**Restoration Trials Team Action Plan**

**April 2019 – Updated November 2019**

**Background and Introduction**

Presently, the Florida Reef Tract (FRT) is experiencing one of the most widespread and virulent disease outbreaks on record. Described as Stony Coral Tissue Loss Disease (SCTLD), this outbreak has resulted in the mortality of thousands of colonies encompassing at least 20 species of stony corals, including primary reef builders and species listed as Threatened under the Endangered Species Act. First reported near Key Biscayne in 2014, by late 2019 SCTLD had spread to the northernmost extent of the FRT and southwestward beyond Key West. Although a concerted effort is underway to identify the etiological agent(s), evaluate its mode and rate of transmission, and develop and test potential intervention techniques, our still limited understanding of SCTLD has greatly hindered our ability to implement management efforts to control or prevent the spread of this disease or develop and implement a much-needed restoration strategy for affected areas of the FRT.

In July 2018, the Florida Department of Environmental Protection’s Florida Coastal Office, the Florida Keys National Marine Sanctuary (FKNMS), and the National Oceanographic and Atmospheric Administration’s Coral Reef Conservation Program hosted a multidisciplinary coral disease workshop with the goal of developing a response plan that would guide and coordinate scientific and management efforts to address the SCTLD outbreak in Florida.

Acting upon specific recommendations from this workshop, several multi-agency multi-disciplinary teams were assembled. The Restoration Trials Team (RTT) was assembled to plan, coordinate, and implement coral reef restoration activities designed to mitigate the effects of SCTLD throughout the area of FRT previously affected by the disease. These activities may include, but not necessarily be limited to, experimental and restoration-scale coral outplanting, coordination of multi-organizational coral nursery activities, and restoration activities of other reef-associated species. However, the term ‘restoration’ in this context and throughout this document, refers to coral outplanting (not whole ecosystem restoration).

In August 2019, the Coral Disease Technical Workshop was held to review the progress on different aspects of the SCTLD research and response and to identify goals and actions moving forward. Given the progression and ongoing nature of SCTLD over the last several years, restoration continued to be identified as a priority, with an emphasis on increasing the information on outplanting success within the endemic zone (currently upper Florida Keys to Martin County).

The RTT recognizes that reef restoration activities should occur in two phases. The first phase of restoration should address the management question of when it is safe to continue coral restoration practices by assessing the specific ecosystem risks and information gaps associated with conducting coral restoration under the persistence of SCTLD. Accordingly, this action plan identifies specific research activities to assess these risks, recommends a set of general guidelines under which coral outplanting should proceed toward that assessment, and recommends a standardized monitoring protocol sufficient to allow the information collected from the various coral outplanting efforts to be evaluated. The RTT recognizes that once these risks are better understood based upon the immediate term actions recommended here, there will be a need to update the action plan to guide longer-term and larger scale restoration activities with consideration of restoring key ecosystem services (e.g. physical structure, coral diversity, fish biomass, etc.). The RTT anticipates that the outcome from the monitoring of these initial actions may lead to the need to design and conduct larger scale and more rigorous experimentation to understand restoration within the SCTLD outbreak. Eventually, these activities will include expanding husbandry and research/restoration efforts to include additional coral species with the vision of scaling-up restoration efforts to an ecologically meaningful scale. Furthermore, future restoration activities should identify specific goals to achieve from outplanting efforts. For example, coral restoration activities could be used for increasing biological diversity, maintaining physical structure, simply increasing coral cover, or several goals in concert. The goal of the restoration activity would certainly influence the appropriate techniques used within the effort and the metrics measured for success. These techniques and metrics should be considered when planning restoration activities within the SCTLD outbreak.

**Key Research Questions**

The RTT has identified three key research and management questions to assess the specific risks and information gaps associated with conducting coral restoration under the persistence of SCTLD:

1. Are acroporid corals a potential vector of SCTLD?
2. Will outplant sites of SCTLD-susceptible coral species serve as a new source of disease flare-ups or increase the severity of the outbreak in the surrounding coral community?
3. Can SCTLD-susceptible species be outplanted on the Florida Reef Tract with acceptable survival rates to warrant attempting coral restoration efforts on a larger scale?

To address these key questions, the RTT recommends a two-pronged approach that consists of both directed experimental coral outplanting within areas affected by SCTLD coupled with a concerted monitoring effort of the numerous coral outplanting efforts that have either been planned for in the near-term or have been recently completed. This plan outlines several recommended activities designed to evaluate these research and management questions. However, this action plan does not prescribe specific details of experimental design or the outplant design for any individual project. That decision will be left to the organization designing the project. The RTT recognizes that the restoration activities recommended herein will entail many different multi-species coral outplantings conducted by several agencies and organizations across varied reef architecture. However, the RTT encourages all outplanting activities described herein include coordination with the RTT. Of paramount consideration to the RTT is that restoration activities should limit the movement of SCTLD-susceptible coral colonies from diseased to non-diseased zones to reduce, to the extent possible, the likelihood of transmission of the disease. However, outplanting of coral colonies that have not been exposed to SCTLD into the pre-invasion zone should continue within the normal framework of the restoration permitting process.

Although this action plan addresses outplanting within each disease zone of the FRT, activities that will occur in the endemic zone may have particular importance in the long-term as all regions may eventually become part of the endemic zone if SCTLD does not completely dissipate. It is in this zone that the bulk of restoration will occur in the near future. The essential management question for future guidance is “***when will it be safe to expand outplanting in the endemic zone?***”. This question is especially pertinent for eventual outplanting activities using coral colonies sourced from specimens currently being housed at land-based facilities (*See* Rescue Coral Action Plan). The answers to questions two and three will influence the timing and level of activity associated with returning a portion of these rescue corals to the south Florida reefs and *in situ* nurseries (once genetic management targets has been met).

The RTT recognizes that many of the experiments /actions identified in this plan will not be fully controlled experiments, because incorporating independent control sites will be challenging. We also recognize there is a reasonable likelihood that the outcomes of field trials will result in no observable disease-related effects, especially at the nearby coral communities. Hence, much of the information may be comprised of “negative results”. Therefore, consideration should be given to ensure that enough repetition of outplantings occur, particularly within the endemic zone, so that managers can use a “preponderance of evidence” approach to make the judgement call regarding the essential management question outlined above.

Question 1: Are acroporid corals a potential vector for SCTLD?

Most coral restoration that has occurred along the FRT has used acroporids. *Acropora palmata* and *A. cervicornis* have not been observed to exhibit SCTLD despite being subjected to the unknown infectious agent at many locations throughout the FRT during disease progression, even when being outplanted in the epidemic/invasion zone. We conclude from these observations that acroporids are not susceptible to SCTLD. However, concerns have been expressed that acroporid corals could serve as a vector for SCTLD. Consequently, should that be the case, conducting restoration activities using nursery corals that have been exposed to the disease could pose an additional risk to spreading the SCTLD, especially if outplanted in the pre-invasion zone. Assessing the risk of continued restorative activities using acroporids is paramount if these activities are to continue.

*Recommended Experiments/Activities*

1. In a laboratory setting, place *A. palmata* and *A. cervicornis* that have been sufficiently exposed to the SCTLD into tanks. This could include nursery-reared corals collected from nurseries located within the epidemic zone (*e.g.*, Looe Key nurseries), fragments taken from reefs that are experiencing an active outbreak, or fragments that were exposed to SCTLD through physical contact with diseased corals within a controlled laboratory environment. Add colonies of SCTLD susceptible corals to these tanks. Ideally, this experiment will include colonies of the “more susceptible” (*e.g.*, *Dichocoenia stokesii*, *Meandrina meandrites*, *Colpophyllia natans*) species, perhaps acquired from the pre-invasion zone as well as other “less susceptible” (*e.g.*, *Siderastrea siderea*, *Stephanoceonia intersepta*, *Solenastrea bournoni*) species and perhaps species believed to be unaffected by SCTLD (*e.g.*, *Porites astreoides*, *P. porites*). Incorporate control tanks where fragments of the same coral colonies are placed in tanks that contain acroporids that have not been exposed to SCTLD. These may be acquired from the pre-invasion zone or from land-based nurseries that do not expose corals to reef water from the diseased zones (*e.g.*, well water, artificial seawater, locations outside of the FRT). If the susceptible corals show signs of disease at a greater rate than the controls, then the results would suggest that the acroporids may be carriers of SCTLD. If the susceptible corals do not show signs of disease at greater rates than controls, then the results would suggest that acroporids are likely not carriers of SCTLD.
2. Outplant *A. cervicornis* and *A. palmata* colonies that have been exposed to SCTLD to sites containing susceptible corals that are not diseased, but are located within diseased zones. This could include both nursery-reared corals collected from nurseries located within the epidemic zone (*e.g.*, Looe Key nurseries), fragments taken from reefs that are experiencing an active outbreak, or fragments that were exposed to SCTLD through physical contact with diseased corals within a controlled laboratory environment. This field approach could be conducted simultaneously to lab experiments in any of the diseased zones. The susceptible coral species used in these experiments should come from the pre-invasion zone and have not been previously exposed to the pathogen as well as corals taken from *in situ*/*ex situ* nurseries as these may behave very differently. If the susceptible corals placed near the acroporids do not show signs of SCTLD within one month after outplanting, then the RTT Team would conclude that acroporids are likely not carriers of the disease. However, if the susceptible corals placed near the acroporids do show signs of SCTLD, then it could be a result of the acroporids, from other corals, ecological factors within the surrounding reef, or from exposure to pathogens within invasion or endemic reefs. In this case, we could not attribute any emergence of SCTLD to the acroporid outplanting activity, as other unknowns or variables could influence disease dynamics. Therefore, if disease was observed on the outplanted acroporids, this experiment would not have a conclusive result. To better clarify this question, further experiments and monitoring under the direction of the RTT should take place.

Questions 2-3:

1. Will outplant sites of SCTLD-susceptible coral species serve as a new source of disease flare-ups or increase the severity of the outbreak in the surrounding coral community?
2. Can SCTLD-susceptible species be outplanted on the Florida Reef Tract with acceptable survival rates to warrant attempting coral restoration efforts on a larger scale?

These questions represent the broader essential management question to determine when it is safe to continue and scale-up coral restoration practices using historical rates and practices. In effect, any field outplanting or directed experiment will have the opportunity to address both questions simultaneously. Consequently, the recommended experiments/actions are the same for both questions. However, depending on the results, the management response could be markedly different. For example, if outplanting susceptible species within the endemic zone causes new disease flare-ups at the nearby coral community, then a cautionary management approach would be warranted that could result in the cessation of further outplanting activities until its relationship to disease prevalence is better understood. On the other hand, if an outplanting results simply in an increased rate of disease in the newly outplanted colonies, then the management response may be to continue encouraging outplanting to better understand the timing and risks associated with bringing fragments from rescued corals into *in situ* nurseries. In either case, frequent monitoring (at least monthly) is necessary to assess the impact to outplants and the surrounding community. When drawing conclusions to answer Question #2 through experimental outplanting, it is important to recognize that other unknowns or variables may influence disease dynamics. Therefore, conclusions from these field experiments would be correlative rather than causative. Further experiments and monitoring under the direction of the RTT is recommended.

*Recommended Experiments/Activities*

Conduct a cooperative, multi-organizational, multi-species coral outplanting effort using SCTLD-susceptible species throughout the FRT, at both nearshore and offshore reef habitats. This experimental effort would be tailored slightly to the specific geographical reef/region. Paired with lab-reared corals and those that have survived SCTLD exposure *in situ*, it is preferred that the same species and genotypes would be used in these experiments*.* Prior to outplanting, initial surveys should be conducted at each site to determine the disease prevalence of the reef area at time zero.

The RTT recognizes that recommending detailed standardized restoration protocol on an effort of this scale being conducted by multiple organizations would not be easily implemented. However, these outplanting efforts should consider the following protocols to facilitate an effective meta-analysis of these restoration efforts. Because it is unknown whether colony size and density influence disease transmission dynamics, the RTT recommends that all outplanting efforts record both of these metrics. The RTT recommends utilizing initial pilot data that have already been taken by several partner organizations to inform decisions on these metrics. Initial outplantings could include the species presently being reared in *ex-situ* and *in situ* nurseries. If possible, standardizing genotypic diversity within the outplanted scheme would be advantageous. Corals should be outplanted as simultaneously as possible to reduce temporal effects. Post-outplant monitoring should occur at a frequency sufficient to evaluate the relative incidence of disease of the outplanted corals and assess the disease prevalence of the surrounding reef area to determine any change in disease activity that may have been related to adding restoration corals to the site. Criteria of success should be established and tailored to each outplant site. Additionally, if disease is observed in the outplants, the following was recommended during the August 2019 Technical Workshop to be considered:

* Disease on small colonies (< 30 cm): outplant/surrounding colonies are culled immediately.
* Disease on large colonies (> 30 cm): treated using the current and best treatment method.

**Recommended Monitoring Actions**

All coral restoration efforts that include outplanting SCTLD-susceptible coral species should be monitored sufficiently to address Questions 2-3. The monitoring protocol should include a pre-restoration evaluation of the coral community of the restoration site itself and of an adjacent location over an area sufficient to evaluate changes in disease dynamics related to outplanting activities. Periodic post-outplant monitoring should be conducted to assess colony-specific disease prevalence of the outplanted coral colonies along with roving surveys around the restoration site and an adjacent area for the presence/absence of new incidence of SCTLD. Post-outplant surveys will ideally occur at one week, two weeks, one month, three months, and six months post-outplant.

Given that the disease spread appears to be waterborne, a true control may be neither possible nor practical. It may be possible that sites separated from outplant sites are at less risk of experiencing a resurgence of SCTLD than the outplant sites or those sites nearby. If so, the monitoring protocol described above should detect this. However, it is possible that SCTLD-susceptible corals at any location within the endemic zone are equally at risk for acquiring SCTLD, and presently there is insufficient information to determine that level of risk. The RTT believes a reasonable approach to evaluate this is to establish a series of regional control sites more distant from restoration activities.

Monitoring Methodology

*Restoration Site*

When the site is established, determine the baseline prevalence of SCTLD using a 30-minute roving diver survey. As these surveys will certainly include at least two divers, the search effort could be divided amongst divers, but their combined search time should total 30 minutes and not overlap in area. The survey should record the number of SCTLD-susceptible coral colonies, their size (cm diameter), and health status (healthy or diseased). Colony size can be estimated and binned into one of four size classes: < 10 cm, 10-25 cm, 25-50 cm, >50 cm diameter. If disease is observed, photodocumenation is recommended. Using the same 30-minute survey methodology, monitor the restoration site at one week, two weeks, one month, three months, and six months post-outplanting for changes in SCTLD prevalence.

Outplanted colonies should be monitored for survival and the presence of disease at the same intervals. If additional colonies are outplanted within the restoration site within the above monitoring schedule, the new outplants should be monitored at one week and two weeks post-outplanting, but the remaining monitoring remains unchanged.

*Adjacent Site*

An additional 30-minute roving survey of the surrounding coral community should also be conducted sufficient to provide a reasonable assessment of SCTLD prevalence in the area at the time of outplanting. The protocol should be the same as described above. The number of SCTLD-susceptible coral colonies, their size (cm diameter), and health status (healthy or diseased) should be recorded. Colony size can be estimated and binned into one of four size classes: < 10 cm, 10-25 cm, 25-50 cm, >50 cm diameter. The size and configurations of these restoration areas could vary widely and will dictate how the survey will be conducted. If the outplant site is located within a large area of generally contiguous reef habitat (*e.g*., an offshore bank reef), the recommended protocol dictates that the survey be conducted approximately 100 m from the perimeter restoration site. If the restoration site is a discrete patch of habitat (*e.g*., a patch reef) of insufficient size to permit a roving survey at the recommended distance, the adjacent site could be a nearby patch reef. This site should be monitored at the same frequency as the restoration site (*i.e.*, one week, two weeks, one month, three months, and six months post-outplanting).

*Regional Control Sites*

Since 1995, The Florida Keys National Marine Sanctuary Coral Reef Evaluation and Monitoring Project (FKNMS CREMP) has maintained a series of long-term monitoring sites along the FRT. No coral reef restoration efforts have occurred at these locations and consequently they are particularly suitable to serve as regional control sites. The RTT recommends establishing two control locations in the Upper, Middle, and Lower Florida Keys. At each of those six locations, three CREMP sites, one in each of three strata: offshore, mid-channel, and near-shore be selected to serve as control sites. Each site should be monitored quarterly using the same protocols detailed above.

**A Meta-Analysis Approach**

The RTT acknowledges the limitations within the previous described approach, such as variations in outplant design, timing that outplanting occurred, disease incidence and prevalence within the outplant location, species composition of outplants, as well as the density and size of the outplanted corals. Additionally, natural spatial and temporal variation within the SCTLD dynamics has the potential to influence results if statistical power is not robust. However, the Action Plan recommends a meta-analysis approach to amalgamate data into a centralized analysis that aims to detect changes in disease activity because of outplanting regardless of the variability among outplant efforts. Meta-analysis is the statistical procedure for combining data from multiple studies. When the treatment effect (or effect size) is consistent among these studies, meta-analysis can be used to identify this common effect. A key benefit of this approach is the aggregation of information leading to a higher [statistical power](https://en.wikipedia.org/wiki/Statistical_power) and more robust estimation compared with any individual study.

**Recommendation for Funding a Dedicated Monitoring Team**

The RTT recognizes that conducting the compressive monitoring effort detailed herein will require a large investment of time and dedicated funding. Such is the scope of this monitoring effort that will not be feasible without the formation of a monitoring team dedicated to coordinate and monitor all (or an adequate subset) of restoration sites. This approach also ensures that the monitoring effort yields consistent information gathered across the disparate restoration efforts that will yield the most instructive meta-data analysis to address Questions 2-3 detailed in this Action Plan. Securing dedicated funding for this monitoring effort should be prioritized to accomplish this objective. The RTT recommends that financial support from FL Department of Environmental Protection or other appropriate dedicated sources, if available, be provided to an independent monitoring team. The focus of this team will be to quantify the data essential to determine whether outplanting coral species susceptible to SCTLD may cause increased disease severity within the outplanted reef or neighboring reefs and to assess whether large-scale restoration can occur without adding a significant risk to the remaining coral community.

**Current State of Knowledge ‘Living’ Documents**

Results from lab and field-based experiments, as well as restoration activities of SCTLD-susceptible species, will be incorporated into comprehensive summary documents that will be available on the RTT webpage after approval by the members of the working group. These compiled results will help to make more informed decisions surrounding the three key research and management questions. These documents will continue to be updated as more information becomes available.