FIELD GUIDE
for Monitoring Coral Disease Outbreaks in the Mesoamerican Region

MAR FUND

INTEGRATED RIDGE TO REEF MANAGEMENT OF THE MESOAMERICAN REEF ECOREGION PROJECT

Integrated Ridge to Reef Management of the Mesoamerican Reef Ecoregion Project (MAR2R)

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Disclaimer

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List of Acronyms

AGRRA	Atlantic and Gulf Rapid Reef Assessment Program
BCD	Buoyancy Compensation Device
BICA	Bay Island Conservation Association
CCAD	Central American Commission on Environment and Development
CONANP	National Commission for Natural Protected Areas/ Comisión Nacional de Áreas Naturales Protegidas
FKNMS	Florida Keys National Marine Sanctuary
FoH	Fragments of Hope
GCFI	Gulf and Caribbean Fisheries Institute
GEF	Global Environment Facility
GPS	Global Positioning System
HRI	Healthy Reefs for Healthy Peoples Initiative
IUCN	International Union for the Conservation of Nature
MAR	Mesoamerican Reef
MAR2R	Mesoamerican Reef Transboundary Integrated Management Project
MAR Fund	Mesoamerican Reef Fund
MPA	Marine Protected Area
MR	Marine Reserve
NAP	National Action Plan
NGO	Non-government Organization
NP	National Park
NPA	Natural Protected Areas
NOAA	National Oceanic and Atmospheric Administration
RAG	Regional Advisory Group of Experts
RDG	Regional Dialogue Group
RDP	Regional Demonstration Project
RMP	Roatan Marine Park
RRI	Reef Restoration Initiative
RRN	Reef Restoration Network
SCTLD	Stony Coral Tissue Loss Disease
SERNA	Secretary of Environment and Natural Resources
SICA	El Sistema de la Integración Centroamericana
UNAM	Universidad Nacional Autónoma de México
UNESCO	United Nations Educational, Scientific and Cultural Organization
USVI	U.S. Virgin Islands
WWF	World Wildlife Fund for Nature
ZOLITUR	Comisión Administradora Zona Libre Turística de Islas de la Bahía

Regional Organizations Addressing SCTLD

Central American Integration System (SICA): SICA has as its fundamental objective the realization of the integration of Central America. One of the purposes of SICA is to establish concerted actions aimed at the preservation of the environment through respect and harmony with nature, ensuring the balanced development and rational exploitation of the natural resources of the area.

Central American Commission on Environment and Development (CCAD): CCAD was established with the mission of developing a regional cooperation and environmental integration regime that contributes to improving the quality of life of the populations of its Member States.

MAR2R: The MAR2R project aims to support regional collaboration for integrated ridge to reef management of the Mesoamerican Reef ecoregion (MAR). The MAR2R project is executed by the CCAD in coordination with the environment ministries of Belize, Guatemala, Honduras, and Mexico with financing from the Global Environment Facility (GEF) through the World Wildlife Fund (WWF).

MAR Fund: MAR Fund is a private regional environmental fund established in alliance among four national funds preexisting in the four Mesoamerican Reef countries (Mexico, Belize, Guatemala, and Honduras). The mission of the MAR Fund is to drive regional funding and partnerships for the conservation, restoration, and sustainable use of the Mesoamerican Reef. Among its initiatives includes the Reef Rescue Initiative (RRI), which aims to increase the MAR resilience and recovery capacity and conserving the environmental and cultural services it provides. This initiative is implemented by MAR Fund in cooperation with CCAD. A Technical Project Committee leads the RRI and includes representatives from the four MAR countries.

Atlantic and Gulf Rapid Reef Assessment Program (AGRRA): AGRRA's mission is to catalyze coral reef conservation by providing scientific, technical, and educational support through the curation and distribution of data, research, and training materials. AGRRA has provided training on coral reef monitoring and stony coral tissue loss disease, developed a Caribbean regional database and maps to track SCTLD's progression throughout the region, developed basic and detailed survey forms to collect data, and continues to participate in collaborative research on the disease outbreak. AGRRA, in collaboration with MPAConnect, has also developed a SCTLD Dashboard with SCTLD information for the Caribbean that is available in both English and Spanish.

Healthy Reefs for Healthy People Initiative (HRI): HRI is a multi-institutional effort that tracks the health of the MAR Reef and evaluates how socio-economic, cultural, and policy factors influence reef health. They have been actively involved in responding to SCTLD through outreach, monitoring, treatment initiatives, and webinars. HRI facilitates the MAR Regional Coral Bleach Watch Network to mobilize and support teams of partners across the region to monitor coral bleaching and recently disease. HRI encourages dialogue and collaboration to strengthen efforts to protect the Mesoamerican Reef.

MPAConnect: MPAConnect, a partnership between the Gulf and Caribbean Fisheries Institute and NOAA's Coral Reef Conservation Program, addresses MPA management capacity building needs in 32 MPAs from 11 countries and territories in the WCR. Since the SCTLD outbreak, MPAConnect has hosted learning exchanges for affected or susceptible countries, hosted webinars, and online training sessions on how to monitor for and identify SCTLD, developed educational materials, and provided funding for site-specific projects. Resources and materials on SCTLD have been disseminated in English, Spanish, and French. MPAConnect through GCFI implemented the first small grants program in support of SCTLD capacity building.

SCTLD Caribbean Cooperation Team: As a component of Florida's response to SCTLD, the Caribbean Cooperation Team (CCT) is coordinated by National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program and AGRRA. The CCT facilitates communications with regional networks and initiatives, shares technical knowledge and lessons learned, and helps identify resources to support capacity building and response.

Preface

The Regional Demonstration Project (RDP) for Action Planning against stony coral tissue loss disease (SCTLD) is supported by the Central American Commission for Environment and Development (CCAD) through the project "Integrated Ridge to Reef Management of the Mesoamerican Reef Ecoregion" (MAR2R-CCAD/GEF-WWF), in coordination with the four governments of the MAR ecoregion and facilitated by the Mesoamerican Reef System Fund (MAR Fund). The objective of the RDP is to respond to the SCTLD threat and promote governance in the ecoregion through capacity building among relevant partners.

The project focuses on supporting: 1) A Regional Dialogue Group (RDG) for capacity building on the SCTLD in the four countries of the MAR. 2) Standardization of SCTLD monitoring in the region and training of key actors in data collection based on the AGRRA SCTLD platform, 3) Action Plans for response to SCTLD in the four MAR countries, and 4) An Emergency Declaration Agreement of the Council of Ministers of the MAR on the regional importance of SCTLD.

Actions to date include:

1. **Strengthening the regional coordination through the establishment of the RDG in attention to SCTLD.**

   The RDG is the technical governance of the RDP. The purpose of this group is to create capacities on SCTLD response in coordination with experts, local communities, the scientific and academic community and with the government entities responsible for the biodiversity and coastal marine resources administration in the MAR ecoregion. The RDG is composed of 11 members including representatives from the government agencies responsible for coastal marine biodiversity in each MAR country, MAR2R-CCAD/GEF-WWF and MAR Fund.

   In addition, the RDG formed the Regional Advisory Group of Experts (RAG), composed of five (5) experts, to receive recommendations and scientific, technical, strategic and/or advocacy support related to SCTLD in the MAR region.

2. **Establishment of an Emergency Declaration Agreement of the MAR Council of Ministers on the regional importance of SCTLD.**

   In July 2021, the CCAD Council of Ministers approved the Emergency Declaration Agreement for SCTLD in the MAR region (below). The joint efforts of the RDG and the Council of Ministers succeeded in establishing an Emergency Declaration Agreement that has been of utmost importance for the MAR ecoregion. It is a high-level political and strategic action that has promoted lines of coordination between countries and key partners to seek comprehensive solutions to combat SCTLD, including research, exchange of experiences and knowledge, and technical and financial resources.

3. **Standardization of monitoring for SCTLD in the region and training of key stakeholders in its application and the recording of data collected in the Atlantic and Gulf Rapid Reef Assessment (AGRRA) SCTLD platform.**

   a) Two virtual workshops were held to build capacity in the MAR region for understanding and monitoring SCTLD. More than 180 people were trained. The workshops were a space to exchange experiences and discuss advances and innovation in the region for the detection, monitoring and treatment of SCTLD and the immediate response actions being implemented.

   - In June 2021, the RDG hosted the virtual workshop "SCTLD in the Mesoamerican Reef: Update on Science and Monitoring, Status and Trends, and Exchange of Experiences". The objectives of the workshop were to promote the exchange of experiences on the monitoring and data collection of SCTLD in the MAR region, train participants in the identification and monitoring of the disease in its different stages and the introduction of data collected into the AGRRA interface. More than 100 people participated. This workshop was organized in collaboration with AGRRA and HRI. The recording of the workshop can be viewed here: https://www.youtube.com/watch?v=0aR9OUR2Yiw

- In March 2022, the second SCTLD virtual workshop "SCTLD in the MAR- Past, Present & Future" was held in collaboration with AGRRA. The workshop focused on showcasing advances on the Action Plans of the MAR countries and immediate response actions for 2022. More than 80 people participated. Recordings can be found here:

  English: https://youtu.be/bSqZtWCLPHM
  Spanish: https://youtu.be/nJrn95koF8M

- In August 2022, in Utila Honduras, a field workshop was held to train local experts to monitor SCTLD. Nine people from the Utila diving community were trained, as well as two members of BICA-Guanaja. This activity is part of the capacity building efforts lead by the RDG with the support of MAR2R-CCAD/GEF-WWF and MAR Fund.

  b) Based on the exchange of experiences and knowledge shared at the workshops, the following monitoring guide for SCTLD was developed for the MAR region. The guide integrates monitoring recommendations and methodologies for the different stages of SCTLD and is an important tool for planning and implementing actions to address SCTLD.

4. **Development, implementation, and updating national action plans for the treatment of SCTLD in the four MAR countries.**

- **Mexico:** With the support of the National Commission of Natural Protected Areas (CONANP), the National Plan was implemented through a theoretical and practical training course on SCTLD in the Cozumel Reefs National Park. Ten people were trained in treatment, monitoring, and restoration techniques. This course can be replicated in the MAR region to train more people in response and restoration actions for coral species affected by SCTLD.

- **Belize:** In close collaboration with the Fisheries Department, 12 information sessions were conducted in seven coastal communities affected by SCTLD. The sessions were an opportunity to raise awareness of SCTLD among tourism service providers and to increase community participation in monitoring the disease and promoting best practices to prevent its spread. The sessions were conducted in Caye Caulker, San Pedro, Belize City, Dangriga, Placencia, Hopkins, and Punta Gorda, with a total of 177 participants.

- **Guatemala:** With the support of the Ministry of Environment and Natural Resources (MARN), the National Action Plan for the detection, attention, and monitoring of SCTLD was developed. The development of the Plan was a participatory process, which integrated more than 30 key stakeholders representing government, academia, NGOs, private sector and civil society, generating a practical, inclusive and coherent framework for addressing SCTLD in the country, validated by experts.

- **Honduras:** The National Action Plan for attention to SCTLD was developed with the support of the National Institute for Forest Conservation and Development, Protected Areas, and Wildlife (ICF) and the Biodiversity Department (DiBio), with the financial support of the Swiss Cooperation and MAR Fund. The plan was validated with local and national authorities, and with key actors through two participatory workshops financed by the MAR2R-CCAD/GEF-WWF project. The government institutions, Secretary of Natural Resources and Environment (SERNA), DiBio, and ICF worked together to conduct the validation of the Plan for its subsequent officialization.

COMISIÓN CENTROAMERICANA DE AMBIENTE Y DESARROLLO

Sistema de la Integración Centroamericana

EMERGENCY DECLARATION AGREEMENT BEFORE STONY CORAL TISSUE LOSS DISEASE (SCTLD) IN THE MESOAMERICAN REEF SYSTEM

The Council of Ministers of the Environment of Central America and the Dominican Republic in the context of the implementation of the Framework Regional Environmental Strategy (ERAM in Spanish), to promote the sustainability of natural resources for the benefit of the inhabitants of the region, of strategic territories such as the Mesoamerican Reef Ecoregion and,

CONSIDERING

That the Mesoamerican Reef System (MAR) is a system of interconnected watersheds, coasts and marine ecosystems that extends through the territorial waters of Mexico, Belize, Guatemala and Honduras, area of action of the Integrated Ridge to Reef Management of the Mesoamerican Reef ecoregion (MAR2R-CCAD/WWF-GEF) project and other initiatives of different regional actors with whom it coordinates.

That the MAR includes extensive mangrove forests, seagrass beds, coastal lagoons, and coral reefs that border more than 1,000 linear km of coastline, making this ecosystem one of the largest trans-boundary coral reefs in the world.

That the MAR provides valuable ecosystem goods and services to the four countries that share it and to humanity, including among others: contribution to food security, natural attractions for tourism and coastal protection, as it is the region's first line of defense against hurricanes and tropical storms.

That the MAR hosts rich biodiversity, of great importance for the well-being of more than 2 million people, including indigenous communities, who inhabit the region and for whom the MAR is the source of livelihood.

That the scenic beauty of the MAR attracts more than 21 million visitors annually and that the economic value of the MAR for tourism, commercial fishing, and coastal development sectors is equivalent to 6,647 million dollars per year (in 2017 prices), with tourism being the main contributor.

That a collaboration framework is defined between the countries of the CCAD and SEMARNAT of Mexico to work in the shared ecosystems defined by the Memorandum of Understanding signed between them.

That there is a regional strategic framework that guides, articulates, and strengthens action, including the Regional Climate Change Strategy (ERCC), the Regional Agro-environmental and Health Strategy (ERAS), and the Regional Blue Growth Strategy (SICA -ERCA).

RECOGNIZING

That the goods and services that the MAR provides are at risk due to Stony Coral Tissue Loss Disease (SCTLD).

What SCTLD represents:

- a particularly important threat to the reefs of the MAR due to its wide geographic range, extended duration, high mortality rates, and the large number of affected coral species.
- a threat that is affecting more than 34 species of hard corals: the labyrinth coral, pillar coral, flower coral, especially susceptible soft and elliptical star coral, being the first species affected during an outbreak.
- total mortality in one to two months for colonies affected and no definitive cure.
- a critical threat to the region since July 2018, when it was detected in northern Quintana Roo, registered in northern Belize in 2019; in Roatan, Honduras, in 2020 and in Guanaja, Honduras, in 2021.
- a threat that is affecting the health of corals and therefore the goods and environmental services that they provide to local communities and to the four countries of the region.

That, by virtue of the foregoing, this situation generates the urgent need for responses at the local, national, and regional level.

Therefore,

WE AGREED

1. Declare Stony Coral Tissue Loss Disease as an emergency for the Mesoamerican Reef region.

2. Affirm CCAD's commitment to, in coordination with the countries of the ecoregion, stakeholders regional and local, seek comprehensive solutions to respond to the SCTLD that include the planning, investigation, detection, monitoring, treatment, rescue and restoration actions of healthy corals, exchange of experiences and knowledge, and the technical and financial resources to carry them out.

3. Urge the international community and development partners to urgently join in addressing this emergency, to increase resilience and implement actions that allow reversing the SCTLD in the MAR region.

Guatemala, July 9, 2021

Introduction

Photo: ©Zara Zuniga

Extending over 1,000 km along the coastlines of Mexico, Belize, Guatemala and Honduras, the coral reef ecosystems of the Mesoamerican Region (MAR) are valuable biological and economic resources. Supporting rich marine biodiversity and providing food security, shoreline protection, cultural importance and tourism significance, the reef system is valued at more than US $4 billion. Coral reef condition in the MAR region has declined due to coral bleaching and disease, unsustainable and illegal fishing, poor water quality due to inadequate sewage and waste control, unregulated coastal and agricultural development, and climate-related threats.

Coral disease has affected the region's coral reefs since the late 1970-80s when a region-wide outbreak of white band disease decimated populations of two important reef building corals *Acropora palmata* (elkhorn coral) and *A. cervicornis* (staghorn coral). The 1983 die-off of the key herbivorous sea urchin, *Diadema antillarum,* contributed to a rapid increase in macroalgal cover. Coral bleaching due to elevated sea surface temperatures has also affected coral condition, with the first significant mass bleaching events in the MAR first occurring in 1995 and 1998, along with coral disease-related mortality.

More recently, stony coral tissue loss disease (SCTLD) is an emergent, aggressive coral disease devastating Caribbean coral reefs. First described off the coast of Florida in 2014 (Precht et al., 2016; Muller et al., 2020), it has since been reported in at least 25 countries/territories in the region. The disease outbreak is of great concern because it affects >34 species of corals, causes high coral mortality, may be waterborne and contagious, and spreads quickly among corals and across reefs (e.g., Precht et al., 2016; Walton et al., 2018; Aeby et al., 2019; Muller et al., 2020; Sharp et al., 2020).

In 2017, the disease was reported in Jamaica and has continued to spread throughout large portions of the Caribbean, including the Mesoamerican Reef when it was first observed in Mexico in 2018. The mechanism of transmission is not known, but may be influenced by water currents, sediments, bacteria, surface runoff, and/or ballast water. The causative disease agent has not been identified, although recent research suggests bacteria may be involved (Aeby et al., 2019), and viruses found in the coral's algal symbionts may cause a disruption of the host-symbiont relationship followed by subsequent tissue necrosis (Landsberg et al., 2020; Work et al., 2021). The disease causes significant coral mortality, with losses of 30-60% reported in Florida (Walton et al., 2018), ~46% loss in Cozumel (Estrada-Saldivar et al., 2020) and 32% loss in Turks and Caicos (Heres et al., 2021).

This Guide is a complementary tool for managers, specialists, students, policy makers and a general audience who are interested in learning more about monitoring and responding to coral disease outbreaks in the Mesoamerican Region. The purpose of this summary guide is to provide:

- An overview of key characteristics of stony coral tissue loss disease
- A summary of the current status of SCTLD in the Mesoamerican reef region including an overview of response efforts in each of the four MAR countries
- An introductory guide to the coral species susceptible to SCTLD in the MAR
- A brief overview of coral condition, diseases and how to distinguish SCTLD
- Guidance on how to monitor SCTLD and potential future coral disease outbreaks
- Resources on SCTLD

This summary guide is presented as a broad overview of this new emergent disease impacting the region's reefs, as well as a look into the tremendous response efforts undertaken in the region.

Recommendations for coral disease response actions

While stony coral tissue loss disease has had devastating impacts on the region's coral reefs, the collaborative response efforts of the various partners in the MAR at the local, country, and regional level are significant and have made a positive difference. The following actions are recommended to continue to guide future coral reef management and restoration:

1. **Outreach and Communication –** Continue to increase awareness about coral condition, promote best practices, and build capacity for coral disease detection, prevention and intervention.
2. **Research and monitoring –** Support efforts for coral reef monitoring and research to increase understanding of reef condition and disease outbreaks and to guide management responses.
3. **Data management –** Promote data collaboration and sharing and support the regional SCTLD/Bleach Watch data tracking platform hosted by AGRRA.
4. **Partnerships –** Expand local, regional, and international partnerships for adopting best management practices and opportunities for collaborative response planning. Expand partnership with tourist providers in the region to address collaborative actions and raise awareness among visitors and reef users.
5. **Coral restoration –** Support local and regional coral rescue, propagation, restoration and cryopreservation efforts to preserve genetic diversity, increase coral populations, and restore ecosystem function.
6. **Management –** Reduce stressors to coral reefs by having local governments improve water quality, install adequate sewage and solid waste treatment, reduce sediment and contaminants, promote sustainable fisheries, and adopt best management practices for watershed management and ballast and ship water treatment. Implement actions to increase ecosystem resilience to climate change.
7. **Government involvement –** It is important the Ministries of Environment review and update the Emergency Declaration in support of implementing SCTLD Country Action Plans and strategies, and to integrate these strategies in policies and regional instruments.
8. **Building capacities –** The RDG and RGA continue working together to build capacities and assist the MAR countries in implementing strategies in address SCTLD and work with the national and local authorities to install emergency response groups, and to implement this guide.
9. **Funding –** The RDG continue working with local and national authorities, MAR Fund, CCAD, and RRN-MAR to raise funds for the successful implementation of the National Action Plans and this monitoring guide.

Specific priority actions to implement over the next two years include:

- Encourage local governments to support the implementation of SCTLD Country Action Plans.
- Develop priority actions that address coral disease response at the regional level.
- Support annual regional coral reef monitoring/disease training and update training materials.
- Support biannual regional coral reef monitoring and annual Coral Bleach Watch program led by Healthy Reefs Initiative, and support data sharing platforms.
- Establish at least four 'legacy' sites per country to collect photomosaics to provide a digital baseline to track reef condition over time.
- Work regionally to identify locations of pillar coral colonies and develop targeted restoration efforts to save this rare coral as well as other endangered coral species.
- Support efforts to use coral disease and reef condition data to guide regional coral restoration opportunities after the disease outbreak.
- Host regular meetings with RDG and regional partners to share disease updates and action planning and support an annual meeting to review monitoring and management actions.

These recommendations were developed with the best information available at the time and will need to be updated yearly and/or as new information becomes available.

Characteristics of SCTLD

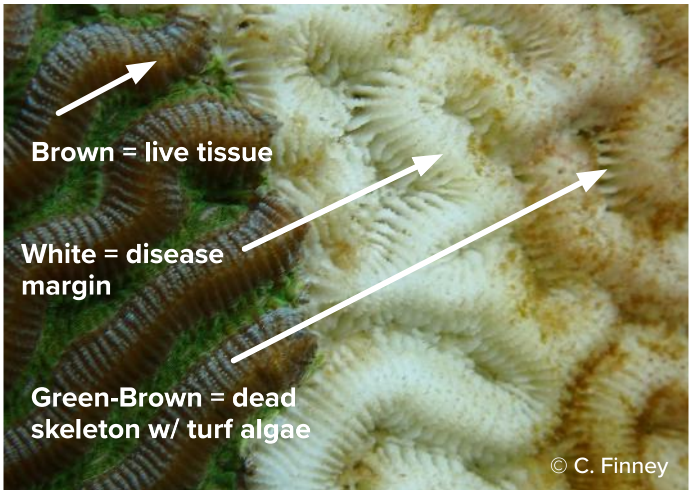
Corals are colonial animals that are unique as they can experience partial tissue death and still remain alive. As corals grow, they are exposed to continual natural and anthropogenic disturbances that may result in mortality of part of their colony. Corals can regenerate partial dead areas if the lesions are small (<1 cm) relative to the remaining living tissues but may not regenerate tissue if lesions are too large, too many, or if little live tissue remains. Dead skeletal areas are quickly overgrown or eroded by algae or other organisms. Small corals tend to have no or very low partial mortality, while larger colonies often have greater partial mortality due to their larger surface areas and longer exposure as they grow over time.

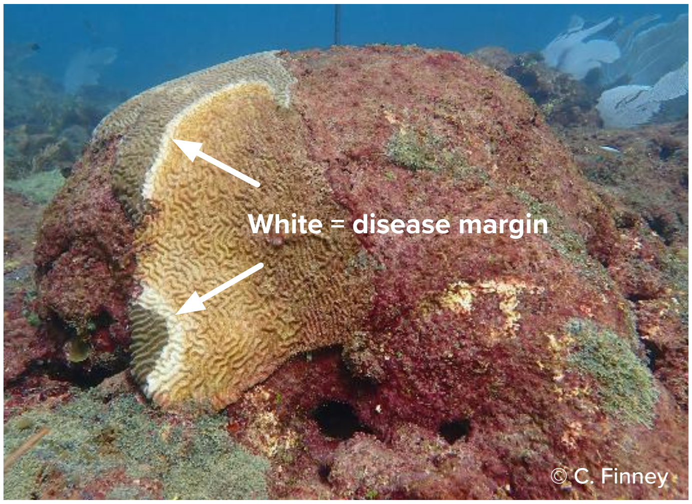
Corals are dependent upon their symbiotic relationship with their microscopic algae, zooxanthellae, which live in their tissues and provide the coral much of their energy requirements and color. Corals respond to various disturbances by expelling these algae resulting in a loss of color. Corals are highly sensitive to changes in water temperature, with increases of only 1 to 2°C triggering corals to release their pigment-rich zooxanthellae called 'bleaching'. Temporary, mild bleaching does not always kill coral polyps; however, polyps will die if the stress is severe or lasts for an extended time. Coral diseases are an impairment that interferes with the performance of a coral's normal function and involves the interaction between the coral host, the causative agent, and the environment. Little is known about what causes coral diseases or how they are transmitted but increases in disease outbreaks have been associated with stresses such as elevated temperatures, toxins, infectious agents, or combinations of these. Coral diseases can result in tissue mortality and interfere with growth and reproduction. There has been an increase in the frequency and intensity of mass coral bleaching and disease outbreaks.

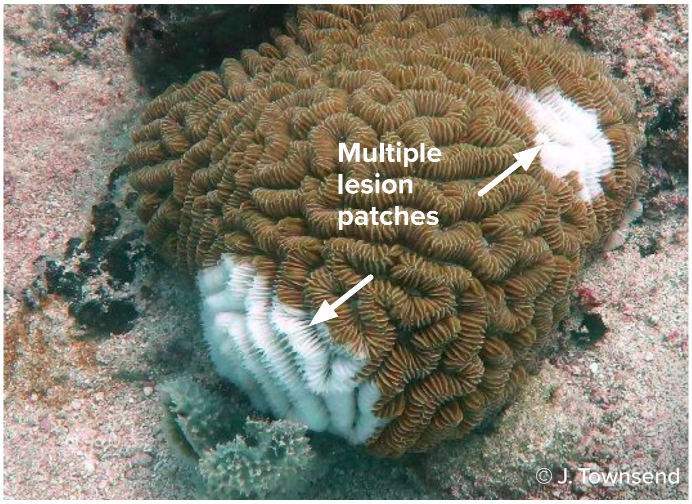
The recent outbreak of stony coral tissue loss disease has had widespread, lethal impacts. SCTLD resembles one of the white tissue loss diseases called 'white plague', which is characterized by a sharp distinct line between healthy coral tissue and freshly exposed dead skeleton, with no microbial mat along the disease interface. However, stony coral tissue loss disease has several characteristics that differ from white plague or other diseases (FKNMS Case Definition, 2018; Croquer et al., 2021). When SCTLD is first observed on a reef, numerous corals at the same time will be affected and appear white due to the rapid loss of tissue exposing the underlying white skeleton. Coral species highly susceptible to the disease and affected early on include *Meandrina meandrites* (maze coral), *Dendrogyra cylindrus* (pillar coral), *Pseudodiploria strigosa* (symmetrical brain), *Dichocoenia stokesii* (elliptical star coral), *Eusmilia fastigiata* (smooth flower coral), and *Colpophyllia natans* (boulder brain coral). Tissue bordering the disease margin may have pale bleached but alive tissue and/or tissue sloughing off (Weil et al., 2019). As the disease progresses, susceptible species often suffer complete mortality and their skeletons are quickly colonized by turf, macroalgae or other biota and may be indistinguishable from surrounding reef substrate.

While there are some similarities to other diseases, researchers identified differences including: its ability to cause faster rates of tissue loss, higher prevalence of mortality, rapid geographic expansion, and extended duration of outbreak (FKNMS Case Definition, 2018; Walton et al., 2018). The disease has decimated coral populations especially of key reef-building coral species and has decreased reef functionality such as habitat complexity and calcium carbonate production (Alvarez-Filip et al., 2022). The current disease outbreak may likely become the most lethal coral disturbance recorded in the Caribbean (Alvarez-Filip et al., 2022).

Stony coral tissue loss disease (SCTLD) characteristics







The SCTLD outbreak is significantly impacting coral reefs:

- Affects many coral species at the same time (~34+ spp., not *Acropora*)
- Causes rapid tissue mortality and whole colony death (weeks to months)
- High transmission rates (spreads rapidly, possible bacterial pathogen)
- Large geographic range (outbreaks over large spatial scales, 10-1000 kms)
- Long duration of outbreak in the Caribbean

Corals affected by the disease outbreak display the following signs:

- Discoloration of natural tissue color, high tissue loss
- White areas are exposed dead coral skeleton, quickly covered by turf algae
- Infection can start anywhere on the colony and progress rapidly
- Tissue loss lesions can be a prominent line of denuded area, single lesions or multiple patches of lesions

FIGURE 1. **Characteristics of stony coral tissue loss disease.**

Coral condition of *Meandrina meandrites*, a species highly susceptible to SCTLD. A) Healthy coral tissue ranges in color from pale yellow to dark orange/brown. B) Colony with paler than normal healthy tissues due to bleaching (expelling of *zooxanthellae*). C) Dying colony on a reef affected by SCTLD in 2021, with exposed dead skeleton (white) and partially covered by light turf algae indicates rapid tissue loss. Only a small portion remains alive (~15%). D) Dying colony on a reef in 2016 prior to SCTLD, with turf algae covering most of skeleton, a thin band of bare skeleton and ~25% alive. Similarities in lesion characteristics make it challenging to distinguish between SCTLD and other white tissue loss disease, thus using other characteristics unique to SCTLD are helpful in confirming its presence. Photos A-B, D: ©K. Marks, AGRRA. Photo C: ©Zara Zuniga.

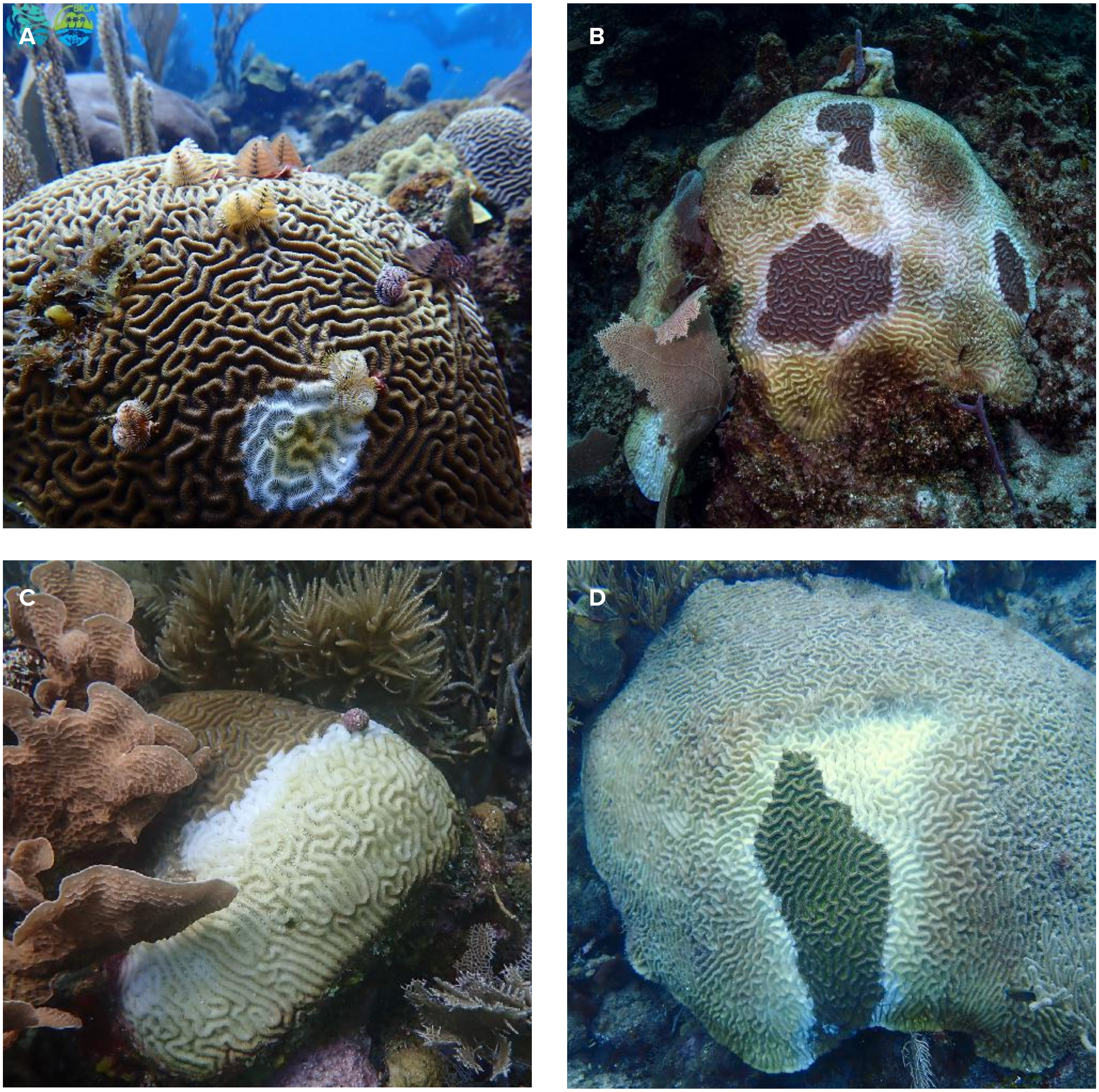
FIGURE 2. Examples of coral condition in *Meandrina meandrites* (maze coral).

Close up of corals with SCTLD. A) Exposed dead skeleton of a *Meandrina meandrites* colony has meandering wide ridges and large thick septa; interconnected polyp mouths in valleys have mostly died. Photo: ©Gaby Ochoa. B) Some of the distinctive, large round polyps of this *Montastraea cavernosa* are still living, although many have recently died or in are in process of dying. Photo: ©Zara Zuniga.

FIGURE 3. Close up photographs of corals with SCTLD.

Differences between SCTLD and WP	Stony coral tissue loss disease (SCTLD)	White plague (WP)
Prevalence	High number of diseased colonies at the same time, especially highly susceptible coral species	Number of colonies diseased at the same time is lower than SCTLD
Rate of tissue mortality	Rapid tissue loss as polyps die quickly, faster rate of lesion progression than WP (cm/day)	Polyps die, but at slower rate of lesion progression than SCTLD (mm/day)
Colony mortality	High, rapid colony mortality, lower probability of colony survival of highly susceptible species which can die within weeks-months	Causes partial mortality, but colonies often survive, lower total colony mortality than SCTLD
Coral species affected	Affects similar coral species as WP (~35 reported so far), especially high mortality in *Meandrina* spp. and *Dendrogyra cylindrus*. Not reported to affect acroporids	Affects >40 coral species, mostly massive corals, severely affecting *Orbicella* spp. Not reported to affect acroporids
Lesion appearance	Focal or multifocal tissue lesions, often coalescing into larger lesions, sometimes a narrow band of bleached tissue appears bordering areas when SCTLD first appears, lesions can start at top, bottom, or edge of colony	Regular bands or unifocal lesions, not as common to have multiple or coalescent lesions, no border of discoloration or bleached tissue, lesions often start at base of colony or concave parts of colony
Seasonality	Disease reported year-round, not related to seasonally high sea surface temperatures/bleaching	Disease often seasonal, prevalent during warmer months and peak sea surface temperatures/ bleaching
Scale/Duration	Spread across Caribbean over past 8 years; rate of spread varies and may (or may not) persist in an area; three phases: invasion, outbreak, endemic	First observance in Florida in 1970s, now reported throughout Caribbean. Usually active for short time frame (e.g., summer), although may reappear subsequent seasons

FIGURE 4. Differences between SCTLD and white plague disease.



Examples of lesions in corals with SCTLD. A lesion is part of the tissue that has been damaged by injury or disease and can vary by color, shape, size, or quantity. Lesions can be focal (one distinct point), multifocal (several), linear or multifocal lesions coalescing (merging together). Arrows indicate live tissue area. A) *Pseudodiploria strigosa* (PSTR) with small round focal lesion, note light brown skeleton covered with turf algae; colony ~5% dead. Photo: ©Zara Zuniga. B) PSTR colony with multifocal, coalescing lesions; colony ~80% dead. Photo: ©Patrick Lengacher. C) PSTR colony with linear tissue loss with coral snail along disease margin; colony ~50% dead. Photo: ©Fragments of Hope. D) *Colpophyllia natans* colony with high tissue loss; colony ~75% dead. Photo: ©L. Searle.

FIGURE 5. Examples of lesions in corals with SCTLD.

Geographic Range of SCTLD

The disease has a large geographic range, impacting corals throughout the Caribbean. Stony coral tissue loss disease was first observed in 2014 in Miami, FL, and continued to spread each year, expanding its range along Florida's reef's. In 2017, it was first reported in the central Caribbean island of Jamaica and by 2018 confirmed in the western Caribbean along Mexico's Caribbean coast and far to the region's east side in Sint Maarten.

By the end of 2019, seven countries/territories confirmed the presence of SCTLD, primarily in island nations, although two of the largest Caribbean reef systems, The Bahamas Archipelago and Belize Barrier Reef, began to show evidence of high coral mortality due to the disease. Through 2020 and 2021, the disease outbreak spread further south along the Eastern Caribbean Island chain, and to the west where it reached Honduras, the southernmost country of the Mesoamerican region. Even remote coral reefs east of Colombia's Sea Flower Biosphere Reserve, have been affected.

The disease epidemic has spread 1,000s of km towards the Caribbean's north, west, east, and southern boundaries. Several reef systems have yet to be reported affected, such as Nicaragua, Panama, coastal Colombia, Venezuela, Trinidad and Tobago, Barbados, and Bermuda. Many of these are further removed from other affected Caribbean reefs. The southern Caribbean islands of Aruba, Curacao and Bonaire have also, up until now, escaped the outbreak. Interestingly, some reefs within highly affected areas remain disease free including Banco Chinchorro, Mexico, Guatemala, and coastal Honduras. It is not known why these areas have remained free of the disease outbreak, but regular monitoring of these reefs should be done.

The disease outbreak has been highly dynamic affecting some areas at different rates and extent. For recent updates see the online interactive AGRRA SCTLD Tracking Map. The disease has not been reported in the Indo-Pacific, but some coral Families susceptible to SCTLD in the Caribbean are found in the Indo-Pacific, thus response planning has begun there (Laforest and McLaughlin, 2022).

The disease outbreak occurred during the COVD-19 pandemic which limited the ability to fully track its impact in parts of the region. The geographic extent of the disease may not be fully known as the signature to identify the disease disappears quickly as corals die and get covered by algae and other reef biota. In the matter of ~8 ½ years, SCTLD has spread across 1,000s of kms and has had a devastating impact on coral reefs in more than 25 countries/territories.

Year	Location	Map ID
2014	Florida	1
2017	Jamaica	2
2018	**Mexico**	3
	Sint Maarten	4
2019	U.S. Virgin Islands	5
	Dominican Republic	6
	Turks and Caicos Islands	7
	Saint-Martin	8
	Belize	9
	Sint Eustatius	10
	The Bahamas	11
	Puerto Rico	12

Year	Location	Map ID
2020	British Virgin Islands	13
	Guadeloupe	14
	St. Lucia	16
	Honduras	17
	Martinique	18
2021	St. Kitts & Nevis	19
	Saba	20
	Saint Barthélemy	21
	Dominica	22
2022	St Vincent & Grenadines	23
	Grenada	24
	Colombia	25

FIGURE 6. Location of countries/territories where SCTLD has been confirmed in Wider Caribbean Region as of July 2022. Dates are the year SCTLD was first reported. (Map designed by AGRRA). For recent updates, see the AGRRA SCTLD Tracking Map.

Coral Species Affected by SCTLD

The disease outbreak has affected numerous coral species, nearly half of species in the Caribbean. To begin to understand the negative effects and loss of corals due to stony coral tissue loss disease (or any disease outbreak), it is important to look at how this disease is impacting coral species as well as coral Families, several of which are only found in the Caribbean. The loss of individual coral colonies on a reef can reduce populations but high mortality across numerous species and genera found only in the Caribbean and wider Atlantic can have negative consequences on the diversity, structure, and function of the reef ecosystem.

When SCTLD was first reported in Florida, it was estimated to mainly affect 20 of ~45 species found in Florida. As the disease has spread regionally over the past eight years to different geographic areas, depths and reef types, coral species previously described initially as 'unaffected or not enough information' have since been affected. There are at least 34 coral species (of ~64 species) reported in the Caribbean to be affected. Given the continued spread and effects of the disease, more species may be affected.

Corals from nine families have been reported as affected by stony coral tissue loss disease in the Caribbean. Faviidae has the greatest number of species affected by SCTLD, followed by Agariciidae, Meandrinidae, Merulinidae, Pocilloporidae, Poritidae, Siderastreidae, Astrocoeniidae, and Montastraeidae. The family Meandrinidae has the most species considered as highly susceptible species and include genera *Dendrogyra, Dichocoenia, Eusmilia,* and *Meandrina*. These four genera are only found in the Atlantic. The Faviidae family contains the greatest number of species affected by SCTLD (highly and intermediate susceptible). Four of the genera affected are only found in the Atlantic including *Colpophyllia, Pseudodiploria, Diploria,* and *Manicina.* The *Orbicella* genus is only found in the Atlantic and includes *O. annularis, O. faveolata* and *O. franksi.* Orbicellids are dominant reef building corals, making up the three-dimensional structure on a reef. Montastraeidae is a monotypic family and has only one coral species, *Montastraea cavernosa*, which is found in the wider Atlantic. Agariciids are very common on reefs, but *Agaricia* and *Helioseris* are genera only found in the Caribbean. *Siderastrea siderea* (of family Siderastreidae) can form large, massive colonies and is found only in the Atlantic. Pocilloporidae has two species affected by SCTLD including *Madracis auretenra,* which is only found in the Caribbean, and *M. decactis.* Poritidae includes two species that are believed to be affected including *Porites porites* and *P. astreoides*. One species in the family Astrocoeniidae has been reported affected, *Stephanocoenia intersepta.* One coral species, *Solenastrea bournoni,* is considered Scleractinia incertae sedis (family placement uncertain).

Caribbean coral reefs have experienced several disease outbreaks. The concern with the current outbreak is the disease is causing high mortality in corals that are unique and endemic to the Caribbean and wider Atlantic.

Coral Families susceptible to stony coral tissue loss disease

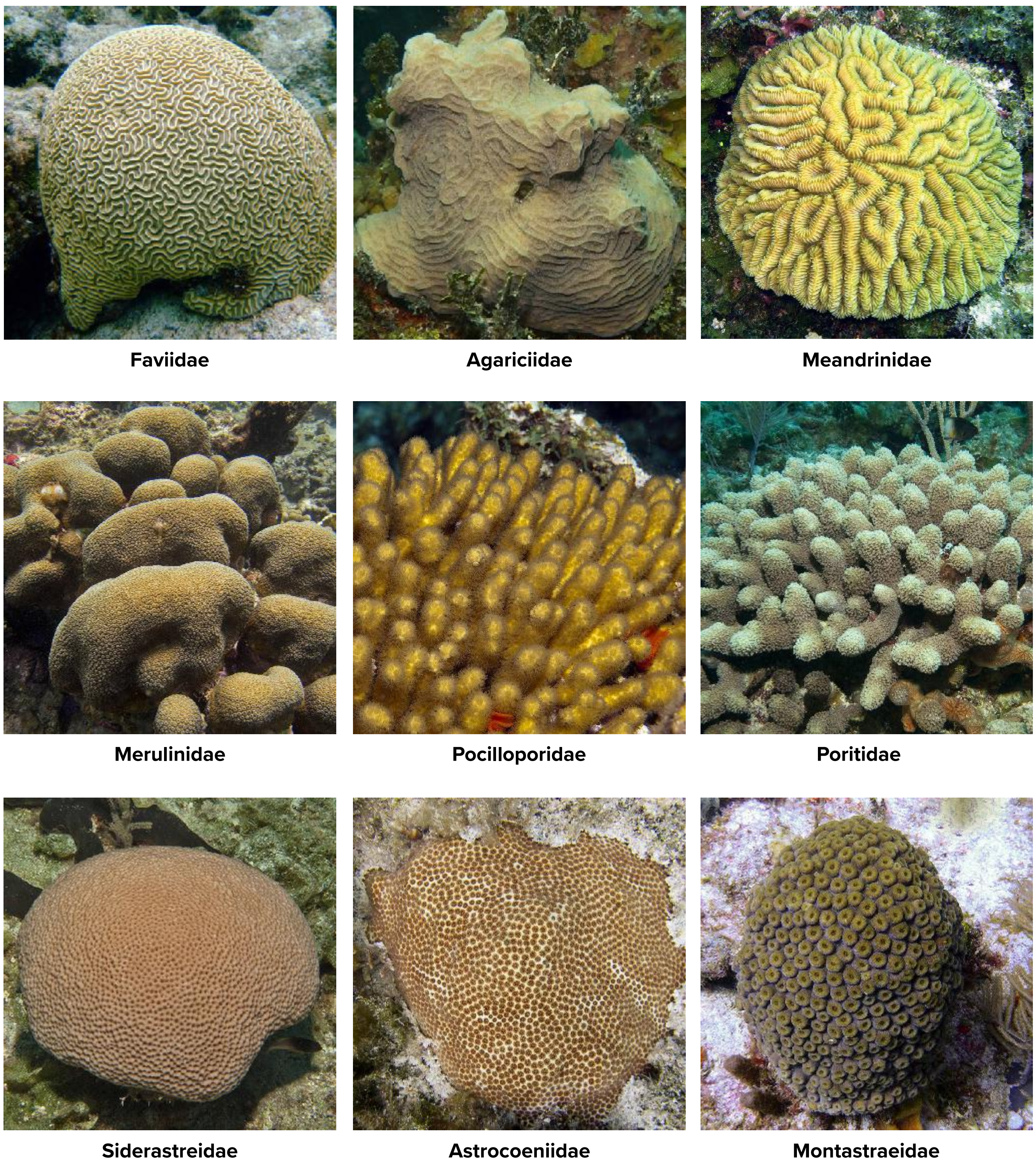


FIGURE 7. Coral families susceptible to stony coral tissue loss disease. Photos: ©Ken Marks, AGRRA.

Susceptibility of Corals to Disease and Mortality

SCTLD can affect coral species differently. Some species are more susceptible, and the disease signs may be different even within the same coral species (FKNMS, 2018, Bruckner, 2019). The first case definition of stony coral tissue loss disease described four categories of susceptibility related to the timing of the outbreak and severity including: highly susceptible, intermediately susceptible, presumed susceptible and low or unknown (FKNMS, 2018). Susceptibility of each species is provided in the Table to the right. Numbers refer to if the species was reported as affected in one of the Mesoamerican countries (Mexico = 1, Belize = 2, Honduras = 3, Guatemala has not reported SCTLD). As additional research is conducted, the case definition is likely to be updated.

- **Highly susceptible** species includes those that are first affected during an outbreak (early onset). The disease rapidly progresses, with total mortality ranging from one week for small colonies to complete mortality over 1-2 months for larger colonies. Usually, *Meandrina meandrites* (maze coral, MMEA) and *D. stokesii* (elliptical star coral, DSTO) are affected first, followed by *C. natans* (boulder brain coral, CNAT) and then the other highly susceptible species.

- **Intermediately susceptible** species include those where the beginning of tissue loss occurs about a month after the onset in highly susceptible species, although a few of these species may show disease signs before, or at the same time as, the highly susceptible species. Smaller colonies tend to die completely over months and larger colonies tend to suffer new lesions and associated mortality over years.

- **Presumed susceptible** are species that were originally believed to be affected by SCTLD, but at the time not enough information was available. This category has been updated to the term **'Reported presence of SCTLD'** and includes species where field observations consistent with the case definition have been reported and was compiled from published literature, AGRRA SCTLD Caribbean database, and other sources.

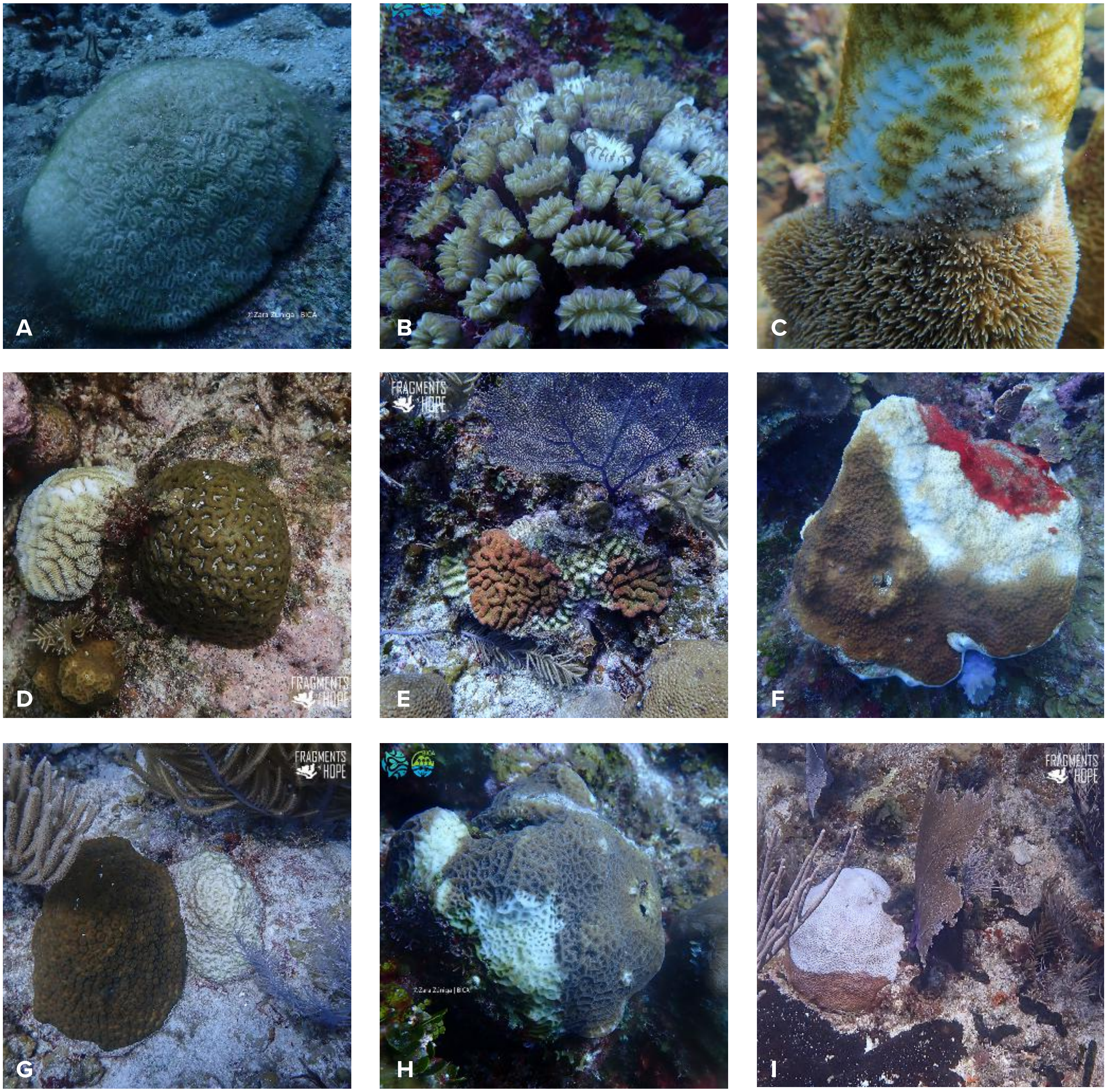
- **Low/unknown susceptible** are species that have a low likelihood of being affected by SCTLD or not enough information is yet available to categorize it.

In Florida, highly susceptible species like *P. strigosa* (PSTR), *D. stokesii*, *C. natans*, *Eusmilia fastigiata* (EFAS), *Dendrogyra cylindrus* (DCYL) and *D. labyrinthiformis* (DLAB) were some of the earliest species to show signs of SCTLD (Precht et al., 2016; Gintert et al., 2019; Williams et al., 2021). A similar pattern of species susceptibility was observed along the Mexican Caribbean coast, although some differences in prevalence were seen (Alvarez-Filip et al., 2019). In the USVI, several species whose susceptibility had been categorized as 'less affected or unknown' in Florida were confirmed to be affected in U.S. Virgin Islands including *Agaricia* spp., *Madracis* spp., *Mycetophyllia* spp. and *Porites astreoides* (Brandt et al., 2021). Observations from deep mesophotic reefs (20-40m depth) off Vieques Island, Puerto Rico had different susceptibility patterns and prevalence, where 98% of species affected were *Orbicella* spp. (ORBI), although other species included *A. grahamae, A. lamarcki* (ALAM), *M. cavernosa* (MCAV) and *P. astreoides* (Williams et al., 2021). Surveys from Cozumel found species not previously reported as affected including *Helioseris cucullata, Isophyllia rigida* (IRIG), and *A. tenuifolia* (Estrada Saldivar et al., 2021). Patterns to the susceptibility of SCTLD are similar in several areas, although some differences may be related to predominate species present, habitat type or depth, the loss of formerly common species, or the timing of the survey in relation to outbreak stage.

Highly Susceptible Species	Intermediately Susceptible Species	Species with reported SCTLD†	Unknown/not affected Species
Colpophyllia natans [1*,2*,3*] Boulder brain coral	*Orbicella annularis* [*1*,2*,3*] Lobed star coral	*Agaricia agaricites* [1,2,3] Lettuce coral	*Porites divaricata* Thin finger coral
Dendrogyra cylindrus [1*,2*,3**] Pillar coral	*Orbicella faveolata* [1*,2*,3*] Mountainous star	*Agaricia lamarcki* [1, 2*,3] Lamarck's sheet coral	*Oculina* spp. Bush corals
Dichocoenia stokesii [1*,2*,3*] Elliptical star coral	*Orbicella franksi* [1*,2*,3*] Boulder star coral	*Agaricia humilis* [1] Low-relief lettuce coral	*Cladocora arbuscula* Tube coral
Diploria labyrinthiformis [1*,2*,3*] Grooved brain coral	*Montastraea cavernosa* [1*,2,3] Large-cup star coral	*Agaricia tenuifolia* [1,3] Thin leaf lettuce coral	*Acropora palmata* Elkhorn coral
Eusmilia fastigiata [1*,2,3*] Smooth flower coral	*Siderastrea siderea* [1*,2,3*] Starlet coral	*Helioseris cucullata* [1,2] Sunray lettuce coral	*Acropora cervicornis* Staghorn coral
Meandrina meandrites [1*,2*,3*] Maze coral	*Stephanocoenia intersepta* [1,3] Blushing star coral	*Meandrina jacksoni* [1*,3*] White valley Maze Coral	
Pseudodiploria strigosa [1*,2*,3*] Symmetrical brain	*Solenastrea bournoni* Smooth star coral	*Mussa angulosa* [1,2*,3*] Spiny flower coral	
Pseudodiploria clivosa [1*,2,3*] Knobby brain coral		*Isophyllia rigida* [1*] Rough star coral	
		Mycetophyllia lamarckiana [1*,2,3] Ridged cactus coral	
		Favia fragum [1] Golf ball coral	
		Siderastrea radians [1] Lesser starlet coral	
		Madracis auretenra [3*1] Pencil coral	
		Porites astreoides [1,2,3] Mustard hill coral	
		Porites porites [1,2] Finger coral	
		Porites furcata [1] Branched finger coral	
		Isophyllia sinuosa Sinuous cactus coral	
		Mycetophyllia aliciae Knobby cactus coral	
		Mycetophyllia ferox Rough cactus coral	
		Agaricia grahamae Graham's sheet coral	
		Madracis decactis Ten-ray star coral	
		Scolymia cubensis + wellsi Artichoke corals	

Notes: †- This category was originally "Presumed susceptible' in the 2018 Case definition and has been updated to include species with signs of SCTLD from information by Alvarez-Filip et al., 2022, Lee Hing et al., 2022, and Kramer et al., 2022. Numbers (1, 2, or 3) signify coral species with SCTLD reported by each country: 1=Mexico, 2=Belize, 3=Honduras. Asterisk* identifies corals in the Mesoamerican country with >10% SCTLD prevalence based on sources above. *Mycetophyllia lamarckiana* refers to *Mycetophyllia lamarckiana + danaana*. This list may change as more surveys are done and as the disease progresses.

FIGURE 8. Corals susceptible to SCTLD based on updates to the Florida Case Definition (FKNMS, 2018) in the Caribbean and Mesoamerican Reef Region.



Example of corals affected during the SCTLD outbreak in the MAR. Arrows show disease margin. A) Total recently dead colony of DSTO; DSTO was one of most affected species in Honduras and Belize likely because surveys were conducted during invasion/outbreak stage; in Mexico, fewer sick or dead DSTO were observed, but several small alive colonies were observed in 2022 (L. Alvarez-Filip pers. comm.). B) EFAS. C) DCYL. D) Total recently dead colony MMEA (left), not affected IRIG (right). E) MLAM. F) ORBI. G) Recently dead colony MCAV (right) and healthy colony (left); MCAV with SCTLD was reported during surveys in Mexico but observations in Belize and Honduras occurred after surveys. H) *Agaricia agaricites*. I) *Siderastrea siderea* with pale tissue. Photos A, B, C, F, H: © Zara Zuniga, Honduras. Photos: D, E, G, I: ©Fragments of Hope, Belize.

FIGURE 9. **Example of corals affected in the MAR during SCTLD outbreak.**

Stages of SCTLD Outbreak

One aspect of the current stony coral tissue loss disease outbreak that is different from other white syndromes or diseases is its persistence through seasons and time. Several coral diseases have been associated with seasonally high sea surface temperatures such as black band disease and white plague. However, high water temperatures do not appear to directly influence SCTLD prevalence or virulence. The disease outbreak has persisted regionally for eight years as it has spread throughout the Caribbean.

Several stages of disease outbreaks have been characterized:

Pre-Invasion Stage: During this stage, stony coral tissue loss disease is not present, although other diseases may be present at low or baseline levels (2-3%).

Invasion Stage: During the invasion stage, most highly susceptible coral species such as brain, pillar and maze corals start to have tissue mortality and whole colony mortality. In some cases, lettuce corals and smooth flower corals also may die. Intermediate or low susceptible species are often not affected. The stage happens quickly within the first few months (e.g., 1-7 months).

Epidemic Stage: As a reef transitions from an invasion stage to an epidemic stage, star and great star corals start to die and there will be fewer alive colonies of highly susceptible species, and if they are present, many will be infected and dying. This can be prolonged from several months to a year.

Endemic Zone: After the initial outbreak, disease prevalence is lower but still present and remaining corals may have chronic tissue lesions. Often there are few highly susceptible species alive, while non-susceptible species may increase.

Disease Outbreak Terms

Disease – Any impairment that interferes with the performance of a coral's normal function, including responses to environmental factors such as temperature stress, toxins or infectious agents, or combinations of these factors.

Baseline – The amount of a particular disease that is present in a coral community is referred to as the baseline and is the expected level of the disease.

Emergent disease – Any new disease in a population or resurging disease that was previously at low levels.

Invasion – The time between arrival of the pathogen (or causative agent) and the first appearance of disease signs.

Epidemic (Epizootic) – The occurrence of disease at levels above what is expected in a population. It can also be a single case in a new area. Epidemics may last for a few days, weeks, months, or years. Outbreaks can quickly become an epidemic if the disease is not contained.

Endemic – Following a disease outbreak, endemic refers to the level of disease consistently always present, with low spread or limited to a particular region. This level is not necessarily the desired level (e.g., zero), but rather is the observed level following an outbreak.

Prevalence – The number of diseased colonies relative to the total number of colonies present within a defined area at a specific point in time.

Incidence – The number of new cases of disease over a specified time period.

Stages of stony coral tissue loss disease progression

Invasion	Epidemic	Endemic
1 -7 months (often <3 months)	3 months - 1 year	1 - 4+ years

Disease Prevalence

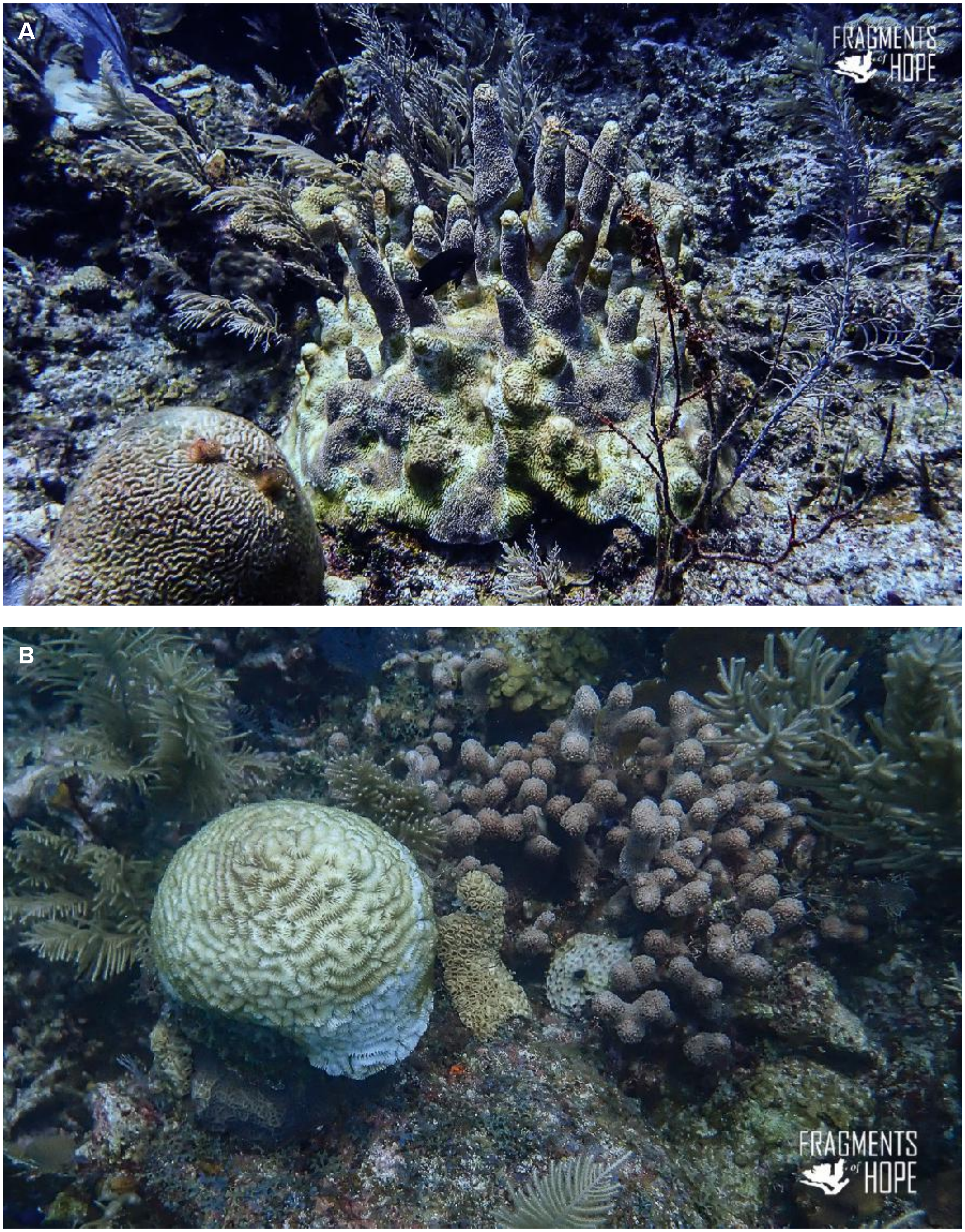
LOW	HIGH	LOW
Acute lesions in species most susceptible	Acute lesions in all susceptible species	Least susceptible corals with acute and chronic lesions

Coral Community

All species still present; species most susceptible start dying	Rapid transition to many early susceptible, and then progressively less, susceptible species	Few or no susceptible species remain. Coral cover reduced; proportion of non-susceptible species has increased

(Adapted from Neely, 2018a, Lang 2020)

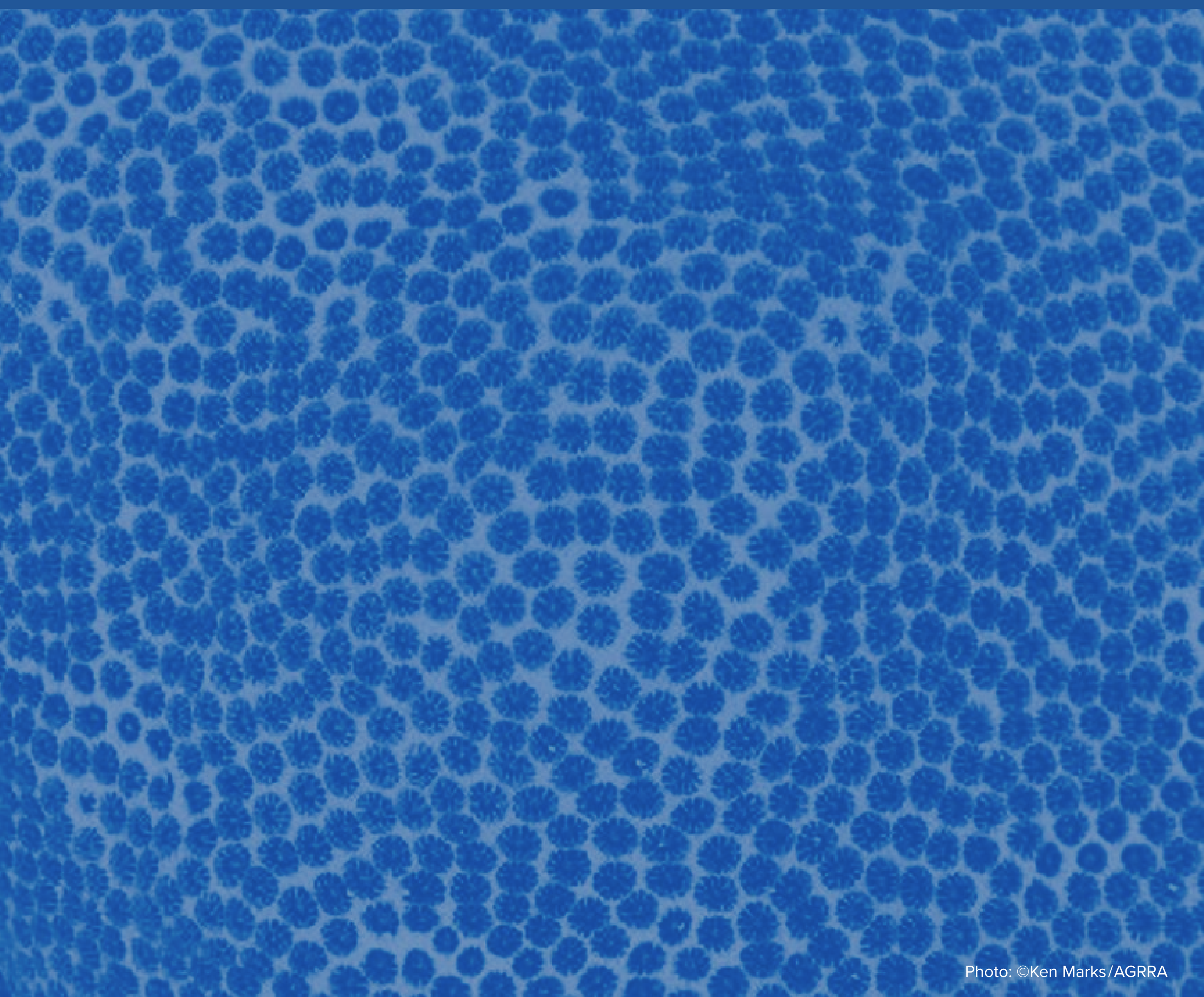
FIGURE 10. Stages of stony coral tissue loss disease progression.



Numerous susceptible species suffered total mortality. A) Total recently dead colony of PSTR (left) and high recent mortality of DCYL (middle); recently dead skeleton covered with turf algae. B) Recently total dead colony of MMEA (left) and unaffected PPOR (right). Photos: ©Fragments of Hope, Belize.

FIGURE 11. Examples of coral reefs in Belize during the invasion/outbreak disease phase.

Status of Disease in the Mesoamerican Reef Region



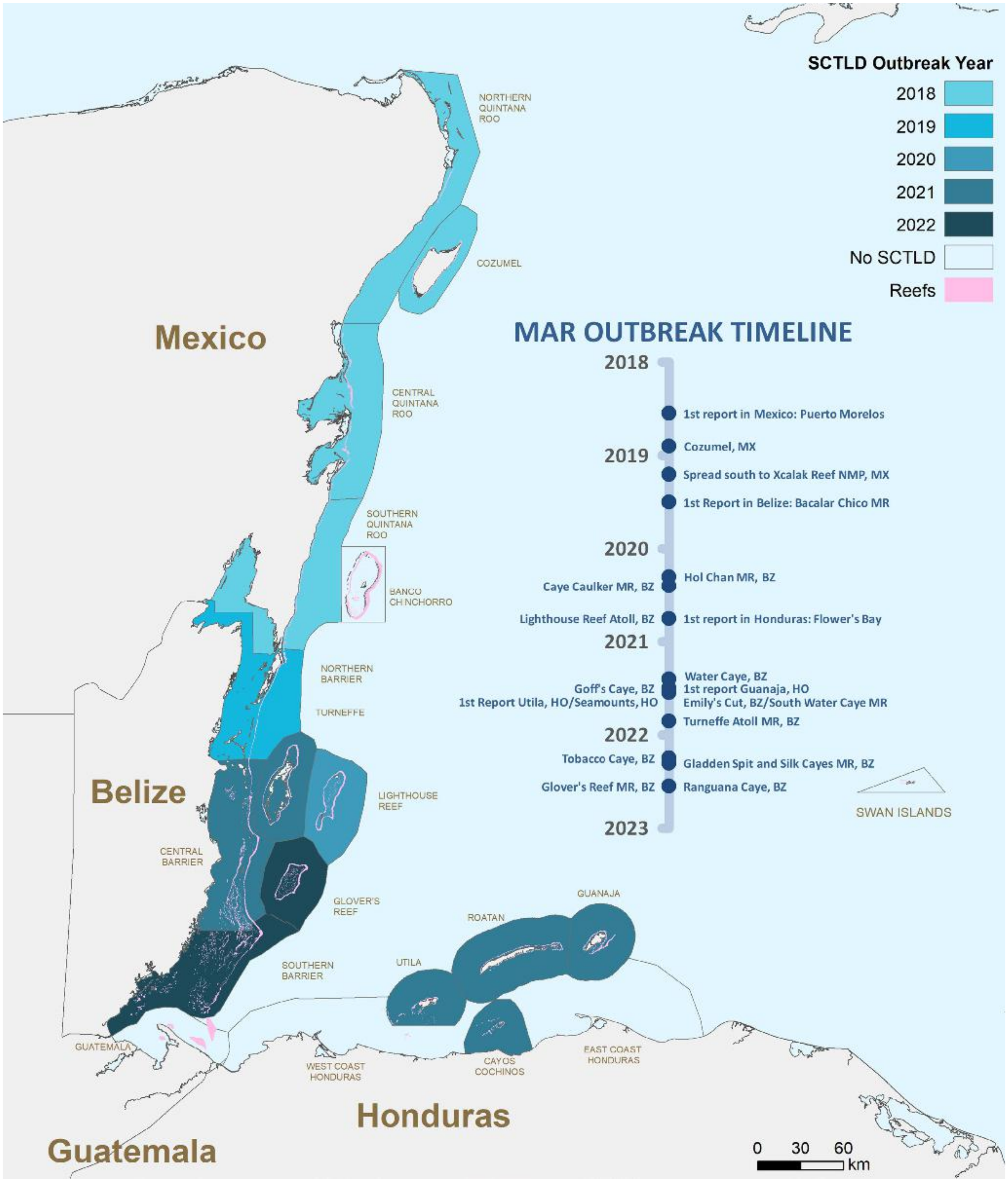


FIGURE 12. Map of stony coral tissue loss disease in the Mesoamerican Reef Subregions. Colors represent when the disease was first observed in a subregion. Note, while a subregion may be colored, not all reefs within a subregion may be affected or reefs within a subregion may have been affected at different times. See the following country maps for reef specific data (Data compiled from reports to AGRRA SCTLD Tracking map from 2018-July 2022 and for Mexico data based on Alvarez-Filip et al., 2022. Subregion boundaries based on HRI, 2020; Map developed by AGRRA).

Mesoamerican Reef Regional Overview

The Mesoamerican Reef (MAR) extends more than 1,000 km from the northern tip of Mexico's Yucatan Peninsula southward through the waters of Belize, Guatemala, and northern Honduras. The reef ecoregion reaches inland to include the Caribbean watersheds of the four countries, and it stretches 1,000 km offshore. This reef system, which includes the Western Hemisphere's longest barrier reef, is one of the world's biodiversity hotspots.

SCTLD was first believed to be epidemic and found only in Florida, but since 2017, it has spread to reefs in multiple countries in the Caribbean, including the Mesoamerican Reef Region. Evidence of the disease outbreak have been reported for Mexico, Belize, and Honduras, but not Guatemala.

In July 2018, stony coral tissue loss disease was first reported in the Mexican Caribbean near Puerto Morelos. The disease quickly spread along the entire 450 km coastline over just a few months. By December 2018, the disease reached southwest Cozumel and spread rapidly. Banco Chinchorro atoll is the only area that has not yet been affected by the outbreak in Mexico.

In June 2019, stony coral tissue loss disease was first observed in Belize at Bacalar Chico National Park and Marine Reserve in the northernmost part of Belize. Unlike the rapid spread observed in Mexico, the disease outbreak progressed slower at first in Belize. In April 2020, it was found in Hol Chan MR and by May detected in Caye Caulker. At that time, it had traveled ~55 km since it was first detected about a year earlier. The disease outbreak reached the northern portion of the remote offshore atoll, Lighthouse Atoll, in September 2020. By May 2021, the disease had spread from northern barrier to Sergeant's Caye in the central barrier area off Belize City and the second atoll was affected in June 2021 at Turneffe Atoll and along central barrier near Emily's Cut (July 2021). In March/April 2022, the disease appeared further along the barrier and was observed in Tobacco Caye and South Water Caye Marine Reserve south into Gladden Spit and Silk Cayes Marine Reserve. By July 2022, the disease had reached as far south as Ranguana Caye and for the first time was reported at the last offshore atoll, Glover's Reef Atoll. The Sapodilla Cayes Marine Reserve, Port Honduras Marine Reserve and interior patch reefs have not yet been affected.

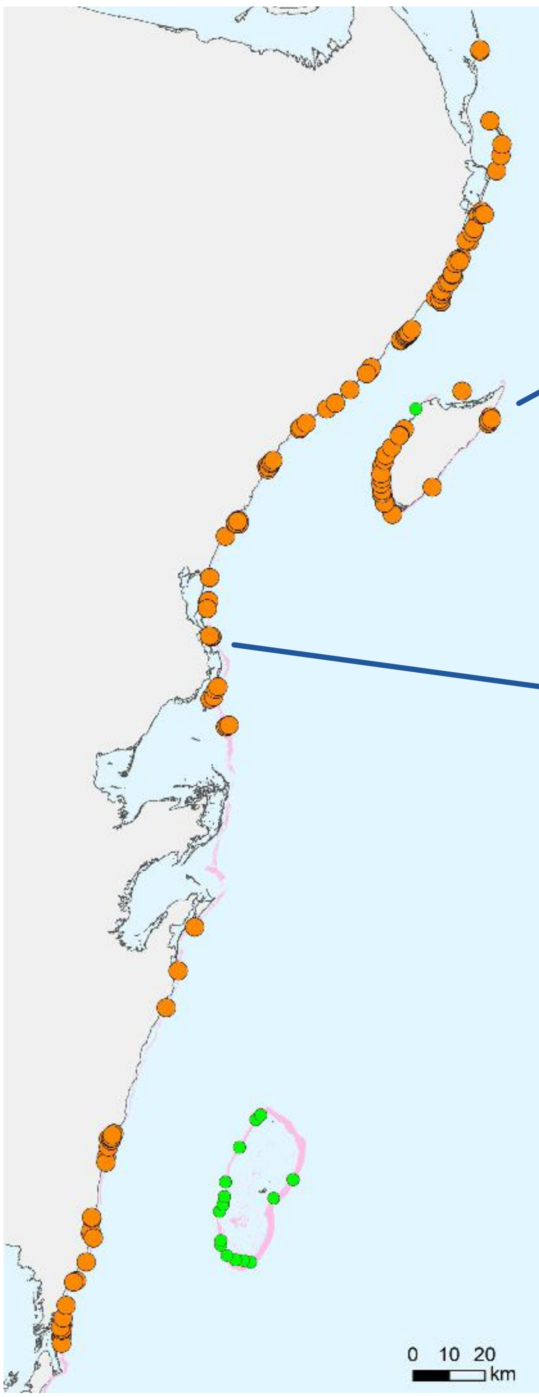
Guatemala surveys in 2021 and early 2022 found no evidence of the disease outbreak.

In Honduras, the disease was first reported in Roatan in September 2020, in Utila in June 2021, the seamounts in July 2021 and limited reports in Guanaja in June 2021. Reefs at Cayos Cochinos MR and Tela along the mainland coast have not reported signs of the disease. In Roatan, the disease has affected >85% of the island with the northwest and southwest areas being affected the most. The disease has also impacted most of Utila's reefs.

The disease has affected more than 30 coral species, causing high rates of tissue mortality, and has likely killed thousands of corals. The full impact of the outbreak may not fully be known as monitoring was limited during the COVID-19 pandemic. Despite the challenges, each country responded quickly to develop monitoring programs and management actions.

The following country reports are a brief overview of the status of the disease outbreak and a list of response actions.

Stony Coral Tissue Loss Disease in Mexico



Presence / absence of stony coral tissue loss disease in Mexico. The disease outbreak affected 450 km of coastline and Cozumel. Banco Chinchorro has not been affected by SCTLD. Orange circles represent sites where the disease was observed. Green circles represent sites with no signs of the disease. Note different lesion patterns on same type of coral species (*P. strigosa*). Data compiled from Alvarez-Filip et al., 2022 and reports to AGRRA SCTLD Tracking map.

Top photo of *P. strigosa* (PSTR) Jan 6, 2022, Ha'nan II Reef, Cozumel (©Núñez-Inzunza). Bottom Photo of *P. strigosa* (PSTR) Jan 2021, Yuyum Reef (©EPerezCervantes).

FIGURE 13. **Map of presence / absence of stony coral tissue loss disease in Mexico.**

Mexico Overview

Mexico's Yucatan Peninsula has a long fringing coral reef system extending 450 km along the coastline from Isla Contoy south to Xcalak, including offshore islands like Cozumel and Banco Chinchorro atoll. Coral reef habitat naturally varies with northern reefs having partial reef development and many *Acropora palmata* (elkhorn coral) stands, and the central and southern areas containing continuous, better-developed fringing reefs. Cozumel Island and Banco Chinchorro, the largest atoll in the Mesoamerican Reef region and a UNESCO Biosphere Reserve, have a variety of well-developed reefs. In 2016, the Mexican Caribbean Biosphere Reserve was established and provides protection to nearly the entire territorial sea of Quintana Roo. Continued population growth in the region is having a compounding negative impact on the reef ecosystems. Reefs are threatened by expansive coastal development, lack of sufficient sewage and wastewater control, and a history of fishing and growing demand. The reefs are highly vulnerable to land-based contaminants and nutrients due to the porous, karstic aquifer.

Prior to 2018, coral cover (16%) had slightly increased from previous years. In July 2018, stony coral tissue loss disease (known as 'white syndrome' in Mexico) was first reported in Mexico at reefs near Puerto Morelos. Over the next few months, the disease spread across the entire coastline affecting 21 coral species and causing mortality rates of 10-94% (Alvarez-Filip et al., 2019). Most corals of the *Meandrinidae* (maze corals) and subfamily *Faviinae* (brain corals) sustained losses of > 50%. Once a coral showed disease signs, tissue mortality occurred quickly. Disease prevalence of highly susceptible species was similarly high at different habitats, depths, and coral population densities, suggesting the spread of the disease was related to the pathogen(s) ability to be transported through the water column within a reef and from reef to reef. Reefs closer to urban populated areas were impacted more by the disease. By December 2018, the disease reached southwest Cozumel and quickly spread (Estrada-Saldivar et al., 2021). By summer 2019, between 33-95% of corals (*Meandrinidae* and *Montastraeidae*) were affected. The die-off resulted in a 46% loss of coral cover followed by a subsequent increase of algal overgrowth. Banco Chinchorro, separated by the Yucatan Current and more isolated from human development, has not yet been affected by the disease even though highly susceptible coral species are present. The significant loss of coral has resulted in reduced populations of key reef-building corals allowing for algae and smaller opportunistic corals to become more dominant (Alvarez-Filip et al., 2022).

In response to the disease outbreak, numerous organizations have initiated outreach campaigns to quickly inform and engage the communities. The National Commission for Natural Protected Areas (CONANP) in collaboration with stakeholders developed and implemented the SCTLD action plan: "Action Plan For The Stony Coral Tissue Loss Disease In Coral Reef Systems Of The Mexican Caribbean." The Action plan promotes sustainable tourism, integrated coastal zone and water management, sustainable fishing, and academic research and monitoring. The main actions of the plan aim to:

1) Improve water management and implement tertiary wastewater treatment.

2) Respond to massive sargassum influx and alleviate deterioration of water quality.

3) Restore marine-coastal ecosystems.

4) Create genetic banks of the affected coral species.

5) Promote the sustainable coastal infrastructure and sustainable tourism activities; and

6) Encourage use of protective clothing to avoid the use of sunscreen.

Extensive research has been, and continues to be, conducted to evaluate the long-term effects of the disease. Numerous collaborative and innovative efforts are underway in response to the outbreak.

Response Efforts in Mexico

- In July 2018, the presence of the SCTLD was detected in different sites of the Costa Occidental of Isla Mujeres, Punta Cancun, and Punta Nizuc National Park, as well as in the Arrecife de Puerto Morelos National Park, mainly affecting different species of the genus: *Dendrogyra, Meandrina, Pseudodiploria, Eusmilia, Siderastrea, Diploria, Montastraea, Stephanocoenia, Colpophyllia, Siderastrea* and *Orbicella*.

- The National Commission for Natural Protected Areas (CONANP) in coordination with various actors from government entities, civil society organizations, academy, and users of reef ecosystems, have developed and implemented the SCTLD action plan: "Plan de Acción del Síndrome Blanco en Arrecifes Coralinos del Caribe Mexicano" To attend the disease. (https://www.gob.mx/conanp/documentos/plan-de-accion-del-sindrome-blanco-en-los-arrecifes-del-caribe-mexicano).

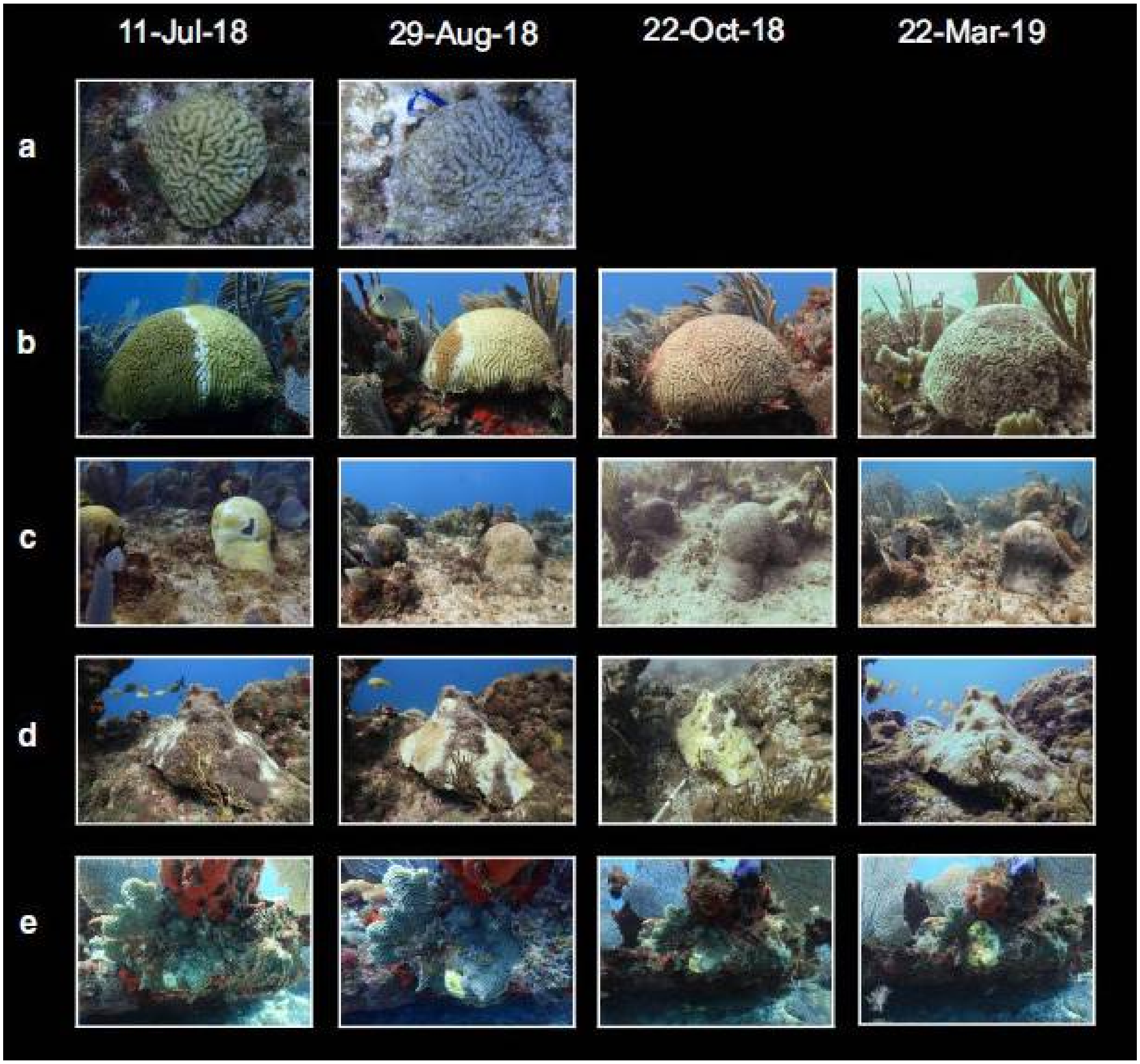
- The impact of the SCTLD in 8 Natural Protected Areas (NPA) has been evaluated and communication strategies for the disease were implemented in the state of Quintana Roo, in order to strengthen management strategies through the participation of local communities and key stakeholders of the different NPA.

- With the support of the National Commission of Protected Areas (CONANP), a theoretical and practical training course on SCTLD was designed and implemented in the Cozumel Reefs National Park. Ten people were trained in treatment, monitoring, and restoration techniques. This course can be replicated in the MAR region to train more people in response and restoration actions for coral species affected by SCTLD.

Mexico Coral Species	Code	Healthy Colonies	Colonies with SCTLD	Colonies with Other Conditions	Total Colonies	% SCTLD
Meandrina jacksoni	MJAC	0	5	0	5	**100.0%**
Dendrogyra cylindrus	DCYL	1	18	0	19	**94.7%**
Meandrina meandrites	MMEA	9	63	0	72	**87.5%**
Colpophyllia natans	CNAT	21	31	3	52	**59.6%**
Pseudodiploria strigosa	PSTR	420	562	0	982	**57.2%**
Eusmilia fastigiata	EFAS	53	51	0	104	**49.0%**
Diploria labyrinthiformis	DLAB	44	37	0	81	**45.7%**
Siderastrea siderea	SSID	1482	630	28	2112	**29.8%**
Montastraea cavernosa	MCAV	560	188	3	748	**25.1%**
Dichocoenia stokesii	DSTO	56	15	0	71	**21.1%**
Orbicella faveolata	OFAV	659	155	12	814	**19.0%**
Orbicella annularis	OANN	337	72	4	409	**17.6%**
Mycetophyllia lamarckiana	MLAM	82	14	0	96	**14.6%**
Isophyllia rigida	IRIG	47	8	0	55	**14.5%**
Pseudodiploria clivosa	PCLI	74	10	0	84	**11.9%**
Agaricia lamarcki	ALAM	47	4	1	51	**7.8%**
Orbicella franksi	OFRA	167	11	3	178	**6.2%**
Siderastrea radians	SRAD	107	7	1	114	**6.1%**
Favia fragum	FFRA	63	4	0	67	**6.0%**
Helioseris cucullata	HCUC	124	7	0	131	**5.3%**
Agaricia agaricites	AAGA	7694	416	9	8110	**5.1%**
Agaricia tenuifolia	ATEN	633	33	0	666	**5.0%**
Agaricia humilis	AHUM	114	2	0	116	**1.7%**
Stephanocoenia intersepta	SINT	404	7	0	411	**1.7%**
Porites astreoides	PAST	6400	108	0	6508	**1.7%**
Porites furcata	PFUR	170	2	0	172	**1.2%**
Porites porites	PPOR	1308	15	1	1323	**1.1%**
Madracis decactis	MDEC	96	1	0	97	**1.0%**
Acropora cervicornis	ACER	184	0	8	185	**0.0%**
Acropora palmata	APAL	382	0	5	382	**0.0%**
Agaricia fragilis	AFRA	19	0	0	19	**0.0%**
Isophyllia sinuosa	ISIN	10	0	0	10	**0.0%**
Madracis auretenra	MAUR	12	0	0	12	**0.0%**
Mussa angulosa	MANG	3	0	0	3	**0.0%**
Mycetophyllia ferox	MFER	1	0	0	1	**0.0%**
Porites divaricata	PDIV	164	0	0	164	**0.0%**
Scolymia sp.	SCUB	12	0	0	12	**0.0%**
Solenastrea bournoni	SBOU	6	0	0	6	**0.0%**
Total		**21,965**	**2,476**	**78**	**24,442**	**10.1%**

FIGURE 14. List of coral species susceptible to SCTLD in Mexico (Source: Lorenzo Alvarez-Filip, UNAM, pers. comm.).

Disease progression in different coral species in Mexico

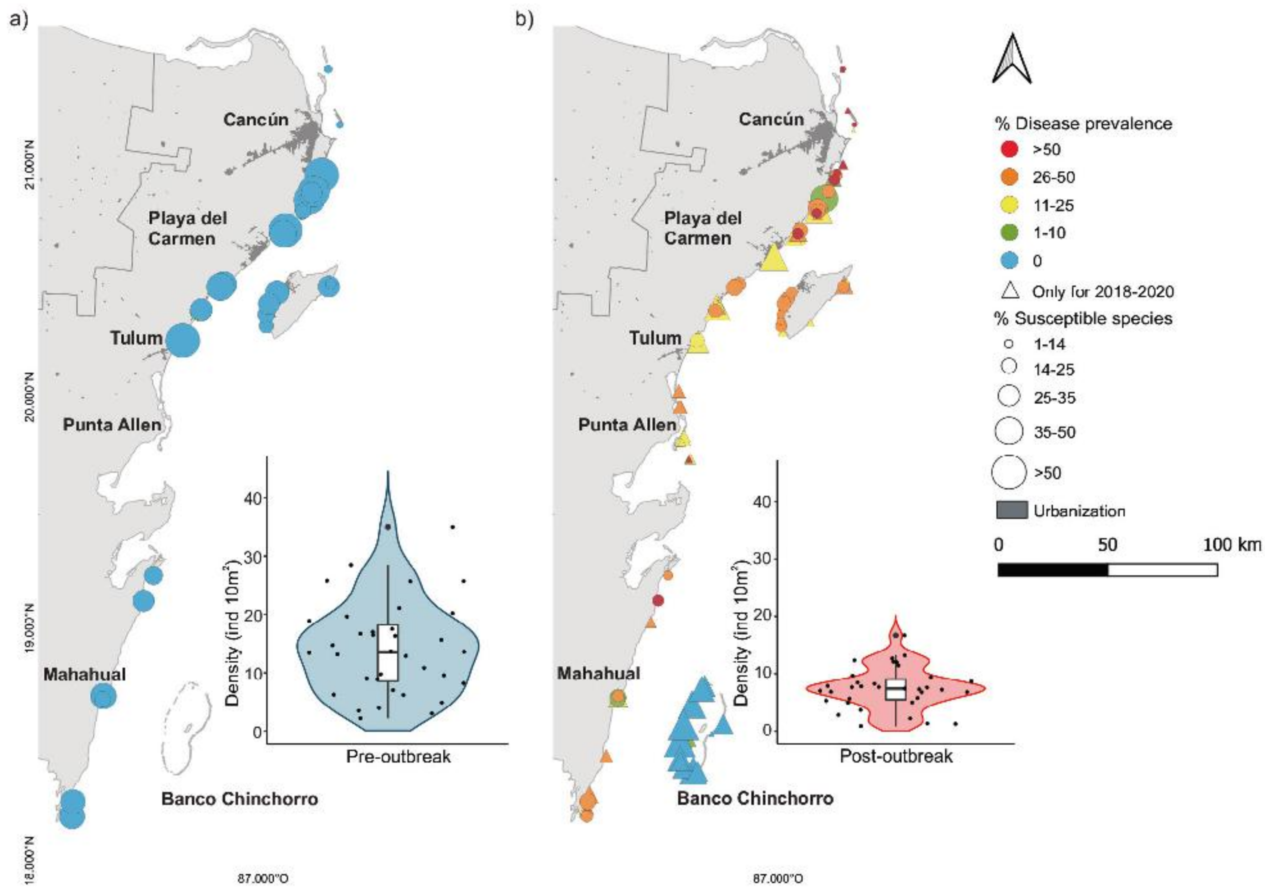


Disease progression in five different coral colonies in Fish Market from July 2018 to March 2019. a) *Meandrina meandrites*, b) *Diploria labyrinthiformis*, c) *Pseudodiploria strigosa,* d) *Orbicella faveolata*, and e) *Agaricia agaricites.* (Original figure from Estrada-Saldivar et al., 2020).

Stony coral tissue loss disease was first observed in Mexico at a patch reef near Puerto Morelos called Fish Market. Disease prevalence of susceptible coral species was at first high (57%) and recent mortality low (1%), but as the disease spread and tissue loss continued, more colonies of susceptible species suffered complete mortality. Tissue loss varied by species, colony size/shape, and duration of exposure to the disease. Some colonies died quickly (weeks-months) as lesions advanced (1a-c); while other colonies had slower rates of disease prevalence and mortality (1 d-e).

FIGURE 15. Disease progression in different coral species near Puerto Morelos, Mexico.

Prevalence of stony coral tissue loss disease in Mexico

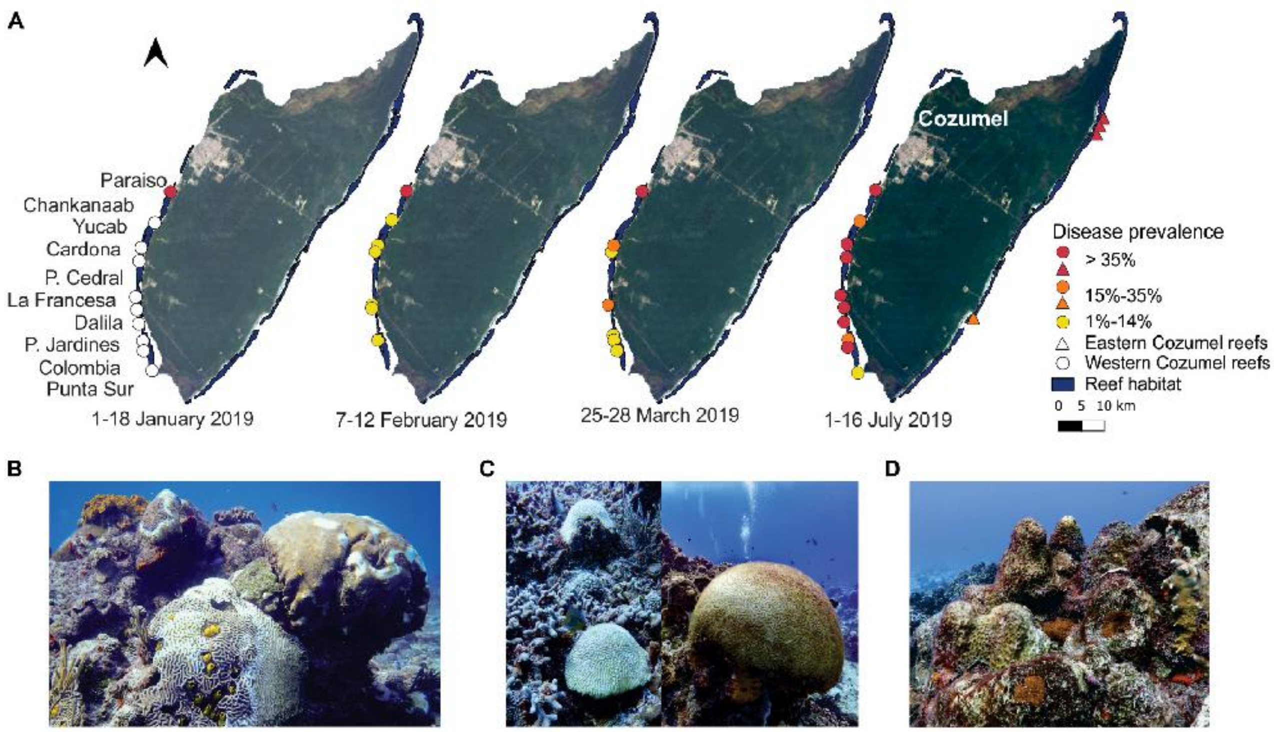


Prevalence of stony coral tissue loss disease (SCTLD) in highly susceptible species in the Mexican Caribbean (figure reproduced from Alvarez-Filip et al., 2022). Spatial patterns of coral species surveyed at 101 sites along the Mexican coast and Cozumel a) 2016, 2017 and b) 2018, 2020 suggest reefs adjacent to human pressures were highly affected by the disease outbreak.

Figure notes: a) White plague-type disease prevalence in species highly susceptible to SCTLD in 35 sites surveyed before the outbreak of the disease (2016 and 2017). b SCTLD prevalence (i.e., diseased and recently deceased colonies) in highly susceptible species during or after the SCTLD outbreak (2018 and 2020). In a) and b), the circles represent the locations of the reefs that were sampled before and after the outbreak. Triangles represent sites that were only surveyed during or after the outbreak. The size of the figure indicates the percentage of healthy colonies of highly susceptible species based on the total number of surveyed colonies at each site and time period (including all coral species). Insets in a) and b) represent the distributions of the densities of live coral colonies of highly susceptible species across all surveyed sites for each period. Data points represent each surveyed site, and the box plots depict the median (horizontal line), the first and third quartiles (box height), and 95th percentiles (whiskers). Shaded area (violin plot) depicts the kernel density showing the probability of data at different values. Highly susceptible species are those with more than 10% disease prevalence.

FIGURE 16. Prevalence of stony coral tissue loss disease in highly susceptible species in the Mexican Caribbean.

Progression of stony coral tissue loss disease in southwestern Cozumel



Progression of stony coral tissue loss disease (SCTLD) in southwestern (SW) Cozumel from January to July 2019 (figure from Estrada-Saldivar et al., 2021). Reefs in SW Cozumel are structurally complex and have a history of high diversity and coral cover. The first disease observation, January 2019, was at Paraiso Reef on the northwest where ~60% of highly susceptible colonies had signs of disease. By July, the disease rapidly spread across 20 km of reefs in the south and east coast in ~ 25 days, increasing disease prevalence and coral colony mortality. These reefs were affected by the disease after the original outbreak along the mainland coast, with the delay in disease arrival possibly due to a deep-water channel and the fast-moving Yucatan Current that separates the island from the mainland. While the outbreak source is not known, the disease may be associated with cruise ships/ballast water discharge as there are three cruise ship piers on Cozumel, one at Paraiso; or delayed transmission via smaller currents; or through recreational divers.

Figure notes: (A) Cozumel maps with the locations of the various surveyed reefs. The colors represent SCTLD prevalence for highly susceptible species. The triangles represent the reefs found in eastern Cozumel, which presented SCTLD as of September 2018 (Alvarez-Filip et al., 2019). The white circles represent the reefs studied from July 2018 to April 2020, which did not present SCTLD in January. (B) Different coral colonies of highly susceptible species with SCTLD found in Paraiso in January 2019. (C) Colonies with recent mortality: two bare (white coral skeleton) of Pseudodiploria strigosa *(left), and one colony of* Diploria labyrinthiformis *covered by a thin layer of filamentous algae (right). All colonies were found in Paso del Cedral reef in April 2019. (D) Standing dead coral (old mortality) colonies of* Montastraea cavernosa *with overgrowth of cyanobacterial and filamentous algal mats found in Colombia reef in November 2019.* Photo credits: L. Alvarez-Filip. For more see original figure 1 from Estrada-Saldivar et al., 2021.

FIGURE 17. **Progression of stony coral tissue loss disease in southwestern Cozumel.**

Collaborating to conserve Cozumel's coral reefs

Along the southwest coast of Cozumel, the well-developed coral reefs are a popular destination for divers, Caribbean cruise ships, and vacationers. When the disease outbreak was first observed in December 2018, park managers of Cozumel Reef National Park teamed up with the tourism sector to monitor the disease. They conducted extensive surveys to locate pillar colonies which were rare and highly susceptible to the disease. Due to the growing concern about the disease, the Cozumel Reef National Park Advisory Council, represented by government, businesses, tourism industry, academics, and fishermen, took the extraordinary action of implementing a rotating closure of portions of the Park's reefs to minimize human impacts and allow the reefs to recover. In 2019, ~20% of the reefs were closed for 2 months. The temporary closures were an innovative way to balance the need to provide extra protection for the diseased reef and allow some reef tourism to continue. While the disease has had negative effects on coral communities, it activated a valuable collaboration between MPA managers, academics, businesses, and the tourism sector to collectively monitor reefs, raise public awareness about the disease outbreak and increase the importance of reef management.

Training future generations of reef ambassadors

To further support disease response actions, the Mexico SCTLD Action Plan recommended the need to increase scientific training and capacity of tourism operators. With support from MAR Fund-MAR2R, the Biodiversity and Reef Conservation (BARCO) Laboratory at UNAM developed an in-depth training course for tourism operators of Cozumel that incorporated both theoretical and field training for ten people. The students first participated in a thorough 16-hour theoretical portion of the course which covered coral reef ecology, status of the disease, monitoring techniques of corals and diseases, response efforts by park managers and citizen scientists, and efforts to rescue, treat and restore corals affected by the disease. The trainees then had the opportunity to work side by side with scientists on four dives to practice underwater what they learned, including coral identification, how to evaluate coral condition, and how to monitor reefs using the bar drop and AGRRA methods. The training course provided the skills and knowledge to help the newly trained science divers to help monitor and respond to the disease outbreak or future disturbances. Offering the course to other Marine Parks and communities in the MAR will continue to help build future generations of reef ambassadors.

Coral reef monitoring training course in Cozumel. Photos: ©A. Gonzalez-Posada.

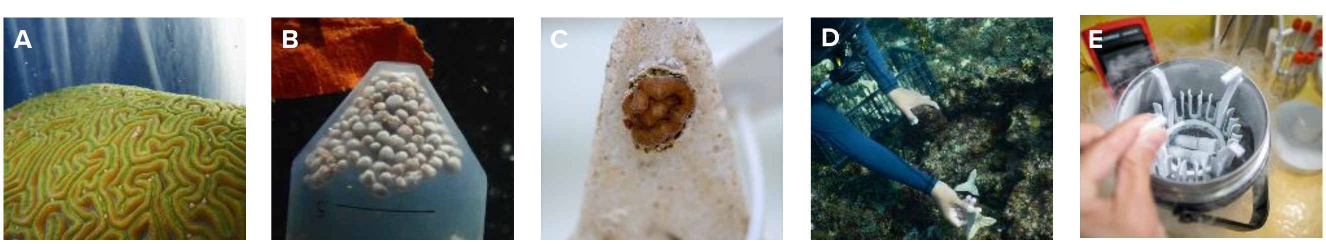
FIGURE 18. **Response actions to the disease outbreak in Cozumel, Mexico.**

Coral rescue and gene banks provide hope for Mexico's reefs

With coral populations suffering dramatic population declines due to the disease along the Caribbean Mexican coast, a new forwarded thinking project was initiated in 2020 to rescue living coral tissue and gametes from highly susceptible corals to avoid their local extinction. The project is a collaboration of the Regional Center for Fisheries Research of the National Institute of Fisheries (CRIAP-INAPESCA), Autonomous University of Mexico's (UNAM) Coralium Lab, Healthy Reefs Initiative, Amigos de Isla Contoy A.C. and Xcaret Group Aquarium. Rescue efforts focused on saving highest risk species including *Dendrogyra cylindrus* (pillar coral), *Diploria labyrinthiformis* (brain coral), and *Meandrina meandrites* (maze coral) by rescuing surviving colonies from the wild, cryopreserving coral gametes and facilitating the production of sexual recruits.

First, scientists and park managers teamed up with the local community to conduct large scale searches to find any surviving colonies of high-risk species. Fragments of surviving corals were collected from the reef and transported to the aquariums to first undergo a quarantine period. Corals are housed and cared for at two aquariums and two mesocosms installed at CRIAP-INAPESCA and two aquariums (one closed system and one semi-closed) located at the Xcaret Group Aquarium. After quarantine, healthy colonies are transferred to aquariums or to larger mesocosms and receive continued care by experienced aquarists. Corals have synchronized breeding once or twice a year where coral polyps release millions of tiny egg and sperm bundles, called gametes, at the same time into the water which rise to the surface to find other bundles to join together as an embryo and develop into a floating coral larva. It is during this time that the researchers collect coral spawn from the coral for either cryopreservation or to be used in assisted fertilization of new sexual recruits. A parallel effort is done on the reefs where dive teams use cone-shaped nets underwater to collect coral spawn, then bring into lab tanks to concentrate the sperm and eggs to increase the chance of fertilization. Larvae reared in the aquariums settle onto special settlement substrates developed by SECORE and allowed to grow and are later outplanted back to the reef. Some sperm is collected for cryopreservation, a process of freezing and storing tissues at very low temperatures, to save them in gene banks for future use in species conservation. Two gene banks have now been established at Coralium and CRIAP INAPESCA.

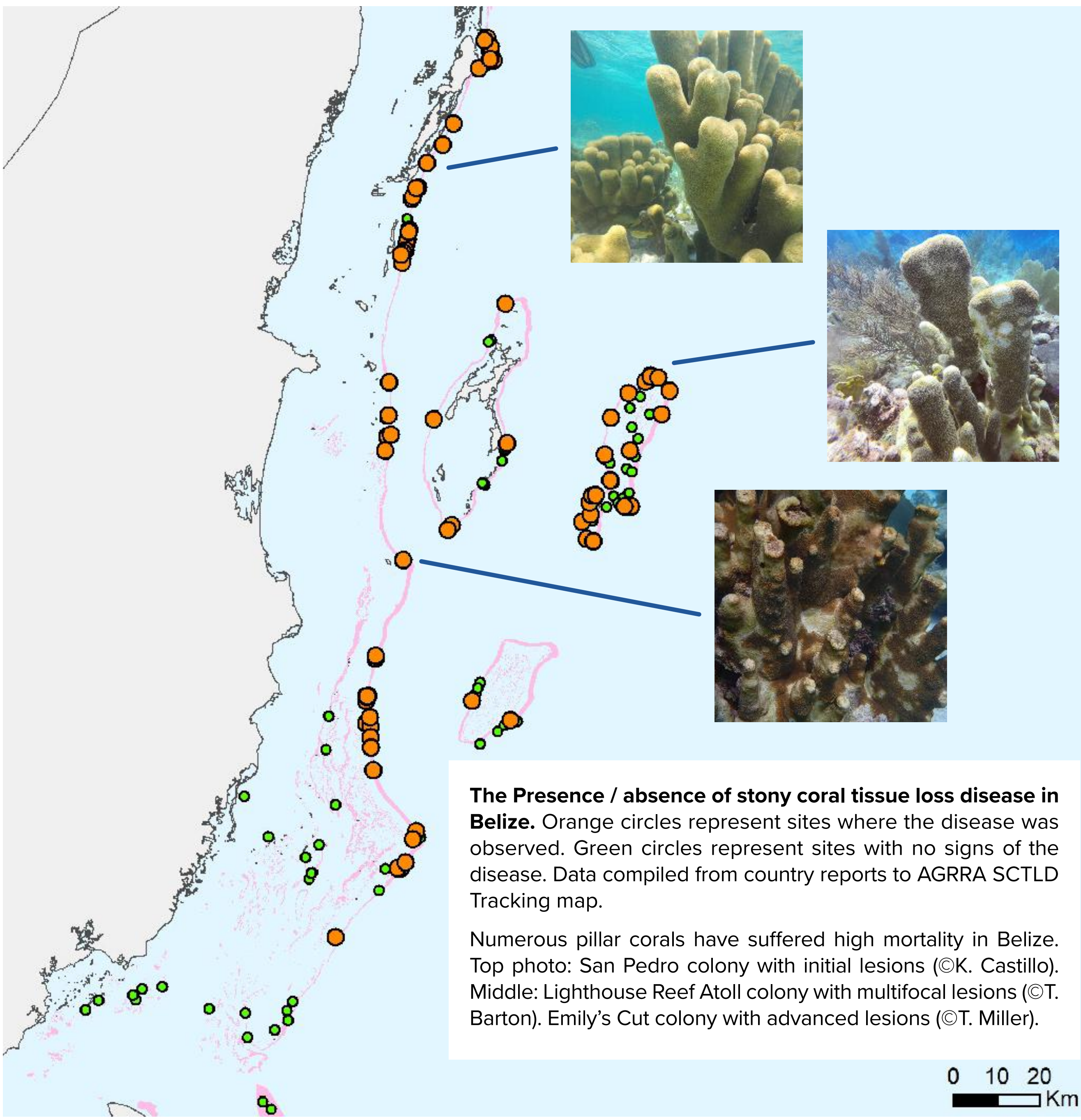
Now, CRIAP-INAPESCA has 12 new colonies of high-risk species (*D. cylindrus, D. labyrinthiformis, M. meandrites, M. jacksoni, Orbicella annularis,* and *Pseudodiploria strigosa*) and Xcaret Aquarium has 25 fragments of 5 species (*D. labyrinthiformis, M. meandrites, O. faveolata, O. annularis* and *Montastraea cavernosa*). Over 12,000 sexual recruits raised from coral larvae from the reef are at UNAM-Coralium and Xcaret Aquarium. The gene banks now house 11 vials of cryopreserved *D. cylindrus*, 62 vials of *D. labyrinthiformis*, 13 of *O. annularis*, 53 of *O. faveolata*, and 31 of *P. strigosa*. The multi-tiered approach of coral rescue and care; assisted fertilization of sexual recruits; and cryopreservation gene banks provides hope for the recovery of coral reefs in Mexico and the Mesoamerican region.



A) Spawning *D. labyrinthiformis.* B) Gametes are collected for assisted fertilization and culture. C) Sexual recruit of *D. labyrinthiformis* settled on substrate. D) Diver outplanting coral recruits on the reef. E) Frozen coral repositories for the coral gene bank. Information provided by A. Banaszak/Coralium. Photos A, B and C: @ Sandra Mendoza. Photos D and E: @ © Paul A. Selvaggio / Pittsburgh Zoo.

FIGURE 19. **Mexico's collaborative project on coral rescue, assisted fertilization and culture, and cryopreservation for gene banks.**

Stony Coral Tissue Loss Disease in Belize



The Presence / absence of stony coral tissue loss disease in Belize. Orange circles represent sites where the disease was observed. Green circles represent sites with no signs of the disease. Data compiled from country reports to AGRRA SCTLD Tracking map.

Numerous pillar corals have suffered high mortality in Belize. Top photo: San Pedro colony with initial lesions (©K. Castillo). Middle: Lighthouse Reef Atoll colony with multifocal lesions (©T. Barton). Emily's Cut colony with advanced lesions (©T. Miller).

FIGURE 20. Map of presence / absence of stony coral tissue loss disease in Belize (Map developed by AGRRA).

Belize Overview

The Belize Barrier Reef Reserve System is the second largest barrier reef complex in the world. It has a wide variety of reef types including fringing, patch, and pinnacle reefs and three unique isolated atoll-like structures: Glovers Reef, Lighthouse Reef and Turneffe Island. Designated a UNESCO World Heritage Site in 1996, the Belize Barrier Reef System has several important marine protected areas that protect >25% of its territorial seas such as Bacalar Chico NP and MR, Blue Hole Natural Monument, Half Moon Caye Natural Monument, South Water Caye Marine Reserve, Glover's Reef Marine Reserve, Laughing Bird Caye National Park, and Sapodilla Cayes Marine Reserve. Reef condition continues to be impacted by coastal development, agricultural runoff, incomplete sewage treatment, illegal fishing, as well as reoccurring coral bleaching, blooms of *Sargassum* seaweed, and now the new outbreak of disease.

The disease outbreak had spread along the Caribbean Mexican coastal reefs by the end of 2018. In April 2019, Healthy Reefs Initiative (HRI) and Fragments of Hope (FOH) hosted the first national workshop in Belize to proactively plan and develop a response strategy and produced the SCTLD Monitoring and Action Plan for Belize. In June 2019, stony coral tissue loss disease was first observed at Bacalar Chico MR in the northernmost part of Belize.

Since the first observation, Belize organizations have continued to monitor their reefs and have submitted data and photos to the AGRRA Caribbean SCTLD Disease Tracking Map. Preliminary results for October 2020 to November 2021 were summarized by Hing et al., 2022. The database was recently updated (July 2022) and includes 259 surveys submitted by 27 surveyors, with >108 of those reporting stony coral tissue loss disease present.

Of the 259 surveys, 148 were entered in the "Detailed Coral Disease and Bleach Survey' online portal and included coral count and condition data obtained using the 'bar-drop' method. Forty-seven of the 148 surveys reported SCTLD. There were 4,741 coral colonies observed in the detailed surveys and included 18 different coral species affected by the disease outbreak, 11 of these were considered 'highly susceptible' (based on Alvarez-Filip et al., 2019 criteria of >10% affected). Corals with the highest prevalence rates (>20%) included *Dichocoenia stokesii, Meandrina meandrites, Dendrogyra cylindrus, Agaricia lamarcki, Orbicella franksi, Pseudodiploria clivosa, Colpophyllia natans* and *Diploria labyrinthiformis*. Eleven species observed were healthy, including *Acropora* species. Few pillar coral were seen on surveys, although more than half were affected. Of the three *Orbicella* species, *O. franksi* had the highest prevalence.

As of August 2022, Belize had two Endemic subregions (Northern Barrier and Lighthouse Reef Atoll), two Epidemic subregions (Central Barrier, Turneffe) and two new Invasion Subregions (northern part of the Southern Barrier Reef and the most recent at Glover's Reef (July 2022). Only the southernmost portion of the southern barrier and adjacent interior patch reefs have not reported the disease outbreak.

Belize has implemented a wide range of response efforts to reduce the impact of the disease including monitoring, intervention/treatments, in-water rescue, outreach, training, and communication. TIDE, with support from MPA Connect/NOAA, created the first Marine Protected Area specific response plan for Port Honduras MR.

Response Efforts in Belize

- In June 2019, the Fisheries Department confirmed the SCTLD for the first time in the Bacalar Chico National Park and Marine Reserve.

- A Task Force with members of the National Coral Reef Monitoring Network was subsequently created to assess the spread of the disease and conducting trials with possible treatment options. The help of partners in the region and the Caribbean was sought and a plan of action started to materialize to address SCTLD.

- In October 2019, the meeting "Health and management of Mesoamerican reefs: response to Stony Coral Tissue Loss Disease" was held, organized by the Belize Marine Fund and the Reef Rescue Initiative, both MAR Fund initiatives. As a result of the meeting, the document "SCTLD in the Mesoamerican Reef region. Recommendations to address the disease" was prepared and distributed.

- In April 2020, SCTLD was detected in Hol Chan Marine Reserve. The country was on complete lockdown due COVID-19, which prevented the team from going out into the field and carrying out pilot treatments in Hol Chan reefs.

- By May 2020, SCTLD was detected in the Caye Caulker Marine Reserve.

- In July 2020, permission was granted by the Fisheries Department to start using CoreRx Base2B and amoxicillin in the Bacalar Chico NPMR and Hol Chan Marine Reserve. Treatment was sponsored by Healthy Reefs Initiative (HRI) and Fragments of Hope (FOH). Simultaneously, in situ nurseries were established in Bacalar Chico NPMR and Hol Chan Marine Reserve.

- In September 2020, SCTLD was detected in Lighthouse Reef Atoll and permission was granted for them to use the approved treatment. MAR Fund has supported to carrying out treatment and continued monitoring of the area.

- In December 2020, an in-situ nursery was established in the Caye Caulker Marine Reserve.

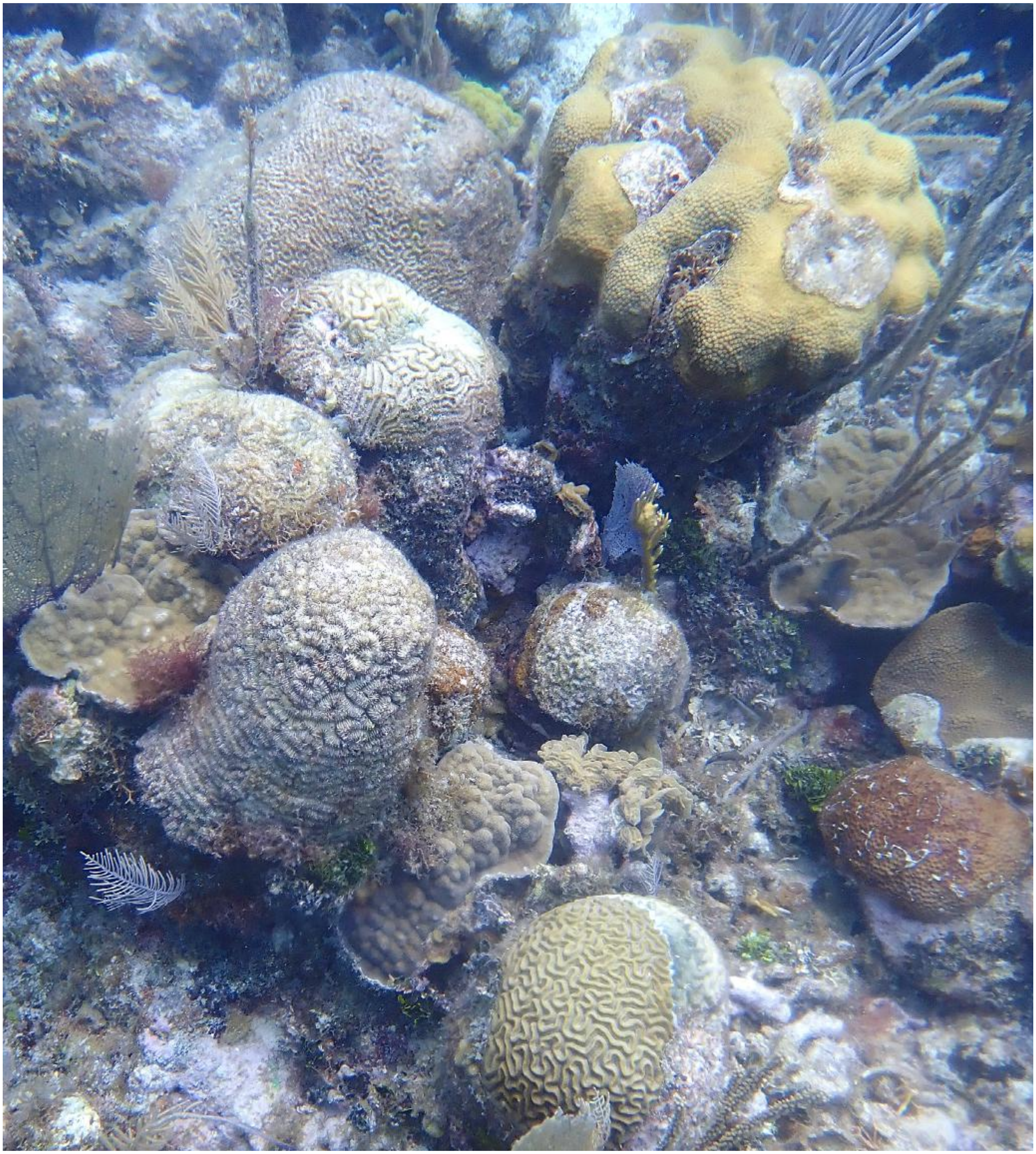
- In May 2021, SCTLD was confirmed in the Sergeant's Caye zone.

- SCTLD spread some 140 miles along the barrier from Bacalar Chico NPMR south to Ranguana Cay. It has also been confirmed in all three Belize atolls.

- In close collaboration with the Fisheries Department, 12 information sessions were conducted in seven coastal communities affected by SCTLD. The sessions were an opportunity to raise awareness of SCTLD among tourism service providers and to increase community participation in monitoring the disease and promoting best practices to prevent its spread. The sessions were conducted in Caye Caulker, San Pedro, Belize City, Dangriga, Placencia, Hopkins, and Punta Gorda, with a total of 177 participants.

Belize Coral Species	Code	Healthy Colonies	Colonies with SCTLD	Colonies with Other Conditions	Total Colonies	% SCTLD
Dichocoenia stokesii	DSTO	26	64	10	100	**64.0%**
Meandrina meandrites	MMEA	36	80	13	129	**62.0%**
Dendrogyra cylindrus	DCYL	4	6	0	10	**60.0%**
Agaricia lamarcki	ALAM	4	6	2	12	**50.0%**
Orbicella franksi	OFRA	99	83	12	194	**42.8%**
Pseudodiploria strigosa	PSTR	276	143	71	490	**29.2%**
Colpophyllia natans	CNAT	54	24	7	85	**28.2%**
Diploria labyrinthiformis	DLAB	58	19	18	95	**20.0%**
Mussa angulosa	MANG	213	54	34	301	**17.9%**
Orbicella faveolata	OFAV	73	14	21	108	**13.0%**
Orbicella annularis	OANN	180	30	68	278	**10.8%**
Agaricia agaricites	AAGA	563	52	23	638	**8.2%**
Eusmilia fastigiata	EFAS	17	2	7	26	**7.7%**
Siderastrea siderea	SSID	234	36	296	566	**6.4%**
Mycetophyllia lamarckiana	MLAM	24	1	5	30	**3.3%**
Pseudodiploria clivosa	PCLI	24	1	11	36	**2.8%**
Porites astreoides	PAST	861	9	68	938	**1.0%**
Porites porites	PPOR	204	2	27	233	**0.9%**
Acropora cervicornis	ACER	49	0	26	75	**0.0%**
Acropora palmata	APAL	35	0	6	41	**0.0%**
Acropora prolifera	APRO	3	0	0	3	**0.0%**
Agaricia tenuifolia	ATEN	130	0	60	190	**0.0%**
Madracis auretenra	MAUR	11	0	3	14	**0.0%**
Madracis decactis	MDEC	25	0	1	26	**0.0%**
Manicina areolata	MARE	2	0	0	2	**0.0%**
Meandrina jacksoni	MJAC	7	0	0	7	**0.0%**
*Montastraea cavernosa**	MCAV	2	0	0	2	**0.0%**
Porites divaricata	PDIV	0	0	0	0	**0.0%**
Stephanocoenia intersepta	SINT	83	0	29	112	**0.0%**
Totals:		**3297**	**626**	**818**	**4741**	**13.2%**

FIGURE 21. List of corals susceptible to SCTLD in Belize (AGRRA tracking map, 2022). *MCAV was not recorded with SCTLD on survey transects in this data set but has subsequently been confirmed affected by SCTLD.



Coral reefs along Belize's central barrier reef during the disease invasion/outbreak phase in June 2021. SCTLD and recent mortality were observed mostly on PSTR, MMEA, DLAB and DSTO, although PAST was not affected at the time. Many of these highly susceptible species suffered total colony mortality.

FIGURE 22. Coral reefs along Belize's central barrier reef during the disease invasion/outbreak phase in June 2021. Photo: ©Linda Searle, ECOMAR.

In water coral rescue and restoration

Dendrogyra cylindrus (pillar coral), a unique coral listed as Vulnerable on IUCN Red list, is highly susceptible to stony coral tissue loss disease. In Belize, colonies are found in a variety of reef types and range in size, with many large colonies. Shortly after the outbreak appeared in Belize in 2020, Fragments of Hope and Belize Fisheries Department initiated a coral rescue program in three marine reserves: Bacalar Chico, Hol Chan, and Caye Caulker. They established in-water coral nursery tables (right) as a pilot project to a) rescue pillar coral fragments and b) enhance restoration efforts of non-susceptible acroporid populations to improve populations and provide habitat.

While mortality and disease occurred on some fragments, several lessons were learned including:

- Collect fragments from parent colonies with no signs of disease and from disease-free areas
- Check nursery tables frequently for disease (minimum every two weeks)
- Treat or remove diseased fragments

Proactive, dual-purpose efforts like this to both rescue highly susceptible species and restore non-susceptible species can help preserve genetic diversity and provide fragments for future restoration. The project also provided the opportunity to expand restoration sites and provide restoration training in northern Belize. Since the pilot project, the disease outbreak has continued to spread south along the Belize barrier reef causing high mortality of more pillar coral colonies. In May 2022, Fragments of Hope transplanted two healthy pillar corals (one colony in bottom left photo) ahead of the SCTLD "disease front" from south of Ranguana Caye and relocated the colony to Laughing Bird Caye NP, an area not affected by SCTLD. In August 15, 2022, the same relocated coral (bottom right) was healthy (L. Carne, pers. comm). The missing fragment in right photo below is also transplanted at Laughing Bird Caye NP and the lesion is healing with no signs of infection. Relocation of healthy pillar corals ahead of the disease front to unaffected areas may help preserve this highly susceptible species. FOH has been recording and mapping the location of pillar corals in Belize.

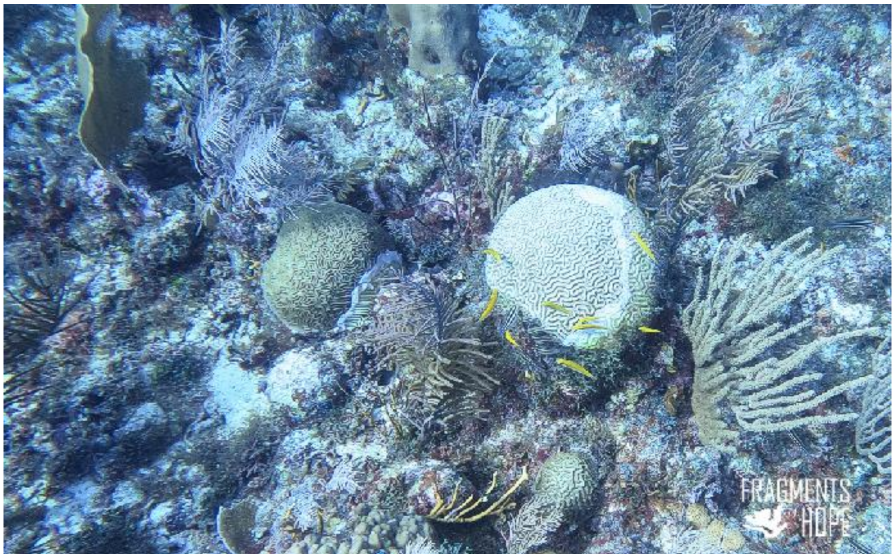
FIGURE 23. In water coral rescue and restoration in Belize. Photos: ©Fragments of Hope.

Belize's Coral Disease Intervention Efforts

While the cause of the disease is not known, one intervention strategy used to treat affected corals is the in-situ antibiotic treatment of lesions with a topical application of amoxicillin trihydrate powder and Coral Ointment Base2B (CoreRx Base2B; Neely et al., 2020). Belize developed an intervention strategy to select priority reefs and corals for treatment using specific criteria including ecological importance (e.g., colony size), priority species (e.g., *D. cylindrus, C. natans*), stakeholder importance (e.g., tourism), and treatability (e.g., >75% living, <5 lesions, near other treated corals). Bacalar Chico Marine Reserve tested CoreRx Base2B + Amoxicillin paste on affected lesions at two high priority sites, with an 88% success rate of preventing lesion expansion (Belize Fisheries Department, 2021, webinar).

With a grant from MAR Fund to HRI and WWF, several disease intervention trainings have been held and disease treatments using CoreRx and amoxicillin have been applied on 497 coral colonies of 17 different species at 21 sites. Areas treated include reefs at Bacalar Chico MR, Hol Chan MR, Goff's Caye/Rendezvous, and South Water Caye MR and were applied by 5 trained groups including HRI, Fragments of Hope, Belize Fisheries Department, Belize Audubon Society, and University of Belize Environmental Research Institute. The two species treated the most were *Pseudodiploria strigosa* (191 colonies or 38% of all colonies treated) and *Montastraea cavernosa* (91 or 18%). Other species included *Orbicella annularis* (42 colonies), *Diploria labyrinthiformis* (41), *O. franksi* (24), *Colpophyllia natans* (24), *Dendrogyra cylindrus* (21), *Agaricia agaricites* (21), *O. faveolata* (17), *Siderastrea siderea* (8), *Meandrina meandrites* (5), *Porites astreoides* (4), *A. fragilis* (3), *Stephanocoenia intersepta* (2), *Helioseris cucullata* (1), *Dichocoenia stokesii* (1), and *A. tenuifolia* (1). A subset of these colonies (n=80) was treated and monitored every 30 days, for 90 days. If mortality increased after the initial application, then the CoreRx and amoxicillin was reapplied. The first treatment halted lesions in 42 of the 80 colonies. The second treatment stopped lesions in 15 colonies. Treatment was considered successful (after 2 applications if needed) in 71% percent or 52 of the colonies. Treatment was considered unsuccessful if lesions continued to spread after the second treatment, or upon the third visit. Treatment was unsuccessful in 29% (n=23) of colonies (N. Craig, pers comm., webinar). As the disease continues to spread, Belize will continue to monitor the effectiveness of their treatment intervention program.

Treating a PSTR colony along the disease margin.



Two coral colonies, DLAB (to left) and PSTR (to right) treated with CoreRx and amoxicillin.

FIGURE 24. Belize's coral disease intervention efforts. Photos: ©Fragments of Hope.

Guatemala - Response Planning for Stony Coral Tissue Loss Disease

Guatemala's Caribbean coast stretches for 150 km along the Gulf of Honduras and contains extensive mangroves, coastal lagoons, seagrass beds, and coral reefs. Several freshwater rivers flow into the Gulf creating turbid, sediment-laden waters which are not typical habitats for corals to grow. Yet numerous patch reefs are found nearshore and deeper (10-13 m) spur and groove reefs with high coral cover (20%) extend offshore. The Healthy Reefs Initiative has monitored reef condition of the Guatemalan reefs since 2006. In 2014, HRI staff together with fishers discovered a unique reef area in the Gulf of Honduras which they named Corona Cayman or Cayman Crown that straddles the maritime boundary of Guatemala and Belize. The deep spur and groove reef has both high complexity and coral cover (>50% at the shelf) with steep walls that drop vertically from the shelf edge at 30 m to waters >300 m deep. Guatemala designated Cayman Crown reef as its first no fishing area in 2020 for 10 years. To the north, Belize extended protection for Cayman Crown through the expansion of Sapodilla Cayes Marine Reserve. The reefs are impacted by increased pollution, nutrients and sediments from major rivers, a lack of herbivory, and a growing demand for fish.

In 2021, HRI surveyed three reefs near Cabo Tres Puntas and two reefs at Motaguilla, with additional monitoring carried out August - September, December 2021, and February 2022 at four reefs at Cayman Crown and found no evidence of stony coral tissue loss disease, although coral bleaching has been observed in the past. Data have been uploaded into the AGRRA Caribbean SCTLD tracking database and map.

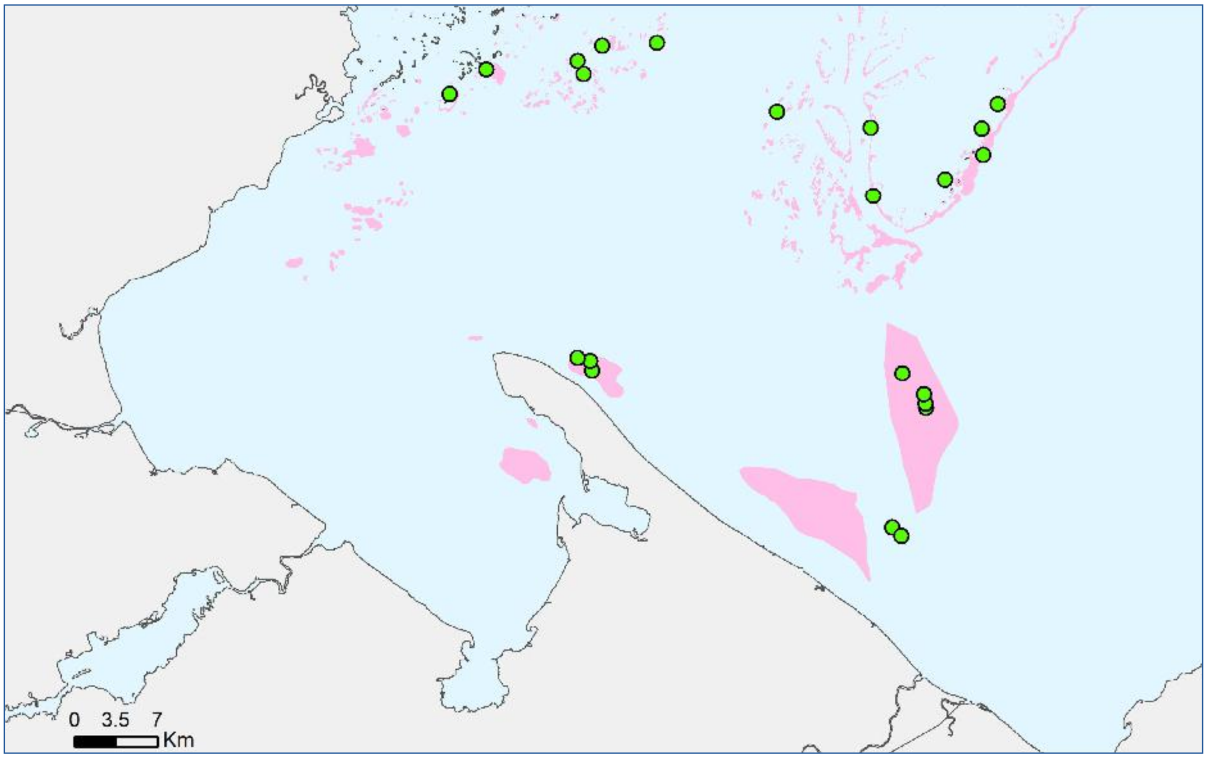


FIGURE 25. Map of presence / absence of stony coral tissue loss disease in Guatemala (2021). Circles: Green = absent, Red = present (Map developed by AGRRA).

To further prepare for the disease outbreak, a consultancy by HRI and Pixan'Ja, was conducted from September 2021 to April 2022 on the "Development of a National Action Plan for the detection, care and monitoring of Stony Coral Tissue Loss Disease (SCTLD) of Guatemala".

The development of the NAP (National Action Plan) to address the SCTLD was designed as a comprehensive process in which different approaches were included to strengthen the design of the tool, promoting the participation of the key actors (academia, government, NGOs and the private sector), to encourage a prompt appropriation of it, which supports its subsequent implementation. The process to produce the document took eight months (from September 2021 to April 2022), through which complementary products to this document were generated to directly support the future implementation of the NAP:

1) Mapping of key actors and database (directory) at the national level.

2) Strategic communication document.

3) Repository of documents, tools, and online pages relevant to the disease and actions to address it in the Caribbean region.

The NAP's strategy to address the SCTLD in Guatemala reflects the participatory process for the identification and prioritization of actions that allow to more effectively address the crisis that the disease is generating from different fronts, integrating the national context. The five strategic lines group the most relevant issues to address the disease in the country in a practical way, facilitating its subsequent implementation in actions related to: 1) Communication, 2) Preventive measures, 3) Monitoring, 4) Treatment of species and colonies, and 5) Ecological Restoration. These strategies also respond to the umbrella of general actions that have been tested in other Caribbean countries under three main categories: 1) Prevention, 2) Preparedness and Early Warning, and 3) Mitigation.

A five-year validity of the plan was proposed (2022-2027) to allow adequate implementation, monitoring and evaluation, so that, if necessary, it is possible to carry out adaptive management to adjust, modify and strengthen what is necessary in a timely manner.

A directory database was developed of 166 stakeholders and represents the most comprehensive and updated list for the country of partners directly or indirectly related to reefs.

Next steps in the process include:

- Continue with reef monitoring focused on SCTLD.
- Implement the National Action Plan.

Response Actions in Guatemala

- The HRI's Coordinator for Guatemala belongs to the SCTLD Response Caribbean Cooperation Team.

- In November 2020, HRI with the support of Pixan'Ja and MPAConnect, led the first webinar on the SCTLD for Guatemala, announcements were done about its generalities and proposed actions for the country. Response plans and actions in the Caribbean were also discussed. This webinar was the first approach focused on NGOs, academy and government; it had a participation of more than 80 people.

- During the monitoring that HRI carried out in 2021, there was no signs of stony coral tissue loss disease.

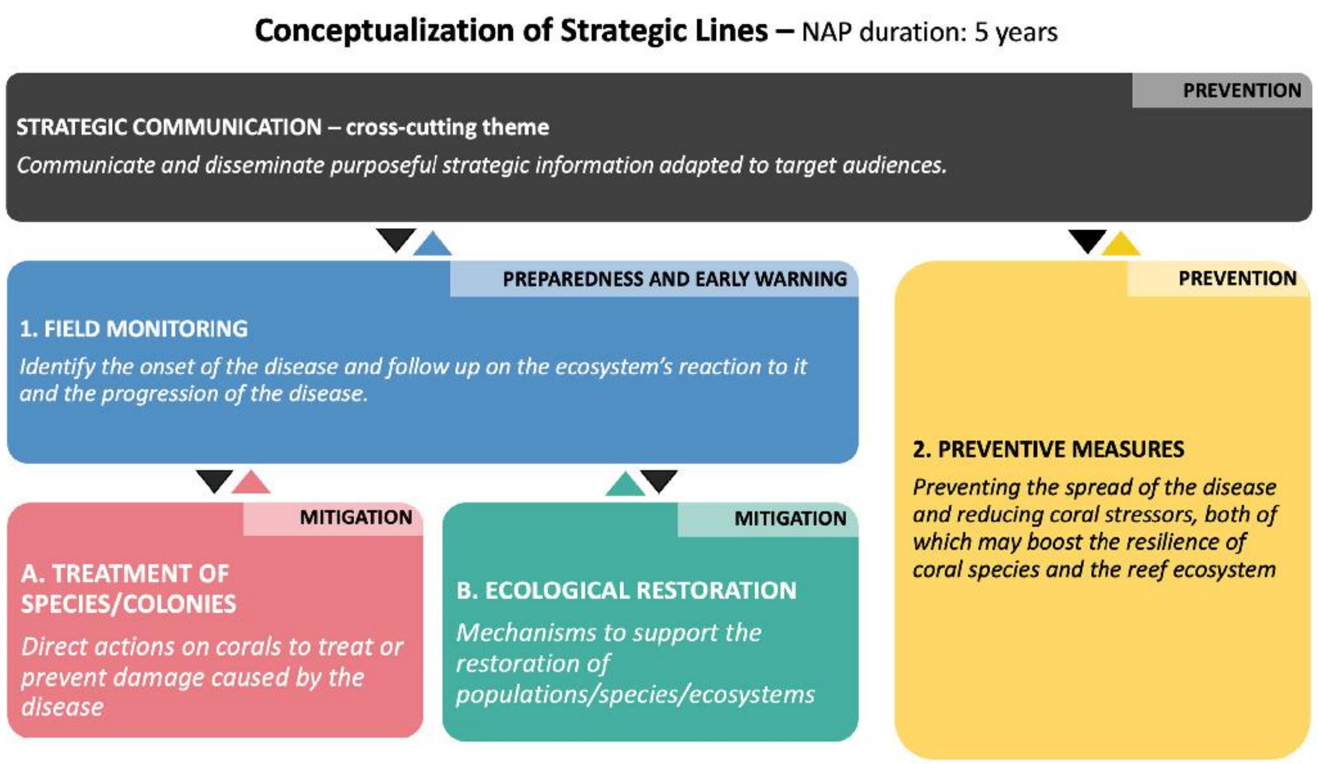
- With the support of the Ministry of Environment and Natural Resources (MARN), the National Action Plan for the detection, attention, and monitoring of SCTLD was developed. The development of the Plan was a participatory process, which integrated more than 30 key stakeholders representing government, academia, NGOs, private sector and civil society, generating a practical, inclusive and coherent framework for addressing SCTLD in the country, validated by experts.

Lettuce coral (*A. tenuifolia*), a species less affected by SCTLD, is abundant at Cayman Crown.

High diversity of stony corals and sponges on Cabo Tres Puntas (Photos: ©Ana Giro).

FIGURE 26. Stony coral tissue loss disease has not been reported on Guatemala's coral reefs.

National Action Plan to address SCTLD in Guatemala



The development of the draft NAP incorporated a participatory approach with the main organizations and stakeholders. During the development of the NAP strategy several lessons were learned including:

- The level of knowledge of the key partners related to reefs in the country and their level of familiarity with the disease outbreak was low; indicating the importance of improving communication and education activities to generate greater interest, understanding and commitment to addressing the disease.
- Early discussion and understanding of the research licenses and permits needed for management actions is important to facilitate more efficient and immediate response to diseased colonies and promote restoration actions. This includes any permits necessary to import treatment products and/or export tissue samples for analysis.
- The implementation of the plan needs a leader to coordinate activities among the various organizations involved, provide support on a day-to-day basis, follow-up to actions and promote the responsibility of the parties and facilitate effective communication.

FIGURE 27. Conceptualization of the strategic lines of the National Action Plan to address SCTLD in Guatemala (Mojica and Giro, 2022).

Stony Coral Tissue Loss Disease in Honduras

The northern coast of Honduras contains sandy beaches, large rivers, bays, and several coral reefs dotting the coastline. More extensive reefs are found on the large offshore Bay Islands of Cayos Cochinos, Utila, Roatan, and Guanaja and to the north, the Swan Islands. Coral reef types include shallow fringing reef crests, patch reefs and reef walls extending from the shelf-edge to depths of >70 m. Two unique reef areas include Tela Bay with two reef areas containing abundant healthy elkhorn (*Acropora palmata*) corals and in Capiro Banks, Roatan with >50% coral cover of lettuce coral (*Agaricia tenuifolia*). Located at the "headwaters" of the MAR Region, Honduras' nearshore and oceanic currents play an important role in the connectivity with the rest of the region. Prior to the coral disease outbreak, live coral cover had increased from 21% in 2016 to 27% in 2018 and macroalgae decreased from 27% to 24% (McField et al., 2020). Coral reefs are threatened by pollution due to inadequate sewage treatment and lack of infrastructure, poor watershed management, rapid tourism growth and unsustainable practices, illegal fishing, and increased demand on natural resources.

Honduras proactively prepared for the disease outbreak prior to its arrival by attending the MPAConnect's 'Coral Disease Learning Exchange' in Key West in 2019, which was the start of an extensive response effort. Roatan Marine Park, with funding from MPAConnect, hosted several disease trainings to prepare divers for monitoring, which included members of Bay Island Conservation Association (BICA), MarAlliance, Zona Libre Turistica (Zolitur), Utila Coral Restoration, and local dive professionals. A preliminary survey of 8 sites in January 2020 found no evidence of the disease.

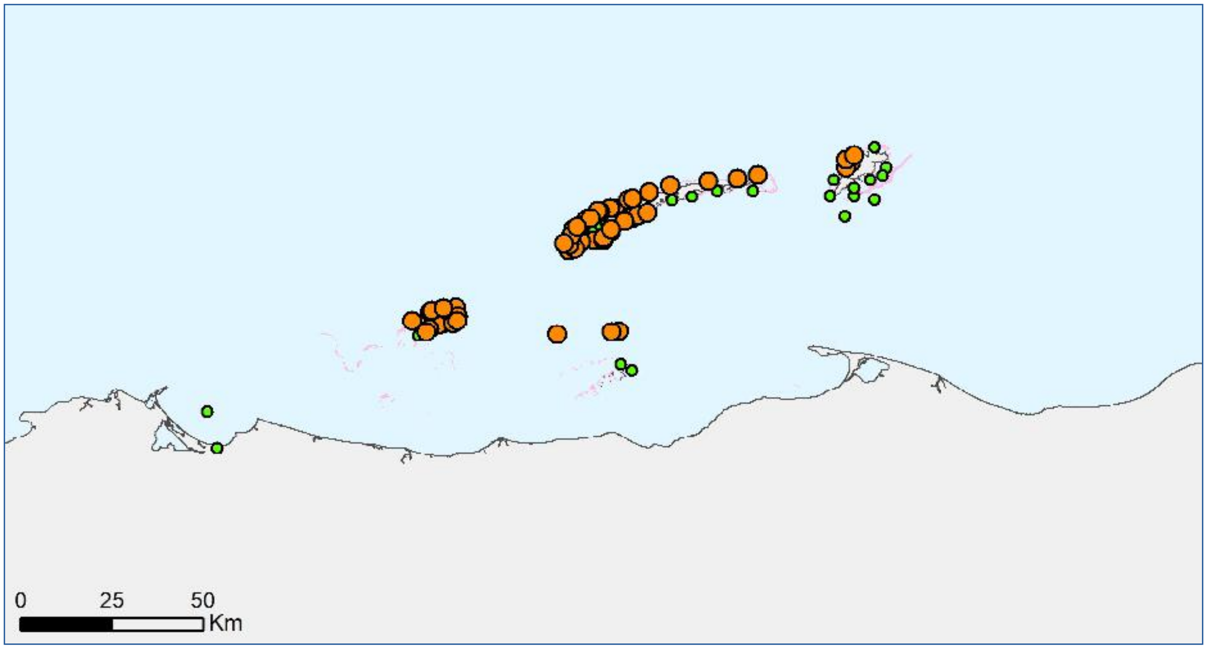


FIGURE 28. Map of presence / absence of stony coral tissue loss disease in Honduras. Orange circles represent sites where the disease was observed. Green circles represent sites with no signs of the disease. Data compiled from country reports to AGRRA SCTLD Tracking map.

Stony coral tissue loss disease was first reported in Roatan in September 2020, in Utila in June 2021, and the seamounts on Roatan Bank in July 2021. Reports of reefs potentially affected in Guanaja were submitted in June 2021, although due to the pandemic and fewer survey opportunities, additional reports were not available. A suspected case in Cayos Cochinos was reported on a single pillar coral with signs of lesions in February 2021, although more recent reports (summer 2022) suggest it is present in Cayo Menor and Cayo Mayor.

Honduras organizations submitted data to the AGRRA Caribbean SCTLD Disease Tracking Map. The database for the country was recently updated (July 2022) and include 241 surveys (49 basic, 192 detailed), with 117 of those reporting stony coral tissue loss disease present (26 basic, 91 detailed). A total of 14,564 colonies were surveyed, with 22 species affected by the disease outbreak. Fifteen of these species were considered 'highly susceptible' (based on Alvarez-Filip et al., 2019 criteria of >10% affected). Corals with the highest prevalence rates (>20%) included *Meandrina meandrites, Dendrogyra cylindrus, Dichocoenia stokesii, Meandrina jacksoni, Eusmilia fastigiata, Colpophyllia natans, Pseudodiploria strigosa, Diploria labyrinthiformis, Pseudodiploria clivosa,* and *Orbicella annularis*. Acroporid species were not affected. Preliminary results for Roatan were summarized by Hing et al., 2022.

Roatan's first case occurred on the south side of Roatan near Flowers Bay. In January 2021, Roatan Marine Park, with a grant from the Swiss cooperation, began a long-term monitoring program to assess the spread of SCTLD at 21 AGRRA sites around the island. From the first report of SCTLD in September 2020 to September 2021, the disease spread to 85% of the island, with the northwest and southwest being the most affected areas. By January 2022, the disease was present in 100% of the sites monitored. The "Endemic" or terminal phase was observed in sites that had the disease for more than seven months, with a prevalence of more than 35%. A decline in prevalence was observed at sites that had been affected by SCTLD for more than one year, likely due to susceptible species not being present and/or only resilient colonies of these species remaining (G. Ochoa, pers. comm).

Coral reefs in Utila were not affected by the disease outbreak in November 2020; but by June 2021, the Utila SCTLD Response Team reported the first observation of the disease outbreak at Whale Rock Reef in the northeast corner of the Island. The most affected species were *Meandrina meandrites, Dichocoenia stokesii, Eusmilia fastigiata, Pseudodiploria strigosa,* and *M. jacksoni.* Colonies of *Orbicella annularis* and *Siderastrea siderea* also had signs of tissue loss lesions. By December 2021, additional surveys conducted by BICA, HRI and trained divers reported the disease had spread along the northern coast west towards the edge of Turtle Harbor Marine Reserve and along the south coast towards Little Bight (near East Harbor). In 2022, the disease further spread along the south coast to Diamond Cay.

In Guanaja, surveys by RMP and HRI reported no signs of stony coral tissue loss disease in late 2020. In June 2021, the first reports of corals showing signs similar to the disease outbreak were reported at reefs near the Michael Rock Special Marine Protection Zone on the north coast. Coral species affected included *Dendrogyra cylindrus* and *P. strigosa*, with other species also showing signs of recent mortality. Few follow up surveys were able to be done because of the pandemic. In July and August 2021, deeper reefs (12-18 m) on Roatan Bank north of Cayos Cochinos (locally called sea mounts) were affected by the disease including *E. fastigiata, M. jacksoni, M. meandrites, Montastraea cavernosa*, and *P. strigosa.* Colonies of *O. franksi* and *S. siderea* also had signs of tissue loss.

National SCTLD Action Plan

The development of the draft National Action Plan to address tissue loss disease in hard corals was based on the Area Conservation Planning methodology to support open standards for the practice of conservation. Twenty-two local organizations and institutions were involved in the planning process. The action plan focuses on three main themes: water quality, tourism, and fishing and 15 strategies were identified to reduce the threat of stony coral tissue loss disease on reefs.

Response Actions in Honduras

- The disease was confirmed on September 24, 2020, in the southern part of the island of Roatan, in front of Flowers Bay community. The environmental authorities issued a press release and decided to close the area to recreational diving indefinitely. After these initial actions, a working group was created with actors from the insular area and government institutions including the General Directorate of the Merchant Marine, the Institute of Forest and Wildlife Conservation, the Ministry of Natural Resources and Environment and the Honduran Institute of Tourism.

- Local organizations such as the Roatan Marine Park (RMP) and Bay Islands Conservation Association (BICA) have been working through the Bay Islands - Marine National Park Technical Committee creating capacities for the identification and detection of the disease within the marine protected area. In addition, monthly monitoring of reefs for SCTLD around Roatan were conducted for 12 months.

- Given the appearance of the SCTLD in Honduras, several actions have been taken to protect the reefs in the country. On December 30, 2020, the National Decree PCM-151-2020 was published, which issues the emergency declaration about the appearance of the SCTLD on the Honduran coasts, a joint effort among the Government of Honduras with the support and technical advice of the NGO co-managers of the Bay Islands Marine National Park.

- 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 January 2022, all sites across Roatan had SCTLD; west and north sites were in the endemic phase, east and south sites were in the epidemic phase, and southwest sites in the endemic phase.

- The National Action Plan for attention to SCTLD was developed with the support of the National Institute for Forest Conservation and Development, Protected Areas, and Wildlife (ICF) and the Biodiversity Department (DiBio), with the financial support of the Swiss Cooperation and Mar Fund. The plan was validated with local and national authorities, and with key actors through two participatory workshops financed by the MAR2R-CCAD/GEF-WWF project. The government institutions, Secretary of Natural Resources and Environment (SERNA), DiBio, and ICF worked together to conduct the validation of the Plan for its subsequent officialization.

A) Colonies close together were often affected by the disease such as these dead MMEA and MCAV colonies, with the adjacent CNAT colony starting to suffer recent mortality. Photo: © Patrick Lengacher. B) Pillar corals, which are rare, suffered high mortality. Photo: © Zara Zuniga.

FIGURE 29. Highly susceptible corals had high mortality in the Bay Islands.

Honduras Coral Species	Code	Healthy Colonies	Colonies with SCTLD	Colonies with Other Conditions	Total Colonies	% SCTLD
Meandrina meandrites	MMEA	325	356	2	683	**52.1%**
Dendrogyra cylindrus	DCYL	173	166	1	340	**48.8%**
Dichocoenia stokesii	DSTO	178	129	0	307	**42.0%**
Meandrina jacksoni	MJAC	34	20	1	55	**36.4%**
Eusmilia fastigiata	EFAS	153	88	3	244	**36.1%**
Colpophyllia natans	CNAT	460	204	12	676	**30.2%**
Pseudodiploria strigosa	PSTR	1556	652	27	2235	**29.2%**
Diploria labyrinthiformis	DLAB	627	183	8	818	**22.4%**
Pseudodiploria clivosa	PCLI	175	49	0	224	**21.9%**
Orbicella annularis	OANN	1058	299	64	1421	**21.0%**
Orbicella franksi	OFRA	258	61	1	320	**19.1%**
Siderastrea siderea	SSID	1121	278	178	1577	**17.6%**
Mussa angulosa	MANG	856	177	10	1043	**17.0%**
Manicina areolata	MARE	14	2	0	16	**12.5%**
Orbicella faveolata	OFAV	938	114	21	1073	**10.6%**
Mycetophyllia lamarckiana	MLAM	103	10	1	114	**8.8%**
Agaricia lamarcki	ALAM	78	5	0	83	**6.0%**
Agaricia agaricites	AAGA	1471	86	24	1581	**5.4%**
Agaricia tenuifolia	ATEN	778	27	19	824	**3.3%**
Stephanocoenia intersepta	SINT	355	10	2	367	**2.7%**
Madracis auretenra	MAUR	56	1	0	57	**1.8%**
Porites astreoides	PAST	438	4	4	446	**0.9%**
Acropora cervicornis	ACER	12	0	3	15	**0.0%**
Acropora palmata	APAL	5	0	0	5	**0.0%**
Acropora prolifera	APRO	0	0	0	0	**0.0%**
Madracis decactis	MDEC	3	0	0	3	**0.0%**
*Montastraea cavernosa**	MCAV	3	0	0	3	**0.0%**
Porites divaricata	PDIV	2	0	0	2	**0.0%**
Porites porites	PPOR	32	0	0	32	**0.0%**
Totals:		**11262**	**2921**	**381**	**14564**	**20.1%**

FIGURE 30. List of corals susceptible to SCTLD in Honduras (Kramer et al., 2022). *MCAV was not recorded with SCTLD on survey transects in this data set but has subsequently been confirmed affected by SCTLD.

Managers and divers team up to halt the decline of corals in Roatan Marine Park

In late September of 2020, the first signs of SCTLD were reported in the Roatan Marine Park (RMP) in Honduras. In less than a year, the disease had spread to over 85% of the island mostly in the northwest and southwest. The response from the managers at RMP serves as a case example to highlight the critical role of outreach, communication, and education.

After reports of SCTLD spreading in the Caribbean in 2019, RMP began recruiting community volunteers and holding workshops to train divers in survey methods and SCTLD identification. Together they surveyed over 1500 corals at 8 sites.

Still, with the threat of an outbreak looming, the team also began a video and poster campaign providing resources for snorkelers and divers on SCTLD identification and a decontamination protocol to prevent the further spread of the disease. After SCTLD was first reported in Roatan in September 2020, the RMP redoubled survey efforts and began communicating with key stakeholders about the serious impacts of the disease. RMP collaborated with government institutions to draft nationwide press releases as well as assisting with the decision to close a high-risk portion of the RMP. Additionally, RMP was integral in the decision to declare an environmental state of emergency for SCTLD in Honduras. RMP began a long-term monitoring program in January 2021 at 21 AGRRA sites and recorded 51,000 observations of 36 coral species.

By autumn 2021, SCTLD in Roatan was an epidemic with 85% of the island's reefs affected. By January 2022, the disease was present in 100% of monitored sites. To save the already infected corals, RMP began a treatment program with CORE Rx to slow the spread of disease on infected colonies. The Adopt-a-Dive Site program was created to give local dive centers the opportunity to participate in these response efforts. In total, more than 1,500 corals were treated for SCTLD, with 500 of these treated by citizen scientists alone and are currently being monitored by 12 different dive centers on the island.

The strategic planning and response from RMP exemplify the importance of outreach and involvement from the community level all the way to the highest levels of government. A rapid response of this scale required the participation of scientists, surveyors, managers, community members, and government officials, all cooperating to tackle a seemingly insurmountable problem.

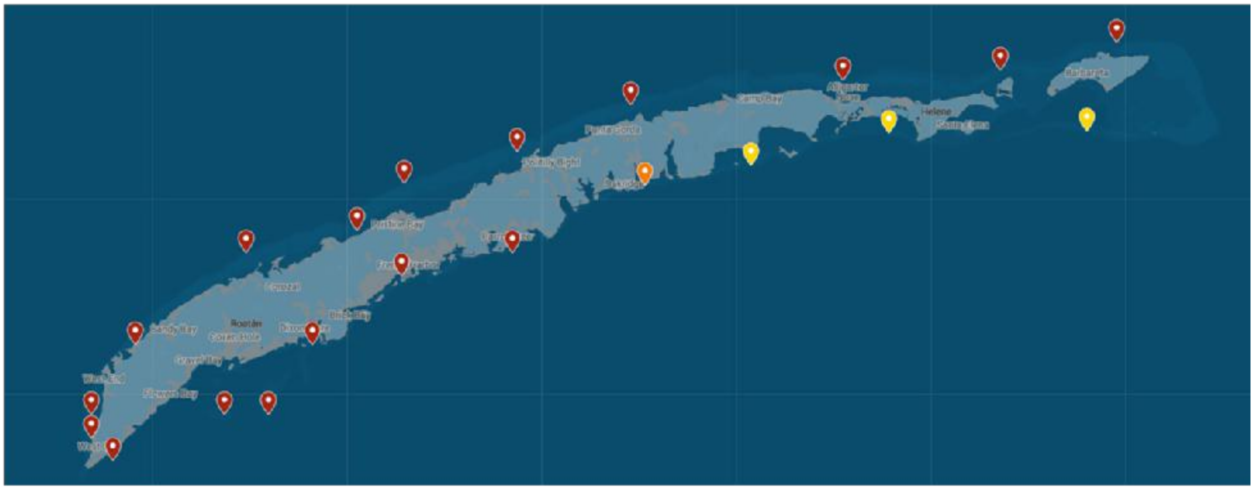
Key takeaways:

- Begin community outreach early
- Involve all levels of stakeholders
- Consider enlisting and training dive centers to assist in monitoring and treatment programs
- Use different forms of media to reach the widest possible audience (posters, webinars, videos, etc.)

Additional response efforts to the disease outbreak include Outreach, Videos, Posters, Presentations, Adopt a Dive Site Program, social media, Webinars, Capacity Building, and Management.

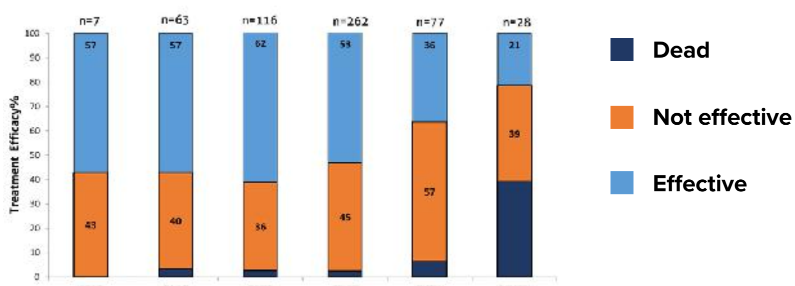
FIGURE 31. Response efforts in Roatan Marine Park. Photo: @Antonio Busiello

SCTLD Outbreak Map January 2022



Endemic Epidemic Invasion Pre invasion

a) Outbreak condition of SCTLD as of January 2022 in the island of Roatan, Honduras. (Source: Z. Guifarro).



b) In 2021, the RMP team treated 1,650 colonies at 60 sites around the island with the help of 12 dive centers. The species with the highest efficacy of the highly susceptible species was *Pseudodiploria strigosa* (symmetrical brain coral), followed by *Diploria labyrinthiformis* (grooved brain coral). In the intermediate susceptible species, *Orbicella annularis* had the highest efficacy (Photo ©Z. Zuniga, Graph, Z. Guifarro, pers. comm.).

FIGURE 32. Roatan outbreak map and treatment efficacy of highly susceptible species (Z. Guifarro, pers com).

How to Identify Corals Susceptible to SCTLD

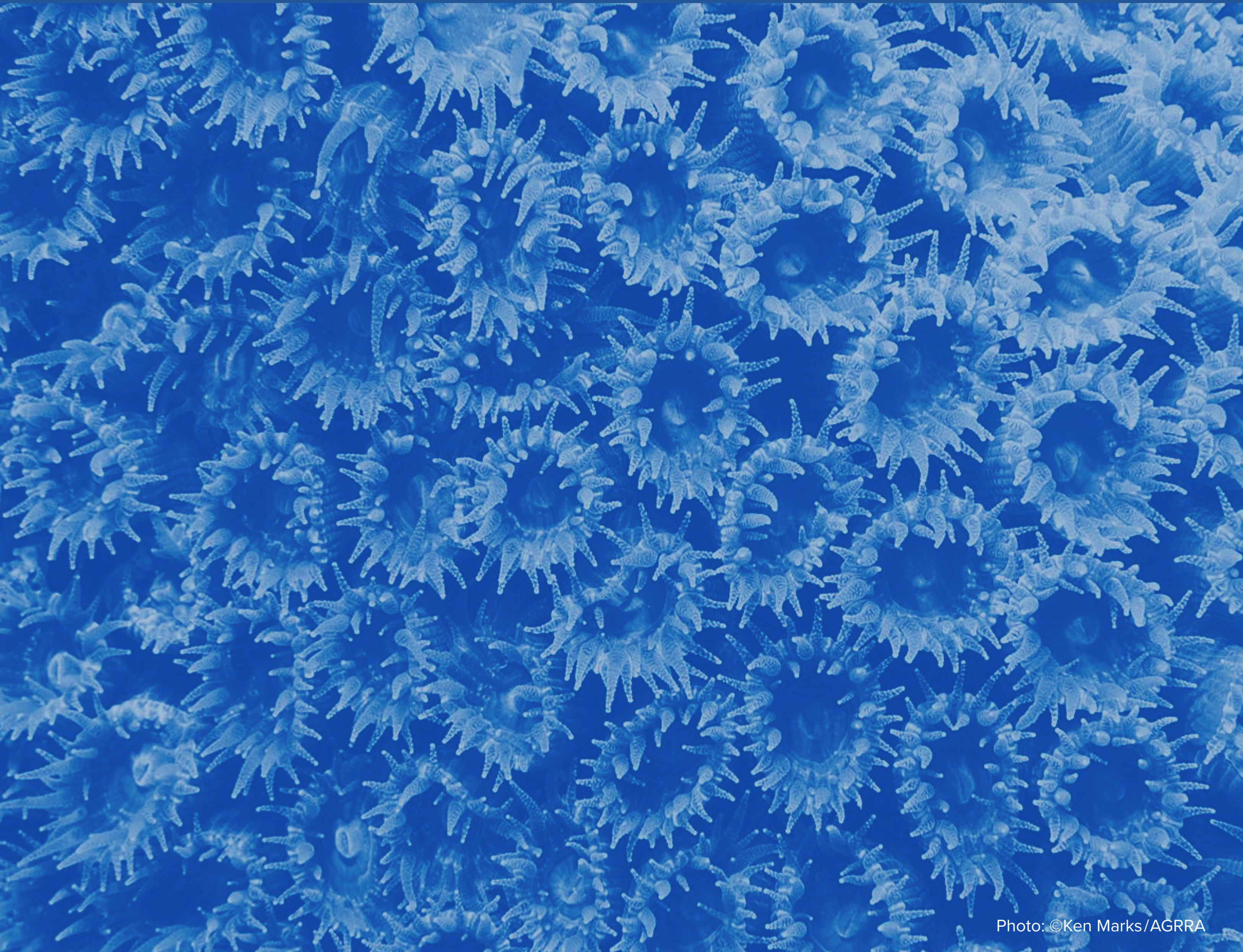


Photo: ©Ken Marks/AGRRA

The following section is a brief description of the corals observed with stony coral tissue loss disease in the Mesoamerican Reef Region. The descriptions are based on AGRRA Coral Identification training materials (Lang et al., 2021, All images are Copyright © by Ken Marks, New World Publications). We encourage the reader to learn more about these corals by reading field guides and other publications. The corals are listed in alphabetical order.

Each coral description includes:

Scientific name: (example) *Agaricia agaricites*

Four letter coral code: is the first letter of the coral genus and first 3 letters of species = AAGA

Common name: Lettuce Coral (note common names may vary)

Description: A brief description of distinguishing features of the coral

Countries observed with SCTLD: The country name is listed if this species was observed with stony coral tissue loss disease in one of the four MAR countries. Note, this may be updated as the disease spreads. If a country is bolded with an asterisk, it indicates that over 10% of observed colonies of that species were infected with SCTLD in that country.

MAR Size Range: The size range (length in cm) of a coral colony based on MAR site averages (Data HRI, 2020). Example: MAR Size Range: 15-30 cm

Stony corals are animals with soft, sac-like bodies above a hard calcareous skeleton. The shape, size, and color of the polyps and the colony are used to help identify coral species.

Coral polyps, like this *M. cavernosa* (MCAV), have soft tissue with a ring of tentacles surrounding their mouth.

Polyp shape and color help identify coral species. Brown tissue is healthy, white is exposed dead skeleton (MCAV).

Colony shape is often used to help identify coral species but may vary with depth, light or other conditions (MCAV).

FIGURE 33. The size and shape of a coral colony and its polyps are used to help identify species in the field. Photos: ©AGRRA.

Agaricia agaricites (AAGA)

Lettuce Coral

Description: Plate coral with small polyps in long rows or short reticulations; pointed at the ridge tops. Tan to brown in color (can also fluoresce). Many colonies may settle and grow close together.

Countries observed with SCTLD:
Mexico, Belize, Honduras

MAR Size Range: 5-79 cm

Agaricia humilis (AHUM)

Low-Relief Lettuce Coral

Description: Plate coral with tiny, densely packed, polyps defined by deep centers and reticulate ridges with pointed tips. Yellowish to dark brown in color.

Countries observed with SCTLD:
Mexico

MAR Size Range: 4-35 cm

Agaricia lamarcki (ALAM)

Lamarck's Sheet Coral

Description: Plate coral with conspicuous, white-mouthed polyps organized in long rows or short reticulations. Forms wide, heavy plates with thick, rounded ridges. Yellow to dark brown in color.

Countries observed with SCTLD:
Mexico, **Belize***, Honduras

MAR Size Range: 5-80 cm

Agaricia tenuifolia (ATEN)

Thin Leaf Lettuce Coral

Description: Plate coral with thin, vertical keels that are elongate or dissected. Small polyps are organized in long rows or short reticulations. Yellowish, grey, or brown in color.

Countries observed with SCTLD:
Mexico, Honduras

MAR Size Range: 9-113 cm

Colpophyllia natans (CNAT)

Boulder Brain Coral

Description: Largest of the meandroid corals, with narrow grooves along tops and sides of ridges. Narrow septa connect polyp mouths tissues and may have one or more colors.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 4-115 cm

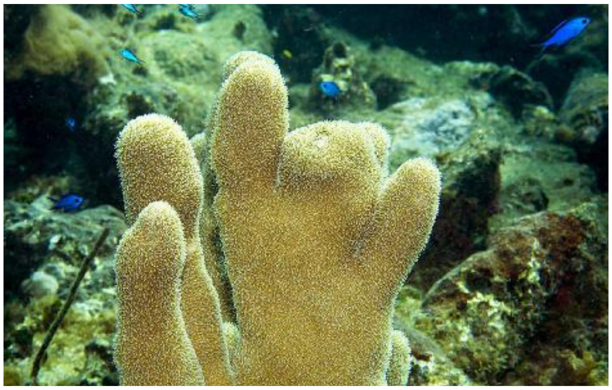
Dendrogyra cylindrus (DCYL)

Pillar Coral

Description: Solitary coral characterized by tall columns above a massive base. Columns usually wide and flat on top with polyps expanded during daylight hours. Tan, yellow, or dark brown in color.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 15-60 cm



Dendrogyra cylindrus (DCYL)

Pillar Coral

Description: Solitary coral characterized by tall columns above a massive base. Columns usually wide and flat on top with polyps expanded during daylight hours. Tan, yellow, or dark brown in color.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 15-60 cm

Diploria labyrinthiformis (DLAB)

Grooved Brain Coral

Description: Meandroid coral with a prominent groove along top of ridges that can be deeper or wider than valleys. Tan to brown in color (valleys can also fluoresce). Grows in rounded mounds.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 5-93 cm

Eusmilia fastigiata (EFAS)

Smooth Flower Coral

Description: Flower coral with round or ovoid, stalked polyps only alive at the tips. Smooth septa are visible through tissues. Yellow-brown, brown, or grey in color.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 4-42 cm

Favia fragum (FFRA)

Golfball Coral

Description: Small boulder coral with somewhat exsert, round (or elongated) polyps. Septa have small teeth. Pale yellow to brown in color. Grows in very small mounds.

Countries observed with SCTLD:
Mexico

MAR Size Range: 4-8 cm

Helioseris cucullata (HCUC)

Sunray Lettuce Coral

Description: Plate coral with very thin plates. Polyp mouths are found at the bases of step, thick, outward-facing ridges. Tan, yellow-brown, or brown in color (can also fluoresce blue, green, or grey).

Countries observed with SCTLD:
Mexico, Belize

MAR Size Range: 5-35 cm

Isophyllia rigida (IRIG)

Rough Star Coral

Description: Small solitary coral with very short, irregularly shaped valleys. Each valley has 1-3 polyp mouths and distinct septal teeth. Ridge tissues are tan and brown in color, valleys are pale or white.

Countries observed with SCTLD:
Mexico

MAR Size Range: 9-20 cm

Isophyllia sinuosa (ISIN)

Sinuous Cactus Coral

Description: Small solitary coral with fleshy polyps organized in short, deep valleys. Large ridges are characterized by distinct septal teeth. Grey, green, yellow, or brown in color (can also fluoresce).

Countries observed with SCTLD:
Not recorded in MAR (observed in wider Caribbean)

MAR Size Range: 5-18 cm

Madracis auretenra (MAUR)

Pencil Coral

Description: Branching coral with thin, near-parallel, densely packed branches with blunt tips. Often display expanded tentacles during daylight hours. Cream, yellow, or brown in color.

Countries observed with SCTLD:
Honduras

MAR Size Range: 7-45 cm

Meandrina jacksoni (MJAC)

White valley Maze Coral

Description: Meandroid coral low, narrow ridges. Septa are short, thick, and widely spaced. Often display conspicuous white tentacles. Pale cream or yellow in color. Often grows in irregular shapes.

Countries observed with SCTLD:
Mexico*, Honduras*

MAR Size Range: 9-113 cm

Meandrina meandrites (MMEA)

Maze Coral

Description: Meandroid coral with wide ridges and thick septa. Valleys are deep and narrow. Yellow to dark orange/brown in color. Grows in plates, mounds, or columns.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 4-70 cm

Montastraea cavernosa (MCAV)

Large-cup Star Coral

Description: Boulder coral with distinct large, round, exsert polyps. Brown, yellow, green, or grey in color. Can also fluoresce green or orange naturally, especially at depth.

Countries observed with SCTLD:
Mexico*, Belize, Honduras

MAR Size Range: 6-50 cm

Mussa angulosa (MANG)

Spiny Flower Coral

Description: Flower coral with large, fleshy polyps only alive at tops of stalks. Large, distinct septal teeth. Opaque grey, green, yellow, or brown in color (can fluoresce).

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 5-80 cm

Mycetophyllia aliciae (MALI)

Knobby Cactus Coral

Description: Meandroid coral that grows in thick crusts or plates. Long, wide valleys radiate away from colony center. Brown, green, or yellow in color; may also have white or green spots on ridges.

Countries observed with SCTLD:
Not recorded in MAR (observed in wider Caribbean)

MAR Size Range: 10-35 cm

Mycetophyllia ferox (MFER)

Rough Cactus Coral

Description: Meandroid coral that grows in crusts or plates. Low, narrow ridges fork and cross each other. Raised septal margins surround polyps. Grey, green, or yellow, in color (can fluoresce).

Countries observed with SCTLD:
Not recorded with SCTLD in the MAR (observed in wider Caribbean)

MAR Size Range: 10-35 cm

Mycetophyllia lamarckiana (MLAM)

Ridged Cactus Corals

Description: Meandroid coral complex that includes *M. danaana*. Grows in mounds or inverted cones with distinct septal margins not raised around polyp mouths. Brown, yellow, grey, or green in color.

Countries observed with SCTLD:
Mexico*, Belize, Honduras

MAR Size Range: 6-50 cm

Orbicella annularis (OANN)

Lobed Star Coral

Description: Boulder coral with small, round, exsert polyps alive at the tops of lobe-like columns. Subdivides to form columns or basal plates (under low light conditions). Light or yellow-brown in color.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 8-217 cm

Orbicella faveolata (OFAV)

Mountainous Star Coral

Description: Boulder coral characterized by small, round polyps with exsert walls. Grows in thick plates or mounds surrounded by skirted edges. Green, brown, or grey in color (can fluoresce).

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 11-210 cm

Orbicella franksi (OFRA)

Boulder Star Coral

Description: Boulder coral characterized by irregular bums with large, exsert polyps that are pale or lack zooxanthellae. Large polyps along margin. Green, yellow, brown, or grey in color.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 6-70 cm

Porites astreoides (PAST)

Mustard Hill Coral

Description: Branching coral with tall, thin polyps growing in mounds or plates. Polyps appear fuzzy when expanded. Grey, brown, yellow, or green in color. Multiple colors can occur in the same coral.

Countries observed with SCTLD:
Mexico, Belize, Honduras

MAR Size Range: 5-30 cm

Porites furcata (PFUR)

Branched Finger Coral

Description: Branching coral with long, finger-like branches 1-2 cm wide. Branches are thin, long, and widely spaced, often with rounded tips. Grey, tan, or brown in color.

Countries observed with SCTLD:
Mexico

MAR Size Range: No size data

Porites porites (PPOR)

Finger Coral

Description: Branching coral with thick (>2 cm), irregular branches that are blunt-tipped. Elongate polyps often expand during daylight hours. Light grey, cream, yellow-brown, or blue in color.

Countries observed with SCTLD:
Mexico, Belize

MAR Size Range: 5-119 cm

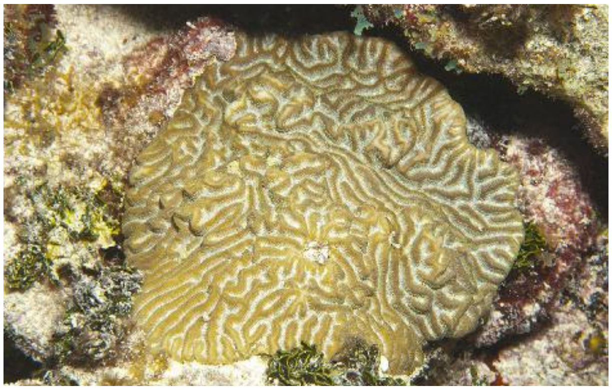
Pseudodiploria clivosa (PCLI)

Knobby Brain Coral

Description: Meandroid coral with narrow ridges that lack grooves. Grows in flattened or irregular crusts at shallow depths. Yellow, brown, green, or grey in color. Valleys may be lighter than ridges.

Countries observed with SCTLD:
Mexico*, Belize, **Honduras***

MAR Size Range: 7-65 cm



Pseudodiploria strigosa (PSTR)
Symmetrical Brain Coral

Description: Meandroid coral with characteristic narrow (often indistinct) groove along ridge tops. Grows in mounds or plates. Yellow, brown, green, or grey in color. Valleys may be lighter than ridges.

Countries observed with SCTLD:
Mexico*, Belize*, Honduras*

MAR Size Range: 5-160 cm

Siderastrea radians (SRAD)
Lesser Starlet Coral

Description: Small boulder coral characterized by sunken polyps with thick septa. Grows in crusts, low mounds, or unattached nodules. Pale yellow to brown in color, polyp walls are lighter than centers.

Countries observed with SCTLD:
Mexico

MAR Size Range: 4-23 cm

Siderastrea siderea (SSID)
Starlet Coral

Description: Boulder coral characterized by small, sunken polyps with very thin septa. Grows in rounded mounds (though smaller mounds may be encrusting). Uniform grey, yellow, or brown in color.

Countries observed with SCTLD:
Mexico*, Belize, Honduras*

MAR Size Range: 5-61 cm

Stephanocoenia intersepta (SINT)
Blushing Star Coral

Description: Boulder coral characterized by round, sunken polyps with thick septa. Grows in thick crusts or irregular mounds. Tan with brown polyps that turn red ("blush") when contracting.

Countries observed with SCTLD:
Mexico, Honduras

MAR Size Range: 4-41 cm

How to Identify SCTLD and Distinguish from other Diseases

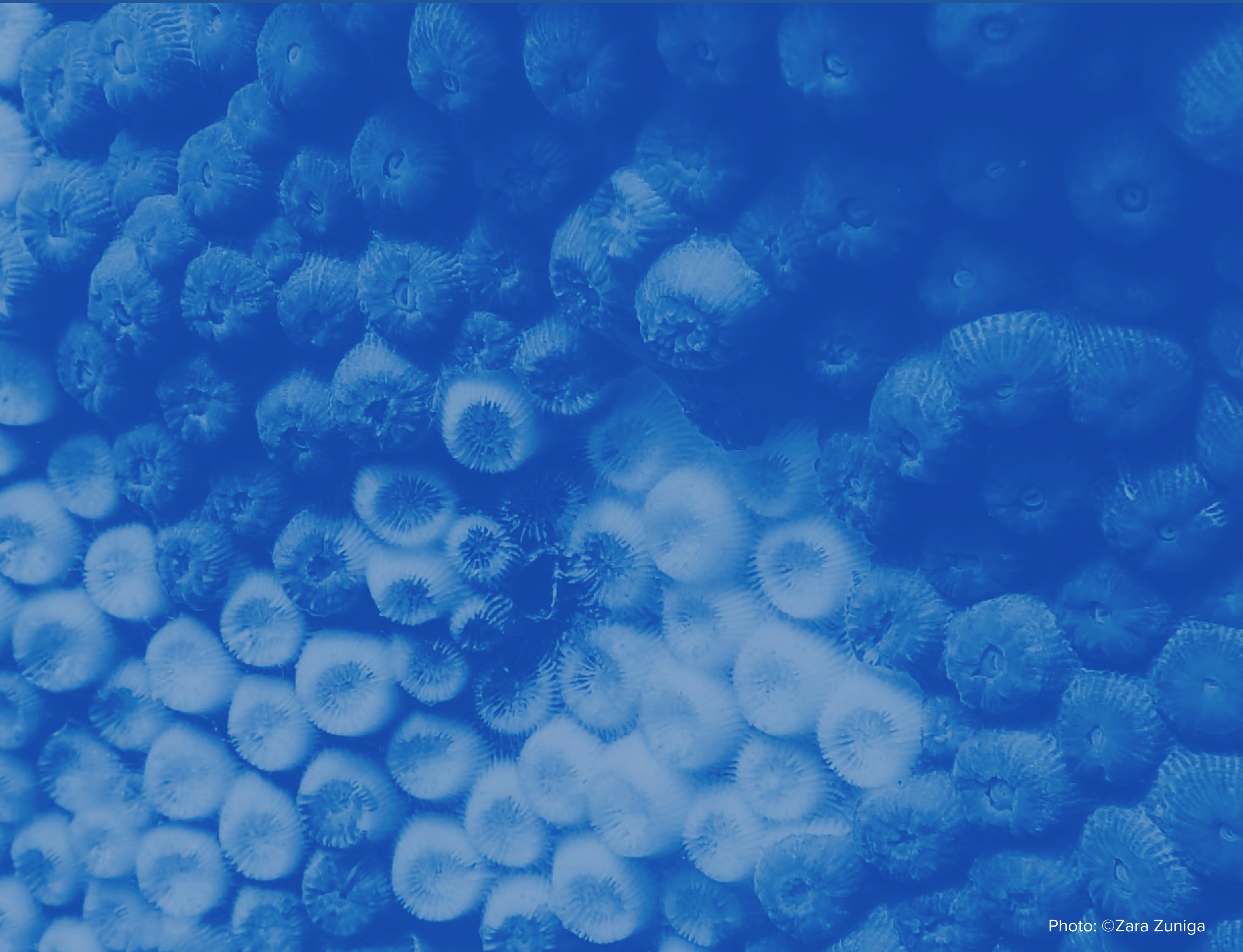


Photo: ©Zara Zuniga

Corals are unique in that they can experience partial tissue death and still remain alive. As corals grow, they are exposed to disturbances like disease that can cause part of the colony to die although the rest of the colony continues to live. Corals have an amazing ability to regenerate new tissue over small areas of tissue loss, but if the extent or severity of mortality is too much, then the dead skeleton areas become overgrown by algae or other bioeroding organisms.

To understand the condition of corals, we look at how healthy a coral's tissues are and measure the amount of healthy area and/or partial mortality area of a coral colony's surface through visual observations. Coral diseases are often characterized in terms of their physical appearance (e.g., black band disease) and their prevalence (the percentage of total colonies affected). SCTLD can be difficult to differentiate from other diseases or causes of tissue mortality especially other white disease syndromes, or scars from predation (e.g., *Coralliophila abbreviata*, *Hermodice carunculata*, fish bites) or physical damage.

One of the key characteristics of stony coral tissue loss disease is the high amount of recent mortality it causes. One sign to look for is if the reef has numerous corals, especially highly susceptible species, which have recent mortality.

Corals with tissue mortality should be examined closely to distinguish SCTLD from other sources of mortality.

FIGURE 34. Multifocal tissue loss due to SCTLD. Photo: ©Caroline Power Photography.

Healthy Corals

Healthy corals have tissues intact with few signs of damage. Small corals often tend to have no or very low partial mortality, while larger colonies often have greater partial mortality (as a result of being exposed to more disturbances over time). Normal, healthy coral tissue color varies with coral species, depth, and other factors. Photo: © Ken Marks.

Recent tissue mortality

Refers to when a coral's tissue has recently died, but the underlying corallite skeletal structure is visible and identifiable to species. **Recent "new"** mortality appears white (having died in past minutes to days). **Recent "transitional" mortality** has corallite structures that are often covered with a thin layer of algae, sediment, or bacteria (having died in previous days to months). Photo: © Ken Marks.

Old Mortality

Old mortality refers to any non-living parts of a coral in which the corallite structures are either gone or covered over by organisms that are not easily removed (e.g., algae, sponges). The coral's soft tissues likely died within the previous months to years to decades. Photo: © Ken Marks.

Standing dead

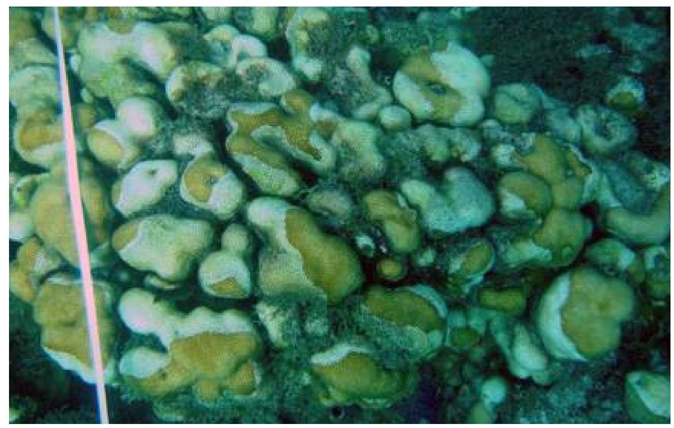
Standing dead refers to colonies that are completely or 100% dead and identifiable to generic level based on colony morphology (e.g., *Acropora*) or corallite character (e.g., *Diploria species*). Although corals may be 100% dead, they still provide important habitat for other reef creatures. Photo: © Fragments of Hope.

White tissue loss diseases

SCTLD = Stony coral tissue loss disease

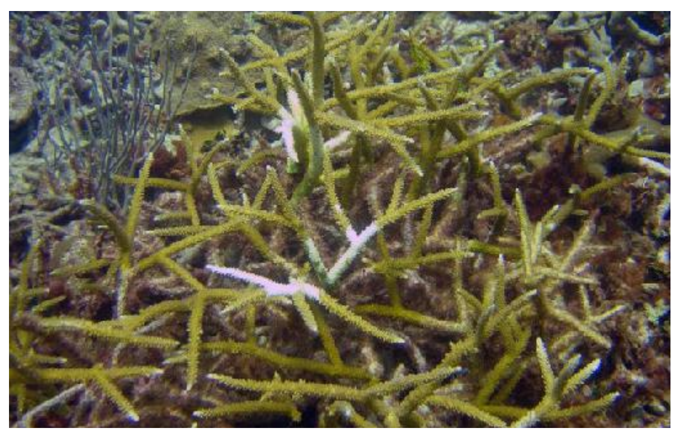
Sharp distinct line between healthy tissue and new exposed dead skeleton, no microbial mat along disease interface, skeleton is intact. Focal, multifocal, linear or coalescing lesions. Differs as it causes rapid tissue loss on many susceptible corals at same time and results in whole colony mortality. Photo: © Lisa Carne.

WP = White plague



The most similar disease to SCTLD. Differences include infection from the margin or base of coral, shorter duration of disease, and seasonal fluctuations (white plague subsides in winter months). Rarely causes whole colony death. White plague is most common in massive corals. Denuded skeleton is intact. Photo: © Jeff Miller.

WB = White band



Differs from SCTLD as it is found on acroporids only. Exposes skeleton in a band advancing from the base toward the branch tips. Tissue adjacent to lesion may appear healthy or form a narrow band of disintegrating coral tissue that is peeling off the skeleton. Rate of tissue loss varies from 1-21 mm/day (mean = 5.5 mm/day); No skeletal damage. Photo: © Marilyn Brandt.

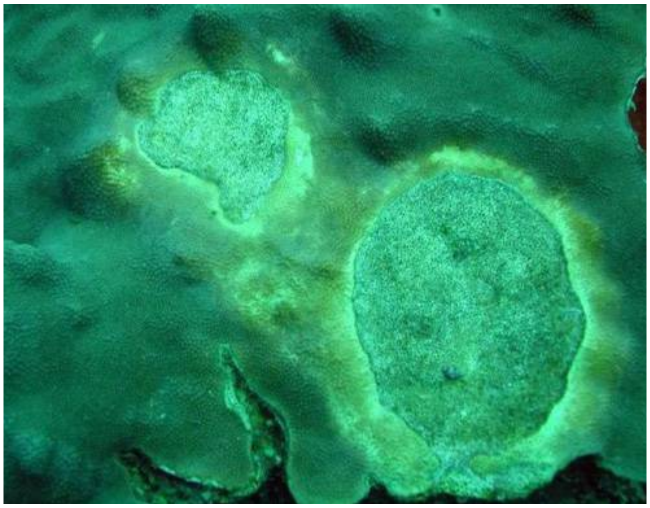
WS = White pox (or spot)

Differs from SCTLD in species effected; white pox is found on acroporids only. It forms a white, patchy necrosis with irregular lesions on the top sides of branches, 5-10 cm diameter. Re-infection results in a mosaic of recently exposed and older, algae-covered lesions. Photo: © Caroline Rogers.

Discolored tissue loss diseases

YB = Yellow band

Visually distinguishable from SCTLD by bright yellow band around infected region. It first appears as a circular area of light-yellow tissue surrounded by healthy, fully pigmented living tissue. As the disease progresses, tissue in the middle dies and is colonized by turf algae and a yellow band 1-5 cm wide is formed. Multiple lesions may appear and coalesce as they continue to expand. It progresses and kills coral tissue at a slower rate than other diseases (3-6 in/yr). Photo: © Robert Ginsburg.



DS = Dark spot

Visually distinguishable from SCTLD by much darker color. Dark spot disease appears as circular to irregular dark patches of discolored tissue. Darkened tissue spots grow in size over time as polyps slowly die, although some polyps may recover. Surface is often slightly depressed. New mortality is rarely seen. More common on *Siderasterea siderea, Stephanocoenia, Agaricia, Orbicella,* and *Montastraea*. Photo: © Andy Bruckner.

Coral Bleaching

Differs from SCTLD as tissue is still present in pale or bleached areas. Coral bleaching results when the symbiotic zooxanthellae are released from the original host coral due to stress. Bleached tissue may appear white (translucent) or pale, but you can still see the polyp tissue above the skeleton. The severity of bleached tissue is categorized as: Pale - discoloration of coral tissue; Partly Bleached of fully bleached or white tissue, and Bleached - all tissues are fully bleached, no zooxanthellae visible. Photo: © Ken Marks.

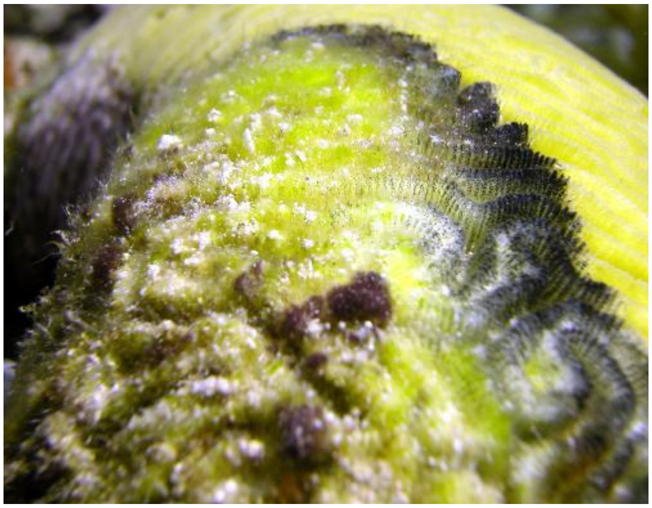
Tissue loss – color band over tissue

BB = Black band

Visually different from SCTLD by distinct fleshy black band and less virulent. Forms a distinct, dark reddish-brown to black mat of filamentous material at the interface between live polyps and newly dead coral skeleton. Band is concentric or linear, 1-30 mm wide. More prevalent during increased sea surface temperatures in the summer. Photo © Tom Szlyk.

CCI = Caribbean Ciliate Infection (CCI)

Visually distinguishable from SCTLD by grey/brown ciliate patches throughout the infected region. A dark, scattered, or dense, band of ciliates that follows behind another disease line such as white plague or yellow band. Photo © Ernesto Weil.



RB = Red band disease

Visually distinguishable from SCTLD by distinct red color. RBD may look similar to black band disease with a dense maroon filamentous cyanobacteria band (1-25 mm wide), although it is less mat like than BBD. The distinct band separates living coral tissue from exposed white skeleton. RBD is less common than black band disease. Photo: © Andy Bruckner.

Other forms of tissue mortality – Predation

Coral-feeding snails

Differs from SCTLD by presence of snails or snail-shaped lesions. Coral snails (*Coralliophila abbreviata*) remove tissue in a semicircular pattern causing focal to multifocal lesions. Two species include: *C. abbreviata* feeds mainly on scleractinian and hydrozoan corals, while *C. caribaea* prefers gorgonians and zoanthids. Photo: © Fragments of Hope.

Damselfish & algal gardens

Damselfish are aggressive, territorial fish that create algal gardens by taking small bites of living coral tissue, then cultivating turf algae that colonizes on the new exposed skeleton. They create small (1-3 cm) lesions that are round or irregular in shape. Distinguishable from SCTLD by the presence of damselfish accompanied by turf algae growing on affected areas. Photo: © Ken Marks.

Parrotfish grazing

Differs from SCTLD by the presence of individual bite marks as well as gouges into the coral skeleton. As parrotfish graze, they use their beak-like jaws to scrape and excavate algae from carbonate substrates and corals causing two different lesion types: small 'spot biting' (1-2 cm) and larger 'focused biting' (2-50 cm) of both tissue and skeleton through repeated bites by *Sparisoma viride* (stoplight parrotfish). Photo: © B Kakuk.

Beaded fireworm (bristle worms)

Hermodice carunculata, a common worm on Caribbean reefs, feeds on coral leaving patches of exposed skeleton or consuming entire branch tips. Feeding can remove a uniform margin of tissue between coral skeleton and live tissue. Photo: © Ken Marks.

Monitoring Disease Outbreaks like Stony Coral Tissue Loss Disease

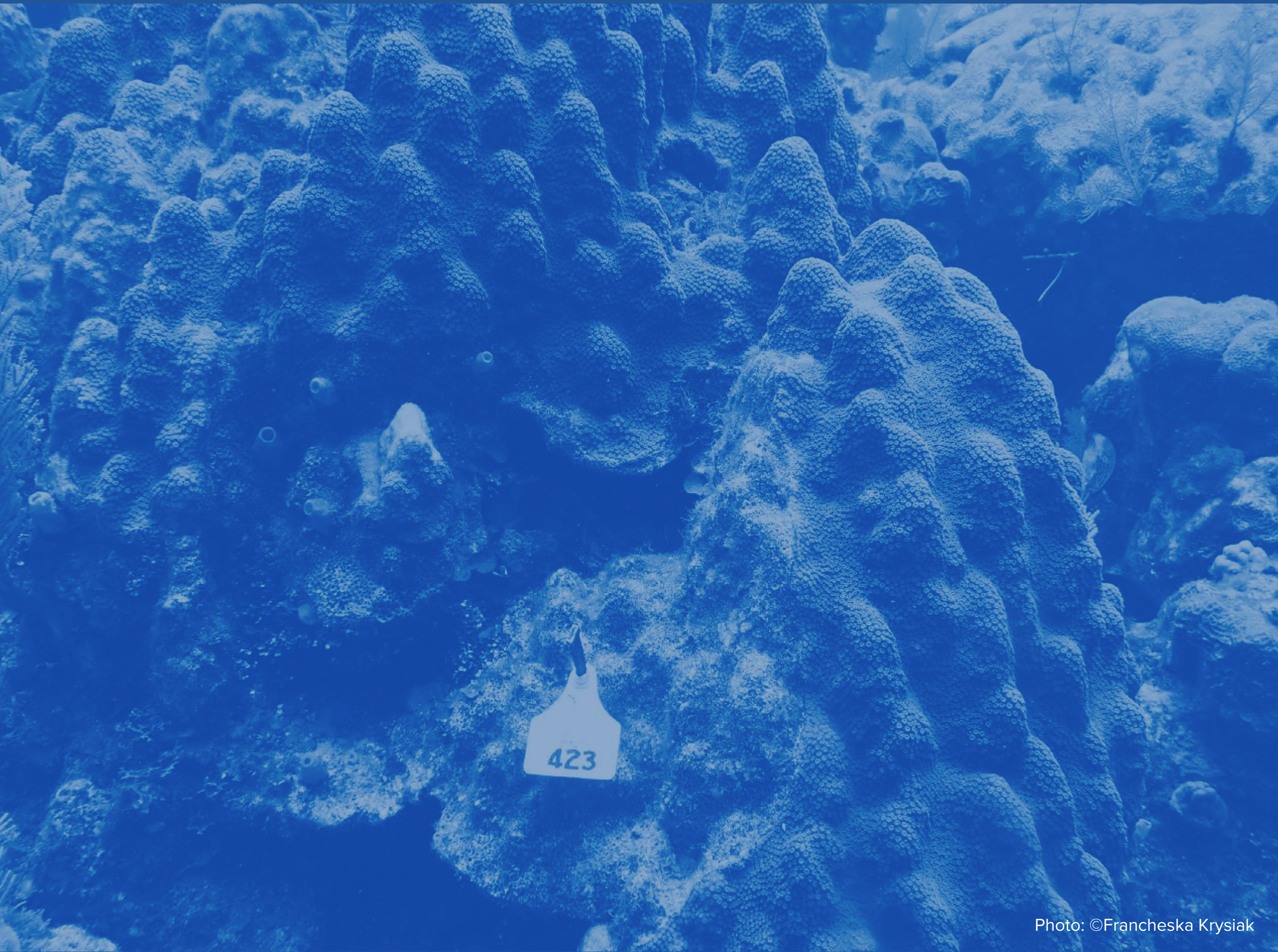


Photo: ©Francheska Krysiak

A wide variety of methods have been used to monitor the condition of coral reefs in the Mesoamerican Reef Region. The Healthy Reefs Initiative (www.healthyreefs.org), together with more than 70 of their partner groups, have conducted regional biannual monitoring of the reefs in Mexico, Belize, Guatemala, and Honduras since 2006. HRI publishes the results on the status of the MAR reefs in biannual Coral Reef Report Cards (https://www.healthyreefs.org/cms/report-cards/) and makes the data available in the MAR Data Explorer (http://bit.ly/HRIExplorer). To enhance standardization and accuracy of data collection, HRI uses the AGRRA coral reef monitoring protocols (www.agrra.org) and conducts regular training of surveyors. Additional targeted research monitoring is conducted by national universities, marine parks, fisheries departments and numerous non-governmental organizations (e.g., National Autonomous University of Mexico (UNAM), National Commission of Natural Protected Areas (CONANP), College of Belize, Belize Fisheries Department, Roatan Institute of Marine Sciences, etc.; see list of HRI partners at https://www.healthyreefs.org/cms/what-we-do/).

Methods for monitoring SCTLD vary depending often on the research question and management need (e.g., Precht et al., 2016; Sharp and Maxwell, 2018; Aeby et al., 2019; Alvarez-Filip et al., 2019; Weil et al., 2019; Meiling et al., 2020; Muller et al., 2020). In the Caribbean, some of the challenges to monitoring SCTLD monitoring has been the lack of sufficient funding to support monitoring efforts and inability to survey due to the COVID-19 pandemic restrictions.

Two main approaches in the MAR region for monitoring coral condition and disease outbreaks are:

1. **Rapid assessments –** These allow a surveyor to quickly characterize a reef at a single point in time with the ability to cover large areas of reef. Methods include rover diver surveys, bar drop method, timed-swims and manta tows. HRI coordinates a MAR regional Coral Bleach Watch program using the bar-drop method, which has been expanded to include SCTLD.

2. **Monitoring –** Monitoring programs are established to help characterize key structure and functional reef processes and track change over time. HRI coordinates regional, large-scale monitoring using the AGRRA method, which includes a focus on coral condition and disease. A variety of additional monitoring is conducted within each country and is often designed to answer specific research or management questions.

Designing a monitoring approach that includes both rapid assessments and monitoring provides a comprehensive overview of coral condition and the impacts of a disease outbreak. Which approach to use depends on the 'stage' of SCTLD present in an area and the questions being asked.

To provide guidance to Caribbean natural resource managers, MPAConnect developed a guide on how to develop monitoring objectives and monitoring methods (Doyle and O'Sullivan, 2020) and has hosted two educational webinars on *Identifying SCTLD and How to Monitor SCTLD*. Additional educational webinars are provided in the Resource Section of this document. AGRRA, together with HRI, hosted training workshops for >100 people in June 2020 on how to monitor coral reefs with a focus on monitoring SCTLD.

For more information on monitoring recommendations see MPAConnect's monitoring guide (Doyle and O'Sullivan, 2020); Florida Coral Disease Intervention Plan (Neely, 2018a); Action plans and resources at AGRRA (www.agrra.org). Four stages of SCTLD disease outbreak have been described based on if, and how long, a reef has been affected by SCTLD. A brief overview of suggested methods to be used for the MAR region during each stage of disease outbreak are described in the table.

Stage	Duration / timing	Coral Community	Disease Prevalence	Management Objective	Monitoring approach
Pre-invasion-status baseline	Monitor baseline every year or biannual	Normal pre-disease coral community	**None to very low (<1%)**	Establish baseline of reef condition / track condition over time	AGRRA-type surveys (or standardized protocol)
Invasion	**1 – 7 months (< 3 months)**	Coral species present, but early susceptible species start to experience recent mortality	**Low** Acute lesions visible only on susceptible species, increasing new partial and total mortality	Detect new occurrence of disease Approximate colony prevalence of SCTLD and geographic extent	Stakeholder reporting Rover diver, bar drop or manta tow surveys Photos
Epidemic	**3 months to a year**	Rapidly changing, increased prevalence of diseased colonies, absence of highly susceptible species	**High** Lesions acute as well as chronic	Track progression and spread of SCTLD at colony and reef scale Quantify spatial extent of SCTLD If treating colonies, assess SCTLD interventions	Colony level – Tag & Mark colonies, photo series Reef scale – establish sentinel reef sites Visual inspection / photo series
Endemic	**1- 4+ years**	Few to no remaining susceptible species. Lower coral cover, potentially higher algal cover, and more non-susceptible species	**May be low-chronic** Highly susceptible species likely died and rare. Chronic lesions present on remaining susceptible species	Determine impacts on coral reef ecosystems including other key reef metrics (e.g., fish, algae, benthic)	6 months to 1 year repeat of AGRRA- type surveys at long term monitoring sites affected and unaffected by SCTLD

FIGURE 35. Stages of stony coral tissue loss disease progression (Adapted from Neely, 2018a).

Overview of Disease Monitoring Process

Objective 1: Detect new occurrence of disease

A. Coral Colony – Identify coral species affected and signs of disease
- Develop a host list of all taxa apparently affected by each disease seen
- Describe lesions using standardized nomenclature and try to identify cause
- Tag colonies for regular monitoring of disease progression.

B. Reef population – Determine geographic extent of where coral disease is present
- Mark the boundary of where disease is present which will help track the rate at which disease in an affected area is spreading spatially and temporally
- Examine areas outside of diseased area

C. Photograph colonies and reef area affected to document extent of disease

D. *If possible and permitted, collect tissue samples for disease verification*

Data goal: Presence/absence, species affected, geographic extent

Methods: Use rapid assessments to characterize traits, use photography to document

Objective 2: Quantify prevalence of SCTLD

A. Colony level – Identify priority corals to monitor, mark colonies and lesions, quantify number of colonies affected by disease and assess condition

B. Reef population – Identify priority reefs to monitor, number of species affected, overall reef condition

Data goal: Determine prevalence of disease

Methods: Monitoring approaches like AGRRA, belt transects, photos

Objective 3: Track progression of disease

A. Colony level – Determine rate of disease progression, determine case fatality rate overall and by coral species

B. Reef population – Track the geographic spatial extent of disease, number of colonies affected

Data goal: Determine fatality rate and partial mortality at colony level and population level

Methods: Monitoring approaches like AGRRA, photo tracking, tagging

Objective 4: Assess effects of SCTLD

A. Assess effects of SCTLD on the reef community including benthic and fish communities

B. Assess the efficacy of SCTLD intervention treatments

C. Assess socio-economic effects

Quick look at methods for stage of invasion

Preinvasion – Long-term, representative monitoring provides a baseline of key metrics of coral reef condition and allows for the ability to detect disease outbreaks

Invasion – Rapid assessments using bar drop method or rover diver

Epidemic – Monitoring using visual surveys and/or photographic methods

Endemic – Long-term monitoring of priority sites

Calculating disease metrics	
Prevalence	**Measures existing cases of coral disease and is expressed as a proportion** *Prevalence (P) = (# diseased colonies/total # of colonies) x 100*
Incidence	**Measures new cases of disease and is expressed as number of new cases over time** *Incidence (I) = number of new infections within a time period, T*
Mortality Rate	**Measures the loss of colonies over time** *M = number of colonies dying per survey area per unit time/ total number of colonies within survey area*
Partial colony mortality	**Measures amount of partial mortality on any given colony (can be separated into recent (new or transitional), old or standing dead)**
Reef mortality	**Measures the number of colonies on a reef with partial mortality**

FIGURE 35. Metrics used to calculate disease condition, prevalence, and incidence. Photo of diver conducting surveys in Belize. Photo: ©Fragments of Hope.

OBJECTIVE 1: Detect new occurrence of disease

When a new disease outbreak is suspected, field surveys should be conducted to gather further information on affected individual colonies and coral individuals within the population. The objective of monitoring during the invasion stage is to detect and confirm the occurrence of new disease. Several approaches can be used including rapid assessments and photo-documenting. A combination of both approaches provides ability to rapidly assess the situation (rapid surveys) and to photo catalog the disease event. Steps to take are:

1. **Reef description –** Describe characteristics of the reef affected including habitat type (fringing, patch), water depth, benthic composition, reef relief, water clarity, proximity to potential disturbances (rivers, outfalls). These can be qualitative observations. Take GPS coordinates.

2. **Coral Colony –** For each coral showing signs of disease, especially SCTLD susceptible species, identify corals to species and develop a list of all taxa apparently affected. On each colony, describe the type of lesions observed (following standardized nomenclature) and use information to try to identify potential cause.

3. **Reef population –** To determine the geographic spatial extent of the disease, swim and survey the affected area in a systematic way (e.g., manta tow, rover diver, time swims), which will allow you to determine boundaries of the disease and later determine the rate at which an affected area is spreading spatially and temporally. Examine areas outside of diseased area.

4. **Photodocument –** Take photographs of the affected colonies and reef area to document the extent of disease. Use scale bars in photographs and take photos of reefscape and for individual colonies, take photos in a) planar view, b) from different angles and c) and close-ups of affected area.

5. **Tissue Sampling –** If possible and permitted, collect tissue samples for disease verification following established national protocols.

Rapid Assessment Methods

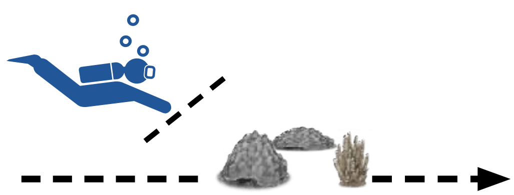
Roving Diver or Bar drop Surveys: Roving diver surveys provide a quick look at a reef to observe if SCTLD is present and can inform if additional monitoring is needed (Neely, 2018a; UNEP, 2021). Roving diver surveys entail a census swim of a reef focusing on SCTLD-susceptible species. If possible, quantitative counts using roving diver surveys should be done and corals assessed for healthy corals, presence of SCTLD, evidence of bleaching or other diseases, and recently dead corals.

A similar method used by the Healthy Reefs Initiative is the bar-drop method which surveys 100-200 colonies along swum transects (McField, 1999). Survey data can be entered into the Caribbean SCTLD Online Data Tool and Tracking Map (https://www.agrra.org/coral-disease-outbreak/).

Rapid Assessment Methods

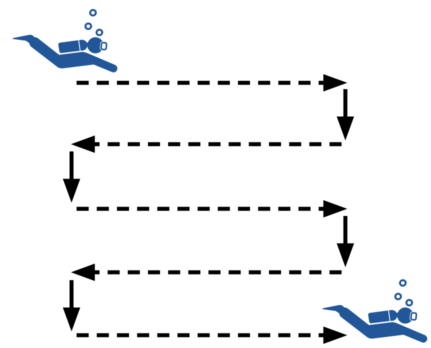
Bar drop method

- Diver swims in straight line along reef contour or compass bearing
- Hold bar perpendicular to swim transect
- Every three kick-cycles place bar on substrate
- Measure species and condition of coral >10cm under the 5 bar marks
- After surveying 50 colonies, swim 5 m away and begin a new transect
- Survey 200 colonies per site



Rover diver method

- Diver swims across reef in a 'lawn mower' pattern to span survey over reef or can do a timed swim
- Survey 100-200 SCTLD-susceptible corals unless susceptible species are rare, to gain a representative sample of the habitat
- Avoid counting the same corals twice, keep ~2 m apart from other divers



For each coral assess:

- Healthy
- SCTLD
- SCTLD + Bleaching (As BL, PB, P)*
- Bleaching (As BL, PB, P)*
- Other Diseases
- Recently Fully Dead
- Enter data in Caribbean SCTLD Online Data Tool (https://www.agrra.org/coral-disease-outbreak/).

Survey Tips

☑ Record site information (e.g., lat/long, reef type, depth)

☑ Start surveys before SCTLD invades or when in outbreak stage.

☑ Survey non-affected sites in advance of the outbreak (boundary).

☑ Repeat surveys at the same site to allow disease incidence estimates

☑ Take photos or videos

FIGURE 37. Overview of bar drop and rover diver methods to rapidly assess coral disease outbreaks. Both are used in the MAR.

OBJECTIVE 2: Quantify prevalence of disease

Once a disease outbreak like SCTLD has been confirmed, the next step is to determine the prevalence of the disease by monitoring priority sites. Selected sites can be based on strategic selection of priority sites or randomly distributed sites to represent a reef zone/area. Monitoring should include colony level and reef level metrics. Coral belt transects, such as non-fixed AGRRA-coral transects, can be conducted to quantify the extent of the disease in spatially defined transects (e.g., Alvarez-Filip et al., 2019; AGRRA 2021). The bar drop method also includes condition metrics (except for size) but differs as it estimates area surveyed (kick cycles) and does not use belt transect lines. A brief overview of the condition metrics used in the AGRRA method to quantify prevalence is described here:

A. For all colonies >4 cm measure colony size:
Length: Maximum length perpendicular to the axis of growth in cm.
Width: Maximum width at right angles to the maximum length in cm.
Height: Maximum height parallel to the axis of growth in cm. (note: size is not measured in bar-drop method).

B. Estimate the amount of partial mortality and record the % of the entire outward-facing (planar) surface for amount of new, transitional, and old mortality as described:

New mortality is where skeletal structures are intact unless live tissues have just been bitten or scraped by a fish or otherwise abraded and have no sediment, bacterial/microalgal biofilms, turf algae, etc., on their bright white surfaces.

Transitional mortality is where skeletal structures covered with sparse turf algae, microbial biofilms, or thin layer of sediment, unless they have just been bitten or scraped by a fish or otherwise abraded, thereby exposing the underlying bright white skeleton.

Old mortality is where skeletal structures are completely covered over by organisms that are not easily removed such as thick algal turfs, invertebrates–unless they have just been bitten by a fish or otherwise broken, thereby exposing the underlying, bright white skeleton.

C. Estimate the amount of bleached tissue of the entire planar surface and distinguish as:
Pale: The percent (%) of the entire planar surface that is pale.
Bleached: The percent of the entire planar surface (and not just the proportion of live tissues) that is fully bleached (e.g., 30P, 10BL = 30% pale + 10% bleached).

D. Estimate signs of disease by examining the entire surface of each colony and record the presence of any signs of disease. Examine individual lesions on a colony, count the number of lesions and describe lesions (e.g., color, size, shape, location), following standardized nomenclature. Use information to try to identify type of disease using colored codes (e.g., BB=-black band disease).

E. Quantify number of colonies affected by disease and assess condition.

F. When finished surveying, record the total number of square meters with completed surveys of all ≥ 4 cm stony corals.

G. Take representative photographs of the affected colonies and reef area to document the extent of disease. Use scale bars in photographs. Take photos of reefscape and for individual colonies, take photos in a) planar view, b) from different angles and c) and close-ups of affected area.

H. Quantify spatial extent of invasion zone. Continue surveys to determine disease boundary.

I. Identify and select priority colonies for fate tracking monitoring.

J. Identify and select priority or sentinel sites for surveying over time (e.g., repeat or fixed).

KEY CORAL METRICS TO SURVEY

Describe types of lesions and mortality.

This *Orbicella* colony affected by SCTLD has several large lesions in the middle of the colony (near tag). Exposed skeleton has been covered by turf algae. Photo: © Francheska Krysiak

Estimate percent of mortality in planar view.

This colony has~80% of the colony recently dead and 20% of living tissue remaining. Multi-focal lesions have coalesced to form a large diffuse patch of exposed skeleton. Photo: © Francheska Krysiak

Measure size of colonies as length, width, and height.

A coral colony’s size is used as a proxy for age to understand population dynamics. Coral size varies naturally by coral species, reef type, water depth and disturbance. Measuring sticks can be used to estimate size of colonies and lesions. Photo: ©BICA

FIGURE 38. **Key metrics for disease surveys are types of lesions, amount of mortality and colony size.**

OBJECTIVE 3: Track progression of disease

Once SCTLD has been identified and the spatial extent delineated, the progression of SCTLD can be determined by surveying priority coral reef sites and coral colonies. The main objectives during this stage are to identify reefs and individual corals to follow the progression of SCTLD at the colony and reef scale, changes in mortality, and survivorship of individual corals. This information can be used to guide management actions and to consider for potential interventions. Fate tracking can be done a variety of ways such as 2-D photographs, photomosaic and newer technology for 3-D imaging.

A. **2-D Photos:** To assess the effects of SCTLD on individual corals, particularly susceptible corals, time-series photos (2-D) can be taken to document, confirm and track progression of the disease. Photographs should be taken at a variety of perspectives including a) Reefscape view of affected reef (with scale bars) and b) several photos of SCTLD-affected corals (with scale bars) Corals can be tagged using a variety of methods and several views of corals should be taken such as the colony from top and side, close-up of disease margin, and surrounding corals (see Zimmermann, 2021). Along the lesion(s), a scale or marker (e.g., small nails) can be placed on the dead part of coral skeleton) to demarcate the lesion boundary and allow for tracking lesion growth. This is an easy, low-cost method, but can be time intensive if tagging numerous colonies.

B. **Photomosaics:** A photomosaic is a spatially explicit, georeferenced composite image created by combining hundreds to thousands of individual overlapping images. The mosaic can be used to create digital representations of large reef areas (100's m2). There are a variety of approaches that can be used to collect, create, and extract data from photomosaics (see webinars on www.agrra.org/resources). They are beneficial in documenting the effects of SCTLD and other disturbances on a larger reef-scale and tracking changes over time. Benefits of photomosaics include a high power to detect change, the ability to take past history into account of coral dynamics if available, a rapid field technique for surveying the entire benthic reef community and provides a historic digital record (Gleason et al., 2007; Carne et al., 2016; Gintert et al., 2018; Greene, 2020; Lang, 2021). Individual corals within a mosaic can be followed over time without extensive tagging and the image provides a permanent historic record; however, it requires a financial investment in the initial camera costs, training on processing and additional time to interpret images.

C. **3D Photogrammetry:** New technology is available that allows for the construction of 3-D photo-models to track the condition of corals. Since corals are semi-spherical, three-dimensional animals, these new models allow for calculating metrics such as tissue loss due to SCTLD, mortality or amount of bleaching at a higher resolution (Meiling et al., 2020). This approach also provides a historic high-resolution record, but initial costs and time to process are extensive.

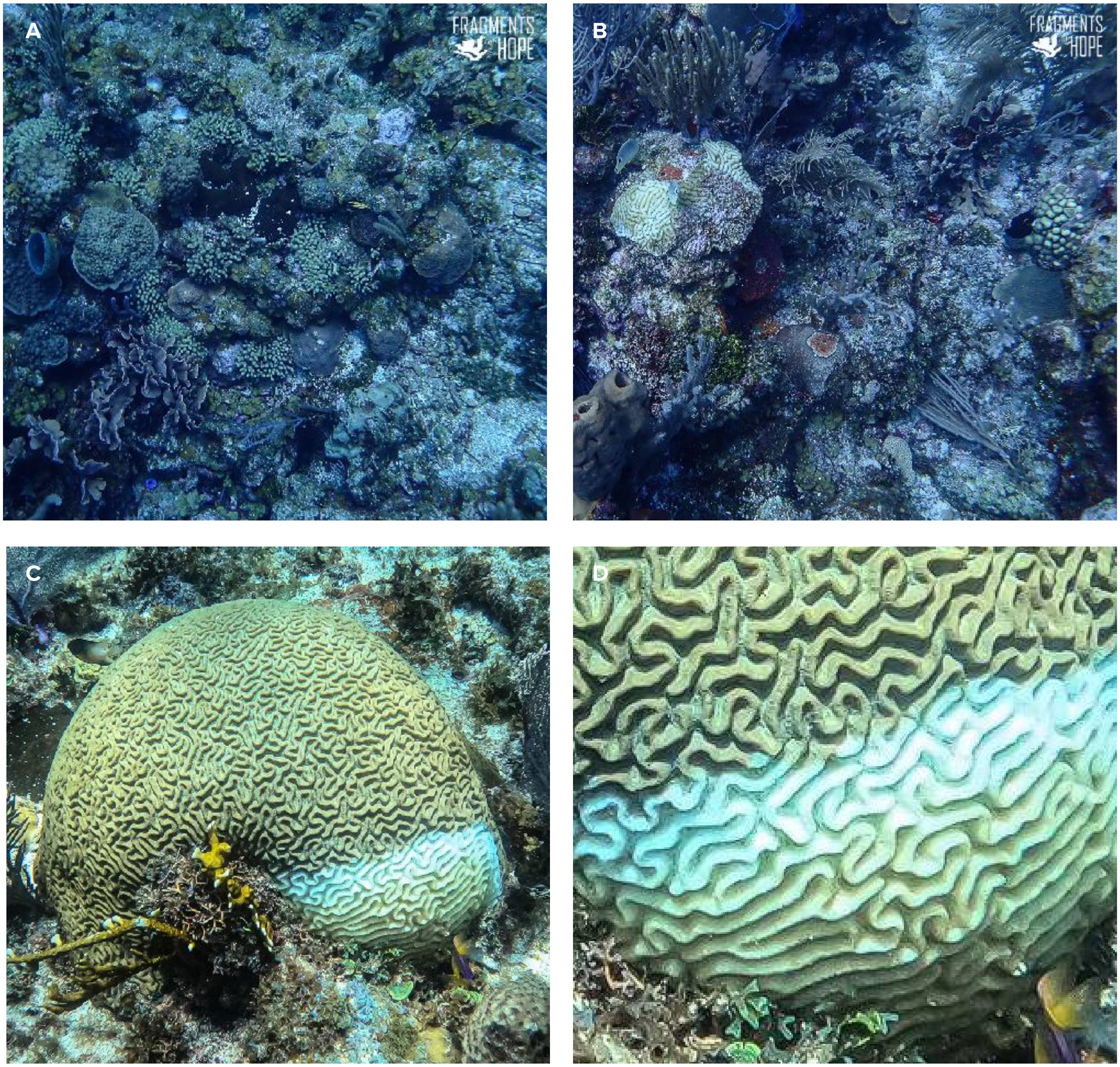
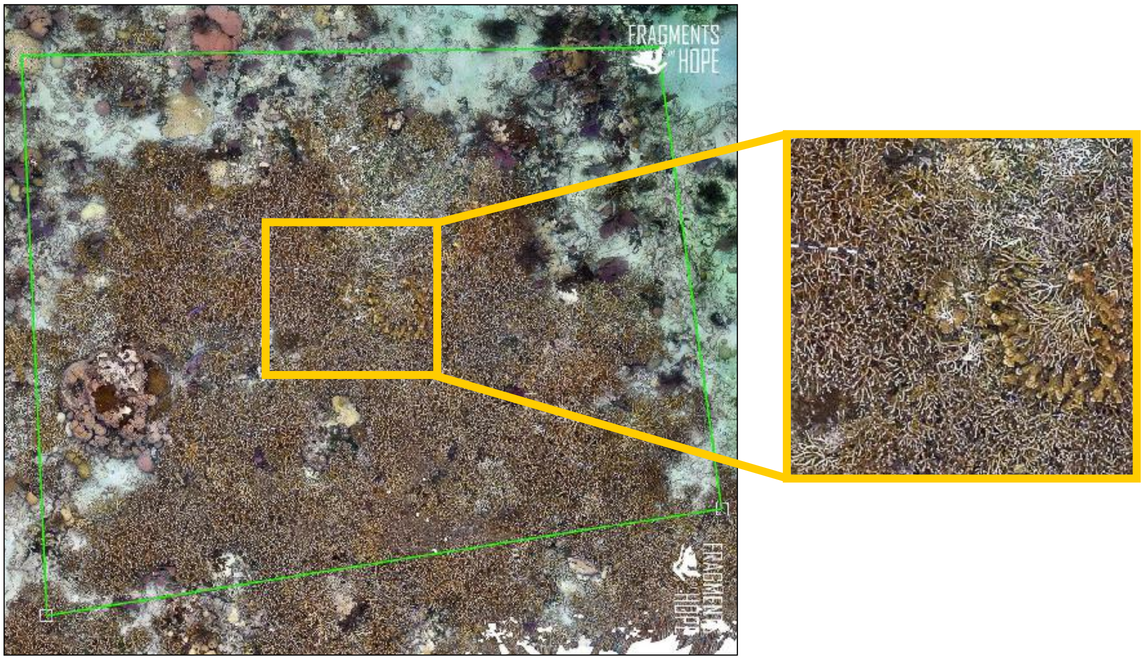


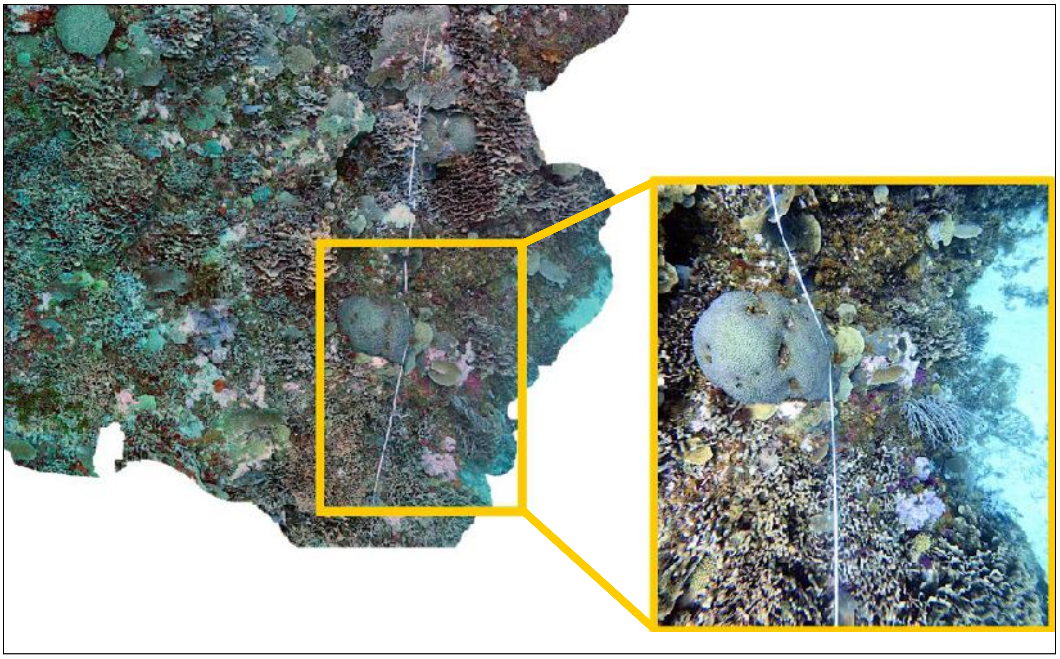
Photo-documentation

Taking good photos for your report can be just as useful as collecting data. Photographs should capture reef condition and disease in a variety of scales and context. A) If possible, take photographs of your reefscape prior to disease outbreaks to put baseline or preinvasion condition into context. B) Once signs of disease start to appear (invasion stage), capture photos of disease prevalence in context to its surrounding reef community as this can provide an overall indication of how disease is distributed on the reef. C) To understand disease signs, take photos of the entire colony from different angles as this type of image helps to indicate the severity of the signs and which part of the colony is affected. D) Zoom in and take close-up photos of the affected area as this type of image helps to show the small-scale distribution of dead and live coral tissue and any associated signs. If lesions vary across the colony, take a variety of different angles. Photos A-D: ©Fragments of Hope.

FIGURE 39. Examples of different photos to document disease.

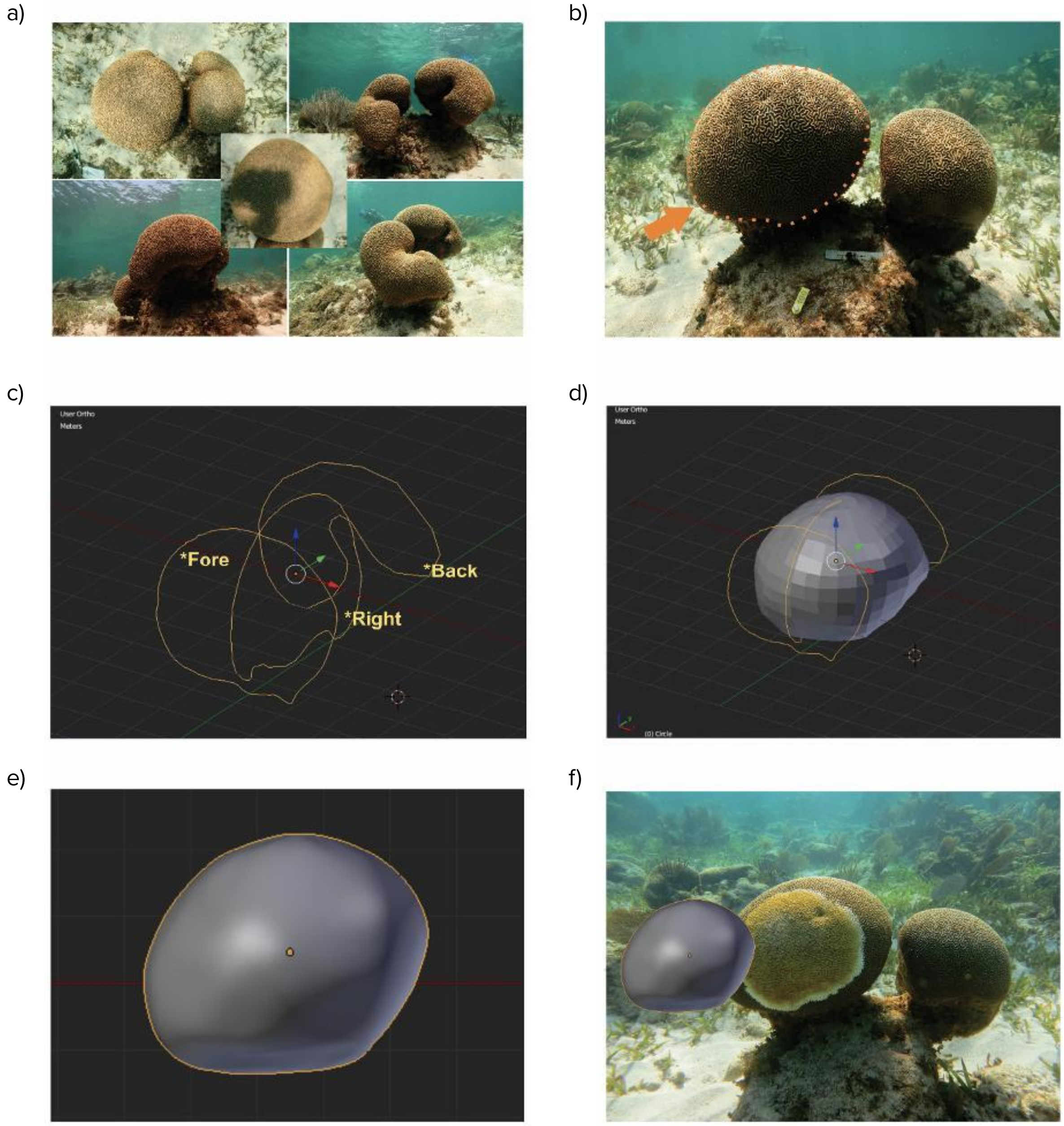


Fragments of Hope uses photomosaics, like this one from Laughing Bird Caye NP, as one way to track their coral outplant sites for changes in live coral cover and impacts from coral bleaching and hurricanes (Carne et al., 2016). Photo: ©Fragments of Hope.



Healthy Reefs Initiative and Pixan'Ja recently took high resolution photomosaics of their monitoring site at Cayman Crown reef to use as a baseline to track coral condition overtime, including disease or bleaching. Photo: ©A. Giro.

FIGURE 40. Photomosaics are used in the MAR to track reef condition and coral colony health.



Using 3D models to track the progression of coral mortality (figure from Camacho-Vite et al., 2022). To track the progresion of mortality at the colony level in Limones, Mexico, Camacho-Vite et al. (2022) used a series of photographs of *Pseudodiploria strigosa* to create 3D models with the open source software Blender 2.80. From the models they were able to estimate total live tissue of each colony before disease occurred, as well as quantify mortality and lesion type as the disease progressed. This was a feasible, lower cost approach compared to other 3D methods. *(Figure caption from Camacho-Vite et al. (2022): Building a 3D model a) Selection of the five photographs of each side of the colony b) Perimeter delimitation. c) Perimeter adjustment to the shape of the colony. d) Modification of a sphere to adjust the perimeter of the colony. e) Model with smooth vertices. f) The perimeter of the lesion was trace*d and placed on the original model for each time, maintaining the tridimensional structure of the lesion.)

FIGURE 41. 3-D photo-models are created to track the coral condition in Mexico.

OBJECTIVE 4: Assess broader, long-term effects of disease

Epidemic/Endemic Zone

Continued monitoring should be done to track disease progression, spatial spread, effects of SCTLD outbreaks on reef ecosystems and ecosystem services, and to assess the effectiveness of SCTLD intervention methods.

A. Assess effects of SCTLD on the reef community including benthic and fish communities

B. Assess the efficacy of SCTLD intervention treatments

C. Assess socio-economic effects

A. Assess the effects of SCTLD on surrounding reef community.

AGRRA surveys: The loss of numerous corals is likely to affect the surrounding benthic composition and may affect fish communities. AGRRA surveys, or national monitoring protocols that assess overall reef condition should be done to evaluate reef community structure and function (Alvarez-Filip et al., 2019; Estrada-Saldivar et al., 2020).

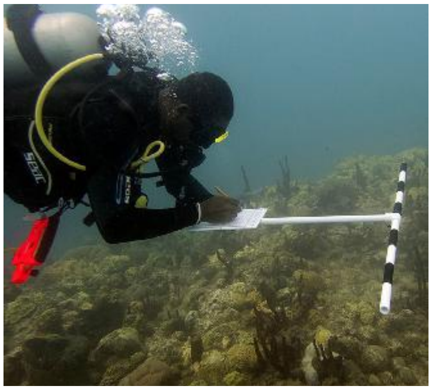
AGRRA Benthos Survey Methodology

Point counts along transects
- Corals (*species - live, recent dead, bleached, diseased*)
- Aggressive Invertebrates
- Non-aggressive invertebrates
- Functional algal groups (macroalgae, crustose coralline, calcareous, turf)
- Cyanobacteria

Quadrats
Juvenile corals (<4 cm), substrate type

Belt transects
Other important motile species

AGRRA Fish Survey Methodology



Belt transects
- Species (*ecologically and economically important species*)
- Fish Size
- Fish density
- Reef Height

AGRRA Coral Survey Methodology

Belt transects
- Coral species
- Coral abundance
- Coral size
- Coral condition *(mortality, bleaching, disease, predation)*

FIGURE 42. AGRRA surveys are used to assess reef condition in the MAR. Photos: ©AGRRA.

B. Assess efficacy of SCTLD intervention treatments.

If individual corals have been treated with intervention treatments (e.g., CoreRx Base2B, antiseptics etc.), long-term monitoring should be done to determine the effectiveness of these treatments. Fate tracking of individual corals can be done through 2-D photos or 3D photogrammetry (Neely, 2018a; Neely et al., 2020, Zimmermann, 2021; Meiling et al., 2020). This colony below (left) suffered high recent mortality due to SCTLD. Fragments of Hope, Belize, treated this colony with CoreRx (right) to reduce lesion spread and increase survivability. In situ observations are being made and photos of this coral taken to assess the effectiveness of treatments in slowing or halting mortality progression.

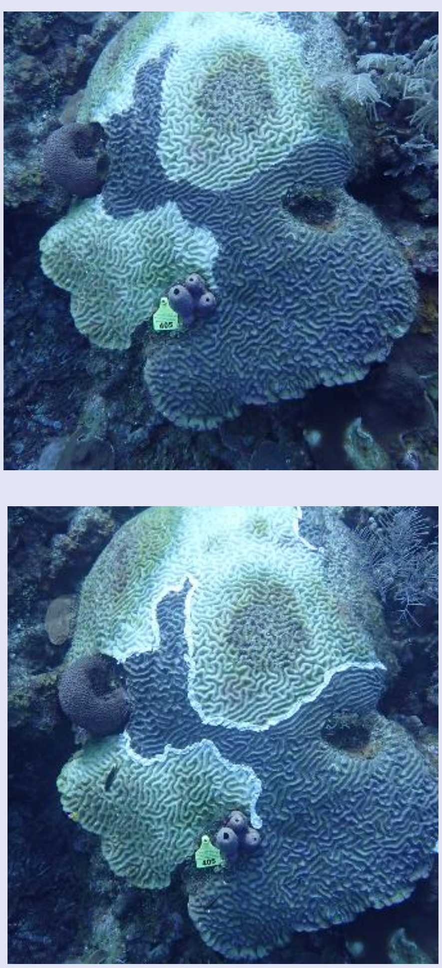


FIGURE 43. Documenting coral treatments helps determine effectiveness. Photo: © Francheska Krysiak.

C. Broaden monitoring to include effects on socioeconomics.

Most SCTLD monitoring has focused on the ecological consequences of the disease outbreak, but there is a need to investigate the social effects on coastal communities including effects on marine-related management, economics (tourism, fisheries), cultural values, and ecosystem services (shoreline protection). Several guides on incorporating socioeconomic metrics are available (e.g., Pena et al., 2012). Socioeconomic monitoring could include such issues as:

1. Community Awareness and Perceptions

- Identify reef-associated community, assets, and businesses that are potentially affected by SCTLD in the MAR.
- Conduct multi-stakeholder focus group surveys to iDentify stakeholder perceptions, attitudes, and knowledge of SCTLD, as well as awareness of ongoing management and conservation.
- Identify opportunities to improve outreach and awareness.

2. Socio-cultural-economic Value

- Identify the social, cultural, and economic value of the reef. And potential socio-economic impacts related to SCTLD.
- Assess potential impacts related to SCTLD on social, cultural, or economic activity.

3. Communications and Outreach

- Continue to develop outreach materials and best practice guides for various stakeholder groups and evaluate effectiveness.
- Develop a guide or process to evaluate how SCTLD and related loss of reef processes affects social, cultural, and economic activities
- Develop guidelines for engaging policymakers on how to incorporate socioeconomic impacts of SCTLD in the decision-making and management actions.

Site Selection

Many different coral species are susceptible to stony coral tissue loss disease. Prioritizing which reefs to survey, monitor or implement management actions can help focus efforts, identify specific monitoring objectives, and determine appropriate response actions. Below are criteria to help guide the site selection process. AGRRA developed an interactive map of Mesoamerican coral reef data to allow easy access for users to view coral cover data (recorded in HRI-AGRRA benthic surveys) of SCTLD-susceptible coral species. Examples of how these maps can be used are provided in the maps below.

Identifying Priority Reef Sites:

Several guiding principles (Neely, 2018a; Doyle and O'Sullivan, 2020) can be considered when selecting and prioritizing reefs to monitor including:

Ecological

- Presence of SCTLD susceptible corals
- Coral density
- Coral composition
- Coral demographic structure
- Isolation

Regulatory

- Iconic Coral
- Within an MPA
- Within a recreational area
- Other high value reefs

Identifying Priority Corals for Intervention:

Several guiding principles (Neely, 2018a; Doyle and O'Sullivan, 2020) can be considered when selecting and prioritizing individual corals to monitor and treat including:

Ecological

- Reef structure builder (e.g., *Orbicella* spp.)
- Large-sized corals
- Localized reproductive capacity

Regulatory

- Iconic coral (e.g., endangered, pillar coral)
- Within an MPA
- Within a recreational area

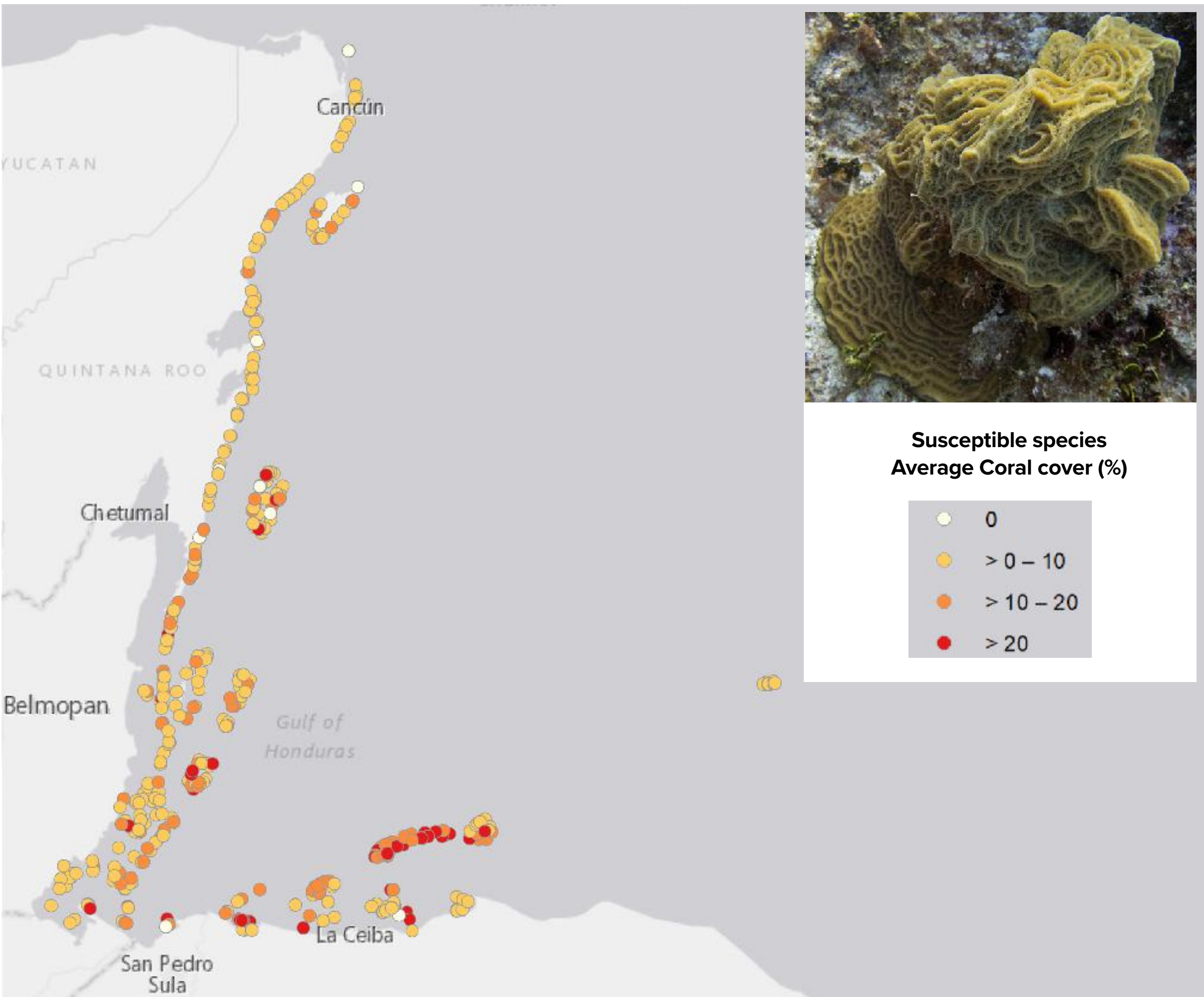
Selecting individual corals for treatment

- Portion of colony unaffected (e.g., >75% of colony is still alive)
- Number of active SCTLD lesions (e.g., colonies with <5 lesions are more treatable than those with more lesions)
- Monitoring efficiency (ease of which to conduct subsequent monitoring and retreatment)

Criteria	Guiding Principles	Justification
Ecological (Sentinel Reef Sites)	**Presence of SCTLD susceptible corals**	Does the reef contain species susceptible to SCTLD? Information on the distribution of susceptible corals within Caribbean countries/territories may be found on AGRRA's map on the distribution of susceptible species.
	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 (loss of species is less likely to disrupt the entire ecosystem function).
	Coral density	A high density of corals may provide greater habitat complexity, more ecosystem services, 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 pathogen.
	Coral composition	Sites that contain many colonies of susceptible corals may be prioritized.
	Coral demographic structure	Sites with large, reproductively active, framework structure-producing corals contribute proportionately more 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 survey and may be easier to treated.
Ecological (Sentinel Corals)	**Structure builder**	Some susceptible species contribute substantially to reef-building and associated ecosystem services especially *Orbicella* spp., *Montastraea cavernosa*, and *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 are also likely to substantially contribute more 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 (Sentinel Reef and Coral Species)	**Iconic corals**	Corals identified by stakeholders as important for historical, educational, or economic reasons. These could include frequently visited colonies at popular SCUBA diving sites.
	Within a marine protected area	Corals within zones of extra protection may be living under better environmental conditions and should be prioritized.
	Within a recreational area	Corals near mooring balls are likely to receive greater visitation. This could provide greater visibility for monitoring and treatment efforts and potentially create greater citizen engagement. Or, if recreational diving is large-scale and unsupervised, they are more likely to perish than corals in other areas.

FIGURE 44. Guiding principles to select which coral reef sites and coral species should be prioritized for monitoring (Adapted from Neely, 2018a and Doyle & O'Sullivan, 2020).

Coral cover of species susceptible to the disease



Susceptibility to stony coral tissue loss disease map

This map shows percent cover of coral species with high or intermediate susceptibility to stony coral tissue loss disease in the MAR Region. The data can be used to identify and prioritize reefs for monitoring. Baseline data also provide a benchmark to measure future change.

Data are from the Healthy Reefs Initiative's monitoring program of AGRRA data (2006 to 2018 benthic transects). The interactive map is available on the AGRRA's website. Each point can be selected to show details of the data (site, date, cover of each species). See online map of Coral Cover of Susceptible Species.

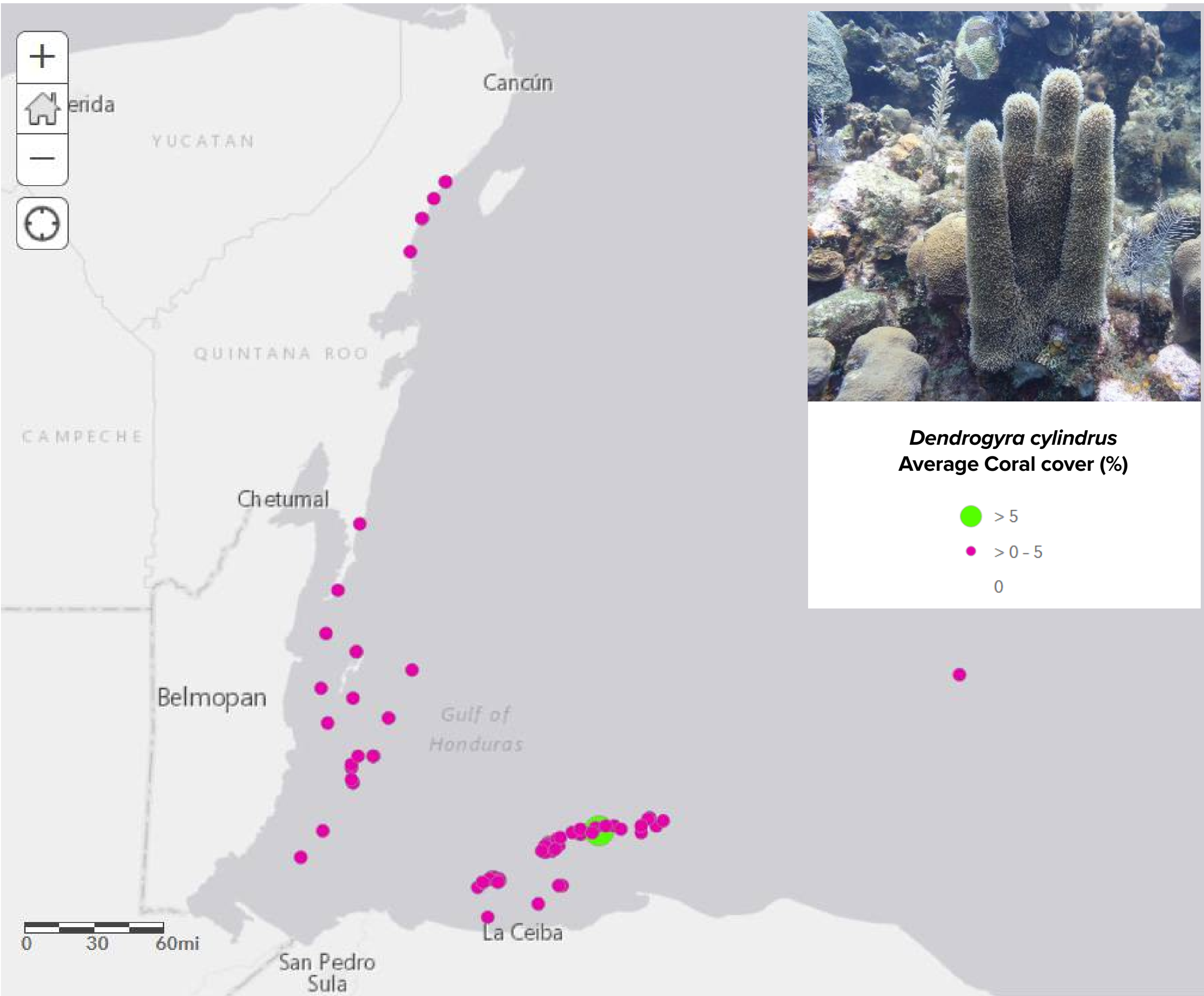
MAR baseline data

- Susceptible corals
- Coral cover by date
- Reef types affected
- Baseline for selecting sites to monitor

Species included in this map are *Colpophyllia natans, Dendrogyra cylindrus, Dichocoenia stokesii, Diploria labyrinthiformis, Eusmilia fastigiata, Meandrina meandrites, Pseudodiploria strigosa, P. clivosa, Orbicella annularis, O. faveolata, O. franksi, Siderastrea siderea, Agaricia agaricites,* and *Agaricia* spp.

FIGURE 45. Map of coral cover of highly susceptible species to SCTLD in the MAR. Map by AGRRA. Photo: © Ken Marks/AGRRA.

Coral cover of *Dendrogyra cylindrus* (pillar coral)



***Dendrogyra cylindrus* (pillar coral) is a rare and unique coral as it is the:**

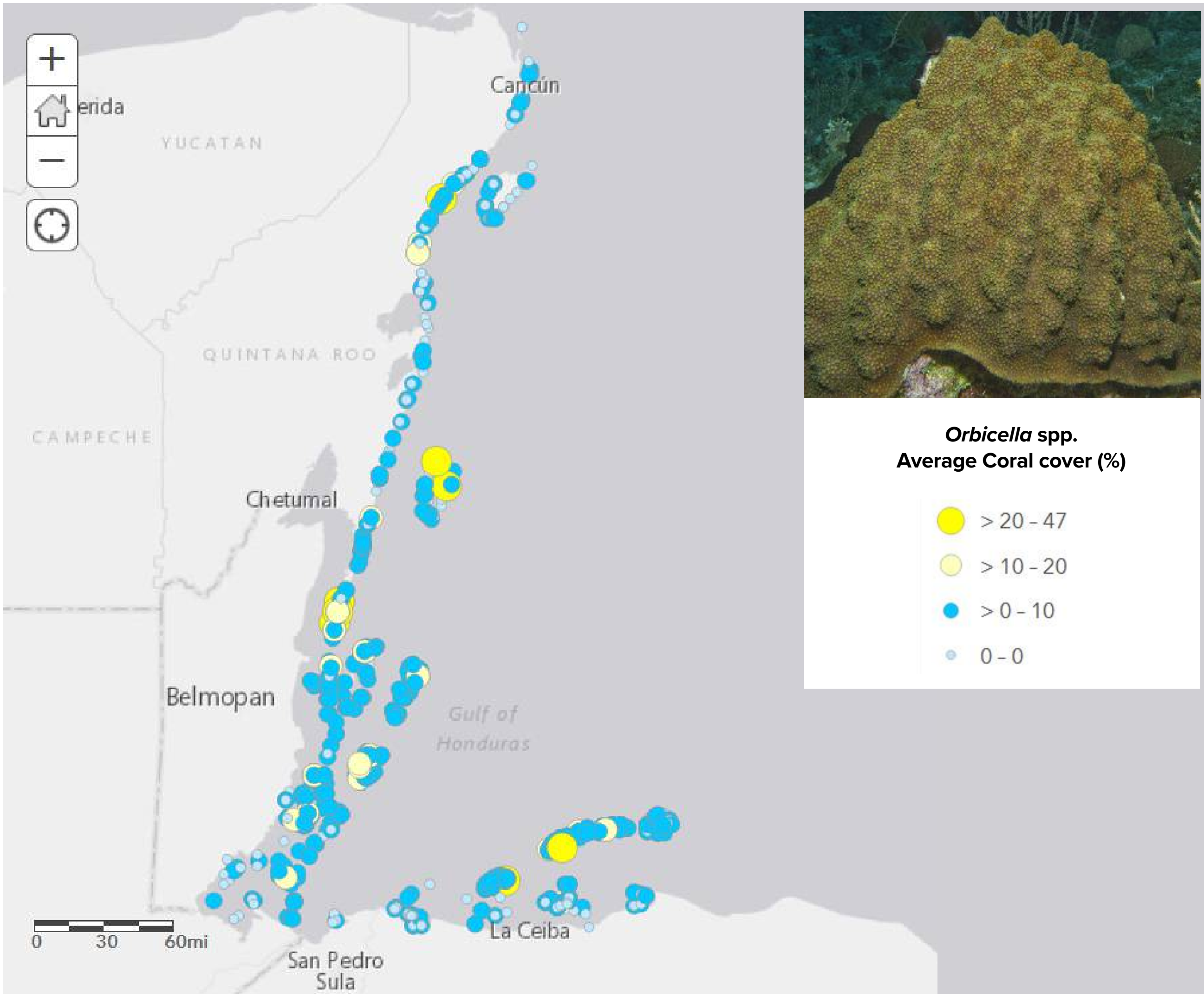
- *Only Caribbean columnal coral*
- *Only member of its genus*
- *Extends polyps day and night*
- *Listed as Vulnerable on IUCN Red list*
- *At risk for local or geographic extinction*

Pillar corals have suffered significant declines from past stressors and now stony coral tissue loss disease. Populations are so low in some areas they may be functionally extinct. Some reefs with higher pillar coral cover in the MAR are NE Roatan (HO), NW Turneffe (BZ), and Tulum (MX) (green circles above). Monitoring efforts should include mapping remaining populations and monitoring condition. Response efforts underway in the MAR include rescue, restoration, cryopreservation, and intervention treatments. Data Source: HRI-AGRRA 2006-2018, Avg (%) cover. A quantile scale was used because of low cover. Coral Cover of Susceptible Species.

Coral species at high risk
- Endangered coral
- Iconic Coral
- Prioritize for monitoring and response

FIGURE 46. Map of coral cover of *Dendrogyra cylindrus* (pillar coral) in the MAR. Map by AGRRA. Photo: © Francheska Krysiak.

Coral cover of *Orbicella* spp.



Orbicella species complex (boulder star corals) are one of the most important builders of the reefs' 3-D structure.

They are at high risk to population declines because of their:

- *Slow growth, long life spans*
- *Lower recruitment*
- *Susceptibility to disease, including SCTLD*
- *Susceptibility to high partial mortality*
- *Declining populations*

In the MAR, *Orbicella* spp. corals are locally abundant at different habitat types (yellow circles) and can be highly susceptible to SCTLD tissue loss. Two genetically distinct populations may exist, one in southern Belize and one in northern Mexico, separated by currents. Monitoring programs should regularly monitor this key reef building coral and consider it a good candidate for restoration or intervention. Data Source: HRI-AGRRA 2006-2018, Avg (%) cover from benthic transects. See Coral Cover of Susceptible Species to explore site specific data.

Ecologically Important Species

- Build reef structure
- Large corals
- Prioritize for monitoring and response

FIGURE 47. Map of coral cover of the important reef building coral, *Orbicella spp.* in the MAR. Map by AGRRA. Photo: © Ken Marks/AGRRA.

Reporting Disease Outbreaks

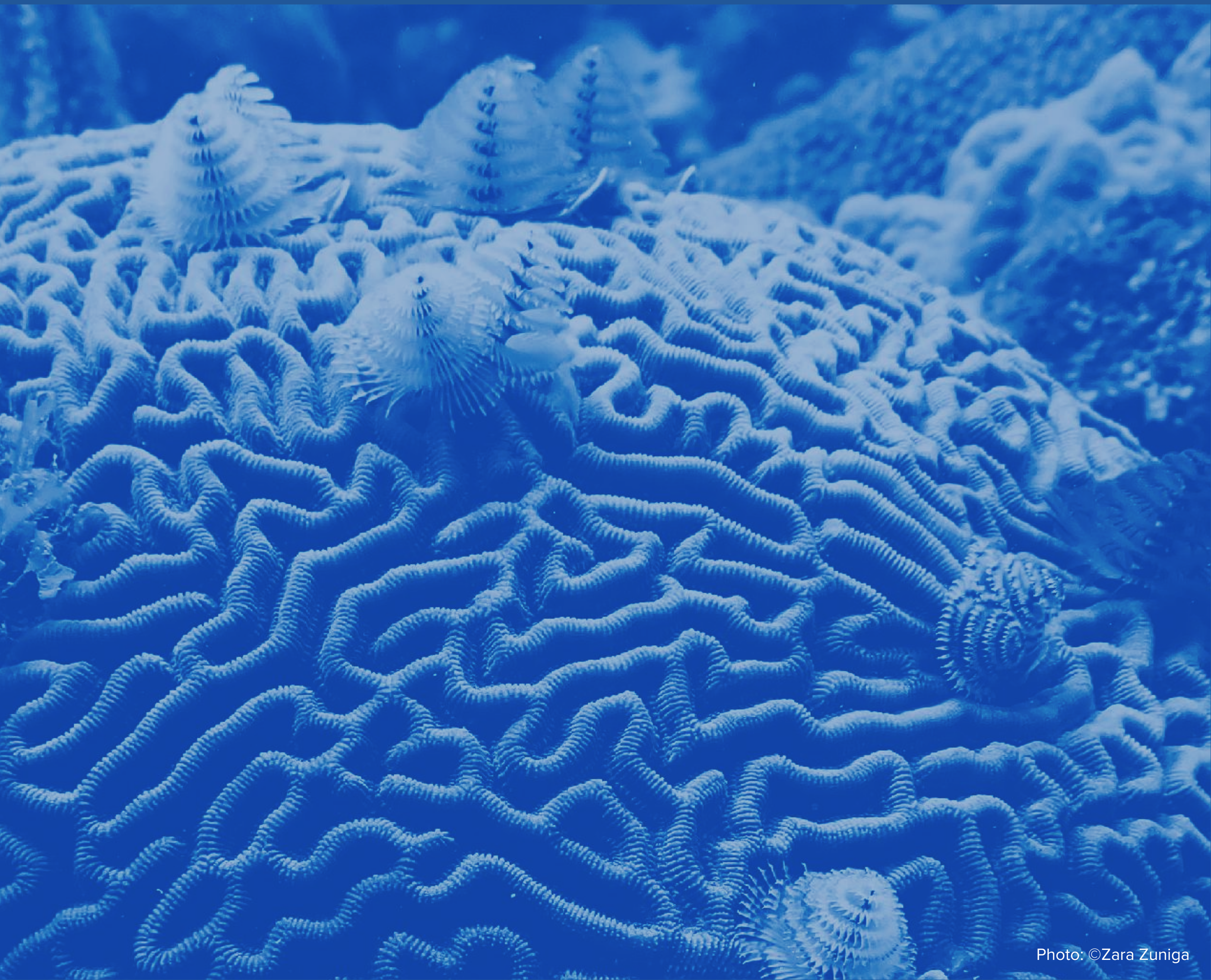


Photo: ©Zara Zuniga

SCTLD Survey Form

To help monitor and track the spread of SCTLD in the Caribbean, AGRRA developed an open-access, online Caribbean Coral Health Watch Data Entry Tool and interactive SCTLD Tracking Map to show where SCTLD and Coral Bleaching have been reported in the Caribbean (https://www.agrra.org/coral-disease-outbreak/) (Kramer et al., 2022). AGRRA's Caribbean Coral Health Watch Data Entry Tool allows surveyors to enter quantitative data, if available, on key coral condition metrics including:

1. **Healthy Corals –** Normal healthy tissue color, no active disease, bleaching or unusual signs of stress
2. **Colonies with SCTLD –** based on the Florida Case Definition (FKNMS, 2018)
3. **Bleached Corals including:**
    - **Pale:** discoloration of coral tissue, polyps are just starting to bleach or are in recovery
    - **Partly Bleached:** some polyps are fully bleached, and others are either unbleached or pale
    - **Bleached:** all (>90%) polyps are fully bleached, no zooxanthellae visible
4. **Other Diseases** (e.g., yellow-band, black band)
5. **Recently Fully Dead –** coral tissue has recently died, but the underlying corallite skeletal structure is visible and identifiable to species or corallite structures has been covered with a thin layer of algae, sediment, or bacteria (having died in previous days to months)

There are two different forms available to collect SCTLD observations, Basic and Detailed. Both these forms collect site and surveyor information as well as data on SCTLD and Bleaching. The basic form at its simplest collects presence/absence information on the different conditions observed during the survey. If the survey was more in depth and species level information was collected, estimates could be provided if known. The detailed form allows for more quantitative data to be submitted at the species level such as the different levels of bleaching as described above. AGRRA developed the 'detailed' version of the survey form in collaboration with the Healthy Reef's Initiative to also use as the main data platform to collate their data for the Mesoamerican Regional Coral Bleach Watch program. Both forms allow you to upload photo confirmation of the conditions observed. The forms are in English but have a translation document available in Spanish. A video tutorial of how to enter data into the detailed survey form is available and was made by HRI and AGRRA.

The compilation of specific coral condition metrics is providing important information on prevalence of SCTLD disease, species susceptibility, amount of coral mortality and other signs of coral stress such as bleaching, and location of hot spot areas. The online survey forms help organizations better use the analytical capabilities of GIS technology. This new data platform can help support strategic decision and policy making and in providing information for management and conservation recommendations.

As of August 2022, the Caribbean Coral Health Watch Data Entry Tool had recorded 494 basic and 851 detailed surveys with SCTLD confirmed in 25 countries/territories. All these surveys are visually displayed on the AGRRA SCTLD and Bleaching Tracking Maps.

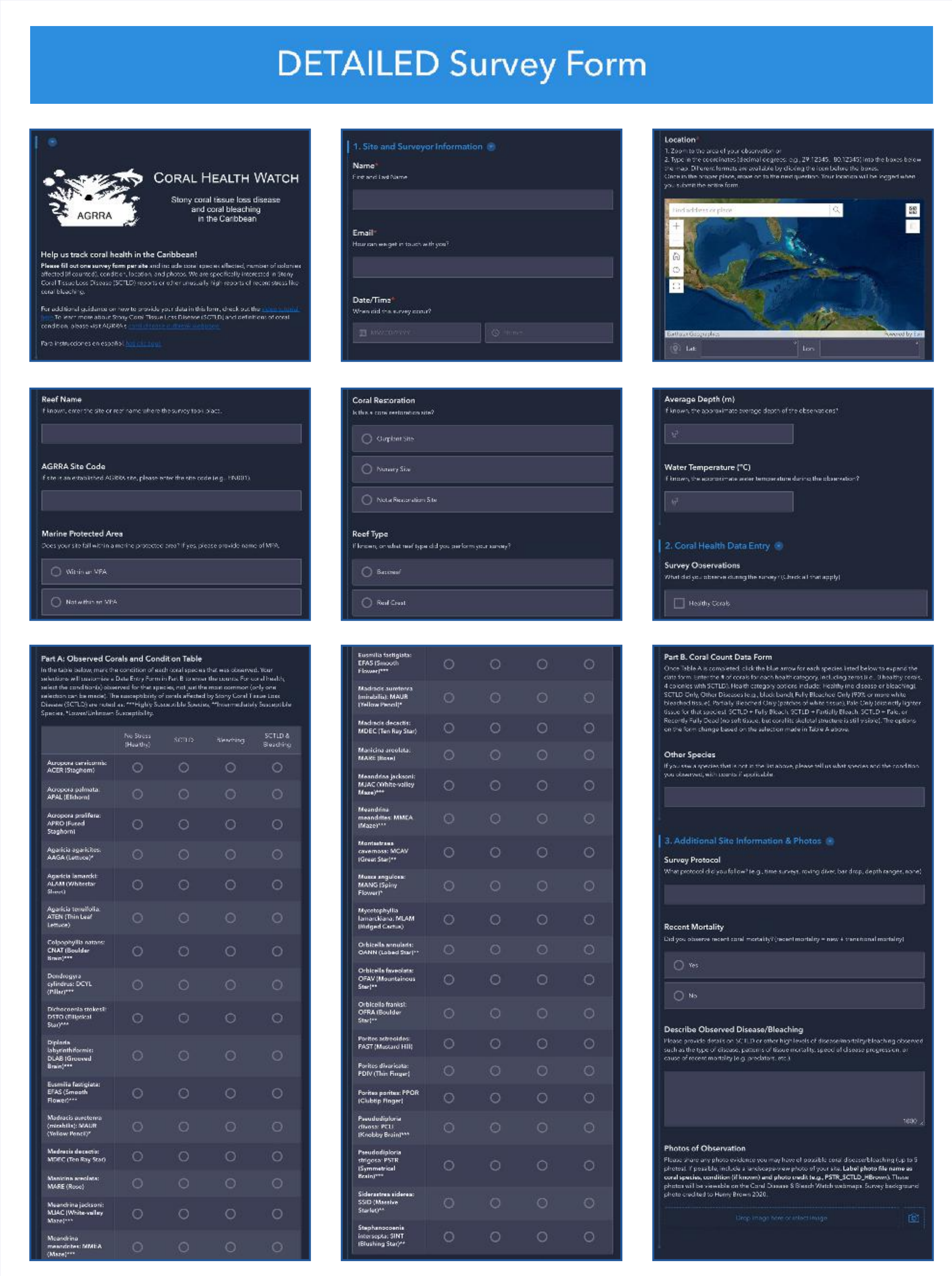


FIGURE 48. Caribbean Coral Health Watch Data Entry Tool. Example of the detailed version of the survey form (Kramer et al., 2022).

SCTLD Tracking Map

Once sightings are submitted through the online Coral Health Watch Data Entry Tool (either basic or detailed survey forms), they appear on the interactive SCTLD Tracking Map as purple markers while the information is thoroughly reviewed by a team of scientists. Once a report is reviewed, the markers are turned green if SCTLD is not present, yellow if SCTLD may be present, but more information is needed, or red if the presence of SCTLD is confirmed. The Caribbean SCTLD Tracking Map also automatically incorporates data provided by Florida Fish & Wildlife Conservation (FWC) Fish & Wildlife Research Institute and The U.S Virgin Islands Coral Disease Advisory Committee. Additional SCTLD data, not presented in the Tracking Map, may also be available from national datasets (e.g., Bahamas, Cayman Islands).

The map features several useful options to allow users to explore data at different spatial and temporal scales. The map layers can be viewed by data source and by year, allowing users to view the surveys through time. These layers can be turned on and off using the "Layers" button on the map toolbar and viewing what is turned on using the "Legend" button. At the site level, all site markers can be clicked to open a pop-up table of additional information and data. Some sites have photos included and are accessible through the pop-up tables. The "Basemaps" button allows users to choose different background maps for the data which could prove useful if one wanted to create a map to fit certain purposes and export it using the "Share" and "Print" buttons.

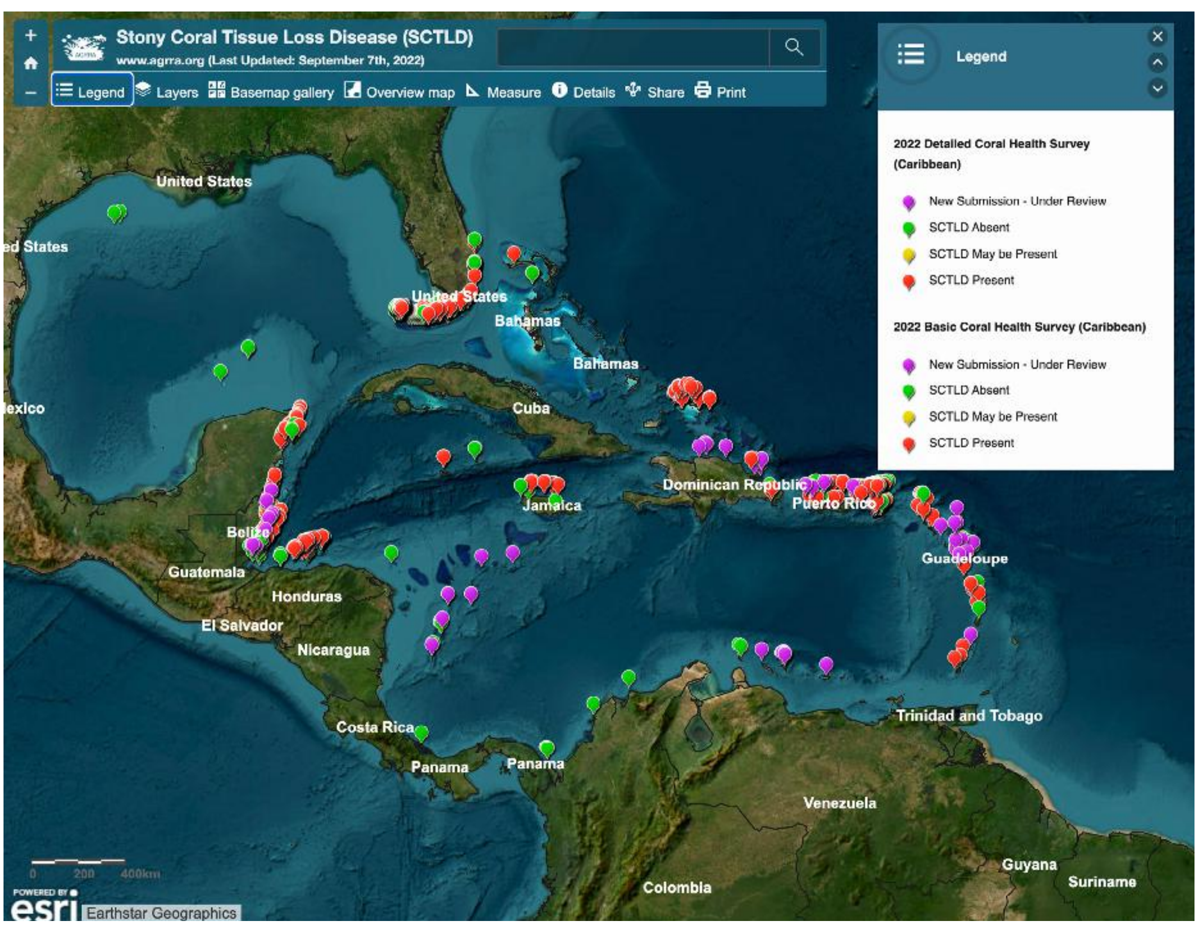


FIGURE 49. Caribbean Stony Coral Tissue Loss Disease Map. Legend shows data from basic and detailed surveys, with markers representing presence, absence or not confirmed status. Data shown include 2017-August 2022 (Kramer et al., 2022).

Bleaching Tracking Map

Once sightings are submitted through the online Coral Health Watch Data Entry Tool (either basic or detailed survey forms), they appear on the interactive Caribbean Coral Bleach Map. This Caribbean Coral Bleach Map shows site information, presence/absence of coral bleaching and available photos. We have further developed the map to include additional data in the pop-up tables as well as in separate layers to be turned on and off as needed (e.g., pale, partly bleached, fully bleached corals, and bleaching severity index). As with the SCTLD Tracking Map, this map has several features allowing users to customize the map to allow for printing and sharing as needed. Additional information, data, and photos (if included) are also available by clicking on any individual surveys on the map.

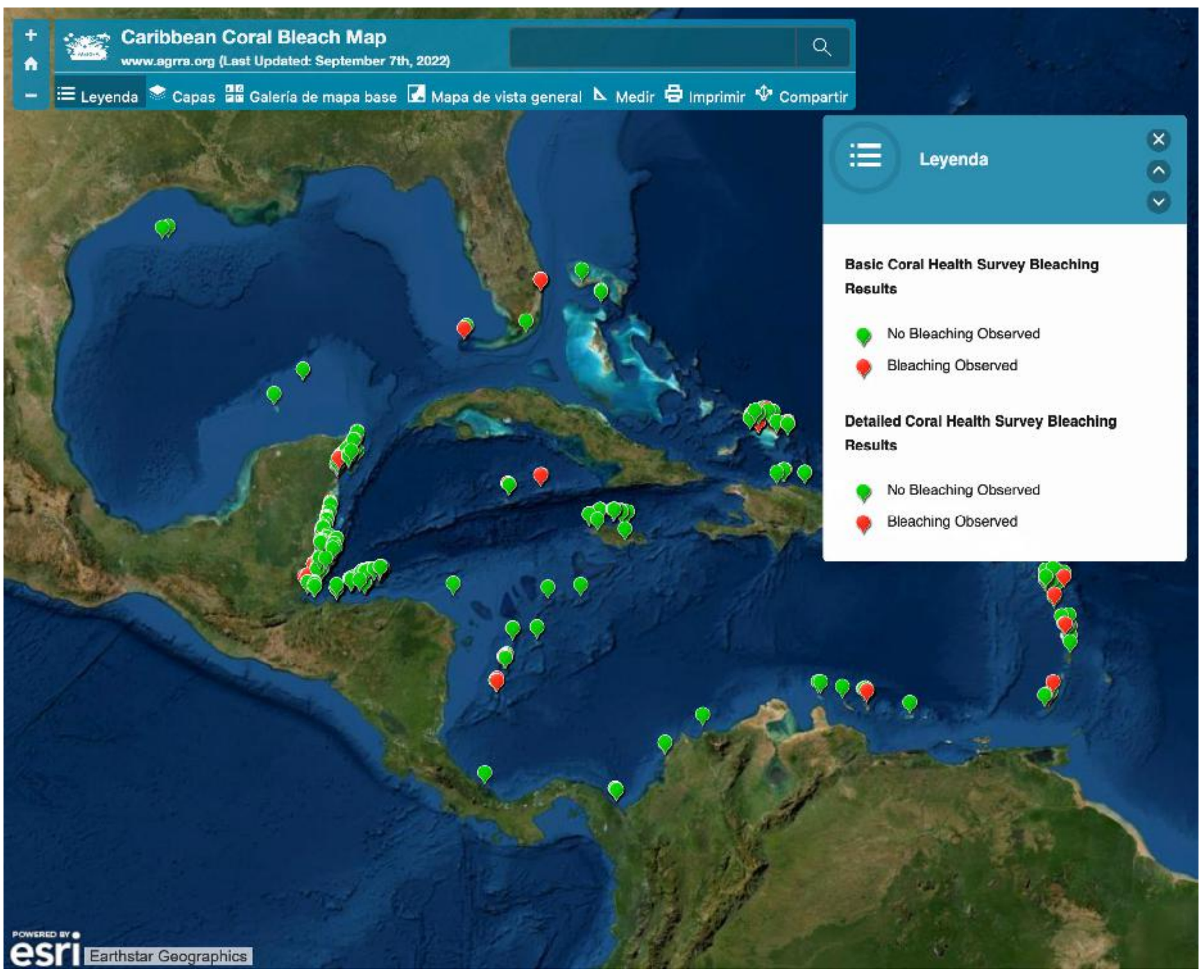


FIGURE 50. Caribbean Coral Bleaching Map. Legend shows data from basic and detailed surveys, with markers representing presence, absence or not confirmed status. Data shown include 20017-August 2022 (Kramer et al., 2022).

SCTLD Dashboard

The Caribbean SCTLD Dashboard provides summary information on the outbreak of SCTLD in the Caribbean and the regional efforts to respond to the disease. At the MPAConnect regional peer-to-peer learning exchange on SCTLD held in August 2019, Caribbean coral reef managers recommended the development of a regional dashboard to indicate the status of SCTLD and show the spread of the disease in the Caribbean. This dashboard was developed based on that request. The interactive online dashboard was developed by AGRRA, in collaboration with MPAConnect, Gulf and Caribbean Fisheries Institute (GCFI), and NOAA. The dashboard is available in English and Spanish.

Dashboard features include statistics on countries affected and management response activities. Maps and statistics on presence and absence of SCTLD as well as response activities (training, education, monitoring, treatment) occurring around the region are included as well as a time-lapse map that shows how SCTLD has been reported over time in the region. Coral species affected by SCTLD are displayed by the number of countries reporting them as diseased. To date (May 2022), SCTLD has been confirmed in 25 countries/territories.

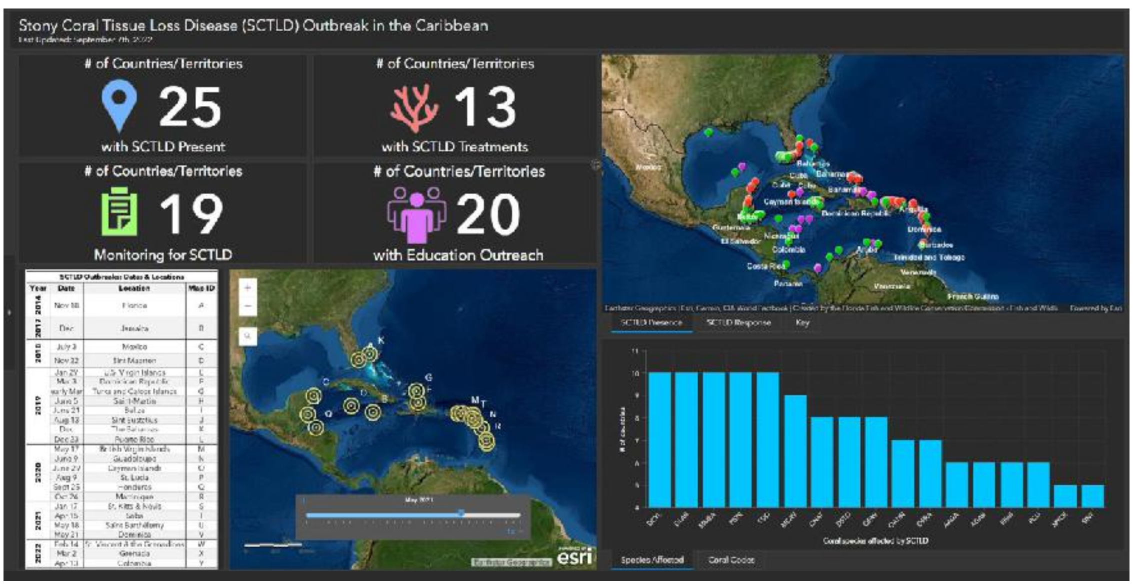


FIGURE 51. Caribbean SCTLD Dashboard. This disease dashboard has a variety of interactive infographics.

Training Materials

A wide selection of webinars and presentations hosted by MPAConnect, NOAA, AGRRA, MAR Fund and others can be accessed at https://www.agrra.org/webinars/ and https://www.gcfi.org/emerging-issues-florida-coral-disease-outbreak/.

Useful training materials include:

Identifying stony coral tissue loss disease (September 20, 2020) http://gcfi.adobeconnect.com/pqc7j15sbrw4/?OWASP_CSRFTOKEN=4d04cd13e3452f0a58f4000188387e9a38e42c3798878aa41f0188b63cf04945

How to recognize and describe stony coral tissue loss disease lesions (September 15, 2020) https://www.agrra.org/wp-content/uploads/2020/09/SCTLD-ID-sep-2020- Bruckner.pdf Downloadable disease identification cards are available on the FKNMS website: https://floridakeys.noaa.gov/coral-disease/disease.htm

Response efforts in the Mesoamerican Region

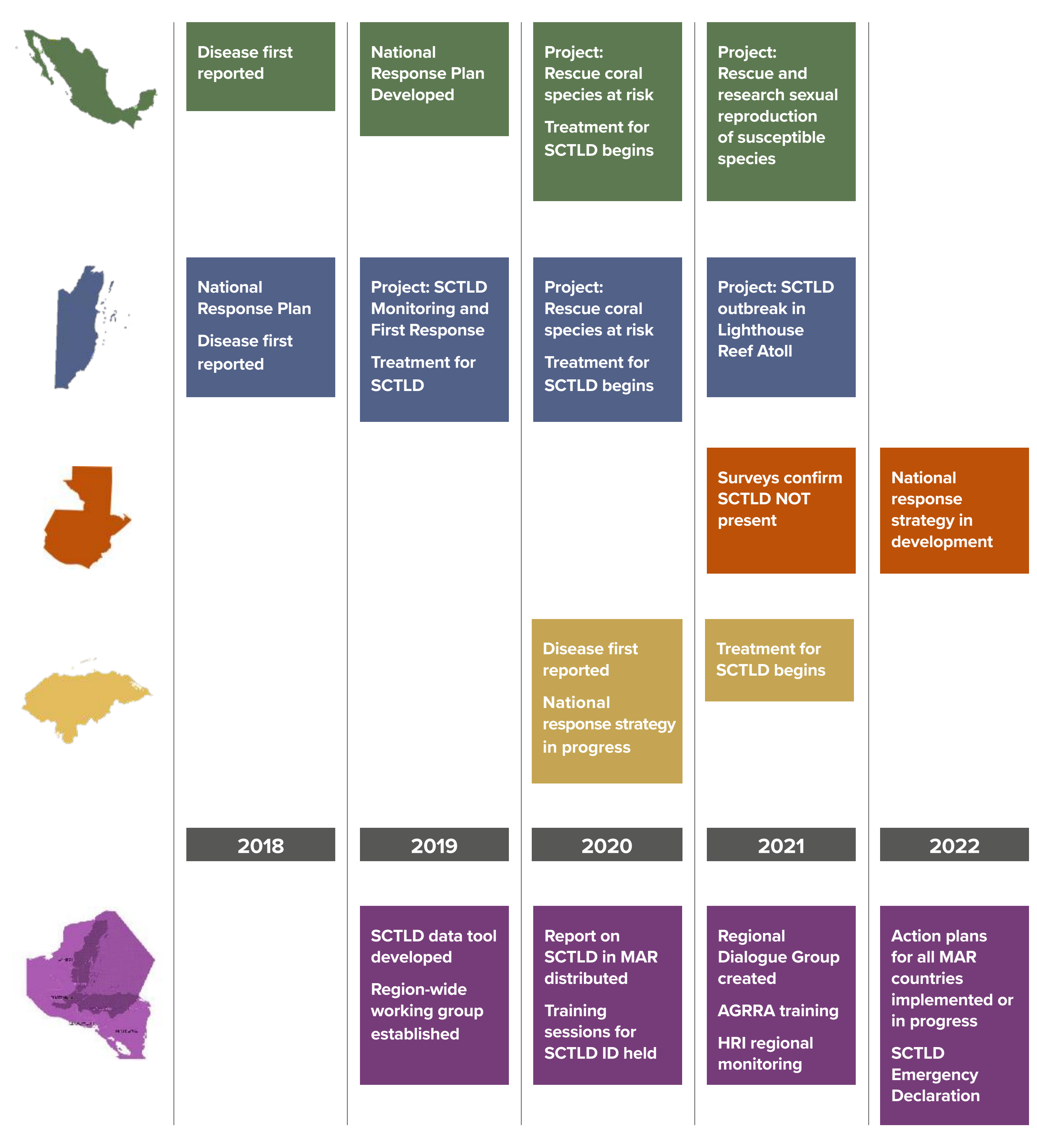


FIGURE 52. Overview of SCTLD in the MAR and response actions.

Resources on Stony Coral Tissue Loss Disease

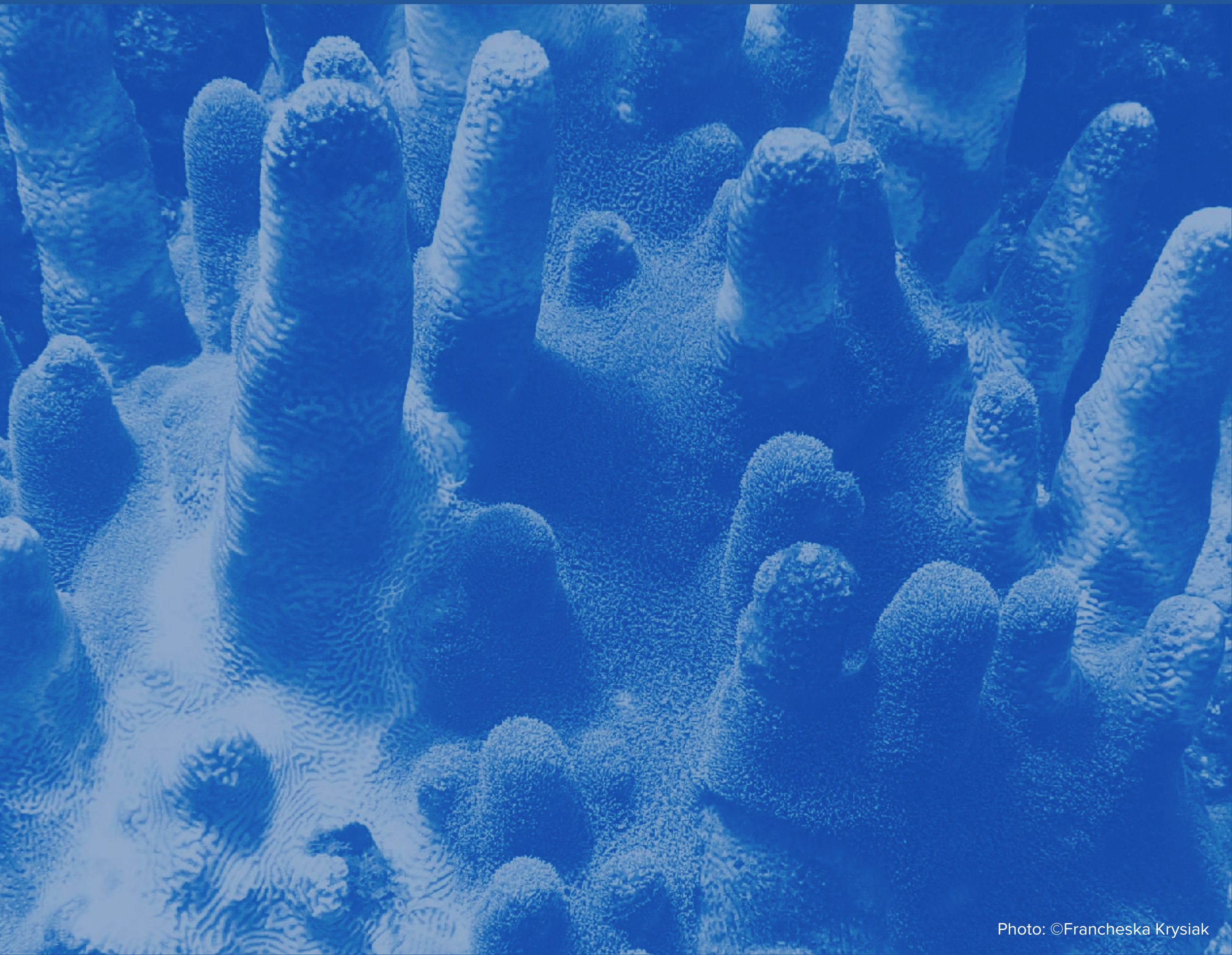


Photo: ©Francheska Krysiak

Webinars

- SCTLD in the Mesoamerican Reef: Updates, Status & Trends and Exchange of Experiences (June 23, 2021)
- SCTLD in the MAR: Updates on Science and Monitoring, Status and Trends, and Exchange of Experiences (March 30, 2022)
- Stony coral tissue loss disease webinar (September 15, 2020)
- Monitoring reefs for stony coral tissue loss disease (January 26th, 2021)
- Caribbean coral rescue in the face of stony coral tissue loss disease (March 14, 2022)
- Technical workshop on SCTLD treatment and intervention approaches (June 14, 2021)
- AGRRA's SCTLD Webinar Hub

SCTLD websites

- Atlantic and Gulf Rapid Reef Assessment Program (AGRRA) (Caribbean, data, education)
- AGRRA's Caribbean SCTLD Dashboard
- Biodiversity and Reef Conservation (BARCO) Laboratory, UNAM
- Roatan Marine Park
- MPAConnect
- Florida Keys National Marine Sanctuary (FKNMS)
- Florida Department of Environmental Protection (DEP)
- American Zoological Association (AZA) -Florida Reef Tract Rescue
- Florida's Coral Disease Intervention Dashboard
- Florida's Coral Rescue - Coral Monitoring Dashboard

Action Plans

- MAR - SCTLD IN THE MESOAMERICAN REEF REGION. An output of the Joint Session on Stony Coral Tissue Loss Disease Belize City October 8th, 2019
- Mexico Action Plan for the Stony Coral Tissue Loss Disease in Coral Reef Systems of the Mexican Caribbean, CONANP, Mexico, Integrated Management Project "from the Basin to the Reef [es. De la Cuenca al Arrecife]" of the Ecoregion of the Mesoamerican Reef - MAR2R / CCAD
- Action Plans from U.S and other Caribbean Locations

SCTLD Data Management

- Link to AGRRA's Caribbean SCTLD/Coral Bleach Watch Data Platform
- Basic SCTLD Datasheet Coral Disease & Bleach Survey
- Detailed SCTLD Disease & Bleach Survey
- Datasheet Combined SCTLD /coral bleaching survey data sheet
- Coral SCTLD Datasheet by Species Common Name (ENG, ESP, FRA)

Identification guides

- Field Guide to identify Stony Coral Tissue Loss Disease (Bruckner, 2019)
- How to identify the appearance of Stony Coral Tissue Loss Disease (SCTLD) on susceptible corals in Florida (Neely, 2019)

SCTLD Guidance Documents

- White paper on SCTLD in Wider Caribbean
- SCTLD Template for Monitoring and Response Action Plan
- Reporting Template for Stony Coral Tissue Loss Disease
- Ballast Water Best Management Practices to Reduce the Likelihood of Transporting Pathogens That May Spread Stony Coral Tissue Loss Disease

MPA Connect Videos

- How Divers Can Help to Prevent Stony Coral Tissue Loss Disease available in English and Spanish
- How Fishers Can Help to Prevent Stony Coral Tissue Loss Disease available in English and Spanish
- How to Document Stony Coral Tissue Loss Disease available in English and Spanish
- How to Monitor for Stony Coral Tissue Loss Disease (Monitoring Part 1) available in English and Spanish
- How to Analyze the Data Collected While Monitoring Your Reefs (Monitoring Part 2) available in English and Spanish
- How To Treat Corals Affected by Stony Coral Tissue Loss Disease available in English and Spanish
- How to Mix the Treatment for Stony Coral Tissue Loss Disease (Treatment Mixture Part 1) available in English and Spanish
- How to Prepare the Mixture for Application to Reefs (Treatment Mixture Part 2) available in English and Spanish

MPAConnect SCTLD Information posters:

- Detection (ENG, ESP, FRA)
- Diver awareness (ENG, ESP, FRA)
- Prevention (ENG, ESP, FRA)

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Photo: ©Ken Marks/AGRRA

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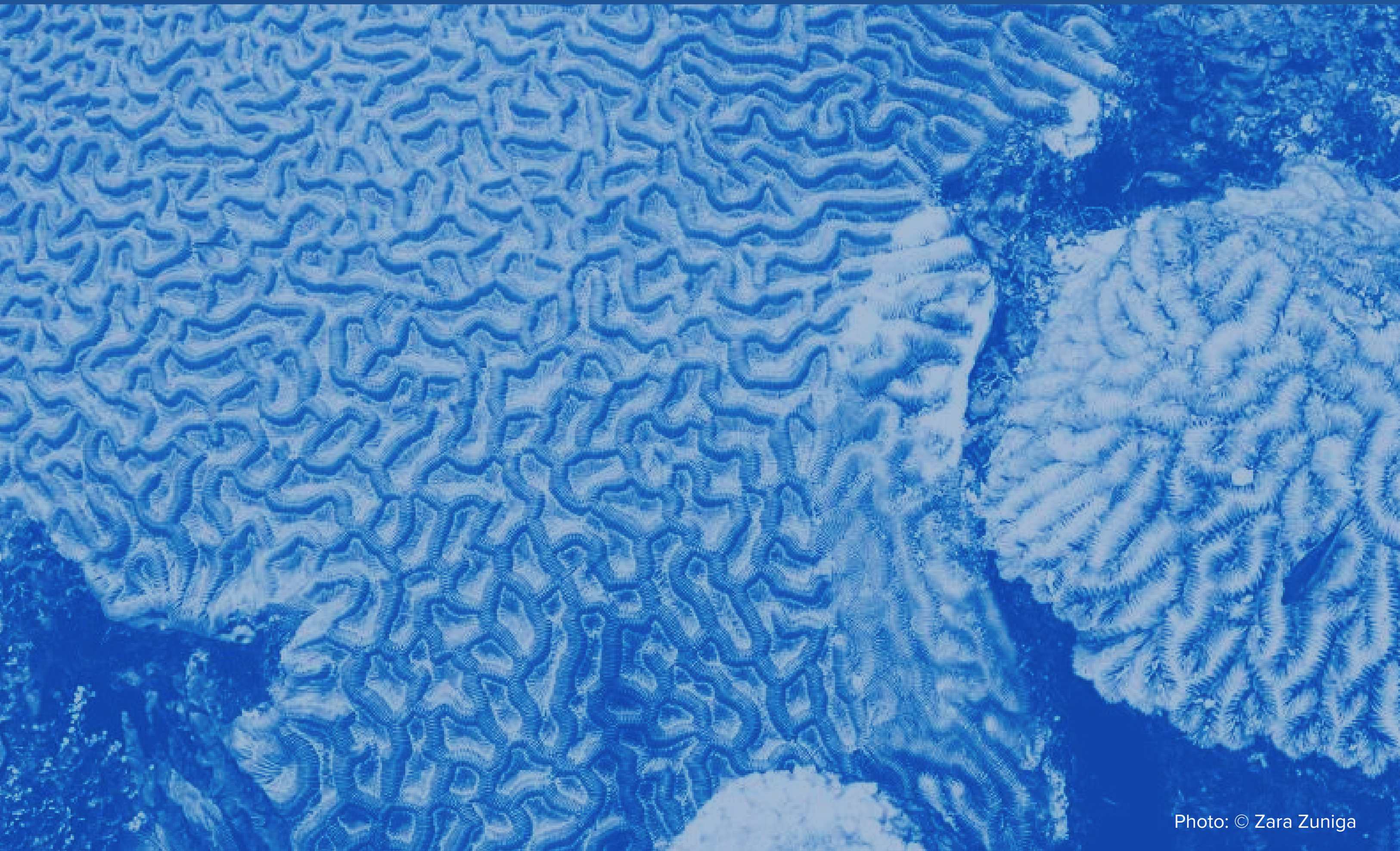
Appendices



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Appendix 1. Case definition list of corals susceptible to stony coral tissue loss disease

Case Definition: Stony Coral Tissue Loss Disease (SCTLD) October 2, 2018

Highly Susceptible Species: Early onset (the species first affected during an outbreak), rapid progression, and total mortality ranging from one week for smaller colonies to complete mortality over 1-2 months for larger colonies. Typically, *M. meandrites* and *D. stokesii* are the first to become affected at a site, followed by *C. natans*, and then the others show disease signs shortly thereafter.

Colpophyllia natans (boulder brain coral)
Dendrogyra cylindrus (pillar coral)*
Dichocoenia stokesii (elliptical star coral)
Diploria labyrinthiformis (grooved brain coral)
Eusmilia fastigiata (smooth flower coral)
Meandrina meandrites (maze coral)
Pseudodiploria strigosa (symmetrical brain coral)
Pseudodiploria clivosa (knobby brain coral)

Intermediately Susceptible Species: Onset of tissue loss typically occurs about a month after onset in highly susceptible species, but lower numbers may also show disease signs before or as those species are affected. Smaller colonies die out over months, and larger colonies may show new lesions continuing with possible mortality occurring over years.

Orbicella annularis (lobed star coral)*
Orbicella faveolata (mountainous star coral)*
Orbicella franksi (boulder star coral)*
Montastraea cavernosa (large-cup star coral)
Solenastrea bournoni (smooth star coral)
Stephanocoenia intersepta (blushing star coral)
Siderastrea siderea (starlet coral)**

Presumed Susceptible but insufficient data to categorize onset.

Agaricia agaricites (lettuce coral)
Agaricia spp. (plate/saucer corals)
Mycetophyllia spp. (cactus coral)
Madracis auretenra (pencil coral)
Favia fragum (golf ball coral)
Helioseris cucullata (sunray lettuce coral)
Mussa angulosa (spiny flower coral)
Scolymia spp. (disc coral)
Isophyllia spp. (sinuous cactus coral; rough star coral)

Low Susceptible Species: During outbreaks, the following corals are rarely or not affected.

Porites astreoides (mustard hill coral)
P. porites (finger coral)
P. divaricata (thin finger coral)
P. furcata (branched finger coral)
Acropora palmata (elkhorn coral)*
A. cervicornis (staghorn coral)*
Oculina spp. (bush corals)
Cladocora arbuscula (tube coral)

* Endangered Species Act (ESA) listed species.

** *S. siderea* may show disease signs before highly susceptible species, during outbreaks, and after the outbreak has progressed through a reef system. The presentation of disease may be similar to SCTLD in some but not all cases, and the epidemiology, e.g., the patterns of lesion spread within and among colonies and duration of tissue loss, does not always match those of other species. This raises some uncertainty about inclusion of *S. siderea* in this case definition.

Appendix 2. Prevalence of coral species susceptible to SCTLD in the Mesoamerican Region

Data compiled from reports to AGRRA SCTLD Tracking map from 2018-July 2022 for Belize and Honduras and Mexico data from Alvarez-Filip et al. (2022). Some species not listed in surveys as affected by SCTLD in Belize and Honduras were later found to be affected (e.g., *M. cavernosa*). Species differences among the countries may be related to species present, reef types surveyed, or stage of disease outbreak.

Coral Species	Belize	Honduras	Mexico
Acropora cervicornis	0	0	0
Acropora palmata	0	0	0
Acropora prolifera	0	0	-
Agaricia agaricites	8	5	5
Agaricia fragilis	-	-	2
Agaricia humilis	-	-	8
Agaricia lamarcki	50	6	0
Agaricia tenuifolia	0	3	5
Colpophyllia natans	28	30	60
Dendrogyra cylindrus	60	49	95
Dichocoenia stokesi	64	42	21
Diploria labyrinthiformis	20	22	46
Eusmilia fastigiata	8	36	49
Favia fragum	-	-	6
Helioseris cucullata	-	-	5
Isophyllia rigida	-	-	15
Isophyllia sinuosa	-	-	0
Madracis auretenra	0	2	0
Madracis decactis	0	0	1
Manicina areolata	0	13	-
Meandrina jacksoni	0	36	100
Meandrina meandrites	62	52	88
Montastraea cavernosa	0	0	25
Mussa angulosa	18	17	0
Mycetophyllia ferox	-	-	0
Mycetophyllia lamarckiana	3	9	15
Orbicella annularis	11	21	18
Orbicella faveolata	13	11	19
Orbicella franksi	43	19	6
Porites astreoides	1	1	2
Porites divaricata	0	0	0
Porites furcata	-	-	1
Porites porites	1	0	1
Pseudodiploria clivosa	3	22	12
Pseudodiploria strigosa	29	29	57
Scolymia sp.	-	-	0
Siderastrea radians	-	-	6
Siderastrea siderea	6	18	30
Solenastrea bournoni	-	-	0
Stephanocoenia intersepta	0	3	2

Appendix 3. Rover Diver Protocol

Roving diver protocol (adapted from Neely, 2018b; Doyle & O'Sullivan, 2020):

1. Swim around the reef 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 data sheet (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) f) Initial depth of survey g) Habitat surveyed and any additional notes.

3. Record the species code of stony coral species observed during the survey. Exclude milleporids, and acroporids. Focus on colonies greater than 4 cm in diameter.

   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 should be included here.

   c) Non-diseased colonies with signs of concern (i.e., colonies that do NOT have any active mortality due to SCTLD but are showing unusual pale spots or focal bleaching).

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

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

5. Submit data to local authorities and upload into the AGRRA SCTLD Tracking Map.

AGRRA SCTLD-Bleaching Survey Datasheet

Surveyor Name:	Date: Time:	Latitude: Longitude: (or Location):	Reef Name *(if known)*:
Detailed Surveys: AGRRA Site Code if any:	*Detailed Surveys:* MPA Status: Yes? No? Unsure?	*Detailed Surveys:* If a Restoration Site: Outplant? Nursery?	Reef Type: Backreef? Reef Crest? Patch Reef? Fore Reef? Other *(Describe)*:
Average Depth: m? or ft?	Bottom Temp.: °C or °F?	Site Comments (*e.g.*, major organisms):	

Tally all corals (including clumps) of species known to be susceptible to SCTLD.

Species	# Healthy Corals	# SCTLD Corals	# Corals with SCTLD &/or Fully Bleached (BL), Partially Bleached (PB), or Pale (P)			# Corals Fully Bleached (BL), Partially Bleached (PB), or Pale (P)			# Corals with other Diseases(s)	# Recently Fully Dead Corals	Notes; any Photos?
			BL	PB	P	BL	PB	P			
OFTEN SEEN *Colpophyllia natans:* CNAT (Boulder Brain)***											
Dendrogyra cylindrus: DCYL (Pillar)***											
Dichocoenia stokesii: DSTO (Elliptical Star)***											
Diploria labyrinthiformis: DLAB (Grooved Brain)***											
Eusmilia fastigiata: EFAS (Smooth Flower)***											
Meandrina jacksoni: MJAC (White-valley Maze)***											
Meandrina meandrites: MMEA (Maze)***											
Montastraea cavernosa: MCAV (Great Star)**											
Orbicella annularis: OANN (Lobed Star)**											
Orbicella faveolata: OFAV (Mountainous Star)**											
Orbicella franksi: OFRA (Boulder Star)**											
Pseudodiploria clivosa: PCLI (Knobby Brain)***											
Pseudodiploria strigosa: PSTR (Symmetrical Brain)***											
Siderastrea siderea: SSID (Massive Starlet)**											
Stephanocoenia intersepta: SINT (Blushing Star)**											
SEEN LESS OFTEN *Agaricia agaricites*: AAGA (Lettuce)*											
Agaricia lamarcki: ALAM (Whitestar Sheet)											
Agaricia tenuifolia: ATEN (Thin Leaf Lettuce)											
Space for other species, e.g., *Porites astreoides?:* PAST (Mustard Hill)?											

Describe the survey protocol used:	*Detailed Surveys:* What % of all corals at the site have each kind of partial mortality? New? Trans? Old?	*Detailed Surveys:* How were the data collected? Qualitatively? Quantitatively?	Other Comments

* numbers represent **usual** order of contracting SCTLD, from first (***) to last (*), if known.

Revision 2021-02-16

Appendix 4. Bar Drop Methodology

(Adapted from McField, 1999; Searle et al., 2014)

Due to the previous use of this method, further use would allow comparisons within the Mesoamerican reef system. The Bar Drop Method or the "Weighted-bar Swimming-transect Method" which was developed as a bleaching assessment tool in 1995 by McField (1999) and modified by Kramer and Kramer (2000) to include information on disease and mortality. The Bar Drop Method enables observers to cover large areas of reef in either deep water, while scuba diving, or in shallow water, while snorkeling. Because no transect lines are set, more data are collected for the time expended and a larger area of reef can be covered. The method also increases the number of samples of more rare and smaller coral species as compared with traditional line intercept methods.

The Bar Drop Method utilizes a one-meter, small diameter (2.54 cm) PVC tubing filled with stones or sand and capped at both ends, or left open to fill with water (Figure 8). Each bar is marked with five strips of black electrical tape (or other marking) spaced 0.25 meters apart. Thus, there are five marks per bar, including the two ends. The observer swims in a straight line along a compass bearing or depth contour (parallel to the reef crest axis), holding the bar perpendicular to the line of the swimming transect. Every three kick-cycles (one full push down and up for both legs is one kick-cycle) the bar is dropped/placed straight down onto the substrate. The number of kick cycles can be varied according to reef configuration and desired size of study area. Kramer and Kramer (2000) used 10 kicks. The species and condition of corals equal to or greater than 10 centimeters (=>10 cm) lying under the 5 marks are recorded. Condition refers to that of the entire colony and not to the individual polyps under the mark. If a mark does not fall directly on top of a coral, record the condition of the nearest coral colony to the mark that falls within a 12.5 cm radius of the mark. This distance of 12.5 cm is fairly easy to gauge since it is half the distance between any two marks. Thus, the bar demarcates five adjacent but non-overlapping circles each centered on a mark. If no coral lies within a given circle no data is recorded for that mark, therefor, for each "bar-drop",

One-meter PVC bar, with 5 marks 0.25 m apart.

- Swim in straight line along reef contour or compass bearing
- Hold bar perpendicular to swim transect
- Every three kick-cycles place bar on substrate
- Measure species and condition of coral >10cm under the 5 bar marks
- After surveying 50 colonies, swim 5 m away and begin a new transect
- Survey 200 colonies per site

Each bar is marked with five strips of black electrical tape (or other marking) spaced 0.25 meters apart. Thus, there are five marks per bar, including the two ends anywhere from zero to five corals are assessed. As such it may be necessary to drop the bar more than 20 times to record 100 observations. While swimming, observers should look into the distance along the compass bearing and avoid looking down at the substrate until the bar is resting on the bottom. The "size" of each transect can be delimited by dive time, distance traveled, or number of coral condition records desired (like 100 records per transect), depending on habitat and sampling conditions. Each transect should remain within a pre-defined depth range or habitat zone. Several observers can swim parallel to each other to increase the sample size per dive at each site. Observers should remain at least ten meters apart and cover approximately equal distances by swimming at the same speeds.

- Where possible, more than one surveyor should record data at a given site.
- At each site 200 colonies are to be counted, therefore if there are two surveyors then each would count 100 colonies.
- After recording 50 colonies, swim 5 meters away and begin a new transect, counting 50 more colonies.
- Each site should therefore have 4 "transects" of 50 colonies each if two persons are conducting the survey.
- For continuity it is crucial that the sites monitored be surveyed each time and that the name of the site remains the same.
- Only stony corals and fire corals should be recorded.
- If other species are observed bleaching (soft corals, sponges or zoanthids) please make note of how many per transect.
- Abbreviated names of coral species should be used consistently the first letter of the genus and first three letters of the species in all caps.
- Methodology states that coral colonies only greater than 10 cm must be recorded.
- Goal is to complete six sites per area. At minimum four must be completed. There should be an equal number of deep sites and shallow sites, and preferably in close proximity to each other.
- For each site surveyed the GPS coordinates, map datum, reef zone and depth must be recorded.

Surveyor:	Site Name:	Reef Type:		Subzone/Habitat:
Date:	Site Code:		Latitude:	Area Surveyed (m2):
Start Time:	Selection Method:		Longitude:	Total # colonies surveyed:
Start Depth: ft/ m	Surface Temp.: °C/ °F		Site Comments:	
End Depth: ft/ m	Bottom Temp.: °C/ °F		Transect Comments:	
All ≥ 10 cm Corals	Colonies			

Number of corals	Coral Species Code	BLEACHING WATCH							Disease	Comments
		Bleach and severity (N,P,PB,BL)				% Partial Mortality				
		Normal N	Pale P	Partially Bleached PB	Bleached BL	New	Trans	Old		
1										
2										
3										
4										
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Appendix 5. AGRRA Coral Protocol

AGRRA Coral Protocol

Updated Summary Instructions, June 2021

www.agrra.org

The **AGRRA Coral UW Datasheet** is formatted to be printed on 8.5" x11" underwater paper ("DuraCopy" Copier/Laser Paper 6511). To reduce expenses, print this form on both sides of each sheet of UW paper.

Each coral surveyor should have a complete set of coral survey equipment. Be sure to take enough **AGRRA Coral UW Datasheets** when making more than one survey during any given field outing. Attach a copy of the **AGRRA Coral UW Codes** list printed on UW paper to the underside of your clipboard or slate if needed for reference.

Site Information

Complete before the dive.

Surveyor: Name of the person making the survey or his/her corresponding 4-letter code (e.g., Anna Reyes = ANRE).

Date: Enter date as: year, month, day (e.g., 2009-10-09 = Oct. 9, 2009).

Site Name: Name of dive site or description of area (e.g., between Boston Beach & Splash Hotel).

Lat/Long: Latitude & Longitude for the site: decimal degrees (WGS84) are the preferred format, but decimal minutes or degrees/minutes/seconds may be used if first converted to decimal degrees. UTM coordinates are not supported so please convert to latitude/longitude.

AGRRA Code: Sequential site code (e.g., MEX007 = seventh Mexican site).

Once on site at the start of the dive.

Lay Transect Line. Chose starting point **haphazardly.** Loop the free end of the line to a dead piece of coral or another secure object that will not easily be damaged. Unwind the transect line from the quadrat while avoiding the transect lines of other divers and–unless instructed otherwise by the team leader–avoid reef edges, unusual reef features, abrupt slope changes, deep grooves and large patches of sand or rubble. When the entire transect line is unwound, pull tightly to ensure that it is taut, and secure to the bottom by wrapping the quadrat around or over some sturdy object.

As you return towards the starting point, straighten the line if necessary, by repositioning one of its ends, by pulling it off the bottom in high-relief reefs or by disentangling it from gorgonians, sponges, *etc.*

If the line sways a little due to strong surge or bottom current during the survey, locate the midline of the belt by noting its position in the middle of its swing.

If lionfishes (Pterois *spp.) are present, pay close attention to any that remain in the immediate vicinity of the transect line!*

Transect Information

Complete at the start of the transect.

Start Time:	Time at the start of the transect.
Bottom Temperature:	If you can: numerical value at the depth of the survey habitat; circle the appropriate unit (° C or ° F).
Start & End Depths:	Depths at the 0-m and 10-m marks; circle the appropriate unit (ft or m).

Corals:

Complete during the belt transect.

Starting on one side of the line, survey all ≥ 4 cm stony corals, except for *Millepora alcicornis*, for which any part, no matter how small, is located ***inside*** a 50-cm-wide belt between the 0-m and the 10-m marks, as specified below. Ignore dead corals that can no longer be identified at least to genus and dead branching corals in which most of the branches are missing. Then continue in a 50-cm-wide belt on the 2nd side of the transect line, being careful not to resurvey corals that are under the line.

In high-relief reefs it may be easier to survey both sides of the line at the same time. However, you should still try to spread your assessment along the line in reefs containing too many corals to complete the entire 10 m^2 survey within one dive. ***Optional:*** *Before the dive, you can randomly write the numbers between 0 and 9 on your datasheet to determine the order of surveying the meters along the line.*

If all the corals in the belt transect cannot be surveyed during the dive (e.g., due to a large number of corals), tally by species all remaining ≥ 4 cm corals as colonies, clumps or fragments.

Coral Terms. **Colony**: one genetic individual, even if the soft tissues naturally divide into separate units. Put any **solitary** *Scolymia* here.

Clump: (i.e., thicket or cluster): a group of similar appearing corals of the same species for which individual colony borders are indistinct, e.g., branching species and large groups of lobate [e.g., *Orbicella* (ex-*Montastraea) annularis]* and platy [e.g., *Agaricia tenuifolia]* corals.

Fragment: detached coral, often broken and easily moved; unlikely to remain in its current location for long.

Information for each ≥ 4 cm Coral

CORAL Code: Record its 4-letter coral code (e.g., CNAT = *Colpophyllia natans).* Use genus code if unsure of species (e.g., ORBI for the *O. annularis* complex).

Sketch and briefly describe any unfamiliar corals and try to identify them after the dive. Include any standing dead corals that can be identified at least to genus and for which the original size can still be estimated.

 # Isolates, or put CLump or FRag: If a **colony** or **solitary coral,** put the total number of soft tissue isolates resulting from prior or ongoing perturbations. Put 0 if entire colony is standing dead, i.e., skeleton is intact but has no live tissues. Put 1 if the soft tissues lack *externally produced* sub-divisions. Put 1 for colonies of species that subdivide naturally as they grow (e.g., *O. annularis, P. porites, E. fastigiata*) if the soft tissues lack *externally produced* sub-divisions. If >10 isolates, estimate to the nearest 5 as 15, 20, *etc.*

If a **fragment** or **clump**, do not count isolate number but write FR or CL, respectively.

Colony margins (needed for # isolates and max. sizes) can be difficult to recognize when parts of a coral have died and are overgrown by other organisms–particularly other corals of the same species. Whenever possible, look for connected live tissues, basal skeletal connections, and at the size and color of the separated tissues.

Size of Each Colony, Solitary Coral and Clump (No Fragments)

Max. Size (cm). As appropriate for the corals' size, use the ruler, 50-cm pole or 1-m pole to measure its maximum dimensions, as seen in planar view, to the nearest 1 cm up to 10 cm, to the nearest 5 cm up to 50 cm, to the nearest 10 cm up to 200 cm, to the nearest 20 cm up to 500 cm, and the nearest 50 cm if > 5 m (some "large" clumps). Record:

Length: Maximum length perpendicular to the axis of growth in cm.

Width: Maximum width at right angles to the maximum length in cm.

Height: Maximum height parallel to the axis of growth in cm.

Measure the maximum sizes of large colonies and clumps even when they extend outside the belt transect.

How to assess colonies, solitary corals or clumps that are detached from the substratum:

If fallen and shows no reoriented growth, measure as if in original growth position**.**

If fallen and wedged, or shows reoriented growth, measure in the new growth position.

Condition of Outward-Facing Coral Surfaces: (no Fragments)

Each Colony, Solitary Coral and "Small" (<2 m) Clump

Examine the ***outward-facing (planar) surface*** and, for **bleaching condition,** estimate each of the following to the nearest 5% *(*e.g., 35%), unless very small amounts or very large–in which case try to round to the nearest whole number *(*e.g., 3%, 99%):

% Pale: The percent of the entire planar surface (*and not just the proportion of live tissues)* that is pale.

% Bleach: The percent of the entire planar surface *(and not just the proportion of live tissues)* that is fully bleached *(*e.g., 30P, 10BL = 30% pale + 10% bleached).

Remember that some bleached corals have fluorescent purple, pink or blue colors**.**

Leave blank if 0%.

For **partial mortality,** record the % of the entire outward-facing (planar) surface (as above for bleaching) for any of the following:

New: for any new mortality, i.e., skeletal structures are intact unless live tissues have just been bitten or scraped by a fish or otherwise abraded and have no sediment, bacterial/microalgal biofilms, turf algae, *etc.*, on their bright white surfaces; and/or

Trans: for any transitional mortality, i.e., skeletal structures are slightly eroded at most and covered with fine layer of sediment, microbial/microalgal biofilms, or sparse turf algae–unless they have just been bitten or scraped by a fish or otherwise abraded, thereby exposing the underlying bright white skeleton; and/or

Old: for any old mortality, i.e., skeletal structures are completely covered over by organisms that are not easily removed, e.g., thick algal turfs, many macroalgae and invertebrates–unless they have just been bitten by a fish or otherwise broken, there by exposing the underlying, bright white skeleton.

Although most large colonies have some dead areas, ignore any that are restricted to the sides or bases, and thus not visible when their outward-facing surface is viewed from above.

When corals are partially or completely overgrown by a CZOO (brown or black zooxanthellate *Cliona)*, the live coral polyps are replaced by sponge tissues with their characteristic ostia and oscules (openings). Even though the coral skeleton may be visible beneath the sponge, include the affected area in your estimate of old mortality.

Leave blank if 0%.

Each "Large" (≥ 2 m) Clump

Tally the condition of the points at regular intervals across the maximum length (Max L) of each clump with the 1-m pole for scale, using the following codes:

Point Counts for "Large" CLUMPS: **L** for number of points over live tissues with "normal" pigmentation; **P** for number of points over pale live tissues; **BL** for number of points over fully bleached live tissues; **NM** for number of points over new mortality; **TM** for number of points over transitional mortality; **OM** for number of points over old mortality (includes other organisms overgrowing dead parts of the clump); **OTHER** for number of points over anything that is not part of the clump *(*e.g., 15 L, 3 P, 4 TM, 8 OM, 5 OTHER = 15 live, 3 pale, 4 transitional mortality and 8 old mortality points on the clump; 5 points not on the clump).

Suggested interval lengths: 20-cm from 2 - 5 m Max L; 50-cm from 5 - 10 m Max L; 1-m for > 10 m Max L. ***Note the interval length used.***

Disease Information for Each Coral (No Fragments)

Signs of Disease. Examine the ***entire surface*** of each colony, solitary coral and clump. Record the presence (but not %) of any signs of disease (new mortality with no evidence of bleaching, breakage or predators, etc.*)* as X if disease is present*, or* code as:

Disease Names: **CBD** (colored band disease with conspicuous tissue loss), or distinguish as **BBD** (black band disease), or **CCI** (Caribbean ciliate infection).

For a white disease or syndrome with conspicuous tissue loss:

- If not *Acropora*, try to distinguish as **WPD** (white plague disease) or **SCTLD** (stony coral tissue loss disease); or put **CWS** (Caribbean white syndrome).
- If *Acropora,* try to distinguish as **WBD** (white band disease), **WSD** [white (spot) patch disease] or **RTL** (rapid tissue loss); or use **AWD** (acroporid white disease).

Any conspicuous tissue discoloration as **DSD** (dark spots disease) or **YBD** [(Caribbean) yellow band disease).

Any conspicuous tissue anomalies, including gigantism, as **GAN** (Growth Anomaly).

Put **UNK** when an unknown disease or as instructed by the team leader.

Take photographs of any injured coral, and/or describe any **UNK** (unknown) disease.

Leave blank if none seen.

Comments

Space is also available here for any other relevant observations about the coral. Note any bleaching condition or mortality state by its code that is present on the sides or base of the coral and not seen in planar view.

If ***conspicuous***, note the effects of any predators, *e.g.,* **PFB** for Parrotfish Bites, **DFB** for Damselfish Bites, **DFG** for Damselfish Algal Gardens**, CABB** for short coral snail, *Coralliophila abbreviata*, **HCAR** for bristle worm, *Hermodice carunculata,* or any major spatial competitors by name or AGRRA code. If appropriate, note any "unhealthy looking" tissues as **CHC** for compromised coral health.

If coral is photographed, note image number here.

Periodically check your bottom time and air supply. After completing the belt on one side of the line, return along the second side. If remaining time and available air both permit, assess all ≥ 4 cm corals that are at least partially within a 0.5-m wide belt. ***Be careful not to resurvey any coral beneath the line that was examined during the first transect.***

Area Surveyed (m^2): When finished surveying, record the total number of square meters with completed surveys of all ≥ 4 cm stony corals.

Remember that the area between each 1-m mark on one side of the transect line = 0.5 m^2.

Tallied ≥ 4 cm Corals

If at any time during the dive you don't have enough time and/or air left to complete the survey, use any blank spaces remaining on your datacard to tally the numbers of each species of any remaining ≥ 4 cm colonies, solitary corals, clumps and fragments in the belt transect using their 4-letter coral codes *(*e.g., COL: OFAV 卌 II, CNAT IIII; CLUMP: PPOR II; FRAG APAL I = 7 colonies of *O. faveolata*, 4 colonies of *C. natans*, 2 *P. porites* clumps and 1 *A. palmata* fragment).

Area Tallied (m^2): When finished tallying, record the total number of square meters in which all ≥ 4 cm stony corals were tallied by species and as colonies, clumps or fragments.

Transect Comments

Summarizing for the belt transect as a whole: Define any unique codes used. Add any other important observations about the transect, including the number of any lionfish.

If any group of benthic organisms in the belt is ***conspicuously*** pale, bleached, diseased or otherwise perturbed: record: its name or AGRRA code; its approximate abundance by % cover or by number; and the approximate % cover or number affected by the perturbation *(*e.g., 35% PCAR/ 50% BL = *Palythoa caribaeorum* covers 35% of transect & 50% are bleached; 1/2 XES die or 1/2BAR die = 1 of 2 *Xestospongia muta* or barrel sponges are dying).

Coral teams should survey a total of 2 transects; more are acceptable.

Complete before the end of the dive: **Safety Stop**

Site Comments: While conducting your safety stop at the end of the dive, add any other notes about the site, including number of any lionfishes, turtles, sharks, or other large vertebrates not in the belt transects, or any conspicuously pale, bleached or diseased benthic organisms.

Data Entry & Backup

Complete after the dive:

Enter all your data, including any comments, on a daily basis ***online*** or in a copy of the **AGRRA Coral Data Entry *spreadsheet*. (If the latter, use a separate copy of the spreadsheet for each site.) Always back up your own data daily and store your files in a safe place.**

If you have invented any additional benthic codes: first check the complete list of Benthic Codes found in the expanded **AGRRA Benthic Codes** file and, if any are found, substitute it for your provisional code. If there is no pre-existing code, use your code and be sure to include an explanation of what it means in the relevant transect or site comments cell.

AGRRA 2021 CORAL CODES (by shape group)				DISEASES/SYNDROMES
MOUND & BOULDER		**FLOWER & SOLITARY**		***CBD = Colored Band, Tissue Loss:***
DSTO	***Dichocoenia stokesii***	**EFAS**	***Eusmilia fastigiata***	**BBD** = Black Band Disease
				CCI = Caribbean Ciliate Infection
FFRA	*Favia fragum*	MANG	*Mussa angulosa*	***non-Acroporid White Diseases***
				WPD = White Plague Disease
MCAV	***Montastraea cavernosa***	SCOL	*Scolymia*	**CWS** = Caribbean White Syndrome
		SCUB	*Scolymia cubensis+wellsi*	**SCTLD** = Stony Coral Tissue Loss Disease
ORBI	*Orbicella* (ex *Montastraea*)	SLAC	*Scolymia lacera*	***Acropora White Diseases = AWD, or***
OANN	***Orbicella annularis***			**WBD** = White Band Disease
OFAV	***Orbicella faveolata***			**WSD** = White (Spot) Patch Disease
OFRA	***Orbicella franksi***	**AGARICIID**		**RTL** = Rapid Tissue Loss
PAST	***Porites astreoides***	AGAR	*Agaricia* (also called *Undaria*)	**DSD** = Dark Spot Disease **YBD** = Yellow Band/Blotch Disease
		AAGA	***Agaricia agaricites***	**GAN** = Growth Anomaly
SIDE	*Siderastrea*	AFRA	*Agaricia fragilis*	**UNK** = Unknown (try to describe)
SRAD	***Siderastrea radians***	AHUM	*Agaricia humilis*	**BLEACHING STATES**
SSID	***Siderastrea siderea***	ALAM	*Agaricia lamarcki*	**P** = Pale
		ATEN	***Agaricia tenuifoila***	**BL** = Bleached
SOLE	*Solenastrea*			**COMMON PREDATORS/BITES**
SBOU	*Solenastrea bournoni*	**HCUC**	***Helioseris cucullata***	**CABB** = *Coralliophila abbreviatum*
SHYA	*Solenastrea hyades*			**HCAR** = *Hermodice carunculata*
		BRANCHING		**DFB** = Damselfish Bites
SINT	***Stephanocoenia intersepta***	ACRO	*Acropora*	**DFG** = Damselfish Algal Gardens
		ACER	***Acropora cervicornis***	**PFB** = Parrotfish Bites
		APAL	***Acropora palmata***	**FB** = Fish Bite (of unknown origin)
MEANDROID		**APRO**	*Acropora prolifera*	**COMMON ALGAE**
CNA				**CCA** = Crustose Coralline Alga
DCYL	*Dendrogyra cylindrus*	MADR	*Madracis*	**CYAN** = Cyanobacteria
		MAUR	***M. auretenra (ex mirabilis)***	**TA** = Turf Algae, **TAM** = Turf Algal Mat
DLAB	***Diploria labyrinthiformis***	MCAR	*Madracis carmabi*	**TAS** = TA + Sediment Mat
		MDEC	***Madracis decactis***	**STA** = Sediment>>Turf Algae
IRIG	*Isophyllia rigida*	MFOR	*Madracis formosa*	**PEYS** = Peyssonnelid (fleshy or calcareous)
ISIN	*Isophyllia sinuosa*	MSEN	*Madracis senaria*	**BFMA, GFMA or RFMA** = Brown,
				Green or Red Fleshy Macroalga or code:
MARE	*Mancina areolata*	OCUL	*Oculina*	**DICT** = *Dictyota*; **LOBO** = *Lobophora*
		ODIF	*Oculina diffusa*	**CLAD** = *Cladophora*
MEAN	*Meandrina*			**MICR** = *Microdictyon*
MJAC	***Meandrina jacksoni***	PDIG	"digitate" *Porites*	**GCMA or RCMA** = Green or Red
MMEA	***Meandrina meandrites***	**PDIV**	*Porites divaricata*	Calcareous Macroalga or code:
		PFUR	***Porites furcata***	**HALI** = *Halimeda*; **JANI** = *Jania*
MYCE	***Mycetophyllia.***	**PPOR**	***Porites porites***	**HALM** = *Halimeda* Mat
MALI	*Mycetophyllia aliciae*			**FMA-CMA** = mixed FMA & CMA
MDAN MFER	*M. lamarckiana f. danaana* *Mycetophyllia ferox*			**ND-algal code** = any newly-dead alga
MLAM	***Mycetophyllia lamarckiana***	**FIRE CORALS**		**"AGGRESSIVE" INVERTEBRATES**
PSEU	*Pseudodiploria* (ex *Diploria*)	MILL	*Millepora*	**CDEL** = *Cliona delitrix* (red-orange) **CZOO** = Zooxanthellate *Cliona*
		MCOM	***Millepora complanata***	**CCAR** = *Chondrilla caribensis*
PCLI	***Pseudodiploria clivosa***	MSQU	*Millepora squarrosa*	**MALC** = *Millepora alcicornis*
PSTR	***Pseudodiploria strigosa***			**ECAR** = *Erythropodium caribaeorum*
				PCAR = *Palythoa caribaeorum*
				TSOL = *Trididemnum solidum*

 Revision: 2021-06-10

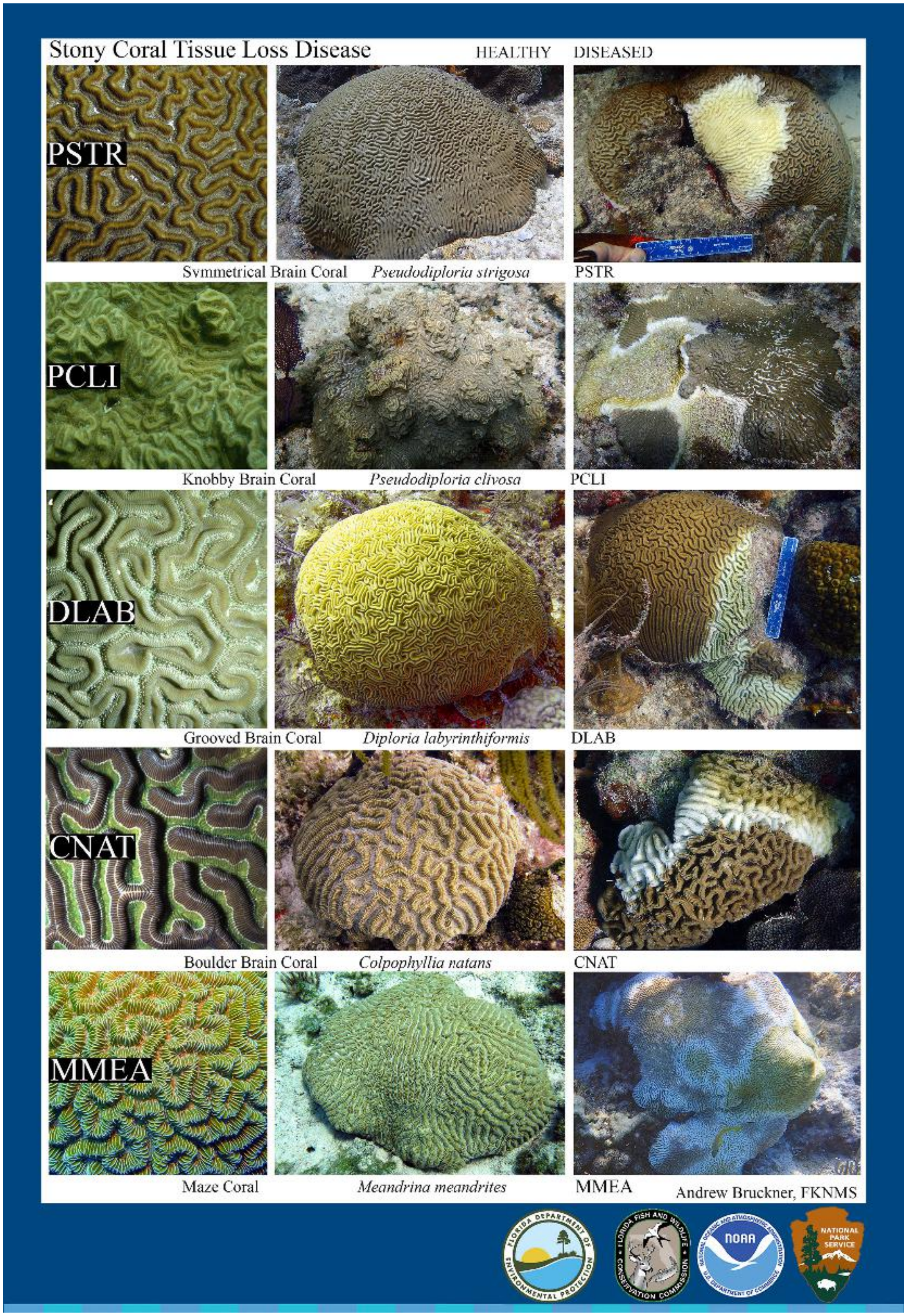
Surveyor:	Date:	Site Name:	Lat:	Long:	AGRRA Code:	Start Time:
Depth–Start: End: ft or m?		Site Comments *(e.g.,* major organisms, bottom temp.):				
Area–Surveyed (m^2): Tallied (m^2):		Transect Comments:				

All ≥ 4 cm Corals		All Colonies, Solitary Corals and Clumps (no Fragments)									
Species Code	# Isolates, or put CLump or FRag	Max. Size (cm)			Outward-facing Surface				Disease: code	Point Counts for "Large" CLUMPS (as L, P, BL, NM, TM, OM, Other)	Comments
		Length	Width	Height	% Pale % BLeach	% Partial Mortality					
						New	Trans	Old			

 Revision: 2021-04-12

Appendix 6. Coral Disease Identification Aids

(Bruckner, 2019 see: https://www.agrra.org/coral-disease-identification/)

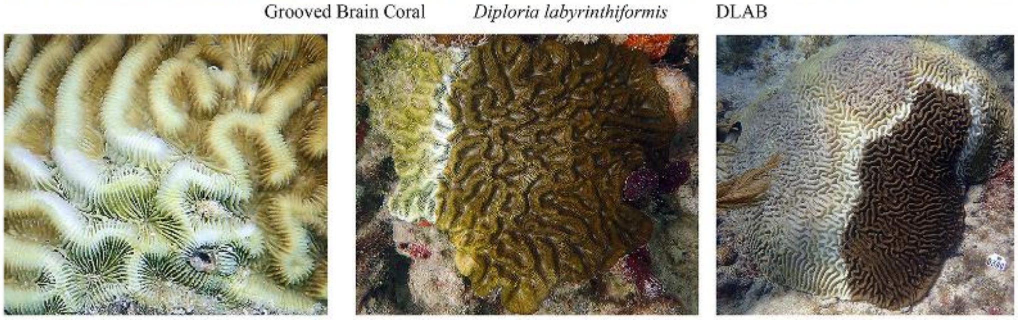


Stony Coral Tissue Loss Disease

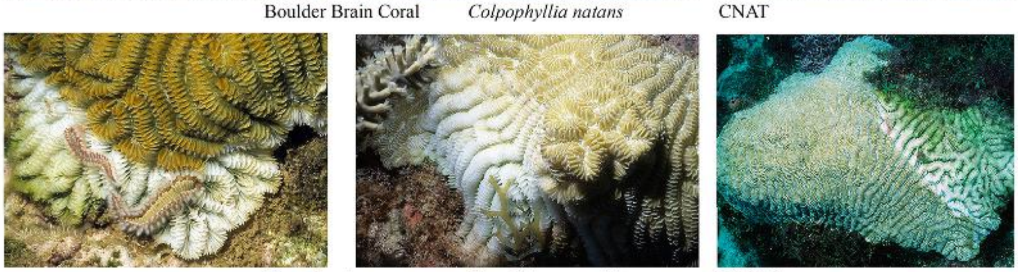
Symmetrical Brain Coral *Pseudodiploria strigosa* PSTR

Knobby Brain Coral *Pseudodiploria clivosa* PCLI

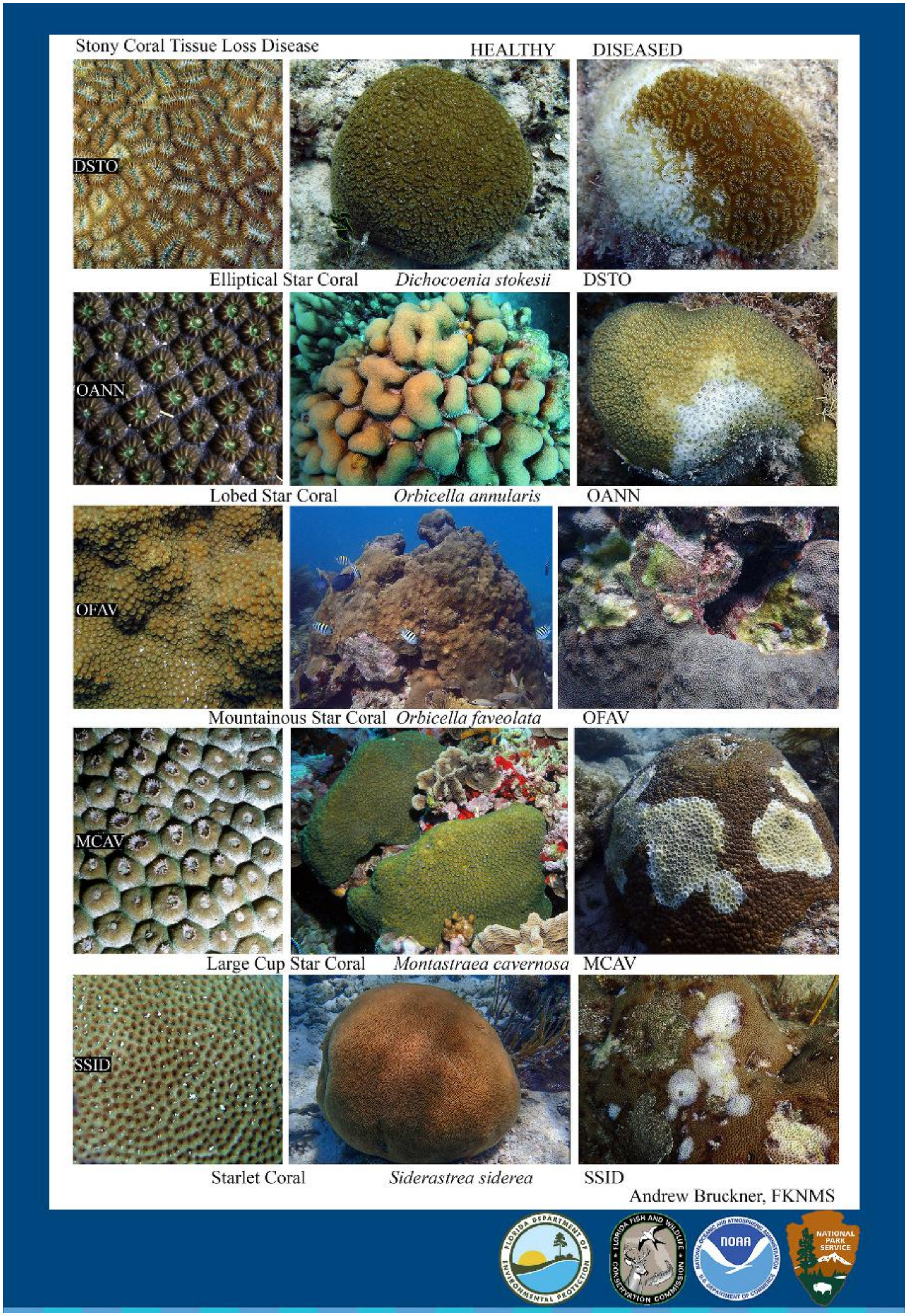
Grooved Brain Coral *Diploria labyrinthiformis* DLAB

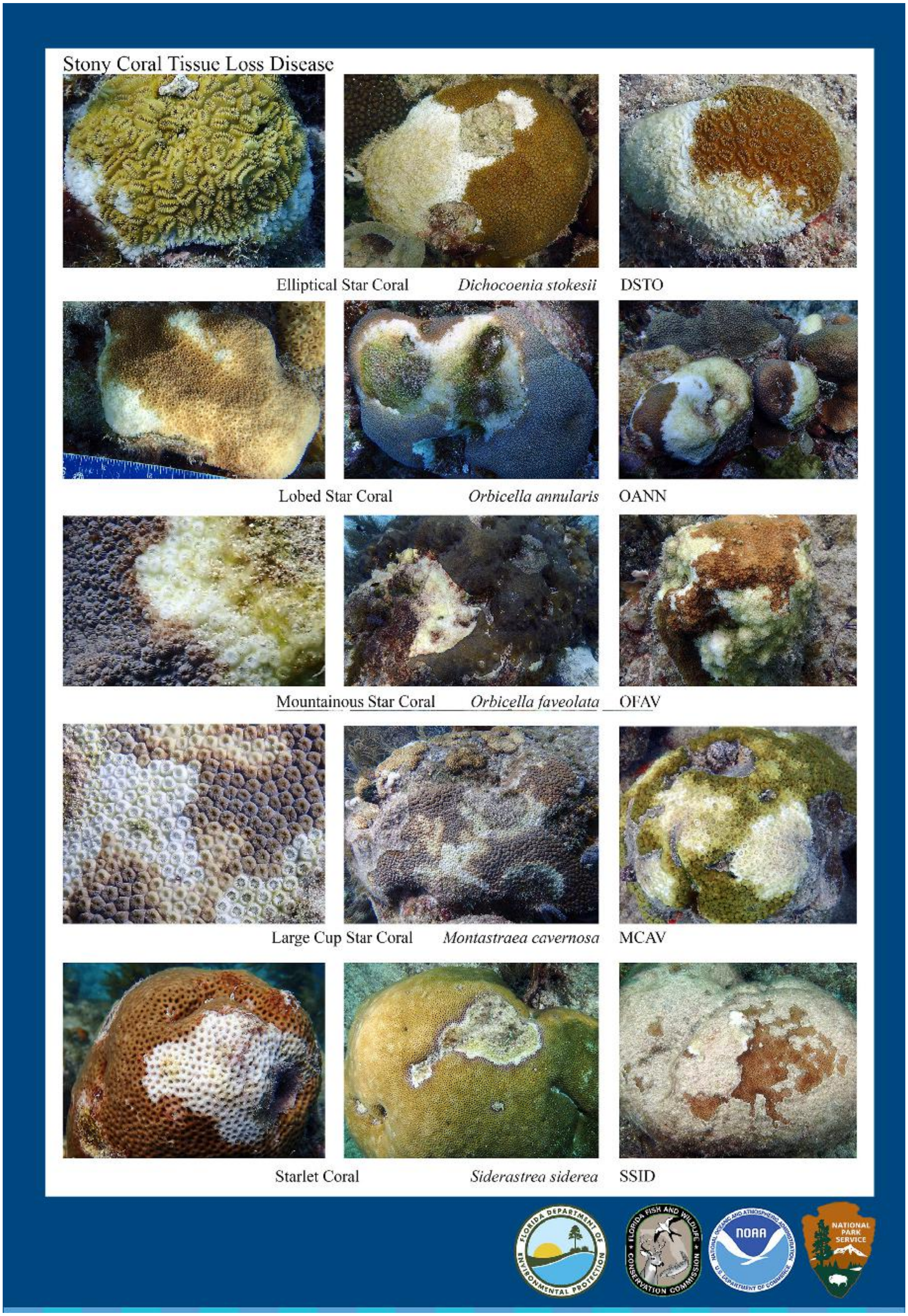


Boulder Brain Coral *Colpophyllia natans* CNAT

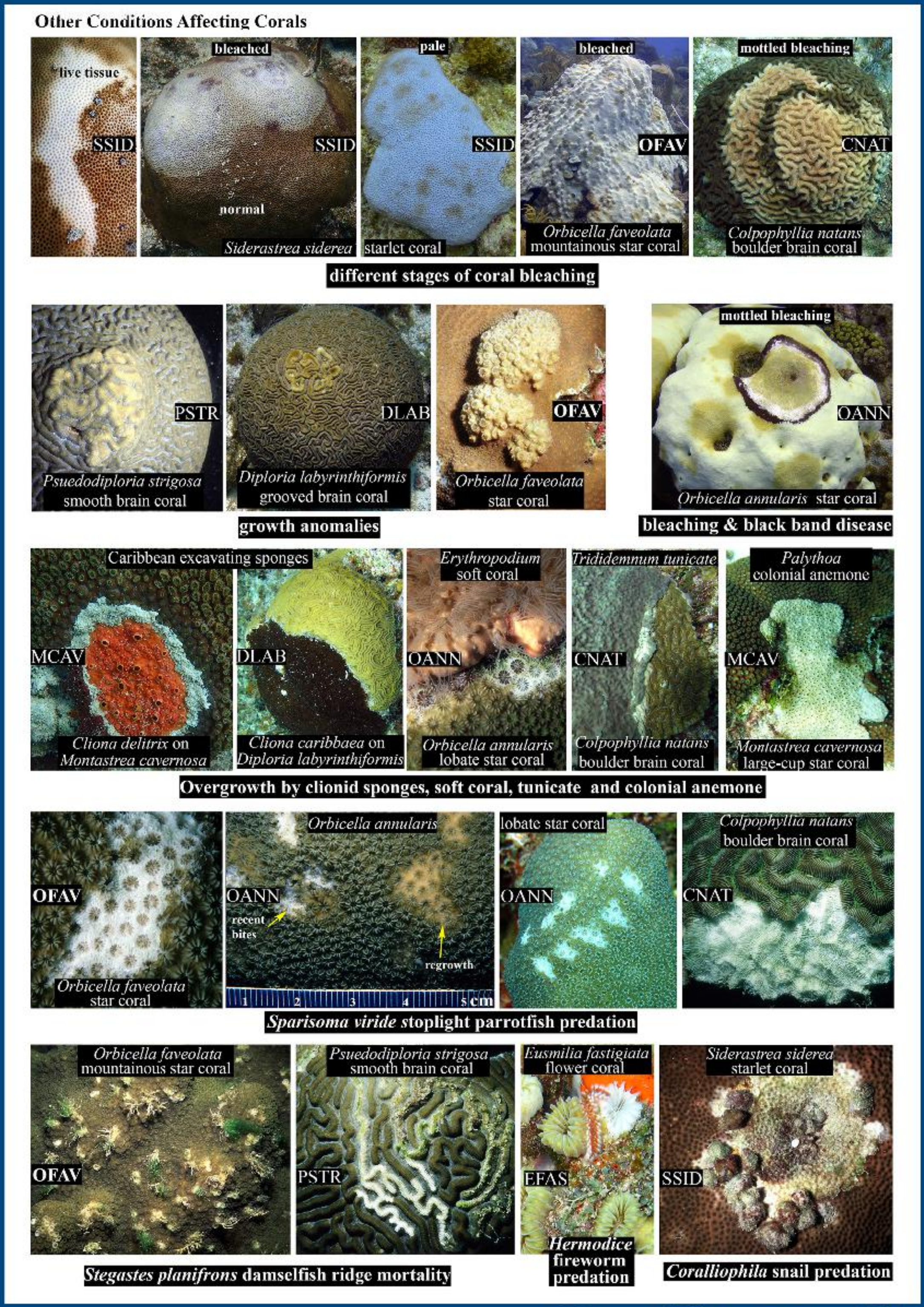


Maze Coral *Meandrina meandrites* MMEM


Stony Coral Tissue Loss Disease
HEALTHY
DISEASED
DSTO
Elliptical Star Coral
Dichocoenia stokesii
DSTO
OANN
Lobed Star Coral
Orbicella annularis
OANN
OFAV
Mountainous Star Coral
Orbicella faveolata
OFAV
MCAV
Large Cup Star Coral
Montastraea cavernosa
MCAV
SSID
Starlet Coral
Siderastrea siderea
SSID
Andrew Bruckner, FKNMS

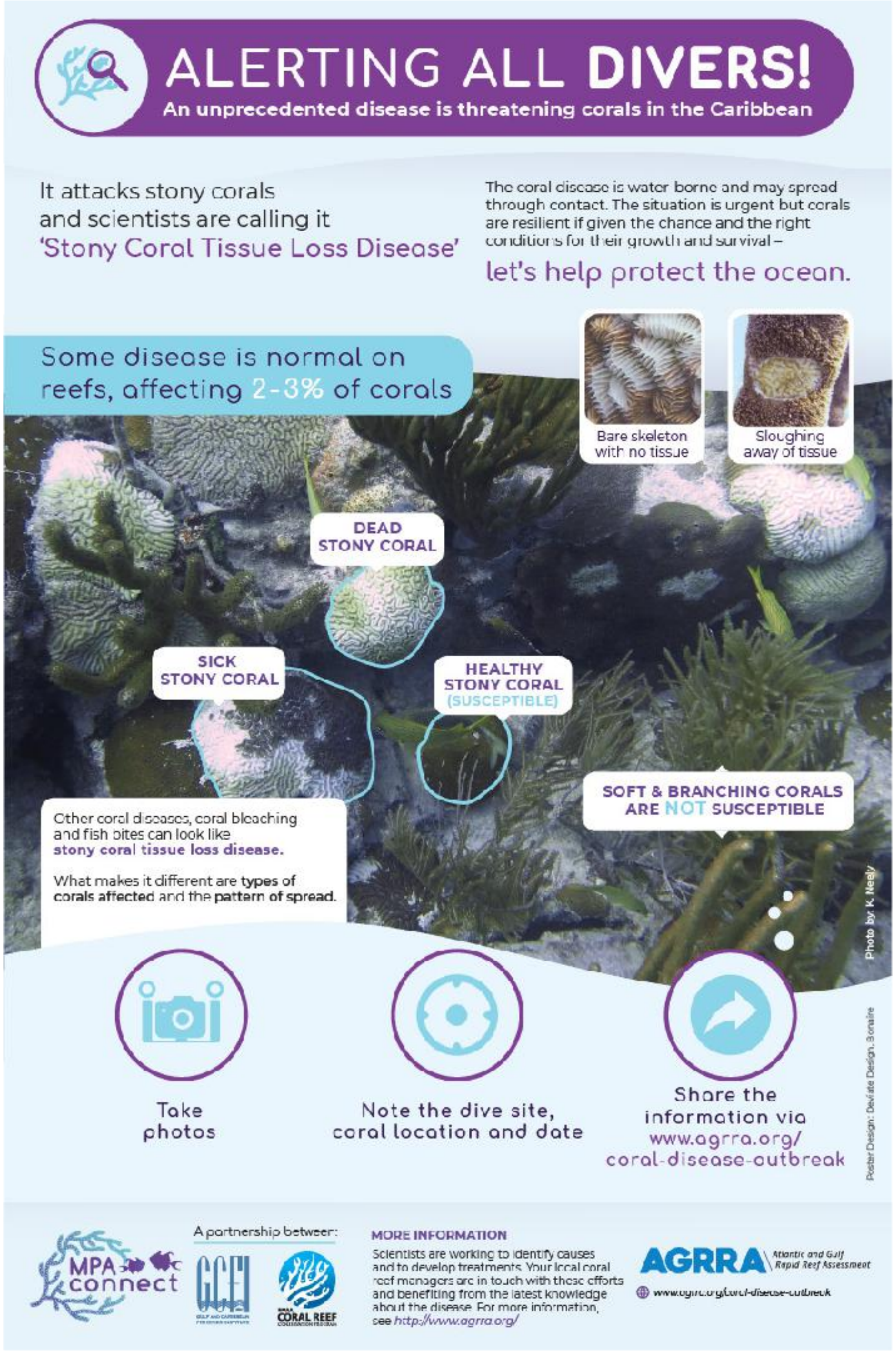

Stony Coral Tissue Loss Disease
Elliptical Star Coral
Dichocoenia stokesii
DSTO
Lobed Star Coral
Orbicella annularis
OANN
Mountainous Star Coral
Orbicella faveolata
OFAV
Large Cup Star Coral
Montastraea cavernosa
MCAV
Starlet Coral
Siderastrea siderea
SSID


Other Coral Diseases
SSID
Starlet coral
Siderastrea siderea
MCAV
Large-cup star coral
Montastrea cavernosa
PSTR
Symmetrical brain coral
Psuedodiploria strigosa
OFAV
Star coral
Orbicella faveolata
black band disease (BBD)
OFAV
OANN
live
dead
OFAV
OFAV
Star coral Orbicella annularis & O. faveolata
yellow blotch disease (YBD)
OFAV
OANN
OFAV
DLAB
Grooved brain coral
Diploria labyrinthiformis
Star coral Orbicella annularis & O. faveolata
Caribbean ciliate infection (CCI)
SINT
Blushing star coral
Stephanocoenia intersepta
OANN
Lobate star coral
Orbicella annularis
SSID
SSID
Starlet coral Siderastrea siderea
dark spots disease (DSD)
OFAV
OANN
DSTO
CNAT
Star coral Orbicella faveolata & O. annularis
Elliptical star coral
Dichocoenia stokessi
Boulder brain coral
Colpophyllia natans
white plague (WP)
Andrew Bruckner, FKNMS


Other Conditions Affecting Corals
live tissue
SSID
bleached
SSID
normal
Siderastrea siderea
pale
SSID
starlet coral
bleached
OFAV
Orbicella faveolata
mountainous star coral
mottled bleaching
CNAT
Colpophyllia natans
boulder brain coral
different stages of coral bleaching
PSTR
Psuedodiploria strigosa
smooth brain coral
DLAB
Diploria labyrinthiformis
grooved brain coral
OFAV
Orbicella faveolata
star coral
growth anomalies
mottled bleaching
OANN
Orbicella annularis star coral
bleaching & black band disease
Caribbean excavating sponges
MCAV
Cliona delitrix on
Montastrea cavernosa
DLAB
Cliona caribbaea on
Diploria labyrinthiformis
Erythropodium
soft coral
OANN
Orbicella annularis
lobate star coral
Trididemnum tunicate
CNAT
Colpophyllia natans
boulder brain coral
Palythoa
colonial anemone
MCAV
Montastrea cavernosa
large-cup star coral
Overgrowth by clionid sponges, soft coral, tunicate and colonial anemone
OFAV
Orbicella faveolata
star coral
Orbicella annularis
OANN
recent
bites
regrowth
1
2
3
4
5 cm
lobate star coral
OANN
Colpophyllia natans
boulder brain coral
CNAT
Sparisoma viride stoplight parrotfish predation
Orbicella faveolata
mountainous star coral
OFAV
Psuedodiploria strigosa
smooth brain coral
PSTR
Stegastes planifrons damselfish ridge mortality
Eusmilia fastigiata
flower coral
EFAS
Hermodice
fireworm
predation
Siderastrea siderea
starlet coral
SSID
Coralliophila snail predation

Appendix 7. MPAConnect Outreach Materials

In response to the SCTLD outbreak, MPAConnect, a partnership between GCFI and NOAA's Coral Reef Conservation Program, has developed resource materials that will help with the identification, monitoring and treatment of the disease, including posters, webinars and videos and may be found at https://www.gcfi.org/emerging-issues-florida-coral-disease-outbreak/. An example of the outreach materials is below.



Appendix 8. Coral Disease Decontamination Guidelines

STONY CORAL TISSUE LOSS DISEASE

GUIDELINES

FOR DISINFECTION OF DIVE GEAR

1 Soak all of your gear for 10 minutes in a 0.1% bleach solution

Use immediately after mixing

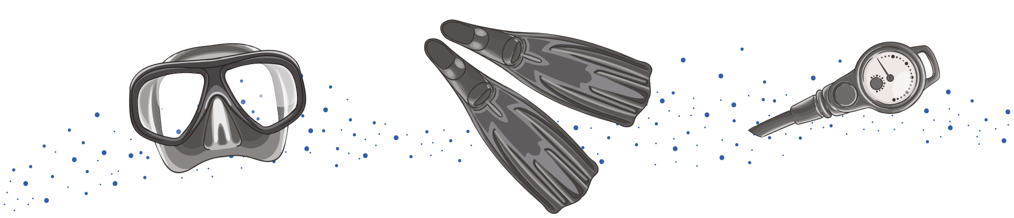
1/3 cup of bleach for every 1 gallon of fresh water.

Don't forget your BC internal bladders!

2 Rinse all of your gear in fresh water (e.g., in a 5 gallon bucket)

Properly dispose of disinfectant solutions by rinsing waste into sink or shower. Remember, chlorine will break down in the sun!

3 Allow gear to air dry thoroughly



ROATAN MARINE PARK

Connecting you with the ocean.
#BE PART OF IT

Coral Disease Decontamination Protocol

Reduce the spread of disease by cleaning and decontaminating dive gear

Neoprene gear, such as wetsuits, booties, and gloves, and the internal bladder of buoyancy compensation devices (BCDs) can harbor and proliferate pathogenic bacteria and other microorganisms by remaining damp and trapping water. These pathogens can also adhere to other dive and snorkel gear, especially when the diver directly contacts the bottom and touches corals and other benthic organisms. Pathogens on dive gear may survive for extended periods and can be transferred among reefs on subsequent dives, and, potentially, transmitted to reefs internationally, unless your gear is disinfected.

Dive and snorkel gear can contribute to the overall transmission of pathogenic bacteria among reefs. Just like handwashing is a common practice to prevent the spread of disease among humans, disinfecting gear and following other best practices is recommended to prevent the accidental transmission of coral disease between reefs. Divers and snorkelers can reduce their likelihood of encountering and transferring pathogenic bacteria through proper buoyancy and by avoiding touching marine organisms. As a precautionary approach, they can further minimize transmission of pathogens by sanitizing dive equipment between dives and before and after each dive excursion, especially when travelling between countries or between infected and uninfected locations.

Ammonium-based disinfectants and chlorine bleach are effective antiseptics that minimize the spread of disease-causing pathogens from infected reefs and corals to uninfected sites. However, proper use and technique are necessary to properly sanitize gear and avoid harming equipment. Freshwater washing alone will not eliminate pathogens.

General Guidelines for Disinfection

- All divers should decontaminate dive gear at the end of the day.
- Divers should inspect all dive gear and equipment carefully and remove any debris, such as seagrass, algae and sediment, following each dive.
- Divers should sanitize all gear between dives at sites with a high prevalence of disease, especially if subsequently moving to an uninfected site, and if coming into close contact with diseased corals or the bottom. The preferred option is to dive the “cleanest” site first and move to the “dirtiest” site last.
- Gear should be decontaminated between dive sites separated by large distances (>10 km), and in sensitive areas.
- Gear should be decontaminated when travelling between countries.
- To minimize spillage on dive platforms and ocean contamination, quaternary ammonium solutions should only be used to decontaminate dive gear when returning to shore. Sanitization between dives should involve a bleach solution kept in a sealed container to disinfect equipment that makes contact with corals (transect tapes, gloves, tools), and other gear should be washed in freshwater containing an antibacterial soap.
- Properly dispose of disinfectant solutions and rinse water in a sink, tub or shower. Never pour into the ocean or a storm drain. Quaternary ammonium wastewaters should not be drained through septic systems because of the potential for system upset and subsequent leakage into groundwater.

Gear-Specific Guidelines for Disinfection

Tools, collection bags, sampling gear, transect tapes, clipboards, underwater slates, weight belts and other equipment that comes in contact with the bottom should be decontaminated using diluted chlorine bleach. Bleach is extremely corrosive to metals and should not be used to decontaminate regulators or neoprene wet suits as it can compromise the integrity of polymers such as neoprene and silicone rubber components in regulators. Bleach should never be mixed with ammonia-based solutions. Bleach rapidly degrades and must be used immediately after mixing; it should be changed daily.

- After each dive, soak non-sensitive equipment and tools for 10 minutes in a 1% bleach solution (1/2 c. bleach/2 gal. water prepared in a 5-gallon bucket with a lid).
- Rinse with fresh water, air dry.

Wetsuits, Buoyancy Compensation Devices (BCDs), masks and fins should be decontaminated using quaternary ammonium disinfectants such as Virkon S[1], RelyOn[1] and Lysol[1] All Purpose Cleaner. These are broad spectrum disinfectants and are effective for treating bacteria, viruses, fungi, larval mollusks and other microorganisms.

- After each dive, soak dive gear for 10 minutes in one of the following: 0.5% RelyOn1 (four 5 g. tablets/1 gal. water), 1% Virkon S1 (1.3 oz./2 gal. water), 6.6% Lysol[1] (1 qt./1 gal. water), or an equal concentration of another quaternary ammonium disinfectant.
- Remove from disinfecting solution, soak in fresh water for 10 minutes, and allow to air dry.

Particular attention needs to focus on decontaminating wetsuits and the internal bladders of BCDs because of their ability to trap water that can house transmissible pathogens. Pour approximately ½ liter solution into the mouthpiece of the BCD's exhaust hose while depressing the exhaust button, inflate the BCD, and gently rotate the BCD in all directions to ensure the solution has reached all of the internal parts. Allow the BCD to sit for 10 minutes, and then immediately dump the solution into a container for proper disposal on land Flush the BCD two times with fresh water.

Regulators, computers, gauges, underwater cameras and other sensitive scientific equipment should be decontaminated using fresh water with antibacterial dish soap or an isopropyl alcohol wipe and let dry.

- Prepare a solution of warm water and antibacterial dish soap or OdoBan1 (5 oz./gal.). After each dive, soak regulators and other sensitive equipment for 20 minutes, rinse in fresh water and allow to dry.
- Additionally/alternatively, equipment can be wiped down with isopropyl alcohol. Be sure to wipe any small areas where water might accumulate.

[1] This protocol does not endorse, recommend, or favor any specific commercial product, process, or service, or the use of any trade, firm or corporation name and is provided only to inform the public. Safety data sheets for chemicals and user's manuals for equipment developed by product manufacturers provide critical information on the physical properties, reactivity, potential health hazards, storage, disposal, and appropriate first aid procedures for handling, application, and disposing of each product in a safe manner. Familiarization with the Safety data sheets for chemical products, and manufacturer's product care and use standards, will help to ensure appropriate use of these materials and safeguard human health.

Source: https://nmsfloridakeys.blob.core.windows.net/floridakeys-prod/media/docs/coral-disease-decontamination-protocol.pdf

Guide developed and written by:

Perigee

AGRRA