Caribbean Cooperation Team & AGRRA Partners Meeting

Acropora 2023:

Heat-related Mortality, Resistance or Rescue

What's happening? What can we learn? What's next?

November 13, 2023

Hosted by: Judith Lang & Patricia Kramer (AGRRA)

Photo: Fragments of Hope

Guest Speakers

Introduction

Esther Peters: Mysteries Abound: ***Pathogenic Agents of Disease***

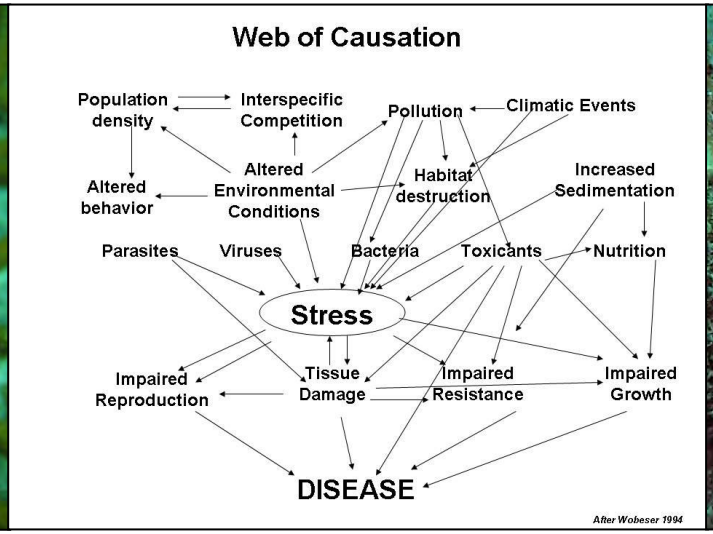
Examples of Mortality, Resistance or Rescue

- Genevieve Renaud-Byrne & Ruleo Camacho: Antigua
- Lisa Carne: Belize
- Felix Charnley: Jamaica
- Emily Becker: Florida

Group Discussion:

Rethinking Coral Rescues for a Warmer World

“Mysteries Abound” (J. Lang): The Exposome and Coral Diseases



GEORGE MASON UNIVERSITY

CORAL DISEASE & HEALTH CONSORTIUM
SOLUTIONS TODAY FOR REEFS TOMORROW.

Esther C. Peters, Ph.D.

George Mason University

Environmental Science & Policy

Coral Diseases

"This coral disease stuff is bigger than any one of us, and we need as many bright minds as possible to contribute and move this forward."

Thierry Work, DVM
U.S. Geological Survey

Wildlife Disease Specialist
National Wildlife Health Center

Honolulu, Hawaii

What is Disease?

- Any impairment that interferes with or modifies the performance of normal [structure] and functions, including responses to environmental factors such as nutrition, toxicants, and climate; infectious agents; inherent or congenital defects; or combinations of these factors (G. Woebeser, 1981).

- Any impairment of an organism's vital functions, organs, or systems, including interruption, cessation, proliferation, or other malfunction, originating from either a biotic or abiotic source (Stedman's Medical Dictionary, 1982).

- Health is the state of an organism when it functions optimally without evidence of disease or abnormality. (Controversy: Coral health vs. coral reef [or other ecosystem] health→ organisms in ecosystem are not diseased, high genetic diversity, relatively rapid recovery when stressed).

Criteria for Disease

- At least two of the following:

Alzheimer's disease: signs, symptoms, brain changes, but pathogen(s?) unknown

✓Recognized etiologic agent(s)

Pathogen - Any virus, microorganism, or other substance causing disease **(biotic or abiotic)**

✓Identifiable group of **signs** (and, in the case of humans, symptoms)

✓Consistent **anatomical alterations**

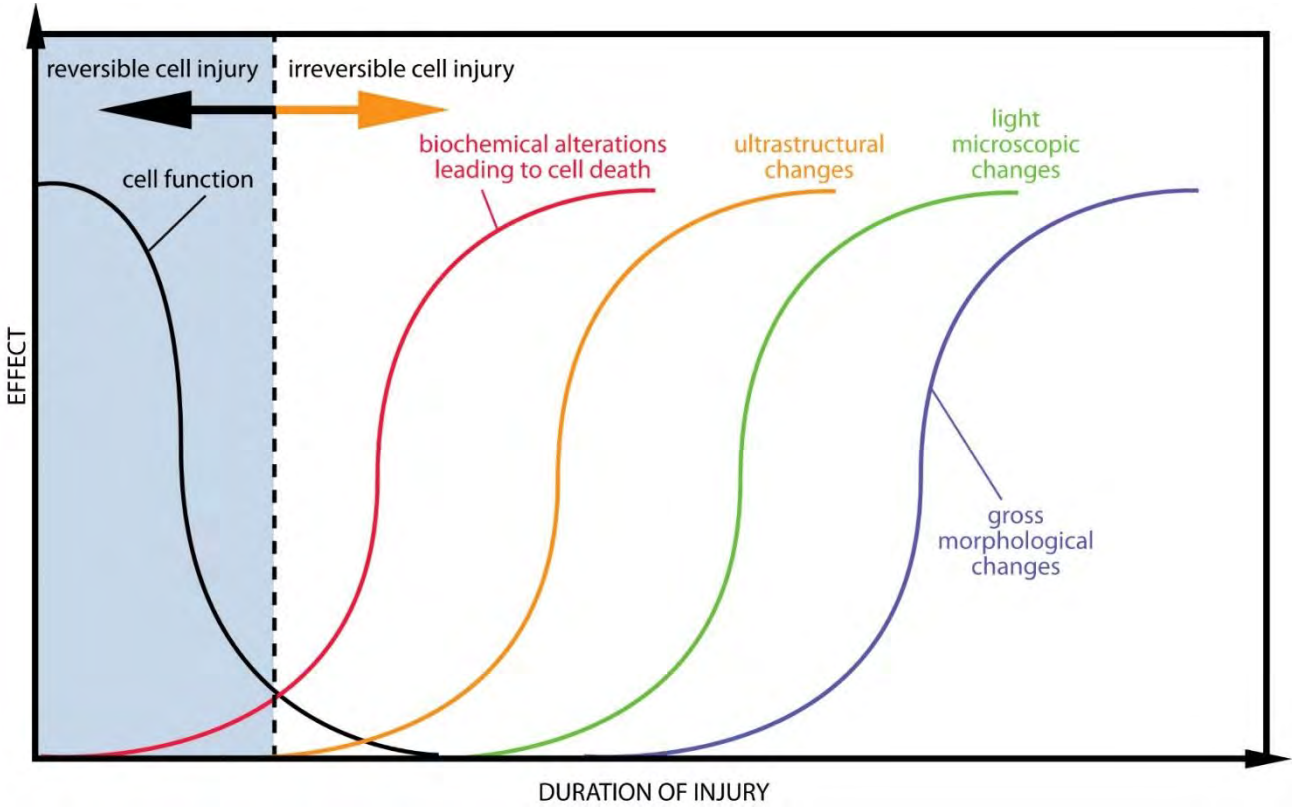
Identifying Coral Diseases

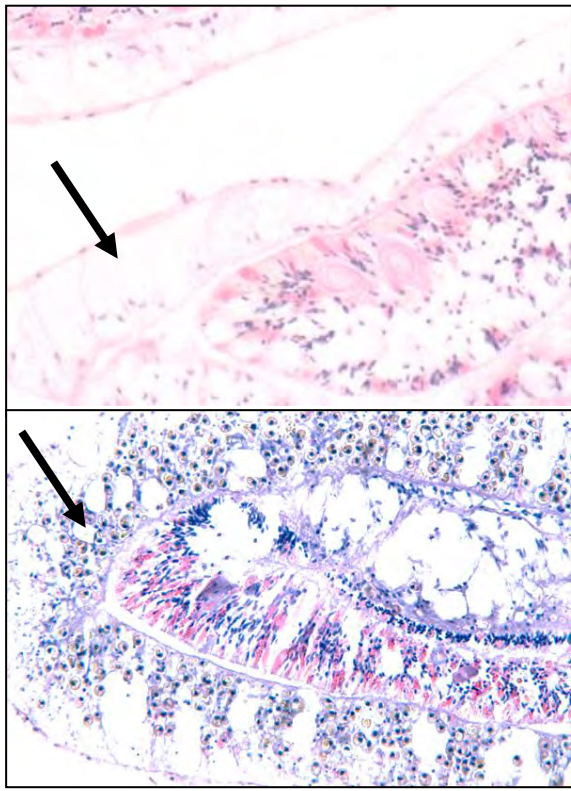
- **Appearance of healthy** coral (microscopic and gross):
  - Normal behavior for the species (tentacle expansion, mouth opening, polyp contraction)
  - Uniform covering of tissue over skeleton (no lesions)
  - Uniform coloration indicating presence of zooxanthellae
  - Skeletal deposition pattern and rate appropriate to the species

- **Functional impairment** in corals:
  - Abnormal polyp behavior
  - Unusual tissue coloration (darker or lighter or different color)
  - Abnormal skeletal deposition pattern or rate of deposition
  - Slow or rapid disappearance of tissue from the skeleton

The Healthy (?) Coral

Tissue changes may be present before visually evident





Graph adapted from Robbins and Cotran Pathologic Basis For Disease 8th Edn., by A. Richards Donà

Pathology – Paradigms of Disease

Koch's Postulates

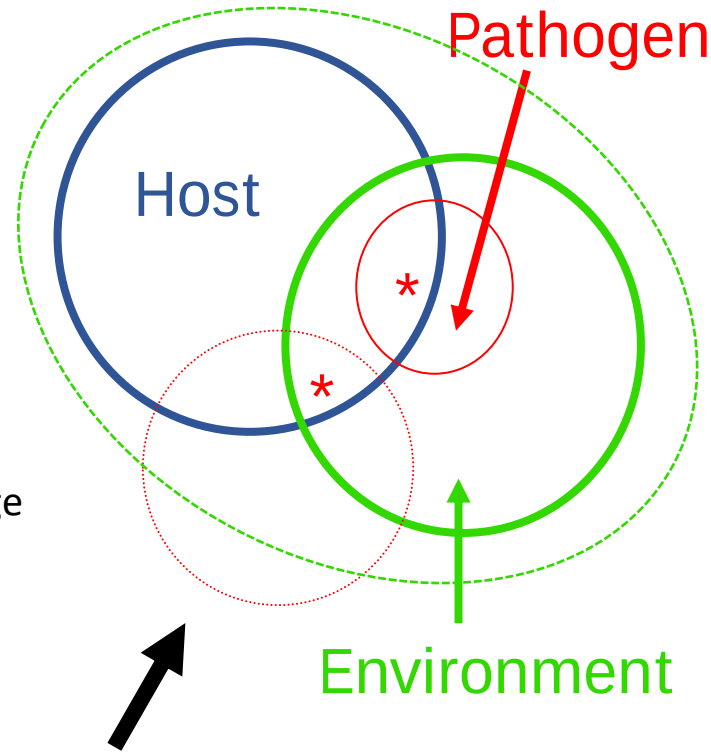
- 1884 – Robert Koch and Friedrich Loeffler
- Four criteria
- Single infectious agent causes one disease, should not be found in healthy organisms, must be grown in culture and reisolated after infecting another individual, and should cause the same disease signs and symptoms in that individual
- Later exceptions: asymptomatic cases, microorganisms that cannot be cultured, other issues

Hill's Rules of Causation

- 1965 – Austin Bradford Hill
- Nine "viewpoints"
- When can associations be interpreted to be causal in epidemiologic studies?
- More likely to be causal when they are specific, meaning the exposure causes only one disease.
- Knew some diseases had multiple causes or risk factors, but he suggested that "if we knew all the answers we might get back to a single factor" responsible for causation.

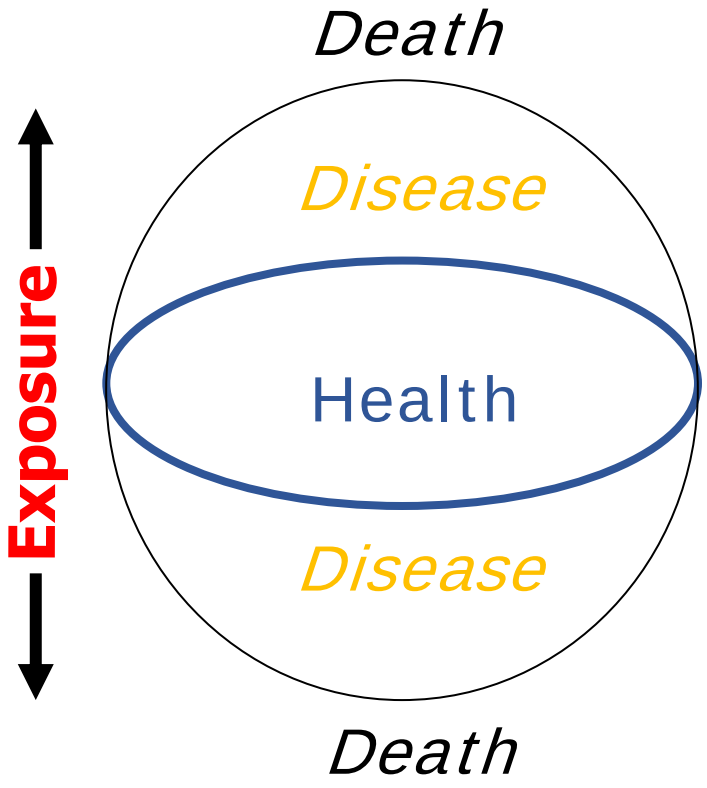
Potential Pathogens

- **Abiotic**
  - ✓ Water quality
  - ✓ Temperature
  - ✓ Light
  - ✓ Nutrients
  - ✓ Pollutants
  - ✓ Toxins
  - ✓ Physical damage
- **Biotic**
  - ✓ Viruses
  - ✓ Bacteria
  - ✓ Protozoa
  - ✓ Fungi
  - ✓ Algae
  - ✓ Metazoa
  - ✓ **Introduced and invasive species**



Epidemiologic Triad

Optimum Envelope



New Paradigm – The Exposome

As more types of data collected for diseased individuals, realized:

Infectious pathogenic (disease-causing) microorganisms may have intermediate, non-diseased hosts as part of their cycle

Single infectious agent may cause several different diseases

Multiple infectious agents can cause diseases (mixed infections)

Single disease requires interaction of several causes

Primary and secondary causes of disease may affect organisms

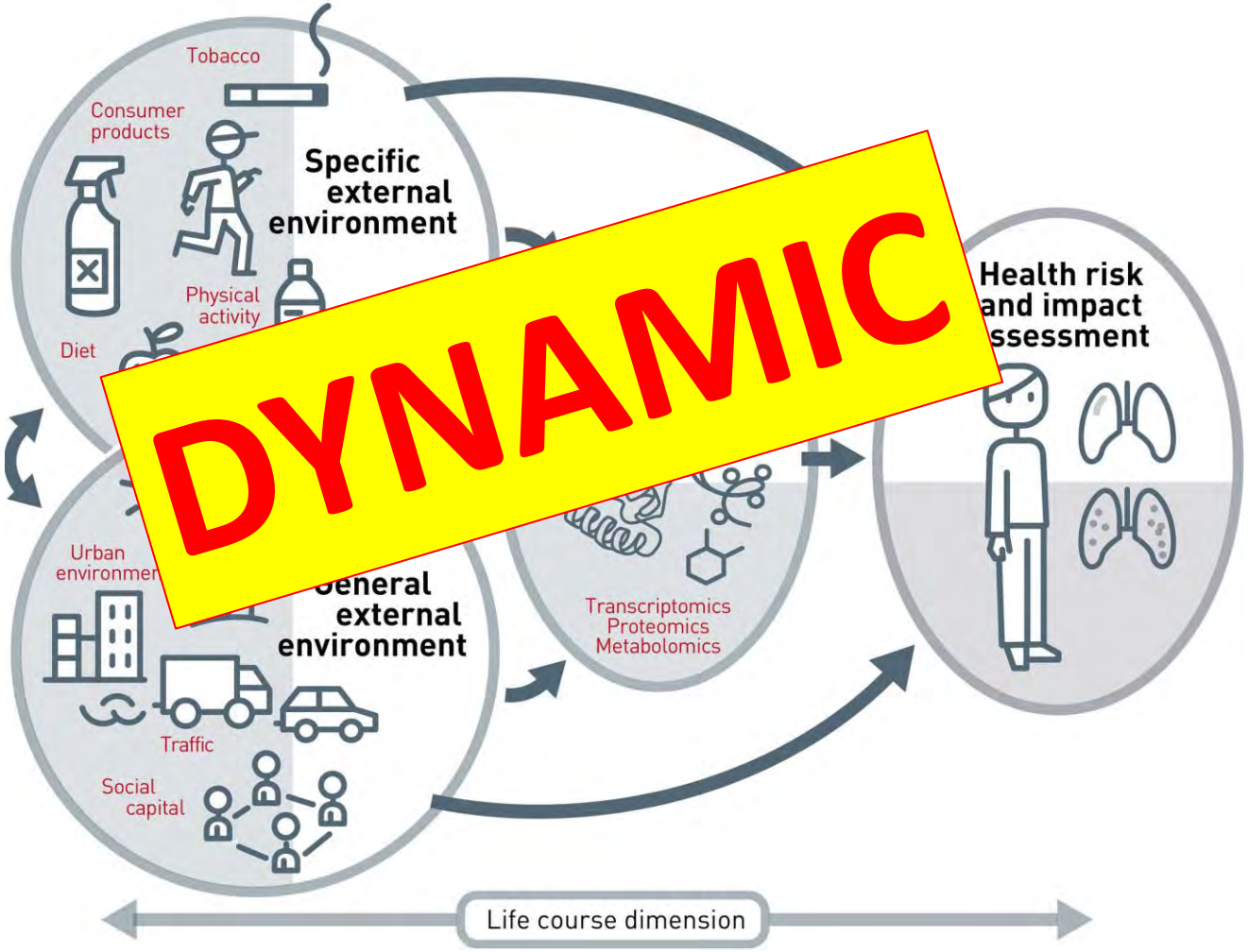
Realized few agents are necessary and sufficient to produce disease over a wide range of environmental conditions

Diseases caused by non-infectious pathogens exist: e.g., biotoxins, metals, pollutants, nutritional, genetic, radiation

Predisposing factors may lead to disease → → → → →

"The **exposome** is composed of every exposure to which an individual is subjected from conception to death." Wild, C.P. 2012. The exposome: from concept to utility. *International Journal of Epidemiology* 41:24–32. doi:10.1093/ije/dyr236

The Exposome Concept

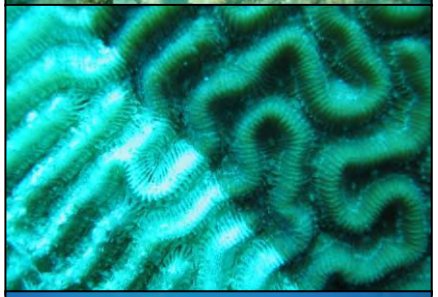


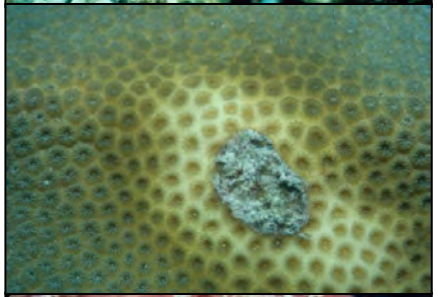
Vrijheid, M. 2014. The exposome: a new paradigm to study the impact of environment on health. *Thorax* 69:876–878.

Tissue Loss
or
White Diseases

FOCUS ON ACROPORA

Tissue
Discolorations





White Band

White Plague

White Pox

White Syndrome

Stony Coral Tissue Loss Disease

Others

Bleaching

Yellow Band

Dark Spots

Dark Band

Others

Differential Diagnoses

- **Bleaching**

- **Tissue Loss**

A systematic comparison and contrasting of similar disease signs and findings to determine which of two or more diseases is present.

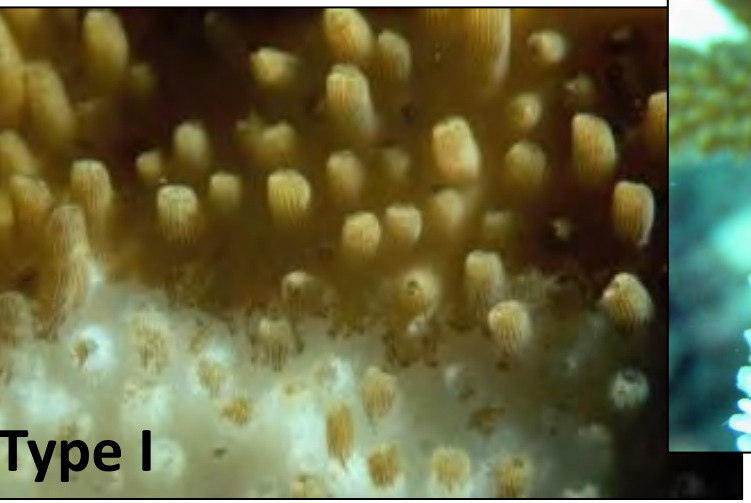
Same visual (macro) signs, same or different etiologic agents?

Coral individual or species differences or different diseases?

Must study multiple parameters!

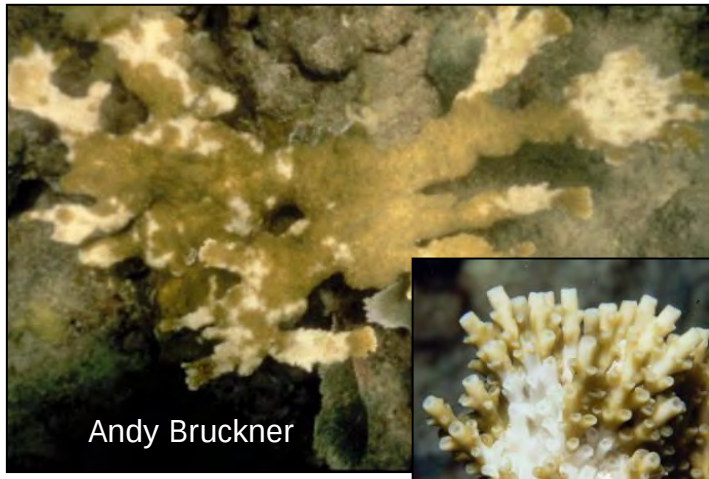
White-band disease
Caribbean elkhorn, staghorn corals

Type I



Type II

White pox/patch disease - elkhorn coral



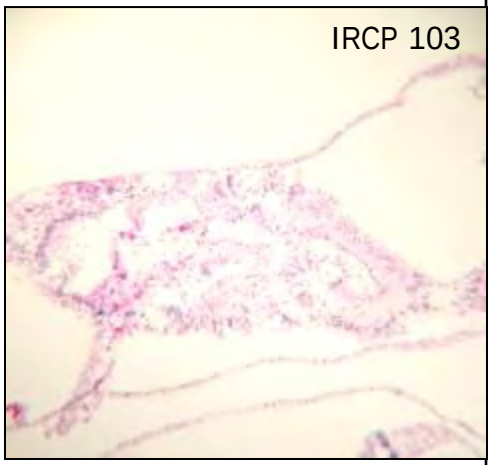
Rapid tissue loss – staghorn coral

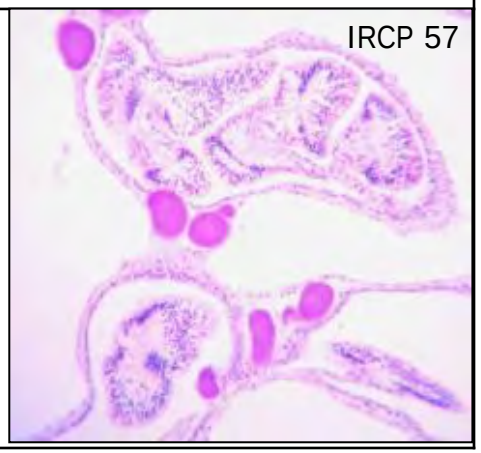
Etiology(ies)?

Disease (Publication Year)	**Species Affected Region**	**Etiologic Agent**
White band (1983)	elkhorn, staghorn, hybrid Caribbean	**Bacterial aggregates?** 
White pox (2001)	elkhorn coral Caribbean	***Serratia marcesans* or not? (2014)**
White band type II (1998)	staghorn coral Bahamas	***Vibrio carchariae/harveyi***
White band types I and II (2006)	Puerto Rico	**And other bacteria Ciliates?**
White band type I (2006, 2011, 2014)	Panama, Venezuela	
White disease/RTL (2005, 2007)	staghorn coral Florida Keys	**Bacterial aggregates? = *Pseudomonas* spp.**

Acroporid Tissue Loss, Florida Keys, July 2003

Species	Location	Gross Signs	Histopathological Findings
A. cervicornis	Elkhorn Reef Marker 3 Reef White Banks Little Grecian White Shoal	Rapid tissue loss	Necrosis of mesenterial filaments Serratiosis?
A. palmata	Little Grecian Palmata Patch	Rapid tissue loss	
A. cervicornis *A. prolifera*	White Shoal Prolifera Patch	Rapid tissue loss	Ovoid basophilic bodies in mesoglea of basal body wall White band disease?



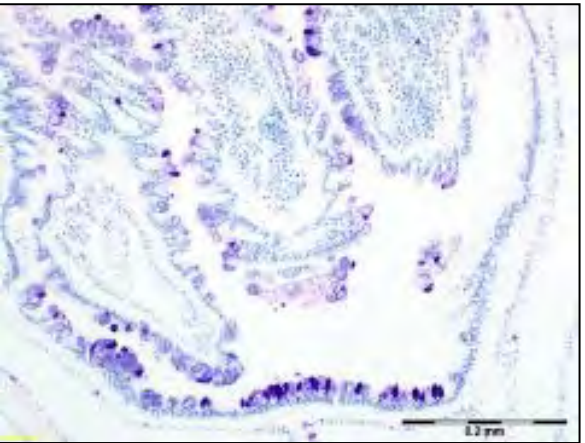


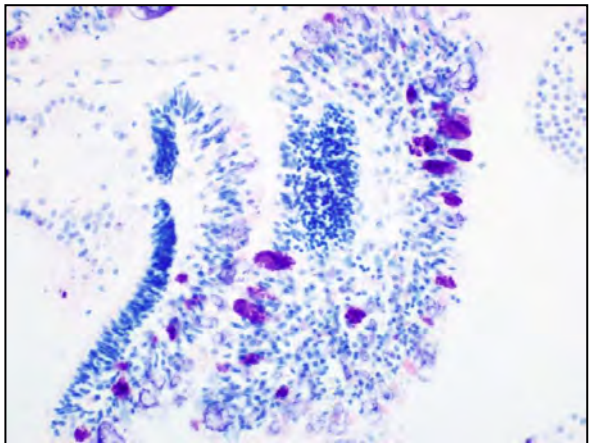
Biscayne National Park Key Largo Sanctuary Reefs Dry Tortugas National Park

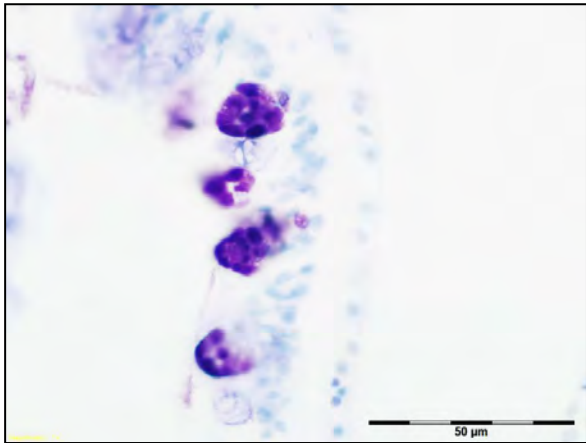
Microbial-Molecular Studies

- Casas, Kline et al. 2004 (*Environ. Microbiol.*): **Widespread association of a *Rickettsiales*-like bacterium with reef-building corals.**
  - Since present in both healthy and diseased *A. cervicornis*, as well as several other species, concluded it was not the pathogen of WBD
  - But RLOs are nonculturable, obligate intracellular parasites and known pathogens in other animal species!

Primary pathogen, infects polyp mucocytes, kills these cells, affects coral defenses – *Cand.* Aquarickettsia rohweri (Klinges et al. 2019) – 100% of Caribbean acroporids examined histologically are infected, present populations of acroporids in weakened condition, chronic!

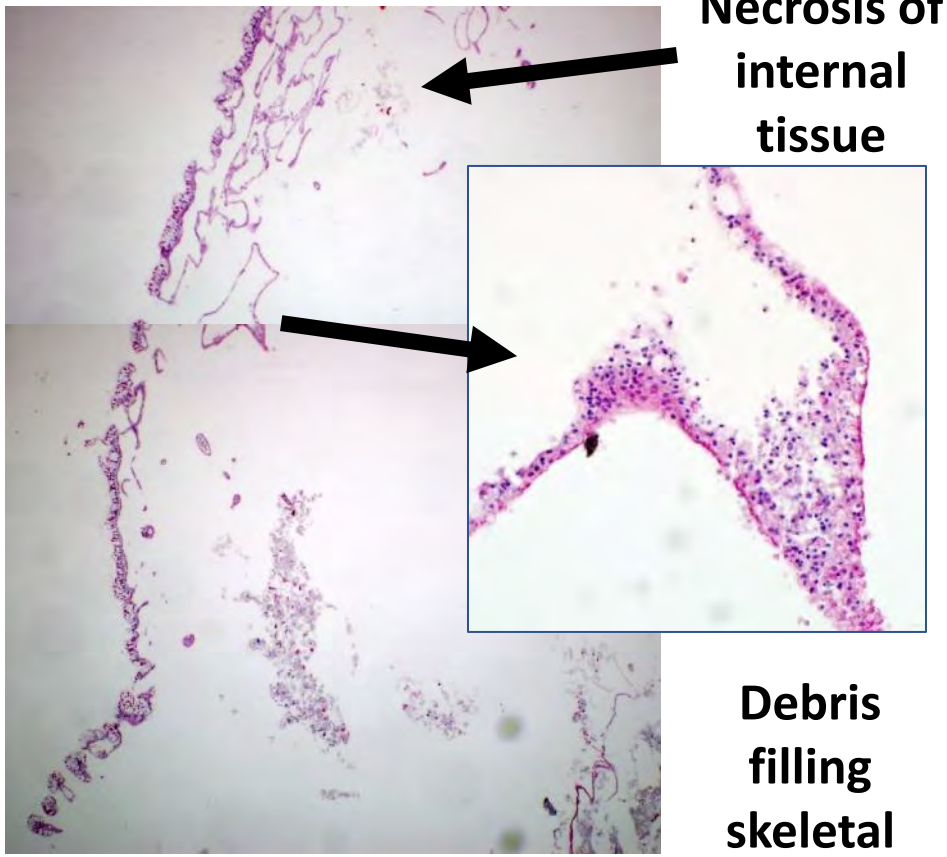






The Diseased Coral

Only where the skeleton is showing, RIGHT?



Tissue loss margin this end

WRONG!!!

Bleaching: Important Sign of Disease

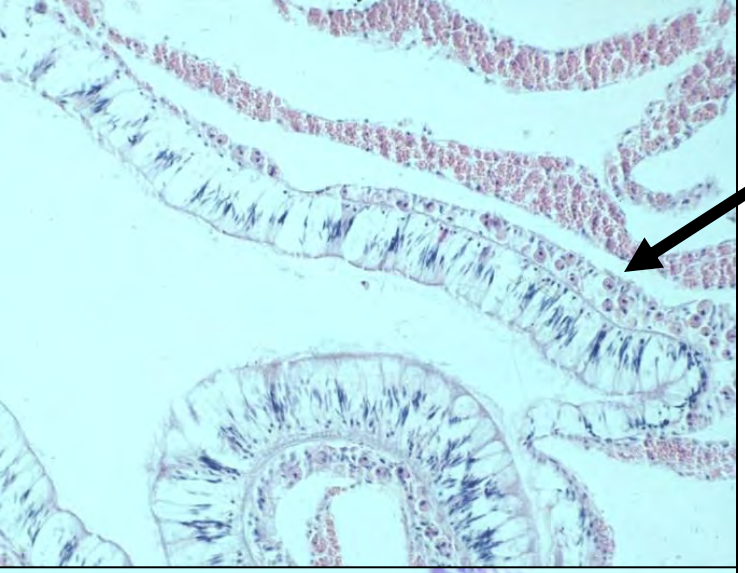
Loss of endosymbiotic algae (zooxanthellae) that live in coral tissue or loss of or damage to their pigments or cells indicates metabolic imbalance in most tropical corals = functional impairment = disease!

Many causes:

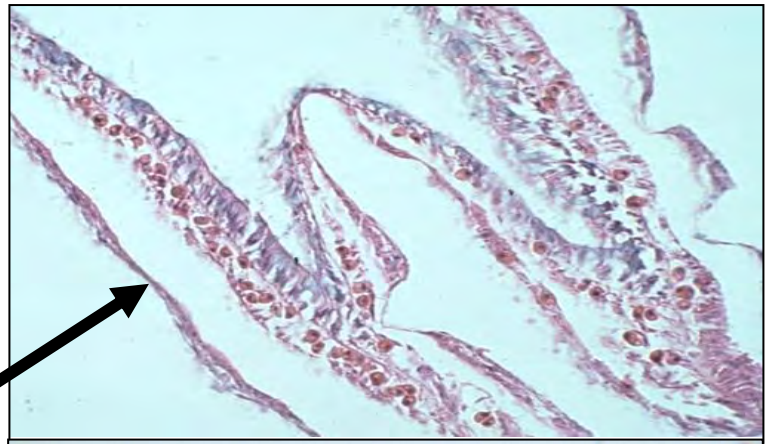
Abiotic factors first identified: increased or decreased temperature, salinity, light, UV-radiation; combinations of factors

Worldwide prevalence and periodic mass bleaching events since 1980 associated with global warming and local conditions (2016 GBR)

Agaricia agaricites, normal



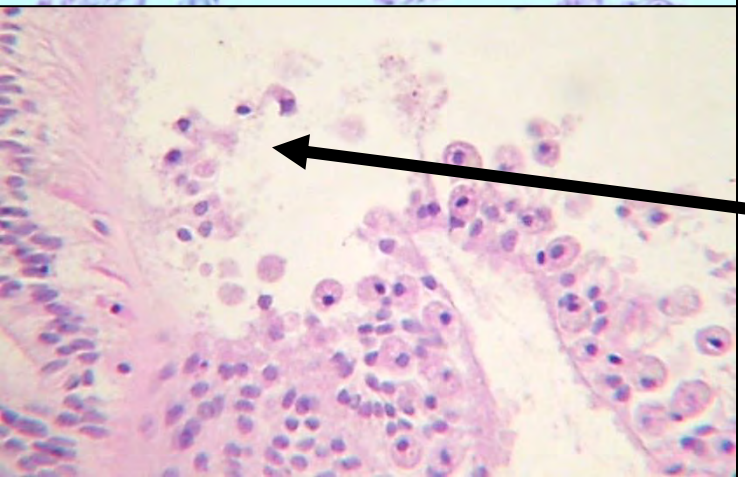
Bleached



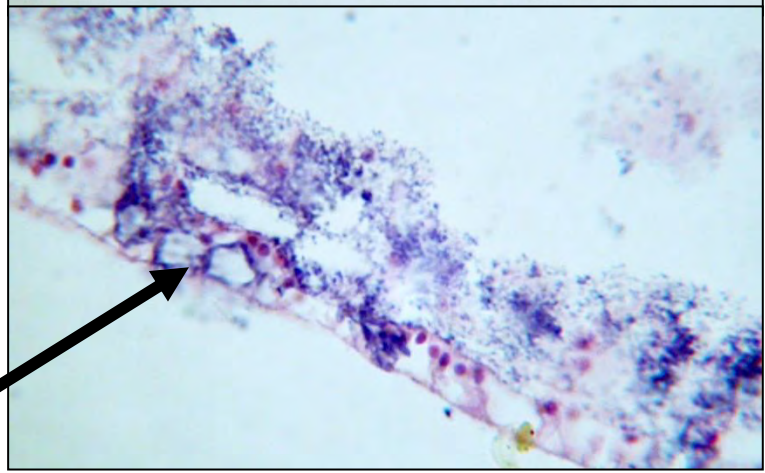
Damaged algal symbionts

Loss of algal symbionts

Acropora palmata, sloughing gastrodermis



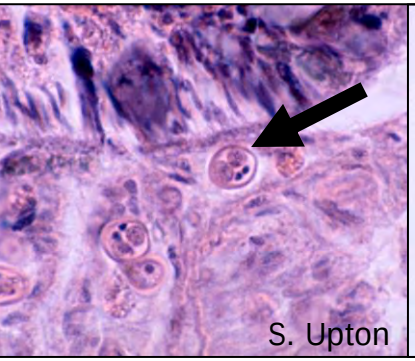
Bacteria

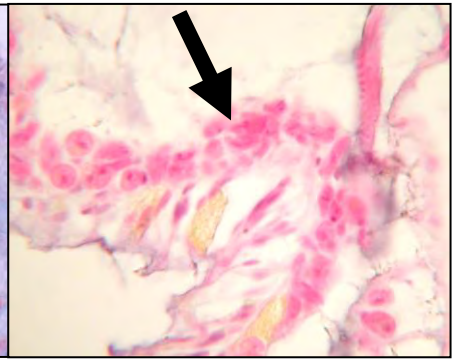


Biotic Agents of Bleaching

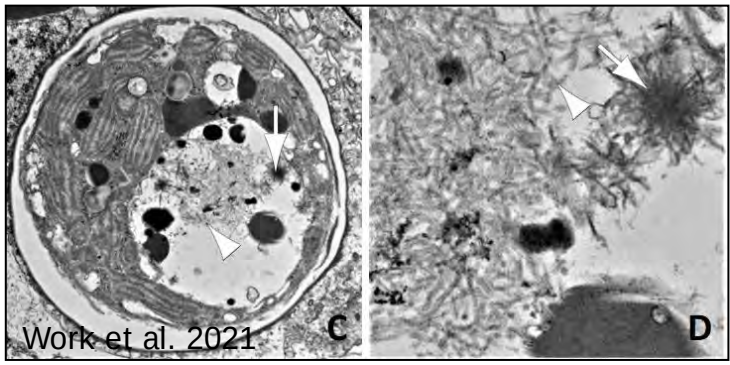
Vibrio coralliilyticus, V. carchariae, V. mediterraneae (shiloi/shiloni)

Corallicolids, apicomplexan parasites in gastrodermal cells. Hosts may bleach in patches or no visible effect

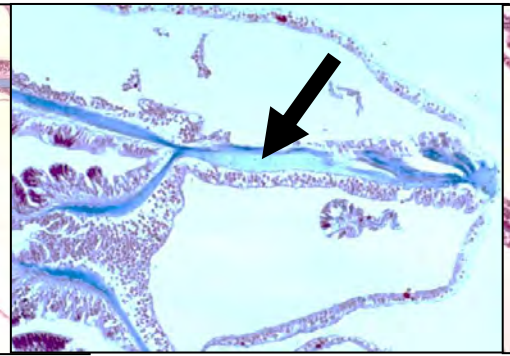




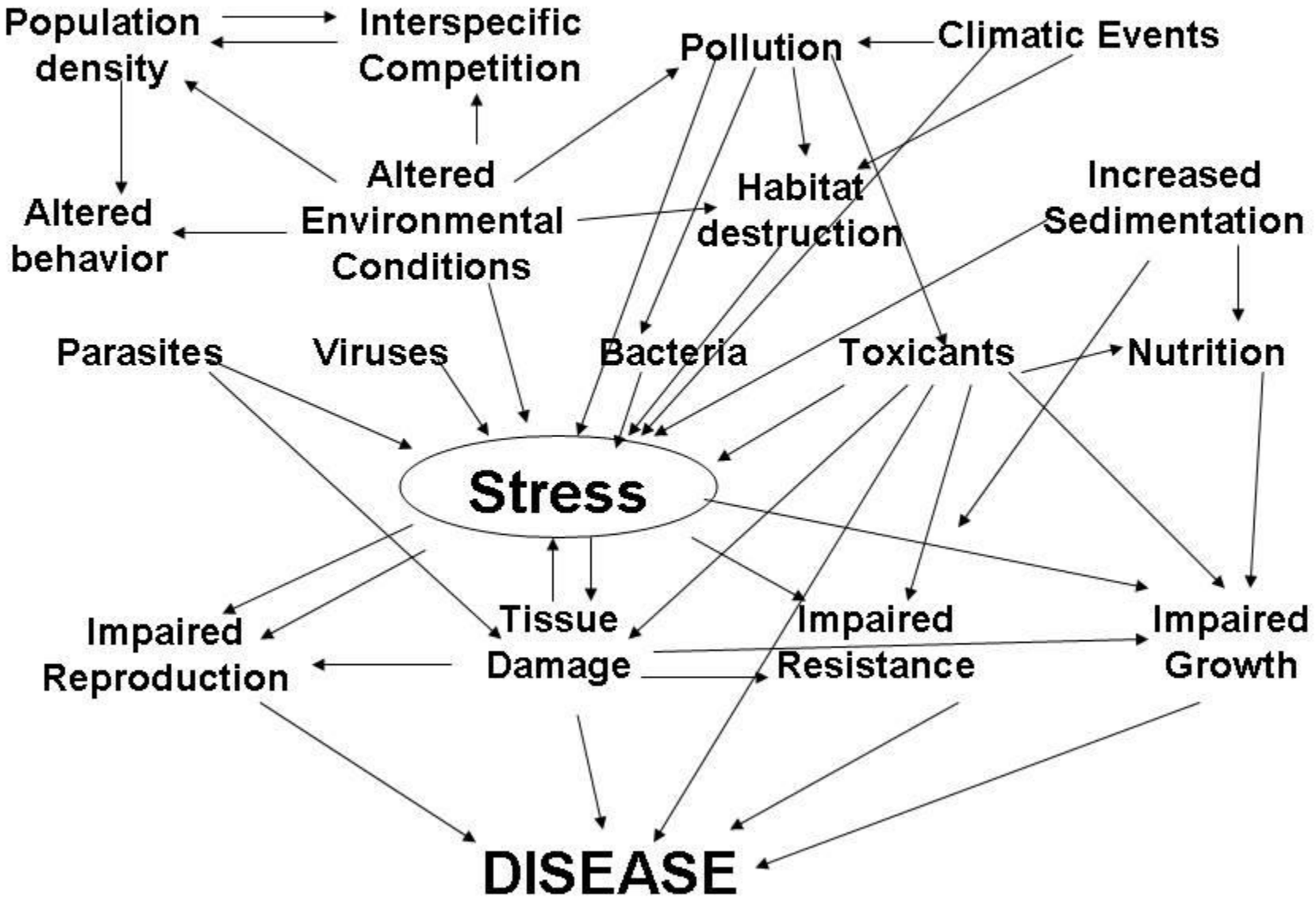
Viruses that infect and kill endosymbionts



Unknown cause, resulting in biochemical change in collagen (mesogleal disease?)



Web of Causation



After Wobeser 1994

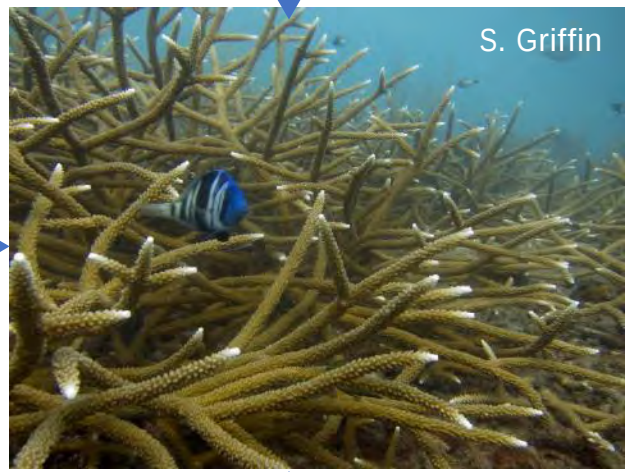
Multifactorial:
Chronic infection with biotic pathogen(s) and then ?

Death

High Levels--> STRESS

★ Proper Levels:

Temperature
pH, Alkalinity
Nutrition
Light, Salinity
Toxicants
Sedimentation



Disease

Health

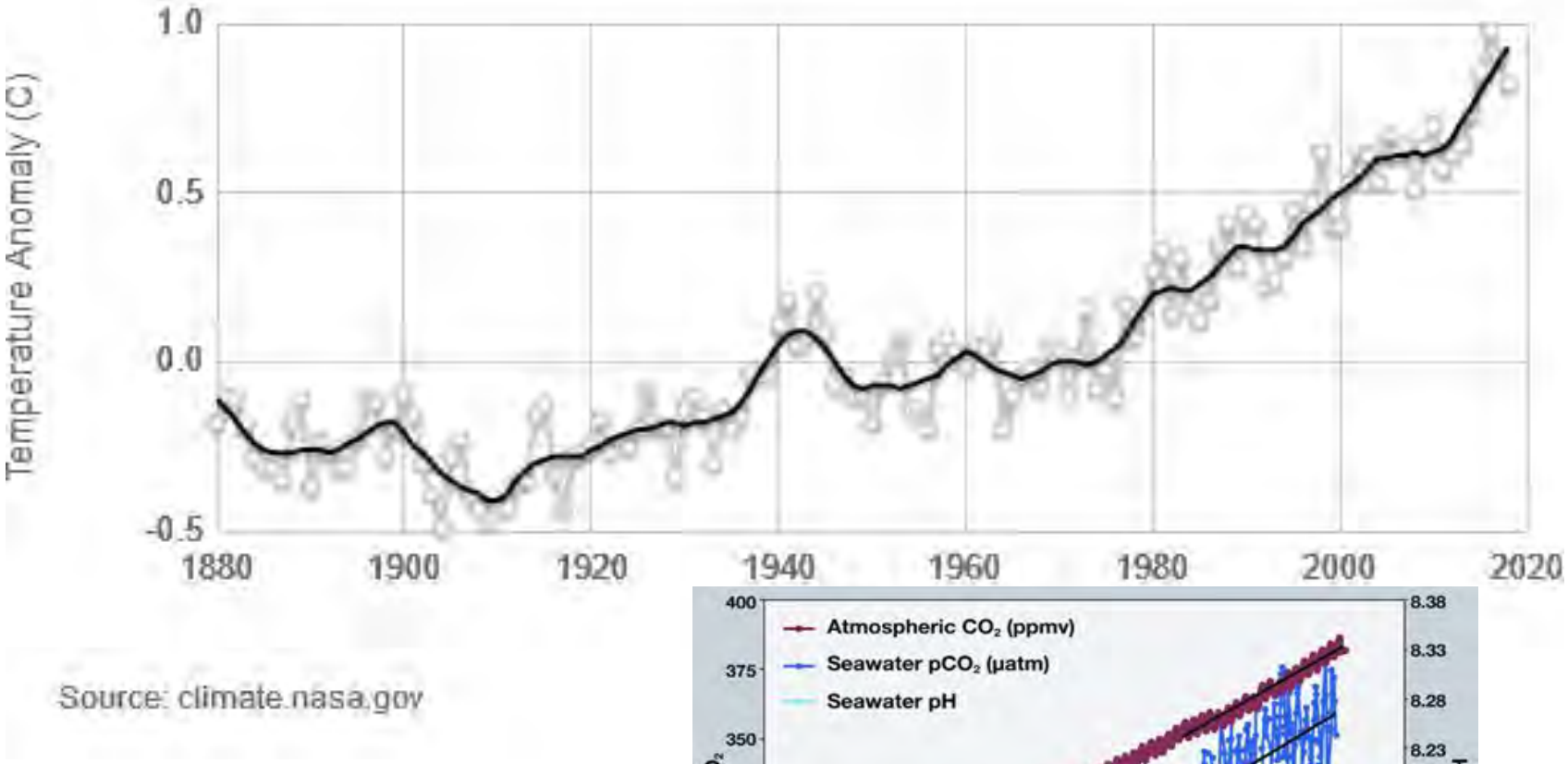
Disease

Death

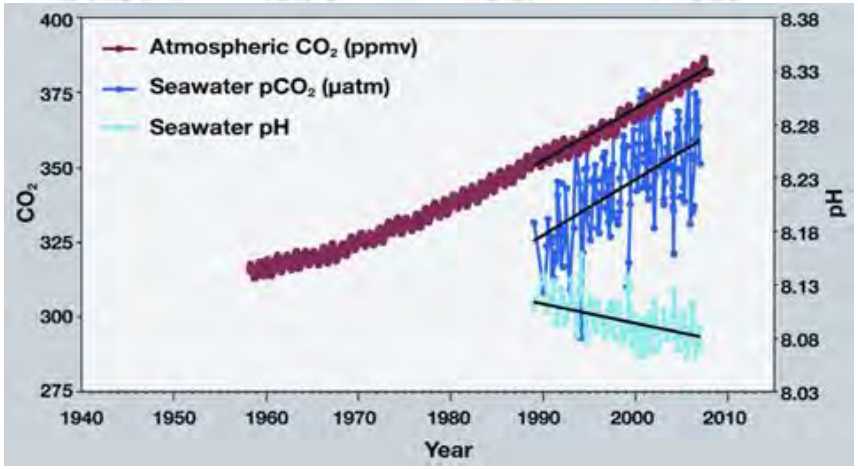
★ Abiotic pathogens
(for organisms), not drivers
(for physical phenomena)

Low Levels--> STRESS

https://climate.nasa.gov/vital-signs/global-temperature/



Human population increases, elevated CO_2, pollution, etc. = ecosystem distress syndrome



This is not just about zoonotic diseases or infectious pathogens, also ecosystems!

If it is not safe for corals, it is not safe for other organisms or PEOPLE!

A collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment. (Centers for Disease Control and Prevention)

Important Reminders from Pathology

- **Disease names are not capitalized!**
  - "White band Disease" should be "white-band disease" ("white" and "band" form a compound adjective of "disease")
  - Stony Coral Tissue Loss Disease should be stony coral tissue loss disease (SCTLD)
- **Disease is NOT TRANSMITTED and disease DOES NOT "infect" organisms.**
  - Only infectious pathogens that may cause disease can be transmitted from one host to another
  - Corals are not infected with SCTLD or other disease
  - Only an infectious pathogen (prion, virus, bacterium, protist, metazoan) that can infect a host (invade the body and then multiplies) can cause disease (by attacking host cells or tissues or releasing toxins that kill cells or tissues).

Questions?

Contact: Esther Peters, epeters2@gmu.edu

Rapid Tissue Loss & Coral Bleaching

Antigua & Barbuda

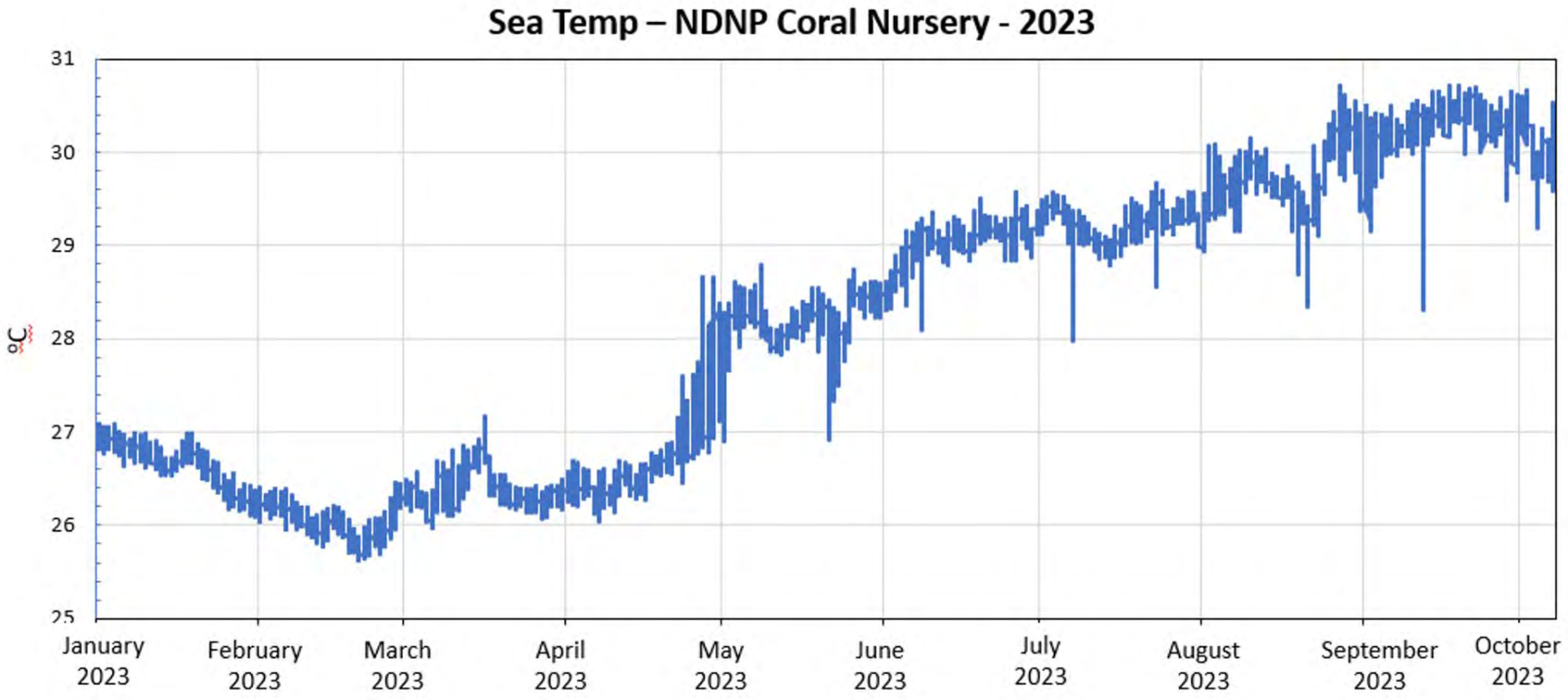
Nov 13, 2023

Ruleo Camacho & Geneviève Renaud-Byrne

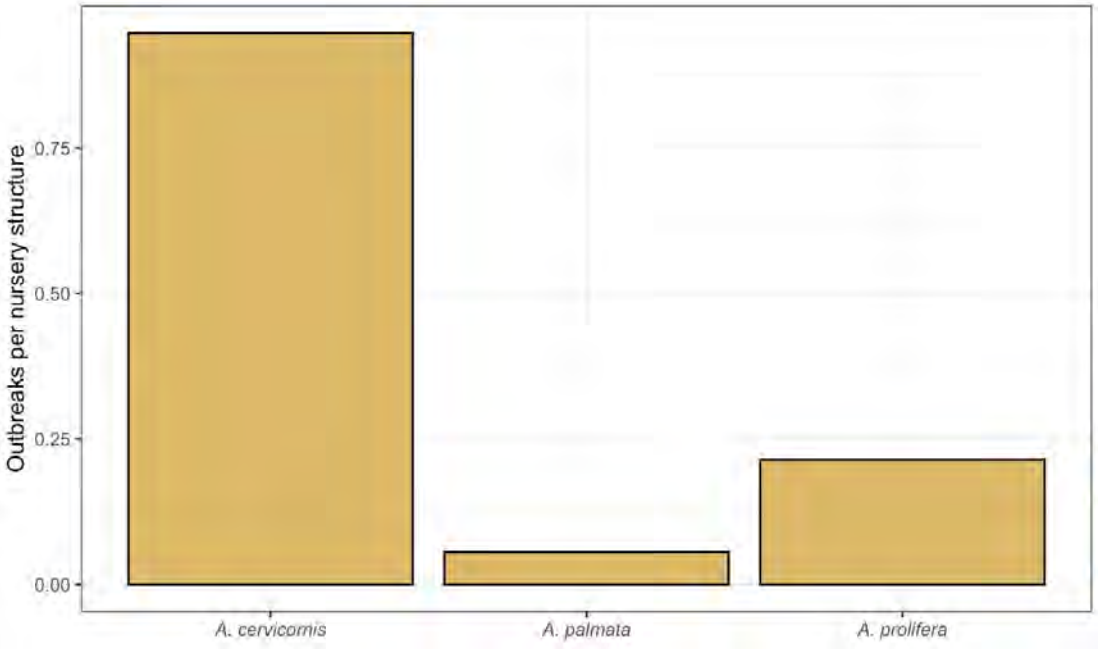
Elkhorn Marine Conservancy
Antigua, W.I.

ANTIGUA & BARBUDA NATIONAL PARKS

Temperature



Rapid Tissue Loss in nurseries



Number of RTL outbreaks observed per structure by species in EMC's York Island nursery between May-Aug 2023

Bleaching observed in Aug-Nov 2023

Hell's Gate, NEMMA, 2021

Hell's Gate, NEMMA, Oct 2023

Bleaching in NPA's nursery

	Healthy	Bleached/Pale	RTL	Dead/Missing
ACER	2%	45%	0%	52%
APAL	16%	59%	0%	24%
APRO	43%	53%	0%	4%
PPOR	0%	80%	0%	20%
Total	**7%**	**47%**	**0%**	**46%**

Bleaching in EMC's nursery

October 9, 2023

Healthy	Diseased	Bleached/Pale	Dead
16.10%	0.84%	73.39%	7.63%

November 6, 2023

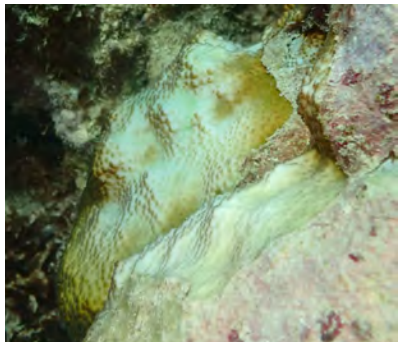
Healthy	Diseased	Bleached/Pale	Dead
22.6% ↑	1.2%	15.3% ↓	60.9% ↑

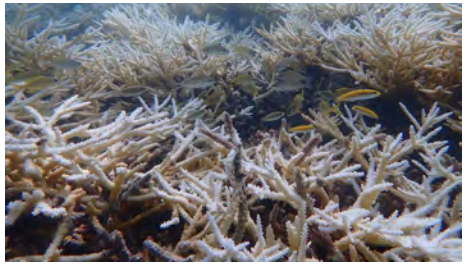
Bleaching in the wild

Bleached species observed (sept-Nov, 2023):

- All Acroporids (APAL, APRO, ACER)
- CNAT
- DCYL
- SINT
- MCAV
- OANN
- OFAV
- OFRA
- ISIN
- PSTR
- PCLI
- SSID
- SRAD
- AAGA
- ALAM
- PAST
- PDIV
- PPOR
- PFUR
- MARE
- MAUR
- EFAS
- MCOM
- MALC

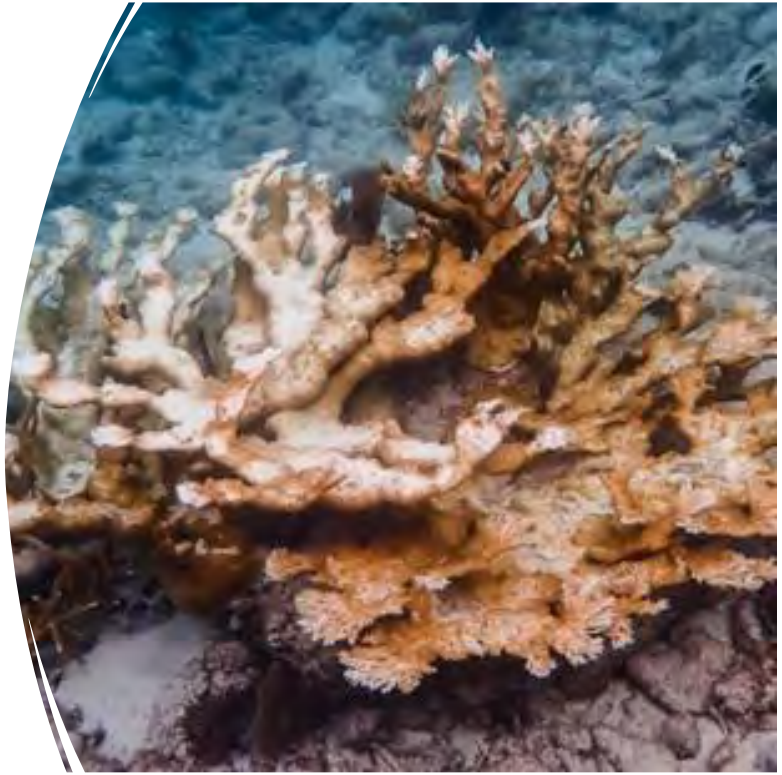



Colonies of hope: Genotype specific resistance to thermal stress

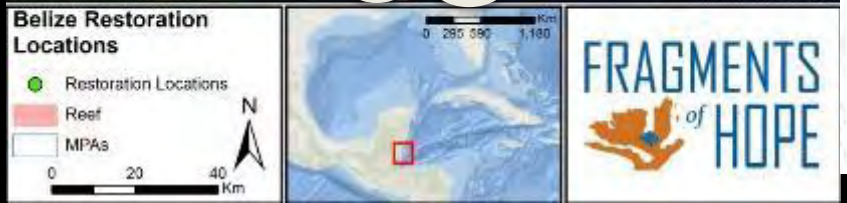
Belize Coral Bleaching 2023



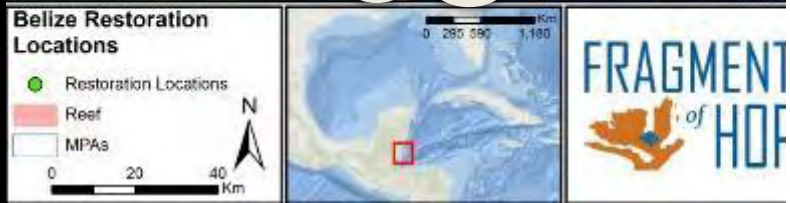
Lisa Carne

November 13, 2023

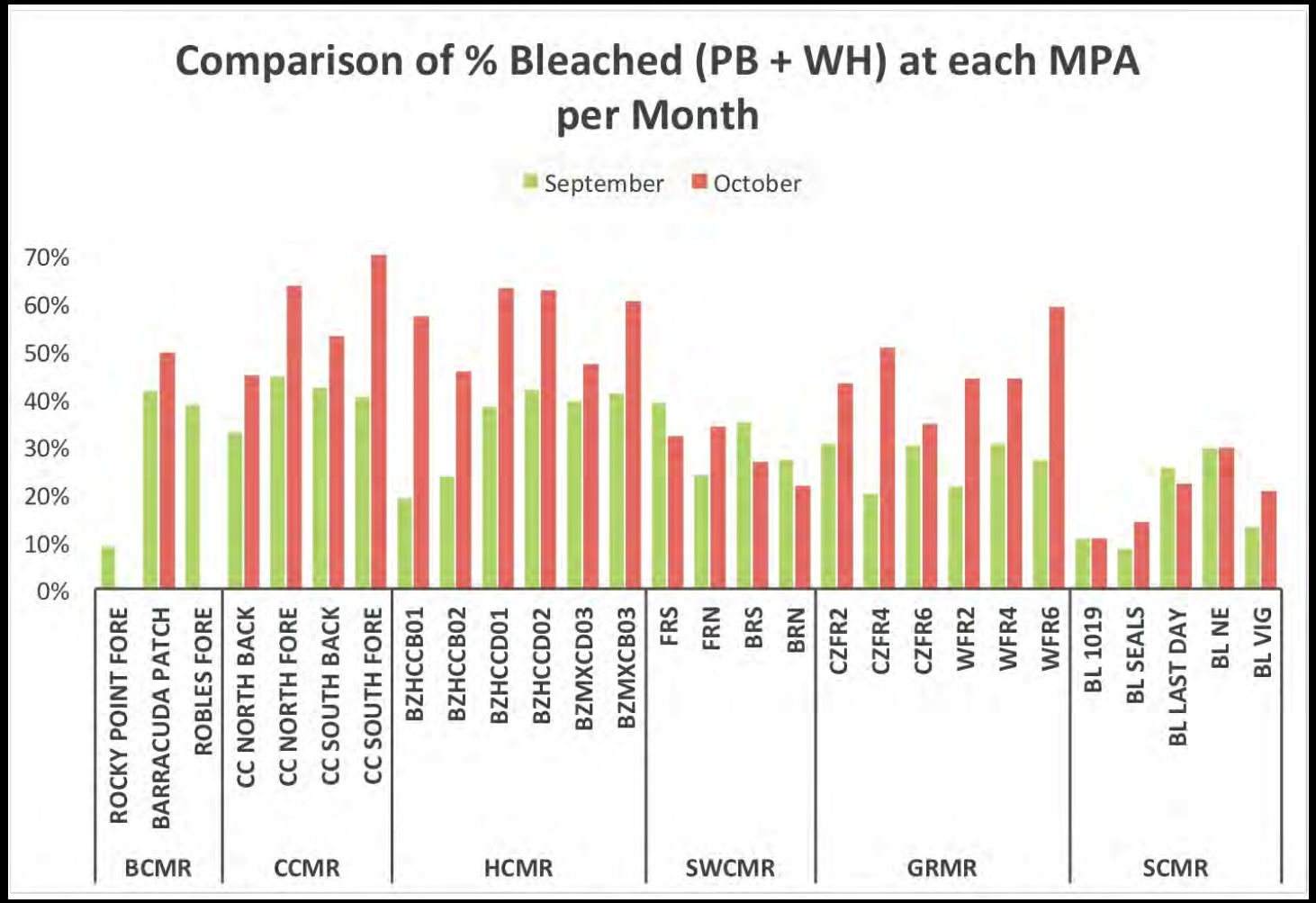
FRAGMENTS of HOPE

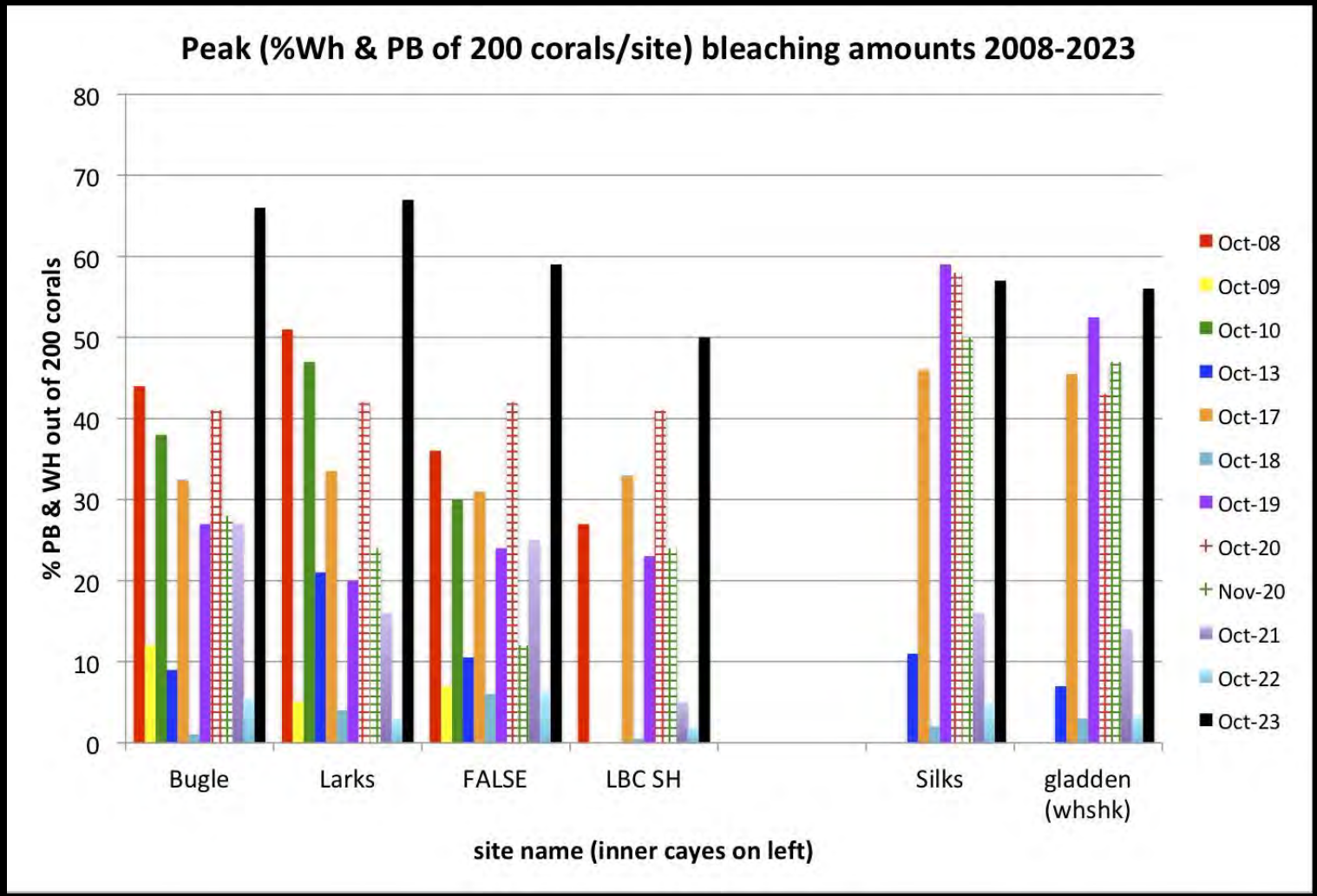


genet source ACER	Outplant locations: Moho	LBCNP	Silks
saddle	X	X	
lazy	X	X	X
gladden buoy		X	
gladden pillar patch		X	
tarpon	X	X	X
whipray	X	X	X
glens bank		X	
loggerhead	X	X	X
moho (genetics reveal it's APRO)	X	X	
FALSE	X	X	X
harvest	X	X	X
hatchet deep	X	X	X
mid silks	X	X	X
bl silks		X	X
near silks nursery table	X	X	
cramp	X	X	
crawl	X	X	X
andria	X	X	X
dale's reef	X	X	
lil bugle		X	
LBCNP		X	
Jeremy patch	X	X	X
RG patch	X		X
south cramp caye	X	X	X
Total *A. cervicornis* genets	**17**	**21**	**14**



genet source APAL	Moho	LBCNP	Silks
gladden buoy	X	X	
gladden pillar patch	X	X	X
gladden crest	X	X	X
gladden Bleaching site			X
loggerhead1	X	X	X
loggerhead2	X	X	X
bugle		X	
larks	X	X	
larks2	X	X /X	X
s silk caye s			X
s silk caye n			X
middle silk caye1			X
midddle silk caye2			X
nursery patch silks1			X
nursery patch silks2			X
nursery patch silks3			X
french louie	X		
Mosquito caye1		X	
mosquito caye2 (need genetics?)		X	
mosquito caye 3 (need geentics)		X	
17 genets from 2006		15	
south cramp caye	X		
loggerhead patch	X		
BL silks patch	X/X		X/X
Abigail Caye		X	
Total *A. palmata* genets	**11 or 12**	**28**	**14**
Moho caye/apal over sea fan	X		


Comparison of % Bleached (PB + WH) at each MPA per Month
September
October
70%
60%
50%
40%
30%
20%
10%
0%
ROCKY POINT FORE
BARRACUDA PATCH
ROBLES FORE
CC NORTH BACK
CC NORTH FORE
CC SOUTH BACK
CC SOUTH FORE
BZHCCB01
BZHCCB02
BZHCCD01
BZHCCD02
BZMXCD03
BZMXCB03
FRS
FRN
BRS
BRN
CZFR2
CZFR4
CZFR6
WFR2
WFR4
WFR6
BL 1019
BL SEALS
BL LAST DAY
BL NE
BL VIG
BCMR
CCMR
HCMR
SWCMR
GRMR
SCMR


Peak (%Wh & PB of 200 corals/site) bleaching amounts 2008-2023
% PB & WH out of 200 corals
0
10
20
30
40
50
60
70
80
Bugle
Larks
FALSE
LBC SH
Silks
gladden (whshk)
site name (inner cayes on left)
Oct-08
Oct-09
Oct-10
Oct-13
Oct-17
Oct-18
Oct-19
Oct-20
Nov-20
Oct-21
Oct-22
Oct-23

Our strategy to date/success indicators:

- Mapping extant acroporids (during hottest months)
- SHALLOW SITES!
- Host & symbiont genetics
- Outplanting multiple genets in proximity & documenting spawning (success!)

Demonstrating effective Caribbean acroporid population enhancement: all three nursery-grown, out-planted taxa spawn August 2015 & 2016 in Belize

Lisa Carne[1] and Iliana Baums[2]
[1]Fragments of Hope, Ltd., Placencia, Belize; email: lisa.carne.belize@gmail.com
[2]Department of Biology, The Pennsylvania State University, 208 Mueller Lab, University Park; email PA baums@psu.edu

Successful in situ coral cultivation has been

Figure 1. Spawning in nursery reared, outplanted *Acropora palmata* (above) and *A. prolifera* (below). Photos: Annelise Hagen.

- Long term monitoring growth, survival, thermal tolerance (success!)

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Genet Locations
Source
AGRRA
FOH
Fogarty
UB
Reef
MPAs
Tunnel's Atoll
Lighthouse Reef
0 10 20
Km
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


2011


FRAGMENTS OF HOPE
21Aug23


Genet Locations
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AGRRA
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Fogarty
UB
Reef
MPAs
Tunnel's Atoll
Lighthouse Reef
N
0 10 20
Km
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2011


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20Oct23


FRAGMENTS
of
HOPE


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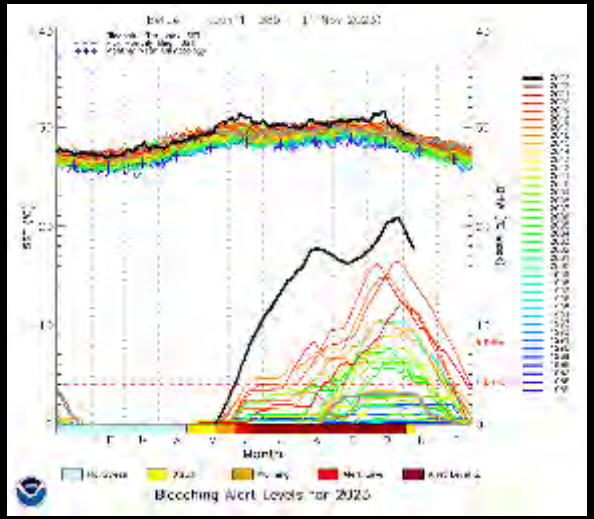
HOPE


False
Crawl Caye
Lazy
Larks
Saddle Caye
Loggerhead
Cramp Caye
Andria Caye
Harvest
Dales Reef
BLsilks
silks table
silks wall (deep)
Pumpkin
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Google earth
Imagery Date: 4/9/2013 16 Q 356500.52 m E 1817436.46 m N elev -17 ft eye alt 42.99 mi


FRAGMENTS
HOPE

Lessons learned

- More diversity always better
- Donor corals mostly holding patterns at transplanted sites
- Plant ACER genets as mixed as you want but
- Keep APAL genets somewhat separate
- Do not remove bleached corals from nurseries until 100% dead
- Follow up surveys-mapping



Belize Fisheries Department 2023 surveys funded by the Great Barrier Reef Foundation

Acropora rescue and recovery Jamaican response

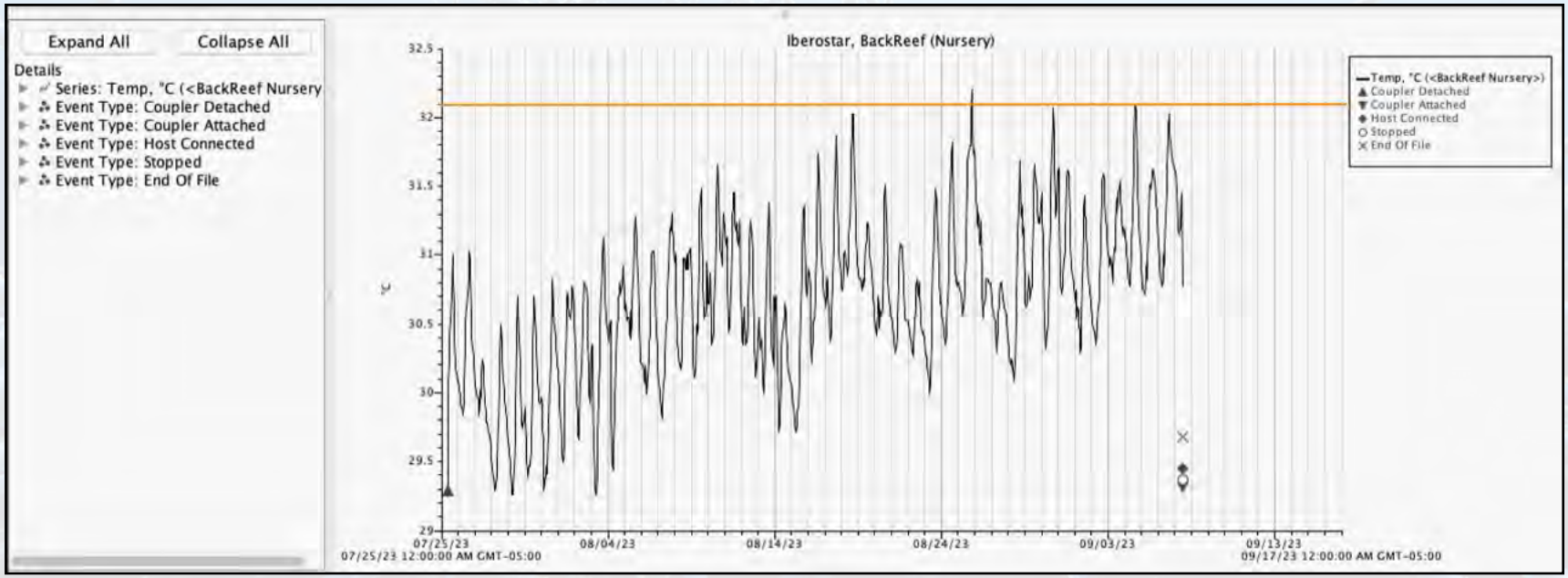
Felix Charnley - White River Fish Sanctuary

Resilient Coral Mapping Network - Jamaica

- Avg. temp = 32 C from mid August to early October; 31-32 C through October; now 30-31 C (early November)

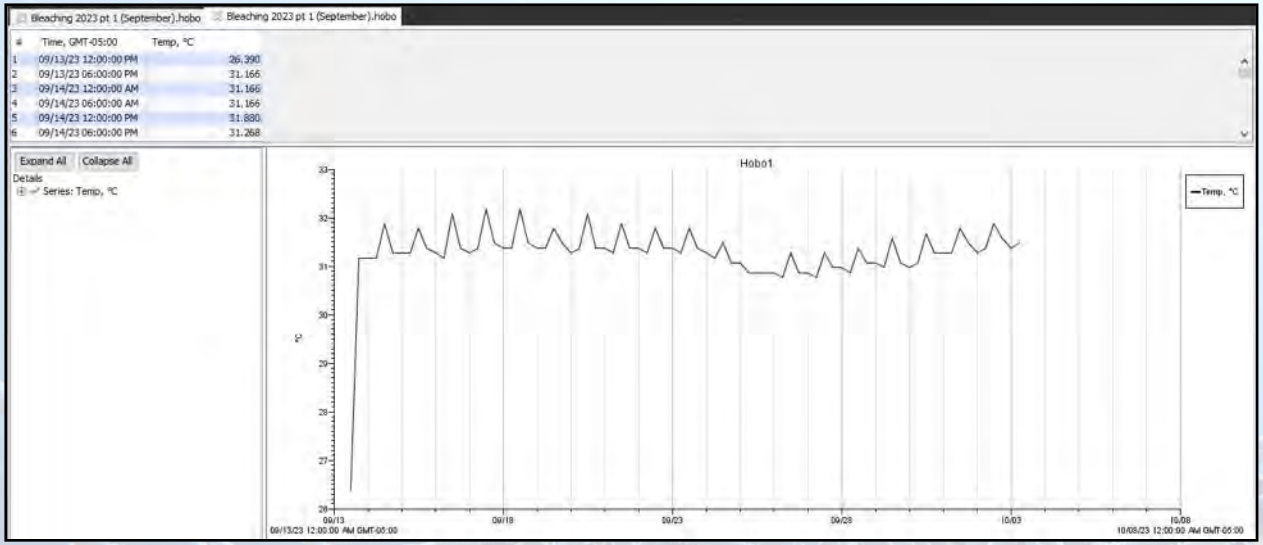
- Hot summer and nighttime temperature reductions in early September were still over 30 C = final straw

- Reduced late-summer hurricane frequency

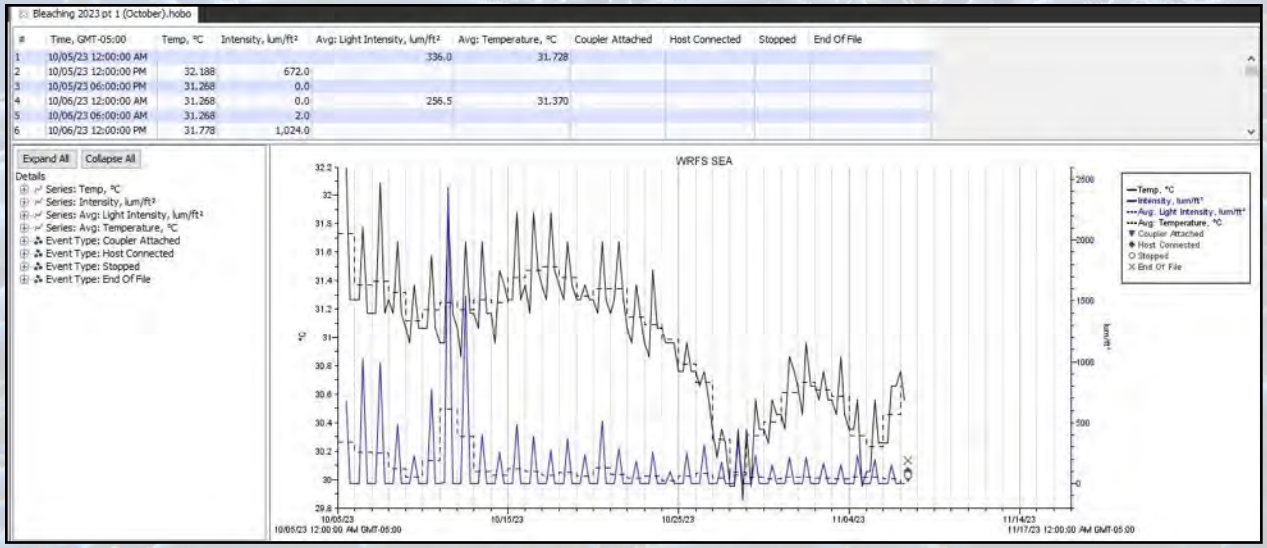


Iberostar back reef, Montego Bay. July 25 - September 11 (Source: Seascape Caribbean)

White River Fish Sanctuary, Ocho Rios



September



October

Rio Bueno West

Before and After

September 9, 2023

Source: Annabelle Cox

October 6, 2023

Source: Felix Charnley

November 3, 2023

Source: Felix Charnley

Scenario and setbacks

- Near genus level extirpation for *Acropora spp*.
- Loss of almost all wild stock; >90% at a glance
- Loss of donor sources for nursery programmes
- Major setback to genetic variation
- Increased predation of few surviving
- Tissue loss disease/stress observed prior to bleaching and now present in survivors

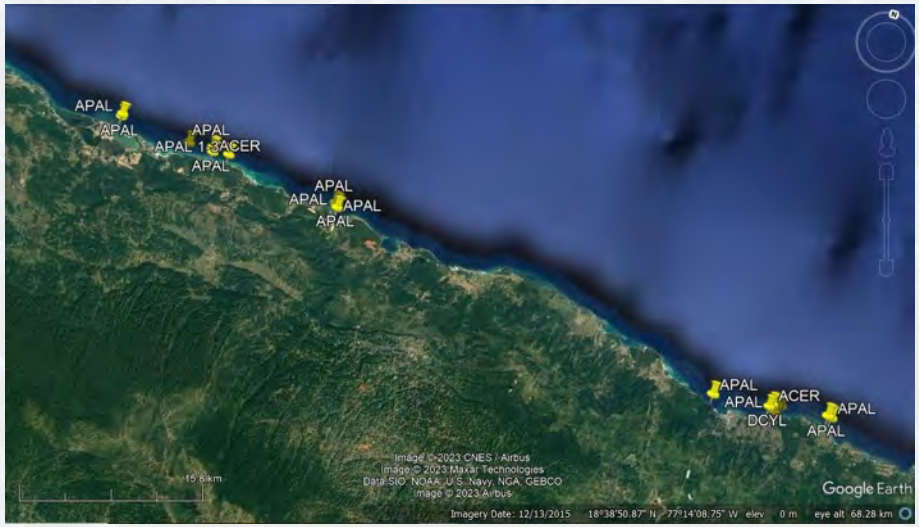
APAL

ACER

APRO

Response

- Attempted shading and relocating to no avail. Probably acted too late, circa Sep 5.
- Main focus now genetics
- Now looking for, geo-referencing and tagging surviving colonies
- Criteria: live, non-bleached (full colour) colonies that will/should survive 33 C / next event; stressed “potential recoverers”- can invest in and pair with the thermally tolerant corals as may have genes that resist other stressors
- National WhatsApp group, now 20 participants in 6 parishes (going on 7), reef managers, swimmers, government, coastal property owners, fishers(?); all long distance swimmers.
- Cover ground, fill gaps between swim routes, remove predators
- Materials: GPS, flagging tape, camera, float/kayak



Results so far:

- 28 surviving isolates and counting (-St. James) across 2 parishes (45 miles as the crow flies)
- 5 ACER, 21 APAL, 1 DCYL; 0 APRO

ACER



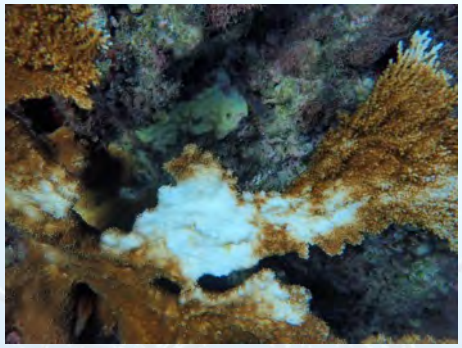
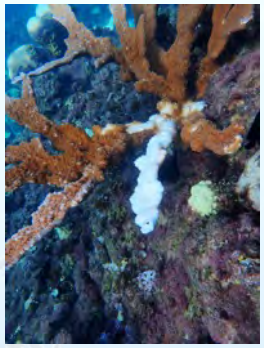
APAL



Photos: Felix Charnley/WRFS

Continued threats to survivors

Late bleaching

Disease and Predation (?)



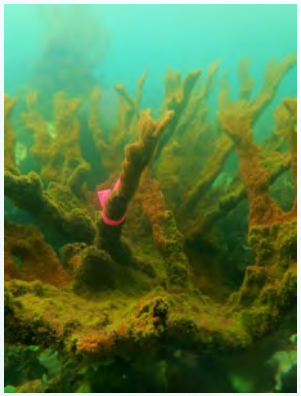


Photos: Felix Charnley/WRFS

Tissue Loss

September 9

November 3



November 3

Pre-bleaching RTL(?), August 30

Same (?), November 01

Photos: Felix Charnley/WRFS

Next steps

In situ

- Adjacent culture, mindful of sites, minimalist, low impact, low harvest, easily relocatable

Photo: Felix Charnley/WRFS

Ex situ

- Spawn capture, rearing, recruitment, induced broadcast spawning (Craggs et al 2017)
- SECORE/Fundemar/Cayman DoE/CoralAssistLab, Newcastle/Coral Spawning Lab, U Derby to Alligator Head/TNC - centralised national spawning station
- ASAP as donors may not last in situ

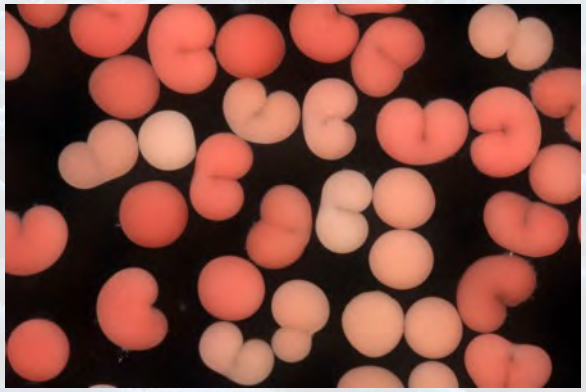
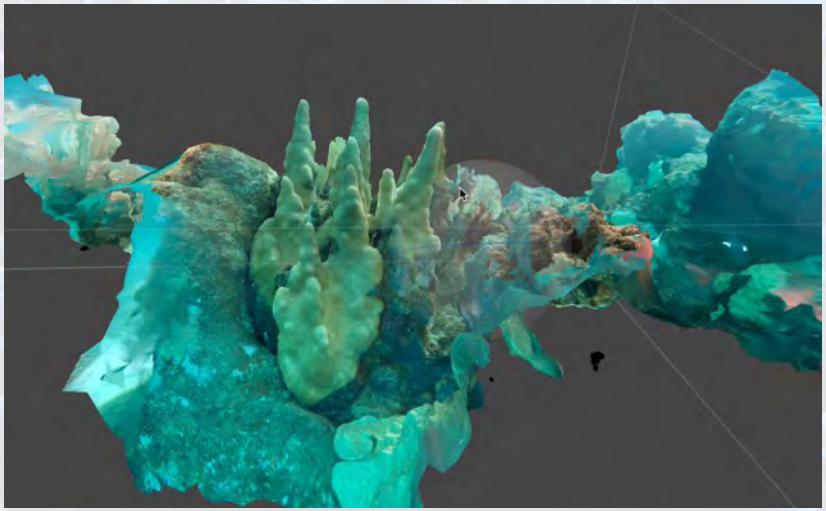


Photo: Coral Spawning Lab Ltd.

Re: SCTLD species

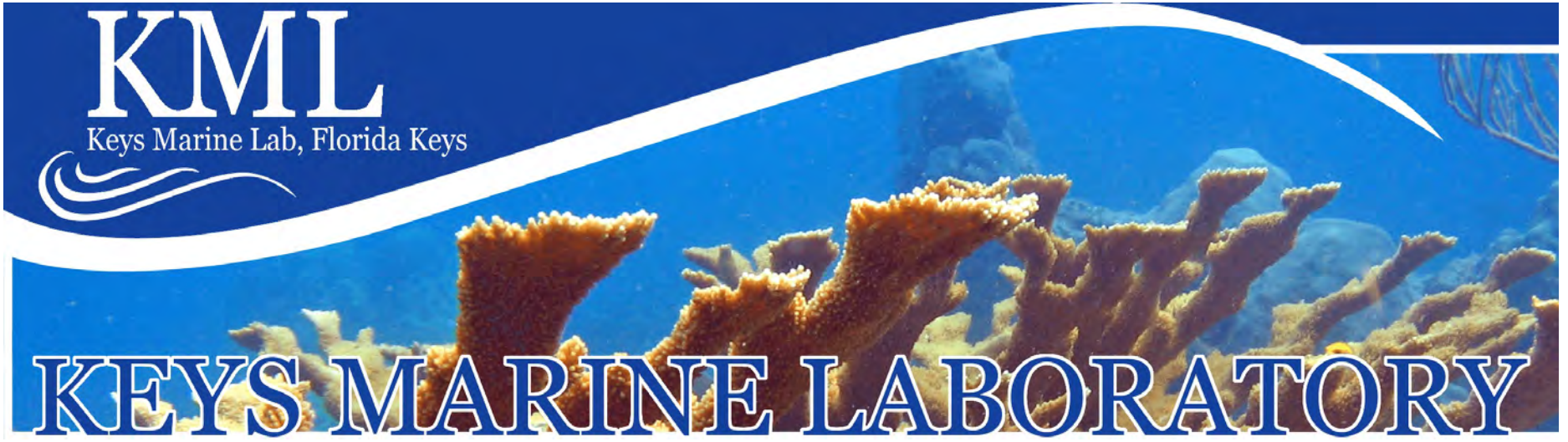
- Some SCTLD lesions prior to bleaching
- Most SCTLD species still only bleached; likely to recover, keeping an eye out.
- Strong DCYL



Images: Felix Charnley/WRFS

Contact: lisasinbelize@gmail.com & fragmentsofhope.org

The Pew Fellows Program in Marine Conservation at The Pew Charitable Trusts



2023 Coral Bleaching Emergency Response At Keys Marine Laboratory

Land-Based Seawater Facilities

Long Key, Florida Keys

Emily Becker

Seawater Systems Manager

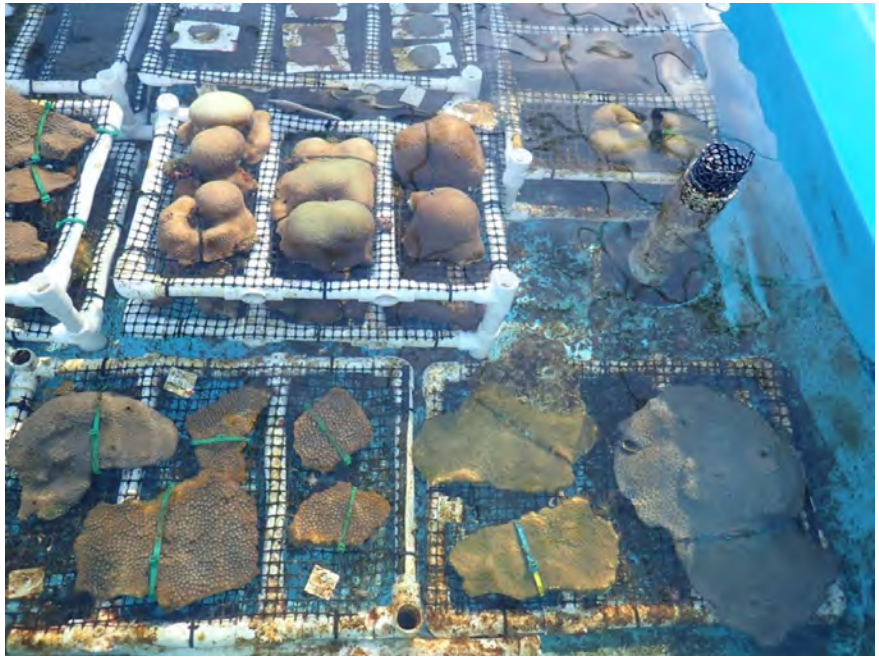
Sr. Biological Scientist

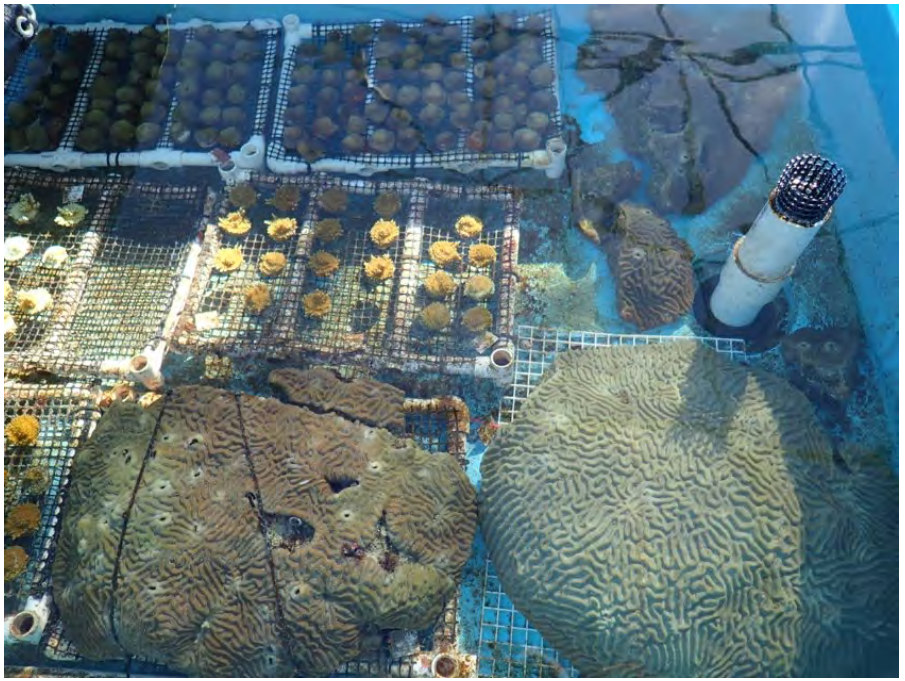
Land-Based Seawater Facilities

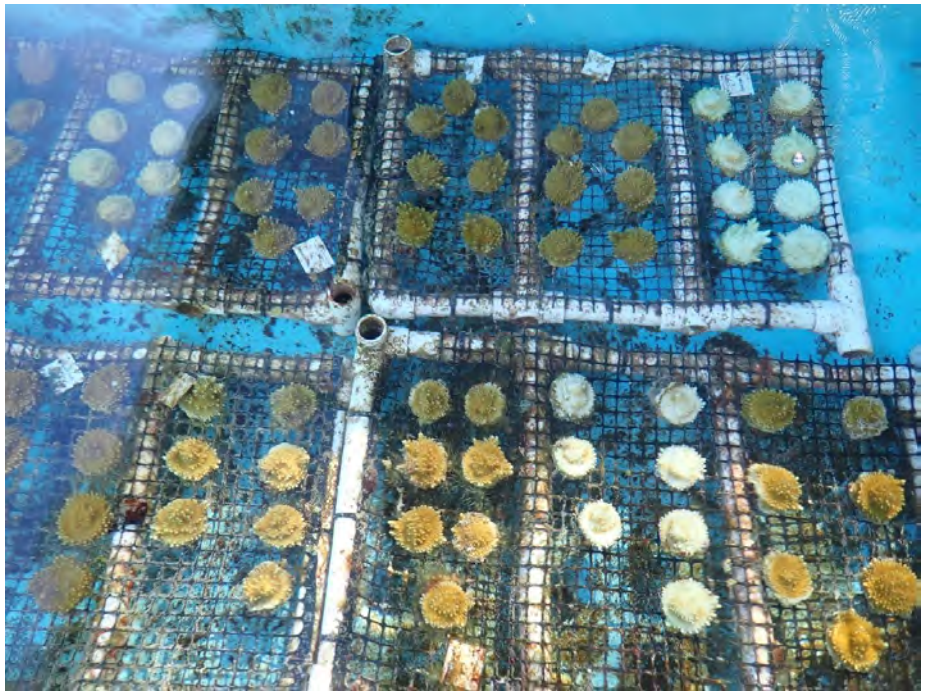
- Capacity: 60+ SW tables (40-gal to 250-gal)
- SW Source: ~30’ deep seawater well
- Pumping >120-gals/minute thru 2 air-stripper/degassing towers
- Maintaining coral tables at 83.9°F – 85.1°F
- 8 temperature-controlled SW reservoirs (total 15,000-gal)
- Five 5-ton heater/chiller units

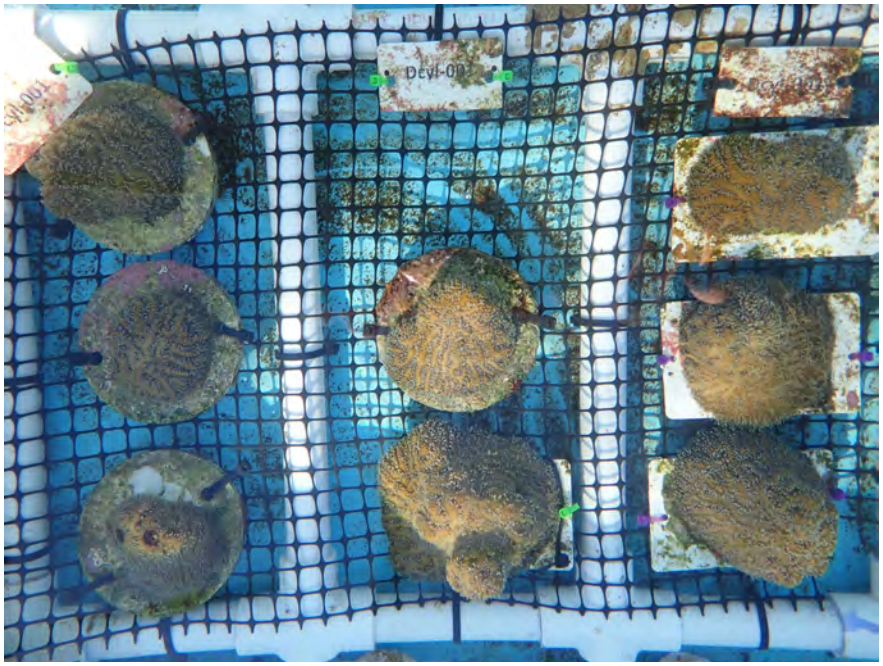
Movement of coral from offshore nurseries to land based facilities

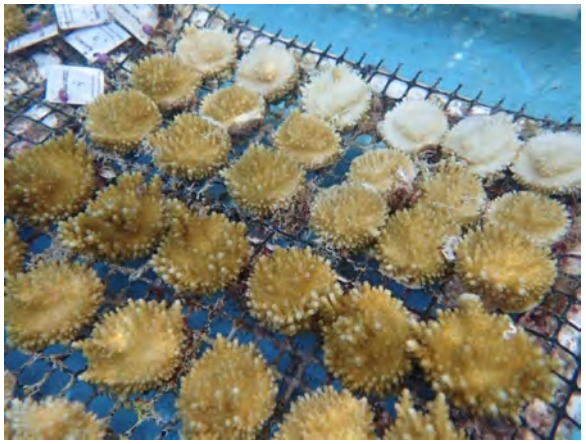
- ~100% capacity for all SW tables at KML
  - Aug through Oct
- More than 5,000 coral fragments, 8-10 coral species
  - Endangered or threatened species

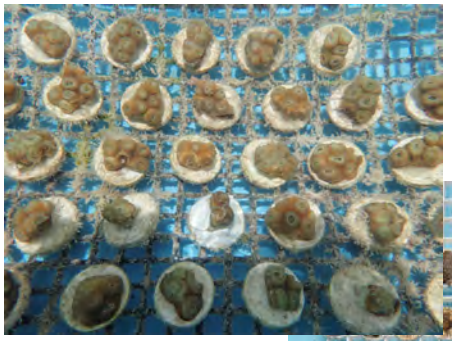


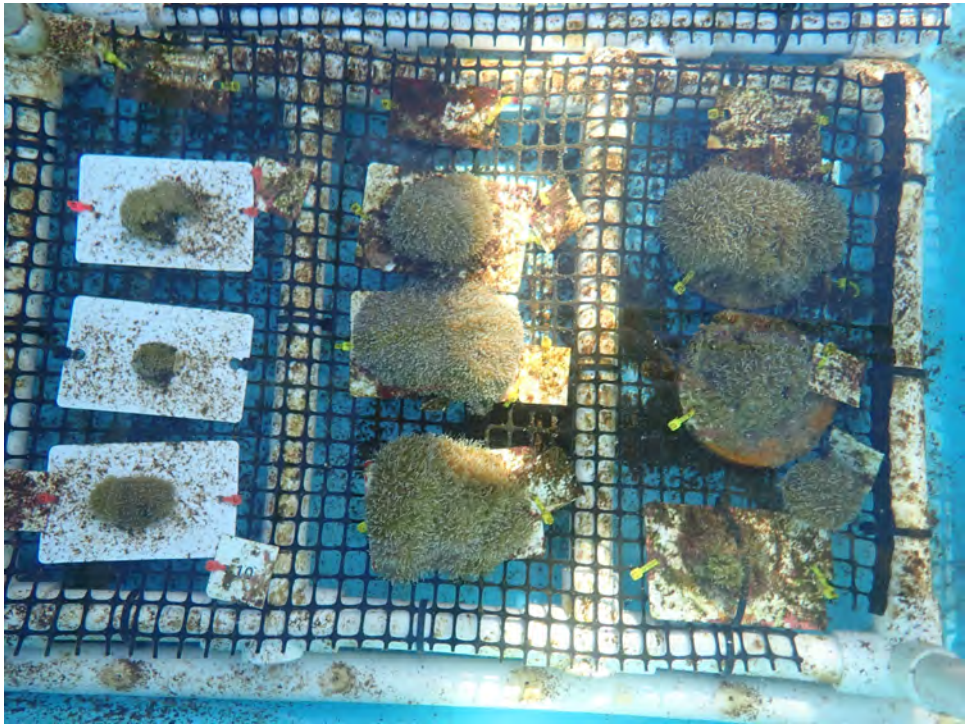


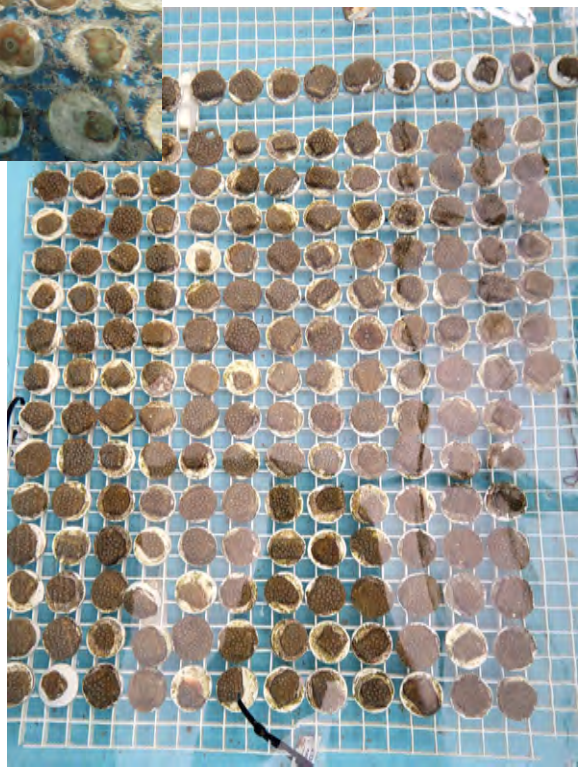


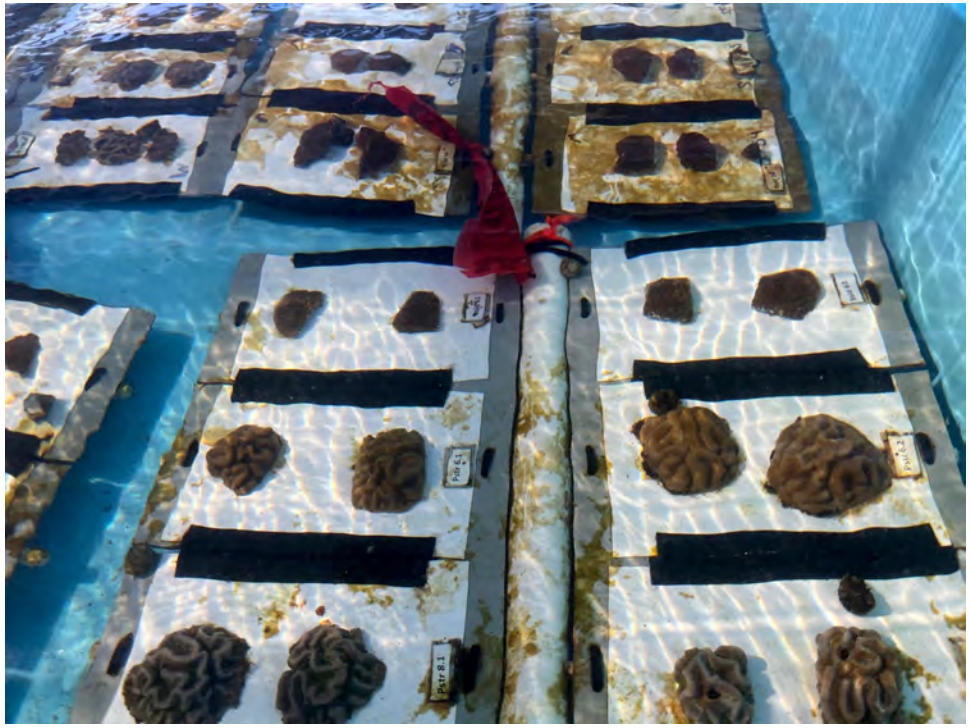

Devl-09

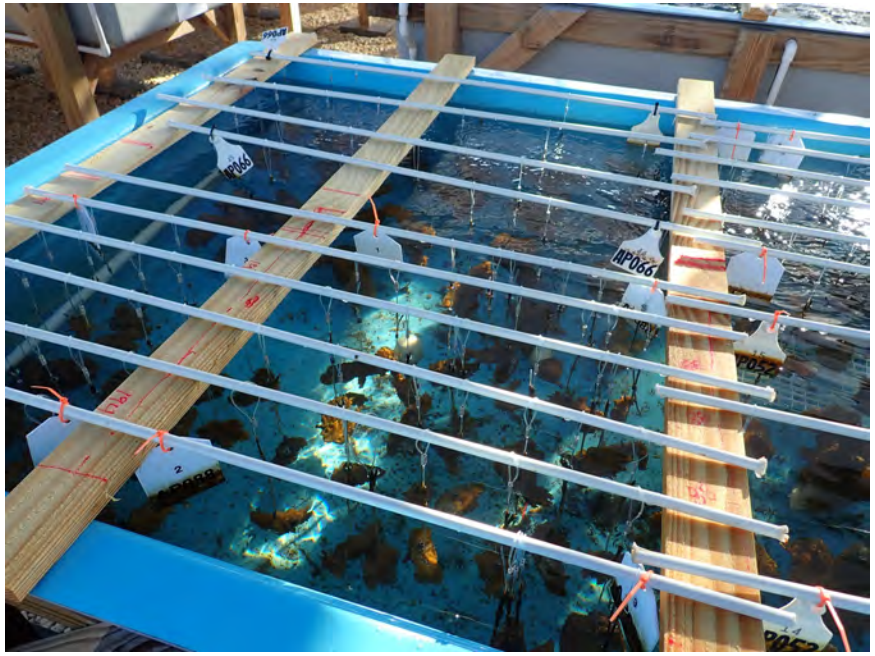


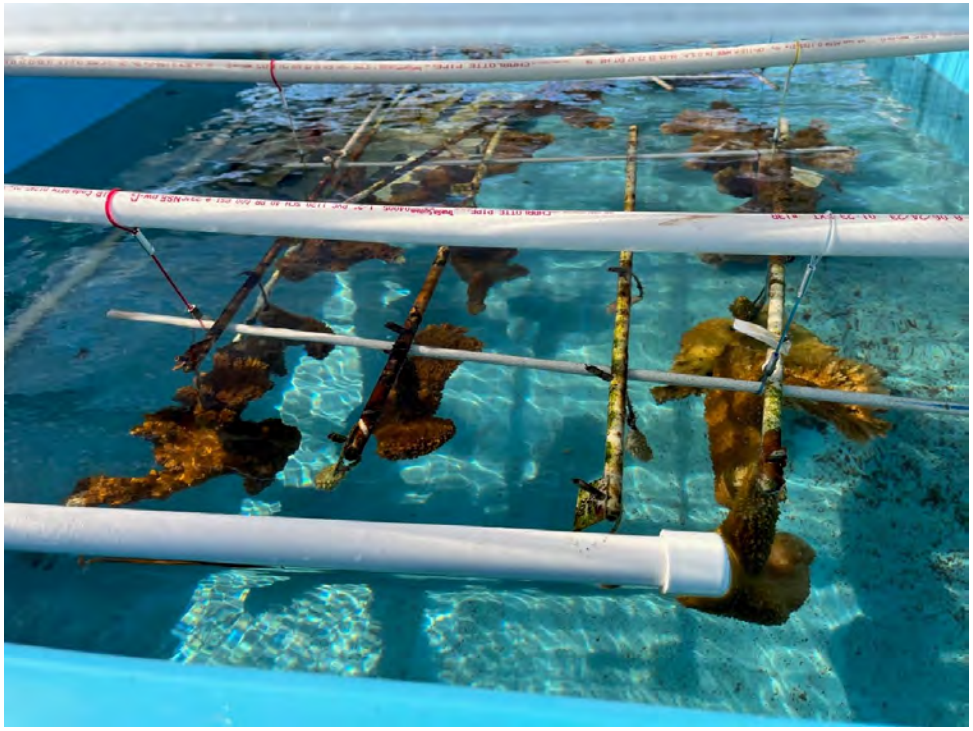


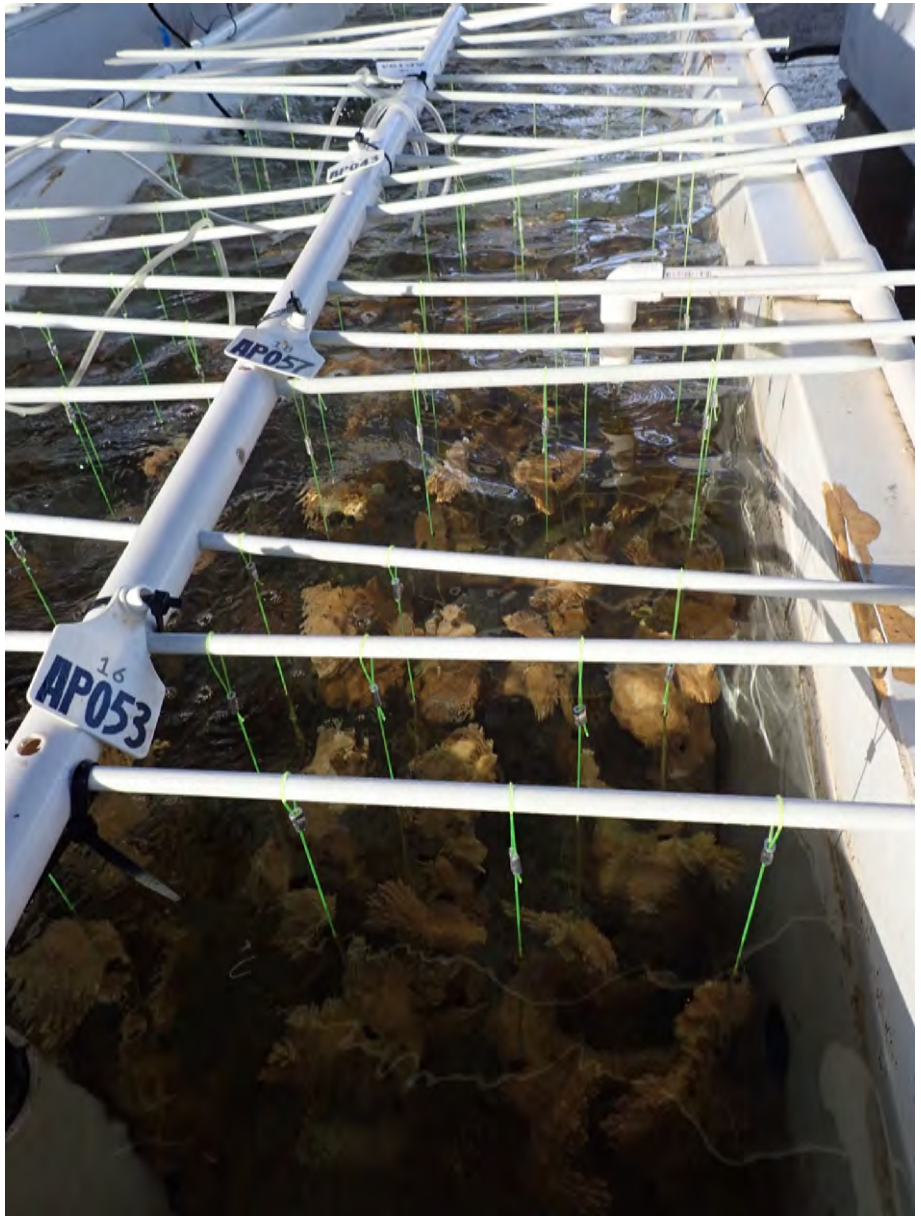


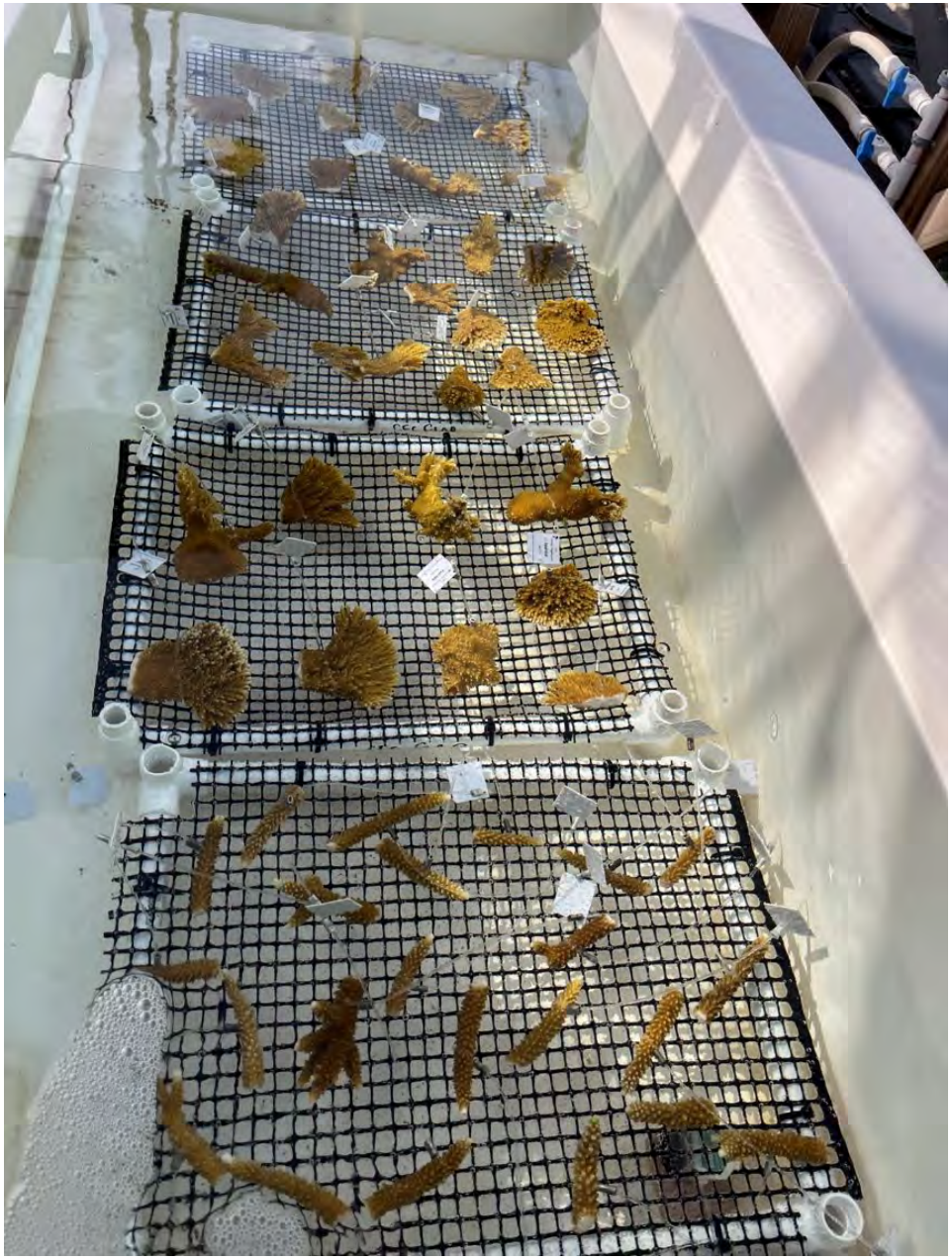




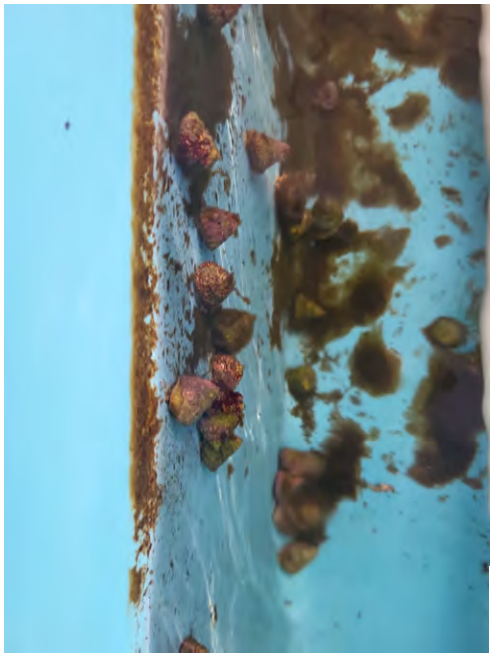

AP066




AP057
AP053



Husbandry



AZA HeaRT Team

-Helped to establish coral treatment/husbandry protocols, trained practitioners in basic diagnostics

Moving Coral back offshore

Return **of rescued coral from land-based facilities to *in situ* coral nurseries**

- Collaborating agencies: NOAA & FWC
  - Protocols & guidelines
- After Oct 15, 2023 and
- Water temps on reef below 30.5C/**86.9F** for <u>at least 1 week</u>

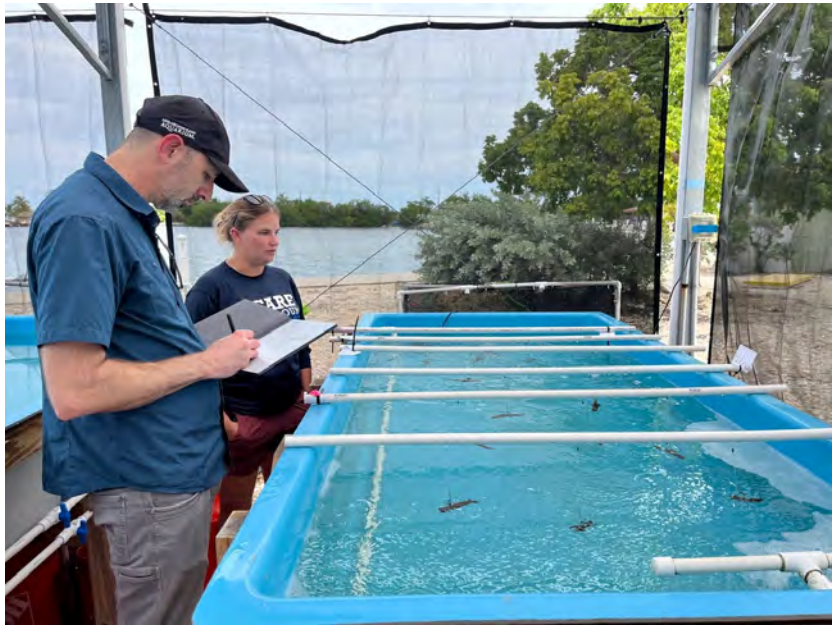
Protocols for all thermally stressed corals held in land-based nurseries:

- No direct outplanting from land-based nurseries to the reef
- Preparation of in situ nurseries
  - Removal of all dead and/or diseased corals

- <u>Coral Health Certification assessment</u>
  - in person by certified Coral Health Veterinarian
  - Valid for 30-days from assessment

- <u>Request approval</u> from FWC Coral Restoration Protocols team to transfer corals to in situ nursery

- Transferred corals will be quarantined in their nursery for 30-days prior to any outplant to the reef; Visual health assessments of all corals



So what did we learn?

- Learning curve for coral practitioners moving from offshore to land-based nurseries.

- Acroporids were challenging to hold on site. More successful with Boulders.

- Develop protocols, hold training sessions, husbandry

- Biosecurity

- Planning well before coral need to be moved:
  - Parameters outlining when to pull coral from offshore
  - transporting coral
  - Protocols/husbandry practices in place and explained to staff