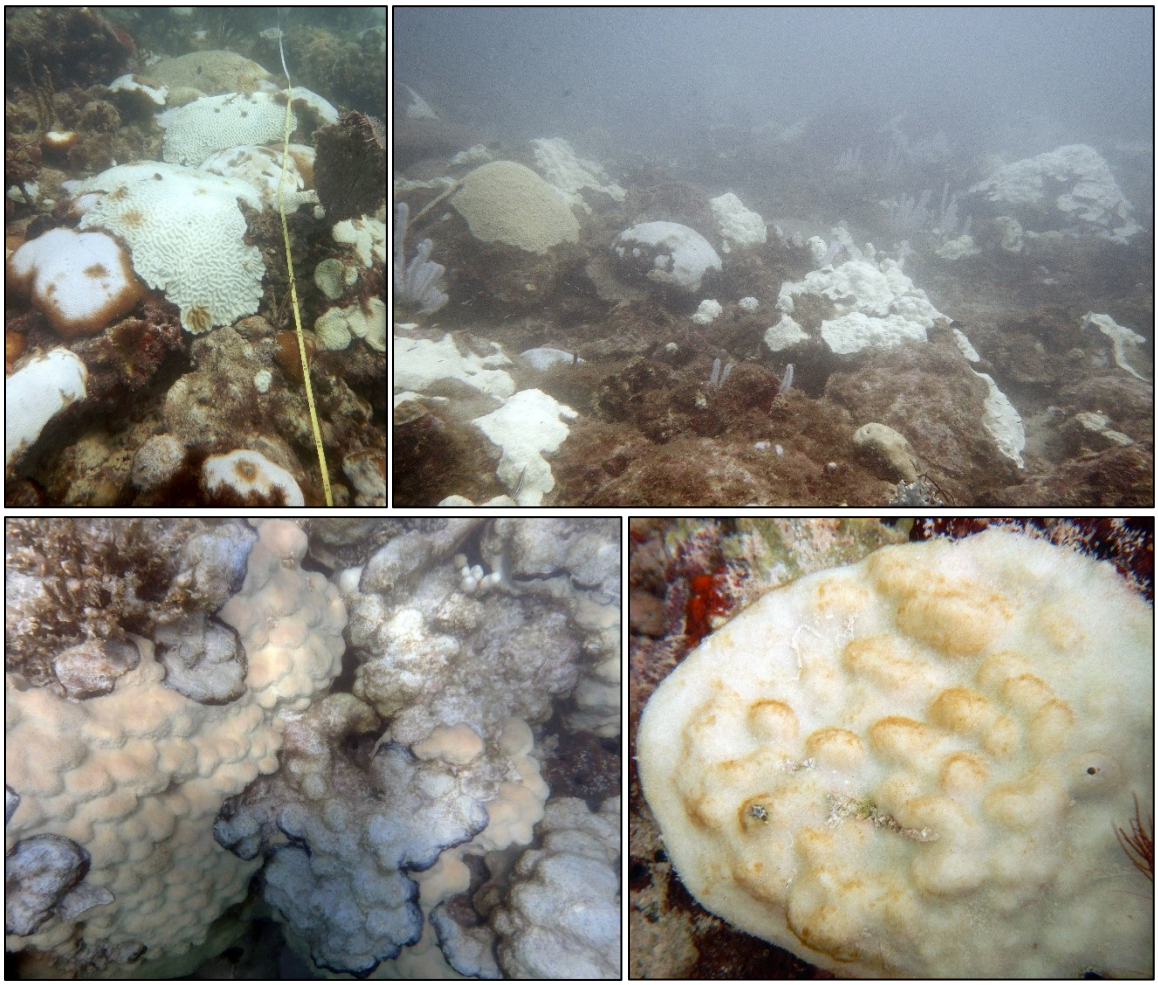
Disturbance Response Monitoring
2023 Summer Quick Look Report



Prepared by:

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

Authors: Jennifer Stein and Rob Ruzicka

This report presents data from annual summer surveys conducted between July 17 and October 31 of 2023.

Financial Support To The Disturbance Response Monitoring Program in 2023 was provided by:

EPA South Florida Geographic Initiative
Cooperative Agreement X7-02D02321

State Wildlife Grant F23Af02628

The National Oceanic and Atmospheric Administration and The Nature Conservancy Cooperative Agreement NA22NOS4820123

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Cover Page Photographs: Upper left: Bleached corals at Newfound Harbor located in the Lower Florida Keys (credit: FWRI). Upper Right: Bleached corals in the Dry Tortugas along the deep forereef (credit: FWRI). Bottom left: Bleached *Orbicella annularis* colony with Black Band Disease located in the Upper Keys (credit: John Pennekamp Coral Reef State Park). Bottom right: *Porites astreoides* colony with tissue loss from prolonged bleaching (credit: FWRI). All photos were taken during the 2023 surveys.

Suggested citation: Stein J. and Ruzicka R. 2023. Disturbance Response Monitoring 2023 Summer Quick Look Report. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL. 34 pp.
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INTRODUCTION

Created and first implemented by the former Florida Reef Resilience Program (FRRP), the Disturbance Response Monitoring (DRM) program was developed to annually assess coral condition during the months of peak thermal stress along Florida's Coral Reef (FCR). The 2005 severe coral bleaching event in the Florida Keys prompted the establishment of the DRM program, which has continued to implement these surveys every year.

DRM is a collaborative effort among local, state, and federal environmental managers, scientists, conservation organizations, and coral restoration practitioners, all of whom are driven by a common goal of providing valuable and timely coral condition data to all reef stakeholders. The primary goal of the DRM program has always been to provide a condition report on the annual status of bleaching along the reef tract. This information is used to identify resilient areas of the reef, promote appropriate management or conservation strategies for reef areas based on resilience, and aid management in research and restoration decisions. In addition to the extensive dataset the DRM program provides, it offers the opportunity for partners from across the jurisdictions of FCR to work together under a unified effort. This collaboration across agencies, universities, and organizations provides multiple sources of input and expertise to the program while also generating transparency across managers and researchers. This type of collaboration is becoming more important as the threats to the reef continue to grow.

During its tenure, the DRM program has modified its experimental design to account for new disturbances, such as the adaptation of its protocols in response to the outbreak of stony coral tissue loss disease (SCTLD). Now that the entire reef tract is endemic to SCTLD (i.e., the epidemic stage has concluded), an additional focus on assessing the surviving population of corals that were most susceptible to SCTLD has been added to the goals of DRM. These data will aid in identifying reef areas resilient to SCTLD and capable of natural recovery, as well as impacted reef areas that can support restoration and recovery now that SCTLD has subsided. To accommodate these new goals, DRM instituted several changes to the survey design beginning in the 2020 season that were maintained through the 2023 season. First, the survey area at each site was expanded from two to four belt transects. The two additional transects were designed to specifically target the species most affected by SCTLD, thus increasing the effort on locating these now rare individuals. Second, a juvenile census of the most SCTLD-susceptible coral families was added along all four transects. These data will provide an assessment of survivorship and/or the post-SCTLD recruitment of these susceptible coral species, which could determine whether recovery will occur broadly or locally along the reef.

During the 2023 season, 608 sites were surveyed throughout FCR, including a fifth year of surveys within the Marquesas. This accomplishment was possible due to the committed efforts of the 2023 partners, including Biscayne National Park, Broward County, Dry Tortugas National Park, Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission, Islamorada Conservation and Restoration Education, John Pennekamp Coral Reef State Park, Keys Marine Laboratory, Miami-Dade County, Mote Marine Laboratory, National Oceanic and Atmospheric Administration, Nova Southeastern University, Palm Beach County,

Palm Beach Zoo, Shedd Aquarium, The Nature Conservancy, and University of Miami's Rosenstiel School of Marine and Atmospheric Science.

This Quick Look Report describes the prevalence of coral bleaching, paling, and disease in 2023 as historically assessed through the survey methodology employed by DRM. For the past three years, annual DRM Quick Look Reports included a temporal comparison of coral density and diameter for 10 SCTLD-susceptible coral species over a now 14-year period. These summaries provided insight into the impact of SCTLD on these species. These comparisons are presented again with the 2023 data included, to update the continued impacts from SCTLD and assess any potential recovery. The 2023 DRM season marked the fourth year of a juvenile coral census for three SCTLD-susceptible (sub)families along all transects at a site. The species *Montastraea cavernosa* was added to the juvenile coral census in 2022. Juvenile results from 2020-2023 are presented in this report.

METHODS

The DRM program surveys coral populations using a probabilistic sampling design based on how corals are distributed spatially within and across different regions, subregions, and zones of FCR. Regions include Southeast Florida, Florida Keys, Marquesas, and Dry Tortugas. Reef zones were classified by cross-shelf position, distance from shore, and depth, while subregions were stratified latitudinally. The Southeast Florida region includes the Martin, North and South Palm Beach, and Broward-Miami subregions and the Florida Keys region includes the Biscayne, Upper Keys, Middle Keys, and Lower Keys subregions. Each year, new sites are randomly selected from this spatial framework. This sampling design is applied to all regions except the Marquesas, where, due to its lack of detailed benthic habitat maps, random site allocation is not possible. Instead, Marquesas sites in 2023 were selected in the same manner as in 2019-2022: chosen a priori based on known areas of hardbottom and reef habitat, where coral had been previously documented.

Surveys consisted of four independent 1 x 10m belt transects that were haphazardly placed within a 50 x 50 m sample area. Transects 1 and 2 included surveys of all stony coral species ≥4cm, while Transects 3 and 4 targeted a subset of 10 coral species (≥4cm) known to be highly susceptible to SCTLD, including: *Colpophyllia natans*, *Dichocoenia stokesii*, *Diploria labyrinthiformis*, *Meandrina meandrites*, *Mussa angulosa*, *Mycetophyllia aliciae*, *Mycetophyllia ferox*, *Mycetophyllia lamarckiana*, *Pseudodiploria clivosa*, and *P. strigosa*. Juvenile corals (<4cm) belonging to three target (sub)families (Faviinae, Mussinae, Meandrinidae) and one species (*M. cavernosa*) were tallied for each of Transects 1-4.

At all sites, stony corals ≥4cm were measured for size (maximum diameter and height), assessed for bleaching (whole or partial colony areas of complete color loss), or paling (a precursor to bleaching where coral color is lighter than normal), disease, and percent morality. Percent mortality was assigned as either old mortality, recent mortality due to disease, or recent mortality due to other biotic or abiotic factors. If disease was the cause of recent mortality, surveyors described the rate of tissue loss spread and recorded the recognized disease, if known. The tissue

loss rate and SCTLD disease code (STL) were adopted into the data collection in 2018 to better identify and describe lesions associated with SCTLD.

Prevalence values for bleaching (whole plus partial bleaching), the combination of bleaching and paling, and disease were calculated by pooling coral data across Transects 1 and 2 at each site and by zone within each subregion. Prevalence values represent the percent of corals affected along Transects 1 and 2 within a site or zone population. Prevalence values were compared across zones and subregions to identify spatial differences in coral bleaching and paling, as well as spatial patterns in disease prevalence.

Paling is included in a separate prevalence analysis, which combines bleaching and paling, because any visible loss of color indicates significant stress on a coral colony. It is advised, however, that paling results be interpreted with caution, due to the subjectivity inherent in how surveyors across the wide range of DRM partners interpret variations in coral color in the field.

In 2023, due to the early onset of high sea surface temperatures in late June and early July in the southern half of FCR, surveyors began reporting tissue sloughing and recent mortality on coral colonies from prolonged thermal stress. To document this condition, the DRM program added a thermal stress code to the data collection methods ("TRS"). The code TRS stands for: TR = thermal and S = stress. The addition of this code will help identify potential declines in coral density and the increase in partial mortality from prolonged bleaching.

Density values for the 10 target SCTLD-susceptible coral species and the target juvenile coral families and species were calculated by pooling the total count across all four transects and dividing by $40m^2$. The density for all sites and for each of the target adult coral species was averaged for each region (Southeast Florida, Florida Keys, Marquesas, and Dry Tortugas) and then compared across the past 13 years of DRM summer survey data (excluding targeted survey efforts such as post-Hurricane Irma or winter surveys). Mean maximum diameter for each of the target adult coral species was calculated similarly to density and compared across the past 13 years of DRM summer survey data. Mean density values of the target juvenile families were calculated by region.

RESULTS

A total of 608 sites were surveyed across the nine subregions of FCR during the 2023 DRM season (**Table 1)**. Nineteen sites were surveyed in the Martin subregion, 35 in Palm Beach, 99 in Broward-Miami, 64 in Biscayne, 106 in the Upper Keys, 44 in the Middle Keys, 90 in the Lower Keys, 55 in the Marquesas, and 96 in the Dry Tortugas. The total number of sites surveyed in each subregion across all historic DRM summer survey events is presented in **Table 1**.

Table 1. Total number of sites surveyed in each subregion for all DRM summer survey events (2005-2023).

Year	Martin	Palm Beach	Broward-Miami	Biscayne	Upper Keys	Middle Keys	Lower Keys	Marquesas	Dry Tortugas	Total
2005	3	3	25	14	17	8	25	0	0	95
2006	6	2	25	29	29	10	20	0	0	121
2007	0	11	25	25	24	13	31	6	14	149
2008	6	7	50	25	42	31	43	0	0	204
2009	6	12	45	42	44	24	48	0	36	257
2010	6	8	44	32	44	22	44	0	0	200
2011	6	6	37	43	55	31	54	0	5	237
2012	6	3	32	31	58	29	34	0	41	234
2013	0	4	12	26	21	16	21	0	0	100
2014	2	6	34	19	25	17	42	0	29	174
2015	6	8	80	28	23	21	63	0	20	249
2016	6	7	26	9	13	32	40	0	29	162
2017	0	0	23	0	0	5	15	0	31	74
2018	0	3	47	22	33	11	29	0	50	195
2019	0	15	67	15	37	18	54	31	48	285
2020	13	20	83	10	38	32	85	47	61	389
2021	6	29	70	34	50	26	74	35	54	378
2022	14	30	114	31	63	41	88	20	49	450
2023	19	35	99	64	106	44	90	55	96	608
Total Summer Survey Sites										**4561**

Bleaching

The prevalence of colonies along Transects 1 and 2 that were bleached (partially or fully) or were bleaching and/or paling (combined), was pooled by zones (**Figures 1** and **2**) and by sites (**Tables 2** and **3**) within each subregion. Prevalence values were broken into three categories: mild (0-20%), moderate (21-50%), and severe (>50%). Pooled by subregion-zone, the prevalence of bleached and partially bleached corals (excluding pale colonies) was severe in all subregion-zone combinations from Biscayne down through the Dry Tortugas, with the only exception being the Mid-Channel zone in the Marquesas, which was moderately bleached. The Marquesas region was surveyed in October when temperatures were beginning to decrease and therefore severe bleaching likely occurred within that zone earlier in the summer. In Southeast Florida, bleaching prevalence was mild from Martin down through Palm Beach and the Broward-Miami subregions, with the exception of the Deep Patch Reef in Northern Palm Beach, which was moderately bleached (**Figure 1**) solely due to bleached and partially bleached colonies of *Siderastrea radians*.

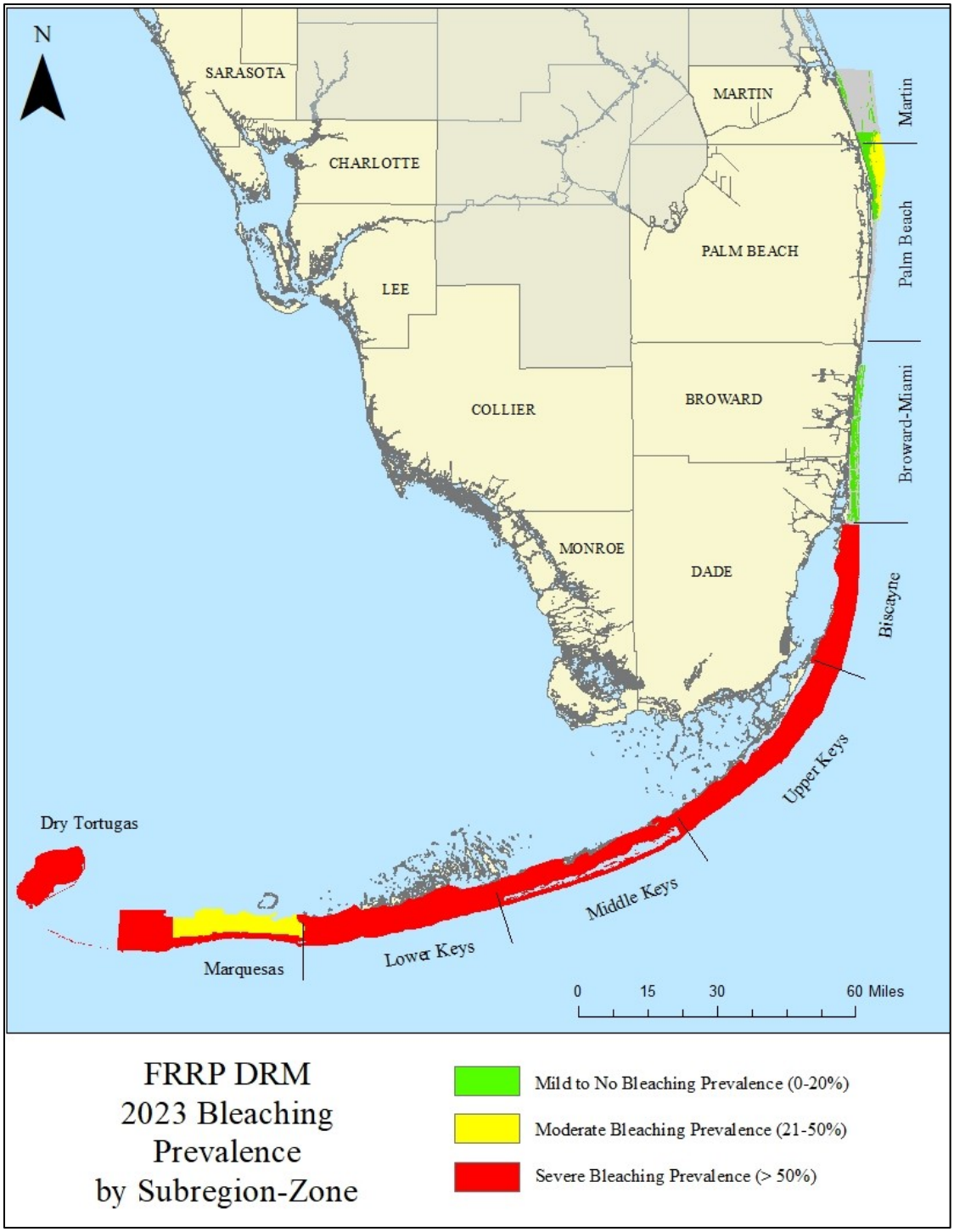

Figure 1. 2023 bleaching prevalence of surveyed coral colonies by subregion-zone.

There was a stark contrast in bleaching prevalence between the northern and southern portions of the reef tract. Despite the milder conditions experienced in Southeast Florida, 2023 was the worst bleaching year documented by the DRM program, with 58% of the total sites severely bleached.

Across all sites, 351 sites had severe bleaching prevalence and 116 had moderate bleaching prevalence (**Table 2**).

Table 2. Total number of sites within each subregion recorded with mild, moderate, or severe bleaching prevalence of coral colonies.

Subregion	Mild (0-20%)	Moderate (21-50%)	Severe (>50%)
Martin	18	1	0
North Palm Beach	8	1	0
South Palm Beach	22	3	1
Broward-Miami	80	17	2
Biscayne	1	15	48
Upper Keys	6	23	77
Middle Keys	3	7	34
Lower Keys	3	21	66
Marquesas	0	24	31
Dry Tortugas	0	4	92
Total Sites	141	116	351

Pooled by species, several major reef building species experienced high levels of bleaching in 2023, such as *C. natans* (58% bleaching prevalence), *M. cavernosa* (62% bleaching prevalence), and *Orbicella* spp. (83% bleaching prevalence). These values were profound for *Orbicella* spp. considering the surveyed population was over 1,200 colonies and not an artifact of small sample size. The weedy coral species had even higher bleaching prevalence values when compared to reef building species: *Porites astreoides* had 73% bleaching prevalence, branching *Porites* spp. had 88% bleaching prevalence, and *Agaricia* spp. had 92% bleaching prevalence across the surveyed populations. *Siderastrea* spp., one of the most abundant coral species on FCR, had half (50%) of the surveyed population experience bleaching.

When paling was included within the bleaching analysis, prevalence values rose to moderate (21-50%) across all surveyed zones in the Broward-Miami subregion, across the Nearshore and Offshore Reef zones of South Palm Beach, and along the Deep Ridge zone of both North Palm Beach and Martin subregions (**Figure 2**). Within the Southeast Florida region, the species *S. siderea, S. radians*, *Stephanocoenia intersepta*, and *P. astreoides* had the greatest abundance of pale colonies.

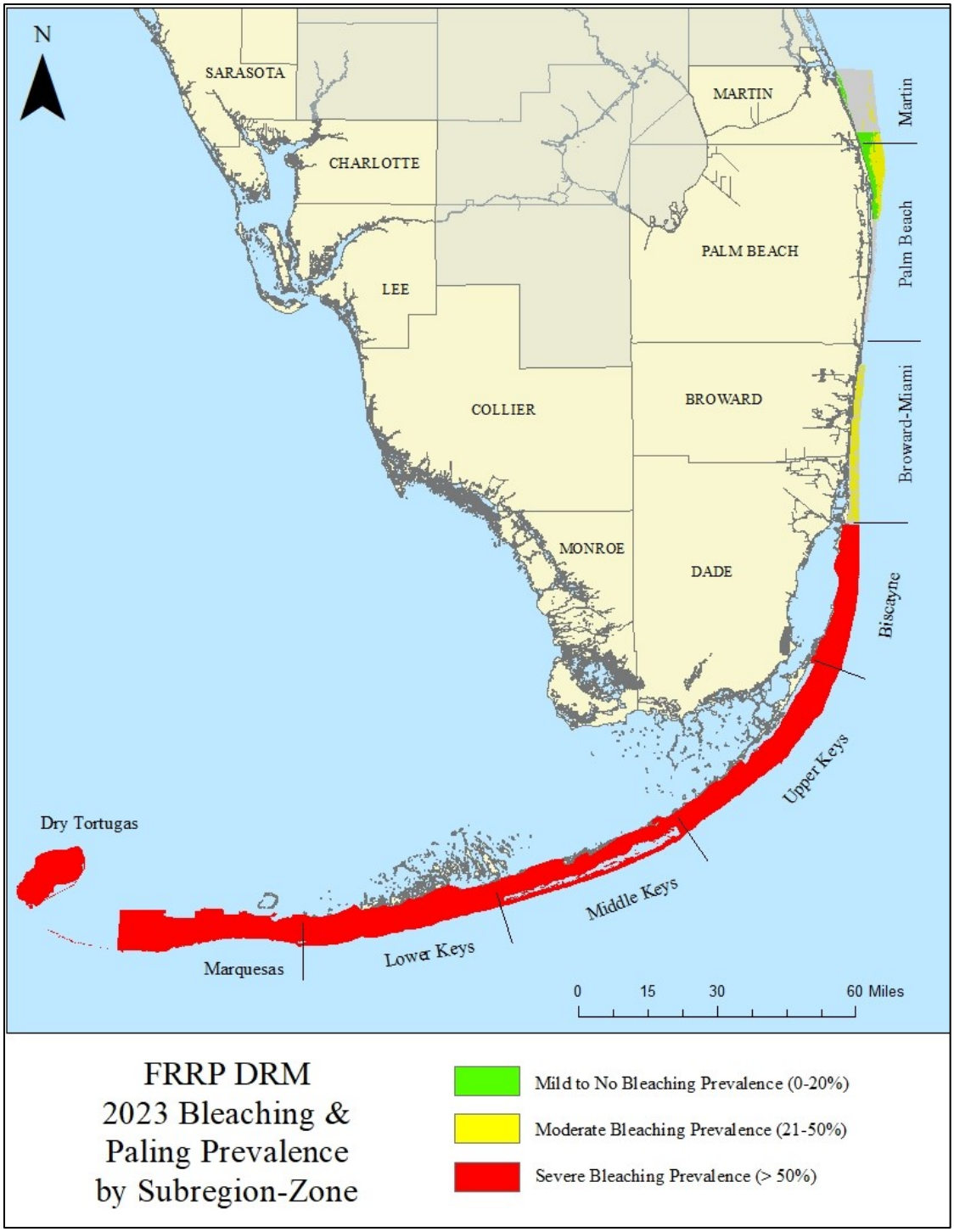

Figure 2. 2023 bleaching and paling prevalence of surveyed coral colonies by subregion-zone.

Across all FCR regions, 449 sites experienced severe bleaching and paling, while 87 sites experienced moderate bleaching and paling, totaling 88% of the sites surveyed in 2023 (**Table 3**). From Biscayne down through the Upper, Middle, and Lower Keys, over 90% of the surveyed sites were severely bleached and/or pale. Within the Dry Tortugas, 99% of the sites were severely bleached and/or pale. Images of severely bleached and pale survey sites and coral

species in the Dry Tortugas subregion are provided in **Figure 3**. Overall, bleaching and paling was substantially worse in 2023 compared to all historic prevalence values in the Dry Tortugas, Marquesas, and the Florida Keys.

Table 3. Total number of sites within each subregion recorded with mild, moderate, or severe bleaching and paling prevalence of coral colonies in 2023.

Subregion	Mild (0-20%)	Moderate (21-50%)	Severe (>50%)
Martin	13	4	2
North Palm Beach	4	4	1
South Palm Beach	13	11	2
Broward-Miami	42	38	19
Biscayne	0	5	59
Upper Keys	0	8	98
Middle Keys	0	2	42
Lower Keys	0	2	88
Marquesas	0	12	43
Dry Tortugas	0	1	95
Total Sites	72	87	449

In August of 2023, surveyors began reporting colonies with tissue loss directly attributable to the thermal stress in the Florida Keys. In response, the code TRS (TR = thermal, S = stress) was added to the DRM data collection methods to document this cause of mortality. Regionally, less than 1% of all surveyed colonies across Southeast Florida were recorded with TRS. In the Florida Keys, 7% of the surveyed population was recorded with TRS and most observations were in the Biscayne and Lower Keys subregions. Among the reef zones in Biscayne and the Lower Keys, the Inshore reef had the highest prevalence of TRS in both subregions at 22% and 23% of the surveyed population respectively. Among the species with the highest prevalence of TRS, *Acropora palmata* with 25 colonies recorded in the Upper Keys had TRS recorded on 60% of the surveyed colonies. *Acropora cervicornis*, with 208 colonies recorded across six subregions, had TRS recorded on 32% of surveyed colonies. Among some of the major reef building species, 15% of *Orbicella* spp, 15% of *P. clivosa*, and 13% of *C. natans* colonies were recorded with TRS across FCR.

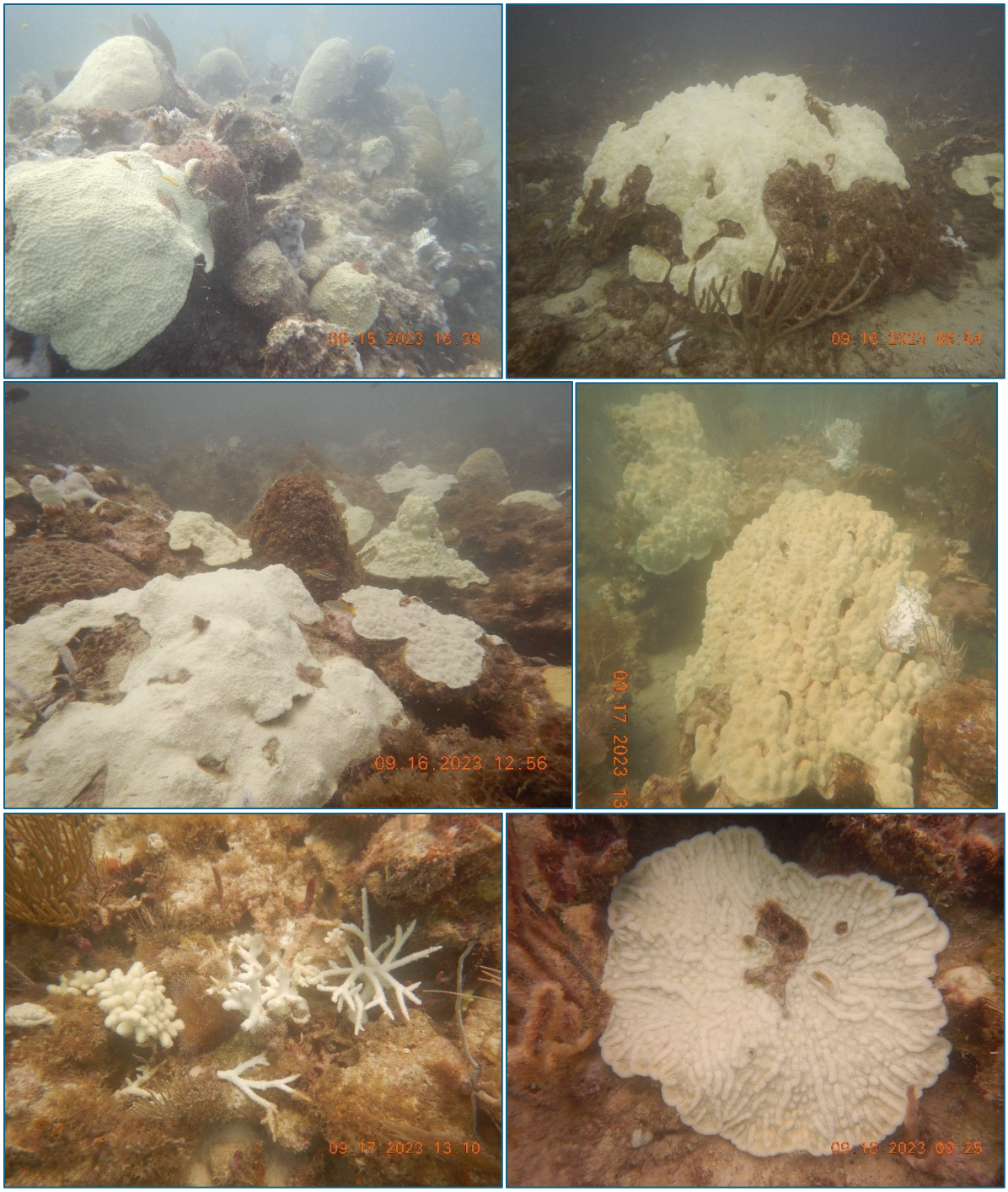

Figure 3. Images of bleached corals in the Dry Tortugas during the DRM survey event in September 2023.

Disease

The prevalence of disease along Transects 1 and 2 was pooled by zones (**Figure 4**) and by sites (**Table 4**) within each subregion. Disease prevalence values were broken into four categories: no tissue loss (0%), low (>0-5%), medium (6-10%), and high (>10%). These prevalence values

were calculated only from diseases that result in tissue loss and, therefore, do not include Dark Spot Syndrome or other discoloration conditions. Pooled by zone within each subregion, all disease prevalence values were either low or zero, apart from the Deep Patch Reef zone in South Palm Beach (**Figure 4**). Only one site was surveyed in the Deep Patch Reef Zone, where 18 total colonies were recorded, and the high disease prevalence was the result of two colonies of *S. siderea* recorded with unknown tissue loss disease.

When disease prevalence was analyzed by site, only four of the 608 surveyed sites had high disease prevalence and eight had medium disease prevalence (**Table 4**). Among the sites with high disease prevalence, one was in South Palm Beach, one was in Broward-Miami, and two in the Upper Keys. Again, the one site in South Palm Beach with high disease prevalence was the result of two *S. siderea* colonies with unknown tissue loss disease. In Broward-Miami, the site with high disease prevalence was the result of nine *A. cervicornis* colonies recorded with White Band Disease. Only one other observation of White Band Disease was recorded across the reef tract in 2023, also located in the Broward-Miami subregion on *A. cervicornis*. One of the Upper Keys sites with high disease prevalence had only four total corals recorded, where one *P. clivosa* colony was recorded with Black Band Disease. The other site in the Upper Keys with high disease prevalence was the result of 10 colonies of *O. faveolata* recorded with Black Band Disease.

Overall, Black Band Disease had the highest number of observations among the tissue loss diseases in 2023 (45 colonies), with the majority of cases in the Upper Keys (22 colonies) and the Lower Keys (20 colonies) on *O. faveolata*. Unknown tissue loss disease was recorded on 44 total colonies with 23 of those recorded on *S. intersepta* in the Middle Keys, Lower Keys, and Dry Tortugas subregions. Across Transects 1 and 2, SCTLD was only observed three times across the reef tract. In South Palm Beach, one *M. cavernosa* colony was recorded with SCTLD and in the Upper Keys, two colonies of *S. siderea* were recorded with the disease. Although Transects 3 and 4 are not included in the disease prevalence calculations, there were two additional *C. natans* recorded with SCTLD in the Upper Keys, totaling 5 colonies recorded with the disease across the reef tract in 2023.

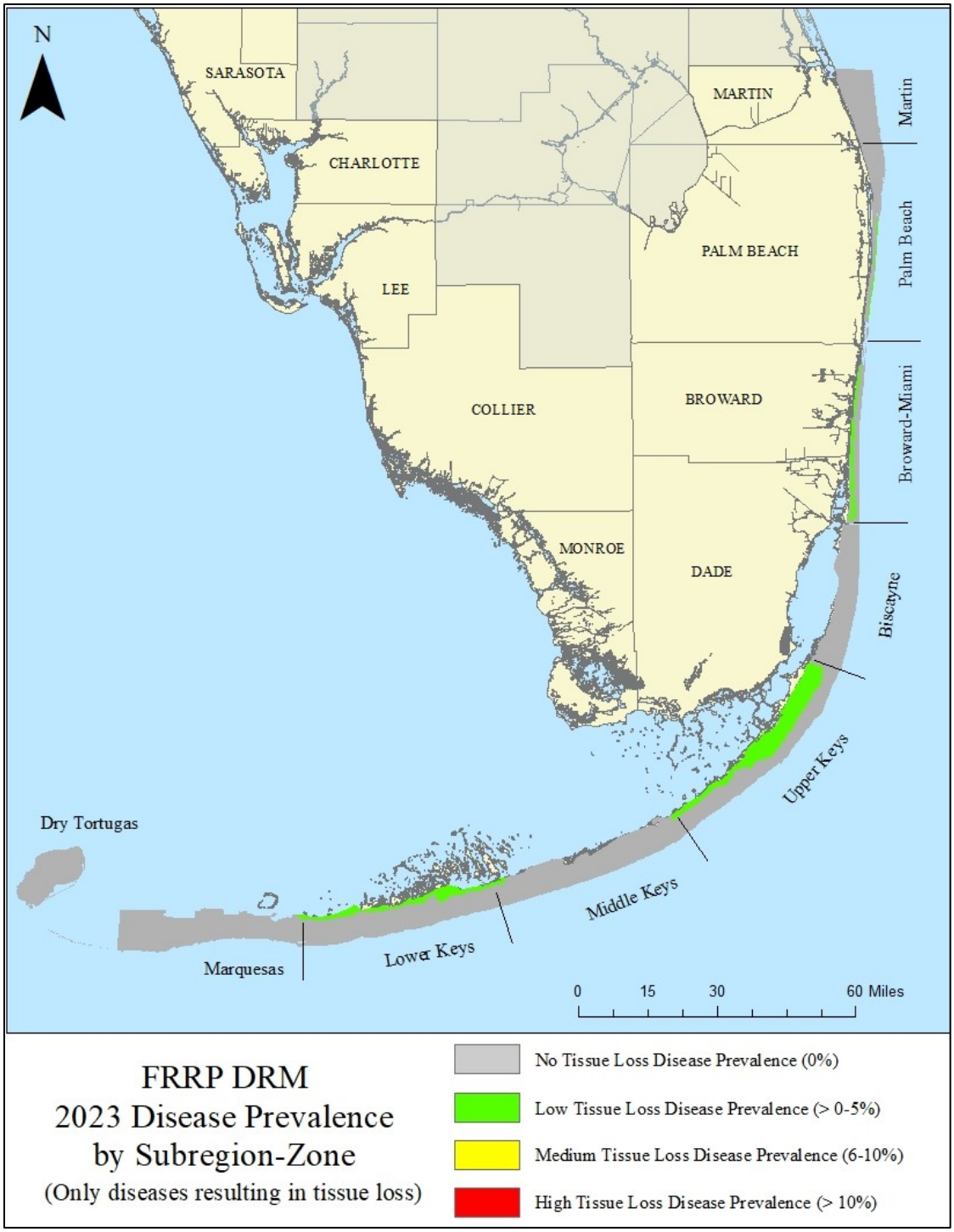

Figure 4. 2023 tissue loss disease prevalence of surveyed coral colonies by subregion-zone.

Table 4. Total number of sites within each subregion recorded with low, medium, or high disease prevalence.

Subregion	None (0%)	Low (>0-5%)	Medium (6-10%)	High (>10%)
Martin	19	0	0	0
North Palm Beach	9	0	0	0
South Palm Beach	22	1	2	1
Broward-Miami	92	4	2	1
Biscayne	61	3	0	0
Upper Keys	92	11	1	2
Middle Keys	37	7	0	0
Lower Keys	76	11	3	0
Marquesas	53	2	0	0
Dry Tortugas	92	4	0	0
Total	553	43	8	4

ADULT TARGET CORAL SPECIES

Now that the entirety of FCR is classified as endemic for SCTLD, it is important to assess the population status of the coral species most susceptible to the disease. Starting in 2020, DRM extended the survey area at each site by adding two belt transects specifically designed to target 10 of the most SCTLD susceptible species. This resulted in four, 1 x 10m transects per site ($40m^2$ total survey area per site for these species). This level of effort was maintained through 2023 to strengthen the estimates for calculating density changes and increase the survey area for recording juveniles.

Table 5. Mean ± SE density (no. of colonies/m^2) of the 10 target SCTLD-susceptible species in each region in 2023.

Target Species	SE Florida	Florida Keys	Marquesas	Dry Tortugas
Colpophyllia natans	0.004 ± 0.001	0.02 ± 0.003	0.02 ± 0.005	0.027 ± 0.003
Dichocoenia stokesii	0.022 ± 0.003	0.041 ± 0.003	0.022 ± 0.004	0.011 ± 0.002
Diploria labyrinthiformis	0.004 ± 0.001	0.018 ± 0.002	0.002 ± 0.001	0.01 ± 0.002
Meandrina meandrites	0.022 ± 0.003	0.003 ± 0.001	0.01 ± 0.002	0.003 ± 0.001
Mussa angulosa	0 ± 0	0.001 ± 0.001	0.001 ± 0.001	0.004 ± 0.002
Mycetophyllia aliciae	0.005 ± 0.001	0.003 ± 0.001	0.012 ± 0.003	0.011 ± 0.002
Mycetophyllia ferox	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Mycetophyllia lamarckiana	0 ± 0	0.002 ± 0.001	0 ± 0	0.002 ± 0.001
Pseudodiploria clivosa	0.005 ± 0.002	0.01 ± 0.001	0.001 ± 0.001	0.011 ± 0.003
Pseudodiploria strigosa	0.008 ± 0.001	0.015 ± 0.001	0.022 ± 0.003	0.048 ± 0.006

Density for each target species was calculated by summing the species count across all four transects at each site. The mean density and maximum diameter for each species were then

averaged across all sites within each region (Southeast Florida, Florida Keys, Marquesas, and Dry Tortugas; **Table 5** and **Figures 5-11**).

In Southeast Florida, *D. stokesii* and *M. meandrites* had the highest densities among the target species while all other target species were ≤ 0.01 colonies/m^2. Among the target species in the Mussinae subfamily, *M. aliciae* was the most common across the regions. The other three species (*M. angulosa, M. ferox*, and *M. lamarckiana*) are rarer and reach their northern limit of growth in Southeast Florida. Both *M. angulosa* and *M. ferox* were not observed in Southeast Florida and *M. lamarckiana* had only one observation in the Broward-Miami subregion.

In the Florida Keys, *D. stokesii* again had the highest density among the target species followed by *C. natans*, which had less than half the density of *D. stokesii* in that region (**Table 5**). The density of *M. ferox* in the Florida Keys was less than 0.001 colonies/m^2, as only five colonies were recorded across the entire reef tract (one colony in the Middle Keys, three in the Lower Keys and one in the Dry Tortugas).

In the Marquesas, *D. stokesii*, *P. strigosa*, and *C. natans* had the highest densities among the target species, however all were below 0.025 colonies/m^2. Density values of *M. angulosa* were low across the Florida Keys, Marquesas, and Dry Tortugas regions but its lowest value was in the Marquesas, where only one colony was recorded.

In the Dry Tortugas, *P. strigosa* had the highest density with 0.048 colonies/m^2, which was also the highest density across all target species in all regions in 2023. *Colpophyllia natans* had the second highest density in the Dry Tortugas at 0.027 colonies/m^2 while all other target species densities were at or below 0.011 colonies/m^2.

Since 2020, the DRM Summer Quick Look Reports have summarized mean density and mean maximum diameter values within each region to evaluate the impacts of SCTLD on each target species. The 2023 mean density and mean maximum diameter values were incorporated into the time series beginning in 2010 and are included as **Figures 5 - 11** in this report. Density values between 2020 and 2023 were calculated from four 1 x 10m transects; for prior years, data were calculated from two 1 x 10m transects.

If any target species had less than 10 total colonies recorded within a region for a majority of the 13 survey years, that species or species complex was omitted from the time series for the corresponding region. Abundance values of *M. angulosa* were <10 across all regions and survey years, so it was omitted from the time series for all regions. *Mycetophyllia* spp. (*M. aliciae, M. ferox*, and *M. lamarckiana*) were pooled together in each region due to low total colony counts for each species. In Southeast Florida, *C. natans, D. labyrinthiformis*, and *P. clivosa* were omitted from the time series comparison because of low abundance values. In the Marquesas, *D. labyrinthiformis* and *P. clivosa* were also omitted. While some species were omitted from the regional interpretive discussion, their values are still included in **Figures 5 - 11** for reference. As a result, **Figures 5 - 11** plot the mean density and mean maximum diameter for six target species and the *Mycetophyllia* spp. complex between 2010 and 2023. While low abundance values will limit the statistical appraisal of changes in some species abundance, the time series graphs

provide an illustrative reference to aid in understanding the changes in abundance of species vulnerable to SCTLD.

The DRM surveys were not executed in all regions of FCR for some years. In the Dry Tortugas, DRM data was not collected in 2010, 2011, and 2013. Due to the impacts of Hurricane Irma in 2017, the Florida Keys survey effort did not employ the traditional stratified sampling design. Therefore, these data were omitted from the time series in the Florida Keys region. Finally, DRM monitoring in the Marquesas began in 2019, providing only five years of data.

Southeast Florida

Stony coral tissue loss disease was first documented in Southeast Florida in 2014 off Miami-Dade County and spread throughout the region over the next two years. Of the target SCTLD-susceptible coral species, only *D. stokesii, M. meandrites*, and *P. strigosa* had sufficient abundance values across the 14 survey years to interpret SCTLD impacts (**Figures 6**, **8**, and **11** respectively). The most significant changes in density and maximum diameter for these three species occurred between 2014 and 2016. These changes coincided with the epidemic stage (when the disease first arose) of SCTLD in Southeast Florida, which resulted in high disease prevalence and coral mortality. As a result, a new, post-SCTLD baseline was established in 2017 for these species in Southeast Florida after the epidemic stage concluded. The 2023 survey in Southeast Florida marked the sixth assessment after the establishment of the post-SCTLD baseline.

After the large declines in 2014 and 2015, *D. stokesii* has slowly increased in density in Southeast Florida. While the 2023 density of *D. stokesii* was still below the average of its pre-disease values, it has been steadily getting closer. While maximum diameter of *D. stokesii* increased slightly from 2022 to 2023, it has been relatively stable since 2016, likely indicating the survival and growth of smaller colonies entering into the adult population. Similar to *D. stokesii*, density of *M. meandrites* has slowly increased since 2016 in Southeast Florida. Maximum diameter of *M. meandrites* has been relatively unchanged since its lowest value in 2017 but slightly increased from 2022 to 2023.

Density of *P. strigosa* has remained consistently low since 2015 in Southeast Florida. Maximum diameter has been variable over the survey years, with an overall downward trend towards a smaller size. Over the past three survey years, the diameter has been about half of what it was during pre-disease years.

Florida Keys

SCTLD first spread into the Biscayne and Upper Florida Keys subregions during the winter of 2016. It then progressed through the Middle Keys and reached the Lower Keys subregion in 2018. Because the progression of SCTLD took several years to move through the Florida Keys, the reductions in density for the target species occurred over multiple years. The most pronounced disease impacts occurred between 2017 and 2020, when SCTLD was in the epidemic stage in the Middle and Lower Keys. The entirety of the Florida Keys is now considered endemic, but the timeline for establishing post-SCTLD baselines varies depending on subregion (e.g., the Upper Florida Keys post-SCTLD baseline began after 2017 whereas the

Lower Florida Keys baseline began in 2021). The declines in density associated with SCTLD are evident over the last 14 years (excluding the 2017 Irma dataset) for six of the target species (*C. natans, D. stokesii, D. labyrinthiformis, M. meandrites, P. clivosa*, and *P. strigosa* (**Figures 5-8**, **10-11**, respectively). For all six of these species, the lowest density was recorded in either 2020 or 2021.

The SCTLD related declines in density for both *D. stokesii* and *M. meandrites* in the Florida Keys began in 2018 and continued through 2020. By 2020, both species reached their lowest density values for all survey years. Since then, density of *D. stokesii* has only slightly increased and maximum diameter has been variable, with no noticeable trend in size. Both density and maximum diameter for *M. meandrites* have remained unchanged since reaching the low values in 2020. This indicates a very small but relatively stable population of *M. meandrites* persisting in the Florida Keys with no signs of recovery over the past four years similar to *D. stokesii*.

Density of *C. natans* has been slightly variable but mostly unchanged since 2020 when the epidemic stage had mostly concluded in the Lower Keys. Maximum diameter of *C. natans* has also been variable across the survey years but was higher the last two years compared to the lowest value reached in 2021. Density of *P. strigosa* has been generally steady since 2019 when it first declined from SCTLD. Maximum diameter continued to drop between 2018 and 2021, when it reached its lowest value. This extended decline in maximum diameter across three years indicates the wide geographic spread of larger *P. strigosa* colonies as the disease progressed from the Upper Keys down through the Lower Keys continually killing these larger colonies. Since 2021, however, diameter of *P. strigosa* has remained low but has begun to stabilize at about one third less than its pre-disease values.

Density of *D. labyrinthiformis* has steadily increased in the Florida Keys since 2020 when its lowest value across the survey years was recorded. As a result, density values of *D. labyrinthiformis* are now similar to values recorded prior to the arrival of SCTLD. Maximum diameter has remained relatively stable since 2020, likely indicating the introduction of smaller colonies into the adult population. Similar to *D. labyrinthiformis*, density of *P. clivosa* has slowly increased since 2020. Maximum diameter also slowly increased from 2020 to 2022, but slightly declined from 2022 to 2023, indicating the likely introduction of smaller colonies into the adult population.

Due to their low abundance, *Mycetophyllia* spp. (*M. aliciae, M. ferox*, and *M. lamarckiana*) in the Keys were pooled together to calculate mean density and mean maximum diameter. From 2012 to 2023, the density of *Mycetophyllia* spp. in the Florida Keys has been slightly variable, with no large increases or declines (**Figure 9**). This suggests that SCTLD impacts were minimal or difficult to detect for *Mycetophyllia* compared to other susceptible species. In 2021, density was the lowest value recorded across all other survey years, while maximum diameter was the highest value recorded. However, it is difficult to attribute these values to a loss of smaller colonies because of the low abundance of *Mycetophyllia* spp. and its potentially patchy distribution.

Marquesas

Surveys in the Marquesas region began in 2019 to track the western movement of SCTLD towards the Dry Tortugas. During the 2019 survey event, SCTLD had not yet been identified in the region; however, the disease was at the westernmost extent of the Lower Keys subregion boundary at that time. During the survey in 2020, the disease had spread across the entire extent of the Marquesas. With declines ongoing through 2021 and 2022, the 2023 survey in the Marquesas may be considered the first assessment after the post-SCTLD baseline.

By 2020, *C. natans*, *D. stokesii*, *M. meandrites*, *Mycetophyllia* spp., and *P. strigosa* had all declined to less than half of their density recorded in 2019 (**Figures 5-6**, **8-9**, and **11, respectively**). *Dichocoenia stokesii* alone declined to one third of its density recorded in 2019. Since that initial decline, the density of *D. stokesii* has remained low, with the lowest value recorded in 2023. Maximum diameter followed a similar pattern with the lowest value recorded in 2023.

Density and maximum diameter of *C. natans* and *M. meandrites* in the Marquesas region continued to decline from 2020 through 2022 when they reached their lowest values across the survey years. From 2022 to 2023, there was a slight increase in density and maximum diameter for these species, however, both remain low compared to their pre-disease densities.

Density and maximum diameter of *P. strigosa* and *Mycetophyllia* spp. continued to decline from 2020 to their lowest values in 2021. Density of both species has increased slightly from 2021 to 2023, potentially indicating a stabilizing population. Maximum diameter of *P. strigosa* increased from 2021 to 2022 but then declined from 2022 to 2023, indicating the introduction of smaller corals into the adult population. Maximum diameter of *Mycetophyllia* spp. has remained relatively stable since 2021.

Dry Tortugas

Prior to the 2021 DRM surveys within the Dry Tortugas, National Park Service staff identified SCTLD along the eastern side of the park. During the five months between the first observation reported and the DRM cruise, SCTLD spread quickly throughout much of the park. When the DRM surveys were conducted in September 2021, SCTLD was recorded at 33 of the 54 sites surveyed, covering the east, west, south, and central portions of the park. However, the 2021 densities and maximum diameters of the target species in the Dry Tortugas were relatively consistent with previous years. This was due to most colonies with active lesions, but live tissue remaining, being included in the density and maximum diameter summaries (**Figures 5-11**).

For all target species, the density values recorded in 2022 were the lowest ever recorded across the 10 survey years, except for *P. strigosa* in 2012 and 2017. Among the hardest hit by the disease were *C. natans*, *M. meandrites*, and *Mycetophyllia* spp., which all declined to less than a third of their 2021 density values. From 2021 to 2022, maximum diameter of *C. natans* increased to its highest value ever recorded likely due to the loss of small and medium sized colonies to SCTLD while larger colonies had not yet suffered complete mortality. From 2022 to 2023, those larger *C. natans* colonies succumbed to the disease resulting in a decline of maximum diameter to its lowest value recorded.

From 2022 to 2023, the density of *D. labyrinthiformis*, *P. strigosa*, and *D. stokesii* had very little change. The maximum diameter of each species also changed very little, with a slight increase for *D. labyrinthiformis* and a slight decline for *D. stokesii*. For *M. meandrites*, both density and maximum diameter continued to decline from 2022 to 2023 to its lowest values recorded across the survey years.

Despite their sizeable declines from 2021 to 2022, *C. natans* and *Mycetophyllia* spp. both slightly increased in density from 2022 to 2023, indicating some stabilization in the population. The sharp decline in maximum diameter, however of *C. natans* from 2022 to 2023 could be due to smaller colonies that survived the epidemic stage of SCTLD entering into the >4cm population. The maximum diameter of *Mycetophyllia* spp. increased from 2022 to 2023, approaching a value consistent with the range of values recorded pri006Fr to the disease epidemic. The density of *P. clivosa* also increased slightly, coupled with an increase in maximum diameter. However, both values have been highly variable over the years, making it difficult to attribute losses due to SCTLD or gains after the disease subsided.

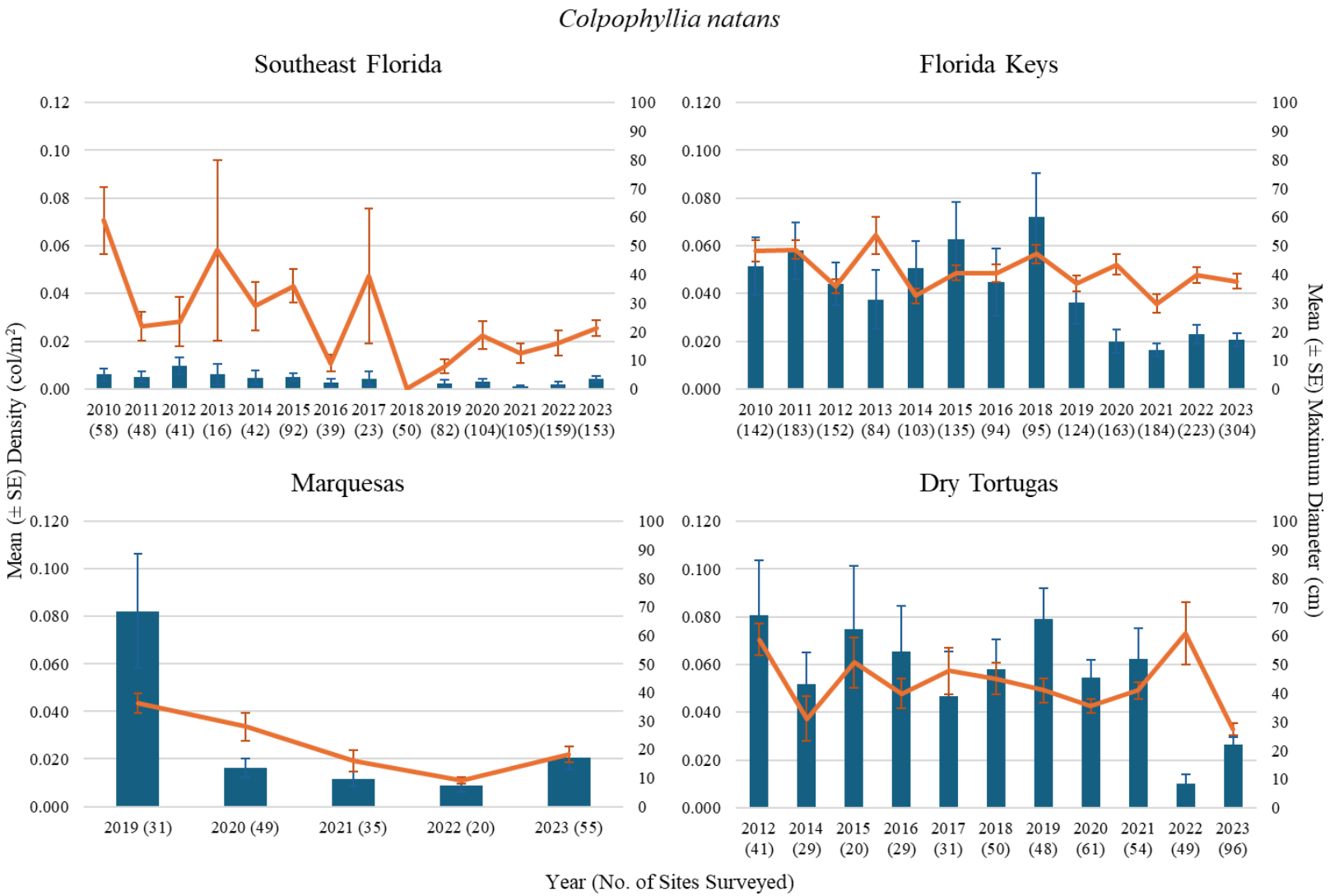

Figure 5. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Colpophyllia natans* across the four regions for each survey year. No *C. natans* colonies were recorded in Southeast Florida in 2018.

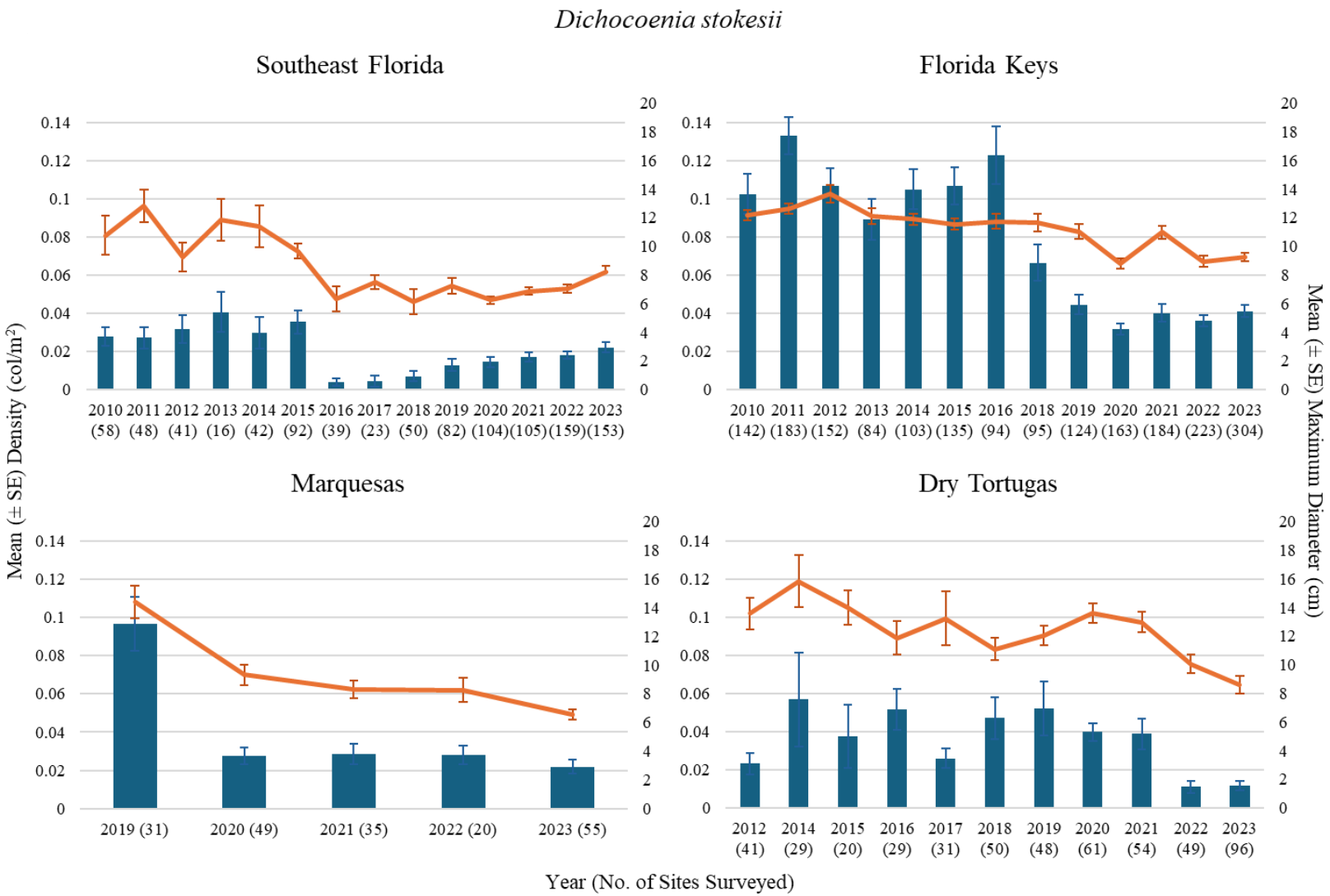

Figure 6. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Dichocoenia stokesii* across the four regions for each survey year.

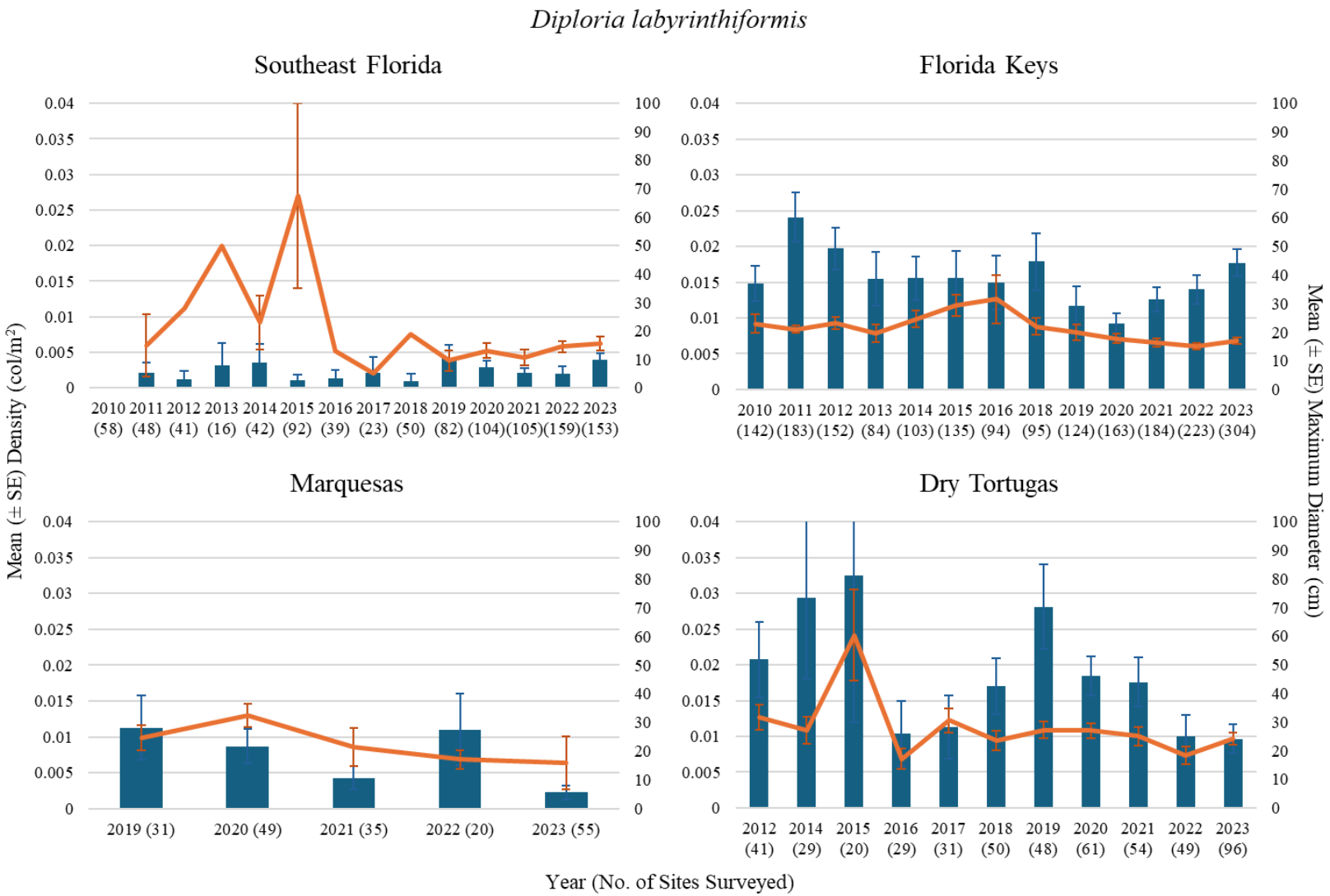

Figure 7. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Diploria labyrinthiformis* across the four regions for each survey year.

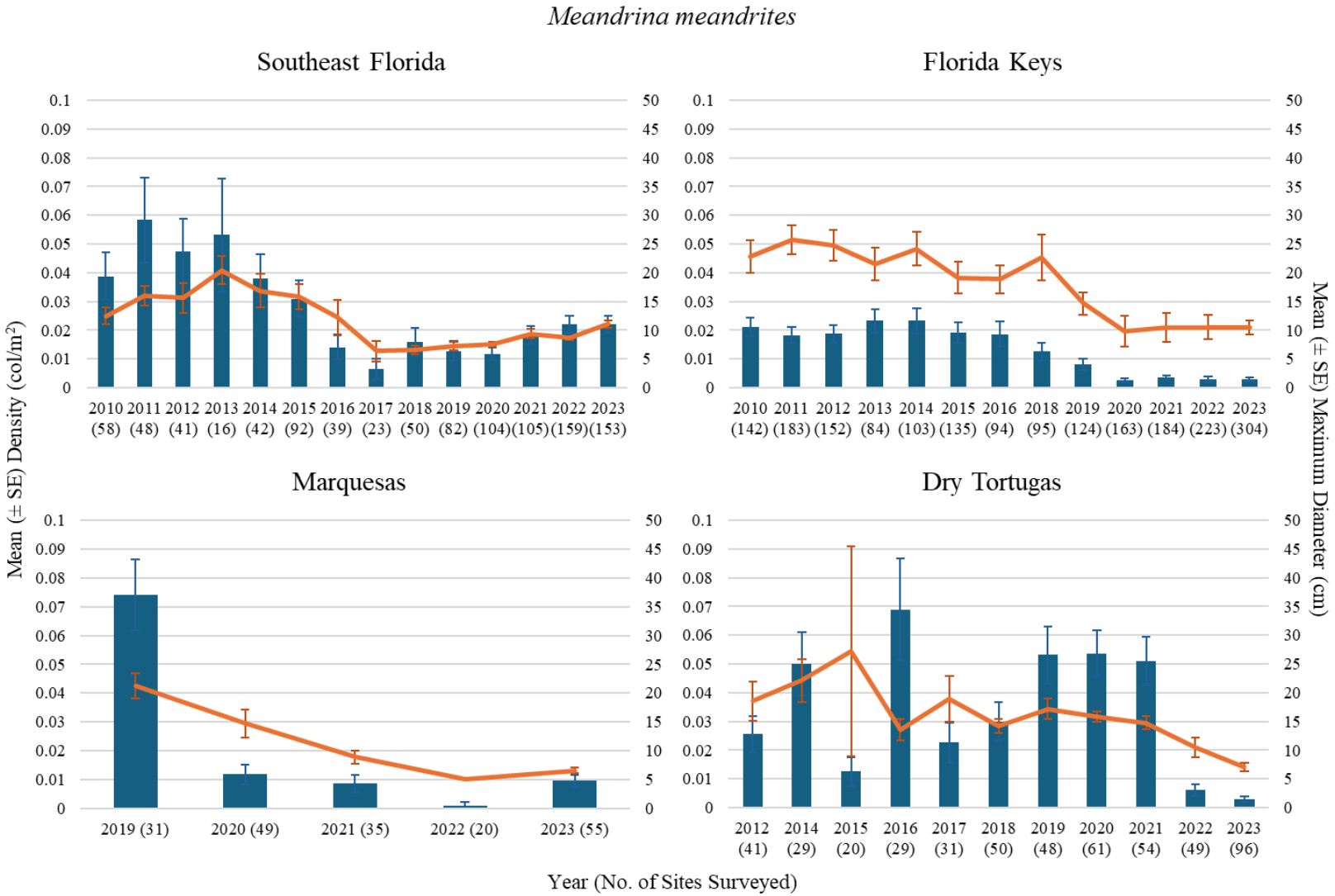

Figure 8. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Meandrina meandrites* across the four regions for each survey year.

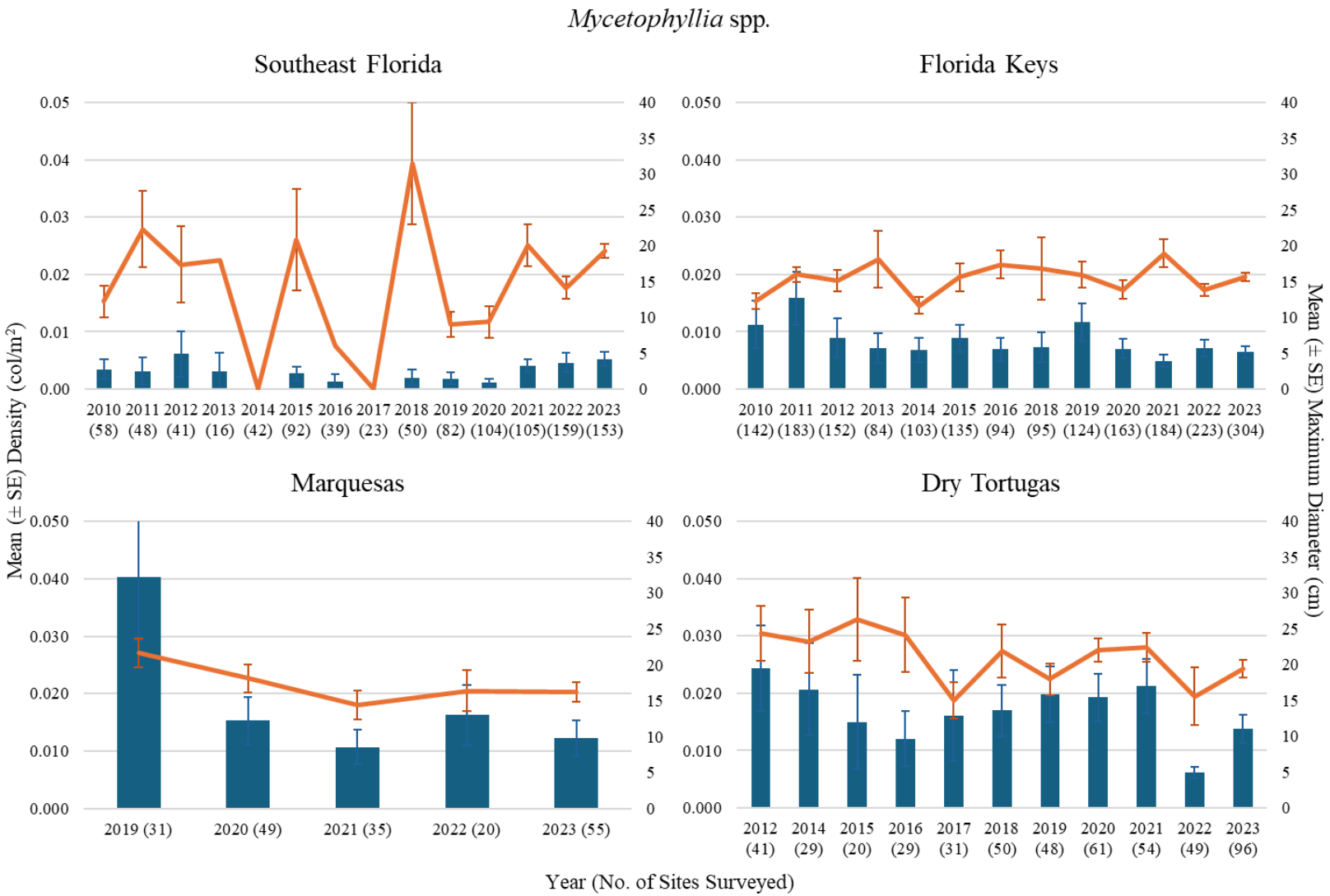

Figure 9. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target genus *Mycetophyllia* (pooled for *M. aliciae, M. ferox*, and *M. lamarckiana*) across the four regions for each survey year. No *Mycetophyllia* spp. colonies were recorded in Southeast Florida in 2014 and 2017.

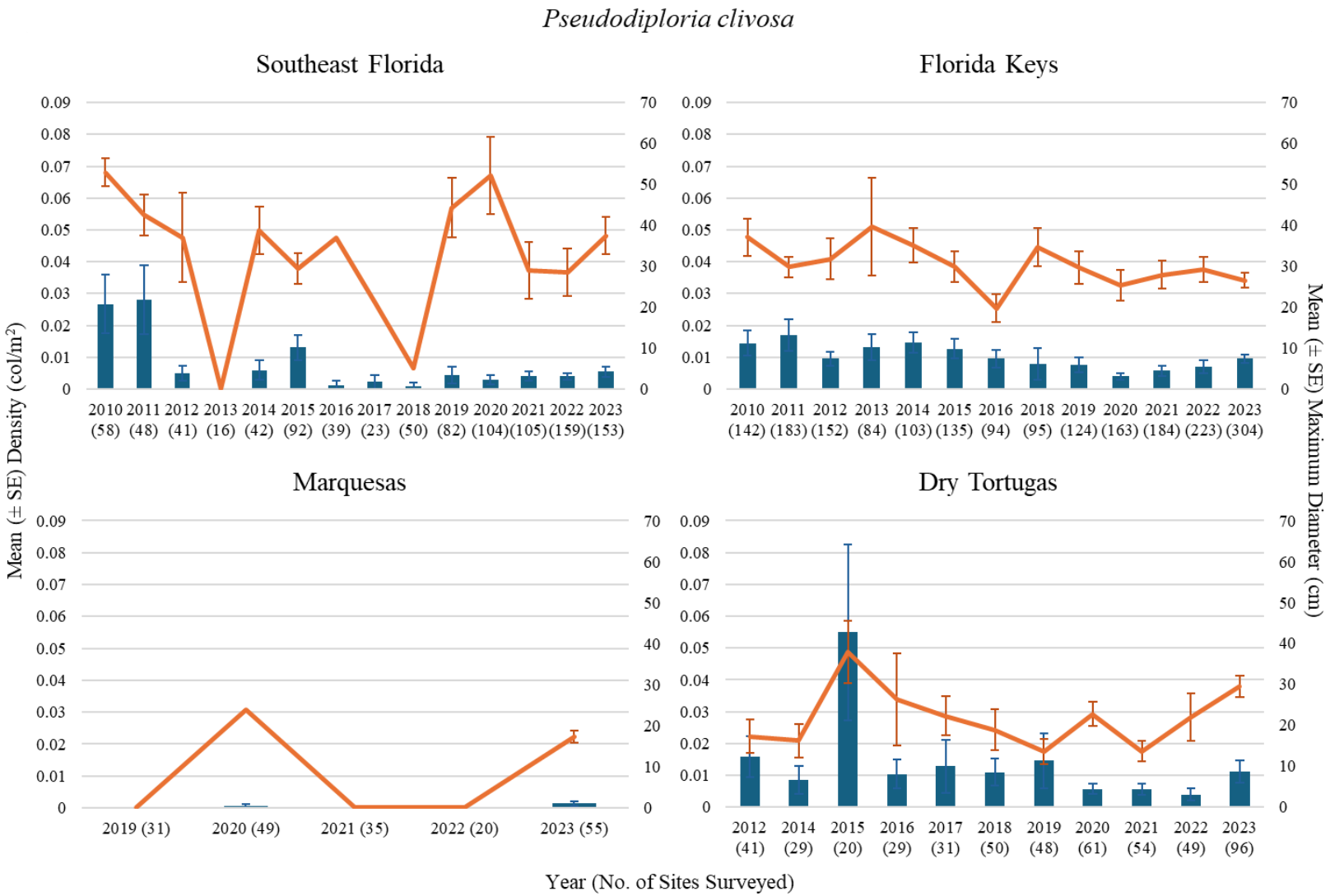

Figure 10. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Pseudodiploria clivosa* across the four regions for each survey year. No *P. clivos*a colonies were recorded in Southeast Florida in 2013 or the Marquesas in 2019, 2021, and 2022.

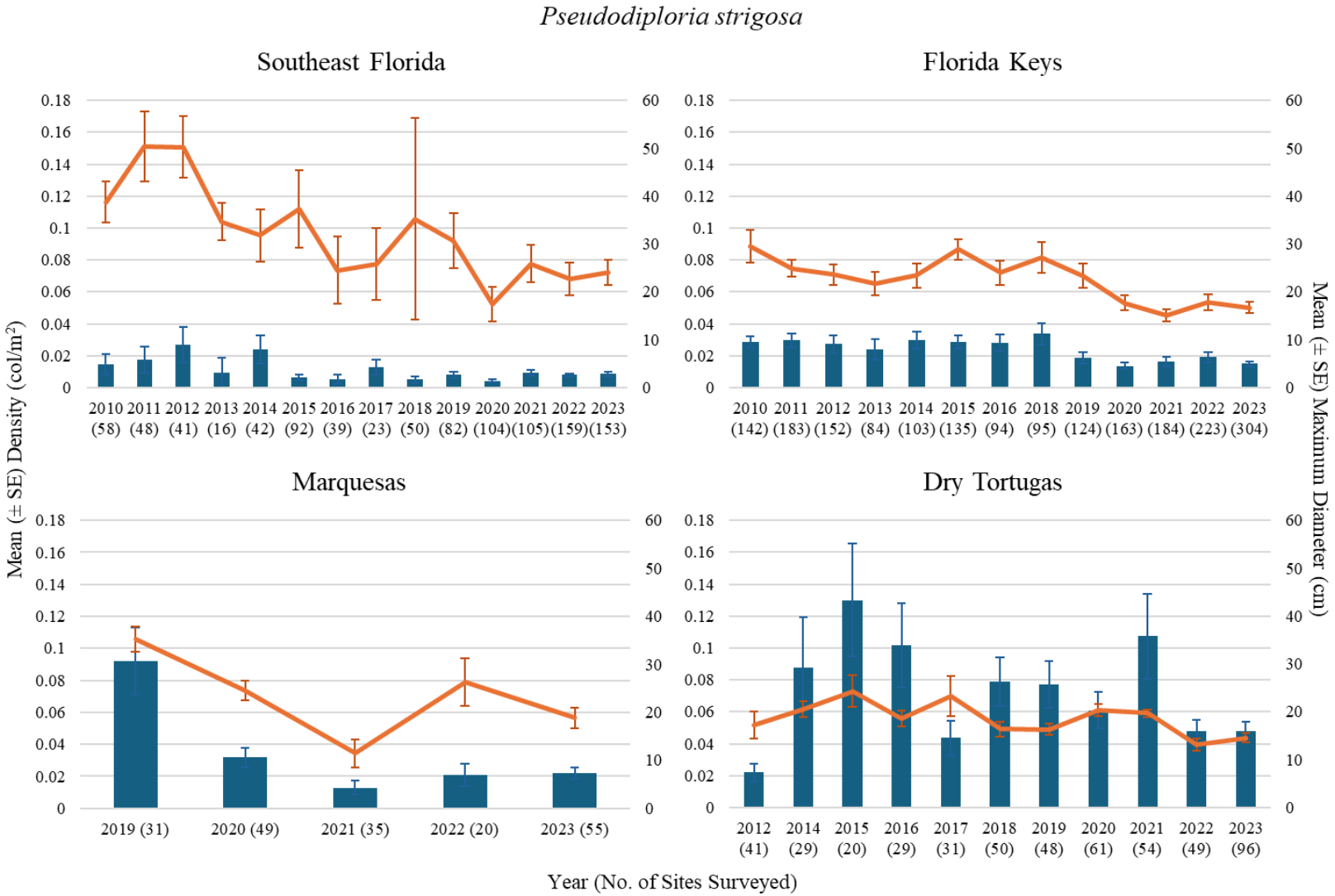

Figure 11. Mean density ± SE (blue columns, primary Y axis) and mean maximum diameter (orange lines, secondary Y axis) of target species *Pseudodiploria strigosa* across the four regions for each survey year.

JUVENILE TARGET CORALS

Starting in 2020, the DRM program incorporated juvenile coral counts of three SCTLD susceptible coral (sub)families into the survey methods. Starting in 2022, the species *M. cavernosa* was also added to the juvenile coral counts. These (sub)families and species have been enumerated along all four transects over the past four survey years (2020-2023). The three (sub)families encompass the 10 SCTLD-susceptible coral species targeted along Transects 3 and 4. *Montastraea cavernosa*, another SCTLD susceptible species and the only member in its family (Montastraeidae) in Florida, is relatively easy to identify at small sizes (<4cm) and was therefore added to the survey count. *Montastraea cavernosa* is not considered a rare species and is very common in most reef habitats. A list of coral species included within each target (sub)family is included in **Table 6**. Site density for each of the target juvenile (sub)families was calculated by summing the tallies across all four transects at each site and dividing by $40m^2$. The regional density for each (sub)family and *M. cavernosa* were then averaged across all sites within each region (Southeast Florida, Florida Keys, Marquesas, and Dry Tortugas; **Table 7** and **Figures 12-15**).

Table 6. List of coral species included under each target juvenile (sub)family.

Faviinae	Mussinae	Meandrinidae	Montastraeidae
Colpophyllia natans	*Isophyllia* spp.	*Dendrogyra cylindrus*	*Montastraea cavernosa*
Diploria labyrinthiformis	*Mussa angulosa*	*Dichocoenia stokesii*	
Favia fragum	*Mycetophyllia* spp.	*Eusmilia fastigiata*	
Manicina areolata	*Scolymia* spp.	*Meandrina* spp.	
Pseudodiploria spp.			

Across the 608 sites surveyed in 2023, 449 sites had at least one target juvenile colony. Mussinae was present at 194 sites, Faviinae at 227 sites, Meandrinidae at 303 sites, and *M. cavernosa* at 407 sites. Seventy-seven sites had more than 20 total juveniles recorded and 21 of those had more than 40 total juvenile colonies. Similar to 2022, many of the 2023 sites with high juvenile counts were in the Marquesas region and were dominated by *M. cavernosa* and Mussinae juveniles. *Montastraea cavernosa* had the highest density among the target juveniles across all regions in 2022 (**Figure 15**) and 2023 (**Table 7**). Second to *M. cavernosa* was the Meandrinidae family, which had greater densities in Southeast Florida and the Florida Keys regions compared to Mussinae or Faviinae across all four years. Mussinae, however, had greater densities than Meandrinidae in both the Marquesas and Dry Tortugas.

In Southeast Florida, Faviinae, Mussinae, and Meandrinidae juvenile densities have remained relatively consistent across all four survey years (**Table 7**, **Figures 12-15**). In the Florida Keys, density of Faviinae, Mussinae, and Meandrinidae has been relatively steady, however, the density of all three subfamilies, as well as *M. cavernosa*, declined slightly from 2022 to 2023. Faviinae, Mussinae, and Meandrinidae density values were higher in the Florida Keys compared to Southeast Florida, while juvenile *M. cavernosa* densities in the Florida Keys were similar to those in Southeast Florida.

Table 7. Mean density ± SE (no. of colonies/m^2) by region of the three-target juvenile (sub)families, which are highly SCTLD susceptible, and *M. cavernosa* in 2023.

Region	Mussinae	Faviinae	Meandrinidae	***Montastraea cavernosa***
Southeast FL	0.007 ± 0.001	0.003 ± 0.001	0.009 ± 0.001	0.077 ± 0.01
FL Keys	0.019 ± 0.003	0.026 ± 0.003	0.051 ± 0.005	0.072 ± 0.006
Marquesas	0.131 ± 0.025	0.042 ± 0.012	0.078 ± 0.009	0.324 ± 0.035
Dry Tortugas	0.101 ± 0.022	0.054 ± 0.007	0.024 ± 0.005	0.209 ± 0.024

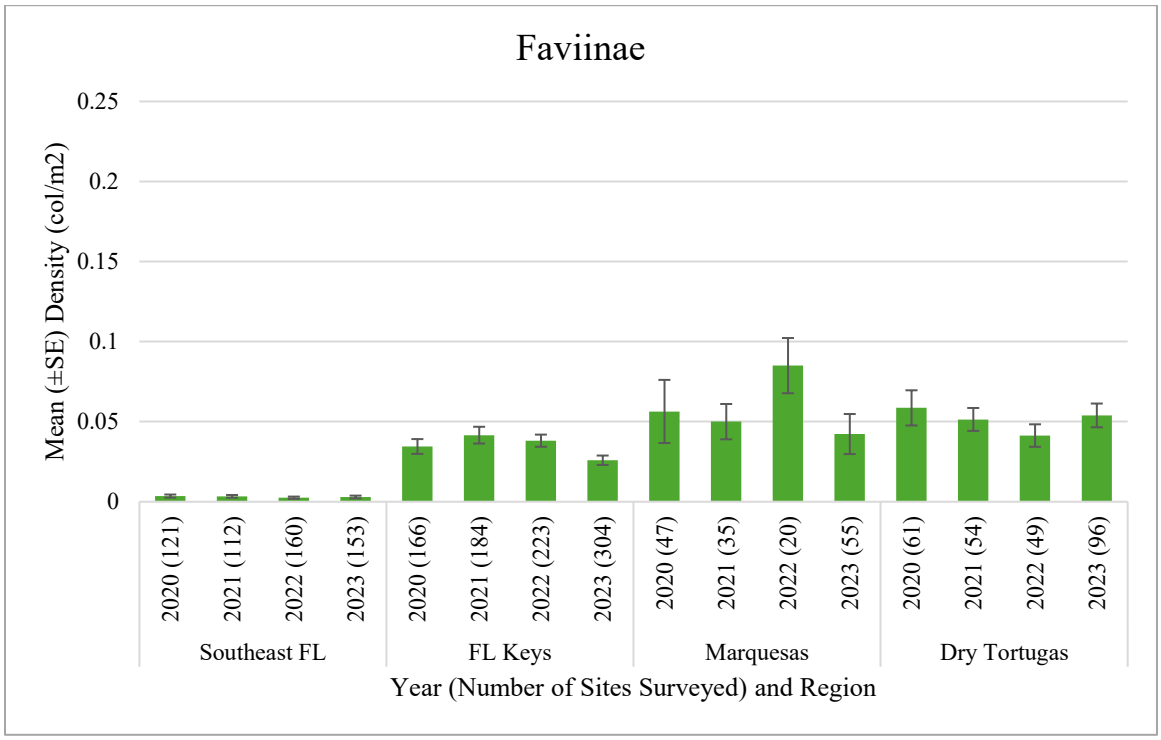

Figure 12. Mean density ± SE of juvenile target subfamily Faviinae across the four regions for each survey year.

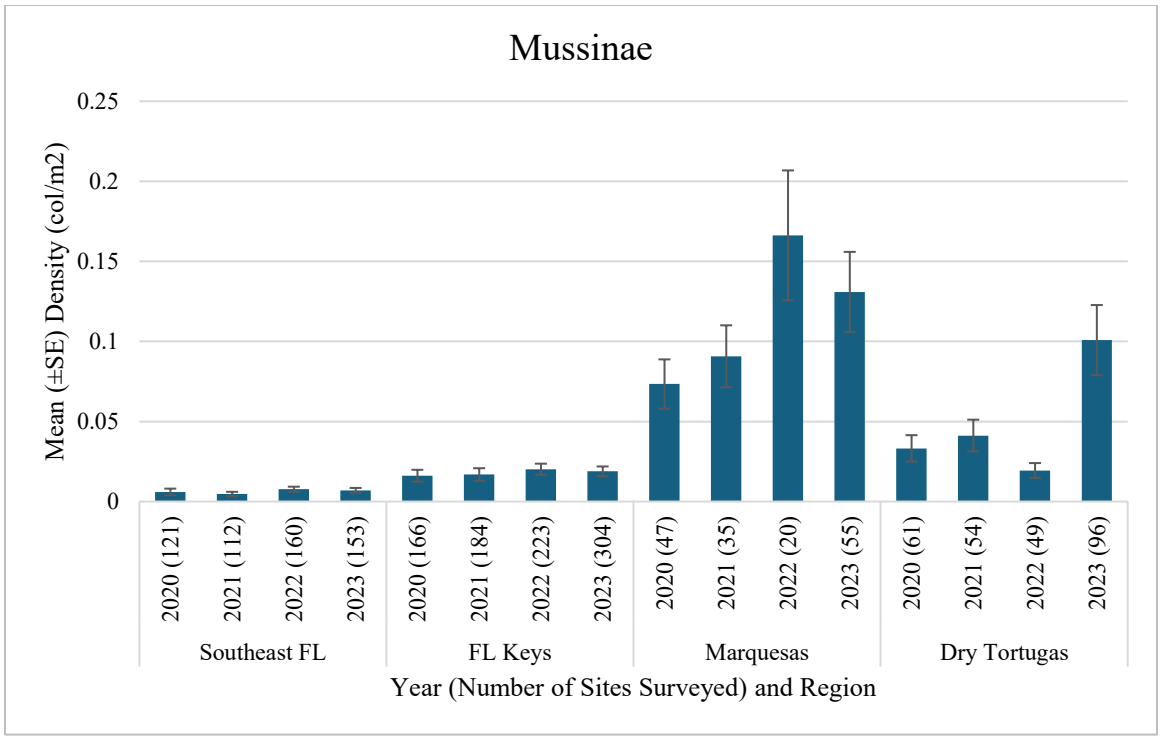

Figure 13. Mean density ± SE of juvenile target subfamily Mussinae across the four regions for each survey year.

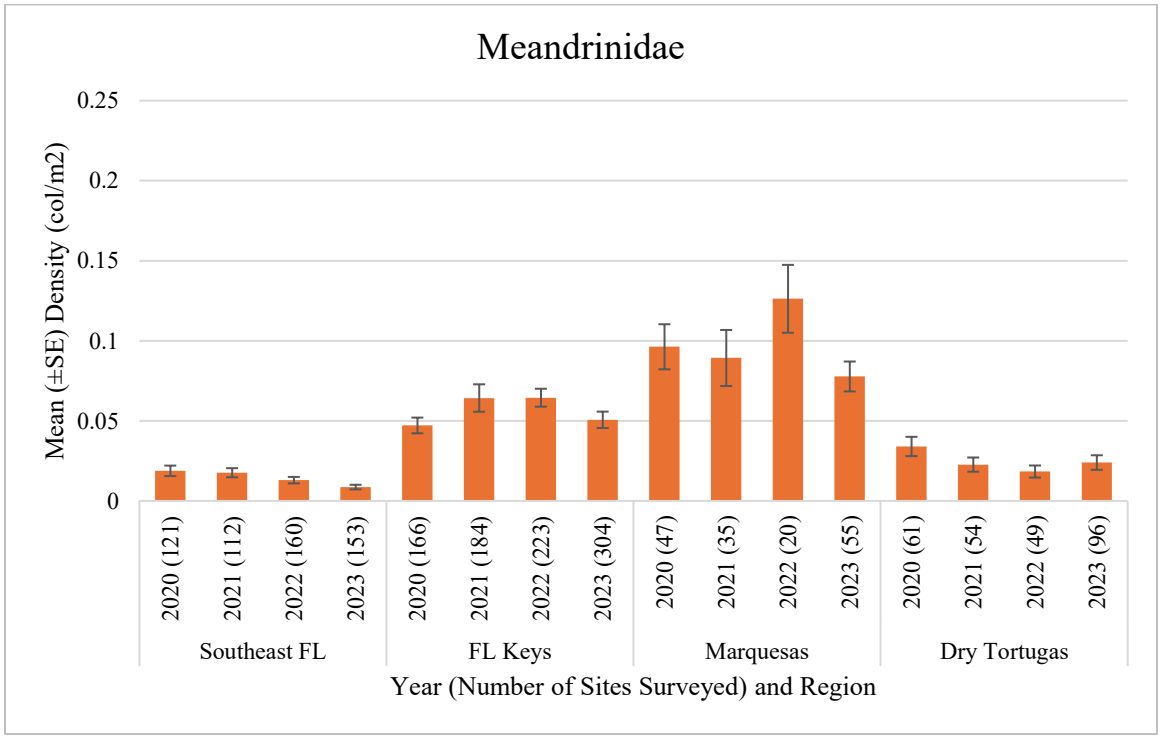

Figure 14. Mean density ± SE of juvenile target family Meandrinidae across the four regions for each survey year.

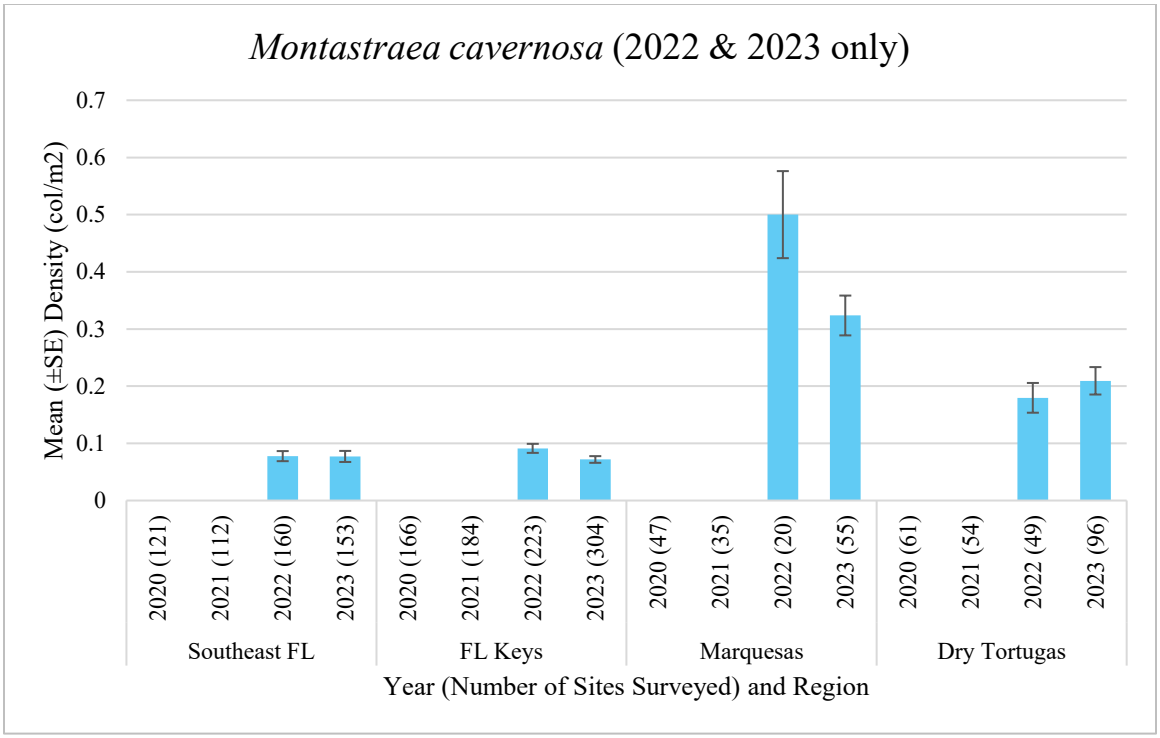

Figure 15. Mean density ± SE of juvenile target species *M. cavernosa* across the four regions for each survey year. Note the difference in the y-axis scale compared to the other three (sub)families.

In the Marquesas region, Mussinae, Faviinae, and Meandrinidae densities all increased from 2020 to 2022, with 2022 having the highest values recorded for each (sub)family in that region (**Table 7, Figures 12-15**). From 2022 to 2023, however, all three (sub)families and *M. cavernosa* declined in the Marquesas region, with Faviinae and Meandrinidae reaching their lowest values across all four survey years. In the Dry Tortugas region, with the exception of Mussinae, juvenile (sub)family densities have remained relatively steady from 2020 to 2023. Mussinae reached its lowest density in 2022 but the value was substantially higher in 2023, approaching similar density values of Mussinae in the Marquesas. Density of *M. cavernosa* in the Dry Tortugas increased slightly from 2022 to 2023.

SUMMARY

The 2023 DRM summer survey marked the largest DRM survey effort in the history of the program, with 608 sites completed across FCR. The increased number of sites can be mostly attributed to the heightened urgency to complete surveys in response to the unprecedented heatwave and mass coral bleaching in 2023. Across the 608 sites, 351 (58%) were severely bleached and 116 (19%) were moderately bleached (excluding pale colonies) (**Table 2**). Pooled by zone within each subregion, 19 subregion-zones were severely bleached, including every zone from Biscayne through the Dry Tortugas, and excluding the Mid-channel in the Marquesas subregion which was surveyed in October when elevated water temperatures had begun to subside (**Table 8**). With more subregion-zones categorized as severely bleached in 2023 than in

any other year, the 2023 survey signifies the worst bleaching year in the history of the program despite the milder conditions experienced by the northern portion of the reef tract. In addition, within the severely bleached subregion-zones, the percentage of sites that were categorized as severely bleached was higher than ever recorded in the DRM program, again highlighting the severity of the event.

Table 8. Number of subregion-zones recorded with mild, moderate, or severe bleaching prevalence, and combined bleaching and paling prevalence, for each DRM summer survey event.

DRM Summer Survey	Bleaching Prevalence			Bleaching and Paling Prevalence			Total Subregion-Zones Sampled
	Mild (0-20%)	Moderate (21-50%)	Severe (>50%)	Mild (0-20%)	Moderate (21-50%)	Severe (>50%)	
2005	9	6	1	1	10	5	16
2006	20	0	0	16	4	0	20
2007	27	1	1	16	12	1	29
2008	21	0	0	17	4	0	21
2009	23	2	0	9	16	0	25
2010	22	0	0	15	7	0	22
2011	20	5	0	7	16	2	25
2012	23	1	0	21	3	0	24
2013	23	0	0	16	7	0	23
2014	7	13	8	2	9	17	28
2015	14	14	1	4	14	11	29
2016	28	0	0	13	14	1	28
2018	24	2	0	9	14	3	26
2019	31	0	0	14	16	1	31
2020	24	1	0	8	15	2	25
2021	30	0	0	15	15	0	30
2022	20	7	2	6	21	2	29
2023	11	2	19	3	8	21	32

Across species, the Acroporids were some of the most impacted corals by the bleaching event, with 100% bleaching prevalence recorded on the 25 *A. palmata* colonies surveyed and 54% bleaching prevalence on the 208 *A. cervicornis* colonies surveyed. Among the reef building species, *C. natans* had 58% bleaching prevalence and *Orbicella* spp. had 83% bleaching prevalence. Among the weedy species, *P. astreoides* had 73% bleaching prevalence and *Agaricia* spp. had 92% bleaching prevalence. These prevalence values are the result of not only unprecedented high-water temperatures throughout the summer but also the prolonged bleaching season that began in early July and ran through early October.

The prolonged period of thermal stress coupled with temperatures often exceeding the bleaching threshold along the southern portion of the reef tract resulted in direct mortality from bleaching related tissue loss. To document mortality from heat stress, the DRM program added a “tissue

loss from thermal stress" code ("TRS") to the data collection methods. The reef zones with the highest prevalence of TRS were the nearshore reefs in the Biscayne and Lower Keys subregions, with 22% and 23% prevalence respectively. With almost a quarter of the population in these reef zones experiencing tissue loss from thermal stress, it is likely that populations of less thermally tolerant species will suffer losses in density and increases in partial mortality.

The prevalence of diseases resulting in tissue loss across all subregion-zones was either zero or low (0-5% disease prevalence) in 2023 (**Figure 4**). Despite the introduction of SCTLD in the Dry Tortugas in May 2021, there were zero observations of SCTLD across the 94 sites surveyed in that subregion and only five total colonies recorded with the disease across the reef tract. Black Band Disease was the most prevalent tissue loss disease, with 45 observations spread mostly between the Upper and Lower Keys and almost entirely on *O. faveolata* colonies. The higher incidence of Black Band Disease has been documented with elevated water temperatures in previous bleaching years and could be the result of weakened immune systems on severely bleached corals.

The time series figures for the SCTLD highly susceptible species indicate a variety of responses in the wake of SCTLD. In Southeast Florida, both *D. stokesii* and *M. meandrites,* have steadily increased in density and maximum mean diameter following SCTLD, indicating some population recovery (**Figures 6** and **8**). For *P. strigosa,* density values have changed very little and mean maximum diameter has been variable however, both are still much lower than the range of annual values preceding the SCTLD outbreak (**Figure 11**). In the Florida Keys, densities of the target species have remained low but somewhat stable after their initial decline, with only slight increases or decreases except for *D. labyrinthiformis* (**Figure 7**). After declining to its lowest value in 2020, density of *D. labyrinthiformis* in the Florida Keys has been increasing, approaching values similar to those prior to the SCTLD outbreak. However, mean maximum diameter of *D. labyrinthiformis* has remained low, indicating that juvenile colonies are entering into the adult population. Similar to the Florida Keys, the density of the target species in the Marquesas has remained low but relatively stable since their initial decline, with no substantial increases or decreases following the conclusion of the epidemic stage of SCTLD in that region.

The 2023 survey in the Dry Tortugas marked the first post-SCTLD assessment. Among the species hit hardest by the disease were *C. natans*, *D. stokesii*, and *M. meandrites* (**Figures 5-6** and **8** respectively). Like elsewhere on FCR, SCTLD took multiple years to spread across the Dry Tortugas and the effects on the corals reflect that. For example, between 2021 and 2022, the density of *C. natans* dropped considerably, while its diameter increased. This was likely due to the whole mortality of smaller colonies while large colonies that had active lesions but still had live tissue remaining were recorded at the time of the 2022 survey. By 2023, however, density of *C. natans* had mostly stabilized but there was a large decrease in the mean maximum diameter. This change reflected the complete loss of those larger colonies and potentially the entry of some of the small colonies that survived the epidemic phase and grew large enough to be included in the adult population. *Mycetophyllia* spp. density was also higher in the Dry Tortugas in 2023

compared to 2022, nearly reaching pre-disease values (**Figure 9**) potentially indicating the start of recovery for those species in the wake of SCTLD.

Among the groups included in the DRM juvenile census, *M. cavernosa* had higher densities than any of the three (sub)families (Faviinae, Meandrinidae, and Mussinae) in all four regions (Southeast Florida, Florida Keys, Marquesas, and Dry Tortugas) in both 2022 and 2023 (**Figures 12-15**). This was expected since *Montastraea cavernosa* is not considered a rare species and is very common in most reef habitats. Counts of juvenile *M. cavernosa* were only collected in 2022 and 2023.

Across all four survey years, densities of Faviinae, Meandrinidae, and Mussinae have been relatively similar within the four regions. Among the regions, the density of all three (sub)families were consistently higher in Marquesas than in the other three subregions. In Southeast Florida, the density of all three (sub)families were consistently lower compared to the other three regions. The highest juvenile densities were recorded for Mussinae corals in the Marquesas in 2022 and 2023. The lowest juvenile densities were recorded for Faviinae corals in Southeast Florda across all four years (**Figure 13**).

Among (sub)families, the density of juvenile Meandrinidae corals was greater, on average than Favinae and Mussinae in Southeast Florida and the Florida Keys compared to the Marquesas and Dry Tortugas. The density of Meandrinidae and Mussinae corals were comparable in the Marquesas region and both greater than Faviinae (**Figure 14**). Densities of Faviinae juveniles in the Dry Tortugas were higher than densities of both Meandrinidae and Mussinae families.

Due to the inherent spatial variability with a random-stratified sampling design, any patterns or trends in the juvenile coral density should be interpreted with caution with only four years of data collected. Annual increases or decreases in juvenile density could be reflective of spatial variability in survey location rather than a realized difference in juvenile density due to recruitment or mortality in (sub)families. However, some regional and (sub)family patterns are emerging and appear consistent like spatial differences in the density of (sub)families across regions or differences in abundance between (sub)families within regions. A transition in the composition of the juvenile community is clearly associated with longitudinal and latitudinal differences throughout FCR. Additional years of juvenile data are needed to help establish annual ranges in juvenile density to determine if any post-SCTLD recovery is reflected by increases in juvenile density.

For more information about FRRP and its DRM effort, see the website http://ocean.floridamarine.org/FRRP/. For more information about the Summer 2022 DRM results, contact the Fish and Wildlife Research Institute at CoralDRM@MyFWC.com.