SE FL Reef-building-coral Response to Amoxicillin Intervention and Broader-scale Coral Disease Intervention

Florida Department of Environmental Protection
Office of Resilience and Coastal Protection

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Final Summary 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
SE FL	Southeast Florida

Acknowledgements

Thank you to the Florida Department of Environmental Protection's Office of Resilience and Coastal Protection (FDEP ORCP) 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 FDEP CRCP staff including Kristi Kerrigan for contract and report-review coordination. Thank you to Samantha Buckley, Alysha Brunelle, Elizabeth Fromuth and Shelby Eagan at the NSU GIS and Spatial Ecology lab.

1. PROJECT DESCRIPTION

The purpose of this project was to perform disease intervention on reef-building coral species with active disease in SE FL (Miami-Dade and Broward counties). This includes restoring coral health by smothering diseased tissue, creating a "fire break" to arrest disease progression and covering the newly exposed skeleton. These activities are essential to saving corals in SE FL affected by disease that have the potential of recovering and building new reef structure. Treatments include the use of chlorinated epoxy and amoxicillin. Previous work has indicated that chlorinated epoxy does not have a high success of treating disease lesions on *M. cavernosa* (Walker and Brunelle, 2019). Higher success was achieved by using amoxicillin in CoreRx base2, a material designed by CoreRx to specifically deliver antibiotic to the coral tissue over a two-day period (Neely, 2018). Therefore, this comparison study was designed to evaluate the effectiveness of the two treatments in the SE FL Coral Reef Ecosystem Conservation Area (Coral ECA).

This report describes how *Montastraea cavernosa* colonies respond to amoxicillin treatments versus chlorinated epoxy in SE FL in a short timeframe (2 months). Based on the success, this information was used to decide which treatment option to apply on the *M. cavernosa* corals in the broader-scale disease intervention efforts. The broader-scale efforts continued through June 2019 and were conducted in partnership with FAU, DEP, Broward County, and Miami-Dade County.

The findings of this project were incorporated into the on-going coral disease response effort which seeks to improve understanding about the scale and severity of the Florida Reef Tract coral disease outbreak, identify primary and secondary causes, identify management actions to remediate disease impacts, restore affected resources and, ultimately, prevent future outbreaks. Collaboration amongst partners and the Disease Advisory Committee has ensured alignment of needs and avoided duplication.

2. METHODOLOGY

This work was conducted under the State of Florida Special Activity License SAL-18-2022B-SRP which authorized the cutting of firebreaks in diseased corals of any species and/or the application of disease treatments to such corals including the use of amoxicillin and chlorine.

2.1. Amoxicillin vs Chlorinated epoxy

Reconnaissance for the comparison sites began on April 10, 2019 to identify and set up locations with numerous infected *M. cavernosa* colonies. Site set up entailed measuring and photographing infected colonies and mapping them from a central GPS location by distances and headings. Five recon days were conducted before setting up the first site near Golden Beach, FL (GB1) on April 17, 2019 (Figure 1). After four additional dive days of conducting recon, the first site near Surfside (SS1) was set up on April 29, 2019, followed by a second location near Surfside (SS2) on May 7, 2019.

Colony location, size, number of lesions, and the percent of diseased tissue versus healthy-looking tissue were used to determine the treatment for each colony in efforts to keep the treatments equivalent. No colonies had mixed treatments at the onset of the study.

At the onset of the study, 34 lesions on 18 corals were treated with chlorinated epoxy and 52 lesions on 22 corals were treated with amoxicillin at three sites in northern Miami-Dade. On May 6, 2019 at GB1, 23 lesions on 10 colonies were treated with Chlorinated Epoxy and 36 lesions on 14 colonies with Amoxicillin in CoreRx base2. On May 6, 2019 at SS1, 8 lesions on 5 colonies were treated with Chlorinated Epoxy and 5 lesions on 4 colonies with Amoxicillin in CoreRx base2. On May 8, 2019 at SS2, 3 lesions on 3 colonies were treated with Chlorinated Epoxy and 11 lesions on 4 colonies with Amoxicillin in CoreRx base2. New treatments and corals were added upon subsequent visits as required. Once it was evident that the initial chlorinated epoxy treatments were not effective, all subsequent treatments entailed amoxicillin on margins without firebreaks; even on corals previously treated with epoxy.

Each site was revisited weekly (May 15, May 21, May 29, June 5, and June 19) where high-resolution photographs and video were collected of the treated corals as a permanent record of their condition in the same orientation. Whole-colony nadir photographs were taken as well as photos of individual treatments collected perpendicular to the colony center at the lesion at a fixed distance away with a standard measuring scale in the image.

Colony and lesion photos were evaluated to track treatment success. The coral species, size, estimated percent recent and old mortality were tallied along with treatment type, the number of treated lesions, number of disease lesions halted by the treatment, number of firebreaks, number of firebreaks halting disease progression, the number of new lesions, and the success of new lesion treatments.

During treatment all colonies were tagged with a yellow cattle tag with a unique number and instructions to photograph the coral and submit the photo to www.SEAFAN.net/tags (Figure 1).

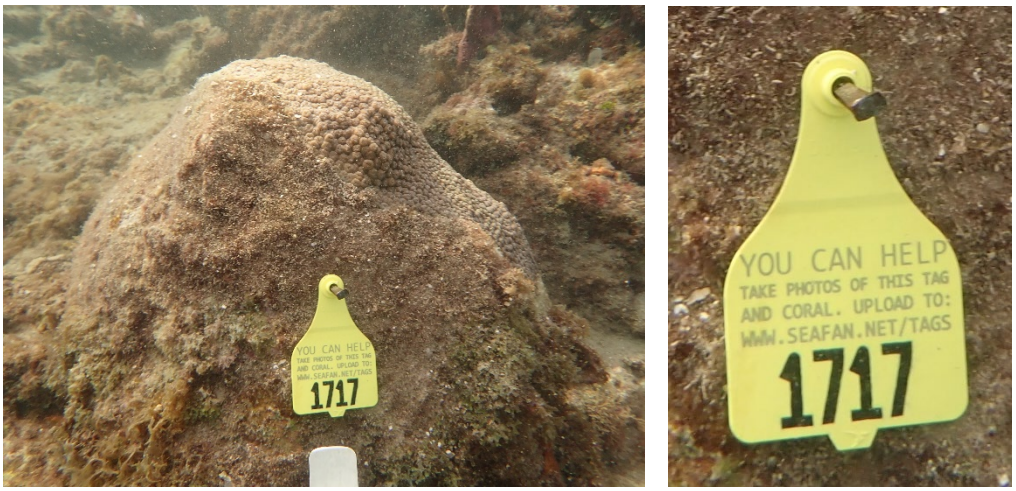

Figure 1. Example of coral tag placed on or next to each treated coral.

2.2. Broad-scale Coral Disease Intervention Strike Team

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 FAU Harbor Branch strike team focused on the reefs north of Port Everglades, thus the NSU efforts discussed in this report targeted locations between Port Everglades and Biscayne National Park while avoiding known existing monitoring stations. 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 to link to a point on the GPS track. Each coral was tagged and measured and treated. Detailed photographs were taken of the coral before and after treatment, as well as all treatments. At the end of the day the GPS coordinates were loaded into ArcGIS and the locations that corresponded to each time recorded during treatment were copied into a GIS file.

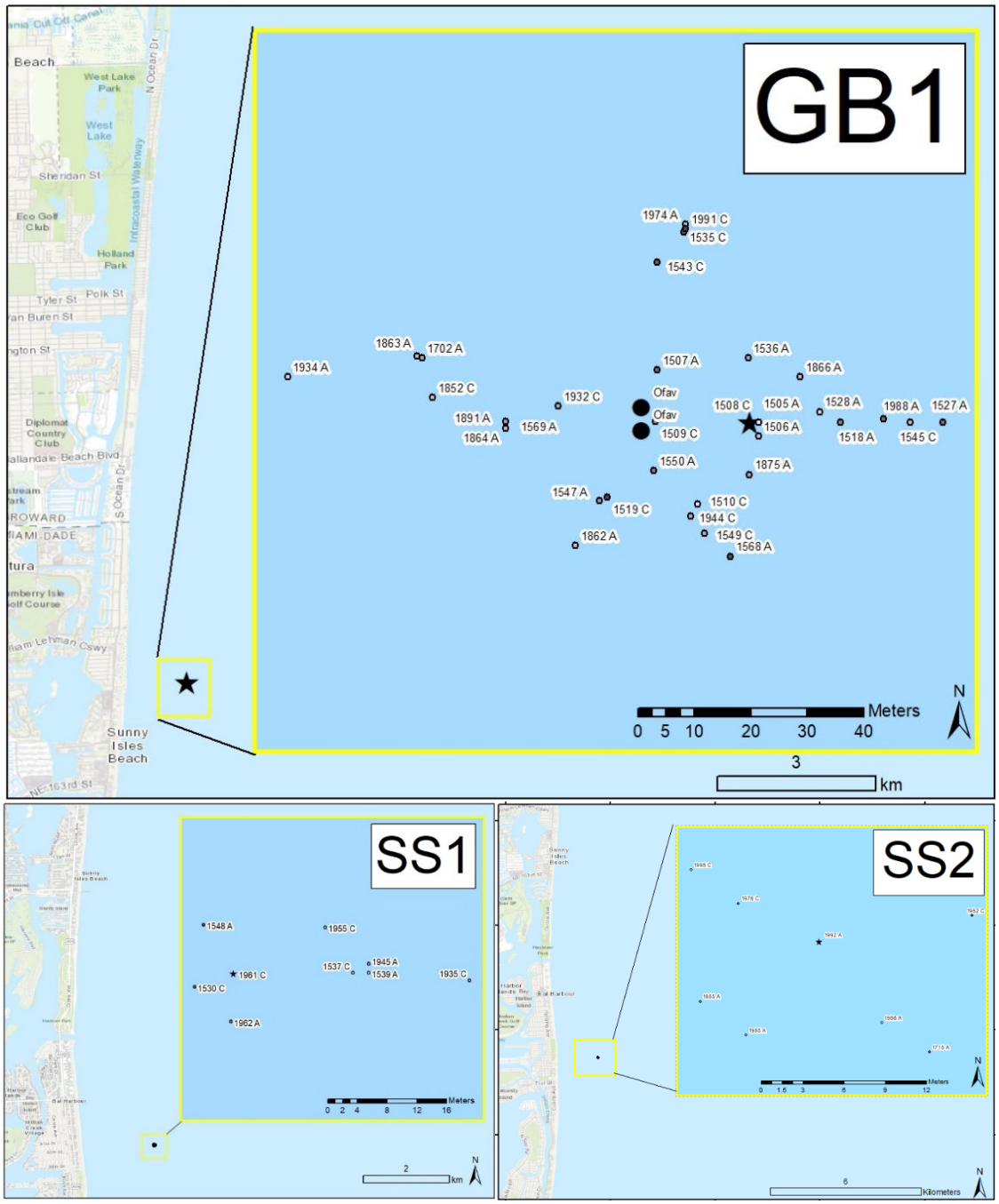

Figure 2. Map of treated corals at the Montastraea cavernosa *comparison sites GB1, SS1, and SS2 as of June 21, 2019. Each coral is labeled with its tag number and initial treatment type. A for amoxicillin and C for chlorinated epoxy.*

3. RESULTS

3.1. Amoxicillin vs Chlorinated epoxy

Experimental treatment corals were treated on May 6 and 8 and revisited weekly (May 15, May 21, May 29, June 5, and June 19). By June 19, there were 36 lesions on 20 corals treated with chlorinated epoxy and 86 lesions on 29 corals treated with amoxicillin at GB1, SS1, and SS2 combined (Table 1, Figures 3 and 4). The reason for the uneven number of margin treatments was that after the initial failure of epoxy treatments on May 15, it was decided to only treat new and existing lesions with amoxicillin in CoreRx Base 2.

Treatment success varied drastically by treatment type on margins treatments (Table 2, Figure 5). Amoxicillin margin treatments were 71.4% successful whereas Epoxy were 11.4%. This agrees with previous reports on the ineffectiveness of chlorinated epoxy on *M. cavernosa* margins (Walker and Brunelle 2018). Firebreak treatments were successful using either treatment type, however Amoxicillin was higher (Table 3). Amoxicillin firebreaks were 85.7% successful and Epoxy firebreaks were 75.9%.

Only firebreaks where the disease reached the firebreak and tested its ability to stop the disease were counted in the firebreak success. Thus, although 37 and 35 firebreaks were created using amoxicillin and epoxy respectively, only 14 amoxicillin and 29 epoxy firebreaks were actually tested. This discrepancy was a result of the margin treatment success of each treatment. The low success of epoxy margin treatments led to 29 epoxy firebreaks being tested, whereas the high margin success of the amoxicillin treatments kept the disease from reaching 23 of the amoxicillin firebreaks.

One interesting note on the amoxicillin firebreaks is that the CoreRx Base2 adhered to relatively few firebreaks overnight or longer timeframes. Almost all firebreaks with CoreRx Base2 and amoxicillin were bare the next day. However, the success of stopping the disease was better than those firebreaks filled with epoxy. This could mean that bare firebreaks are more effective than epoxy firebreaks. When considering the amoxicillin firebreak combined with the amoxicillin margin, treatment success was 94.6%. The success of the combined epoxy treatments was only 42.9% effective (Table 4). These results suggest that the use of the amoxicillin margin combined with the amoxicillin firebreak may be the most effective strategy moving forward. Adopting this method would reduce material cost and treatment time and could increase success.

Furthermore, tissue regrowth over firebreaks with freshly cut skeleton appears to be much faster than over firebreaks filled with epoxy. These stats still need to be quantified, however, initial observations indicate that if the disease is halted by the firebreak before the coral tissue can regrow across it, then the corals could heal faster than if epoxy is used.

Ideally, treatment would be a one-time event without needing to return to the colony for additional treatments. In this study, the successes of employing a one-time treatment where all lesions are treated with a margin and firebreak differed between treatments. The amoxicillin treatments stopped the disease on 20 of 29 colonies (69%), whereas the epoxy

stopped the disease on 6 of 20 colonies (30%). Based on these numbers, it is recommended that future disease interventions on *M. cavernosa* should use Amoxicillin with CoreRx Base2. This will ensure that a greater number of treated corals will survive. Revisiting treated corals will further increase the number of survivors.

Table 1. The number of treated corals and disease lesions at the M. cavernosa *comparison sites GB1, SS1, and SS2 as of June 21, 2019.*

	Amoxicillin		Chlorinated Epoxy	
Site	Coral	Lesions	Corals	Lesions
GB1	21	64	11	27
SS1	4	8	5	8
SS2	5	14	3	3
Total	30	86	19	38

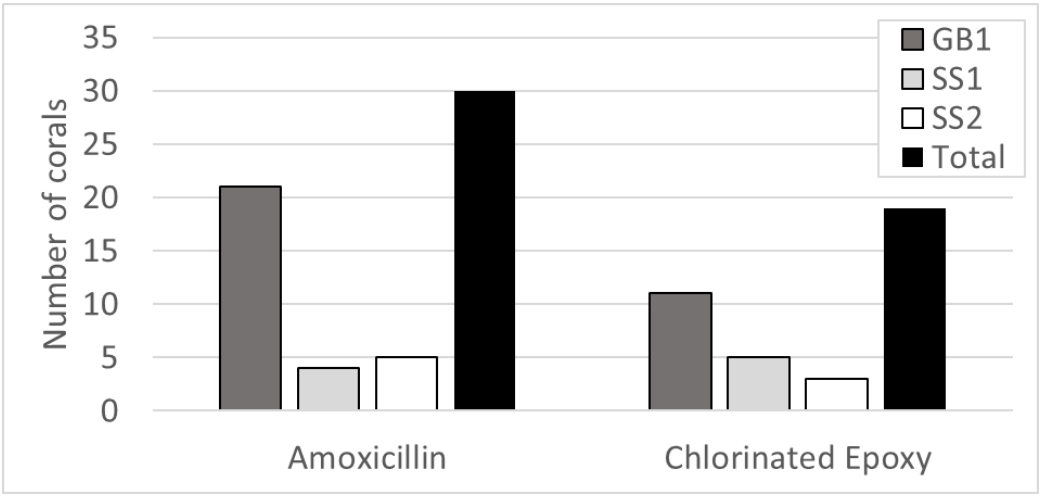

Figure 3. A chart of the number of treated corals at the M. cavernosa comparison sites GB1, SS1, and SS2 as of June 21, 2019.

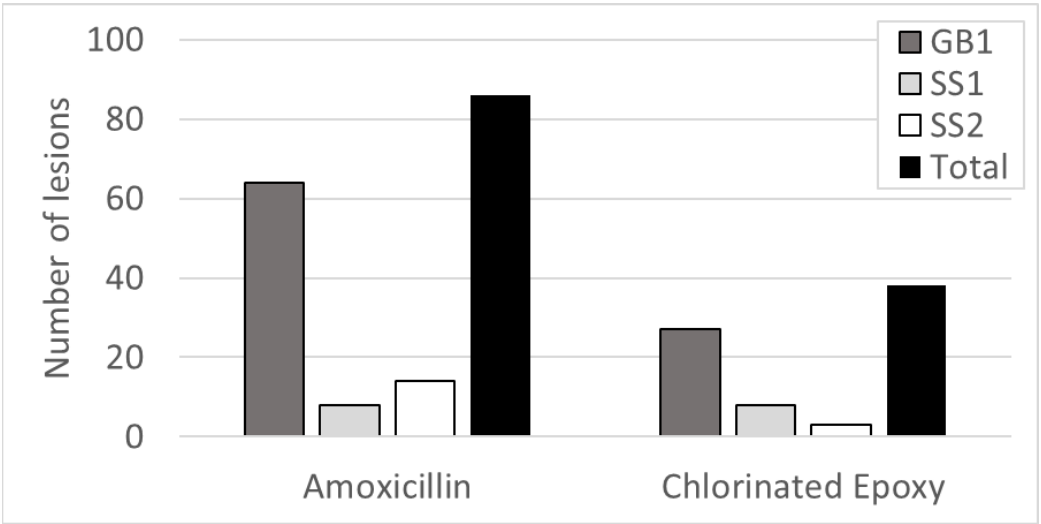

Figure 4. A chart of the number of treated lesions at the M. cavernosa comparison sites GB1, SS1, and SS2 as of June 21, 2019.

Table 2. Disease lesion margin treatment stats by treatment type.

Treatment	Failed Margins	Total Margins	Failure Rate	Success Rate
Amoxicillin	20	86	23.3%	76.7%
CL Epoxy	31	36	86.1%	13.9%

Table 3. Tested firebreak treatment stats by treatment type.

Treatment	Failed Firebreaks	Total Firebreaks	Failure Rate	Success Rate
Amoxicillin	2	14	14.3%	85.7%
CL Epoxy	7	29	24.1%	75.9%

Table 4. Combined Firebreak with margin stats by treatment type.

Treatment	Failed Margin/Firebreak	Total Margin/Firebreak	Failure Rate	Success Rate
Amoxicillin	2	37	5.4%	94.6%
CL Epoxy	20	35	57.1%	42.9%

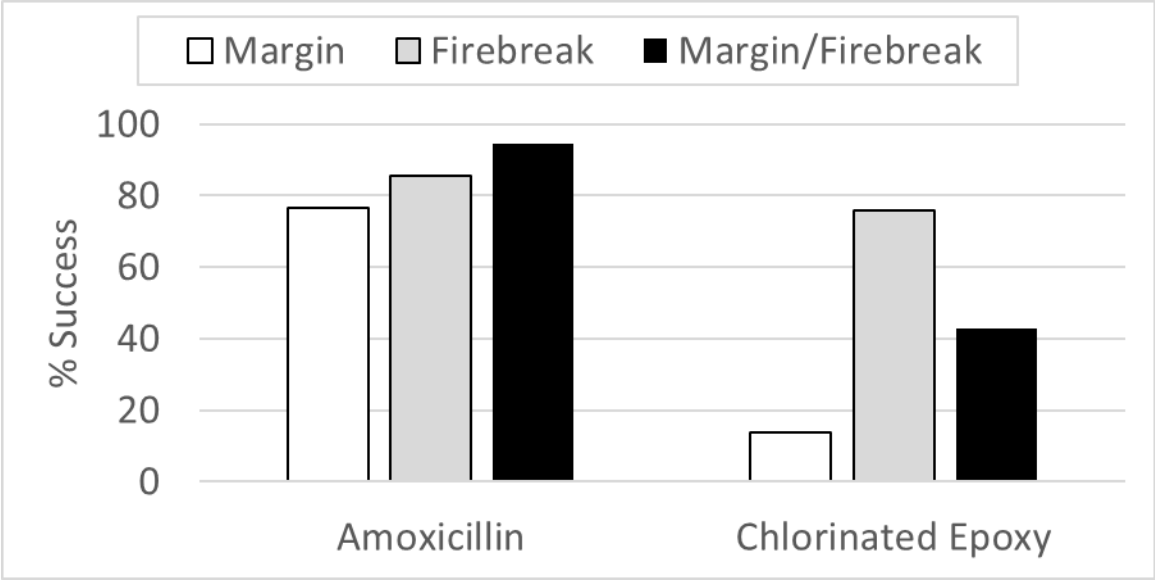

Figure 5. The percent success of each treatment material by treatment method.

Table 5. Treatment breaks by treatment type and date at comparison sites.

	Amoxicillin			Chlorinated Epoxy		Total
Date	Firebreak	Firebreak Margin	Margin	Firebreak	Margin	
6-May	0		0	0	0	0
8-May	0		0	0	0	0
15-May	1		24	1	60	86
21-May	0		1	1	9	11
29-May	2	0	2	7	6	17
5-Jun	0	3	3	10	0	16
19-Jun	0	2	3	7	0	12
Grand Total	3	5	33	26	75	142

3.2. Broad-scale Coral Disease Intervention Strike Team

In total as of June 21, 2019, 270 colonies were treated by the coral disease interventions strike teams throughout southern Broward and northern Miami-Dade (including the comparison sites) (Figure 2). The number of treatments by species were 244 *M. cavernosa*, 14 *O. faveolata*, 7 *Pseudodiploria strigosa*, 3 *Pseudodiploria clivosa*, and 2 *Colpophyllia natans* (Figure 6).

In total, 161 corals were treated with amoxicillin in CoreRx Base 2 (142 *M. cavernosa*, 10 *O. faveolata*, 5 *P. strigosa*, 3 *P. clivosa,* and 1 *C. natans*) and 109 with chlorinated epoxy (102 *M. cavernosa*, 4 *O. faveolata*, 2 *P. strigosa*, and 1 *C. natans*).

A total of 92.76 meters (9,276 cm) of amoxicillin treatments and 68.59 meters (6,859 cm) chlorinated epoxy treatments were performed totaling 161.35 meters (16,135 cm). The total average treatment length was 60.2 cm per coral which varied by species: *M. cavernosa* = 61.3 cm, *O. faveolata* = 52.9 cm, *P. strigosa* = 50.3, *P. clivosa* = 33.3, and *C. natans* = 45 cm.

The average treated colony length was 63.7 cm and height was 34.8 cm. The maximum colony length was 200 cm and height was 100 cm both of which were *Orbicella* colonies. GPS locations were obtained for all of the treated corals however, as of June 21, 2019, none have been revisited to measure the success of the treatments. Coral tags have instructions for the general public to photograph and upload photos to a website. If this happens, we will be able to compare our previous photos and measure treatment success. Efforts are now being coordinated to engage the public. Project Baseline is leading this by a call to action to their divers. We recently supplied the locations of the treated corals to them. If they follow through, we can get some idea of the strike team success outside of the experimental sites. The strike team efforts are now funded and will continue as possible through June 2020.

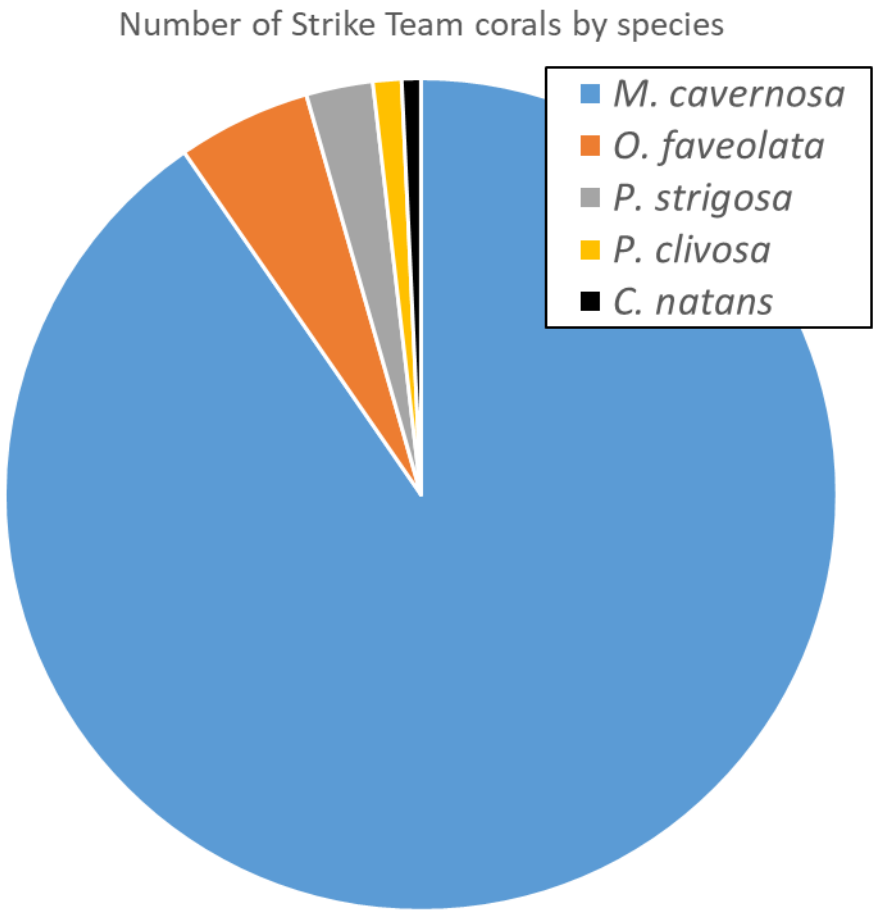

Figure 6. The number of colonies treated by the coral disease interventions strike teams throughout southern Broward and northern Miami-Dade by species as of June 21, 2019.

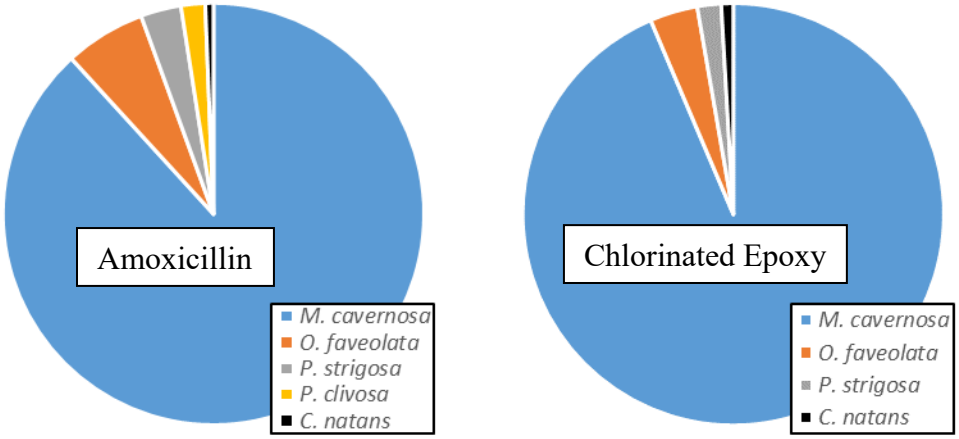

Figure 7. The number of colonies treated with Amoxicillin (left) and Chlorinated Epoxy (right) by the coral disease interventions strike teams throughout southern Broward and northern Miami-Dade by species as of June 21, 2019.

4. SUMMARY

In summary, this study found that amoxicillin was much more successful on *M. cavernosa* margins than epoxy and both treatment types were similarly successful on firebreak treatments. This is encouraging as previous attempts to save *M. cavernosa* have had very low success (47.4%) (Walker and Brunelle, 2019). Amoxicillin margin treatment success on *M. cavernosa* in this study (71.4%) was more similar to the chlorinated epoxy margin treatments on the large *O. faveolata* (82.8%) (Walker and Brunelle, 2019).

Overall, the most successful treatment strategy was the CoreRx Base 2b with amoxicillin margin treatment combined with the amoxicillin firebreak (94.6% success). Out of 37 treatments only 2 failed. Although 23 of the firebreaks were not needed because the disease was stopped at the margin, the success of the treatment combination could be acceptable enough to not require multiple visits to the treated corals. This would provide a huge cost savings and allow for efforts to focus on treating new areas rather than revisiting sites multiple times. However, the high success in this study could be due to the short monitoring timeframe and may go down over time. It has been noted that corals with previous disease lesions seem to get new lesions more frequently than those that have never shown a lesion (Walker and Brunelle, 2019). Therefore, we recommend continued monitoring of the treated corals in this study to determine if success decreases over time.

It is unknown if the CoreRx Base 2b with amoxicillin provides a benefit in the firebreak. This should be tested to determine if it is necessary. It appears that coral healing over the firebreak lesion after the disease stops may be much faster without the presence of epoxy. It is possible that many of the 23 needless firebreaks without epoxy may heal over relatively quickly.

The high success and efficient application of the CoreRx Base 2b with amoxicillin treatment makes this the preferred disease intervention material. The CoreRx Base 2b is premade in syringes and can be easily dispensed onto the coral disease margin within a minute or two. By contrast, the chlorinated epoxy is messy and requires more preparation time above and below water. Once a diseased coral is encountered it takes about 5 minutes of mixing the two parts underwater before it can be applied. Once mixed, the epoxy only lasts about 30 minutes before it is too hard to apply. We did not calculate the waste, but we estimate about half of each epoxy container gets onto a coral treatment. The rest is either stuck to gloves, paper, dispensing utensil, container, or too old to set once mixed.

The biggest issue with lesion-level disease interventions is that they do not appear to keep the colony from being re-infected. Corals with previous disease lesions have new lesions more frequently than those that have never shown a lesion (Walker and Brunelle, 2019). A method that is able to prevent new lesions from forming will require less monitoring which could lead to large cost savings.

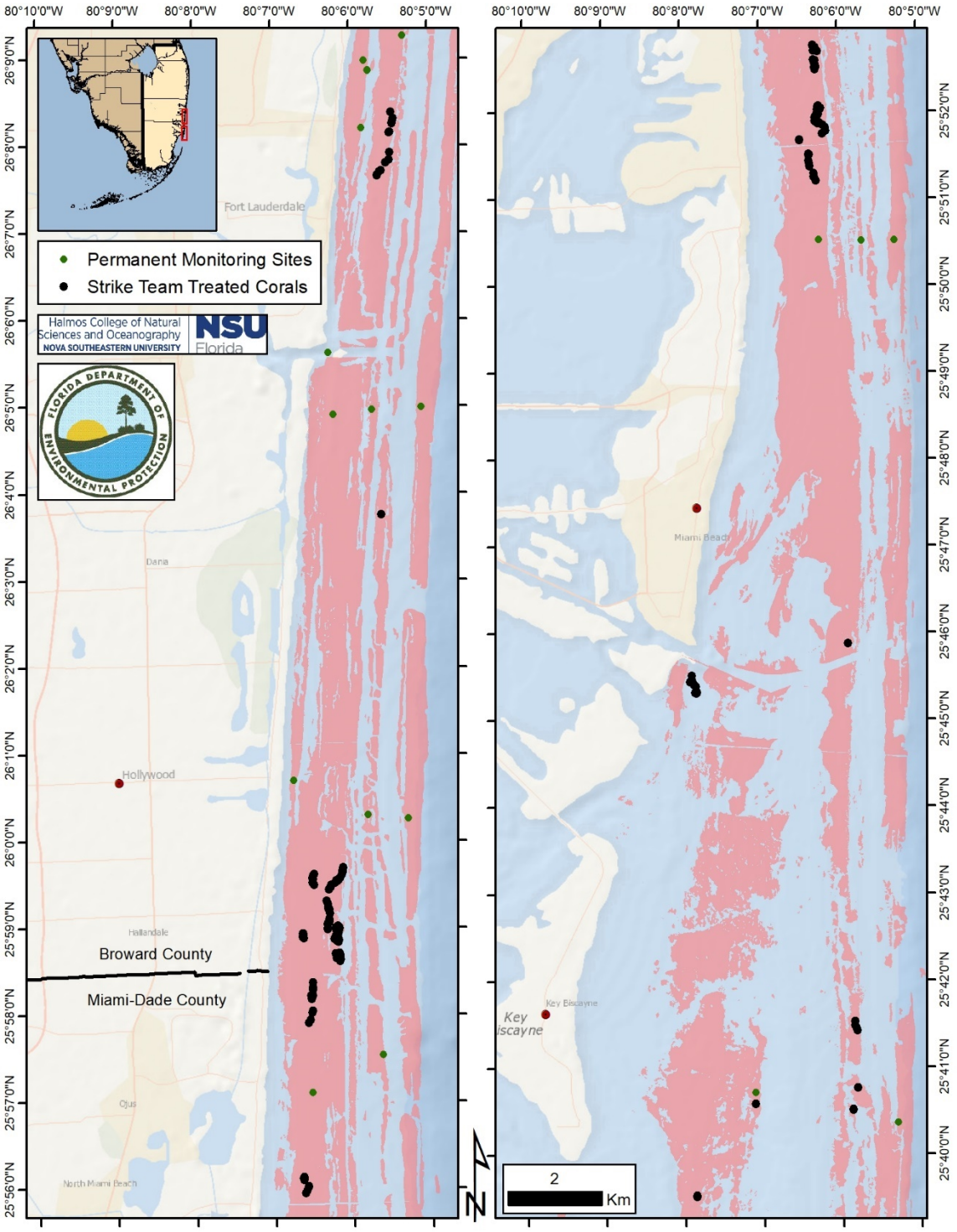

Figure 8. The location of the strike team treated corals as of June 21, 2019.

5. RECOMMENDATIONS

Continue measuring comparison site success – Since success decreases with time, it is important to continue monitoring the treated corals to determine their longer-term success.

Continue strike team efforts – Conducting strike team efforts with a 94.6% success on saving corals is worth continuing. This activity reduces the active disease prevalence and saves the genetic diversity remaining on the reef.

Switch to CoreRx Base 2 and amoxicillin – Given the success with amoxicillin in CoreRx Base 2, we recommend switching all non-experimental treatments to this material and including a firebreak. This includes the large *O. faveoata* to see if there is a higher success on those colonies than the epoxy treatments previously used.

Test CoreRx Base 2 without amoxicillin – There is some concern about using antibiotics in the treatments due to the possibility of creating antibiotic resistance. Our one-week monitoring revealed that the treatment appears to kill all coral tissue it contacts. This could be acting more like an antiseptic than an antibiotic treatment. We recommend testing a select number of corals with CoreRx Base 2 treatments without antibiotics to measure the effect of the applications of the antibiotic itself versus the delivery medium.

Consider using a bare firebreak – Amoxicillin firebreaks were 85.7% successful in this study even though the material did not stay in the firebreak overnight. This indicates that perhaps a bare firebreak would be just as effective. A bare firebreak would allow tissue to regrow quickly after the disease has passed. The risk is that the disease progression is slower than tissue regrowth. In which case it may not be effective in halting the disease.

Do not use chlorinated epoxy on M. cavernosa margin treatments or O. faveolata firebreaks – This study showed dismal success of this approach. Walker and Brunelle (2019) show very low success of tested *O. faveolata* firebreaks (48.9%).

Continue testing to improve treatment success.

Revisit strike team treated corals other than M. cavernosa and O. faveolata to gauge amoxicillin success on other species.

Use caution when revisiting corals treated with CoreRx Base 2 and amoxicillin as they can still appear diseased and the diver may retreat without knowing, especially with frequent visiting (weekly).

Consider abandoning epoxy treatments – Epoxy treatments are only comparatively successful on *O. faveolata* margins. The material is expensive, and treatments are time consuming.

6. CITATIONS

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