Occurrence of Stony Coral Tissue Loss Disease on Vauxhall Reef and a Breakwater in the Folkstone Marine Protected Area of Barbados

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GEOG 496

McGill University

April 2023

Contents

Abstract

Stony Coral Tissue Loss Disease (SCTLD) is a highly contagious and fatal coral disease that has been detected in various islands of the Caribbean. In early 2023, it was suspected to have spread to the Barbadian coast; therefore, this study explores the presence and abundance of SCTLD on the West coast of Barbados. Two sites, Vauxhall Reef and the breakwater near "Surfside" in Holetown, were examined and data were collected through photographing. *Pseudodiploria strigosa* and *Pseudodiploria clivosa* were the most abundant species observed in both locations, with *Pseudodiploria strigosa* demonstrating the highest rates of infection of coral diseases. The study examines the presence of SCTLD as well as White Plague Disease (WPD) affecting the corals along the reef and breakwater. Through a comparative analysis conducted with previous photos taken at the Surfside breakwater site, the change in cover by WPD was found to have increased over sixteen days. SCTLD was identified on a variety of coral species in both locations, however, accurately differentiating symptoms of SCTLD and WPD was a barrier to confident identification. WPD was found to be more abundant at both sites than SCTLD, and SCTLD was more abundant at Vauxhall Reef than the Surfside breakwater, specifically on the first shipwreck at Vauxhall Reef.

Introduction

Coral reefs contain the highest biodiversity of all aquatic ecosystems, providing an essential habitat for more than 25% of marine life (UNEP, 2021). Coral reefs provide a variety of ecosystem services, such as food provision and buffering against extreme climate events (Eddy et al., 2021). Furthermore, reefs protect coastal areas from erosion and generate sediments that contribute to the growth and maintenance of beaches (Brathwaite et al., 2022). Beyond ecological importance, Barbadian reefs strongly support the national economy by their appeal to foreigners as important areas of coastal tourism (Fabian Hinds of CZMU Barbados, personal communication, Feb. 27, 2023). Coral reefs are threatened by anthropogenic activities, ocean acidification and sea surface temperature rise due to climate change, and spread of coral diseases (Aichelman, et al., 2021).

Barbadian Reefs

Actively growing coral reefs tare currently largely restricted to the leeward coast, primarily between Shermans and Bridgetown. The fringing coral reefs in this area are divided into 6 main zones, extending from the beach to the deep ocean floor: the Reef Flat, *Diploria-Palythoa* Zone, Reef Crest, Seaward Slope, Reef Front, and Deep-Water communities (Lewis, 1960).

Lewis (1960) describes the 6 main zones as follows: The Reef Flat has a depth of less than one foot of water (0.3 m), primarily consisting of “reef debris, flat circular stones, loosely cemented calcareous fragments mixed with sand, or a flat rock pavement” (1135). This area experiences limited coral colonization, although one encrusting species, *Siderastrea radians,* is present in small colonies. This area stretches around 50 meters in width and adjoins the *Diploria-Palythoa* Zone. Per the name, this approximately 10-meter width zone is dominated by the coral species *Pseudodiploria clivosa* (syn *Diploria clivosa*) and *Palythoa mammillosa*, which is a colonial zoanthid. The following zone, the Reef Crest, is the climax zone of the reef supporting prolific coral growth; tops of the reef in this zone lie at 2-4 ft (0.6 to 1.2 m) below Mean Low Water and the shallowest parts are exposed on the lowest tides. This zone ranges between 20 to 100 meters wide, and the coral lives on spurs and ridges that compose the area. Next is the

Seaward Slope in which the reef slopes gradually downwards to the bottom 5- or 6-meter depth and is elevated 1-3 m above the bottom. Finally, on the fringing reef, there is the Reef Front characterized by scattered patches of coral at depths of circa 5-10 m. These two zones are dominated by the corals *Orbicella annularis* (syn *Montastrea annularis*) and *Siderastrea siderea*, where *Siderastrea siderea* are often an important structural element within the reef and can be a primary colonizer in areas where *Montastrea annularis* is less abundant. Beyond are Lewis's (1960) Deepwater Communities at 10-30 m depth.

As described above, *Montastrea annularis* plays a primary role in developing the reefs and are the primary structural coral of reefs in Barbados. *Montastrea annularis* is composed of large clumps and sheets that secondary coral use to establish new growth. This secondary establishment is the dominant reef development process in the Reef Crest, Seaward Slope, and Reef Front as previously described.

Stony Coral Tissue Loss Disease

SCTLD is a highly contagious and fatal infection affecting reef-building coral organisms (Meyer et al., 2019). It was first discovered on the coast of Florida in 2014 (Heres et al., 2021). Since then, it has spread across the Caribbean, threatening coral development and reef ecosystems in the region. AGRRA, the Atlantic and Gulf Rapid Reef Assessment Program, tracks the disease and maintains an interactive map of its confirmed occurrence and presumptive or possible occurrence through the Tropical Atlantic region (see https://www.agrra.org/coral-disease-outbreak/). Prior to Mar 3, 2023, there were 3 reports of possible occurrence on deep reefs (11 to 30 m) on the west coast of Barbados (those made on Nov 18, 2022, Dec 1, 2022, Jan 5, 2023 by S Howell and R. Suckoo); two reports of possible occurrence on the Bajan Queen (shipwreck in Carlisle Bay on the south coast) by M. Alvarado (Jan 1, and Feb 23, 2023), and 18 reports of its possible occurrence within the Folkstone MPA by D. Patriquin (Jan 11 to Feb. 25, 2023). As of submitting this report, April 4th 2023, AGRRA had still not officially confirmed the presence of SCTLD in Barbados. Circa May 1st, 2023, AGRRA has subsequently confirmed its presence at many sites.

The disease initially appears as multiple lesions on coral, resulting in tissue loss, with later stages of the disease killing portions of the coral body and revealing bright white skeletons that become covered by turf, macroalgae, or sediment (Estrada-Saldívar et al., 2020). SCTLD has very similar physical properties to a more established disease in the region, White Plague Disease (WPD). WPD also affects the tissue of reef-building corals, and two strains (WPDI and WPDII) have been found in the region. WPD, first reported in 1977 (Morais et al., 2022), has been recorded in Barbados in the past (Hoetjest et al., 2002). Initially, SCTLD was suspected to be a third strain of WPD due to its similarities, such as SCTLD's extremely contagious properties (Cróquer et al., 2021). WPD typically begins at the base of a coral and gradually spreads across the entire organism, whereas SCTLD has been observed to begin an infection with multiple lesions which spread simultaneously to take over the organism. However, even with these diagnostic tools, experts continue to experience great difficulty differentiating between SCTLD and WPD in the field due to their striking similarities (Cróquer et al., 2021). Not all stony corals are susceptible to SCTLD; *Acropora cervicornis*, *Acropora palmata*, and *Porites asteroides* are a few species that have shown resistance (Coral Disease, 2023).

Preventing the disease before it spreads requires an understanding of what facilitates initial disease spread. Ballast water has been suggested as a possible vector of the disease, as it is known to transport various microorganisms, with variably effective management practices currently in place in the United States to prevent this. However, no direct connection has been found between SCTLD outbreaks and ballast water dumping. Further research is needed to continue to investigate ballast water and ship vessels as possible vectors for SCTLD (Rosenau et al., 2021). Increased water temperatures have also been found to increase the ability of the disease to spread, carrying implications for the future of Caribbean reefs in a warming climate (Heres et al., 2021). Changes in other environmental factors, such as increased rainfall, altered ocean circulation, and ocean acidification may also have additional effects on coral disease spread, but research on this is ongoing (Sokolow, 2009). Additionally, decreased water quality and nutrient pollution from anthropogenic activities on coasts housing coral reefs has been found to negatively impact coral species' ability to fight infection from various coral diseases (Estrada-Saldívar et al., 2020).

Potential Treatment and Restoration

Several treatment methods to slow down and prevent the spread of SCTLD have been explored, including antibiotics, gray infrastructure, and nature-based solutions. Amoxicillin antibiotics have had success slowing the progression of SCTLD on various stony coral species, however further research on their use for SCTLD is needed (Neely et. al, 2020). Different antibiotics have had varying outcomes, with Base 2B being applied alongside amoxicillin antibiotics showing a high success rate in preventing the spread of lesions (Neely et. al, 2020). However, while there has been such success at the lesion-level, the treatment did not necessarily prevent SCTLD lesions at the colony-level when studied long-term, or secondary infections. Antibiotic treatment remains a hopeful intervention against SCTLD, however, there remain shortcomings in the efficacy of the treatment to be explored in future studies (Shilling et al, 2021; Walker et al., 2021).

In addition to direct treatment by antibiotics, gray infrastructure is being implemented to support overall reef health through ecosystem restoration. Gray infrastructure refers to physical interventions such as breakwaters, sea walls, and bulkheads for coastal protection or reefs. These structures can provide protection from wave damage and areas for new habitat. However, gray infrastructure is challenged by large expenses associated with construction, inability to adapt to changing conditions, inability to self-maintain, alteration of the natural character of a site, and degradation of the health of existing coral reefs (Brathwaite et al., 2022).

Nature based solutions includes interventions such as coral gardening and fishery marine protected areas (MPAs). Reef restoration is important not only for individual coral health but also for the enhancement of total reef ecosystem resiliency by encouraging biodiverse coral and fish species. As not all corals are affected by WPD and SCTLD; reef ecosystems that are more diverse are not as vulnerable as reefs composed of only susceptible coral species (Sweet et al., 2019). Coral gardening can encourage strategic growth of non-susceptible species in areas at risk to reduce disease spread. Additionally, increasing functionally diverse fishes through MPAs can lessen the frequency of coral disease infections and spread. Corallivorous fish species feed primarily on damaged or diseased coral, thereby acting as possible vectors for coral diseases.

Maintaining a healthy and biodiverse reef ecosystem introduces predation of and competition with these corallivorous fish populations (Raymundo et al., 2009).

Furthermore, fish are critical to maintaining healthy reef ecosystems and provide nutrients to the reefs through deposits of carbon, nitrogen, and phosphorus (Allgeier et al., 2016). Fish also remove macroalgae from corals, preventing the algae from smothering coral and outcompeting coral on the reef (Ceccarelli et al., 2018). The fish present at these locations are vital to the survival of the coral, especially as more corals are becoming infected with SCTLD and WPD. Consequently, fish also depend on the habitat created by corals so coral diseases could pose a threat to reef fish in areas of high vulnerability.

Research Statements

Research Statement

To investigate the presence or absence of Stony Coral Tissue Loss Disease and White Plague Disease at two sites, on different coral species and in different reef zones, in the Folkstone Marine Protected Area of Barbados.

Objectives

The purpose of this research study is to analyze the presence and distribution of Stony Coral Tissue Loss Disease (SCTLD) contributing to further coral degradation. This study includes the collection of data, via photographs, of two Barbadian coastal sites: Vauxhall Reef and the Holetown breakwater near “Surfside” (hereto referred to as “Surfside breakwater”). Thereafter, this data was compared with photos taken sixteen days prior at the Surfside site.

Hypothesis

We hypothesize that infected corals with symptoms of SCTLD and of WPD will be present on some corals and sites and have increased at areas of previous observation, definitively marking Barbados as an emerging zone of infection.

Considerations

Based on the current literature, an increase in infection presence could be exacerbated by regional impacts, including climate change effects, such as increased rainfall, ocean acidification, or sea surface temperatures (Sokolow, 2009; Williams et al., 2021). Human activity may introduce local impacts, such as pollutants or physical disturbances, that increase the vulnerability of specific locations to disease (Lamb & Willis, 2011). With a higher presence of SCTLD we also predict to also observe a higher presence of WPD as more coral will be vulnerable in the area. In observation of WPD or SCTLD cases, there was no prior expectation of infection frequency, except that the Atlantic and Gulf Rapid Reef Assessment Program (AGRRA) had not yet confirmed the presence of SCTLD based on reports to date (AGRRA, Mar. 24, 2023; David Patriquin, personal communication, based on discussions he had with Judith Land of AGRRA in Feb. 2023).

Methods

The study took place at two western coastal locations, with the first being the Surfside breakwater and the second being Vauxhall Reef further south along the coast. These locations were chosen due to their diversity and the density of coral species of concern, as well as the suspected presence of SCTLD. Additionally, the shipwreck adjacent to Vauxhall Reef is thought to be one of the first places affected by SCTLD (D. Patriquin, personal communication). Research was conducted under the advisory of Dr. Patriquin, a retired biologist who volunteers with CORALL (see www.corallbarbados.org) while in Barbados, who had conducted earlier observations on infected corals in the area (see www.versicolor.ca/barbados). The route used for analysis followed the same route that was previously photographed by Dr. Patriquin, starting at the Surfside beach shore and the Vauxhall shore, going outwards along the reef (Appendix A). Dr. Patriquin geo-located reference points to accurately position photos along the reef. With these points, coral distribution was accurately measured between the reef zones in the subsequent analysis.

Data collection took place during low tide to ensure the reefs were shallow enough to dive and photograph affected corals. Two sets of photos were taken sixteen days apart, with two cameras. The initial set of photos was taken by Dr. Patriquin on February 15th on a SeaLife MICRO 3.0. The same camera was used for data collection by students on March 3rd and 4th, with Dr. Patriquin taking additional photos on these days with an Olympus Tough TG6. On March 3rd at Surfside breakwater, 188 photos were captured using the SeaLife MICR0 3.0 and 550 photos on the Olympus Tough TG6. On March 4th at Vauxhall Reef, 214 photos were captured on the SeaLife MICR0 3.0 and 270 photos on the Olympus Tough TG6.

Figure 1. Pseudodiploria strigosa infected with WPD

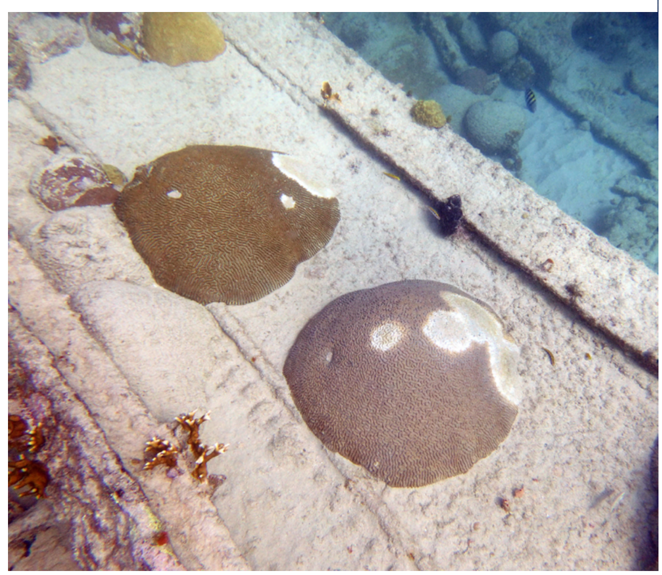

Figure 2. Pseudodiploria strigosa infected with SCTLD

Analytical Methods

Photos of coral were examined separately by location, with data collected for Vauxhall Reef and for the Surfside breakwater. Infected coral species were identified based on photo ID kits, reference photos, and guidance from marine experts (AGRRA, Jan. 17, 2023; D. Patriquin, personal communication, March 29, 2023). Different brain coral species were identified through specific criteria including the size, shape, space between ridges. Disease was then identified in photos, either WPD or SCTLD, assigning a count of the abundance of each identified disease to the identified species of coral. The diseases were identified through the physical differentiations of SCTLD and WPD given by Cróquer et al. (2021). Infected corals showing a more defined white line, with the infection starting in a singular spot on the coral and gradually enveloping the rest of the organism were identified as being infected with WPD (see Figure 1), while corals with multiple textured lesions and sloughing tissue were identified as being infected with SCTLD (see Figure 2). Despite these differences, both diseases present very similar physical symptoms, which created difficulty in confidently determining which disease was being observed.

The spatial information collected at the Vauxhall Reef with the Olympus Tough TG6 was used to designate the photos into 11 different sublocations along the reef. This information was placed in a table to examine the abundance of each of the diseases among separate locations and sublocations, as well as among a variety of species of coral (Appendix B). At the Surfside breakwater, no geo-located points were taken as the study followed the breakwater in a straight line. The breakwater was subdivided into smaller sections by visual landmarks to ensure the distribution of infected corals was accurately counted. Additionally, photos from each camera were cross-referenced to ensure no infected corals were double counted.

The coral species of the reef and breakwater included hard corals such as *Acropora cervicornis*, *Acropora palmata*, *Siderastrea siderea*, *Orbicella annularis*, *Montastraea cavernosa*, *Porites asteroides*, and species in the families *Mussidae* and *Merulinidae,* brain corals. Documented brain corals include *Pseudodiploria strigosa* and *Pseudodiploria clivosa.* Not all coral species observed showed signs of infection with WPD and SCTLD; some corals exhibited symptoms of other diseases and damage (Appendix C).

Results

SURFSIDE	Stony Coral Tissue Loss Disease			White Plague Disease			TOTAL	
	Pseudodiploria clivosa	*Pseudodiploria strigosa*	*Siderastera radians*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastera radians*	SCTLD	WPD
TOTAL	1	3	1	10	126	1	5	137
- ZONE TOTALS -								
ZONE 1 (1-2)	0	0	0	0	9	0	0	9
ZONE 2 (2-3)	1	0	0	2	29	0	1	31
ZONE 3 (3-4)	0	0	0	1	19	0	0	20
ZONE 4 (4-5)	0	0	0	1	9	0	0	10
ZONE 5 (5-6)	0	0	0	0	4	0	0	4
ZONE 6 (6-7)	0	3	1	1	32	1	4	34
ZONE 7 (7-8)	0	0	0	5	24	0	0	29

Table 1. Total number of corals infected with SCTLD and WPD at the Surfside breakwater

VAUXHALL	Stony Coral Tissue Loss Disease						
	Pseudodiploria clivosa	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*
TOTAL	1	15	0	3	2	1	0
- ZONE TOTALS -							
DIPLORIA-PALYTHOA (1-2)	0	0	0	0	0	0	0
REEF CREST (2-3)	0	1	0	3	0	0	0
SEAWARD SLOPE (3-4)	0	0	0	0	0	0	0
REEF FRONT (4-5)	1	4	0	0	0	0	0
WRECK I (5-6)	0	5	0	0	0	0	0
WRECK II (6-7)	0	0	0	0	0	0	0
REEF FRONT #2 (7-8)	0	2	0	0	0	0	0
WRECK III (8-9)	0	0	0	0	0	0	0
REEF FRONT #3 (9-10)	0	1	0	0	0	0	0
SEAWARD SLOPE #2 (10-11)	0	1	0	0	0	0	0
REEF CREST #2 (11-12)	0	1	0	0	2	1	0

Table 2. Number of corals infected with SCTLD at Vauxhall Reef

VAUXHALL	White Plague Disease							TOTAL	
	Pseudodiploria clivosa	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*	SCTLD	WPD
TOTAL	9	130	1	28	5	0	6	22	179
- ZONE TOTALS -									
DIPLORIA-PALYTHOA (1-2)	0	0	0	0	0	0	1	0	1
REEF CREST (2-3)	0	3	1	5	1	0	0	4	10
SEAWARD SLOPE (3-4)	1	6	0	0	0	0	0	0	7
REEF FRONT (4-5)	1	13	0	0	0	0	5	5	19
WRECK I (5-6)	4	26	0	0	0	0	0	5	30
WRECK II (6-7)	0	6	0	3	0	0	0	0	9
REEF FRONT #2 (7-8)	2	35	0	12	0	0	0	2	49
WRECK III (8-9)	0	3	0	0	0	0	0	0	3
REEF FRONT #3 (9-10)	1	14	0	0	0	0	0	1	15
SEAWARD SLOPE #2 (10-11)	0	4	0	0	1	0	0	1	5
REEF CREST #2 (11-12)	0	20	0	8	3	0	0	4	31

Table 3. Total number of corals infected with SCTLD and WPD at Vauxhall Reef

SURFSIDE Feb. 15	Stony Coral Tissue Loss Disease		White Plague Disease			TOTAL	
	Pseudodiploria clivosa	*Pseudodiploria strigosa*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Dichocoenia stokesii*	SCTLD	WPD
TOTAL	0	1	3	38	1	1	42

Table 4. Total number of corals infected with SCTLD and WPD at the Surfside breakwater on February 15th

Discussion

Coral Disease Spread

Presumed cases of WPD and SCTLD were recorded at both sites, with each disease having far more abundance in some subsections than others. WPD was far more abundant in both locations, with 137 cases total of WPD to 5 total cases of SCLTD at the Surfside breakwater and 179 total cases of WPD to 22 total cases of SCTLD at Vauxhall Reef. Both diseases, especially SCTLD, were quite abundant at the Wreck I subsection at Vauxhall Reef. This could indicate that this location facilitates an environment that renders coral more prone to disease spread, although it also hosts many corals in general, which could result in higher counts of infected coral. Higher infection rates were not recorded at Wreck II or III sites, and more research on what could be causing this and whether it is a numerical anomaly would be needed to draw any definitive conclusions. Certain coral, particularly *Pseudodiploria strigosa*, presented far higher rates of infection than other species, however without knowing the proportion that each of these species make of the general coral population of the site, an extrapolation to susceptibility to the disease is difficult to make. Additionally, certain species had no instance of infection with either disease. *Acropora palmata, Acropora cervicornis,* and *Porites asteroides* had no instances of SCTLD, as expected due to their previously recorded low susceptibility to the disease.

Figure 3. Pseudodiploria strigosa infected with WPD (photo taken February 15^{t} , 2023)

Figure 4. Progression of Pseudodiploria strigosa WPD infection (photo taken March 3rd, 2023)

Photos of coral with WPD taken on February 15th and March 3rd showed the rapid progression of the disease on individual coral over 16 days (see Figures 3 & 4) This demonstrates the alarming rate at which these coral diseases spread, emphasizing the importance of properly identifying the diseases at initial infection in order to treat and prevent them further spread to protect coral reefs.

In general, the ambiguity between WPD and SCTLD created difficulty in differentiating between the diseases. WPD and SCTLD having high abundance in similar subsections of the reef and breakwater could indicate environmental susceptibility or could indicate that WPD simply has cases that resemble SCTLD. This poses challenges in identifying new infections in previously uninfected locations, preventing researchers from better understanding mechanics of disease spread and managing infected sites. More research into accurately detecting the disease in the field as well as increased sampling to detect the disease in a more reliable lab setting could be extremely valuable tools in preventing this extremely contagious and fatal disease from continuing to spread among reefs globally. Treatments for SCTLD are currently promising but limited and far from rectifying the ecological consequences of the disease, especially when barriers to identification allow it to spread unnoticed and untreated.


Figure 5. *Chilomycterus antillarum (Web Burrfish)*

Aquatic Biodiversity

Additionally, many aquatic species were identified from the photos taken at the Vauxhall Reef and Surfside breakwater to analyze the biodiversity in the area surrounding the coral. These species include corallivorous fish including *Chilomycterus antillarum* (Web Burrfish), *Scarus vetula* (Queen Parrotfish), and *Scarus guacamaia* (Rainbow Parrotfish), omnivorous fish including *Abudefduf saxatilis* (Sergeant Major), and carnivorous fish including *Dactylopterus volitans* (Flying Gurnard) and *Hypanus americanus* (Southern Stingray). Additional non-fish species overserved included *Eretmochelys imbricata* (Hawksbill Turtle) and *Diadema antillarum* (Long-spined Sea Urchin). These are promising observations as they provide evidence of functionally diverse fish populations at Vauxhall Reef and the Surfside breakwater which will contribute to the resilience of these ecosystems to SCTLD and WPD (Appendix 4).

Limitations

Although frameworks set out by Cróquer et al. (2021) were followed to identify the diseases, the lack of clear differences in symptoms defined by the literature could have decreased the accuracy of SCTLD identification in this study. Possible misidentification of coral species may also have contributed to error in data analysis. Photos in the field were taken of corals recognized to be infected, therefore human error could have resulted in lower counts of infected coral than the actual number of infected corals.

Future Research

Future studies would find value in acquiring a count of both healthy and infected coral through transects or quadrats of each site to draw more comparisons and conclusions than can be determined with only a count of infected coral, as done in this study. There is also a great need for additional studies to find more definitive ways of detecting SCTLD in the field, as this will permit greater tracking and understanding of the disease.

Conclusion

Coral reefs are an invaluable ecosystem. They provide a vital habitat for many species of fish and other aquatic organisms. Their high biodiversity, coastal protection, nutrient cycling, attraction as a tourist destination, and the various other ecosystem services they play a part in face numerous threats from anthropogenic actions and a warming climate. Diseases such as SCTLD increase the threats faced by coral, and it is in the interest of researchers, conservationists, and coastal managers to contain the spread of this disease by understanding which species are most vulnerable, the mechanisms through which it spreads, and the efficacy of different treatments. This is only possible if researchers can properly identify SCTLD. This study has identified a potential new spread of SCTLD in Barbados and encourages future research to be conducted in the region to assess infection spread and impact of the disease on Barbadian corals and reef ecosystems.

Acknowledgements

This study would not have been possible without the insight and expertise of Dr. David Patriquin, retired Professor of Biology at Dalhousie University and volunteer with CORALL in Barbados, who aided in determining study locations, coral and disease identification, and provided cameras for analysis. Dr. Patriquin and Claire Rodger aided in data collection at the sites and in identification of aquatic biodiversity. Ingrid Knapp and Susan Mahon of CORALL provided initial training and furnished snorkeling equipment to facilitate research and data collection. María Beckles and the CORALL team provided local knowledge indispensable to the success of this study. Finally, Professor Thomas Meredith, Professor of Geography at McGill University, provided the support and guidance necessary to coordinate and perform field research in Barbados and produce a final report.

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Appendix A: Route Maps

Figure A1. Route taken at the Surfside breakwater

Figure A2. Route taken at Vauxhall Reef

Appendix B: Tables of Disease Identification by Photo Code

VAUXHALL	Stony Coral Tissue Loss Disease							White Plague Disease						
Photo code	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*
- INTO DIPLORIA-PALYTHOA ZONE (1) -														
P3040035														1
- INTO REEF CREST ZONE (2) -														
P3040052		1												
P3040060									2					
MICR0303										1				
MICR0294														
MICR0295														
MICR0296											3			
MICR0299				3										
MICR0303											1			
MICR0301									1					
MICR0305											1	1		
- INTO SEAWARD SLOPE ZONE (3) -														
P3040075								1						
MICR0307									1					
MICR0312									1					
MICR0315									1					
MICR0316									2					
MICR0317									1					
- INTO REEF FRONT ZONE (4) -														
P3040136									1					
P3040146														5
P3040150									3					
P3040157		3							1					
P3040172									2					
P3040186								1						
P3040193	1								4					
P3040201									1					
P3040206									1					
P3040208		1												
- REEF FRONT ZONE / WRECK I (5) -														
P3040099									9					
P3040102								3	7					
P3040113		1							3					
MICR0328		2												
MICR0343		1						1	3					
MICR0344		1							1					
MICR0355									3					
- REEF FRONT ZONE / WRECK II (6) -														
MICR0384											3			
MICR0393									1					
MICR0394									2					
MICR395									3					
- REEF FRONT ZONE CONTINUED (7) -														
MICR0396									3					
MICR0400		1							2					
MICR0403									3					
MICR0404									1					
MICR0405									3					
MICR0406		1							2					
MICR0408									1		5			
MICR0409									2					

MICR0411									1					
MICR0412									5					
MICR0413								1	1					
MICR0415									1		6			
MICR0416											1			
MICR0417								1						
MICR0418									1					
MICR0419									1					
MICR0421									3					
MICR0425									1					
MICR0426									1					
MICR0428									2					
MICR0429									1					
- REEF FRONT ZONE / WRECK III (8) -														
MICR0432									1					
MICR0433									1					
MICR0435									1					
- REEF FRONT ZONE CONTINUED (9) -														
MICR0437									2					
MICR0438									2					
MICR0439									6					
MICR0440								1	2					
MICR0442									1					
MICR0444		1							1					
- INTO SEAWARD SLOPE ZONE (10) -														
P3040222		1												
P3040229												1		
MICR0448									1					
MICR0449									3					
- INTO REEF CREST ZONE (11) -														
P3040238									1					
P3040239									1					
P3040250									1					
P3040253		1												
P3040262											1	1		
P3040266					2						1	1		
P3040269									1					
P3040277									1					
P3040282												1		
P3040288									1					
P3040289									2					
MICR0459						1								
MICR0464									1					
MICR0465									3					
MICR0466									1					
MICR0468									1					
MICR0470											2			
MICR0472											2			
MICR0474									1		2			
MICR0475									1					
MICR0476									1					
MICR0483									1					
MICR0486									2					
- AT SEAWARD POST OF BREAKWATER (12) -														
Photo code	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastrea siderea*	*Orbicella annularis*	*Montastraea cavernosa*	*Siderastera radians*	*Acropora cervicornis*
	Stony Coral Tissue Loss Disease							**White Plague Disease**						

Table B1. Total SCTLD and WPD infections recorded in photo observations at Vauxhall Reef

SURFSIDE	Stony Coral Tissue Loss Disease			White Plague Disease		
Photo code	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastera radians*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastera radians*
- NORTHERN POINT OF BREAKWATER (1) -						
P3030281					1	
P3030283					2	
P3030284					1	
MICR0011					1	
P3030286					2	
P3030288					1	
P3030289					1	
- ELKHORN (2) -						
MICR0012					1	
MICR0014					2	
MICR0015					3	
P3030293					1	
P3030295					2	
P3030296					2	
MICR0016					1	
MICR0017					1	
P3030298					2	
P3030300					2	
P3030301					1	
P3030304					1	
MICR0019					1	
MICR0021					2	
MICR0023					1	
P3030307				1		
P3030313					1	
P3030327				1		
P3030334					1	
P3030347					1	
MICR0027					1	
MICR0028	1				2	
- STICKS AND LOGS (3) -						
MICR0029					1	
P3030365					1	
MICR0031					1	
MICR0032					2	
MICR0033					1	
MICR0035					4	
MICR0037					1	
P3030389				1	2	
P3030399					1	
P3030401					1	
P3030407					1	
P3030409					1	
MICR0039					1	
MICR0042					1	
- STEEL ROD (4) -						
MICR0043					1	
MICR0044				1		
P3030423					1	
P3030426					1	
P3030428					1	
MICR0045					2	
MICR0046					1	
MICR0049					1	
P3030440					1	
- FRIED EGG (5) -						
MICR0056					1	
P3030449					1	
P3030451					1	
MICR0086					1	
- GROUP SWAP (6) -						
P3030535					1	
P3030552					1	
MICR00115					1	
MICR0116			1			1
MICR0122					1	
MICR0123					1	
P3030560					1	
MICR0130					1	
MICR0133					1	
P3030573					1	
MICR0134					1	
MICR0135		1			1	
MICR0141					1	
MICR0142					1	
MICR0143					1	
P3030600					2	
P3030604					1	
P3030612					2	
P3030617					1	
P3030619		1				
P3030620					1	
MICR0144					1	
P3030624					3	
MICR0147					1	
P3030632					1	
P3030633					1	
P3030635				1		
P3030636					1	
P3030638					1	
P3030639		1				
P3030652					1	
MICR0152					1	
- THE CIRCLE (7) -						
MICR0155				2	2	
P3030661					1	
MICR0157					1	
MICR0158					1	
P3030662					1	
MICR0159					2	
P3030675					1	
MICR0162					1	
P3030677					1	
MICR0166					3	
P3030680					3	
P3030681				1	2	
P3030683					1	
P3030704					1	
P3030722					1	
P3030734				1		
P3030737					1	
P3030739					1	
P3030740				1		
- SOUTHERN POINT OF BREAKWATER (8) -						
Photo code	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastera radians*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Siderastera radians*
	Stony Coral Tissue Loss Disease			White Plague Disease		

Table B2. Total SCTLD and WPD infections recorded in photo observations at the Surfside breakwater

SURFSIDE Feb. 15	Stony Coral Tissue Loss Disease		White Plague Disease		
	Pseudodiploria clivosa	*Pseudodiploria strigosa*	*Pseudodiploria clivosa*	*Pseudodiploria strigosa*	*Dichocoenia stokesii*
MICR2599				1	
MICR2600				1	
MICR2601				3	
MICR2603					1
MICR2604				1	
MICR2609				1	
MICR2611				1	
MICR2612			1		
MICR2614				1	
MICR2615				1	
MICR2618				1	
MICR2622				1	
MICR2623				1	
MICR2625				2	
MICR2628				1	
MICR2631				1	
MICR2632		1			
MICR2642				1	
MICR2645			1		
MICR2646				1	
MICR2648				2	
MICR2652				4	
MICR2656			1		
MICR2657				1	
MICR2658				2	
MICR2659				1	
MICR2662				1	
MICR2663				1	
MICR2664				1	
MICR2668				2	
MICR2670				1	
MICR2672				1	
MICR2674				1	
MICR2675				1	

Table B3. Total SCTLD and WPD infections recorded in photo observations at the Surfside breakwater on February 15th

Appendix C: Photos of Infected Corals

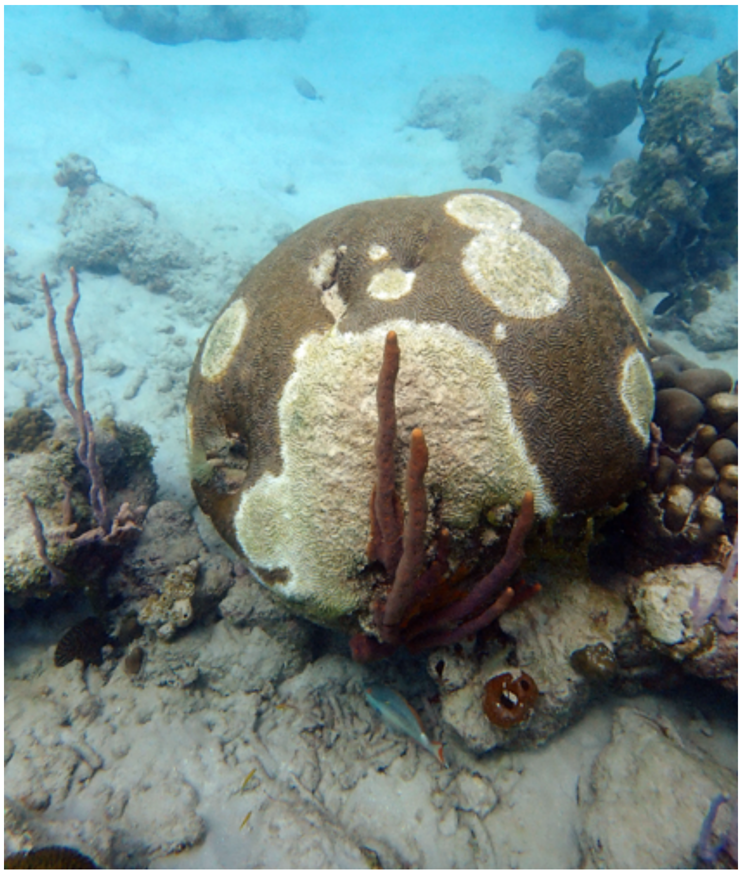


Figure C1. Pseudodiploria strigosa with SCTLD

Figure C2. Pseudodiploria strigosa with WPD

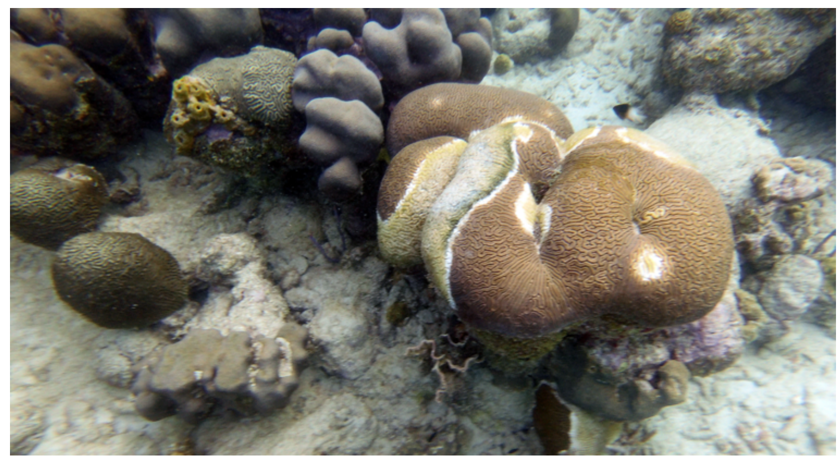


Figure C3. Pseudodiploria strigosa with SCTLD

Figure C4. Pseudodiploria strigosa with WPD

Figure C6. Porites asteroids (mustard hill coral) with grazing damage

Figure C5. Diploria labyrinthiformis with Caribben Ciliate Infection

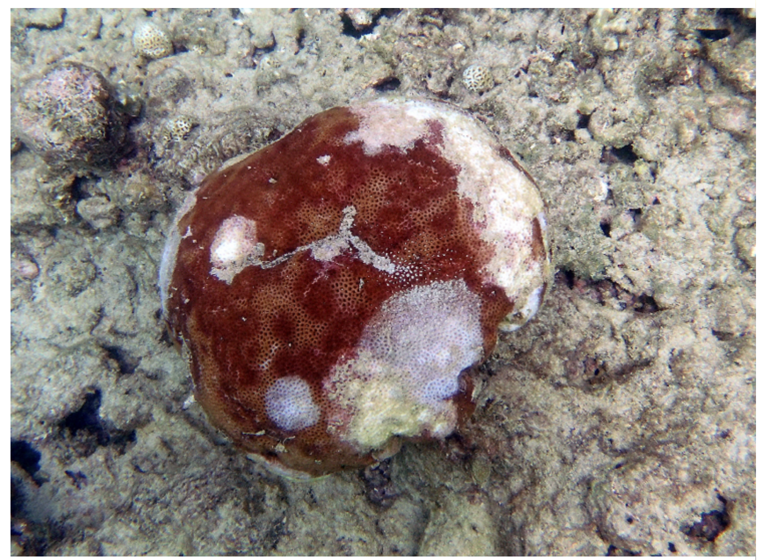
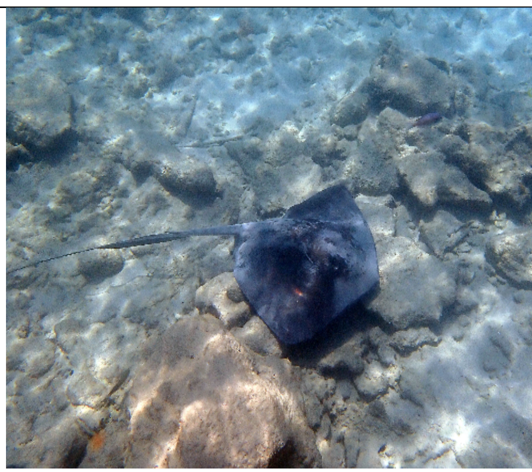
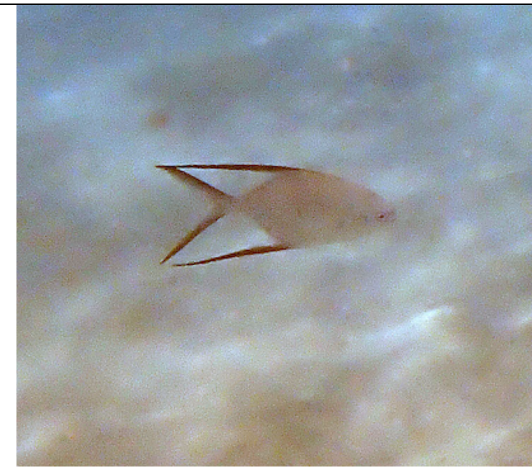
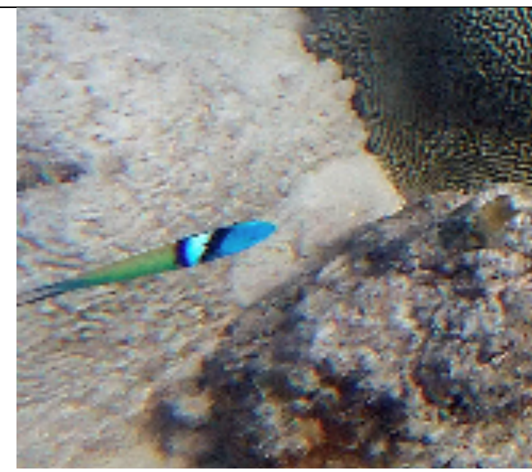


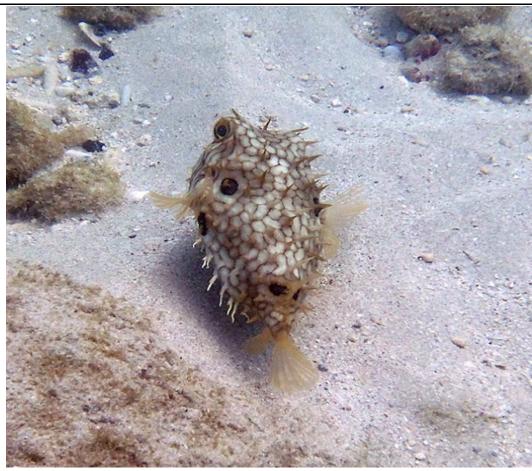
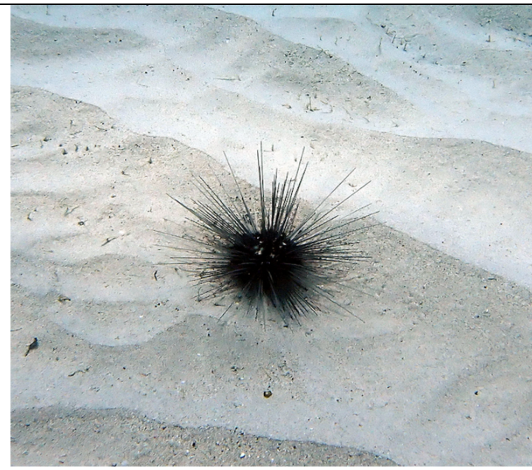
Figure C7. Siderastrea radians with SCTLD

Appendix D: Table of Aquatic Biodiversity

		
Lactophyrus triqueter (Smooth Trunkfish)	*Dactylopterus volitans* (Flying Gurnard)	*Eretmochelys imbricata* (Hawksbill Turtle)
		
Hypanus americanus (Southern Stingray)	*Abudefduf saxatilis* (Sergeant Major)	*Hippocampus reidi* (Slender Seahorse)

		
Scarus vetula (Queen Parrotfish)	*Scarus guacamaia* (Rainbow Parrotfish)	*Sparisoma viride* (Stoplight Parrotfish)
		
Hemiramphus brasiliensis (Ballyhoo)	*Acanthurus coerulbus* (Atlantic Blue Tang)	*Myrichthys breviceps* (Sharptail Snake-Eel)

		
Mulloidichthys martinicus (Yellow Goatfish)	*Aulostomus maculatus* (Trumpetfish)	*Trachinotus goodei* (Polometa Jack)
		
Holocentrus rufus (Longspine Squirrelfish)	*Chromis multilineata* (Brown Chromis)	*Thalassoma bifasciatum* (Bluehead Wrasse)

		
Chilomycterus antillarum (Web Burrfish)	*Diadema antillarum* (Long-Spined Sea Urchin)	*Haemulon flavolineatum* (French Grunt)
		
Caranx latus (Horse-Eye Jack)	*Hypoplectrus sp.* (Hybrid Black Hamlet)	*Jenkinsia lamprotaenia* (Dwarf Round Herring)