Rapid Assessment of the occurrence of Stony Coral Tissue Loss Disease (SCTLD) along the southern coast of Grand Bahama, Bahamas

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Submitted by

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Overview

Stony Coral Tissue Loss Disease (SCTLD) is a newly reported disease of Caribbean corals. It was first reported during coral monitoring associated with work on the port of Miami in 2014 (Precht et al. 2016). Since this first report it has spread throughout coral reefs of the Florida reef tract from their northern extent in Palm Beach County to the area west of Key West in the southwest, leaving just the Dry Tortugas without reports of the disease (Muller et al. 2020). The disease has also been reported in other countries and islands in the wider Caribbean region including Mexico, Belize, Jamaica, Dominican Republic, Turks and Caicos, Puerto Rico, US Virgin Islands, Saint Martin, and Saint Eustacius (Kramer et al. 2019). SCTLD is one of approximately 10 diseases and syndromes affecting Caribbean coral species, but it is of particular concern due to: (1) its rapid spread across individual colonies, (2) high mortality rate, (3) rapid spread between reefs, (4) high infection rate, and (5) broad range of corals infected by the disease, which is thought to be around 22 species — roughly half of the coral species reported from The Bahamas. Furthermore, researchers have yet to identify the specific pathogen causing the disease, although it is presumed to be bacterial based on application of antibiotics to corals halting the progression of the disease on some colonies. <u>Along with climate change, this disease is believed to represent one of the greatest, if not the greatest threat to Caribbean corals</u>.

Until 2019, the disease was not reported from The Bahamas and was not detected in approximately 300 rapid coral reef assessments conducted in The Bahamas using AGRRA methodology since 2015 (Dahlgren in prep.). Coral surveys following AGRRA protocols specifically look for diseases to coral colonies and mortality rates within colonies. <u>In AGRRA surveys, SCTLD was never reported in any assessment in The Bahamas from 2015-2019, and other active diseases were reported from an average of only 1.4% of over 28,000 corals assessed</u>. In these surveys, the site with the greatest outbreak of any disease had a maximum of 17% of corals infected, but the majority of sites had no active disease observed.

In December 2019, Mr. Joseph Oliver of Coral Vita reported what appeared to be an outbreak of white plague disease along the southern Coast of Grand Bahama in depths of 2-17m, affecting brain corals (*Pseudodiploria strigosa, P. clivosa, Diploria labrynthiformis*), and other meandroid corals (*Meandrina* spp.), as well as *Dichocoenia stokesi* and *Montastraea cavernosa*. Later, photos of tagged corals showing signs of the disease, including photos of the same colonies taken at three intervals between November 2019 and January 2020 (Fig. 1) were shared with Dr. Craig Dahlgren, who became concerned that the corals may be infected with SCTLD.

Figure 1. Time series of *Pseudodiploria strigosa* brain coral infected with SCTLD from November 8, 2019 (left) to November 27, 2019 (middle) to January 16, 2020 (right). The scale bar in the right photo is marked in one inch increments (Photos courtesy of Coral Vita).

The initial suggestion of white plague disease was also the initial diagnosis of SCTLD in Miami in 2014 (Precht et al. 2016) before it was examined further and found to be a new disease, but several indicators suggested that the disease reported in Grand Bahama was actually SCTLD. First, the species reported to be infected were among the more susceptible species for SCTLD. Second, very little coral disease and only one case of white plague disease was reported from the southern shoreline of Grand Bahama during AGRRA surveys in November 2018 or October 2019, shortly after Hurricane Dorian (Dahlgren in prep.), suggesting a rapidly spreading disease with high infection rates like SCTLD. After sharing the photos with other researchers who are working on SCTLD in the Caribbean, experts agreed with the diagnosis of SCTLD. Outside experts also suggested (1) verifying its presence through in water visual assessments and (2) determining the scale, scope and severity of the disease. While in water assessments were planned for February and early March 2020, weather prevented these assessments until March 12-15.

The assessments conducted in March 2020 were very rapid assessments aimed at:

- Identifying the spatial extent of the disease (alongshore from east to west and onshore to offshore from shallow to deep reefs)
- Determining which coral species and what % of colonies of each species were infected
- Using these data to try to understand how the disease outbreak has spread.

This last factor is particularly important for developing strategies to contain the spread of the disease. Because SCTLD rapidly kills corals (within weeks) and some species are more vulnerable or show more rapid signs of the disease, it may be possible to determine if the outbreak is spreading across the reef in one direction, out from a point of origin in either direction, or in patches that may correspond oceanographic currents, or to any specific threats, stresses or impacts that may influence its spread (e.g., hurricane damage, proximity to land based sources of pollution or nutrients, dive sites, etc.).

Rapid Assessments of SCTLD

Over four days from March 12-15, a team of researchers assessed the extent of the disease, conducting rapid assessments of 25 reefs between High Rock in the east and Bootle Bay in the west, a distance of approximately 65 km (nearly 40 miles) along Grand Bahama's southern shoreline (Fig. 2). Surveys consisted of a team of 2-4 snorkelers (<5m depths) or divers (5-20m depths) assessing corals at each site for 15 minutes. At each site at least one trained diver identified all species infected with SCTLD (and other diseases) and classified and counted infected colonies, colonies without infection and ones that appeared to have died recently for each species. This recently dead category included all colonies that were still white, having skeleton exposed with no living tissue, as well as those covered with amicrobial film or sparse turf algae. It also included colonies covered with dense turf algae but where skeletal features (ridges, septa etc.) could clearly be seen with minimal erosion, consistent with the appearance of corals that had died within 2 months in as observed in photos provided by Coral Vita (Fig. 1). At sites where few species were infected, only those species with individuals exhibiting signs of SCTLD were identified and grouped into disease effect categories, with other species noted but not counted. At sites where coral colonies were particularly abundant, counts were limited to 100-120 colonies for the most common species. In addition to quantifying infection rates, other divers took photos and videos at each site to help describe the site and assess the progression of the disease across individual colonies.

Figure 2. Map of sites surveyed for SCTLD in March 2020. Sites <5m deep are shown in red and sites 10-18m are shown in blue.

Results

A total of 25 sites were assessed, including 18 shallow reefs (2-5m) spread between High Rock in the east and Bootle Bay in the west, including one site in Lucayan National Park and one in Peterson Cay National Park. Seven reefs deeper (10-18m) were also assessed, including one in Lucayan National Park, two between Lucayan National Park and Peterson Cay National Park, and four sites between the Grand Bahama Waterway and entrance to Bell Channel (Fig. 2).

In total approximately 3,630 corals were assessed with over 930 or 25% infected with SCTLD across all sites. The 18 taxa observed to be affected by SCTLD included (Fig. 3):

- *Pseudodiploria strigosa* (symmetrical brain coral)[1]
- *Pseudodiploria clivosa* (knobby brain coral)[1]
- *Diploria labyrinthiformis* (grooved brain coral)[1]
- *Montastraea cavernosa* (large-cup star coral)[1]
- *Colpophyllia natans* (boulder brain coral)[1]
- *Dendrogyra cylindrus* (pillar coral)[1]*
- *Dichocoenia stokesii* (elliptical star coral)[1]
- *Eusmilia fastigiata* (smooth flower coral)[1]
- *Meandrina meandrites* (maze coral)[1]
- *Siderastrea siderea* (starlet coral)*
- *Orbicella annularis* (lobed star coral)*
- *Orbicella faveolata* (mountainous star coral)*
- *Orbicella franksi* (boulder star coral)*
- *Solenastrea bournoni* (smooth star coral)
- *Stephanocoenia intersepta* (blushing star coral)
- *Agaricia agaricites* (lettuce coral)
- *Mycetophyllia* spp. (cactus coral)
- *Favia fragum* (golfball coral)

Taxa that were observed at sites but were not observed to have SCTLD included:

- *Agaricia* spp. (plate/saucer corals)
- *Porites astreoides* (mustard hill coral)
- *Porites porites*(finger coral)
- *Porites divaricata* (thin finger coral)
- *Porites furcata* (branched finger coral
- *Acropora palmata* (elkhorn coral)*
- *Acropora cervicornis* (staghorn coral)*
- *Acropora prolifera* (fused staghorn coral –hybrid between the other 2 *Acropora* species)
- *Scolymia* spp. (disc coral)
- *Siderastrea radians* (lesser starlet coral)

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[1] Indicates corals most vulnerable to SCTLD; * indicates critically endangered species (www.agrra.org)

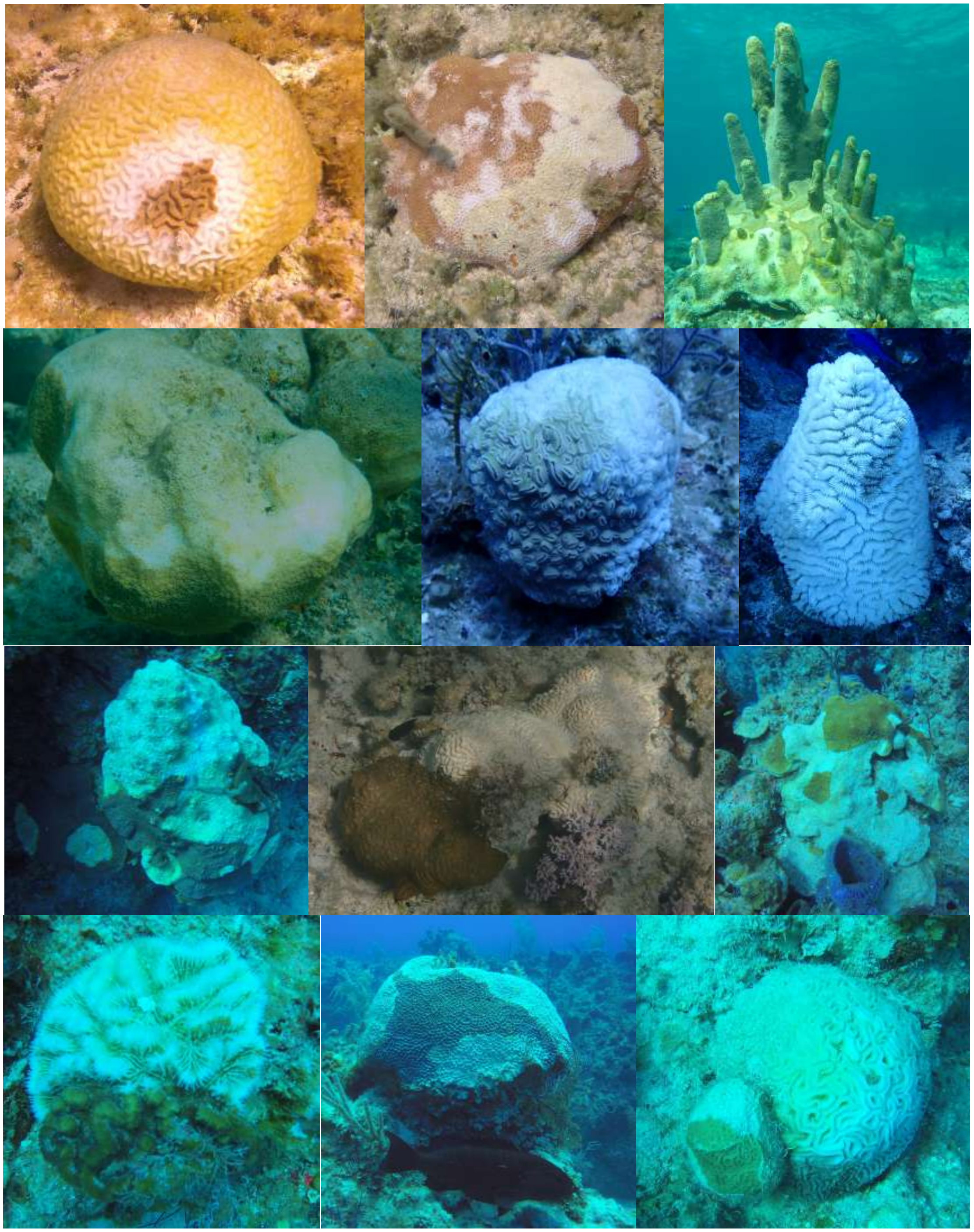

Figure 3. Examples of corals infected by SCTLD off Grand Bahama including (top row, L to R): *P. strigosa, S. Siderea, D. cylindrus*; (2nd row L to R): *O. annularis, D stokesi, Meandrina* sp.; (3rd row L to R): *O. franksi, P. clivosa, O. faveolata*; (Bottom row L to R): *Meandrina sp. M. cavernosa, A. agaricites* (left) and *D. labrynthiformis* (right).

The number of species infected per site ranged from 2-9 species (Fig. 2) with an average of approximately five species per site for both deep (5.1 species per site) and shallow (4.8 species per site) reefs. Up to 40% of coral colonies belonging to species vulnerable to SCTLD at shallow sites were infected while less than 5% of coral colonies belonging to vulnerable species were observed to be infected at deeper sites. An additional average of 16% of corals were recently dead at shallow sites, while only 2% were recently dead at deeper sites.

Of the species infected with SCTLD, *Pseudiploria strigosa* was most affected, showing signs of disease or newly dead colonies at every site where it was observed to occur. On shallow reefs, where it was one of the dominant species, the average percentage of *P. strigosa* colonies that were infected with SCTDL was 50%, and 30% of colonies on average were recently dead, with a high of 77% infected and 88% dead. At over half of shallow sites, the sum of infected and dead colonies of *P. strigosa* totaled at least 75% (Fig. 4).

Other species commonly infected on shallow reefs included other brain corals like *Pseudodiploria clivosa* (42% infected, 1% recently dead), *Diploria labrynthiformis* (34% infected, 8% recently dead) and the massive *Montastraea cavernosa* (39% infected, 2% recently dead) (Fig. 4). While not common, eight of the 12 *Dendrogyra cylindrus* colonies observed on shallow reefs were infected and three were recently dead, leaving only one colony healthy.

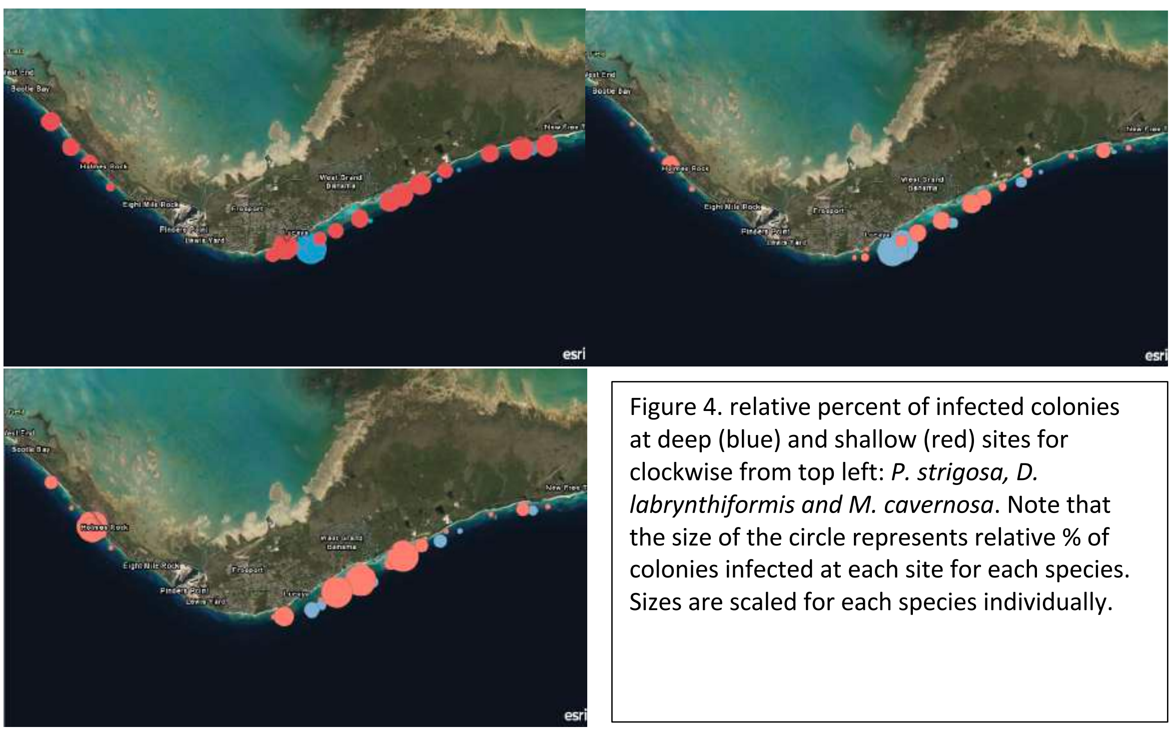

Figure 4. relative percent of infected colonies at deep (blue) and shallow (red) sites for clockwise from top left: *P. strigosa, D. labrynthiformis and M. cavernosa*. Note that the size of the circle represents relative % of colonies infected at each site for each species. Sizes are scaled for each species individually.

On deeper reefs, the number of species infected per site ranged from 2-4 at the three eastern sites and 6-9 at the sites to the west of the Grand Bahama Waterway (Fig.5), suggesting that closer to Freeport, the disease has spread to a greater extent. On deeper reefs *Montastraea cavernosa* was the most frequently infected species with 21% of colonies infected on average across all sites and, 14% recently dead. Another species with a high infection rate, but lower overall abundance was *Diploria labrynthiformis*, with 20% of colonies infected and 9% recently dead across all sites. More common *Orbicella* spp. that were one of the dominant species on deeper reefs had up to 10% of colonies infected and no observations of recent total mortality (Fig. 6). Other common species at deep sites like *Agaricia agaricites* were not observed to be infected at the three eastern sites, but a few colonies (<1% of total number of colonies observed at any site) were infected at three of the four sites to the west, off the main population center of Freeport.

Figure 5 number of species affected at deep (blue) and shallow (red) sites. Size of circle reflects relative number of species observed to be infected, ranging from two (small circles) to 9 (largest circle at westernmost deep site visited).

Based on the rapid assessment of these reefs, we can make several inferences and draw several conclusions about SCTLD around Grand Bahama. In shallow waters, the disease has spread over a very large area. Because we saw SCTLD at every site we visited and it was prevalent in *P. strigosa* at all shallow sites, it is reasonable to expect that the disease may have already spread across the entire south coast of Grand Bahama from West End to McLean's Town. While we saw some infected colonies on all of our deeper surveys the disease may not have spread as much for deeper reefs. Spatial patterns suggest that the center of spread of the disease may be in the Freeport area between the port and Bell Channel area. This conclusion is based on the lower infection rates on deeper reefs to the east and the infection primarily occurring in only the most vulnerable species. To the west it is difficult to ascertain the spatial extent of the disease since reef area in the 10-20m range is limited west of the port. High infection and mortality rates of *Orbicella* spp. and other species on shallow reefs to the west of the Port, however, suggest that the spread of SCTLD westward may be more advanced than the eastward progression of the disease.

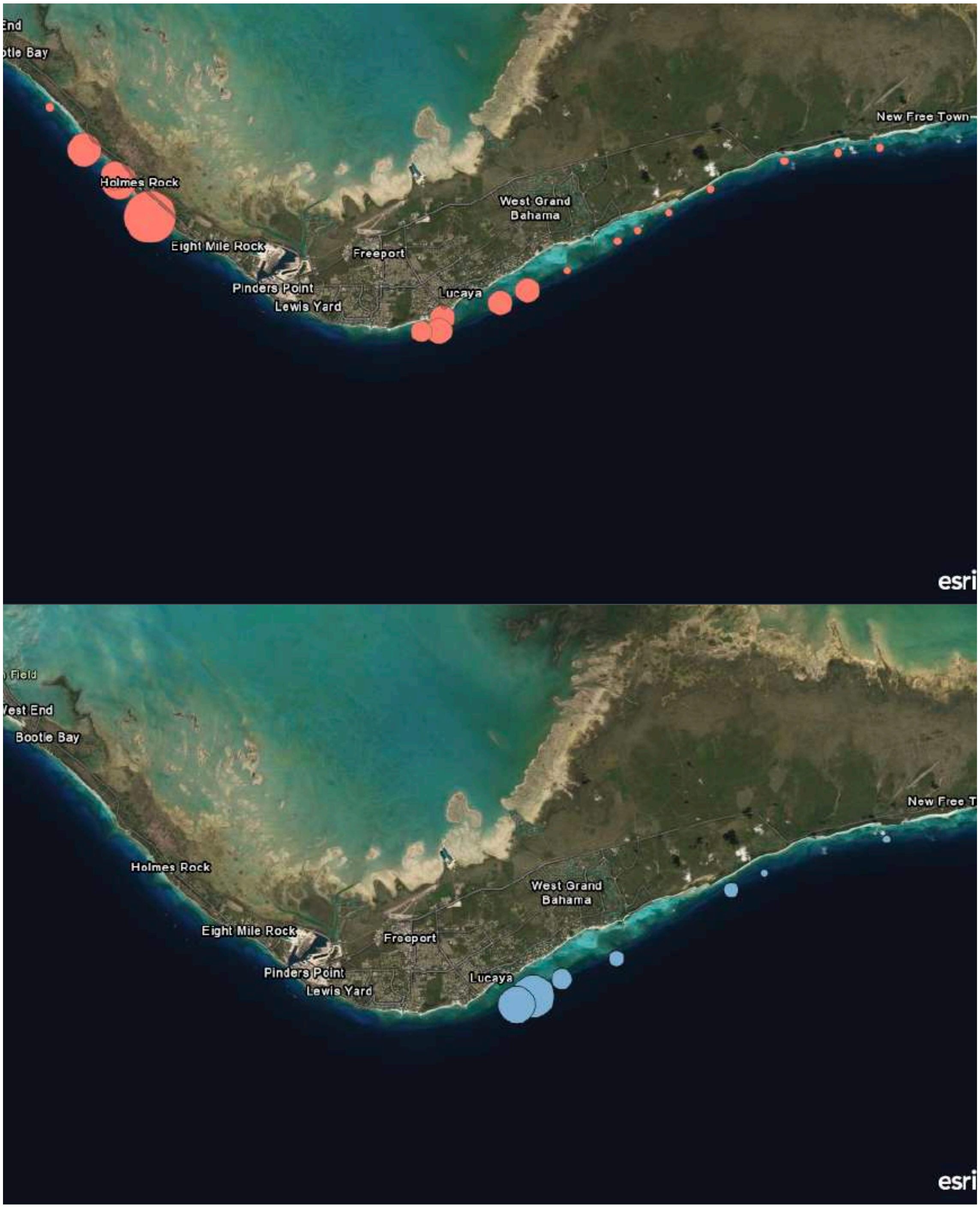

Figure 6. Percent of *Orbicella* spp. colonies infected by SCTLD on shallow (top) and deep (bottom) reefs. This includes *Orbicella annularis, O. faveolata and O. franksi* combined, with O. annularis dominating shallow reefs, but not found on deeper reefs and O. franksi being common on deeper reefs but absent from shallow reefs. For both deep and shallow reefs, the general pattern is for higher infection rates close to the port and/or Port Lucaya areas.

The observed spatial patterns suggest that the disease may not have reached Grand Bahama by natural current eddies originating in Florida or other infected areas, in which case we would expect patterns of highest mortality and greatest infection rates at westernmost sites. INsrtead it is more likely that SCTLD reached Grand Bahama through vessel traffic into and out of Freeport. Most likely ballast water from large commercial vessels (cruise ships or cargo ships) coming from Miami or another infected area are the culprit and may present the greatest threat to spread of the disease (Fig. 7). Since its introduction, however, the disease has spread over vast areas on shallow reefs, probably due to alongshore currents. In speaking with dive operators in the area, Coral Vita found that they began to see "corals die off" as early as July 2019 around Freeport. Natural flow of ocean currents that carry the water borne pathogen that causes SCTLD (Muller et al. 2020) may be responsible for spread of the disease between sites, but transmission by commercial and private vessels via ballast or bilge water, dive gear, fishing gear and other means is believed to contribute to spread of the disease. Hurricane Dorian may have also played a role in either transport of the disease through water movement, advancing the progression of the disease to the east after the storm. Hurricane Dorian may have had additional effects on the spread of the disease through the stress that it caused corals such as "sand blasting" living coral tissue, sediment resuspension, temperature shock (as temperatures rapidly dropped 4-6°C), introduction of new microbes from inland wetlands, or other stressor that may have made corals susceptible to SCTLD.

Figure 6. Ship outside of the Freeport container port dumping ballast water on March 13, 2020. It is unknown where the water was taken onboard, but this may be the means by which the pathogen causing SCTLD was transported to Grand Bahama.

<u>At present it may be too late to halt the progression of the disease on shallow reefs of Grand Bahama, but there may be options for some deeper sites where the disease may just be starting to gain a foothold</u> to the east, in the area of Lucayan National Park and East Grand Bahama. In these areas, culling infected coral and removing them from the system before they can spread the disease is a potential option for controlling the disease. Also, the possibility of treating individual infected coral colonies with antibiotics, as they are doing in Florida, is a potential option. However, the feasibility of this option is questionable in terms of cost and logistics based

on the remoteness of this area, uncertainty about the effectiveness of antibiotic treatments, lack of information on water flow and the possible spread of disease from inshore to offshore reefs, and the sheer scale of the undertaking given the vast extent of reef in the area. The option of culling corals is also a significant undertaking with its own logistical issues. Effective implementation of either option must begin early, however, before the disease spreads more and increases the number of coral colonies that require intervention at a site.

Another suite of options would be to try to limit human-facilitated transmission of the disease. This could be done through limiting access to certain areas or implementing mandatory or recommended biocontainment practices including use of disinfecting agents (e.g., bleach solution, ammonia, sodium perchlorate or other disinfectants) to treat gear (e.g., diving or fishing) and ballast/bilge water. This may help contain the anthropogenic spread of the disease but will not prevent the natural spread of the disease through water transport or other vectors (e.g., corallivores such as certain snail species or butterflyfish).

It should also be noted that while it may be too late to eradicate the disease or contain it along the southern coast of Grand Bahama, it is critical to the reefs of The Bahamas that action is taken to prevent its further spread throughout the archipelago. Containment of the disease to Grand Bahama may be possible through actions to limit human transmission of the disease. This effort should start immediately and will require a significant investment in communicating appropriate actions and the need for such actions to promote the changes to prevent the spread of the disease. Communications to fishers, dive shops and boaters to teach them best practices to prevent spread of disease and to report potential outbreaks of the disease in the future is critical. Effective restrictions on ballast water exchange by shipping and cruise ships is also needed.

Additional studies may also be helpful to (1) identify resistant or resilient coral genotypes or areas less affected by the disease; (2) contribute to regional efforts to identify and develop a means of controlling the spread of pathogen(s) causing SCTLD; and (3) monitor reefs to detect any progression of the disease and attempt to eradicate it before it has a chance to spread as it has in Grand Bahama. Research in to restoring corals to infected reefs is also necessary to help promote recovery of reefs that have been damaged by the disease. While these research and monitoring priorities are possible at present, resources for these actions are insufficient at present and current restrictions on sampling and exports will be prohibitive to some of these activities.

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