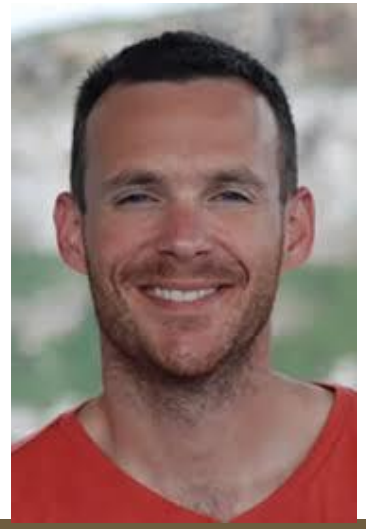
Lessons Learned from the 2023 Caribbean Bleaching Event and Preparing for 2024

Caribbean Coordination Team Meeting
May 13, 2024

AGRRA | MPA connect | ORE Ocean Research & Education Foundation | NOAA CORAL REEF CONSERVATION PROGRAM | Reef Resilience Network | The Nature Conservancy

Dr. Derek Manzello



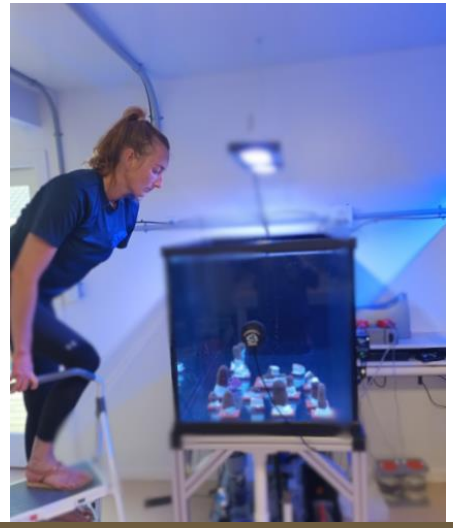
Dr. Carlos Toledo-Hernàndez

Simon Walsh

Rachel Ionata

Matt Davies

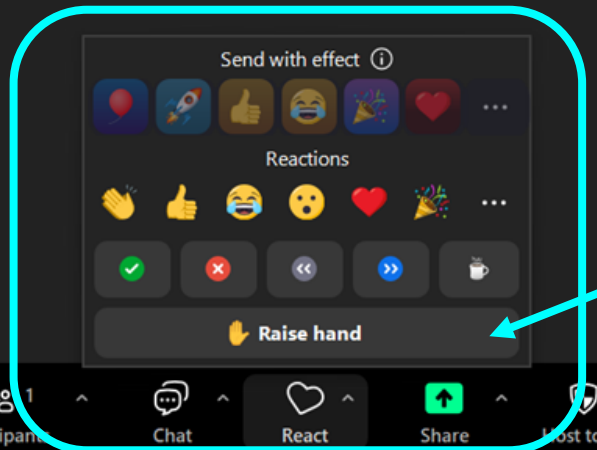
Logan Williams



zoom
Workplace

View

Caitlin Lustic

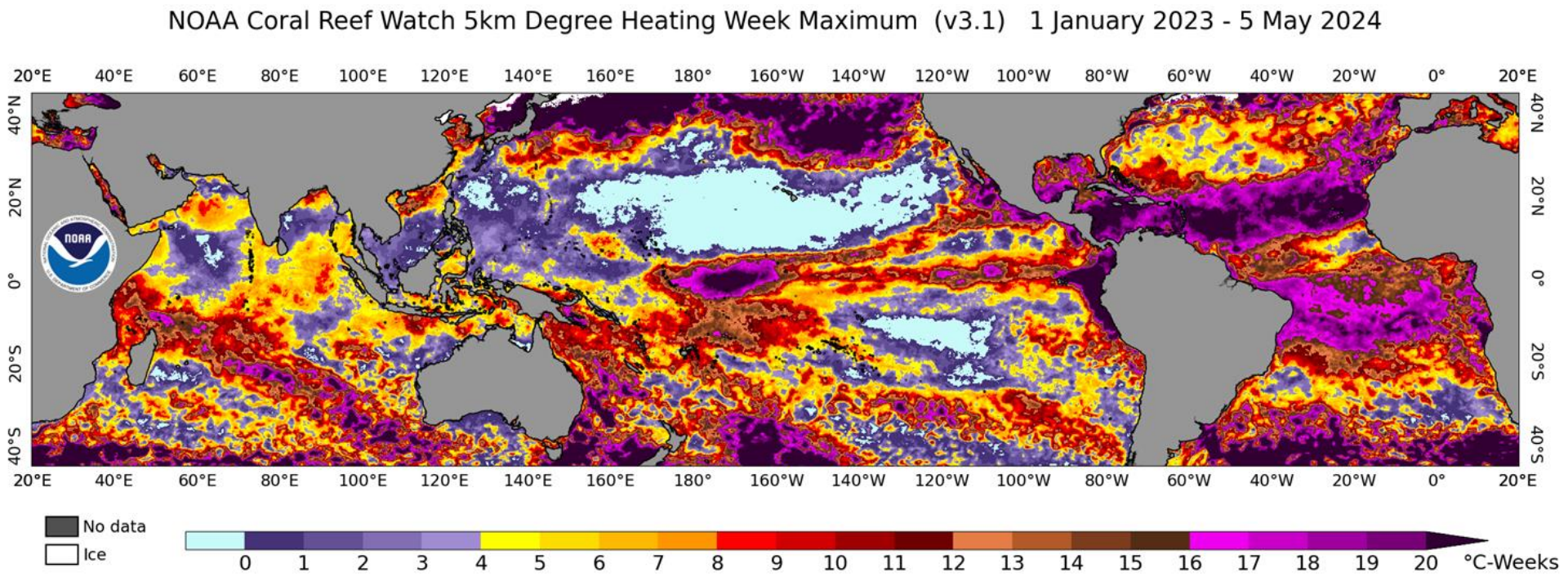


Caitlin Lustic

Audio | Video | Participants 1 | Chat | React | Share | Host tools | AI Companion | More | End

The 4th Global Coral Bleaching Event (GBE4): 2023 - ?

Derek Manzello, Ph.D.
NOAA Coral Reef Watch



NOAA CORAL REEF CONSERVATION PROGRAM

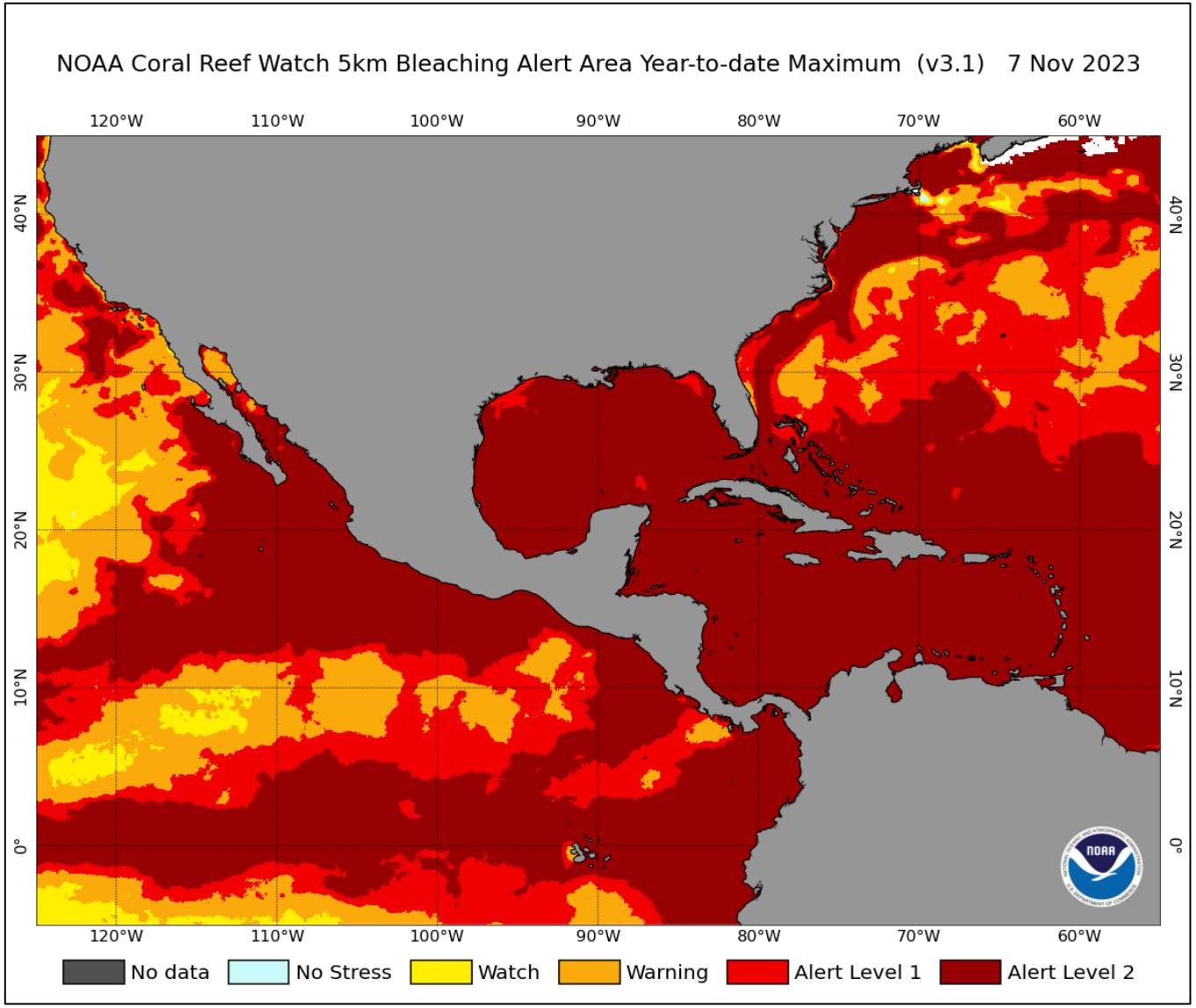
cisess Cooperative Institute for Satellite Earth System Studies

NOAA CORAL REEF WATCH

Bleaching Alert Levels: *A New Reality*

Bleaching Alert Level 1 (4 < DHW < 8)
Significant Bleaching Likely

Bleaching Alert Level 2 (DHW > 8)
Severe Bleaching and Significant Mortality Likely



New Bleaching Alert Levels

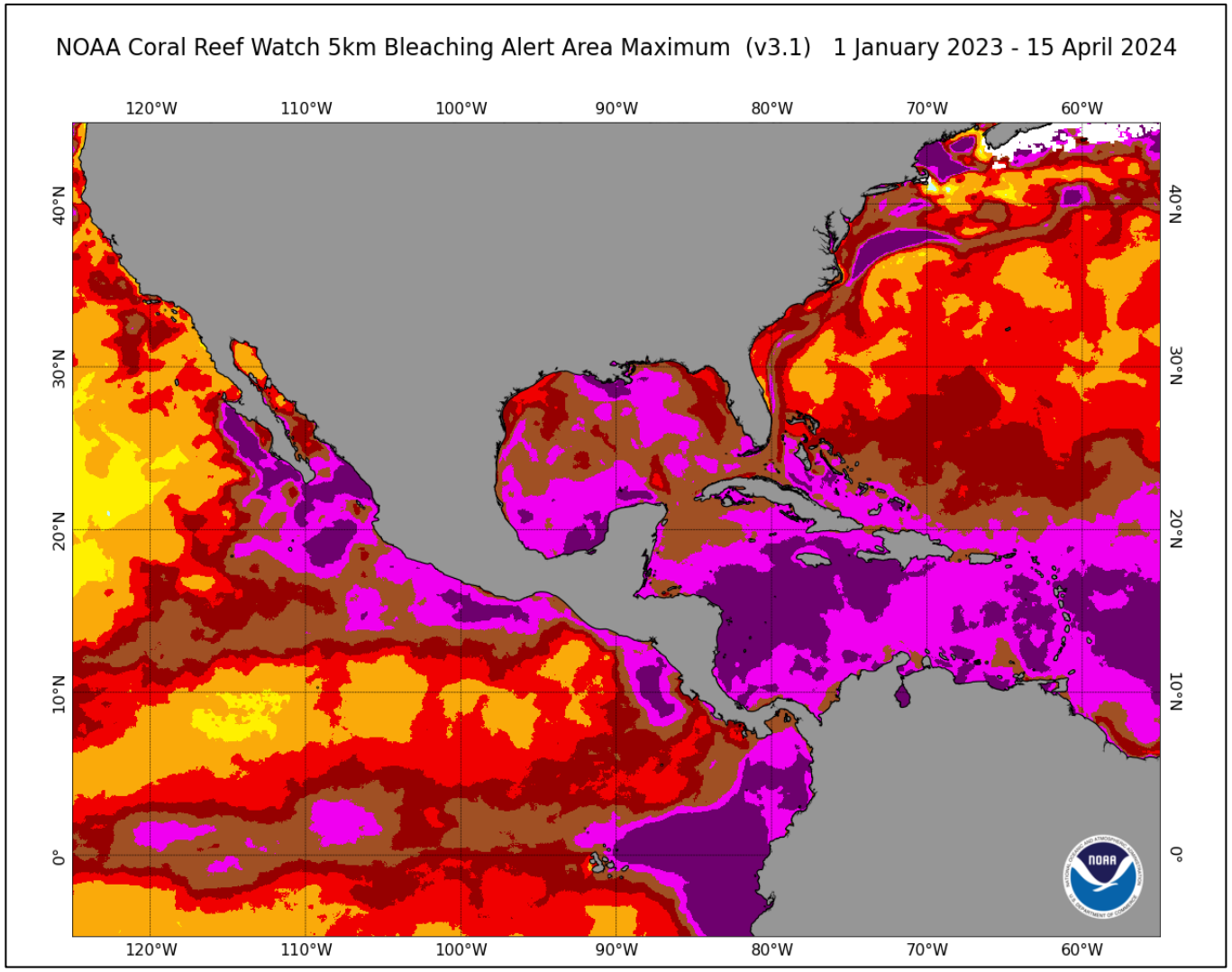
Bleaching Alert Level 1 (4 < DHW < 8)
Reef-Wide Bleaching

Bleaching Alert Level 2 (8 < DHW < 12)
Reef-Wide Bleaching with Mortality of Heat-Sensitive Corals

Bleaching Alert Level 3 (12 < DHW <16)
Multi-Species Mortality

Bleaching Alert Level 4 (16 < DHW < 20)
Severe, Multi-Species Mortality (> 50% of corals)

Bleaching Alert Level 5 (DHW > 20)
Near Complete Mortality (> 80% of corals)



New Bleaching Alert Levels

Bleaching Alert Level 1 (4 < DHW < 8)
Reef-Wide Bleaching

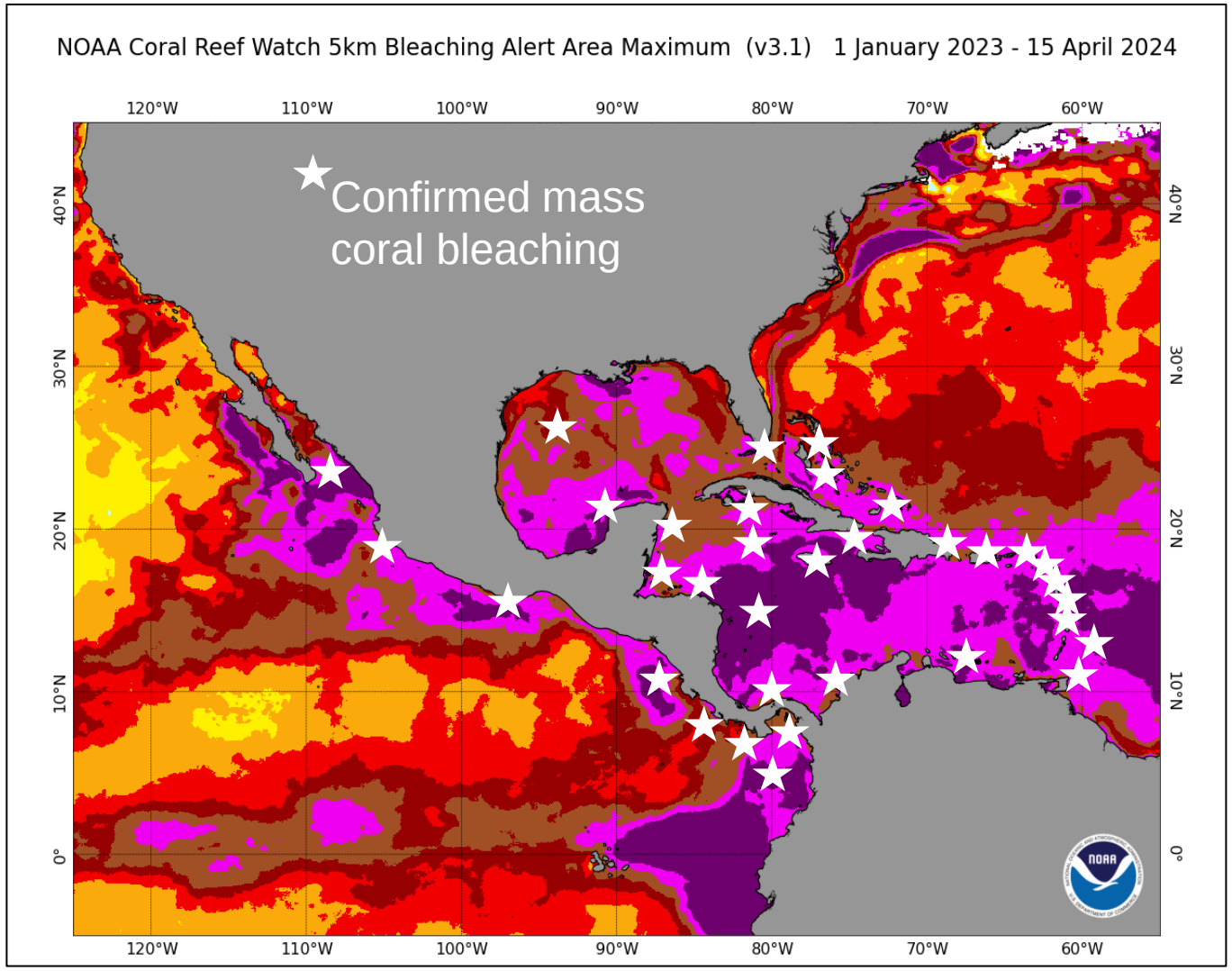
Bleaching Alert Level 2 (8 < DHW < 12) *
Reef-Wide Bleaching with Mortality
of Heat-Sensitive Corals

Bleaching Alert Level 3 (12 < DHW <16)
Multi-Species Mortality

Bleaching Alert Level 4 (16 < DHW < 20)
Severe, Multi-Species Mortality
(> 50% of corals)

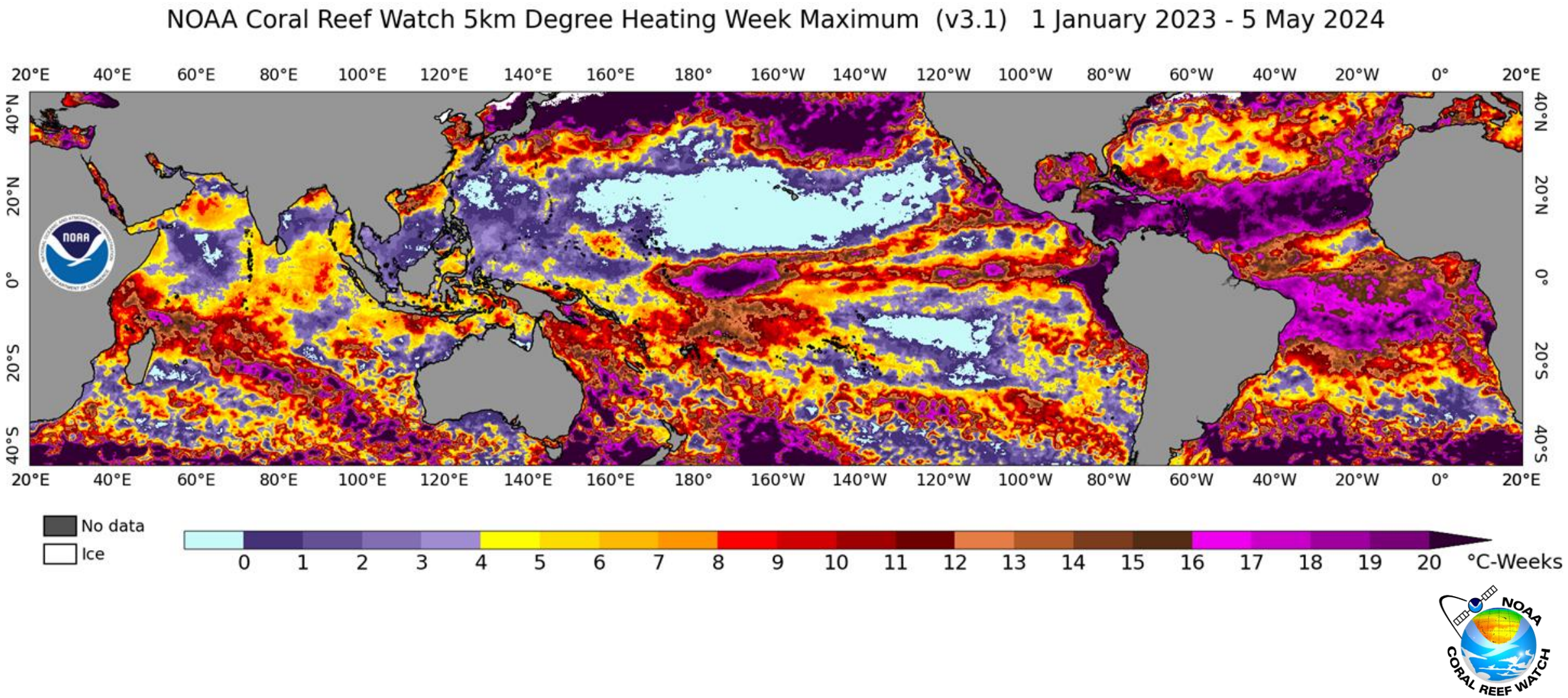
Bleaching Alert Level 5 (DHW > 20)

Near Complete Mortality (> 80% of corals)

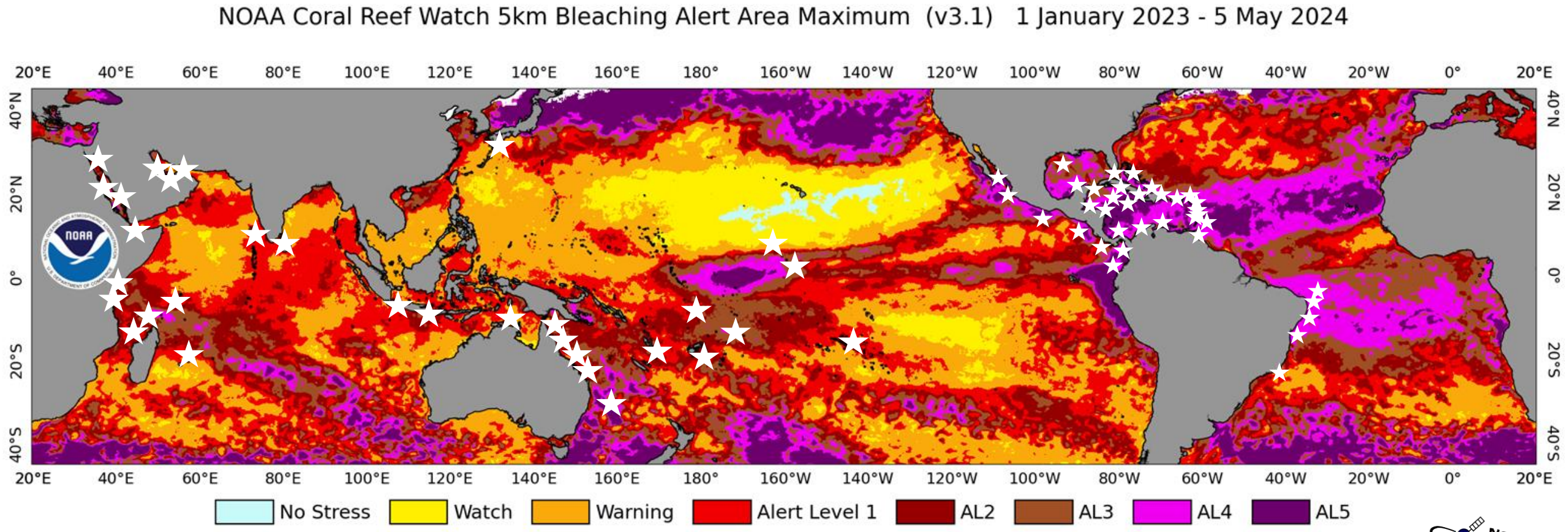


* **Severe coral mortality can occur at AL2:**
-for heat sensitive species (*Acropora*)
-when a reef experiences 1st event (e.g., NGBR 2016)

Max Degree Heating Weeks: 2023 - 2024



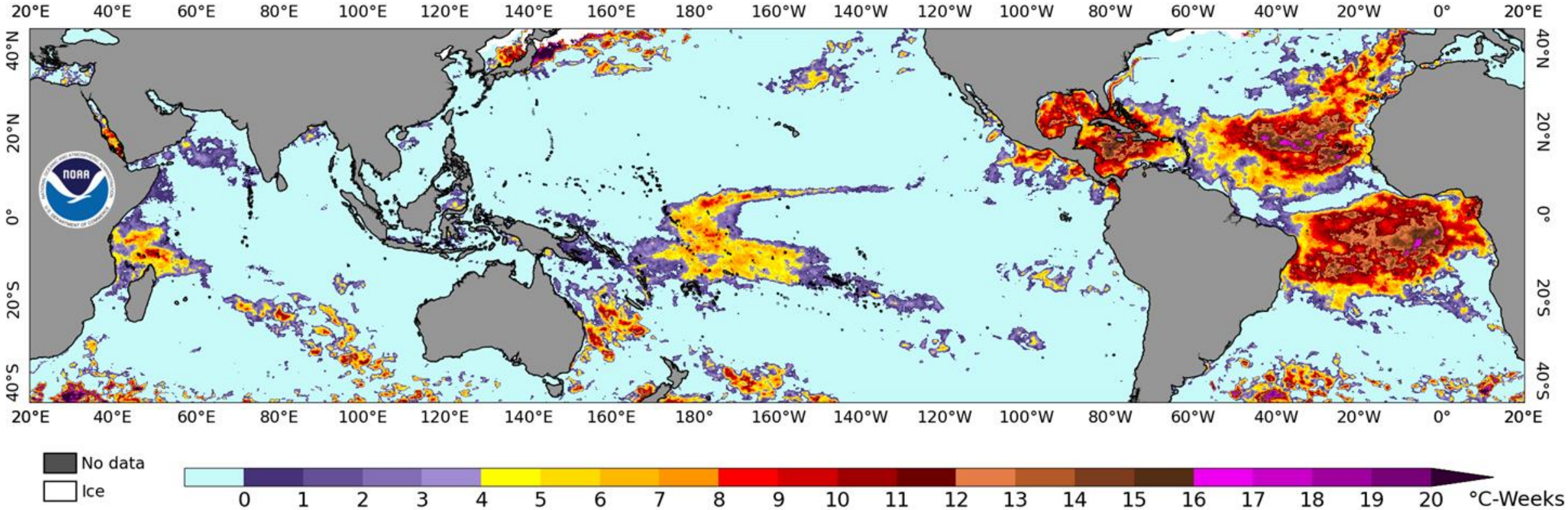
Max Bleaching Alert Area: 2023 - 2024



Mass bleaching confirmed in at least 56 countries/territories

Record-Setting Heat Stress

ΔDHW = (Max DHW$_{2023\text{-}2024}$) - (Max DHW$_{1985\text{-}2022}$)



Ranking the 4 Global Coral Bleaching Events

Global Bleaching Event Index*

Event	Years	Peak % Reef Area Impacted
GBE1	1998	20%
GBE2	2010	35%
GBE3	2014-2017	56.1%
GBE4	**2023-?**	**59.0% and increasing**

*GBE Index developed by Skirving et al. (2019, *Coral Reefs*)
Measure of % reef pixels experiencing bleaching-level heat stress within past 365 days

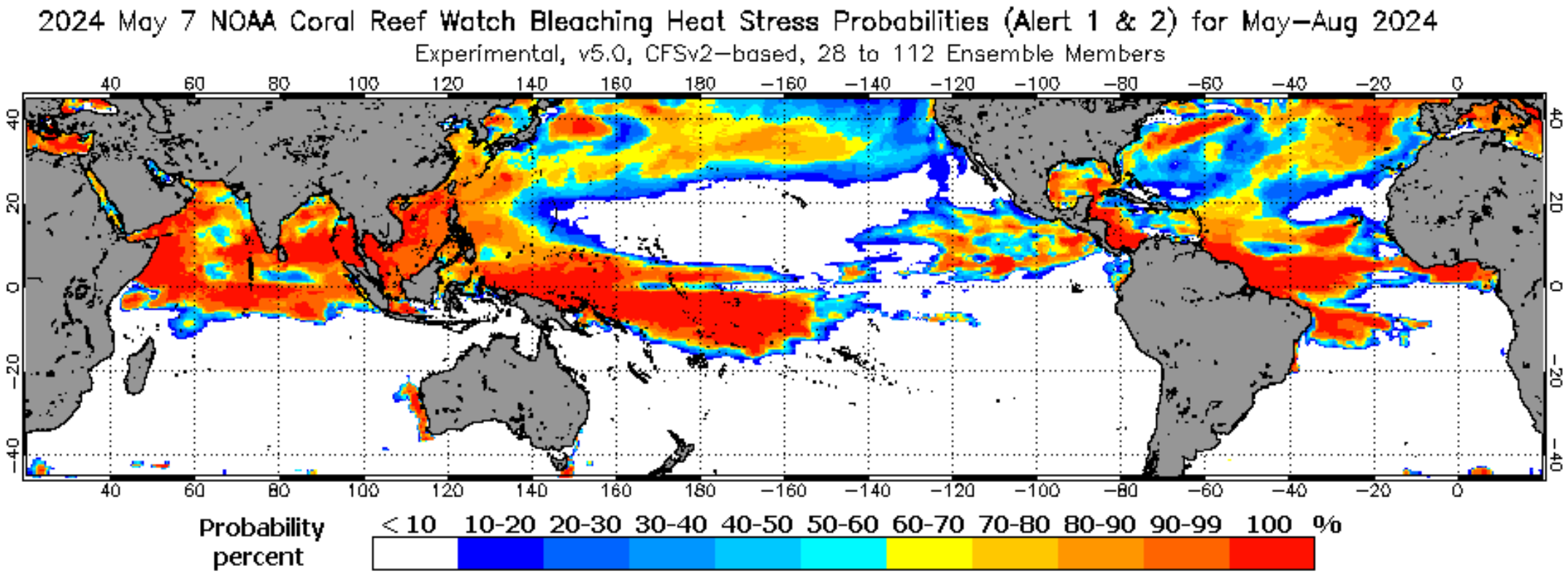
Resultant Impacts

- 8% of world's corals died in 1998
- 14% further loss from 2009-2018

Source: Status of Coral Reefs of the World: 2020

>99% of Atlantic reef areas have experienced bleaching-level heat stress within past year

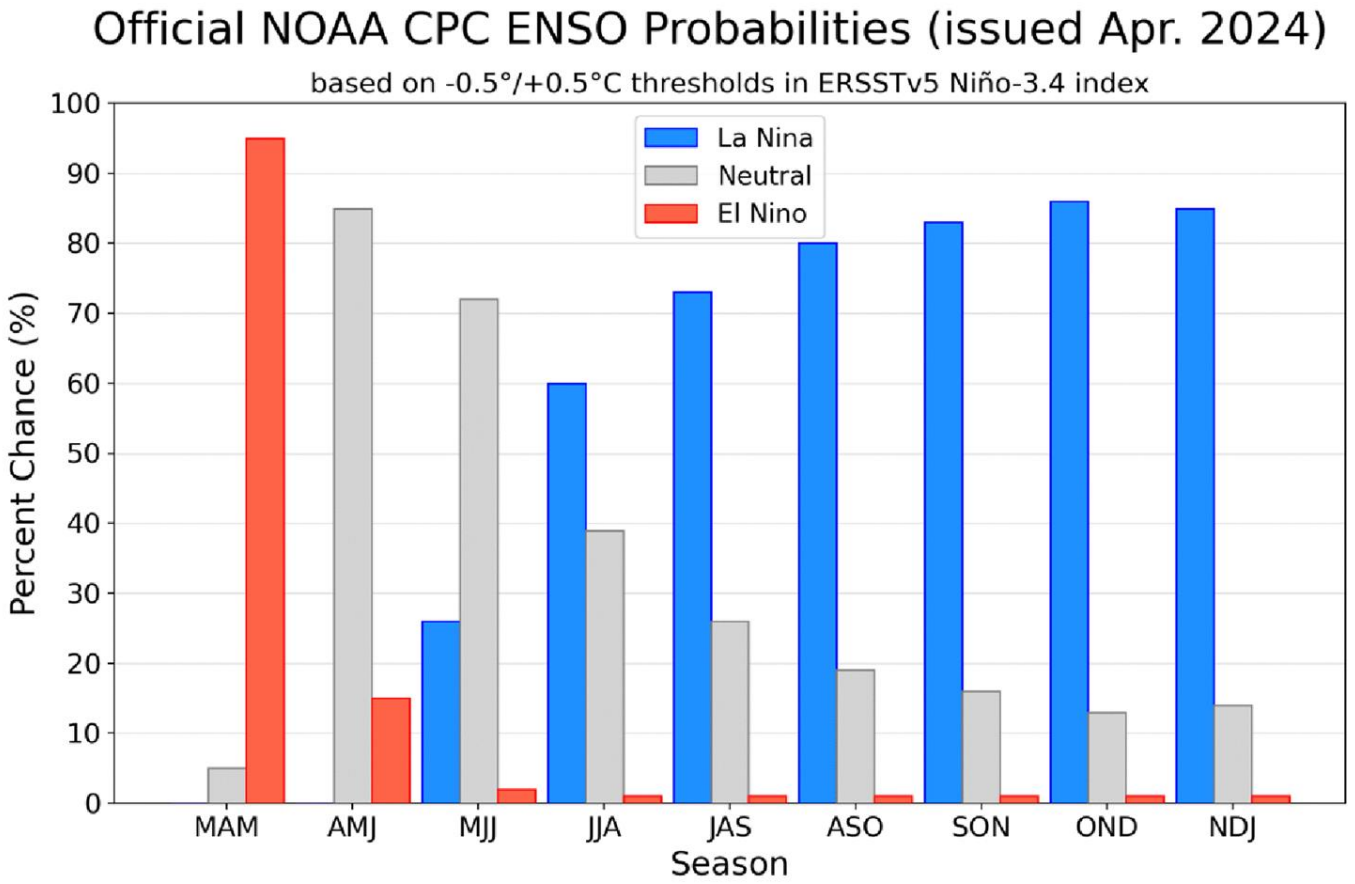
Four-Month Coral Bleaching Outlook (Updated weekly)



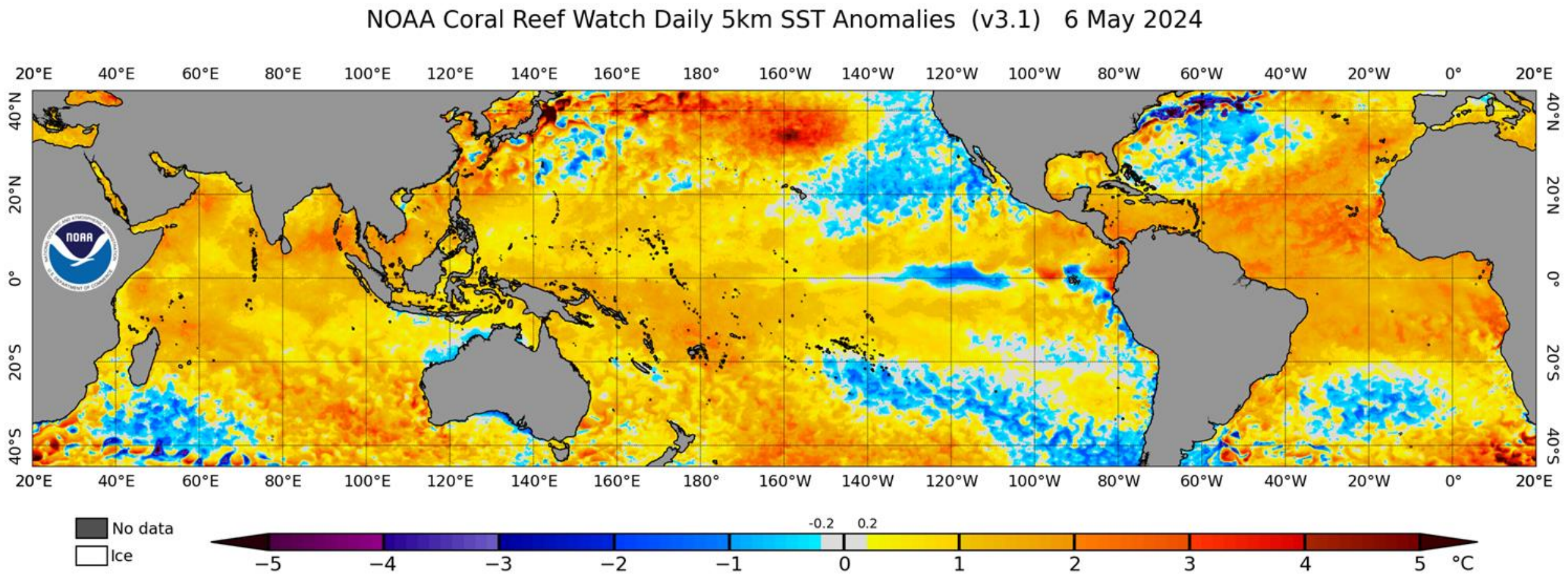
NOAA Coral Reef Watch

Good Riddance, El Niño!

"A transition from El Niño to ENSO-neutral is likely by April-June 2024 (85% chance), with increasing odds of La Niña developing in June-August (60% chance)."



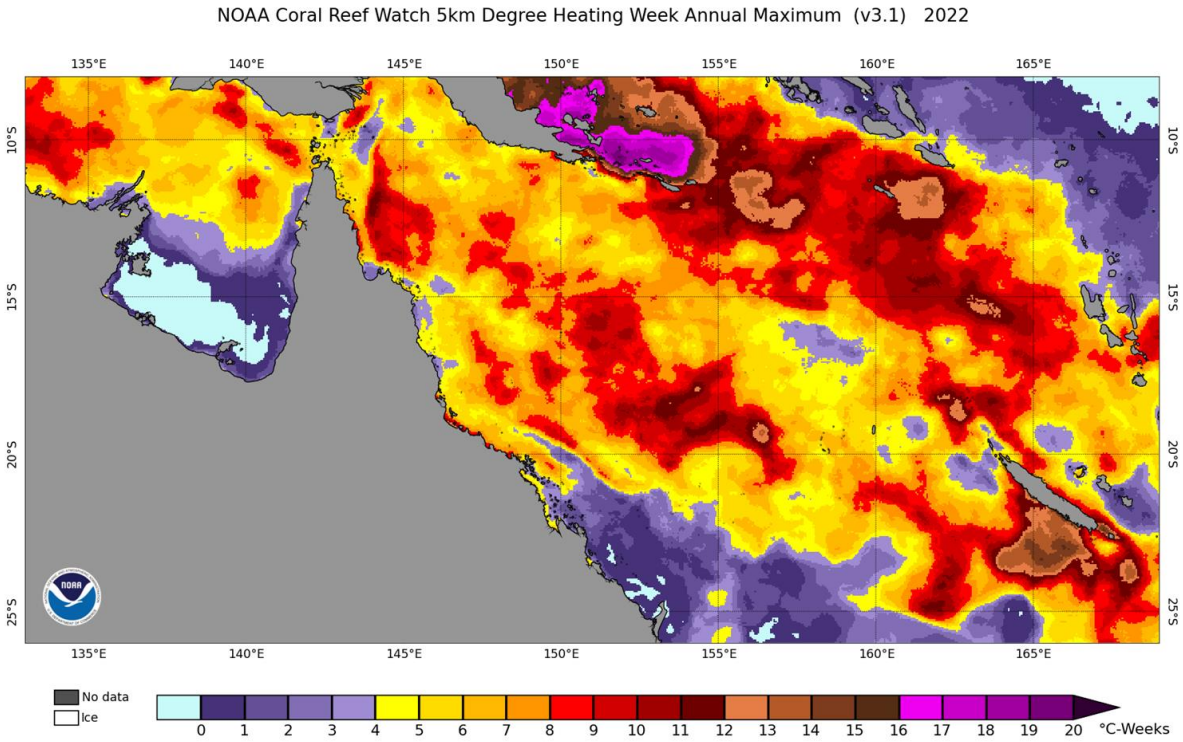
…*But, the ocean is still running a serious fever*…



…and mass bleaching is now occurring during all phases of ENSO…

- First mass bleaching event on the Great Barrier Reef during La Niña in 2022 (Spady et al. 2022, F1000)

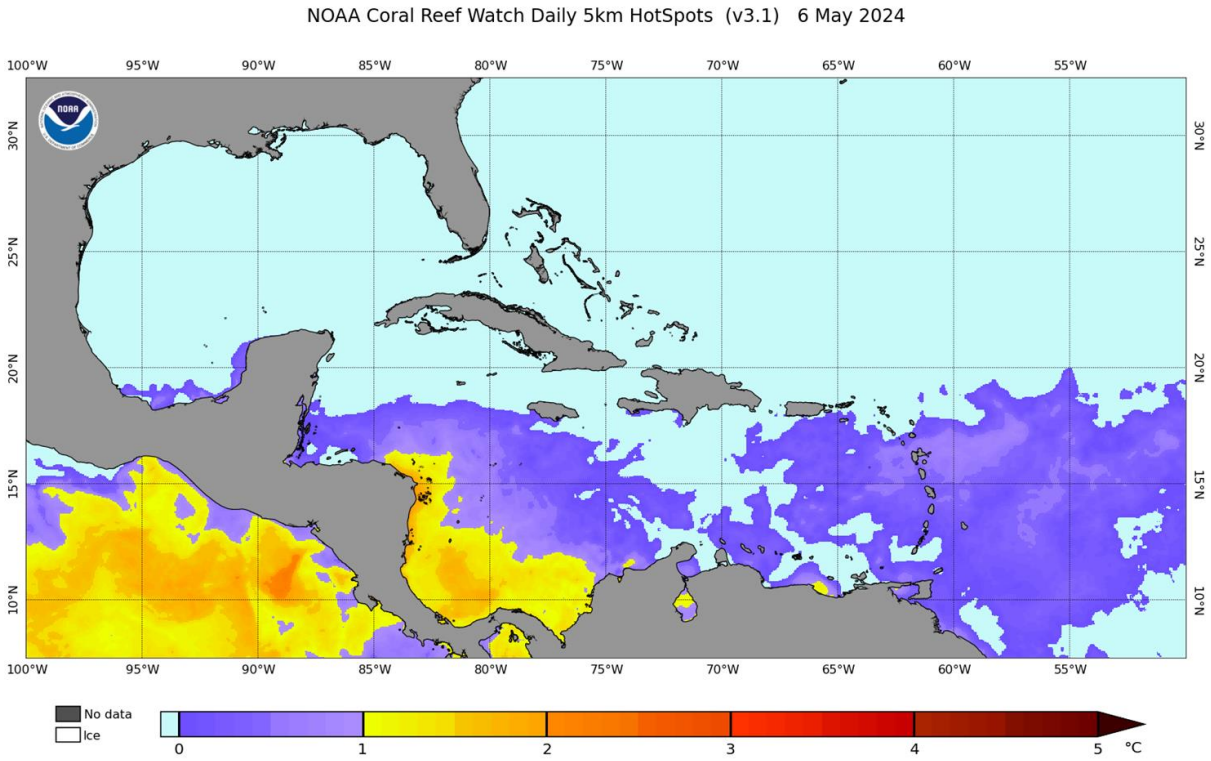
- Ocean temps have warmed to where large-scale bleaching now occurs out of phase with El Niño



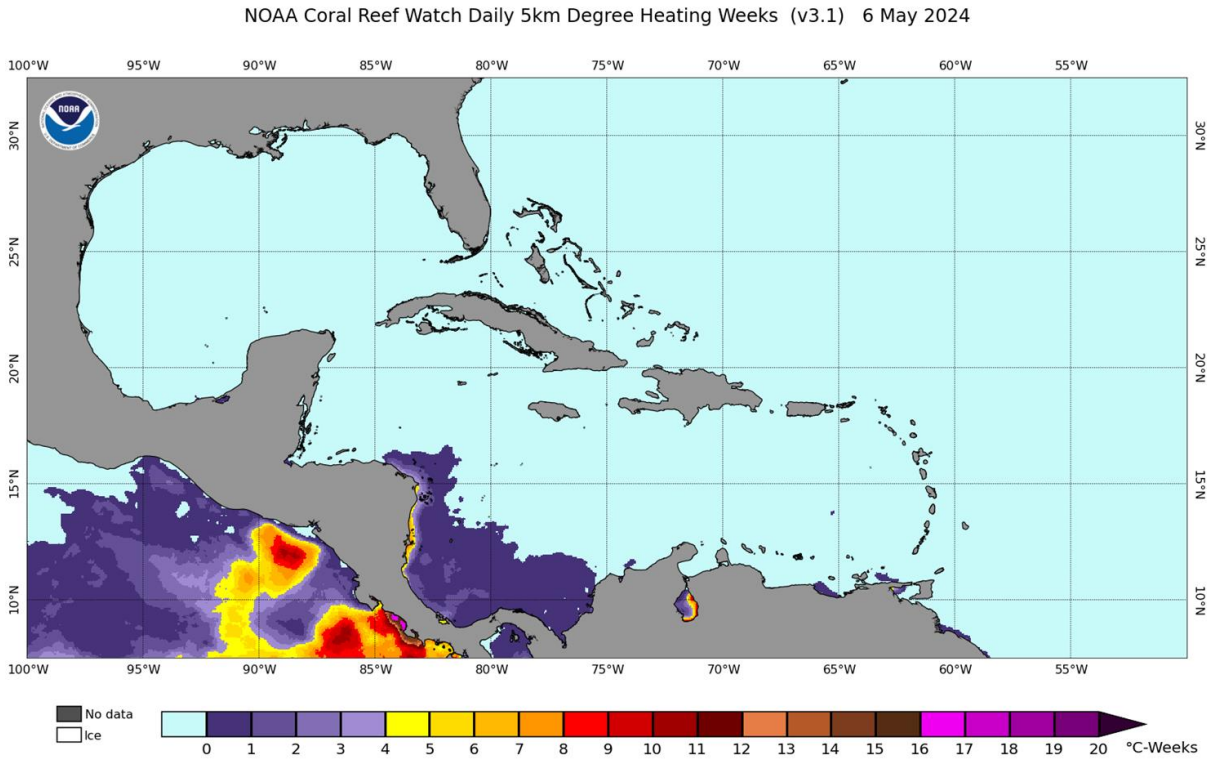
Max 2022 DHW for GBR

This is very concerning…

Hotspots



Degree Heating Weeks

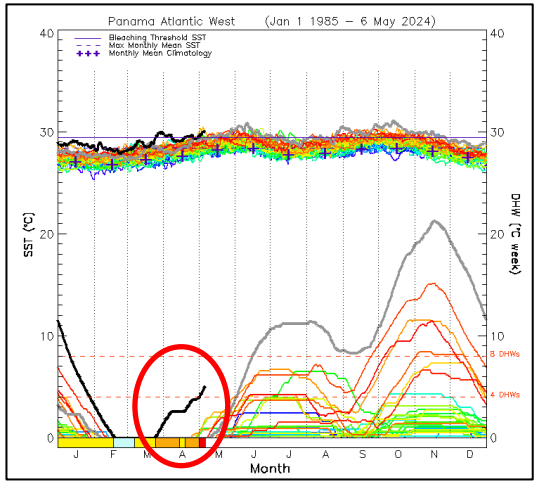


DHWs ALREADY accumulating in S. Caribbean!!!

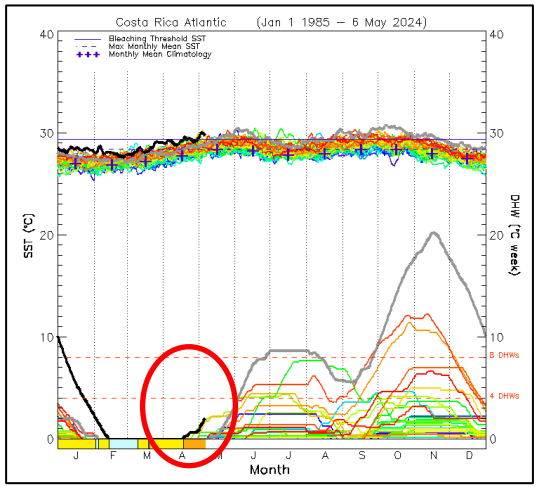
DHWs ALREADY accumulating in S. Caribbean!!!

Caribbean
Panamá

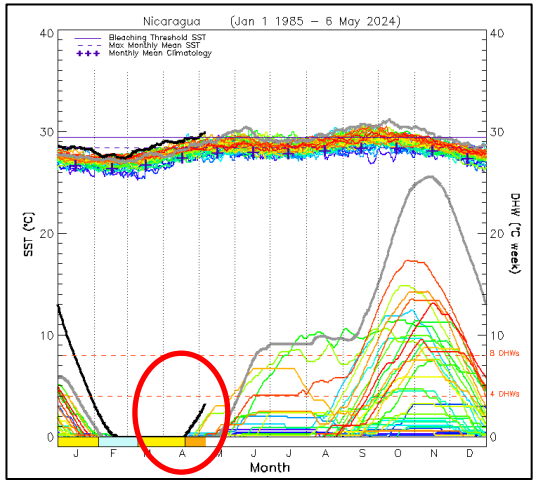
One of 1st Atlantic location to bleach In 2023



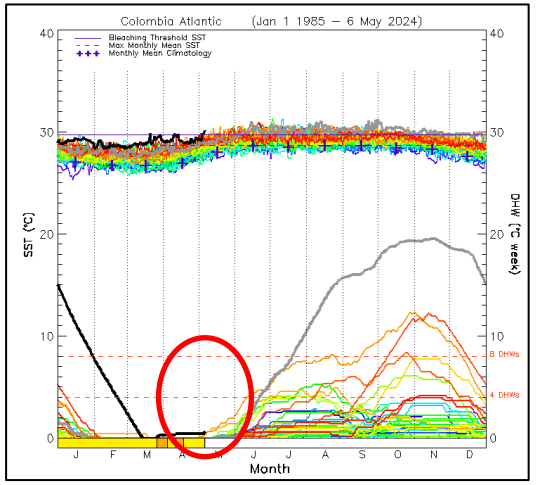
Caribbean
Costa Rica



Nicaragua



Caribbean
Columbia



Summary and Conclusions

- Since February 2023, severe coral bleaching reported from 56 countries/territories spanning all ocean basins

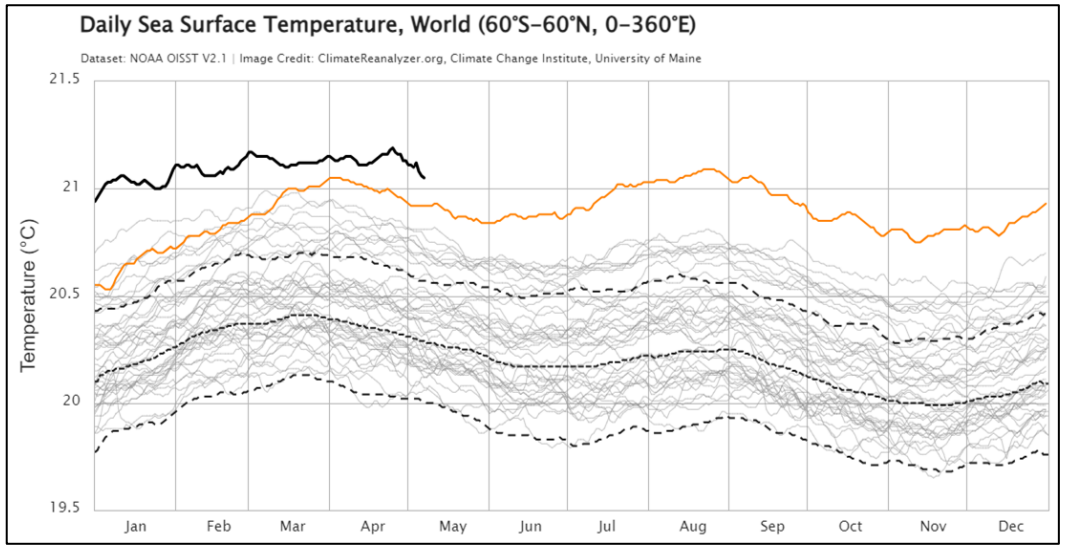
- As of May 6, 59% of the world's coral reef area has experienced bleaching-level heat stress in past year
  - ***This is a new record and is still increasing!***

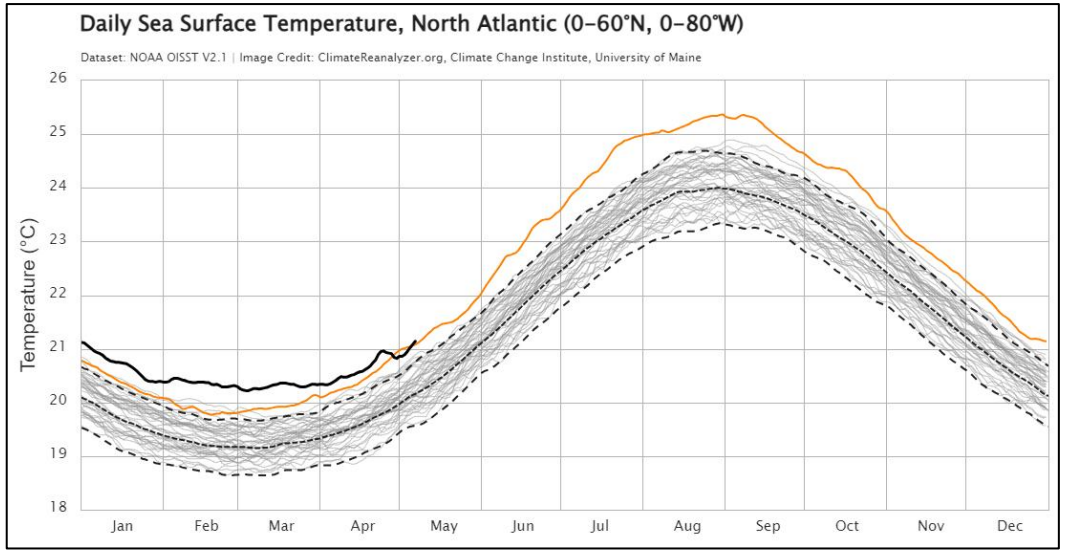
- Impacts from this event will take 1-2 years to fully understand
  - We do know there were severe impacts to *Acropora* in wider Caribbean
  - First publication on this event from Mexican Pacific – 50-93% mortality in Huatulco, Oaxaca (Lopez-Perez et al. 2024, Oceans)

- Monitoring data needed during bleaching and 1-2 years after heat stress subsides!
  - Allows identification of resilient reefs, species, and genotypes
  - Provides blueprint for how to save corals during the next, inevitable coral bleaching event

Summary and Conclusions II

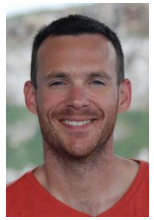
- These are “strange days” for global ocean temps
- Dissipating El Niño is good news…
  - …but ocean still running a serious fever
- Important to understand the timing of subsequent disease and corallivore outbreaks
  - Many corals can survive bleaching, but later die from disease or predation
  - Preventing a local extinction could be as simple as picking snails off recovering corals!!





NOAA CORAL REEF WATCH

Thank you from the NOAA Coral Reef Watch Team!!



Derek Manzello (NOAA/NESDIS)
Federal Coordinator

Gang Liu (NOAA/NESDIS)

Jacquie De La Cour (UMD-CISESS)

Erick Geiger (UMD-CISESS)

William Skirving (ReefSense)

Blake Spady (ReefSense)

Andrew Norrie (ReefSense)

https://coralreefwatch.noaa.gov
coralreefwatch@noaa.gov

Coral Reef Watch @CoralReefWatch

Florida's Coral Reef Resilience Program (FCRRP)
2023 Bleaching Lessons Learned

[vers. 04.12.24]

https://docs.google.com/document/d/1MPSAyTLbJUngN_7TvGjst3wY0ybpWm51/edit

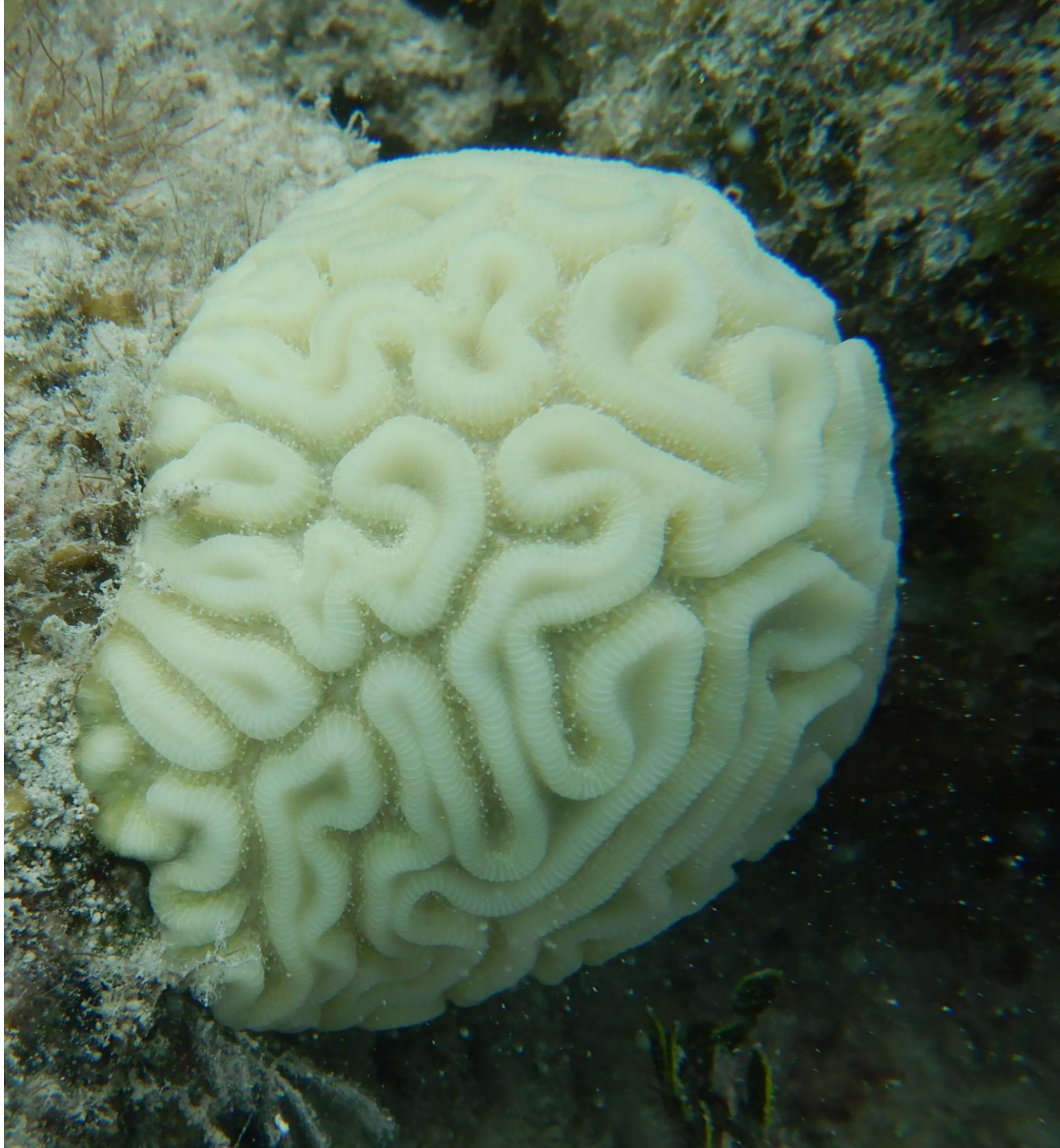
This living document captures lessons learned from practitioners, managers, and other partners who responded to severe coral bleaching in summer 2023 in Florida. The opinions held in this document do not reflect the position of any given organization or entity. Sincere thanks to all those who shared their experiences for our community to learn from, including through the Disturbance Advisory Committee, Mission: Iconic Reefs workshop, FCRRP Team meetings, and in direct conversations.

This document includes a table summarizing several management strategies that were taken in response to coral bleaching in Florida followed by bullet point lessons learned in four areas: general takeaways, response strategies, communication and coordination, and funding.

Response Strategy	Description of Action	Status & Considerations
Ex situ genetic banking	Maintain fragments of unique genotypes (w/ focus on founders) in appropriate land-based facilities for long-term genetic banking.	Several gene banks are operational (Mote) or being established (Reef Institute, Reef Renewal) in Florida. Genotyping corals in holding may be necessary to determine/confirm genetics, identify duplicates and/or gaps; however, particularly for species at risk of local extirpation, prioritize getting corals to a safe place even if that requires sorting out the genetics later. This is preferable to moving large biomass into land-based facilities.
In situ genetic banking	Maintain fragments of unique genotypes (w/ focus on founders) in permanent ocean-based nurseries in multiple locations thought to be more resistant to thermal impacts (e.g., higher latitude,	One nursery operational in deeper water (Tavernier, 70 ft.), two more established but not utilized (Looe, Sombrero). Generally, corals fared well -- need to ensure sufficient light. Shallow water species (e.g., APAL) should not be kept at depth long-term, though certain nursery structures like trees can be raised and lowered in the water column as needed to balance light and temperature needs. Need to consider operations at depth and re-acclimating corals to shallow water.

General takeaways

- Have a plan ahead of time
  - Doesn’t need to be complex
  - Agree on triggers for action
  - Consider obtaining permits preemptively for likely response actions
- Prioritize protecting genetic diversity over biomass
- Act early, before seeing obvious signs of stress
- Monitor as much as possible to understand long-term impacts
- Build redundancy into programs
- Communicate frequently

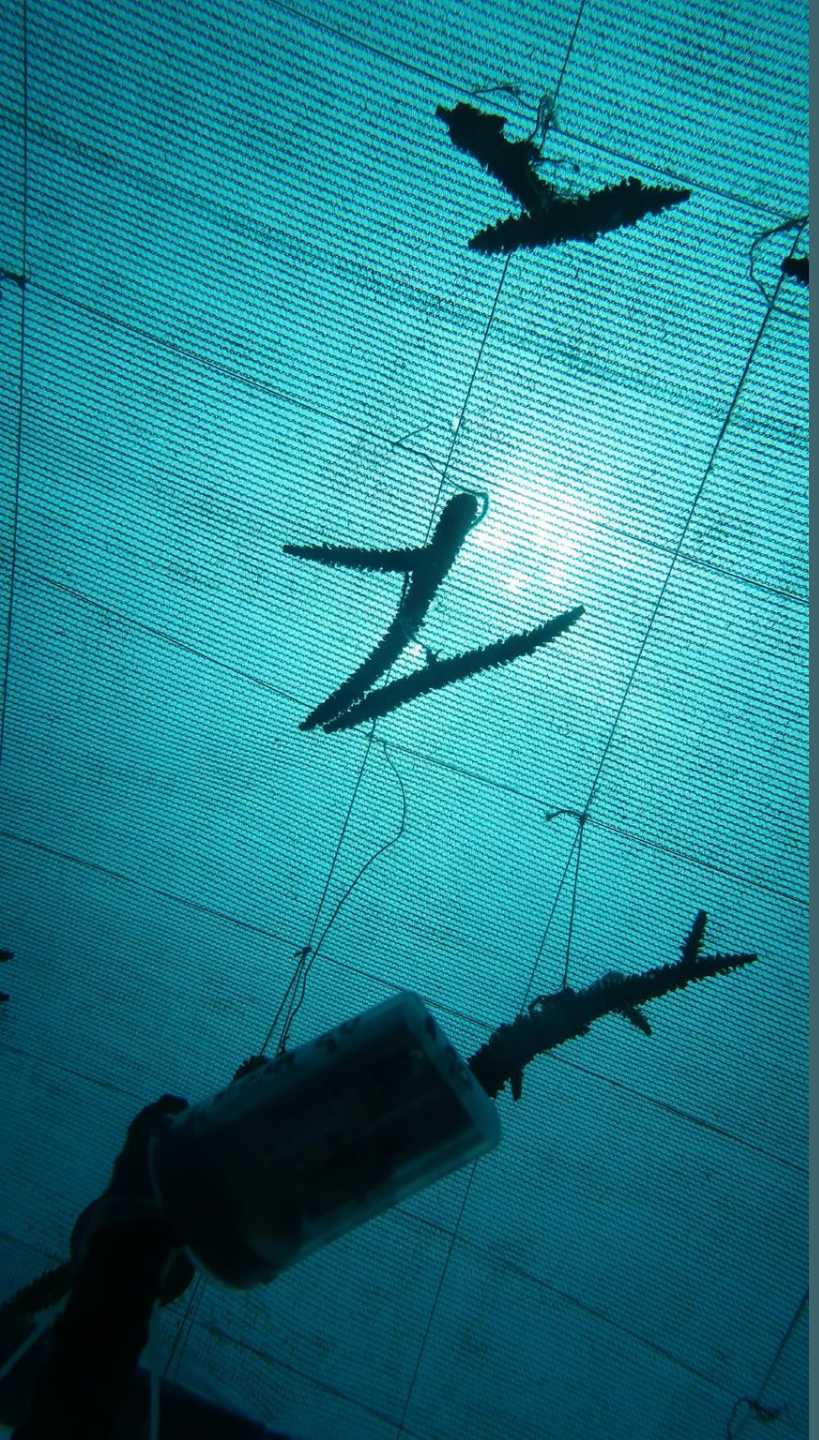


Nursery shading

Dr. Carlos Toledo-Hernàndez, Dr. Claudia Patricia Ruiz-Diaz, Samuel Suleiman
Sociedad Ambiente Marino
Puerto Rico

Key considerations:

- Should be deployed in advance of thermal stress
- Needs considerable maintenance
- Plan ahead for removal during storms
- May be no difference between all-day and solar noon (~4 hours)



Artificial shedding as a strategy to mitigate heat stress on corals in Puerto Rico 2023

Carlos Toledo-Hernández, Ph.D

Claudia Patricia Ruiz-Diaz, Ph.D.

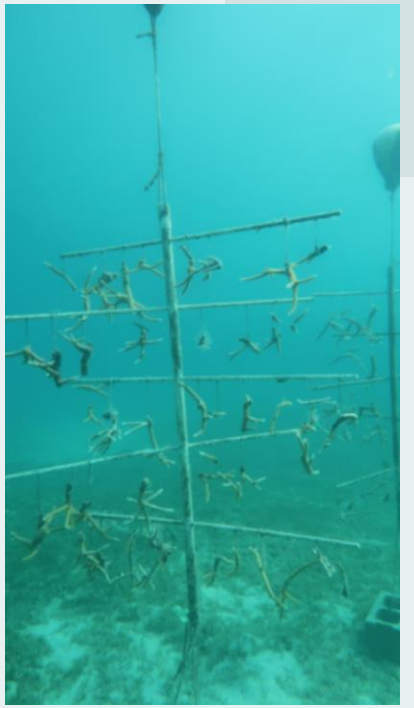
Samuel Suleimán-Ramos, M.ed.

SOCIEDAD AMBIENTE MARINO

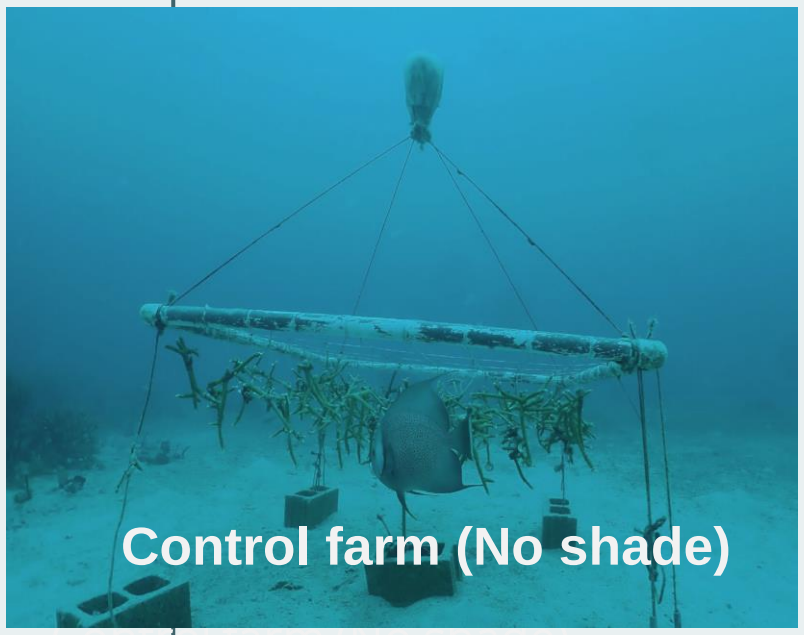
sampr.org

May 13 2024

Coral Bleaching in Culebra, Puerto Rico



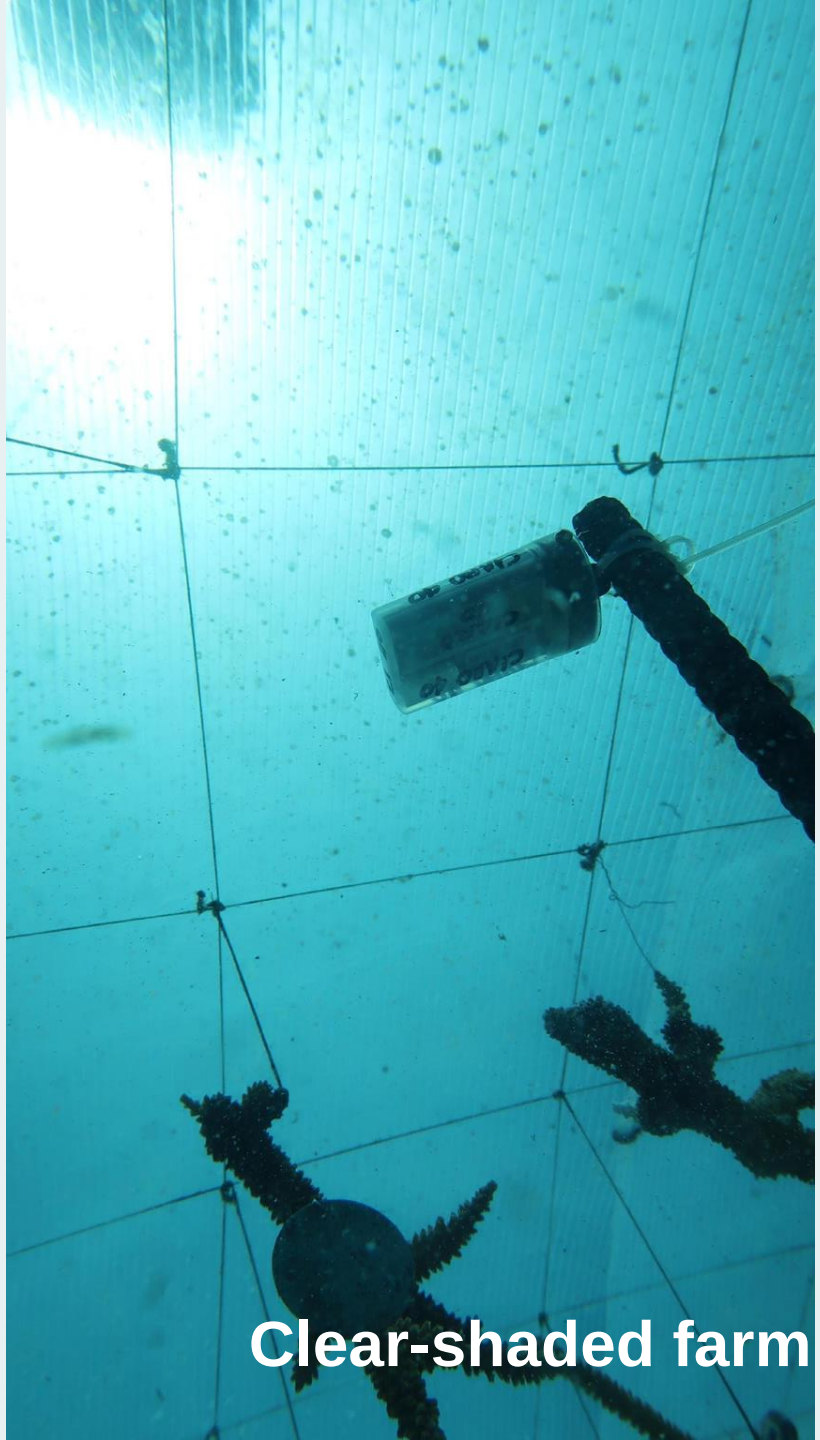
Experimental Design

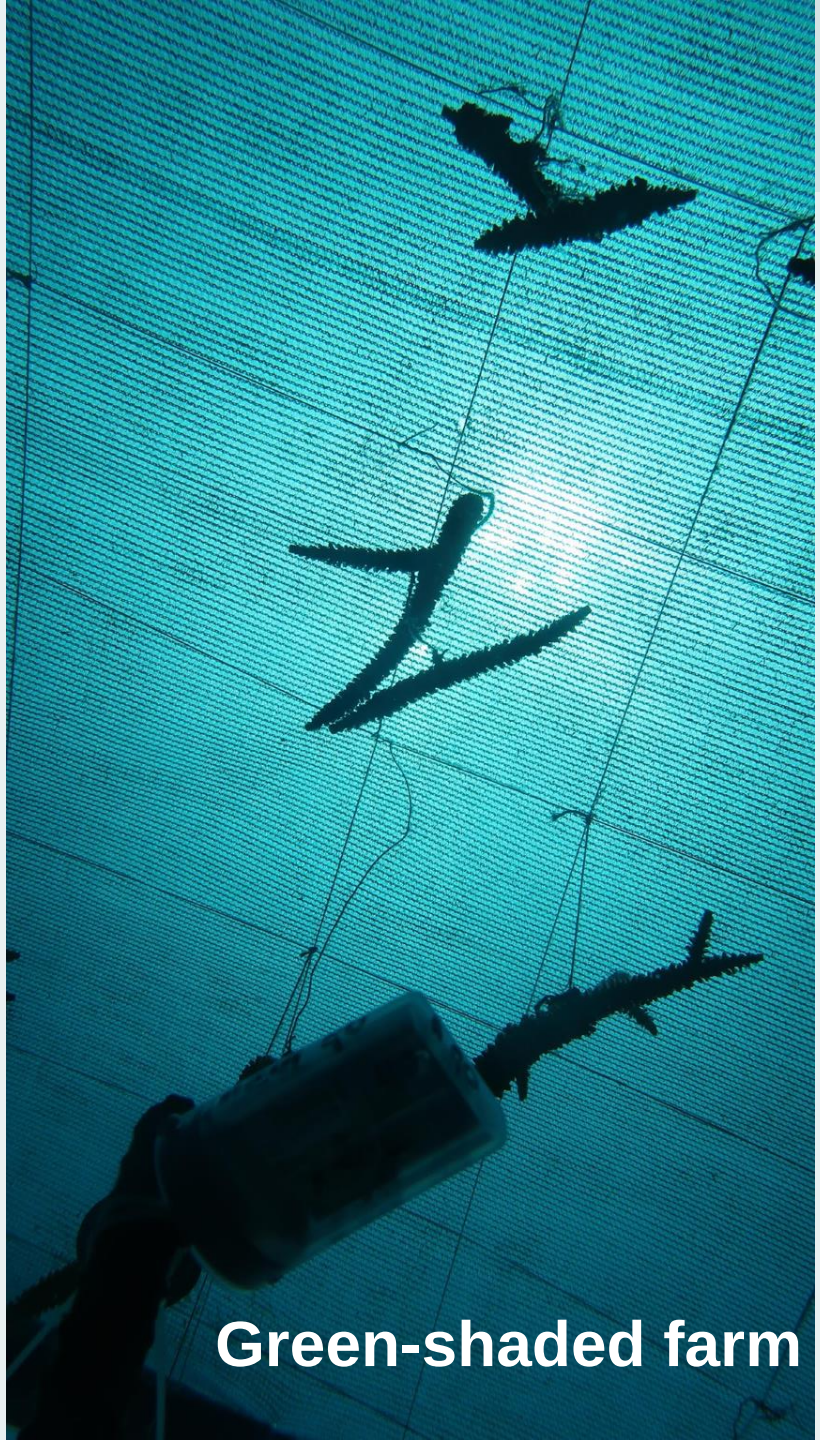


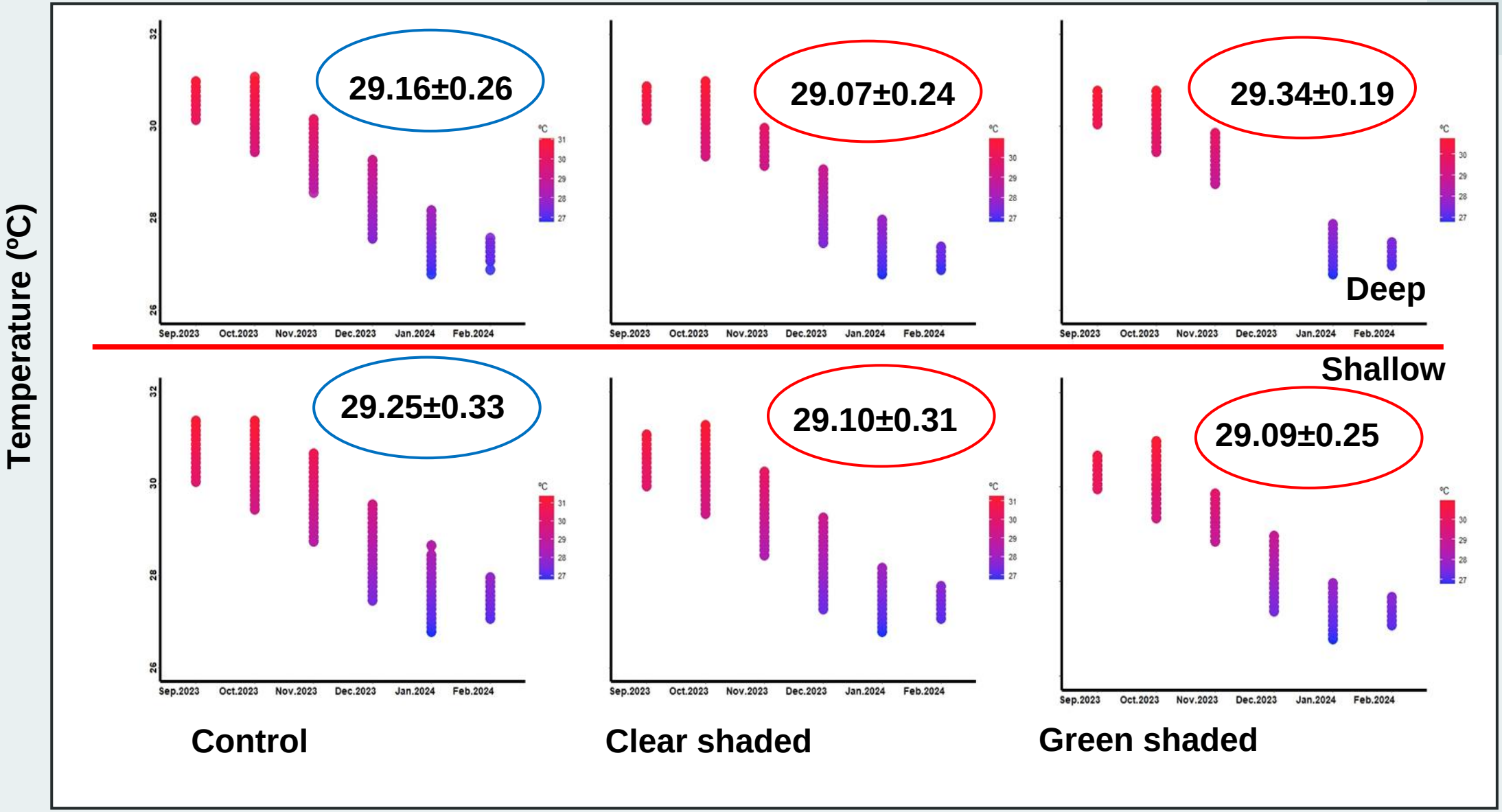
- **Six in-situ horizontal floating frames (i.e., coral farms)**
- **Shades created from two materials**
  - **Translucent vinyl sheets**
  - **Saran mesh**
- **Two depths: 6m and 12m**
  - **3 farms per depth (1 control, 1 clear and 1 green farm)**

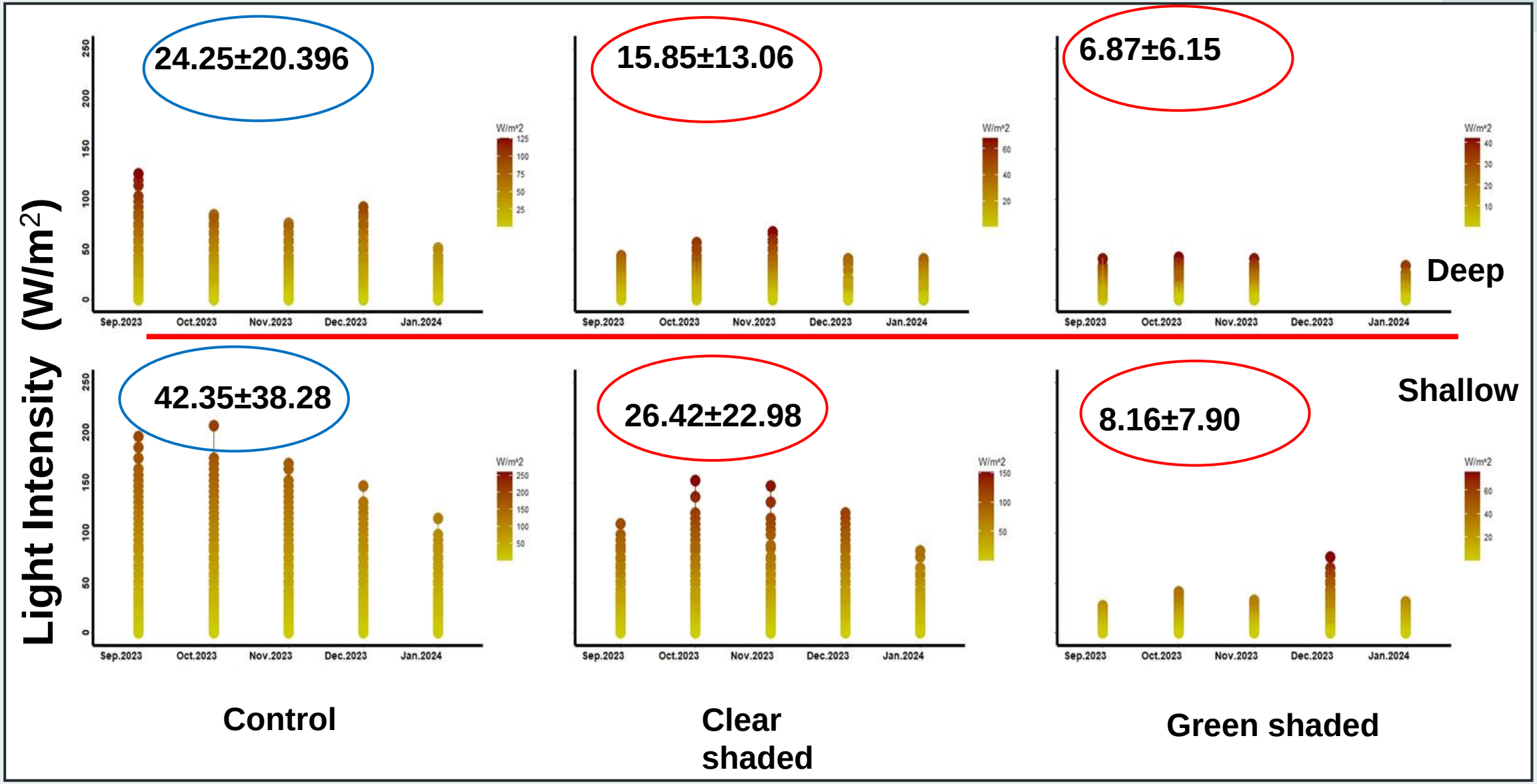
- **485 *A. cervicornis* fragments (69-91 fragments per farm)**
- **10 fragments per farm tagged**
- **1 Temp/light intensity device per farm**
- **September 2023 to February 2024**

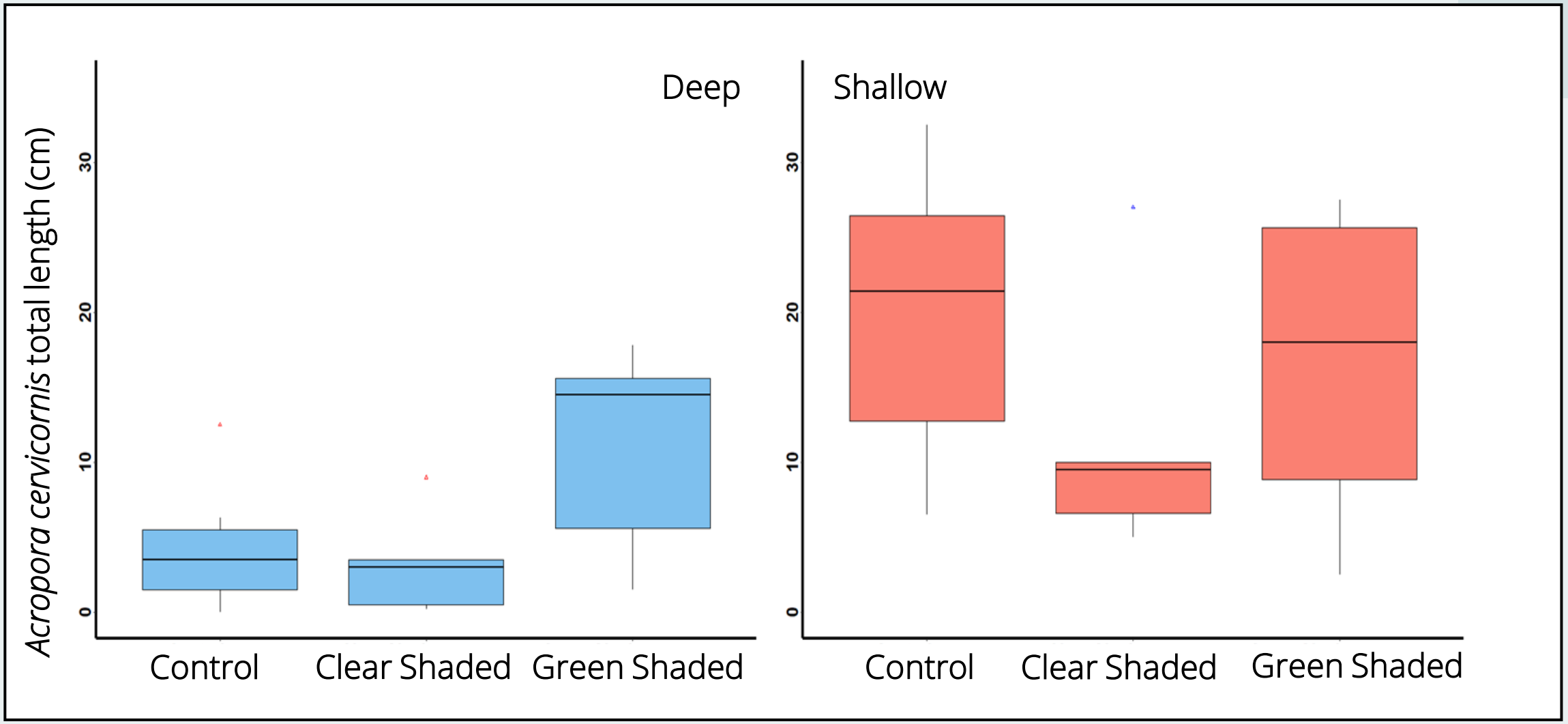

Control farm


Clear-shaded farm


Green-shaded farm


Temperature (ºC)
29.16±0.26
29.07±0.24
29.34±0.19
Deep
Shallow
29.25±0.33
29.10±0.31
29.09±0.25
Control
Clear shaded
Green shaded
Sep.2023
Oct.2023
Nov.2023
Dec.2023
Jan.2024
Feb.2024


Light Intensity (W/m²)
24.25±20.396
15.85±13.06
6.87±6.15
42.35±38.28
26.42±22.98
8.16±7.90
Deep
Shallow
Control
Clear shaded
Green shaded
Sep.2023
Oct.2023
Nov.2023
Dec.2023
Jan.2024
W/m^2


Deep
Shallow
Acropora cervicornis total length (cm)
0
10
20
30
Control
Clear Shaded
Green Shaded
Control
Clear Shaded
Green Shaded

Fragment mortality

	Control	Clear S	Green S
Deep	8 (7/91)	10 (8/81)	1 (1/67)
Shallow	14 (11/77)	4 (3/80)	2 (2/89)

- **Overall mortality relatively low in all farms.**
- **Mortality lower in the green shaded farms compared to the clear shaded and control farms.**
- **No depth effect in the green shaded farms.**
- **Mix results in the clear shaded farms - low mortality in the shallower area and high mortality in the deep area.**

Future Projects

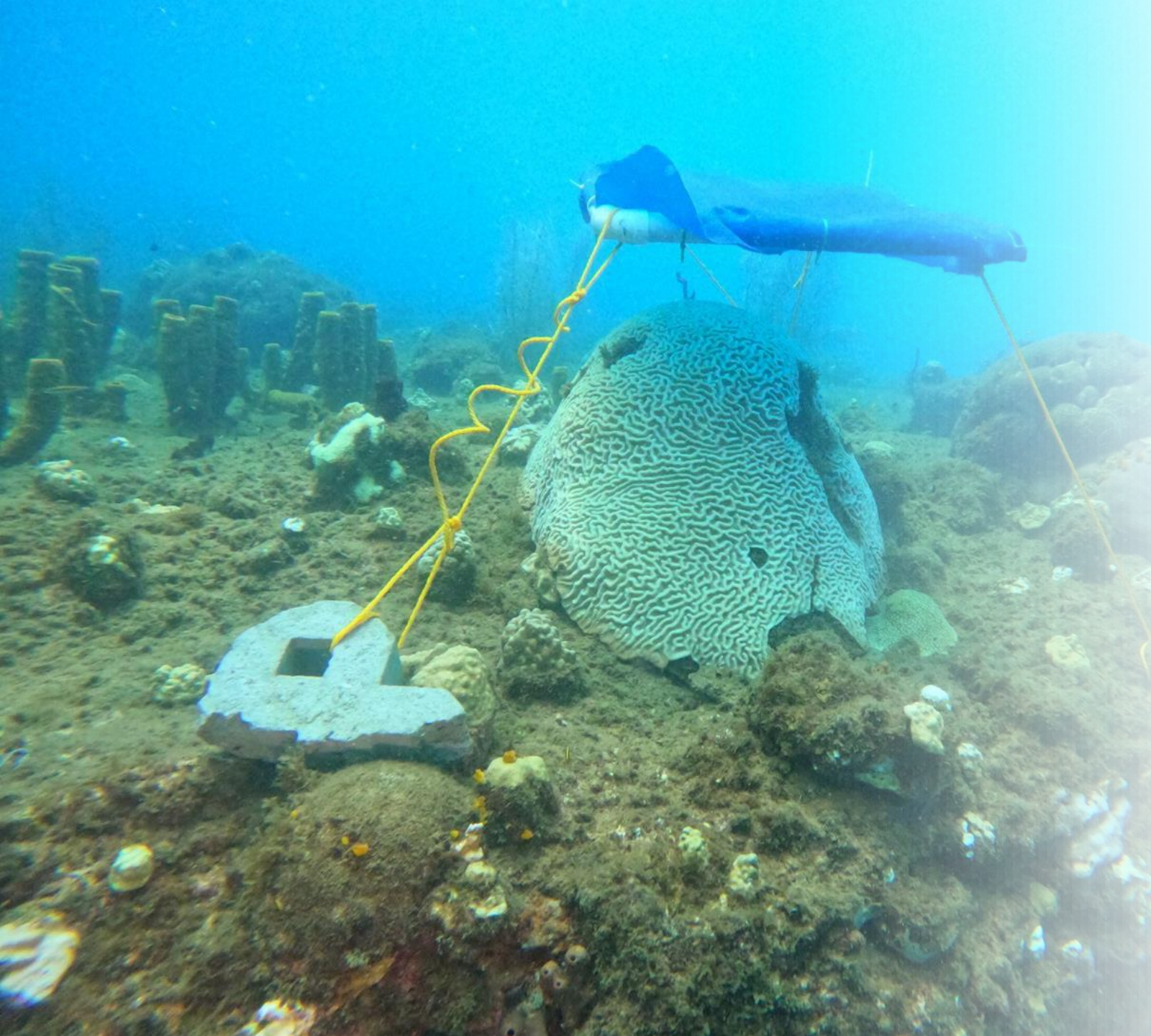
- **Expand the shading to outplanted corals**
- **Increase the number of farms with shades**
- **Study the effects of shading at the physiological level**
- **Compare intermittent vs permanent shading**

Gracias

- Roger Guzman
- Ileana Calderon
- Jeremy Velasquez
- Julimar Nevarez
- Pedro Gomez
- Dolian Lugo
- Gero Cabrera
- Cecilia Pedraza

- Y a Ustedes

carlostoledo@sampr.org and claudiaruiz@sampr.org



Nursery relocation

Simon Walsh

Oceans Forward, Nature Island Dive Dominica

- **Key considerations:**
  - Focus on founding population(s), a few representatives of genotypes, or a percentage of stock
  - Move corals from heavy impact to less impact, based on bleaching projections and local knowledge

Dominica Response 2023 Bleaching event

The Dominica Approach

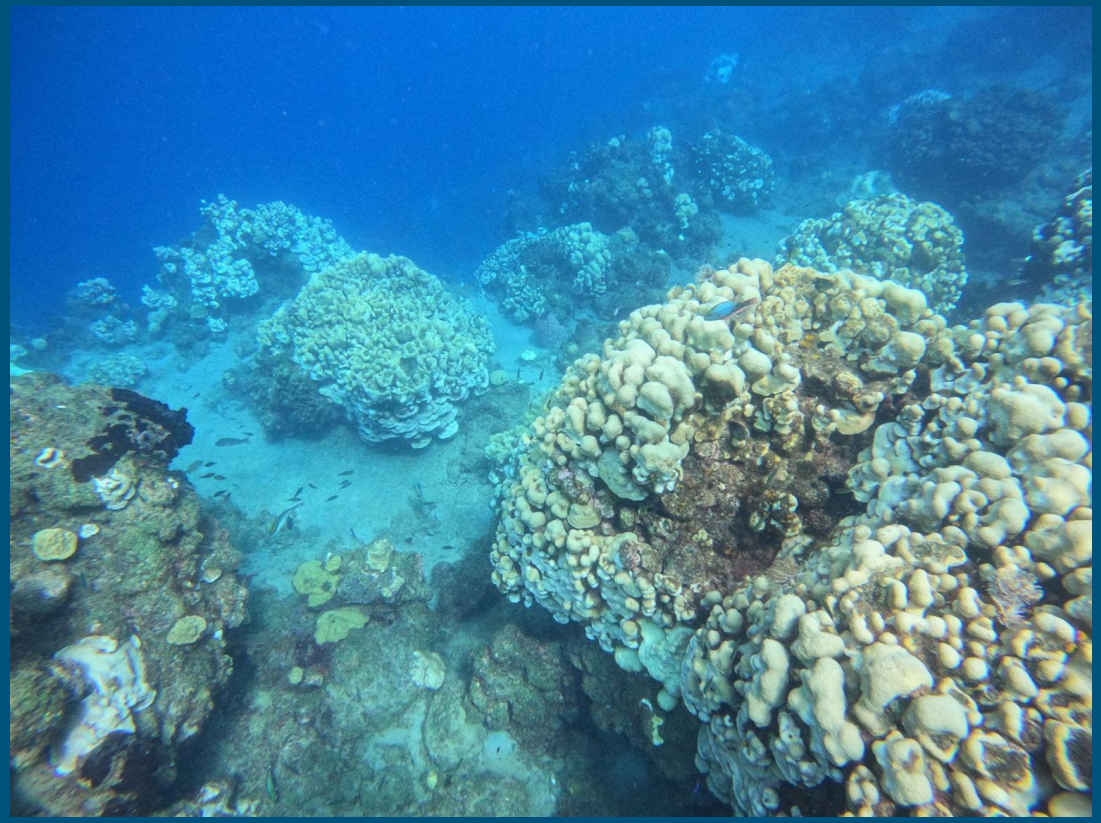
Bleaching Timeline 2023

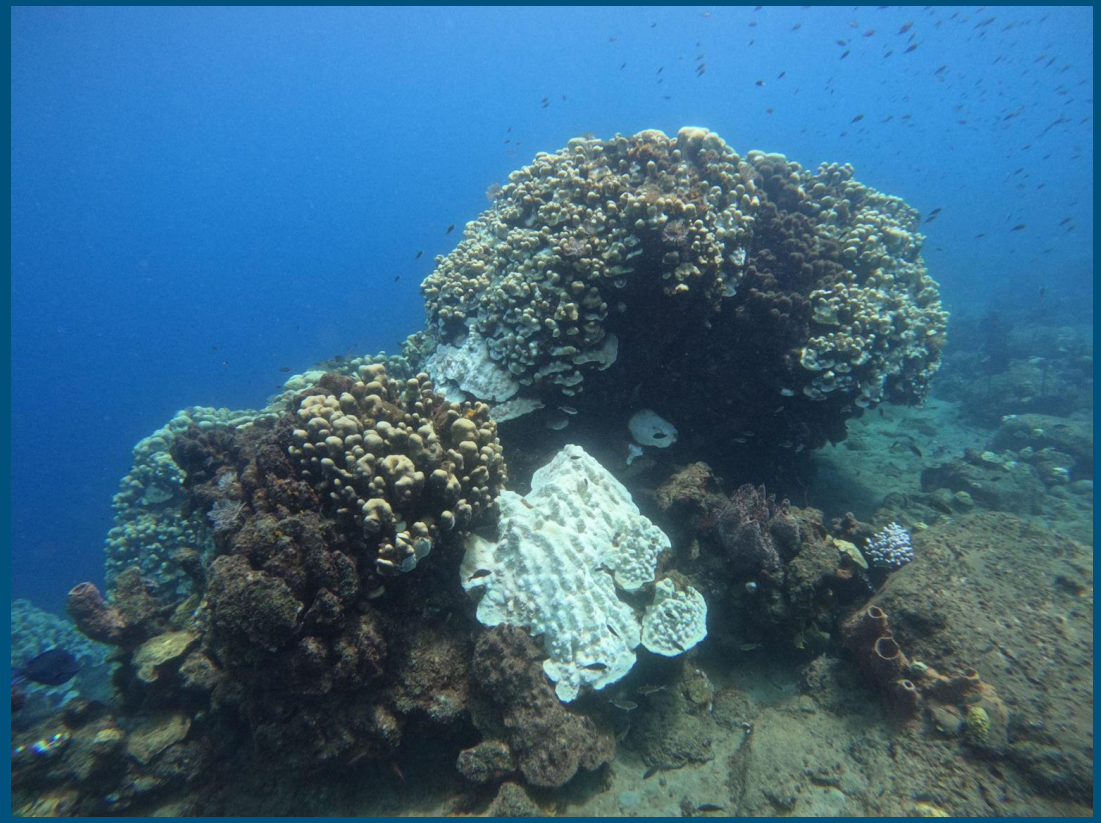
At the time of the 1 st CCT Bleaching presentation on Sept 10, 2023 Dominica water temps were 86f/30c. There were no indications of bleaching.

- September 11th. First Signs of paling CNAT and AGAR
- September 11th. We initiated a phased 4 step intervention program
- September 12th Step 1. Nursery Trees shaded
- September 19th Step 2. Nursery trees pulled to deeper water
- September 21st Step 3 Reef CNATs shaded.
- October Step 4 DCYL Feeding

September 20th water temps of 87.9 f /31c

Rapid Onset Bleaching September 21, 2023

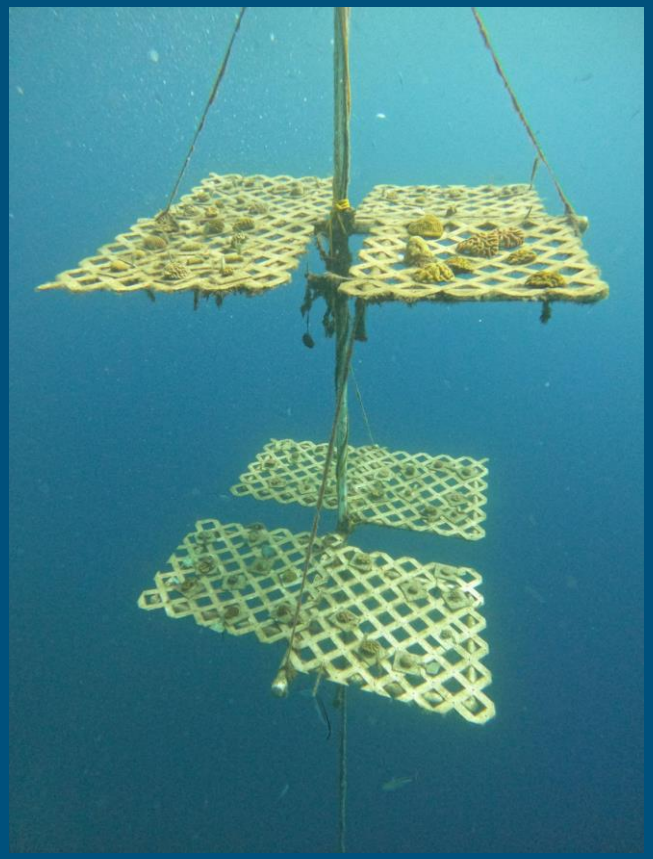


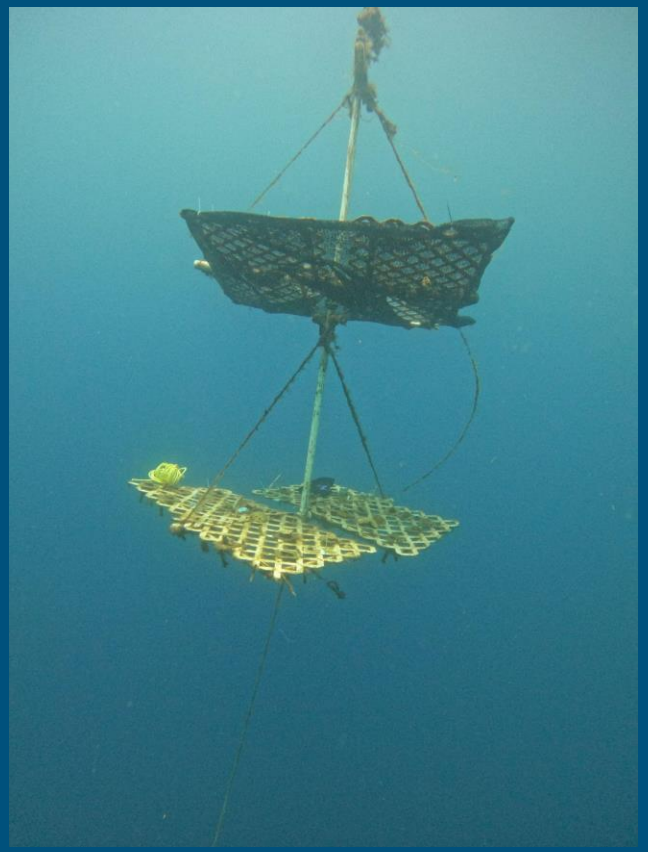


Step One: Protect Nursery Colonies

Nursery Tree Shading. September 12 th 2024

- Tray Tree: Removed upper-level colonies to lower level and built shading over upper level. Only 2 Colonies bleached.

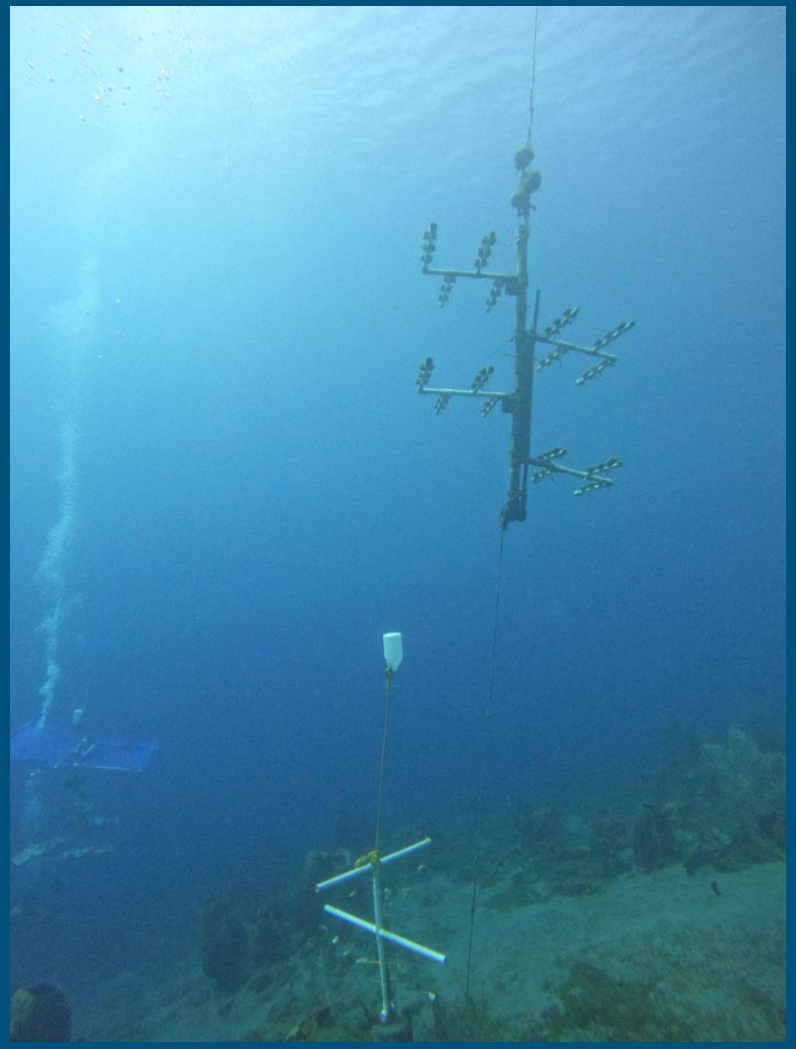




Pillar Tree: Shading for DCYLs

DCYL on the left was shaded early and started to recover in patches but ended up dead. Right DCYL never bleached badly as is fine today.

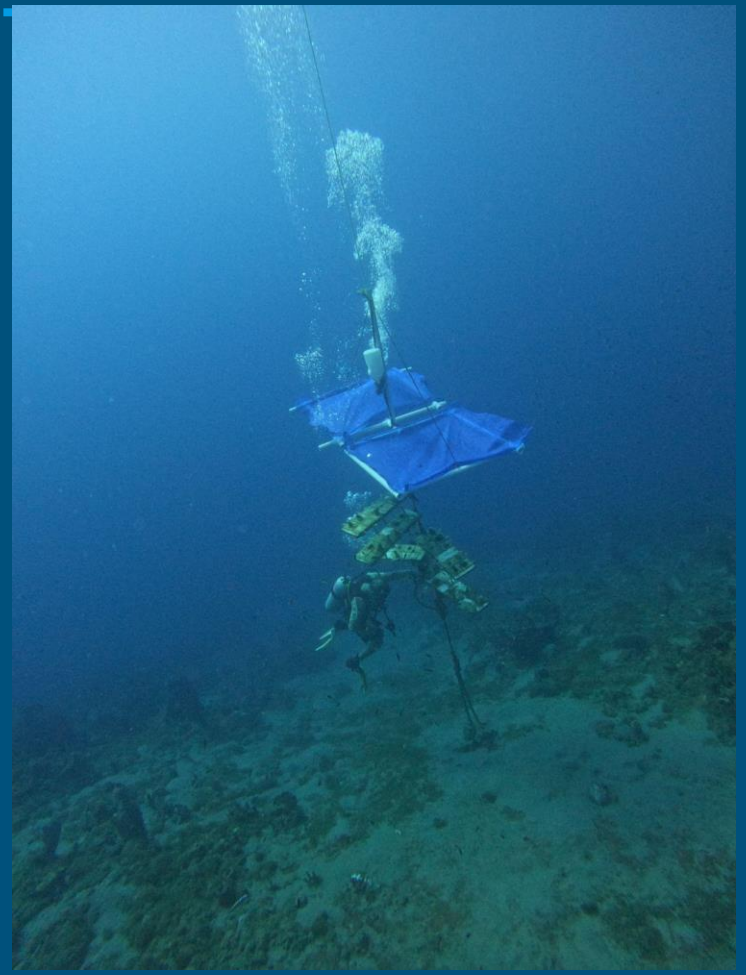
STEP 2: Pulling Trees into deep Water, September 19, 2023



- Trees pulled down to between 20 m and 24 m
- Some were ALSO shaded
- At 32 M Temps were 86f/30c. Not cool enough to allow recovery

- Interventions terminated when temps cooled in Late October.

Conclusions for Tree Shading and Depth Increase in the Nursery



- Shading Trees early helped to slow bleaching progression
- Shading ALREADY bleached colonies did not allow them to recover during high temps.
- Out of 290 Colonies on Nursery trees we lost 5 colonies
    - 2 x DCYL (pillar)
    - 1 x MANG (flower)
    - 1x AGAR (plate)
    - 1 OFAV (star)

Step 3: In Situ Coral Feeding

To compensate for lack of light due to shading and depth we fed DCYLs throughout the bleaching period. None of our nursery colonies that we fed died from bleaching.

The bag was left on for about 10 mins to 15 mins while we did other nursery jobs.

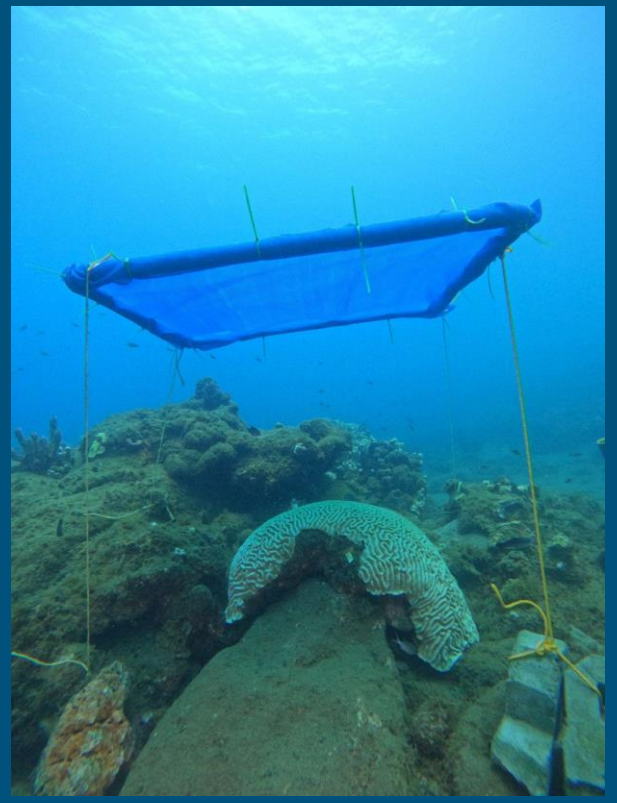
STEP 4: Shading In-situ Colonies on Dive Sites, September 21, 2023

We Shaded 25 CNATS until temps cooled in Late October

Custom made for each Colony

All 25 survived

3 have since died from SCTLD



Conclusions from 2024

- Act early. This year as soon as we reach 86f/30c, we will shade.
- Our efforts resulted in increased survivability in the Coral Nursery.
- In-situ, while all shaded CNATS survived we had no controls and by mid- October the oceanic temps had started to drop.
- We were surprised that there was very little difference in temperatures at depth.
- Coral Feeding seemed to help.

Questions Remaining

If temps are not significantly lower at depth, is it necessary to lower trees AND shade?

How deep could we take DCYLs and for how long?

Are there any studies on bleached corals and feeding?

Long-term Solutions

In Partnership with Oceans Forward, REZDM, The Fisheries Division and the Soufriere Scotts Head Marine Reserve, we currently have an Ex-situ tank system under construction.

Active feeding

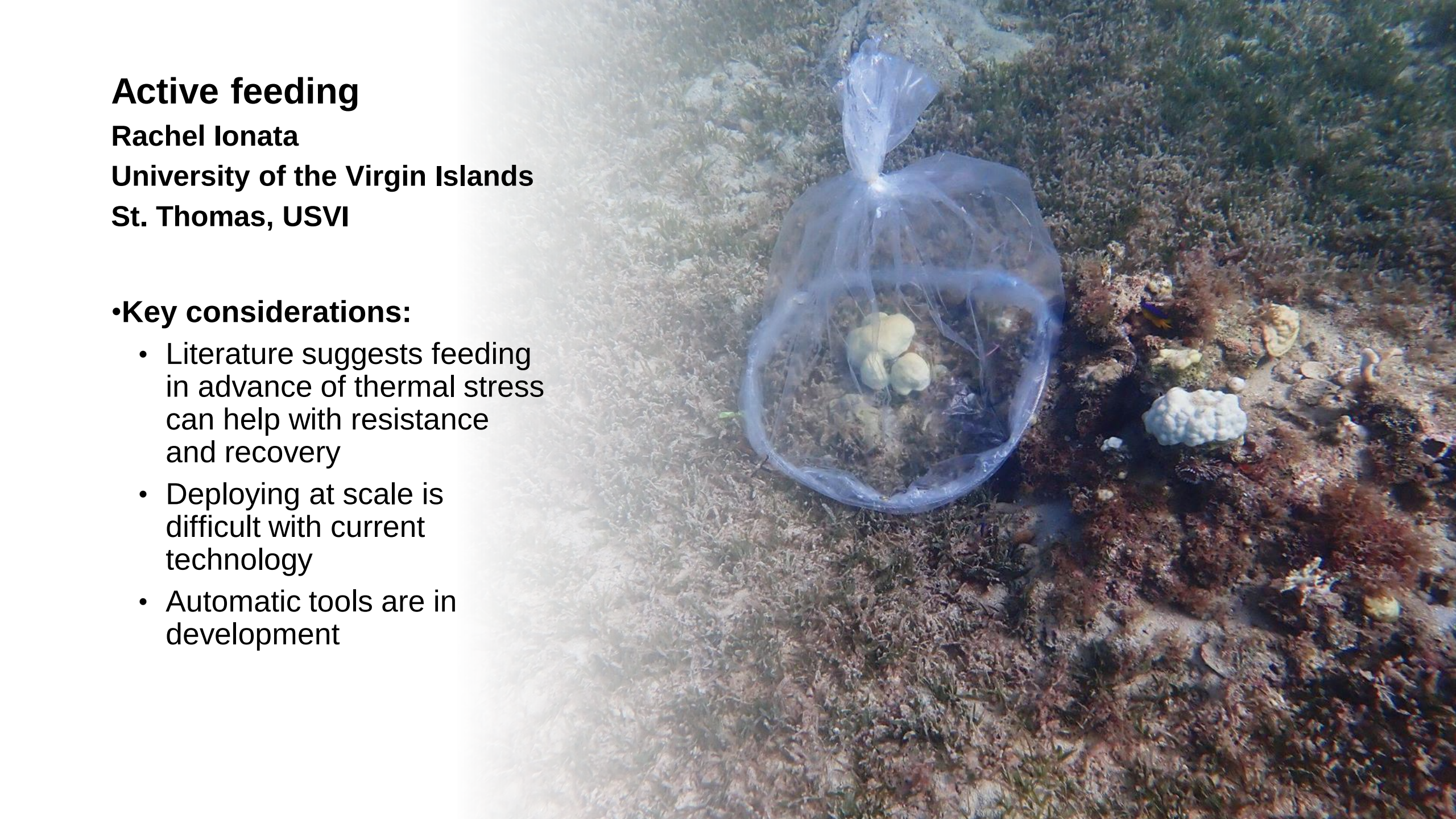
Rachel Ionata

University of the Virgin Islands

St. Thomas, USVI

•**Key considerations:**

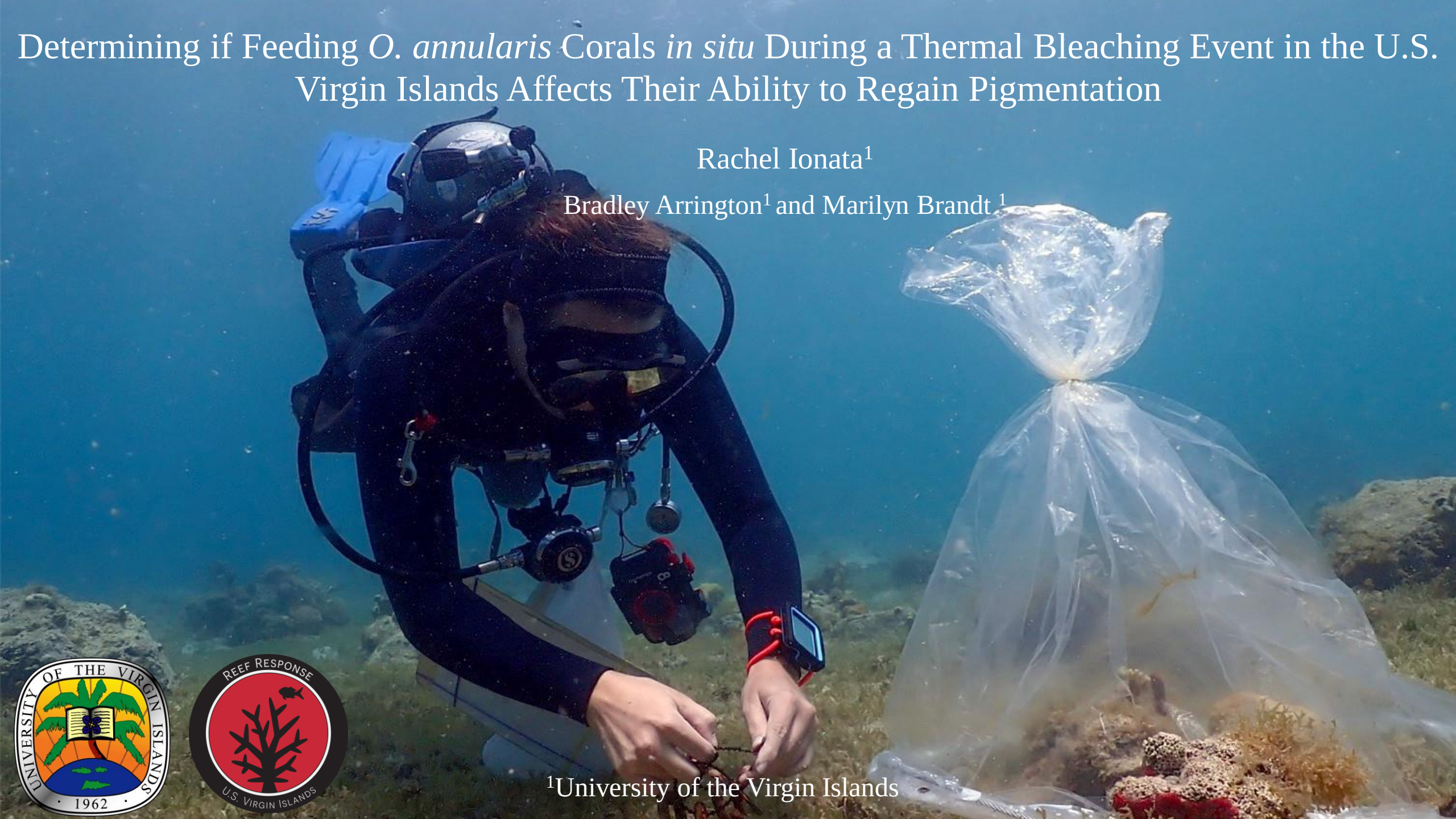
- Literature suggests feeding in advance of thermal stress can help with resistance and recovery
- Deploying at scale is difficult with current technology
- Automatic tools are in development



Determining if Feeding *O. annularis* Corals *in situ* During a Thermal Bleaching Event in the U.S. Virgin Islands Affects Their Ability to Regain Pigmentation

Rachel Ionata[1]

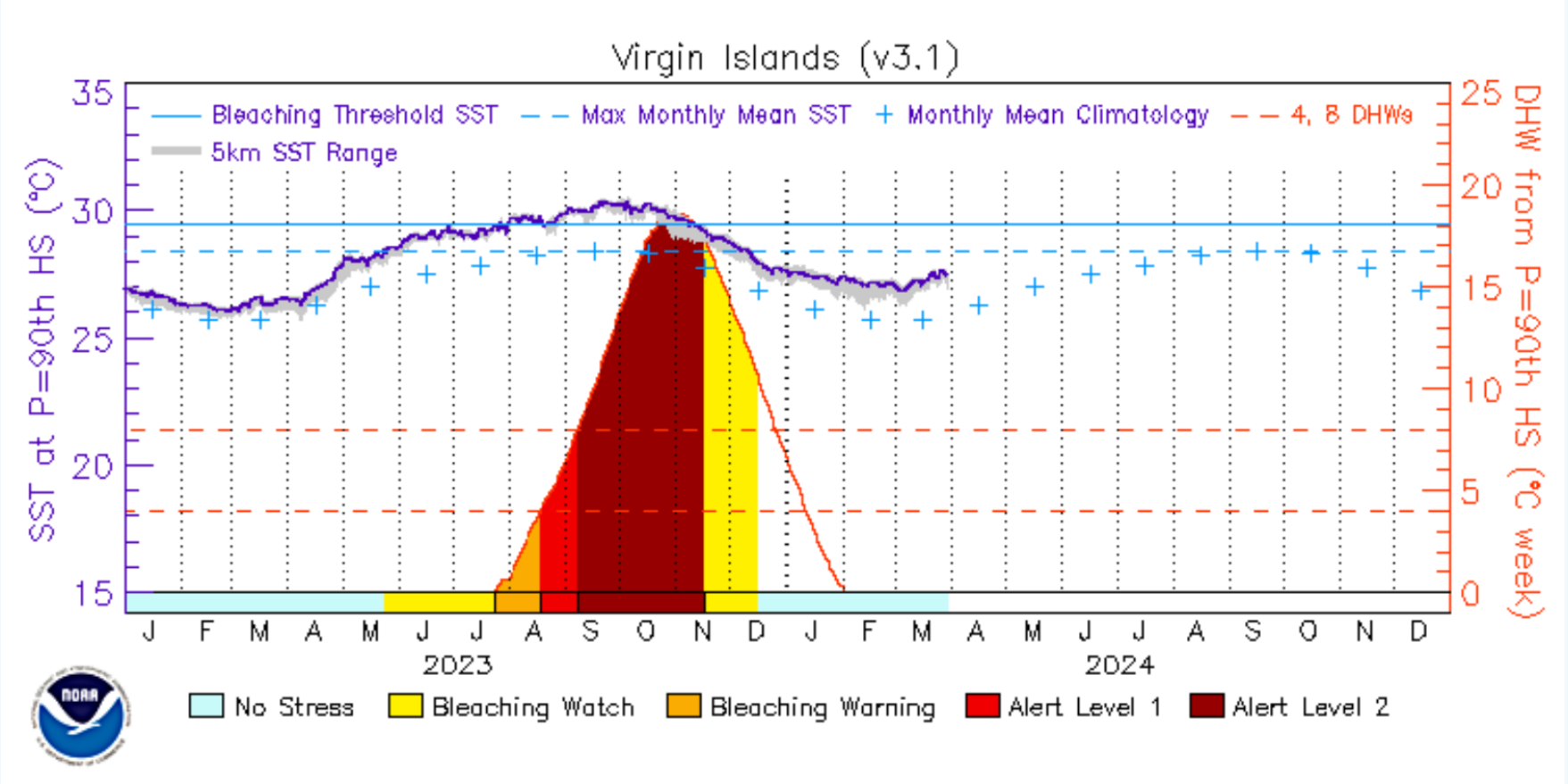
Bradley Arrington[1] and Marilyn Brandt [1]



[1]University of the Virgin Islands

2023 Mass Bleaching Event

- USVI reached a max temperature of 30.6 ℃
- 18 DHW
- 119 consecutive days at or above bleaching threshold of 29.4 ℃ (July 21- Nov 16)



https://coralreefwatch.noaa.gov/product/vs/timeseries/caribbean.php#usvi

Study Site: Range Cay, St. Thomas, USVI

Methods

Orbicella annularis

Common name is the lobed star coral

Reef building stony coral

ESA listed coral

Methods

N= 18 fully bleached *O. annularis*

N=6 per treatment; 3 treatments

6 corals were covered with bag
and CoralAmino, and left for 3

6 corals were covered with bag
were not fed

6 were untouched controls

Methods

Once a week for 8 weeks:

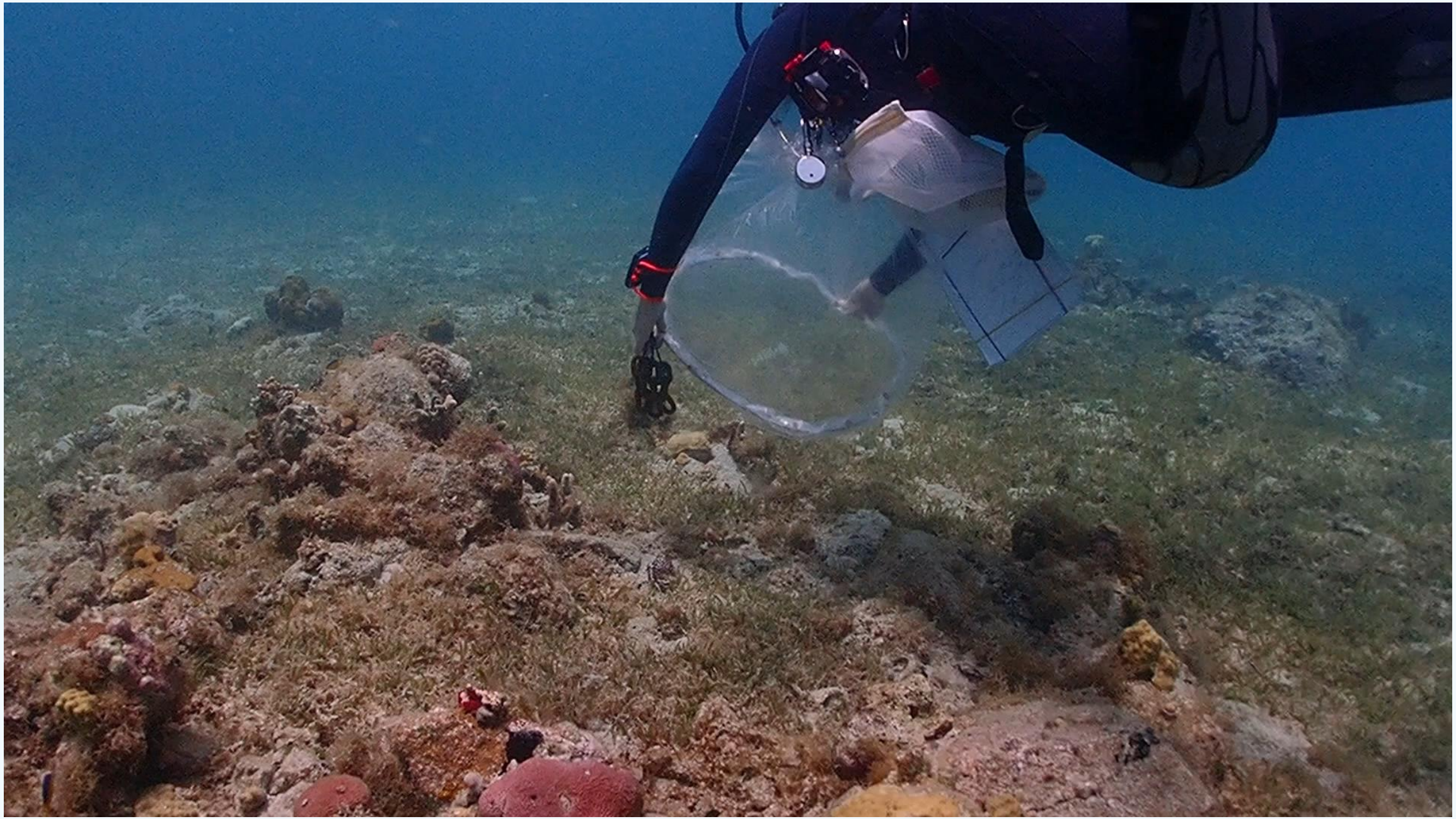
During daytime hours

Starting October 31, 2023

Needed to get supplies
Needed to get approval

Thermal max in USVI was October 5th

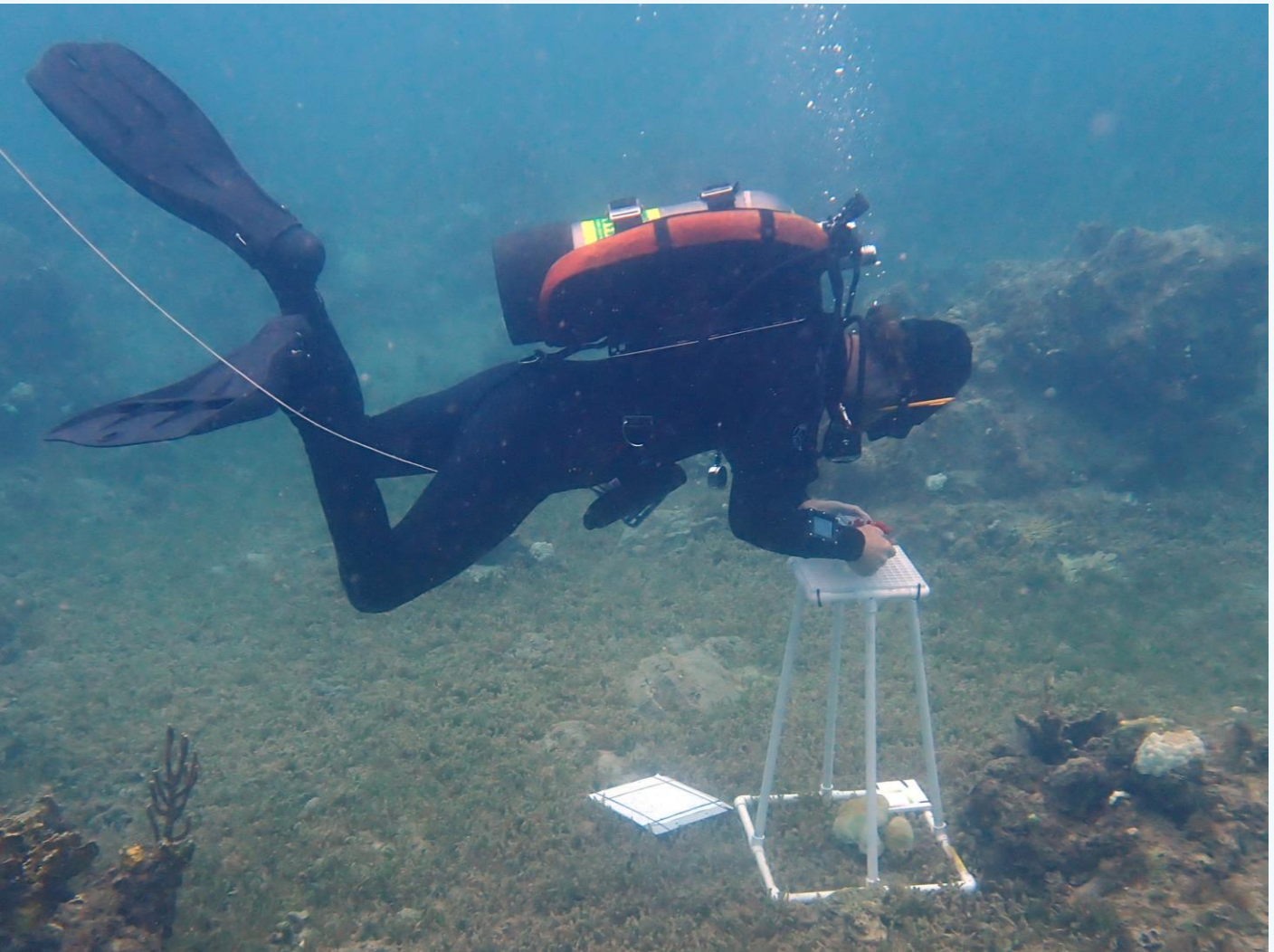
Methods



Jason Quetel

Methods

- Framer Photos
- Health:
  - % Bleaching & % Paling
  - % Recent Mortality

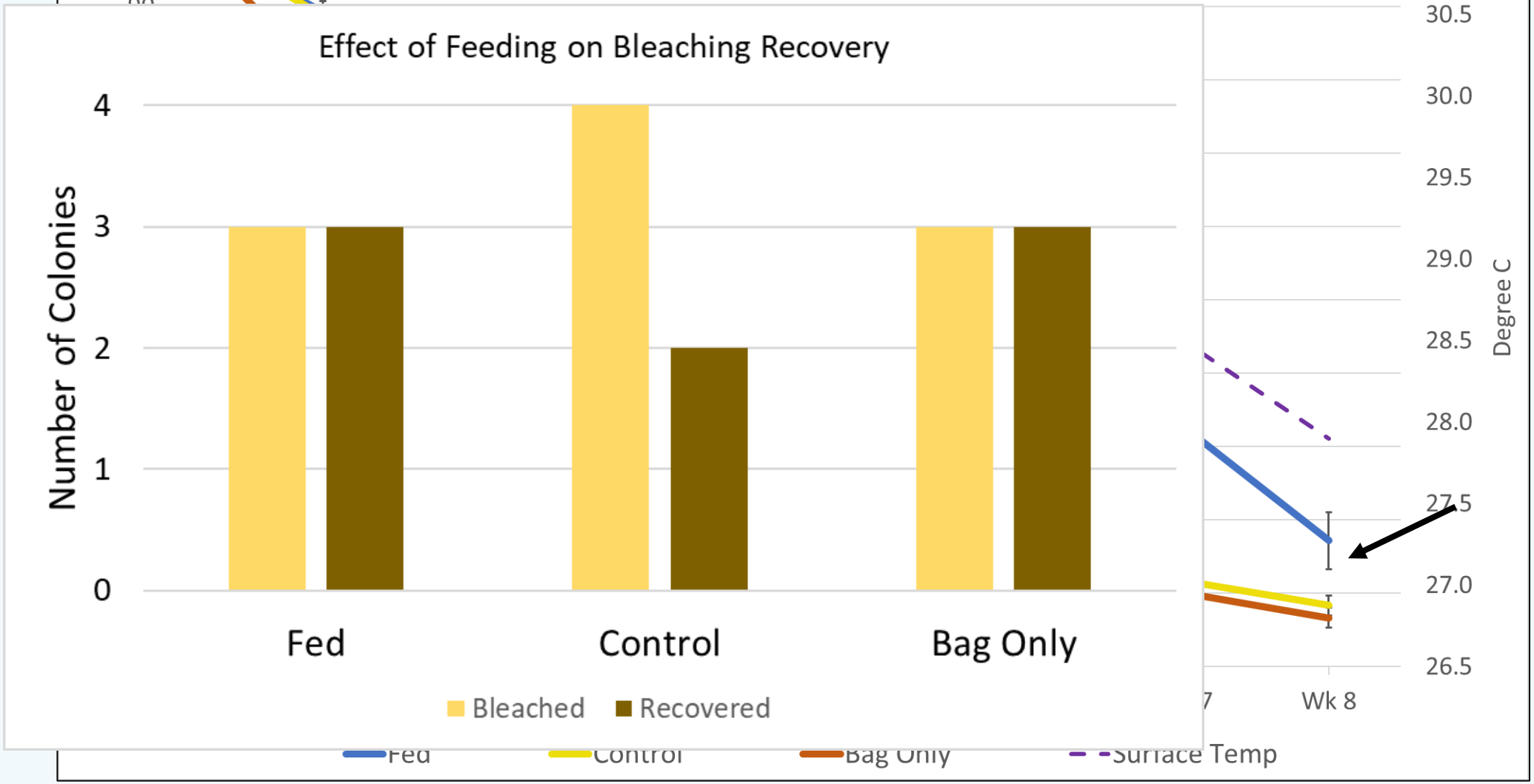


Results/Discussion

Repeated Measures ANOVA: Significant effect of time (p=<.001), but no effect of treatment (p=0.77)

chi-square: There is no significant difference in recovery among treatments ($X^2 = 0.45$; $p = 0.80$)

Visually, fed corals remained in a bleached/stress state longer



Recommendations

Feeding *Orbicella annularis* during thermal bleaching is not worth the cost

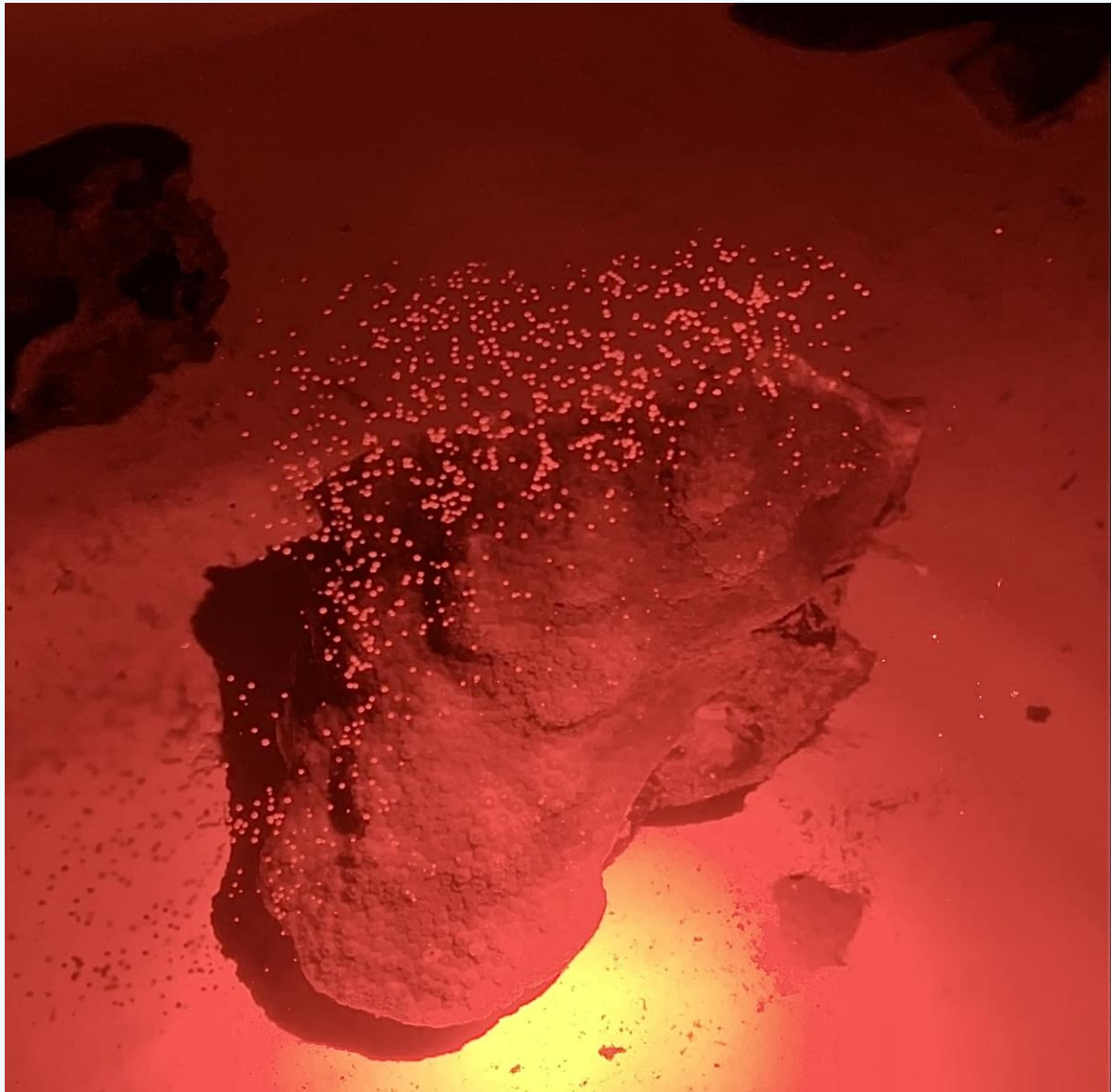
Item	Quantity	Price	Full price
Assembled bag	6	10.69	64.11
Reef roids	57.6	0.27	15.60
Aminos	48	0.06	2.70
Boat	8	70.00	560.00
Tanks	16	10.00	160.00
Total			**$802.42**

Recommendations

Continue monthly monitoring

- Observe if there is a difference between treatments in spawning the year after thermal bleaching
- Focus on your keystone species/broodstock corals

Feed/feed more heavily before heatwave rolls through

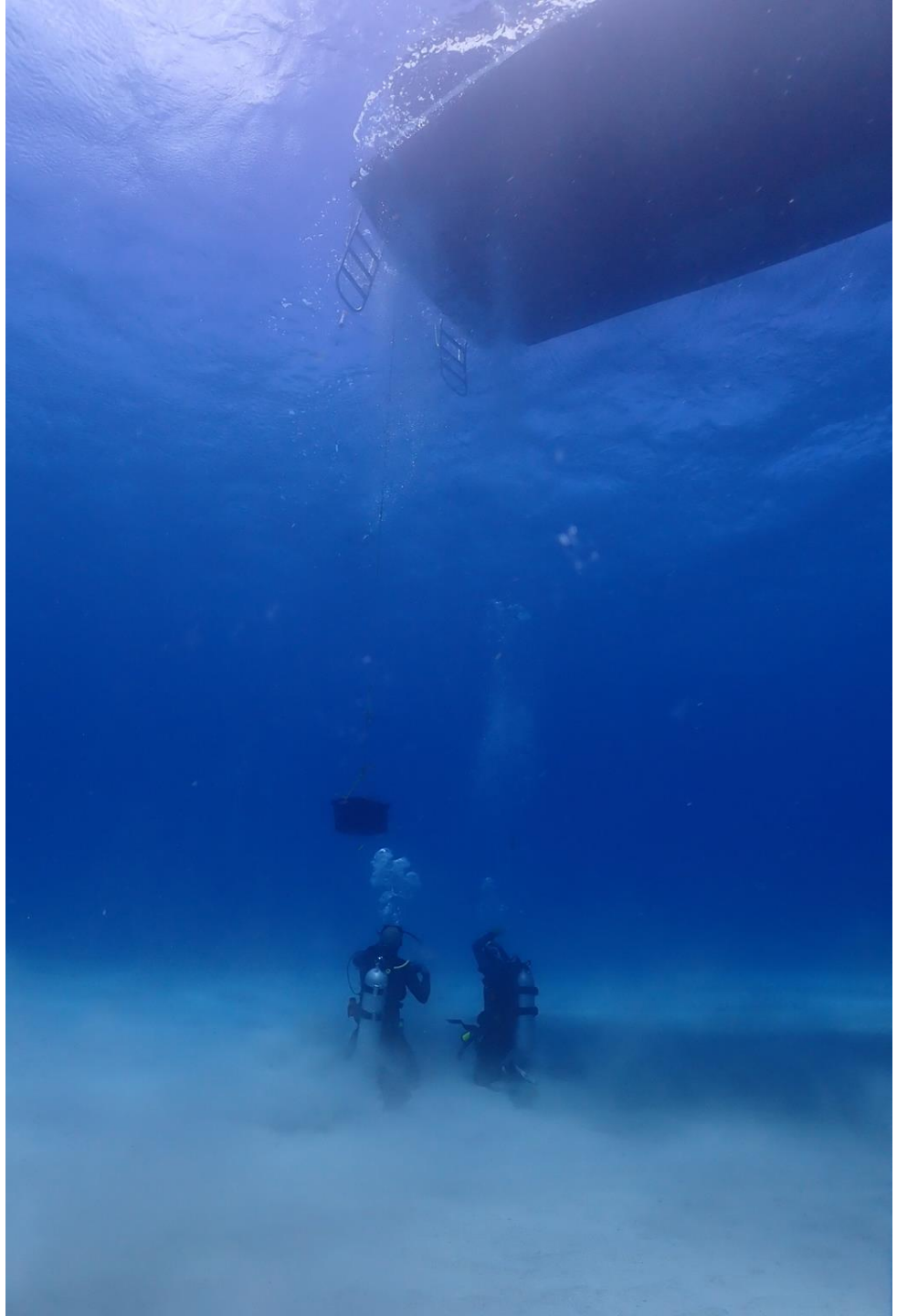


Nursery evacuation

Matt Davies
The Nature Conservancy
St. Croix, USVI

Key considerations:

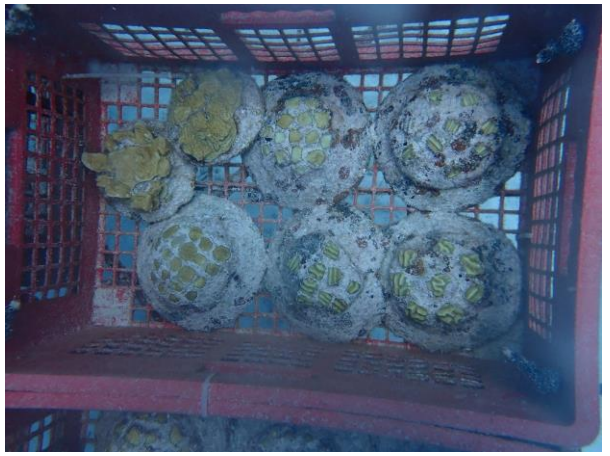
- Requires significant effort, funding, preparedness; less feasible at scale but an option for founders, a few representatives of unique genotypes, or a percentage of stock
- Should be considered only in severe circumstances and occur prior to accumulated thermal stress
- Massives fared better than branching corals
- Facilities need suitable, ready-to-use infrastructure, expertise, and space
- Knowing when to move corals back to the field-based nursery is difficult
- Transport stress should be considered



CORAL EVACUATIONS TO AN EX-SITU FACILITY

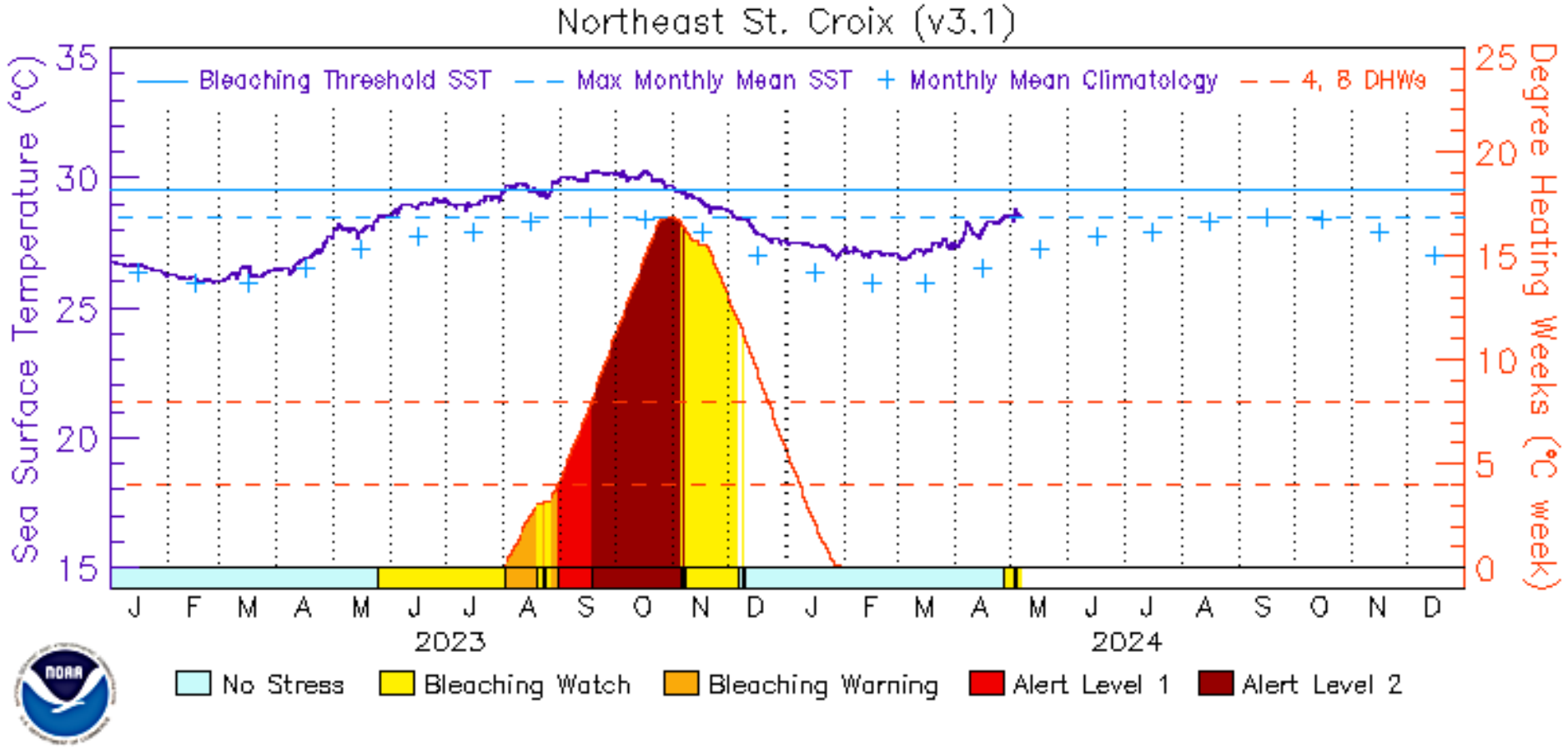
Matt Davies

Field Coordinator - Virgin Islands Program



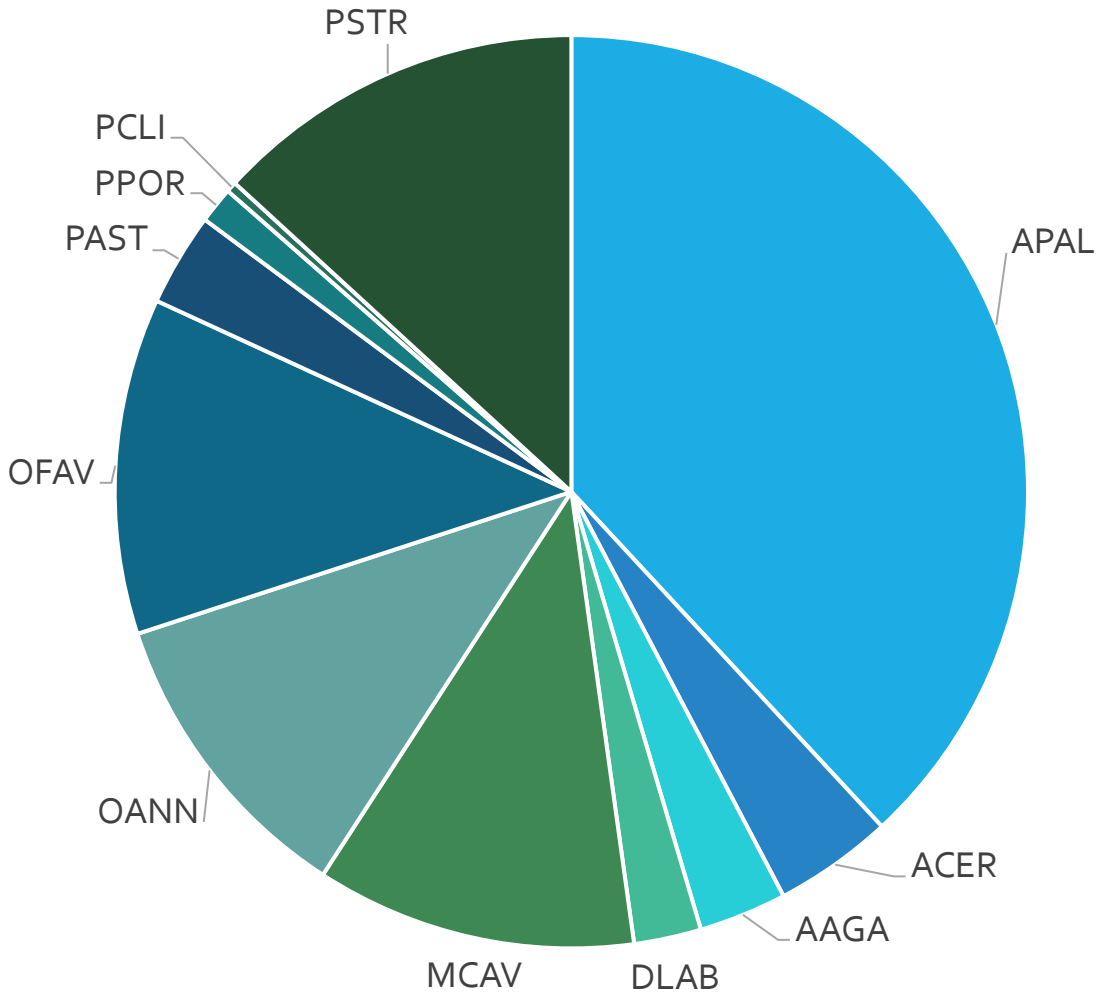
U.S. Virgin Islands CORAL INNOVATION HUB

The Nature Conservancy



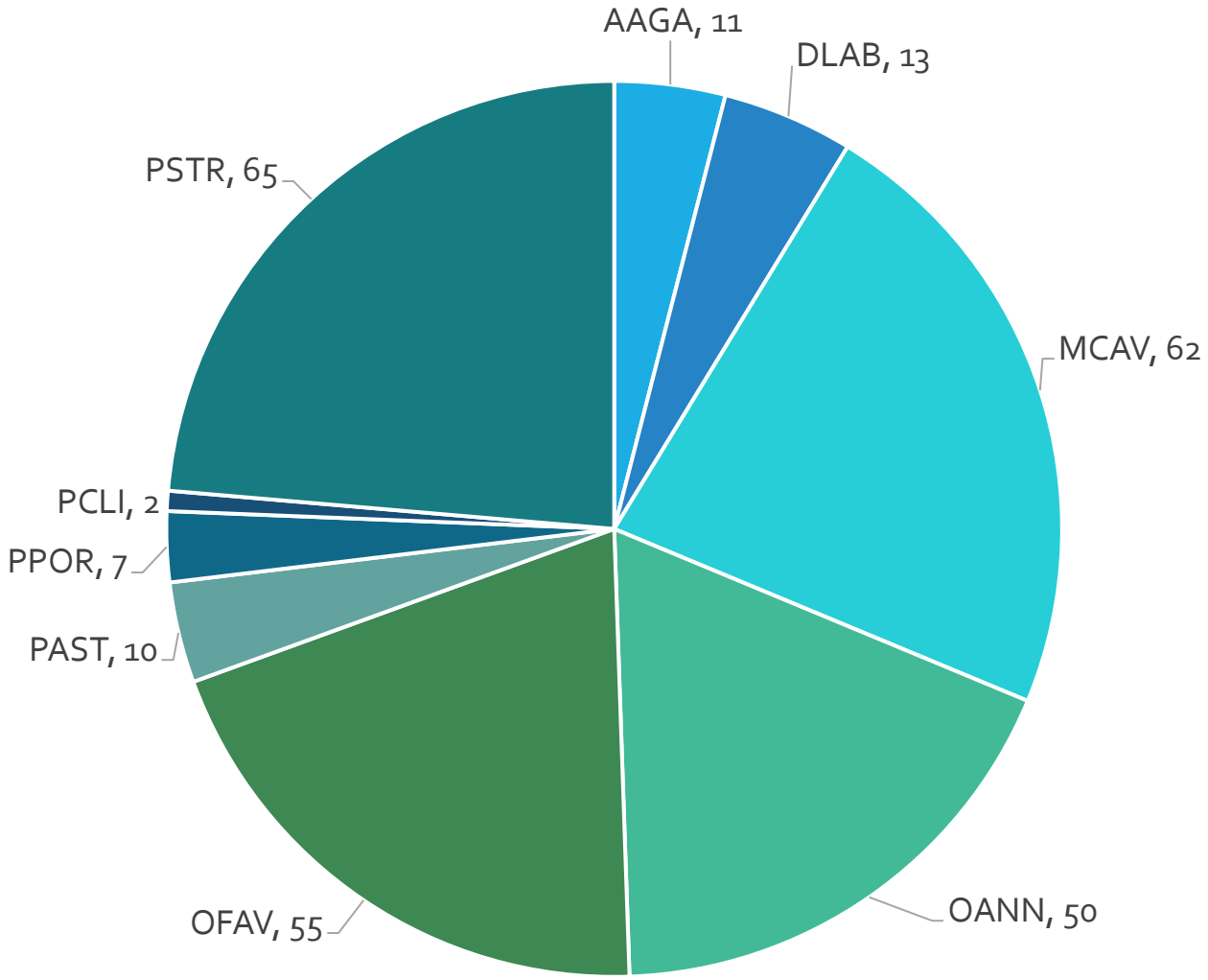
Coral evacuations initiated on August 24th

Field Nursery Inventory July 2023



Total = 546

Corals evacuated August 24th – September 07



Total = 275
Approx. 50% of stock
85% of non-Acroporids

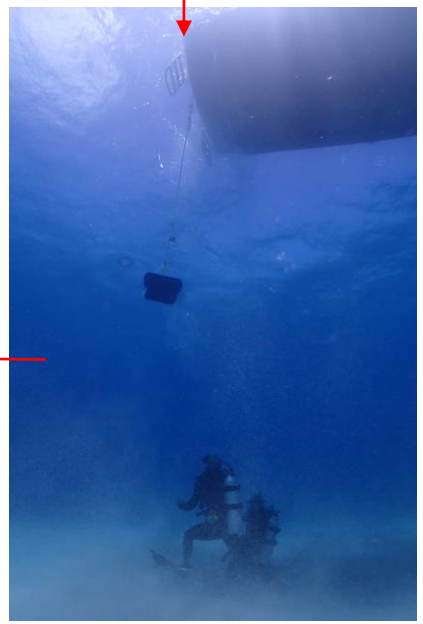
Evacuation Procedures

1. Removed substrates from in-situ nursery structures (tables), prioritizing substrates with most living tissue
2. Lifted corals to boat in milk crates
3. Transport to land facility in coolers (approx. 45 – 60 min transfer time)
4. Drip acclimation followed by removal of unwanted organisms (e.g., ramicrusta, boring sponges) and a 15 min iodine bath

Time Investment

Field team – Two full days (5-6 divers plus captain)
Land team – 2-3 hours per intake (2-3 staff)

Total – 50-70 human-hours



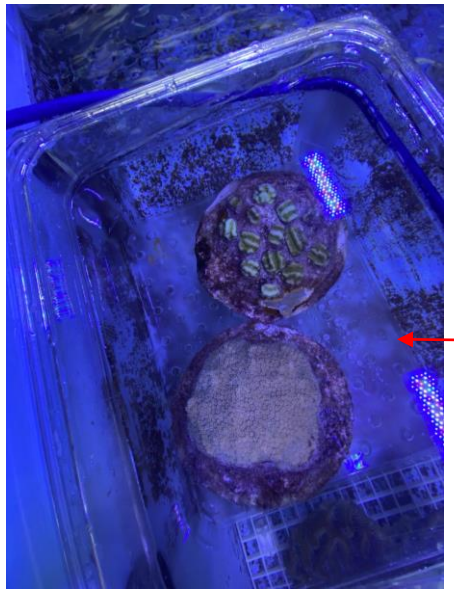


Photo credit: Macallan Durkin

Successes

- Most evacuees recovered fully and were returned to field nurseries in December/January
- The remainder were outplanted at Buck Island last month or further fragmented into second generation ramets

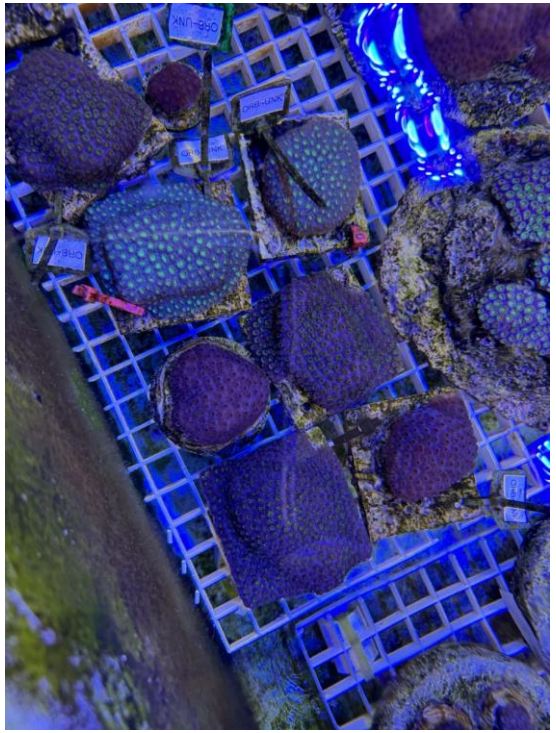


Photo credit: Macallan Durkin

Challenges

- Ex-situ nursery not able to house Acroporids – 80-90% mortality in field nurseries
- Removal from nursery structures was time-consuming
- Ramicrusta
- Record keeping
- Ammonia spikes and ciliate outbreaks

Future planning

- Initiate interventions earlier
- Prioritize genetic diversity over volume – time and space-dependent
- Keep representatives of all Acroporid genets in ex-situ nursery
- Improved nursery design and substrate attachment methods to facilitate easier stocking and removal

Ex-situ genetic banking

Logan Williams
Coral World
St. Thomas, USVI

Key considerations:

- Focus on founding population(s), a few representatives of genotypes, or a percentage of stock
- In an emergency, get corals to safe keeping and sample for genetics later

Ex-situ Coral Bleaching Intervention Efforts

LOGAN WILLIAMS
Coral Scientist

CWORI
CORAL WORLD OCEAN AND REEF INITIATIVE

(340)-643-5435
logan.williams@cwori.org
www.cwori.org

6450 Coki Point
St. Thomas, VI 00802

Introduction

Background information

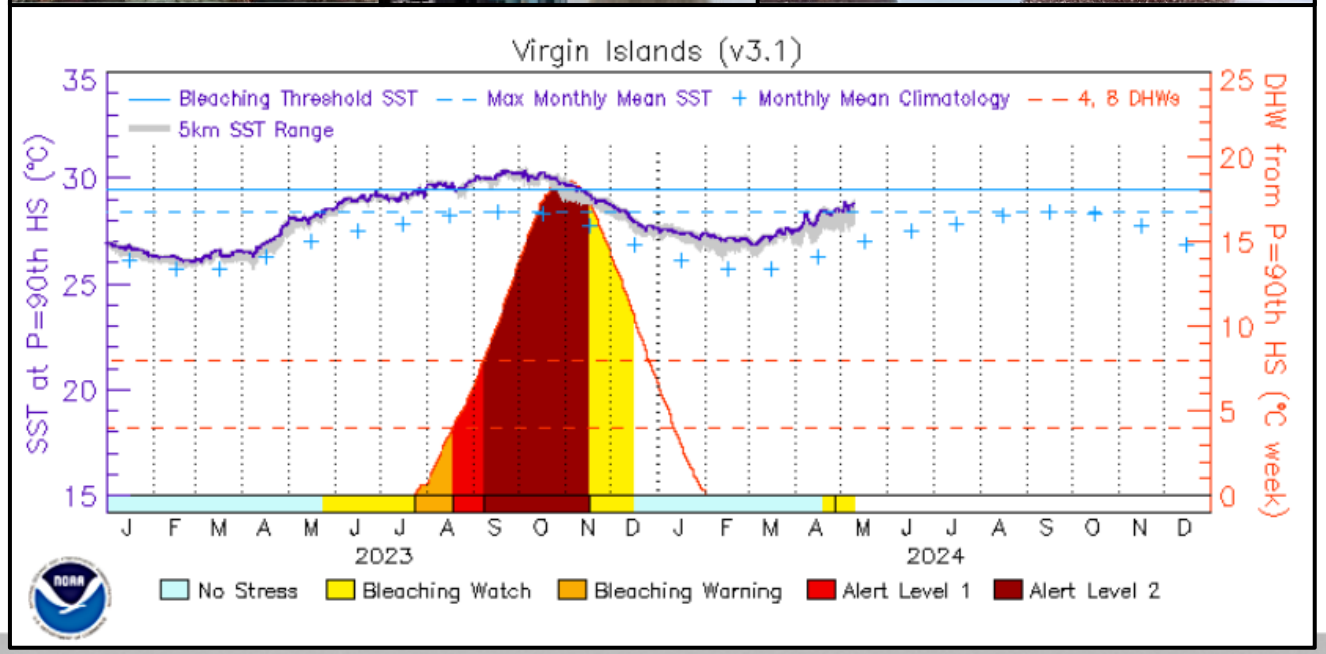
NFWF Rescue to Rehabilitation Project

- Pillar corals were rescued for ex-situ treatment and rehabilitation, between January and May of 2023.

NOAA Coral Reef Watch (CRW) Predictions

- Coral rescue to rehab project close to completion in May 2023, one month before a bleaching watch was issued for the territory.
- Ex-situ bleaching intervention started in late May of 2023.
- Mitigation efforts focused on preserving rehabilitated, pillar coral broodstock.

Rescue **Treatment** **Rehabilitation**



Challenges

Critical Issues

Outdoor Nursery Facility

Exposure to elements, little control over ambient conditions.

Saltwater System Operations

Open, saltwater system, raceway water pulled directly from ocean.

Absence of Aquarium Chillers

Absence of aquarium chillers to regulate raceway temperatures.

Intervention Approaches of 2023

Detailed Overview

Irradiance Reduction Measures

Installed pop-up tents over raceways equipped with adjustable drawstring tarps for controlled shading.

Targeted Feeding

An augmented feeding regimen was implemented to counteract reduced light effects. Corals were fed a diet consisting of artemia, copepods, mysis shrimp, rotifers, spirulina, golden pearls, and amino acid supplements regularly. Each coral was target-fed approximately 2-4 ml of food mixture.

Air and Water Circulation Optimization

Installation of fans over raceways and positioning of powerheads to enhance water circulation and facilitate cooling.

Key Observations

Pillar Coral Resilience

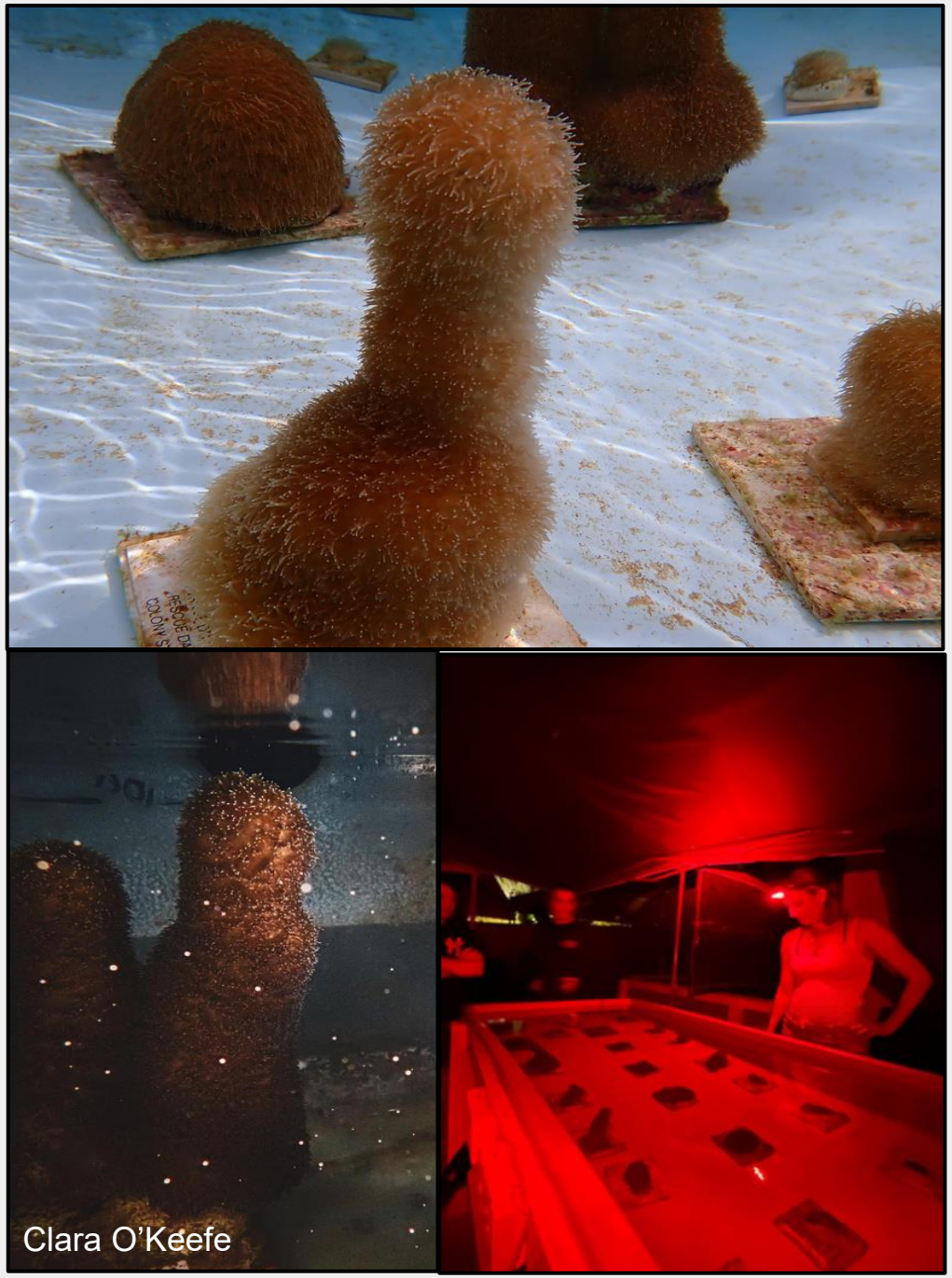
Resilience was observed in Pillar coral broodstock during the 2023 bleaching event.

Reproductive Activity

Corals showed reproductive activity in August, releasing both male and female gametes.

Thermal Stress Indications

Minimal indication of thermal stress was observed compared to other corals on property.



Challenges Faced

Operational Difficulties

Labor and Fatigue

Intensive labor and fatigue experienced by the team.

Extreme Environmental Conditions

High temperatures (100-112°F) and humidity encountered.

Raceway Maintenance

Elevated nutrient levels demanded increased maintenance efforts.

Ciliate Outbreaks

Ciliate outbreaks in November and December were possibly linked to heightened feeding rates and thermal stress.

Future Recommendations

Improvement Suggestions

Aquarium Chillers

Installation aquarium chillers in addition to shading for enhanced temperature regulation.

Industrial Fans

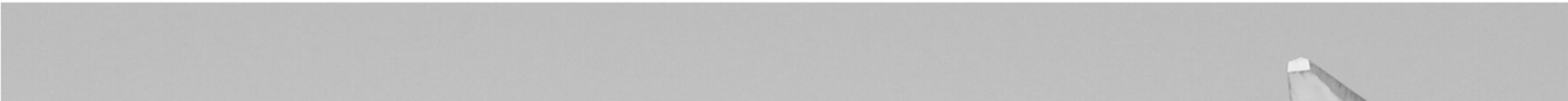
Deployment of industrial fans to ensure comfortable working conditions for staff.

Feeding Adjustments

Adjustments to feeding regimens to mitigate nutrient spikes.

Ciliate Prevention

Establishment of a ciliate management plan to prevent and mitigate future outbreaks.



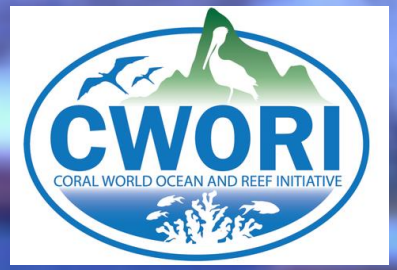
Strategy for 2024

Forward Planning

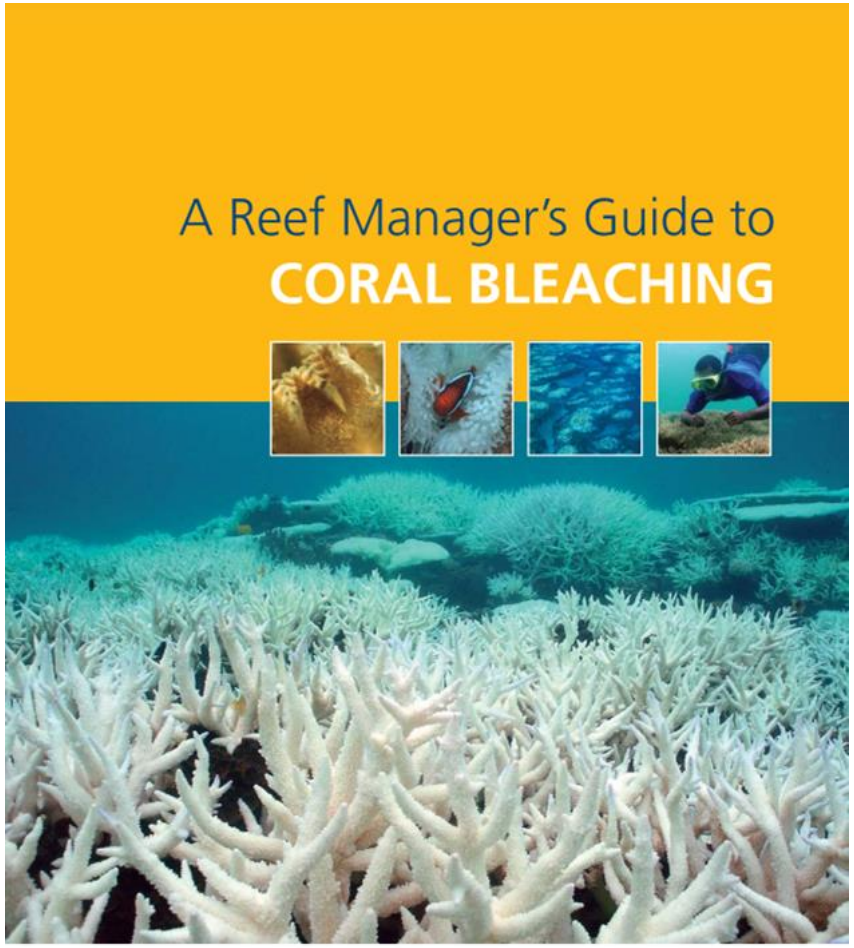
CWORI Coral Genetic Rescue

- Adoption of the CWORI Coral Genetic Rescue and Propagation Ark for future interventions.
- Indoor, climate-controlled facility with independent recirculating life support systems.
- Artificial saltwater parameters are controlled and monitored using the Neptune Apex system.

Acknowledgments



Other useful resources

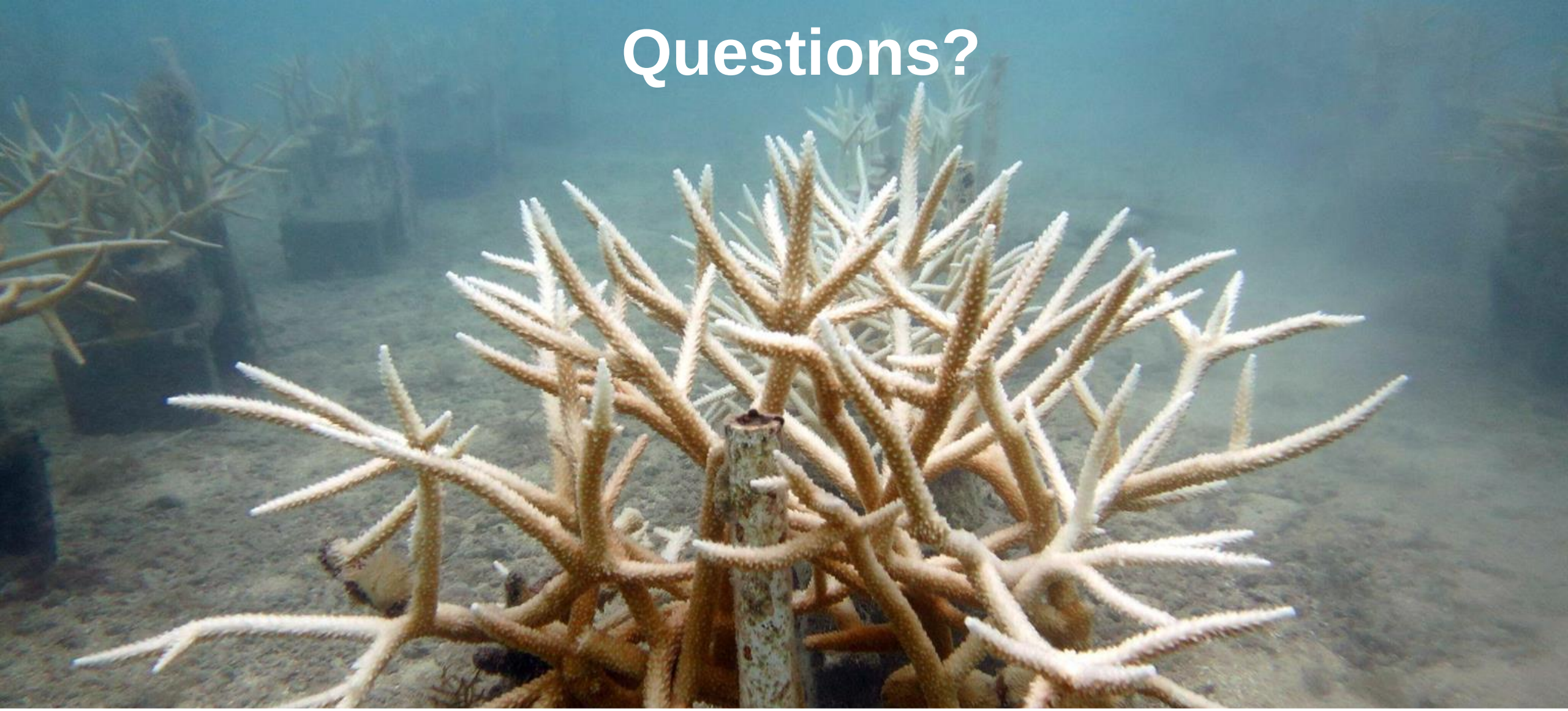


Introducing the Coral Bleaching Toolkit & Comprehensive Guide, A Crucial Step Towards Coral Reef Conservation

08.24.2023 / Posted in CORAL Updates

NOAA Coral Reef Watch Homepage and Near Real-Time Products Portal

Questions?



AGRRA

MPA connect

ORE
Ocean Research & Education Foundation

NOAA CORAL REEF CONSERVATION PROGRAM

Reef Resilience Network

The Nature Conservancy