STONY CORAL TISSUE LOSS DISEASE
TEMPLATE MONITORING AND RESPONSE ACTION PLAN
FOR CARIBBEAN MARINE NATURAL RESOURCE MANAGERS

Photo: E. Doyle

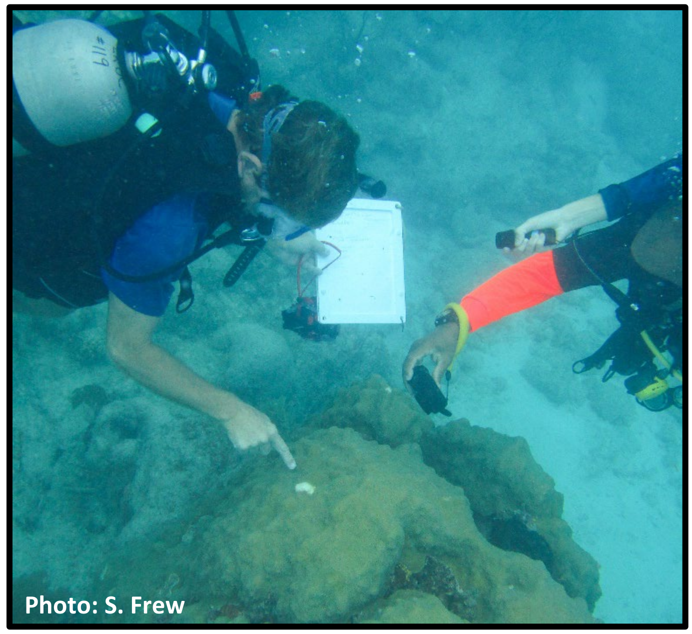

Photo: S. Frew

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Introduction

While coral diseases are common on reefs, this disease was undocumented before 2014 and, unlike other coral diseases, has been proven to persist for a long time in the environment, infect several species of coral and cause rapid die-offs. In order to assist natural resource managers throughout the Caribbean tackle the possible transmission of this disease into their waters a meeting was held in Key West, Florida on the 1st and 2nd of August, 2019. The meeting brought Caribbean natural resource managers from affected and susceptible countries together with experts from Nova Southeastern University, the National Oceanic and Atmospheric Administration, the International Maritime Organization and the Atlantic and Gulf Rapid Reef Assessment Program who are actively working to combat SCTLD. The meeting discussed disease identification, intervention and treatment methods. This document details the possible intervention measures that may be undertaken by natural resource managers to monitor, treat and prevent the spread of SCTLD within their waters. It is based on the discussions held during the August 2019 meeting, as well as the Coral Disease Intervention Action Plan developed by Karen Neely in 2018 (Neely, 2018).

Background

- Stony coral tissue loss disease (SCTLD) is no longer just a Florida problem. Unfortunately, other locations in the Caribbean have started to see similar disease signs and, as of August 1, 2019, the disease is confirmed in the Caribbean countries and territories of Jamaica, Mexico, Sint Maarten, the Dominican Republic, the U.S. Virgin Islands (St. Thomas), the Turks and Caicos Islands and Belize. SCTLD is contagious between individual corals and among coral species but does not affect humans. It is water-borne and can also spread through contact. Work is ongoing to determine the pathogen(s) involved and although none have been determined, applications of the antibiotic amoxicillin have arrested disease progression in both laboratory and field experiments, so a bacterial component is highly likely.
- The correct identification of SCTLD depends on multi-factor field diagnosis. Note that it can be difficult to distinguish between lesions on stony corals caused by disease, predation, overgrowth, competition or physical damage, and this makes it difficult to diagnose SCTLD based on single observations or photos alone. Key steps in the identification of SCTLD are based on the characteristics described on the MPAConnect poster guide to SCTLD (Figure 1). They are as follows:
  - If multiple lesions are observed, check whether there's total loss of tissue/denuded skeleton and no bleached tissue remaining, and whether tissue is visibly sloughing off.
  - Check affected coral species – SCTLD has a distinct pattern of spread among susceptible species.
  - Check for higher than normal prevalence of disease on the stony corals that are known to be most susceptible to SCTLD, which can be 66-100% versus a "normal" background coral disease level of 2-3%.

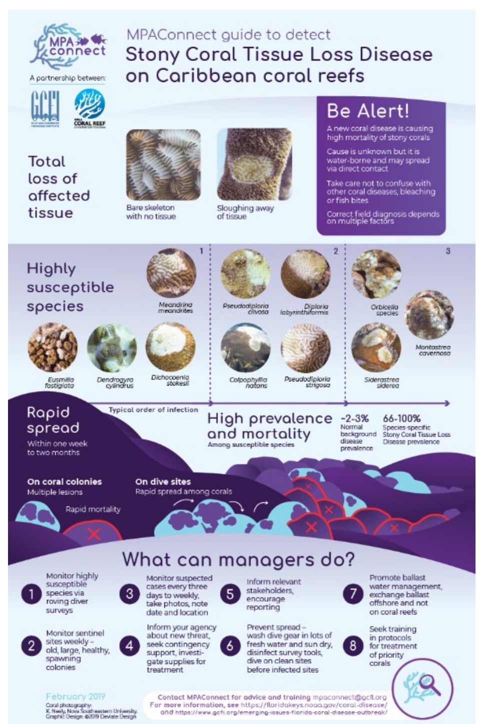


Figure 1: MPAConnect guide for managers to detect and identify SCTLD

- Check for rapid rate of spread of the disease on the affected coral colonies and between corals on the reef. Check for rapid and high mortality of affected corals (within a week or up to 2 months).
- The disease will remain active throughout the year and over multiple years.

- Over 20 species of hard coral are susceptible to contracting SCTLD, with varying degrees of susceptibility. The first species affected by SCTLD is usually *Meandrina meandrites*, followed by *Colpophyllia natans* (AGRRA, 2019a). Highly susceptible species may experience rapid progression of the disease with complete mortality seen between one week for smaller colonies to 1-2 months in larger colonies. Intermediately susceptible species may become infected about a month after highly susceptible species contract the disease. The progression is slower with smaller numbers showing signs of the disease, with death of the corals occurring after months, in smaller colonies, to years in larger colonies (AGRAA, 2019a). The total list of susceptible species, and their degree of susceptibility, are shown in Table 1.

Table 1: Degree of Susceptibility Found in Hard Coral Species (Adapted from Atlantic and Gulf Rapid Reef Assessment Program, 2019a).

High Susceptibility	Intermediate Susceptibility	Presumed Susceptibility	Low/No Susceptibility
Colpophyllia natans (Boulder brain coral)	*Orbicella annularis* (Lobed star coral)	*Agaricia agaricites* (Lettuce coral)	*Porites astreoides* (Mustard hill coral)
Dendrogrya cylindrus (Pillar Coral)	*Orbicella* faveolata (Mountainous star coral)	*Agaricia* spp. (Plate / saucer corals)	*Porites porites* (Finger coral)
Dichocoenia stokesii (Elliptical star coral)	*Orbicella franksi* (Boulder star coral)	*Madracis arenterna* (Pencil coral)	*Porites divaricata* (Thin finger coral)
Diploria labyrinthiformis (Grooved brain coral)	*Montastraea cavernosa* (Large-cup star coral)	*Favia fragum* (Golfball coral)	*Porites furcata* (Branched finger coral)
Eusmilia fastigiata (Smooth flower coral)	*Solenastrea bournoni* (Smooth star coral)	*Mussa angulosa* (Spiny flower coral)	*Acropora palmata* (Elkhorn coral)
Meandrina meandrites (Maze coral)	*Stephanocoenia intersepta* (Blushing star coral)	*Scolymia* spp. (Disc coral)	*Acropora cervicornis* (Staghorn coral)
Pseudodiploria strigosa (Symmetrical brain coral)	*Siderastrea siderea* (Starlet coral)	*Isophyllia* spp. (Sinuous cactus coral; rough star coral)	*Oculina* spp. (Bush corals)
Pseudodiploria clivosa (Knobby brain coral)			*Cladocoraarbuscula* (Tube coral)

- A multi-step SCTLD monitoring approach is recommended at the sub-regional level depending on the management need and the stage of the disease (Figure 2).

Monitoring - what is your objective?

Management need	Recommended monitoring approach
Define broad spatial limits of disease	Manta tows, stakeholder reporting
Approximate prevalence of SCTLD	Roving diver surveys
Track progression of SCTLD	Marked colonies, establish sentinel reef sites, photo series
Quantify spatial extent of SCTLD	AGRRA-type surveys (or standard national protocol)
Assess SCTLD interventions	Visual inspection of treated lesions, photo series
Determine impacts on coral reef ecosystems including fish	6-monthly repeat of AGRRA-type surveys at long-term monitoring sites affected and unaffected by SCTLD

A network for learning among Caribbean marine resource managers

Figure 2: Multi-step SCTLD monitoring approaches based on management needs

- In order to prevent the spread of SCTLD, no-cost best practices such as diving healthy reefs before diving infected reefs are recommended. Local rental of dive and snorkel gear is highly recommended if traveling to or from a known contaminated site. Decontamination of gear involves soaking for 10 mins in 1% bleach solution, rinse in fresh water, air dry. The wash solution should be left out in the sun for 1 day to break down the bleach and it can then be disposed of without causing pollution.
- The recommendation from SCTLD experts in Florida (NOAA, Nova Southeastern University, Florida Fish and Wildlife Commission, Florida Department of Environmental Protection, Florida Keys National Marine Sanctuary) is to treat the disease as quickly and as aggressively as possible once identified in new locations. Large-scale field trials indicate that the best practice is currently the application of amoxycillin powder with CoreRx Base2B (a silicone formulation)1:8 ratio, given high failure rates of alternatives (see image 2). This involves small scale, topical use of antibiotics for in situ disease mitigation on coral species that are highly susceptible to rapidly spreading SCTLD. Expert opinion indicates that the success of the amoxycillin on rescued coral in controlled laboratory settings, combined with the rapid and catastrophic loss of the species in the wild, justifies the limited and targeted application of antibiotics.
- In order to address concerns of antibiotics in the environment, the quantity of antibiotics being introduced through SCTLD treatment has been compared to backgrounds levels and found to be relatively low. Research is also ongoing into the effectiveness of other kinds of antibacterial compounds. Partners are assisting with securing an affordable supply of CoreRX Base2B material.

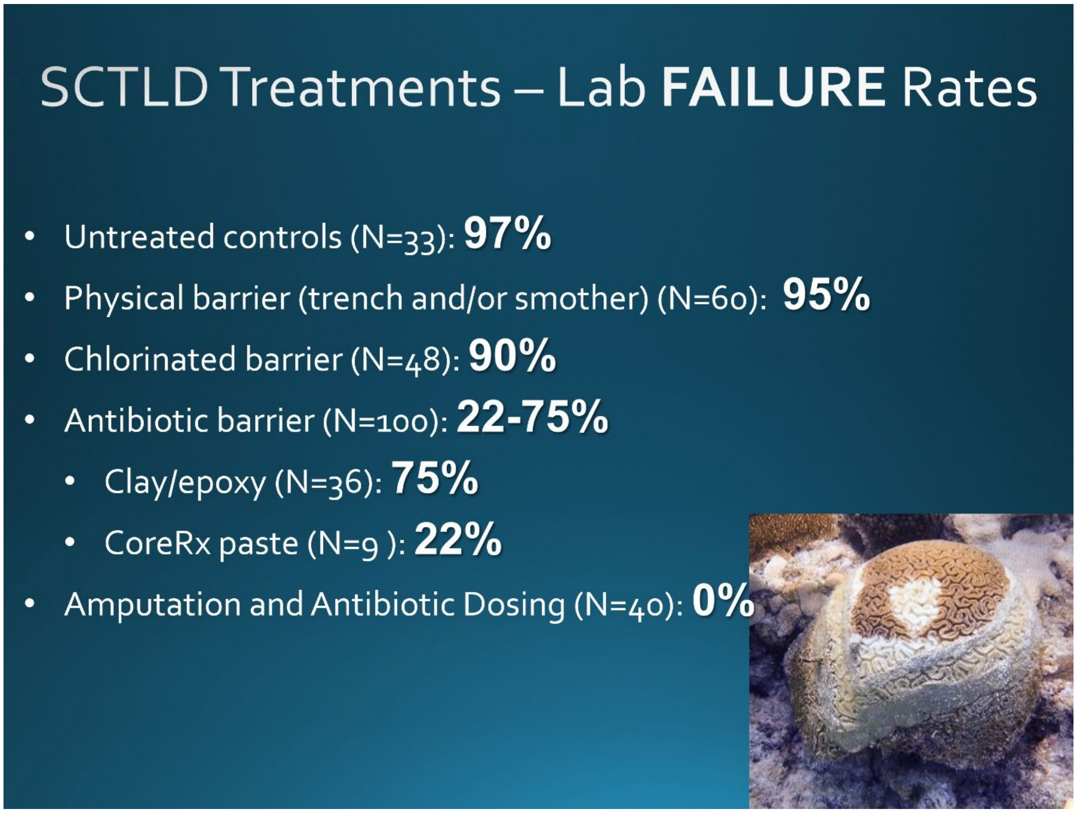


Figure 3: showing failure rates of various treatment methods (source: K. Neely)

- Selection criteria must guide the prioritization of SCTLD-affected coral reef sites and coral colonies for monitoring and treatment - large coral colonies close to others of the same species are priorities for monitoring and treatment, and colonies with a large amount of remaining tissue and a small number of active lesions are considered more treatable. Site selection criteria relate to the regulatory framework, for example, sites within an MPA may respond more positively to treatment since they may not be affected by additional stressors such as fishing pressure.
- Crisis communications measures are justified by managers in the face of the threat posed by SCTLD to coral reefs and associated economies with unified messaging by agencies and careful choice of language.
- The progression of the disease may be categorized as one of four conditions (Table 2): Pre-invasion; Invasion; Outbreak; Endemic.

Table 2: Exposure Categories for Coral Reefs that are, or may be, Affected by Stony Coral Tissue Loss Disease. Adapted from Neely, 2018.

Condition	Duration of Exposure	Disease Prevalence	Coral Community
Pre-Invasion	None	None	Normal, pre-disease coral communities
Invasion	1-7 months, usually < 3 months	Low. Acute lesions visible only on early susceptible species	Still has full suite of species, though early susceptible ones will be experiencing mortality
Outbreak	3 months – 1 year	High. Lesions acute as well as chronic	Rapidly transitioning between pre-diseased community and one with lower abundances / absence of susceptible species
Endemic	1 – 4 years	May be low since susceptible species are rare. May be chronic on remaining susceptible species	Few to no remaining susceptible species. Diminished coral cover and higher proportion of non-susceptible species

Monitoring Protocol

Objective: Identify early signs of the disease in a pre-invasion area

The recommended approach to determine the prevalence of the disease among susceptible species is roving diver surveys. A diver will conduct a census swim of the site, focusing on species that are primarily impacted by this disease outbreak. Multiple divers can conduct the survey at one site, but should partition the site amongst themselves, either vertically by depth and/or horizontally in opposite directions from a common starting point, or in parallel rows (as on narrow reef lobes). Their data should be entered separately.

1. Swim around the site (no greater than 50 m from the recorded coordinates) for at least 10 minutes or longer for a more complete sample size.
2. On the datasheet (next page), record the following metadata:
    a. Name
    b. Date
    c. Site Name
    d. Latitude and Longitude in Decimal Degrees
    e. Time start and Time end of roving diver swim (10 minutes minimum, but longer is fine)
    f. Depth interval of survey.
    g. Habitat surveyed.
3. Record the species code of stony coral species seen on the swim. Exclude Milleporids, Acroporids, and *Porites astreoides* (PAST). Focus on colonies greater than 4 cm. For each species, tally the number of colonies exhibiting each of the following conditions:
    a. Newly dead colonies (bright white skeleton, polyp structure intact) Colonies with obvious other causes of mortality (breakage, toppling) should be excluded.
    b. Actively diseased colonies. Colonies with any level of SCTLD disease should be included here.
    c. Undiseased colonies with signs. i.e., colonies that do NOT have any active mortality due to SCTLD, but are showing unusual pale spots or focal bleaching. Colonies with dark spot disease

should also be included here. (In meta-analyses, these colonies will be lumped in with “non-diseased” colonies.)

d. Healthy colonies. No active disease or unusual signs.

4. Photos can be taken of unusual or interesting disease sightings

Table 3: Roving Diver Survey Data Sheet

NAME:	SITE:	TIME START:
DATE:	LATITUDE:	TIME END:
Exclude Milleporids, SSID, and PAST	LONGITUDE:	

Species Code	Tally colonies w/ recent mortality (likely due to disease)	Tally actively diseased colonies	Tally undiseased colonies w/ symptoms of concern (pale spots or focal bleaching)	Tally undiseased colonies

Objective: Documenting progression of the disease in the invasion zone

Once SCTLD has been identified from roving diver surveys, it’s progression can be tracked by identifying priority coral reef sites and priority corals for monitoring using time-series photography and/or videography.

The following guiding principles can be used to help select priority sentinel coral reef sites, tailored according to the local reef area and diversity of reef types (barrier, fringing, atolls, faros, pinnacles, patches):

- Reef types affected by SCTLD: aim for representatives of each type as constituent corals are locally adapted to different environments with respect to wave exposure, sediment stressors and ambient illumination.
- Coral diversity: a diverse community may provide more opportunity to protect an intact ecosystem and preserve reproductive capacity of many species with less effort (the loss of particular species is less likely to disrupt the ability of the entire ecosystem to function).

- Coral density: a high density of corals may provide greater habitat complexity, more ecosystem services to other organisms and experience higher reproductive potential. However, crowded sites may also be more susceptible to infectious diseases, especially if many corals are clonemates and equally susceptible to the particular pathogen involved.
- Coral composition: sites that contain a high number of desired colonies of particular species (see below) may be prioritized.
- Coral demographic structure: Sites with large, reproductively active, framework structure-producing corals contribute disproportionately to habitat and propagation. These sites are often high-relief spur-and-groove reefs or large patch reefs.
- Isolation: Sites isolated by sand or hard bottoms lacking many live corals may be less susceptible to ongoing or high infection rates from water-borne pathogens. Discrete sites are easier to scout/search and may be able to be treated more effectively.

The following guiding principles can serve to identify priority sentinel corals for monitoring:

- Structure builder: Some susceptible species contribute substantially to reef-building and the associated ecosystem services that provides (especially *Orbicella* spp., *Montastraea cavernosa*, *Colpophyllia natans*). These species may be prioritized over others that are not primary framework builders.
- Size: Larger colonies are likely to have greater reproductive capacity and provide more habitat. Corals of species that grow larger than 2 meters may be prioritized for these features.
- Relative size: Colonies that are large for their species are likely to be older and thus more resilient to long-term environmental conditions. They also likely contribute more substantially to reproduction than their smaller conspecifics. Corals in the top 5% of size for their species may be prioritized.
- Localized reproductive capacity: A coral surrounded (in the same general reef area) by other live colonies of the same species probably has greater reproductive potential than a more isolated coral because its fertilization rates are likely to be greater.

Regulatory factors to include in the selection of priority coral reef sites and priority sentinel corals for monitoring include:

- Iconic coral: Corals identified by stakeholders as important for historical, educational, or economic reasons. This could include colonies popular at dive sites.
- Within an MPA: Corals within zones of extra protection may be living under better environmental conditions.
- Within a recreational area: Corals near mooring balls are likely to have more visitors who utilize the resource. This could provide additional awareness of treatment action and potentially greater involvement through citizen engagement. (Alternatively, if recreational diving is large-scale and unsupervised, they are more likely to perish than corals in other areas.)

Once the priority coral reef sites and priority sentinel corals have been identified for monitoring, it is suggested that the following monitoring methodology from Florida be adapted to suit site needs (Neely, 2018).

Methodology — During November and December 2017, Divers using SCUBA surveyed and marked coral colonies with 'cow ear' tags of the following species if present: *C. natans*, *D. labyrinthiformis*, *D. stokesii*, *M. cavernosa*, *M. meandrites*, *O. faveolata*, and *P. strigosa*. A central buoy was placed on the site, and a distance and bearing from this buoy to each marked coral was recorded to aid the diver's navigation of the site during routine monitoring. When each colony was initially marked, the proportion of older exposed skeleton that was not the result of the white blotch disease was recorded. We also measured each colony's length, width, and height to the nearest cm. At approximate two-week intervals, each marked coral head was examined for the presence of white blotch disease and if noted, the proportion of the colony affected was recorded. If disease was observed, a photo was taken of the colony.

Objective: Quantify spatial extent of SCTLD on the reef

In areas where SCTLD is known to be present and any treatments are being implemented, especially if in MPAs, then experienced coral surveyors should be encouraged to conduct at least six, non-fixed AGRRA-coral transects/site to quantify the extent of the disease in spatially-defined transects. These surveys should be repeated at six-monthly intervals to provide periodic assessments of the success of the interventions.

Complete AGRRA-type surveys at long term monitoring sites affected and unaffected by SCTLD can also be used to determine impacts of the disease on coral reef ecosystems including fish populations.

Intervention Treatment Protocol

The recommendation from SCTLD experts in Florida (NOAA, Nova Southeastern University, Florida Fish and Wildlife Commission, Florida Department of Environmental Protection, Florida Keys National Marine Sanctuary) is to treat the disease as quickly and as aggressively as possible once identified in new locations. Mechanical, chemical and biological treatment protocols have been tested in Florida and the lowest failure rates have been achieved by treating SCTLD-affected corals with antibiotics directly applied to lesions. Large-scale field trials indicate that best practice to date is application of amoxycillin trihydrate powder with CoreRx Base2B (manufactured by Ocean Alchemists). Note that amoxycillin belongs to the Beta-Lactams class of antibiotic to which some people are allergic, so it is imperative to verify that no one on dive teams that may be applying this treatment is allergic to Beta-Lactams.

Recognizing limitations in capacity, corals should be prioritized for treatment according to the following guiding principles:

- Portion of colony unaffected: Treatment is likely to be more effective if the majority of the coral survives as a result. A recommended guideline is if greater than 75% of colony is still alive.
- Number of active SCTLD lesions: Each lesion requires initial treatment as well as follow-up. A greater number of lesions may also signify poorer overall health of a colony and thus a higher chance of new lesions developing. Colonies with fewer than 5 lesions are more treatable than those with more.
- Monitoring efficiency: Colonies in proximity to other treated corals, sites, or other ongoing projects will ease subsequent monitoring and re-treatment events.
- Suitability for treatment: Certain colonies may be disqualified for treatment for external reasons. For example, certain treatments (e.g. removal) may not be practical if the coral is attached to a cultural resource. Individual sites and projects should consider these additional factors.

Per Neely, 2018, the protocol for preparing and applying antibiotics is as follows:

- Mix powdered amoxycillin into the base in a 1:8 by weight ratio on the same day as it is being used in a glass beaker or other small container. The total amount prepared depends on how many corals can realistically be treated during the day in question.
- Pack the mixture into 30cc or 60cc syringes.
- In a dive bag pack rubber gloves, antibiotic syringes and modelling clay. Use the syringe to cover the lesion and the immediate area surrounding the lesion. Use your fingers to apply the compound to ensure that it adheres to the lesion (Figure 6) (Neely, 2018).
- Modelling clay can then be applied over the paste to increase adhesion to the coral (Doyle & O'Sullivan, 2019).
- Alternative or additional intervention can be accomplished by creating and treating a firebreak approximately 5 cm away from the disease margin (Neely, 2018).

If CoreRx Base2B is being used then mix with amoxycillin powder just prior to application, otherwise the antibiotic will become ineffective after a few days. Dr. Andy Bruckner of Florida Keys National Marine Sanctuary, suggested that in the absence of CoreRx Base2B, managers apply whatever locally available, cheaper material they may have from the lesion interface over the live tissues as well, in anticipation that this measure will kill the pathogen(s).

Treatment Monitoring

Objective: Assess SCLD interventions

The recommended methodology is visual inspection of treated lesions by capturing photos for photo series comparisons [protocol under development by AGRRA]. This should be repeated at two-week intervals to assess the efficacy of the intervention.

Prevention Methods

Dive Site Selection

In order to possibly prevent the transmission of SCTLD from infected sites to unaffected sites it is recommended that divers not dive infected sites before travelling to unaffected sites. This will help reduce the possibility of transmitting the disease on dive gear.

Decontamination of Dive Gear

After diving on an affected site it is recommended that all dive gear be decontaminated (Figure 4). Decontamination methods will differ depending on equipment.

- Non-sensitive equipment and tools should be soaked for 10 minutes in a 1% bleach solution, rinsed with fresh water and allowed to air dry.
- The bleach wash solution should be allowed to break down in the sun for 24 hours before disposal
- Wet suits, Buoyancy Control Devices (BCDs), masks and fins may be decontaminated in quaternary ammonium disinfectants such as Virkon s, RelyOn and Lysol All Purpose Cleaner. Dive gear should be soaked for 10 minutes in either a .5% solution of RelyOn, 1% solution of Virkon or a 6.6% solution of Lysol and then allowed to air dry.
- Regulators, computers, gauges, underwater cameras and other sensitive equipment should be decontaminated using fresh water and anti-bacterial dish soap or an isopropyl alcohol wipe and then dried (Neely, 2018).

Figure 4: Decontamination poster developed by MPAConnect

Ballast Water Disposal

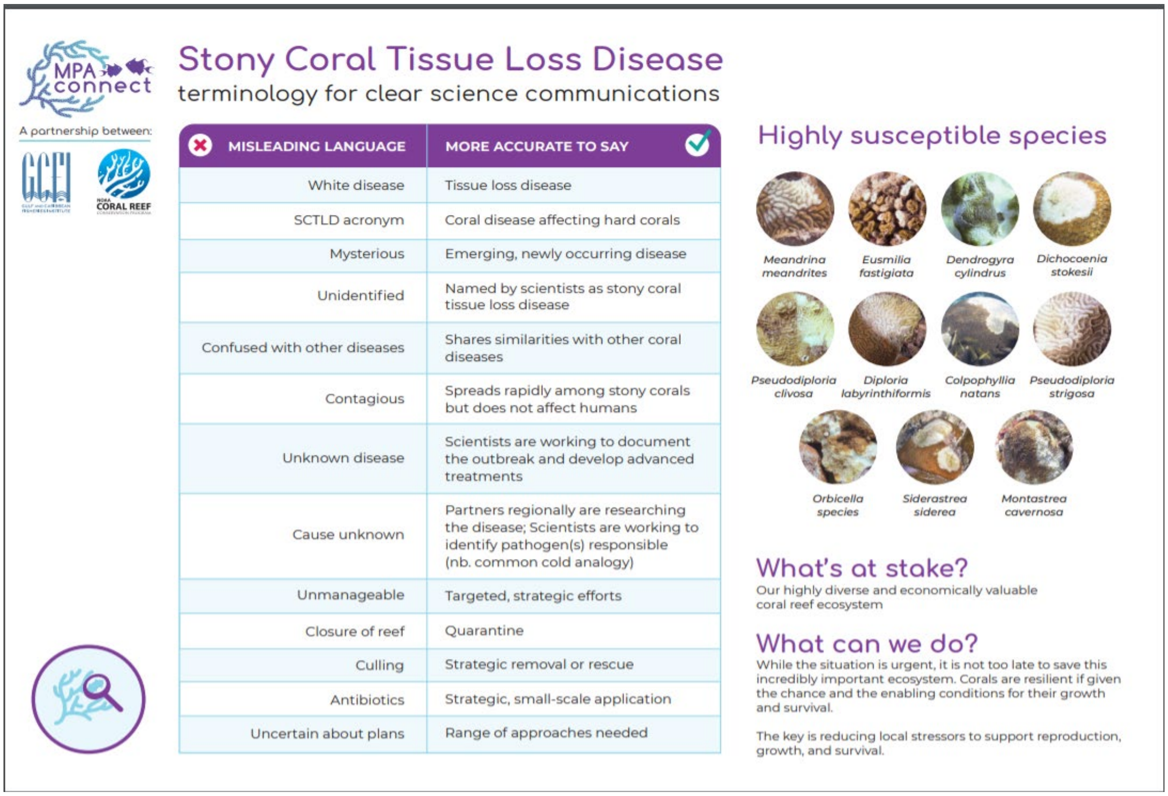
While there is currently no connection between the disposal of ballast water and the transmission of SCTLD there is some concern that it may contribute to it since ballast water exchange containing the SCTLD pathogen may be released through ballast water into unaffected sites. In order to prevent possible transmission by this method additional regulations under the Ballast Water Management Convention may need to be established since current regulations allow for the disposal of ballast water within the same bio-region and this may transmit SCTLD to unaffected sites.

Coral Rescue

In order to protect Caribbean reef diversity, where facilities and capacity to do so exists, it may be necessary to collect representative samples of healthy coral species and house them ex situ until the disease has been effectively treated in the wild. These representatives of susceptible coral species may then be re-introduced into the wild at a later date, maintaining reef diversity. The corals will then be transplanted back at their original site or at a site with a similar habitat.

Communications

Crisis communications measures are justified by managers in the face of the threat posed by SCTLD to coral reefs and associated economies. The lesson learned in Florida has been to ensure unified messaging by all partners involved in the disease, with careful use of appropriate language, minimum use of abbreviations, acronyms and technical jargon. Suggested language for use by managers in describing coral disease is summarized in Figure 5.



MISLEADING LANGUAGE	MORE ACCURATE TO SAY
White disease	Tissue loss disease
SCTLD acronym	Coral disease affecting hard corals
Mysterious	Emerging, newly occurring disease
Unidentified	Named by scientists as stony coral tissue loss disease
Confused with other diseases	Shares similarities with other coral diseases
Contagious	Spreads rapidly among stony corals but does not affect humans
Unknown disease	Scientists are working to document the outbreak and develop advanced treatments
Cause unknown	Partners regionally are researching the disease; Scientists are working to identify pathogen(s) responsible (nb. common cold analogy)
Unmanageable	Targeted, strategic efforts
Closure of reef	Quarantine
Culling	Strategic removal or rescue
Antibiotics	Strategic, small-scale application
Uncertain about plans	Range of approaches needed

Figure 5: Suggested language for use by managers in describing coral disease

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