# Corals

Staff Review
May 2, 2019

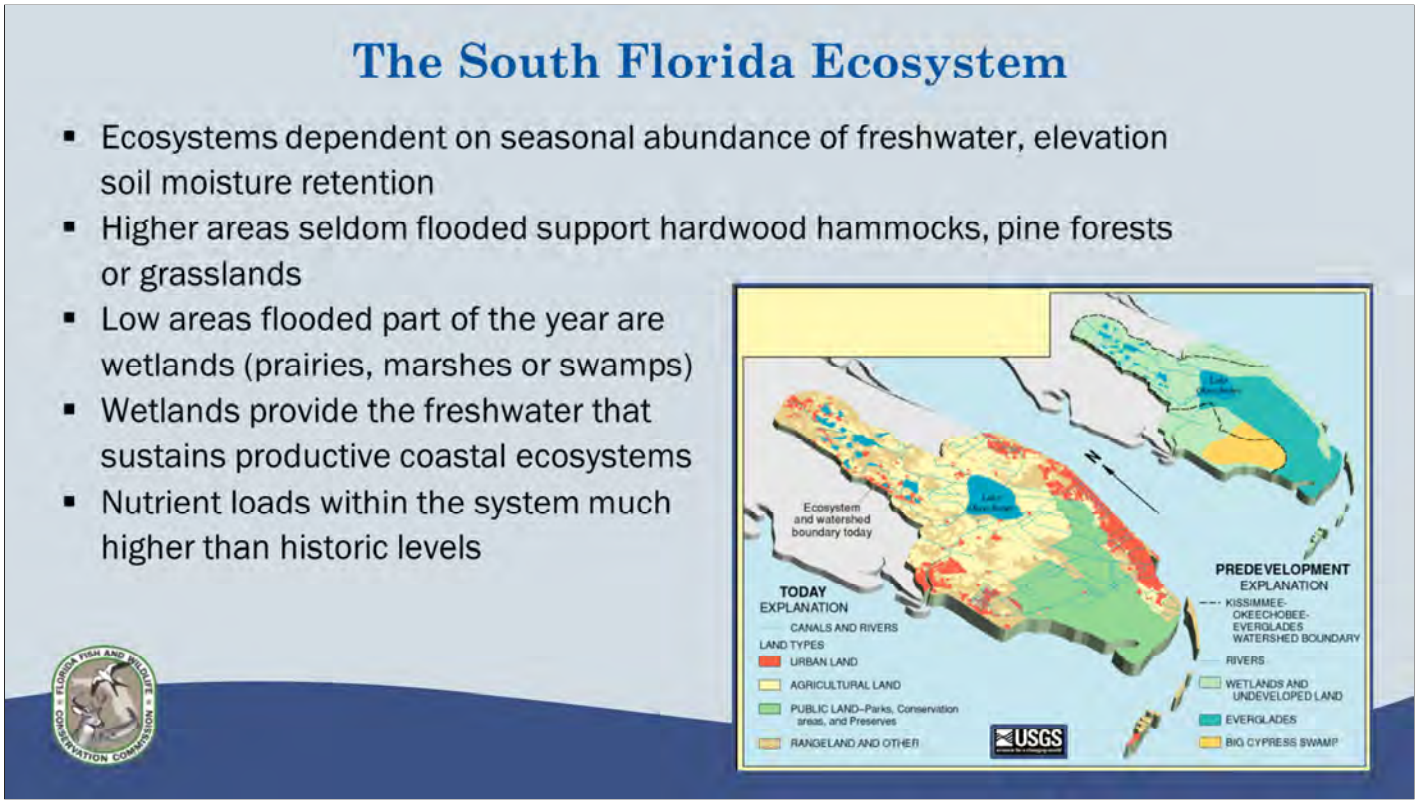
Florida Fish and Wildlife Conservation Commission

Version 1

Review and discussion of Florida's coral reefs with an emphasis on the multi-agency response to the stony coral tissue loss disease (SCTLD) event that began in 2014 and is ongoing.

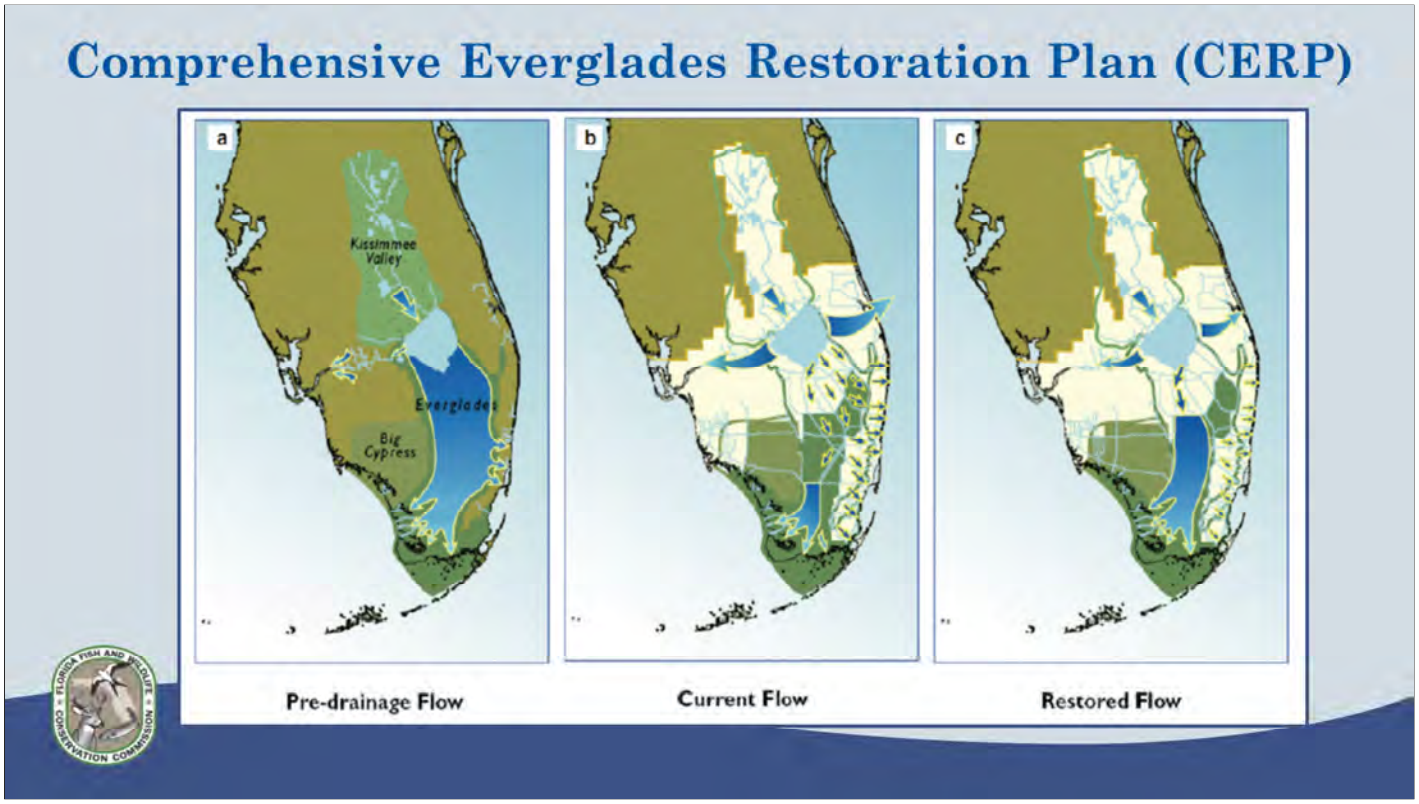
# Outline

- The South Florida Ecosystem and Florida's Coral Reef Tract
- Stony Coral Tissue Loss Disease (SCTLD) and Response
  - Epidemiology and Research
  - Disease Reconnaissance and Intervention
  - Coral Rescue and Genetic Banking
  - Coral Restoration
- Strategy Moving Forward
- Panel Discussion/Question and Answer

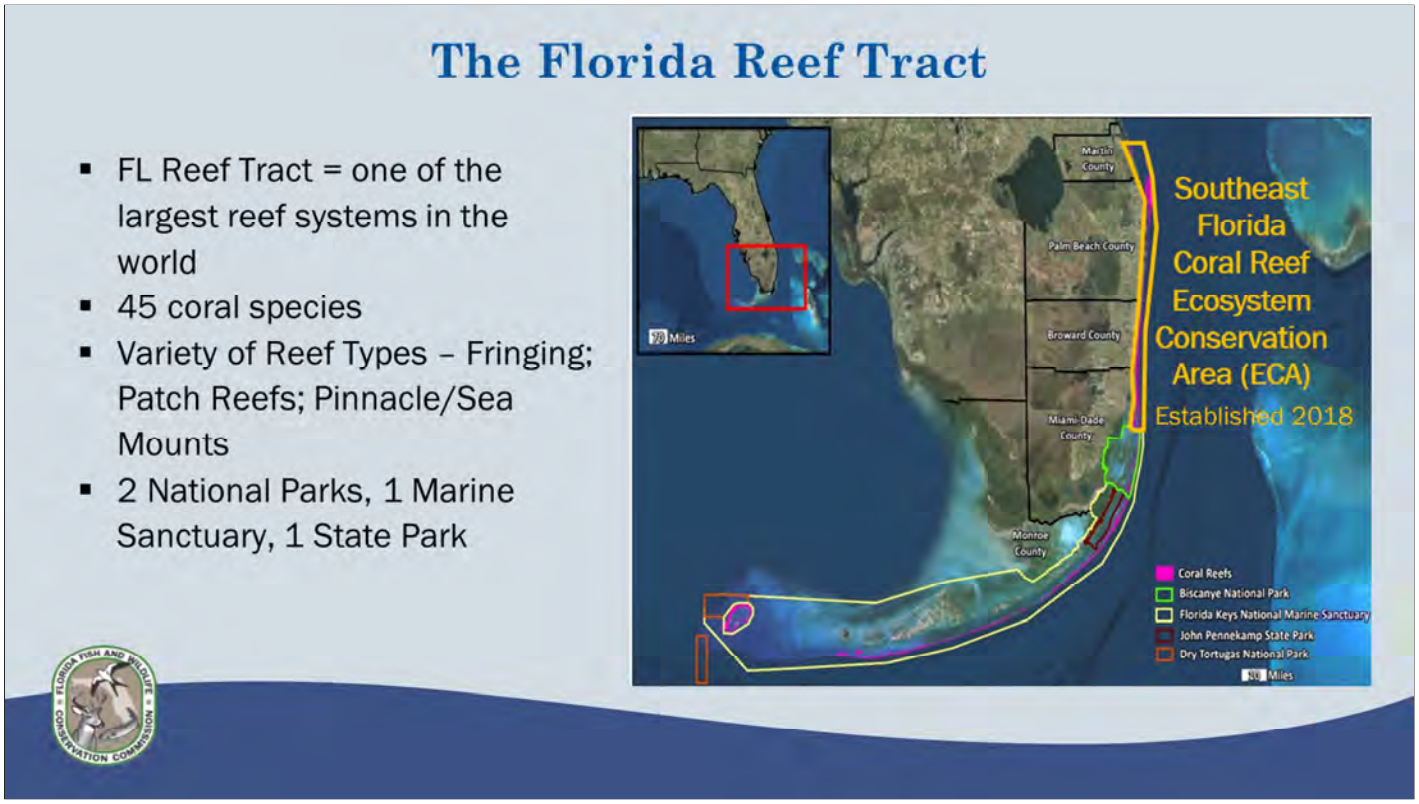



Prior to development, as well as today, the nature of south Florida ecosystems have been driven by a seasonal abundance of freshwater, moisture retention in the soil or by the duration and the depth of flooding. High areas that are seldom flooded usually support pine forests, hardwood hammock forests, or grassland systems. Low areas that are flooded part of the year are wetlands, which include prairies, marshes, or swamp systems. Fire, tropical storms, frost and cold weather, saltwater intrusion, and man also affect the systems. Freshwater is a key environmental factor in that it not only affects the system directly but it also affects other controlling environmental factors such as fires, soil, temperature, and saltwater intrusion. Freshwater is also a key factor manipulated by man.

Drainage projects begun in the early 1900s have resulted in the construction of more than 1,400 miles of primary canals and more than 100 water-control structures. Three major interests compete for water: urban, agriculture, and the natural ecosystem. The natural ecosystem requires water low in nutrients, seasonal wet and dry periods, and occasional periods of flooding and drought. Accommodating all three interests is a challenge for water managers.




Pre-drainage, current and future flow patterns in South Florida (post implementation of the Comprehensive Everglades Restoration Plan – CERP)




Florida's coral reef tract is nearly contiguous from the Dry Tortugas to St. Lucie Inlet. Healthy corals require a relatively narrow range of temperatures, salinity and clean, clear water. In addition the main (fringing) reef tract, thousands of patch reefs occur nearshore and in Hawk Channel between the fringing reef and the Keys islands. There are multiple, large hardbottom terraces in Southeast Florida (referred to as nearshore, 1st, 2nd, and 3rd reef terraces). Pinnacle reefs which arise like sea mounts are unique to the Dry Tortugas.

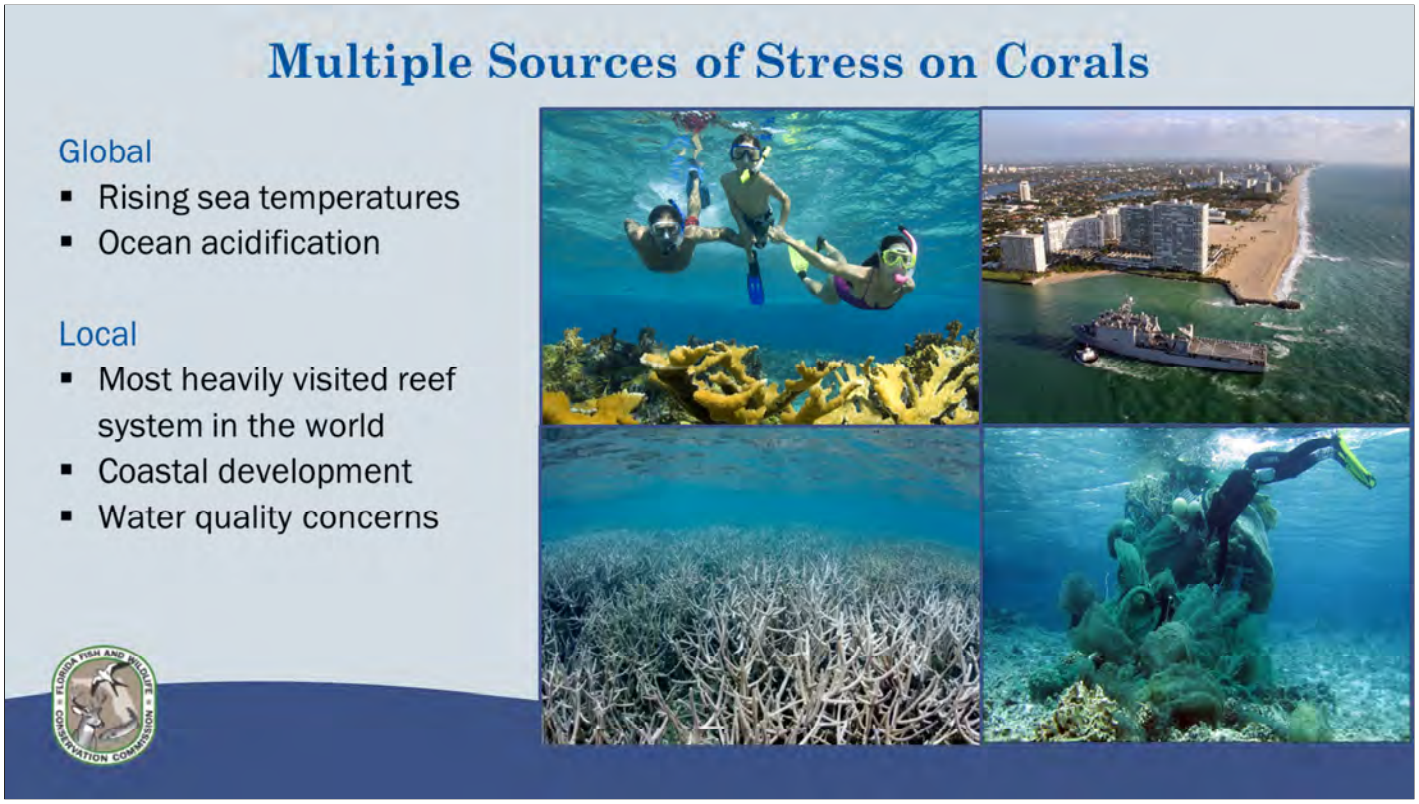
Several different jurisdictional authorities, local, state and federal, share the responsibility for stewardship of Florida's coral reefs.

## Significance of the Florida Corals

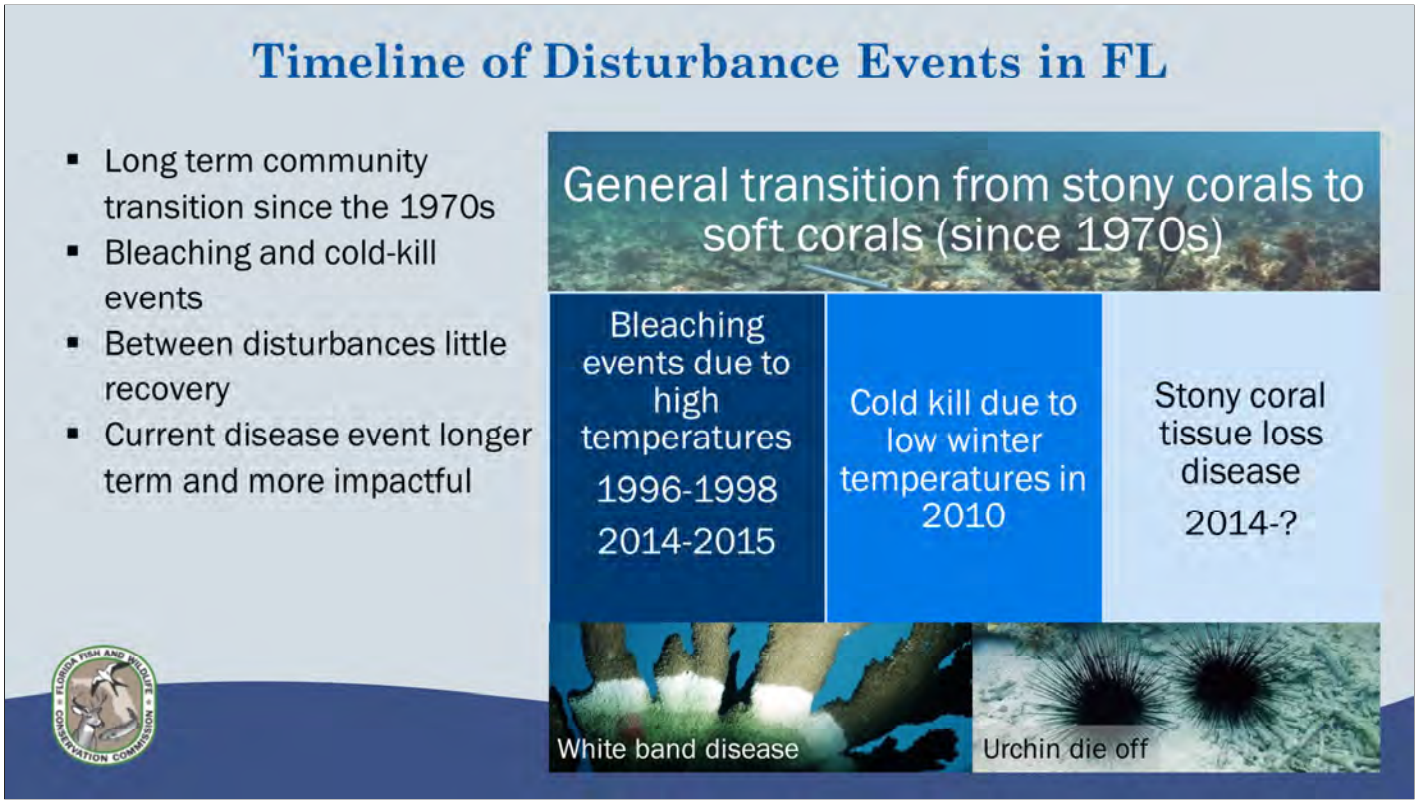
- Among the most biodiverse ecosystems on earth
- Habitat for fish & invertebrates
- Economic impact is more than $7 billion annually
- Coastal protection from storms
- Pharmaceuticals

A recent study estimates that over $130 billion in additional major storm damages would occur globally if average reef height were reduced by 1 meter.

Highly diverse ecosystems are often valuable sources for compounds that can lead to life saving pharmaceuticals.




Both large scale and local factors cause stress on coral ecosystems.




A combination of environmental stressors have resulted in a long term shift of coral communities from stony coral dominated systems to those with more soft coral.

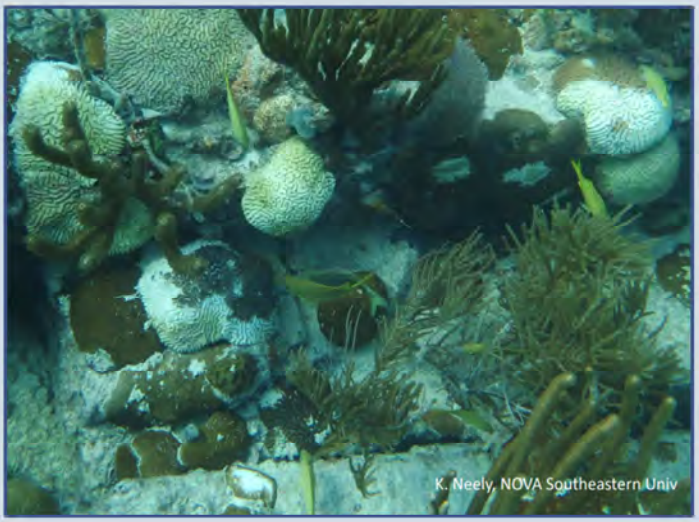
Significant bleaching events (caused by high water temperatures) have occurred twice in the last 25 years as well as widespread mortality due to an exceptionally cold winter in 2010.

Mass mortalities caused by unidentified pathogens in the past have generally only targeted one or two species (e.g. White band disease on staghorn and elkhorn corals, die off of large spine sea urchins). This is not the case with the SCTLD where more than 20 different coral species have been confirmed with lesions.


This is a classic visual by Phil Dustan (College of Charleston) that shows a time series of Elkhorn loss at Carysfort Reef off North Key Largo.

## Stony Coral Tissue Loss Disease

- Impact is unprecedented
- > 20 coral species affected
- Highly lethal – majority of susceptible colonies killed entirely
- Duration – Now entering 5th year in FL
- Scale – reef building corals (boulder and star corals) on majority of reef affected

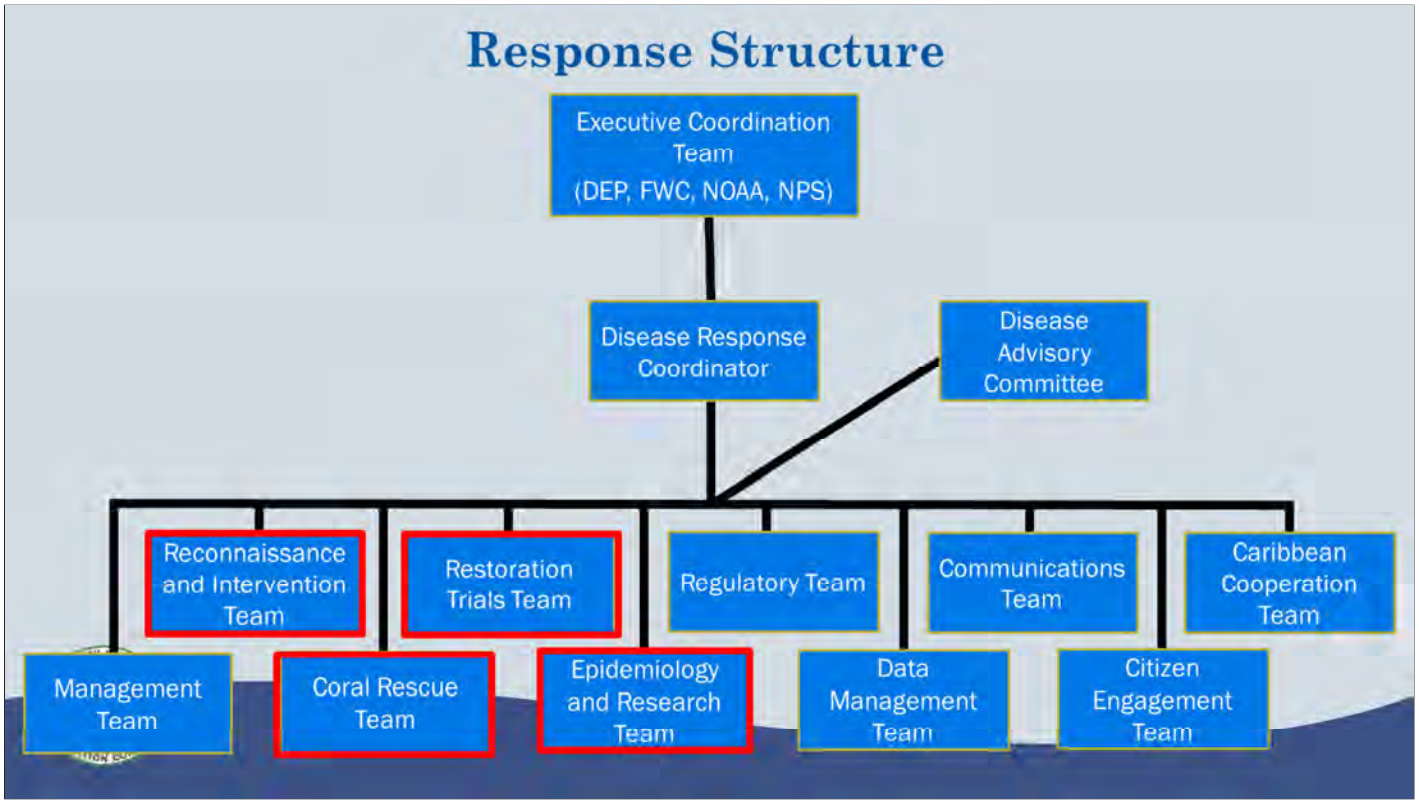



Stony coral tissue loss disease is different from previous stressors in intensity, geographic and ecological scope, and duration.


Progress of the disease front 2014-2019. First detected off Miami-Dade county the disease quickly spread north and south. It spread quickly to the northernmost end of the reef tract. Currently the disease front is southwest of Key West. Coral rescue activities began shortly after the disease front reached Looe Key in 2018.

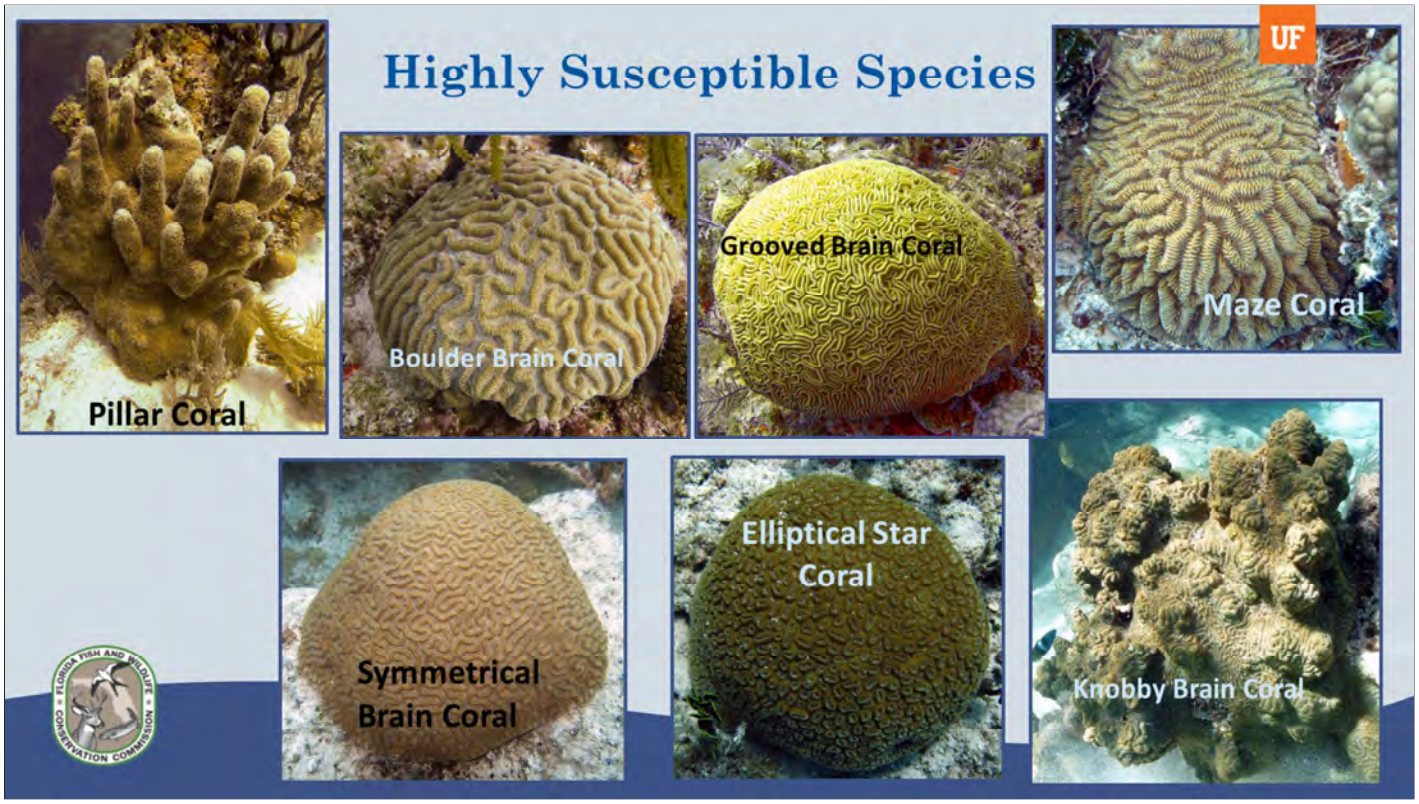

What appears to be the same (or similar) disease has been documented elsewhere in the Caribbean including Mexico, Jamaica, St. Maarten, St. Thomas ( U.S. Virgin Islands), and the Dominican Republic. The scattered nature of these detections (counter to prevailing currents) have lead some to hypothesize that the disease may be related to shipping activities or ballast water management activities.

Note that observations are dependent on dive programs conducting surveys. The disease may be present in other areas where surveys are not currently being conducted.




The disease response is organized into multiple teams. The organization is lead by a group of senior managers from the Florida Department of Environmental Protection, FWC, the National Oceanic and Atmospheric Administration, and the National Park Service. This overview will focus on the roles and progress made by the four teams outlined in red.


Dozens of partners make up the response effort thus far and this number is likely to grow substantially.




These massive framework corals, which are critical in building and maintaining the structure of our corals reefs are the most susceptible to the disease. In many parts of the reef, these individuals have been wiped out entirely. Much of the focus of coral rescue and intervention activities has been on these species.

Pillar coral is federally listed as threatened under the Endangered Species Act.

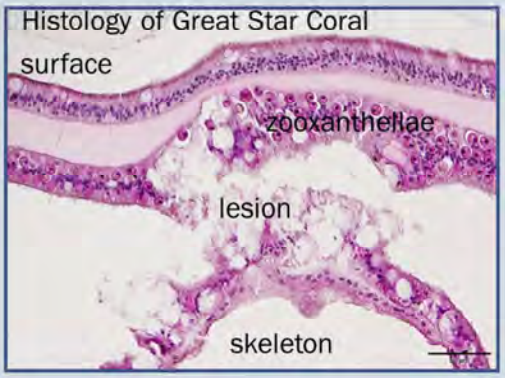

These species are susceptible to the disease but do not always experience whole colony mortality.

Lobed and mountainous star corals are federally listed as threatened under the Endangered Species Act.


This time series of photos demonstrates how rapidly the disease can spread and result in whole colony mortality.

## Epidemiology: Finding the Pathogen

- Pathogen is waterborne
- Lesions in 5 species are similar, progress internal to external
- Lesions as if "tissue is dissolved"; bacteria not found microscopically
- Distinct bacterial community in diseased tissue slurry mix, with 2-3 dominant groups
- Lesions on 3 species (in lab) halted with antibiotic treatments;
- Bacteria important for disease progression, but disease may be due to a complex of pathogens




Although much work remains, there are some initial results regarding the potential pathogen(s) associated with the disease.

## Epidemiology: Next Steps

- Microbiome (coral microorganism community) analyses
- Histopathology of diseased, "apparently healthy", and healthy colonies
- Experimental transmission studies
- Genetic sequencing to target DNA for potential pathogens
- Sample sites to determine if same microbiome is present through time (transition from healthy to disease)
- Develop probiotics (good microbes) to treat SCTLD in field and in rescued corals to prevent SCTLD transmission


Disease vectors in corals are notoriously difficult to determine. Analyses of microbiomes and genetic techniques will be used to speed up the process.

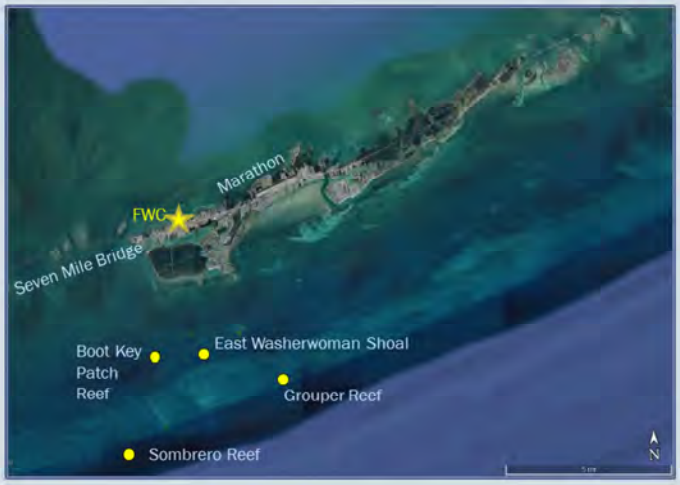
## Spatial Epidemiology: How the Disease Progresses

- Jan 2018: Before diseased arrived established four 'Sentinel Sites' in the middle Keys
- Created detailed maps of each site
- Tracked each coral colony for disease
- > 20 species, 1,350 colonies

FWC staff organized an intensive field effort ahead of the disease front beginning in January 2018.

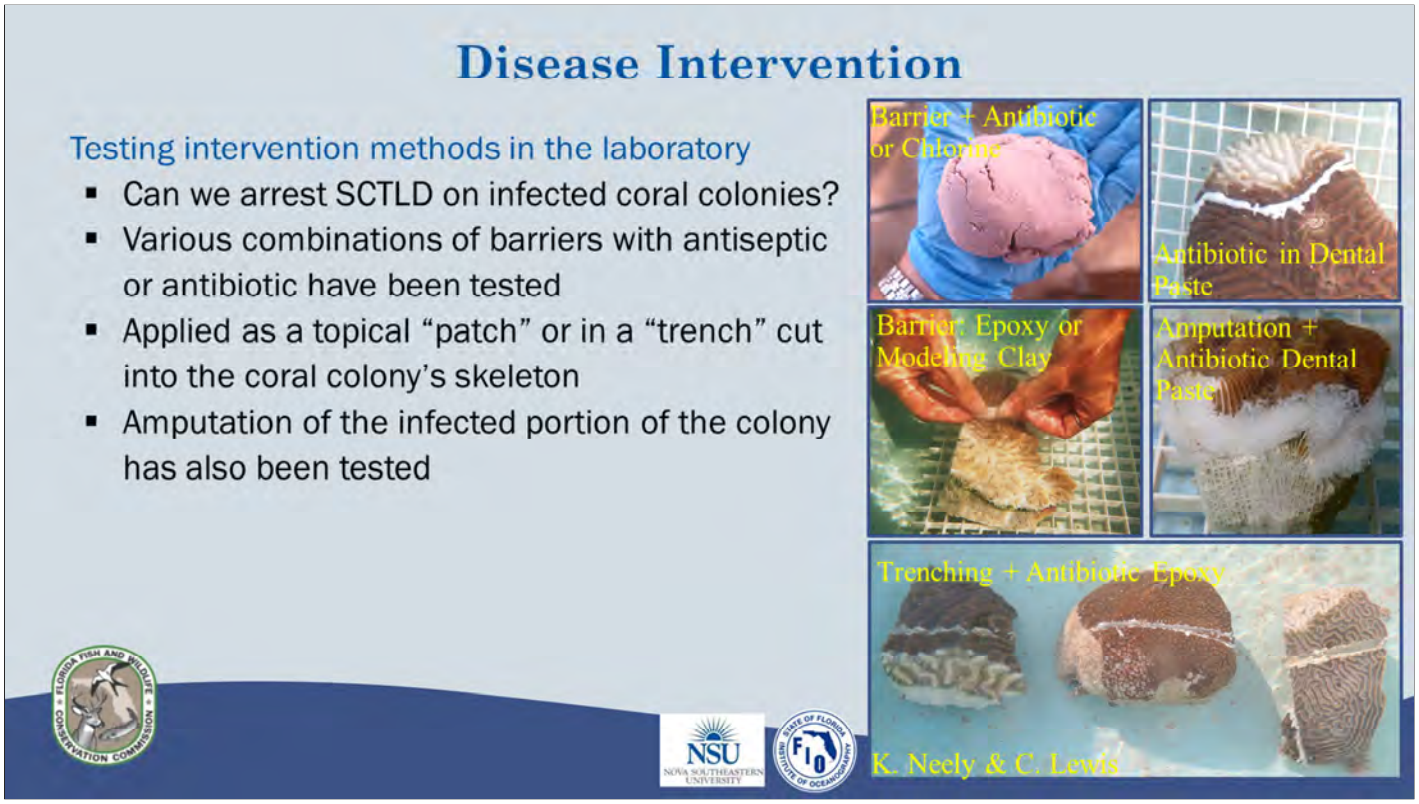
## Spatial Epidemiology: How the Disease Progresses

- Disease arrived at all four sites simultaneously even though some separated by several miles
- Within each site no evidence that disease moved from colony to colony
- Large swaths of the reef are infected simultaneously
- Each coral colony is infected independently

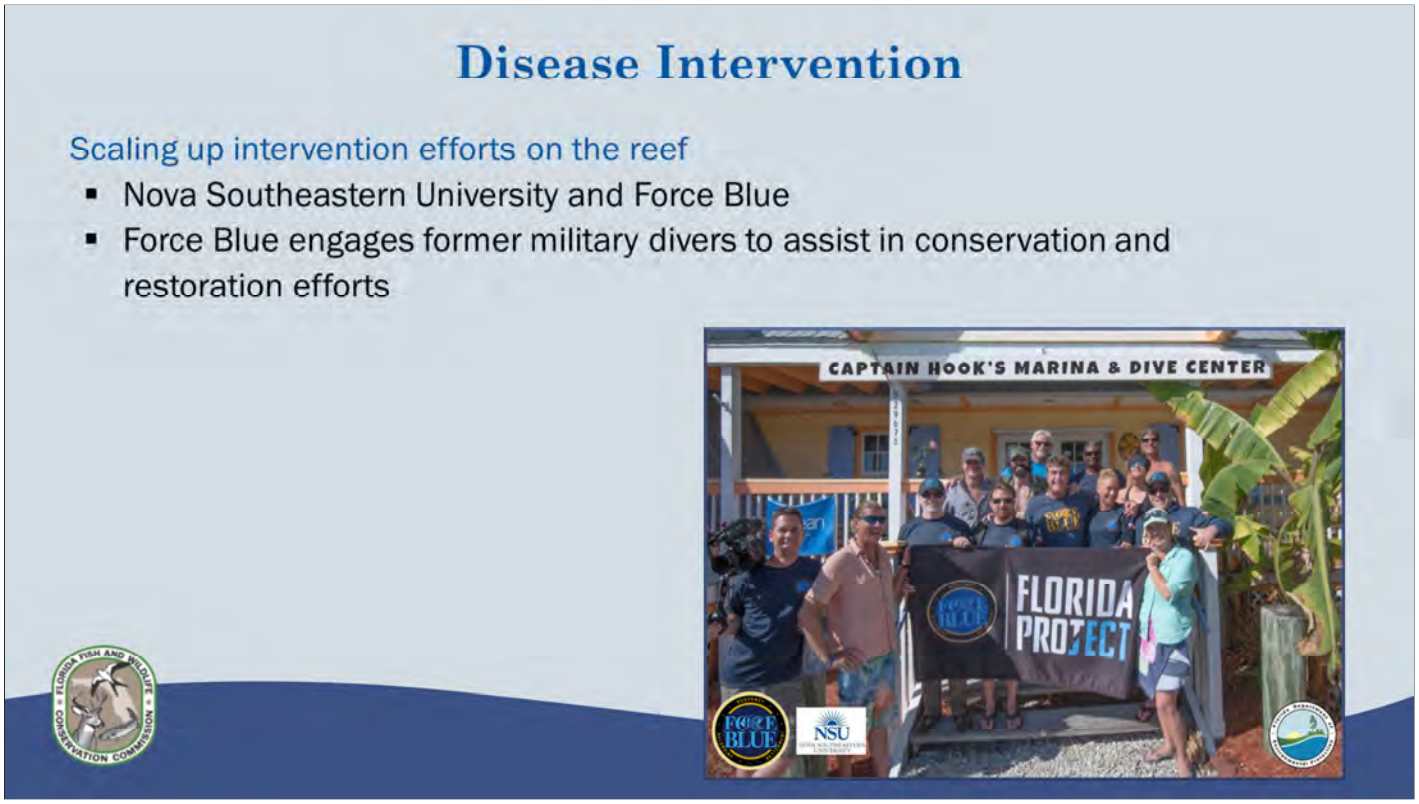



The disease moved through this area quickly. It was first detected in late February 2018 and most colonies of highly susceptible species were dead within a month.

Detailed monitoring will valuable information on the nature of the disease and how it spreads.




A number of intervention, or treatment, techniques have been tested in the lab. Applications of antibiotics or chlorine embedded in a patching compound coupled with trenching of the coral skeleton to create a barrier have been the most promising.




Field treatment of corals for disease is a labor intensive effort and will require additional support from volunteers. One group, force blue, in conjunction with Nova Southeastern University, has been very active and helpful in this regard.

# Disease Intervention

Testing intervention on the reef

- Nova University and Force Blue have treated ~650 diseased coral colonies in the upper and middle Florida Keys this year
- Infected colonies treated with two methods
- Amoxicillin base applied with a syringe to the disease margin
- Chlorine/Epoxy applied to disease margin and in a trench 5cm away from the disease margin


To date nearly 700 coral colonies have been treated with one or more treatment methods.

# Disease Intervention

Testing intervention on the reef

- Failure rates: percentage of colonies where the disease has crossed the barrier
- Failure rates lower on colonies treated with amoxicillin than those treated with chlorine
- Failure rates remain higher than desired

| Laboratory Trials | |
|---|---|
| Failure Rate: Amoxicillin | Failure Rate: Chlorine |
| 22% | 90% |

| Field Trials | |
|---|---|
| Failure Rate: Amoxicillin | Failure Rate: Chlorine |
| 23% | 59% |

Failure rates are relatively high with these treatments but somewhat lower with antibiotics than chlorine treatments.

## Disease Intervention: Results to Date

- For highly susceptible corals, new colonies regularly becoming infected
- ~25% of colonies treated by patches have required further trenching
- Even when patches hold, new lesions appear, requiring further patching
- Some colonies have required additional patches on five different occasions
- Intervention of this type not feasible on a reef-wide scale

Current treatment methods are only moderately effective and intervention of this type is not feasible on a reef wide scale.

# Disease Intervention

Testing intervention on the reef

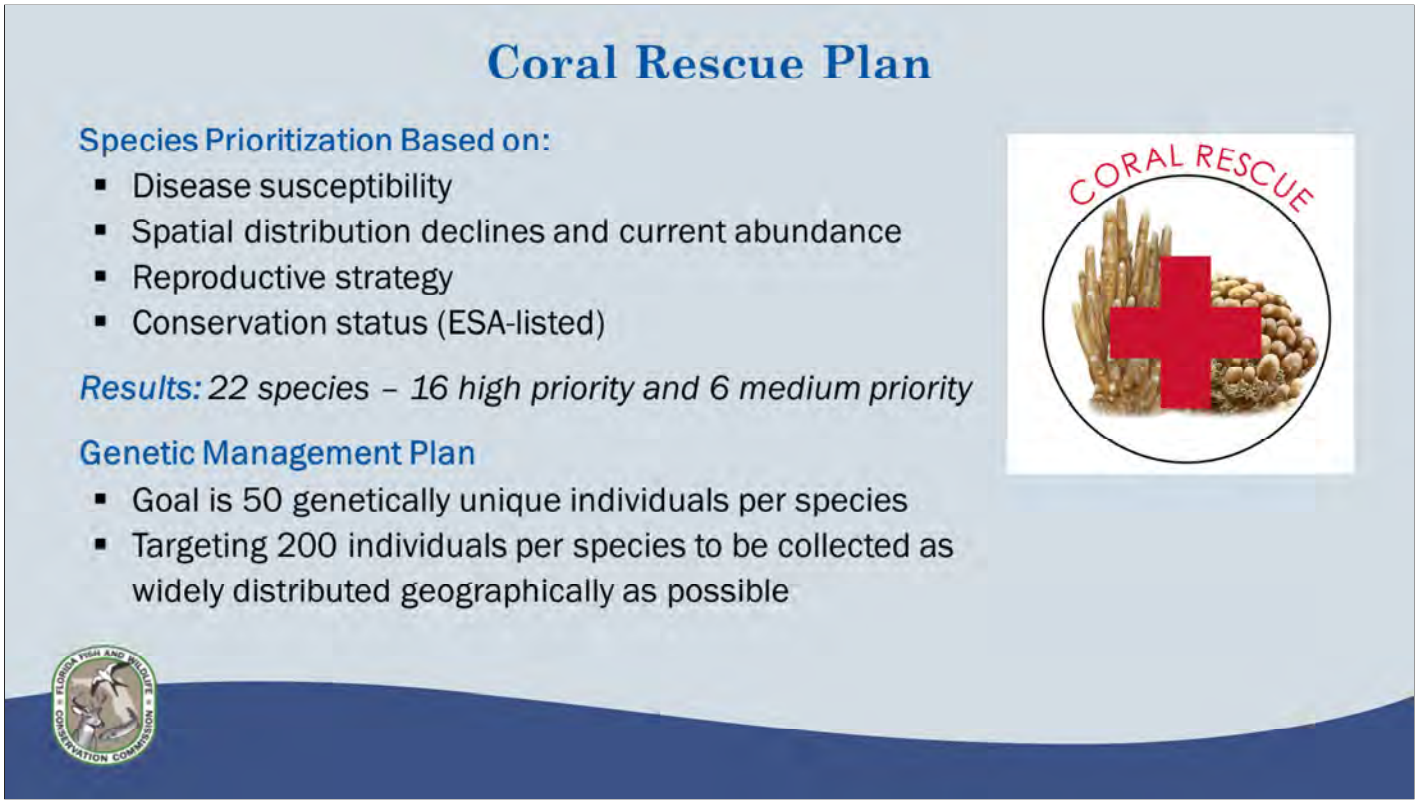
- Can we mitigate SCTLD on a moderate scale with these methods?
- FWC testing this premise on Mote Marine Lab's sentinel sites
- Mapped every coral colony within three 100m2 plots (>1000 colonies)
- Treating all diseased coral colonies and will compare with untreated sites


Treatment will continue intensively on Mote Marine Laboratory sentinel sites off Summerland Key. Every coral colony on this site is mapped and will provide valuable data on treated vs. untreated sites.

## Coral Rescue

- Removing healthy corals from the wild is unprecedented
- Efforts to rescue colonies of priority species ahead of the disease front
- Rescued corals to be kept in on-land facilities for future restoration efforts
- Genetic analyses conducted to gauge diversity
- Rescued corals serve as broodstock for propagation efforts

Due to the rapid spread of the disease to the lower Keys, FWC and NOAA made the unprecedented decision to remove healthy corals from the wild ahead of the disease front.

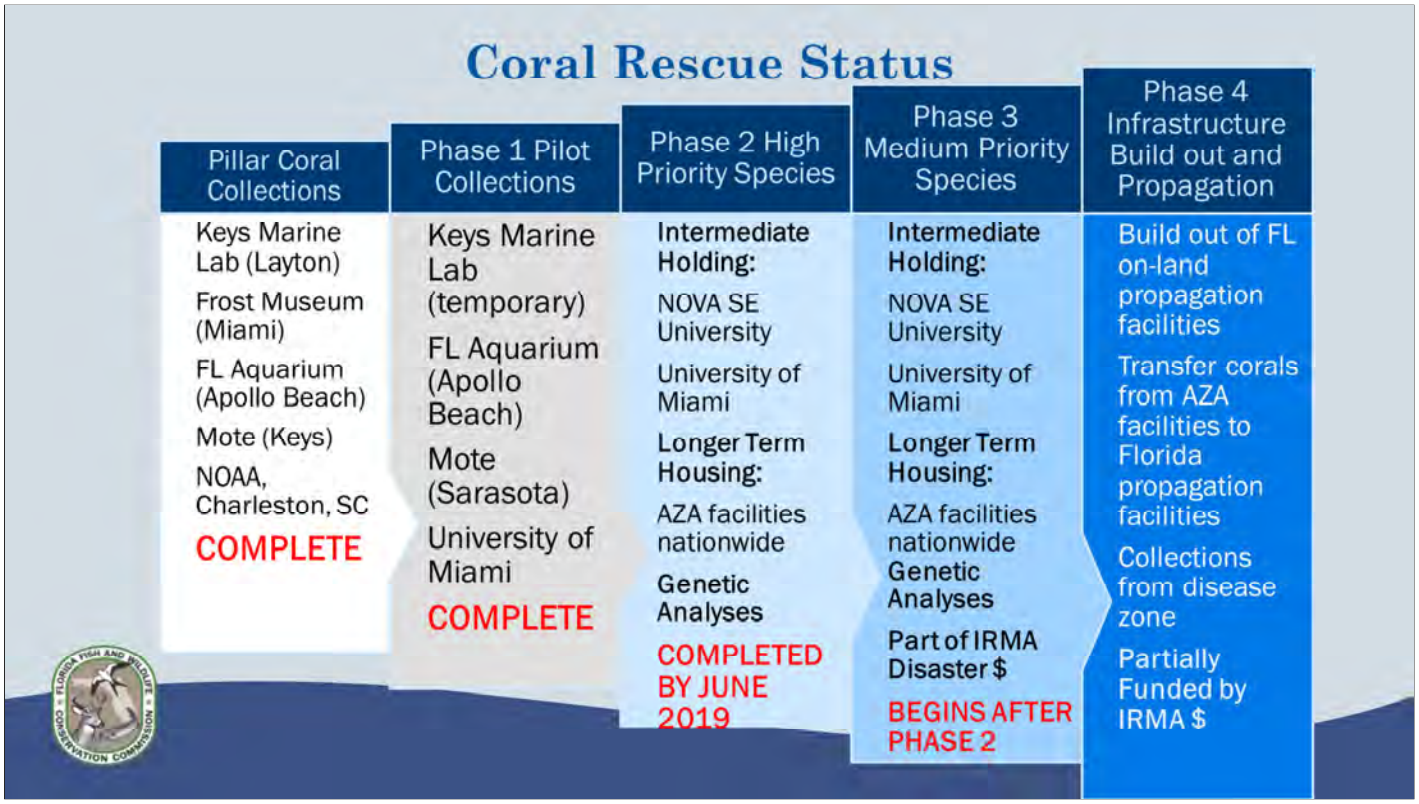



Coral rescue efforts were prioritized by species. The prioritization resulted in 16 high priority and 6 medium priority species – 22 species total.

The team developed a Coral Rescue Genetic Management Plan to guide coral Rescue Collections, and to ensure that sufficient genetic diversity will be collected to support restoration activities. The target number for restoration was 50 genetically unique individuals per species, which would require 200 individuals per species to be collected as geographically spread out as possible. With only a limited amount of the reef tract considered disease free, this will be a challenge.


One of the more challenging aspects of coral rescue is to find suitable facilities to house and provide care for the 4,500 corals that will be collected over the course of the Rescue Plan. The Association of Zoos and Aquariums (AZA) has helped us take on this challenge.

In November 2018, AZA established the Florida Reef Tract Rescue Project, hired a project coordinator, and identified the "Florida Four" which are the Florida AZA facilities that would be taking on the bulk of the responsibility for housing and caring for rescued corals. These facilities are Florida Aquarium, Sea World, Disney, and Mote Marine Aquarium. AZA then developed a survey to identify interested AZA facilities nationwide and vet their ability to participate in this project. As a result of the survey and vetting process, 12 primary holding facilities have been identified as ready to take corals immediately, 6 facilities have been identified as secondary holders and could be ready to take corals within a year, and 42 facilities did not meet the project requirements but have been identified as project friends and will support the project in other ways. This is the first time that AZA professionals and resources have been sought out to assist State and Federal agencies with responding to a marine environmental crisis, and it has resulted in a national public-private partnership for the conservation and restoration of Florida's corals



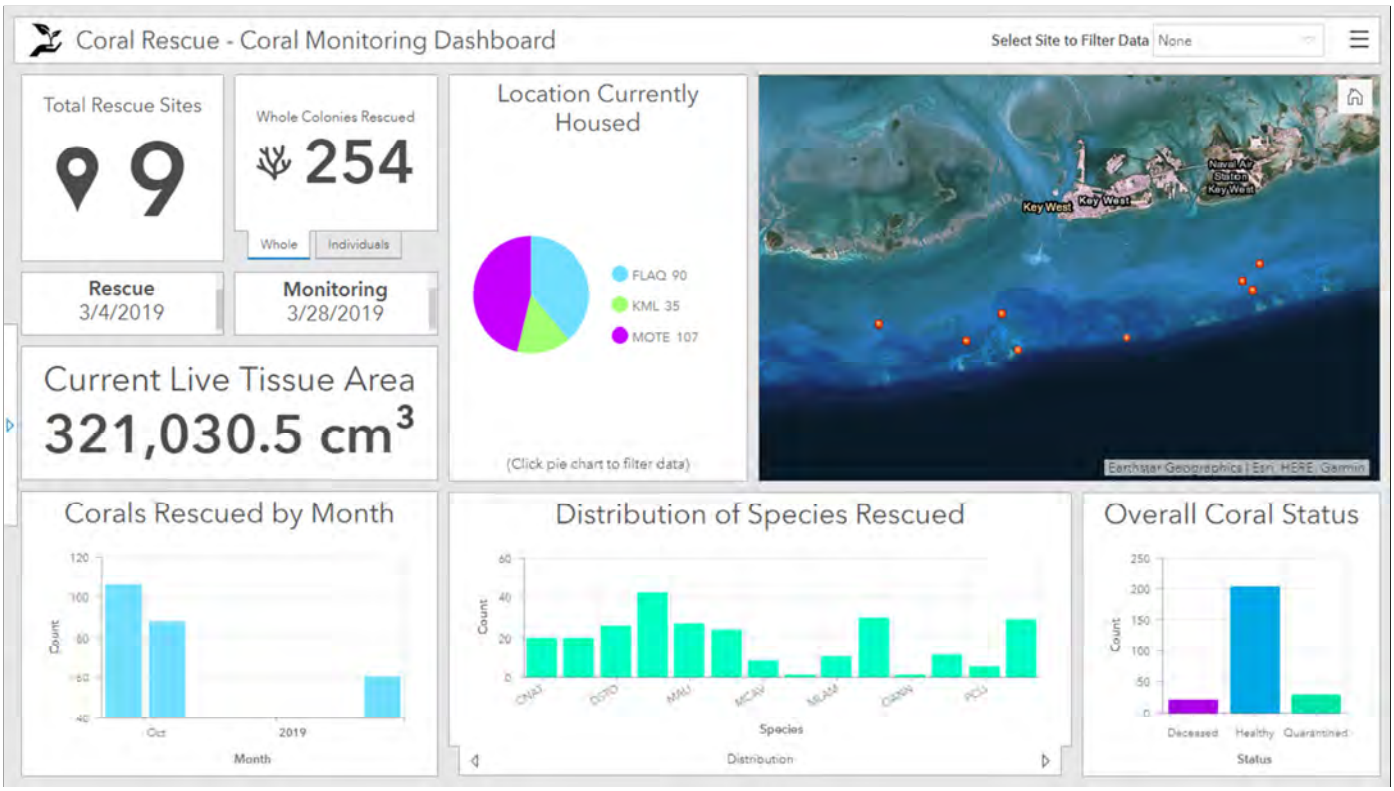

This graphic summarizes coral rescue activities in the plan. Due to the high susceptibility of pillar corals and concern over localized extinction, fragments of this species were collected as early as 2016. The main portion of the rescue plan will occur in five phases.

Phase 1 – Pilot collections of high priority species were conducted to test protocols for collections and transport; determine staff and contractor resources required; identify coral care needs; and initiate genetic analyses.

Phase 2 – This phase is currently ongoing and consists of collecting and transporting high priority corals (3000 total) to intermediate holding facilities where they will be maintained for up one year before being transferred to AZA facilities nationwide for longer-term holding. Phase 2 has been funded by the National Fish and Wildlife Foundation and is anticipated to be completed by June 2019.

Phase 3 will start after the completion of Phase 2 and consists of the collection of the medium priority coral species (~1,200 corals and transport to intermediate holding facilities and eventually longer-term AZA facilities nationwide. Phase 3 is proposed to be funded by FWC Irma Fishery Disaster Funds and will begin as soon as funds become available. AZA is also fundraising to support their facilities coral care obligations.

Phase 4 will consist of building out Florida on-land propagation facilities – the goal is to have four of these facilities; transporting corals from AZA holding facilities to the Florida on-land propagation facilities; the collection of high and medium priority corals or their gametes that remain in the disease zone to incorporate potentially resilient genes during propagation activities; and expansion of in-water nurseries to support the grow-out of propagates. Funding for building out of the first Florida on-land propagation facility (Florida Aquarium, Center for Conservation) will be partially covered by Irma Fishery Disaster Funds. Additional funding to complete implementation of Phase 4 has not yet been identified.




A web based coral rescue dashboard has been built to track rescued corals (http://myfwc.maps.arcgis.com/apps/opsdashboard/index.html#/eba7dc2cabc64f60819e6d4b084d94cd)

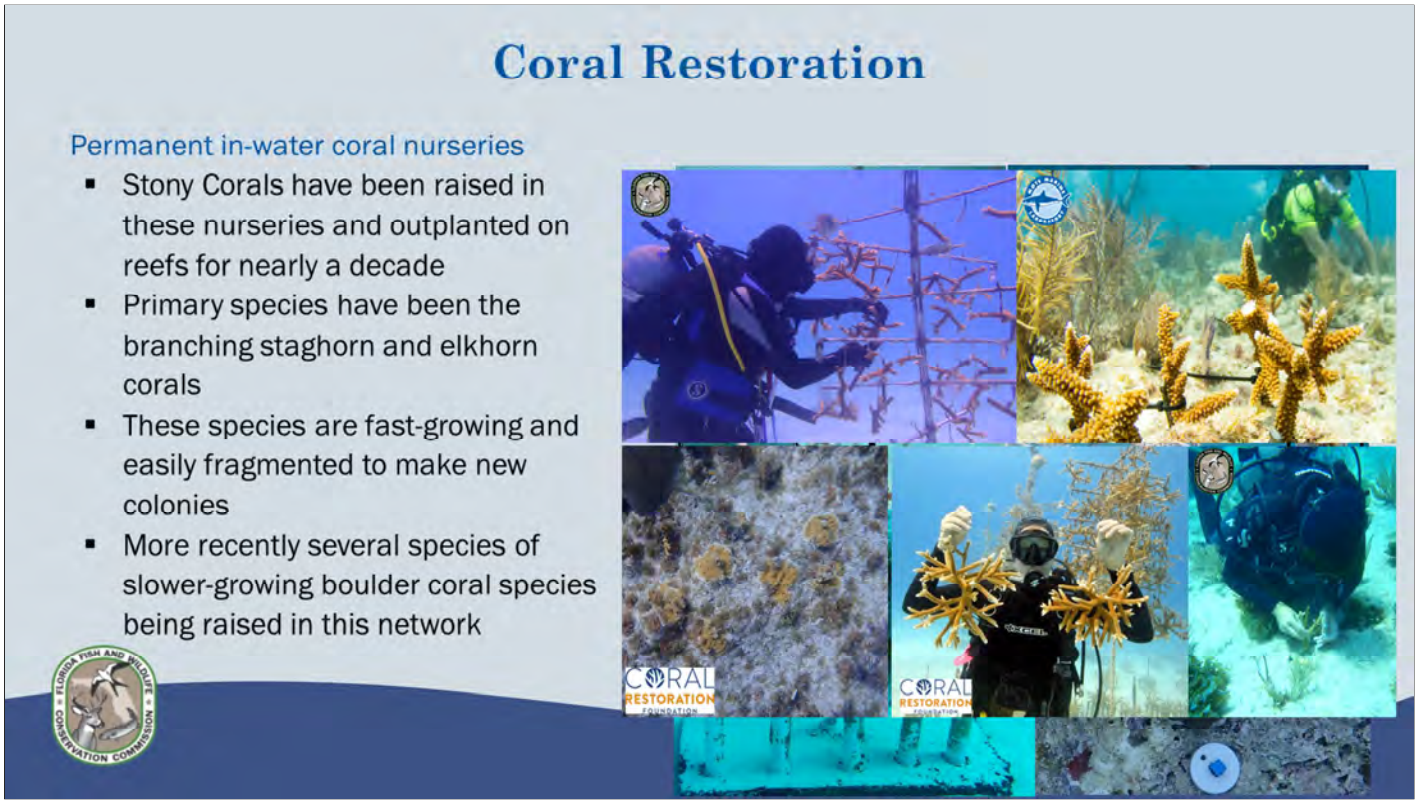

33 corals arrived at the National Mississippi River Aquarium

Up to date (4/15) shipments to AZA partners - 33 Corals to NMRA in Iowa, 60 corals to Adventure Aquarium in New Jersey, 60 corals to Moody Gardens Aquarium in TX.


Rescued corals held at the Florida Aquarium have produced young corals that are now settling on tiles in the aquaria. These young corals are from species that brood their young – so they brought the babies with them. A good sign that the corals are doing well.


Current restoration methods for corals include both in-water and land-based nurseries. Corals can be reproduced asexually (micro-fragmentation) or sexually. Sexual reproduction adds genetic diversity.


A network of in-water coral nurseries has been built in multiple locations over the years. This network will need to be expanded for scaling up restoration in the future.

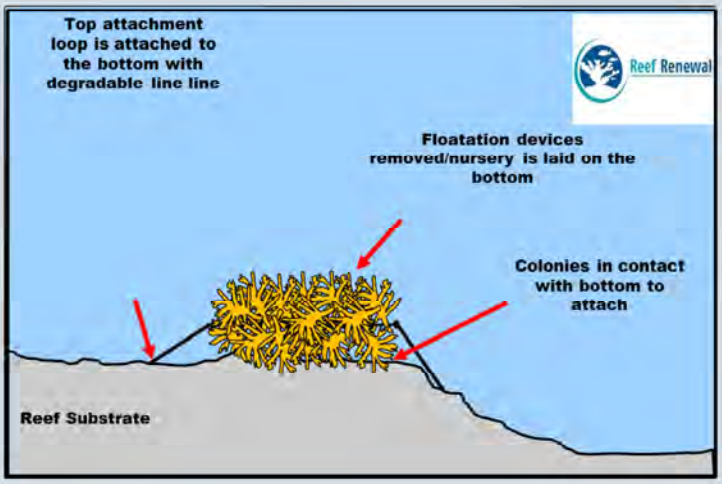



Restoring the foundational species has long been the strategy of ecosystem restoration in terrestrial ecosystems. The comparatively new efforts in coral reef ecosystems has mimicked this strategy by focusing on restocking foundation species – namely, the reef building "hard" or "stony" corals. Throughout the Caribbean, there are more than 150 coral propagation operations spanning over 20 countries raising corals within either land-based or in-water nurseries for use in restoration efforts. In south Florida, a network of in-water coral nurseries have been established along the Florida Reef Tract in addition to a few land-based nurseries.

# Coral Restoration

Temporary pop-up in-water coral nurseries

- "Pop-up" nurseries – new concept
- Temporary nurseries established on the reef to be restored
- Degradable materials
- Coral colonies left to grow
- Entire nursery lowered to substrate




Unlike current in water nurseries, which are typically on sand flats, pop-up nurseries are set up on the reef itself. As the corals grow over time the entire nursery is lowered to the substrate so the coral can attach to the reef.

# Coral Restoration

## Land-based micro-fragmenting and reskinning

- Pioneered by Mote Marine Laboratory
- Land-based process to enhance propagation of slow-growing boulder coral species
- Micro-fragmenting uses a diamond blade band saw to separate small amounts of tissue from donor colonies
- Fast growing: A 1 $cm^2$ fragment will cover over a tile in 4-12 months; can then be subdivided into 5-10 new micro-fragments

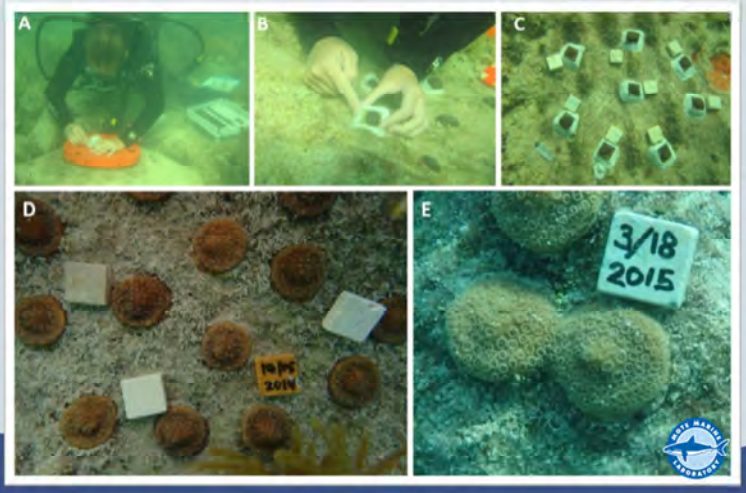
Micro-fragments growing at Mote Marine Laboratory

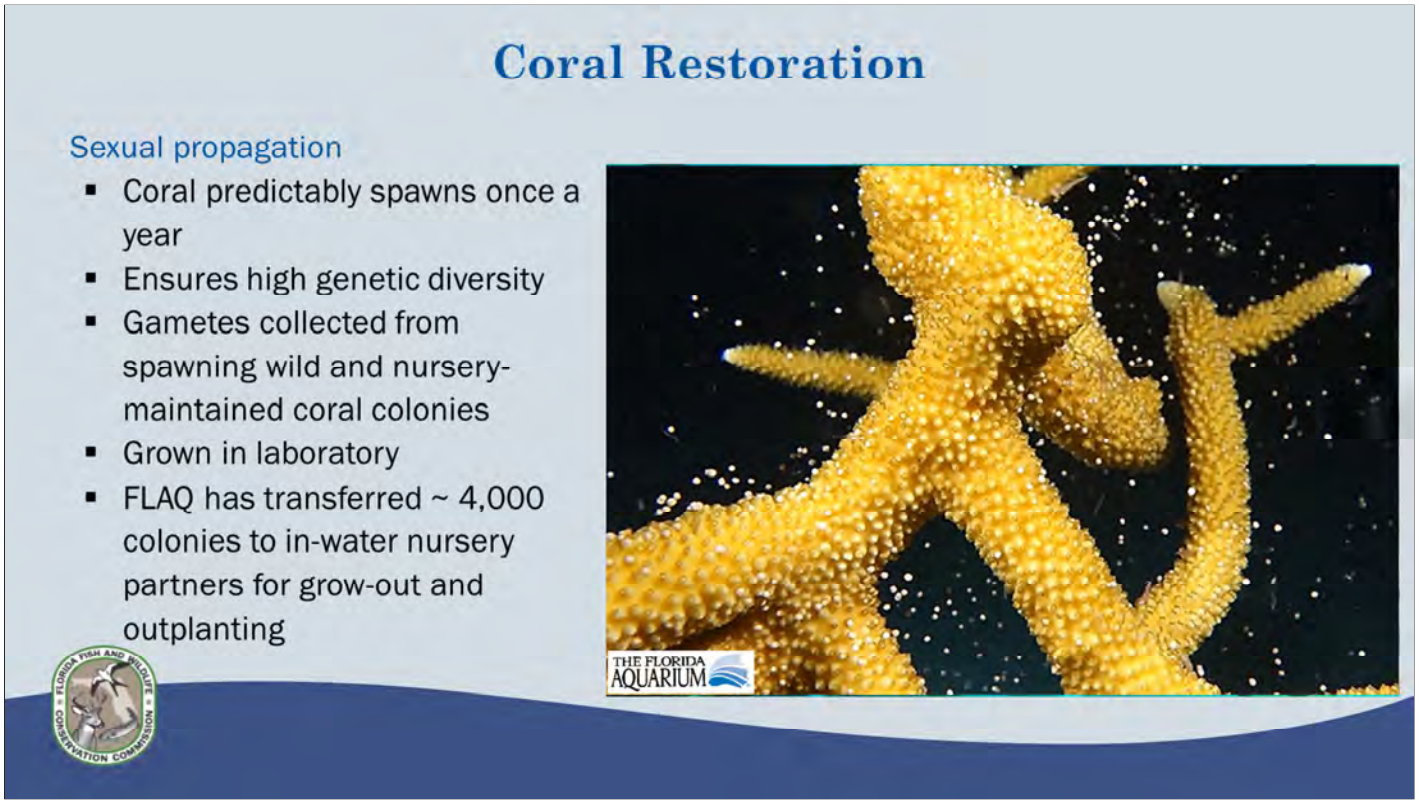
Micro-fragmentation and reskinning is a process that has been very successful for the massive framework building corals.

# Coral Restoration

## Land-based micro-fragmenting and reskinning

- Fragments outplanted by epoxying them to the skeleton of a dead coral where they grow together, eventually "reskinning" the skeleton



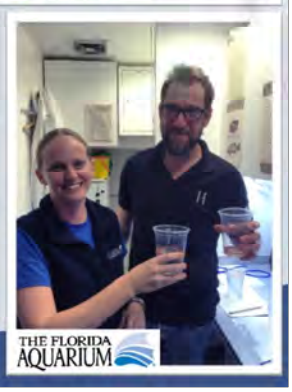



Gametes (eggs and sperm) can be collected during spawning events, which occur predictably once a year and us to raise corals in the lab.

# Coral Restoration

Induced sexual propagation

- New technique – Predictably spawning coral species in the laboratory
- Florida Aquarium and other partners will use this method to produce coral for Florida's restoration efforts
- Use rescue corals to create genetically diverse offspring for restoration efforts
- First fully lab-induced spawning event planned for August 2019


Several organizations, including the Florida Aquarium and Mote Marine Laboratory are readying efforts to induce spawning in the lab. While an individual coral will still only spawn once per year, these techniques show great promise for increasing genetic diversity and the number of corals available for restoration work.

# Coral Restoration

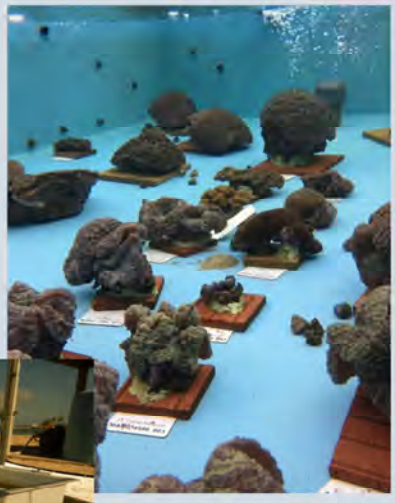
Restoration in the context of the ongoing disease event

- The ongoing disease event along the south Florida reef tract has made restoration event more urgent
- All of these coral propagation techniques will be vital
- Increasing the capacity of each technique will be necessary
- Coral reef restoration in Florida will require a sustained long-term effort by all partners


Restoration of corals will be an important activity for many years and needs to be scaled up significantly.

# Summary of Strategy Moving Forward

- Investigation into cause of the disease and potential treatment will continue
- Disease surveillance and intervention treatments will continue with the aid of volunteer networks
- Rescue ahead of disease front top priority, AZA support is critical
- Identification and genetic analysis of survivors in the disease zone
- Build out of propagation and restoration infrastructure for long term efforts



# Panel Discussion

Panel Members:

- Michael Crosby, Mote Marine Laboratory
- Sarah Fangman, NOAA Florida Keys National Marine Sanctuary
- Andy Wood, Florida Aquarium
- Scott Graves, Coral Restoration Foundation
- Blake Ushijima, Smithsonian Marine Station, Fort Pierce
- Joanna Walczak, DEP Florida Coastal Office