Florida Keys Coral Disease Intervention Strike Teams

Florida Keys Coral Disease Intervention Strike Teams

Final Report

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Management Summary

The Florida Keys disease intervention strike team conducted over 1173 hours of underwater work treating and monitoring SCTLD-affected corals in the Florida Keys. From July 1, 2022 – June 30, 2023, a total of 1506 newly infected corals were assessed and treated. Additionally, new lesions on 902 previously-treated corals were treated. In total, the estimated tissue protected from mortality during this fiscal year is 5,071 m^2. This tissue is equivalent to ~1.95 million restoration outplants, which would cost an estimated \$3.9 – \$58.6 million if needed to replace tissue saved by intervention efforts.

The number of new corals treated exceeds that from all previous intervention years, largely because of unprecedented SCTLD prevalence rates on inshore/mid-channel patch reefs. Overall, SCTLD rates on offshore reefs have continued to decline, but inshore reefs experience pulses of disease, with many reefs exhibiting extreme levels of SCTLD between April and June 2023.

Fate-tracking of treated corals documents a 92% survival rate after four years, with minor but significant differences between onshore/offshore reefs and among species. Disease intervention continues to be of incredibly high importance to preserve corals, particularly on inshore reefs. We show that regular visitations to a small number of reefs can lead to high survival of treated corals on those reefs, but that treating corals with less regularity at a large number of reefs would ultimately save a much larger number of corals.

Executive Summary

The Florida Keys Disease Intervention Strike Team was funded to treat and monitor SCTLD-affected corals during the 2022-23 fiscal year. Between July 1, 2022 and June 30, 2023, intervention work was conducted over 251 diver-days, including 808 dives and 1173 hours of underwater work. Over 246 acres of reef throughout the Florida Keys were surveyed every two months. During this time frame, a total of 1506 newly infected corals were tagged, measured, mapped, photographed, and treated. This exceeds the number of newly treated corals in all previous treatment years. Newly treated corals were from 17 species, with an average diameter of 94 cm. Additionally, 903 corals treated during previous years required new treatments. The estimated amount of coral tissue protected from SCTLD lesions during this fiscal year was 5071 m^2. This tissue area is equivalent to over 1.95 million outplants, the cost of which to raise and outplant is estimated to be between $3.9 - $58.6 million.

Regular site visitation every two months has created a substantial monitoring dataset allowing for colony fate-tracking as well as site assessments of SCTLD prevalence. Fate tracking documents survival rates of 92% of treated corals after four years. Survival rates are greater at onshore sites than offshore sites. Fate-tracking also identifies that 36% of corals do not reinfect for at least one year after the initial treatment. It also identifies that most new lesions occur within 1-2 months after initial treatment, and that approximately half of corals treated after those infections do not reinfect again. Thus, a single site visit is expected to save 36% of treated corals, and two visits are expected to save 58%. We calculate hypothetical examples of intervention regimes and show that regular visitation to a small number of sites will be highly impactful at saving corals at those sites, but at the cost of sacrificing non-visited sites. In contrast, visiting a large number of sites only once results in lower site-specific survival rates, but much greater numbers of overall corals saved.

By assessing the proportion of known SCTLD-susceptible colonies (colonies which were treated at some point during intervention work) with active lesions at each monitoring time point, we can assess patterns in SCTLD at treatment sites. Offshore sites have had steadily declining SCTLD, while inshore sites have peaks and valleys of prevalence, often increasing in spring and summer, and then subsiding during summer paling/bleaching events. As of June 2023, inshore reefs have very high levels of SCTLD prevalence, with Hen and Chickens and Cheeca Rocks in particular at epidemic levels.

We recommend that intervention requirements be more flexible, allowing sites with little to no SCTLD to be removed from monitoring regimes so as to allow more effort to be expended on saving corals within the highly dense, species-rich, and heavily impacted inshore reefs. We also recommend reconsidering management goals to consider whether preserving a small number of sites is worth sacrificing the large number of corals that could be saved using broad-scale intervention techniques. And we encourage consideration of efficient treatment regimes such as those implemented in Dry Tortugas which allow for large numbers of corals to be rapidly treated.

Acknowledgements

We thank Florida Department of Environmental Protection and the National Fish and Wildlife Foundation for funding this work. All work was conducted under Florida Keys National Marine Sanctuary permits FKNMS-2020-077 and FKNMS-2019-177.

The NSU Disease Intervention lab members put in countless hours underwater as well as topside, and this work would not be possible without them. Michelle Dobler, Sydney Gallagher, and Sami Miller conducted the work during this fiscal year, but many others have also contributed in past years. We also thank the entirety of the Florida coral disease response for collaborative efforts to move the science and conservation of SCTLD-affected reefs forwards.

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Table 1: Hypothetical examples of intervention strategies ranging from regular visitation on small number of sites to one-time visitation to a large number of sites. Table shows estimated values of corals saved at each site as well as overall corals saved.

List of Acronyms

DEP: Department of Environmental Protection
FKNMS: Florida Keys National Marine Sanctuary
FY: Fiscal year
H&C: Hen and Chickens reef
KLDR: Key Largo Dry Rocks reef
QA: Quality assurance
SCTLD: Stony coral tissue loss disease

Coral Codes:
AAGA: *Agaricia agaricites*
CNAT: *Colpophyllia natans*
DLAB: *Diploria labyrinthiformis*
DSTO: *Dichocoenia stokesii*
MALI: *Mycetophyllia aliciae*
MCAV: *Montastraea cavernosa*
MLAM: *Mycetophyllia lamarckiana*
OANN: *Orbicella annularis*
OFAV: *Orbicella faveolata*
OFRA: *Orbicella franksi*
PAST: *Porites astreoides*
PCLI: *Pseudodiploria clivosa*
PSTR: *Pseudodiploria strigosa*
SBOU: *Solenastrea bournoni*
SINT: *Stephanocoenia intersepta*
SSID: *Siderastrea siderea*

1. DESCRIPTION

The arrival and spread of stony coral tissue loss disease (SCTLD) throughout Florida's Coral Reef has had catastrophic impacts on corals and reef functionality. SCTLD has resulted in unprecedented mortality rates on a variety of susceptible species (Precht et al. 2016), has led to the functional extinction of at least one coral species in Florida (Neely et al. 2021a), and caused significant declines in coral density and percent coral cover (Walton et al. 2018).

Though the pathogen for SCTLD is to date unknown, antibiotics have proven effective at halting active disease lesions (Neely et al. 2020; Neely et al. 2021b; Shilling et al. 2021; Walker et al. 2021). The use of a topical paste is thus a management tool for preventing the mortality of corals and/or sites. Since 2019, the Florida Keys disease intervention strike team has developed and utilized methodology to treat SCTLD-affected corals within the Florida Keys National Marine Sanctuary to preserve iconic reefs and corals. This report outlines the work done during the 2022-2023 fiscal year, as well as provides a summary of all similar work to date.

2. METHODS

To conduct strike team work, a trained team of divers visited each FKNMS intervention site approximately every two months. Treatments were an amoxicillin and Base 2b paste developed and utilized since 2019. The use of this protocol was outlined in the 2019 QA plan (Neely 2019) and the Coral Disease Intervention Action Plan (Neely 2018).

During each visit to any reef site, the entire area was surveyed. At two sites (Sombrero Reef and Cheeca Rocks), all previously-treated colonies were actively visited and monitored for health status. At all other sites, the full area was surveyed, but only actively diseased colonies were prioritized for action.

At the full monitoring sites (Sombrero Reef and Cheeca Rocks), protocol were as follows:

- Search the entire area for SCTLD-affected colonies.
- Newly diseased coral colonies:
  - Place tag at the base of the colony for follow up monitoring
  - Record data on the tag number, species, size, percent live cover, number of treatments applied, and location
  - Apply treatment to all active lesions
  - Take photos of the full coral colony and all lesions
- Previously treated/tagged colonies with active disease lesions:
  - Record data on the number of treatments applied, date, and tag number
  - Apply treatment to all active lesions
  - Take photos of the full coral colony and all new lesions
- Previously treated/tagged coral colonies that are dead:

    - Record date, location, and tag number
    - Take final photograph of the full coral colony
    - Remove tag and any nails.
- Previously treated/tagged coral colonies with no active disease:
    - Record data on colony health status (no active disease)
    - Take photographs of the full coral colony

At all other sites, protocol were:

- Search the entire area for SCTLD-affected colonies.
- For affected colonies that have previously been tagged, record the tag number as well as the number of treatments. Take photos of whole colony and lesions. Treat all active lesions.
- For affected colonies that have not previously been tagged: tag colony, collect information on size and percent live cover, map colony, take photos of full colony and all lesions, and treat all active lesions.
- Revisit approximately every two months.

Data on new corals and any coral monitoring data were entered into the intervention database, which is stored in an online cloud and remains continually accessible to FKNMS and DEP managers. These data are also presented as a deliverable to DEP twice per year. Information on the number, location, and species of treated corals are also uploaded to the FWC Intervention Dashboard (Florida Fish and Wildlife Research Institute 2019), a public-facing product that compiles and presents intervention information across all practitioners and regions.

The strike team was contracted for 200 person-on-water days. All work was conducted under Sanctuary permit FKNMS-2020-077.

3. RESULTS

3.1. Work Conducted: 2022-23 Fiscal Year

From July 1, 2022 through June 30, 2023, the Florida Keys Strike Team conducted 251 intervention-specific diver days, well above the 200 funded days. A total of 808 dives were conducted by strike team members, totaling 1173 hours of underwater work.

Across all intervention sites, over 246 acres of reef were surveyed every two months (Figure 1). These reef areas were Carysfort (North and South), Grecian Rocks, Key Largo Dry Rocks, Molasses, Hen and Chickens, Cheeca Rocks, Marker 48 mid-channel patch reefs, Sombrero Reef, Newfound Harbor, Looe Key, and Sand Key. Coffins Patch has very few corals but was opportunistically visited twice during this fiscal year.

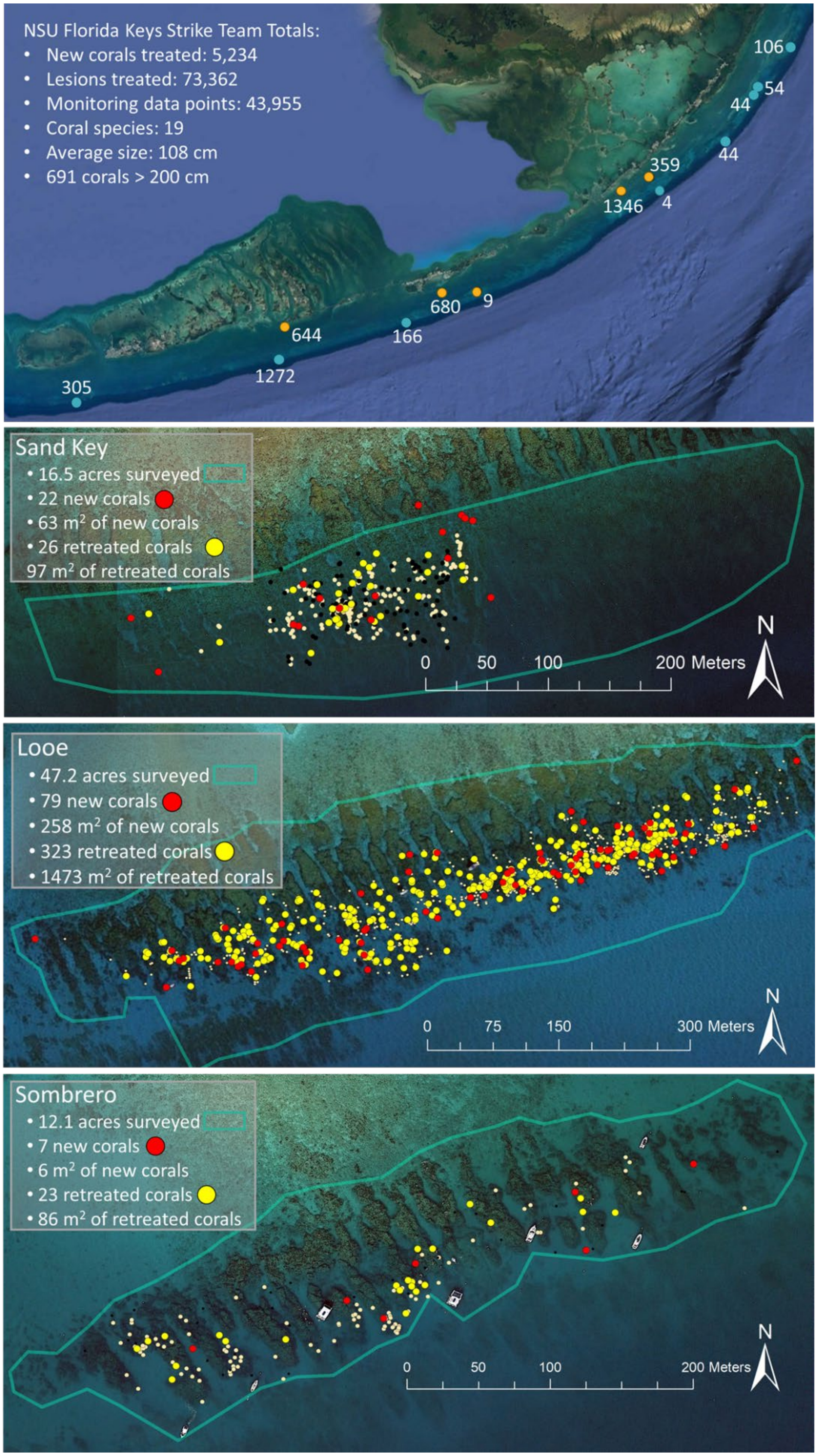
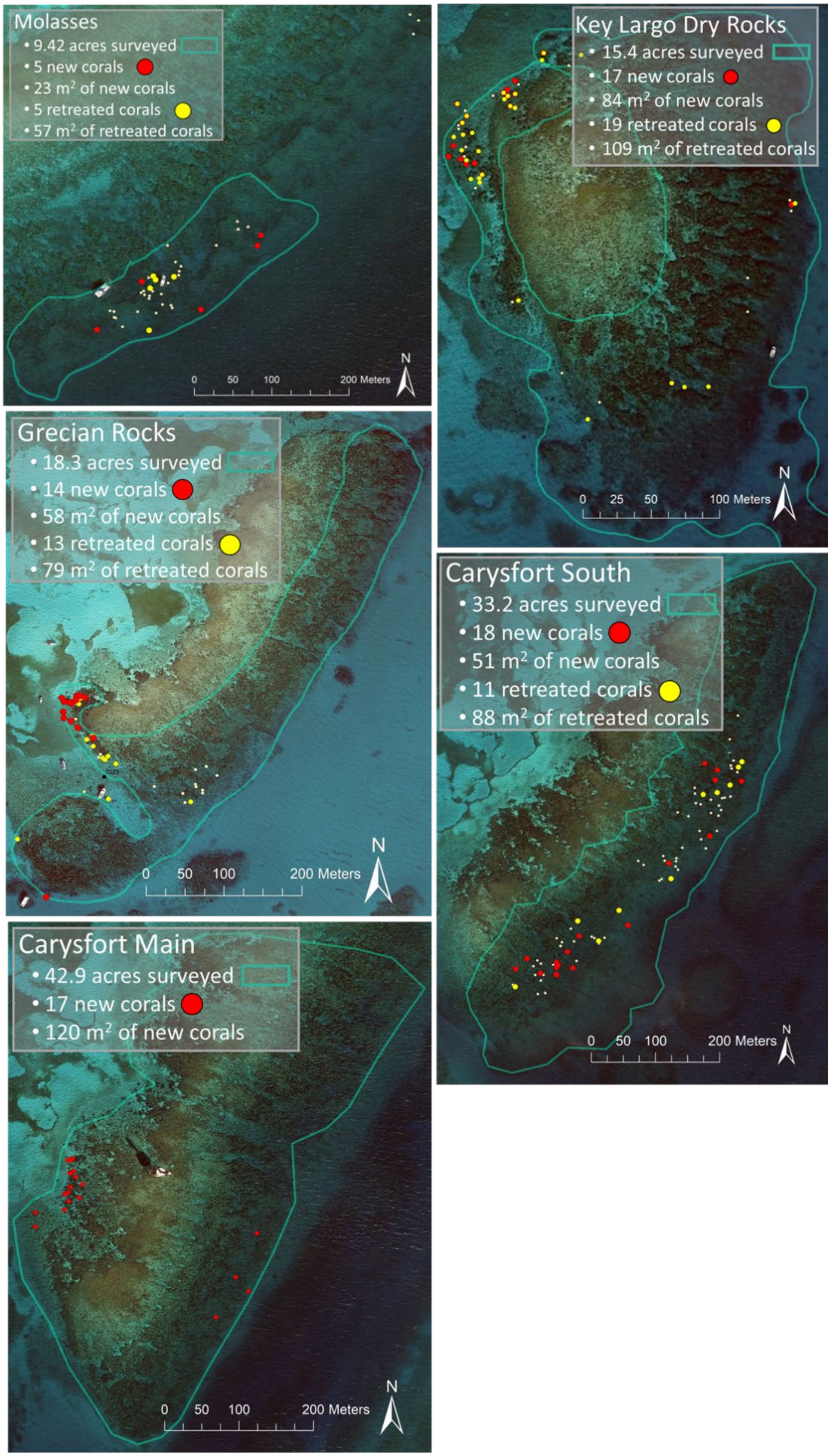
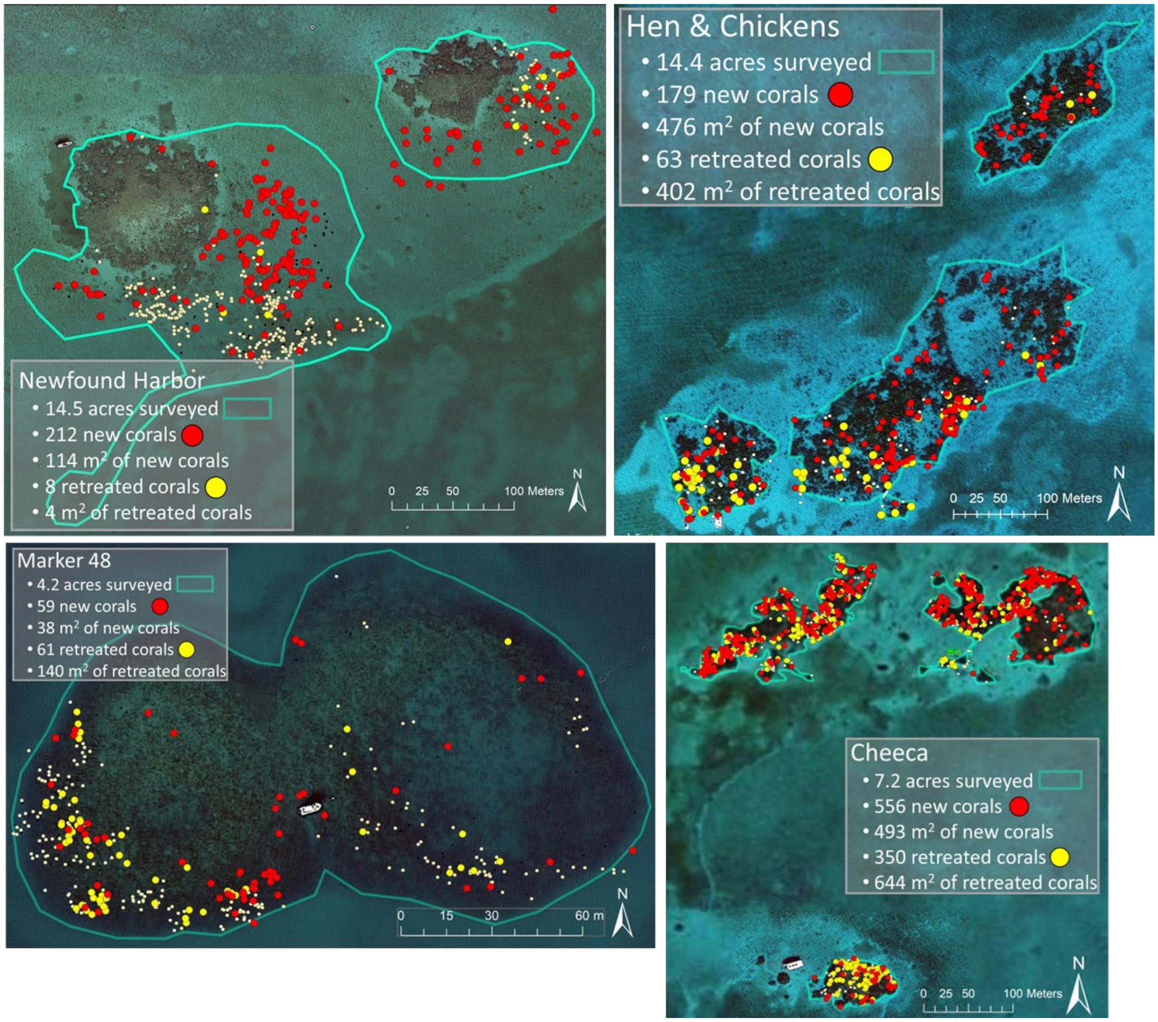


Figure 1. Map of the Florida Keys showing treated reefs (top). Offshore sites are blue; inshore sites are orange. The total number of treated corals, lesions, and monitoring points are shown for the entirety of the strike team project (2019-June 30, 2023).

Treatments within the 2022-23 fiscal year are shown for each reef. Blue outlines show the area surveyed during each monitoring event. Large red dots are corals treated for the first time this fiscal year. Large yellow dots are previously treated corals requiring retreatment during the 2022-23 fiscal year. Smaller beige dots are previously-treated corals that were healthy throughout the 2022-23 fiscal year.

Figure 1 continues on next two pages.


Molasses
• 9.42 acres surveyed
• 5 new corals
• 23 m² of new corals
• 5 retreated corals
• 57 m² of retreated corals
0 50 100 200 Meters
N
Key Largo Dry Rocks
• 15.4 acres surveyed
• 17 new corals
• 84 m² of new corals
• 19 retreated corals
• 109 m² of retreated corals
0 25 50 100 Meters
N
Grecian Rocks
• 18.3 acres surveyed
• 14 new corals
• 58 m² of new corals
• 13 retreated corals
• 79 m² of retreated corals
0 50 100 200 Meters
N
Carysfort South
• 33.2 acres surveyed
• 18 new corals
• 51 m² of new corals
• 11 retreated corals
• 88 m² of retreated corals
0 50 100 200 Meters
N
Carysfort Main
• 42.9 acres surveyed
• 17 new corals
• 120 m² of new corals
0 50 100 200 Meters
N



From July 1, 2022 through June 30, 2023, a total of 1506 newly infected corals were tagged, measured, mapped, and treated across all sites. Newly treated corals were from 16 different species, and had an average maximum diameter of 94 cm. Average percent live cover on treated corals was 63%. The most commonly treated species were *Colpophyllia natans* (26%), *Montastraea cavernosa* (21%), *Orbicella faveolata* (18%), and *Pseudodiploria clivosa* (17%) (Figure 2a). The vast majority, 87%, of newly treated corals were located on inshore or mid-channel patch reefs rather than offshore reefs. Reefs with the highest numbers of newly treated corals were Cheeca Rocks (37%), Hen and Chickens (19%), and Newfound Harbor (19%)(Figure 2b).

We can estimate the amount of live coral tissue on treated colonies using the size measurements and percent cover assessments. We estimate the surface area of each colony as a calculation of a hemisphere: 2π*height*(diameter/2). Surface area is then multiplied by the proportion of live tissue on the colony (% live cover / 100). Using these calculations, an estimated 1890 m^2 of live tissue on newly treated colonies was protected from active SCTLD lesions during this fiscal year. We can also estimate the

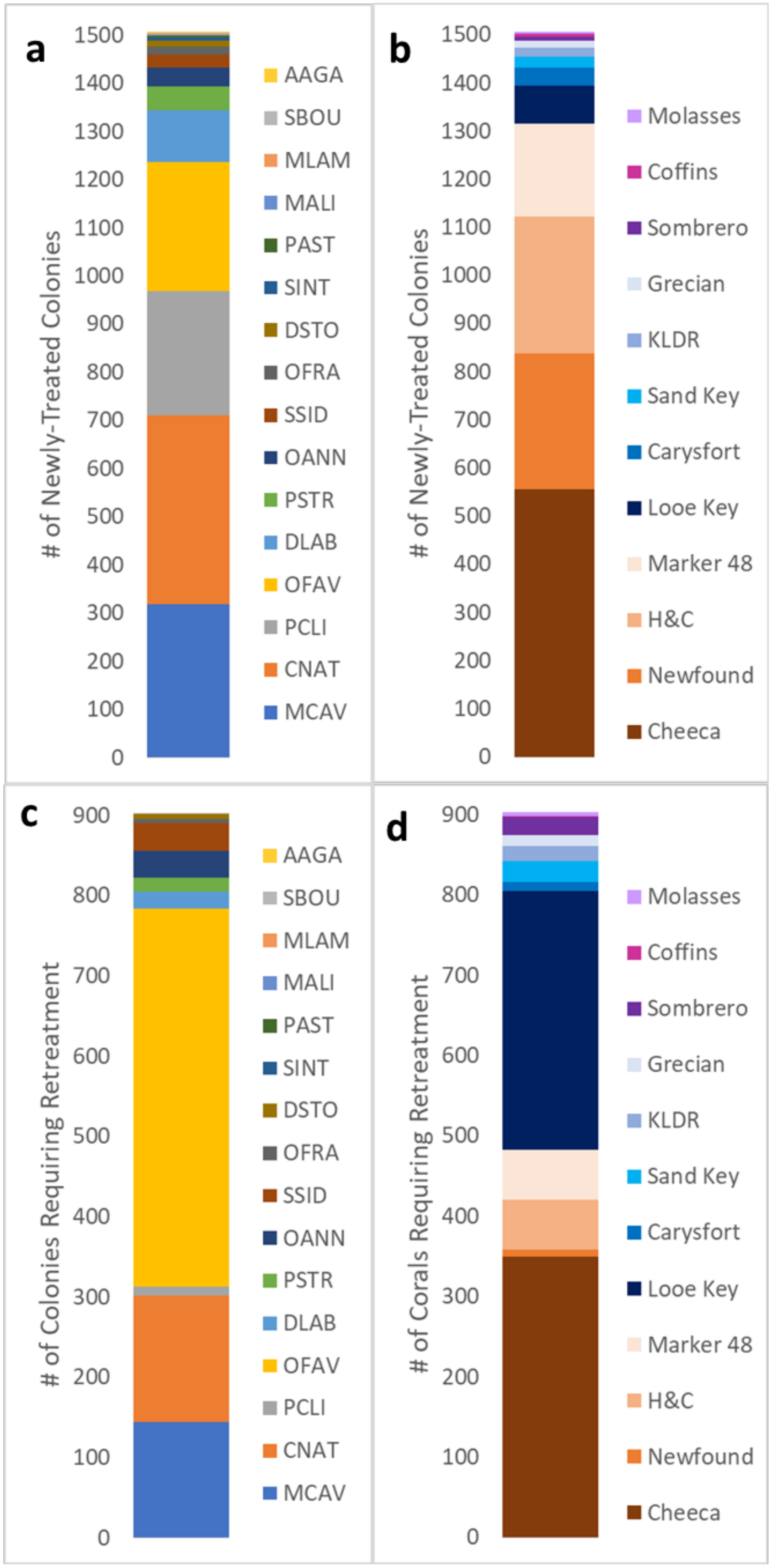


Figure 2. (a) Species distribution of the 1506 newly-treated corals during the fiscal year. (b) Geographic distribution of the 1506 newly-treated corals during the fiscal year. Offshore sites are in blue tones; inshore sites are in orange tones. (c) Species distribution of the 902 previously-treated corals requiring additional treatments during the 2022-23 fiscal year. (d) Geographic distribution of the 902 newly-treated corals during the fiscal year. Offshore sites are in blue tones; inshore sites are in orange tones.

restoration equivalency of these actions by multiplying the live tissue by the number of outplants required to reskin that area. We use an outplant density estimate of 385 outplants per m^2. As such, the number of outplants that would be needed to replace the tissue lost without intervention on newly diseased corals from July 1, 2022 to June 31, 2023 would be 727,729.

In addition to treating newly infected corals, in-water work also involves treating lesions on previously-treated corals. From July 1, 2022 to June 30, 2023, 903 previously-treated corals required new treatments. Some of these corals required new treatments during more than one monitoring visit, for a total of 2465 treatment events on previously-treated corals. The majority (52%) of corals requiring retreatments were *Orbicella faveolata* (Figure 2c). While the majority of newly treated corals were on inshore reefs, the geographic distribution of the 793 previously-treated corals requiring new treatments was reflective of the number of corals previously treated at each reef. Looe Key and Cheeca Rocks sites had the most retreated corals (36% and 39% of the totals respectively) (Figure 2d). We can again estimate the tissue area saved via these retreatments and the restoration equivalency using the same formulas. The estimated tissue saved via these retreatment events is 3181 m^2, and the restoration equivalency 1,224,725 outplants. Many of these retreated colonies are extremely large *Orbicella faveolata*, which account for a substantial portion of these values.

3.2 Work Conducted Since 2019

The work during this fiscal year builds on and exceeds that of previous years. The first year of intervention work (FY2018-2019) focused almost exclusively on treating corals, and included assistance from the Force Blue team. During that year, 1234 new corals were treated, with about 50% of those getting retreated during the same fiscal year. Monitoring efforts were small, with only 1646 monitoring events. From FY2019-20 through February 2022, strike team time was dominated by monitoring events. The number of new corals treated each year ranged from 572 – 979, the number of retreated corals ranged from 1844 – 2131, and the number of monitoring points ranged from 5871 – 12,872. Though every coral was being visited every two months, few of these required attention, and capacity to monitor or explore additional areas was non-existent.

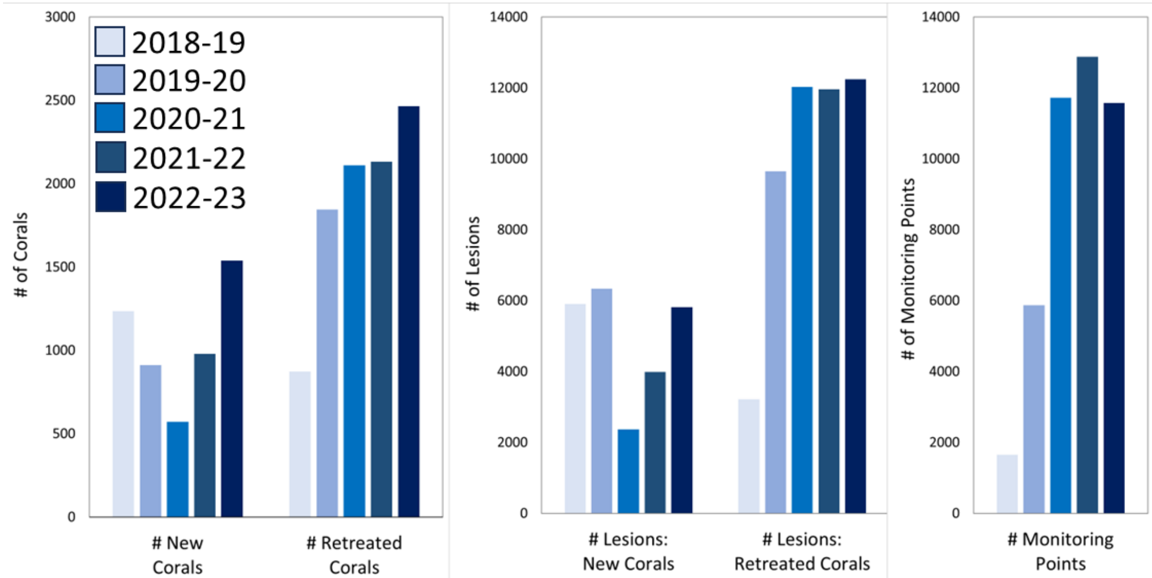


Figure 3. Comparison of number of corals treated, number of lesions treated, and number of monitoring points across all fiscal years of strike team work.

Beginning in February 2022, permitting was altered to allow for only diseased corals to require attention at most sites. As a result, we were able to expand our area covered from 59 acres to 246 acres. One result of this expanded coverage is the ability to find and treat more corals. Additionally, the prevalence of disease on the inshore reefs has been extremely high during this fiscal year, resembling or exceeding the initial outbreak periods. As a result, we have treated a record number of new corals and retreated corals this fiscal year. Monitoring points are slightly below the 2020-2021 and 2021-2022 years as a result of the changed protocol, but still exceed 11,500 data points, and are notably above the first two project years (Figure 3).

In total, from late 2018 through June 30, 2023, a total of 5234 diseased corals have been treated within the Florida Keys National Marine Sanctuary by the strike team. This equates to 68,084 disease lesions. Treated corals are from 19 different species. The average treated coral size is 108 cm, and 691 of these corals have a maximum diameter of over 200 cm. Additionally, 43,955 monitoring data points have been recorded, which provide valuable information about the status and trends of these treated corals. Accounting for treated corals across all years, 9876 square meters of coral have been preserved from immediate disease-related mortality. The restoration equivalency of that tissue is over 3.8 million coral outplants.

3.3 Mortality and Reinfection Rates

With many diseased corals being treated in early 2019, we have been able to assess long-term mortality rates. By standardizing all initial treatments to Time 0, we can look at survival curves across species and sites. When new lesions are found on previously-treated orals, they generally appear within the first few months after the first lesions are treated and seen. If these new lesions are not caught in time, colony mortality is the frequent outcome. As such, it is not surprising that most mortality (7% of treated corals) occurs within the first eight months. Survival rates plateau after that, with 92% of treated corals still alive after nearly four years (Figure 4).

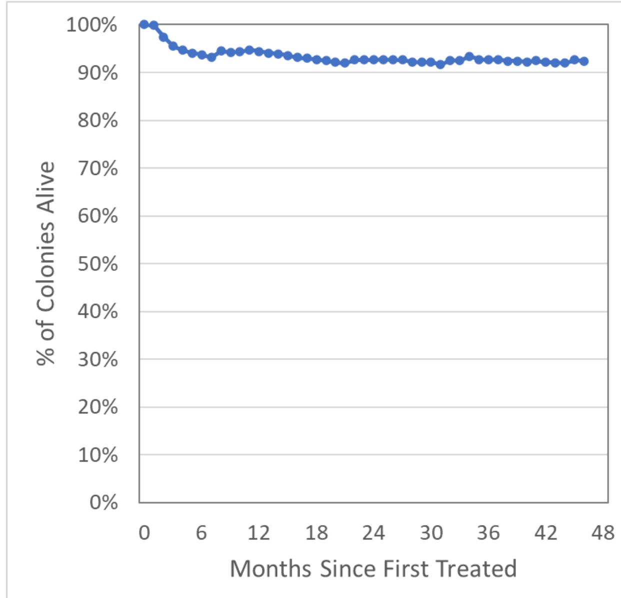


Figure 4. Mortality rates of treated corals, tracked every two months and treated for new lesions as needed.

We can also assess survival rates between habitats (inshore and offshore reefs) and among species (Figure 5). We compared survival at 24 months, as this allowed for over half of the corals treated to date to be assessed. Inshore reefs had significantly higher survival rates than offshore reefs ($p = 0.024$). At inshore reefs, there were no significant differences among species survival rates at two years, but at offshore reefs, *Montastraea cavernosa* and *Orbicella faveolata* had significantly higher survival rates than *Colpophyllia natans* and *Diploria labyrinthiformis* ($p<.001$ for *O. faveolata* comparisons; $p = .005$ for *M. cavernosa* comparisons).

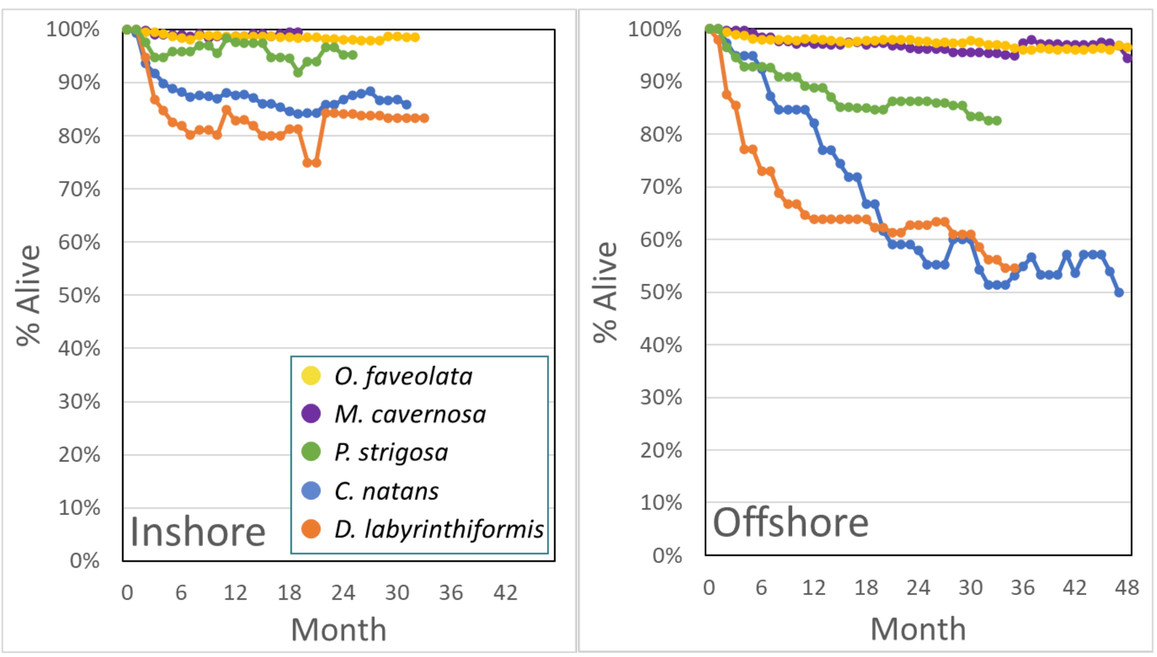


Figure 5. Mortality rates of treated corals, tracked every two months and treated for new lesions as needed. Mortality rates are shown for the five most common coral species (*Orbicella faveolata*, *Montastraea cavernosa*, *Pseudodiploria strigosa*, *Colpophyllia natans*, and *Diploria labyrinthiformis*) and separated into inshore and offshore reefs.

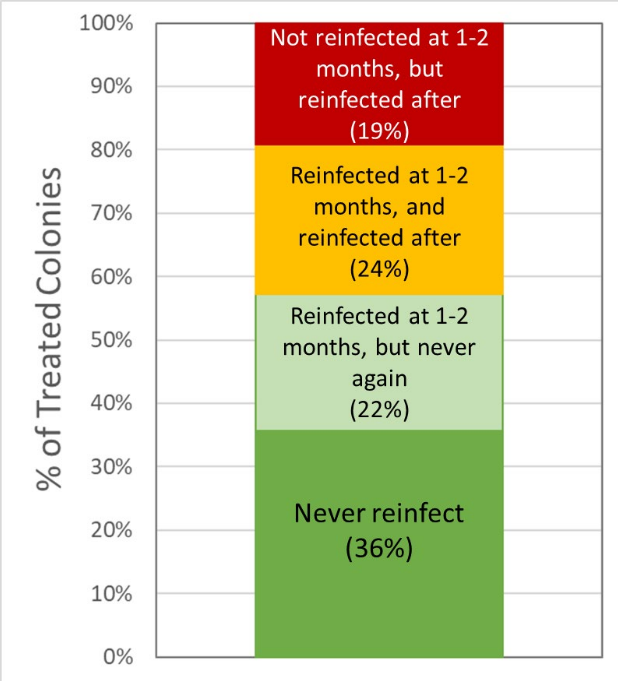


Figure 6. Fate of treated corals monitored for at least one year after initial treatment (N=2718). Corals that showed new lesions were retreated.

We also began assessing reinfection rates on previously treated corals. Because corals are fate-tracked every two months, we can determine when new lesions develop. We assessed all corals that had regular fate-tracking data for at least one year after initial treatment (N=2718; Figure 6). Of these, 36% showed no additional signs of disease within a year after initial treatment. Of the 64% that did develop new lesions, 75% of them (46% of the total) did so within the first two months after initial treatments. Because these new lesions were all treated as part of standard protocol, we could follow the fate of these colonies as well; nearly half did not develop subsequent lesions. The other half did develop additional lesions within the year. Of the total corals tracked, 19%

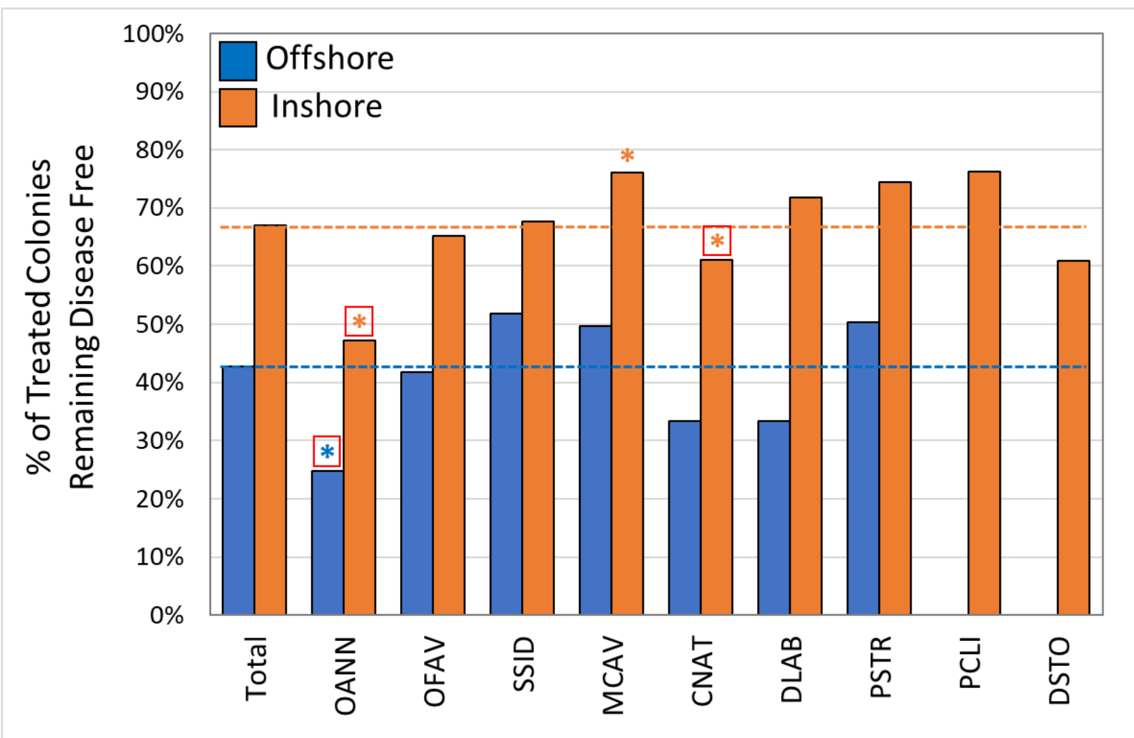


Figure 7. Percentage of treated colonies that remained disease free for at least one year after an initial treatment and a second treatment at 1-2 months if necessary. Asterisks within red boxes indicate species for which the proportion was significantly lower than average within each habitat; the asterisk without a box indicates the proportion was significantly higher than average.

did not develop additional lesions within the first two months after initial treatment, but did develop lesions at some point afterwards (Figure 6).

We assessed what the probable fate of corals would be if they were only visited and treated as needed twice: initial treatment plus a follow-up visit at two months. Overall, we estimate that 36% of SCTLD-affected corals require only the initial treatment, and that 22% of corals would only need two treatments before no longer showing lesions for at least one year. Assuming all other corals would experience mortality, this two-visit regime would be expected to save 58% of treated corals.

We assessed these percentages across habitat (inshore/offshore) and among species (Figure 7). Overall, inshore corals were much more likely to remain disease free after two visits (67%) than offshore corals (43%). There were also minor, but significant, species differences. *Orbicella annularis* were less likely than average to remain disease free regardless of habitat. At inshore reefs, *C. natans* were less likely than average to remain disease free, but *M. cavernosa* were more likely.

3.4 Temporal Patterns

Revisitation of treated colonies allows for a modified assessment of SCTLD prevalence. Because all treated corals are known to be susceptible to SCTLD, and colonies are revisited bimonthly, we can assess the proportion of known susceptible colonies which have active lesions through time. We assess this modified prevalence during each visit to each site with the following equation:

$$\frac{\#\,New + \#\,T + \#\,New\ Dead}{\#\,Total - \#\,Old\ Dead}$$

- # New is the number of never-before treated colonies first identified with lesions and treated during the monitoring event
- # T is the number of previously treated colonies with active lesions requiring new treatments during the monitoring event
- # New Dead is the number of colonies first documented as dead during the monitoring period with mortality signs characteristic of SCTLD
- # Total is the total number of corals ever treated at the site
- # Old Dead is the number of corals documented as dead before the current monitoring period

We then compare the proportion of SCTLD affected colonies at each site between each time period to assess flare-ups or downturns of modified disease prevalence, defined as a significant difference change in the proportion of affected colonies from the previous monitoring period (z-test; $\alpha < 0.05$).

At offshore sites, the general trend of modified SCTLD prevalence is downwards through time. The three assessed offshore sites (Sand Key, Looe Key, and Sombrero Key) had initial SCTLD modified prevalence values between 20% and 65% (meaning that of all known susceptible corals, 20-65% of them were first found with SCTLD during the first treatment events). By April/May 2023, all modified prevalence values were less than 10% (Figure 8a).

In contrast, inshore reefs (Newfound Harbor, Marker 48, Cheeca Rocks, and Hen & Chickens) have highly variable patterns of modified SCTLD prevalence. Most sites showed rapid significant decreases in SCTLD prevalence after initial treatment efforts, which generally remained below 20%. However, there are notable spikes at all sites, with significant flare-ups and downturns. Usually, but not always, significant flare-ups occur between February and July, while downturns occur August through November (Figure 8b). One notable difference between offshore and inshore reefs is that inshore corals have paled or bleached every summer since 2019 while offshore corals have not. Further, while SCTLD has recently declined to low modified prevalence levels at offshore sites, at inshore reefs it is exceptionally high. At Cheeca Rocks and Hen and Chickens, modified prevalence is higher than at any point since monitoring and treatment began.

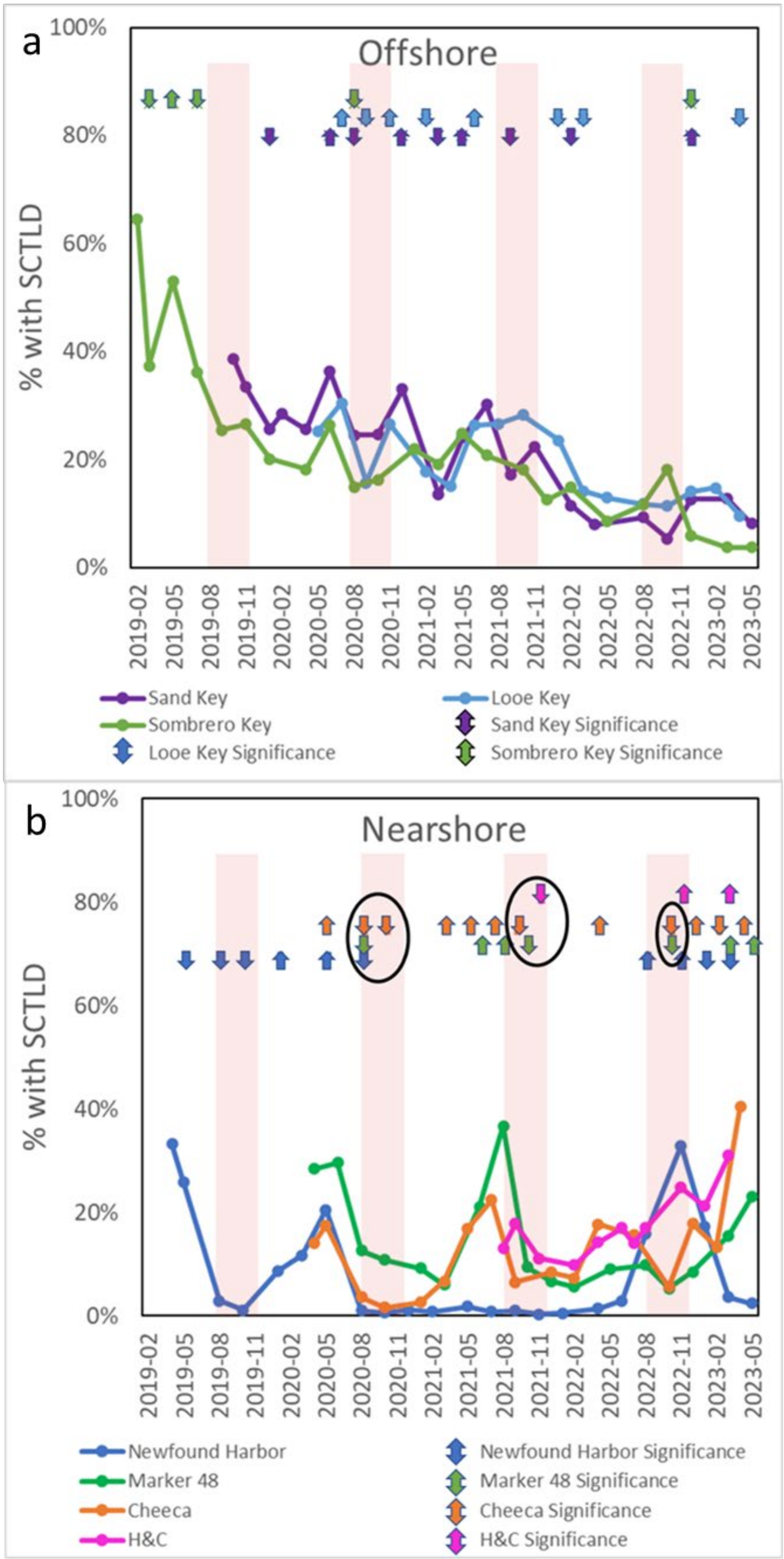


Figure 8. Modified prevalence of SCTLD on treated corals. Arrows indicate significant increases (up arrows) or decreases (down arrows) in modified prevalence from the previous monitoring event. Red bars represent periods of hyperthermal stress (August – November), causing paling/bleaching on nearshore reefs. Significant decreases during hyperthermal events on nearshore reefs are circled.

4. DISCUSSION

4.1. Benefits of work conducted and management applications

By preventing the mortality of SCTLD-affected corals, the strike team has preserved many of the iconic corals and reefs of the Florida Keys. With a 92% survival rate after four years, intervention is an effective and relatively cost-effective way to prevent mortality of the largest and oldest animals in Florida. On average, a coral takes approximately two minutes and $2 in materials to treat active lesions. The time and cost to replace a lost coral through restoration is orders of magnitude more. The surface area of coral preserved via Florida Keys intervention efforts since 2019 is estimated to be equivalent to approximately 3.5 million coral outplants. Costs of outplanting vary dramatically based on origin of fragments, type of nursery, rearing or grow-out time, and labor and boat costs, but based on available literature (Edwards et al. 2010; Guest et al. 2013), we provide two bookends for restoration costs: $2 and $30 per outplant. At $2 per outplant, replacing the tissue saved via intervention from July 1, 2022 to June 30, 2023 would cost $3.9 million (approximately an order of magnitude more than strike team costs). At $10 per outplant, replacement costs would be $19.5 million. At $30 per outplant, replacement costs would be $58.6 million. For all efforts to date (2019-present), intervention efforts are equivalent to between $7.6 million and $114 million in restoration costs.

Through monitoring efforts, we have identified patterns in reinfection rates and differences in SCTLD infections between inshore and offshore habitats. By fate-tracking corals, we have provided estimates of what alternate intervention protocol would look like in terms of coral survival. While we have kept 92% of treated corals alive over four years, the revisitation and monitoring require lots of time and resources spent at sites with few corals or mostly healthy corals. We show that intervention only once would be expected to save 36% of treated corals, while a second visit at 1-2 months to treat new infections would increase that proportion to 58%.

Intervention efforts can exist on a spectrum of concentrated effort based on intervention goals. Visiting a site frequently allows higher survival of corals at that site, but is inefficient, and conducted and at the cost of sacrificing other sites which can not be visited. In contrast, visiting many sites only once will result in lower survival of treated corals at those sites, but allow for many more corals to be treated and ultimately a higher number saved. As an example, we provide hypothetical scenarios with the following assumptions:

1. A treatment team has 100 days of fieldwork available to them within a year.
2. There are 100 possible treatment reefs, each with 500 SCTLD-affected corals.
3. All 500 corals at a site can be treated within one day by the treatment team.
4. Each treatment visit will save 33% of SCTLD-affected corals. One visit will save 33%. Two visits will save the original 33%, plus 33% of the remaining 67% (total 55%), and so on.

At one hypothetical extreme, the team visits each site once. At each site, 33% of the SCTLD-treated corals are saved, with 165 corals at each site surviving. However, with 165 corals saved at each of the 100 sites, the total number saved through the year is

16,500. At the other extreme, the team focuses on only eight sites, but visits each location every month. In this case, 99% of treated corals (496) at each of the eight sites are saved, but because only eight sites are treated, the total number of saved corals is only 4133. It is clear that management goals must decide between preservation of a small number of iconic sites or preservation of total number of corals (Table 1).

Table 1: Hypothetical examples of the number of corals saved per site and overall based on various intervention strategies ranging from regular visitation at a small number of sites to one-time visitation at a large number of sites.

	% corals saved per site	# corals saved per site	# corals saved overall
100 sites; visited only once	33%	165	16,500
17 sites; visited every 2 months	91%	455	7580
8 sites; visited every month	99%	496	4133

Our regular visitation to sites, particularly inshore patch reefs, shows that while SCTLD has declined on treated offshore reefs, many inshore reefs are currently (spring 2023) experiencing unprecedented levels of SCTLD infections. These reefs are largely overlooked in traditional monitoring programs, particularly during spring months. These reefs represent the most coral-dense and species-rich reefs remaining in Florida, and are currently being lost. Without rapid and continued intervention at these sites, losses are expected to be extreme.

4.2. Recommendations

1. Allow sites where SCTLD is no longer prevalent to be removed from 2-month monitoring efforts.
2. Allow treatment efforts to focus on inshore and mid-channel patch reefs where SCTLD is at epidemic levels.
3. Consider the management goals of intervention, particularly whether preserving a small number of sites is more valuable than saving large numbers of corals.
4. Consider allowing some sites to receive non-monitored intervention in order to more efficiently save corals. We suggest a model similar to that used on Dry Tortugas cruises where corals are treated and tallied, but not tagged, mapped, or monitored in order to quickly move through sites. We suggest that visiting sites like this twice would be expected to quickly save about 58% of treated corals in a highly efficient manner.
5. Acknowledge the value of intervention as a cost-effective tool in reef management and restoration, and include its use within restoration funding mechanisms.

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