercept**	**Year**
P porosa	DF	1	3
	F	51.736	4.5996
	P	<.0001	0.0035

Friedman's Test results

Variable	**Level**	**Value**
E. calyculata	Chi-squared	2.4839
	DF	3
	P	0.478
G. ventalina	Chi-squared	1.4194
	DF	3
	P	0.701
A. americana	Chi-squared	8.8737
	DF	3
	P	0.031
E. flexuosa	Chi-squared	4.6508
	DF	3
	P	0.199

ANOVA post hoc Tukey Test

Variable	**Years**	**Est.**	**SE**	**z**	**P > |z|**
P. porosa	2014 - 2013	-4.7500	3.5240	-1.348	0.5309
	2015 - 2013	-7.4920	3.2030	-2.339	0.089
	2016 - 2013	-11.3900	3.1260	-3.643	0.0014
	2015 - 2014	-2.7430	3.3180	-0.827	0.8411
	2016 - 2014	-6.6410	3.3010	-2.012	0.1824
	2016 - 2015	-3.8980	2.8340	-1.376	0.5131