MOTE MARINE LABORATORY & AQUARIUM

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Coral Reef Research and Restoration:

An Update on Activities and Accomplishments during 2020

Summary

Mote Marine Laboratory's Coral Reef Research and Restoration initiatives supports numerous scientists working across multiple disciplines to reverse decades of ecosystem decline, bringing new life and new hope to Coral Reefs around the world. Over the last decade, Specifically, Mote is:

- Identifying disease-resistant and climate-resilient corals and using this knowledge to ensure the success of long-term reef restoration efforts
- Creating new genetic diversity within coral species through sexual propagation of branching corals and micro-fragmenting of massive corals
- Restoring Florida's Coral Reef through outplanting disease-resistant and climate-resilient corals, bringing degraded reefs back to life with living coral coverage
- Preserving genetic diversity for future research, propagation, and restoration by establishing a storm-safe, inland coral gene bank
- Expanding capacity to increase coral spawning from once-yearly to year-round through new spawning methods and technology

Current coral health and disease research initiatives include:

- Identifying resilient corals for restoration by quantifying phenotypic variability to three major stressors: high water temperature, ocean acidification, and disease
- Developing methods for the treatment of coral diseases at Virgin Islands National Park, St. John and Buck Island Reef National Monument, St. Croix USVI
- Collaborating with the Department of Environmental Protection, the University of Miami, and NOAA AOML to find a biomarker for resistance for SCTLD and use the information to reproduce disease-resistant corals creating new resistant genotypes
- Collaborating with Oregon State University to examine the effect of nutrients (like manmade runoff, fertilizer, agriculture) in water on disease susceptibility
- Collaborating with FWC and NOAA AOML, to characterize the microbiome of corals with SCTLD to determine if a specific microbial signature exists among species
- Finalizing development of a long-term deployment 'Coral Cam' which will greatly enhance the capability of scientists to identify not only when coral mortality occurs, but

also how it occurs - allowing scientists to pick the best genotypes to resist specific stressors

- Exploring how one particular species of butterflyfish (Chaetodons) use sensory cues to locate infected corals from long distances and target SCTLD-lesioned corals
- Evaluating the epigenetic/microbiome-mediated mechanisms underlying the heritability of disease resistance in staghorn corals (in collaborations with Texas A&M University and University of Oregon, respectively)

Reef Restoration Breakthroughs

Mote Marine Laboratory recently celebrated two major breakthroughs in coral reproduction science:

During the summer of 2020, Mote became the first scientific organization to carry out every step of the staghorn coral sexual propagation process— from spawning and outgrowing in the laboratory, to outplanting and maintaining on the reef until they reach sexual maturity, become gravid, and spawn again to create an entire second generation of disease-resistant and climate-resilient corals. In the coming year, Mote will study the fecundity of this second generation of corals to learn if there are trade-offs between their known resilience and their ability to contribute to future generations of this endangered coral.

In another breakthrough, Mote-grown mountainous star corals that were outplanted to the reef grew to sexual maturity and spawned in record-time. Mountainous star corals are critical to the long-term survival of our reefs, but are extremely slow-growing. It typically takes several decades for these massive, reef-building species to reach sexual maturity and begin propagating in the wild. This summer, however, colonies of Mote-grown corals spawn on the reef in just five years— the first time this has happened anywhere in the world. This newfound accelerated growth cycle for outplanted corals makes it possible to literally shave decades off the reef restoration process.

Using these and other science-based methods, Mote has outplanted over 100,000 corals to date, restoring approximately 100 acres of degraded reef tract. Mote's multi-year goal is to increase by 25% the amount of living coral on Florida's Coral Reef at which point, Mote believes, coral colonies will achieve a critical mass than enables them to propagate, cross-fertilize, and create diverse new strains and generations of corals all on their own, without continued human intervention.

Current restoration initiatives include:

- Determining the cost and benefit associated with outplanting corals of different sizes from Mote's land-based nursery
- Comparing growth rates between field and land-based nurseries after the microfragmentation process
- Characterizing the changing physiology of corals as outplanting occurs from Mote's land-based nursery (collaboration with University of Alabama)
- Developing methods to deter predation on newly outplanted corals (in collaboration with Florida International University)

- Integrating 3D photogrammetry to assess ecosystem recovery of restoration sites
- Quantifying survival and changing physiology of Acroporid corals outplanted to multiple sites in the lower Keys (in collaboration with University of Southern California)
- Assessing the application of probiotics to protect against SCTLD (in collaboration with Smithsonian Research Institute)
- Quantifying the variability of SCTLD occurrence on outplanted corals among sites, regions, and coral species
- Assessing the survival of SCLTD-susceptible corals after conducting regional restoration efforts (in collaboration with FWC, UM, Nova Southeastern University, Florida Atlantic University, Coral Restoration Foundation)
- Assessing the physiology of corals grown using trees versus blocks under different climate change and ocean acidification scenarios
- Assessing impacts of *in-situ* restoration methods on global change resilience of *Acropora cervicornis* (in collaboration with California Academy of Sciences)
- Researching mangroves as refugia for coral against acidification (in collaboration with Woods Hole Oceanographic Institute, UM)
- Assessing the effect of growth material, genotype, and 'mother plug' on growth and survival of elkhorn coral fragments grown in the lab (Mote REU project)
- Assessing the utility of 3D coral scanning to measure coral growth and area in an unbiased way to facilitate global collaboration (Mote REU project)
- Assessing drivers and correlates of staghorn coral condition and survival across the Florida Reef Tract
- Monitoring the growth, health, and sexual maturation of Mote-restored coral populations on the reef
- Tracking sexual reproduction (e.g., timing and synchronicity of spawning) of Mote-restored coral populations over time
- Investigating local environmental drivers, including chemical/developmental toxicity and underlying delayed sexual maturation of restored staghorn populations (collaboration with NOAA)
- Evaluating reproductive compatibility in terms of spawning synchronicity and fertilization success among staghorn broodstock
- Developing and optimizing assisted sexual reproduction protocols including methods for spawning, fertilization, settlement, and rearing of multiple coral species
- Testing for trade-offs between fecundity and disease-resistance among staghorn broodstock
- Optimizing post-settlement survivorship of mountainous star coral sexual recruits

- Using 3D laser scanning as a tool to measure growth rates of live coral microfragments used for restoration
- Exploring the potential for using coral pheromones to regulate spawning timing
- Establishing a technique to identify the gender of great star coral colonies using novel methodologies like microfragmentation-fusion and technologies such as induced spawning
- Developing tools and methodologies for more quickly creating (*ex-situ*) sexually mature colonies to be used for assisted sexual reproduction research
- Using *ex-situ* spawning systems to induce spawning in corals outside of their typical spawning times for various research objectives
- Evaluating the efficacy of outplanting sexually mature adult colonies for promoting the faster recovery of sexually reproducing restored populations
- Assessing endosymbiont differences among corals in the land-based nursery vs. field-based nursery vs. outplant site
- Using parent-offspring staghorn samples to construct genetic maps (in collaboration with Penn State University)
- Expanding Mote's genetic library of genotypes used for restoration including corals from Mote's land-based and offshore nurseries

Special Initiatives

Mission: Iconic Reefs - Mote is a part of an unprecedented effort to restore seven ecologically and culturally significant coral reefs within Florida Keys National Marine Sanctuary. Led by NOAA and informed by years of research, successful trials, and expertise, the mission represents one of the largest investments ever undertaken in coral restoration. By focusing additional efforts on coral reef habitat, *Mission: Iconic Reefs* complements NOAA's ongoing Florida Keys National Marine Sanctuary Restoration Blueprint and management plan.

The effort to put Florida Keys coral reefs on track for recovery is an enormous undertaking requiring long-term collaboration between many partners. *Mission: Iconic Reefs* engages world-renowned scientists, local restoration partners, and other federal and state agencies to save these important, iconic resources. By restoring corals at seven iconic reef sites in Florida Keys National Marine Sanctuary, we can change the trajectory of an entire ecosystem and help save one of the world's most unique areas for future generations.

Upper Keys and Biscayne National Park Expansion Projects

Mote has established a new coral nursery in the Upper Keys to produce new restoration corals with a priority for the restoration of the Cheeca Rocks Sanctuary Preservation Area, one of the seven iconic reefs. Located on Islamorada, the nursery will house 10,000 coral fragments and produce up to 5,000 corals annually for outplanting each year. The overall footprint will allow facilities expansion and increased production numbers over time. By maintaining 10,000 corals

per year, half of which are outplanted annually, the nursery will become a source of renewable material for ongoing coral restoration in the Upper Keys.

Mote is also expanding its reef restoration footprint in several ways. Mote is collaborating with Biscayne National Park on Florida's east coast, for example, to help restore another species of coral, the critically endangered elkhorn coral (*Acropora palmata*), on a different part of Florida's Coral Reef. Through this effort, Mote will outplant a total of 1,000 elkhorn corals on the reef. Closer to home, on Islamorada in the Florida Keys, Mote is working to establish a new coral nursery that will create the capacity for a citizen science outplanting project at Cheeca Rocks. Currently, there are no reef restoration efforts in the Islamorada area. Mote's expansion here will fill a critical gap in restoration coverage.

Land-based Coral Gene Bank

Mote has created a large-scale, land-based National/International Coral Gene Bank that will serve as a "Noah's Ark" to preserve species and genetic diversity for future research, propagation, and restoration. The facility is located in an environmentally hardened building with redundant power and re-circulating seawater systems on the 200-acre Mote Aquaculture Research Park campus ~ 20 miles inland from the coast. Mote's initial strategy is to maintain dozens of different genotypes each of ~30 corals species endemic to Florida, stored in triplicate independent raceway systems. These coral species and genotype holdings (currently over 1,600 genotypes from 17 species, with ~3,600 additional genotypes from 3 species that will be added over next two years) represent the source of future generations of coral which can be used both for restoration outplanting and resiliency research. Corals grown for research liberate us from needing to harvest wild coral species that are already in decline. Mote has now expanded this facility's focus to include multiple genotypes of additional species that are endemic to the broader Caribbean and other regions around the globe and become a true Global Coral Gene Bank.

The goals of the Mote coral gene bank include: providing a safe-haven for corals that are on the brink of local and regional extinction; maintaining genetically diverse broodstock for future generations of corals; ensuring genetic diversity within restoration populations; creating thousands of new corals through assisted sexual reproduction; eliminating the need for harvesting corals in the wild for research based purposes; enabling year-round spawning; and studying and preserving resilient corals for biomarker development and resilient reef restoration activities.

At present, Mote can screen 20-30 coral genotypes per year. In order to keep up with its own production of new coral genotypes, Mote scientists need to be able to screen hundreds of new genotypes each year to make sure that only those corals that are most resistant to disease and resilient to changing ocean conditions are selected for outplanting on the reef. In 2021, Mote and its partners seek to develop new methods for screening corals to high temperatures and ocean acidification more quickly which will in-turn, speed up Mote's reef restoration process.

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Collaborative Partners (Partial List)

Research Partners

Association of Marine Laboratories of the Caribbean
Association of Zoos & Aquariums
Biosphere 2 Arizona State University
California Academy of Sciences
CARMABI (Caribbean Research and Management of Biodiversity)
Coral Restoration Foundation
Florida Aquarium
Florida Atlantic University
Florida Department of Environmental Protection – Florida Coastal Office, Florida Park Service
Florida Fish and Wildlife Conservation Commission – Fish and Wildlife Research Institute
Florida Institute of Technology
Florida International University
Florida Keys National Marine Sanctuary
George Mason University
Louisiana State University
National Fish and Wildlife Foundation
National Marine Sanctuary Foundation
National Park Service (Biscayne National Park, Dry Tortugas National Park, South Florida/Caribbean Network)
NOAA (Coral Reef Conservation Program, National Centers for Coastal Ocean Science, Florida Keys National Marine Sanctuary)
NOAA Atlantic Oceanographic and Meteorological Laboratory
Nova Southeastern University/National Coral Reef Institute
OceanX
Oregon State University
Penn State University
Perry Institute of Marine Science
Rice University
Scripps Oceanographic Institute
Smithsonian Conservation Biology Institute
Smithsonian Institution
The Nature Conservancy
United States Geological Survey (National Wildlife Health Center)
University of Alabama
University of Florida

University of Louvain, Belgium
University of Miami
University of Miami Rosenstiel School of Marine and Atmospheric Science
University of South Florida
University of Southern California
University of Texas Arlington
University of Texas, Galveston
University of the Virgin Islands
Woods Hole Oceanographic Institute

Restoration Partners
Biscayne National Park
Florida Fish and Wildlife Conservation Commission
National Marine Sanctuary Foundation
National Oceanic and Atmospheric Association
Reef Renewal
Coral Restoration Foundation
The Nature Conservancy
University of the Virgin Islands

Community Partners
Boy Scouts of America SEABASE Program
Captain Hook Dive Center
Combat Wounded Veteran Challenge
DiveN2Life
Florida Keys Eco-Discovery Center
I-CARE: Islamorada Conservation and Restoration Education
Junior Scientists in the Sea
Scubanauts, International