Long-term Monitoring of Selected Coral Reefs in Dry Tortugas National Park 2021-2022 Biennial Report

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This biennial report presents data collected in project years 2021 and 2022. Comprehensive analyses from project inception through 2022 are provided.

Cover Page Photographs: corals infected with stony coral tissue loss disease from Black Coral Rock in 2022. Upper left: *Montastraea cavernosa*. Lower left: *Orbicella franksi*, *Colpophyllia natans*, *Siderastrea siderea*, and *M. cavernosa*. Right: *M. cavernosa*.

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Executive Summary

Coral reefs are a critically important natural resource in Dry Tortugas National Park (DRTO). Although DRTO reefs have been described as some of the most pristine on Florida's Coral Reef (FCR), they have undergone considerable declines during the last 40 years, including substantial losses of previously abundant acroporid and orbicellid species. For a time, it was believed the isolation of the Dry Tortugas would mitigate against the effects of land-based activities (e.g., pollution, sedimentation, deteriorating water quality) that promote environmentally stressful conditions to coral reefs. While in some instances its remoteness has insulated DRTO reefs against these disturbances, it has not stemmed the impact of regional stressors such as disease outbreaks or mass bleaching events.

The Fish and Wildlife Research Institute's (FWRI) Coral Reef Evaluation and Monitoring Project (CREMP) has been assessing the status and trends of benthic communities in the Tortugas region since 1999. Twelve reefs encompass the survey effort. Sites were selected to evaluate changes of common and rare coral reef types and include stands of acroporid corals and pinnacle reef structures that are unique features to the Tortugas region of FCR. As part of the cooperative agreement between DRTO and FWRI, comprehensive biennial reports are prepared to provide an update on coral resource condition within DRTO. This report includes data collected in all project years with an emphasis on the two most recent years of data collection, 2021 and 2022. Both short- and long-term comparisons were completed for the percent cover of benthic taxa (corals, octocorals, macroalgae, and sponges) and densities of corals and octocorals at all sites, and similar analyses were conducted for ESA-listed acroporid (*Acropora cervicornis, A. palmata,* and *A. prolifera*), and orbicellid species (*Orbicella annularis, O. faveolata,* and *O. franksi*) at sites where they were most common. Short-term analyses compared the results averaged for the last biennial time period (2019-2020) against those of this one (2021-2022); long-term analyses compared the average for the first four years of monitoring at each site to the most recent four years, 2019-2022. The two- and four-year means calculated for the short- and long-term timeframes, respectively, were performed to minimize interannual variability and reduce the effect of ephemeral events that could substantially alter percent cover or abundance values in a given year. The design of the analyses allowed for an interpretation of recent findings while also providing historical context. The results were delineated into three broader sections: 1) an appraisal of benthic community structure with percent cover and density serving as the metrics to evaluate changes, 2) the status of the ESA-listed coral species, and 3) user pressure and the impact of the SCUBA diving activities on Research Natural Area (RNA) pinnacle reefs.

Changes in benthic community structure were determined by evaluating short- and long-term differences in mean cover (% ± SE) of corals, macroalgae, octocorals, and sponges at 12 reefs and mean coral and octocoral density (no. of colonies per m^2 ± SE) at 11 reefs. For the short-term comparisons, between the 2019-2020 and 2021-2022 reporting periods, there were no significant differences in coral cover detected for any site. Octocoral cover significantly increased at three sites and decreased at one site. Macroalgae cover significantly decreased at five sites and increased at two sites, and mean sponge cover significantly decreased at two sites. Mean coral and octocoral

density (no. of colonies/m^2 ± SE) did not significantly change at any of the 11 sites over the short-term analysis.

The long-term results were mostly consistent with the 2019-2020 biennial report with one notable change. Six sites now demonstrate a long-term significant decline in coral cover, whereas five sites had a long-term decline in the previous report. All five sites that showed a negative change in coral cover in the previous report maintained that outcome herein. On the opposite side of the ledger, the three sites there were reported to have significantly higher coral cover long-term in the previous report maintained that result herein. Two of those sites are predominantly occupied by acroporid corals. For the other three benthic taxa groups (macroalgae, octocorals, and sponges), long-term changes have consisted of significant increases in cover. Six sites have had a significant long-term increase in octocoral cover, consistent with the number of sites in the previous report, but one site was new and replaced another site that no longer had a change in cover. For macroalgae, the results are duplicative from the previous report - 9 of the 12 sites had significant increases in cover, including all sites for which the inception of monitoring pre-dates 2009. Sponge cover was significantly greater at eight of the 12 sites, two more than in the previous long-term analysis.

The long-term changes in mean coral density were also mostly consistent with the previous biennial report. Coral density was significantly lower at one site and significantly greater at five sites, down from six during the last report. Long-term changes in mean octocoral density were similar to those found in the previous report as well. All six sites that showed a positive change in octocoral density in the previous report still maintained that outcome herein. One additional site also significantly increased in octocoral density during this reporting period.

The arrival of stony coral tissue loss disease (SCTLD) was confirmed by DRTO park management in May 2021. This highly lethal coral disease was observed at six CREMP sites in October 2021 and was documented at two additional sites in August 2022. In 2022, SCTLD disease prevalence was still at epidemic levels with lesions observed on 7.9% of the coral colonies surveyed by CREMP. Between 2021 and 2022, clear declines in abundance for several of the most SCTLD-susceptible species were observed, but significant site-level declines were not detected in the short-term analysis from 2019-2020 to 2021-2022 at any CREMP site due to the time-averaging of the statistical analyses. Total coral abundance within the CREMP stations decreased by >400 colonies between 2021 and 2022, and although we cannot conclusively assign all mortalities to SCTLD, many of the differences in abundance were associated with changes to coral species that are highly susceptible to SCTLD. Combined for both years in this report, SCTLD was directly observed on 191 colonies representing 12 coral species.

The status of ESA-listed corals was determined by evaluating short- and long-term differences in the percent cover of the acroporid species at their respective reefs and percent cover and density of orbicellid species across reefs where it was historically most abundant. For the acroporid corals, the cover of *A. palmata* significantly increased between this and the previous biennial report, while no changes were observed for *A. cervicornis* and *A. prolifera*. Long-term results for the acroporid species were similar to the previous report. *Acropora palmata* and *A. prolifera* cover has nearly doubled long-term (over 15 years) at their respective sites, but because the increases are highly

variable among the survey stations significant long-term differences were only detected for *A. prolifera*. At the two sites where *A. cervicornis* was previously abundant, cover values have remained close to zero since the initial four-year period of monitoring at one site and was significantly lower at the other. While *A. palmata* and *A. prolifera* have fared well over the last 15 years, *A. cervicornis* has not rebounded after losses during early years of monitoring.

Consistent with the previous report, *Orbicella* spp. cover has significantly decreased long-term at all sites and for the combination of five sites that represent the RNA pinnacle reefs. Dating back to the first four years of monitoring, more than half the total *Orbicella* spp. cover has been lost at one site (Bird Key Reef), more than 40% at three sites (Black Coral Rock, Little Africa and Prolifera Patch), and more than 25% for the RNA pinnacle reefs. *Orbicella* spp. cover also declined at Bird Key Reef in the short-term. In addition, this was the first report that confirmed a significant long-term decrease in *Orbicella* spp. density at two sites (Bird Key Reef and Black Coral Rock) and the RNA pinnacle reefs. *Orbicella* spp. are susceptible to SCTLD and the total abundance pooled for all CREMP stations decreased by at least 30 colonies between 2021 and 2022. While this difference did not drive any significant short-term decreases in density at the site level, the long-term differences due to SCTLD are likely to grow because 35 of the ~150 *Orbicella* spp. colonies counted in 2022 were recorded with active SCTLD lesions. From the resource management perspective, the continued decline of *Orbicella* spp. is of paramount concern. Massive corals within the *Orbicella* genus have been the most spatially abundant corals (e.g., the largest contributor to coral cover) at many sites in the Tortugas region and often comprised 50% or more of the total coral cover at many sites historically. Due to SCTLD, further declines in *Orbicella* spp. in the upcoming years are to be expected and will exacerbate the previously reported associated losses stemming from other disease outbreaks and thermal stress.

Although evaluating the impacts from SCTLD will be the principal focus in the upcoming years, another pervasive issue has been persistently high macroalgal cover across the majority of sites. This issue has been described in full detail in previous biennial reports and while there was a significant short-term decline in cover at five sites in this report, macroalgae was still the greatest contributor to benthic cover at 10 of the 12 sites in 2021-2022. While initially believed that the rapid proliferation of macroalgae commenced with documented upwelling in 2009, the elevated macroalgae values have persisted for 15 years. Upwelling along the Florida shelf is common but generally ephemeral, and if the bloom was fostered by upwelling it would be expected that over a decade after the bloom macroalgal cover would have begun to subside. The root cause of the persistently high macroalgae values is still unknown because other factors that exert control on macroalgae abundance have changed little. For example, there should have been little to no change in herbivory pressure during the last twenty years as herbivorous fishes are protected by DRTO regulations and the State of Florida Marine Life Rule, Chapter 68B-42 of the Florida Administrative Code, and, even though the overall abundance of the grazing urchin *Diadema antillarum* in DRTO is likely still lower than historical populations, macroalgal cover did not increase for nearly two decades after the *Diadema* die-off in the mid-1980s. Thus, a change in factors beyond herbivory control must be responsible. The increased macroalgal cover remains of principal concern because it is primarily driven by two noxious genera (*Dictyota* and *Lobophora*

spp.) that are highly effective at out-competing corals for space along the reef and potentially impede coral recovery.

Lastly, as part of the CREMP research directives in the DRTO, five pinnacle reefs inside of the RNA were used to investigate if concentrating SCUBA diving activities at sites designated with mooring buoys would result in harm or stress to the reef communities. Three pinnacle reefs received mooring buoys and serve as treatment sites, while two pinnacle reefs without mooring buoys act as reference sites. Differences between the treatment and reference sites were evaluated by comparing changes in percent cover and density of corals and octocorals. Data for the three treatment and two reference sites were pooled and for long-term analyses the first four years were standardized to 2009-2012 across treatment and reference sites. Short-term, between the 2019-2020 and 2021-2022 time periods, there were no significant differences in mean coral and octocoral cover and density. Long-term, between 2009-2012 and 2021-2022, there was a significant decline in mean coral cover at the treatment sites but no significant change at the reference sites. Coral density and octocoral cover significantly increased long-term at both the treatment and reference sites, and octocoral density significantly increased at the reference sites. The decrease in mean coral cover at the treatment sites was mostly due to the loss of *Orbicella* spp., which, as outlined above, was a consistent finding across all sites analyzed for *Orbicella* spp. Because the loss of *Orbicella* spp. has been well documented in DRTO and elsewhere in Florida and the Caribbean, the decline at the treatment sites was likely unrelated to SCUBA diving pressure. Further, considering there were significant increases in overall coral density and octocoral cover and density, the results suggest that the current level of SCUBA diving activity has not had a deleterious effect on the benthic communities at the RNA pinnacles with mooring buoys.

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Introduction

Situated at the western terminus of Florida's Coral Reef (FCR) approximately 70 miles west of Key West, the Dry Tortugas are a mosaic of coral reefs, sedimentary shoals, seagrass meadows, and small islands that lie at the convergence of the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean (Jaap 1984, Jaap et al. 1994). Remotely located and separated from terrestrial impacts, this biologically diverse area is an important breeding ground for numerous seabirds and turtles and is known to be important in providing a larval supply for various fishes throughout the FCR (Dahlgren et al. 2001, Domeier 2004, Burton et al. 2005). The region is also home to more than 40 species of stony corals, numerous soft corals and sponges, and various other marine invertebrates. Coral reef structures in the Dry Tortugas, the focus of this report, are varied and include deep-water reef terraces, bank/barrier reefs, high relief patch or pinnacle reefs, and shallow monotypic stands of acroporid corals (Franklin et al. 2003, Jaap et al. 2008).

The Dry Tortugas is an important area for numerous corals species, including several that are listed as threatened under the Endangered Species Act: *Acropora cervicornis*, *A. palmata*, *Orbicella faveolata*, *O. annularis*, and *O. franksi*. Historically, the Dry Tortugas was known for extensive populations of staghorn coral, *A. cervicornis* (Agassiz 1885, Davis 1982, Porter and Meier 1992). Declines in the population of *A. cervicornis* over the last century are well documented for the Dry Tortugas (Davis 1982) and have been attributed to a variety of stressors, including disease, cold-water events, harmful algal blooms, and hurricanes. *Acropora palmata* has followed a similar fate with the populations of both acroporid species in the Dry Tortugas estimated to have been reduced by >95% from early studies to the present (Roberts et al. 1982, Jaap and Sargent 1993, Precht and Miller 2007). Declines in the iconic *Orbicella* spp. have also occurred with once extensive populations experiencing slow but persistent losses due to chronic coral diseases and repetitive bleaching events throughout the Dry Tortugas and FCR as a whole (Bruckner 2006, Edmunds 2015). The loss of both *Orbicella* spp. and *A. palmata* is particularly concerning as both are known to be important framework building corals. Both *A. cervicornis* and *A. palmata* were listed as "threatened" under provisions of the U.S. Endangered Species Act in 2006. *Orbicella* spp. followed, acquiring the "threatened" listing in 2014.

Throughout the twentieth century numerous legislative actions were taken to promote the conservation of cultural and biological resources in the Dry Tortugas, culminating in the designation of Dry Tortugas National Park (DRTO) in 1992. Since the establishment of the park further conservation efforts have been made with the designation of the Tortugas Ecological Reserves in 2001 by the Florida Keys National Marine Sanctuary and the Research Natural Area (RNA) in 2007 by the National Park Service (NPS). The Tortugas Northern Ecological Reserve (TNER), located to the northwest of Dry Tortugas National Park within the Florida Keys National Marine Sanctuary, prohibits all consumptive activities. The RNA, located within the park and making up nearly half of the park's geographic area, adds further protection for marine resources and prohibits resource extraction and anchoring and provides mooring balls at several sites that have been designated as dive or snorkel locations. Currently, DRTO covers approximately 100 square miles (25,900 hectares), with more than 99% of the park containing submerged resources.

The Fish and Wildlife Research Institute's (FWRI) Coral Reef Evaluation and Monitoring Project (CREMP) is a repeated measures monitoring program which provides information on coral reef status and temporal trends. CREMP first started long-term monitoring of benthic resources in the Dry Tortugas in 1999 with three sites originally selected because of their historical or ecological significance: Bird Key Reef, a bank reef that has been surveyed periodically since the early 1970s; White Shoal, a large patch reef once dominated by *A. cervicornis*; and Black Coral Rock, a deep pinnacle reef located inside the TNER. In 2004, five additional monitoring sites were established to meet specific management objectives outlined in the DRTO management plan. Three sites were selected to monitor remaining stands of acroporid corals in DRTO (Loggerhead Patch, Palmata Patch, and Prolifera Patch) and two sites were established on well-known pinnacle reefs (Temptation Rock and Mayer's Peak). In 2009, three additional pinnacle reef sites (The Maze, Davis Rock, and Texas Rock) were added to the survey effort within the RNA to assess whether concentrating diving and snorkeling activities at sites designated with mooring buoys would lead to adverse effects on coral reef communities at these sites. Although most of the sites monitored by CREMP were selected to address specific research or management objectives, collectively, all study sites provide a general assessment of benthic habitat condition in DRTO.

This report summarizes CREMP data collected through 2022 and provides analyses of the temporal changes in benthic community cover and the densities of corals and octocorals in recent years (2019-2022) and between the starting and ending points of monitoring (1999-2022). To better understand stressors affecting coral condition, as well as the general health of coral communities, summaries on disease prevalence and water temperature are also provided.

It should be explicitly mentioned that stony coral tissue loss disease (SCTLD) arrived in DRTO in May 2021. SCTLD is a lethal condition which inflicts high rates of mortality across more than 20 species (Walton et al. 2018, Muller et al. 2020). The disease was first documented off Virginia Key in Miami-Dade County in 2014. It slowly spread south and west along Florida's Coral Reef, and subsequently reached the southeastern reefs of DRTO seven years later. SCTLD was observed at six CREMP sites in October 2021, but because it was in the early epidemic phase in the Dry Tortugas at this time, most susceptible corals had active lesions just developing during the 2021 surveys. By 2022, SCTLD had spread throughout most of DRTO, and impacts were more recognizable at CREMP sites as many colonies had already suffered complete mortality or had rapid, ongoing tissue loss that encompassed most, if not all of the colony. The Results section provides an assessment of coral condition across DRTO and the impacts of SCTLD are discussed.

Methods

Site Descriptions

The CREMP sampling effort encompasses a variety of coral reef habitats found in the Dry Tortugas, including high-relief pinnacle reefs that occur at various depths, a high-relief spur and groove reef, and several shallow, mostly monotypic stands of ESA-listed acroporid species. Currently 12 sites are surveyed annually with surveys having commenced at various points in time (Figure 1, Table 1).

Table 1. Geospatial and descriptive information for the CREMP DRTO survey sites.

Site Name	Reef Type	Depth (m)	Location	Start Year	Rationale/Description
Bird Key Reef	Bank reef with spur and groove	15	24° 36.703 -82° 52.212	1999	Representative of typical spur and groove reef type on the outer edge of Florida Keys; historical periodic monitoring since 1975
Black Coral Rock	Pinnacle reef	24	24° 41.956 -83° 00.131	1999	Representative of a common reef community type within the TNER
Davis Rock	Pinnacle reef	10	24° 41.225 -82° 54.429	2009	Representative of a common DRTO reef community within RNA
Loggerhead Patch	*Acropora cervicornis* patch reef	2	24° 38.138 -82° 54.939	2005	Representative of *A. cervicornis* dominated coral community once common in DRTO
Little Africa	*Orbicella* spp. patch reef	<1	24° 38.148 -82° 55.230	2007	A shallow nearshore *Orbicella* spp. dominated community within RNA
Palmata Patch	*A. palmata* patch reef	3	24° 37.243 -82° 52.042	2004	One of two known extant DRTO *A. palmata* populations with the highest abundance
Prolifera Patch	*A. prolifera* patch reef	3	24° 37.239 -82° 52.180	2004	Largest known population of *A. prolifera* in Florida; only known population in DRTO
Mayer's Peak	Pinnacle reef	10	24° 36.480 -82° 56.644	2004	Representative of a common DRTO reef community type within RNA.
The Maze	Pinnacle reef	14	24° 36.542 -82° 56.974	2009	Representative of a common DRTO reef community type within RNA.
Temptation Rock	Pinnacle reef	8	24° 38.587 -82° 55.844	2004	Representative of a common DRTO reef community type within RNA.
Texas Rock	Pinnacle reef	15	24° 40.832 -82° 53.115	2009	Representative of a common DRTO reef community type within RNA.
White Shoal	Sloping bank reef (w/o spur and groove)	7	24° 38.703 -82° 53.769	1999	Representative of *A. cervicornis* dominated coral community once common in DRTO

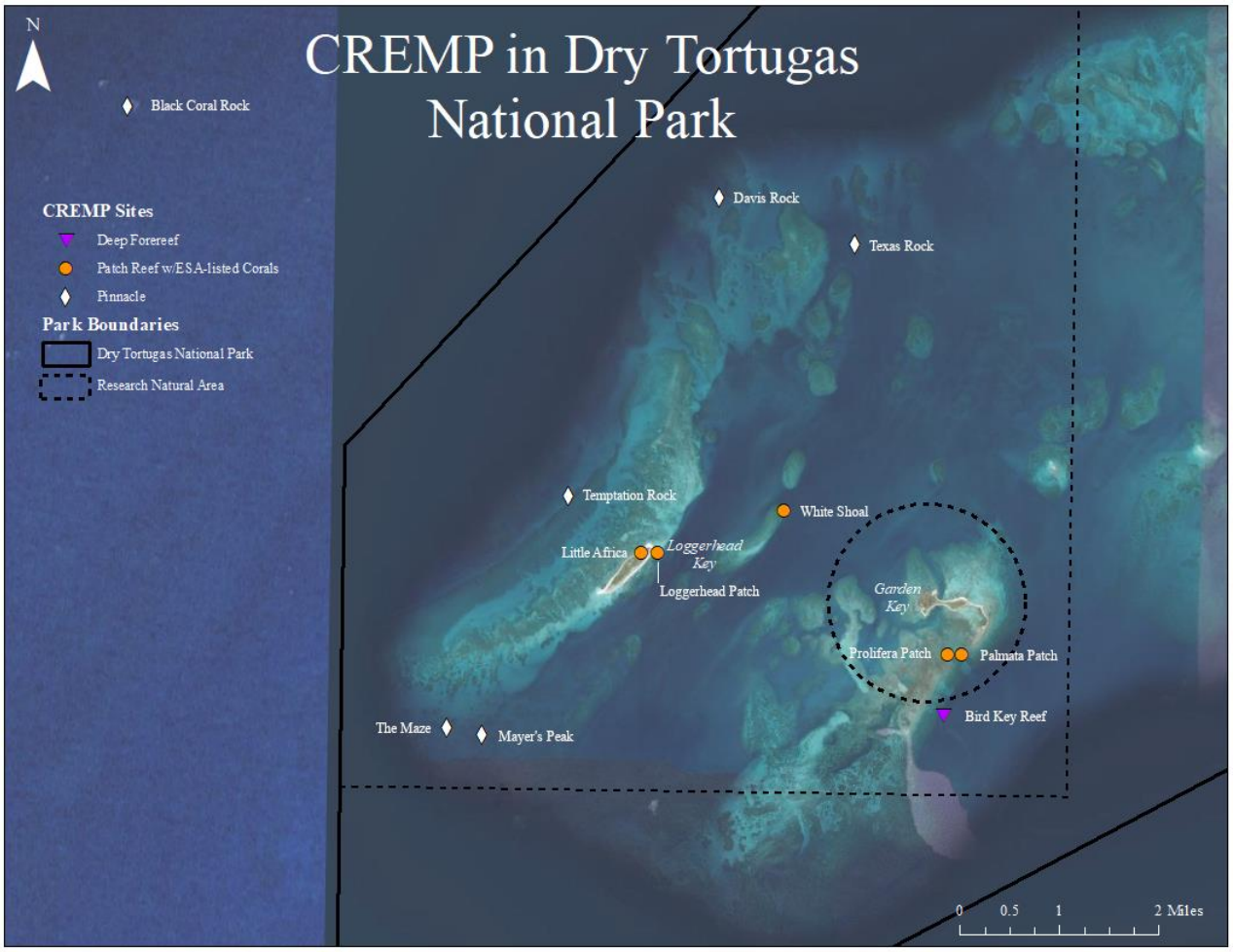

Figure 1. CREMP coral reef monitoring sites within Dry Tortugas National Park and the Research Natural Area.

Pinnacle reefs in the Dry Tortugas are located in the northern and western sections of DRTO and throughout the TNER. Pinnacle reefs provide high vertical relief and include diverse coral and octocoral assemblages. Five pinnacle reefs are surveyed by CREMP in DRTO. These pinnacle reefs crest at 10-15m depth with surrounding sand flats at ~20m depth. Monitoring surveys commenced in 2004 at two of these sites, Mayer's Peak and Temptation Rock. In 2009 three sites were added, all of which were designated for mooring buoy installation as part of the RNA science plan: The Maze, Davis Rock, and Texas Rock. Another pinnacle reef, Black Coral Rock, surveyed by CREMP since 1999, is located outside DRTO boundaries in the TNER. Black Coral Rock crests at 24m depth with surrounding sand flats at 30m depth. Black Coral Rock is generally not grouped with the other pinnacle reefs because of its location in the TNER, greater depth, and longer period of surveys. Historic substrate coverage at Black Coral Rock also contains a larger proportion of *Orbicella* spp. than other pinnacle reefs.

The ESA-listed coral species *Acropora cervicornis*, *A. palmata*, *A. prolifera* and *Orbicella* spp. are located throughout the park. Two sites, White Shoal and Loggerhead Patch, were selected because they were historic stands of *A. cervicornis*. White Shoal is a large, submerged shoal between Loggerhead Key and Garden Key first surveyed as part of CREMP in 1999. Loggerhead Patch is located off the eastern edge of Loggerhead Key in less than 3m of water and was first surveyed in 2006. Two sites, Palmata Patch and Prolifera Patch, target stands of acroporid corals in the lagoon south of Garden Key. Both sites are ~1km from Fort Jefferson, < 3m depth and have been monitored since 2004. Little Africa is a mostly monotypic stand of *Orbicella* spp. located in < 2m depth, close to the northwest shore of Loggerhead Key. This site can be exposed at extreme low tides. CREMP surveys at Little Africa began in 2007. While these shallow patch reefs are largely composed of monotypic stands of their associated species, several large boulder corals (e.g., *Orbicella* spp., *Montastraea cavernosa*, and *Siderastrea siderea*), as well as numerous octocorals, are also present.

Bird Key Reef is a bank reef located south of the Garden Key lagoon, ~2km south of Fort Jefferson. Reef development here was offshore Bird Key, which disappeared in the impacts from the Labor Day Hurricane of 1935 (Dilley 1950). The reef forms a high-relief spur and groove pattern, more commonly seen near the Florida Keys, that quickly drops off to sand flats at ~22m depth. Surveys at Bird Key Reef are conducted along reef spurs at ~15m depth. Bird Key Reef has been surveyed as part of CREMP since 1999.

Survey Stations

Each repeated measures survey station is ~22m in length and demarcated by two permanently placed steel pins indicating the starting and ending boundaries. All pinnacle reef sites (Black Coral Rock, Mayer's Peak, Temptation Rock, The Maze, Texas Rock, and Davis Rock), Bird Key Reef, and White Shoal have four survey stations. Due to their smaller size, the shallow acroporid assemblages have a reduced number of stations: three stations at Prolifera Patch and two stations each at Palmata Patch and Loggerhead Patch. Due to the extremely shallow depth, different survey methods are used at Little Africa, and no permanent stations are present.

Historically, CREMP performed three major surveys at each station: 1) a video survey to estimate benthic cover along three parallel transects, 2) a bio-eroding sponge survey, and 3) a coral species inventory survey that quantified coral species richness within the station boundaries (Figure 2). In 2011, survey methods were modified to provide a more robust assessment of the benthic community and to streamline survey efficiency:

- The video survey was replaced with still photographs.
- For all sites with four stations, image surveys were reduced from the three parallel transects to a single centered transect (Figure 3).
- Coral species inventories were replaced by coral and octocoral demographic surveys conducted on the first ten meters of the center transect at all stations.
- The bio-eroding sponge survey was discontinued.

For more detailed information on discontinued survey methodology please refer to previous CREMP reports.

Image Transects

Prior to changing image survey methods two statistical analyses were conducted to ensure that images and data acquired through digital point and shoot cameras were consistent with those acquired using previous/other video technologies (Morrison et al. 2012), and to confirm that long-term trends derived from only the center transect were consistent with the trends observed from data acquired from all three parallel transects. These confirmed that still imagery did not result in different estimates when compared to video imagery and that trends for all the major benthic taxa (e.g., corals, octocorals, sponges and macroalgae) were similar at >84% of all stations whether all three or the single, centered transect was sampled. This allowed a reduction from three parallel transects to one at most stations. Three parallel image transects per station (Figure 2) are still performed are at Loggerhead Patch, Palmata Patch and Prolifera Patch - sites that have less than four stations, and which target a particular ESA-listed species where individual colonies can be difficult to distinguish in coral demographic surveys.

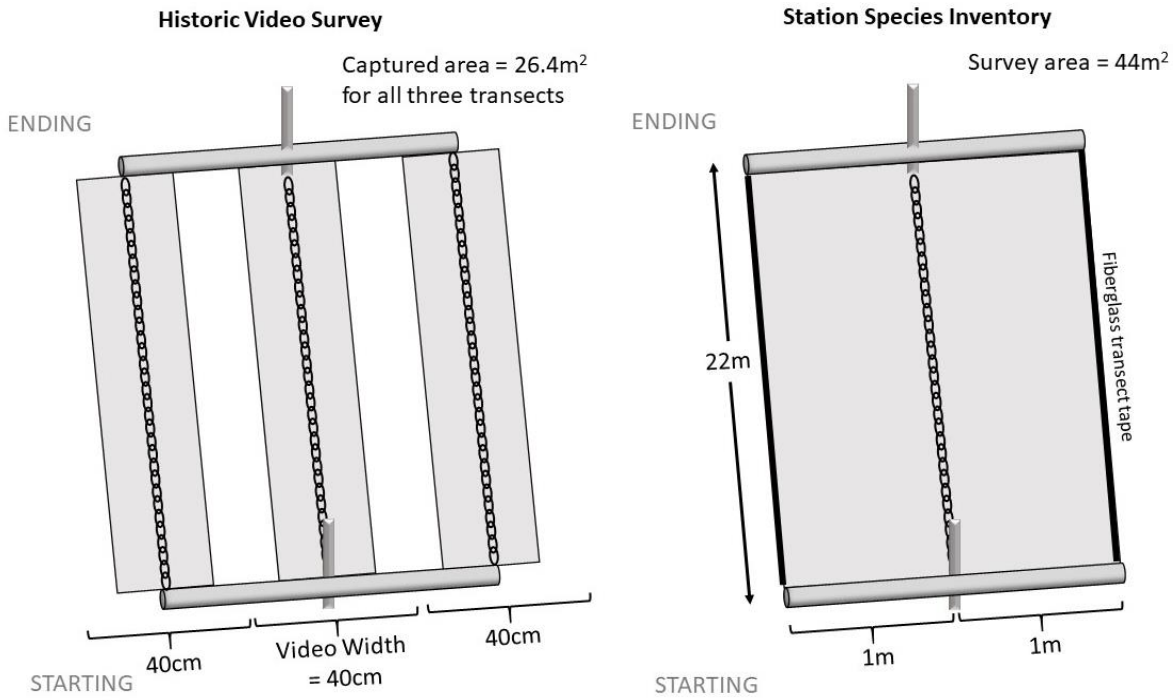

Figure 2. CREMP survey design prior to 2011. Three video transects and a timed coral station species inventory were conducted annually at each station. The center line of each transect was demarcated by a plastic chain laid upon the substrate. This sampling effort for image acquisition has been retained at Loggerhead Patch, Palmata Patch and Prolifera Patch because each of these sites has less than four stations (Figure 3). Station Species Inventories are no longer conducted.

Station transects are prepared by securing a fiberglass tape between the two permanent marker stakes and then laying a plastic chain directly underneath the tape along the substrate (Figure 3).

At stations where three parallel transects are used, a 2m aluminum pole is placed atop each permanent stake. The three transects are laid in the same manner as above using the marker stake and either end of the aluminum poles as start and end points, such that the center of each transect is 1m apart (Figure 2). From 2011 to 2016 images were captured using a Canon PowerShot SD1100 IS and since 2017 using an Olympus TG-4. All images are captured at a distance of 40cm above the reef, resulting in images that are ~40cm wide, with each image transect containing approximately 60 images. An aluminum bar attached to the bottom of the camera housing aids in maintaining a constant height above the substrate. To ensure minimal overlap between images, visual reference points on the substrate are used to proceed along a transect. Each photographic transect constitutes a sampling area of ~9 m^2. In the lab, images are formatted for PointCount '99 image analysis software (Dustan, 1998). Fifteen random points are overlaid on each image. Underneath each point, corals and other select benthic taxa are identified to species (all Scleractinia, plus *Gorgonia ventalina*, *Xestospongia muta*, and *Palythoa caribaeorum*), several macroalgal types to genera (*Dictyota* spp., *Halimeda* spp., and *Lobophora* spp.), and other flora and fauna at higher taxonomic levels (e.g., encrusting or branching octocoral, crustose coralline algae, zoanthid, sponge, and macroalgae). Identification of substrate includes a variety of reef surfaces; carbonate rock, unconsolidated sand or rubble, and areas colonized by small, filamentous turf algae. After all images are analyzed, the data are checked for quality assurance and compiled into a Microsoft Access database.

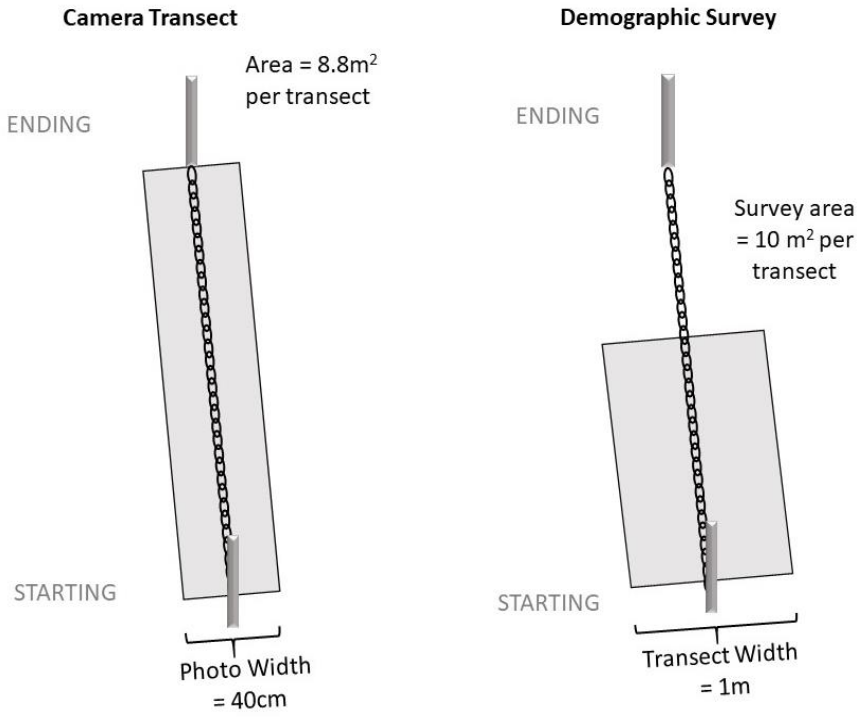

Figure 3. Current CREMP survey design. At all sites with four stations, still camera transects survey the center transects demarcated with a plastic chain and encompass 8.8m^2 of reef per station. Octocoral and coral demographic surveys are 1m x 10m belt transects and are performed at all sites.

Coral Demographic Survey

The demographic survey protocol is similar to that used by the Atlantic and Gulf Rapid Reef Assessment Program (AGRRA) and the Florida Reef Resilience Program (FRRP) (Lang et al. 2010, Wagner and Willis 2010). At all stations divers conduct a single 1m x 10m belt transect beginning at the starting stake (Figure 3). Every coral species present is recorded and all colonies ≥4cm are measured to the nearest centimeter with a ruler affixed to a 0.5m PVC stick. The maximum diameter and height taken along the growth plane, presence of diseases and/or bleaching, visual estimates of old tissue mortality, and visual estimates and cause of new mortality are recorded for each colony. If a disease condition cannot be positively identified it is recorded as unknown and a series of diagnostic records describing the condition are recorded. Mortality is considered "recent" only if the corallite structure can be clearly distinguished and there is minimal overgrowth by algae or other fouling organisms. Otherwise, mortality is classified as "old", and causality not assigned. *Millepora alcicornis* is only recorded as present or absent. *Millepora complanata* is measured and assessed as described. Since 2018 all colonies <4cm are identified to the lowest possible taxonomic level and are counted but are not measured or assessed. Data are validated using established quality assurance/quality control protocols at the FWRI lab, which includes verification that data was correctly transcribed from field datasheets into a pre-formatted Microsoft Excel data entry template.

Octocoral Demographic Survey

Similar to the coral survey, divers conduct a 1m x 10m octocoral survey at each station at all sites (Figure 3). All octocoral colonies within the belt transect are counted, regardless of species. This provides a measurement of overall octocoral density. Five species of octocorals - *Antillogorgia americana* (formerly *Pseudopterogorgia americana*), *Antillogorgia bipinnata* (formerly *Pseudopterogorgia bipinnata*), *Eunicea flexuosa* (formerly *Plexaura flexuosa*), *Pseudoplexaura porosa*, and *Gorgonia ventalina* - are measured and assessed. A sixth species, *Eunicea calyculata*, was surveyed from 2011-2016 but is no longer included. These species were selected because they can be easily distinguished in the field and are relatively abundant in their preferred reef habitat. For each colony maximum height is measured to the nearest centimeter with a ruler affixed to a 0.5m PVC stick. A visual estimate of disease and bleaching is recorded for each species in addition to any condition leading to compromised health of the colony (e.g., predation, overgrowth). Data are validated using established quality assurance/quality control protocols back at the FWRI lab which includes verification that data was correctly transcribed from field datasheets into a pre-formatted Microsoft Excel data entry template.

Little Africa Survey

Little Africa is a shallow patch reef dominated by a large monotypic stand of star corals in the *Orbicella* genus. Many of the colonies are in depths <1m which has prevented the installation of traditional CREMP stations. Instead, ten random transects are delineated using a measuring tape, and are photographed with a still camera each survey year. Each transect is 10m long and made up of 20 consecutive abutting photographs. Transects are oriented parallel to each other and are evenly

spaced such that the whole patch reef is surveyed. Still images were analyzed using Point Count '99, in the same manner as images captured from video transects at permanent stations. Coral and octocoral demographic surveys are not conducted at Little Africa.

Temperature

HOBO Water Temp Pro v2 loggers (model U22-001; Onset Corporation) were initially deployed at four locations (Bird Key Reef, Black Coral Rock, Mayer's Peak, and Temptation Rock) in September 2006. Additional loggers were added at Palmata Patch in 2008, Texas Rock in 2010, The Maze in 2013, White Shoal and Davis Rock in 2016, and Loggerhead Patch and Prolifera Patch in 2017. Loggers are attached to the stainless-steel station marker pins at the reef substrate. Loggers record temperature hourly and are downloaded annually. Two time series for water temperature between 2009 through 2022 were summarized. The first summary shows the average number of days in which the mean daily water temperatures exceeded 30°C or 31°C averaged for all sites in a given year. The second summary shows the average number of days per year in which the mean daily water temperature exceeded 30°C or 31°C for each site. The daily mean water temperature was calculated using the 24-hourly observations for each day.

Descriptive & Statistical Analyses

Statistical analyses were conducted to examine: 1) temporal changes in the percent cover of four major benthic taxa (corals, octocorals, macroalgae, and sponges) at each site, 2) temporal changes in total abundance of corals and octocorals at each site, summed for all species for each taxa, 3) temporal changes in percent cover for four ESA-listed species at sites where they are most abundant, 4) temporal changes in the abundance of *Orbicella* spp. at sites where they are most abundant, and 5) temporal changes in the percent cover and abundance of corals and octocorals at pinnacles reefs within the RNA, which includes three pinnacle reefs with mooring buoys and two pinnacle reefs without mooring buoys. All temporal changes for both percent cover and abundance were examined at two timescales: 1) short-term, where the two most recent years (2021-2022) of data were pooled and compared to the previous two years (2019-2020) and 2) long-term, where the first four years of data collected at each site were pooled and compared to the most recent four years (2019-2022). Data were pooled across years in this way to minimize the effect of statistical outliers or ephemeral events that could substantially alter cover or abundance values in any given year.

All statistical analyses were conducted using R version 4.3.2 and the glmmTMB and emmeans packages. All model fits were examined using the DHARMa package. For each analysis several candidate models were examined and the models with the lowest Akaike Information Criterion (AIC) values were reported. All statistical inference was made at $\alpha = 0.05$.

Tables reporting year group means and standard errors were calculated from annual station values in Microsoft Excel. All model estimated means and standard errors from statistical comparisons are reported in Appendix G for percent cover and Appendix H for demographic data. This differs from previous reports where either the model estimated means or raw data generated means and

standard errors were reported. This was done to maintain consistency in the values provided in future reports because model estimated means, even for earlier time periods, may vary as new years of data are included, whereas means calculated directly from the raw data will be unchanged. It should also be noted that model estimated means in this report may vary from previous reports due to differences in the statistical software used for analyses. SAS Enterprise Guide 8.3 and earlier versions were used to conduct statistical analyses in previous reports while R was used for this report.

Percent Cover

All percent cover data were analyzed using generalized linear mixed models with a binomial distribution and logit link function. For the analysis of each taxon, all points identified for each station were included as present/absent values. For both short-term and long-term analyses year groupings and sites as well as their interaction were included as fixed effects. Two random effects were included in each model to account for 1) the nesting of values within stations and years and 2) the repeated measures of stations across year groups. To examine differences within sites between time frames pair-wise post hoc comparisons were made; however, no post-hoc adjustment to p-values were included. These were omitted because of the small number of post-hoc comparisons and because the adjustments were often too conservative for meaningful interpretation of the differences in results. For the analysis of acroporid cover at White Shoal, Loggerhead Patch, Palmata Patch, and Prolifera Patch only the data for each respective site was used and the fixed effects for sites and the interaction of sites and year grouping were omitted. These fixed effects were similarly removed for the analysis of *Orbicella* spp. at Bird Key Reef, Black Coral Rock, and Prolifera Patch. Analyses of *Orbicella* spp. at Pinnacle Reefs and stony corals and octocorals at RNA site groups included the fixed effects for sites and the interaction term. Because Little Africa is sampled using a different procedure this site was analyzed separately for each major taxon group and for *Orbicella* spp.; similar generalized linear mixed models were used and included year grouping as a fixed effect and transect as a random effect. The statistical outputs for each site and/or the sites that were pooled (e.g., RNA sites with moorings or Orbicella spp.) are provided in Appendix G.

Coral and Octocoral Demographics

All demographic data were analyzed using generalized linear mixed models with either a Poisson distribution or a negative binomial with a log link function. A Poisson distribution was used unless significant over- or under-dispersion was detected; this resulted in a negative binomial model used for the analysis of total stony coral abundance and a Poisson model used for all other analyses. Aside from the difference in the assigned distribution, demographic analyses were similar to percent cover analyses; for each taxon untransformed abundance data were modeled using year groupings and sites as well as their interaction as fixed effects. Two random effects were included in each model to account for 1) the nesting of values within stations and years and 2) the repeated measures of stations across year groups. To examine differences within sites between time frames pair-wise post hoc comparisons were included; however, no post-hoc adjustment to p-values were included. These were omitted because of the small number of post-hoc comparisons and because

the adjustments were often too conservative for meaningful interpretation of the differences in results. For the analysis of *Orbicella* spp. abundance at Bird Key Reef, Black Coral Rock, and Prolifera Patch only the data for each respective site was used and the fixed effects for sites and the interaction of sites and year grouping were omitted. Analyses of *Orbicella* spp. at the pinnacle reefs and stony corals and octocorals at RNA site groups included the fixed effects for sites and the interaction term. The statistical outputs for each site and/or the sites that were pooled (e.g., RNA sites with moorings or *Orbicella* spp.) are provided in Appendix H.

Results and Discussion

Corals

Percent Cover

For this report, two analyses were completed to compare short- and long-term changes in the mean coral cover (% ± SE) of benthic taxa groups and mean density (no of colonies/m^2 ± SE) of corals and octocorals. Short-term changes in percent cover compared the pooled averages of the two-year period for this biennial report (2021-2022) against those in the previous report (2019-2020) while long-term differences in precent cover compared a pooled mean for the first four years of monitoring (varies by site) against those calculated for the last four years (2019-2022). Short-term, none of the 12 sites had a significant change in coral cover (Table 2).

Table 2. Mean coral cover (% ± SE) for 12 sites. Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparisons averaged for the two-year period of the current and previous biennial report. The first four-year period varies and is contingent upon commencement of monitoring at each site: Bird Key Reef, Black Coral Rock, White Shoal = 1999-2002; Palmata Patch, Prolifera Patch, Mayer's Peak, Temptation Rock = 2004-2007; Loggerhead Patch = 2005-2008; Davis Rock, Texas Rock, The Maze = 2009-2012; Little Africa = 2007-2010. *Little Africa is surveyed differently than the other 11 sites (see Methods). Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively. Model estimated means and corresponding p-values can be found in Appendix G.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	18.0 ± 1.4	8.0 ± 0.9	8.9 ± 1.2	7.2 ± 0.7
Black Coral Rock	21.6 ± 1.9	12.0 ± 1.7	13.1 ± 2.0	10.8 ± 1.4
Davis Rock	9.6 ± 2.5	8.6 ± 2.2	8.7 ± 2.5	8.4 ± 2.0
Loggerhead Patch	2.5 ± 0.8	1.2 ± 1.2	0.9 ± 0.9	1.4 ± 1.4
Mayer's Peak	3.7 ± 0.8	4.9 ± 0.8	5.5 ± 0.9	4.3 ± 0.7
Palmata Patch	4.2 ± 2.1	9.9 ± 7.6	8.8 ± 6.8	11.1 ± 8.4
Prolifera Patch	14.0 ± 5.3	20.3 ± 10.4	19.0 ± 9.1	21.6 ± 11.7
Temptation Rock	3.5 ± 0.6	4.5 ± 1.2	4.7 ± 1.4	4.4 ± 1.0
Texas Rock	7.7 ± 1.2	5.7 ± 0.8	6.2 ± 0.9	5.2 ± 1.1
The Maze	11.8 ± 3.9	9.5 ± 2.6	10.1 ± 3.1	8.9 ± 2.0
White Shoal	7.2 ± 1.1	3.6 ± 0.9	3.5 ± 0.8	3.8 ± 0.9
Little Africa*	24.3 ± 4.0	13.1 ± 2.3	14.3 ± 2.6	11.9 ± 2.0

Long-term, three of 12 sites had a significant increase in cover: Mayer's Peak, Palmata Patch, and Prolifera Patch, while six sites had a significant decrease: Bird Key Reef, Black Coral Rock, Loggerhead Patch, Texas Rock, White Shoal, and Little Africa.

Coral cover at Palmata Patch has more than doubled between the long-term time intervals, increasing from 4.2 ± 2.1% (SE) in 2004-2007 to 9.9 ± 7.6% in 2019-2022. While much of the difference long-term can be attributed to the substantial increase in cover that occurred from 2007 to 2011 (Figure 4), significant increases have also occurred recently, following several years of reduced cover during the 2014-15 bleaching years. Coral cover at Prolifera Patch has followed a similar pattern increasing from 14.0 ± 5.3% (SE) in 2004-2007 to 20.3 ± 10.4% in 2019-2022 with decreased values during the 2014-2015 bleaching years. Consistent with the last report, Mayer's Peak demonstrated a significant increase in coral cover over the long-term despite the lower cover values recorded in 2021-2022. Mayer's Peak has been gradually increasing in cover since monitoring began in 2004 (Figure 4).

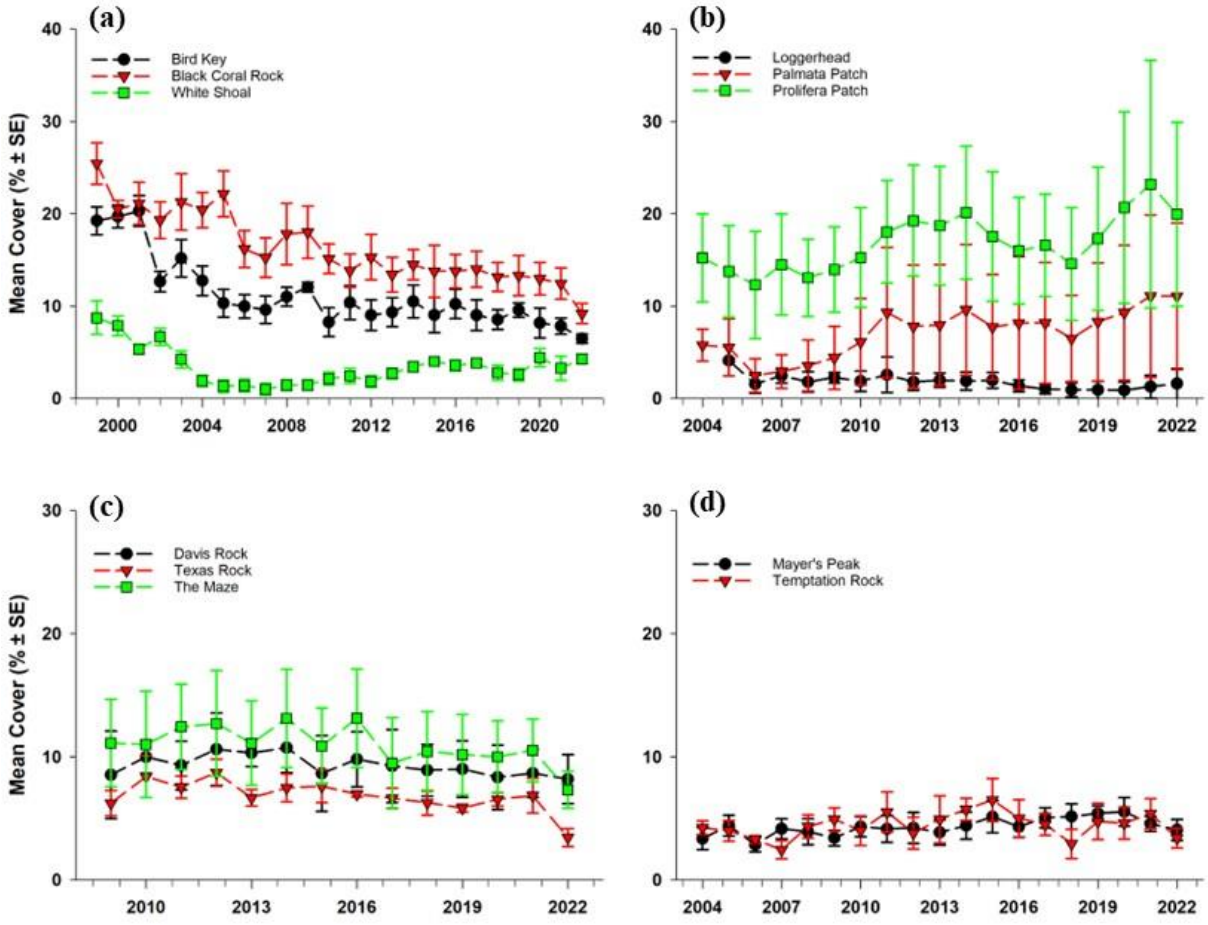

Figure 4. Total coral cover (% ± SE) by site. Graphs organized by timeline for monitoring. A) The three original sentinel sites, started in 1999. B) Three sites added to monitor various ESA species, started in 2004. C) Pinnacle reefs inside the RNA with mooring buoys, started in 2009. D) Pinnacle reefs inside the RNA without mooring buoys, started in 2004. Note: Y-axis scale differs between top and bottom graphs.

All three sites with an initial time interval of 1999-2002 (Bird Key Reef, Black Coral Rock, and White Shoal) had significantly lower mean cover over the last four years of monitoring compared to the first four years, repeating the result from the previous report. Three other sites also had significantly lower mean coral cover values averaged for the last four years of monitoring compared to the first four (2005-2008 for Loggerhead Patch, 2007-2010 for Little Africa, and Texas Rock for 2009-2012) (Table 2); however, the result for Texas Rock was new for this report while Loggerhead Patch and Little Africa repeated findings presented in the previous report. Long-term, the greatest decrease in cover has occurred at Bird Key Reef, Black Coral Rock, and Little Africa. At all three, there has been an 9.6-11.2% decrease in absolute cover which equals a 45-56% relative decrease from the initial cover at each of these sites.

Most of the differences found in coral cover were associated with the changes in the predominant ESA species present at a given site (e.g., *Orbicella* spp. at Bird Key Reef and Black Coral Rock or *A. palmata* at Palmata Patch). A more detailed description of the changes in coral cover at most of these sites is included in the ESA-Listed Species Section below.

Demographics

Coral density (colonies/m^2) has been quantified as part of the coral demographic survey since 2011. Like percent coral cover, short- and long-term means were compared. Short-term analyses compared the pooled means for this biennial report (2021-2022) and the previous report (2019-2020), covering the same period as short-term analyses for percent cover. Long-term analyses compared pooled means calculated for 2011-2014, the first four years of demographic surveys, against 2019-2022. This covers 12 years of demographic surveys and does not align with long-term analyses for percent cover where the earliest time periods were 1999-2002 or 2004-2007 for most sites. Short-term, mean density was not significantly different at any site. Long-term, five of 11 sites had a significant increase in density; one site, Loggerhead Patch, had a significant decline (Table 3).

Coral density at Loggerhead Patch has significantly decreased in the long-term and is the lowest among the 12 survey sites at only 0.1 colonies/m^2 over the 2019-2022 time period. Currently this site is comprised mostly of non-living *A. cervicornis* rubble, which provides a less than optimal substrate that is opportunistically colonized by small, encrusting *Porites* spp. and *Agaricia agaricites* colonies. The unconsolidated rubble at Loggerhead Patch is prone to movement and displacement from storms and surge and these species have an ephemeral existence and/or at times are transient through the survey stations, potentially being recorded in one year but not the next. The unsuitable nature of this habitat has reduced coral abundance at Loggerhead to nearly zero.

Density significantly increased from 2011-2014 to 2019-2022 at Davis Rock, Mayer's Peak, Prolifera Patch, Temptation Rock, and The Maze (Table 3). Texas Rock was the only pinnacle reef site without an increase in density but did show a significant decline in mean coral cover long-term. The results are consistent with those provided in the previous biennial report, which also showed a steady increase in colony density over the last decade at most of the pinnacle reef sites. The greatest increase in density occurred at Mayer's Peak where mean coral density increased

from 5.5 ± 0.9 colonies/m^2 (±SE) in 2011-2014 to 8.2 ± 0.8 colonies/m^2 in 2019-2022 (Table 3), whereas increases at the other pinnacle reefs were generally more moderate (<1.4 colony/m^2). The observed increases in density at the pinnacles are mostly attributed to several species: *Porites astreoides*, *P. porites*, and *Siderastrea siderea* (Appendix D). A small though significant long-term increase in colony density was also found at Prolifera Patch and is mostly attributed to increases in *Agaricia agaricites* (Appendix D); importantly, the dominant species at this site *Acropora prolifera* is omitted from the total as colonies form large thickets that cannot be delineated.

It is both evident and important to recognize that increases in density over the last decade do not

Table 3. Mean density (no. colonies/m^2 ± SE) of corals for 11 sites. Long-term comparisons averaged for the first and last four years of demographic data collection, and short-term comparison averaged for the two-year period for the current and previous biennial report. Demographic surveys are not performed at Little Africa. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$), respectively. **Acropora prolifera* colonies at Prolifera patch are difficult to delineate and are not included in colony densities. Model estimates and p-values can be found in Appendix H.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	5.4 ± 0.9	6.2 ± 0.7	5.8 ± 0.7	6.6 ± 0.7
Black Coral Rock	9.3 ± 0.7	8.5 ±0.7	9.1 ± 0.9	7.9 ± 0.5
Davis Rock	4.7 ± 0.6	5.8 ± 0.5	5.7 ± 0.4	6.0 ± 0.6
Loggerhead Patch	1.3 ± 0.3	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Mayer's Peak	5.5 ± 0.9	8.2 ± 0.8	8.3 ± 0.8	8.1 ± 0.8
Palmata Patch	3.0 ± 2.2	2.8 ± 1.5	3.0 ± 1.7	2.6 ± 1.3
Prolifera Patch*	1.0 ± 0.6	1.3 ± 0.5	1.3 ± 0.5	1.3 ± 0.4
Temptation Rock	3.2 ± 0.4	4.0 ± 0.4	3.7 ± 0.3	4.2 ± 0.5
Texas Rock	6.0 ± 0.9	6.6 ± 0.6	6.8 ± 0.5	6.5 ± 0.8
The Maze	4.0 ± 0.6	5.3 ± 0.5	5.1 ± 0.6	5.6 ± 0.4
White Shoal	3.7 ± 0.8	4.3 ± 1.0	4.4 ± 1.0	4.3 ± 1.0

offset historical losses in percent cover. As we have observed, increases in density at most of these sites is primarily due to the recruitment of small, weedy species that may recruit to the substrate in high numbers but generally do not reach large sizes or contribute considerably to spatial coverage. Furthermore, this analysis does not account for partial mortality that can occur on coral colonies - particularly in large, spatially dominant species like *Orbicella* spp. - which are the predominant species at several sites, including Bird Key Reef where density increased. Partial mortality is problematic; a colony can lose a large portion of living tissue but still be enumerated during the survey which will not result in a decrease in density. Additionally, partial mortality can

often cause colonies to become fragmented, potentially leading to increases in density as the original colony becomes impossible to delineate with time, ultimately resulting in more, albeit smaller, colonies. Conversely, the growth patterns of several species, particularly the acroporids, can often result in large thickets in which individual colonies can become difficult to enumerate, resulting in high variability in annual estimates of colony density. Indeed, at Prolifera Patch coral density comparisons do not include the dominant species, *A. prolifera*, as no attempt was made to enumerate colonies that form large thickets at the site.

Bleaching and Temperature

Coral disease and bleaching are correlated with elevated sea surface temperatures with corals becoming stressed when sea temperatures exceed ~30°C for extended periods of time (Harvell et al. 1999, Jones et al. 2004, Bruno et al. 2007, Eakin et al. 2010, Hoegh-Guldberg and Bruno 2010). In Florida, peak ocean temperatures, which can exceed this thermal threshold, occur during the late summer in August and September (Kuffner et al. 2015, Manzello 2015); estimates of bleaching will therefore be strongly dependent upon when annual surveys occur. Between 2011 and 2017, CREMP surveys were always completed in June, prior to peak thermal stress, whereas after 2017 surveys were completed later in the summer - September in 2018, August in 2019, 2020, and 2022, and October in 2021 - to coincide with the timing of the Disturbance Response Monitoring Program also overseen by FWRI.

CREMP began collecting bleaching prevalence data when the demographic surveys were initiated in 2011. Bleaching prevalence values were lower between 2011 and 2017 because surveys were conducted in June, prior to peak thermal stress. During those years, bleaching prevalence ranged from 0.7% to 5.1% with the highest prevalence recorded in 2017 (Table 4). Most of these values fall within the range considered to be background levels of bleaching in DRTO that is caused by stressors unrelated to seasonal highs in water temperature. Since 2018, the higher prevalence values recorded coincide with CREMP conducting research cruises during the peak months of thermal stress in August or September. Bleaching prevalence in 2021 and 2022 was 3.5 and 2.7%, respectively (Table 4), which was lower than in 2017, 2018, and 2019 when bleaching prevalence was above 5.0% in all three years.

Table 4. Bleaching prevalence (percentage of colonies with total or partial bleaching) pooled for all species for all monitoring sites. Prevalence values reported here may differ from previous reports but are consistent across the 12 years reported.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
# of Colonies	1676	1923	1803	1744	1803	1933	2076	2107	2081	2032	2264	1844
Prevalence (%)	0.7	0.8	0.9	1.0	2.6	2.0	5.1	6.8	5.9	2.0	3.5	2.7

Thermal stress on corals can also be measured by quantifying the number of days in which the mean daily sea temperature was above 30°C or 31°C, with thermal stress becoming more intense as daily temperatures increase (Figure 5). Temperature loggers have been deployed at 11 CREMP sites since 2017 and at five sites since 2009. Although there can be several reasons the level of

thermal stress does not correlate with the bleaching estimates within a given year, the number of days above 30°C still provides an overall measure of stress the corals endured throughout the warmer months. The largest disconnect between the two metrics can result from sea temperatures being recorded across the entire season, whereas bleaching estimates are only made in situ during CREMP surveys which may occur outside of the timeframe of peak thermal stress. The differences across years can be attributed both to the timing of when elevated sea temperatures occur and to differences in the timing of surveys. For surveys occurring in August, if the onset of warmer temperatures doesn't start until mid or late August only the coral species that are the most sensitive to higher water temperatures will have bleached, resulting in lower bleaching estimates. However, if elevated sea temperatures begin in early July, more species will have been affected and the bleaching prevalence observed is likely to be higher. Surveys occurring in September are less likely to be affected by annual variations in the timing of increased sea temperatures as this is a peak bleaching month and all susceptible species would have the potential to be impacted.

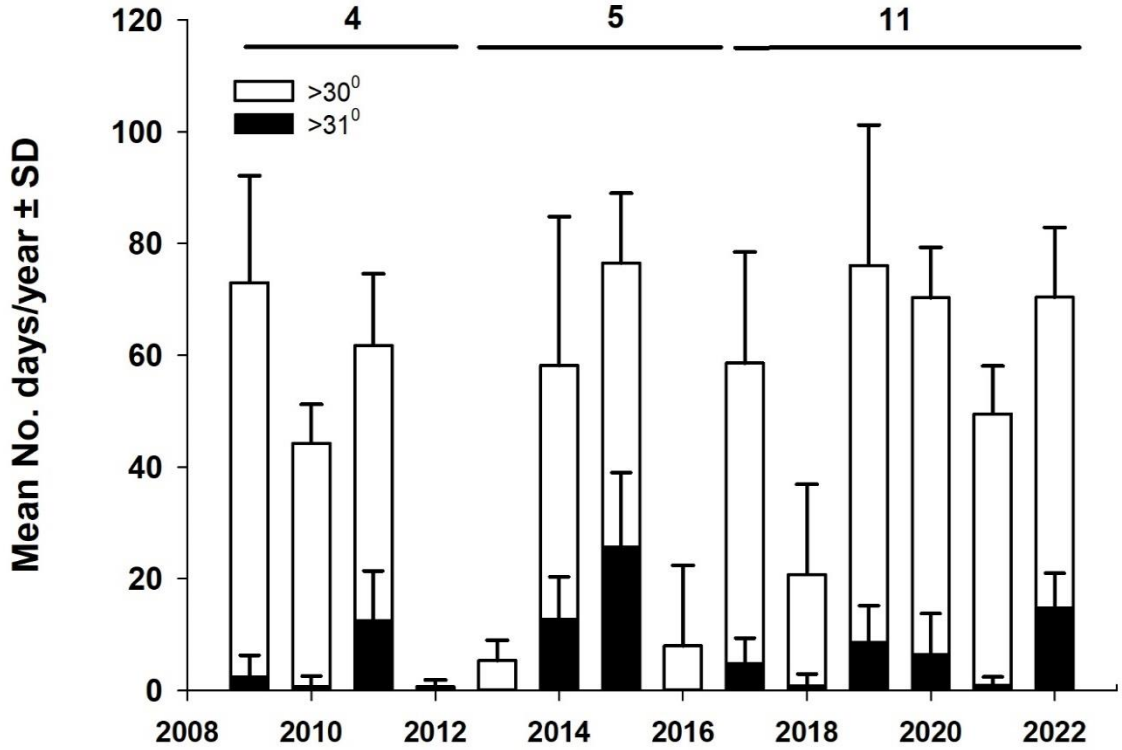

Figure 5. Average number of days (± SD) in which mean daily sea temperatures were above 30°C and 31°C between 2009-2022. Number of sites used to calculate the average for each year are listed above the bars.

Since 2009, when CREMP began deploying temperature loggers, 2022 had the fourth highest number of days with daily mean temperature above 30°C, but the second highest number of days over 31°C (Figure 5). The mean number of days above 30°C and 31°C, averaged for 11 sites in

2022, was 70.4 ± 12.5 (± SD) and 14.9 ± 6, respectively (Figure 5). In 2021, the number of days above 30°C and 31°C was 49.5 ± 8.6, and 1.0 ± 1.5, respectively. For five of the last six years, the number of days the mean daily temperature has been above 30°C has exceeded or been equal to 50 days. The only exception was in 2018 when the mean daily temperature only exceeded 30°C for 20 days. The exceptionally hot years of 2014 and 2015 coincided with a well-documented El Niño which resulted in mass bleaching elsewhere in Florida and the Caribbean (Eakin et al. 2019). In 2015, all sites incurred at least 25 days with daily mean temperatures above 31°C, except for Black Coral Rock which is the deepest of the 11 sites. Although 2022 was not recognized as a mass bleaching year, the number of days in which mean daily sea temperatures were above 31°C was 14.9 ± 6.1, the second highest number of days after 2015 (Figure 5). The difference between the number of days over 30°C and 31°C is becoming important to distinguish because mean daily water temperatures exceeding 30°C have become increasingly commonplace in DRTO. For nine of the last 15 years, mean daily water temperatures exceeding 30°C have been recorded for at least 50 days, while temperatures over 31°C have exceeded 25 days once (in 2015) and 10 days in three years (2011, 2014, and 2022).

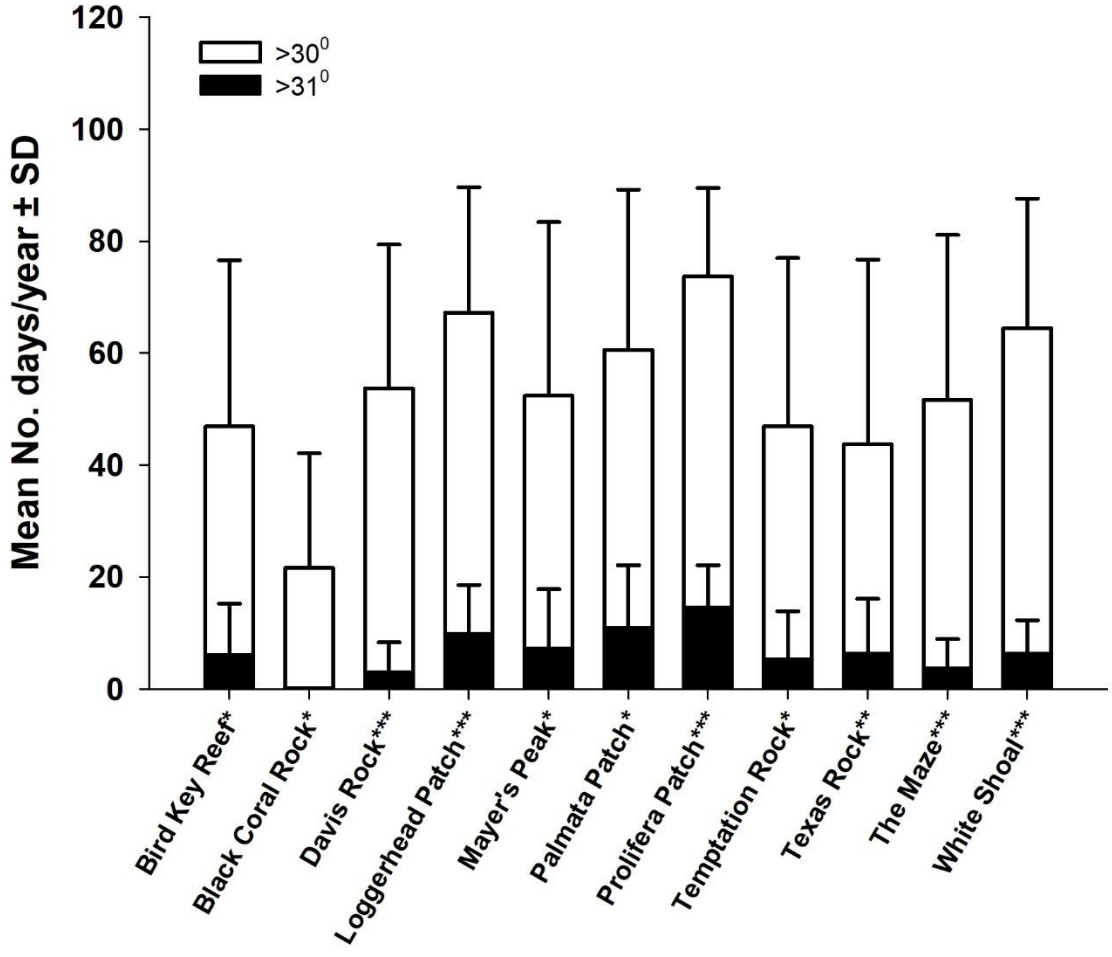

Figure 6. Average number of days (± SD) in which mean daily sea temperatures were above 30°C and 31°C at each site. The number of years used to calculate the average for each site are denoted by an asterisk: * = 2009-2022 (14 years); ** = 2013-2022 (10 years); *** = 2017-2022 (6 years).

The relationship between depth and water temperatures indicates that deeper reefs are afforded some protection against thermal stress. For example, the deepest CREMP site, Black Coral Rock (24m depth), averages 21.6 ± 20.5 days annually with water temperatures >30°C. That is less than half the average number of days recorded at all other sites (Figure 6). The next lowest average was at Texas Rock (15m depth) which logs 43.7 ± 33.0 days annually. Temperature loggers at Black Coral Rock have never recorded a single day with the daily mean temperature >31°C. In contrast, the shallow acroporid reefs are under the most thermal stress on an annual basis (Figure 6), on average having about double the number of days of thermal stress compared to the other CREMP sites. Loggerhead Patch, Palmata Patch, Prolifera Patch, and White Shoal all endure 57.9-73.7 days annually with water temperatures >30°C. All four sites had more than 50 days above 30°C in 2021 and more than 70 days above 30°C in 2022. Similarly, all four sites had at least 15 days above 31°C in 2022.

Disease

Stony coral tissue loss disease (SCTLD) arrived in DRTO during this reporting period. National Park Service staff first recorded it on May 29th, 2021, along the southern boundary of the park, approximately two miles west of Long Key. Thereafter, it began to spread rapidly throughout the park and was observed a week later on the Tortugas Bank, on four reefs approximately three miles south of Loggerhead Key, and at three additional sites east of Long Key. Research cruises conducted by DRTO and external partners in July and August confirmed SCTLD had spread to Pulaski Shoal and had reached the Tortugas North Ecological Reserve. By September, when the annual Disturbance Response Monitoring cruise was completed in DRTO, observations from that cruise confirmed it was widespread throughout the Park.

SCTLD is highly lethal and affects more than half of the Atlantic coral species. It is likely to become the deadliest coral disturbance ever recorded in Florida and the Caribbean. In Florida alone, it is estimated that SCTLD has killed tens of millions of corals and some of the most vulnerable species are at risk of local extirpation. Many large boulder and brain coral species, which are the framework builders of the reef, are highly susceptible to SCTLD and their loss will reduce reef functionality and structural complexity. Coral disease outbreaks have previously been recorded by CREMP and NPS monitoring programs (Kidney 2003, Brandt 2009) and some diseases are always present at low background levels in DRTO (Table 5). This disease is unique because of the number of species it targets, the rapid progression of the lesions, high rates of lethality, and the extended duration of the outbreak as it transitions from attacking early susceptible species to more moderately vulnerable corals in the population. Corals in the Meandrinidae and Faviidae families are the most susceptible, with *Dichocoenia stokesii*, *Dendrogyra cylindrus,* and *Meandrina meandrites* the first coral species to develop lesions. Not only are these species highly prone to developing lesions, the severity of the infection on these species often results in the complete mortality of the colony within weeks. As vulnerable are the species *Colpophyllia natans, Diploria labyrinthiformis, Pseudodiploria strigosa,* and *P. clivosa.* Although these species may

become infected more slowly than those in the Meandrinidae and Faviidea families, the outcome is equally as fatal and rarely leaves any surviving tissue after infection.

Table 5. Coral disease prevalence (percentage of colonies with any disease condition present) pooled for all species for all monitoring sites.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
# of Colonies	1676	1923	1803	1744	1803	1933	2076	2107	2081	2032	2264	1844
Prevalence (%)	3.9	1.6	1.8	2.3	1.9	1.1	0.6	2.0	0.5	1.1	2.6	8.6

All of the species listed above develop lesions during what is referred to as the "epidemic" phase of SCTLD. That is when the rate of lesion formation is greatest among the coral population (exceeding 5% prevalence) and the most vulnerable species contract SCTLD at its highest frequency. As the most susceptible species succumb to SCTLD and the epidemic phase begins to wane, other species can become infected and are regarded as intermediately susceptible species. Intermediately susceptible species can start exhibiting symptoms of SCTLD one month to several months after highly susceptible species but tend to exhibit much slower disease progression over the colonies and a lower lethality rate because the tissue loss associated with the lesions can last several months or years and may not result in complete colony mortality. These species include *Montastraea cavernosa, Orbicella* spp., *Siderastrea siderea, Solenastrea bournoni,* and *Stephanocoenia intersepta*.

Stony coral tissue loss disease was recorded at DRTO sites during CREMP annual surveys in October 2021. As outlined above, this was during the beginning of the epidemic stage of the SCTLD outbreak in DRTO. In 2021, SCTLD was recorded at six CREMP sites: Bird Key Reef, Mayer's Peak, Palmata Patch, Temptation Rock, Texas Rock, and The Maze. These sites are well spaced throughout the park, reaffirming what the September 2021 DRM cruise had already reported: that SCTLD was well established in DRTO by October 2021 (Stein 2022). A total of 45 colonies at the six CREMP sites were infected with SCTLD. Most of the lesions were recorded on the highly susceptible species *Colpophyllia natans, Meandrina meandrites,* and *Pseudodiploria strigosa*. While overall SCTLD prevalence was low at this time, at only 2.0% (Table 6), some intermediately susceptible species like *Montastraea cavernosa* and *Orbicella* spp. had started developing lesions which indicated that SCTLD had been present at some CREMP sites for at least a month or more.

Table 6. Stony coral tissue loss disease prevalence (percentage of colonies with disease condition present) pooled for all species for all monitoring sites. SCTLD arrived in DRTO in May 2021.

Year	2020	2021	2022
# of Colonies	2032	2264	1844
Prevalence (%)	0.0	2.0	7.9

The impacts of SCTLD were clearly evident by the time of the 2022 survey. Stony coral tissue loss disease prevalence was still at epidemic levels and the number of corals with lesions recorded during was nearly four times higher than in 2021. A total of 146 colonies were observed in 2022 equaling 7.9% prevalence. Most of the corals displaying active lesions were intermediately susceptible species, in particular at the northernmost sites, Davis Rock and Black Coral Rock; two sites where the disease was not present in 2021. With the exception of a few remaining *C. natans* colonies, most active lesions were on *M. cavernosa* and *Orbicella* spp. in 2022 because nearly all the highly susceptible species had already succumbed to the disease (Table 7); combined, *M. cavernosa* and *Orbicella* spp. accounted for 52% of all SCTLD observations. In comparison, *Montastraea cavernosa* and *Orbicella* spp. only accounted for 27% of all SCTLD observations in 2021.

Table 7. Stony coral tissue loss disease prevalence (percentage of colonies with disease condition present) on ten susceptible species in 2021 and 2022. N represents the total number of colonies of each species found for each year. NA indicates a species was not found in a given year.

Species	2020	2021	2022
Colpophyllia natans	(N=29)	11.1 (N=27)	40.0 (N=5)
Dendrogyra cylindrus	NA	NA	NA
Dichocoenia stokesii	(N=5)	0.0 (N=5)	0.0 (N=2)
Diploria labyrinthiformis	(N=2)	0.0 (N=5)	0.0 (N=1)
Eusmilia fastigiata	(N=13)	0.0 (N=11)	NA
Meandrina meandrites	(N=13)	40.0 (N=10)	0.0 (N=1)
Pseudodiploria strigosa	(N=28)	6.5 (N=31)	0.0 (N=5)
Pseudodiploria clivosa	(N=2)	0.0 (N=2)	NA
Montastraea cavernosa	(N=210)	4.2 (N=213)	36.7 (N=120)
Orbicella spp.	(N=177)	1.6 (N=183)	42.2 (N=147)

The changes in abundance for the most susceptible species mirror results that had been previously reported from Southeast Florida and the Florida Keys (Precht et al. 2016, Walton et al. 2018, Toth et al. 2019, Toth et al. 2023). Colony losses often exceeded 50% for the highly vulnerable species. Two species, *Eusmilia fastigiata* and *Pseudodiploria clivosa*, were completely absent at DRTO CREMP sites in 2022 (Table 7), and from 2021 to 2022 the number of *M. meandrites* colonies was reduced from 10 to 1, the number of *P. strigosa* colonies reduced from 31 to 5, and the number of *C. natans* colonies reduced from 27 to 5. The negative changes in abundance for the intermediately susceptible species *M. cavernosa* was also more pronounced in DRTO than in Southeast Florida and the Florida Keys. Analyses from CREMP monitoring in Southeast Florida and the Florida Keys indicated that this species may have up to a 65% survival rate after exposure to SCTLD, but the preliminary results here indicate that survival may be lower and only approach ~50% in the Dry Tortugas (Table 7).

During this biennial reporting period, SCTLD was documented at all CREMP sites except two, Prolifera Patch and Loggerhead Patch. Neither site contains many SCTLD-susceptible species within the survey area, although there are several large *Orbicella* spp. colonies located on the south side of Prolifera Patch stations that had not yet been infected. It will require at least another year of data collection for a more comprehensive understanding of the impacts of SCTLD on the DRTO coral population at CREMP sites. Although it may be presumptuous to assign all changes in abundance between 2021 and 2022 to SCTLD related mortalities, total coral abundance declined by 471 colonies, many of which were individuals of highly vulnerable and intermediately susceptible species. At the time of preparing this report this represented a nearly 20% change in the CREMP DRTO coral population. Besides the species listed in Table 7, other species documented with SCTLD in 2022 included *Stephanocoenia intersepta, Madracis decactis, M. senaria, Porites astreoides,* and *Undaria agaricites* complex.

The prevalence of and mortality caused by SCTLD in 2021 and 2022 strongly overshadowed any mortality caused by other coral diseases. If the occurrence of SCTLD is removed from the prevalence assessments, the prevalence of all other diseases was only 0.6% and 0.7% in 2021 and 2022, respectively. Apart from 2011, combined for all other non-SCTLD conditions, disease prevalence has always been well under 3% every year (Table 5). This is consistent with or even lower than normal ranges of disease prevalence documented elsewhere along Florida's Coral Reef by CREMP or other research efforts (Santavy et al. 2005, Weil and Cróquer 2009, Muller and van Woesik 2012). The primary diseases included here were black band, white band, white pox, white plague, and dark spot syndrome. Other diseases that are less common but observed included yellow band, red band, rapid tissue loss, and ciliate conditions.

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Octocorals

Percent Cover

Short-term, between the 2019-2020 and 2021-2022 reporting periods, significant increases in octocoral cover were detected at Mayer's Peak, Texas Rock, and The Maze, and a significant decrease was observed at Bird Key Reef (Table 8). While short-term increases at Mayer's Peak, Texas Rock, and The Maze reflect the general increase in octocoral cover observed at most sites short-term and long-term, the significant decrease at Bird Key Reef is a contrasting result which may be associated with the passage of several tropical systems, particularly Tropical Storm Fred and Hurricane Elsa, in the weeks prior to surveys that may have affected Bird Key Reef disproportionately.

Long-term, of the three sites surveyed since 1999 (Bird Key Reef, Black Coral Rock, and White Shoal) only White Shoal had a significant increase in octocoral cover, which matches previous findings. All three sites were consistent in indicating a pattern of decline during the earlier years of monitoring with each site reaching its lowest recorded values between 2004-2008 (Figure 7a). Following this low point, octocoral cover increased in most years at each site and has had a generally positive trajectory. The gradual increase over the last 10 to 15 years at Black Coral Rock and at Bird Key Reef (Figure 7a) has returned octocoral cover to levels observed during the first four years of monitoring at these sites (1999-2002). In contrast, compared to Bird Key and Black Coral Rock, octocoral cover at White Shoal has increased at a faster rate, and despite several years in the last decade with considerable decreases that appear to be associated with major ecological events (e.g., 2014-2015 El Niño or Hurricane Irma; Figure 7a), octocoral cover at White Shoal was 1.7 times higher during the most recent four years of monitoring compared to the initial four years (Table 8).

Surveys at the other nine sites began during the time period when the lowest octocoral cover values were recorded for the three original sites discussed above. Long-term significant increases in octocoral cover were found at five of the nine sites: Davis Rock, Loggerhead Patch, Mayer's Peak, Palmata Patch, and The Maze. Of these, only Mayer's Peak did not have a significant long-term increase in the previous report. Mayer's Peak has the highest octocoral cover of all DRTO CREMP sites. Octocoral cover at Mayer's Peak has increased in most years and a significant increase over both short- and long-term analyses are found in this report (Figure 7, Table 8). Although octocoral cover values are lower than at Mayer's Peak, The Maze is a nearby pinnacle reef and, similar to Mayer's Peak, octocoral cover has increased in most years with significant short- and long-term increases found herein. At Davis Rock, the other pinnacle reef with a significant long-term increase in octocoral cover, octocoral cover values are much lower and changes are more moderate, but it is notable that they are mostly the result of increases in encrusting octocoral species rather than branching ones. The greatest relative increase in octocoral cover has occurred at Palmata Patch with recent values from 2019-2022 more than 5 times greater than cover values during the first four years of monitoring. Loggerhead Patch has the lowest octocoral cover of the DRTO CREMP sites and long-term increases at this site, while significant, were <1.0%. One site, Little Africa,

had a long-term increase in octocoral cover during the previous reporting period but that result was not found in the current analysis.

Table 8. Mean octocoral cover (% ± SE) for 12 sites. Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. The first four-year period varies and is contingent upon commencement of monitoring at that site: Bird Key Reef, Black Coral Rock, and White Shoal = 1999-2002; Loggerhead Patch, Palmata Patch, Prolifera Patch, Mayer's Peak, Temptation Rock = 2004-2007; Davis Rock, Texas Rock, The Maze = 2009-2012; Little Africa = 2007-2010. Little Africa is surveyed differently than the other 11 sites (see Methods). Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively. Model estimates and P-values can be found in Appendix G.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	19.0 ± 1.6	17.7 ± 1.7	19.5 ± 2.2	15.9 ± 1.3
Black Coral Rock	10.3 ± 1.2	10.0 ± 1.1	9.3 ± 0.7	10.7 ± 1.4
Davis Rock	0.7 ± 0.2	3.0 ± 0.7	2.8 ± 0.8	3.1 ± 0.6
Loggerhead Patch	1.0 ± 0.4	1.8 ± 1.1	2.1 ± 1.4	1.6 ± 0.9
Mayer's Peak	22.4 ± 1.5	28.0 ± 1.8	25.2 ± 2.0	30.7 ± 1.6
Palmata Patch	2.5 ± 0.9	12.7 ± 4.9	13.1 ± 5.8	12.4 ± 4.0
Prolifera Patch	5.3 ± 1.1	6.2 ± 2.0	6.2 ± 1.7	6.2 ± 2.4
Temptation Rock	15.2 ± 4.3	16.5 ± 1.8	15.5 ± 1.5	17.5 ± 2.2
Texas Rock	4.1 ± 1.2	4.4 ± 0.8	3.4 ± 0.6	5.4 ± 1.0
The Maze	7.1 ± 1.4	12.2 ± 1.5	10.7 ± 1.8	13.6 ± 1.3
White Shoal	9.1 ± 3.3	15.8 ± 2.8	14.5 ± 2.4	17.1 ± 3.2
Little Africa	5.4 ± 1.6	7.8 ± 2.1	8.3 ± 1.9	7.3 ± 2.3

Increases in octocoral cover following losses of stony corals have been reported from elsewhere along Florida's Coral Reef (Ruzicka et al. 2013). Two of the six sites that increased in octocoral cover over their associated long-term intervals, Loggerhead Patch and White Shoal, also had a significant decrease in coral cover (Table 2). However, Palmata Patch and Mayer's Peak had concomitant increases in both coral and octocoral cover over the long-term (Tables 2 and 8), so it appears that a loss of stony corals does not always precipitate an increase in octocoral cover. In terms of reef structure and composition, Mayer's Peak and Palmata Patch are extremely different from each other. The octocoral increase at Mayer's Peak is likely the expansion and ongoing maturation of a large, existing octocoral canopy that has been present at this site since the inception of monitoring and has not impeded the growth and expansion of stony corals. At Palmata Patch, the recovery and expansion of *A. palmata* has not occurred evenly between the two survey stations (See ESA Listed Species Section below). At the survey station where coral cover has remained

low, particularly of *A. palmata*, new octocorals have colonized open areas of substrate and octocoral cover is now more than double that of the other survey station where *A. palmata* cover has considerably increased since the first four years of surveys (Appendix A).

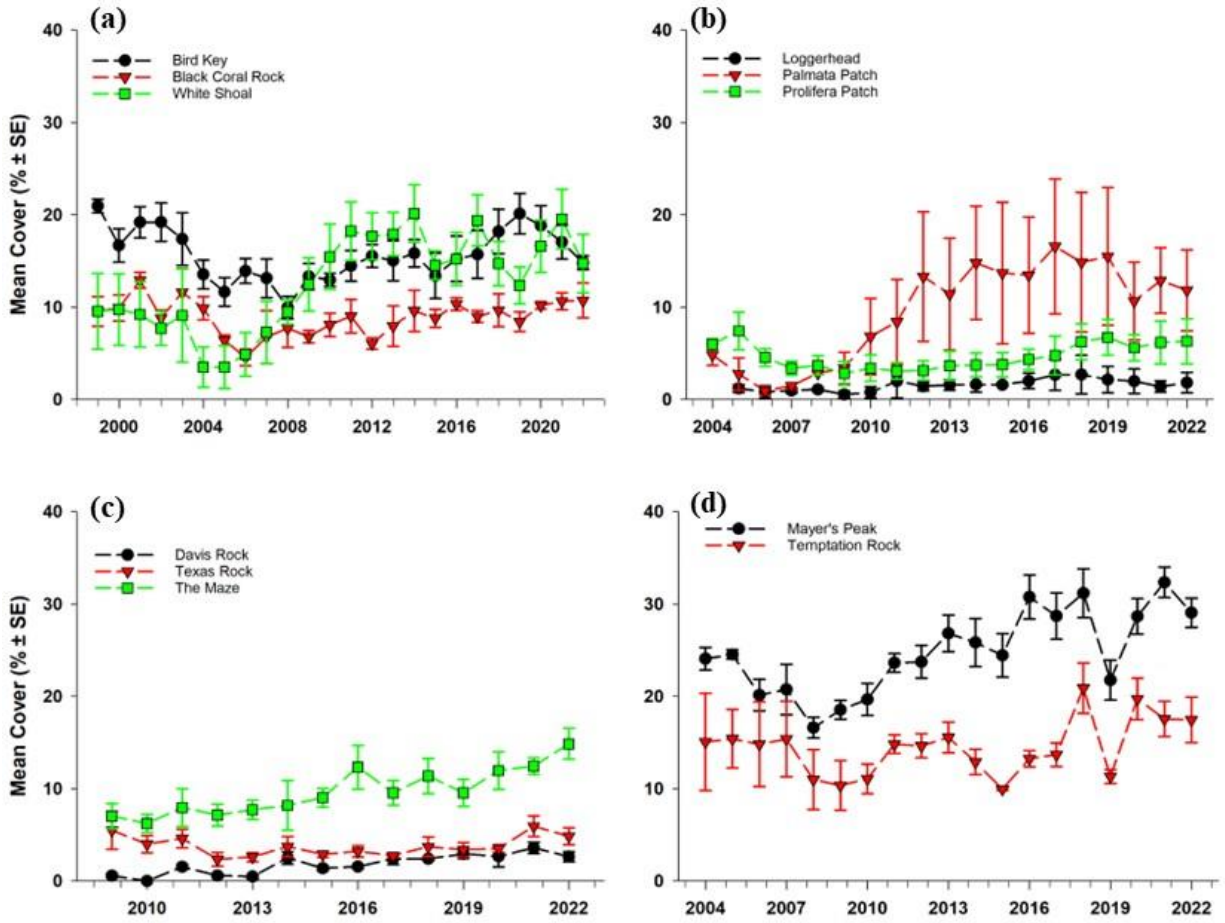

Figure 7. Mean octocoral cover (% ± SE) by site. A) The three original sentinel sites, started in 1999. B) Three sites added to monitor various ESA species, started in 2004. C) Pinnacle reefs inside the RNA with mooring buoys, started in 2009. D) Pinnacle reefs inside the RNA without mooring buoys, started in 2004.

Demographics

Octocoral density (no. of colonies/m^2 ± SE) has been measured as part of the octocoral demographic survey since 2011. Octocoral demographic surveys have been conducted over a twelve-year period when octocoral cover has generally been increasing at many DRTO sites, and the long-term results for density mostly mirror those reported for percent cover (Tables 8 and 9). Short-term, no sites exhibited a significant difference in density. Long-term, a significant increase in density was observed at seven of 11 sites: Bird Key Reef, Loggerhead Patch, Mayer's Peak, Palmata Patch, Prolifera Patch, The Maze, and White Shoal (Table 9). Black Coral Rock was the only site that significantly decreased in density over the long-term, though the magnitude of decrease was relatively small compared to the increases at the aforementioned sites.

The largest long-term increases (2011-2014 compared to 2019-2022) in octocoral density occurred at Bird Key Reef and Mayer's Peak. At Bird Key Reef, octocoral density increased by >9 colonies/m^2, from 13.3 ± 2.5 (SE) to 22.4 ± 5.3 colonies/m^2 between long-term time intervals (Table 9). This increase can be largely attributed to increases in *Antillogorgia bipinnata* (Appendix E). At Mayer's Peak, octocoral density increased by ~6 colonies/m^2, rising from 20.7 ± 2.5 to 26.6 ± 2.0 colonies/m^2 between the long-term time intervals. The octocoral communities at Mayer's Peak are diverse and the increase in octocoral density can be attributed to an array of species increasing in abundance. White Shoal octocoral density increased from 9.2 ± 0.9 to 14.1 ± 1.9 colonies/m^2, an increase of almost 5 colonies/m^2. Although significant changes in octocoral density occurred at five other locations, the increases were smaller in scale compared to Bird Key Reef, Mayer's Peak, and White Shoal, and do not necessarily correspond with changes in abundance of one or more of the five target species. At Black Coral Rock the primary species has been *Antillogorgia bipinnata* throughout the decade of monitoring and decreases at this site were primarily due to decreases of this species and to a lesser extent *Antillogorgia americana* (Appendix E).

Table 9. Mean density (no. colonies/m2 ± SE) of octocorals for 11 sites. Long-term comparisons averaged for the first and last four years of demographic data collection, and short-term comparison averaged for the two-year period for the current and previous biennial report. Demographic surveys are not performed at Little Africa. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in density, respectively. Model estimates and p-values can be found in Appendix H.

	Long-term	Long-term	Short-term	Short-term
Site	**2011-2014**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	13.3 ± 2.5	22.4 ± 5.3	23.9 ± 5.7	20.9 ± 4.9
Black Coral Rock	9.7 ± 1.2	8.0 ± 1.3	7.8 ± 1.0	8.2 ± 1.5
Davis Rock	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
Loggerhead Patch	0.7 ± 0.1	2.3 ± 0.5	2.5 ± 0.1	2.2 ± 0.9
Mayer's Peak	20.7 ± 2.5	26.6 ± 2.0	27.3 ± 2.2	25.8 ± 1.9
Palmata Patch	3.3 ± 2.3	4.1 ± 2.3	4.4 ± 2.6	3.7 ± 1.9
Prolifera Patch	2.0 ± 0.6	2.7 ± 0.8	2.4 ± 0.7	3.0 ± 0.8
Temptation Rock	4.2 ± 0.7	4.1 ± 0.8	4.4 ± 1.0	3.8 ± 0.7
Texas Rock	0.6 ± 0.3	0.7 ± 0.2	0.8 ± 0.1	0.7 ± 0.2
The Maze	5.3 ± 1.2	6.8 ± 1.5	7.1 ± 1.6	6.4 ± 1.5
White Shoal	9.2 ± 0.9	14.1 ± 1.9	14.6 ± 1.8	13.5 ± 1.9

Changes in octocoral densities do not always necessarily correlate with changes in octocoral cover. Even large increases in density due to pulses in recruitment will not equate to an immediate change in percent cover because it will take several years or more for branching octocorals to attain a size that would be large enough to raise the percent cover estimates. At five sites, Mayer's Peak, Loggerhead Patch, Palmata Patch, The Maze, and White Shoal, it does appear the increase in density during the last 12 years does correspond with a significant increase in long-term cover at these sites (Tables 8 and 9). Even though the testing periods for long-term comparisons in octocoral density and percent cover are asynchronous, results from both surveys reflect that octocoral recruitment, growth, and survival are translating into establishment of mature communities that are likely increasing in canopy size. Additionally, it is also worth highlighting that octocoral cover did significantly increase at Davis Rock while octocoral density remained unchanged at or near zero colonies/m^2 (Tables 8 and 9). At Davis Rock, upright, branching species of octocorals are only observed around the periphery of the pinnacle and the significant increase in cover was entirely due to the expansion of the two encrusting species, *Briareum asbestinum* and/or *Erythropodium caribaeorum*, that are not counted in demographic surveys. These species are not identified separately during the image analysis, but both form thick encrusting mats that can overgrow the substrate and other benthic taxa.

Macroalgae

Short-term, between the 2019-2020 and 2021-2022 reporting periods, five of the 12 sites had a significant decrease in macroalgae cover, Black Coral Rock, Mayer's Peak, Prolifera Patch, Temptation Rock, and The Maze, while two sites, Bird Key Reef and Loggerhead Patch, had significant increases. This result contrasts with results from the previous report in which three sites had significant increases and only one had a significant decrease in macroalgae cover short-term, from 2017-2018 to 2019-2020. Mayer's Peak and The Maze, which both exhibited a significant short-term increase in macroalgae cover in the previous report had short-term decreases in this report (Figure 8; Table 10), whereas Bird Key Reef exhibited a significant short-term decrease in macroalgae cover in the previous report but significantly increased over the short-term in this report. This reflects the potential ephemeral nature of macroalgae cover. Long-term, all but three of the 12 sites had a significant increase in cover - Davis Rock, Texas Rock, and The Maze. This result matches the long-term changes found in the previous report. Although no significant increase was found over the long-term for these three sites, these are the most recent sites to have been added to the CREMP survey and monitoring did not commence until 2009, following a notable increase in macroalgae cover that occurred at nearly all sites in 2008 (Figure 8). Macroalgae cover was above 30% during the initial four years of monitoring at Davis Rock, Texas Rock, and The Maze, whereas the initial macroalgae cover at all other sites was less than 15% (Table 10).

The short-term increase in macroalgae cover at Bird Key Reef and Loggerhead Patch were sizable; at Bird Key Reef macroalgae cover increased by nearly 15% and at Loggerhead Patch it increased by nearly 17%, more than doubling the 2019-2020 value. Bird Key Reef and Loggerhead Patch already had elevated macroalgae cover in the 2019-2020 time period, and the 2021-2022 values put them on par with sites that have the highest macroalgae cover in DRTO. In contrast, macroalgae cover declined by more than 10% at four of the five sites to have a significant decrease from 2019-2020 to 2021-2022, and two sites, Mayer's Peak and Prolifera Patch, had macroalgae cover of <10% for the 2021-2022 reporting period (Table 10).

Since 2009 the contribution of macroalgae to the benthic assemblage in DRTO has been greater than any other taxa group. Long-term, all nine sites surveyed prior to 2009 had significantly higher macroalgae cover values in the most recent four-year interval (2019-2022) compared to their initial four years of surveys. Over the 2019-2022 interval the cover of macroalgae exceeded 20% at nine sites with Mayer's Peak, Palmata Patch, and Prolifera Patch being the exceptions.

Prior to 2010, the CREMP image analysis lumped all macroalgae and cyanobacteria into a single major taxa group identified as 'macroalgae' primarily because these different groups were difficult to distinguish in older CREMP imagery. Starting in 2010, to refine the CREMP analysis three macroalgae genera were individually recognized (*Dictyota* spp., *Lobophora* spp., and *Halimeda* spp.) and cyanobacteria was given its own taxa grouping separate of macroalgae. Genera like *Dictyota* and *Lobophora* are fleshy alga and are viewed unfavorably because they proliferate quickly after disturbances, out-compete other benthic organisms for reef space or even inflict direct mortality (Kuffner et al. 2006, Paul et al. 2011), whereas calcareous algae like *Halimeda* spp. are

considered as a positive contributor to reef integrity (Vroom et al. 2003). Cyanobacterial mats have been increasing on many Caribbean reefs and can foster negative feedback loops that lead to coral decline and contribute to long-term shifts from coral-dominated reefs to algae-dominated ones (Ford et al. 2018).

Table 10. Mean macroalgae cover (% ± SE) for 12 sites. Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. The first four-year period varies and is contingent upon commencement of monitoring at that site: Bird Key Reef, Black Coral Rock, and White Shoal = 1999-2002; Loggerhead Patch, Palmata Patch, Prolifera Patch, Mayer's Peak, Temptation Rock = 2004-2007; Davis Rock, Texas Rock, The Maze = 2009-2012; Little Africa = 2007-2010. Little Africa is surveyed differently than the other 11 sites (see Methods). Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively. Model estimates and p-values can be found in Appendix G.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	14.2 ± 4.4	37.2 ± 3.3	30.2 ± 2.3	44.2 ± 4.2
Black Coral Rock	9.2 ± 2.8	38.8 ± 3.9	44.7 ± 4.1	32.9 ± 3.7
Davis Rock	44.9 ± 3.6	47.0 ± 3.1	49.5 ± 2.1	44.5 ± 4.1
Loggerhead Patch	4.2 ± 0.7	26.5 ± 5.0	17.6 ± 4.8	35.4 ± 5.1
Mayer's Peak	2.9 ± 0.9	19.2 ± 2.1	28.7 ± 2.3	9.7 ± 1.9
Palmata Patch	2.3 ± 1.1	18.2 ± 4.1	20.0 ± 6.4	16.3 ± 1.7
Prolifera Patch	3.0 ± 1.5	10.7 ± 4.2	12.9 ± 5.4	8.5 ± 3.0
Temptation Rock	8.4 ± 2.2	31.4 ± 4.1	37.5 ± 4.5	25.4 ± 3.8
Texas Rock	32.5 ± 3.5	39.6 ± 4.9	39.5 ± 4.7	39.6 ± 5.1
The Maze	34.9 ± 6.5	33.7 ± 3.8	39.3 ± 2.9	28.0 ± 4.7
White Shoal	8.2 ± 4.0	27.5 ± 5.5	27.6 ± 6.0	27.4 ± 4.9
Little Africa	11.1 ± 1.4	24.5 ± 2.1	26.5 ± 2.5	22.4 ± 1.7

In 2021 and 2022 the mean absolute cover of *Dictyota* spp. for all sites excluding Little Africa) was 17.1 ± 2.8% and 15.2 ± 2.8%, respectively (Appendix C), a decline from the previous reporting period. This represented 59.4% and 54.5% of the total macroalgae assemblage in each of those years. As reported previously, *Dictyota* continues to be a major constituent of the total macroalgae cover and is often the dominant genera (Appendix C). Considering that total macroalgae cover was generally <10% during the first decade of monitoring (1999-2008), the increase in *Dictyota* was clearly substantial because *Dictyota* cover alone in 2021 and 2022 was greater than the total macroalgae cover of the earlier years.

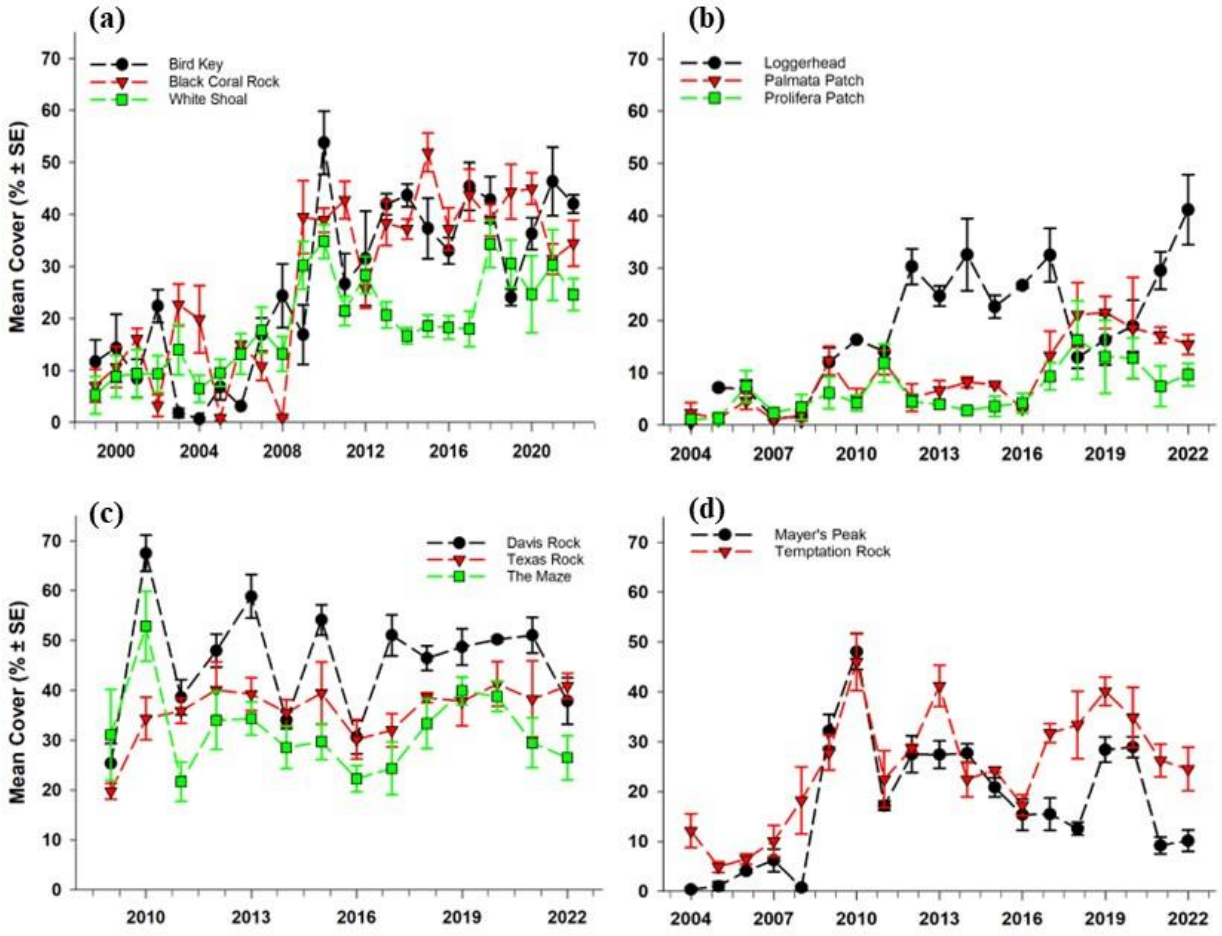

Figure 8. Mean macroalgae cover (% ± SE) by site. A) The three original sentinel sites, started in 1999. B) Three sites that monitor acroporid ESA species, started in 2004. C) Pinnacle reefs inside the RNA with mooring buoys, started in 2009. D) Pinnacle reefs inside the RNA without mooring buoys, started in 2004.

Lobophora has also been an important contributor to the macroalgae assemblage. Although not as widespread as *Dictyota* on shallow reefs, *Lobophora* can cover large portions of deeper reefs. *Lobophora* cover at Bird Key Reef and Black Coral Rock in many years has exceeded the cover of *Dictyota* (Appendix C). While *Dictyota* can form large blooms near the substrate, it is often loosely attached and can be cleared by the wave-energy associated with powerful storms. In contrast, *Lobophora* is well-attached to the substrate being nearly encrusting in nature and can have much longer residence on reef habitats.

Cyanobacteria serve as important nitrogen fixers on coral reefs but usually compose <1% of the benthos; however, higher coverage can lead to detrimental impacts on reefs and can be an indicator of sub-optimal water quality (Charpy et al. 2012). Multiple factors may be supporting the increase in cyanobacteria including ocean acidification, rising seawater temperatures, higher sewage and nutrient input, and phosphorus enrichment (Ford et al. 2018). In general, Bird Key Reef, Black Coral Rock, Davis Rock, Temptation Rock, Mayer's Peak, Texas Rock, The Maze, White Shoal, and Little Africa have had higher cyanobacteria cover the last four years than in years previous

(Appendix A). Bird Key Reef and Black Coral have consistently higher cyanobacteria cover compared to other DRTO CREMP sites. At Black Coral Rock and Davis Rock cyanobacteria cover was higher during this reporting period than in any other years. Cyanobacteria cover at Black Coral Rock averaged 21.0% in 2021-2022, which was up from the 2019-2020 average of 12.1% (Appendix A).

The proliferation and persistence of fleshy macroalgae, like *Dictyota* and *Lobophora*, and cyanobacteria is concerning. Furthermore, it is likely that values for both macroalgae genera and for cyanobacteria reported here are underestimated because they are often mixed with accumulations of various macroalgae and are counted as 'other macroalgae' in the CREMP image analysis when they cannot be readily distinguished.

Sponges

Short-term, between the 2019-2020 and 2021-2022 reporting periods, two sites had a significant decrease in sponge cover (Davis Rock and White Shoal), and the other ten sites had no significant changes in sponge cover (Figure 9; Table 11). Long-term, eight of the 12 sites had a significant increase in cover and none of the sites had a significant decline (Table 11). At sites with increases in sponge cover, some nearly doubled between the reporting periods of the long-term analysis; however, the cover values are much smaller for sponges compared to those of corals, octocorals, and macroalgae. Averaged for 2021-2022, sponge cover ranged from a high of 6.0 ± 0.8% at Texas Rock to a low of 0.5 ± 0.1% at Little Africa. Sponge cover was much higher on the pinnacle reefs than on the shallow acroporid reefs, and even though three of the four acroporid reefs significantly increased in cover in the long-term analysis, total sponge cover at those sites were still less than ≤1%. Despite the recent decrease in cover at two sites and generally lower cover than other taxa groups, a slow but persistent increase in sponge cover seems to be occurring in DRTO. This result matches what is found in other areas of Florida's Coral Reef and the greater Caribbean Sea (Pawlik and McMurray 2020, Coral Research Program 2023).

Table 11. Mean sponge cover (% ± SE) for 12 sites. Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. The first four-year period varies and is contingent upon commencement of monitoring at that site: Bird Key Reef, Black Coral Rock, and White Shoal = 1999-2002; Loggerhead Patch, Palmata Patch, Prolifera Patch, Mayer's Peak, Temptation Rock = 2004-2007; Davis Rock, Texas Rock, The Maze = 2009-2012; Little Africa = 2007-2010. Little Africa is surveyed differently than the other 11 sites (see Methods). Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively. Model estimates and p-values can be found in Appendix G.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	1.1 ± 0.6	1.1 ± 0.3	1.1 ± 0.2	1.2 ± 0.3
Black Coral Rock	4.1 ± 1.1	4.3 ± 0.4	4.4 ± 0.4	4.1 ± 0.3
Davis Rock	2.3 ± 0.4	3.4 ± 0.5	4.1 ± 0.7	2.7 ± 0.4
Loggerhead Patch	0.3 ± 0.1	0.9 ± 0.2	0.7 ± 0.2	1.0 ± 0.2
Mayer's Peak	2.6 ± 0.4	4.4 ± 0.9	4.6 ± 1.0	4.2 ± 0.8
Palmata Patch	0.2 ± 0.1	0.7 ± 0.2	0.8 ± 0.2	0.6 ± 0.1
Prolifera Patch	0.2 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.6 ± 0.1
Temptation Rock	1.2 ± 0.3	2.6 ± 0.3	2.6 ± 0.2	2.6 ± 0.4
Texas Rock	4.7 ± 0.8	6.5 ± 0.7	7.0 ± 0.6	6.0 ± 0.8
The Maze	3.9 ± 0.7	4.7 ± 0.7	4.7 ± 1.0	4.8 ± 0.5
White Shoal	2.8 ± 0.8	2.7 ± 0.9	3.4 ± 1.1	2.0 ± 0.7
Little Africa	0.3 ± 0.1	0.5 ± 0.1	0.6 ± 0.2	0.5 ± 0.1

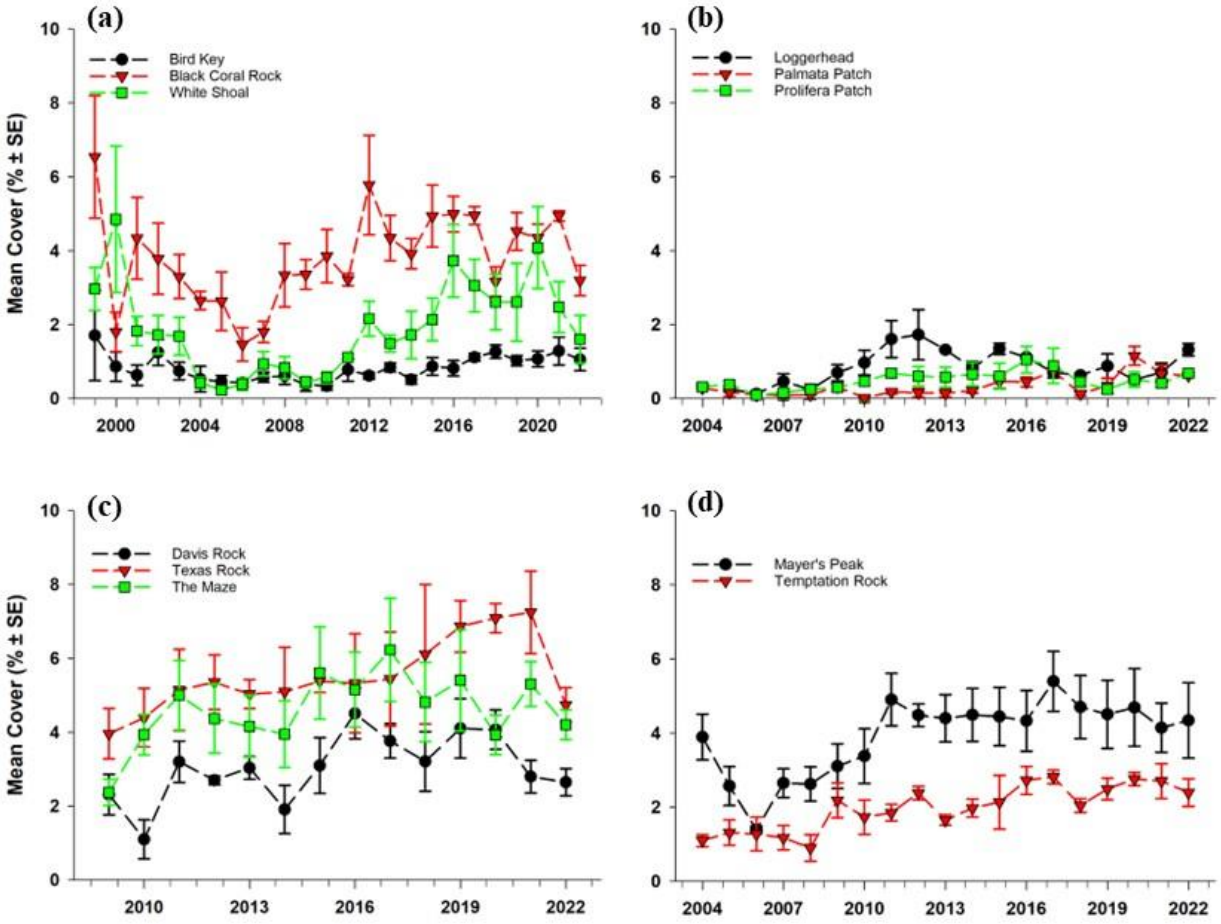

Figure 9. Mean sponge cover (% ± SE) by site. A) The three original sentinel sites, started in 1999. B) Three sites that monitor acroporid ESA species, started in 2004. C) Pinnacle reefs inside the RNA with mooring buoys, started in 2009. D) Pinnacle reefs inside the RNA without mooring buoys, started in 2004.

Endangered Species Act Listed Species

Acropora palmata

Palmata Patch is the only CREMP site where *Acropora palmata* is found in DRTO. Because the distribution of *A. palmata* colonies is relatively confined at this location CREMP only established two monitoring stations to survey their condition. Short-term there was a significant increase in mean *A. palmata* cover between 2019-2020 and 2021-2022, from 7.0± 6.6% (SE) to 9.5± 8.4%. (Figure 10a, Table 12). Long-term, even though *A. palmata* cover increased from 3.2 ± 1.6% to 8.2 ± 7.5%, the change in cover was not significant due to unequal populations between the two survey stations (see below).

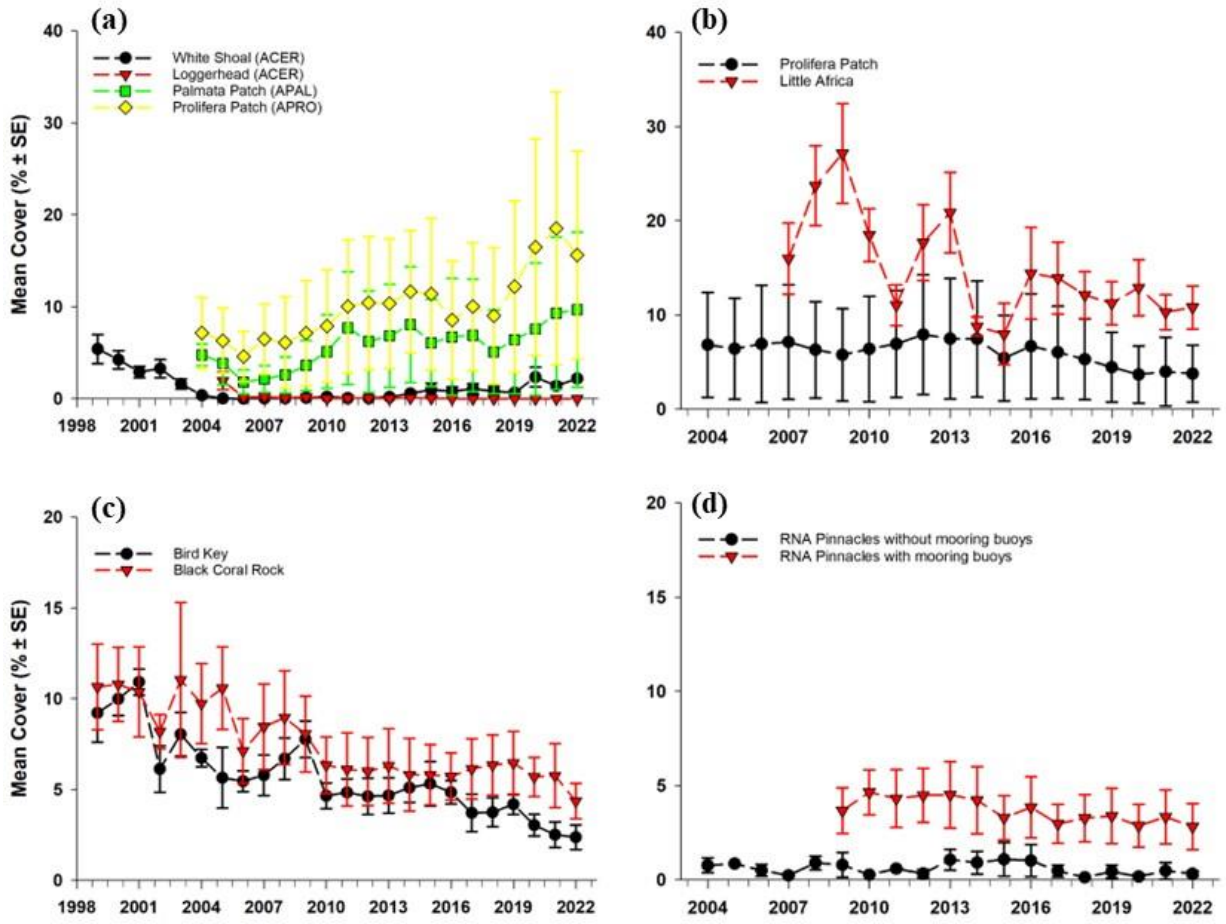

Figure 10. Mean coral cover (% ± SE) for four ESA corals. A) *Acropora cervicornis* (ACER) at White Shoal and Loggerhead Patch, *A. palmata* (APAL) at Palmata Patch, and *A. prolifera* (APRO) at Prolifera Patch. B) *Orbicella spp.* cover at Prolifera Patch and Little Africa. C) *Orbicella spp.* cover at Bird Key and Black Coral Rock. D) *Orbicella spp.* cover at RNA sites with or without mooring buoys. Note: Y-axis scale differs between top and bottom graphs.

The initial four-year monitoring timeframe included the 2004 and 2005 hurricane seasons which fragmented and scattered or destroyed many of the *A. palmata* colonies present at Palmata Patch

(see previous reports; Figure 10a). During this time, the loss of *A. palmata* cover did not occur evenly across the two surveys stations. Between 2004 and 2006, *A. palmata* cover decreased from 3.6% to 0.5% at Station 1 and from 6.0% to 3.1% at Station 2. All colonies were lost at Station 1 except one, which has severely limited the recovery of percent cover values within this station; as of 2022 *A. palmata* cover was only 0.4%. In contrast, at Station 2, *A. palmata* cover was 14.8% in 2022, the highest value recorded for this survey station during the period of monitoring. Given the considerable increase in *A. palmata* percent cover over the long-term a significant result may be expected; however, the widely different *A. palmata* values results in high variance and makes the detection of statistical differences difficult. Furthermore, while mean *A. palmata* cover at Station 2 increased by more than 10% from the initial four years (2004-2007) to the most recent (2019-2022), mean *A palmata* cover actually decreased at Station 1 during this time period. This contrasts with the short-term analysis, where despite the large difference in values between the two survey stations *A. palmata* did increase in cover at both stations.

Table 12. Mean coral cover (% ± SE) for the three Acroporid corals, *A. cervicornis*, *Acropora palmata*, and *A. prolifera*¸ at their respective sites. Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. The first four-year period varies and is contingent upon commencement of monitoring at that site: Loggerhead Patch = 2005-2008; Palmata Patch and Prolifera Patch = 2004-2007; White Shoal = 1999-2002; The last four years represents 2019-2022. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively. Model estimates and P-values can be found in Appendix G. *no analysis, all values are zero.

	Long-term	**Long-term**	**Short-term**	**Short-term**
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
***Acropora palmata* (Palmata Patch)**	3.2 ± 1.6	8.2 ± 7.5	7.0 ± 6.6	9.5 ± 8.4
***Acropora prolifera* (Prolifera Patch)**	6.1 ± 3.5	15.7 ± 11.8	14.3 ± 10.6	17.1 ± 13.1
***Acropora cervicornis* (White Shoal)**	4.0 ± 1.0	1.6 ± 0.5	1.5 ± 0.7	1.8 ± 0.3
***Acropora cervicornis* (Loggerhead Patch)**	0.6 ± 0.3	0.0 ± 0.0	0.0 ± 0.0*	0.0 ± 0.0*

While there has been some annual variability in the density of *A. palmata* colonies at Station 2, Station 1, as mentioned above, has been composed of a single colony (equivalent to a density of 0.1 colonies/m^2) throughout the 12 years of demographic surveys. Density at Station 2 has fluctuated, ranging from 1.7 colonies/m^2 in 2015 to 3.2 colonies/m^2 in 2022 (Table 13). The combination of density and substrate coverage suggests that the maintenance and growth of *A. palmata* at Palmata Patch is largely due to the regeneration and fragmentation of existing colonies. While CREMP performs an annual census, additional monitoring efforts carried out by FWC at this site fate-track *A. palmata* individuals multiple times per year. Their results corroborate that

increases in cover are due to tissue regeneration on existing colonies because the density within their plots have remained similar or even slightly decreased over the last four years (Boisvert and Ruzicka 2022). While it is encouraging that cover and density of *A. palmata* is stable or expanding, without sexual recruitment the long-term prospects of further population expansion by *A. palmata* will be limited to fragmentation and tissue growth of the extant population.

Table 13. Density (no. of colonies/m^2) of *A. palmata* at the two CREMP stations monitored at Palmata Patch.

Station	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.1
2	1.9	2.0	2.5	2.4	1.7	2.3	2.6	2.0	2.2	2.8	1.5	3.2

Since 2004, octocorals have proliferated at Palmata Patch. Although they don't span the same time periods, octocoral cover and density have both significantly increased long-term (Table 8 and 9); particularly at the station with only a single *A. palmata* colony. Mean octocoral cover increased fivefold to 12.7% ± 4.9% (SE) between the long-term time intervals of 2004-2007 and 2019-2022. Mean octocoral density increased from 3.3 ± 2.3 to 4.1 ± 2.3 (SE) colonies/m^2 between the long-term time intervals of 2011-2014 and 2019-2022. The transition to octocorals becoming the most abundant taxa or being the largest contributor to benthic cover on shallow reefs where acroporid corals were once dominant has also occurred in the Florida Keys (Ruzicka et al. 2013) and elsewhere in the Caribbean (Tsounis and Edmunds 2017). Even without significant increases in octocoral abundance the rapid growth of existing octocoral communities can create an expansive canopy that may prevent the settlement of *A. palmata* larvae and affords octocorals an advantage in spatial competition.

Hurricane Ian, a major Category 4 storm, made landfall in the Dry Tortugas in September 2022, after the 2022 CREMP surveys occurred. Hurricane Ian's impacts at Palmata Patch will be discussed in the 2023-2024 report.

Acropora cervicornis

Acropora cervicornis was present throughout much of DRTO. Previous reports have described the declines of *A. cervicornis* in DRTO since the start of CREMP monitoring (Ruzicka et al. 2018). It is estimated that >95% of the population throughout DRTO has disappeared over the last 50 years as this species has been decimated by disease, hurricanes, and cold-water anomalies (Davis 1982, Roberts et al. 1982, Jaap and Sargent 1993, Porter and Porter 2002). CREMP monitors two legacy sites, White Shoal (surveyed since 1999) and Loggerhead Patch (surveyed since 2005), to evaluate the changes at these sites where there were once large stands of this species.

Short-term, at White Shoal, there was no significant difference in mean *A. cervicornis* cover between the 2019-2020 and 2021-2022 intervals. Mean *A. cervicornis* cover was 1.5 ± 0.7% (SE) in 2019-2020 and 1.8 ± 0.3% in 2021-2022 (Figure 10a, Table 12). While there were no significant differences based on this analysis it is notable that *A. cervicornis* cover at White Shoal increased considerably from 2019 to 2020, with increases at all four survey stations and one station

increasing in cover from 1.1% to 5.2%. Long-term, the four-year average calculated from 2019-2022, 1.6 ± 0.5%, is significantly less than the mean for 1999-2002, 4.0 ± 1.0%. At Loggerhead Patch, there has been no re-establishment of colonies after the decline at this site. *A. cervicornis* was recorded at its highest cover in 2005, the first year of surveys, when it represented 1.9% of the benthic cover. Loggerhead Patch was decimated during the 2005 hurricane season, and *A. cervicornis* cover rapidly declined thereafter and has not been present since 2015 (Appendix B). Because *A. cervicornis* cover at Loggerhead Patch plummeted to nearly near zero in 2006 and 2007, those two years lower the first four-year mean so substantially that no long-term difference was detected (Table 12).

The reduction of *A. cervicornis* at White Shoal and near absence of it at Loggerhead Patch has allowed other benthic taxa to become the prominent benthic features. The most concerning change is the proliferation of macroalgae, which has significantly increased at both sites long-term (Table 10). Fleshy macroalgae species are mostly responsible for the elevated levels observed since 2009. Although cover for *Dictyota* has varied considerably since 2010, in some years it has accounted for up to 86% of the total macroalgal cover at Loggerhead Patch and up to 52% of the total macroalgal cover at White Shoal (Appendix C). The sustained levels of greater macroalgal cover that have persisted over the last decade has likely prevented the recovery of *A. cervicornis* at these sites. *Dictyota* spp. and several other fleshy macroalgae species are known inhibitors of coral recruitment that diminish the establishment of new sexually-derived recruits due to spatial competition and can inflict direct mortality on nearby fragments because they possess toxic allelochemicals, which reduces the expansion of extant colonies through asexual fragmentation (Kuffner et al. 2006, Morrow et al. 2017).

Similar to Palmata Patch, the emergence of octocorals at White Shoal may also be inhibiting *A. cervicornis* recovery. Octocoral cover at White Shoal has nearly doubled long-term from 9.1 ± 3.3% in 1999-2002 to 15.8 ± 2.8% in 2019-2022 (Table 8). The octocoral community appears well established at White Shoal and continues to expand. Mean octocoral density significantly increased during the last decade and averaged 14.1 ± 1.9 colonies/m^2 in 2019-2022, up from 9.2 ± 0.9 colonies/m^2 in 2011-2014 (Table 9).

Acropora prolifera

Prolifera Patch is believed to be the only site where *A. prolifera* is found in DRTO. Similar to the distribution of *A. palmata*, the presence of *A. prolifera* is confined to a small area and CREMP only established three monitoring stations. Prolifera Patch is likely composed of a single genet that is distributed as isolated colonies and small thickets throughout the site. Overall, the cover of *A. prolifera* has expanded and increased both short- and long-term. Short-term, the mean cover of *A. prolifera* increased from 14.3 ± 10.6% in 2019-2020 to 17.1 ± 13.1% in 2021-2022 (Figure 10, Table 12). Long-term, *A. prolifera* cover nearly doubled, significantly increasing from 6.1 ± 3.5% in 2004-2007 to 15.7 ± 11.8% in 2019-2022 (Table 12).

Up until the last four years, *A. prolifera* cover had remained relatively similar between 2009 and 2018 (Figure 10a). Similar to the synopsis for Palmata Patch, the 2004 and 2005 hurricane seasons

decimated much of the *A. prolifera* thickets, with cover between 2004-2007 averaging only 6.1 ± 3.5%. The increase in *A. prolifera* cover is notable because the site lies in close proximity to Palmata Patch and the expansion of the primary species at these two sites (*A. prolifera* and *A. palmata*) have either supported an overall increase in coral cover at the site or maintained the level observed at the start of surveys. Given that sexual recruitment of *Acropora* in Florida is rare (Williams et al. 2008, Miller et al. 2014) and that the genetic diversity is likely restricted to a single genotype, the increase in *A. prolifera* cover is only due to expansion of the existing thicket through asexual fragmentation. While the recent observations for *A. prolifera* are encouraging and do not parallel those for *A. cervicornis,* the population's lack of genetic diversity and the confined spatial distribution continues to place the species at risk.

Unlike the changes observed at the *A. cervicornis* sites, it does not appear that increased macroalgae cover has an adverse effect on *A. prolifera* cover. Although there has been a significant long-term increase in macroalgae cover at Prolifera Patch (Table 10), it significantly declined in short-term analysis in this report. It also had the lowest macroalgae cover of any site, averaging 8.5 ± 3.0% for 2021-2022. Similarly, there were no significant differences detected in octocoral cover and density both short- and long-term at Prolifera Patch. The lack of changes in the other benthic taxa groups cover at Prolifera Patch versus White Shoal and Loggerhead may partially explain why *A. prolifera* cover has recovered or even expanded after disturbance, while *A. cervicornis* cover has remained persistently low.

Orbicella spp.

For the CREMP image analyses, the *Orbicella* species are aggregated into a complex of three recognized species: *Orbicella annularis*, *O. faveolata*, and *O. franksi*. The three species are pooled into a single complex because it can be challenging to distinguish between them in Point Count imagery. The three species of *Orbicella* are distinguished in the demographic surveys and the data are presented by species in Appendix D. At sites where *Orbicella* populations are monotypic, the appropriate species is mentioned. *Orbicella* spp. historically are one of the major reef-builders on Florida's Coral Reef (Ginsburg and Shinn 1994, Toth et al. 2019). It has been the most spatially abundant coral (e.g., the largest contributor to coral cover) at Bird Key Reef, Black Coral Rock, Davis Rock, Loggerhead Patch (until it became devoid of stony corals entirely in 2021), The Maze, and Little Africa (Appendix B).

Short-term, between the 2019-2020 and 2021-2022 time periods, only Bird Key Reef had a significant decline in mean *Orbicella* spp. cover (Table 14). Long-term, *Orbicella* spp. cover has significantly declined at all sites and the pinnacle reefs (Figure 10b-d, Table 14). No significant differences in *Orbicella* spp. density were found short-term across any of the sites (Table 15), but significant long-term reductions were recorded at Bird Key Reef, Black Coral Rock, and the pinnacle reefs. This was the first report to indicate a significant decrease in density at these sites long-term. Generally, there has been a disconnect between the significant declines in percent cover and the lack of differences observed for density for *Orbicella* spp. because many colonies can experience substantial partial mortality but still be recorded as alive. Additionally, enumerating individual *Orbicella* spp. colonies can be difficult when large monotypic stands are present

because distinguishing these colonies as autonomous can be extremely challenging. Their plating or lobing growth forms and the large amount of partial mortality and fragmentation these corals typically undergo can lead to over- or underestimation of their abundance and increase the variance around the annual density measures. Only a small amount of living tissue needs to be observed for the colony to be recorded as alive; thus, while 99% of the live tissue may have been lost to mortality, the presence of the individual colony would still be reflected in density values. While incidences of partial mortality due to thermal stress, disease, or other disturbances have become more frequent on *Orbicella* spp. in recent decades, there was an expectation that this reflected the life history of *Orbicella* spp. and while parts of the colony would be lost, there were tissue fragments that would endure and survive. Because of their long-lived nature, monumental size, and scalloped and lobate growth form, *Orbicella* spp. colonies with fragmented isolates of tissue were common but now that detectable differences in density are occurring, this indicates that entire colonies are disappearing.

Table 14. Mean coral cover (% ± SE) for *Orbicella* spp. at four sites and averaged for five pinnacle reefs (includes Davis Rock, Texas Rock, The Maze, Mayer's Peak, and Temptation Rock). Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. The initial four-year period for the long-term comparison varies and is contingent upon commencement of monitoring at that site or at the pinnacle reefs: Bird Key Reef and Black Coral Rock = 1999-2002; Prolifera Patch = 2004-2007; Little Africa = 2007-2010; pinnacle reefs = 2009-2012. The last four years represents 2019-2022. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover.

	Long-term	Long-term	Short-term	Short-term
Site	**First Four**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	9.1 ± 1.1	3.0 ± 0.6	3.6 ± 0.6	2.4 ± 0.7
Black Coral Rock	10.0 ± 2.0	5.6 ± 1.4	6.1 ± 1.4	5.1 ± 1.4
Little Africa	21.3 ± 4.0	11.3 ± 2.4	12.1 ± 2.6	10.6 ± 2.1
Prolifera Patch	6.8 ± 5.8	4.0 ± 3.4	4.1 ± 3.4	3.9 ± 3.3
Pinnacle Reefs	2.8 ± 1.2	2.0 ± 1.0	2.0 ± 1.0	2.0 ± 1.0

Examining changes at the site level, the long-term decline of *Orbicella* spp. has been most apparent at Bird Key Reef. *Orbicella* spp. cover has historically accounted for approximately 30-40% of the total coral cover at Bird Key Reef (Jaap 1980, Jaap 2015) and the sloping forereef is comprised of a mixed assemblage of *O. faveolata* and *O. franksi*. During the first four-year timeframe (1999-2002), mean *Orbicella* spp. cover was 9.1 ± 1.1% (Figure 10c, Table 14). During the last four years (2019-2022) mean *Orbicella* spp. cover averaged 3.0 ± 0.6% representing a relative loss of over 67% of the total *Orbicella* spp. cover and a long-term contraction in absolute cover of over 6% between the two time periods at Bird Key Reef. *Orbicella* spp. cover started to decline in 2002 (Figure 10c) with the most precipitous drop occurring between 2001 and 2002 when an outbreak from an unknown disease was observed on *Orbicella* spp. and *Colpophyllia natans* (Coral Research Program 2023). Other significant declines occurred between 2009 and 2010, from the

thermal stress endured during the 2014-15 El Niño, and another unknown stressor between 2019-2020 (Figure 10b-d). Stony coral tissue loss disease was observed starting in 2021 at Bird Key Reef and 15 out of 40 *Orbicella* spp. colonies were recorded with lesions in 2022. While it is difficult to fully ascertain the impact of SCTLD on large corals like *Orbicella* spp., there does appear to be a substantial effect. In this report *Orbicella* spp. density significantly decreased over the long-term from 1.5 ± 0.4 colonies/m^2 to 1.2 ± 0.2 colonies/m^2 from 2011-2014 to 2019-2022 (Table 15), which differs from the previous report where no significant long-term change was found, and, in addition to the aforementioned long-term decrease in *Orbicella* spp. percent cover, there was also significant short-term decrease from 3.6 ± 0.6% in 2019-2020 to 2.4 ± 0.7% in 2021-2022 (Table 14). As mentioned previously this was the first time a long-term decrease in density was detected for *Orbicella* spp. at Bird Key Reef and this decrease is likely due to SCTLD killing the remains of colonies that were already mostly dead but still had small, isolated fragments of living tissue prior to the arrival of SCTLD.

Table 15. Mean density (no. of colonies/m^2) ± SE *Orbicella* spp. at three sites and averaged for five pinnacle reefs (includes Davis Rock, Texas Rock, the Maze, Mayer's Peak, and Temptation Rock). Long-term comparisons averaged for the first and last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial report. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in density.

	Long-term	Long-term	Short-term	Short-term
Site	**2011-2014**	**2019-2022**	**2019-2020**	**2021-2022**
Bird Key Reef	1.5 ± 0.4	1.2 ± 0.2	1.2 ± 0.2	1.1 ± 0.2
Black Coral Rock	1.9 ± 0.4	1.6 ± 0.3	1.7 ± 0.4	1.5 ± 0.3
Prolifera Patch	0.7 ± 0.5	0.5 ± 0.4	0.6 ± 0.4	0.5 ± 0.4
Pinnacle Reefs	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.0

Similar to Bird Key Reef, the *Orbicella* spp. community at Black Coral Rock is a mixed assemblage of *O. faveolata* and *O. franksi*. *Orbicella* spp. makes up nearly half of the coral cover at Black Coral Rock (Appendices A and C). During the first four years of monitoring (1999-2002), *Orbicella* spp. cover averaged 10.0 ± 2.0%, the second highest cover of any CREMP site in DRTO. Long-term, *Orbicella* spp. cover has significantly declined by ~50% at Black Coral Rock and averaged 5.1 ± 1.4% between 2019-2022 (Table 14). Similar to Bird Key Reef, most of the losses in cover occurred prior to 2010 with the greatest reductions between 2001-2002 (white disease outbreak), 2005-2006 (documented thermal stress years), and 2008-2010 (unknown causes). Whether the thermal stress in 2005 directly led to mass coral bleaching at Black Coral Rock is unknown because temperature logger data suggest that temperatures at Black Coral Rock rarely exceed thresholds that would promote significant bleaching (Figure 6). SCTLD had a significant impact on *Orbicella* spp. at Black Coral Rock in 2022. Stony coral tissue loss disease was first documented at Black Coral Rock in 2022 and was highly active during CREMP surveys, being recorded on 35 of 54 *Orbicella* spp. colonies or ~65% of the *Orbicella* spp. colonies within the CREMP transects. Although a significant short-term decline in density wasn't substantiated in this

report, there was a significant long-term change with density declining from 1.9 ± 0.4 to 1.6 ± 0.3 colonies/m^2, from 2011-2014 to 2019-2022. Similar to Bird Key Reef, long-term significant decreases in *Orbicella* spp. density were not previously documented for Black Coral Rock. Due to the high prevalence of active SCTLD lesions on *Orbicella* spp. in 2022 and that mortality was still occurring, understanding the full impact of SCTLD will require the data from the 2023 surveys. SCTLD will undoubtedly exacerbate these declines in both *Orbicella* spp. percent cover and density.

The reef at Little Africa primarily consists of *Orbicella faveolata* and *O. annularis*. *Orbicella* spp. comprised more than 95% of the total coral cover in 2022. A significant long-term decline in *Orbicella* spp. percent cover was recorded at Little Africa (Table 14); for the initial time period (2007-2010) mean *Orbicella* spp. cover was 21.3 ± 4.0% (SE) but had declined to 11.3 ± 2.4% for the most recent time period, a relative decrease of ~47%. For the 2021-2022 time period of the short-term analysis *Orbicella* spp. cover was only 10.6 ± 2.1%. While less substantial than the overall decline at Bird Key Reef, the timeframe is shortened by eight years. Not all the factors that have contributed to the loss of *Orbicella* spp. cover at Little Africa are known, but bleaching occurs frequently from thermal stress due to the shallow depth of the site. Although there is no temperature logger deployed at Little Africa the site likely has a comparable water temperature regime to other shallow sites like Loggerhead, Palmata Patch, and/or Prolifera Patch which endure the highest number of days with seawater temperatures >30 or 31°C annually (Figure 6). In addition to undergoing elevated temperature stress on a more frequent basis, another commonality between the Bird Key Reef and Little Africa *Orbicella* spp. communities is that they are largely derived from monotypic stands of colonies which makes the reef community vulnerable to epizootic outbreaks. The prevalence of SCTLD on the *Orbicella* spp. community at this site is unknown because demographic surveys are not performed at Little Africa.

At Prolifera Patch, *Orbicella* spp. colonies are concentrated along the southern side of the stations and primarily consist of large *O. annularis* or *O. faveolata* colonies greater than a meter in height or width. *Orbicella* spp. percent cover at Prolifera Patch had remained relatively similar up until the last biennial report. Although a short-term decline in *Orbicella* spp. cover was not documented in this report (Table 14), there was a significant drop in cover between the 2017-2018 and 2019-2020 timeframes reported in the previous report (Ruzicka 2022). Overall, there has been a relative loss of ~41% of the *Orbicella* spp. cover at Prolifera Patch between the long-term time periods of 2004-2007 and 2019-2022. Stony coral tissue loss disease was not observed within CREMP stations here in 2021 or 2022 and this was the only site that did not show a significant reduction in *Orbicella* spp. density long-term.

Although not nearly as spatially dominant or numerous at the sites described above, large *Orbicella* spp. colonies are a common feature at the pinnacle reefs. There are five pinnacle reefs assessed but three of them (The Maze, Davis Rock, and Texas Rock) were added to the survey in 2009. Therefore, the long-term comparison is between the time intervals of 2009-2012 and 2019-2022 for percent cover. A significant decrease in *Orbicella* spp. cover and density were detected long-term. The change in both cover and density represented ~33% reductions for each metric (Tables 14 and 15). Combined for the five pinnacle reefs, SCTLD was only observed on a single colony

of *O. faveolata* in 2021 at Mayer's Peak. However, consistent with the patterns described above for Bird Key Reef and Black Coral Rock, 12 of 39 *Orbicella* colonies had active SCTLD lesions at the pinnacle reefs in 2022.

Pinnacle Reefs and User Pressure

Established in 2007, the Research Natural Area (RNA) of Dry Tortugas National Park is a 46-square-mile marine reserve designed to restore ecological integrity and capacity for self-renewal by minimizing human disturbance. The RNA is a no-take ecological preserve that allows for recreational diving, snorkeling, research, and education (Ziegler and Hunt 2012). Anchoring is not permitted within the RNA and SCUBA diving activities are only conducted through live-boating or securing the vessel to a reef designated with a mooring buoy. To determine if the use of mooring buoys would concentrate SCUBA diving activities to such an extent that it would result in detrimental effects or damage to benthic communities the CREMP program added three sites in 2009 that were designated for mooring buoy installation. This sub-study compares the changes in benthic communities at these mooring buoy sites to the changes at two similar sites where no mooring buoys are present and was intended to assist the park in establishing a diver "carrying capacity" so that RNA resource stewardship goals were upheld (Ziegler and Hunt 2012).

All five sites used in this assessment are pinnacle reefs located in the northern and western sections of the park. Mayer's Peak and Temptation Rock are the two sites without mooring buoys and serve as the refence sites for this analysis. They were first surveyed as part of CREMP in 2004. Davis Rock, The Maze, and Texas Rock were added in 2009, have mooring buoys and serve as the treatment sites. Survey methods conducted at all three sites are the same as for all CREMP sites. Statistical analyses also follow the same methods detailed above; however, for both long-term and short-term comparisons the data for reference sites and treatment sites were pooled and for long-term analyses the first four years are 2009-2012 for both reference and treatment site groups. To evaluate the differences between the reference sites and the treatment sites we compared changes in percent cover and density of corals and octocorals.

All mooring buoys were securely installed by 2013 and thus the first four-year period in the long-term analysis provides a baseline that predates mooring buoy installation. Several of the RNA mooring buoys have broken off during the study for extended periods of time. Due to the remote location of DRTO the time required for repair or replacement can be considerable, with affected sites having little or no SCUBA activity while moorings were absent. In addition, SCUBA diving effort has been difficult to quantify. The current vessel permit application used by DRTO does not distinguish between SCUBA diving and snorkeling activities. As is, they are currently lumped together in the permit application, and this precludes calculating a precise estimate of the SCUBA diving effort at the RNA sites. Based upon other studies, the most conservative estimates suggest that more than 5,000 to 6,000 divers per site per year are needed to surpass thresholds that would be detrimental to coral reef communities (Hawkins et al. 1999). Based upon communication with DRTO park staff and members of the dive industry that operate within DRTO, the three treatments sites assessed here, at most, receive approximately 1,000 dives per year.

There were no significant differences in coral cover and density short-term at the treatment or reference sites between the 2019-2020 and 2021-2022 time periods. Long-term, between 2009-2012 and 2019-2022, there was a significant decline in coral cover at the treatment sites but no significant change at the reference sites (Table 16). Coral density, however, significantly increased long-term at both treatment and reference sites (Table 17).

Table 16. Mean coral cover (% ± SE) for three RNA sites with mooring buoys and two RNA sites without. Long-term comparisons were made between the average calculated for 2009-2012 and the last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial reports. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

	Long-term	Long-term	Short-term	Short-term
RNA Sites	**2009-2012**	**2019-2022**	**2019-2020**	**2021-2022**
With Moorings (3)	9.7 ± 1.2	7.9 ± 1.2	8.3 ± 1.1	7.5 ± 1.2
Without Moorings (2)	4.3 ± 0.3	4.7 ± 0.2	5.1 ± 0.4	4.4 ± 0.1

Table 17. Mean coral density (no of colonies/m^2 ± SE) for three RNA sites with mooring buoys and two RNA sites without. Long-term comparisons were made between the average calculated for 2011-2014 and the last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial reports. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

	Long-term	Long-term	Short-term	Short-term
RNA Sites	**2011-2014**	**2019-2022**	**2019-2020**	**2021-2022**
With Moorings (3)	4.9 ± 0.6	5.9 ± 0.4	5.9 ± 0.5	6.0 ± 0.3
Without Moorings (2)	4.4 ± 1.1	6.1 ± 2.1	6.0 ± 2.3	6.1 ± 1.9

Across all comparisons (short- and long-term), octocoral cover significantly increased at both the treatment and reference sites (Table 18). Although octocoral density significantly declined at the reference sites short-term, it has significantly increased long-term (Table 18). There were no long-term changes in octocoral density for the treatment sites (Table 19).

Mean coral cover averaged across the three treatment sites was greater than at the two reference sites (Table 16). At the treatment sites coral cover declined 1.8% between the long-term periods analyzed, while at the reference sites there were no significant changes. The primary driver of the decreases in coral cover at the treatment sites was the loss of *Orbicella* spp., which has had relatively low cover values at the two reference locations throughout CREMP monitoring. Among the treatment sites The Maze had the highest *Orbicella* spp. cover with values ranging from 3.7% in 2022 to 7.3% in 2014, whereas among the reference sites Temptation Rock had the highest *Orbicella* spp. cover with values ranging 2.0% in 2015 to 0.1% in 2018 (Appendix B). Because *Orbicella* spp. colonies are massive corals and disproportionally contribute to coral cover

compared to coral density, substantial declines in cover due to partial mortality can occur without decreases in density. Long-term significant increases in coral density occurred at both treatment and reference sites (Table 17) suggesting that coral recruitment is occurring regardless of user differences and that newly settled corals are achieving 4cm in size and are included in the demographic counts. For both treatment and reference sites the increase in density is mostly due to smaller, weedy species as described above in the coral density section.

Table 18. Mean percent octocoral cover (% ± SE) for three RNA sites with mooring buoys and two RNA sites without. Long-term comparisons were made between the average calculated for 2009-2012 and the last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial reports. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

	Long-term	Long-term	Short-term	Short-term
RNA Sites	**2009-2012**	**2019-2022**	**2019-2020**	**2021-2022**
With Moorings (3)	4.0 ± 1.9	6.5 ± 2.9	5.7 ± 2.6	7.4 ± 3.2
Without Moorings (2)	17.1 ± 4.3	22.2 ± 5.7	20.4 ± 4.9	24.1 ± 6.6

Table 19. Mean octocoral density (no of colonies/m^2 ± SE) for three RNA sites with mooring buoys and two RNA sites without. Long-term comparisons were made between the average calculated for 2011-2014 and the last four years of monitoring, and short-term comparison averaged for the two-year period for the current and previous biennial reports. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

	Long-term	Long-term	Short-term	Short-term
RNA Sites	**2011-2014**	**2019-2022**	**2019-2020**	**2021-2022**
With Moorings (3)	2.0 ± 1.7	2.5 ± 2.1	2.7 ± 2.2	2.4 ± 2.0
Without Moorings (2)	12.4 ± 8.2	15.3 ± 11.2	15.9 ± 11.5	14.8 ± 11.0

Although reference sites had far higher octocoral cover and density than treatment sites, both groups exhibited significant increases in octocoral cover short-term and long-term (Tables 18 and 19). The two reference sites, Mayer's Peak and Temptation Rock, had the highest octocoral cover of any DRTO CREMP sites averaged for 2021-2022, with 30.7 ± 1.6% and 17.5 ± 2.2% cover, respectively (Table 8). Mayer's Peak also had the highest octocoral density during the current reporting period, averaging 25.8 ± 1.9 octocorals/m^2 for 2021-2022 (Table 9). The increase in octocoral cover for all time comparisons and for density long-term at the reference sites was primarily driven by the changes at Mayer's Peak. Octocoral cover and density has significantly increased long-term at Mayer's Peak (Tables 8 and 9).

Whether at the treatment or reference sites, the permanency of the elevated macroalgal cover that has persisted over the last decade may be of greater concern than the amount of user pressure. As described in the macroalgae section, all CREMP sites increased in macroalgae cover over the long-

term analyses except the three RNA sites with mooring buoys, and a significant decrease in the short-term was observed at The Maze. However, surveys at the three treatment sites did not commence until after sharp increases in macroalgae had occurred throughout DRTO (Figure 8). At the two reference sites, Mayer's Peak and Temptation Rock, the amount of macroalgal cover observed during recent years, 2019-2022, was over six times and three times higher, respectively, than the first four years of monitoring, 2004-2007.

A significant decrease in coral cover over the long-term occurred at the treatment sites but not at the reference sites. The decrease in coral cover at the treatment sites was mostly due to the loss of *Orbicella* spp. which was a consistent finding across the CREMP sites at which *Orbicella* spp. was analyzed (Tables 14 and 15). Other than the difference in the long-term coral cover results, coral density and octocoral cover were consistent over the long-term for both the treatment and reference sites. The results suggest the level of SCUBA diving activity that has occurred since the mooring buoys were established in 2013 has not had a deleterious effect on the benthic communities. This result aligns with the belief that user pressure during the evaluation period was much lower than that required to adversely affect a coral reef community.

Conclusions

This report provides a preliminary outlook on the impacts associated with stony coral tissue loss disease (SCTLD). Although the short-term analyses did not indicate any significant reductions in total coral cover or density at any site between the timeframe of this biennial report and the last, other metrics that characterize species-specific changes in abundance and density reveal the changes due to SCTLD are altering the coral composition of the reef communities in DRTO. SCTLD was confirmed by DRTO park management in May 2021. It was recorded at a total of eight CREMP sites combined across the two years; six sites during the 2021 survey and seven sites in 2022. Total SCTLD prevalence across the entire coral population was 2.0% in 2021 and 7.9% in 2022. The lower prevalence values in 2021 were because SCTLD had only arrived in DRTO five months before the CREMP survey and lesions were still actively forming on many of the highly susceptible species. During the 2022 survey, SCTLD prevalence had risen to epidemic levels (exceeding 5% of the population) even though many of the colonies displaying lesions were intermediately-susceptible species like *Montastraea cavernosa* and *Orbicella* spp.; combined, *M. cavernosa* and *Orbicella* spp. accounted for 52% of all SCTLD observations in 2022. In comparison, *Montastraea cavernosa* and *Orbicella* spp. only accounted for 27% of all SCTLD observations in 2021.

Between 2021 and 2022, changes in the abundance of the most susceptible species to SCTLD were clearly evident. For large, important framework building species like *Colpophyllia natans*, *Meandrina meandrites,* and *Pseudodiploria strigosa,* the reduction in abundance was greater than 80% within the CREMP stations and other susceptible species (e.g., *Eusmilia fastigiata* and *Pseudodiploria clivosa*) that were found prior to the arrival SCTLD were completely absent at CREMP sites in 2022 (Table 7). In all, total coral abundance declined by 471 colonies between 2021 and 2022, and although we cannot conclusively assign all mortalities to SCTLD, many of the differences in abundance were associated with changes to highly- and intermediately-susceptible species (Table 7, Appendix I). The loss of 471 colonies represented a nearly 20% change in the CREMP DRTO coral population. While this reduction is alarming, it is likely to grow even larger because the prevalence SCTLD was still at epidemic levels in 2022 and more coral mortalities will be observed in subsequent years.

Beyond the impact of SCTLD on corals, there were several short-term changes to the status of the other predominant benthic groups between this biennial report and the previous one. Octocoral cover significantly increased at three sites (Mayer's Peak, Texas Rock, and The Maze) and significantly declined at one site (Bird Key Reef) in the short-term analysis for this report (Table 8), whereas there were no significant differences in octocoral cover at any site in the previous report. Although octocoral cover was greater at three sites, octocoral density was unchanged at all 11 sites in the short-term for this reporting period (Table 9). In the previous report octocoral density was unchanged at 10 of 11 sites. Not surprisingly macroalgae cover exhibited the most differences between this reporting period and the last. Macroalgae cover was significantly higher at two sites (Bird Key Reef and Loggerhead Patch) in 2021-2022 than 2019-2020, but significantly decreased at five sites (Black Coral Rock, Mayer's Peak, Prolifera Patch, Temptation Rock, and The Maze; Table 10). During the previous reporting period only one site (Bird Key Reef) declined in the

short-term, while three sites (Mayer's Peak, The Maze, and Little Africa) significantly increased. Lastly, sponge cover was significantly lower at two sites (Davis Rock and White Shoal), differing from the last report when two sites significantly increased short-term, and one site was significantly decreased.

Most of the long-term changes in coral cover were consistent with what was described in the 2019-2020 biennial report; however, there was a notable change that deserves recognition. Texas Rock became the sixth site that now shows a long-term decline in coral cover. Previous reports have confirmed long-term declines in coral cover at other sites, but as of this report, half the CREMP sites in DRTO have had a significant loss in coral cover long-term. More importantly, at the three sites that have been surveyed since 1999 (Bird Key Reef, Black Coral Rock, White Shoal), all have lost 45% or more of their coral cover (Table 20). Unchanged from the findings in the last report, three sites (Mayer's Peak, Palmata Patch, and Prolifera Patch) still maintained a significant increase in coral cover long-term while the remaining three sites (Davis Rock, Temptation Rock, and The Maze) have had no significant differences. The long-term increase in coral cover at Palmata Patch remains a positive outcome and reflects the growth and stability of the *Acropora palmata* colonies during the last 10 years since little, if any, sexual recruitment has been observed. Coral cover at both Palmata Patch and Prolifera Patch have increased considerably since the initial four years of monitoring with short-term significant increases having been reported when there have been a paucity of disturbances (Tables 2 and 20, Figure 10a).

There were few differences in the long-term results to the other three benthic taxa groups (octocorals, macroalgae, and sponges), and overall, they mostly mirrored those presented in the previous report. The number of sites that significantly increased in octocoral cover remained the same; however, a long-term increase was found for Mayer's Peak herein, whereas Little Africa, which indicated a significant increase in the previous report, no longer demonstrated one in this report. The positive long-term change in octocoral cover at Davis Rock, Loggerhead Patch, Palmata Patch, The Maze, and White Shoal were upheld. The long-term synopsis for macroalgal cover was identical to that in the previous report. The same nine sites demonstrated a significant increase (Table 20), and only the sites added to the project in 2009, after macroalgae cover values had increased region-wide, were without a significant increase in macroalgae cover long-term. Long-term, macroalgal cover increased more than any other taxa at the nine sites where a significant increase in macroalgal cover occurred and, over the most recent years of surveys, macroalgae has been the greatest contributor to benthic cover at 10 of the 12 CREMP sites (Table 20, Appendix A). For sponge cover, the number of sites with a long-term increase rose to eight from six in the previous report, with Little Africa and Texas Rock being the new additions (Table 11). Even though three quarters of the sites demonstrated a significant increase in sponge cover, the overall contribution of sponge cover at many of these sites was still relatively small in comparison to the other benthic groups.

Table 20. Summary table of long-term changes in percent cover of the four primary benthic taxa groups between the first four years (varies by site) and last four years (2019-2022) of monitoring at 12 sites. The first four-year timeframes denoted by A = 1999-2002; B = 2004-2007; C = 2007-2010, D = 2009-2012. The first number is the absolute difference in percent cover between the first and last four-year intervals; the number in parentheses is the relative difference. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

Site	Coral	Macroalgae	Octocoral	Sponge
Bird Key Reef[A]	-10.0 (-55.4%)	+23.0 (+161.9%)	-1.3 (-6.9%)	-0.0 (-0.1%)
Black Coral Rock[A]	-9.6 (-44.6%)	+29.6 (+319.7%)	-0.3 (-3.0%)	+0.1 (+3.4%)
White Shoal[A]	-3.5 (-49.3%)	+19.3 (+235.6%)	+6.8 (+74.7%)	-0.1 (-5.3%)
Loggerhead Patch[B]	-1.3 (-52.7%)	+22.2 (+524.1%)	+0.8 (+81.4%)	+0.6 (+218%)
Palmata Patch[B]	+5.8 (+138.3%)	+15.9 (+696.2%)	+10.2 (+410.4%)	+0.5 (+344.8%)
Prolifera Patch[B]	+6.3 (+45.4%)	+7.7 (+255.1%)	+0.9 (+16.3%)	+0.2 (+96.2%)
Mayer's Peak[B]	+1.2 (+32.3%)	+16.3 (+559.6%)	+5.6 (+25.0%)	+1.8 (+68.4%)
Temptation Rock[B]	+1.0 (+30.0%)	+23.1 (+275.4%)	+1.3 (+8.9%)	+1.4 (+112.9%)
Little Africa[C]	-11.2 (-46.1%)	+13.4 (+120.3)	+2.5 (+45.7%)	+0.3 (+111.9%)
Davis Rock[D]	-1.1 (-11.1%)	+2.1 (+4.7%)	+2.3 (+340.7%)	+1.1 (+46.3%)
Texas Rock[D]	-2.0 (-26.5%)	+7.0 (+21.6%)	+0.3 (+7.5%)	+1.8 (+37.6%)
The Maze[D]	-2.3 (-19.6)	-1.2% (-3.5%)	+5.1 (+72.2%)	+0.8 (+20.2%)

The sustained levels of elevated macroalgae cover continued to be a persistent issue across sites. Even with short-term declines in macroalgal cover observed at five sites in this report, these decreases were not sufficient to reverse the diagnosis of a significant, long-term increase in macroalgae at any of them. Multiple biennial reports have repeatedly documented the sustained levels of elevated macroalgae cover at the majority of sites. Nine of the 12 sites had significantly higher macroalgae cover in the long-term analyses and eight of these nine sites have had macroalgae cover at least double over the course of monitoring (Table 20). The findings presented here appear to be consistent with those reported from the Mesoamerican Reef region in which a pervasive increase in fleshy macroalgae cover has occurred during the last 15 years (Suchley et al. 2016), coincident with the results from this study. In both cases, the rapid proliferation of fleshy macroalgae (e.g., *Dictyota*) were not preceded by acute losses in coral cover nor were such increases co-dependent with declines in herbivorous fish abundance. Conversely, the Mesoamerican reef study found an increase in herbivorous fish biomass during their study, and while herbivorous fish abundance was not quantified for this report, herbivorous fish species are fully protected in DRTO by Florida's Marine Life Rule, so it is expected that their biomass has not declined during the last 20 years. While a fundamental tenet of coral reef ecology has been that

the transition from stony coral- to macroalgae-dominated reef communities in the Caribbean are often accelerated by the loss of herbivorous species (both *Diadema* and herbivorous fishes) following substantial losses in coral cover (Hughes et al. 2007, Bruno et al. 2009, Jackson et al. 2014), the sustained levels of macroalgal cover documented here and in the Mesoamerican study indicate there are additional factors beyond coral mass mortalities and the loss of herbivory that can drive the increased production of macroalgae. Region-wide changes to water quality stemming from increased nutrients, pollution, and rising seawater temperatures associated with climate change could be fostering macroalgae growth, independent of the historical losses to coral cover and herbivory, and exceed current grazing capacity by fishes and present day *Diadema* abundance. While increased macroalgal cover remains of principal concern, assessing its impact on other existing benthic taxa is difficult to quantify. At sites in which there have been substantial declines in coral cover (e.g., Black Coral Rock and Bird Key Reef), elevated macroalgae cover may be impeding coral recovery; however, at some sites coral cover or density has stayed similar spanning several biennial reports, and the cover of other benthic taxa, such as octocorals and sponges has been unchanged or even increased alongside the overabundance of macroalgae.

Table 21. Summary table of long-term changes in percent cover of the four ESA-listed species present in DRTO between the first four years (varies by site) and last four years (2019-2022) of monitoring. The first four-year timeframes denoted by A = 1999-2002; B = 2004-2007; C = 2007-2010, D = 2009-2012. The first number is the absolute difference in percent cover between the first and last four-year intervals; the number in parentheses is the relative difference. Values highlighted in green or red represent a significant increase or decrease ($p < 0.05$) in cover, respectively.

Site	*A. cervicornis*	*A. palmata*	*A. prolifera*	*Orbicella* spp.
Bird Key Reef[A]	-	-	-	-6.0 (-66.6%)
Black Coral Rock[A]	-	-	-	-4.4 (-44.3%)
White Shoal[A]	-2.3 (-58.5%)	-	-	-
Loggerhead Patch[B]	-0.6 (-100.0%)	-	-	-
Palmata Patch[B]	-	+5.1 (+161.7%)	-	-
Prolifera Patch[B]	-	-	+9.6 (+156.2)	-2.9 (-41.8%)
Little Africa[C]	-	-	-	-10.0 (-47.0%)
Pinnacle Reefs[D]	-	-	-	-0.8 (-28.5%)

For the ESA-listed *Acropora* spp. the results of long-term analyses for *A. cervicornis*, *A. palmata*, and *A. prolifera* were similar to the results of the 2019-2020 biennial report. Even though the current analysis for Palmata Patch did not result in a statistically significant increase between the long-term timeframes, the difference in absolute cover for *A. palmata* (5.1%) was larger than in analogous long-term analysis from the 2019-2020 biennial report. The absolute change in *A. prolifera* cover was also greater (9.6%) than in the 2019-2020 biennial. For both species, coral cover has nearly doubled (Table 21) compared to the early years of monitoring. For *A. cervicornis*,

the results for both Loggerhead Patch and White Shoal were consistent with results provided in previous reports. Long-term declines in *A. cervicornis* cover were significant at White Shoal and the species is now absent at Loggerhead Patch (Table 21). Although the 2021-2022 value for *A. cervicornis* cover at White Shoal was slightly greater than the 2019-2020 value, the long-term change still equaled a significant decline *A. cervicornis* cover at this site.

The results for ESA-listed *Orbicella* spp. continue to be concerning. *Orbicella* cover was significantly lower between the long-term timeframes at every site it was analyzed for and aggregated for the pinnacle reefs. Although this result was consistent with the 2019-2020 biennial report the proportional declines in *Orbicella* spp. cover were enlarged compared to two years ago (Table 21). Two-thirds of the total *Orbicella* spp. cover has been lost at Bird Key Reef and nearly half at Black Coral Rock, Little Africa, and Prolifera Patch. The timeframes at Bird Key Reef and Black Coral Rock do span more than 20 years with marked declines in certain years but the changes at Little Africa and Prolifera Patch have been more recent and significant short-term declines in cover have been confirmed in recent biennial reports.

The declines in *Orbicella* spp. in DRTO are consistent with reports from other areas along Florida's Coral Reef (Ruzicka et al. 2013, Toth et al. 2014) and the broader Caribbean (Aronson and Precht 2006, Edmunds and Elahi 2007). Acute stressors, including epizootic outbreaks, elevated seawater temperatures, and powerful hurricanes, have at times rapidly reduced *Orbicella* spp. populations, while recurring instances of partial mortality associated with more chronic conditions have cumulatively led to substantial declines that warranted the ESA listing for *Orbicella* spp. in 2014. Unfortunately, it appears the declining status of *Orbicella* spp. in DRTO will be further exacerbated by the arrival of SCTLD. In addition to the long-term reductions in *Orbicella* spp. cover described above, long-term declines in *Orbicella* spp. density were also detected for the first time in this report and SCTLD was likely responsible for killing the small, remaining fragments on many colonies. The total abundance of *Orbicella* spp. declined by approximately 20% between 2021 and 2022 and the prevalence of colonies with active SCTLD lesions in 2022 was still at epidemic levels. The ongoing loss of *Orbicella* spp. is of paramount concern because of the relatively high contribution of *Orbicella* spp. to coral cover on many reefs in DRTO.

Literature Cited

Agassiz, A. 1885. Explorations of the Surface Fauna of the Gulf Stream, under the Auspices of the United States Coast Survey: The Tortugas and Florida Reefs. Memoirs of the American Academy of Arts and Sciences **11**:107-133.

Aronson, R. B., and W. F. Precht. 2006. Conservation, precaution and Caribbean reefs. Coral Reefs **25**:441-450.

Boisvert, T., and R. Ruzicka. 2022. Semi-Annual Progress Report for Demographic Monitoring and Population Enhancement of Acropora palmata along the Florida Reef Tract. F5416-20-I3.

Brandt, M. E., McManus, J.W. 2009. Disease incidence is related to bleaching extent in reef-building corals. Ecology **90**:2859-2867.

Bruckner, A. W., Bruckner, R. J. 2006. The recent decline of *Montastraea annularis* (complex) coral populations in western Curacao: a cause for concern? Rev. Biol. Trop. (Int. J. Trop. Biol) **54**:45-58.

Bruno, J. F., E. R. Selig, K. S. Casey, C. A. Page, B. L. Willis, C. D. Harvell, H. Sweatman, and A. M. Melendy. 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. PLoS Biol **5**:1-8.

Bruno, J. F., H. Sweatman, W. F. Precht, E. R. Selig, and V. G. W. Schutte. 2009. Assessing evidence of phase shifts from coral to macroalgal dominance on coral reefs. Ecology **90**:1478-1484.

Burton, M. L., K. J. Brennan, R. C. Muñoz, and R. Parker Jr. 2005. Preliminary evidence of increased spawning aggregations of mutton snapper (Lutjanus analis) at Riley's Hump two years after establishment of the Tortugas South Ecological Reserve.

Charpy, L., B. E. Casareto, M. J. Langlade, and Y. Suzuki. 2012. Cyanobacteria in Coral Reef Ecosystems: A Review. Journal of Marine Biology **2012**:259571.

Coral Research Program, F. 2023. CREMP Data.*in* K. Cummings, editor. Coral Reef Evaluation and Monitoring Project (CREMP) <https://myfwc.com/research/habitat/coral/cremp/data/>. Florida Fish and Wildlife Research Institute, Florida Fish and Wildlife Research Institute.

Dahlgren, C., J. Sobel, and D. E. Harper. 2001. Assessment of the reef fish community, habitat, and potential for larval dispersal from the proposed Tortugas South Ecological Reserve.

Davis, G. E. 1982. A Century of Natural Change in Coral Distribution at the Dry Tortugas: A Comparison of Reef Maps from 1881 and 1976. Bulletin of Marine Science **32**:608-623.

Dilley, W. E. 1950. The terns of the Dry Tortugas, June, 1949. Florida Naturalist **23**:67-68.

Domeier, M. L. 2004. A potential larval recruitment pathway originating from a Florida marine protected area. Fisheries Oceanography **13**:287-294.

Eakin, C. M., J. A. Morgan, S. F. Heron, T. B. Smith, G. Liu, L. Alvarez-Filip, B. Baca, E. Bartels, C. Bastidas, C. Bouchon, M. Brandt, A. W. Bruckner, L. Bunkley-Williams, A. Cameron, B. D. Causey, M. Chiappone, T. R. L. Christensen, M. J. C. Crabbe, O. Day, E. de la Guardia, G. Díaz-Pulido, D. DiResta, D. L. Gil-Agudelo, D. S. Gilliam, R. N. Ginsburg, S. Gore, H. M. Guzmán, J. C. Hendee, E. A. Hernández-Delgado, E. Husain, C. F. G. Jeffrey, R. J. Jones, E. Jordán-Dahlgren, L. S. Kaufman, D. I. Kline, P. A. Kramer, J. C. Lang, D. Lirman, J. Mallela, C. Manfrino, J.-P. Maréchal, K. Marks, J. Mihaly, W. J. Miller, E. M. Mueller, E. M. Muller, C. A. Orozco Toro, H. A. Oxenford, D. Ponce-Taylor, N. Quinn, K. B. Ritchie, S. Rodríguez, A. R. Ramírez, S. Romano, J. F. Samhouri, J. A. Sánchez, G. P. Schmahl, B. V. Shank, W. J. Skirving, S. C. C. Steiner, E. Villamizar, S. M. Walsh, C. Walter, E. Weil, E. H. Williams, K. W. Roberson, and Y. Yusuf. 2010. Caribbean Corals in Crisis: Record Thermal Stress, Bleaching, and Mortality in 2005. PLoS ONE **5**:e13969.

Eakin, C. M., H. P. Sweatman, and R. E. Brainard. 2019. The 2014–2017 global-scale coral bleaching event: insights and impacts. Coral Reefs **38**:539-545.

Edmunds, P. J. 2015. A quarter-century demographic analysis of the Caribbean coral, Orbicella annularis, and projections of population size over the next century. Limnology and Oceanography **60**:840-855.

Edmunds, P. J., and R. Elahi. 2007. The Demographics of a 15-Year Decline in Cover of the Caribbean Reef Coral Montastraea annularis. Ecological Monographs **77**:3-18.

Ford, A. K., S. Bejarano, M. M. Nugues, P. M. Visser, S. Albert, and S. C. A. Ferse. 2018. Reefs under Siege—the Rise, Putative Drivers, and Consequences of Benthic Cyanobacterial Mats. Frontiers in Marine Science **5**.

Franklin, E. C., J. S. Ault, S. G. Smith, J. Luo, G. A. Meester, G. A. Diaz, M. Chiappone, D. W. Swanson, S. L. Miller, and J. A. Bohnsack. 2003. Benthic Habitat Mapping in the Tortugas Region, Florida. Marine Geodesy [Mar. Geod.]. **26**:1-2.

Ginsburg, R. N., and E. A. Shinn. 1994. Preferential distribution of reefs in the Florida ReefTract: The past is the key to the present. Pages 21–26 *in* Colloquium on Global Aspects of Coral Reefs: Health Hazards and History. Rosenstiel School of Marine and Atmospheric Science, University of Miami., Miami, FL.

Harvell, C. D., K. Kim, J. M. Burkholder, R. R. Colwell, P. R. Epstein, D. J. Grimes, E. E. Hofmann, E. K. Lipp, A. Osterhaus, R. M. Overstreet, J. W. Porter, G. W. Smith, and G. R. Vasta. 1999. Emerging marine diseases--climate links and anthropogenic factors. Science **285**:1505-1510.

Hawkins, J. P., C. M. Roberts, T. Van'T Hof, K. De Meyer, J. Tratalos, and C. Aldam. 1999. Effects of Recreational Scuba Diving on Caribbean Coral and Fish Communities. Conservation Biology **13**:888-897.

Hoegh-Guldberg, O., and J. F. Bruno. 2010. The impact of climate change on the world's marine ecosystems. Science **328**:1523-1528.

Hughes, T. P., D. R. Bellwood, C. S. Folke, L. J. McCook, and J. M. Pandolfi. 2007. No-take areas, herbivory and coral reef resilience. Trends in Ecology & Evolution **22**:1-3.

Jaap, W. C. 1980. Stony coral community structure at Long Key Reef, Ft. Jefferson National Monument, Dry Tortugas, Florida. Fla. Sci. **43**.

Jaap, W. C. 1984. The Ecology of the South Florida Coral Reefs: A Community Profile. U.S. Fish and Wildlife Service. Washington DC.

Jaap, W. C. 2015. Stony coral (Milleporidae and Scleractinia) communities in the eastern Gulf of Mexico: a synopsis with insights from the Hourglass collections. Bulletin of Marine Science **81**:000-000.

Jaap, W. C., and F. J. Sargent. 1993. The status of the remnant population of *Acropora palmata* (Lamarck, 1816) at the Dry Tortugas National Park, Florida, with a discussion of possible causes of changes since 1881. Pages 101-105 *in* Colloquium on global aspects of coral reefs: hazards and history, University of Miami.

Jaap, W. C., A. M. Szmant, K. Jaap, J. M. Dupont, R. Clarke, P. J. Somerfield, J. S. Ault, J. A. Bohnsack, S. G. Kellison, and T. G. Kellison. 2008. A Perspective on the Biology of Florida Keys Coral Reefs Vol. 1. Pages 75-126 *in* B. Riegl and D. E. Dodge, editors. Coral Reefs of the USA. Springer.

Jaap, W. C., J. L. Wheaton, K. B. Donnelly, B. L. Kojis, J. E. McKenna, Jr., L. J. Miller, and M. L. Kub. 1994. A three-year evaluation of community dynamics of coral reefs at Ft. Jefferson National Monument, Dry Tortugas, Florida, USA. Bulletin of Marine Science.

Jackson, J., M. Donovan, K. Cramer, and V. Lam. 2014. Status and trends of Caribbean coral reefs. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland:1970-2012.

Jones, R. J., J. Bowyer, O. Hoegh-Guldberg, and L. L. Blackall. 2004. Dynamics of a temperature-related coral disease outbreak. Marine Ecology Progress Series **281**:63-77.

Kidney, J., and K. Hackett. 2003. Demise of the Boulder Brain Coral, Colpophyllia natans at Bird Key Reef, Dry Tortugas National Park, Florida. Diseases of Corals and Other Marine Organisms, Mote Marine Laboratory.

Kuffner, I. B., B. H. Lidz, J. H. Hudson, and J. S. Anderson. 2015. A Century of Ocean Warming on Florida Keys Coral Reefs: Historic In Situ Observations. Estuaries and Coasts **38**:1085-1096.

Kuffner, I. B., L. J. Walters, M. A. Becerro, V. J. Paul, R. Ritson-Williams, and K. S. Beach. 2006. Inhibition of coral recruitment by macroalgae and cyanobacteria. Marine Ecology Progress Series **323**:107-117.

Lang, J., K. Marks, P. Kramer, P. Kramer, and R. Ginsburg. 2010. AGRRA protocols version 5.4. Atlantic and Gulf Rapid Reef Assessment Program. University of Miami, Florida. http://www.agrra.org.

Manzello, D. P. 2015. Rapid recent warming of coral reefs in the Florida Keys. Scientific reports **5**:1-10.

Miller, M. W., K. E. Lohr, C. M. Cameron, D. E. Williams, and E. C. Peters. 2014. Disease dynamics and potential mitigation among restored and wild staghorn coral, Acropora cervicornis. PeerJ **2**:e541.

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

Morrow, K. M., K. Bromhall, C. A. Motti, C. B. Munn, and D. G. Bourne. 2017. Allelochemicals produced by brown macroalgae of the Lobophora genus are active against coral larvae and associated bacteria, supporting pathogenic shifts to Vibrio dominance. Applied and Environmental Microbiology **83**:e02391-02316.

Muller, E. M., C. Sartor, N. I. Alcaraz, and R. van Woesik. 2020. Spatial Epidemiology of the Stony-Coral-Tissue-Loss Disease in Florida. Frontiers in Marine Science **7**.

Muller, E. M., and R. van Woesik. 2012. Caribbean coral diseases: primary transmission or secondary infection? Global Change Biology **18**:3529-3535.

Paul, V. J., I. B. Kuffner, L. J. Walters, R. Ritson-Williams, K. S. Beach, and M. A. Becerro. 2011. Chemically mediated interactions between macroalgae Dictyota spp. and multiple life-history stages of the coral Porites astreoides. Marine Ecology Progress Series **426**:161-170.

Pawlik, J. R., and S. E. McMurray. 2020. The Emerging Ecological and Biogeochemical Importance of Sponges on Coral Reefs. Annual Review of Marine Science **12**:315-337.

Porter, J. W., and O. W. Meier. 1992. Quantification of Loss and Change in Floridian Reef Coral Populations. Amer. Zool. **32**:625-640.

Porter, J. W., and K. G. Porter, editors. 2002. The Everglades, Florida bay, and Coral Reefs of the Florida Keys. CRC Press, Boca Raton, FL.

Precht, W. F., B. E. Gintert, M. L. Robbart, R. Fura, and R. van Woesik. 2016. Unprecedented Disease-Related Coral Mortality in Southeastern Florida. Scientific Reports **6**:31374.

Precht, W. F., and S. L. Miller. 2007. Ecological Shifts along the Florida Reef Tract: The Past as a Key to the Future. Pages 237-312 *in* R. B. Aronson, editor. Geological Approaches to Coral Reef Ecology. Springer, NY, p 237-312.

Roberts, H. H., L. J. Rouse, N. D. Walker, and J. H. Hudson. 1982. Cold-water stress in Florida Bay and Northern Bahamas: A product of winter cold-air outbreaks. Journal of Sedimentary Research **52**:145-155.

Ruzicka, R., M. Colella, K. Cummings, T. Boisvert, V. Brinkhuis, A. Ellis, A. Halperin, and L. Huebner. 2018. Long-term Monitoring & Assessment of Selected Coral Reef Sites in the Dry Tortugas National Park. 2015-2016 Final Report. Fish & Wildlife Research Institute/Florida Fish & Wildlife Conservation Commission, Saint Petersburg, FL.

Ruzicka, R., M. Colella, J. Porter, J. Morrison, J. Kidney, V. Brinkhuis, K. Lunz, K. Macaulay, L. Bartlett, M. Meyers, and J. Colee. 2013. Temporal changes in benthic assemblages on Florida Keys reefs 11 years after the 1997/1998 El Nino. Marine Ecology Progress Series **489**:125-141.

Ruzicka, R., M. Colella, K. Cummings, L. Huebner, S. Schopmeyer, T. Boisvert, A. Ellis, J. Stein, and N. Berkebile. 2022. Long-term Monitoring of Selected Coral Reefs in Dry Tortugas National Park 2019-2020 Biennial Report. Fish and Wildlife Research Institute.

Santavy, D. L., J. K. Summers, V. D. Engle, and L. C. Harwell. 2005. The condition of coral reefs in South Florida (2000) using coral disease and bleaching as indicators. Environmental Monitoring and Assessment **100**:129-152.

Stein, J. a. R. R. 2022. Florida Reef Resilience Program Disturbance Response Monitoring 2021 Quick Look Report. FWRI.

Suchley, A., M. D. McField, and L. Alvarez-Filip. 2016. Rapidly increasing macroalgal cover not related to herbivorous fishes on Mesoamerican reefs. PeerJ **4**:e2084.

Toth, L. T., T. A. Courtney, M. A. Colella, and R. R. Ruzicka. 2023. Stony coral tissue loss disease accelerated shifts in coral composition and declines in reef accretion potential in the Florida Keys. Frontiers in Marine Science **10**.

Toth, L. T., A. Stathakopoulos, I. B. Kuffner, R. R. Ruzicka, M. A. Colella, and E. A. Shinn. 2019. The unprecedented loss of Florida's reef-building corals and the emergence of a novel coral-reef assemblage. Ecology **100**:e02781.

Toth, L. T., R. van Woesik, T. J. T. Murdoch, S. R. Smith, J. C. Ogden, W. F. Precht, and R. B. Aronson. 2014. Do no-take reserves benefit Florida's corals? 14 years of change and stasis in the Florida Keys National Marine Sanctuary. Coral Reefs **33**:565-577.

Tsounis, G., and P. J. Edmunds. 2017. Three decades of coral reef community dynamics in St. John, USVI: a contrast of scleractinians and octocorals. Ecosphere **8**:e01646.

Vroom, P. S., C. M. Smith, J. A. Coyer, L. J. Walters, C. L. Hunter, K. S. Beach, and J. E. Smith. 2003. Field biology of Halimeda tuna (Bryopsidales, Chlorophyta) across a depth gradient: comparative growth, survivorship, recruitment, and reproduction. Hydrobiologia **501**:149-166.

Wagner, K. M., and B. L. Willis. 2010. Impacts of bleaching on the soft coral Lobophytum compactum. I. Fecundity, fertilization and offspring viability. Coral Reef **19**:8.

Walton, C. J., N. K. Hayes, and D. S. Gilliam. 2018. Impacts of a regional, multi-year, multi-species coral disease outbreak in Southeast Florida. Frontiers in Marine Science **5**:323.

Weil, E., and A. Cróquer. 2009. Spatial variability in distribution and prevalence of Caribbean scleractinian coral and octocoral diseases. I. Community-level analysis. Diseases of Aquatic Organisms **83**:195-208.

Williams, D. E., M. W. Miller, and K. L. Kramer. 2008. Recruitment failure in Florida Keys Acropora palmata, a threatened Caribbean coral. Coral Reefs **27**:697-705.

Ziegler, T., and J. Hunt. 2012. Implementing the Dry Tortugas National Park Research Natural Area Science Plan: The 5—year Report 2012. South Florida Natural Resources Center, Everglades and Dry Tortugas National Parks, Homestead, FL, USA and the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, USA.

Appendices

Appendix A: Average percent cover of major taxonomic groups for each survey site for each year.

Bird Key Reef:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
1999		11.7%	21.0%	1.7%	0.0%	19.3%	46.4%	0.0%
2000		14.3%	16.7%	0.9%	0.0%	19.7%	48.4%	0.0%
2001		8.5%	19.2%	0.6%	0.0%	20.3%	51.4%	0.0%
2002		22.4%	19.2%	1.2%	0.0%	12.7%	44.5%	0.0%
2003		1.8%	17.4%	0.7%	0.0%	15.2%	64.9%	0.0%
2004		0.7%	13.5%	0.5%	0.0%	12.8%	72.5%	0.0%
2005		6.8%	11.6%	0.5%	0.0%	10.3%	70.8%	0.0%
2006		3.1%	13.9%	0.4%	0.0%	10.0%	72.5%	0.1%
2007		16.9%	13.1%	0.6%	0.0%	9.6%	59.8%	0.0%
2008		24.3%	9.9%	0.6%	0.0%	11.0%	54.0%	0.0%
2009		16.9%	13.3%	0.4%	0.0%	12.1%	57.4%	0.0%
2010	0.4%	53.8%	12.9%	0.3%	0.0%	8.3%	24.1%	0.0%
2011	8.1%	26.6%	14.5%	0.8%	0.0%	10.4%	39.4%	0.0%
2012	1.2%	31.5%	15.5%	0.6%	0.0%	9.0%	42.0%	0.0%
2013	4.3%	42.0%	15.0%	0.8%	0.0%	9.3%	27.9%	0.0%
2014	2.2%	43.7%	15.8%	0.5%	0.0%	10.5%	26.6%	0.0%
2015	6.7%	37.3%	13.4%	0.9%	0.0%	9.0%	31.8%	0.0%
2016	0.6%	33.0%	15.2%	0.8%	0.0%	10.2%	39.7%	0.0%
2017	2.5%	45.4%	15.7%	1.1%	0.0%	9.0%	25.6%	0.0%
2018	1.7%	42.8%	18.2%	1.3%	0.0%	8.5%	27.0%	0.0%
2019	25.3%	24.0%	20.1%	1.0%	0.0%	9.6%	19.5%	0.0%
2020	6.4%	36.3%	18.8%	1.1%	0.0%	8.2%	28.3%	0.0%
2021	10.9%	46.3%	17.1%	1.3%	0.0%	7.8%	15.3%	0.0%
2022	2.9%	42.0%	14.8%	1.1%	0.0%	6.5%	32.0%	0.0%

Appendix A: continued

Black Coral Rock:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
1999		7.0%	9.5%	6.5%	0.0%	25.5%	51.3%	0.1%
2000		10.6%	9.9%	1.8%	0.0%	20.5%	57.1%	0.0%
2001		16.0%	12.9%	4.3%	0.0%	21.1%	45.6%	0.0%
2002		3.3%	8.8%	3.8%	0.4%	19.3%	64.2%	0.1%
2003		22.6%	11.6%	3.3%	0.0%	21.3%	41.0%	0.2%
2004		19.8%	9.9%	2.6%	0.0%	20.4%	47.2%	0.0%
2005		0.9%	6.4%	2.6%	0.0%	22.2%	68.0%	0.0%
2006		15.0%	4.5%	1.5%	0.0%	16.2%	62.7%	0.1%
2007		10.8%	6.7%	1.8%	0.0%	15.3%	65.4%	0.0%
2008		1.0%	7.7%	3.3%	0.0%	17.8%	70.2%	0.0%
2009		39.5%	6.8%	3.4%	0.0%	18.0%	32.4%	0.0%
2010	5.3%	38.9%	8.1%	3.9%	0.0%	15.1%	28.5%	0.0%
2011	5.1%	42.8%	9.0%	3.2%	0.0%	13.8%	25.9%	0.0%
2012	7.0%	25.7%	6.0%	5.8%	0.0%	15.3%	39.3%	0.0%
2013	4.0%	38.3%	7.9%	4.3%	0.0%	13.4%	30.3%	0.0%
2014	8.7%	37.2%	9.6%	3.9%	0.0%	14.5%	25.1%	0.0%
2015	2.2%	51.9%	8.8%	4.9%	0.0%	13.8%	17.6%	0.0%
2016	3.5%	37.2%	10.3%	5.0%	0.0%	13.8%	29.6%	0.0%
2017	2.5%	43.7%	9.0%	5.0%	0.0%	14.0%	24.7%	0.0%
2018	10.0%	38.9%	9.7%	3.2%	0.0%	13.2%	24.2%	0.0%
2019	14.1%	44.4%	8.4%	4.5%	0.0%	13.3%	14.5%	0.0%
2020	10.0%	45.0%	10.2%	4.4%	0.0%	13.0%	16.9%	0.0%
2021	21.3%	31.4%	10.6%	4.9%	0.0%	12.4%	18.6%	0.0%
2022	20.6%	34.5%	10.7%	3.2%	0.0%	9.2%	20.8%	0.0%

Appendix A: continued

Davis Rock:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2009		25.3%	0.6%	2.3%	0.0%	8.5%	59.7%	3.2%
2010	0.5%	67.5%	0.0%	1.1%	0.0%	10.0%	19.6%	1.2%
2011	8.0%	38.6%	1.5%	3.2%	0.0%	9.3%	36.2%	1.9%
2012	0.5%	48.0%	0.6%	2.7%	0.0%	10.6%	35.0%	1.8%
2013	0.2%	58.8%	0.5%	3.0%	0.0%	10.3%	24.2%	1.3%
2014	4.0%	34.0%	2.5%	1.9%	0.0%	10.7%	44.3%	1.8%
2015	0.6%	54.1%	1.4%	3.1%	0.0%	8.7%	30.2%	1.5%
2016	0.9%	30.6%	1.6%	4.5%	0.0%	9.8%	50.1%	1.7%
2017	1.5%	51.0%	2.4%	3.8%	0.0%	9.3%	29.6%	1.2%
2018	5.1%	46.5%	2.4%	3.2%	0.0%	8.9%	31.4%	1.2%
2019	4.1%	48.7%	2.9%	4.1%	0.0%	9.0%	29.2%	0.7%
2020	3.7%	50.2%	2.7%	4.1%	0.0%	8.3%	28.1%	1.2%
2021	2.4%	51.1%	3.6%	2.8%	0.0%	8.7%	28.6%	1.5%
2022	5.8%	37.9%	2.6%	2.6%	0.0%	8.2%	39.3%	1.2%

Loggerhead Patch:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2005		7.1%	1.2%	0.3%	0.0%	4.1%	87.2%	0.0%
2006		6.9%	0.8%	0.1%	0.0%	1.6%	90.6%	0.0%
2007		1.3%	1.0%	0.5%	0.0%	2.5%	94.7%	0.0%
2008		1.6%	1.1%	0.2%	0.0%	1.8%	95.3%	0.0%
2009		12.0%	0.5%	0.7%	0.0%	2.3%	84.4%	0.0%
2010	0.0%	16.3%	0.8%	1.0%	0.0%	1.9%	79.9%	0.0%
2011	0.1%	14.1%	2.0%	1.6%	0.0%	2.6%	79.6%	0.0%
2012	0.0%	30.3%	1.4%	1.7%	0.0%	1.8%	64.4%	0.0%
2013	0.1%	24.6%	1.6%	1.3%	0.0%	2.0%	70.3%	0.0%
2014	0.1%	32.6%	1.6%	0.8%	0.0%	1.9%	62.5%	0.0%
2015	0.0%	22.6%	1.6%	1.3%	0.1%	2.0%	71.6%	0.0%
2016	0.0%	26.7%	2.0%	1.1%	0.6%	1.4%	68.1%	0.0%
2017	0.0%	32.5%	2.7%	0.7%	0.3%	1.0%	62.5%	0.0%
2018	0.0%	12.9%	2.7%	0.6%	0.6%	0.9%	82.1%	0.0%
2019	0.0%	16.3%	2.1%	0.9%	4.7%	0.9%	74.5%	0.0%
2020	0.0%	18.9%	2.0%	0.5%	1.2%	0.9%	76.2%	0.0%
2021	0.0%	29.5%	1.4%	0.7%	1.4%	1.3%	64.5%	0.0%
2022	0.2%	41.2%	1.8%	1.3%	0.9%	1.6%	52.9%	0.0%

Appendix A: continued

Mayer's Peak:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2004		0.4%	24.1%	3.9%	0.0%	3.4%	62.4%	5.8%
2005		1.0%	24.5%	2.6%	0.0%	4.4%	62.8%	4.7%
2006		4.1%	20.1%	1.4%	0.0%	2.9%	66.5%	5.1%
2007		6.2%	20.7%	2.6%	0.0%	4.2%	62.9%	3.3%
2008		0.7%	16.6%	2.6%	0.0%	3.9%	72.1%	4.0%
2009		32.2%	18.5%	3.1%	0.0%	3.4%	38.9%	3.8%
2010	0.0%	48.1%	19.7%	3.4%	0.0%	4.3%	20.6%	3.8%
2011	0.6%	17.1%	23.6%	4.9%	0.0%	4.1%	45.1%	4.1%
2012	0.0%	27.5%	23.7%	4.5%	0.0%	4.2%	34.2%	5.2%
2013	0.2%	27.4%	26.8%	4.4%	0.0%	3.9%	33.6%	3.2%
2014	0.4%	27.7%	25.8%	4.5%	0.0%	4.4%	31.8%	4.3%
2015	0.8%	20.8%	24.4%	4.4%	0.0%	5.1%	40.0%	4.0%
2016	0.5%	15.4%	30.8%	4.3%	0.0%	4.3%	40.0%	4.2%
2017	1.2%	15.5%	28.7%	5.4%	0.0%	5.1%	39.3%	3.8%
2018	0.6%	12.6%	31.2%	4.7%	0.0%	5.1%	40.9%	4.5%
2019	13.1%	28.4%	21.8%	4.5%	0.0%	5.4%	20.9%	4.8%
2020	3.2%	28.9%	28.7%	4.7%	0.0%	5.5%	24.5%	4.2%
2021	7.3%	9.2%	32.4%	4.1%	0.0%	4.6%	37.5%	4.5%
2022	4.2%	10.1%	29.1%	4.3%	0.0%	4.1%	42.3%	5.7%

Appendix A: continued

Palmata Patch:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2004		2.2%	4.8%	0.3%	0.0%	5.8%	86.6%	0.3%
2005		1.3%	2.7%	0.2%	0.0%	5.5%	89.9%	0.3%
2006		4.6%	0.9%	0.1%	0.0%	2.5%	91.7%	0.2%
2007		1.0%	1.5%	0.1%	0.0%	2.9%	94.4%	0.0%
2008		1.9%	2.8%	0.1%	0.0%	3.6%	91.2%	0.2%
2009		12.3%	3.4%	0.3%	0.0%	4.4%	79.1%	0.1%
2010	0.0%	4.9%	6.8%	0.0%	0.0%	6.1%	81.7%	0.2%
2011	0.1%	12.0%	8.4%	0.2%	0.0%	9.3%	69.8%	0.1%
2012	0.1%	5.2%	13.3%	0.2%	0.0%	7.8%	73.0%	0.2%
2013	0.1%	6.6%	11.4%	0.1%	0.0%	8.0%	73.4%	0.1%
2014	0.7%	8.2%	14.8%	0.2%	0.0%	9.6%	66.0%	0.1%
2015	1.7%	7.7%	13.7%	0.5%	0.0%	7.7%	67.9%	0.2%
2016	0.2%	3.1%	13.5%	0.4%	0.0%	8.2%	73.9%	0.2%
2017	0.8%	13.3%	16.6%	0.7%	0.0%	8.2%	59.4%	0.2%
2018	0.0%	21.1%	14.9%	0.1%	0.0%	6.5%	56.8%	0.2%
2019	0.1%	21.5%	15.5%	0.3%	0.0%	8.3%	53.8%	0.2%
2020	0.5%	18.5%	10.6%	1.2%	0.0%	9.3%	59.0%	0.1%
2021	0.7%	17.2%	12.9%	0.7%	0.0%	11.1%	57.2%	0.2%
2022	0.3%	15.4%	11.8%	0.6%	0.0%	11.1%	59.2%	0.2%

Appendix A: continued

Prolifera Patch:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2004		1.1%	6.0%	0.3%	1.9%	15.2%	75.5%	0.0%
2005		1.2%	7.4%	0.4%	1.6%	13.8%	75.4%	0.1%
2006		7.4%	4.5%	0.1%	2.9%	12.3%	72.7%	0.1%
2007		2.3%	3.4%	0.2%	2.2%	14.5%	77.3%	0.0%
2008		3.4%	3.7%	0.2%	1.4%	13.1%	78.1%	0.0%
2009		6.2%	2.8%	0.3%	1.6%	14.0%	75.1%	0.0%
2010	0.0%	4.2%	3.4%	0.5%	2.9%	15.3%	73.6%	0.0%
2011	0.0%	11.9%	3.1%	0.7%	3.9%	18.1%	62.1%	0.0%
2012	0.0%	4.5%	3.1%	0.6%	3.6%	19.3%	68.5%	0.1%
2013	0.0%	4.0%	3.6%	0.6%	2.0%	18.7%	70.7%	0.1%
2014	0.2%	2.8%	3.7%	0.7%	2.5%	20.1%	69.6%	0.0%
2015	0.3%	3.6%	3.7%	0.6%	2.6%	17.5%	71.3%	0.0%
2016	0.3%	4.2%	4.3%	1.0%	3.9%	16.0%	69.9%	0.0%
2017	0.3%	9.3%	4.8%	0.9%	2.1%	16.6%	65.2%	0.0%
2018	0.0%	16.3%	6.2%	0.4%	1.6%	14.6%	60.3%	0.1%
2019	0.0%	13.0%	6.7%	0.2%	1.8%	17.3%	60.6%	0.1%
2020	0.1%	12.8%	5.6%	0.5%	1.7%	20.7%	58.3%	0.1%
2021	0.1%	7.5%	6.2%	0.4%	1.6%	23.2%	60.4%	0.0%
2022	0.2%	9.6%	6.3%	0.7%	1.5%	19.9%	61.1%	0.0%

Appendix A: continued

Temptation Rock:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2004		12.1%	15.1%	1.1%	0.0%	4.2%	55.7%	11.7%
2005		4.9%	15.4%	1.3%	0.0%	4.0%	62.3%	12.1%
2006		6.4%	14.8%	1.3%	0.0%	3.3%	61.1%	13.1%
2007		10.1%	15.4%	1.2%	0.0%	2.4%	60.1%	10.9%
2008		18.2%	11.0%	0.9%	0.0%	4.3%	54.2%	11.4%
2009		27.8%	10.3%	2.2%	0.0%	4.9%	42.6%	12.1%
2010	0.1%	46.0%	11.1%	1.7%	0.0%	4.0%	27.1%	9.9%
2011	2.4%	22.5%	14.8%	1.8%	0.0%	5.5%	40.4%	12.1%
2012	0.4%	28.7%	14.6%	2.4%	0.0%	3.8%	39.3%	10.5%
2013	0.0%	41.2%	15.6%	1.6%	0.0%	4.9%	26.8%	9.3%
2014	0.3%	22.4%	12.9%	2.0%	0.0%	5.7%	45.1%	11.2%
2015	0.8%	24.3%	9.9%	2.1%	0.0%	6.5%	45.4%	10.7%
2016	0.1%	17.3%	13.2%	2.7%	0.0%	5.0%	51.8%	9.5%
2017	0.4%	31.7%	13.7%	2.8%	0.0%	4.5%	35.4%	10.4%
2018	1.7%	33.4%	20.9%	2.0%	0.0%	2.9%	28.4%	10.0%
2019	3.0%	40.1%	11.3%	2.5%	0.0%	4.7%	27.7%	10.4%
2020	1.9%	34.9%	19.7%	2.8%	0.0%	4.6%	25.1%	10.2%
2021	0.1%	26.2%	17.5%	2.7%	0.0%	5.4%	36.7%	10.8%
2022	1.2%	24.5%	17.5%	2.4%	0.0%	3.4%	38.5%	12.1%

Texas Rock:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2009		19.8%	5.5%	4.0%	0.0%	6.2%	60.5%	3.1%
2010	0.4%	34.4%	4.0%	4.4%	0.0%	8.4%	45.9%	2.4%
2011	4.0%	35.9%	4.6%	5.1%	0.0%	7.5%	39.4%	2.3%
2012	0.7%	40.1%	2.3%	5.4%	0.0%	8.7%	38.4%	3.2%
2013	0.6%	39.3%	2.6%	5.0%	0.0%	6.7%	40.2%	2.9%
2014	0.7%	35.5%	3.7%	5.1%	0.0%	7.5%	42.7%	2.4%
2015	2.6%	39.5%	2.9%	5.4%	0.0%	7.6%	38.7%	1.7%
2016	3.1%	30.2%	3.2%	5.3%	0.0%	7.0%	46.3%	1.6%
2017	1.5%	32.0%	2.8%	5.4%	0.0%	6.6%	46.6%	1.5%
2018	4.4%	38.6%	3.7%	6.1%	0.0%	6.3%	35.9%	1.3%
2019	7.8%	37.8%	3.4%	6.9%	0.0%	5.8%	33.7%	1.4%
2020	6.5%	41.3%	3.5%	7.1%	0.0%	6.5%	30.9%	1.0%
2021	2.4%	38.3%	5.9%	7.2%	0.0%	6.8%	35.6%	1.3%
2022	5.1%	40.9%	4.8%	4.7%	0.0%	3.5%	35.9%	1.2%

Appendix A: continued

The Maze:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2009		31.1%	7.0%	2.4%	0.0%	11.1%	45.2%	3.1%
2010	0.0%	52.9%	6.2%	3.9%	0.0%	11.0%	22.6%	3.0%
2011	0.5%	21.7%	7.9%	5.0%	0.0%	12.4%	48.4%	3.5%
2012	0.1%	34.0%	7.1%	4.4%	0.0%	12.7%	38.6%	2.7%
2013	0.2%	34.4%	7.7%	4.2%	0.0%	11.1%	39.8%	1.9%
2014	1.0%	28.5%	8.2%	3.9%	0.0%	13.1%	42.3%	2.3%
2015	0.4%	29.7%	9.0%	5.6%	0.0%	10.9%	40.7%	3.2%
2016	0.6%	22.3%	12.3%	5.2%	0.0%	13.1%	43.2%	2.7%
2017	1.1%	24.3%	9.5%	6.2%	0.0%	9.5%	46.1%	2.6%
2018	1.6%	33.3%	11.4%	4.8%	0.0%	10.4%	35.5%	2.0%
2019	10.4%	39.9%	9.5%	5.4%	0.0%	10.2%	21.8%	2.0%
2020	5.6%	38.8%	11.9%	3.9%	0.0%	10.0%	26.8%	1.8%
2021	1.7%	29.5%	12.4%	5.3%	0.0%	10.5%	37.1%	2.0%
2022	2.1%	26.5%	14.9%	4.2%	0.0%	7.3%	39.9%	3.1%

Appendix A: continued

White Shoal:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
1999		5.3%	9.5%	3.0%	0.0%	8.7%	73.5%	0.0%
2000		8.9%	9.7%	4.9%	0.0%	7.9%	68.7%	0.0%
2001		9.3%	9.2%	1.8%	0.0%	5.3%	74.2%	0.0%
2002		9.3%	7.7%	1.7%	0.0%	6.7%	74.6%	0.0%
2003		14.0%	9.1%	1.7%	0.0%	4.2%	71.0%	0.0%
2004		6.5%	3.5%	0.4%	0.0%	1.9%	87.7%	0.0%
2005		9.5%	3.5%	0.2%	0.0%	1.3%	85.4%	0.0%
2006		13.2%	4.9%	0.4%	0.0%	1.4%	80.2%	0.0%
2007		17.7%	7.3%	0.9%	0.0%	1.0%	73.1%	0.0%
2008		13.2%	9.5%	0.8%	0.0%	1.4%	74.9%	0.0%
2009		30.2%	12.5%	0.4%	0.0%	1.4%	55.3%	0.0%
2010	0.0%	34.8%	15.5%	0.6%	0.0%	2.1%	46.9%	0.0%
2011	6.7%	21.4%	18.2%	1.1%	0.0%	2.5%	49.8%	0.0%
2012	0.5%	28.4%	17.7%	2.2%	0.0%	1.8%	48.9%	0.0%
2013	0.0%	20.7%	17.9%	1.5%	0.0%	2.7%	57.1%	0.0%
2014	2.7%	16.7%	20.1%	1.7%	0.0%	3.4%	55.0%	0.0%
2015	2.1%	18.5%	14.5%	2.1%	0.0%	4.0%	58.2%	0.0%
2016	1.4%	18.2%	15.2%	3.7%	0.0%	3.6%	57.7%	0.0%
2017	1.1%	18.0%	19.4%	3.1%	0.0%	3.8%	53.5%	0.0%
2018	0.3%	34.4%	14.7%	2.6%	0.0%	2.8%	44.4%	0.0%
2019	6.5%	30.5%	12.4%	2.6%	0.0%	2.6%	45.4%	0.0%
2020	3.4%	24.6%	16.6%	4.1%	0.0%	4.4%	46.6%	0.0%
2021	0.2%	30.3%	19.6%	2.5%	0.0%	3.3%	43.2%	0.0%
2022	1.4%	24.6%	14.7%	1.6%	0.0%	4.3%	52.1%	0.0%

Appendix A: continued

Little Africa:

Year	Cyano-bacteria	Macroalgae	Octocoral	Porifera	Seagrass	Stony Coral	Substrate	Zoanthids
2007		4.0%	4.4%	0.4%	0.0%	18.8%	71.3%	0.9%
2008		15.1%	4.5%	0.0%	0.0%	26.4%	53.5%	0.5%
2009		10.4%	5.6%	0.3%	0.0%	29.7%	53.4%	0.3%
2010	2.7%	14.8%	7.0%	0.2%	0.0%	22.2%	51.9%	1.0%
2011	1.0%	21.9%	9.8%	0.3%	0.0%	13.5%	51.7%	1.5%
2012	0.1%	16.0%	4.2%	0.3%	0.0%	20.9%	54.8%	3.6%
2013	4.0%	18.6%	4.5%	0.6%	0.0%	23.7%	46.0%	1.7%
2014	0.1%	12.0%	8.5%	0.3%	0.0%	11.5%	65.0%	2.0%
2015	0.1%	18.3%	4.1%	0.5%	0.0%	10.5%	59.6%	6.6%
2016	0.0%	12.6%	7.0%	0.5%	0.1%	16.4%	59.8%	2.7%
2017	0.2%	21.5%	11.0%	0.3%	0.3%	16.0%	46.9%	2.8%
2018	1.7%	23.9%	8.3%	0.3%	0.0%	14.9%	47.2%	3.2%
2019	8.8%	25.3%	7.9%	0.4%	0.0%	13.2%	38.7%	4.7%
2020	2.8%	27.6%	8.7%	0.8%	0.1%	15.3%	43.1%	0.4%
2021	1.9%	22.7%	8.8%	0.6%	0.0%	12.3%	48.1%	3.6%
2022	2.7%	21.1%	5.9%	0.3%	0.0%	11.4%	52.7%	3.8%

Appendix B: Average percent cover of coral species for each survey site for each year. Species not listed have not been found at the given site. An asterisk (*) denotes a species complex. *Mycetophyllia lamarckiana* includes *M. danaana*. *Orbicella annularis* includes *O. faveolata* and *O. franksi*. *Porites porites* includes *P. furcata* and *P. divaricata*. *Madracis decactis* includes *M. pharensis* and *M. senaria*. *Agaricia agaricites* includes *A. humilus* and *A. tenuifolia*.

Bird Key Reef:

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
*Agaricia agaricites**	0.0%	0.1%	0.0%	0.0%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%
Acropora cervicornis	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	2.1%	3.3%	3.1%	0.7%	0.4%	0.8%	0.3%	0.7%	0.6%	0.8%	0.4%	0.4%
Diploria labyrinthiformis	0.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%
Meandrina meandrites	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	0.7%	0.3%	0.5%	0.3%	0.8%	0.4%	0.4%	0.2%	0.2%	0.5%	0.6%	0.3%
Montastraea cavernosa	2.2%	2.4%	2.1%	2.7%	1.7%	2.0%	0.8%	1.7%	0.8%	0.6%	1.5%	1.2%
Mycetophyllia aliciae	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.3%	0.0%	0.1%	0.2%	0.1%
Mycetophyllia ferox	0.0%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	9.2%	10.0%	10.9%	6.1%	8.1%	6.7%	5.6%	5.5%	5.8%	6.7%	7.8%	4.7%
Porites astreoides	1.1%	0.9%	1.0%	1.4%	1.0%	0.9%	1.0%	0.2%	0.6%	0.5%	0.3%	0.2%
*Porites porites**	0.3%	0.2%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Pseudodiploria strigosa	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Scleractinia	0.3%	0.5%	0.3%	0.0%	0.3%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%
Siderastrea siderea	2.3%	1.3%	1.5%	0.8%	2.1%	1.3%	1.5%	1.3%	1.2%	1.5%	1.1%	0.7%
Solenastrea bournoni	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Stephanocoenia intersepta	0.1%	0.3%	0.3%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%

Appendix B: continued

Bird Key Reef (continued):

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.2%	0.1%	0.2%	0.0%	0.1%	0.2%	0.1%	0.1%	0.2%	0.1%	0.1%	0.0%
Acropora cervicornis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	0.3%	0.4%	0.6%	0.4%	0.6%	0.8%	0.6%	0.3%	0.9%	0.6%	0.1%	0.0%
Diploria labyrinthiformis	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%
Meandrina meandrites	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
Millepora alcicornis	0.4%	0.3%	0.5%	0.5%	0.3%	0.5%	0.5%	0.5%	0.5%	0.4%	0.3%	0.3%
Montastraea cavernosa	1.8%	1.3%	1.1%	0.8%	0.8%	0.8%	0.9%	0.6%	0.9%	0.9%	0.7%	0.3%
Mycetophyllia aliciae	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	4.8%	4.6%	4.7%	5.1%	5.3%	4.8%	3.7%	3.7%	4.2%	3.0%	2.5%	2.4%
Porites astreoides	0.6%	0.4%	0.4%	0.6%	0.8%	0.9%	0.7%	0.7%	0.4%	0.7%	0.9%	0.6%
*Porites porites**	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.3%	0.3%	0.2%	0.5%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.4%	0.0%
Scleractinia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	1.6%	1.6%	1.6%	2.4%	1.0%	1.7%	2.0%	2.0%	1.9%	1.5%	2.3%	2.0%
Solenastrea bournoni	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Stephanocoenia intersepta	0.3%	0.1%	0.0%	0.2%	0.1%	0.3%	0.0%	0.4%	0.0%	0.3%	0.3%	0.3%

Appendix B: continued

Black Coral Rock:

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
*Agaricia agaricites**	0.1%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora cervicornis	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Agaricia fragilis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Agaricia lamarcki	0.1%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	2.7%	1.4%	1.9%	2.5%	1.3%	1.9%	2.1%	1.1%	0.9%	1.1%	1.5%	0.8%
Dichocoenia stokesii	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Helioseris cucullata	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Madracis decactis**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.0%	0.1%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Millepora alcicornis	1.1%	0.5%	0.5%	0.8%	0.7%	0.8%	0.8%	0.5%	0.6%	0.8%	0.9%	0.6%
Montastraea cavernosa	7.7%	5.0%	5.7%	5.9%	6.1%	5.1%	6.4%	5.6%	3.8%	4.9%	4.8%	5.4%
Mycetophyllia aliciae	0.3%	0.2%	0.3%	0.4%	0.2%	0.3%	0.1%	0.4%	0.2%	0.4%	0.4%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.0%	0.0%	0.2%
*Mycetophyllia lamarckiana**	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
*Orbicella annularis**	10.7%	10.8%	10.4%	8.2%	11.0%	9.7%	10.6%	7.1%	8.5%	9.0%	8.1%	6.3%
Porites astreoides	0.5%	0.4%	0.8%	0.7%	0.2%	0.8%	0.7%	0.4%	0.5%	0.5%	0.9%	0.5%
*Porites porites**	0.4%	0.4%	0.3%	0.1%	0.8%	0.4%	0.2%	0.1%	0.3%	0.1%	0.6%	0.2%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Scleractinia	1.1%	0.7%	0.0%	0.3%	0.3%	0.0%	0.1%	0.3%	0.0%	0.2%	0.0%	0.0%
Siderastrea siderea	0.4%	0.3%	0.7%	0.4%	0.1%	0.6%	0.4%	0.4%	0.3%	0.7%	0.5%	0.7%
Solenastrea bournoni	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Stephanocoenia intersepta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%

Appendix B: continued

Black Coral Rock (continued):

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora cervicornis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Agaricia fragilis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Agaricia lamarcki	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Colpophyllia natans	1.5%	1.4%	1.0%	1.6%	1.4%	1.3%	1.3%	1.4%	1.2%	1.7%	1.2%	0.0%
Dichocoenia stokesii	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Helioseris cucullata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Madracis decactis**	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	0.5%	1.0%	0.7%	1.1%	0.8%	1.0%	0.9%	0.7%	0.7%	0.9%	0.9%	0.7%
Montastraea cavernosa	4.5%	4.6%	3.9%	4.5%	4.1%	3.9%	3.4%	3.1%	3.5%	3.2%	2.6%	2.2%
Mycetophyllia aliciae	0.0%	0.2%	0.2%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	6.1%	6.0%	6.3%	5.8%	5.8%	5.7%	6.1%	6.4%	6.5%	5.7%	5.8%	4.4%
Porites astreoides	0.5%	0.6%	0.5%	0.3%	0.6%	0.4%	0.4%	0.4%	0.5%	0.5%	0.7%	0.7%
*Porites porites**	0.0%	0.4%	0.1%	0.2%	0.3%	0.2%	0.2%	0.1%	0.2%	0.1%	0.2%	0.2%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scleractinia	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Siderastrea siderea	0.4%	0.7%	0.4%	0.8%	0.4%	0.6%	0.8%	0.4%	0.6%	0.5%	0.6%	0.6%
Solenastrea bournoni	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stephanocoenia intersepta	0.1%	0.2%	0.1%	0.0%	0.2%	0.5%	0.4%	0.3%	0.1%	0.2%	0.2%	0.2%

Appendix B: continued

Davis Rock:

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	1.8%	0.9%	0.3%	0.7%	0.4%	0.7%	0.6%	1.3%	0.9%	1.0%	1.3%	0.9%	0.8%	0.4%
Diploria labyrinthiformis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.4%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	0.7%	1.5%	1.5%	1.1%	0.9%	1.2%	0.7%	1.4%	1.3%	0.5%	1.2%	1.0%	0.8%	0.3%
Montastraea cavernosa	1.7%	1.6%	1.8%	2.4%	2.2%	2.4%	2.1%	1.5%	1.7%	1.5%	1.5%	1.9%	1.5%	1.3%
Mycetophyllia ferox	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	3.4%	5.4%	4.5%	4.5%	5.7%	4.3%	3.2%	3.4%	3.4%	3.9%	3.1%	2.9%	3.6%	4.3%
Porites astreoides	0.1%	0.2%	0.2%	0.6%	0.4%	0.6%	0.4%	0.7%	0.7%	0.7%	0.7%	0.5%	0.8%	0.7%
*Porites porites**	0.1%	0.2%	0.3%	0.3%	0.2%	0.5%	0.4%	0.4%	0.4%	0.3%	0.3%	0.2%	0.2%	0.3%
Pseudodiploria clivosa	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.2%	0.2%	0.1%	0.0%	0.1%	0.1%	0.2%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.1%	0.3%	0.1%	0.3%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%
Siderastrea siderea	0.2%	0.0%	0.2%	0.3%	0.2%	0.4%	0.5%	0.4%	0.4%	0.6%	0.4%	0.4%	0.5%	0.5%
Solenastrea bournoni	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stephanocoenia intersepta	0.1%	0.0%	0.1%	0.0%	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.3%

Appendix B: continued

Loggerhead Patch:

Species	2005	2006	2007	2008	2009	2010	2011	2012	2013
*Agaricia agaricites**	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Acropora cervicornis	1.9%	0.2%	0.2%	0.1%	0.2%	0.0%	0.1%	0.1%	0.0%
Millepora alcicornis	1.5%	0.7%	1.5%	1.0%	1.5%	1.2%	1.8%	0.8%	1.2%
*Orbicella annularis**	0.4%	0.5%	0.4%	0.6%	0.4%	0.4%	0.6%	0.6%	0.5%
Porites astreoides	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Porites porites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%
Pseudodiploria clivosa	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%

Loggerhead Patch, cont.

Species	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora cervicornis	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	1.1%	1.1%	0.7%	0.7%	0.9%	0.8%	0.8%	1.2%	1.5%
*Orbicella annularis**	0.4%	0.4%	0.4%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%
Porites astreoides	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Porites porites**	0.2%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Pseudodiploria clivosa	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendix B: continued

Prolifera Patch:

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora cervicornis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora prolifera	7.1%	6.3%	4.6%	6.5%	6.1%	7.1%	7.9%	10.0%	10.4%	10.3%
Colpophyllia natans	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Millepora alcicornis	0.3%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.4%	0.3%
*Orbicella annularis**	6.8%	6.4%	6.9%	7.1%	6.3%	5.8%	6.4%	6.9%	7.9%	7.5%
Porites astreoides	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%
Pseudodiploria clivosa	0.1%	0.3%	0.0%	0.2%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%
Pseudodiploria strigosa	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scleractinia	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.5%	0.4%	0.5%	0.4%	0.2%	0.4%	0.4%	0.5%	0.4%	0.4%

Prolifera Patch, cont.:

Species	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
Acropora cervicornis	0.0%	0.0%	0.9%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%
Acropora prolifera	11.6%	11.4%	7.7%	10.0%	9.0%	12.2%	16.5%	18.5%	15.6%
Colpophyllia natans	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%	0.4%
*Orbicella annularis**	7.4%	5.4%	6.7%	6.0%	5.3%	4.5%	3.7%	4.0%	3.8%
Porites astreoides	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%
Pseudodiploria clivosa	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.2%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scleractinia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.5%	0.3%	0.3%	0.2%	0.1%	0.2%	0.1%	0.2%	0.0%

Appendix B: continued

Mayer's Peak:

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acropora cervicornis	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Acropora prolifera	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	0.5%	0.1%	0.3%	0.4%	0.2%	0.4%	0.4%	0.3%	0.4%	0.3%	0.5%	1.0%	0.4%	0.7%	0.8%	0.9%	0.3%	0.4%	0.1%
Dichocoenia stokesii	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Diploria labyrinthiformis	0.3%	0.2%	0.1%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.5%	0.4%	0.4%	0.5%	0.3%	0.5%	0.4%	0.5%	0.4%	0.4%	0.7%	0.6%	0.7%	0.6%	0.6%	0.4%	0.4%	0.0%	0.0%
Millepora alcicornis	0.6%	1.3%	0.8%	0.8%	0.9%	0.7%	1.3%	1.1%	1.4%	1.1%	1.1%	1.3%	0.9%	0.9%	1.4%	1.4%	1.7%	1.8%	1.8%
Montastraea cavernosa	0.3%	0.6%	0.2%	0.7%	0.3%	0.2%	0.4%	0.4%	0.2%	0.4%	0.2%	0.2%	0.2%	0.3%	0.2%	0.3%	0.3%	0.2%	0.1%
Mycetophyllia ferox	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
*Mycetophyllia lamarckiana**	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	0.4%	0.9%	0.2%	0.3%	0.5%	0.1%	0.3%	0.6%	0.1%	0.5%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.2%
Porites astreoides	0.4%	0.3%	0.3%	0.4%	0.3%	0.5%	0.2%	0.2%	0.5%	0.2%	0.5%	0.4%	0.3%	0.6%	0.3%	0.3%	0.4%	0.4%	0.3%
*Porites porites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%
Pseudodiploria clivosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.3%	0.1%	0.2%	0.0%	0.1%	0.2%	0.1%	0.2%	0.2%	0.2%	0.4%	0.1%	0.0%
Scleractinia	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.2%	0.3%	0.3%	0.3%	0.5%	0.2%	0.4%	0.4%	0.3%	0.6%	0.6%	0.8%	0.9%	1.0%	1.0%	1.3%	1.5%	1.0%	0.9%
Stephanocoenia intersepta	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.2%	0.1%	0.1%	0.3%	0.3%	0.4%	0.4%	0.3%	0.4%	0.4%

Appendix B: continued

Palmata Patch:

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Acropora cervicornis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
Acropora palmata	4.8%	3.9%	1.8%	2.1%	2.6%	3.6%	5.1%	7.7%	6.2%	6.8%	8.0%	6.1%	6.7%	6.9%	5.1%	6.4%	7.6%	9.3%	9.7%
Millepora alcicornis	0.2%	0.4%	0.1%	0.2%	0.3%	0.2%	0.2%	0.5%	0.4%	0.3%	0.7%	0.4%	0.4%	0.6%	0.5%	0.7%	0.7%	1.0%	0.8%
Montastraea cavernosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	0.2%	0.4%	0.0%	0.1%	0.2%	0.1%	0.2%	0.2%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.2%	0.1%	0.3%
Porites astreoides	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	0.1%	0.2%	0.1%	0.2%
Pseudodiploria clivosa	0.1%	0.0%	0.2%	0.1%	0.1%	0.1%	0.0%	0.1%	0.2%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	0.2%	0.2%	0.0%
Pseudodiploria strigosa	0.0%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
Scleractinia	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea radians	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.2%	0.4%	0.3%	0.2%	0.2%	0.4%	0.4%	0.6%	0.2%	0.4%	0.4%	0.9%	0.5%	0.4%	0.4%	0.6%	0.3%	0.4%	0.1%

Appendix B: continued

Temptation Rock:

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Colpophyllia natans	0.1%	0.4%	0.7%	0.1%	0.4%	0.2%	0.5%	0.7%	0.4%	0.5%	0.6%	0.5%	0.4%	0.4%	0.2%	0.3%	0.6%	0.7%	0.0%
Diploria labyrinthiformis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%
Millepora alcicornis	1.3%	1.5%	1.2%	1.5%	1.8%	2.0%	2.1%	2.3%	1.6%	1.6%	1.9%	2.3%	1.4%	1.5%	1.0%	1.6%	1.8%	0.8%	1.4%
Montastraea cavernosa	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.3%	0.0%	0.1%	0.0%
Mussa angulosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mycetophyllia ferox	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oculina diffusa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oculina robusta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	1.2%	0.8%	0.8%	0.2%	1.3%	1.5%	0.2%	0.6%	0.5%	1.6%	1.5%	2.0%	1.9%	0.8%	0.1%	0.8%	0.3%	0.9%	0.5%
Porites astreoides	0.0%	0.2%	0.1%	0.2%	0.2%	0.2%	0.2%	0.4%	0.2%	0.2%	0.4%	0.2%	0.4%	0.3%	0.2%	0.2%	0.4%	0.3%	0.4%
*Porites porites**	0.8%	0.3%	0.0%	0.1%	0.1%	0.3%	0.4%	0.2%	0.5%	0.2%	0.3%	0.3%	0.1%	0.0%	0.2%	0.2%	0.2%	0.5%	0.2%
Pseudodiploria clivosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Pseudodiploria strigosa	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.3%	0.0%
Siderastrea siderea	0.4%	0.6%	0.3%	0.2%	0.6%	0.5%	0.3%	0.8%	0.2%	0.4%	0.6%	0.5%	0.6%	1.2%	0.8%	1.0%	0.8%	1.4%	0.8%
Stephanocoenia intersepta	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%	0.2%	0.1%	0.3%	0.1%	0.1%

Appendix B: continued

Texas Rock:

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Colpophyllia natans	0.3%	0.5%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.0%	0.2%	0.2%	0.0%
Dichocoenia stokesii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Eusmilia fastigiate	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Madracis decactis**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
Meandrina meandrites	0.1%	0.3%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Millepora alcicornis	0.8%	1.1%	0.9%	1.0%	1.4%	1.3%	1.0%	0.3%	0.6%	0.4%	0.7%	0.5%	0.5%	0.5%
Montastraea cavernosa	2.3%	2.8%	3.7%	3.3%	2.5%	3.6%	3.7%	3.6%	3.3%	3.1%	2.4%	3.3%	3.2%	0.9%
Mussa angulosa	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mycetophyllia aliciae	0.1%	0.0%	0.1%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.2%	0.1%	0.3%	0.1%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
*Mycetophyllia lamarckiana**	0.0%	0.1%	0.1%	0.1%	0.2%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.3%	0.0%
*Orbicella annularis**	1.7%	2.3%	1.6%	2.0%	1.0%	1.1%	1.3%	1.3%	1.0%	0.9%	1.0%	0.9%	0.8%	0.4%
Porites astreoides	0.2%	0.5%	0.3%	0.5%	0.3%	0.2%	0.2%	0.4%	0.3%	0.4%	0.5%	0.2%	0.2%	0.5%
*Porites porites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%
Pseudodiploria strigosa	0.1%	0.1%	0.2%	0.1%	0.2%	0.2%	0.1%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%
Scleractinia	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.3%	0.5%	0.4%	0.7%	0.5%	0.6%	0.6%	0.7%	0.7%	0.8%	0.6%	0.7%	1.2%	0.7%
Stephanocoenia intersepta	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.0%	0.2%	0.3%	0.2%	0.3%	0.1%	0.2%	0.2%

Appendix B: continued

The Maze:

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%
Acropora cervicornis	0.2%	0.2%	0.2%	0.3%	0.2%	0.4%	0.3%	0.6%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Colpophyllia natans	0.4%	0.5%	0.2%	0.2%	0.6%	0.7%	0.3%	0.5%	0.3%	0.1%	0.2%	0.6%	0.4%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%
Meandrina meandrites	0.1%	0.3%	0.2%	0.3%	0.2%	0.1%	0.0%	0.2%	0.0%	0.3%	0.1%	0.2%	0.0%	0.0%
Millepora alcicornis	1.4%	1.4%	1.7%	2.2%	0.9%	2.2%	1.8%	1.5%	1.0%	1.3%	0.7%	1.2%	0.7%	0.6%
Millepora complanata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Montastraea cavernosa	1.2%	1.1%	1.3%	1.0%	1.2%	0.8%	1.4%	1.5%	1.6%	1.3%	1.6%	1.3%	1.2%	1.2%
Mycetophyllia aliciae	0.3%	0.3%	0.1%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.1%	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	5.9%	6.3%	6.8%	7.0%	6.8%	7.3%	5.4%	6.9%	4.5%	5.1%	6.1%	4.8%	5.7%	3.7%
Porites astreoides	0.5%	0.4%	0.4%	0.4%	0.2%	0.3%	0.4%	0.4%	0.5%	0.5%	0.3%	0.5%	0.5%	0.3%
*Porites porites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Pseudodiploria strigosa	0.1%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
Scleractinia	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.8%	0.3%	0.9%	0.6%	0.6%	0.7%	0.7%	1.0%	1.0%	1.1%	0.8%	0.8%	1.2%	1.1%
Stephanocoenia intersepta	0.0%	0.1%	0.4%	0.4%	0.1%	0.1%	0.3%	0.4%	0.3%	0.3%	0.2%	0.4%	0.5%	0.3%

Appendix B: continued

White Shoal:

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
*Agaricia agaricites**	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%
Acropora cervicornis	5.4%	4.2%	2.9%	3.3%	1.6%	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%
Colpophyllia natans	0.2%	0.6%	0.5%	0.6%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%
Diploria labyrinthiformis	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
Meandrina meandrites	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	1.3%	0.8%	0.5%	1.2%	0.6%	0.4%	0.5%	0.8%	0.3%	0.4%	0.6%	0.7%
Montastraea cavernosa	0.3%	0.1%	0.2%	0.2%	0.1%	0.3%	0.1%	0.0%	0.1%	0.0%	0.1%	0.3%
Oculina diffusa	0.1%	0.0%	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%
Oculina robusta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	0.1%	0.5%	0.4%	0.5%	0.6%	0.2%	0.3%	0.2%	0.1%	0.0%	0.0%	0.1%
Porites astreoides	0.2%	0.3%	0.0%	0.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
*Porites porites**	0.3%	0.3%	0.1%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.3%
Pseudodiploria clivosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pseudodiploria strigosa	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scleractinia	0.3%	0.6%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Siderastrea siderea	0.5%	0.0%	0.4%	0.2%	0.4%	0.3%	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%
Stephanocoenia intersepta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendix B: continued

White Shoal (continued):

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Acropora cervicornis	0.1%	0.1%	0.2%	0.6%	1.0%	0.8%	1.1%	0.8%	0.7%	2.3%	1.4%	2.2%
Colpophyllia natans	0.2%	0.2%	0.1%	0.4%	0.5%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
Diploria labyrinthiformis	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eusmilia fastigiata	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Meandrina meandrites	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	1.0%	0.6%	0.9%	1.0%	0.7%	1.1%	0.9%	0.6%	0.8%	0.5%	0.5%	0.8%
Montastraea cavernosa	0.1%	0.1%	0.1%	0.2%	0.1%	0.2%	0.1%	0.1%	0.1%	0.3%	0.2%	0.5%
Oculina diffusa	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Oculina robusta	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	0.2%	0.1%	0.1%	0.2%	0.3%	0.3%	0.5%	0.3%	0.2%	0.6%	0.7%	0.3%
Porites astreoides	0.1%	0.0%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.2%
*Porites porites**	0.3%	0.3%	0.5%	0.6%	0.7%	0.2%	0.4%	0.3%	0.3%	0.2%	0.1%	0.1%
Pseudodiploria clivosa	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Pseudodiploria strigosa	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Scleractinia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.1%	0.3%	0.2%	0.2%	0.2%	0.3%	0.2%	0.4%	0.2%	0.1%	0.4%	0.1%
Stephanocoenia intersepta	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%

Appendix B: continued

Little Africa:

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
*Agaricia agaricites**	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Colpophyllia natans	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Diploria labyrinthiformis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Favia fragum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Millepora alcicornis	0.3%	0.5%	0.4%	0.9%	0.3%	0.3%	0.4%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.1%
Montastraea cavernosa	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Mycetophyllia ferox	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
*Orbicella annularis**	16.0%	23.7%	27.1%	18.5%	11.0%	17.7%	20.9%	8.8%	8.0%	14.4%	13.9%	12.1%	11.2%	12.9%	10.3%	10.8%
Porites astreoides	1.5%	0.8%	0.7%	1.6%	0.9%	0.9%	0.9%	1.0%	1.3%	0.8%	0.7%	1.2%	0.8%	1.0%	1.0%	0.4%
*Porites porites**	0.1%	0.4%	0.2%	0.1%	0.7%	0.6%	0.5%	0.5%	0.3%	0.9%	0.2%	0.1%	0.2%	0.5%	0.2%	0.1%
Pseudodiploria clivosa	0.0%	0.0%	0.1%	0.2%	0.3%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.2%	0.1%	0.3%	0.1%	0.0%
Pseudodiploria strigosa	0.5%	0.1%	0.9%	0.0%	0.0%	0.7%	0.1%	0.4%	0.5%	0.0%	0.0%	0.2%	0.0%	0.3%	0.2%	0.0%
Scleractinia	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Siderastrea siderea	0.1%	0.7%	0.1%	0.9%	0.1%	0.2%	0.5%	0.3%	0.0%	0.0%	0.8%	0.9%	0.7%	0.1%	0.4%	0.0%
Stephanocoenia intersepta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%

Appendix C: Average percent cover (±SE) of macroalgae genera for each survey site for each year. Annual mean is the mean of all sites, excluding Little Africa due to the different survey method. RNA pinnacles is the mean of the 5 pinnacle reefs.

Sites	Year	*Dictyota* spp.	*Halimeda* spp.	*Lobophora* spp.	Other Macroalgae
Annual Mean	2010	21.8 ± 6.0%	0.5 ± 0.2%	3.5 ± 2.1%	10.8 ± 2.7%
Annual Mean	2011	7.4 ± 1.1%	1.0 ± 0.3%	2.7 ± 1.2%	13.0 ± 1.9%
Annual Mean	2012	7.8 ± 1.7%	0.7 ± 0.3%	2.0 ± 1.1%	17.1 ± 2.6%
Annual Mean	2013	15.7 ± 3.4%	0.5 ± 0.2%	4.0 ± 2.1%	10.4 ± 1.7%
Annual Mean	2014	12.0 ± 2.5%	0.4 ± 0.1%	3.8 ± 1.9%	10.1 ± 1.3%
Annual Mean	2015	13.4 ± 3.4%	0.5 ± 0.2%	5.4 ± 2.9%	9.0 ± 1.5%
Annual Mean	2016	8.6 ± 1.9%	0.6 ± 0.3%	5.3 ± 2.4%	7.2 ± 1.5%
Annual Mean	2017	15.7 ± 3.3%	0.4 ± 0.2%	5.1 ± 2.0%	7.7 ± 1.0%
Annual Mean	2018	16.9 ± 2.1%	0.3 ± 0.1%	1.9 ± 1.1%	11.0 ± 2.1%
Annual Mean	2019	15.0 ± 2.2%	0.5 ± 0.2%	0.8 ± 0.5%	15.0 ± 2.0%
Annual Mean	2020	20.1 ± 2.7%	0.6 ± 0.2%	1.7 ± 0.8%	9.5 ± 1.5%
Annual Mean	2021	17.1 ± 2.8%	0.6 ± 0.4%	0.8 ± 0.5%	10.3 ± 1.8%
Annual Mean	2022	15.2 ± 2.8%	0.7 ± 0.3%	1.8 ± 1.1%	10.2 ± 1.4%
RNA Pinnacles	2010	38.7 ± 7.4%	0.5 ± 0.4%	0.7 ± 0.3%	9.9 ± 3.4%
RNA Pinnacles	2011	7.7 ± 0.8%	1.3 ± 0.7%	1.8 ± 0.7%	16.3 ± 2.7%
RNA Pinnacles	2012	12.3 ± 2.1%	0.4 ± 0.2%	0.9 ± 0.3%	22.0 ± 2.3%
RNA Pinnacles	2013	25.1 ± 3.5%	0.6 ± 0.3%	2.4 ± 0.7%	12.1 ± 1.9%
RNA Pinnacles	2014	17.3 ± 2.3%	0.2 ± 0.1%	1.9 ± 0.9%	10.2 ± 1.0%
RNA Pinnacles	2015	20.7 ± 5.7%	0.1 ± 0.1%	2.3 ± 0.8%	10.5 ± 2.1%
RNA Pinnacles	2016	10.5 ± 2.4%	0.1 ± 0.0%	3.4 ± 1.4%	9.1 ± 2.3%
RNA Pinnacles	2017	18.8 ± 4.9%	0.0 ± 0.0%	4.3 ± 0.7%	7.8 ± 1.1%
RNA Pinnacles	2018	18.7 ± 3.8%	0.0 ± 0.0%	0.6 ± 0.4%	13.5 ± 3.3%
RNA Pinnacles	2019	19.7 ± 3.2%	0.0 ± 0.0%	0.5 ± 0.2%	18.8 ± 1.7%
RNA Pinnacles	2020	25.8 ± 3.5%	0.1 ± 0.1%	0.9 ± 0.4%	12.0 ± 1.9%
RNA Pinnacles	2021	18.4 ± 5.7%	0.0 ± 0.0%	0.1 ± 0.0%	12.4 ± 2.2%
RNA Pinnacles	2022	15.4 ± 3.6%	0.1 ± 0.0%	0.8 ± 0.3%	11.7 ± 2.6%

Appendix C: continued

Sites	Year	*Dictyota* spp.	*Halimeda* spp.	*Lobophora* spp.	Other Macroalgae
Bird Key Reef	2010	20.2 ± 5.1%	0.0 ± 0.0%	18.3 ± 3.0%	15.3 ± 4.4%
Bird Key Reef	2011	7.3 ± 3.8%	0.0 ± 0.0%	11.3 ± 3.9%	8.0 ± 2.9%
Bird Key Reef	2012	2.2 ± 1.4%	0.0 ± 0.0%	5.8 ± 1.3%	23.6 ± 7.8%
Bird Key Reef	2013	13.3 ± 3.0%	0.1 ± 0.0%	8.1 ± 2.5%	20.5 ± 3.0%
Bird Key Reef	2014	8.9 ± 1.4%	0.3 ± 0.3%	17.3 ± 4.6%	17.2 ± 4.1%
Bird Key Reef	2015	9.6 ± 2.5%	0.6 ± 0.6%	18.0 ± 3.0%	9.1 ± 1.2%
Bird Key Reef	2016	5.1 ± 1.4%	0.6 ± 0.6%	21.6 ± 1.9%	5.8 ± 2.1%
Bird Key Reef	2017	15.9 ± 3.3%	0.1 ± 0.1%	21.5 ± 2.8%	7.9 ± 2.5%
Bird Key Reef	2018	23.3 ± 5.9%	0.2 ± 0.2%	11.9 ± 2.0%	7.4 ± 3.9%
Bird Key Reef	2019	11.2 ± 0.5%	0.3 ± 0.3%	0.9 ± 0.2%	11.7 ± 1.9%
Bird Key Reef	2020	26.0 ± 4.8%	0.5 ± 0.5%	5.8 ± 2.7%	4.0 ± 1.7%
Bird Key Reef	2021	22.1 ± 3.9%	0.2 ± 0.2%	3.7 ± 1.3%	20.3 ± 10.4%
Bird Key Reef	2022	29.2 ± 3.2%	0.4 ± 0.4%	4.0 ± 1.7%	8.4 ± 4.2%
Black Coral Rock	2010	8.1 ± 2.6%	0.0 ± 0.0%	16.3 ± 2.4%	14.4 ± 4.8%
Black Coral Rock	2011	16.5 ± 5.5%	1.5 ± 0.7%	9.2 ± 1.4%	15.6 ± 5.1%
Black Coral Rock	2012	5.3 ± 2.4%	0.1 ± 0.1%	11.6 ± 1.5%	8.7 ± 2.5%
Black Coral Rock	2013	3.9 ± 0.9%	0.1 ± 0.1%	24.0 ± 3.5%	10.3 ± 2.7%
Black Coral Rock	2014	6.9 ± 2.6%	0.0 ± 0.0%	15.0 ± 2.9%	15.3 ± 6.4%
Black Coral Rock	2015	16.2 ± 3.4%	0.0 ± 0.0%	29.2 ± 2.1%	6.5 ± 1.8%
Black Coral Rock	2016	5.5 ± 0.9%	0.0 ± 0.0%	19.7 ± 0.5%	12.0 ± 4.3%
Black Coral Rock	2017	24.2 ± 3.1%	0.0 ± 0.0%	12.8 ± 0.9%	6.8 ± 1.8%
Black Coral Rock	2018	16.3 ± 4.1%	0.2 ± 0.1%	5.7 ± 0.4%	16.7 ± 5.7%
Black Coral Rock	2019	20.1 ± 4.4%	0.0 ± 0.0%	5.9 ± 1.0%	18.4 ± 4.7%
Black Coral Rock	2020	21.9 ± 1.4%	0.0 ± 0.0%	8.0 ± 1.8%	15.1 ± 4.3%
Black Coral Rock	2021	20.3 ± 3.2%	0.0 ± 0.0%	4.6 ± 0.7%	6.5 ± 3.2%
Black Coral Rock	2022	16.5 ± 1.7%	0.0 ± 0.0%	12.0 ± 2.1%	5.9 ± 1.4%
Davis Rock	2010	59.1 ± 2.8%	0.3 ± 0.2%	0.2 ± 0.1%	7.9 ± 2.3%
Davis Rock	2011	8.8 ± 3.7%	3.0 ± 0.6%	4.4 ± 1.2%	22.5 ± 5.1%
Davis Rock	2012	17.1 ± 7.5%	0.6 ± 0.3%	2.0 ± 1.0%	28.3 ± 11.2%
Davis Rock	2013	36.0 ± 11.9%	1.4 ± 0.6%	2.8 ± 0.4%	18.7 ± 8.1%
Davis Rock	2014	14.6 ± 2.5%	0.6 ± 0.1%	5.2 ± 1.6%	13.7 ± 2.9%
Davis Rock	2015	42.6 ± 3.4%	0.3 ± 0.3%	3.3 ± 0.2%	7.9 ± 1.2%
Davis Rock	2016	6.3 ± 1.9%	0.1 ± 0.1%	7.6 ± 0.8%	16.6 ± 4.6%
Davis Rock	2017	35.1 ± 2.9%	0.1 ± 0.1%	6.5 ± 1.2%	9.4 ± 1.6%
Davis Rock	2018	30.1 ± 4.1%	0.0 ± 0.0%	2.2 ± 0.3%	14.2 ± 2.4%
Davis Rock	2019	30.7 ± 4.1%	0.1 ± 0.1%	1.2 ± 0.6%	16.7 ± 4.1%
Davis Rock	2020	37.6 ± 3.6%	0.0 ± 0.0%	1.3 ± 0.6%	11.3 ± 2.9%
Davis Rock	2021	37.4 ± 1.7%	0.1 ± 0.1%	0.2 ± 0.1%	13.4 ± 2.0%
Davis Rock	2022	26.1 ± 7.0%	0.0 ± 0.0%	1.9 ± 0.1%	9.8 ± 2.6%

Appendix C: continued

Sites	Year	*Dictyota* spp.	*Halimeda* spp.	*Lobophora* spp.	Other Macroalgae
Loggerhead Patch	2010	9.7 ± 4.1%	1.4 ± 0.2%	0.0 ± 0.0%	5.2 ± 4.4%
Loggerhead Patch	2011	4.1 ± 3.1%	1.2 ± 0.1%	0.0 ± 0.0%	8.9 ± 2.8%
Loggerhead Patch	2012	5.0 ± 5.0%	3.1 ± 1.8%	0.0 ± 0.0%	22.2 ± 10.2%
Loggerhead Patch	2013	18.1 ± 2.0%	0.5 ± 0.4%	0.0 ± 0.0%	6.0 ± 3.5%
Loggerhead Patch	2014	23.0 ± 10.4%	1.3 ± 0.2%	0.0 ± 0.0%	8.3 ± 3.7%
Loggerhead Patch	2015	4.2 ± 0.8%	2.5 ± 0.5%	0.0 ± 0.0%	15.9 ± 0.9%
Loggerhead Patch	2016	20.2 ± 1.9%	3.6 ± 0.1%	0.0 ± 0.0%	2.9 ± 2.3%
Loggerhead Patch	2017	28.0 ± 4.1%	1.3 ± 0.4%	0.0 ± 0.0%	3.2 ± 0.6%
Loggerhead Patch	2018	5.9 ± 1.5%	1.0 ± 0.9%	0.0 ± 0.0%	6.0 ± 0.3%
Loggerhead Patch	2019	5.8 ± 4.0%	2.3 ± 0.4%	0.0 ± 0.0%	8.2 ± 1.1%
Loggerhead Patch	2020	8.6 ± 3.3%	1.2 ± 0.7%	0.0 ± 0.0%	9.0 ± 0.9%
Loggerhead Patch	2021	21.3 ± 0.2%	0.8 ± 0.1%	0.1 ± 0.1%	7.4 ± 3.5%
Loggerhead Patch	2022	26.8 ± 0.8%	1.8 ± 0.7%	0.0 ± 0.0%	12.6 ± 8.1%
Mayer's Peak	2010	46.5 ± 3.1%	0.0 ± 0.0%	0.4 ± 0.2%	1.2 ± 0.6%
Mayer's Peak	2011	4.7 ± 3.0%	0.0 ± 0.0%	0.4 ± 0.2%	12.1 ± 2.5%
Mayer's Peak	2012	8.7 ± 6.3%	0.0 ± 0.0%	0.1 ± 0.1%	18.7 ± 7.0%
Mayer's Peak	2013	15.3 ± 5.4%	0.0 ± 0.0%	1.0 ± 0.9%	11.1 ± 4.1%
Mayer's Peak	2014	18.3 ± 4.6%	0.0 ± 0.0%	0.1 ± 0.0%	9.4 ± 4.4%
Mayer's Peak	2015	13.4 ± 1.5%	0.0 ± 0.0%	0.2 ± 0.1%	7.3 ± 2.3%
Mayer's Peak	2016	12.3 ± 3.3%	0.0 ± 0.0%	0.2 ± 0.1%	2.9 ± 0.9%
Mayer's Peak	2017	5.9 ± 0.5%	0.0 ± 0.0%	2.9 ± 0.9%	6.7 ± 2.1%
Mayer's Peak	2018	8.6 ± 2.1%	0.0 ± 0.0%	0.0 ± 0.0%	3.9 ± 1.3%
Mayer's Peak	2019	13.7 ± 3.9%	0.0 ± 0.0%	0.2 ± 0.1%	14.5 ± 3.3%
Mayer's Peak	2020	21.1 ± 3.3%	0.0 ± 0.0%	0.0 ± 0.0%	7.8 ± 3.3%
Mayer's Peak	2021	2.0 ± 1.5%	0.0 ± 0.0%	0.0 ± 0.0%	7.2 ± 1.3%
Mayer's Peak	2022	5.4 ± 1.1%	0.0 ± 0.0%	0.1 ± 0.1%	4.7 ± 1.6%
Palmata Patch	2010	3.0 ± 2.8%	0.2 ± 0.2%	0.0 ± 0.0%	1.7 ± 0.9%
Palmata Patch	2011	2.8 ± 1.3%	0.2 ± 0.2%	0.0 ± 0.0%	8.9 ± 3.8%
Palmata Patch	2012	0.5 ± 0.2%	0.3 ± 0.1%	0.0 ± 0.0%	4.5 ± 2.2%
Palmata Patch	2013	2.2 ± 1.6%	0.5 ± 0.3%	0.0 ± 0.0%	3.9 ± 0.0%
Palmata Patch	2014	2.5 ± 0.7%	0.5 ± 0.0%	0.0 ± 0.0%	5.2 ± 1.7%
Palmata Patch	2015	3.7 ± 0.5%	0.4 ± 0.4%	0.0 ± 0.0%	3.6 ± 0.7%
Palmata Patch	2016	2.4 ± 0.5%	0.2 ± 0.1%	0.0 ± 0.0%	0.6 ± 0.3%
Palmata Patch	2017	6.5 ± 1.3%	0.2 ± 0.0%	0.0 ± 0.0%	6.6 ± 3.4%
Palmata Patch	2018	17.8 ± 8.8%	0.1 ± 0.0%	0.0 ± 0.0%	3.1 ± 2.6%
Palmata Patch	2019	12.2 ± 2.4%	0.2 ± 0.1%	0.0 ± 0.0%	9.1 ± 0.8%
Palmata Patch	2020	14.6 ± 6.2%	0.3 ± 0.1%	0.0 ± 0.0%	3.7 ± 3.4%
Palmata Patch	2021	11.6 ± 3.8%	0.6 ± 0.0%	0.0 ± 0.0%	5.0 ± 2.3%
Palmata Patch	2022	7.9 ± 3.7%	0.8 ± 0.1%	0.0 ± 0.0%	6.7 ± 1.8%

Appendix C: continued

Sites	Year	*Dictyota* spp.	*Halimeda* spp.	*Lobophora* spp.	Other Macroalgae
Prolifera Patch	2010	0.7 ± 0.4%	0.1 ± 0.1%	0.0 ± 0.0%	3.5 ± 1.8%
Prolifera Patch	2011	8.4 ± 4.0%	0.8 ± 0.4%	0.0 ± 0.0%	2.7 ± 1.3%
Prolifera Patch	2012	1.4 ± 0.5%	1.2 ± 1.1%	0.0 ± 0.0%	1.9 ± 0.5%
Prolifera Patch	2013	1.5 ± 0.7%	0.4 ± 0.3%	0.0 ± 0.0%	2.0 ± 0.7%
Prolifera Patch	2014	0.5 ± 0.4%	0.3 ± 0.3%	0.0 ± 0.0%	2.0 ± 0.6%
Prolifera Patch	2015	1.5 ± 0.9%	0.5 ± 0.3%	0.0 ± 0.0%	1.6 ± 0.8%
Prolifera Patch	2016	1.1 ± 1.1%	0.6 ± 0.5%	0.0 ± 0.0%	2.4 ± 0.2%
Prolifera Patch	2017	2.7 ± 1.2%	0.7 ± 0.4%	0.0 ± 0.0%	5.9 ± 2.2%
Prolifera Patch	2018	13.3 ± 7.2%	0.7 ± 0.2%	0.0 ± 0.0%	2.3 ± 1.7%
Prolifera Patch	2019	9.2 ± 5.7%	1.5 ± 0.7%	0.0 ± 0.0%	2.3 ± 1.1%
Prolifera Patch	2020	8.1 ± 5.3%	1.4 ± 0.5%	0.0 ± 0.0%	3.3 ± 2.8%
Prolifera Patch	2021	5.1 ± 3.4%	0.5 ± 0.2%	0.0 ± 0.0%	1.8 ± 0.6%
Prolifera Patch	2022	2.0 ± 0.8%	0.7 ± 0.2%	0.0 ± 0.0%	6.9 ± 1.1%
Temptation Rock	2010	38.3 ± 6.6%	2.0 ± 0.7%	0.6 ± 0.1%	5.1 ± 1.1%
Temptation Rock	2011	8.2 ± 2.6%	2.8 ± 0.6%	0.8 ± 0.6%	10.7 ± 3.0%
Temptation Rock	2012	6.4 ± 4.4%	1.2 ± 0.1%	1.0 ± 0.3%	20.1 ± 5.1%
Temptation Rock	2013	28.2 ± 2.5%	1.4 ± 0.1%	1.2 ± 0.5%	10.5 ± 2.5%
Temptation Rock	2014	10.3 ± 4.7%	0.1 ± 0.1%	1.1 ± 0.6%	11.0 ± 2.7%
Temptation Rock	2015	10.3 ± 1.9%	0.0 ± 0.0%	3.9 ± 0.9%	10.1 ± 2.7%
Temptation Rock	2016	4.1 ± 1.7%	0.0 ± 0.0%	5.7 ± 1.6%	7.5 ± 2.1%
Temptation Rock	2017	22.8 ± 1.5%	0.0 ± 0.0%	4.3 ± 1.9%	4.6 ± 1.4%
Temptation Rock	2018	14.0 ± 1.4%	0.0 ± 0.0%	0.5 ± 0.1%	18.9 ± 8.0%
Temptation Rock	2019	22.4 ± 4.8%	0.0 ± 0.0%	0.2 ± 0.1%	17.5 ± 4.4%
Temptation Rock	2020	19.2 ± 4.2%	0.0 ± 0.0%	2.2 ± 0.8%	13.5 ± 4.4%
Temptation Rock	2021	14.0 ± 2.2%	0.0 ± 0.0%	0.0 ± 0.0%	12.3 ± 3.1%
Temptation Rock	2022	10.0 ± 1.7%	0.0 ± 0.0%	0.6 ± 0.2%	13.9 ± 3.7%
Texas Rock	2010	14.2 ± 5.2%	0.0 ± 0.0%	0.3 ± 0.3%	19.9 ± 7.8%
Texas Rock	2011	9.6 ± 3.7%	1.0 ± 0.5%	2.3 ± 0.5%	23.0 ± 0.5%
Texas Rock	2012	12.7 ± 6.7%	0.2 ± 0.1%	0.7 ± 0.2%	26.5 ± 6.4%
Texas Rock	2013	20.8 ± 4.2%	0.3 ± 0.3%	5.0 ± 1.0%	13.1 ± 3.0%
Texas Rock	2014	24.1 ± 1.9%	0.5 ± 0.3%	2.1 ± 0.7%	8.8 ± 2.5%
Texas Rock	2015	17.0 ± 2.1%	0.2 ± 0.1%	3.5 ± 1.5%	18.7 ± 5.3%
Texas Rock	2016	17.0 ± 4.5%	0.1 ± 0.1%	1.7 ± 0.8%	11.4 ± 4.2%
Texas Rock	2017	16.1 ± 3.0%	0.1 ± 0.1%	5.1 ± 1.9%	10.7 ± 4.6%
Texas Rock	2018	16.5 ± 2.3%	0.0 ± 0.0%	0.4 ± 0.1%	21.7 ± 2.0%
Texas Rock	2019	16.8 ± 2.8%	0.0 ± 0.0%	0.4 ± 0.2%	20.6 ± 5.1%
Texas Rock	2020	21.5 ± 1.5%	0.3 ± 0.2%	0.9 ± 0.4%	18.6 ± 6.0%
Texas Rock	2021	18.3 ± 5.9%	0.0 ± 0.0%	0.2 ± 0.1%	19.8 ± 5.1%
Texas Rock	2022	19.5 ± 4.9%	0.2 ± 0.2%	1.2 ± 0.3%	20.1 ± 4.3%

Appendix C: continued

Sites	Year	*Dictyota* spp.	*Halimeda* spp.	*Lobophora* spp.	Other Macroalgae
The Maze	2010	35.5 ± 12.9%	0.0 ± 0.0%	1.9 ± 1.0%	15.4 ± 7.7%
The Maze	2011	7.4 ± 3.3%	0.0 ± 0.0%	1.2 ± 0.4%	13.0 ± 2.5%
The Maze	2012	16.5 ± 9.6%	0.0 ± 0.0%	0.8 ± 0.5%	16.7 ± 8.8%
The Maze	2013	25.3 ± 4.7%	0.0 ± 0.0%	2.0 ± 0.6%	7.1 ± 2.0%
The Maze	2014	19.3 ± 5.6%	0.0 ± 0.0%	1.1 ± 0.8%	8.1 ± 2.8%
The Maze	2015	20.4 ± 2.5%	0.0 ± 0.0%	0.7 ± 0.2%	8.6 ± 3.6%
The Maze	2016	13.0 ± 3.7%	0.1 ± 0.1%	2.0 ± 1.3%	7.2 ± 3.3%
The Maze	2017	14.1 ± 3.4%	0.0 ± 0.0%	2.5 ± 1.2%	7.8 ± 2.1%
The Maze	2018	24.6 ± 2.0%	0.0 ± 0.0%	0.1 ± 0.0%	8.7 ± 5.8%
The Maze	2019	14.6 ± 2.6%	0.0 ± 0.0%	0.7 ± 0.5%	24.6 ± 4.3%
The Maze	2020	29.7 ± 4.1%	0.0 ± 0.0%	0.1 ± 0.1%	8.9 ± 1.5%
The Maze	2021	20.4 ± 6.2%	0.0 ± 0.0%	0.0 ± 0.0%	9.1 ± 2.5%
The Maze	2022	16.3 ± 1.6%	0.1 ± 0.1%	0.2 ± 0.1%	9.9 ± 4.1%
White Shoal	2010	4.5 ± 3.6%	1.0 ± 0.5%	0.0 ± 0.0%	29.3 ± 5.7%
White Shoal	2011	3.5 ± 2.1%	0.5 ± 0.1%	0.0 ± 0.0%	17.4 ± 3.2%
White Shoal	2012	9.9 ± 6.0%	1.5 ± 1.1%	0.0 ± 0.0%	17.0 ± 4.2%
White Shoal	2013	8.0 ± 4.5%	1.4 ± 0.5%	0.0 ± 0.0%	11.3 ± 3.4%
White Shoal	2014	3.5 ± 2.0%	1.0 ± 0.6%	0.0 ± 0.0%	12.1 ± 3.5%
White Shoal	2015	8.2 ± 4.1%	0.7 ± 0.2%	0.1 ± 0.1%	9.5 ± 3.0%
White Shoal	2016	7.3 ± 3.2%	1.0 ± 0.2%	0.0 ± 0.0%	9.9 ± 4.0%
White Shoal	2017	1.8 ± 1.2%	1.3 ± 0.4%	0.0 ± 0.0%	14.9 ± 4.0%
White Shoal	2018	15.0 ± 5.3%	1.0 ± 0.4%	0.0 ± 0.0%	18.4 ± 6.6%
White Shoal	2019	8.2 ± 2.3%	1.5 ± 0.6%	0.0 ± 0.0%	20.9 ± 5.6%
White Shoal	2020	13.0 ± 7.2%	2.3 ± 0.7%	0.0 ± 0.0%	9.3 ± 4.5%
White Shoal	2021	15.5 ± 8.8%	4.8 ± 1.7%	0.0 ± 0.0%	10.0 ± 3.2%
White Shoal	2022	7.7 ± 2.9%	3.4 ± 1.7%	0.0 ± 0.0%	13.5 ± 4.6%
Little Africa	2010	2.3 ± 0.6%	8.4 ± 1.1%	0.0 ± 0.0%	4.2 ± 0.6%
Little Africa	2011	3.2 ± 1.3%	4.0 ± 1.1%	0.0 ± 0.0%	14.7 ± 2.1%
Little Africa	2012	0.4 ± 0.1%	7.1 ± 1.0%	0.0 ± 0.0%	8.5 ± 2.0%
Little Africa	2013	1.5 ± 0.5%	6.1 ± 1.1%	0.0 ± 0.0%	11.0 ± 1.4%
Little Africa	2014	0.2 ± 0.1%	4.7 ± 0.6%	0.0 ± 0.0%	7.1 ± 1.2%
Little Africa	2015	0.5 ± 0.2%	10.0 ± 1.6%	0.0 ± 0.0%	7.7 ± 1.2%
Little Africa	2016	0.8 ± 0.2%	6.5 ± 1.5%	0.0 ± 0.0%	5.2 ± 1.1%
Little Africa	2017	2.2 ± 0.8%	9.1 ± 1.7%	0.0 ± 0.0%	10.2 ± 1.3%
Little Africa	2018	2.2 ± 0.6%	8.1 ± 1.2%	0.0 ± 0.0%	13.6 ± 1.6%
Little Africa	2019	2.2 ± 1.0%	8.2 ± 1.5%	0.0 ± 0.0%	14.9 ± 2.3%
Little Africa	2020	12.6 ± 1.9%	8.6 ± 1.3%	0.0 ± 0.0%	6.5 ± 0.9%
Little Africa	2021	4.2 ± 1.2%	7.9 ± 1.4%	0.0 ± 0.0%	10.7 ± 1.2%
Little Africa	2022	3.1 ± 0.8%	10.1 ± 1.4%	0.0 ± 0.0%	8.9 ± 1.0%

Appendix D: Average density (colonies/m^2) for each coral species and summed for all coral species for each site for each year. Only individual colonies ≥ 4cm in max diameter were included. *Orbicella faveolata* and *O. franksi* were counted as *O. annularis* in 2011 and 2012.

Bird Key Reef:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.23	0.18	0.30	0.10	0.33	0.15	0.10	0.13	0.13	0.18	0.20	0.28
Agaricia fragilis	0.38	0.28	0.05	0.23	0.00	0.05	0.13	0.18	0.08	0.13	0.15	0.08
Agaricia humilis	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agaricia lamarcki	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Colpophyllia natans	0.23	0.23	0.20	0.20	0.18	0.18	0.13	0.20	0.15	0.15	0.13	0.00
Dichocoenia stokesii	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00
Diploria labyrinthiformis	0.00	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.00	0.00	0.03	0.00
Eusmilia fastigiata	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helioseris cucullata	0.03	0.03	0.00	0.03	0.03	0.03	0.05	0.05	0.03	0.05	0.05	0.03
Madracis decactis	0.15	0.15	0.05	0.18	0.05	0.18	0.15	0.18	0.15	0.15	0.10	0.18
Montastraea cavernosa	0.70	0.73	0.73	0.55	0.63	0.68	0.50	0.73	0.43	0.48	0.43	0.33
Mussa angulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia aliciae	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.03	0.05	0.08	0.05	0.00
Orbicella annularis	1.53	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Orbicella faveolata			1.68	0.53	0.65	0.58	0.18	0.30	0.18	0.58	0.45	0.53
Orbicella franksi			0.20	0.55	0.55	0.53	0.98	1.25	1.13	0.53	0.78	0.43
Porites astreoides	0.45	0.50	0.40	0.40	0.60	0.40	0.53	0.63	0.60	0.70	0.93	0.90
Porites porites	0.20	0.18	0.23	0.18	0.20	0.20	0.28	0.30	0.48	0.38	0.45	0.60
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Siderastrea radians	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderastrea siderea	1.25	1.55	1.28	1.18	1.25	1.50	1.88	2.73	1.95	1.95	2.80	2.03
Stephanocoenia intersepta	0.53	0.38	0.30	0.23	0.23	0.28	0.40	0.63	0.40	0.55	0.70	0.48
Total Coral Density	5.75	6.93	5.50	4.45	4.78	4.83	5.38	7.35	5.73	5.88	7.23	5.90

Appendix D: continued

Black Coral Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.18	0.13	0.10	0.13	0.18	0.18	0.10	0.13	0.23	0.13	0.13	0.08
Agaricia fragilis	0.08	0.30	0.15	0.10	0.08	0.20	0.28	0.25	0.15	0.20	0.15	0.13
Agaricia lamarcki	0.05	0.13	0.05	0.20	0.03	0.08	0.18	0.15	0.08	0.10	0.15	0.10
Colpophyllia natans	0.33	0.35	0.30	0.25	0.25	0.23	0.18	0.18	0.18	0.18	0.18	0.05
Dichocoenia stokesii	0.05	0.08	0.05	0.08	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.03
Eusmilia fastigiata	0.05	0.03	0.05	0.03	0.00	0.03	0.03	0.03	0.03	0.03	0.00	0.00
Helioseris cucullata	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.03	0.05	0.03	0.03	0.03
Isophyllia sinuosa	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis auretenra	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis decactis	0.73	1.50	0.98	1.48	1.05	1.35	1.60	0.90	1.13	0.63	0.73	0.80
Madracis pharensis	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis senaria	0.05	0.10	0.00	0.08	0.08	0.10	0.15	0.20	0.15	0.45	0.35	0.05
Meandrina meandrites	0.00	0.03	0.03	0.03	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00
Montastraea cavernosa	2.20	2.20	2.00	1.90	1.78	1.78	1.80	1.98	1.75	1.83	1.55	1.00
Mussa angulosa	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia aliciae	0.03	0.05	0.05	0.08	0.08	0.05	0.05	0.05	0.05	0.03	0.03	0.00
Mycetophyllia danaana	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia ferox	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia lamarckiana	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.03	0.05	0.08	0.00
Orbicella annularis	1.78	2.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.53	0.65	1.05	0.65	0.25	0.10	0.23	0.40	0.45	1.15
Orbicella franksi			1.63	1.15	0.73	1.08	1.68	1.63	1.45	1.33	1.18	0.20
Porites astreoides	1.08	0.98	0.95	0.90	0.98	0.93	1.05	0.93	0.93	1.03	1.20	1.18
Porites porites	0.20	0.15	0.15	0.15	0.08	0.13	0.28	0.23	0.20	0.20	0.28	0.28
Scolymia cubensis	0.03	0.03	0.00	0.03	0.00	0.03	0.03	0.08	0.00	0.03	0.05	0.00
Scolymia lacera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.03
Siderastrea siderea	1.13	1.50	1.40	1.35	1.40	1.35	1.85	1.45	1.63	1.45	1.48	1.20
Stephanocoenia intersepta	0.28	0.58	0.53	0.65	0.55	0.75	0.68	0.68	0.88	0.88	0.80	0.70
Total Coral Density	8.33	10.18	9.25	9.28	8.43	9.00	10.23	9.03	9.15	9.03	8.83	6.98

Appendix D: continued

Davis Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.08	0.13	0.10	0.08	0.05	0.08	0.05	0.08	0.05	0.08	0.10	0.10
Agaricia fragilis	0.08	0.03	0.03	0.05	0.00	0.00	0.00	0.03	0.08	0.03	0.00	0.05
Colpophyllia natans	0.05	0.03	0.05	0.05	0.05	0.03	0.03	0.05	0.05	0.03	0.05	0.03
Eusmilia fastigiata	0.03	0.05	0.05	0.03	0.00	0.03	0.03	0.00	0.08	0.05	0.05	0.00
Helioseris cucullata	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Madracis auretenra	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis decactis	0.18	0.23	0.00	0.20	0.15	0.08	0.15	0.13	0.20	0.05	0.13	0.23
Madracis senaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Meandrina meandrites	0.05	0.08	0.05	0.08	0.05	0.03	0.03	0.03	0.00	0.00	0.00	0.00
Montastraea cavernosa	0.45	0.40	0.40	0.35	0.28	0.40	0.33	0.33	0.35	0.33	0.30	0.28
Mycetophyllia ferox	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oculina diffusa	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.40	0.28	0.00	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.23	0.30	0.20	0.30	0.33	0.33	0.28	0.20	0.20	0.25
Orbicella franksi			0.03	0.05	0.08	0.00	0.10	0.03	0.03	0.13	0.13	0.00
Porites astreoides	1.30	1.70	1.68	1.93	1.58	2.03	2.20	2.35	2.28	2.28	2.33	2.55
Porites porites	0.35	0.50	0.60	0.63	0.30	0.53	0.35	0.33	0.40	0.50	0.63	0.58
Pseudodiploria clivosa	0.03	0.03	0.03	0.03	0.03	0.03	0.08	0.03	0.03	0.03	0.03	0.00
Pseudodiploria strigosa	0.13	0.13	0.13	0.10	0.05	0.10	0.03	0.08	0.08	0.10	0.13	0.00
Scolymia cubensis	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderastrea radians	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00
Siderastrea siderea	0.58	0.83	0.75	0.93	0.93	1.15	1.25	1.45	1.45	1.35	1.50	1.45
Stephanocoenia intersepta	0.40	0.43	0.28	0.45	0.38	0.40	0.43	0.43	0.45	0.45	0.45	0.45
Total Coral Density	4.10	4.85	4.48	5.25	4.18	5.23	5.35	5.65	5.78	5.63	6.00	5.95

Appendix D: continued

Loggerhead Patch:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.40	0.25	0.30	0.10	0.20	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Acropora cervicornis	0.30	0.25	0.35	0.10	0.10	0.20	0.10	0.00	0.00	0.00	0.00	0.00
Manicina areolata	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.05	0.05	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Porites astreoides	0.20	0.15	0.15	0.05	0.15	0.05	0.10	0.05	0.00	0.05	0.05	0.05
Porites porites	0.15	0.30	0.25	0.25	0.65	0.90	0.65	0.05	0.00	0.00	0.00	0.00
Pseudodiploria clivosa	0.15	0.15	0.10	0.30	0.20	0.10	0.10	0.05	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.15	0.20	0.15	0.00	0.15	0.15	0.10	0.05	0.05	0.05	0.00	0.00
Total Coral Density	1.40	1.35	1.40	0.85	1.50	1.45	1.15	0.20	0.05	0.10	0.05	0.05

Mayer's Peak:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.15	0.13	0.15	0.08	0.13	0.10	0.08	0.13	0.20	0.33	0.33	0.18
Acropora cervicornis	0.03	0.08	0.08	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.10	0.10
Agaricia fragilis	0.00	0.08	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00
Colpophyllia natans	0.03	0.08	0.05	0.05	0.13	0.05	0.05	0.03	0.05	0.10	0.03	0.03
Dichocoenia stokesii	0.13	0.13	0.15	0.08	0.13	0.10	0.13	0.10	0.10	0.08	0.05	0.03
Diploria labyrinthiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Eusmilia fastigiata	0.03	0.05	0.03	0.05	0.05	0.05	0.05	0.03	0.03	0.03	0.00	0.00
Madracis decactis	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.03	0.03	0.03	0.00	0.03
Manicina areolata	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meandrina meandrites	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.05	0.05	0.05	0.03	0.00
Montastraea cavernosa	0.53	0.55	0.50	0.35	0.48	0.50	0.55	0.58	0.50	0.63	0.58	0.30
Mycetophyllia aliciae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Mycetophyllia lamarckiana	0.05	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.18	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Orbicella faveolata			0.13	0.13	0.10	0.13	0.13	0.08	0.10	0.10	0.10	0.13
Orbicella franksi			0.05	0.05	0.05	0.03	0.05	0.08	0.08	0.03	0.00	0.00
Porites astreoides	0.75	1.03	1.05	1.18	1.33	1.58	1.78	1.40	1.75	1.80	1.83	1.78
Porites porites	0.15	0.13	0.20	0.13	0.10	0.08	0.08	0.10	0.15	0.03	0.03	0.05
Pseudodiploria clivosa	0.00	0.00	0.00	0.03	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.15	0.15	0.15	0.15	0.13	0.13	0.18	0.20	0.18	0.18	0.18	0.03
Siderastrea siderea	1.85	2.15	2.40	2.38	3.08	3.23	3.65	3.33	4.03	3.73	4.00	3.63
Solenastrea bournoni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Stephanocoenia intersepta	0.80	0.75	0.88	0.80	0.98	1.08	1.18	1.05	1.23	1.15	1.35	1.18
Total Coral Density	4.85	5.55	5.95	5.58	6.78	7.10	7.93	7.15	8.45	8.23	8.68	7.45

Appendix D: continued

Palmata Patch:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.65	1.30	0.65	1.70	0.30	0.20	0.65	0.60	0.65	0.60	0.45	0.50
Acropora cervicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.15	0.10	0.10
Acropora palmata	1.00	1.05	1.40	1.25	0.90	1.25	1.35	1.05	1.10	1.45	0.80	1.65
Diploria labyrinthiformis	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Montastraea cavernosa	0.05	0.05	0.10	0.05	0.05	0.00	0.00	0.00	0.00	0.05	0.10	0.00
Orbicella annularis	0.00	0.05	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Porites astreoides	0.10	0.35	0.40	0.40	0.40	0.40	0.50	0.25	0.45	0.45	0.35	0.35
Porites porites	0.05	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.10	0.05	0.10	0.05
Pseudodiploria clivosa	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.00	0.05	0.00	0.00	0.00	0.05	0.15	0.15	0.15	0.15	0.15	0.05
Siderastrea radians	0.10	0.15	0.10	0.15	0.15	0.10	0.10	0.10	0.15	0.10	0.05	0.10
Siderastrea siderea	0.05	0.20	0.30	0.05	0.10	0.20	0.15	0.10	0.05	0.25	0.10	0.10
Total Coral Density	2.00	3.20	3.05	3.70	2.00	2.30	2.95	2.25	2.70	3.25	2.20	2.90

Prolifera Patch: * colonies are not enumerated. Note: *Orbicella* spp. colonies are not differentiated at this site.

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.17	0.13	0.17	0.13	0.17	0.13	0.10	0.43	0.57	0.40	0.33	0.63
Acropora cervicornis	0.00	0.00	0.00	0.03	0.00	0.10	0.00	0.00	0.00	0.00	0.03	0.00
Acropora prolifera	*	*	*	*	*	*	*	*	*	*	*	*
Orbicella spp.	0.77	0.63	0.57	0.67	0.56	0.60	0.37	0.47	0.64	0.50	0.54	0.43
Porites astreoides	0.10	0.03	0.07	0.20	0.23	0.13	0.17	0.13	0.17	0.13	0.27	0.30
Pseudodiploria clivosa	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.07	0.00	0.03	0.03	0.00
Pseudodiploria strigosa	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.03	0.03	0.00
Siderastrea siderea	0.03	0.03	0.03	0.03	0.03	0.07	0.03	0.07	0.07	0.07	0.03	0.00
Total Coral Density	1.13	0.90	0.87	1.13	1.03	1.03	0.67	1.17	1.43	1.17	1.27	1.37

Appendix D: continued

Temptation Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.03	0.03	0.03	0.05	0.05	0.00	0.00	0.05	0.00	0.05	0.10	0.08
Agaricia fragilis	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colpophyllia natans	0.13	0.18	0.15	0.15	0.15	0.18	0.10	0.10	0.10	0.08	0.13	0.00
Dichocoenia stokesii	0.03	0.03	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.03	0.00
Diploria labyrinthiformis	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eusmilia fastigiata	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.03	0.05	0.05	0.00
Madracis decactis	0.00	0.03	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.03	0.05	0.05
Manicina areolata	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Meandrina meandrites	0.05	0.03	0.05	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.03	0.00
Montastraea cavernosa	0.13	0.23	0.10	0.15	0.15	0.18	0.13	0.15	0.15	0.05	0.08	0.05
Mussa angulosa	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia aliciae	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00
Mycetophyllia lamarckiana	0.03	0.00	0.05	0.05	0.05	0.03	0.05	0.00	0.05	0.03	0.05	0.05
Oculina diffusa	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oculina robusta	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.23	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.20	0.20	0.23	0.28	0.13	0.08	0.10	0.15	0.10	0.18
Orbicella franksi			0.00	0.03	0.00	0.00	0.10	0.05	0.05	0.00	0.05	0.00
Porites astreoides	0.55	0.75	0.90	0.73	0.80	1.00	1.05	0.95	0.95	0.98	1.03	1.13
Porites porites	0.43	0.50	0.40	0.35	0.43	0.18	0.33	0.30	0.25	0.38	0.58	0.68
Pseudodiploria clivosa	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.15	0.15	0.15	0.10	0.13	0.15	0.13	0.18	0.15	0.13	0.15	0.03
Scolymia cubensis	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Siderastrea radians	0.05	0.08	0.10	0.05	0.08	0.05	0.03	0.03	0.03	0.03	0.08	0.00
Siderastrea siderea	0.63	0.85	0.68	0.75	1.35	1.20	1.58	1.18	1.43	1.35	1.78	1.15
Solenastrea bournoni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Stephanocoenia intersepta	0.33	0.38	0.38	0.38	0.40	0.38	0.48	0.40	0.38	0.40	0.45	0.35
Total Coral Density	2.93	3.63	3.28	3.13	3.95	3.68	4.18	3.55	3.70	3.78	4.73	3.73

Appendix D: continued

Texas Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.03	0.05	0.05	0.03	0.08	0.05	0.00	0.03	0.03	0.03	0.00	0.00
Agaricia fragilis	0.00	0.03	0.03	0.08	0.03	0.03	0.03	0.05	0.05	0.05	0.00	0.05
Agaricia lamarcki	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Colpophyllia natans	0.13	0.13	0.08	0.18	0.08	0.05	0.13	0.13	0.13	0.15	0.13	0.03
Dichocoenia stokesii	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diploria labyrinthiformis	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.05	0.05	0.05	0.03
Eusmilia fastigiata	0.10	0.08	0.10	0.05	0.05	0.03	0.03	0.03	0.05	0.00	0.00	0.00
Helioseris cucullata	0.03	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis auretenra	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis decactis	0.55	0.70	0.38	0.38	0.75	0.38	0.55	0.43	0.63	0.50	0.40	0.60
Madracis senaria	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.03	0.00	0.03	0.08	0.00
Meandrina meandrites	0.10	0.13	0.08	0.10	0.15	0.15	0.10	0.10	0.08	0.10	0.13	0.00
Montastraea cavernosa	1.45	1.58	1.83	1.53	1.75	1.63	1.40	1.63	1.38	1.45	1.65	0.58
Mussa angulosa	0.03	0.08	0.08	0.03	0.05	0.05	0.05	0.03	0.05	0.08	0.03	0.00
Mycetophyllia aliciae	0.05	0.05	0.05	0.05	0.08	0.05	0.08	0.08	0.05	0.05	0.10	0.00
Mycetophyllia lamarckiana	0.03	0.03	0.03	0.00	0.03	0.03	0.00	0.00	0.03	0.03	0.03	0.00
Oculina diffusa	0.05	0.00	0.03	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.03	0.00
Oculina robusta	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.55	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.28	0.40	0.38	0.58	0.25	0.18	0.23	0.18	0.25	0.20
Orbicella franksi			0.20	0.10	0.15	0.05	0.18	0.38	0.18	0.28	0.28	0.05
Porites astreoides	0.73	0.88	0.75	0.53	0.88	0.88	0.95	0.90	1.00	0.85	1.33	0.80
Porites porites	0.13	0.18	0.20	0.10	0.23	0.15	0.18	0.10	0.23	0.28	0.33	0.15
Pseudodiploria clivosa	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.05	0.03	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.03	0.05	0.00
Scolymia lacera	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Siderastrea siderea	1.05	1.48	1.38	1.28	1.43	1.75	1.83	2.08	2.18	2.03	2.58	1.78
Solenastrea bournoni	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Stephanocoenia intersepta	0.45	0.53	0.58	0.45	0.50	0.48	0.58	0.63	0.45	0.63	0.73	0.55
Total Coral Density	5.60	6.65	6.48	5.33	6.68	6.45	6.48	6.83	6.80	6.75	8.18	4.85

Appendix D: continued

The Maze:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.08	0.10	0.05	0.10	0.13	0.10	0.05	0.10	0.15	0.13	0.15	0.08
Acropora cervicornis	0.03	0.03	0.03	0.03	0.05	0.05	0.08	0.13	0.05	0.03	0.08	0.05
Agaricia fragilis	0.20	0.18	0.13	0.13	0.00	0.03	0.05	0.08	0.05	0.00	0.05	0.05
Agaricia lamarcki	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Colpophyllia natans	0.08	0.08	0.08	0.05	0.05	0.05	0.00	0.05	0.08	0.03	0.05	0.00
Eusmilia fastigiata	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.08	0.05	0.00
Madracis auretenra	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madracis decactis	0.10	0.15	0.03	0.10	0.15	0.05	0.20	0.20	0.15	0.08	0.13	0.08
Madracis senaria	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.00	0.05	0.00
Meandrina meandrites	0.10	0.08	0.10	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.08	0.00
Montastraea cavernosa	0.68	0.58	0.55	0.53	0.55	0.60	0.60	0.58	0.55	0.45	0.70	0.45
Mussa angulosa	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia aliciae	0.03	0.03	0.03	0.03	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mycetophyllia ferox	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Mycetophyllia lamarckiana	0.03	0.03	0.00	0.00	0.00	0.05	0.03	0.03	0.03	0.03	0.03	0.00
Orbicella annularis	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella faveolata			0.15	0.08	0.10	0.18	0.10	0.13	0.08	0.05	0.10	0.15
Orbicella franksi			0.08	0.13	0.10	0.08	0.13	0.08	0.13	0.10	0.08	0.03
Porites astreoides	0.28	0.40	0.48	0.53	0.48	0.65	0.55	0.78	0.70	0.85	0.93	0.93
Porites porites	0.00	0.05	0.03	0.03	0.03	0.08	0.10	0.05	0.10	0.03	0.05	0.00
Pseudodiploria clivosa	0.00	0.03	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.13	0.13	0.10	0.05	0.05	0.13	0.13	0.13	0.08	0.10	0.13	0.05
Scolymia cubensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00
Scolymia lacera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Siderastrea radians	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.00
Siderastrea siderea	1.05	1.28	1.05	1.23	1.30	1.78	2.08	1.98	2.03	1.83	2.33	2.08
Stephanocoenia intersepta	0.70	0.80	0.93	0.78	0.83	0.95	0.98	0.95	1.03	0.85	1.13	1.00
Total Coral Density	3.80	4.35	3.93	3.93	4.05	5.00	5.25	5.45	5.40	4.75	6.15	4.98

Appendix D: continued

White Shoal:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Agaricia agaricites	0.43	0.23	0.23	0.25	0.38	0.35	0.73	1.40	0.78	0.78	0.48	0.15
Acropora cervicornis	0.33	0.28	0.28	0.28	0.30	0.38	0.23	0.88	0.55	0.65	2.08	1.75
Colpophyllia natans	0.03	0.00	0.05	0.03	0.05	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Dichocoenia stokesii	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Diploria labyrinthiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Eusmilia fastigiata	0.28	0.20	0.13	0.05	0.10	0.15	0.20	0.13	0.15	0.10	0.13	0.00
Manicina areolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.03
Meandrina meandrites	0.08	0.08	0.10	0.13	0.08	0.15	0.13	0.08	0.05	0.08	0.00	0.03
Montastraea cavernosa	0.13	0.05	0.05	0.08	0.05	0.03	0.03	0.00	0.03	0.03	0.00	0.03
Oculina diffusa	0.15	0.20	0.18	0.18	0.18	0.25	0.18	0.13	0.13	0.10	0.03	0.00
Oculina robusta	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orbicella annularis	0.03	0.03	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.03	0.00
Orbicella faveolata			0.03	0.03	0.03	0.00	0.00	0.03	0.03	0.03	0.00	0.03
Porites astreoides	0.33	0.45	0.35	0.40	0.73	0.68	0.58	0.63	0.63	0.48	0.43	0.38
Porites porites	1.90	2.13	1.60	1.75	1.43	1.78	1.83	1.75	1.58	1.28	0.90	0.80
Pseudodiploria clivosa	0.08	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudodiploria strigosa	0.03	0.05	0.05	0.05	0.05	0.08	0.08	0.05	0.05	0.05	0.05	0.00
Siderastrea radians	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Siderastrea siderea	0.18	0.25	0.28	0.30	0.33	0.48	0.43	0.43	0.50	0.53	0.50	0.45
Stephanocoenia intersepta	0.05	0.05	0.03	0.00	0.03	0.05	0.13	0.10	0.10	0.13	0.10	0.15
Total Coral Density	4.00	4.03	3.35	3.55	3.73	4.40	4.58	5.58	4.58	4.23	4.75	3.78

Appendix E: Average density (colonies/m^2) for each targeted octocoral species and for all octocorals for each site for each year.

Bird Key Reef:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.2
Antillogorgia americana	0.0	0.1	0.4	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Antillogorgia bipinnata		11.2	11.4	16.3	15.8	19.5	20.8	18.5	23.7	20.8	19.0	18.8
Total Octocoral Density	10.3	12.3	13.5	17.0	15.7	20.8	23.9	20.5	25.1	22.7	21.5	20.4

Black Coral Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina		0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Antillogorgia americana		0.8	0.9	1.0	1.4	1.2	1.2	0.8	0.9	1.1	1.0	0.9
Antillogorgia bipinnata		9.0	8.3	5.2	4.1	4.3	4.2	5.3	5.4	6.2	6.7	6.3
Eunicea flexuosa		0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Octocoral Density		10.3	10.8	8.1	7.0	6.8	6.7	7.5	7.1	8.6	8.7	7.7

Davis Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total Octocoral Density	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0

* No target species recorded

Loggerhead Patch:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina		0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.0	0.0
Antillogorgia americana		0.3	0.2	0.2	0.2	0.4	0.1	0.1	0.2	0.0	0.0	0.7
Eunicea flexuosa		0.3	0.2	0.5	0.1	0.1	0.3	0.1	0.2	0.2	0.4	0.1
Pseudoplexaura porosa		0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Total Octocoral Density		0.6	0.6	0.9	0.8	1.3	1.5	1.1	4.0	1.0	2.3	2.1

Mayer's Peak:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	2.3	2.8	0.9	1.0	1.7	1.6	1.8	1.8	1.5	1.4	1.7	1.6
Antillogorgia americana	2.2	2.7	2.8	2.7	3.6	3.4	3.0	3.2	3.1	2.7	3.0	3.1
Antillogorgia bipinnata		1.9	0.1	0.5	1.4	0.7	0.7	1.3	3.1	0.5	0.2	0.2
Eunicea flexuosa	3.7	5.1	5.3	4.3	4.1	4.0	4.3	4.2	4.7	3.6	4.5	3.3
Pseudoplexaura porosa	0.8	0.6	0.9	0.8	0.8	0.6	0.5	0.5	0.8	0.2	0.3	0.1
Total Octocoral Density	18.1	20.0	22.2	22.3	24.6	24.8	26.3	28.1	30.4	24.3	26.1	25.5

Appendix E: continued

Palmata Patch:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina		0.4	0.6	0.3	0.2	0.4	0.6	0.7	1.0	0.9	0.9	0.8
Antillogorgia americana		1.4	1.8	1.5	1.5	1.5	1.6	1.9	1.5	1.8	1.5	1.6
Eunicea flexuosa		0.0	0.1	0.1	0.0	0.2	0.0	0.2	0.1	0.3	0.1	0.1
Pseudoplexaura porosa		0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.3	0.2	0.1	0.2
Total Octocoral Density		3.0	3.9	2.9	2.8	3.0	3.5	4.6	4.5	4.4	4.2	3.2

Prolifera Patch:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina		0.5	0.4	0.5	0.6	0.5	0.4	0.6	0.6	0.8	1.0	1.0
Antillogorgia americana		0.1	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Eunicea flexuosa		0.6	0.6	0.6	0.7	0.5	0.3	0.2	0.4	0.6	0.5	1.1
Pseudoplexaura porosa		0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.2
Total Octocoral Density		1.9	2.0	2.0	2.5	1.9	1.6	2.2	2.4	2.5	3.0	3.0

Temptation Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	1.1	1.3	1.0	0.7	0.6	0.5	0.5	0.5	0.6	0.6	0.5	0.6
Antillogorgia americana	1.8	1.7	2.0	2.2	1.9	2.0	2.1	2.0	2.2	2.2	2.3	2.0
Eunicea flexuosa	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Pseudoplexaura porosa	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Octocoral Density	4.3	4.0	4.8	3.7	3.8	3.4	3.7	3.8	4.3	4.5	3.8	3.8

Texas Rock:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.3	0.2	0.2
Antillogorgia americana	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Eunicea flexuosa	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.1
Total Octocoral Density	0.7	0.6	0.6	0.7	0.4	0.4	0.4	0.7	0.9	0.7	0.8	0.6

Appendix E: continued

The Maze:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	1.0	1.0	0.4	0.2	0.3	0.4	0.4	0.4	0.4	0.7	0.6	0.5
Antillogorgia americana	0.8	1.0	0.7	1.0	1.1	1.2	1.2	1.1	1.1	1.2	1.3	1.4
Antillogorgia bipinnata		0.9	0.8	1.2	1.1	1.1	0.1	1.0	2.0	1.0	0.2	0.7
Eunicea flexuosa	0.6	1.1	0.8	1.1	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.6
Pseudoplexaura porosa	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Total Octocoral Density	6.1	5.0	4.8	5.3	5.7	5.6	6.4	6.1	7.0	7.2	6.5	6.4

White Shoal:

Species	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gorgonia ventalina	0.2	0.3	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.4
Antillogorgia americana	1.3	0.9	0.7	1.2	1.1	1.2	1.3	1.8	1.7	2.1	1.7	1.9
Eunicea flexuosa	0.2	0.6	0.9	0.7	0.6	0.6	0.7	0.7	1.2	0.9	0.5	0.5
Pseudoplexaura porosa	0.2	0.5	0.6	0.2	0.0	0.3	0.1	0.3	0.3	0.1	0.4	0.1
Total Octocoral Density	6.7	9.0	10.4	10.8	10.0	11.0	12.0	11.7	14.3	15.0	13.7	13.4

Appendix F: Average daily temperature (°C) for each month of peak heating (July – October) for each site for each year. Blanks indicate temperature data is not available for the associated time period. Months where the average daily temperature was at or above the bleaching temperature of 30°C are in bold.

Site	Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Bird Key Reef	Jul	**30.1**	29.6	29.7	28.3	29.3	28.6	28.6	**30.4**	**30.4**	29.5	**30.2**	29.9	**30.8**	29.8	29.3	**30.2**
Bird Key Reef	Aug	**30.4**	**30.3**	**30.3**	**30.5**	**30.8**	29.4	29.7	**31.0**	**31.0**	29.6	**30.2**	28.8	**30.7**	**30.5**	**30.4**	**30.5**
Bird Key Reef	Sep	29.9	28.8	**30.3**	29.9	**30.2**	28.8	29.5	29.9	**30.5**	29.2	30.0	29.5	29.7	**30.5**	**30.2**	**30.6**
Bird Key Reef	Oct	28.7	27.8	29.4	27.7	27.9	27.7	28.8	28.9	28.7	28.3	28.5	28.0	28.9	29.3	29.1	27.9
Black Coral Rock	Jul	29.0	29.4	27.8	24.8	28.0	26.0	27.3	29.2	29.2	26.3	29.6	26.9	29.5	28.4	28.8	29.0
Black Coral Rock	Aug	29.3	29.6	29.3	30.0	**30.0**	27.3	29.3	29.2	**30.2**	26.0	29.3	24.1	29.7	**30.0**	29.9	30.0
Black Coral Rock	Sep	29.9	28.7	**30.0**	29.9	**30.1**	27.4	29.2	29.6	**30.4**	26.5	29.4	28.1	29.6	**30.3**	29.9	**30.3**
Black Coral Rock	Oct	28.7	28.0	29.5	27.9	28.2	27.4	28.5	28.9	28.7	28.0	28.4	26.3	28.9	29.2	28.4	27.9
Davis Rock	Jul										28.4	**30.3**	29.8	**30.4**	29.6	29.3	30.0
Davis Rock	Aug										28.9	**30.3**	28.5	**30.6**	**30.4**	**30.3**	**30.5**
Davis Rock	Sep										28.1	30.0	29.1	29.7	**30.5**	**30.1**	**30.6**
Davis Rock	Oct										28.2	28.4	27.6	28.7	29.2	28.9	27.9
Loggerhead Patch	Jul											**30.5**	**30.3**	**30.5**	**30.2**	29.6	**30.3**
Loggerhead Patch	Aug											**30.4**	29.5	**30.9**	**30.7**	**30.4**	**30.7**
Loggerhead Patch	Sep											**30.1**	29.5	29.9	**30.5**	**30.2**	**30.7**
Loggerhead Patch	Oct											28.4	28.1	29.0	29.2	29.0	27.9
Mayer's Peak	Jul	**30.2**	29.5	29.6	28.7	29.3	28.3	28.7	**30.5**	**30.4**	28.6	**30.4**	**30.2**	**30.4**	**30.1**	29.3	**30.2**
Mayer's Peak	Aug	**30.4**	**30.3**	**30.4**	**30.5**	**31.0**	29.1	29.8	**31.0**	**31.1**	29.5	**30.4**	29.3	**30.7**	**30.5**	**30.3**	**30.6**
Mayer's Peak	Sep	29.9	28.8	**30.5**	29.9	**30.3**	28.5	29.6	**30.0**	**30.6**	28.7	**30.1**	29.4	29.8	**30.4**	**30.2**	**30.7**
Mayer's Peak	Oct	28.6	27.8	29.5	27.8	27.9	27.7	28.7	29.0	28.7	28.2	28.5	27.9	29.0	29.2	29.0	28.0
Palmata Patch	Jul			**30.1**	29.2	29.6	28.8	28.9	**30.6**	**30.6**	29.4	**30.5**	**30.4**	**30.6**	**30.2**	29.5	**30.4**
Palmata Patch	Aug			**30.5**	**30.7**	**31.1**	29.5	29.9	**30.9**	**31.2**	29.9	**30.5**	29.8	**30.9**	**30.7**	**30.4**	**30.6**
Palmata Patch	Sep			**30.6**	**30.0**	**30.4**	28.9	29.6	29.8	**30.6**	29.3	**30.1**	29.6	29.8	**30.5**	**30.2**	**30.6**
Palmata Patch	Oct		27.4	29.5	27.6	27.9	27.7	28.8	28.8	28.7	28.3	28.5	28.1	29.0	29.2	29.1	28.0

Appendix F: continued

Site	Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Prolifera Patch	July											**30.6**	**30.5**	**30.6**	**30.2**	29.6	**30.4**
Prolifera Patch	Aug											**30.6**	29.9	**30.9**	**30.8**	**30.5**	**30.7**
Prolifera Patch	Sep											**30.2**	29.8	29.8	**30.6**	**30.3**	**30.7**
Prolifera Patch	Oct											28.6	28.1	29.0	29.3	29.1	28.0
Temptation Rock	July	**30.1**	29.6	29.4	26.9	29.1	27.3	28.7	**30.4**	**30.2**	27.6	**30.3**	29.7	**30.4**	29.8	29.4	**30.1**
Temptation Rock	Aug	**30.3**	**30.3**	**30.2**	**30.5**	**30.9**	28.4	29.8	**30.8**	**31.0**	28.0	**30.2**	26.8	**30.7**	**30.4**	**30.3**	**30.5**
Temptation Rock	Sep	29.8	28.8	**30.5**	29.9	**30.2**	28.1	29.5	29.8	**30.5**	27.8	30.0	28.9	29.8	**30.4**	**30.1**	**30.6**
Temptation Rock	Oct	28.5	27.7	29.4	27.5	27.8	27.5	28.6	28.8	28.6	28.0	28.3	27.0	28.8	29.1	28.7	27.9
Texas Rock	July				27.8		28.1	28.6	**30.5**	**30.2**	28.5	**30.2**	29.9	**30.3**	29.9	29.4	30.0
Texas Rock	Aug				**30.5**		28.8	29.7	**30.9**	**31.1**	29.0	**30.3**	28.6	**30.7**	**30.5**	**30.3**	**30.5**
Texas Rock	Sep				30.0		28.5	29.4	29.9	**30.5**	28.2	29.9	29.2	29.9	**30.5**	**30.1**	**30.6**
Texas Rock	Oct				27.6		27.6	28.6	28.9	28.7	28.2	28.4	27.7	28.9	29.2	29.0	27.9
The Maze	July							28.8			28.4	**30.3**	**30.1**	**30.4**	29.9	29.3	**30.2**
The Maze	Aug							29.8			29.3	**30.3**	28.7	**30.7**	**30.5**	**30.4**	**30.5**
The Maze	Sep							29.6			28.6	**30.0**	29.2	29.7	**30.5**	**30.2**	**30.6**
The Maze	Oct							28.7			28.2	28.4	27.8	28.9	29.2	29.0	28.0
White Shoal	July										29.0	**30.4**	**30.2**	**30.5**	**30.0**	29.5	**30.2**
White Shoal	Aug										29.6	**30.4**	29.4	**30.8**	**30.6**	**30.4**	**30.5**
White Shoal	Sep										28.7	**30.1**	29.5	29.8	**30.5**	**30.2**	**30.6**
White Shoal	Oct										28.2	28.5	28.1	28.9	29.2	29.0	27.9

Appendix G: Percent cover statistics results for long-term and short-term analyses. Includes model estimated percent cover (±SE) for each year group analyzed and P-value for each comparison. Significant comparisons are emboldened. No short-term analysis was conducted for *Acropora cervicornis* at Loggerhead Patch.

Stony Corals

Site	First Four	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	**17.6 ± 3.6**	**7.8 ± 1.8**	**<0.0001**	8.6 ± 2.7	7.0 ± 2.3	0.1013
Black Coral Rock	**21.3 ± 4.1**	**11.6 ± 2.5**	**<0.0001**	12.8 ± 3.9	10.5 ± 3.3	0.0822
Davis Rock	8.6 ± 1.9	7.7 ± 1.8	0.3973	7.7 ± 2.5	7.8 ± 2.5	0.9665
Loggerhead Patch	**2.0 ± 0.7**	**0.6 ± 0.2**	**<0.0001**	0.3 ± 0.1	0.4 ± 0.2	0.0750
Mayer's Peak	**3.5 ± 0.8**	**4.6 ± 1.1**	**0.0323**	5.2 ± 1.7	4.1 ± 1.4	0.0769
Palmata Patch	**3.2 ± 1.1**	**6.7 ± 2.2**	**0.0001**	5.7 ± 2.7	7.5 ± 3.4	0.1034
Prolifera Patch	**11.9 ± 3.0**	**15.8 ± 3.8**	**0.0280**	15.1 ± 5.1	16.3 ± 5.5	0.5111
Temptation Rock	3.2 ± 0.8	4.0 ± 1.0	0.1086	4.1 ± 1.4	3.9 ± 1.3	0.7658
Texas Rock	**7.3 ± 1.7**	**5.4 ± 1.3**	**0.0132**	6.1 ± 2.0	4.8 ± 1.6	0.0646
The Maze	10.1 ± 2.2	8.4 ± 1.9	0.1185	8.8 ± 2.8	8.0 ± 2.6	0.4383
White Shoal	**6.8 ± 1.6**	**3.3 ± 0.8**	**<0.0001**	3.2 ± 1.1	3.5 ± 1.2	0.5924
Little Africa	**22.1 ± 1.9**	**11.3 ± 1.1**	**<0.0001**	12.2 ± 1.8	10.3 ± 1.5	0.4131

Octocorals

Site	First Four	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	18.8 ± 2.4	17.4 ± 2.3	0.4484	**19.2 ± 2.6**	**15.8 ± 2.3**	**0.0255**
Black Coral Rock	10.0 ± 1.5	9.7 ± 1.4	0.8144	9.1 ± 1.4	10.4 ± 1.6	0.1992
Davis Rock	**0.6 ± 0.1**	**2.7 ± 0.4**	**<0.0001**	2.6 ± 0.5	3.0 ± 0.5	0.3206
Loggerhead Patch	**0.9 ± 0.2**	**1.5 ± 0.3**	**0.0093**	1.6 ± 0.4	1.3 ± 0.3	0.2988
Mayer's Peak	**22.1 ± 2.8**	**27.7 ± 3.2**	**0.0131**	**24.9 ± 3.2**	**30.6 ± 3.6**	**0.0072**
Palmata Patch	**2.0 ± 0.5**	**11.8 ± 2.3**	**<0.0001**	11.8 ± 2.5	11.7 ± 2.5	0.9786
Prolifera Patch	4.9 ± 0.9	5.6 ± 1.0	0.3306	5.7 ± 1.1	5.5 ± 1.0	0.7431
Temptation Rock	14.0 ± 1.9	16.0 ± 2.2	0.1786	15.0 ± 2.2	17.2 ± 2.4	0.1432
Texas Rock	3.5 ± 0.6	4.1 ± 0.6	0.2458	**3.3 ± 0.6**	**5.1 ± 0.9**	**0.0005**
The Maze	**6.7 ± 1.0**	**11.8 ± 1.7**	**<0.0001**	**10.3 ± 1.6**	**13.4 ± 2.0**	**0.0080**
White Shoal	**7.8 ± 1.2**	**15.0 ± 2.0**	**<0.0001**	13.8 ± 2.0	16.4 ± 2.3	0.0657
Little Africa	3.0 ± 0.6	5.1 ± 1.0	0.0674	5.6 ± 1.4	4.7 ± 1.2	0.6221

Appendix G: continued

Macroalgae

Site	First Four	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	**10.4 ± 2.1**	**36.6 ± 5.2**	**<0.0001**	**29.7 ± 3.9**	**44.1 ± 4.6**	**0.0002**
Black Coral Rock	**6.5 ± 1.4**	**38.4 ± 5.3**	**<0.0001**	**44.5 ± 4.6**	**32.6 ± 4.1**	**0.0021**
Davis Rock	44.2 ± 5.5	46.8 ± 5.6	0.6964	49.5 ± 4.7	44.2 ± 4.6	0.2033
Loggerhead Patch	**3.2 ± 1.0**	**24.9 ± 5.9**	**<0.0001**	**17.0 ± 3.7**	**35.0 ± 6.0**	**<0.0001**
Mayer's Peak	**1.6 ± 0.4**	**16.7 ± 3.1**	**<0.0001**	**28.5 ± 3.8**	**9.1 ± 1.6**	**<0.0001**
Palmata Patch	**1.5 ± 0.5**	**17.4 ± 4.5**	**<0.0001**	18.7 ± 4.0	16.2 ± 3.6	0.4403
Prolifera Patch	**1.5 ± 0.4**	**8.2 ± 2.0**	**<0.0001**	**10.2 ± 2.0**	**7.0 ± 1.4**	**0.0299**
Temptation Rock	**7.0 ± 1.5**	**30.5 ± 4.7**	**<0.0001**	**36.9 ± 4.4**	**24.8 ± 3.5**	**0.0005**
Texas Rock	31.7 ± 4.8	39.0 ± 5.3	0.2282	39.2 ± 4.5	38.8 ± 4.5	0.9114
The Maze	33.1 ± 5.0	33.0 ± 4.9	0.9803	**39.2 ± 4.5**	**27.3 ± 3.7**	**0.0011**
White Shoal	**5.4 ± 1.2**	**26.1 ± 4.3**	**<0.0001**	25.8 ± 3.6	26.5 ± 3.7	0.8395
Little Africa	**9.6 ± 0.8**	**23.8 ± 1.6**	**<0.0001**	25.9 ± 1.5	22.1 ± 1.4	0.0566

Sponges

Site	First Four	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	0.9 ± 0.2	1.0 ± 0.2	0.5267	1.0 ± 0.2	1.1 ± 0.2	0.5905
Black Coral Rock	3.6 ± 0.5	4.1 ± 0.6	0.3622	4.4 ± 0.6	4.0 ± 0.6	0.4781
Davis Rock	**2.2 ± 0.3**	**3.2 ± 0.4**	**0.0088**	**4.0 ± 0.6**	**2.6 ± 0.4**	**0.0040**
Loggerhead Patch	**0.2 ± 0.1**	**0.8 ± 0.2**	**<0.0001**	0.7 ± 0.1	1.0 ± 0.2	0.0796
Mayer's Peak	**2.4 ± 0.3**	**4.2 ± 0.6**	**0.0003**	4.4 ± 0.6	4.0 ± 0.6	0.5332
Palmata Patch	**0.1 ± 0.0**	**0.6 ± 0.1**	**<0.0001**	0.7 ± 0.2	0.6 ± 0.1	0.5659
Prolifera Patch	**0.2 ± 0.0**	**0.4 ± 0.1**	**0.0020**	0.4 ± 0.1	0.5 ± 0.1	0.0706
Temptation Rock	**1.1 ± 0.2**	**2.5 ± 0.4**	**<0.0001**	2.6 ± 0.4	2.5 ± 0.4	0.7981
Texas Rock	**4.5 ± 0.6**	**6.3 ± 0.8**	**0.0167**	6.9 ± 0.9	5.8 ± 0.8	0.1645
The Maze	3.6 ± 0.5	4.5 ± 0.6	0.1422	4.4 ± 0.6	4.6 ± 0.6	0.6774
White Shoal	2.4 ± 0.3	2.3 ± 0.3	0.8658	**3.0 ± 0.4**	**1.8 ± 0.3**	**0.0017**
Little Africa	**0.2 ± 0.0**	**0.4 ± 0.1**	**0.0026**	0.5 ± 0.1	0.4 ± 0.1	0.4258

Appendix G: continued

ESA-Listed Stony Coral Species

Site	First Four	2019-2022	P-value	2019-2020	2021-2022	P-value
Acropora palmata (Palmata Patch)	2.3 ± 1.9	3.6 ± 2.9	0.2246	**2.9 ± 3.2**	**4.4 ± 4.8**	**0.0007**
Acropora prolifera (Prolifera Patch)	**4.4 ± 2.7**	**9.1 ± 5.2**	**<0.0001**	8.4 ± 5.9	9.8 ± 6.8	0.2463
Acropora cervicornis (White Shoal)	**3.4 ± 0.7**	**1.3 ± 0.3**	**<0.0001**	0.9 ± 0.3	1.6 ± 0.5	0.2018
Acropora cervicornis (Loggerhead Patch)	0.2 ± 0.1	0.0 ± 0.0	0.9960	-	-	-
Orbicella spp. (Bird Key Reef)	**8.6 ± 1.1**	**2.8 ± 0.4**	**<0.0001**	**3.4 ± 0.6**	**2.2 ± 0.4**	**0.0124**
Orbicella spp. (Black Coral Rock)	**9.4 ± 1.7**	**5.1 ± 1.0**	**<0.0001**	5.6 ± 1.2	4.6 ± 1.0	0.0641
Orbicella spp. (Little Africa)	**18.7 ± 2.0**	**8.9 ± 1.1**	**<0.0001**	9.2 ± 1.8	8.5 ± 1.7	0.7650
Orbicella spp. (Prolifera Patch)	**0.7 ± 1.4**	**0.4 ± 0.8**	**<0.0001**	0.6 ± 1.0	0.5 ± 0.9	0.4530
Orbicella spp. (Pinnacle Reefs)	**0.9 ± 0.3**	**0.5 ± 0.1**	**<0.0001**	0.5 ± 0.1	0.6 ± 0.2	0.3494

RNA Analyses

Site	2009-2012	2019-2022	P-value	2019-2020	2021-2022	P-value
Stony Corals (Sites with moorings)	**8.6 ± 1.1**	**7.1 ± 0.9**	**0.0001**	7.4 ± 0.9	6.7 ± 0.8	0.1329
Stony Corals (Sites without moorings)	3.8 ± 0.5	4.3 ± 0.6	0.2295	4.6 ± 0.7	4.0 ± 0.6	0.2163
Octocorals (Sites with moorings)	**2.4 ± 0.2**	**5.1 ± 0.4**	**<0.0001**	**4.5 ± 0.4**	**6.0 ± 0.5**	**0.0001**
Octocorals (Sites without moorings)	**16.2 ± 0.9**	**21.3 ± 1.1**	**<0.0001**	**19.5 ± 1.2**	**23.2 ± 1.3**	**0.0101**

Appendix H: Demographic statistics results for long-term and short-term analyses. Includes model estimated colony density (colonies/m^2 ± SE) for each year group analyzed and P-value for each comparison. Significant comparisons are emboldened.

Stony Corals

Site	2011-2014	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	5.5 ± 0.9	6.0 ± 1.0	0.1859	5.7 ± 0.8	6.4 ± 1.0	0.2374
Black Coral Rock	9.2 ± 1.5	8.4 ± 1.3	0.1985	9.0 ± 1.3	7.8 ± 1.1	0.1460
Davis Rock	**4.6 ± 0.7**	**5.8 ± 0.9**	**0.0025**	5.6 ± 0.8	5.9 ± 0.9	0.6542
Loggerhead Patch	**1.2 ± 0.3**	**0.1 ± 0.0**	**<0.0001**	0.1 ± 0.0	0.0 ± 0.0	0.6582
Mayer's Peak	**5.4 ± 0.9**	**8.1 ± 1.3**	**<0.0001**	8.2 ± 1.2	7.9 ± 1.2	0.7238
Palmata Patch	2.3 ± 0.5	2.2 ± 0.5	0.5944	2.6 ± 0.6	2.2 ± 0.5	0.3366
Prolifera Patch	**0.9 ± 0.2**	**1.1 ± 0.2**	**0.0468**	1.2 ± 0.2	1.2 ± 0.2	0.9391
Temptation Rock	**3.2 ± 0.5**	**3.9 ± 0.6**	**0.0112**	3.7 ± 0.6	4.2 ± 0.6	0.2879
Texas Rock	5.9 ± 0.9	6.5 ± 1.0	0.1595	6.7 ± 1.0	6.3 ± 0.9	0.6040
The Maze	**3.9 ± 0.6**	**5.2 ± 0.8**	**0.0002**	5.0 ± 0.8	5.5 ± 0.8	0.3946
White Shoal	3.5 ± 0.6	4.0 ± 0.7	0.0637	4.1 ± 0.6	4.0 ± 0.6	0.7626

Octocorals

Site	2011-2014	2019-2022	P-value	2019-2020	2021-2022	P-value
Bird Key Reef	**12.4 ± 2.2**	**20.6 ± 3.7**	**<0.0001**	21.9 ± 3.8	19.2 ± 3.3	0.0515
Black Coral Rock	**9.5 ± 1.8**	**7.8 ± 1.4**	**0.0093**	7.6 ± 1.3	7.9 ± 1.4	0.6550
Davis Rock	0.0 ± 0.0	0.0 ± 0.0	0.2160	0.0 ± 0.0	0.0 ± 0.0	0.9967
Loggerhead Patch	**0.7 ± 0.2**	**2.2 ± 0.6**	**<0.0001**	2.4 ± 0.6	2.1 ± 0.6	0.4243
Mayer's Peak	**20.6 ± 3.6**	**26.2 ± 4.7**	**0.0001**	26.9 ± 4.6	25.6 ± 4.4	0.4152
Palmata Patch	**2.5 ± 0.7**	**3.3 ± 0.9**	**0.0452**	3.7 ± 0.9	3.1 ± 0.8	0.2250
Prolifera Patch	**1.8 ± 0.4**	**2.5 ± 0.5**	**0.0087**	2.2 ± 0.5	2.8 ± 0.6	0.0937
Temptation Rock	3.9 ± 0.7	3.9 ± 0.7	0.7715	4.1 ± 0.7	3.6 ± 0.6	0.1396
Texas Rock	0.5 ± 0.1	0.6 ± 0.1	0.2952	0.7 ± 0.2	0.6 ± 0.1	0.4027
The Maze	**4.9 ± 0.9**	**6.2 ± 1.1**	**0.0022**	6.6 ± 1.2	6.0 ± 1.1	0.2365
White Shoal	**9.0 ± 1.6**	**13.7 ± 2.5**	**<0.0001**	14.3 ± 2.5	13.1 ± 2.3	0.2318

ESA-Listed Stony Coral Species

Site	2011-2014	2019-2022	P-value	2019-2020	2021-2022	P-value
Orbicella spp. (Bird Key Reef)	**1.5 ± 0.2**	**1.1 ± 0.2**	**0.0052**	1.2 ± 0.2	1.1 ± 0.2	0.6069
Orbicella spp. (Black Coral Rock)	**1.9 ± 0.3**	**1.5 ± 0.2**	**0.0188**	1.6 ± 0.3	1.4 ± 0.2	0.2874
Orbicella spp. (Prolifera Patch)	0.1 ± 0.2	0.1 ± 0.2	0.1803	0.1 ± 0.2	0.1 ± 0.2	0.5292
Orbicella spp. (Pinnacle Reefs)	**0.2 ± 0.0**	**0.2 ± 0.0**	**0.0131**	0.2 ± 0.0	0.2 ± 0.0	0.7265

Appendix H: continued

RNA Analyses

Site	2011-2014	2019-2022	P-value	2019-2020	2021-2022	P-value
Stony Corals (Sites with moorings)	**4.7 ± 0.3**	**5.8 ± 0.4**	**<0.0001**	5.7 ± 0.3	5.9 ± 0.3	0.5805
Stony Corals (Sites without moorings)	**4.2 ± 0.3**	**5.6 ± 0.4**	**<0.0001**	5.5 ± 0.3	5.8 ± 0.3	0.3611
Octocorals (Sites with moorings)	0.2 ± 0.1	0.4 ± 0.1	0.1160	0.6 ± 0.1	0.0 ± 2.3	0.9980
Octocorals (Sites without moorings)	**9.0 ± 0.8**	**10.1 ± 0.9**	**0.0032**	**10.6 ± 1.0**	**9.6 ± 0.9**	**0.0449**

Appendix I: Colonies with stony coral tissue loss disease for each site for 2021 and 2022. Counts are the number of colonies for each species exhibiting symptoms of SCTLD. Prevalence is the percentage of colonies of each species exhibiting symptoms of SCTLD. Only species that were found to have SCTLD are listed. SCTLD was not found at Loggerhead Patch, Little Africa or White Shoal. Demographic surveys are not conducted at Little Africa.

Bird Key Reef:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Colpophyllia natans	5	20.0%	0	0%
Montastraea cavernosa	17	5.9%	13	30.8%
Orbicella spp.	49	4.1%	40	37.5%
Siderastrea siderea	112	0.9%	81	N/A

Black Coral Rock:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Colpophyllia natans	7	0.0%	2	50.0%
Madracis senaria	14	0.0%	2	50.0%
Montastraea cavernosa	62	0.0%	40	40.0%
Orbicella spp.	65	0.0%	54	64.8%
Siderastrea siderea	59	0.0%	48	10.4%
Stephanocoenia intersepta	32	0.0%	28	17.9%
Undaria agaricites complex	5	0.0%	3	33.3%

Davis Rock:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Colpophyllia natans	2	0.0%	1	100.0%
Montastraea cavernosa	12	0.0%	11	36.4%
Orbicella spp.	13	0.0%	10	70.0%
Porites astreoides	93	0.0%	102	1.0%
Siderastrea siderea	60	0.0%	58	5.2%
Stephanocoenia intersepta	18	0.0%	18	5.6%
Undaria agaricites complex	4	0.0%	4	25.0%

Mayer's Peak:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Montastraea cavernosa	23	4.3%	12	8.3%
Orbicella spp.	5	20.0%	5	20.0%
Pseudodiploria strigosa	7	14.3%	1	0.0%
Siderastrea siderea	160	8.1%	145	2.1%

Appendix I: continued

Palmata Patch:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Siderastrea siderea	2	50.0%	2	0.0%

Temptation Rock:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Montastraea cavernosa	3	0.0%	2	50.0%
Porites astreoides	41	0.0%	45	2.2%
Siderastrea siderea	71	1.4%	46	4.3%
Stephanocoenia intersepta	18	0.0%	14	7.1%

Texas Rock:

Species	2021Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Colpophyllia natans	5	20.0%	1	0.0%
Meandrina meandrites	5	40.0%	0	0.0%
Montastraea cavernosa	66	10.6%	23	56.5%
Orbicella spp.	21	0.0%	10	30.0%
Pseudodiploria strigosa	2	50.0%	0	0.0%
Siderastrea siderea	103	3.9%	71	7.0%

The Maze:

Species	2021 Count	2021 SCTLD Prevalence	2022 Count	2022 SCTLD Prevalence
Colpophyllia natans	2	50.0%	0	0.0%
Madracis decactis	5	0.0%	3	33.3%
Meandrina meandrites	3	66.7%	0	0.0%
Montastraea cavernosa	28	0.0%	18	27.8%
Orbicella spp.	7	0.0%	7	14.3%
Siderastrea siderea	93	4.3%	83	8.4%