Florida 2017

Coral disease: drivers and management

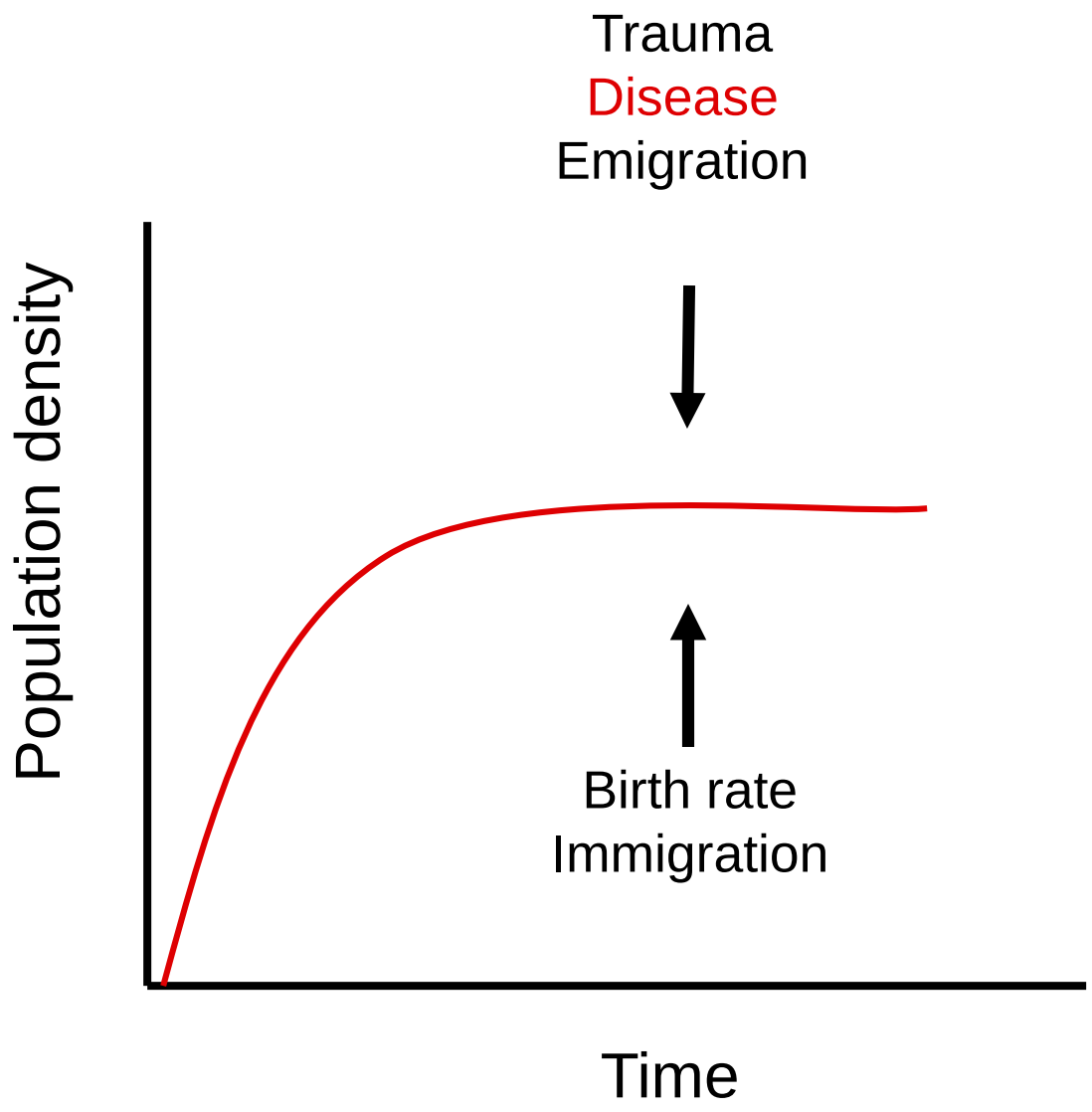
Dr. Greta Smith Aeby
University of Hawaii

Coral Disease

Disease: Any impairment of vital body functions, systems, or organs.

- **Biotic**
  - Causal agent a living organism
    - Pathogen,such as viruses or bacteria
    - Parasites

- **Abiotic**
  - Causal agent an environmental stressor
    - Changes in salinity, temperature, light, etc.
    - Exposure to toxic chemicals


Trauma
Disease
Emigration
Population density
Birth rate
Immigration
Time

Disease Outbreaks

1918: "Spanish flu" H1N1 Pandemic

The most devastating flu pandemic in modern times, killing more than 500,000 people in the United States, and some 50 million people worldwide. Somewhere between 20 and 40 percent of the global population was ill.

An emergency hospital during 1918 influenza epidemic, in Camp Funston, Kansas.

Credit: National Museum of Health and Medicine, Armed Forces Institute of Pathology

Disease Outbreaks

- novel pathogens introduced into naïve host populations

- endemic pathogens spread within a population due to altered external factors, which affect host-pathogen ecology

An emergency hospital during 1918 influenza epidemic, in Camp Funston, Kansas.
Credit: National Museum of Health and Medicine, Armed Forces Institute of Pathology

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Scuba diving damage and intensity of tourist activities increases coral disease prevalence

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Sedimentation
Snorkelling
Thailand
Tourism
White syndrome
Wounds

ABSTRACT

Recreational diving and snorkeling on coral reefs is one of the fastest growing tourism sectors globally. Damage associated with intensive recreational tourist use has been documented extensively on coral reefs, however other impacts on coral health are unknown. Here, we compare the prevalence of 4 coral diseases and 8 other indicators of compromised coral health at high and low use dive sites around the island of Koh Tao, Thailand. Surveys of 10,499 corals reveal that the mean prevalence of healthy corals at low use sites (79%) was twice that at high use sites (45%). We also found a 3-fold increase in coral disease prevalence at high use sites, as well as significant increases in sponge overgrowth, physical injury, tissue necrosis from sediment, and non-normally pigmented coral tissues. Injured corals were more susceptible to skeletal eroding band disease only at high use sites, suggesting that additional stressors associated with use intensity facilitate disease development. Sediment necrosis of coral tissues was strongly associated with the prevalence of white syndromes, a devastating group of diseases, across all sites. We did not find significant differences in mean levels of coral growth anomalies or black band disease between high and low use sites. Our results suggest that several indicators of coral health increase understanding of impacts associated with rapid tourism development. Identifying practical management strategies, such as spatial management of multiple reef-based activities, is necessary to balance growth of tourism and maintenance of coral reefs.

1. Introduction

Global decline in coral reef health is a critical conservation concern, especially for the estimated 275 million people that live within 30 km of coral reefs and draw extensively on them for livelihood and food security (Bellwood et al., 2004; Burke et al., 2011). There is pressing demand to find income-generating alternatives to destructive and extractive uses of marine resources (Birkeland, 1997). Tourism is generally considered a favorable alternative, typically providing an incentive to preserve natural areas, thereby contributing to environmental protection, sustainable use practices, and the restoration of biological diversity (Buckley, 2012). Coral reef-based tourism is one of the fastest growing tourism sectors worldwide (Ong and Musa, 2011). However, because the majority of coral reefs are located in developing and often undermanaged island and coastal regions (Donner and Portere, 2007), the unrestricted growth and rapid development of reef-based tourism often undermines the conservation priorities necessary to sustain it.

Coral disease outbreaks are now recognized as a significant factor in the accelerating degradation of coral reefs, and it is commonly assumed that a variety of human-related activities have altered environmental conditions, potentially impairing coral resistance to microbial infections or increasing pathogen virulence (Altizer et al., 2013). Anthropogenic activities implicated in disease outbreaks and rising prevalence levels (i.e., the number of cases of a disease in a given population at a specific time) include proximity to human population centers (Aeby et al., 2011a), coastal land alteration and dredging (Guilherme Becker et al., 2013; Pollock et al., 2014), terrestrial runoff of sediment or agricultural herbicides (Owen et al., 2002; Haapkylä et al., 2011), sewage outfalls containing human enteric microorganisms (Patterson et al., 2002), increases in nutrient concentrations (Bruno et al., 2003), aquaculture and fish farms (Harvell et al., 1999; Garren et al., 2009), a reduction in the diversity of reef fish assemblages (Raymundo et al., 2009), and sunscreens (Danovaro et al., 2008).

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http://dx.doi.org/10.1016/j.biocon.2014.06.027
0006-3207/

Drivers of coral disease

Host abundance

Thermal stress

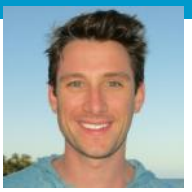
Bleaching stress

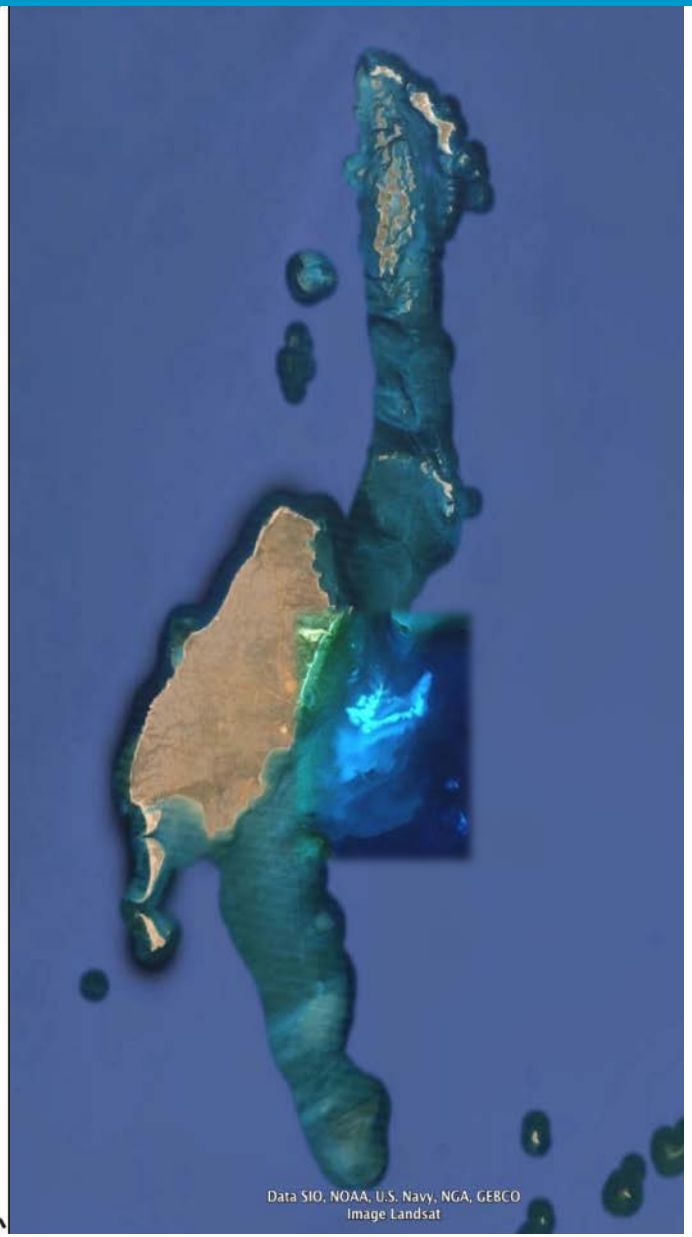
Nutrient stress

Rainfall & Runoff

Injury

Disease drivers: Dredging-related sediments



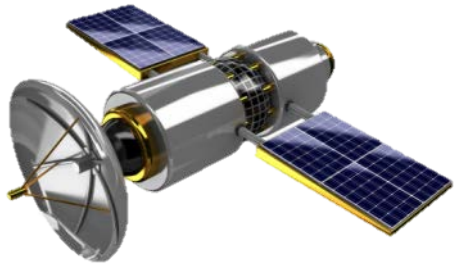


Pollock et al. PLoS One (2014)

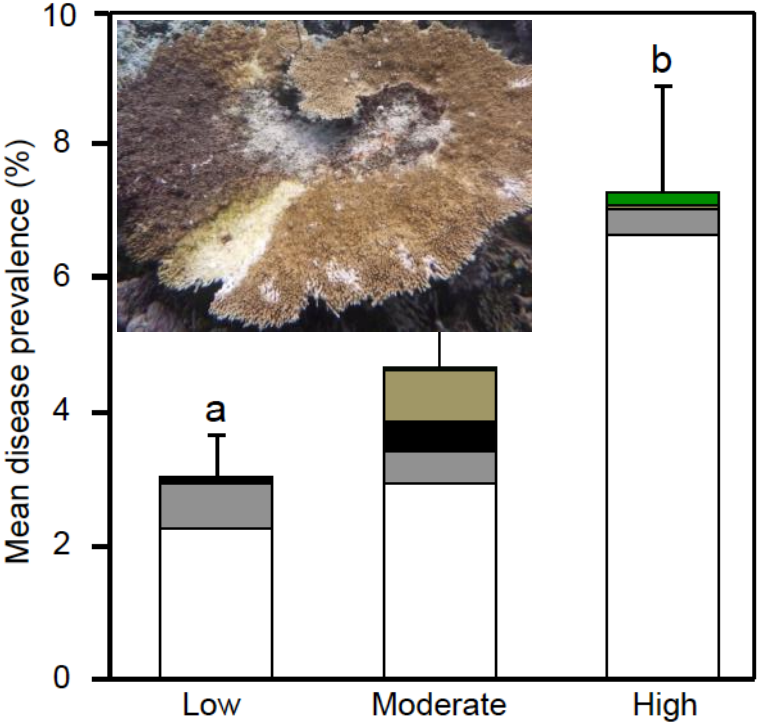
Largest natural gas project in Australia

Removal and dumping of 7.6 million tons of marine sediment
18 month project

NASA MODIS Satellite imagery
Evans et al. 2012



Dredging reveals sedimentation-disease links



➔ 2.5-fold increase overall
➔ white syndromes dominate

➔ 6-fold increase overall
➔ sediment necrosis dominates

Multivariate distance-based linear model (DISTLM):

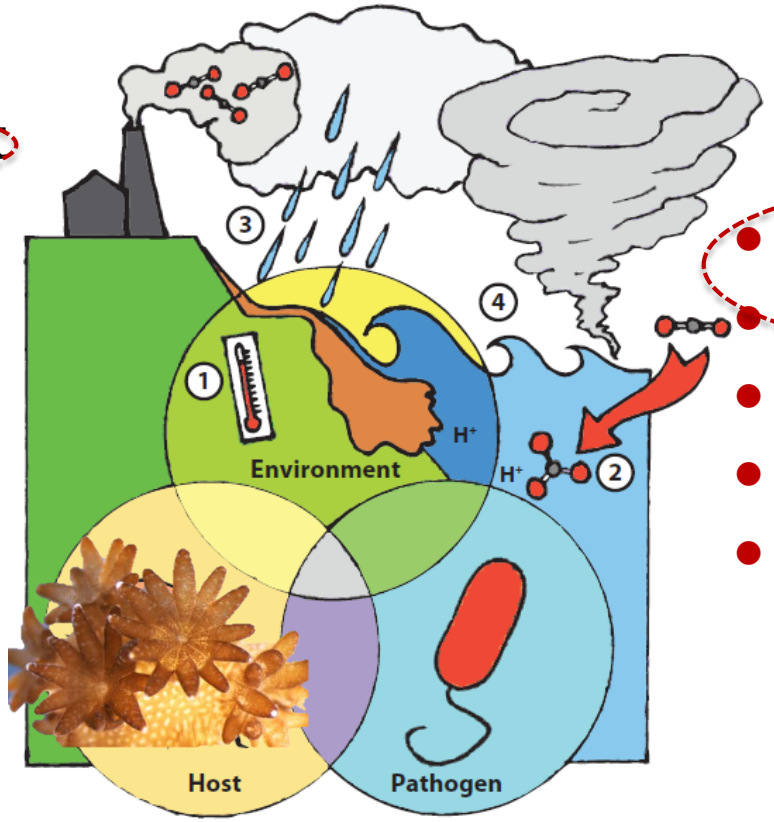
➔ **Sediment plume exposure days is strongest disease driver**
(best fit DISTLM, AICc=216.7, R^2=0.33)

Pollock et al. (2014) *PLoS One* 9:e102498; Correction (2016)

Climate change influences on marine infectious diseases

Changes in Holobiont:

- ↑ susceptibility host
- ↓ *Symbiodinium*
- Δ microbial comm.
- ↓ larval survival
- invasions
- range shifts
- increased stress:
  - physical injury
  - nutrients
  - contaminants
  - salinity



Changes in Pathogen:

- increased abundance
- increased virulence
- new emergence
- invasions
- range shifts

Burge, Willis et al. (2014) *Ann Rev Mar Sci* 6:249-277

Drivers of coral disease

Local human stressors

- Land-based pollution
- Sedimentation
- Overfishing
- Human usage

Global climate change

- increased sea surface temperature
- increased temperature anomalies
- increased frequency of bleaching events
- changes in storm frequency & intensity

Disease Outbreaks

- novel pathogens introduced into naïve host populations

- endemic pathogens spread within a population due to altered external factors, which affect host-pathogen ecology

An emergency hospital during 1918 influenza epidemic, in Camp Funston, Kansas.
Credit: National Museum of Health and Medicine, Armed Forces Institute of Pathology

Management of coral disease

Research

•needed to understand disease ecology

Promote reef resilience

•Improve local water quality
•Increase critical fish stocks
•Reduce other local, compounding stressors

Management actions

•Marine protected areas
•Response plans
•Citizen science
•Direct treatment of diseases

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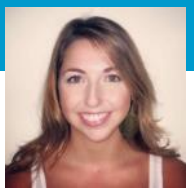
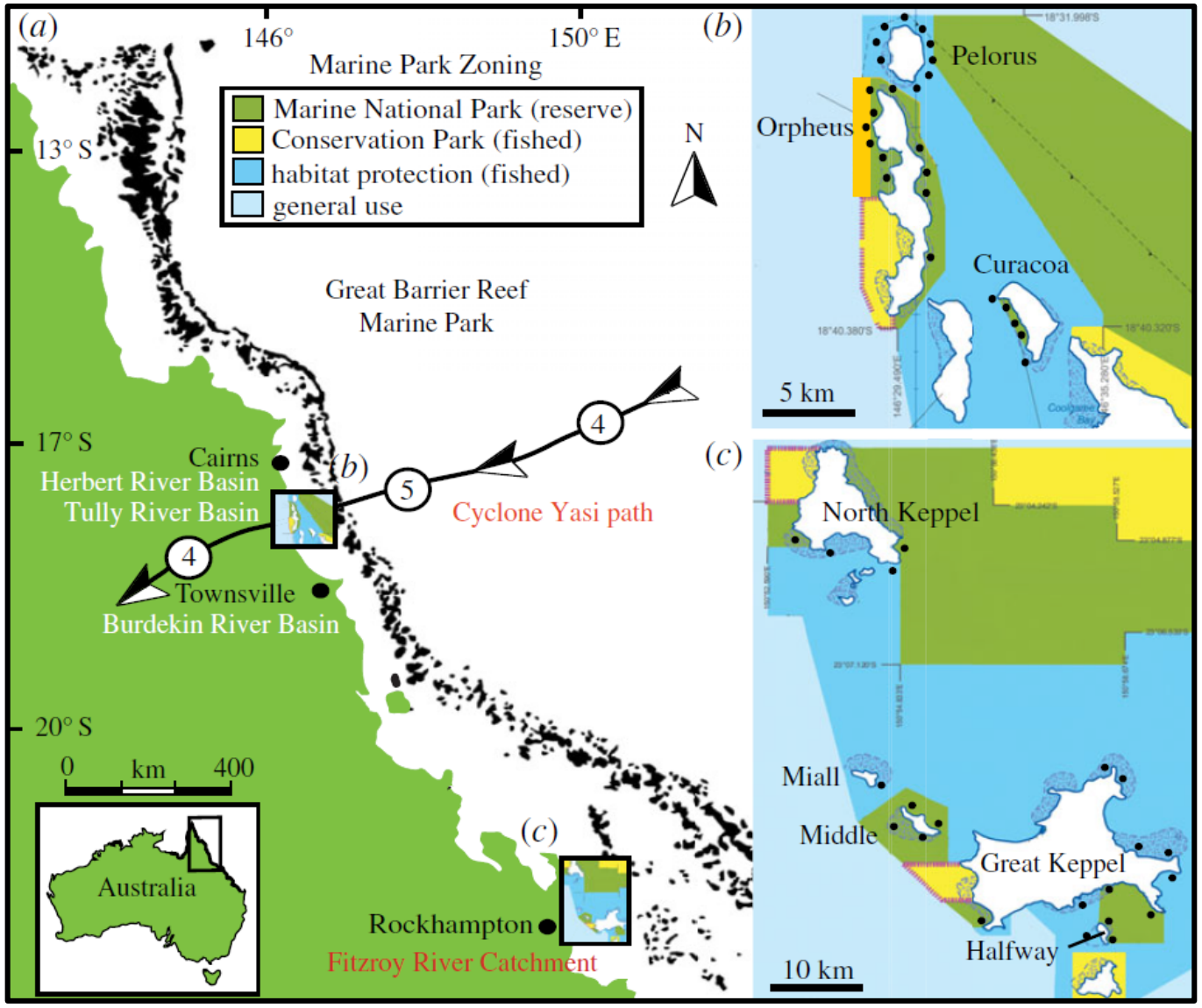
Can marine reserves ameliorate coral health when exposed to acute and chronic stressors?



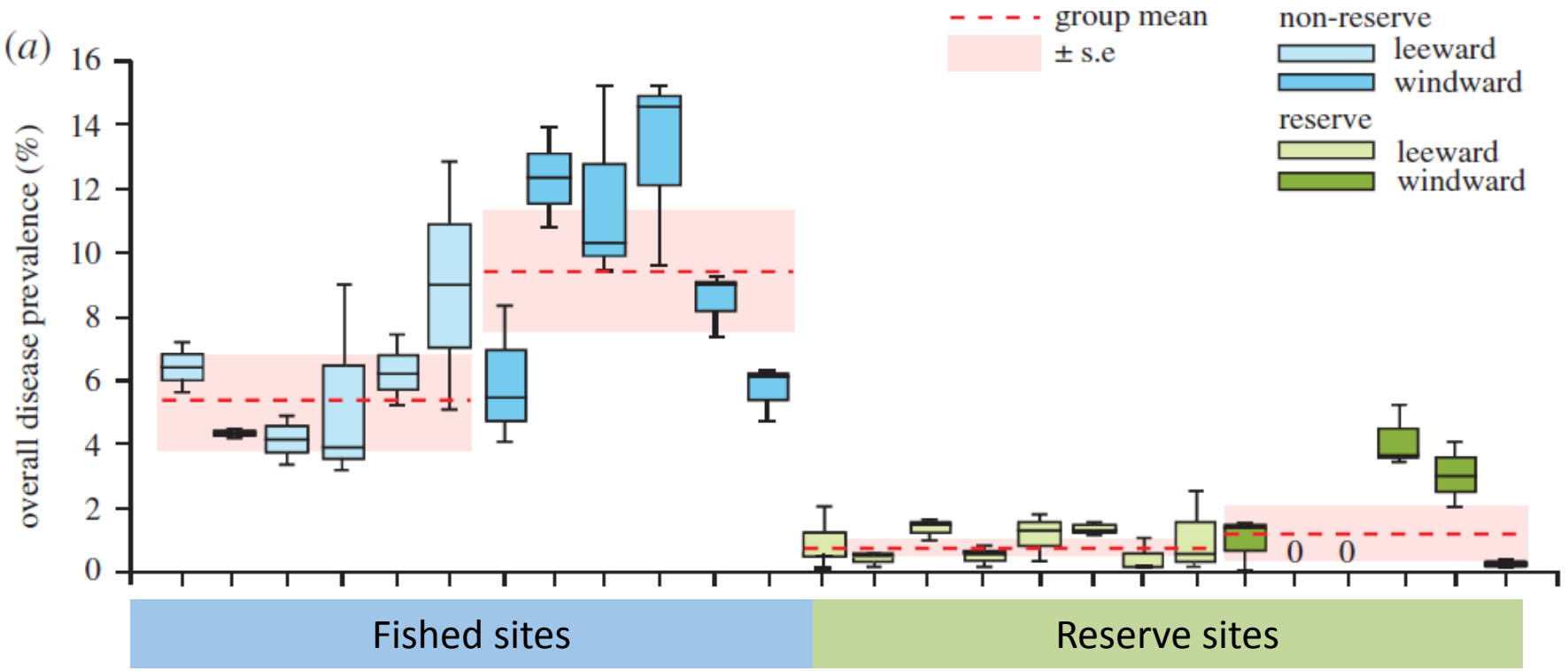


Reserves: 25 sites (75 transects)

Fished: 22 sites (58 transects)

Lamb, Wenger, Devlin, Ceccarelli, Williamson, Willis (2016) *Phil. Trans. R. Soc. B* 371: 20150210

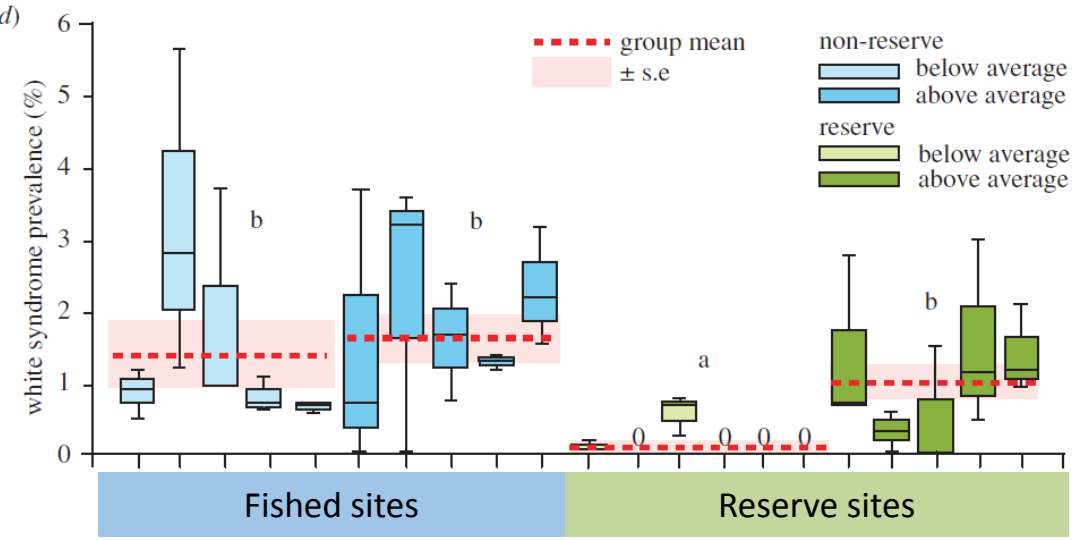
Can marine reserves ameliorate coral health when exposed to acute stressors?

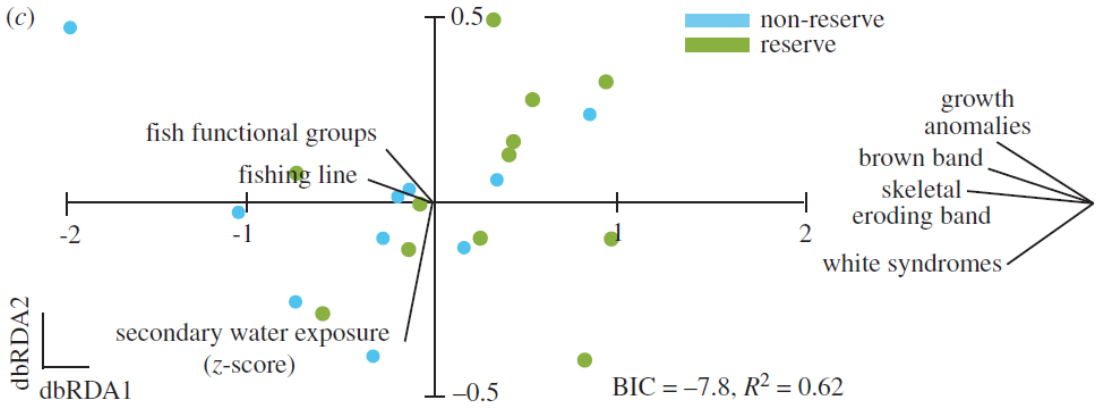


- **7-fold lower disease prevalence in Reserves 1 year after severe cyclone**

Lamb et al. (2016) *Phil. Trans. R. Soc. B* 371: 20150210

Can marine reserves ameliorate coral health when exposed to chronic stressors?





Exposure to plumes *lower* than average:

- 3-fold higher WSs outside reserves

Exposure to plumes *higher* than average

- WSs same inside and outside reserves

➔ **Reductions in water quality undermine efficacy of protected areas to alleviate disease**

Lamb et al. (2016) *Phil. Trans. R. Soc. B*

Management of coral disease

Research

- needed to understand disease ecology

Promote reef resilience

- Improve local water quality
- Increase critical fish stocks
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Management actions

- Marine protected areas
- Response plans
- Citizen science
- Direct treatment of diseases

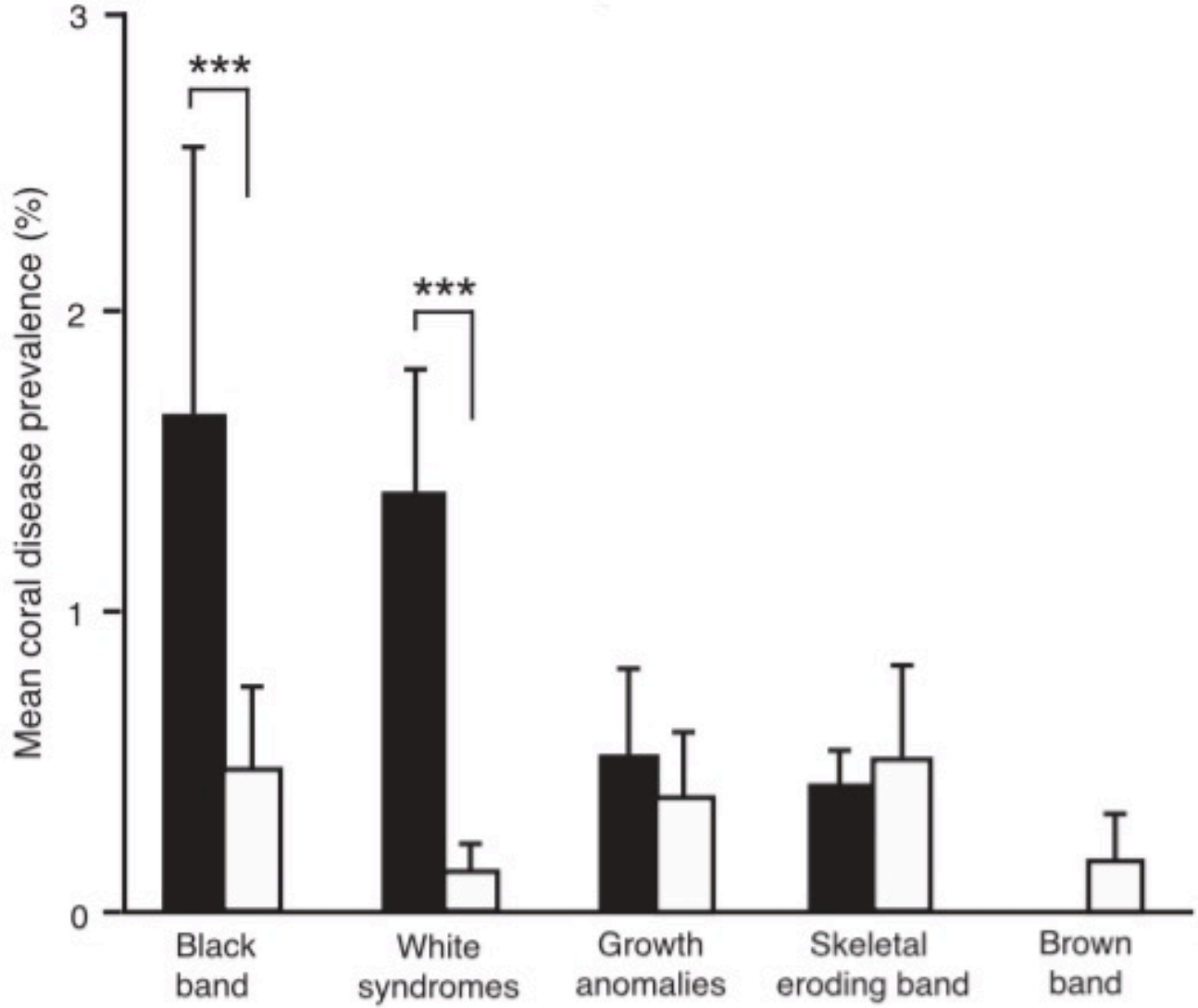
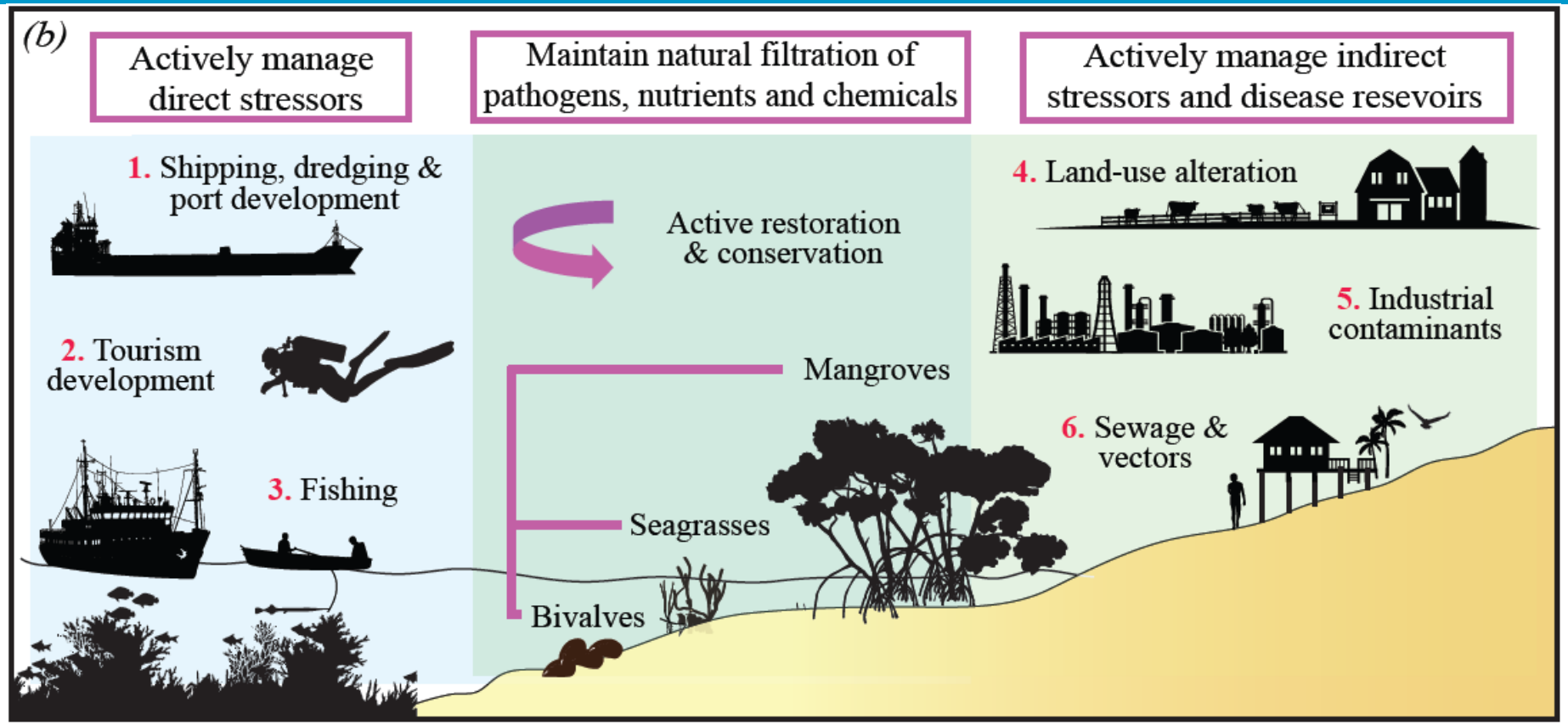


Fig. 3. Diseases of reef-building corals are lower when adjacent to seagrass meadows. Prevalence of surveyed coral diseases (mean ± SE) on reefs with adjacent seagrass meadows (white bars) compared to reefs without seagrass meadows (black bars). Differences were tested using generalized linear mixed models, where $P < 0.001$ (table S10). A total of 8034 reef-building corals were examined at paired sites among four islands.

Effective disease management should target:

- Improving water quality
- Enhancing fish stocks
- Limiting anthropogenic activities that cause injury



Lamb et al. (2016) *Phil. Trans. R. Soc. B*

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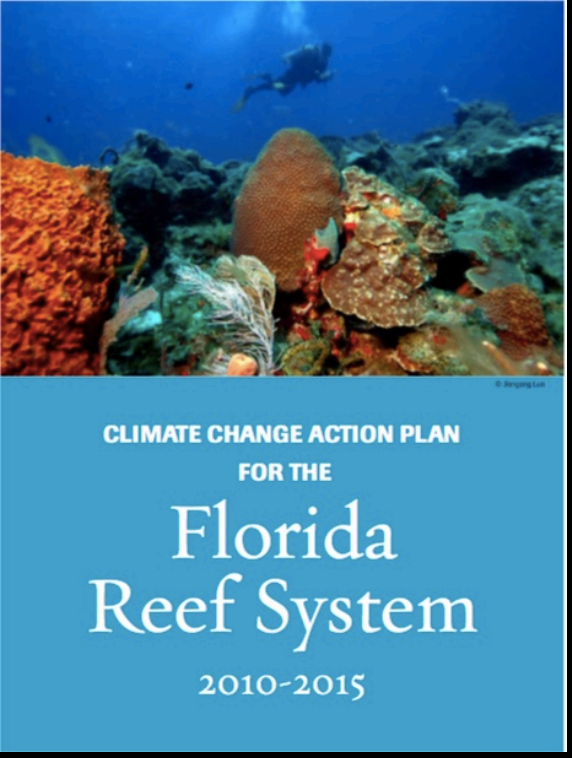
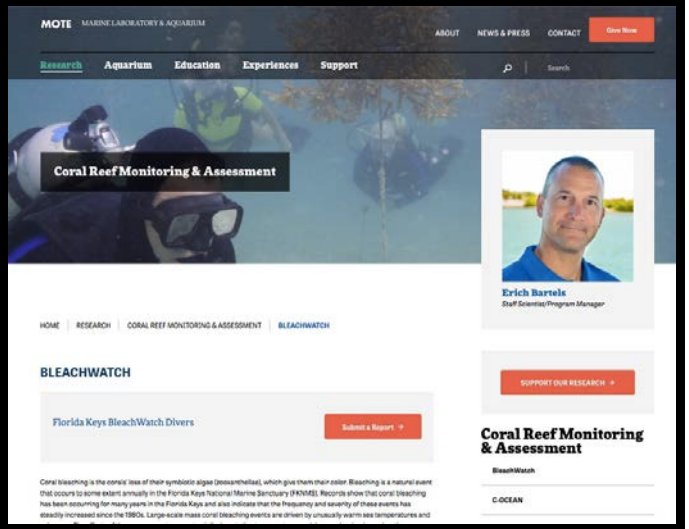


CLIMATE CHANGE ACTION PLAN
FOR THE
Florida Reef System
2010-2015



C-OCEAN

Notice any unusual marine events? Report an Observation →

Community-Based Observations of Coastal Ecosystems and Assessment Network

NOTE: Formerly known as the MEERA Project.

With support from and coordination with the Florida Keys National Marine Sanctuary (FKNMS), C-OCEAN is designed to provide early detection and assessment of biological events occurring in the Florida Keys and surrounding waters. The goal of the network is to help the scientific community better understand the nature and causes of marine events that adversely affect marine organisms, and assist ongoing research efforts to assess and monitor events as they develop. Understanding these events will help scientists and managers determine whether the events are natural or are linked to human activities.

The key to the early detection of marine events is the people who are on the water. Most of them have a considerable knowledge of the area and an understanding of when things are not as they should be. Anyone who is on the water frequently is encouraged to report observations as soon as possible.

There is no paperwork involved, no specialized training needed, and no other participation or effort is required. By simply providing what, where, and when something unusual was observed, residents can provide scientists with the information needed to detect potentially large scale events as they develop. To report an observation contact Cory Walter, Project Coordinator, at (305) 395-8730, or email cwalter@mote.org.

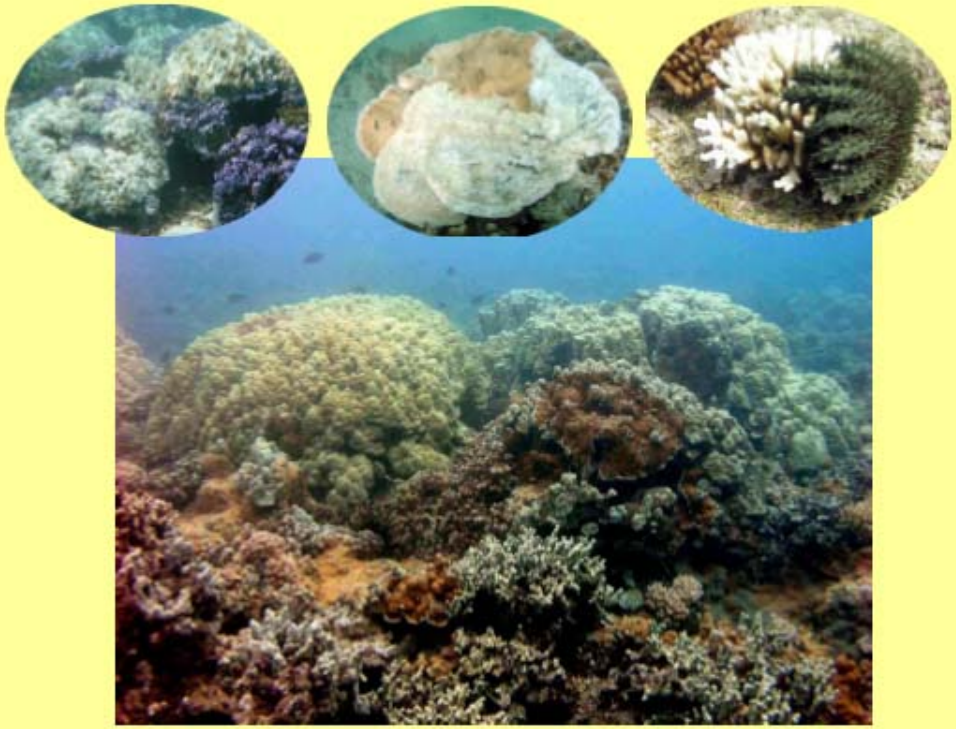
Photo by M

Florida Reef Tract
Coral Bleaching Response Plan

Florida Reef Resilience Program

Hawaii's Rapid Response Contingency Plan

for events of coral bleaching, disease or crown-of-thorns starfish outbreaks

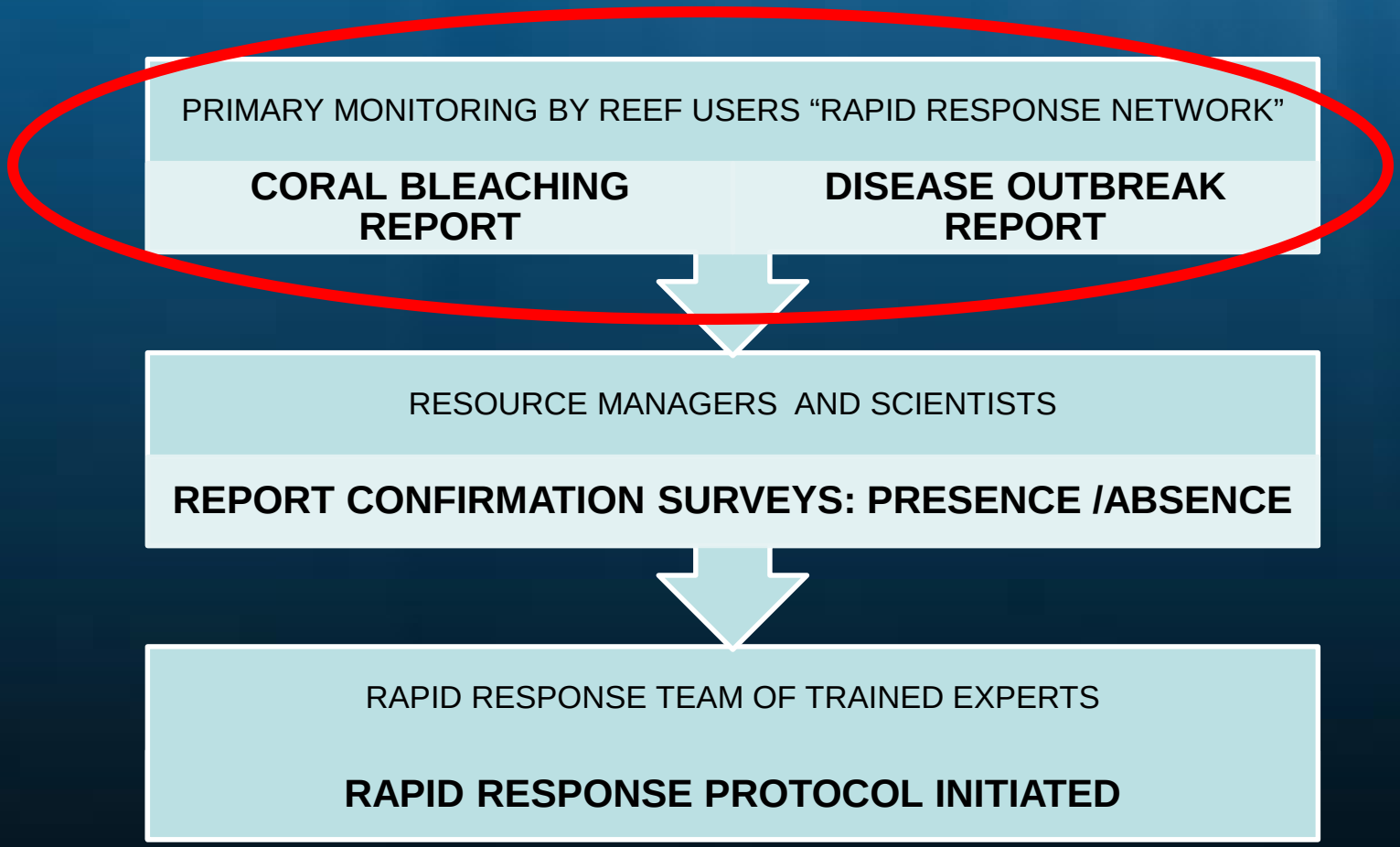


Dr. Greta Smith Aeby, Melanie Hutchinson and Petra MacGowan

Developed in 2008

HAWAII'S RAPID RESPONSE CONTINGENCY PLAN

3 TIERED RESPONSE PROGRAM



Our Reefs: The Facts

- Hawaii's reefs are vast
  - 410,000 acres, representing almost 85% of coral reefs under US protection
  - Over 5,000 species, almost 25% endemic
  - Culturally, economically, biologically critical

EYES OF THE REEF

eorhawaii.org

Community Reporting Network

Coral Bleaching & Disease, COTS and Marine Invasive Species

Threats to Hawaii's reefs

Coral bleaching

Coral disease

COTS

Invasive algae

EYES OF THE REEF

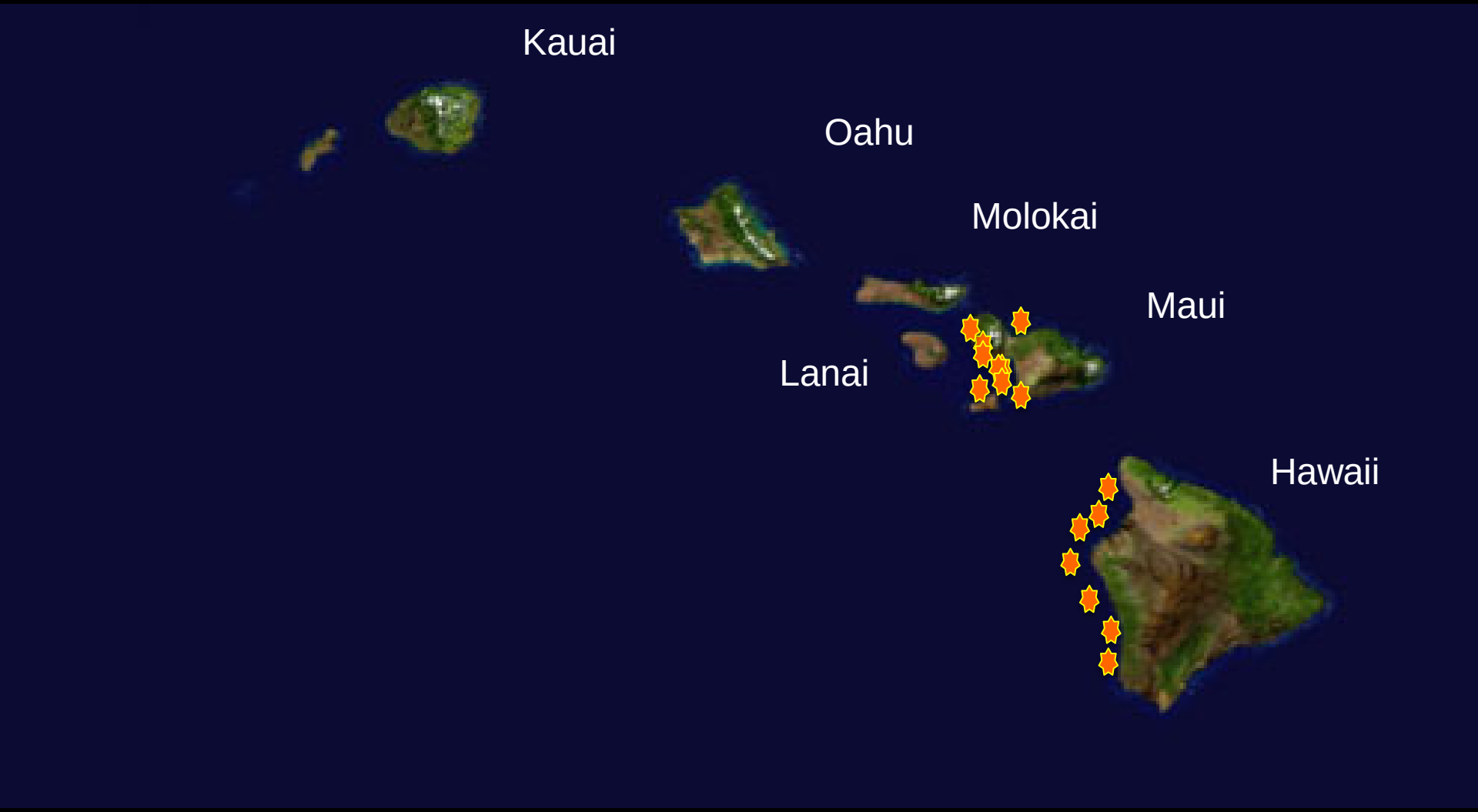
Early Detection → Rapid Response


khon2
NEWS
WEATHER
2015 Haw
By Web Staff
Published: September
SCIENCE
Hawaii's bleaching problem:
How warming waters threaten
coral
SPORTS
TRAFFIC
REPORT
ng Has Begun
2015
coral


2015 bleaching event in Kaneohe Bay

Division of Aquatic Resources (DAR)

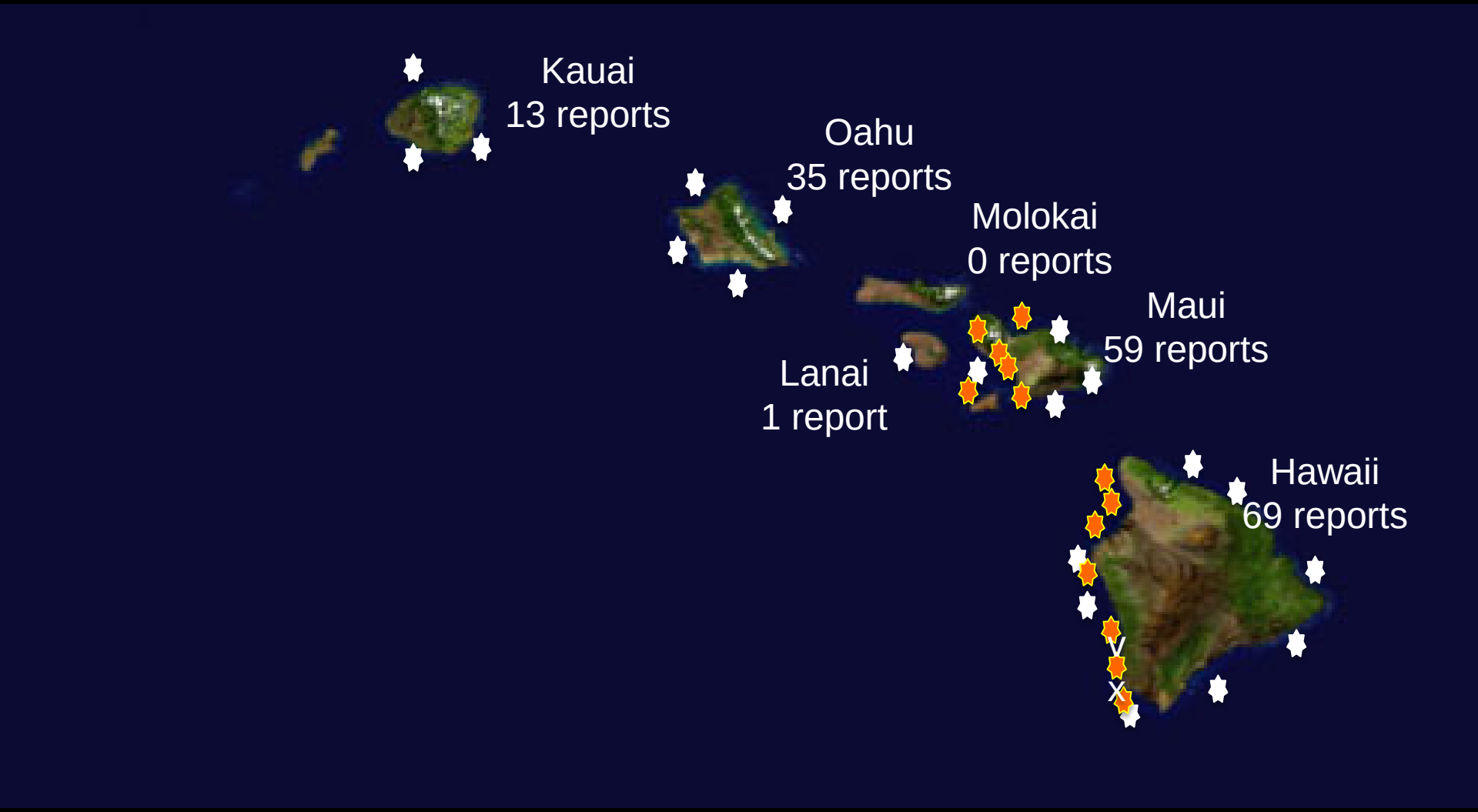
DAR monitoring sites



2015 Bleaching event in the Hawaii

DAR monitoring sites

177 EOR reports



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Eyes of the Reef Hawaii

Community Reporting Network for coral bleaching, diseases, COTS and marine invasives

REPORT Coral Bleaching

REPORT Coral Disease

REPORT Crown-of-Thorn Seastars

REPORT Marine Invasives

REPORT Fish Disease

REPORT Other Observations

Search | search

EOR members help scientists unravel pufferfish die-off mystery

MARCH 7, 2017 2:10 PM

In 2010, pufferfish (*Arothron hispidus*) around the state were dying in large numbers. EOR members were quick to send in reports of dying fish giving scientists valuable information on how widespread and extensive the die-off was. (more…)

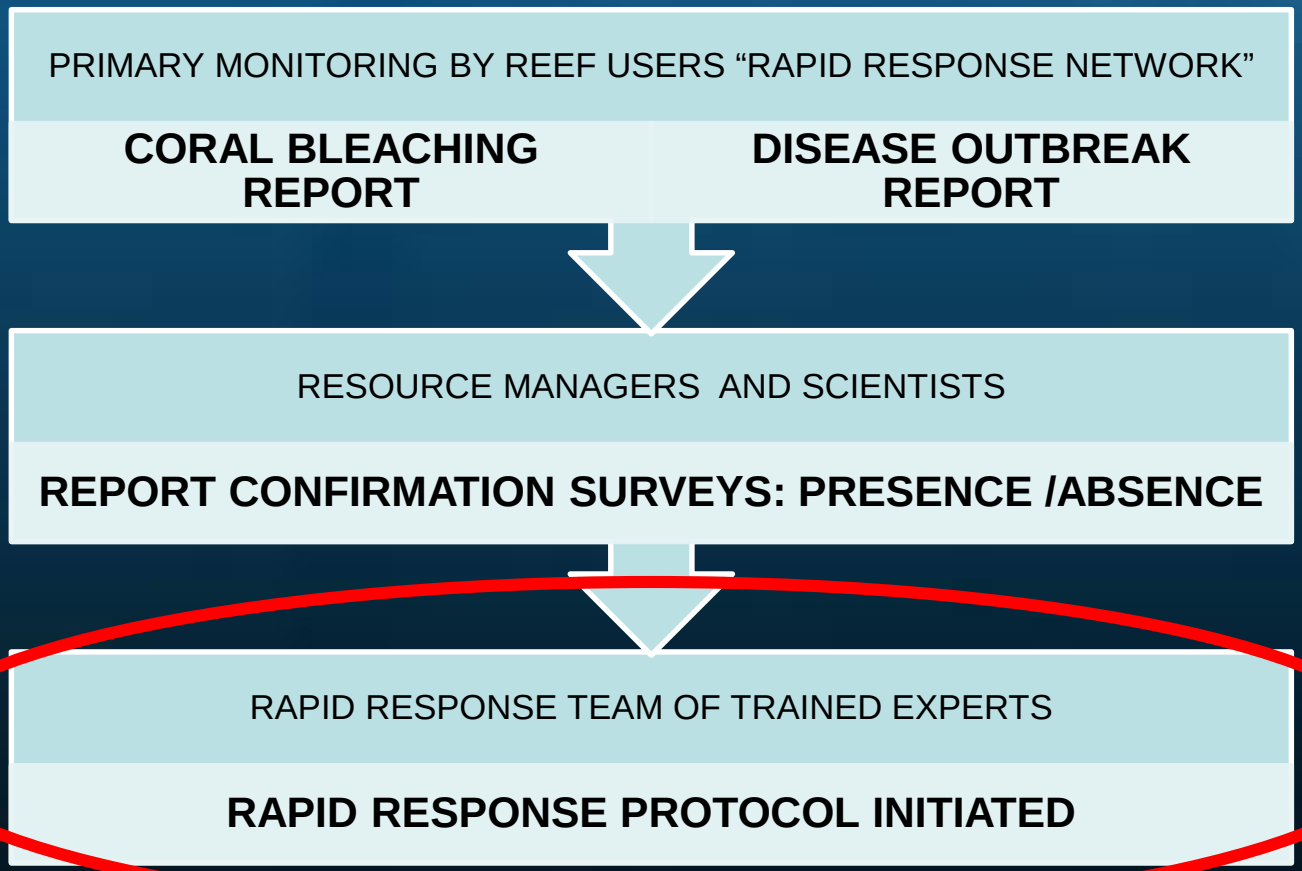
ABOUT EYES OF THE REEF....

The Eyes of the Reef Network (EOR) is an effective statewide reporting system that enables all community members and ocean users to contribute to the long-term protection

Citizen science

HAWAII'S RAPID RESPONSE CONTINGENCY PLAN

3 TIERED RESPONSE PROGRAM



2010

Rapid disease killing coral in Kaneohe Bay

Posted: Apr 02, 2010 10:38 AM
Updated: Apr 02, 2010 7:23 PM

By Jim Mendoza - bio | email

KANEOHE (HawaiiNewsNow) - In Kaneohe Bay the backbone of an ecosystem is under attack.

"What we're starting to see is whole clusters, ten, twenty, thirty colonies all dead in an area as the disease has passed from one other within the last four to five weeks," said Greta Aeby, a researcher with the Hawaii Institute of Marine Biology.

Acute Montipora White Syndrome -- a tissue killing slaughtered more than 100 colonies of red rice c Island.

"It usually comes in as a very bright whi colony. That white is where it's stripp said. "The problems here is that co you're wiping out a decade's wo

Most of the damage is in th quality's the poorest.

"Our reefs have be pollution for de the result of for the shr there's no pl she said.

Aeby and other res zones and are analyzing coral samp

"One thing that we want hat may be causing this disease. So we're using histology, w microbiology, we're using molecular techniques to see might have been caused by a bacterial infection," she said.

LOCAL NEWS

Posted on: Monday, April 5, 2010

Disease hits Kāne'ohe Bay reefs

MWS has killed 100 colonies of red rice coral

Print this page E-mail this article Share

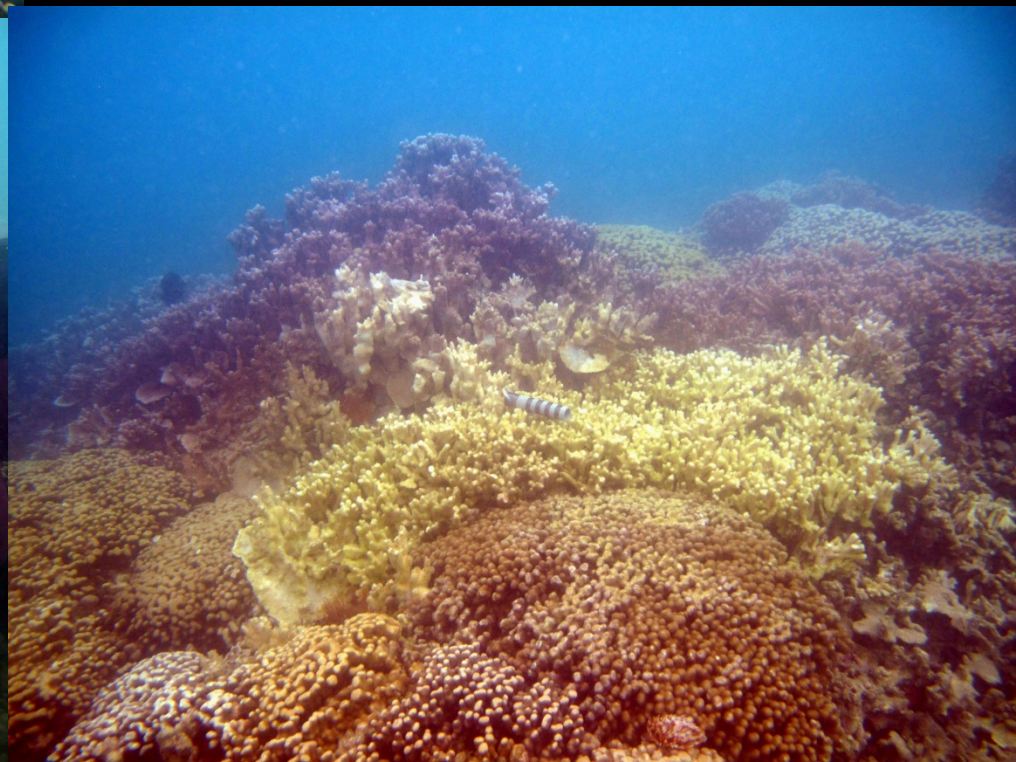
Recommend (1) Comments (15)

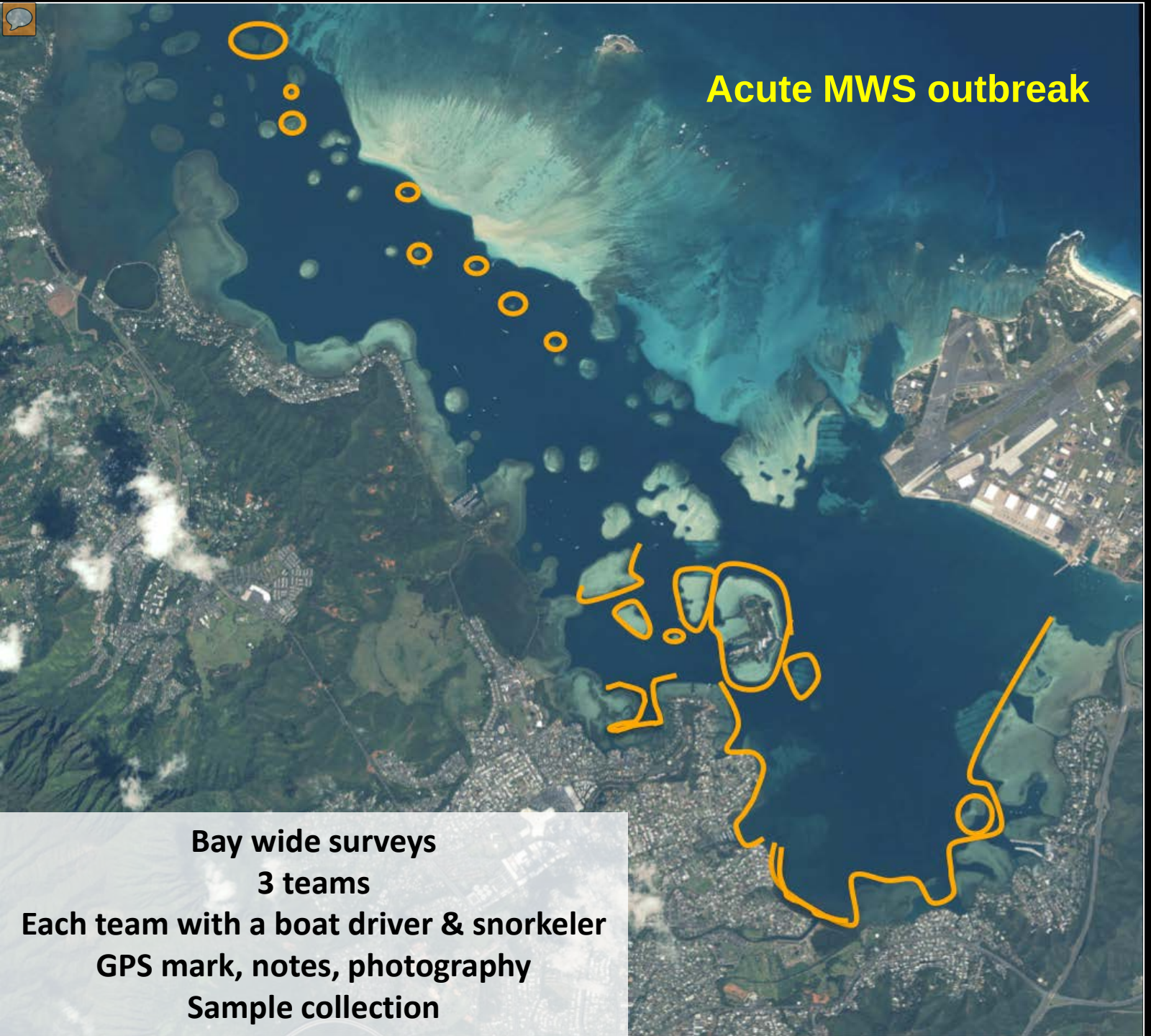
By John Windrow
Advertiser Staff Writer

Hawai'i scientists are battling a new threat to coral reefs in Kāne'ohe Bay that could imperil the biological balance in the bay's ecosystem.

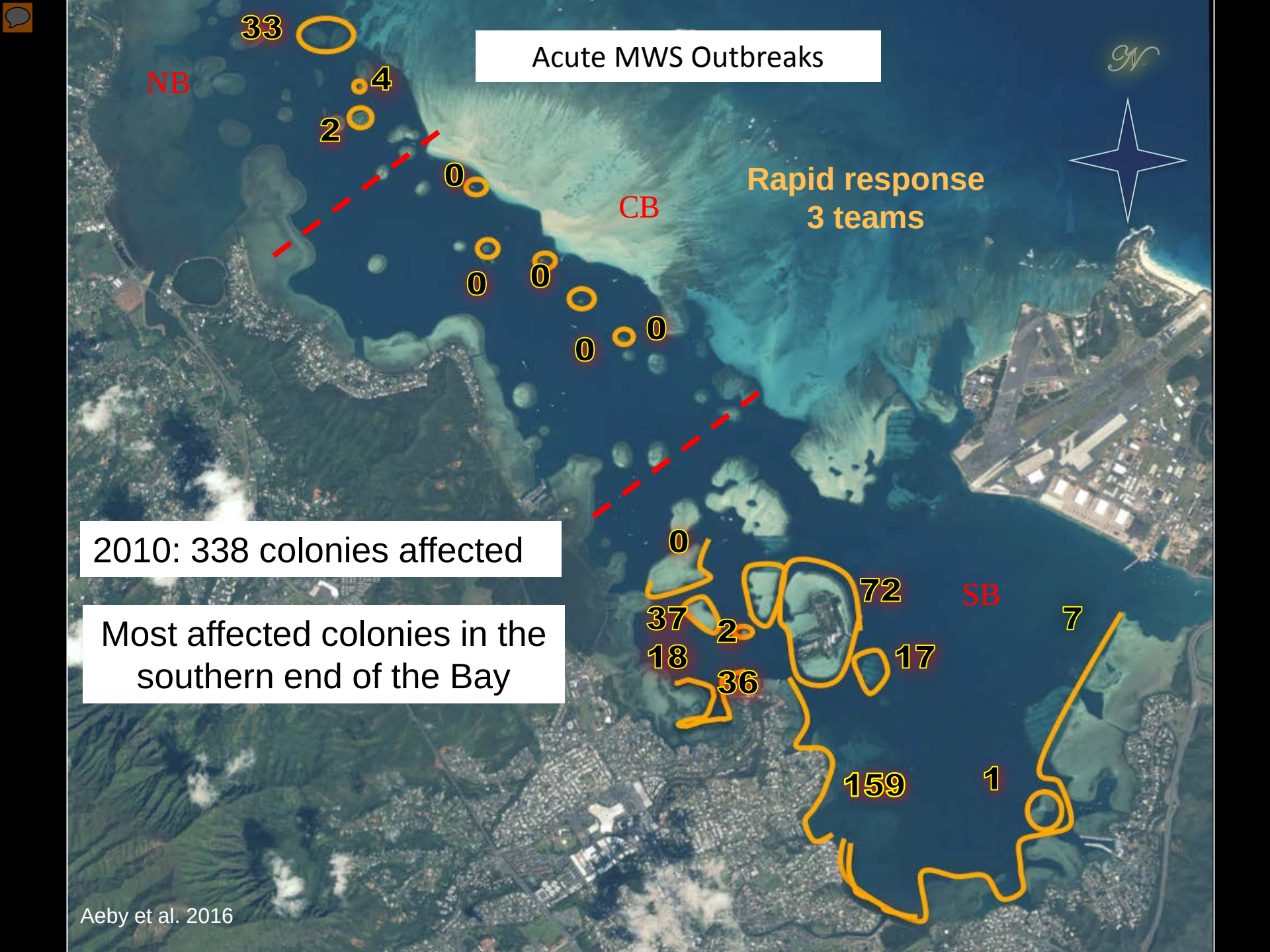
show
homes
crumbles,
bigger guys,"

Rapid response to an acute MWS outbreak in Kaneohe Bay

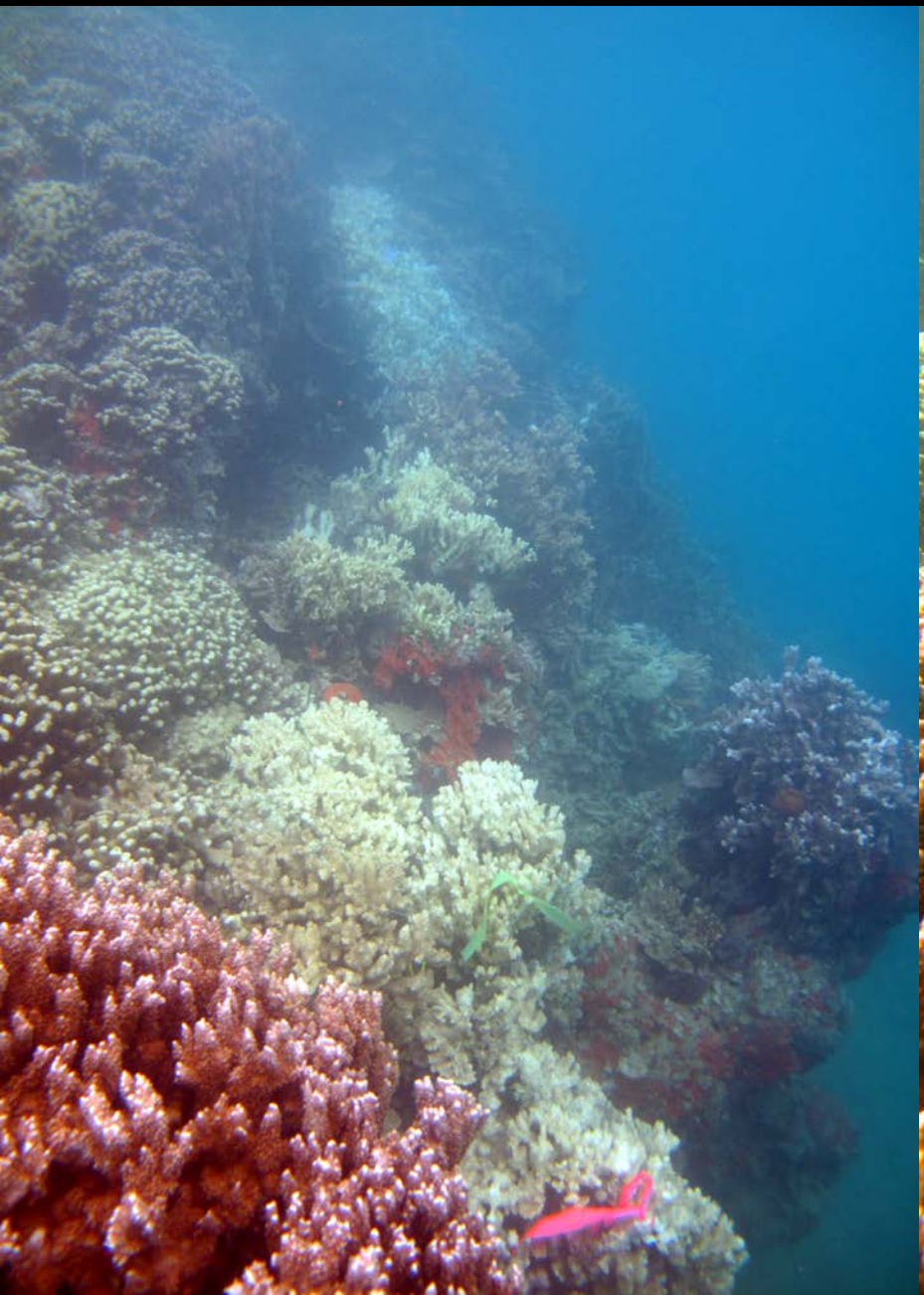




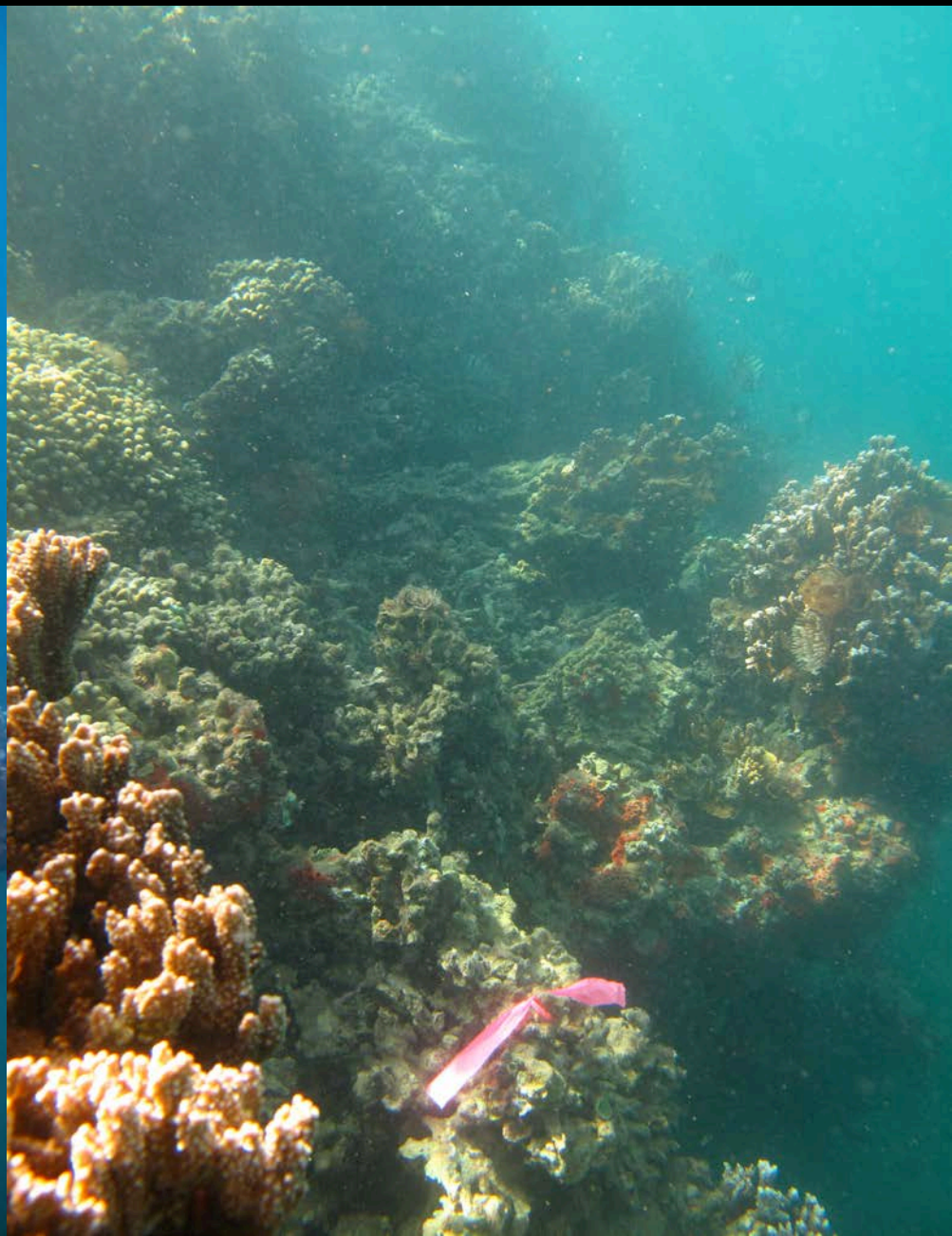
Bay wide surveys
3 teams
Each team with a boat driver & snorkeler
GPS mark, notes, photography
Sample collection


Acute MWS Outbreaks
NB
CB
SB
33
4
2
0
0
0
0
0
Rapid response
3 teams
2010: 338 colonies affected
Most affected colonies in the southern end of the Bay
0
72
37
2
18
36
17
7
159
1
Aeby et al. 2016

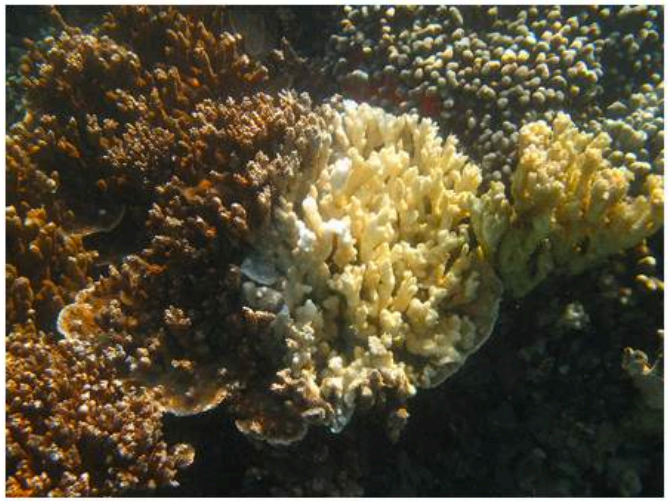
April 2010



April 2011



DIARY



Diseased (white) coral. IMAGE: HAWAI'I MARINE BIO INSTITUTE

Coral Disease Recurs

BY MATTHEW KAIN | JAN 18, 2012

An outbreak of the coral disease known as Montipora White Syndrome (MWS) has again been detected in the reefs of Kaneohe Bay. In March of 2010 an outbreak of MWS killed over 100 colonies of rice coral. Now the disease has reappeared and is killing even more than before, having already affected 198 colonies.

A rapid response team of scientists led by Dr. Greta Aeby of the Hawaii Institute of Marine Biology has been dispatched to document the outbreak. But can it be stopped?

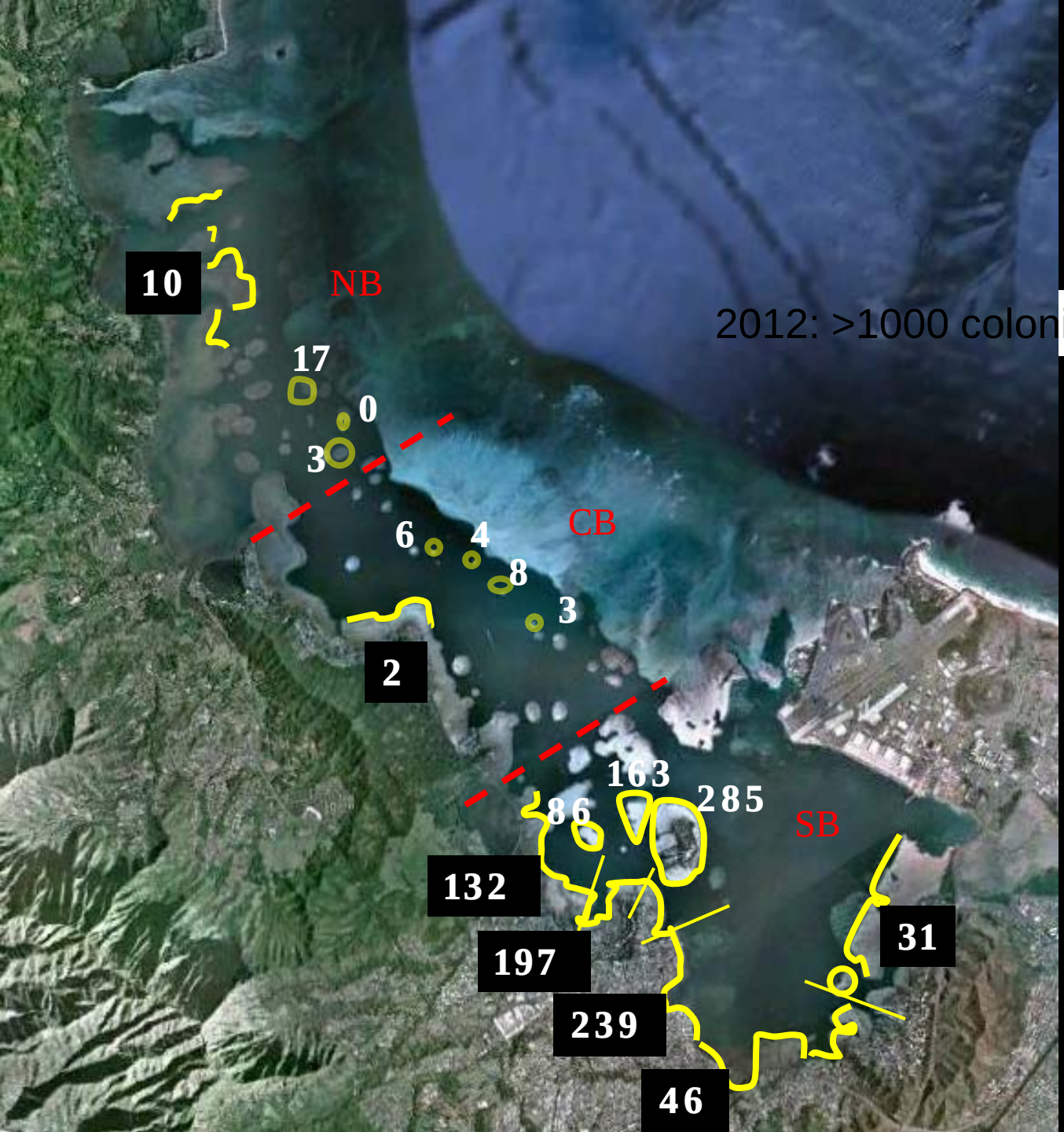
"In corals, like humans, you're never going to get rid of disease," says Aeby. "The amount of death from these outbreaks is what we're trying to restrict."

One hopeful idea involves the response team using bone saws to surgically remove lesions from infected colonies, a method that has been successfully utilized in other areas like Australia. However, funding is still pending to get the operation below sea level.

2nd outbreak of acute MWS

Kaneohe Bay
December 2011

MWS outbreak
2012



2012: >1000 colonies affected

Aeby et al. 2016

2014
DLNR develops capacity for reef response!

Department of Land and Natural Resources
Reef Response

Search this site

http://dlnr.hawaii.gov/reefresponse/

Home | Rapid Response Contingency Plan (RRCP) | Current Rapid Responses | Past Final Reports | Resources

- Make a Report
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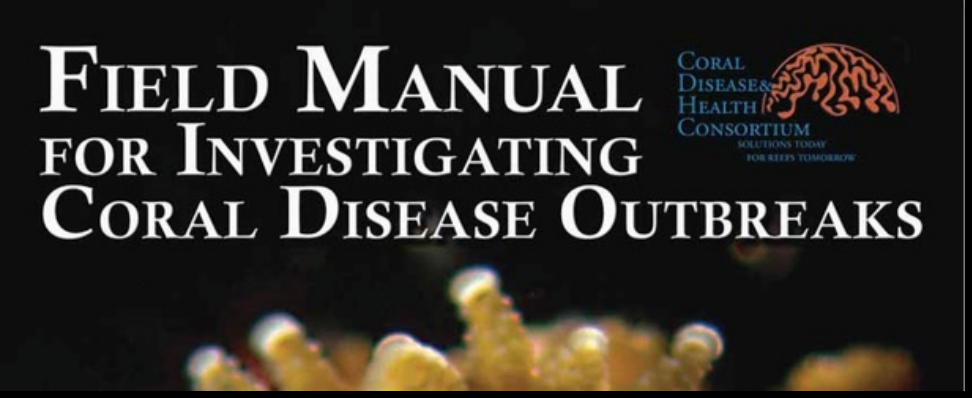
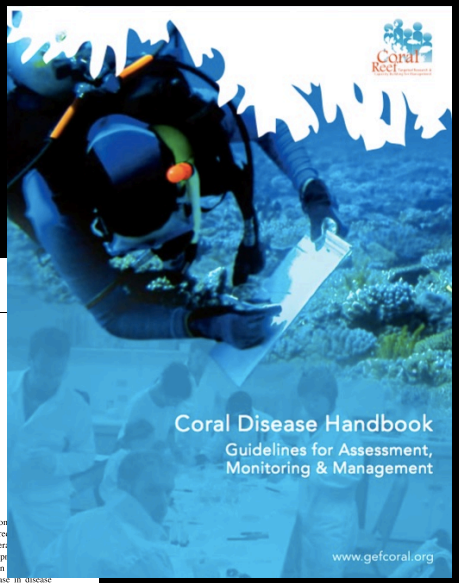
WELCOME TO DAR'S REEF RESPONSE HOMEPAGE!

The Rapid Response Contingency Plan (RRCP) provides the Department of Natural Resources (DLNR), Division of Aquatic Resources (DAR) and its partners with a plan to respond to unusual events including coral disease, coral bleaching, and Crown-Of-Thorn Starfish (COTS) outbreaks

Field Manual for Investigating Coral Disease Outbreaks

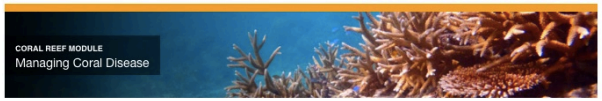
Coral Disease & Health Consortium
Solutions Today for Reefs Tomorrow





Reef Resilience

About Us | Science & Strategies | Webinars | Trainings | Network Forum



Coral Reef Module

- Reefs and Resilience
- Stressors
- Monitoring and Assessment
- **Management Strategies**
  - Managing Local Stressors
  - Marine Protected Areas
  - Fisheries Management
  - Marine Conservation Agreements
  - Reducing Land Based Impacts
  - **Managing for Disturbance**
    - Coral Bleaching
    - **Managing Coral Disease**
  - Ecological Restoration
  - Managing for Social Resilience
  - Managing for Ocean Acidification
  - Integrated Approaches
  - Measuring Effectiveness and Adaptive Management

Managing Coral Disease

Coral disease outbreaks can be a serious threat to coral reefs, causing death to hard and/or soft corals over extensive areas. Managers confronted with a coral disease outbreak are likely to want to predict and communicate ecological implications, measure impacts and understand the ramifications of disease outbreaks for longer term management of reef resilience.

This coral, infected by white band disease, was found on a shallow coral reef near Hsiaoliuchou island (small islet to the south-west of Taiwan). A disease rapid response plan should outline the actions to take when disease outbreaks occur. Photo © Konstantin Tkachenko

A coral disease response plan describes the steps for detecting, assessing and responding to disease outbreaks. Because disease spread is at least partly dependent on transmission, managers may have options for directly intervening with the aim of reducing the severity or extent of impacts by controlling activities that increase risk of disease transfer. Disease can spread rapidly through a coral reef ecosystem, but disease outbreaks can also persist for months to years. This means that monitoring disease response may need to be sustained for many months or even years.

Like bleaching response plans, the type and scale of plan might vary greatly depending on your site and capacity. Recognizing and identifying coral diseases is critical for an effective disease response, and in many locations coral reef managers may need to rely on specialist expertise, or may implement a program to build capacity in this area. Fortunately, there are some excellent guides and tools [PDF] to assist in the identification and management of coral disease.

Developing a Disease Response Plan

Environmental Management (2012) 49:1–13
DOI 10.1007/s00267-011-9770-9

PROFILE

A Framework for Responding to Coral Disease Outbreaks that Facilitates Adaptive Management

Roger Beeden · Jeffrey A. Maynard · Paul A. Marshall · Scott F. Heron · Bette L. Willis

Received: 18 December 2010 / Accepted: 5 October 2011 / Published online: 1 November 2011

Abstract Predicted increases in coral disease outbreaks associated with climate change have implications for coral reef ecosystems and the people and industries that depend on them. It is critical that coral reef managers understand these implications and have the ability to assess and reduce risk, detect and contain outbreaks, and monitor and minimise impacts. Here, we present a coral disease response framework that has four core components: (1) an early warning system, (2) a tiered impact assessment program, (3) scaled management actions and (4) a co… plan. The early warning system combines pre… that monitor the risk of outbreaks of temper… dent coral diseases with in situ observations p… network of observers who regularly report on … and reef state. Verified reports of an increase in disease prevalence trigger a tiered response of more detailed impact assessment, targeted research and/or management actions. The response is scaled to the risk posed by the outbreak, which is a function of the severity and spatial extent of the impacts. We review potential management actions to mitigate coral disease impacts and facilitate recovery, considering emerging strategies unique to coral disease and more established strategies to support reef resilience. We also describe approaches to communicating about coral disease outbreaks that will address common misperceptions and raise awareness of the coral disease threat. By adopting this framework, managers and researchers can establish a community of practice and can develop response plans for the management of coral disease outbreaks based on local needs. The collaborations between managers and researchers we suggest will enable adaptive management of disease impacts following evaluating the cost-effectiveness of emerging response actions and incrementally improving our understanding of outbreak causation.

Keywords Climate change · Coral reefs · Coral disease · Management actions · Outbreaks · Response framework

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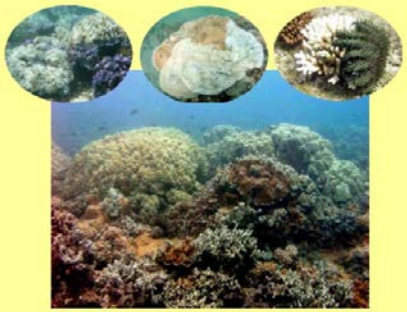
Introduction

Coral diseases can cause widespread coral mortality and have been a key factor in the degradation of important reef

Hawaii's Rapid Response Contingency Plan

for events of coral bleaching, disease or crown-of-thorns starfish outbreaks



Dr. Greta Smith Aeby, Melanie Hutchinson and Petra MacGowan

Australian Government
Great Barrier Reef Marine Park Authority

Reef Health Incident Response System 2011

Great Barrier Reef Marine Park Authority

Hawaii management of coral disease

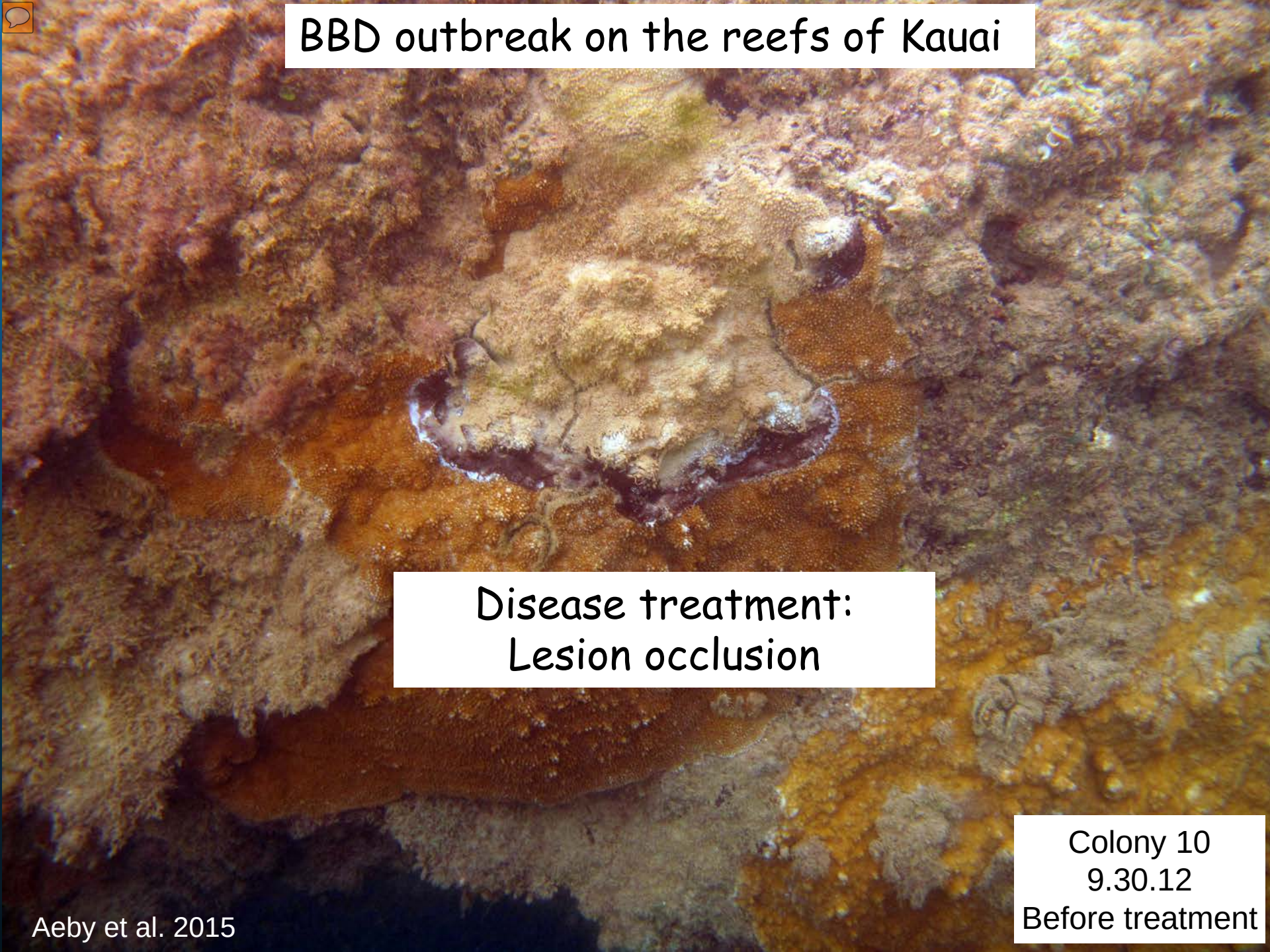
Research - needed to understand disease ecology

Promote reef resilience

- Improve local water quality
- Increase critical fish stocks
- Reduce other local, compounding stressors

Management actions

- Marine protected areas
- Response plans
- Citizen science
- Direct treatment of diseases


BBD outbreak on the reefs of Kauai
Disease treatment:
Lesion occlusion
Colony 10
9.30.12
Before treatment
Aeby et al. 2015


Colony 10
9.30.12
After treatment


Colony 10
11.28.12


Colony 10
May 29, 2013

Disease virulence & treatment

Untreated colonies (n=8)

- Case fatality rate=25%
- Morbidity rate=100%
- Avg. amount of tissue loss/colony=65.9%
- Range=12.8%-100%

Treated colonies (n=8)

- Case fatality rate=0%
- Morbidity rate=50%
- Avg. amount of tissue loss/colony=4.4%
- Range=0%-35.4%

Management of coral disease

Research

•needed to understand disease ecology

Promote reef resilience

•Improve local water quality
•Increase critical fish stocks
•Reduce other local, compounding stressors

Management actions

•Marine protected areas
•Response plans
•Citizen science
•Direct treatment of diseases