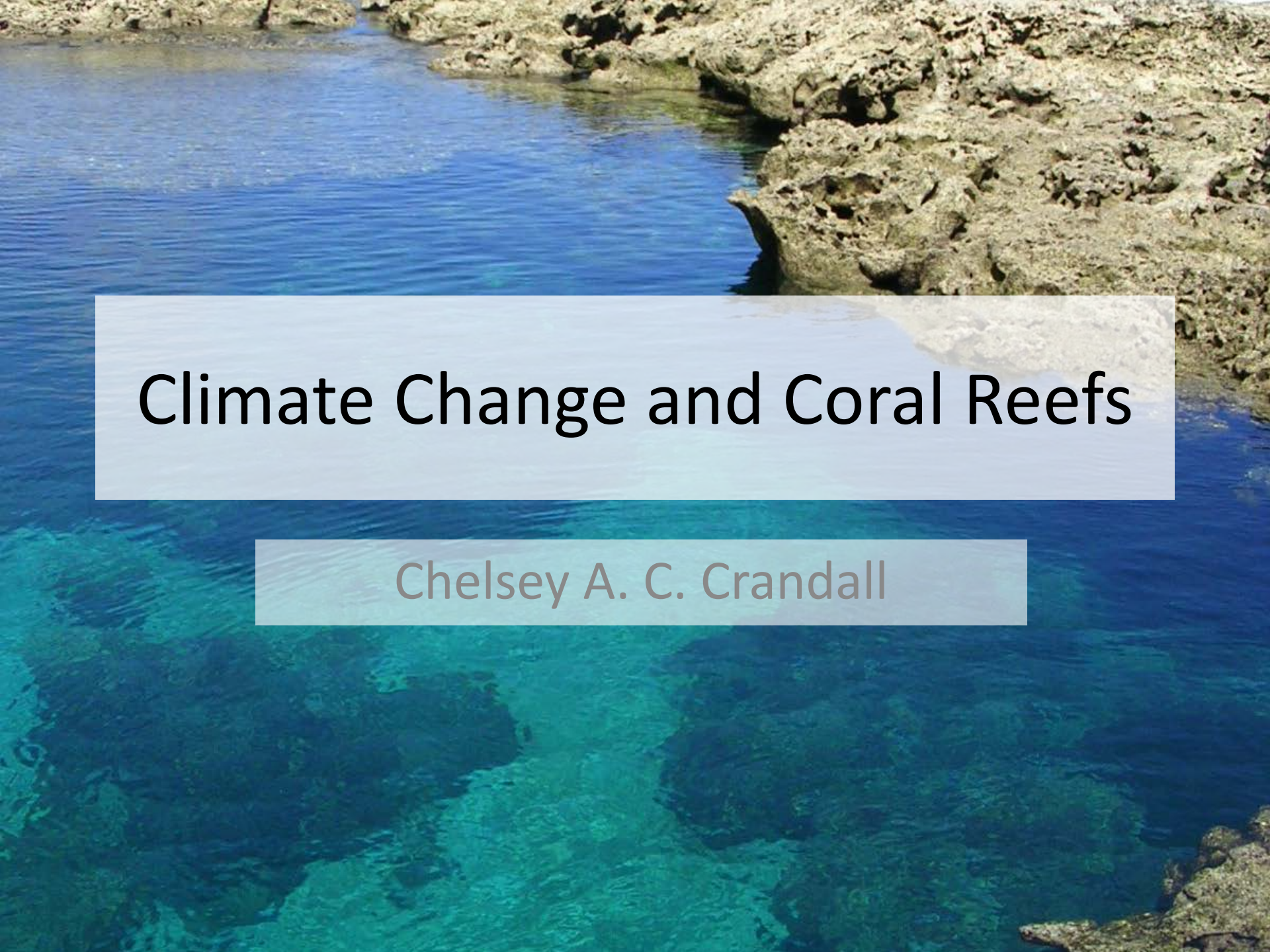


Climate Change and Coral Reefs

Chelsey A. C. Crandall

Session Outline

- Background information
- Activity Demonstrations

Introduction

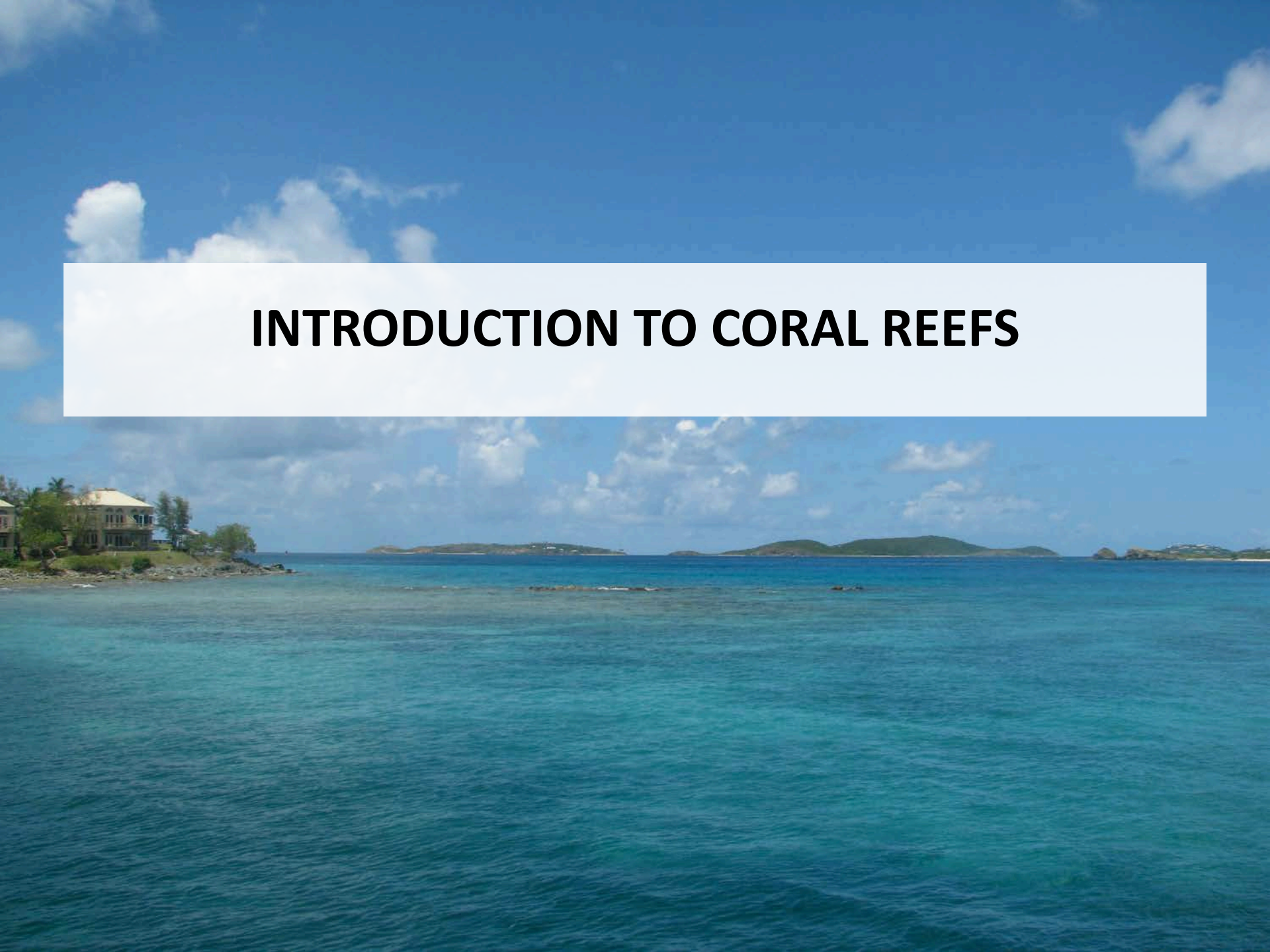
- B.S. University of Florida
- M.S. University of Florida

- Florida Museum of Natural History
  - Malacology

- Florida Program for Shark Research

Introduction

- Invertebrate diversity
- Bleachwatch
- Fish movement and habitat use
- Sex allocation
- Osmoregulation



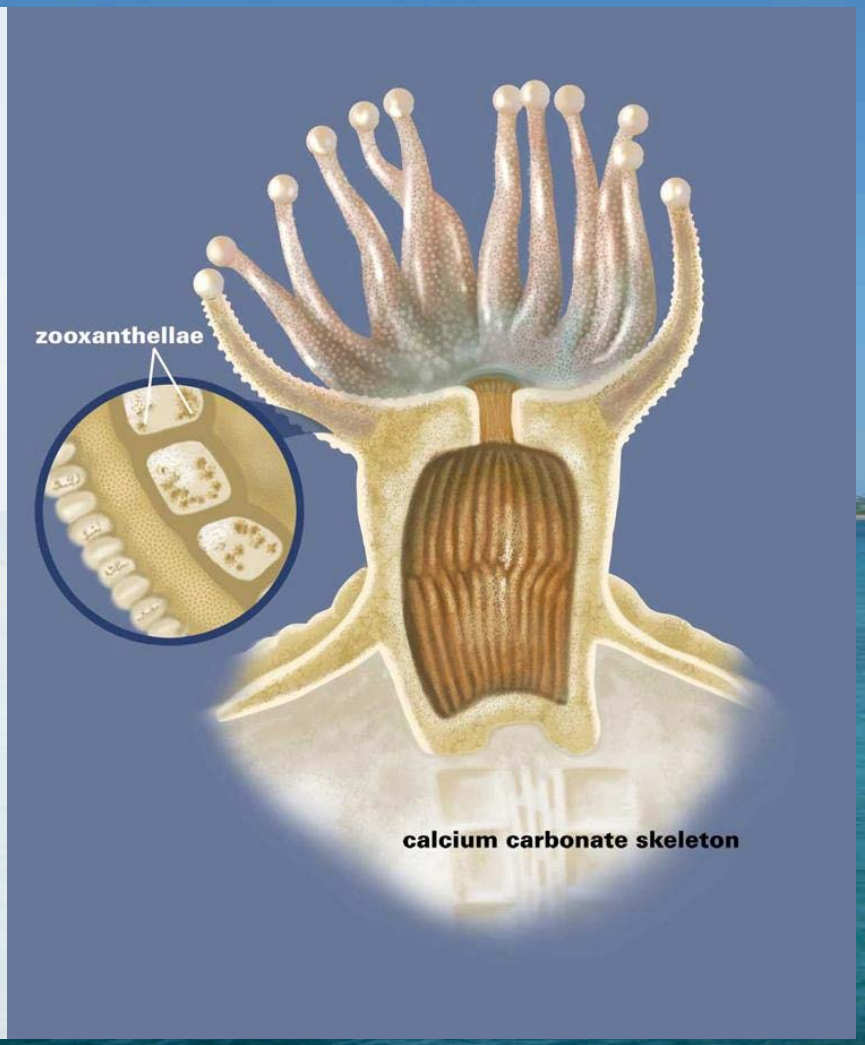
INTRODUCTION TO CORAL REEFS

Coral Reefs: Background

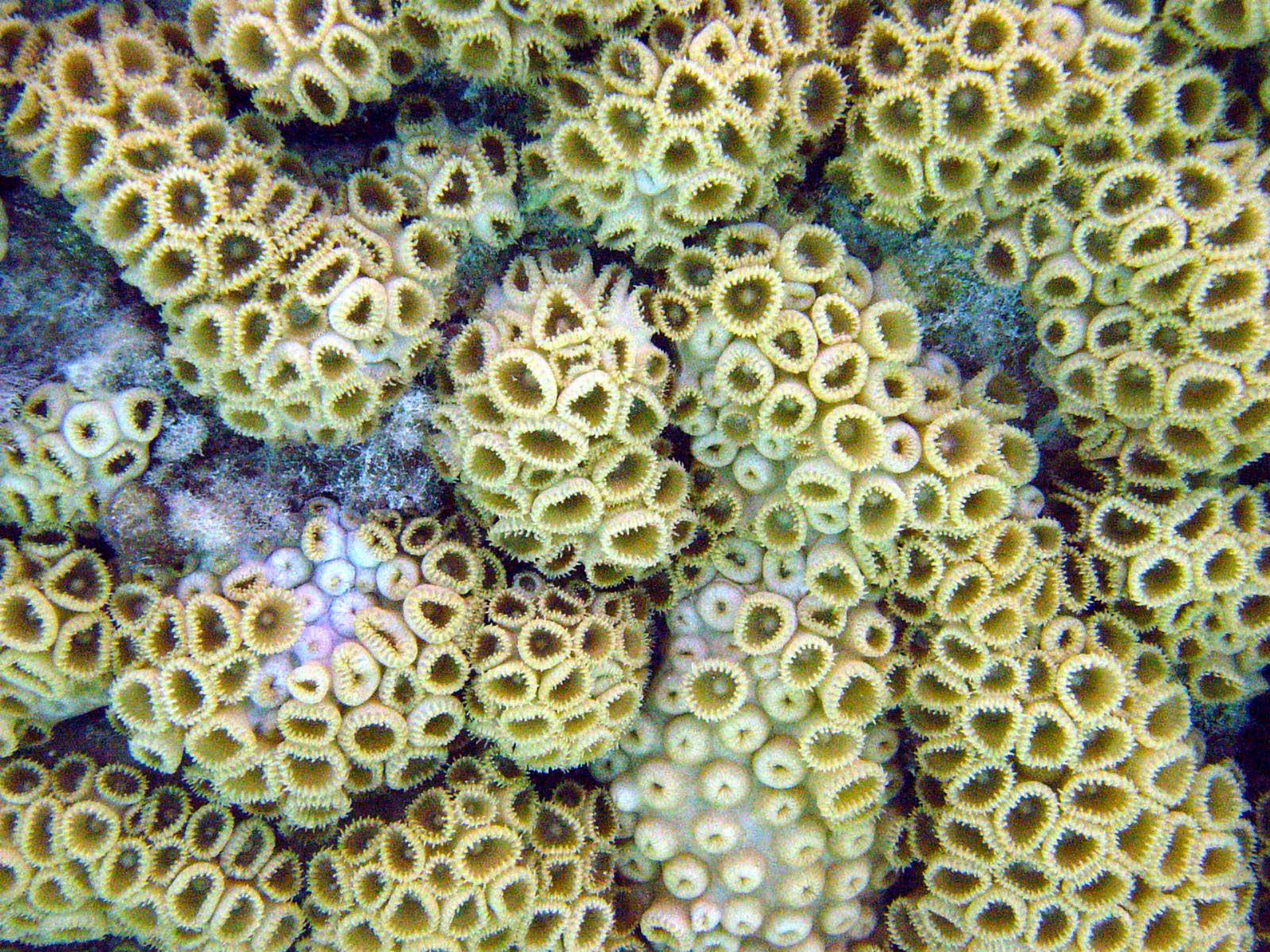
- Hard corals
  - Calcium carbonate
- Soft corals

Coral Reefs: Background

- Coral polyp
- Colonial
- Zooxanthellae




Ocean.si.edu



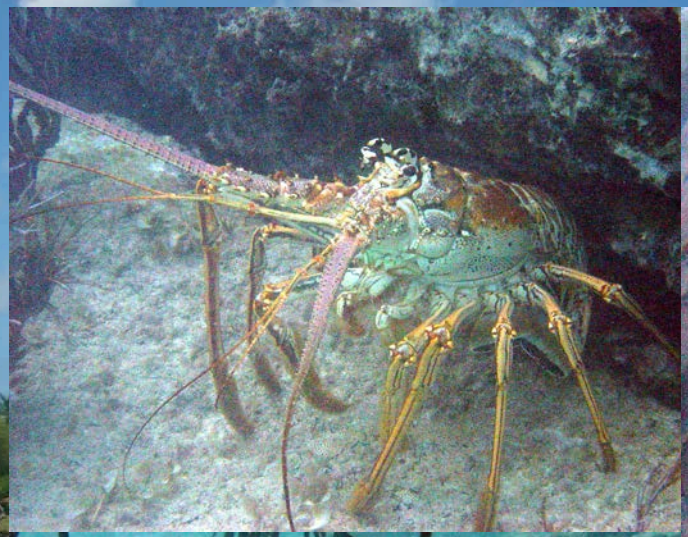
Coral Reefs: Background

- Fringing reefs
- Patch reefs
- Barrier reefs
- Atolls

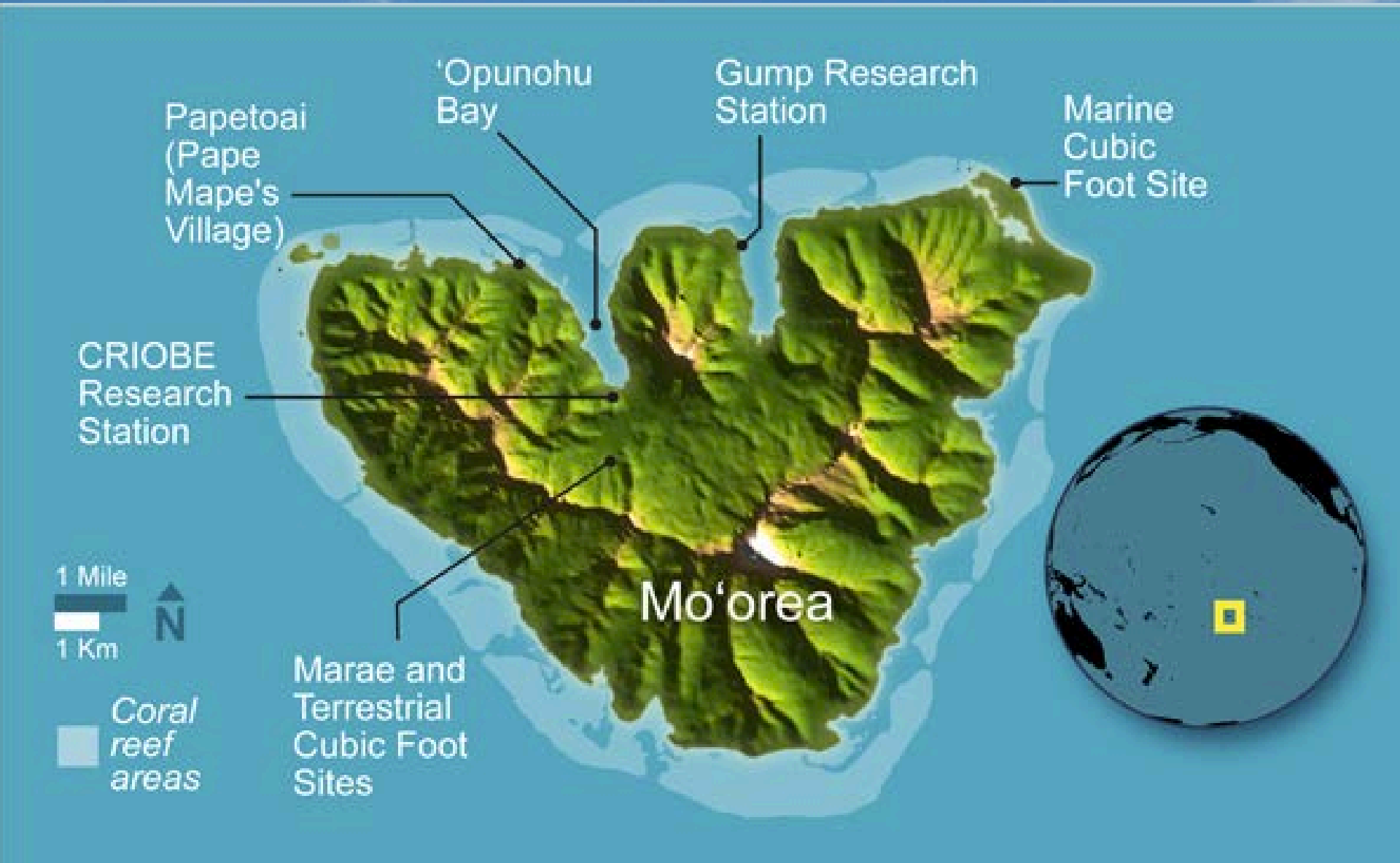
Coral Reefs: Background

- Biodiversity
  - ~25% marine species
  - 4000 fish, 700 coral

Coral Reefs: Background



Moore Biocode Project




one cubic foot

Tourism & Recreation

Coral reefs attract millions of tourists every year, bringing important income to coral reef communities. Some countries derive **more than half of their gross national product** from coral reef industries.

Medicine

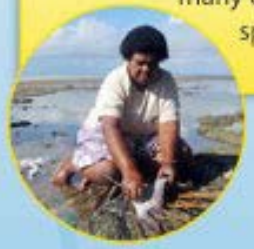
Coral reef species are **providing new medical compounds and technology** to treat serious diseases. More than half of all new cancer drug research is focusing on marine organisms.

Coral Reef

Ecosystem Services

Food & Fishing

Coral reefs sustain the fish and shellfish populations that **provide protein for 1 billion people**. Reefs are nurseries for many commercially valuable species.



Coral reefs provide nearly **$400 billion a year to millions of people** in economic goods and ecosystem services.

Coastal Protection

Coral reefs act as natural wave barriers that **protect coastal communities and beaches** from storm damage.

Coral reefs act as homes and nurseries for 25% of all marine life.

Though they cover less than 1% of the ocean floor, coral reefs provide habitat for **250,000 known species**, including more than **4,000 species of fish and 700 species of coral.**

Many coral reef species have yet to be discovered. Scientists believe that **more than 1 million species** are associated with coral reefs.

Coral Reefs

are created by many tiny **animals** called **coral polyps.**

The coral polyps' **limestone skeletons** build up over time, forming the base of the complex reef habitat that supports the world's **highest level of marine biodiversity.**

Coral reef alliance

Coral Reefs and Climate Change

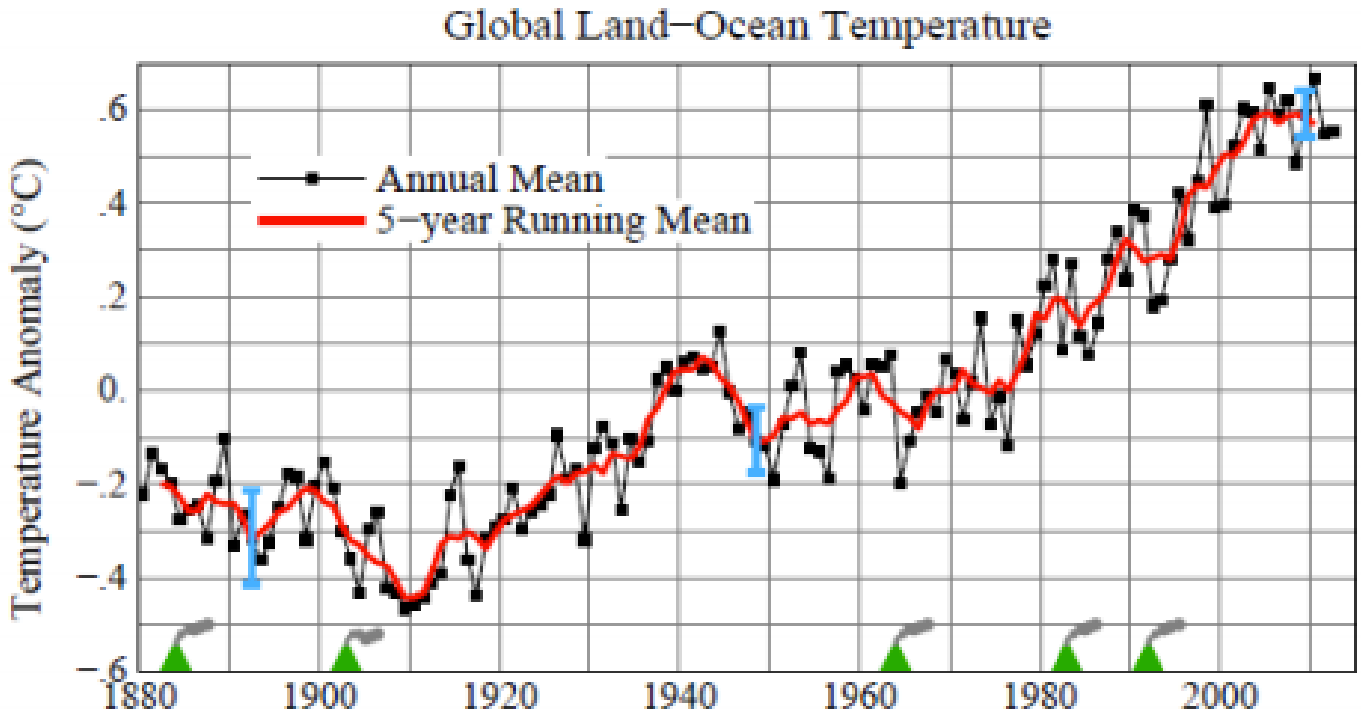
"Climate change impacts have been identified as one of the greatest global threats to coral reef ecosystems"

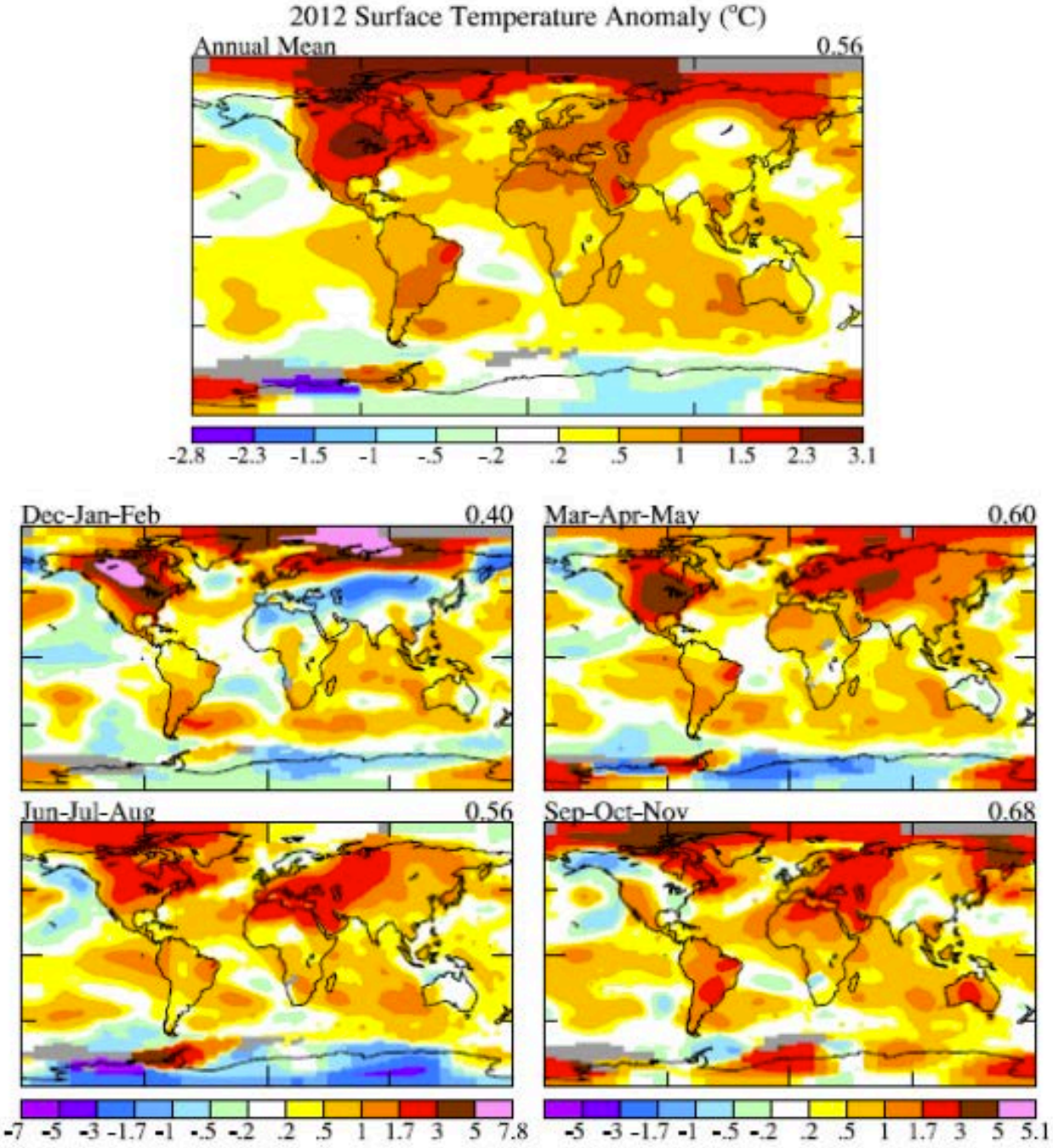
-NOAA

Coral Reefs and Climate Change

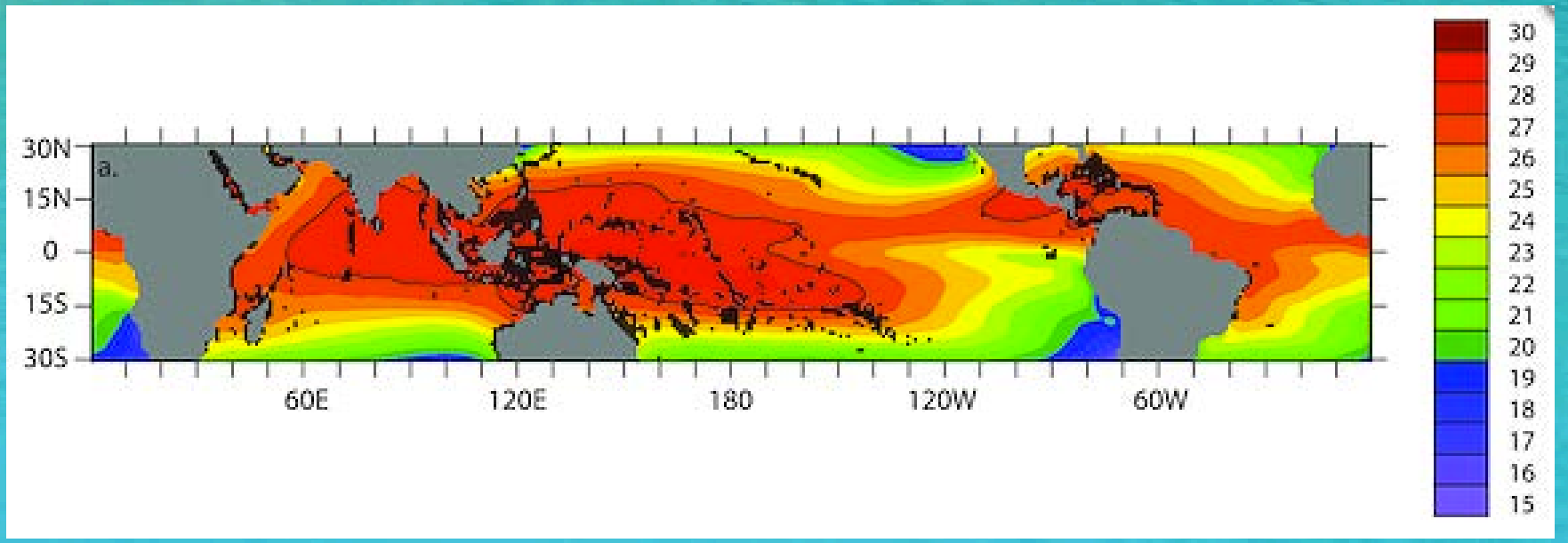
- Temperature Increase
- Acidification

Temperature Effects




2012 Surface Temperature Anomaly (°C)
Annual Mean
0.56
-2.8 -2.3 -1.5 -1 -.5 -.2 .2 .5 1 1.5 2.3 3.1
Dec-Jan-Feb
0.40
Mar-Apr-May
0.60
Jun-Jul-Aug
0.56
Sep-Oct-Nov
0.68
-7 -5 -3 -1.7 -1 -.5 -.2 .2 .5 1 1.7 3 5 7.8
-5 -3 -1.7 -1 -.5 -.2 .2 .5 1 1.7 3 5 5.1

Temperature Effects



Temperature Effects

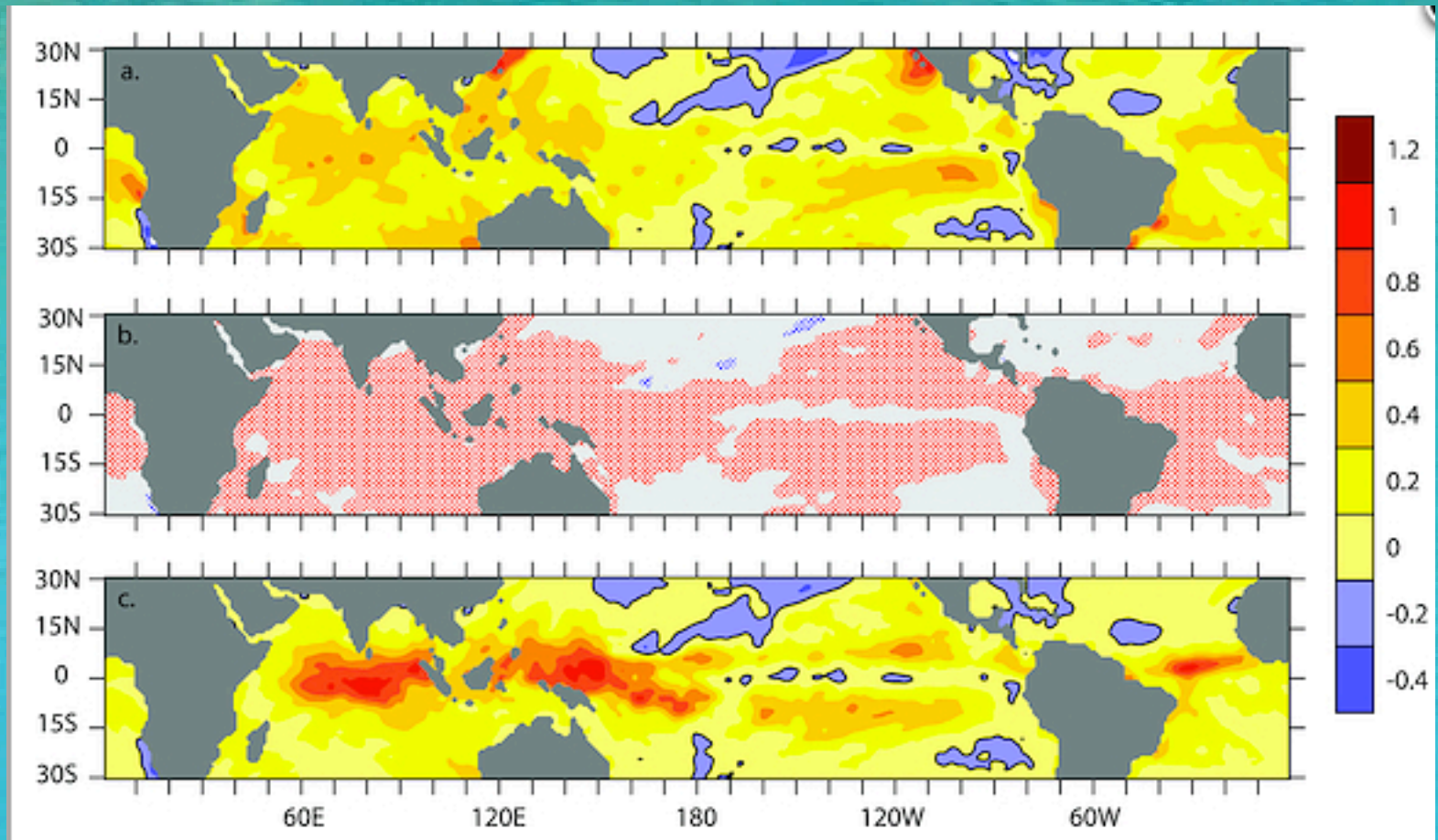
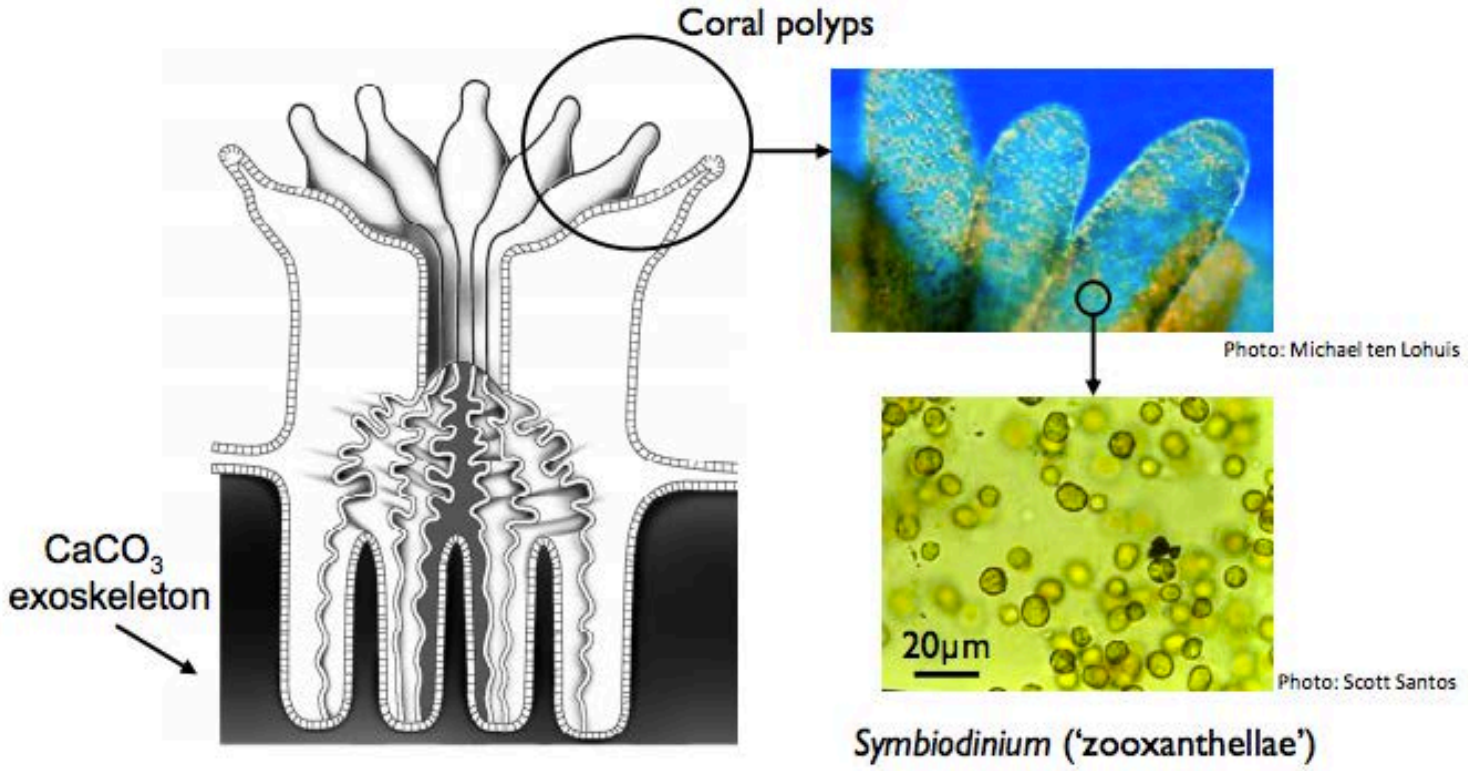


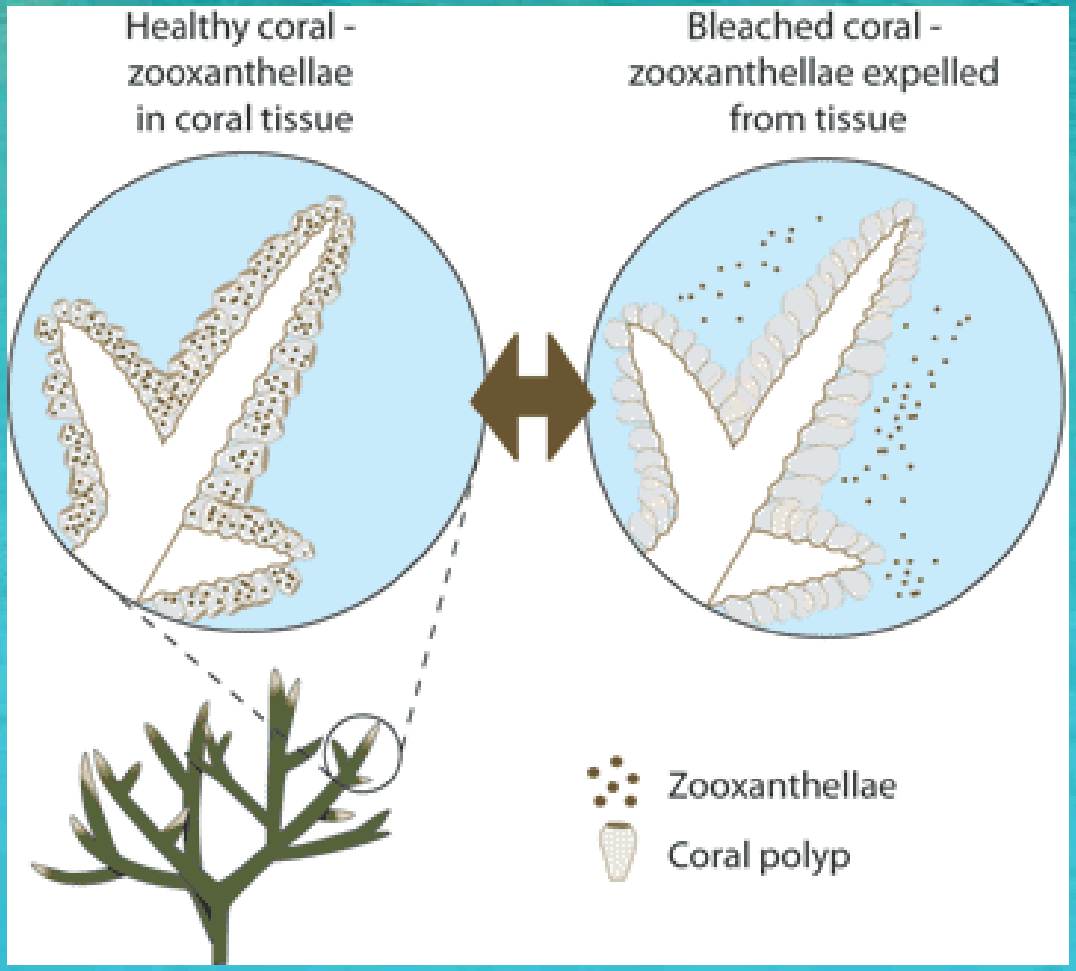
Figure 4. (a) Difference °C between average SST (1981–2011)–(1950–1980), (b) significance of difference; red is significantly warmer, blue is significantly cooler and gray is not significant), and (c) standardized difference between 2 subperiods.

1. Coral Bleaching

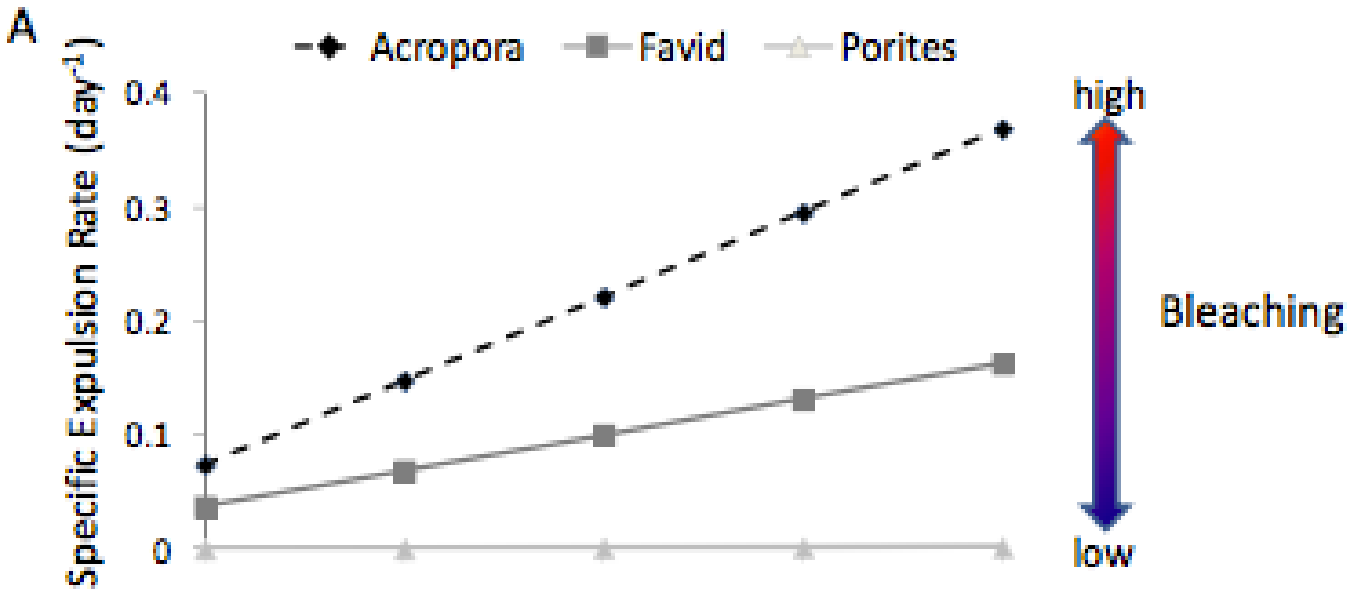
Temperature: Coral Bleaching



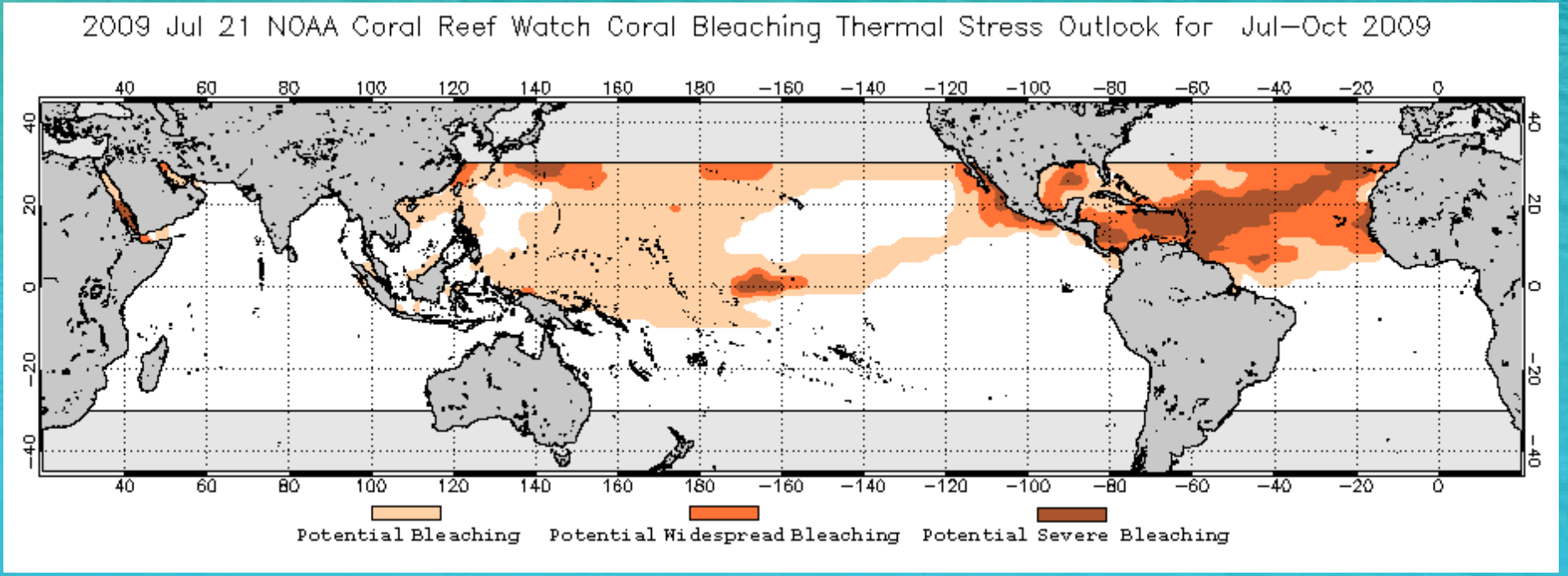
Temperature: Coral Bleaching



Temperature: Coral Bleaching



Temperature: Coral Bleaching



http://coralreefwatch.noaa.gov/satellite/index.html

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

DOC > NOAA > NESDIS > STAR > CRW

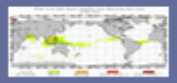
Coral Reef Watch

CRTF | CRCP | CREIOS | CoRIS

CRW Home

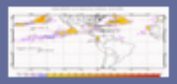
Product Overview

Near-Real-Time Data

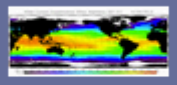


Bleaching Alert Area

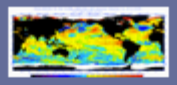
Degree Heating Weeks



HotSpots



Sea Surface Temperature

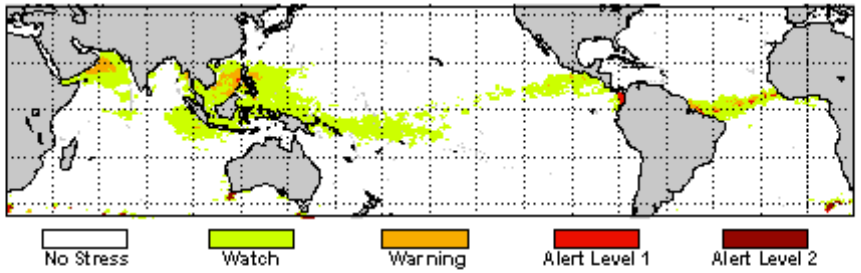


SST Anomaly

Virtual Stations

Coral Reef Watch Satellite Monitoring

NOAA/NESDIS Bleaching Alert Area, 5/23/2013



Alerts | HotSpot | DHW | SST | Anomaly | Outlook | Doldrums | Virtual Stations

NOAA's Coral Reef Watch Program's satellite data provide current reef environmental conditions to quickly identify areas at risk for coral bleaching, where corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die.

Continuous monitoring of sea surface temperature at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. When bleaching conditions occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions.

Announcements

May 17, 2013:
New Coral Reef Watch Publications: NOAA/NESDIS Technical Reports #142 and #143. See detailed announcement.

May 13, 2013:
New: Current atmospheric average monthly CO_2

http://coralreefwatch.noaa.gov/satellite/index.html

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

DOC > NOAA > NESDIS > STAR > CRW

Coral Reef Watch

CRTF | CRCP | CREIOS | CoRIS

CRW Home

Product Overview

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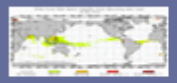
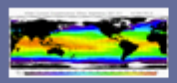


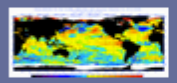
Bleaching Alert Area

Degree Heating Weeks

HotSpots



Sea Surface Temperature

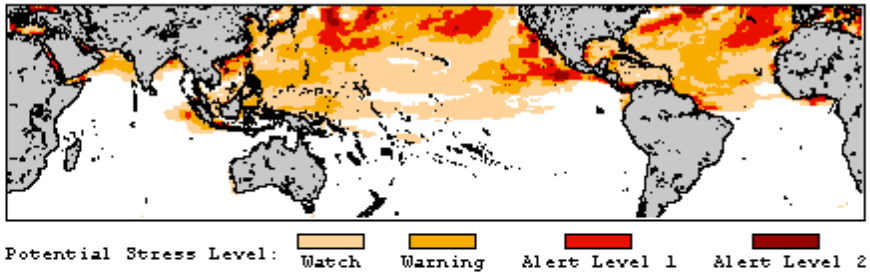


SST Anomaly

Virtual Stations

Coral Reef Watch Satellite Monitoring

2013 May 21 NOAA 60% Probability Bleaching Thermal Stress for Jun–Sep 2013
Experimental, v2.0, CFSv2–based, 28–member



Alerts | HotSpot | DHW | SST | Anomaly | Outlook | Doldrums | Virtual Stations

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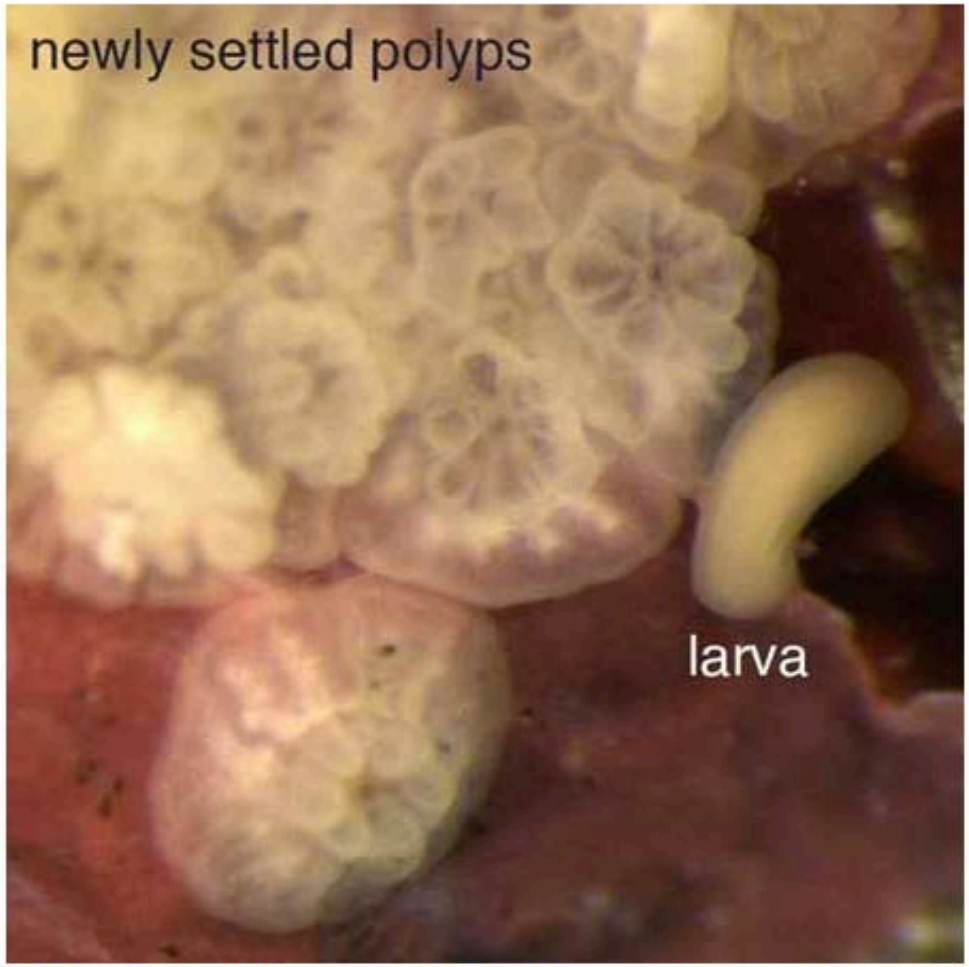
May 13, 2013:
New: Current atmospheric average monthly CO_2

2. Recruitment Survival

Temperature: Recruitment

Temperature: Recruitment



When the larva is ready to settle it goes to the bottom searching for favorable chemical cues, such as those emitted by the pink alga in the photo. It then undergoes settlement and metamorphosis to form polyps such as those shown here. Image credit: Dr Eldon Ball.

Temperature: Recruitment

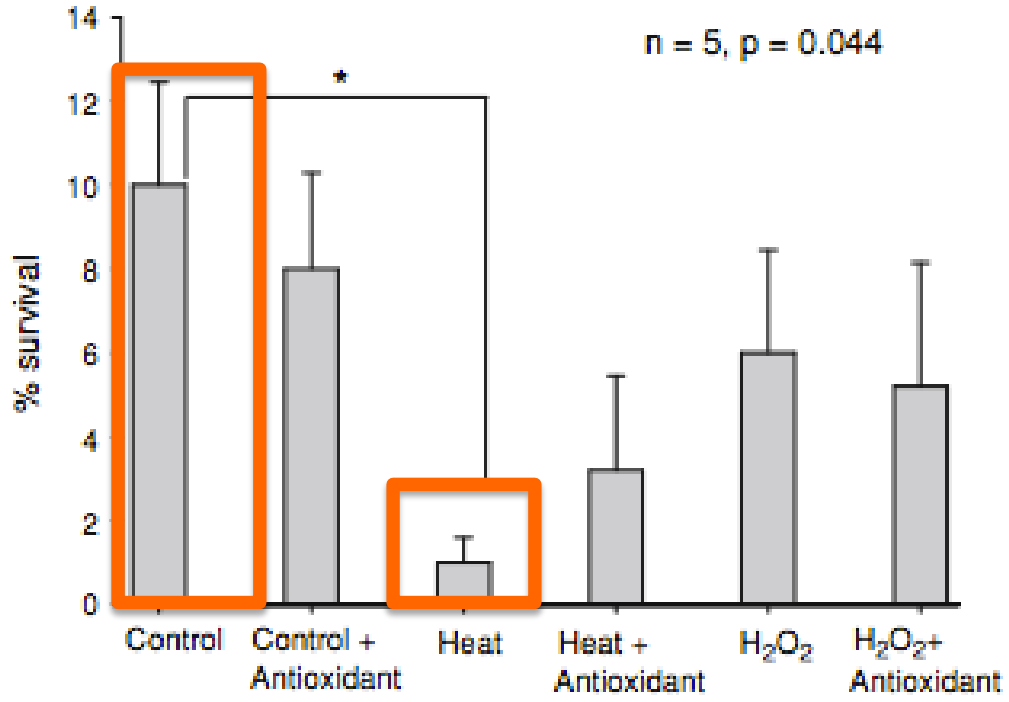
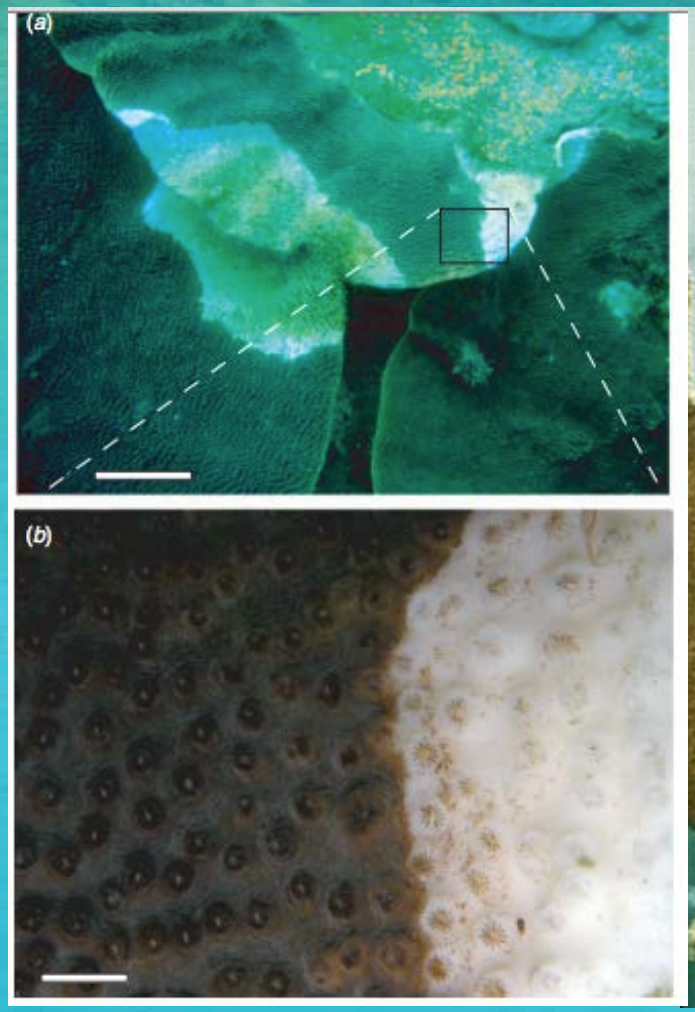


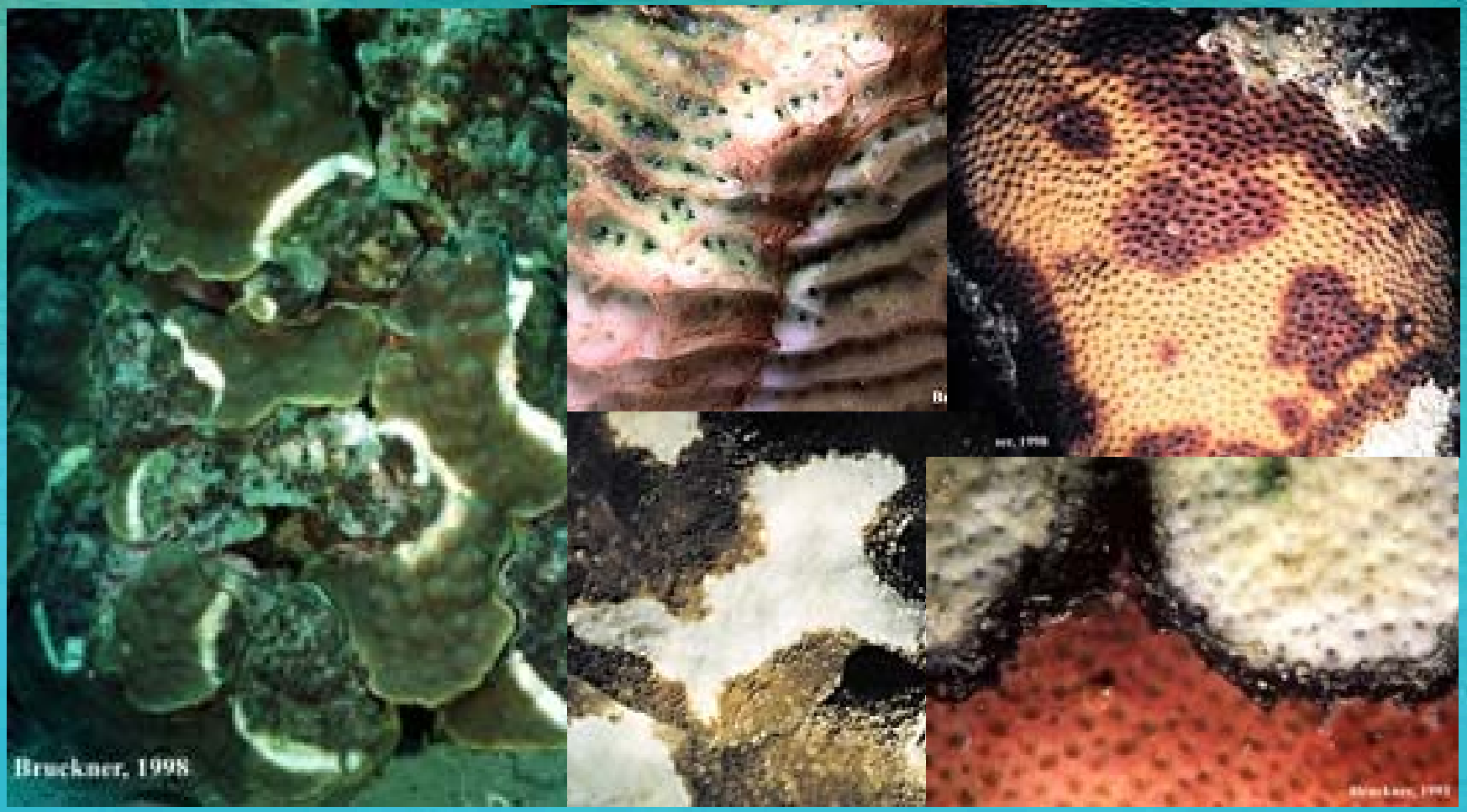
Fig. 6 Percent post-settlement survival after 24 days on a patch reef. *Asterisk* indicates a significant difference between treatment and control (Dunnett's test). *Bars* represent mean +1SE

3. Disease

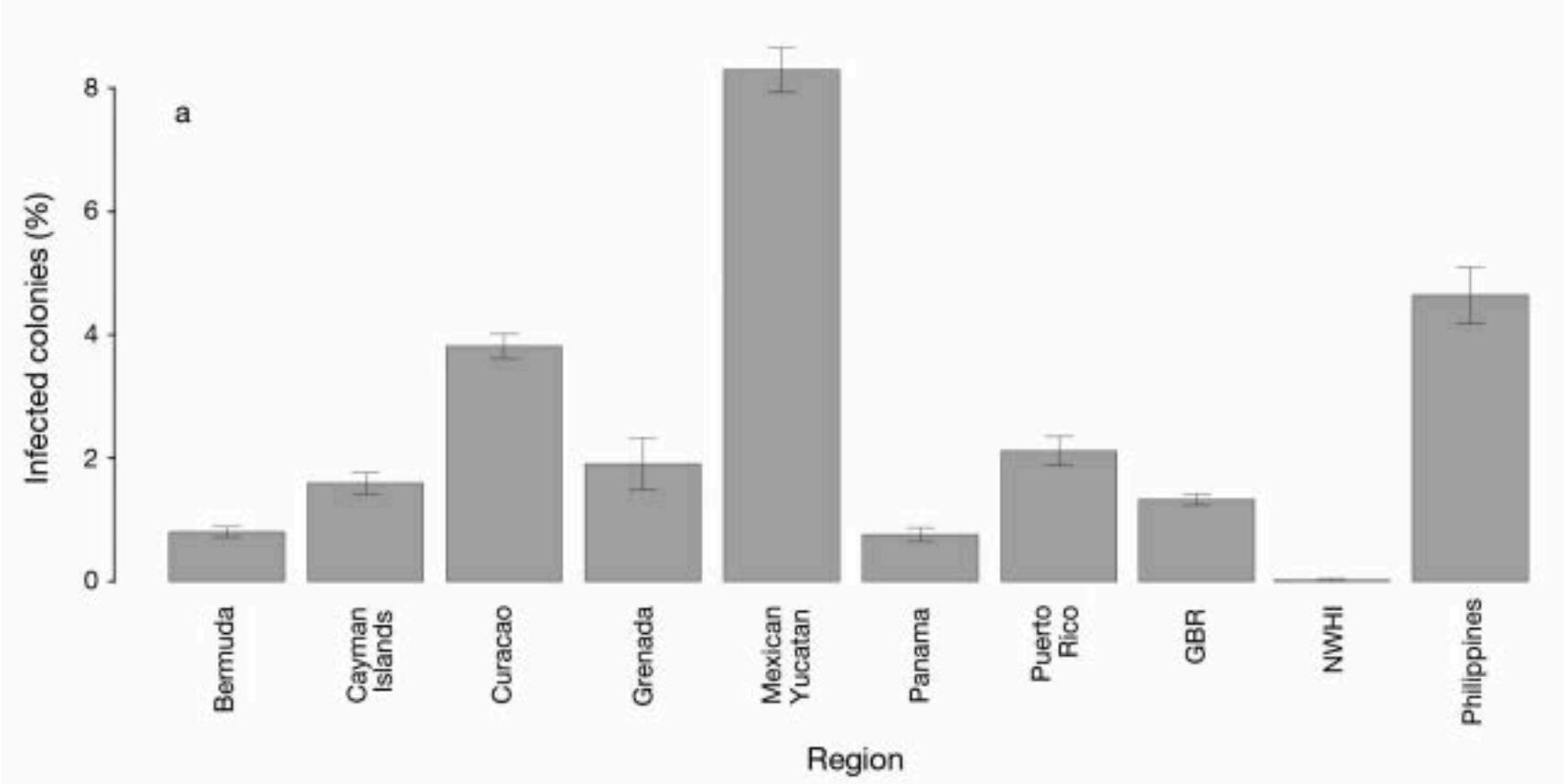
Temperature: Disease



Temperature: Disease



Temperature: Disease



Temperature: Disease

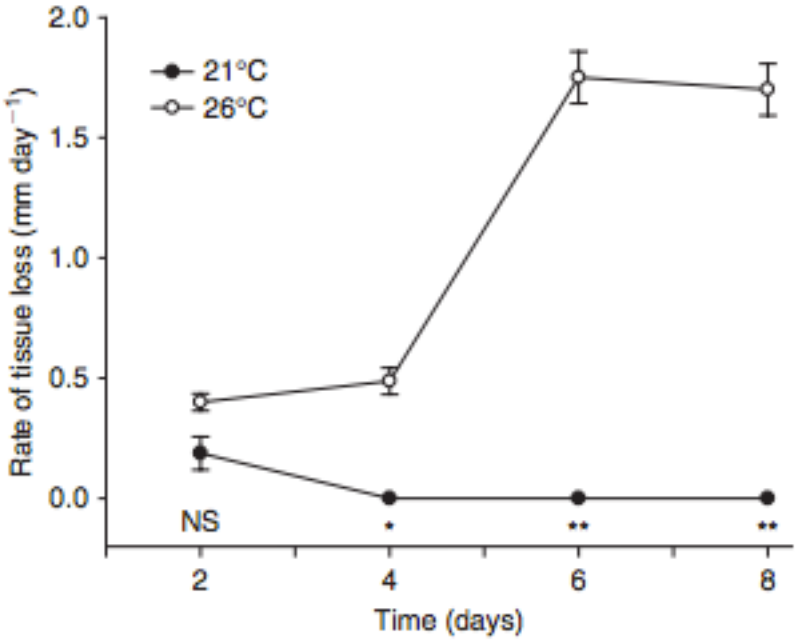


Fig. 5. Mean rate (±s.e.) of coral tissue loss extending across diseased *Turbinaria mesenterina* fragments exposed to 21 and 26°C. Measurements were taken every second day for 8 days. Within-time Tukey *post-hoc* comparisons are shown. NS, not significant; $*P < 0.05$; $**P < 0.001$.

Temperature Effects

- Bleaching
- Recruitment
- Disease

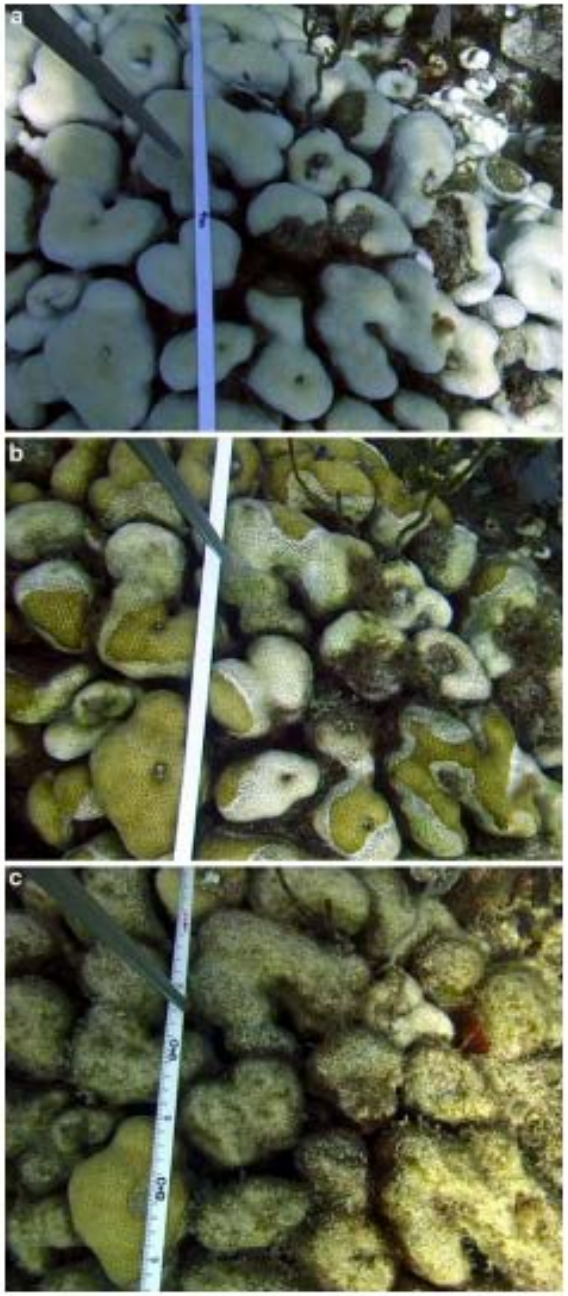


Fig. 3 Time series of identical video captures at Tektite Reef showing **a** bleached *Montastraea annularis*, September 2005, **b** *M. annularis* re-coloring and heavily affected by coral disease, November 2005, **c** near-total mortality of *M. annularis* with surviving portion still pale, January 2006

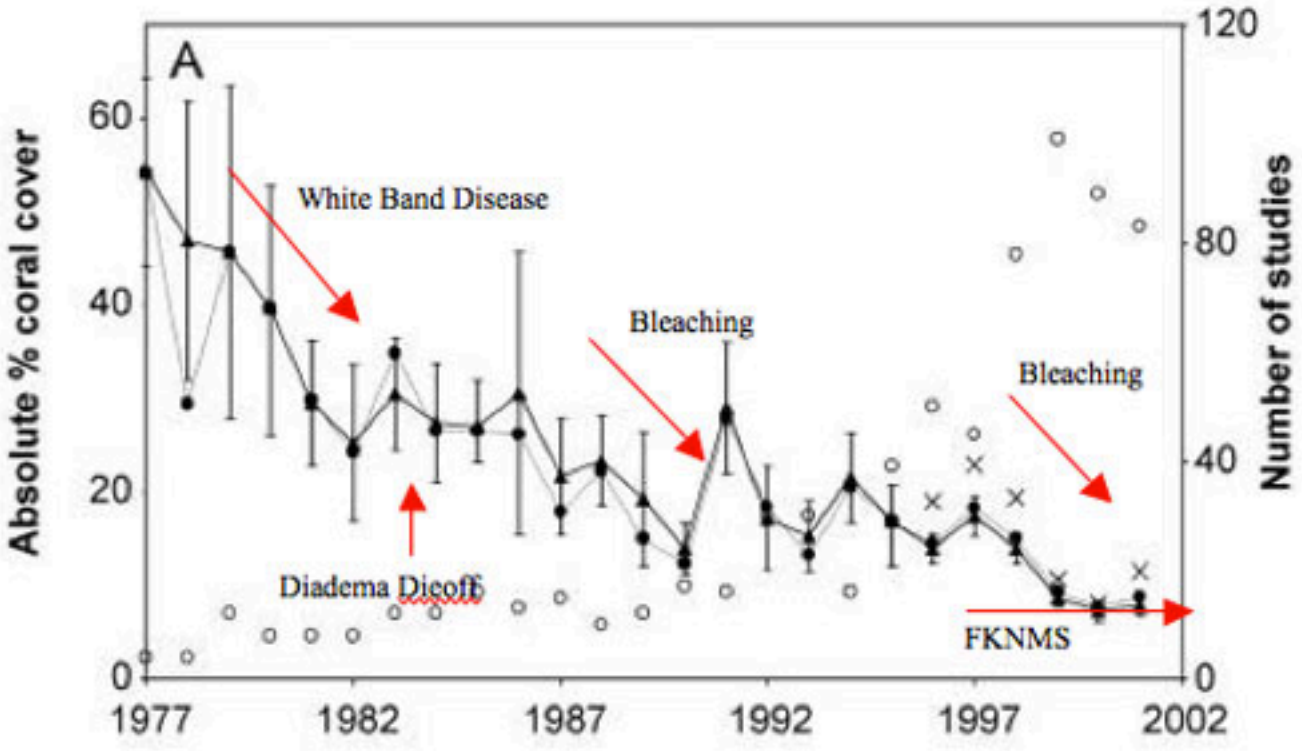


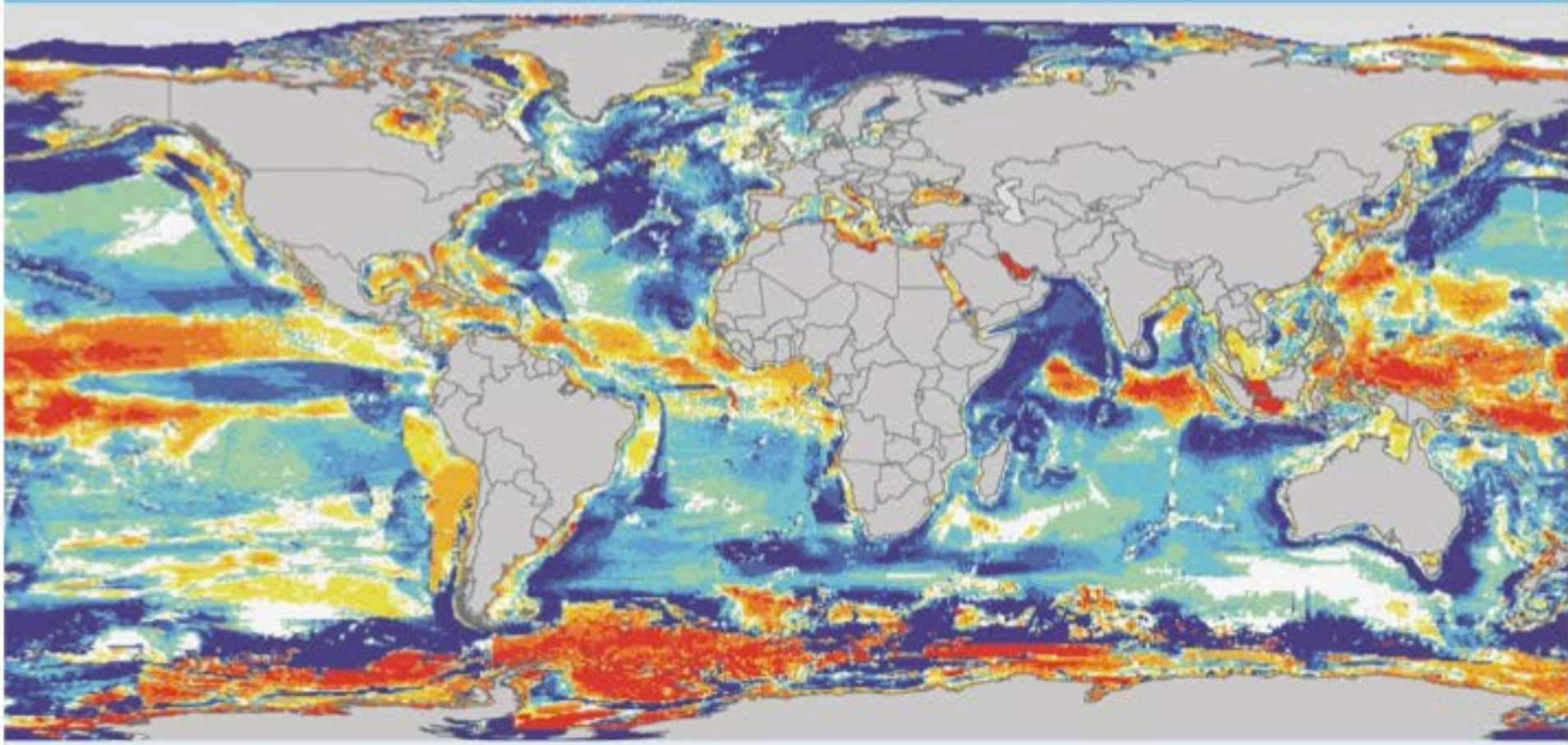
Figure 29. Change in percent coral cover across the Caribbean basin during the past three decades. By the time the Water Quality Protection Program began in 1995, there was already extensive decline in coral cover throughout the region, principally due to coral and urchin diseases, bleaching events, and storms. Annual coral cover estimates (triangles) are weighted means with 95% bootstrap confidence intervals. Also shown are unweighted mean coral cover estimates for each year (solid circles), the unweighted mean coral cover with the Florida Keys Water Quality Protection Program's Coral Monitoring Project (1996-2001) omitted (x), and the sample size (number of studies) for each year (o). *(Source: adapted from Gardner et al. 2003).*

Temperature Effects

And that's just the coral!

- Fish movement
- Spawning events
- Growth
- Food web dynamics

FIGURE 1. CHANGE IN MAXIMUM CATCH POTENTIAL FROM 2005 TO 2055 under the climate change scenario where greenhouse gas concentration is doubled by the year 2100.



Acidification

http://www.youtube.com/watch?v=Wo-bHt1bOsw

Acidification

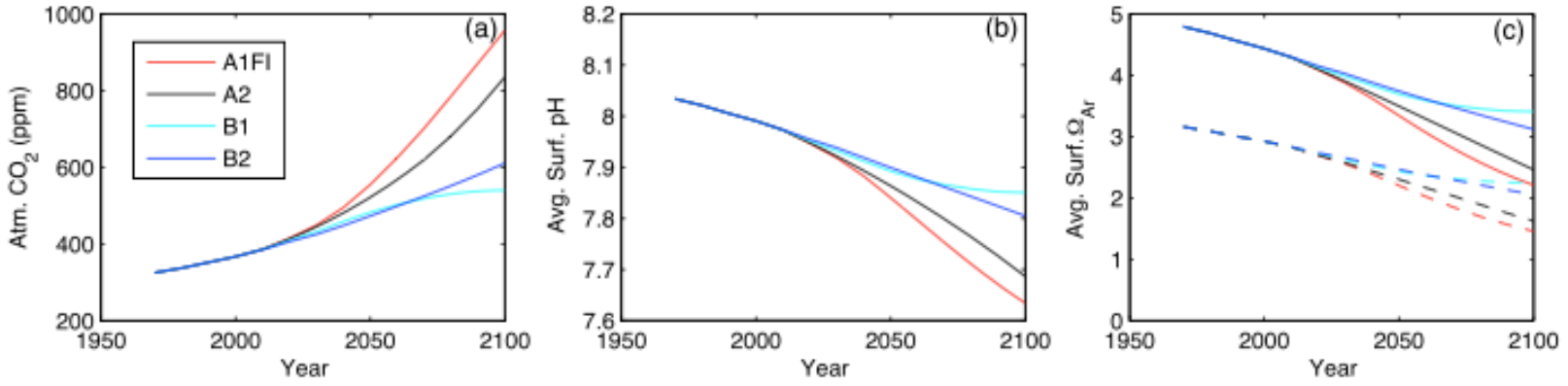


Figure 1. (a) Atmospheric CO_2 anticipated for a variety of scenarios from the Intergovernmental Panel on Climate Change's (IPCC's) Special Report on Emissions Scenarios (SRES): pathways B1, B2, A2, and intensive fossil-fuel dependence pathway A1FI, calculated with the Bern-CC model reference case (IPCC 2001). Surface ocean (b) pH and (c) calcium carbonate saturation state Ω (for calcite, solid; for aragonite, dashed) for each scenario calculated assuming constant temperature, salinity, and total alkalinity.

Acidification

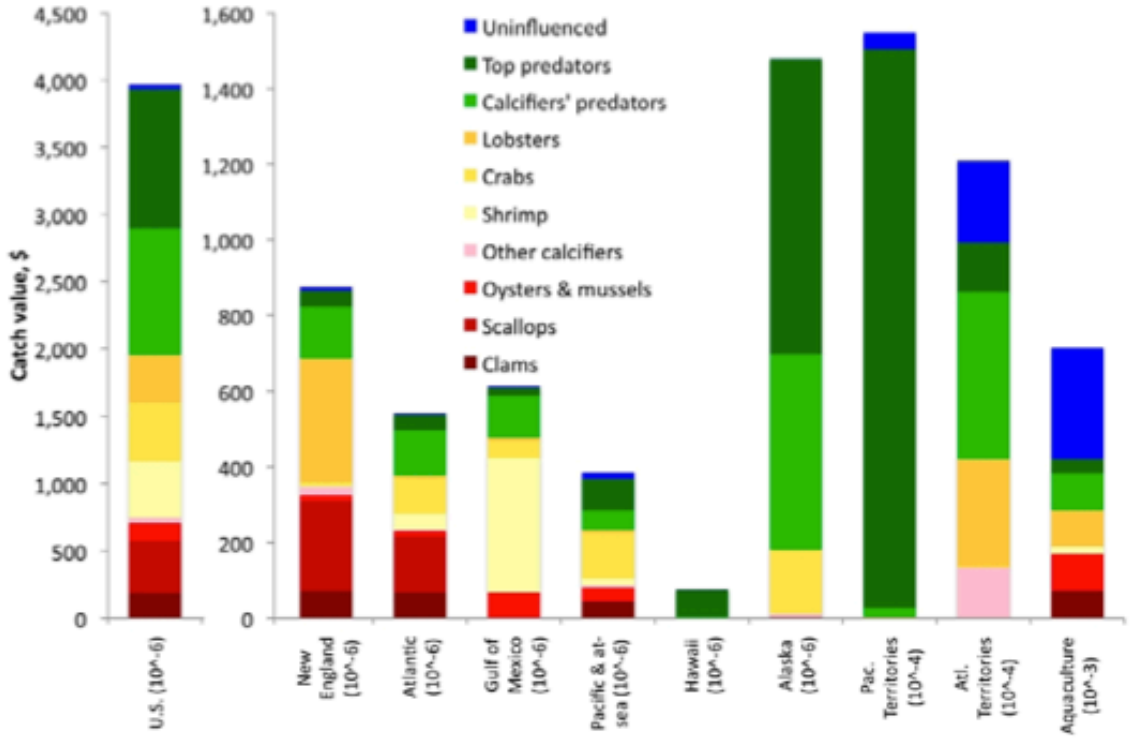
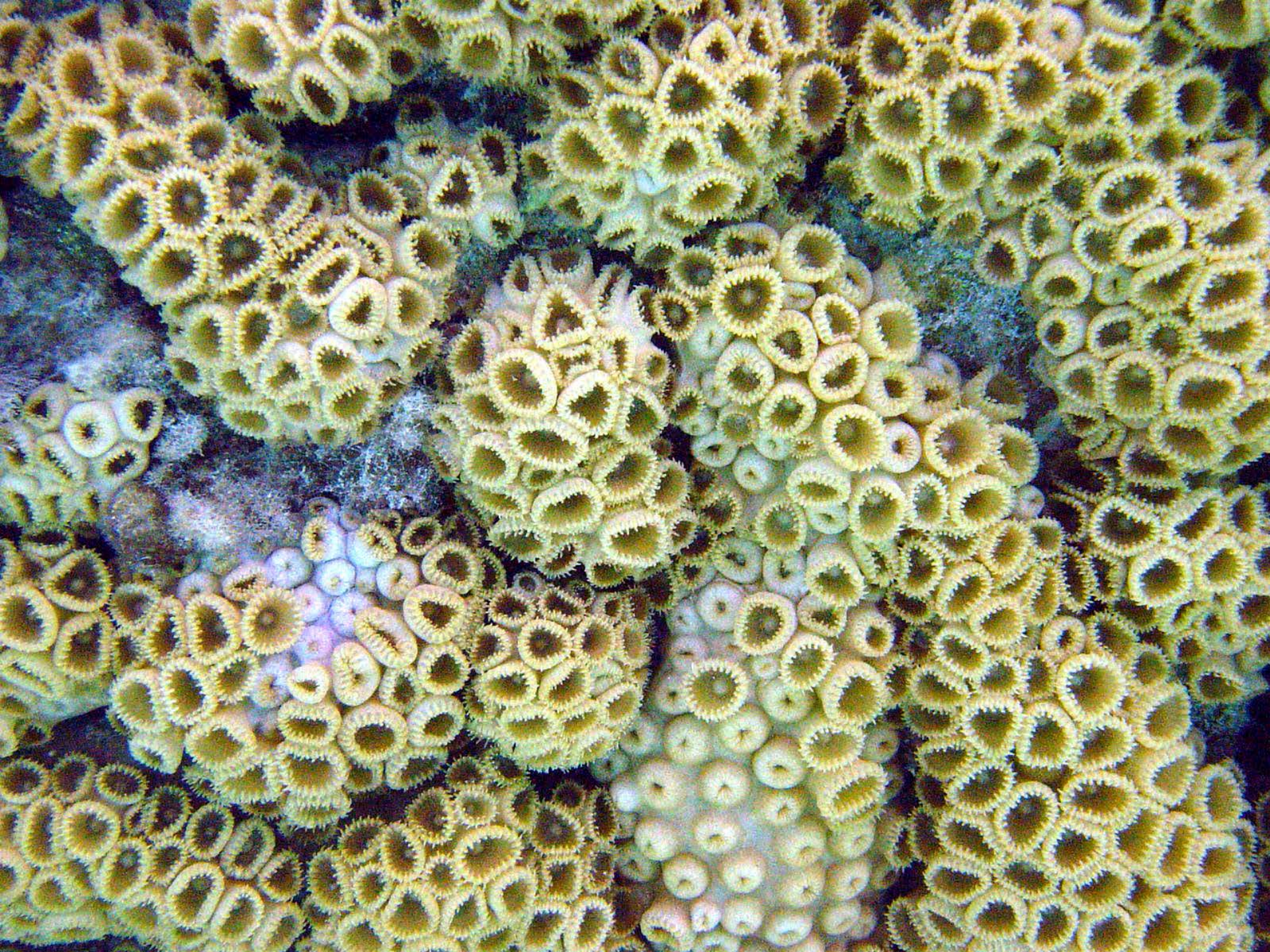


Figure 2. US commercial fishing ex-vessel revenue for 2007 (NMFS statistics, accessed October 2008). Reds indicate organisms containing primarily aragonite, yellows indicate those using primarily calcite, greens indicate predators, and blue indicates species not directly influenced by ocean acidification. (NMFS statistics and Andrews *et al* 2008.)



Summary

- Temperature Effects
  - Bleaching
  - Juvenile Survival
  - Disease
- Acidification

Resources

- http://co2now.org/
- http://coralreef.noaa.gov/education/educators/resourcecd/lessonplans/
- http://coralreef.noaa.gov/education/oa/
- http://coralreef.noaa.gov/education/educators/resourcecd/activities/resources/bleaching_sa.pdf
- http://www.datainthecclassroom.org/content/oa/get-data.html

Curricula & Lesson Plans

Curricula
Grades 4th to 6th
Lesson Plans
Grades 3rd to 6th
Grades 5th to 6th
Grades 6th to 8th
Grades 9th to 12th

Over 50 lesson plans and two full curricula in the Life Science and Earth Science subject areas, from grades 3rd to 12th, are included. These curricula and lesson plans were developed through a partnership between teachers, non-governmental organizations (NGOs) and various branches of NOAA.

Each lesson plan or curriculum is available as a pdf download in the tables below. Supplemental materials are also identified and linked for select lesson plans. File size is listed for each downloadable file; links with no file size listed are not file downloads.

Curricula

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Cicadas have developed an amazing strategy for growth, survival, reproduction, and overcoming predation by...doing nothing. They do nothing for years (except sip at the juice excreted from root structures) before emerging in huge, simultaneous swarms.

The swarm is so huge that predators can't consume even a fraction of it, but so rare that predator populations can't sustain themselves b...

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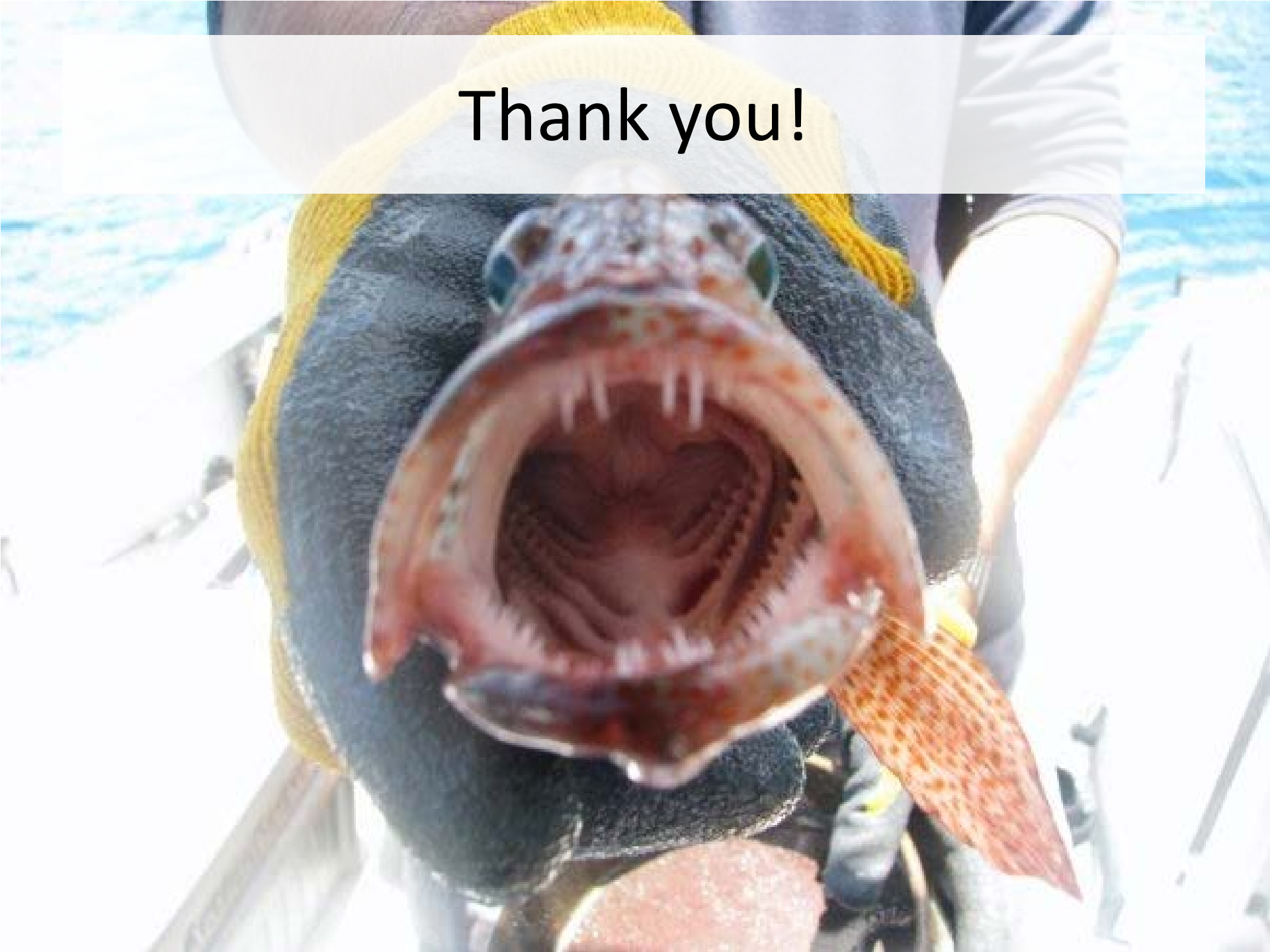

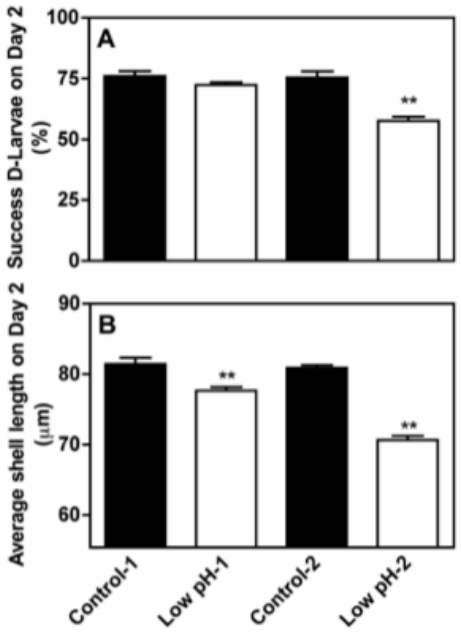

Fig. 1. Proportion of embryos that developed to D-shape larvae **(A)** and average length of D-shape shell **(B)** at the end of the two incubation periods during experiment #1, in control (black bars) and low pH (white bars) seawater. During the first incubation, seawater pH_{NBS} was maintained at 8.15 ± 0.01 (Control-1) and at 7.81 ± 0.01 (Low pH-1). During the second incubation, pH_{NBS} levels of 8.09 ± 0.01 and 7.58 ± 0.01 were used (Control-2 and Low pH-2 respectively). Errors bars represent standard deviations of the triplicate enclosures. **Significant difference between control and low-pH groups.

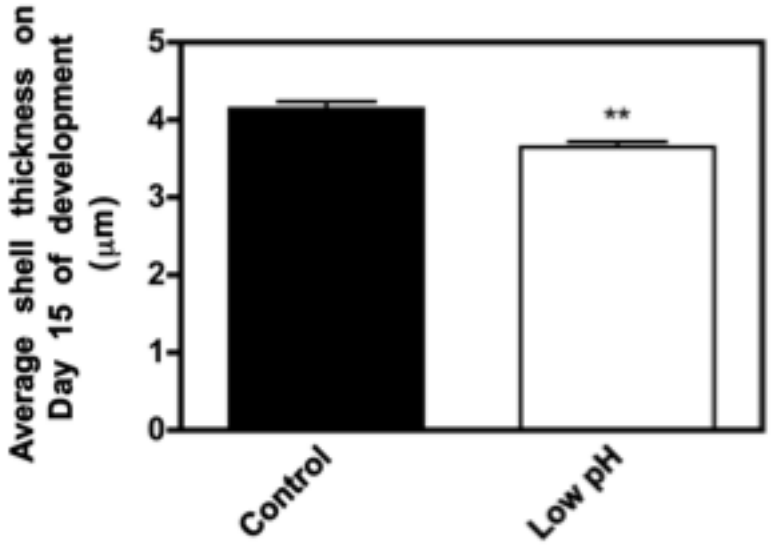

Fig. 3. Average shell thickness at the end of experiment #2 for larvae on Day 15 of development, in control ($pH_{NBS} = 8.03 \pm 0.03$; black bars) and low pH ($pH_{NBS} = 7.78 \pm 0.05$; white bars) seawater. Errors bars represent standard deviations of the triplicate enclosures. **Significant difference between control and low-pH groups.

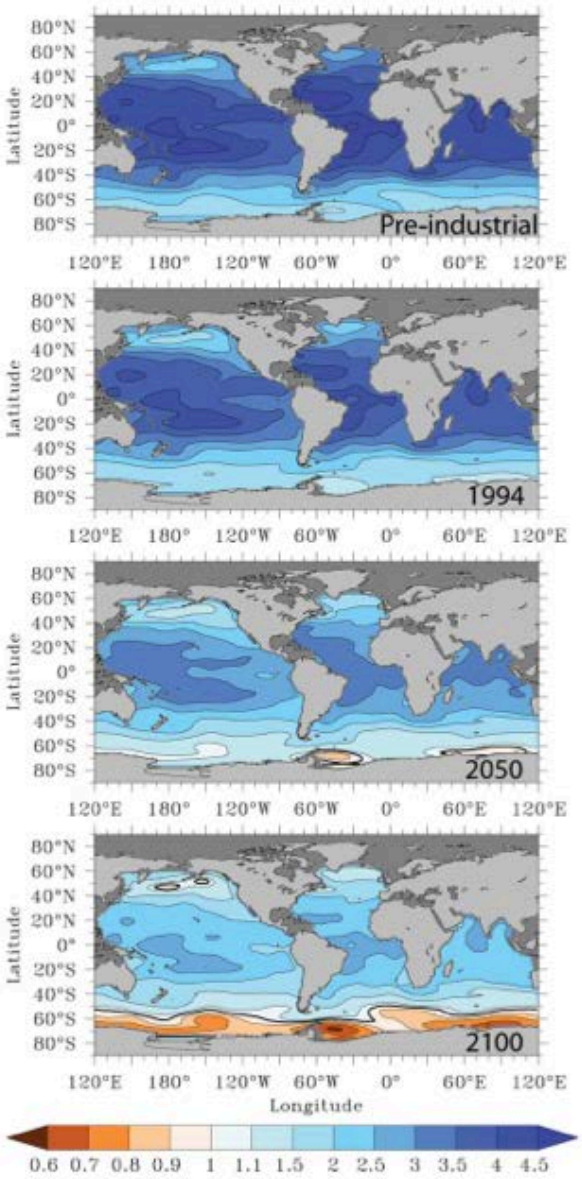

Figure 4. Surface water aragonite saturation state (Ω_{arag}) for the pre-industrial ocean (nominal year 1765), and years 1994, 2050, and 2100. Values for years 1765 and 1994 were computed from the global gridded data product GLODAP (Key *et al.*, 2004), whereas the saturation state for years 2050 and 2100 are the median of 13 ocean general circulation models forced under the IPCC's IS92a "business-as-usual" CO_2 emission scenario (Orr *et al.*, 2005).

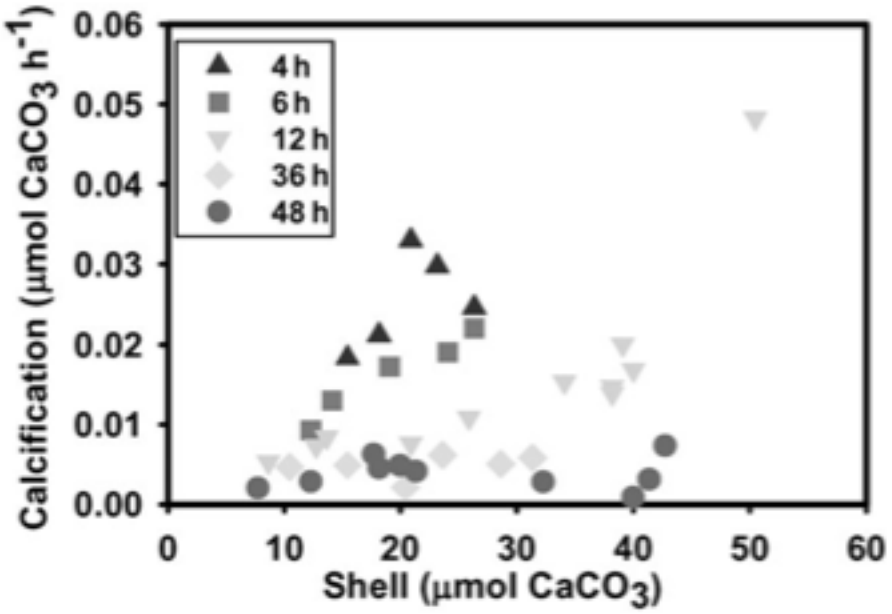

Figure 5. Net calcification (μmol $CaCO_3$ h^{-1}) as a function of shell $CaCO_3$ concentration for the Subarctic Pacific euthecosomatous pteropod *Clio pyramidata*. Different sizes of pteropods were incubated at 10°C in closed 1 l jars for 4–48 h. Net calcification rates decreased with time, as the aragonite saturation state of seawater was progressively reduced owing to respiratory CO_2 in sample containers.