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Management responses in Belize and Honduras, as stony coral tissue loss disease expands its prevalence in the Mesoamerican reef

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Stony Coral Tissue Loss Disease (SCTLD) has affected Caribbean coral reef colonies since it was first detected in Florida in 2014. Its rapid spread and virulent nature are a major concern to coastal nations in the Caribbean Sea. Belize and Honduras have approached their management and strategies in somewhat different ways, but with the same goal of evaluating and controlling the spread and reducing mortality rates of their coral colonies. They both used amoxicillin trihydrate powder with Coral Ointment Base2B which proved effective in halting the spread of the disease and lowered mortality rates in treated corals. In addition to treatment, both countries have continued to monitor the extent of the disease, entering the data into the collaborative disease tracker platform on AGRRA.org. Between October 2020 and November 2021, a total of 14,495 corals from 29 species were assessed at sites in Belize and Honduras that were affected by SCTLD. The overall prevalence (all coral species) of SCTLD at these sites was 14%. Three species (*Meandrina meandrites, Dendrogyra clyindrus* and *Dichocoenia stokesi*) were in the top affected species in both countries, with 42%, 38% and 32% SCTLD prevalence, respectively. The sharing of information allowed Belize and Honduras to be relatively prepared for the onset of SCTLD in their waters through a series of monitoring and intervention actions. Although the treatment has proved to be somewhat effective, it is time and labor intensive. Reducing other well-known anthropogenic including sewage and dredging, is key to supporting coral reef health and resiliency.

KEYWORDS
coral disease, SCTLD, Belize, Honduras, Mesoamerican Reef

Introduction

Caribbean reefs have suffered declines over the last three decades stemming from climate change, overfishing, anthropogenic pollution and habitat loss, and numerous infectious diseases (Hughes et al., 2018). Stony Coral Tissue Loss Disease (SCTLD) is the most recent coral disease now decimating reefs across the Caribbean. SCTLD was first documented near the Port of Miami in 2014 concurrent with a coral bleaching event (fall 2014) and major port dredging (2013-2015). This SCTLD epicenter was also located in close proximity to the ocean outfall pipe from the Central District Wastewater Treatment Plant on Key Biscayne/Virginia Key which discharges 143 million gallons of sewage a day on average and has experienced numerous leaks and spills over the years (Precht et al., 2016; USA et al., vs Miami-Dade 2014; Miller et al., 2016). The disease outbreak was thought to be confined to Florida until summer 2018, after the Healthy Reefs Initiative (HRI) and Atlantic and Gulf Rapid Reef Assessment (AGRRA) issued a "red alert" to the coral reef research community of the Caribbean providing information on how to identify it and requesting reports and photos of any suspected cases. Reports were received from Puerto Morelos, Mexico and Jamaica within several weeks (by early July) of this message being posted on the NOAA coral list and Gulf and Caribbean Fisheries Institute list.

SCTLD was detected at many sites throughout most of the Mexican coastline by the end of 2018, inciting a collaborative response among reef conservation and science agencies and researchers (Alvarez-Filip et al., 2019). These coordinated measures resulted in a monitoring protocol prioritizing disease identification, site selection, site assessments, disease tracking, and treatment, following the recommendations of Neely (2018). There are still many unknowns, including the identity of the main pathogen(s) at the root cause of the disease. Ushijima et al., reported testing hundreds of isolates and finding four potentially pathogenic strains of *vibrio coralliilyticus*. Given the response to antibacterial treatment, it is presumed to be at least partly bacterial (Neely et al., 2021). A number of alternative theories have also emerged as to the identity of the causative agent(s) which may include bacteria or virus(es) affecting the coral host or endosymbionts (Landsberg et al., 2020). Meyer et al. (2019), found microbial shifts in coral microbiome of three species of coral affected with active SCTLD lesions, including five unique ASV sequences (Flavobacteriales, Clostridiales, Rhodobacterales, Alteromonadales, and Vibrionales) that were exact matches to sequences previously associated with other known coral diseases. It is possible that the pathogen could in fact be affecting the healthy coral microbiome, which might help explain the strong palliative response by exposing infected corals to healthy microbiome.

Preparedness is a necessary tool. Due to the time-sensitive nature of disease spread, a colony afflicted with SCTLD may experience total mortality within a matter of weeks to a few months (Doyle and O'Sullivan, 2019). As of the end of 2021, SCTLD has affected all areas in the Florida reef tract and spread throughout much of the Caribbean (**Figure 1** – Timeline). It was first detected in Belize (near the Mexican border) in June 2019. It did not spread immediately, but in April 2020 it was recorded in several other locations in northern Belize and then in Roatan, Honduras by September 2020 (see **Figures 2**, **3**).

SCTLD differentiates itself from other coral diseases by being more persistent, virulent, and affecting a larger number of species than previous diseases, with an ability to rapidly spread and transmit between reefs. (Precht et al., 2016; Weil et al., 2019; Meiling et al., 2020). The lesions progress at a much higher rate than other coral diseases (Precht et al., 2016; Neely et al., 2020). It is a generalist disease affecting approximately 24 scleractinian species many of which are reef building species such as brain and pillar corals (Weil et al., 2019; Muller et al., 2020). As the spread of the disease persists, surveyors have become more capable of distinguishing SCTLD from other coral disease outbreaks (Meiling, 2020).

SCTLD management strategy

HRI is a collaboration of over 73 reef conservation organizations working in the Mesoamerican reef, conducting training and implementing reef monitoring and reporting in biennial Report Cards. The first reports of SCTLD outside of Florida came in from Puerto Morelos, Mexico, and Jamaica, followed by several other countries. The HRI partners quickly accelerated national-level communications and monitored for the prevalence of the disease in summer 2018. By the end of 2018, it had been found along much of the Mexican coastline of Quintana Roo. In April 2019, HRI and Fragments of Hope (FoH) held the first national workshop on SCTLD in Belize, which provided stakeholders with the most updated information needed to detect it and strategize a response. This included media appearances and special news articles to inform and alert the diving industry. By June 2019 SCTLD was first detected in the northernmost part of Belize, in Bacalar Chico Marine Reserve, by Blue Ventures staff. Additional confirmation dives were conducted by the Fisheries Department and HRI staff, with photos, data, and coordinates shared with the AGRRA database and personnel for final confirmation.

This report evaluates the response mechanisms and continued efforts to tackle SCTLD in Belize and Honduras, with Mexico discussed by Estrada-Saldívar et al. (2021). In Belize, once the presence of SCTLD had been confirmed in an area, the local management team discussed treatment options, in consultation with the National Coral Reef Monitoring Network. A US$40,000 grant was supported by the Belize Marine Fund to sponsor monitoring and treatment efforts, coordinated largely by HRI-Belize. Responses in both Belize and Honduras

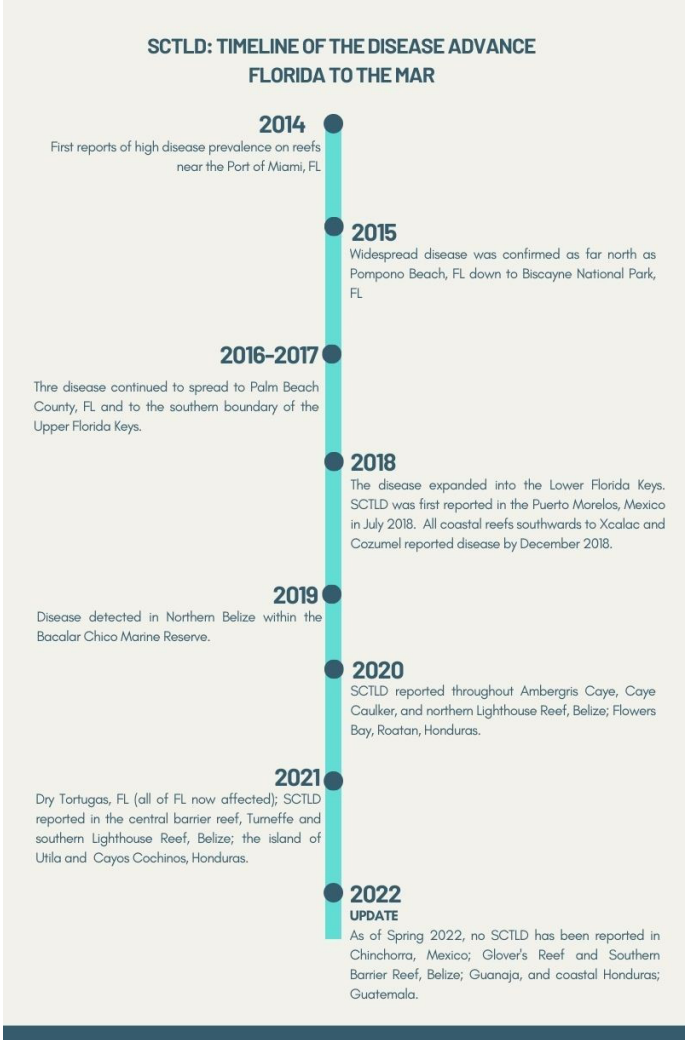

FIGURE 1
SCTLD outbreak timeline in Florida and the Mesoamerican Reef.

have been impacted by COVID-19, as well as the low level of financial resources.

Although much of the nature of SCTLD transmission is still unknown, some cautionary practices have been employed with the hope of reducing the impact of the disease including exchanging ballast water offshore; disinfecting dive gear, tools, and equipment with a diluted hypochlorite solution; and adopting practices of diving unaffected reefs before affected ones and not touching the corals (Belize SCTLD Strategy).

To date, the most effective SCTLD intervention is the *in-situ* antibiotic treatment of lesions on affected corals with an application of amoxicillin trihydrate powder with Coral Ointment Base2B (CoreRx Base2B) (Neely et al., 2020). SCTLD experts have found that due to the infectious nature of the disease, affected corals need immediate treatment. Treatment, however, does not guarantee colony survival, as new lesions may appear on the corals after treatment or multiple treatment applications may be required, which is not feasible at many reef sites due to a lack of resources and/or manpower.

There are four exposure categories of coral reefs affected by SCTLD (Neely, 2018), as follows: 1) *Pre-invasion* is the pre-disease phase; 2) *Invasion* phase occurs within the first few months when the disease prevalence is relatively low, affecting only the early susceptible species; 3) *Epidemic* phase occurs at 3 months to 1 year, when the lesions are considered to be both severe and chronic; 4) *Endemic* phase occurs sometime between one and four years after SCTLD invasion when most of the vulnerable coral species have been decimated leaving behind a higher proportion of SCTLD-resilient species. As of October 2021, Belize had two *Endemic* subregions (Northern Barrier reef and Lighthouse Reef

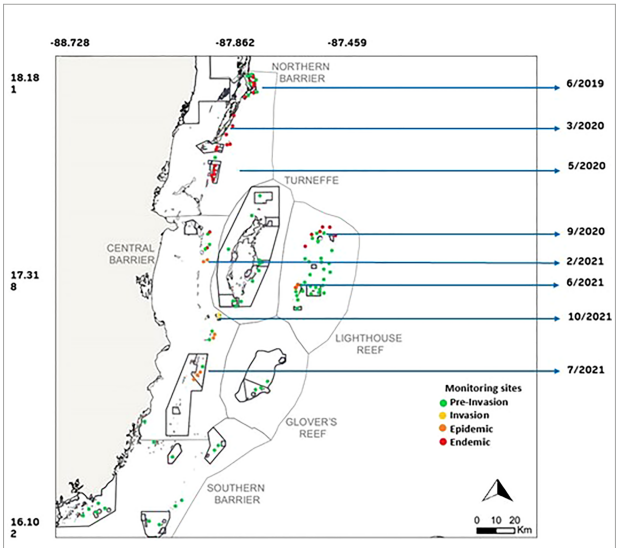

FIGURE 2
Outbreak and progression of SCTLD outbreak throughout with the first known record June 2019.

Atoll) and one *Epidemic* subregion (Central Barrier Reef), and three *Pre-Invasion* subregions (Southern Barrier reef, Turneffe Glovers Atolls).

Management response in Belize

Given the proximity of Mexico's reefs with endemic SCTLD that began in summer 2018, Belize began preparing for the disease in spring 2019. In April 2019 the first SCTLD Workshop was convened by the Healthy Reefs Initiative, through the National Coral Reef Monitoring Network. Information was provided on how to identify and report this disease, the latest about the disease spread through the Caribbean, and on the treatment interventions underway in Florida and Mexico. HRI and Fragments of Hope also made appearances on local television shows in the spring to raise awareness and have the recreational community on the lookout for the disease. In June 2019, an affected pillar coral colony, *Dendrogyra cylindrus*, was the first confirmed sighting of SCTLD in Belize, recorded in the northern region of the Bacalar Chico Marine Reserve (BCMR) recorded by staff of the Blue Ventures – an international Conservation group. Due to the inevitability of the spread, awareness and planning were launched a year earlier, involving preparedness planning and workshops for stakeholders (Lang and McField, 2018; NCRMN 2019). While the BBRS had the advantage of awareness and planning for SCTLD spread, initial pilot SCTLD treatments consisted of chlorine instead of antibiotics, due to concerns with releasing antibiotics into the environment. Unfortunately, the chlorine from July 2019 until July 2020 proved to be unsuccessful.

Between July and August 2019, BCMR tested the efficacy of two approaches not involving antibiotics: 1) a paste of cocoa/shea butter mixed with modelling clay or epoxy to cover SCTLD lesions; 2) covering lesions with cement; both trials were deemed unsuccessful with a 0% success rate. In July 2020, BCMR tested the CoreRx Base2B + Amoxicillin paste on affected lesions which proved largely successful, with 88% of lesions prevented from expanding (BFD, 2021). Lessons from Mexico suggested that the treatment response needed to be rapid in newly affected areas and that the antibiotic paste often had to be reapplied (Neely, 2018). While treatment may not prevent further lesions from developing leading to colony mortality, or containing the spread of SCTLD, it is the most effective treatment plan available at present (BFD, 2021).

In the spring of 2020, there were several new sightings of SCTLD reported in Belize - including the popular Hol Chan Marine Reserve (HCMR), off southern Ambergris Caye, and

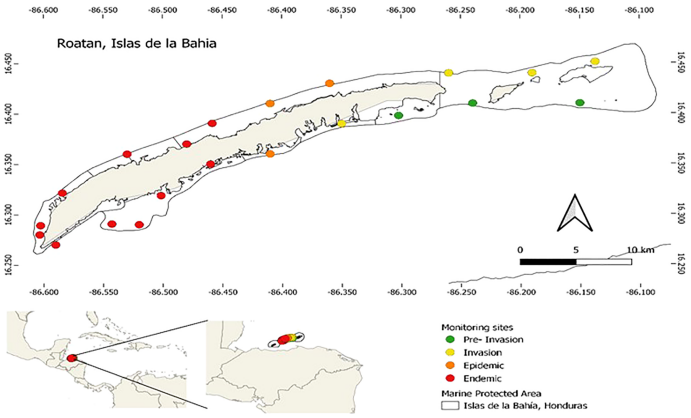

FIGURE 3
Outbreak condition of SCTLD as of September 2021 in the island of Roatan, in the Bay Island MPA, Honduras.

Lighthouse Reef. As a result of the pandemic, response time and monitoring capacity were greatly affected as human health was prioritized over reef health (including many movement restrictions) and the loss of park funding due to the loss of tourist/visitor fees. During this time, SCTLD was detected in the HCMR in April 2020, CCMR in May 2020, Light House Reef Atoll in September 2020, and Sergeant's Caye Area, May 2021 (see **Figure 2**). These treatment efforts are being closely monitored to report on changes in percent mortality of colonies treated using CoreRx Base 2B and amoxicillin over a 3-month period.

Management response in Honduras

SCTLD was first reported in October 2020, in the south side of Roatan near Flowers Bay through a citizen science report. Prior to its detection, the Roatan Marine Park (RMP) devised a multifaceted early SCTLD detection system. They conducted a risk assessment to determine the extent to which local reefs could be susceptible to SCTLD. Using the HRI data provided by the Atlantic and Gulf Rapid Reef Assessment (AGRRA) program, RMP selected eight sites inside the MPA according to the abundance of susceptible species and presence of local stressors that could enhance the disease, to carry out a rapid assessment based on Doyle and Sullivan's (2019) monitoring methodology. This methodology requires a surveyor to follow a transect for 20 minutes and count the coral colonies affected by SCTLD. Trained divers would then tally recent mortality, actively diseased colonies with SCTLD, colonies with signs of concern or other diseases, and healthy colonies. To prepare divers for the rapid assessment, four training sessions were carried out to ensure participants were able to identify corals as well as stony coral diseases. Participants included members of Bay Island Conservation Association (BICA), MarAlliance, Zona Libre Turistica (Zolitur), Utila Coral Restoration, and local dive professionals.

Prior efforts to engage stakeholders and encourage participation in the monitoring effort, involved informational presentations given to members of the West End and West Bay communities, followed by more intensive one-to-one meetings. RMP staff visited 46 dive shops throughout the island (for e.g., in West End, West Bay, and Sandy Bay) and distributed outreach materials on SCTLD in Spanish, English, and French, developed by MPA Connect. These outreach materials were also distributed to the islands of Utila and Guanaja, which are part of the Bay Islands National Marine Park. RMP utilized social media to raise awareness to the general audience through a short video about the disease, management actions towards SCTLD, and how stakeholders can help reduce the impact of SCTLD in the MPA.

The first rapid assessment was carried out at the end of January 2020 with the support of BICA and Zolitur confirming that Roatan was in the pre-invasive phase of SCTLD. During the assessment, the rover team evaluated 1580 coral colonies in the 8 selected sites. In the coral colonies surveyed, the most abundant was *Orbicella annularis*, comprising 25% of the total, followed by *Diploria labyrinthiformis* with 16% and *Monstastrea cavernosa* with 14%. *Eusmilia fastiagiata* and *Stephanoceonia intersepta* were the least abundant, representing 1% of the colonies surveyed. At this time there were no signs of SCTLD, although coral health was of concern as the colonies surveyed showed signs of bleaching and of white plague.

At the end of September 2020, SCTLD was suspected and subsequently confirmed in Flower's Bay, Roatan, through reviews within the AGRRA disease watch website. Within the week rover diver monitoring surveys were conducted, finding SCTLD at 3 out of 8 sites - Church wall, Cara Cara and Cordelia. Affected species were *M. meandrites, D. cylindrus, M. cavernosa, C. natans* and *D. stokesii*. In October 2020, RMP as part of the MPA technical committee, worked with the government to enforce an emergency response plan towards SCTLD and obtain all the required permits to use topical antibiotics to treat coral colonies. In December 2020, RMP monitored 21 sites along the island of Roatan, following the criteria described above. This survey found that sites in the South and West Bay – West End were in the outbreak phase, with highly susceptible species (e.g., *C.natans, P. strigosa*, *M. meandrites, D. labyrinthiformis, D.cylindrus*) and intermediate susceptible species (e.g., *M. cavernosa, O. faveolata and O. annularis*) demonstrating visible SCTLD lesions. Honduras has been able to take the lessons learned from previously affected regions of the MAR (mainly Mexico) to rapidly begin treatments and reduce the damage to the Honduran coral reef system. Continued monthly monitoring has allowed the team at RMP to quantify the prevalence of the disease across the island and describe the changes in coral composition through the SCTLD outbreak. As of September 2021, there are three sites in the Southeast of Roatan still in the pre-invasion phase, four sites are in the invasion phase, three are in the epidemic phase and 11 are in the endemic phase, with phases as described in (**Figure 3**).

Methods

Coral condition was assessed using a modification of the 'bar-drop" randomized colony count method first described in McField (1999) with the addition of SCTLD as a new coral condition / disease (Figure 4). Data were entered into the Atlantic and Gulf Rapid Reef Assessment's "Detailed Coral Disease and Bleach Survey" online portal and database (https://www.agrra.org/coral-disease-outbreak/#sctld-dashboard). A CSV file of all surveys was generated, and then filtered to include only those sites that recorded the presence of SCTLD, so the prevalence rates would not be affected by sites that have not yet been exposed to the disease. Between October 2020 and November 2021, a total

FIGURE 4
Roatan Marine Park staff treating an infected grooved brain coral with Base2b + amoxicillin. Photo credit: Antonio Busiello.

of 220 surveys were conducted in Belize from 19 sites and in Honduras 170 surveys were conducted from 21 sites.

Results

In Belize SCTLD was reported in 26 of the of 220 surveys conducted from 19 sites. In Honduras, the disease was detected in 20 of the 21 sites surveyed. Within the 39 sites affected by SCTLD in Belize and Honduras, a total of 14,495 corals from 29 species were assessed finding the overall prevalence of SCTLD to be 14% (Tables 1, 2). Three species (Meandrina meandrites, Dendrogyra clyindrus & Dichocoenia stokesi) were in the top affected species in both Belize and Honduras, with 42%, 38% and 32% SCTLD prevalence, respectively. Orbicella franksi was the next most affected species overall, but this was much higher in Belize (49%) than in Honduras (17%), while Meandrina jacksoni was much higher in Honduras (34%) than Belize (0%) but only 7 colonies were observed in the Belize surveys: with an opposite pattern in Agaricia lamarcki, with 0% in Honduras and 75% in Belize, but with only 23 colonies overall and a 26% total prevalence.

A total of 9 species have >19% prevalence rates, compared to 11 species with very low prevalence rates, including 7 with no SCTLD recorded. As expected, this includes the three Acropora species, and the two Madracis species observed in this study. Importantly, Agaricia tenuifolia, of the regionally significant reef-building species in the MAR, had a very low SCTLD prevalence (2%) although this will likely increase at the outbreak persists.

Discussion

This paper has described the extent of SCTLD spread into Belize and Honduras between 2018 and late 2021, as well as the country's management efforts. It is notable that the overall spatial pattern did not simply follow general current patterns, particularly with regard to the relatively early disease incidence in Lighthouse Reef atoll, Belize September 2020 and to Roatan, Honduras September 2020. Roatan is a major cruise port and the biofilms adhering to ship hulls have been hypothesized to serve as vectors for disease. However, the reefs closest to Belize City's port (near Goff's Caye) did not experience infections until almost a year later July 2021. In addition, Lighthouse reef does not receive cruise or container shipping traffic although its eastern side is the closest coral reef to major container and cruise ship traffic passing through the Northwestern Caribbean. Belize has adopted the MARPOL ballast water management protocols, and expects ships to be following them, although this would not prevent biofilms on the ships hulls from serving as vectors. Meyer et al. (2019) notes the co-occurrence of other coral-stress events with the rapid and severe SCTLD infestations in Florida, including heat stress/bleaching and port dredging operations, and the suspended sediment and contaminant loading associated with dredging activity. In Mexico, the rapid spread of SCTLD across about 400 km of fringing reefs in close proximity to highly developed coastlines with well-known sewage contamination issues, adds anecdotal evidence to the linkage with anthropogenic stress (Alvarez-Filip et al. 2022). To date, the only reef area in Mexico not yet experiencing SCTLD in Banco Chinchorro, which is virtually uninhabited other than park staff and fishers.

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TABLE 1 List of coral species surveyed in Belize highlighting species health and showing prevalence of SCTLD within colonies.

Species	Healthy colonies	SCTLD present	Other conditions*	Total colonies	%SCTLD
Agaricia lamarcki	2	6	0	8	75
Meandrina meandrites	18	53	7	78	68
Dendrogyra cylindrus	5	5	0	10	50
Orbicella franksi	75	82	12	169	49
Colpophyllia natans	45	21	7	73	29
Diploria labyrinthiformis	47	24	21	92	26
Pseudiploria strigosa	218	92	61	371	25
Dichocoenia stokesii	12	6	7	25	24
Mussa angulosa	166	37	32	235	16
Orbicella faveolata	70	13	21	104	13
Orbicella annularis	164	30	55	249	12
Agaricia agaricites	478	52	23	553	9
Siderastrea siderea	207	35	193	435	8
Eusmilia fastigiata	13	1	7	21	5
Mycetophyllia lamarckiana	18	1	5	24	4
Pseudodiploria clivosa	19	1	6	26	4
Porites porites	159	2	27	188	1
Porites asteroides	775	6	64	845	1
Acropora cervicornis	42	0	7	49	0
Acropora palmata	33	0	6	39	0
Acropora prolifera	3	0	0	3	0
Agaricia tenuifolia	134	0	61	195	0
Manicina areolata	1	0	0	1	0
Madracis auretenra	10	0	4	14	0
Montastraea cavernosa	2	0	0	2	0
Madracis decactis	17	0	1	18	0
Meandrina jacksoni	7	0	0	7	0
Porites divaricata	0	0	0	0	0
Stephanocoenia intersepta	60	0	20	80	0
Total Corals surveyed	2800	467	647	**3914**	**12%**

*Presence of bleaching or other non-SCTLD coral diseases.

The lack of anthropogenic stress in the Bacalar Chico Marine Reserve in Northern Ambergris Caye and the strong Northward prevailing currents could help explain why SCTLD did not spread significantly for almost a full year. However, once SCTLD reached corals in the more populated southern end of Ambergris Caye, near San Pedro, it rapidly spread within these reefs and to other islands along the reef. In addition to stress from anthropogenic contaminants, these reefs are exposed to southerly currents inside and near the barrier reef south of Rocky Point (in Bacalar Chico Marine Reserve), could have contributed to the more rapid disease experienced in 2020-2021. However, the less visited reef region south of Rendezvous Caye to North of Tobacco Caye, remains disease free (as of March 2022). While the more visited areas off Tobacco Caye, Southwater Caye and Carrie Bow Caye have been highly impacted by SCTLD as of March 2022.

In Honduras, the first incidences of SCTLD were noted on the southern coast of Roatan, near Flowers Bay. It expanded rather rapidly across the southern and western coastlines, which are sites with high incidence of touristic activities and highly populated, potentially linking the spread of the disease with anthropogenic stressors. The Roatan Marine Park has worked to create awareness about SCTLD and the need for gear decontamination guidelines for the diving community and have successfully collaborated with them in the intervention and monitoring efforts, increasing the number of treated colonies. Coral Reef Alliance, an RMP partner, has worked analyzing the water quality along the island, alerting the residents and tourism sector about the need to improve the sewage treatment to reduce coral stressors.

To date, only Utila, Cayos Cochinos and Roatan have been affected by SCTLD in Honduras and the country was in a state of environmental emergency due to the disease. RMP has been working with the government in the National Action Plan for SCTLD. This plan describes the actions to mitigate the impact

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TABLE 2 List of coral species surveyed in Honduras highlighting species health and showing prevalence of SCTLD within colonies.

Species	Healthy	SCTLD	Other conditions*	Total	%SCTLD
Meandrina meandrites	286	173	2	461	38
Dendrogyra cylindrus	169	100	1	270	37
Meandrina jacksoni	32	17	1	50	34
Dichocoenia stokesii	174	84	0	258	33
Eusmilia fastigiata	136	59	3	198	30
Colpophyllia natans	403	133	10	546	24
Pseudiploria strigosa	1343	304	19	1666	18
Orbicella franksi	192	40	0	232	17
Pseudodiploria clivosa	151	30	0	181	17
Orbicella annularis	869	171	61	1101	16
Diploria labyrinthiformis	531	95	8	634	15
Mussa angulosa	721	111	8	840	13
Mycetophyllia lamarckiana	69	7	1	77	9
Agaricia agaricites	620	63	24	707	9
Siderastrea siderea	950	107	152	1209	9
Orbicella faveolata	768	63	20	851	7
Manicina areolata	14	1	0	15	7
Agaricia tenuifolia	497	13	15	525	2
Porites asteroides	434	4	4	442	1
Stephanocoenia intersepta	256	2	0	258	1
Acropora cervicornis	10	0	2	12	0
Agaricia lamarcki	15	0	0	15	0
Acropora palmata	5	0	0	5	0
Acropora prolifera	0	0	0	0	0
Madracis auretenra	35	0	0	35	0
Montastraea cavernosa	3	0	0	3	0
Madracis decactis	3	0	0	3	0
Porites divaricata	2	0	0	2	0
Porites porites	32	0	0	32	0
Total Corals surveyed	**8720**	**1577**	**331**	**10628**	**15%**

*Presence of bleaching or other non-SCTLD coral diseases.

of the disease with the collaboration of stakeholders, as well as a national standardized methodology for monitoring and intervention using coral ointment and amoxicillin. Honduras also follows the Ballast Water Management Convention and the MARPOL convention, to manage ballast waters and expects all ships to follow them to mitigate the impact of SCTLD.

In conclusion, both Belize and Honduras were relatively prepared for the onset of SCTLD in their waters. The sharing of information from HRI staff and partners in Mexico and through NOAA's Caribbean Cooperation Team on a routine basis, has assisted with good monitoring data collection that was further enhanced by the web-based data portal to track the disease and quantify the prevalence by species and site over time (Neely et al. 2020; Shilling et al. 2021). The treatment of corals has proven fairly effective but costly in terms of financial and human resources and can only be accomplished at high value managed sites. Reducing other known anthropogenic stressors including sewage, ballast water and overfishing are key elements of the overall strategy to recover reef health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CL and ZG are the first authors. ZG, DD, GO and AN, KF, NC and MM provided data and in field data collection. CL, ZG and DD analyzed data and produced maps. CL, ZG and MM

contributed to conception and design of the study. NC organized the database. CL wrote the first draft of the manuscript. ZG and MM wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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