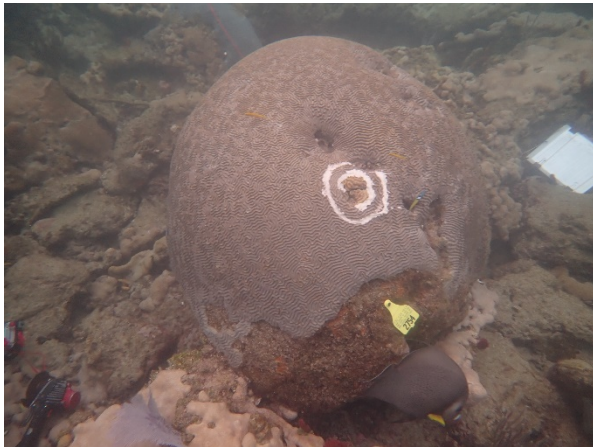


2020-2021 Coral ECA Reef-building-coral Disease Intervention and Preparation for Restoration

Final Report



February 16, 2021



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**Florida Department of Environmental Protection
Office of Resilience and Coastal Protection**



2020-2021 Coral ECA Reef-building-coral Disease Intervention and Preparation for Restoration

Final Report

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List of Acronyms

FAU	Florida Atlantic University Harbor Branch Oceanographic Institute
DEP	Florida Department of Environmental Protection
FWC	Florida Fish and Wildlife Conservation Commission
NSU	Nova Southeastern University
Coral ECA	Southeast Florida Coral Reef Ecosystem Conservation Area
FCR	Florida’s Coral Reef

Acknowledgements

Thank you to the Florida Department of Environmental Protection’s Office of Resilience and Coastal Protection (DEP ORCP) and NOAA CRCP for supporting these efforts. We thank the Florida Coral Disease Advisory Committee for the large number of volunteers assisting in the meeting and planning of coral disease efforts. We thank Lisa Gregg for assisting with permitting. Thanks to the DEP ORCP staff including Kristi Kerrigan for contract and report-review coordination. Thanks to Broward County Environmental Protection and Community Resilience Division and Miami-Dade Regulatory & Economic Resources for field assistance and boat time. Thank you to Elizabeth Fromuth, Kristin Anderson, Thomas Ingalls, and Brooke Enright at the NSU GIS and Spatial Ecology lab.

Executive Summary

SCTLD was first discovered in the SE FL Coral ECA in 2014 and remains present in the region. Regional 2020 NCRMP assessments identified active disease at 13% of the survey sites indicating a relatively high SCTLD prevalence. The majority of these occurred on the shallow Colonized Pavement and Inner Reef in the Broward-Miami ecoregion. As of April 30, 2021, a total of 851 colonies were treated by the coral disease interventions strike teams in the Coral ECA since 2018 (including the experimental sites, but not the large priority corals in section 4.2) totaling 533 meters of treatment. Between April 2020 and April 2021, 311 colonies were treated. The amount and species of corals treated in broad scale recon surveys indicates that there are still some rare survivors of the highly susceptible brain coral species in the area and some are still succumbing to the disease.

Priority corals are still requiring monthly visits to ensure their survival. Of the 106 monitored corals between April 2020 and April 2021, 46 were treated and 18 of those required treatments over multiple periods. Treated lesions yielded an overall intervention success of 82.8%. The number of new infections varies throughout the year. More treatments were required from June through October each year. In July 2020, new treatments more than doubled and remained high through October 2020. After November 2020, number of new infections were minimal with the exception of a spike in February 2021. Monthly visits should continue to maximize treatment success.

As of April 30, 2021, eighteen sites were identified during recon to consider for restoration activities. We identified locations of two previously unknown colonies of *Dendrogyra cylindrus* in Miami-Dade County and several reefs with high densities of *Montastraea cavernosa*. The coral rescue team is now making plans to collect the pillar coral and store in a facility to help increase their genetic diversity of captive stocks.

On February 10, 2021, NSU received a report from The Southeast Florida Action Network about a large *P. strigosa* colony with new disease. On February 16, 2021, strike teams treated the lesion. On May 14, 2021, the treatment was noted as successful at stopping the disease lesion.

NSU assisted the Smithsonian Marine Station at Fort Pierce with probiotics treatments. NSU selected an experimental site with many diseased corals. On September 1, 2020, NSU helped treat and photograph tagged colonies with probiotics. These were revisited a number of times for various activities. Contact Valerie Paul for more information on those experimental outcomes.

The outcomes of last year's task 5 comparing antibiotic paste versus chlorinated epoxy on *Montastraea cavernosa* was published the peer-reviewed publication *Frontiers in Marine Science* as part of the special collection on SCTLD. The paper is titled "Optimizing stony coral tissue loss disease (SCTLD) intervention treatments on *Montastraea cavernosa* in an endemic zone."

The outcomes of the metabolomics analyses at the probiotic treatment sites were submitted for review in *Frontiers in Marine Science* as part of the special collection on SCTLD by Jessica Deutsch and Neha Garg titled "Metabolomics of healthy and stony coral tissue loss disease affected *Montastraea cavernosa* corals." NSU contributed edits, data analyses, and illustrations.

1. BACKGROUND

In 2019-20, DEP funded NSU (PO# B558F2) to continue previous coral disease interventions with the expectation of adapting to new methodologies to improve intervention success in the Southeast Florida Coral Reef Ecosystem Conservation Area (Coral ECA). These actions included increasing the monitoring and continued treatment of 90 priority large corals, conducting broadscale strike team reconnaissance and disease interventions, further testing of permitted intervention techniques and materials, and the identification of unique coral disease survivor sites. This information provided data on treatment effectiveness, saved the largest colonies from extreme tissue loss, initiated probiotics testing, and provided data on tissue loss rates, survivor sites, new infection rates through time, and classified large corals into categories based on infection rates for future hypothesis testing.

In August 2020, DEP funded NSU (PO# B7B6F3) to continue the previous tasks and include additional components using advanced statistical modeling approaches to analyze data and identify possible environmental correlates to the previously observed new infection patterns and hot spot coral disease clustering throughout Florida's Coral Reef (Task 6).

This report summarizes the progress from our continued Coral ECA coral disease interventions through April 2021, including the monitoring and continued treatment of the priority large corals, broadscale strike team reconnaissance and disease interventions, field activities for initial probiotics testing, and the identification of unique coral disease survivor sites.

Concomitantly, a separate report was submitted by Brian Walker (NSU), Gareth Williams, and Jeff Maynard (SymbioSeas) detailing the progress on Task 6: Environmental drivers of stony coral tissue loss disease.

2. PROJECT DESCRIPTION

One goal of this project was to perform disease interventions on the remaining reef-building coral species with active disease in the Coral ECA. These activities are essential to saving the remaining corals in SE FL affected by disease that have the potential of recovering and building new reef structure. The first objective for this goal was to conduct broader-scale strike team reconnaissance and disease intervention efforts in partnership with FAU, DEP, Broward County, and Miami-Dade County to help save diseased colonies throughout the Coral ECA. The second objective was to apply these interventions to 90 priority large corals as necessary on a monthly basis to maintain their health. A third objective was to further field test new permitted intervention techniques and materials including whole colony treatments as they are conceived, developed, and permitted.

Another goal of this project was to collect information to inform and aid in planning future Coral ECA restoration efforts. In order to conduct restoration in the future, it's important to identify and locate survivor colonies to be used for sexual reproduction, genetic analyses, and experimentation on stress hardening and disease resistance. Therefore, we aim to

identify sites with dense populations of survivor colonies, large colonies, and locations of survivors of particularly impacted species to make restoration activities more efficient.

The findings of this project are being incorporated into the on-going coral disease response effort which seeks to improve understanding about the scale and severity of the Florida's Coral Reef coral disease outbreak, identify primary and secondary causes, identify management actions to remediate disease impacts, restore affected resources and, ultimately, prevent future outbreaks. As such, collaboration amongst partners and the Disease Advisory Committee (DAC) is essential to avoid duplication, share lessons learned, and ensure alignment of needs.

3. METHODOLOGY

The antibiotic paste treatments were conducted under the State of Florida Special Activity License Permit SAL-19-2022-SRP which authorized the cutting of disease-breaks and the application of disease treatments containing amoxicillin and chlorine. The probiotics work was permitted under the State of Florida Special Activity License Permit SAL-19-2201-SRP.

3.1. Broad-scale Coral Disease Intervention Strike Team (Task 2)

Southeast Florida coral disease intervention strike teams, consisting of personnel from NSU, Broward County, and Miami-Dade County, conducted disease intervention at various sites throughout both counties. Intervention sites were chosen based on previous information on the locations of diseased corals and high priority county sites. The NSU efforts discussed in this report targeted locations between Hillsboro Inlet and Biscayne National Park while avoiding known existing monitoring stations and experimental sites. At each location, divers towed a GPS buoy synced to a dive computer. Once a diseased coral was located, the time was taken from the dive computer. Each coral was tagged and measured, photographed, and treated. GPS coordinates were loaded into ArcGIS and the locations that corresponded to each time recorded during treatment were copied into a GIS shapefile. All treated coral locations were supplied to FWC for inclusion in the Coral Disease Intervention Dashboard:

<https://novasoutheastern.maps.arcgis.com/apps/opsdashboard/index.html#/55a759f02f3c486eb1d29a95f80fba0a>.

3.2. Apply Interventions to 90 Large Corals (Task 3)

The largest known corals in the region were prioritized for monitoring and disease interventions. From September 2018 – June 2019, approximately 60 corals were monitored and treated on a monthly basis. This increased to 90 colonies in July 2019, but it took several periods to establish all 90. As of February 2021, there are a total of 106 corals in the priority database. All priority corals were photographed monthly and visually assessed by a diver estimating the percentage of live tissue, diseased tissue, bleached tissue, recent mortality, and old mortality. If SCTLTD was found, the lesion was treated with antibiotic paste. All margins were treated with the Ocean Alchemists antibiotic ointment CoreRx B2B with amoxicillin (1:8 ratio by weight). Photographs were taken of all areas before

treatment at both the 0.5 m standard distance and wider scenes. The length of each treatment was estimated using a standardized scale in the photographs. Lesion treatments were determined failures if the active disease continued progressing past the treatment line. Treatment success was calculated as the reciprocal of the percentage of treatment failures. All prioritized colonies were tagged with a yellow tag with a unique number and instructions to photograph the coral and submit the photo to www.SEAFFAN.net/tags (Figure 1).

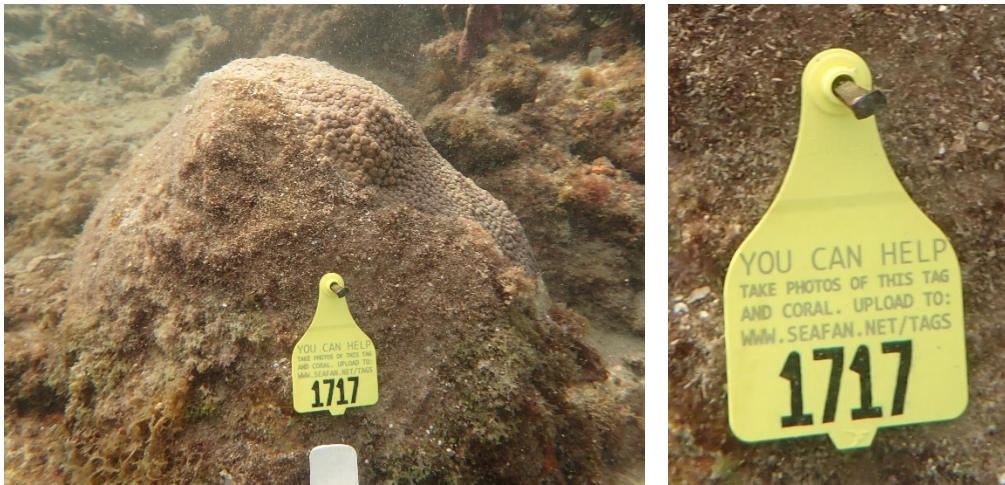


Figure 1. Example of coral tag placed on or next to each treated coral.

3.3. Recon Sites (Task 4)

Reconnaissance throughout Broward and Miami-Dade was opportunistically conducted by strike teams to identify corals and/or sites that respond better to treatments or that have resisted infection to-date and to identify unique coral disease survivor sites to make future restoration activities more efficient. Recon was guided by a desktop analysis of previous datasets that identify historic sites of high coral density and/or richness. Recon is also performed during strike team activities and other opportunistic times. Divers visit identified sites and haphazardly search the area towing a GPS buoy to find locations of visually noticeable high coral density or richness and to identify if disease is present. If disease is found, these locations are treated and mapped. Large colonies of any species and smaller colonies of the species hit hardest by SCTLD (e.g. *M. meandrites*, *E. fastigiata*, *D. stoksii*, *C. natans*, *D. cylindrus*, *D. labyrinthiformis*) are mapped.

3.4. Field test new permitted intervention techniques and materials (Task 5)

3.4.1. Probiotics on *Montastraea cavernosa*

The Smithsonian Marine Station at Fort Pierce is developing several probiotics and several treatment methods to be tested on *M. cavernosa*. We set up two field experiment sites for testing and monitoring the corals' responses.

An experimental site, Broward Site 1 (BS1), was set up on September 26, 2019 (Figure 2). Nineteen corals that looked diseased were tagged and photographed. The site was revisited fourteen days later (10/10/19) and photos were retaken. On this date, six additional diseased corals were tagged to incorporate into the experimental site. Photographs were compared to assess the rate of disease progression and estimate the length of disease margin. Six of the originally tagged corals were excluded due to insufficient disease characteristics (bleaching or burying associated mortality rather than disease). The remaining nineteen corals were randomly selected and treated with probiotics or a control procedure without the probiotics.

A second experimental site location (BS2) was identified on March 16, 2020 and thirteen diseased *Montastraea cavernosa* were tagged, photographed and mapped (Figure 3). The site was revisited seven days later on March 23, 2020 and an additional eight diseased colonies were added to the site. BS2 treatments were delayed due to the coronavirus pandemic. This site was revisited on August 19, 2020 to evaluate disease progression and then treated with whole-colony probiotic treatments soon after. On October 14, 2020, five new diseased colonies were added. On October 30, 2020, five healthy colonies were added to the monitoring and all corals were sampled for metabolomics and genome sequencing.

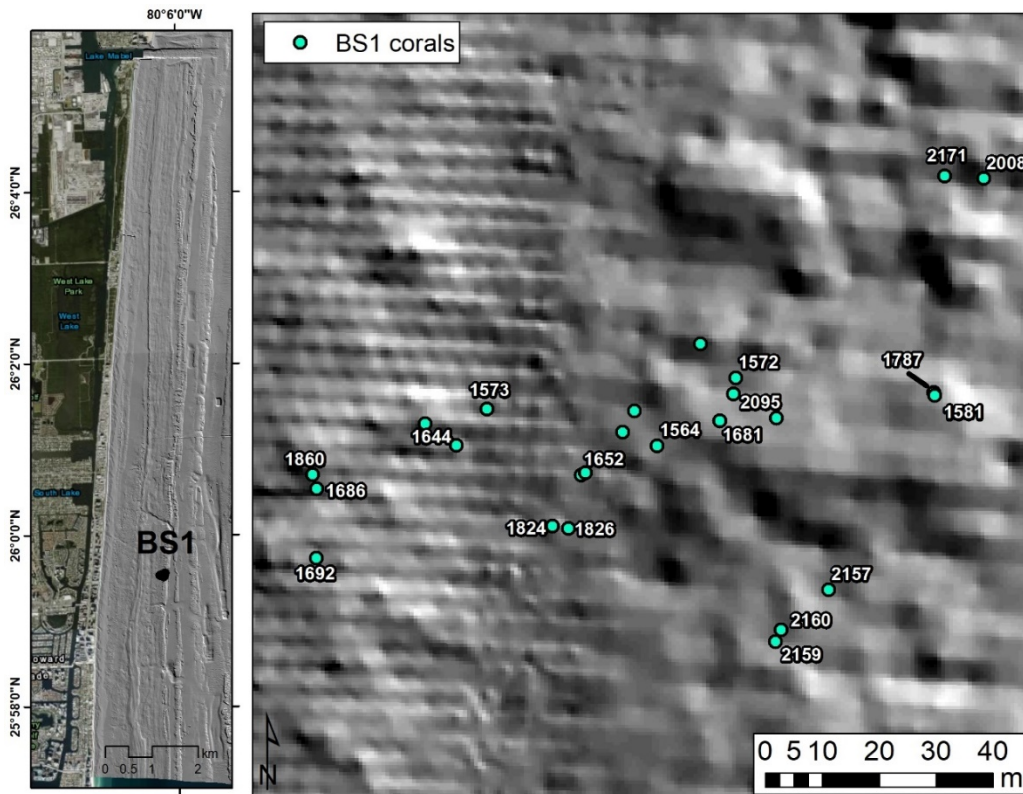


Figure 2. Map of probiotics site BS1 corals established September 26, 2019.

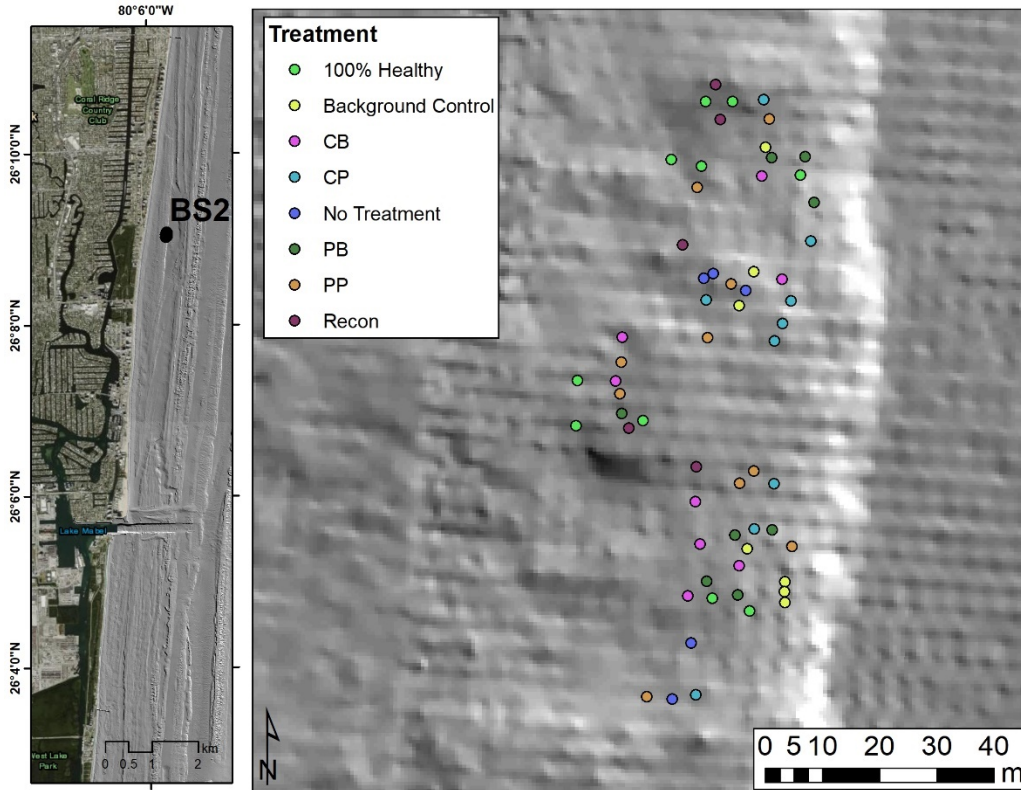


Figure 3. Map of probiotics site BS2 treatment corals established March 23, 2020.

4. RESULTS

Results from 2019-2020 (PO B558F2) task 5 to compare antibiotic paste versus chlorinated epoxy on *Montastraea cavernosa* were published in the SCTL D special of *Frontiers in Marine Science Coral Reef Research*. It can be found here: <https://www.frontiersin.org/articles/10.3389/fmars.2021.666224>

Citation: Walker BK, Turner NR, Noren H, Buckley S, K Pitts. (2021) Optimizing stony coral tissue loss disease (SCTL D) intervention treatments on *Montastraea cavernosa* in an endemic zone. *Frontiers in Marine Science Coral Reef Research*. doi: 10.3389/fmars.2021.666224.

4.1. Broad-scale Coral Disease Intervention Strike Team (Task 2)

As of April 30, 2021, a total of 851 colonies were treated by the coral disease interventions strike teams in the Coral ECA since 2018 (including the experimental sites, but not the large priority corals in section 4.2) (Figure 4). The total number of treatments by species were 750 *M. cavernosa*, 61 *O. faveolata*, 9 *Colpophyllia natans*, 14 *Pseudodiploria strigosa*, 9 *Pseudodiploria clivosa*, 2 *Diploria labyrinthiformis*, 5 *Solenastrea bournoni* and 1 *Siderastrea siderea*.

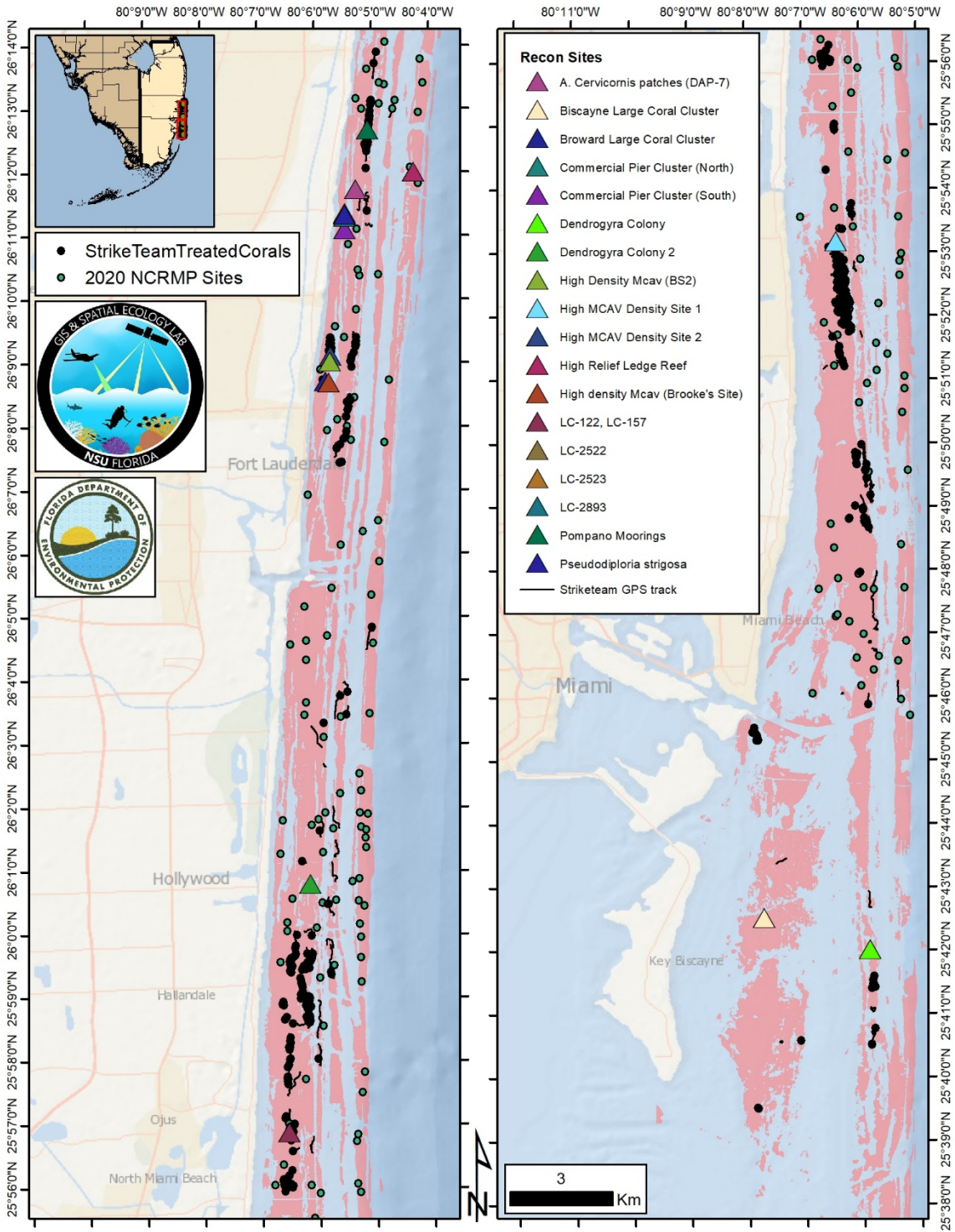


Figure 4. The location of the 851 strike team treated corals and eighteen recon sites for restoration as of April 30, 2021.

Out of the 851 colonies, 726 were treated with antibiotic ointment (635 *M. cavernosa*, 56 *O. faveolata*, 7 *C. natans*, 12 *P. strigosa*, 8 *P. clivosa*, 2 *D. labyrinthiformis*, 5 *S. bournoni* and 1 *S. siderea*); 109 corals were treated with chlorinated epoxy (102 *M.*

cavernosa, 4 *O. faveolata*, 2 *P. strigosa*, and 1 *C. natans*); and 16 treated with CoreRx B2B without antibiotics (that were not successful).

A total of 533.44 meters (53,344 cm) of antibiotic paste treatments, 68.59 meters (6,859 cm) chlorinated epoxy treatments, and 6.4 meters (640 cm) of CoreRx Base treatments were performed totaling 621.85 meters (62,185 cm) (Figure 5). The average treatment length per coral was 73.78 cm which varied by species: *M. cavernosa* = 74.79 cm, *O. faveolata* = 68.04 cm, *P. strigosa* = 56.75, *P. clivosa* = 88.13, *C. natans* = 64.71, *D. labyrinthiformis*= 50.50 *S. bournoni* = 45.40, and *S. siderea* = 100.00 cm.

Between April 2020 and April 2021, a total of 311 colonies were treated with antibiotic paste by the coral disease interventions strike teams in the Coral ECA (not including the large priority corals (Section 4.2) and probiotics (Section 4.4)). The total number of treatments by species were 273 *M. cavernosa*, 23 *O. faveolata*, 1 *C. natans*, 6 *P. strigosa*, 3 *P. clivosa*, 2 *D. labyrinthiformis*, and 3 *S. bournoni*. These totaled 295.72 meters (29,572 cm) of antibiotic ointment treatments were performed. The average treatment length per coral was 95.70 cm which varied by species: *M. cavernosa* = 98.89 cm, *O. faveolata* = 74.13 cm, *P. strigosa* = 64.33, *P. clivosa* = 125.00, *C. natans* = 105, *D. labyrinthiformis*= 50.50, and *S. bournoni* = 34.00 cm.

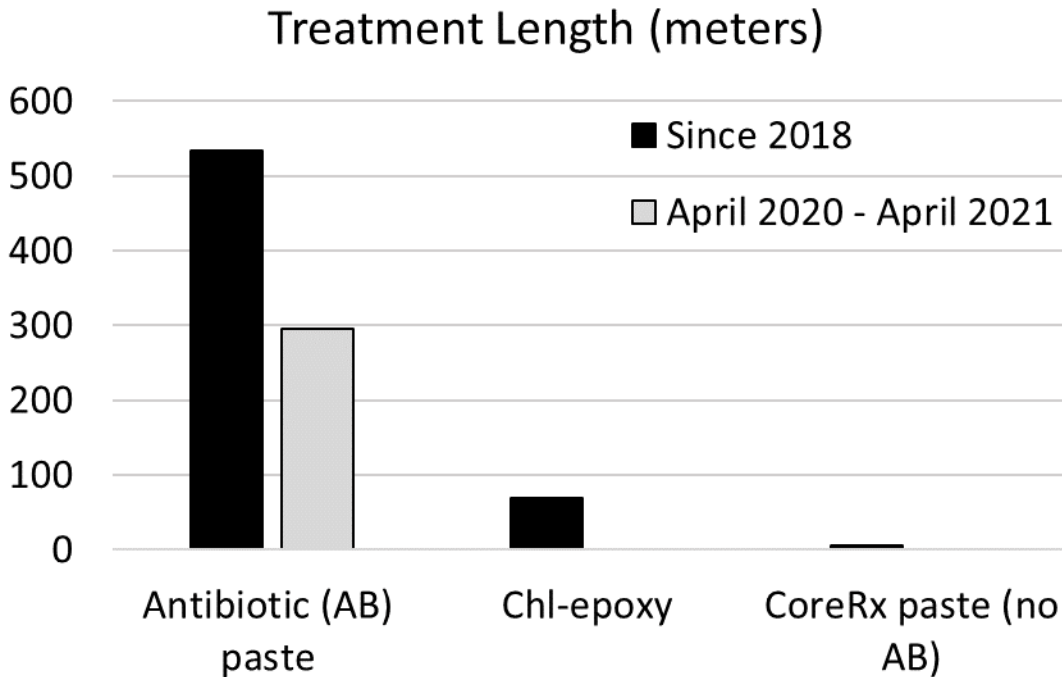
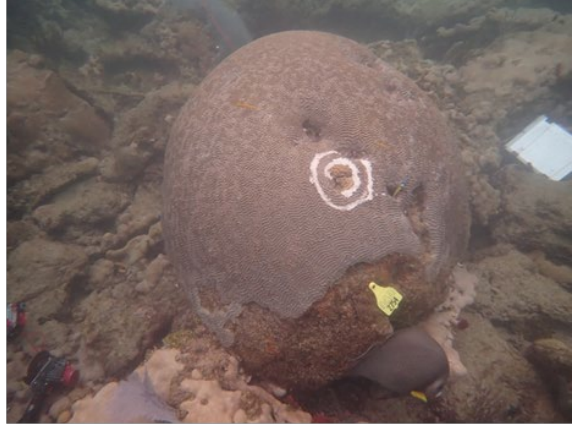


Figure 5. The length of strike team treatment in meters since initial treatments (black) and last year (grey). Only antibiotic treatments are now being applied.

On February 10, 2021 we received a report from the Southeast Florida Action Network (SEAFAN) about a large *P. strigosa* colony with new disease (Figure 6). On February 16, 2021, strike teams treated the lesion (top right). On May 14, 2021 the treatment was noted as successful at stopping the disease lesion from progressing (bottom).



4.2. Apply Interventions to 90 Large Corals (Task 3)

a. Treatment Success

Figure 7 illustrates the locations of all 106 priority corals. Not all monitored corals required treatments with antibiotic paste starting in August 2019 (Figure 8); forty-six corals (43.4%) were treated, and 60 corals (56.6%) did not show active lesions. Eighteen (39.1%) of the treated colonies needed additional treatments over multiple monitoring periods, while 28 (60.9%) of the corals were only treated once. The proportion of colonies requiring treatment were similar between species, with 37 out of the 84 (44.0%) monitored *Orbicella* spp., and 7 of the 14 *M. cavernosa* (50%) requiring treatment.

Both chlorinated epoxy and amoxicillin paste treatments were cumulatively assessed to illustrate all treatments and failures through time (Figure 9). The number of failures decreased substantially after starting antibiotic treatments which is evident by the flattening slope of the failure line after August 2019. For this reason, we are only presenting the success of antibiotic treatments in this report. Please refer to Walker et al. (2020) for more on epoxy treatment success.

Over the most recent year, between April 2020 and April 2021, a total of 197 antibiotic ointment treatments were conducted on 37 individuals across three coral species (Table 1). Thirty-three lesion treatments failed, equating to 82.8% success overall. Success was similar between *Orbicella* spp. treatments (82.0%) and *M. cavernosa* treatments (81.8%) despite large differences in sample size per species. *Orbicella* spp. make up 79.2% of the priority coral database (84/106) and saw a 18.02% failure rate (31 fails), while *M. cavernosa* comprised 13% (14/106) of the database and experienced 2 treatment failures (18.2%). During the most recent year, one (100%) *Siderastraea siderea* treatment was successful, and no treatments to *Pseudodiploria strigosa* colonies were performed.

Cumulative antibiotic ointment treatment success was high and varied between months (Figure 10). Cumulative success ranged from 83% to 73% with a mean of 82% between April 2020 and April 2021. *Orbicella* spp. cumulative treatment success averaged 82% while *M. cavernosa* averaged 74%.

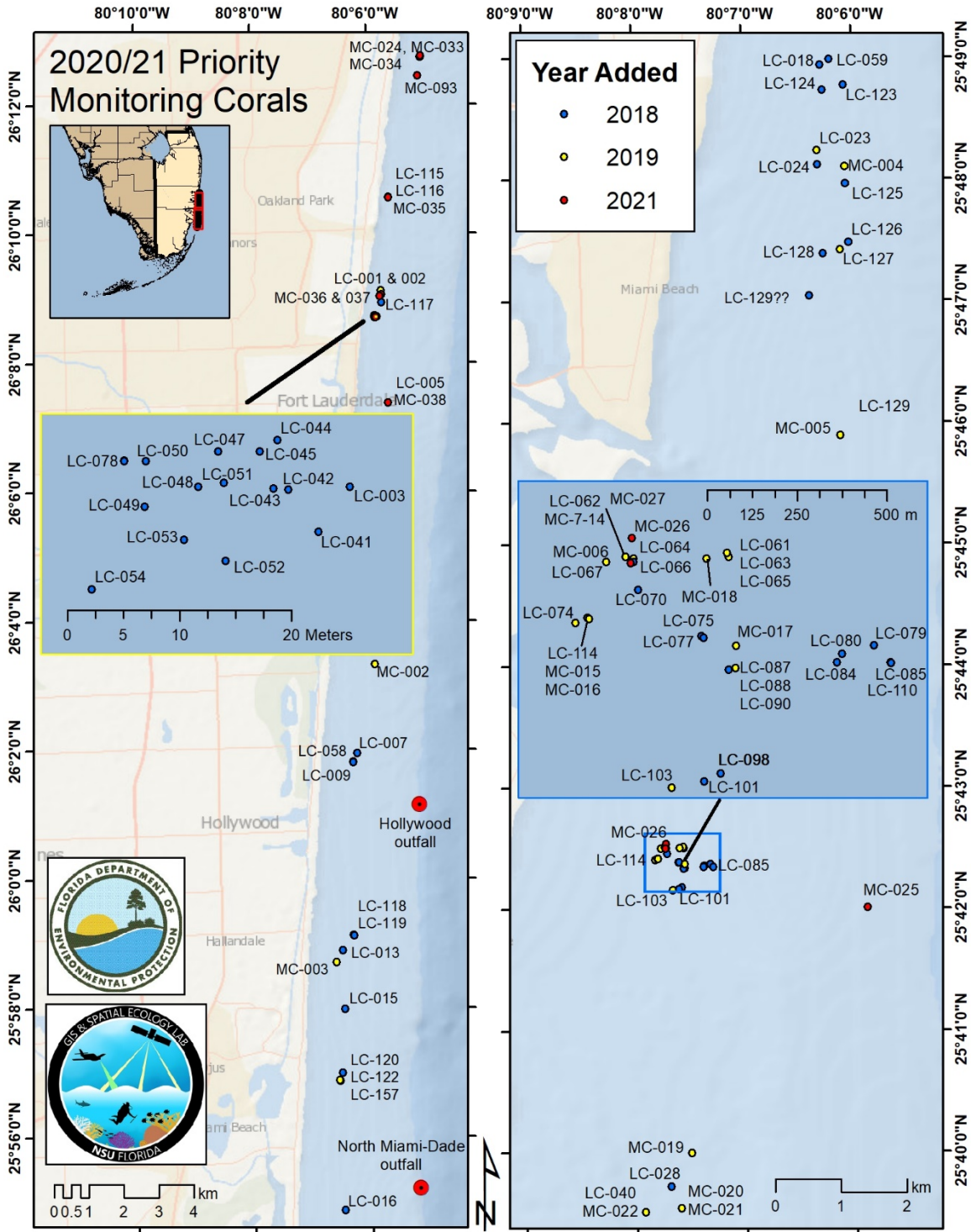


Figure 7. Map of the large priority monitoring corals colored by the year they were added to the monitoring.

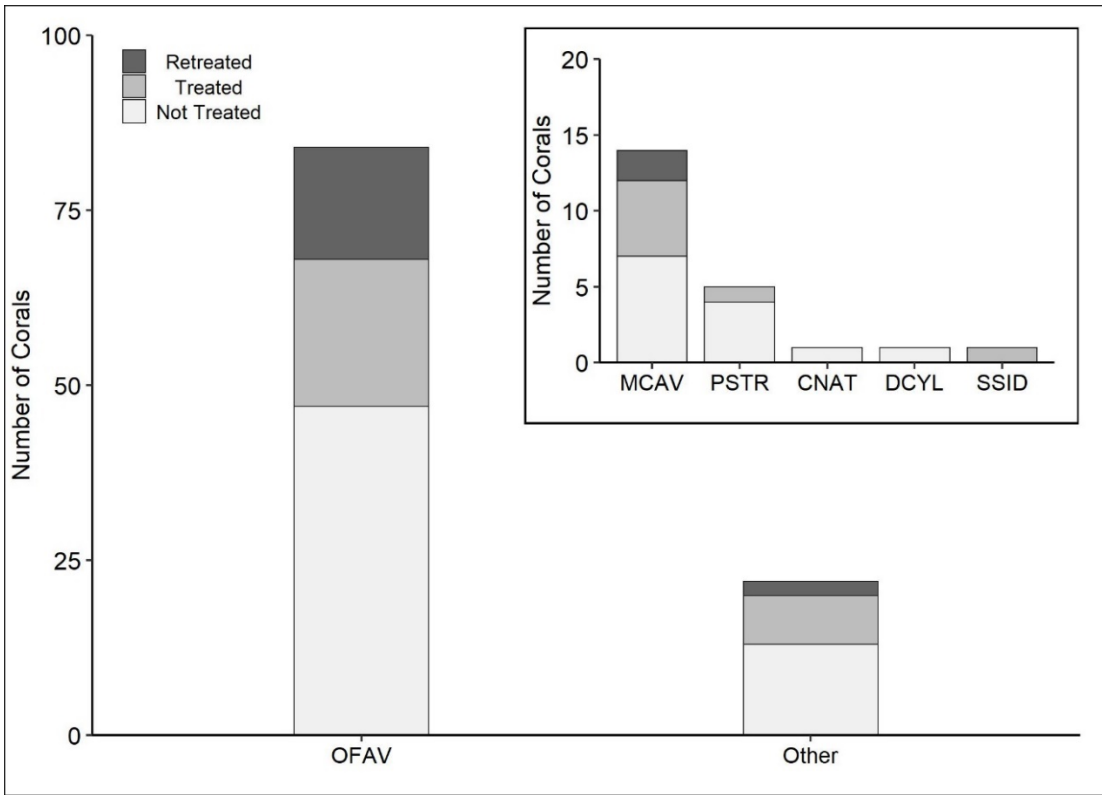


Figure 8. Total number of corals monitored and Not Treated (no disease), Treated (once), and Retreated for each species from August 2020 – April 2021. “Other” has been enlarged to show the number of treatments for the less abundant species.

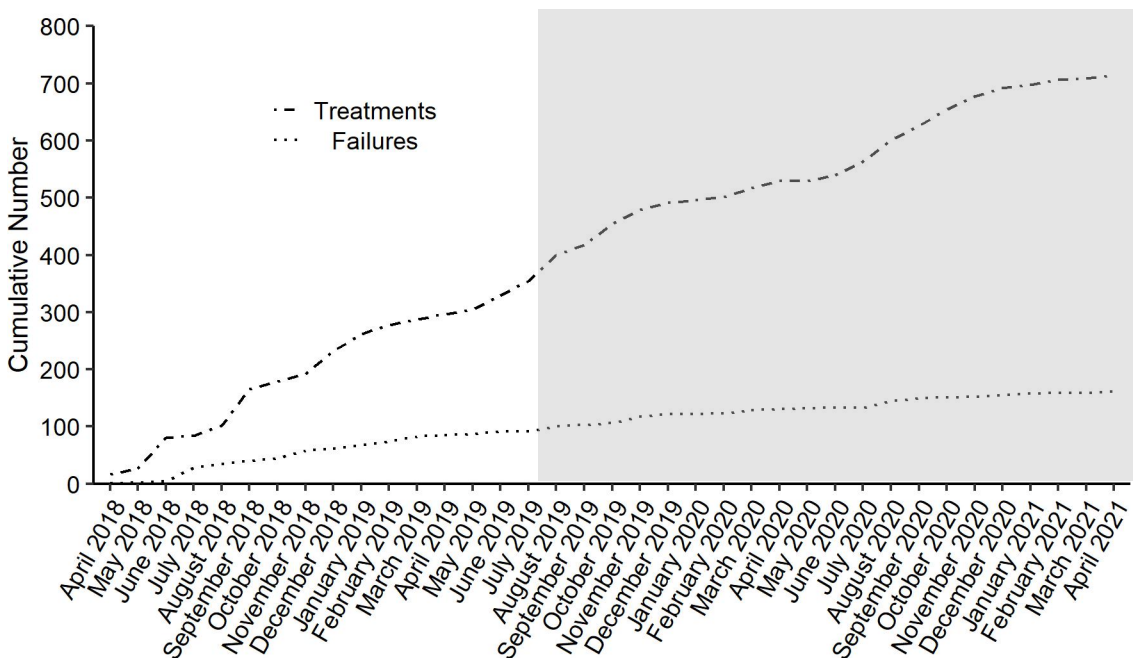


Figure 9. The cumulative total number of treatments (dashed line) and failures (dotted line) per monitoring period for all coral species. Shaded area indicates antibiotic ointment treatments.

Table 1. Total antibiotic ointment treatment failure and success by species from April 2020 – April 2021.

April 2020 – April 2021	MCAV	OFAV	PSTR	SSID	ALL SPECIES
Total Treatments	11	177	0	9	197
% Failure	18.2	18.0	NA	0.0	17.2
% Success	81.8	82.0	NA	100	82.8

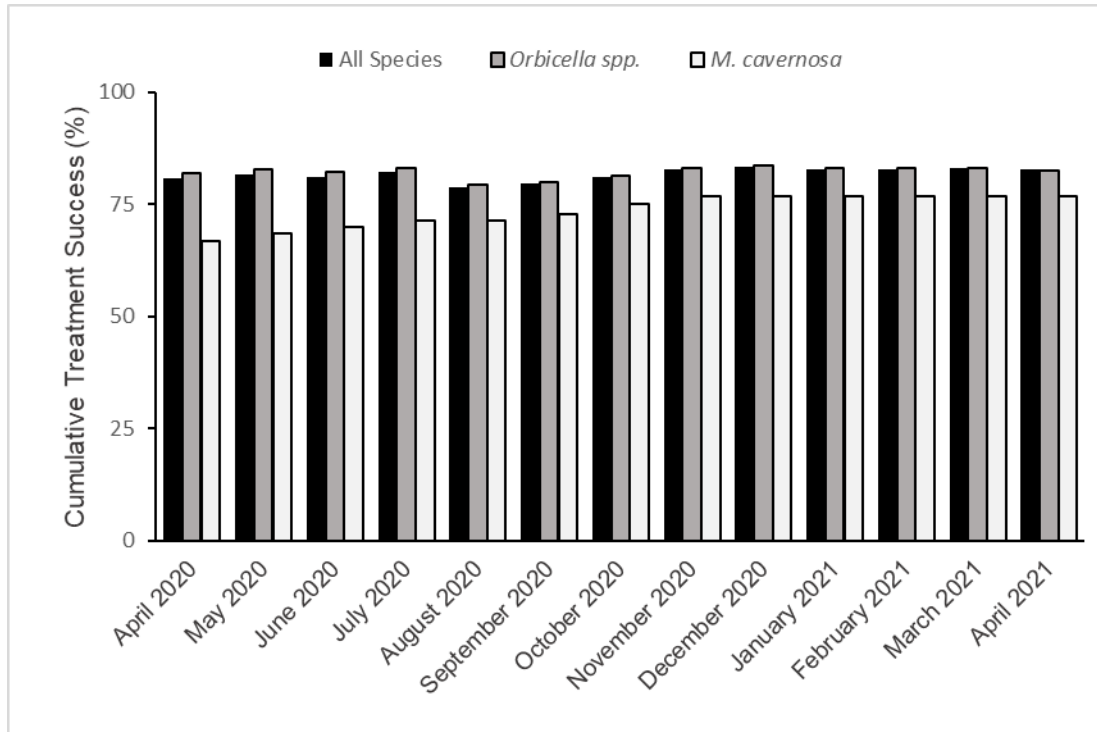


Figure 10. The cumulative percent success of antibiotic ointment treatments on all coral species (black), *Orbicella* spp. (dark grey), and *M. cavernosa* (light grey) during each treatment period.

b. Temporal Infection Patterns

At each monitoring period, all disease lesions were treated, thus the total number of new treatments indicates the amount of new disease found on the monitored corals over time after their initial visit. Figure 11 summarizes the number of new treatments required (black) and number of treated corals (grey) per monitoring period for all corals since September 2018. The number of new infections and corals requiring treatment varied through time. Figure 12 summarizes the amount of treatment required in each period.

Generally, more treatments were required from June through October each year with the exception of December 2018 and January 2019. In June 2019, the number of treatments tripled and remained high until October 2019. New infections remained low but relatively steady from December 2019 through June 2020. In July 2020, new treatments more than doubled and remained high through October 2020. After November 2020, number of new

infections were minimal with the exception of a spike in February 2021. Table 2 summarizes the treatment data for the performance period. See Task 6 progress report submitted separately for statistical modeling new infections with environmental drivers (Walker and Williams, 2020).

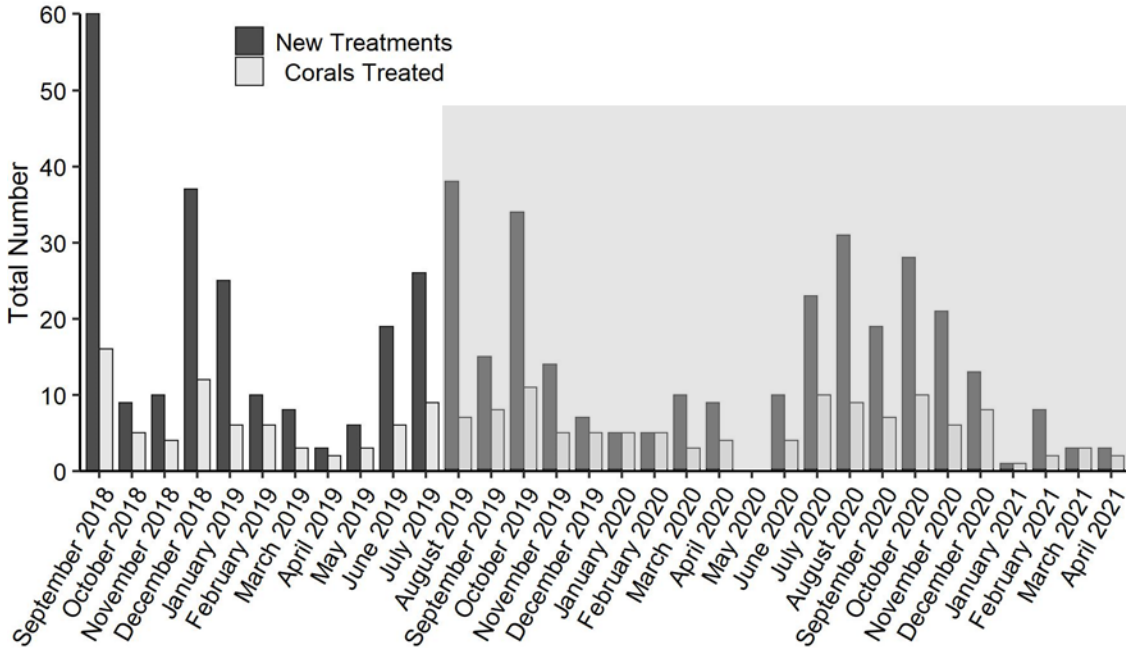


Figure 11. The numbers of new treatments (black) on all corals used as a proxy for new infections and the number of treated corals (light gray) by treatment period. Shaded area indicates antibiotic ointment treatments.

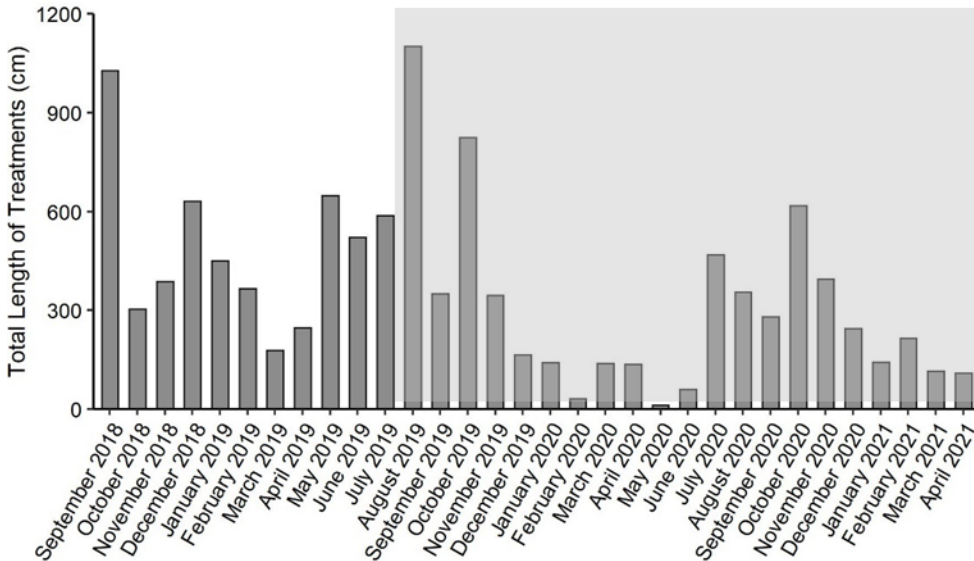


Figure 12. The total treatment length (cm) on all corals by monitoring period. Shaded area indicates antibiotic ointment treatments.

Table 2. The total number of corals assessed, treated, and retreated during the reporting period.

Monitor Period	Number of Corals			Number of		Percent of corals with	
	Visited	Treated	Retreated	Treatments	Retreatments	Treatments	Retreatments
April 2020	90	4	2	9	3	4.4	2.2
May 2020	90	0	1	0	1	0.0	1.1
June 2020	90	4	0	10	0	4.4	0.0
July 2020	90	10	0	23	0	11.1	0.0
August 2020	90	9	4	31	7	10.0	4.4
September 2020	90	7	4	19	6	7.8	4.4
October 2020	90	10	1	28	1	11.1	1.1
November 2020	90	6	1	21	1	6.7	1.1
December 2020	90	8	2	13	2	8.9	2.2
January 2021	90	1	4	1	4	1.1	4.4
February 2021	106	2	1	8	1	1.9	0.9
March 2021	106	3	0	3	0	2.8	0.0
April 2021	106	2	1	3	2	1.9	0.9

4.3. Recon Sites (Task 4)

During our strike team and NCRMP survey activities we searched for areas of high coral density and diversity. Recon efforts are ongoing, funded by NOAA Coral Program Award NA19NOS4820127 and DEP B7B6F3. As of April 30, 2021, out of 233 NCRMP dives and 214 strike team dives to-date, eighteen sites were identified during recon to consider for restoration activities. Table 3 contains the data associated with these sites and Figure 4 illustrates their locations.

We identified several sites of interest that meet these criteria including two previously unknown colonies of *Dendrogyra cylindrus* in Miami-Dade County (Figures 13 and 14) and several reefs with high densities of *Montastraea cavernosa*. One site observed while drifting on safety stop after a NCRMP fish survey appeared to have high relief and rugosity. However, at a depth of ~20 m and limited visibility, individual colonies were not identified. We plan to revisit to investigate further. During our strike team activities, we also found a site with both high coral density and diversity along the Pompano mooring buoys, despite high traffic, a large number of colonies were healthy and of significant size.

On April 8, 2021, a large pillar coral colony was found with one small remnant isolate in Hollywood, FL. This was reported to the coral rescue team who is making plans to collect it and store in a facility to help increase their genetic diversity of captive stocks.

Table 3. Preliminary information on six sites identified for restoration activities.

Nr	Site name	County	Coordinates	Description
1	<i>Dendrogyra</i> Colony 1	Miami-Dade	N 25.700211 W 80.098248	One partly live <i>Dendrogyra cylindrus</i> colony on a shallow reef in South Miami-Dade
2	Pompano Moorings	Broward	N 26.211332 W 80.084531	Nice relief, high coral cover and diversity
3	High Relief Ledge Reef	Broward	N 26.200196 W 80.071329	High rugosity deep reef, appeared to have coral colonies, lots of large fish
4	Broward Large Coral Cluster	Broward	N 26.145267 W 80.097367	Cluster of large OFAV
5	Biscayne Large Coral Cluster	Miami-Dade	N 25.708467 W 80.12895	Cluster of large OFAV
6	High MCAV Density Site 1	Miami-Dade	N 25.886240 W 80.106852	High density of MCAV on a patch reef, when visited not enough disease to make a site but need to revisit
7	High MCAV Density Site 2 (NCRMP site 3204)	Broward	N 26.151909, W 80.095806	Near BS2 High Density of large MCAV and some CNAT, observed some SCTLD
8	LC-122, LC-157	Broward	N 25.94788, W 80.10913	LCM on 11/24/2020 noted many diseased MCAV and OFAV
9	Commercial Pier Cluster (South point)	Broward	N 26.185208, W 80.09145	High density of MCAV
10	Commercial Pier Cluster (North point)	Broward	N 26.189059, W 80.091318	High density of MCAV
11	LC-2893	Broward	N 26.188383, W 80.091359	Large OFAV Colony
12	LC-2523	Broward	N 26.189161, W 80.091371	Large OFAV Colony
13	LC-2522	Broward	N 26.189415, W 80.091368	Large OFAV Colony
14	<i>Pseudodiploria strigosa</i>	Broward	N 26.189059, W 80.091318	Large PSTR Colony
15	High density MCAV (Brooke's Site)	Broward	N 26.144958, W 80.096331	High density of MCAV
16	High Density MCAV (BS2)	Broward	N 26.150397, W 80.09594	SSI Probiotic Site (High density of MCAV)
17	Acropora Cervicornis Multiple patches	Broward	N 26.195693, W 80.088124	Area with extensive <i>A. cervicornis</i> thickets near Dense Acropora Patch 7 (DAP7)
18	<i>Dendrogyra</i> Colony 2	Broward	N 26.01317, W 80.102561	Old <i>Dendrogyra</i> colony skeleton with single live pillar

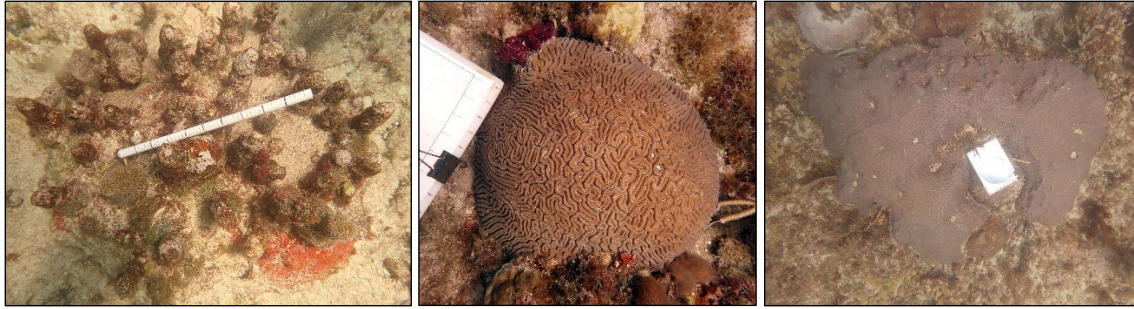


Figure 14. Yellow circle shows the small isolate on a large almost-dead pillar coral colony found in Hollywood, FL that was reported to the coral rescue team for collection.

NSU conducted fish and benthic surveys for the National Coral Reef Monitoring Program (NCRMP) throughout the Southeast Florida region. We used our NCRMP sampling in Miami-Dade, Broward, and Palm Beach counties as recon to identify sites of interest and potential disease intervention locations. Sites with high coral density, susceptible species and disease presence were noted together with GPS location. Sites with high density will be revisited and assessed for possible creation of new experimental sites. Active coral disease was observed at 13% (31 of the 233) of NCRMP sites visited to date (Figure 15). Fast disease progression (>1cm recent mortality along the disease margin) was seen at 18 of those sites (55%). The majority of NCRMP sites with coral disease were seen in Broward County (51.6%); then Miami-Dade County (41.9%). Palm Beach County had the fewest diseased sites (6.5%). The majority of sites with disease were less than 10 m depth (58%),

followed by 10 – 20 m (29%), and >20 m (13%). The Nearshore Colonized Pavement had the most sites with disease (42%), followed by the Inner Reef (26%), Middle Reef (13%), Outer Reef (6.5%), Deep Patch Reef (6.5%), Shallow Patch Reef (3.2%), and the Deep Ridge Complex (3.2%). Based on this recon information, we will continue most strike team efforts in the shallow habitats through the Broward-Miami ecoregion.

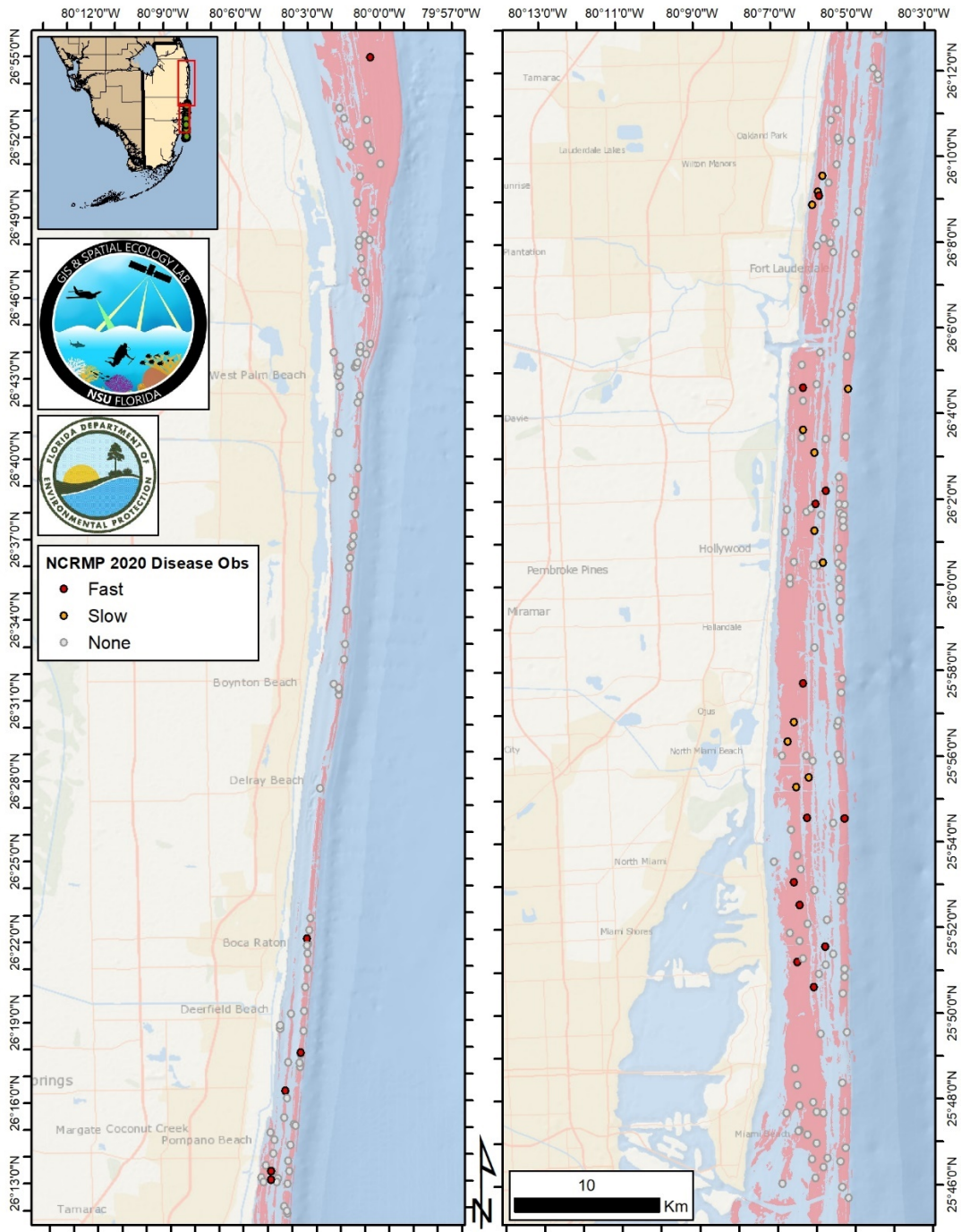


Figure 15. A map of 2020 NCRMP sites with disease observations. Sites were selected based on the presence of at least one lesion seen during any monitoring activity. Lesion progression was recorded as slow or fast depending on the amount of recent dead skeleton present.

4.4. Field test new permitted intervention techniques and materials (Task 5)

4.4.1. Probiotics on *Montastraea cavernosa*

NSU assisted the Smithsonian Marine Station at Fort Pierce with probiotics treatments (Figure 12). Here we report on the NSU field logistics activities. Please contact the main PI for the probiotics work, Valerie Paul, for more information on those experimental outcomes.



Figure 16. NSU diver treating a coral with probiotics at BS1.

On September 1, 2020, NSU treated and photographed the BS2 tagged colonies with probiotics. A total of four treatment types were deployed: Probiotic Bag (PB) n=6, Probiotic Paste (PP) n=9, Control Bag (CB) n=6, Control Paste (CP) n=4. The Probiotic bag treatment consisted of placing a weighted plastic bag over the colony then injecting 50 ml of probiotic mixture into the bag. The Control bag treatment consisted of bagging the coral with only regular seawater. Probiotic paste treatments involved applying a sodium alginate-based paste infused with probiotic bacteria directly over the disease lesion. Control paste treatments involved applying the same paste *sans* probiotics. Bags were left for two hours to allow full dosage of probiotics. After two hours the bags were removed.

NSU revisited the site two weeks post-treatment to photograph colonies and assess disease progression. Based on the photographs, retreatment was deemed necessary. Retreatment occurred on October 14, 2020. Newly discovered diseased colonies (n=6) were incorporated among the controls. Treatments consisted of: PB=6, PP=10, CB=8, CP=8. The site was revisited on October 30, 2020 to photograph and collect tissue samples two weeks after the second treatments. Tissue samples will undergo metabolomics analysis and genome sequencing as well as testing for the coral pathogen *Vibrio coralliilyticus*.

On January 15th, 2021 probiotic treatments were applied and on February 25th, 2021 the site was photographed, and five healthy corals were added. Also, to better understand the disease progression and treatment efficacy, photographs were taken 360° around all the colonies. These photos will be converted into detailed 3D models of the corals. Lastly, on May 7th, 2021, the site was photographed for 3D coral imaging. The final count is PB=8, PP=10, CB=8, CP=9, Background control=7 and 100% Healthy=9.

The metabolomics results were submitted to Frontiers for publication by Jessica Deutsch and Neha Garg on May 25, 2021, to which we contributed edits, data analyses, and illustrations.

5. DISCUSSION

Intervention remains an effective method for preventing mortality of corals from SCTL. This past year, interventions helped maintain species diversity and ecosystem services within the Coral ECA and kept alive some of the largest and oldest animals in Florida. Between April 2020 and April 2021, a total of 197 treatments were conducted on 37 large colonies across three coral species, most of which were the threatened *Orbicella spp.* Additionally, 35 smaller colonies were treated with probiotics and 311 colonies were treated by the intervention strike teams: 273 *M. cavernosa*, 23 *O. faveolata*, 1 *C. natans*, 6 *P. strigosa*, 3 *P. clivosa*, 2 *D. labyrinthiformis*, and 3 *S. bournoni*. These results indicate that disease is still prevalent in the region, that interventions are still needed, and that these efforts are worthwhile.

Intervention activities have saved species and size classes that would take decades to achieve through restoration at a fraction of the cost that equivalent restoration would require to achieve similar coral cover. Considering the Coral ECA large coral monitoring alone, the current live tissue area of all previously treated large corals is 3,578,091 cm² (357.8 m²). This equals 3,851 ft². If 36 outplant plugs covered one sq ft with 100% survival and no disease, that equates to 138,636 plugs. This doesn't include the 851 additional strike team corals we have treated. Granted, we can't assume all tissue would've been lost without treatment or that the treatments are 100% effective or what will be lost if we stop monitoring those corals today, but it gives a rough estimate of the restoration effort required to get a similar amount of tissue. There is also the considerable advantage that the saved corals are already reproductive, and the largest ones have the most reproductive potential. Disease interventions have the added benefit of reducing disease loads as well. But the use of antibiotics poses an unknown risk in the environment. For more on the reproductive aspect, please refer to the final report for PO B77DF8 by Brian K. Walker, Abby Renegar, Alysha Brunelle, Nick Turner, and Joana Figueiredo titled "Field Operations for large *Orbicella* Corals Spawning: Year 2020".

Finally, frequent monitoring and treatment provides new research opportunities. These include analyzing infection and resiliency patterns in relation to space, time, environmental drivers, and the properties of the corals themselves to better understand

SCTLD and the ability of some corals to resist lesion outbreaks. This research would not be possible without effective interventions because the corals would die too quickly.

6. RECOMMENDATIONS

Continue monthly monitoring and treatment of large priority corals – Monitoring these colonies has saved many from extinction. Monthly monitoring and treatment have facilitated the classification of corals based on differing infection rates which has informed the design of the SCTLD Resistance Research Consortium.

Continue broad-scale strike team efforts – Conducting strike team efforts to reduce the active disease prevalence and save the genetic diversity remaining on the reef.

Continue use of antibiotic ointment CoreRx B2B and amoxicillin (1:8 weight ratio) – Perform margin treatment and disease-break interventions using antibiotic paste. This includes the large *O. faveolata*.

Continue recon for potential new monitoring colonies and restoration sites.

Continue public outreach for SEAFAN and other citizen reporting mechanisms to educate the public on reporting diseased corals.

7. CITATIONS

Walker BK, Noren H., Brunelle A., and S. Buckley. 2020. Coral ECA Reef-building-coral Disease Intervention and Preparation for Restoration: Final Report. Florida DEP. Miami, FL., 80p.

Walker BK and GJ Williams. 2020. 2020-2021 Coral ECA Reef-building-coral Disease Intervention, Statistical Modelling, and Preparation for Restoration Task 6 Progress Report: Environmental drivers of stony coral tissue loss disease. Florida DEP. Miami, FL., 33p.