Corals on Acid
Ocean Acidification – The Other CO_2 Problem

Adina Paytan, Arizona State University







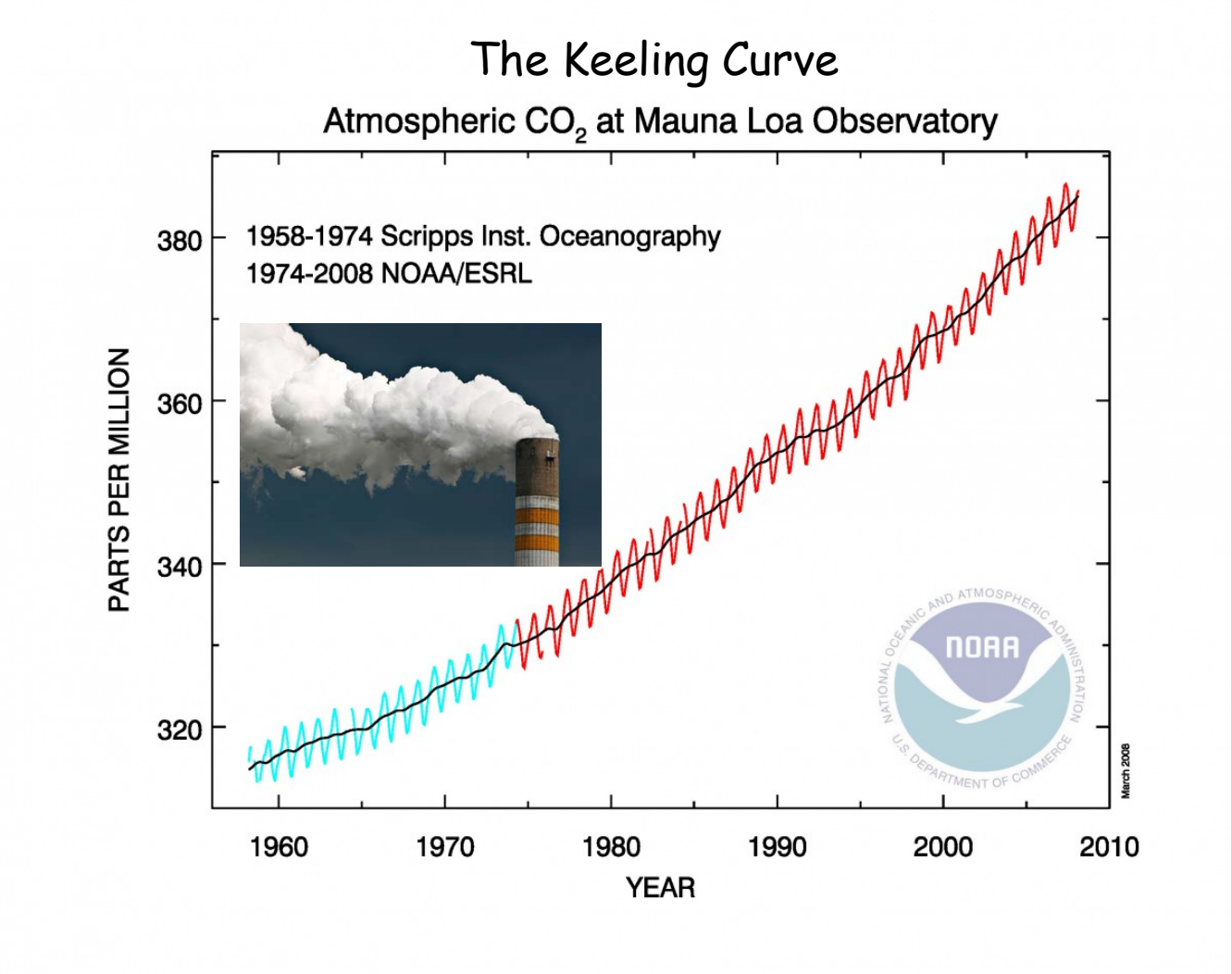




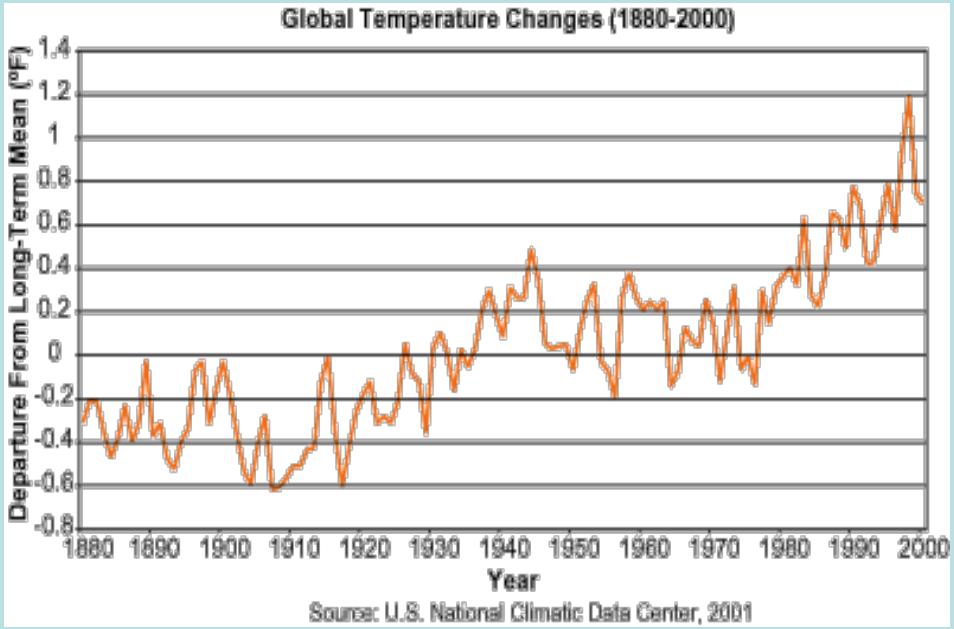
Talk Outline

What is ocean acidification?
How does it work?
Why do we care?
Results from the field

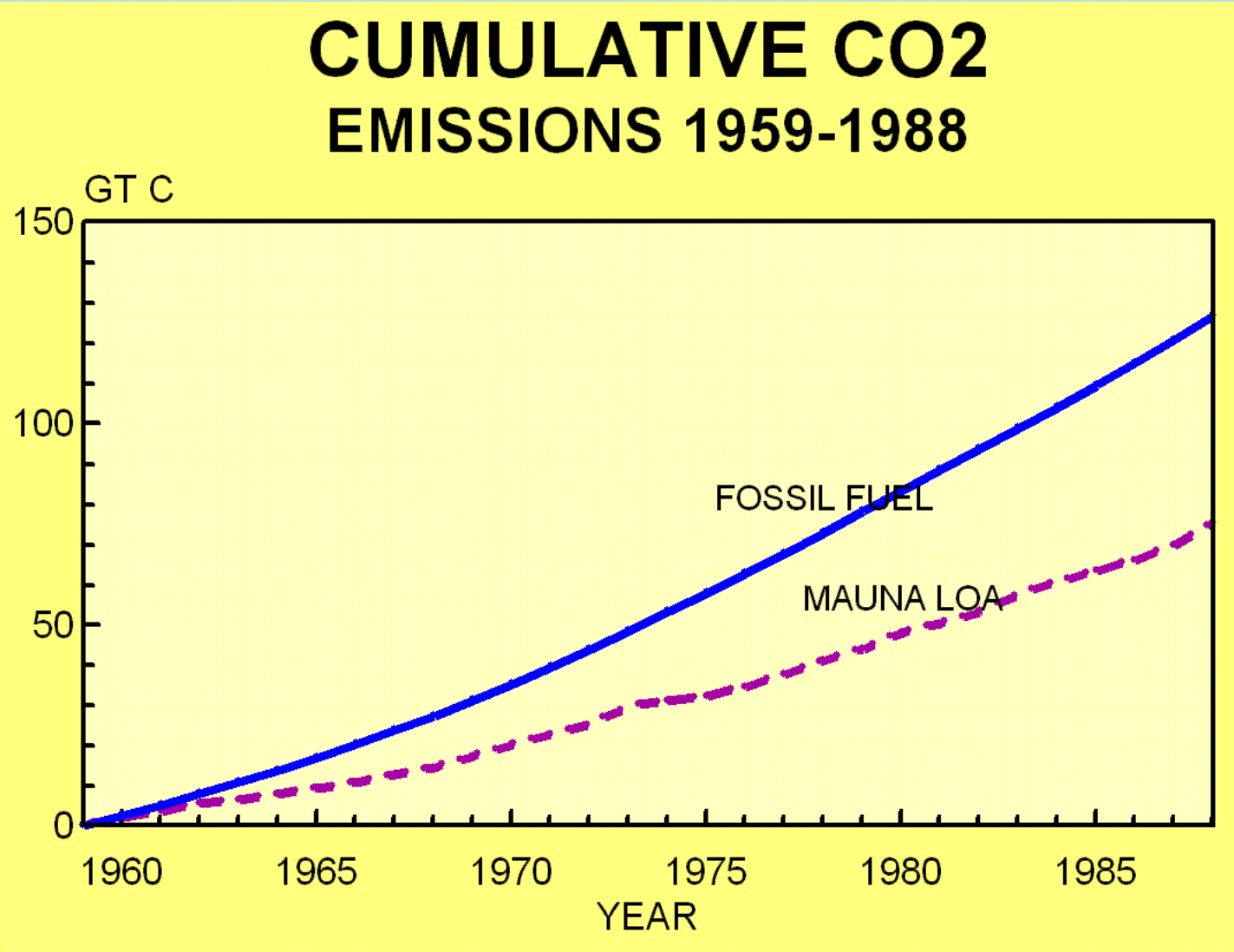
Atmospheric CO_2 has been increasing at unprecedented rates



What are the consequences of the increase in atmospheric CO_2?



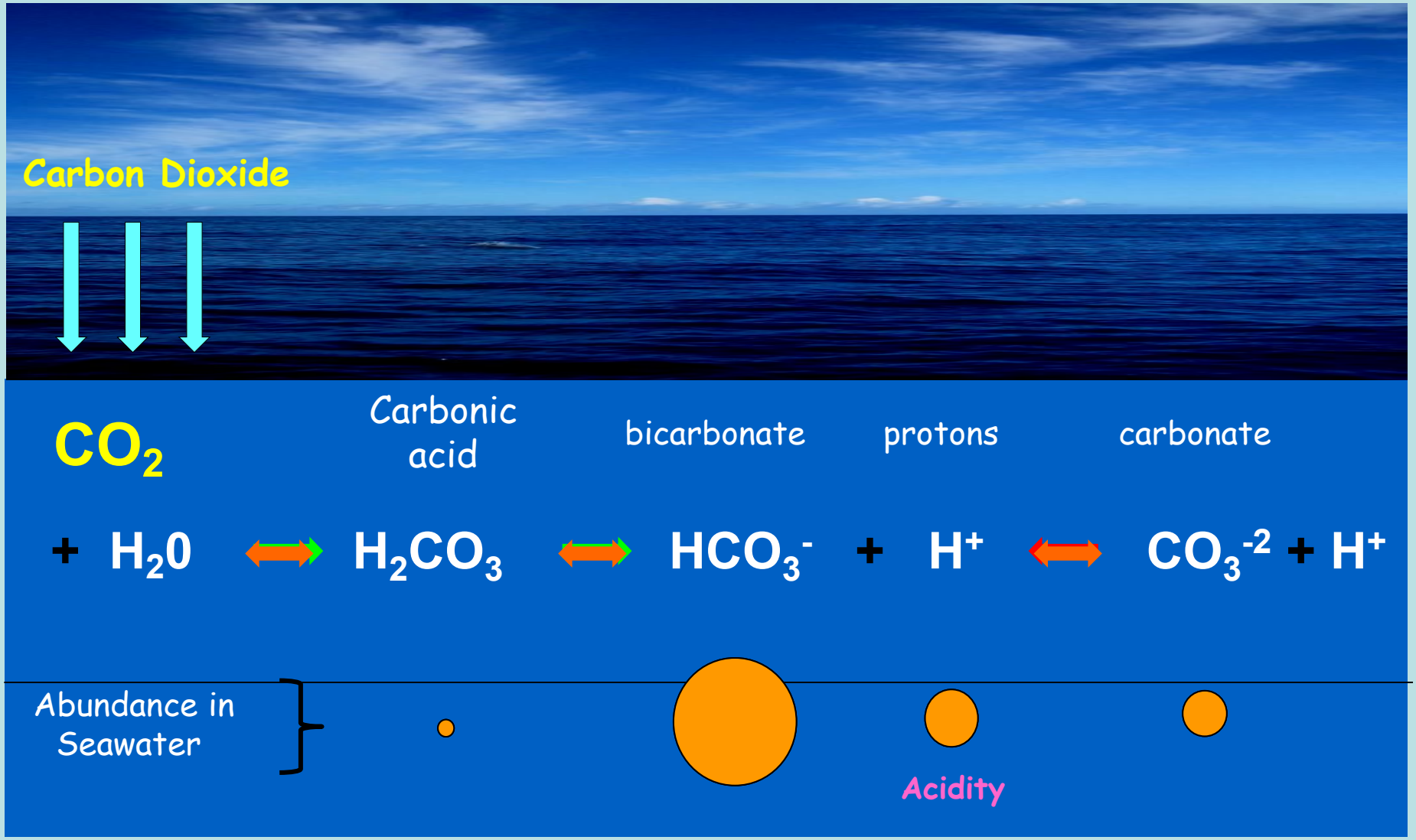
By Arthur Belata / courtesy USACE



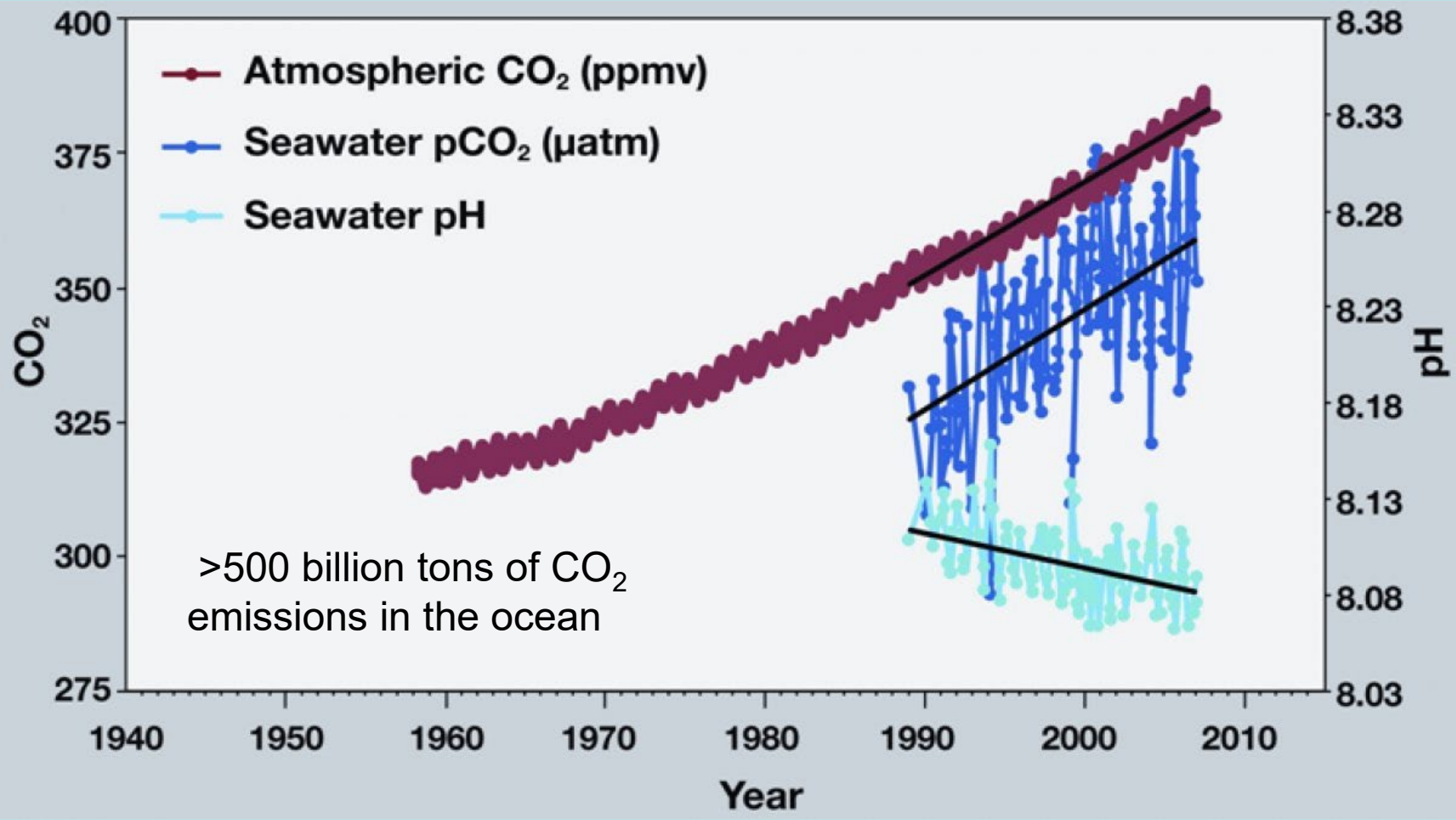
More than 30% of the emitted CO_2 is not in the atmosphere.

Much of this "missing" CO_2 has been adsorbed by the ocean.

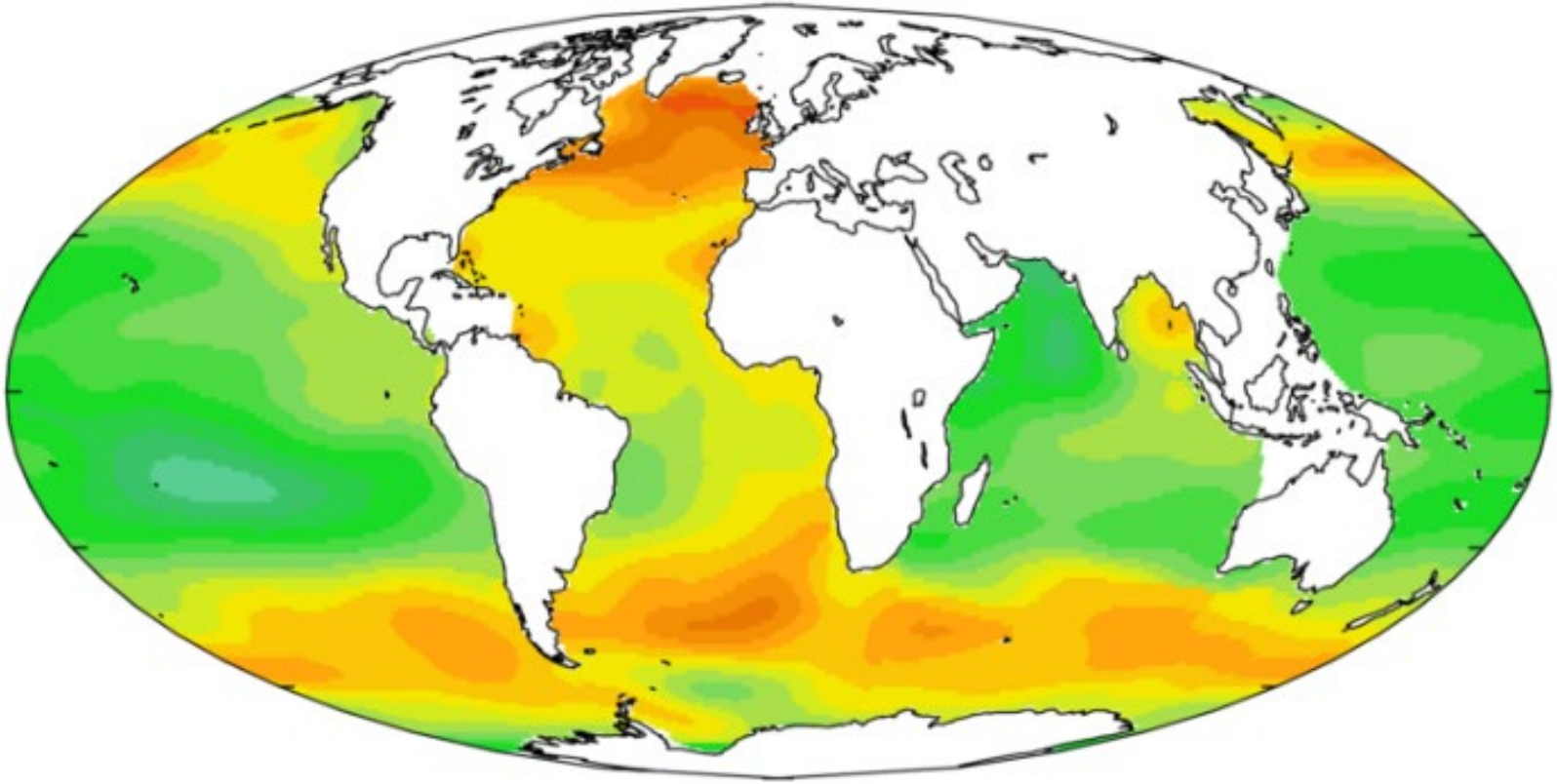
Ocean Acidification – The other CO_2 problem



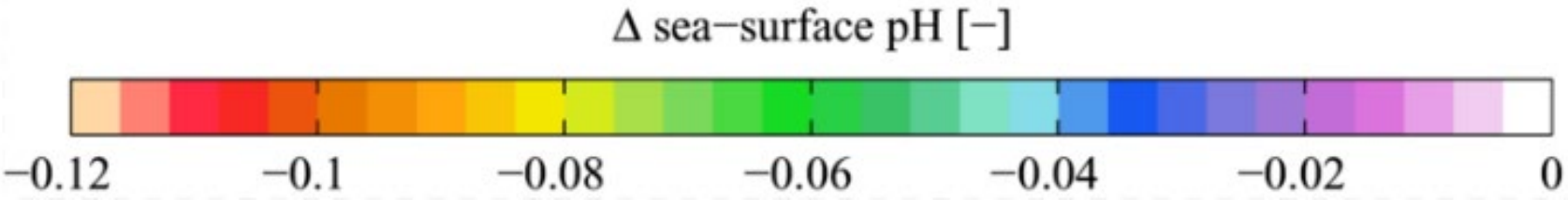
Evidence of Change

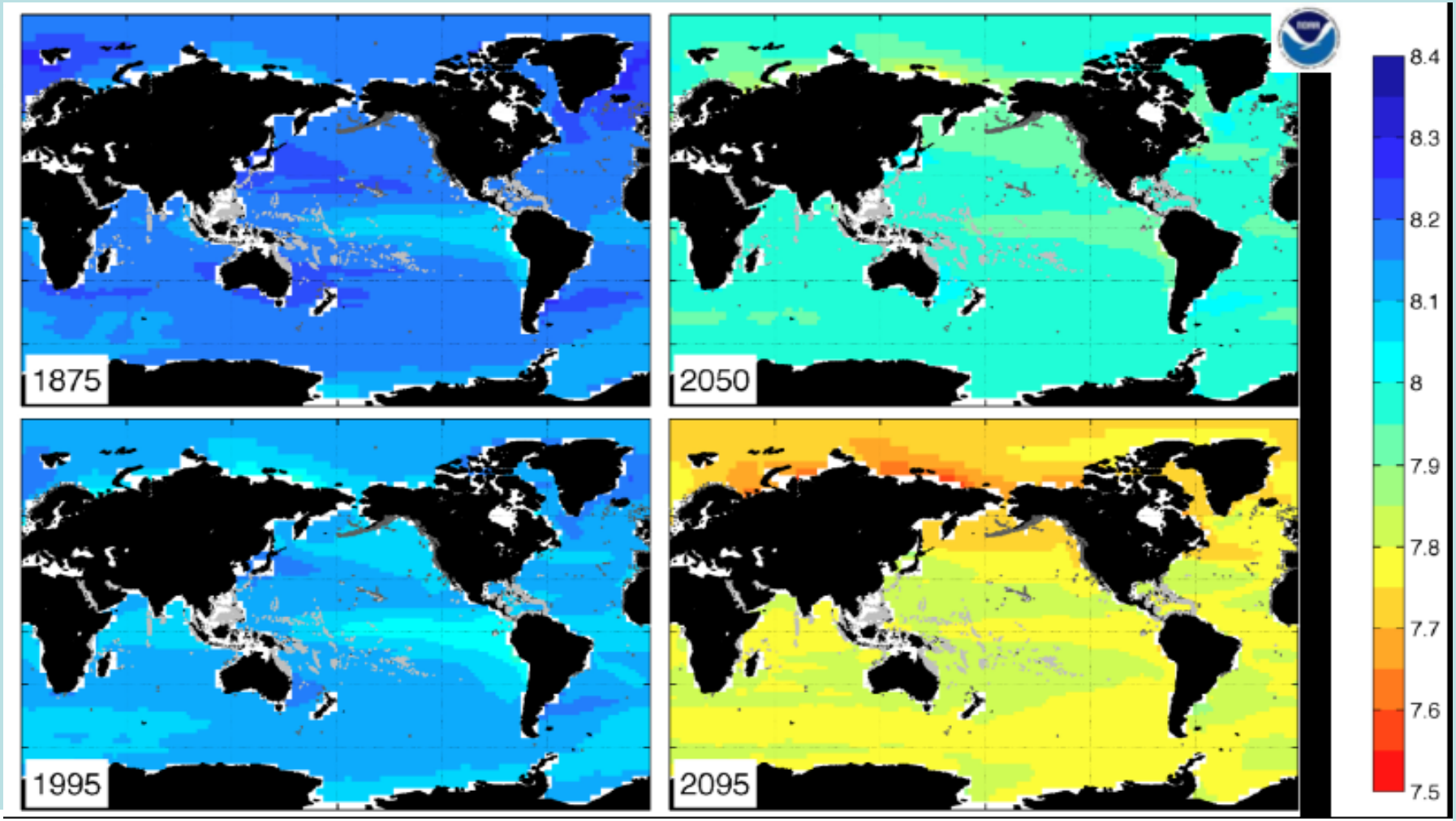


http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt



Change in sea surface pH caused by anthropogenic CO_2 between 1700 and 1990





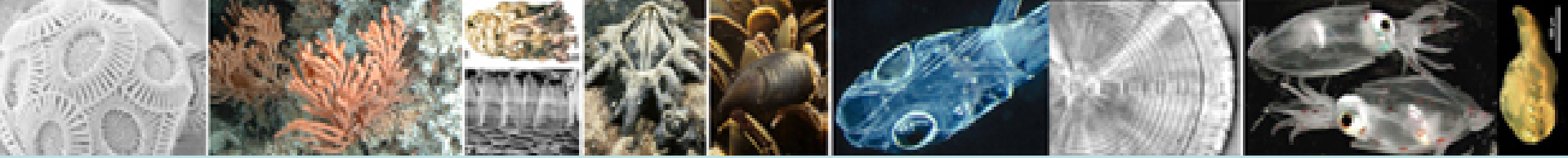
Feely, Doney and Cooley, O*ceanography* (2009) pH

Model results suggest that surface ocean pH will decrease considerably.

Potential impacts on marine organisms & ecosystems

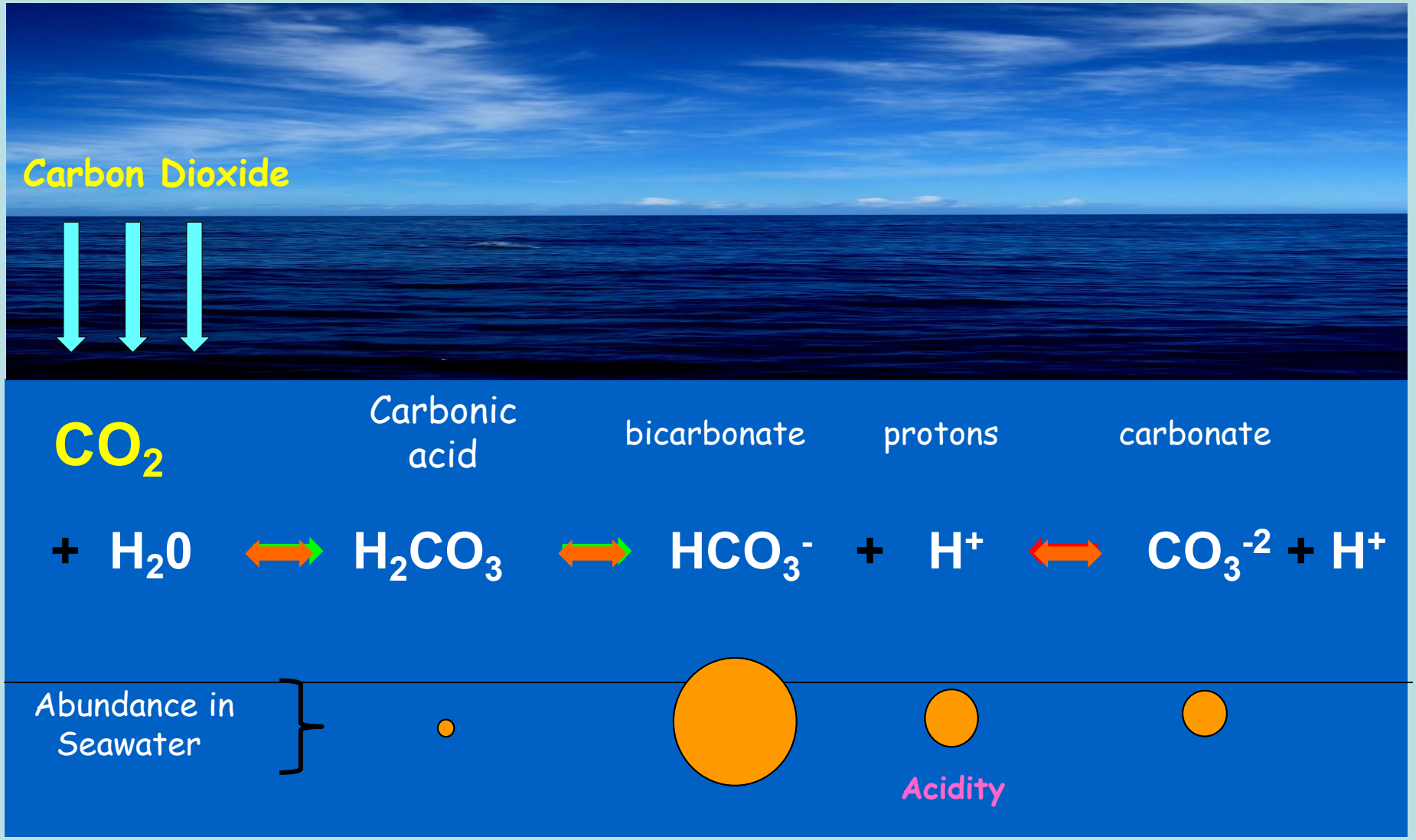
- Reduced calcification rates
- Significant shift in key nutrient and trace element speciation
- Shift in phytoplankton diversity
- Reduced growth, production and life span of adults, juveniles & larvae
- Reduced tolerance to other environmental fluctuations

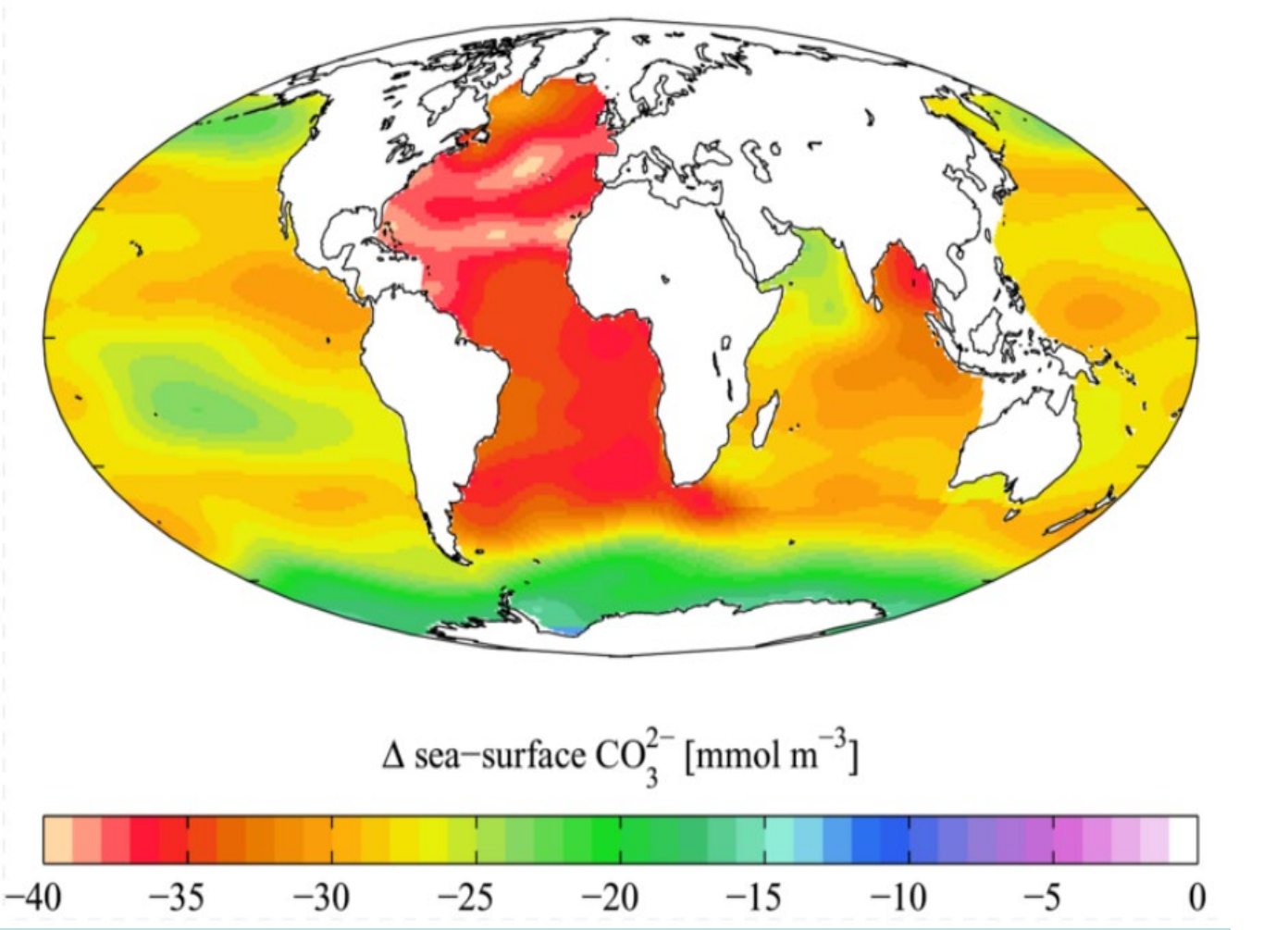
- Changes to:
  - Fitness and survival
  - Species biogeography
  - Key biogeochemical cycles
  - Food webs
- Reduced:
  - Sound Absorption
  - Homing Ability
  - Recruitment and Settlement



Impacts of Ocean Acidification on Calcification

Ocean Acidification – The other CO_2 problem

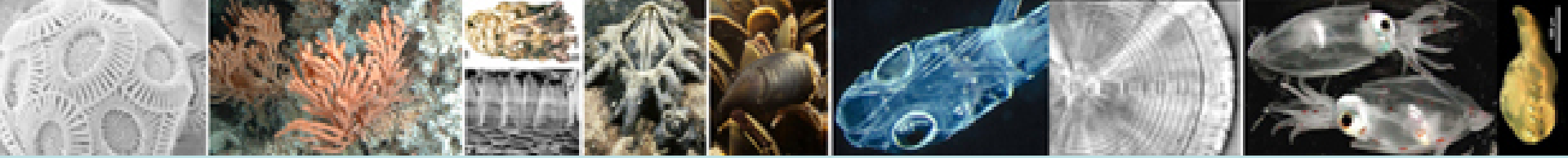


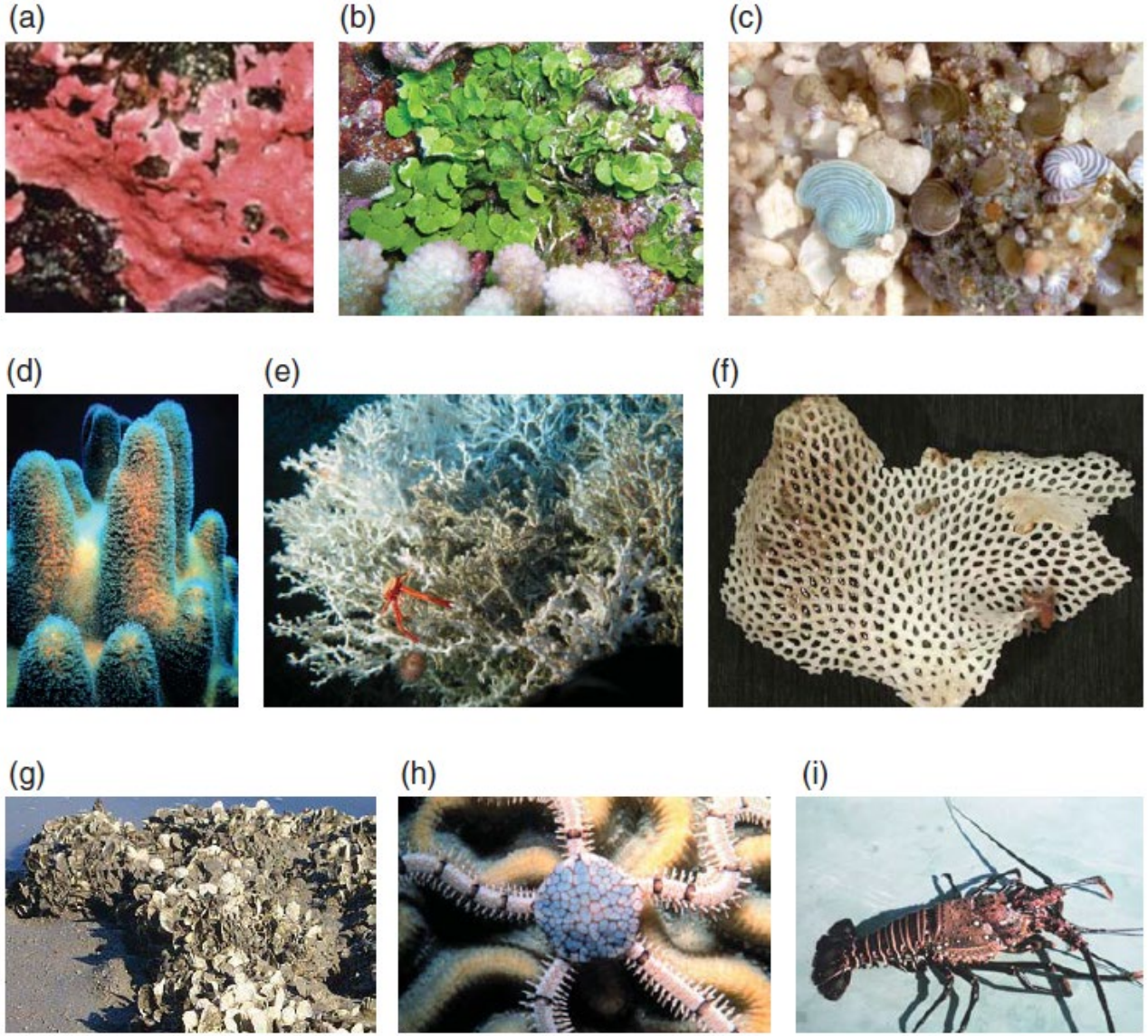


Change in sea surface saturation between 1700 and 1990

Lower CO_3^{2-} ion concentrations means less CO_3^{2-} available for organisms that use carbonate minerals to form supporting skeletal structures.

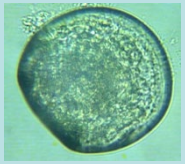
calcification

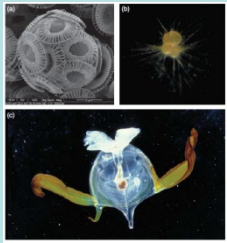


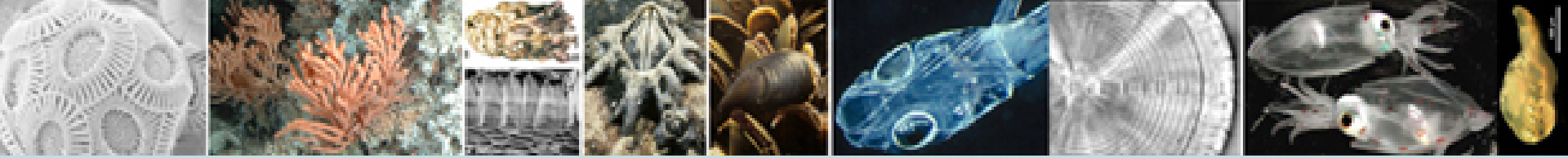


Representatives Calcifiers

(a) Coralline algae
(b) Halimeda
(c) Foraminifera
(d) Reef-building coral
(e) Deep-water coral
(f) Bryozoans
(g) Mollusks
(h) Echinoderm
(i) Crustacean
(j) Sponges
(k) Polychaetes
(l) Coccolithophore
(m) Pteropod
(n) Cephalopods
(o) Various Larva





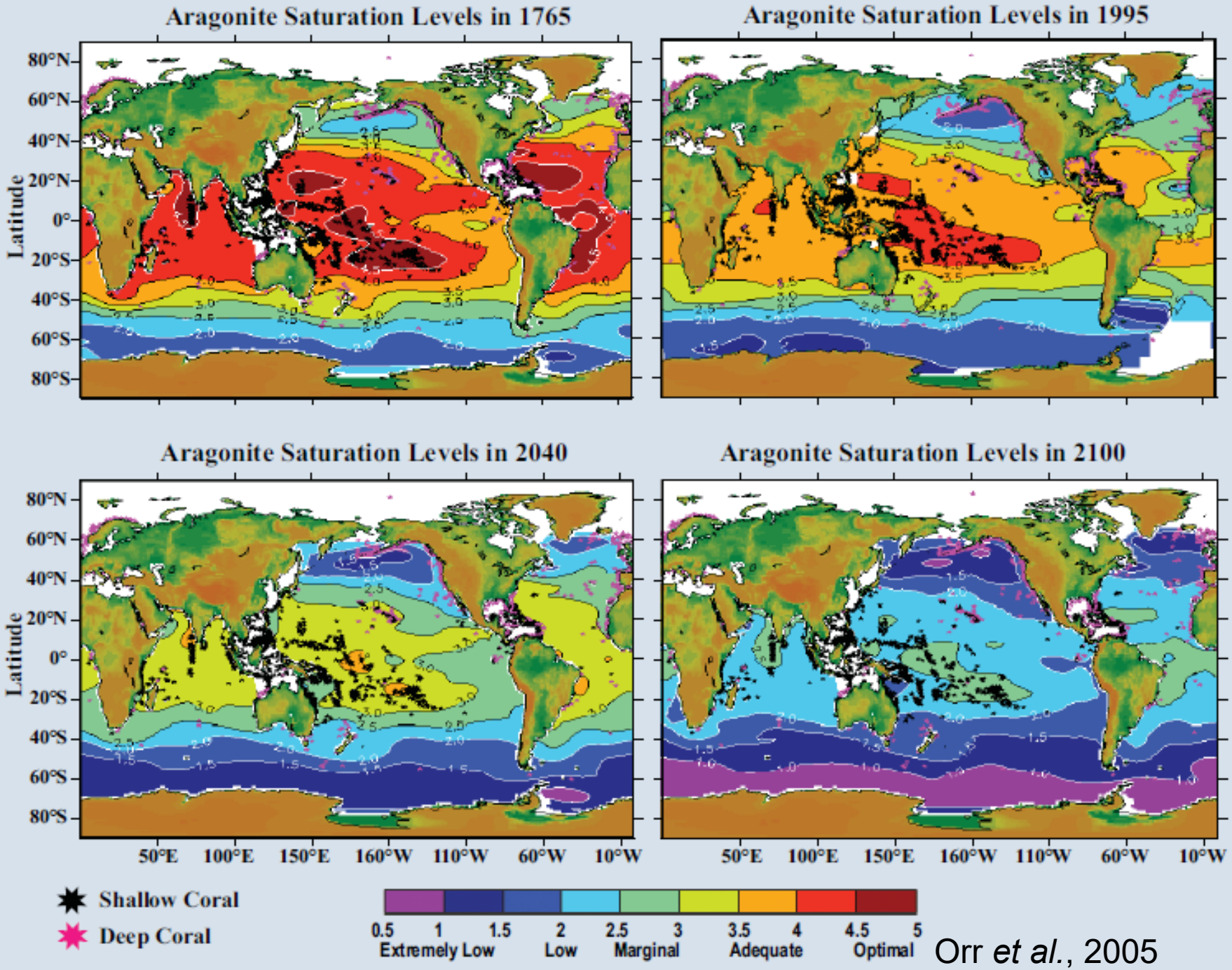


Coral Reefs – The Rain Forests of the Ocean
Rich Ecosystems that Provide Important Services

$CaCO_3$ aragonite skeletons more soluble than calcite

Impacted by many other stressors

May be particularly sensitive to the environment



Orr *et al.*, 2005

Friday, November 25, 2011 | TRAFFIC | 44°F

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Guest columnist

Ocean acidification is most urgent threat to marine conservation

Increasing Ocean Acidification Eroding Coral Reefs

By the middle of the century there will probably be only a few pockets of coral left, in the North Sea and the Pacific. Millions of species of marine life will be wiped out. Photograph: Vladimir Levantovsky/Alamy

Growing Acidity of Oceans May Kill Corals

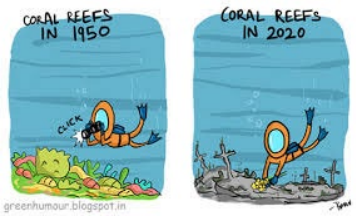
By Juliet Eilperin
Washington Post Staff Writer
Wednesday, July 5, 2006

The escalating level of carbon dioxide in the atmosphere is making the world's oceans more acidic, government and independent scientists say. They warn that, by the end of the century, the trend could decimate coral reefs and creatures that underpin the

Ocean Acidification Hits Great Barrier Reef

Coral growth has been sluggish since 1990 due to an increase in both sea temperature and acidity as a result of global warming

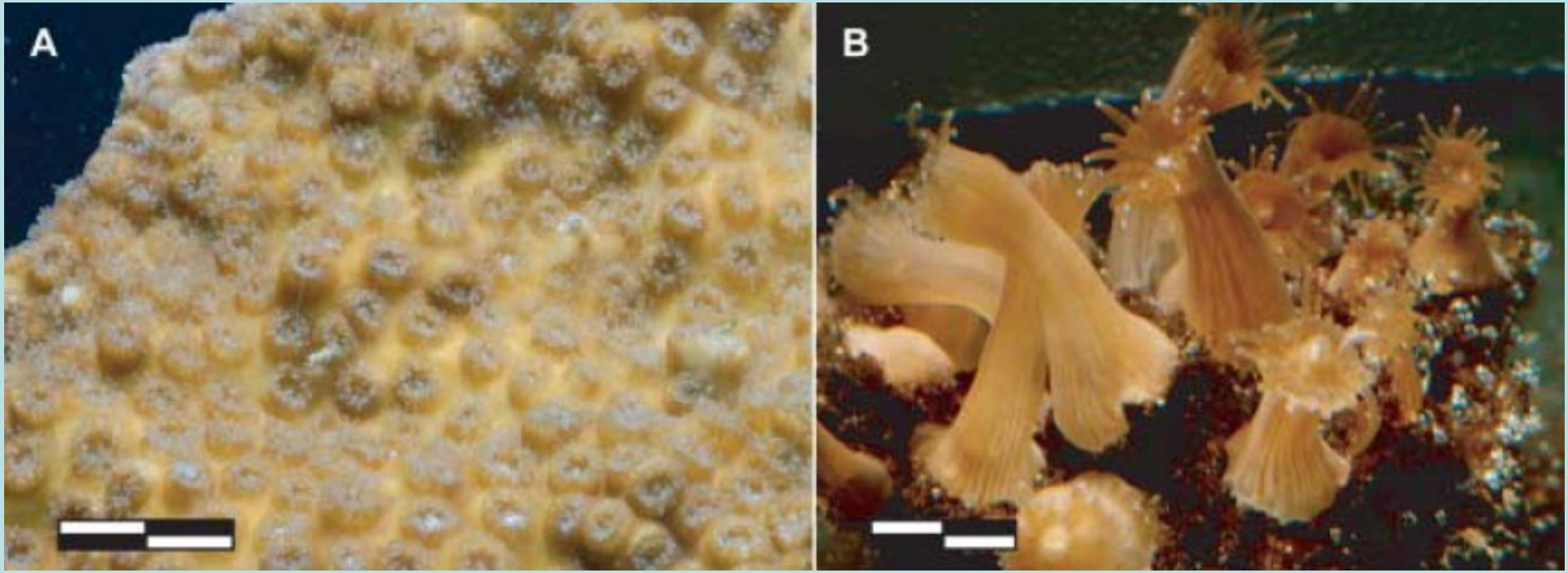
By David Biello | January 1, 2009 | 12



Manipulation Experiments

Fine and Tchernov, 2007

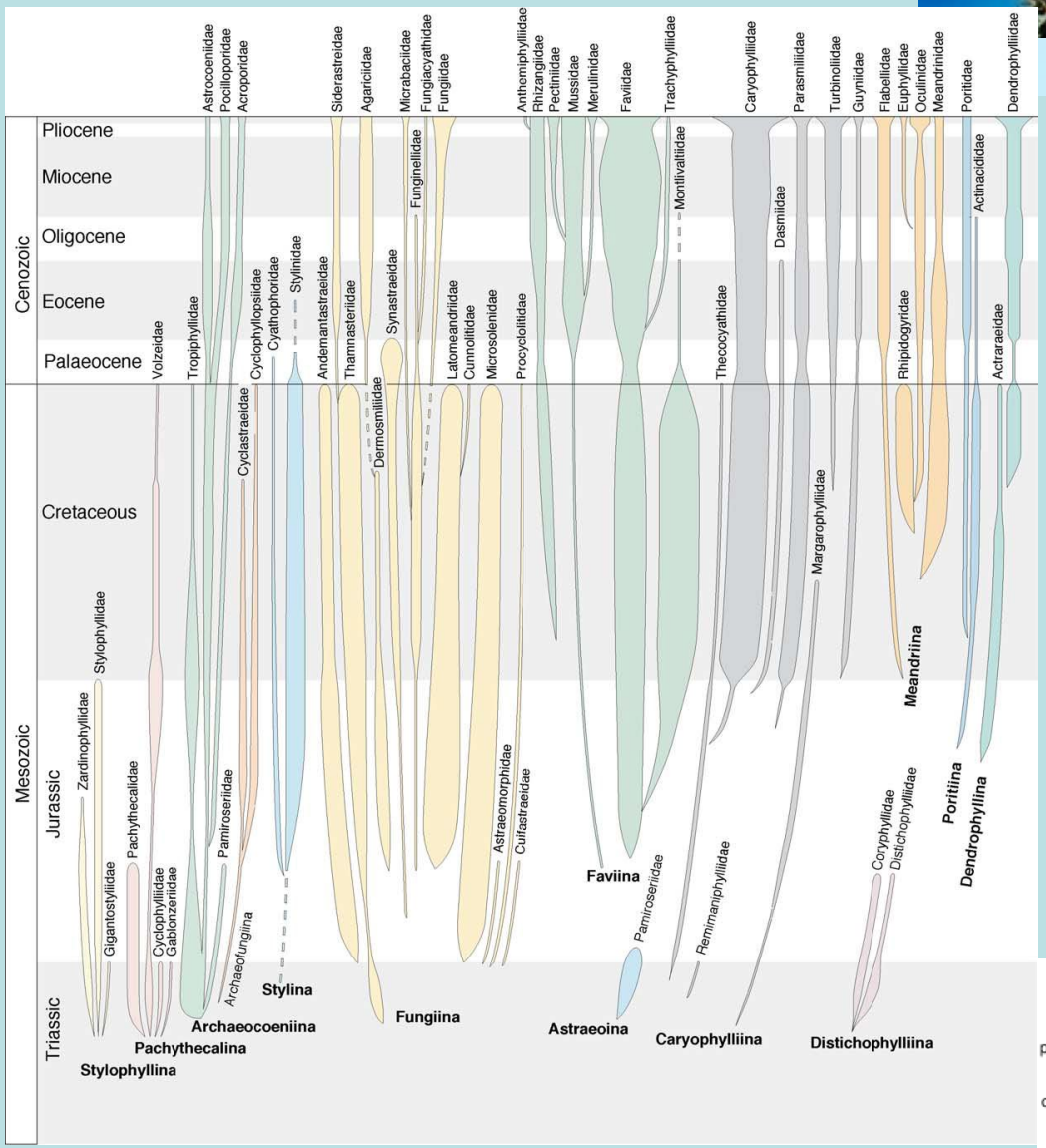
Corals exposed to low pH seawater lost their carbonate skeleton and stopped calcifying but survived well an “naked” polyps



Good news for corals bad news for coral reefs

Coral Evolution

A Family Tree of Scleractinia

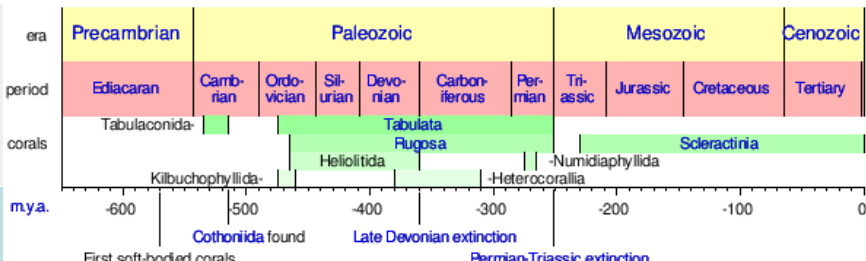


Long-lived in geological time

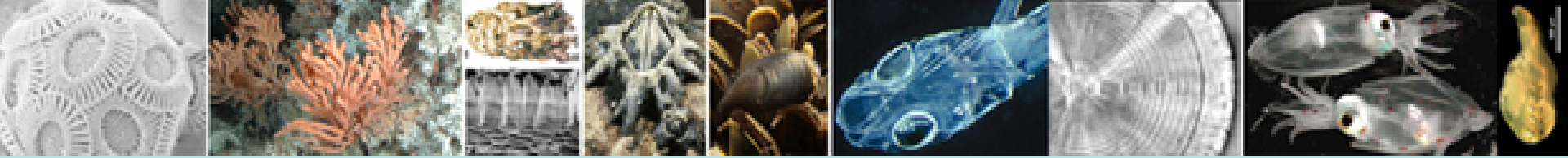
First appearance - Paleozoic

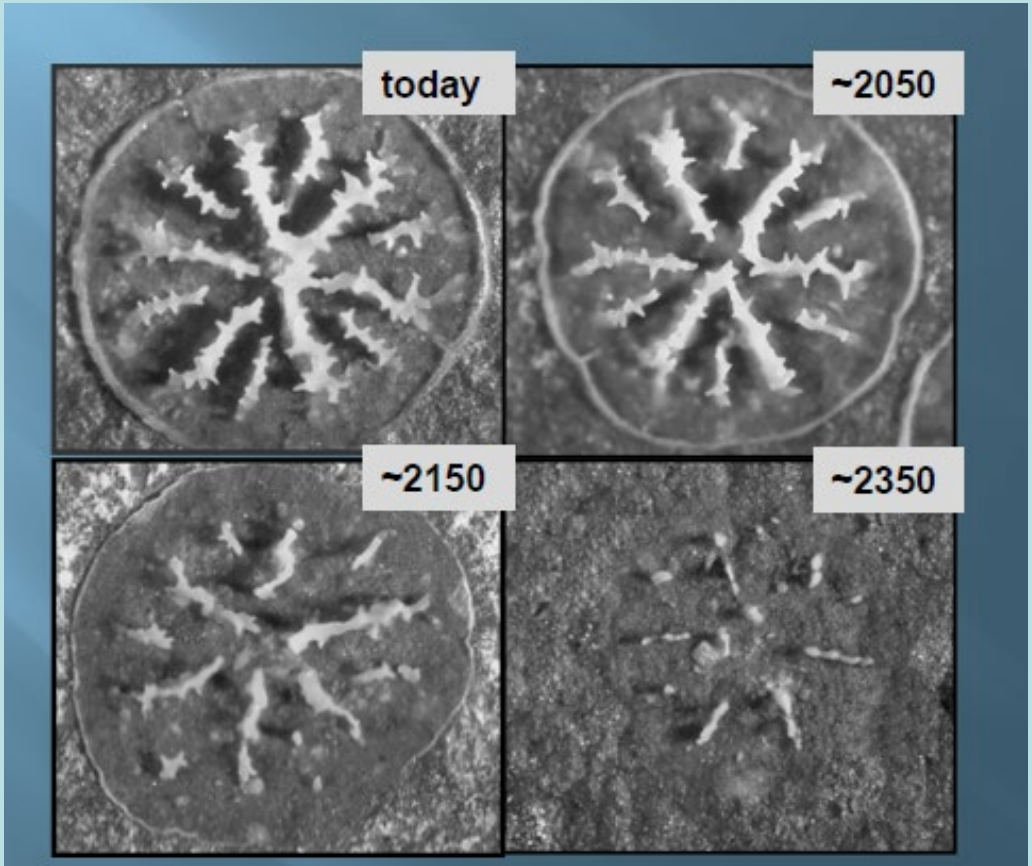
Proliferation in Mid-Triassic

Persisted through several episodes of climate change in the last 450 My

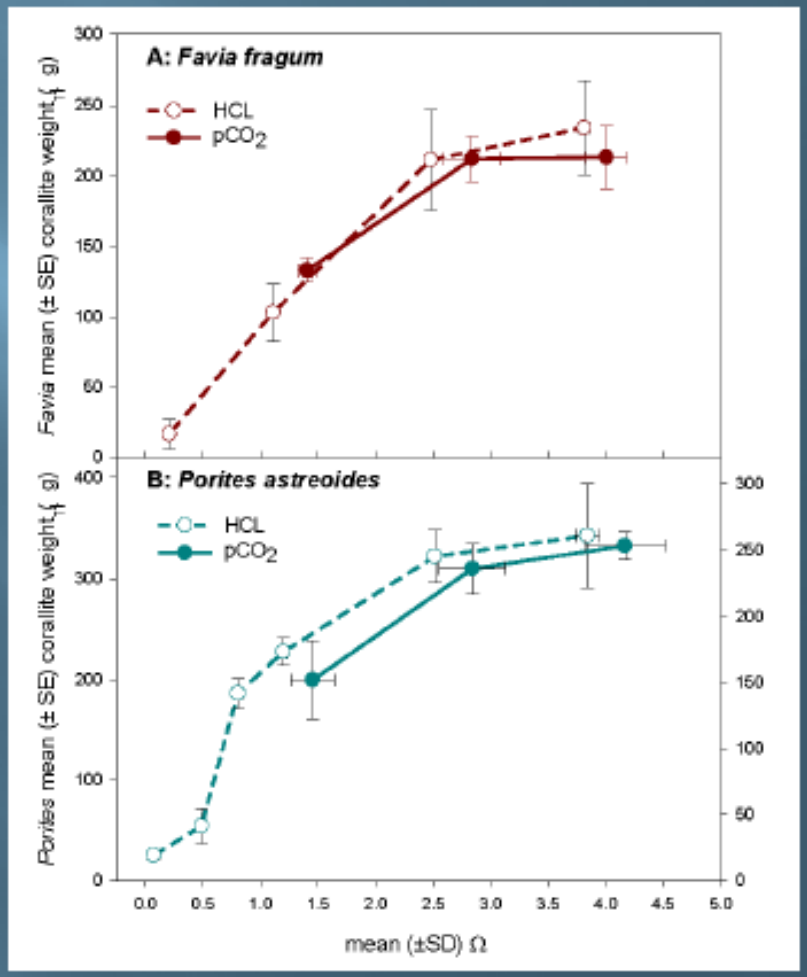


http://coral.aims.gov.au/info/evolution.jsp



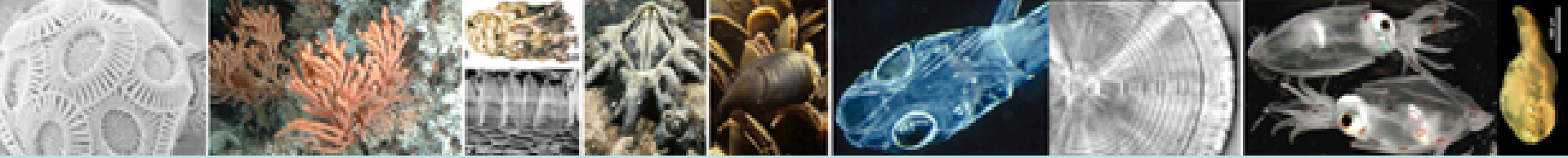


Cohen et al., 2009



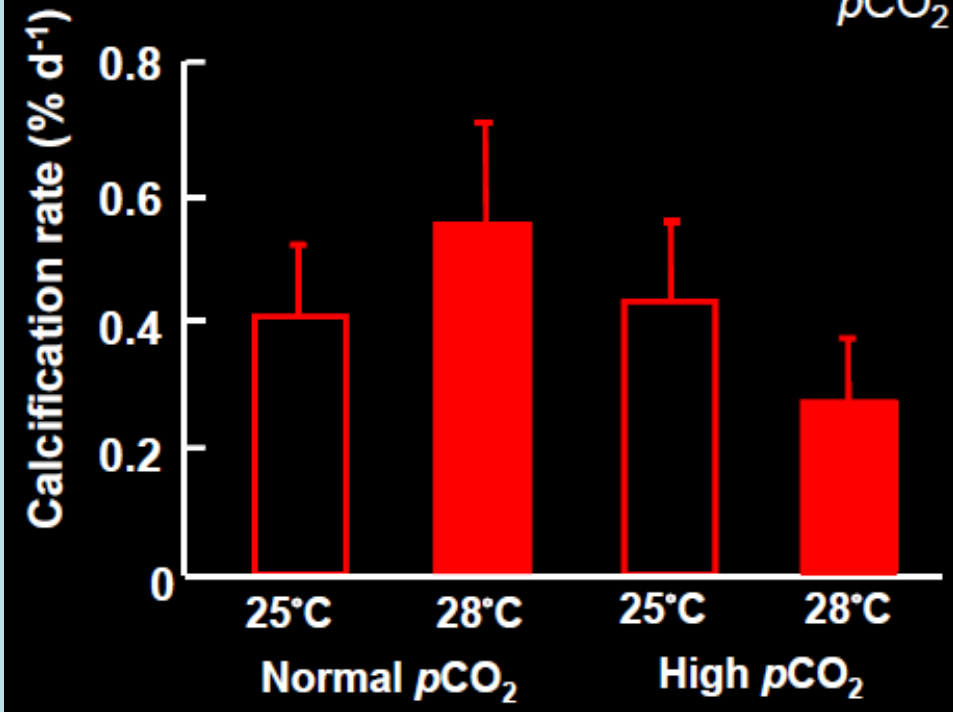
De Putron et al ., 2011

Coral calcification declines sharply below aragonite saturation of 2.5



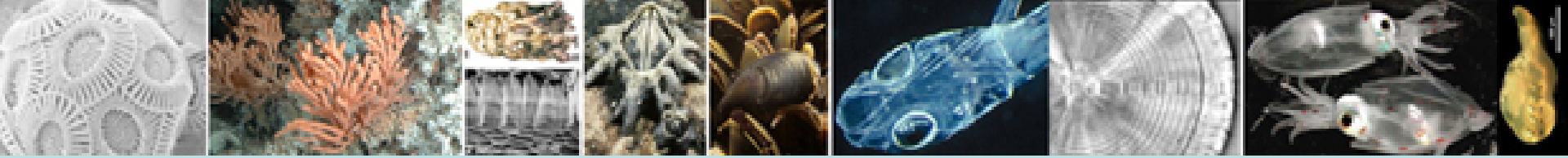
Reynaud et al. 2003

Experimentally-induced by
pCO_2 increase (450 *vs.* 734 µatm)

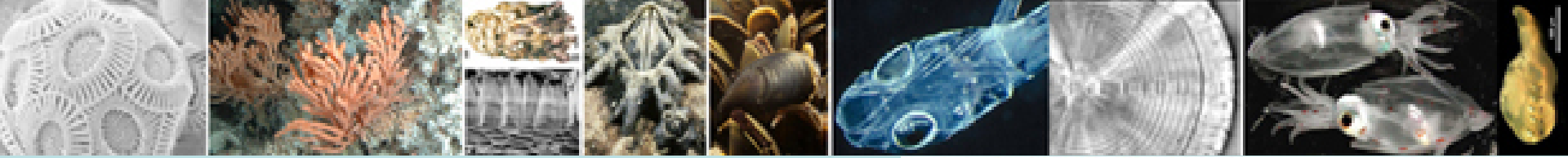


No effect of *doubling* pCO_2 at 25°C

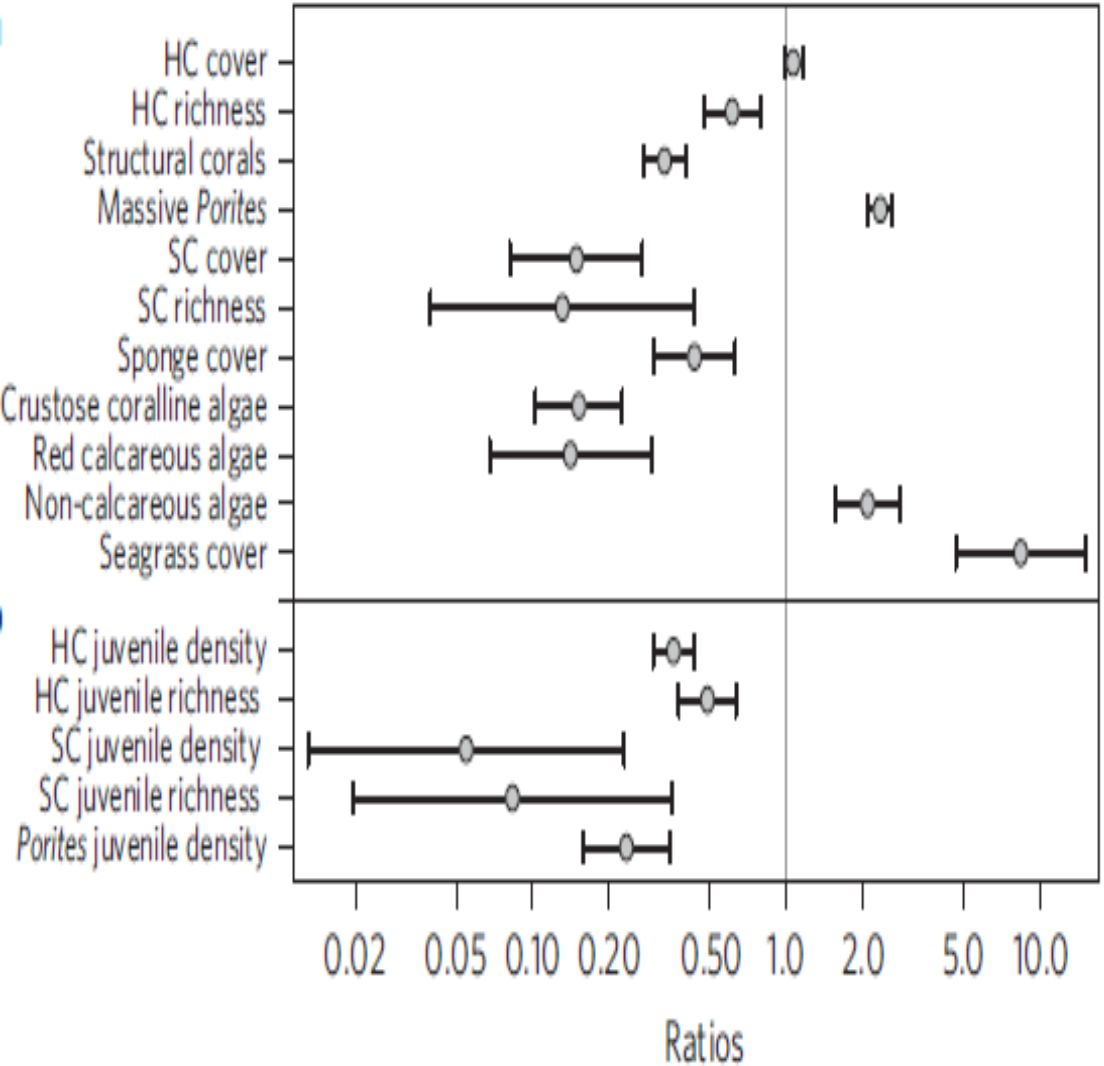
Increase in pCO_2 at 28°C decreases calcification (54%)

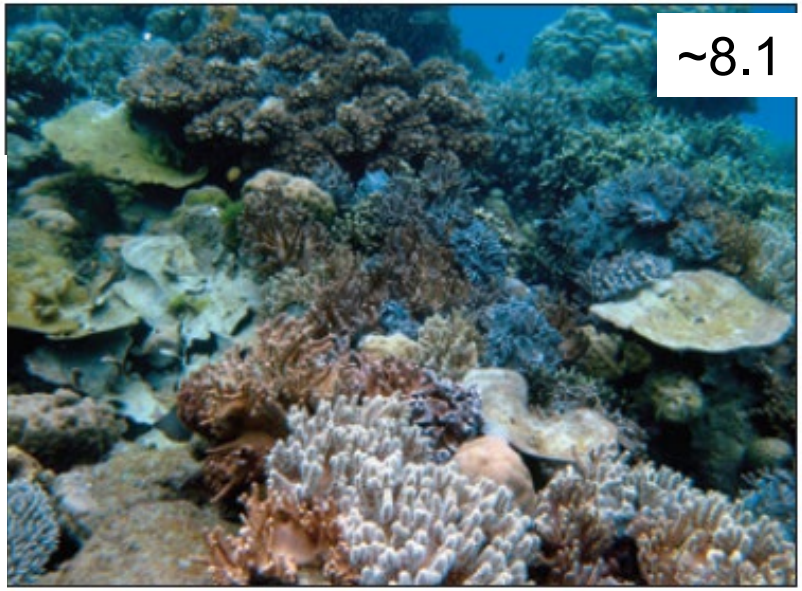


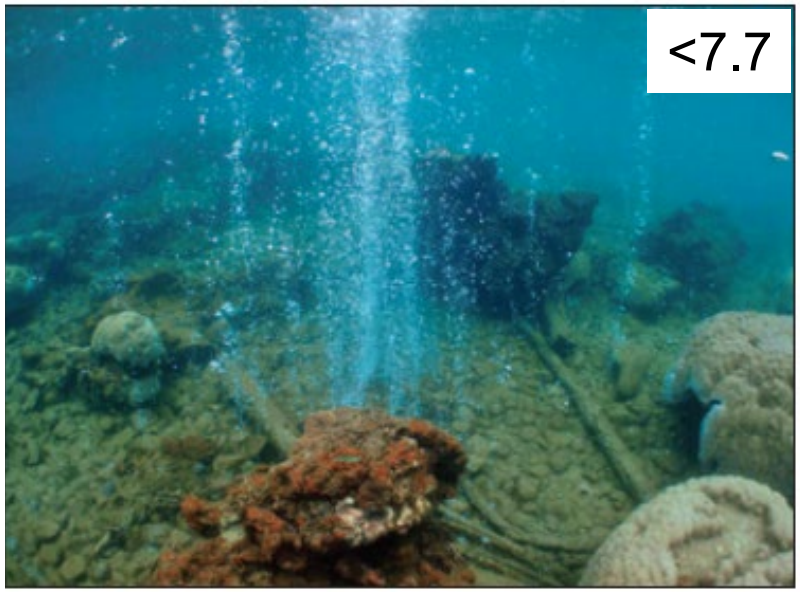
If coral reefs are maintained in healthy condition and are given sufficient time, **will they acclimate or even adapt to ocean acidification and maintain high calcification rate that sustain reef infrastructure and growth**?

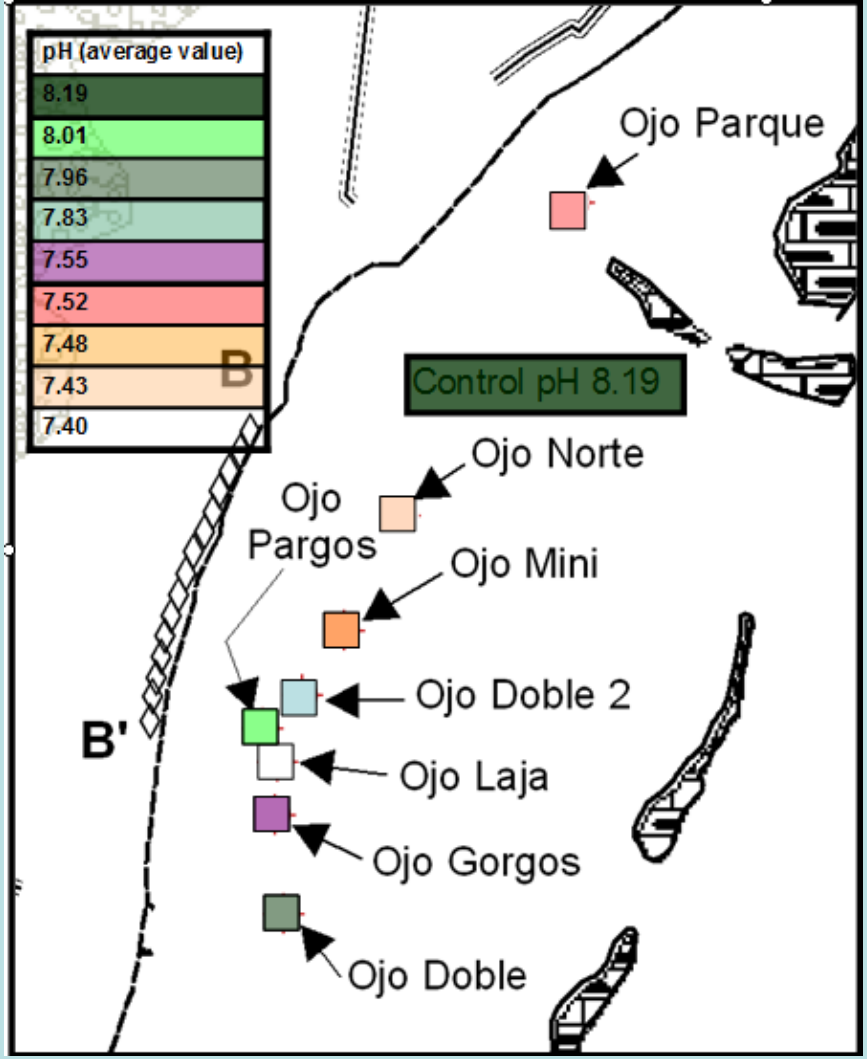


Fabricius et al., 2011

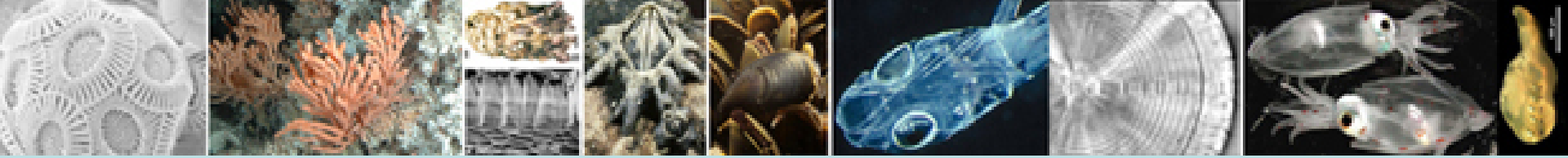


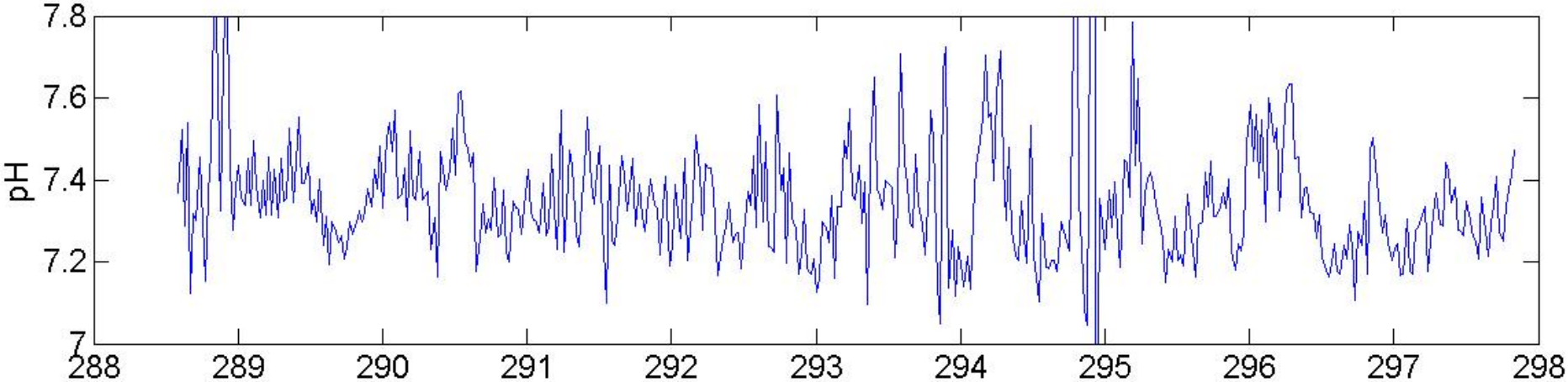




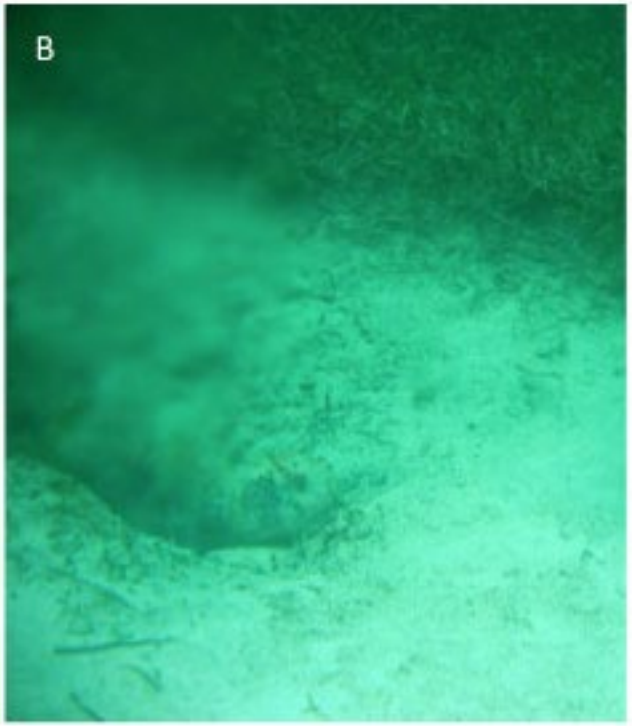


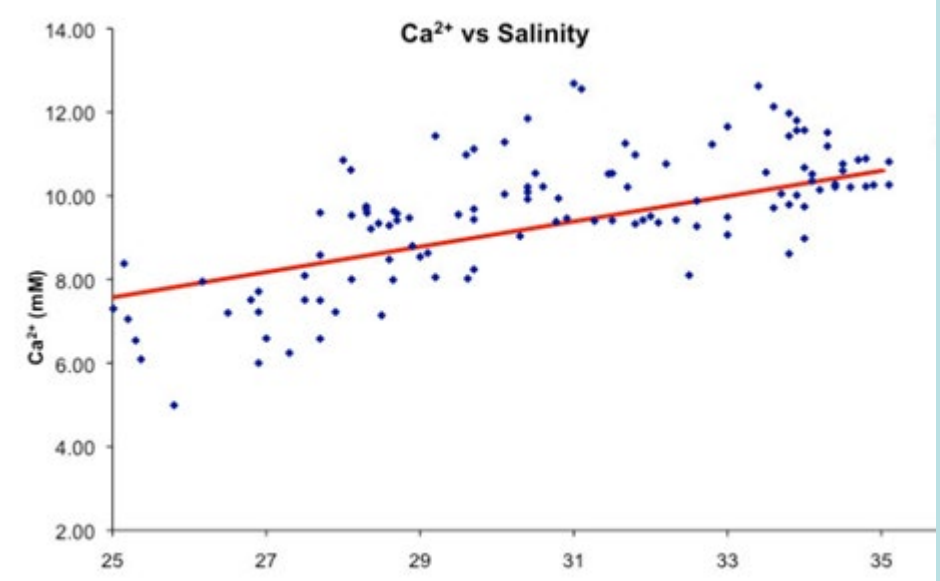
Low pH low saturation springs in the back reef lagoon 500m offshore with "control" sites close by for comparison.

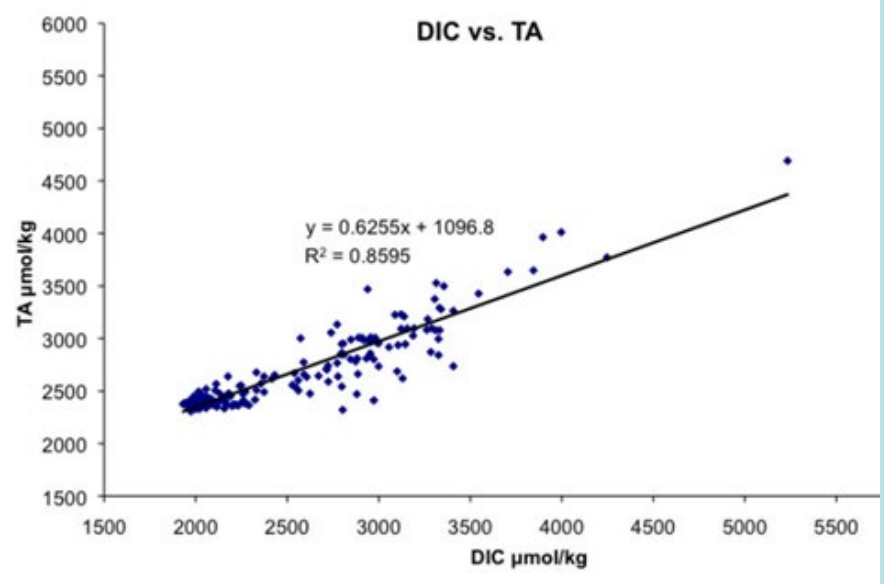


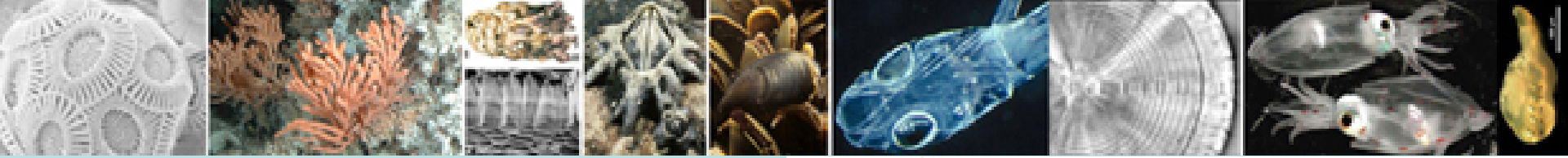

pH
7.8
7.6
7.4
7.2
7
288
289
290
291
292
293
294
295
296
297
298

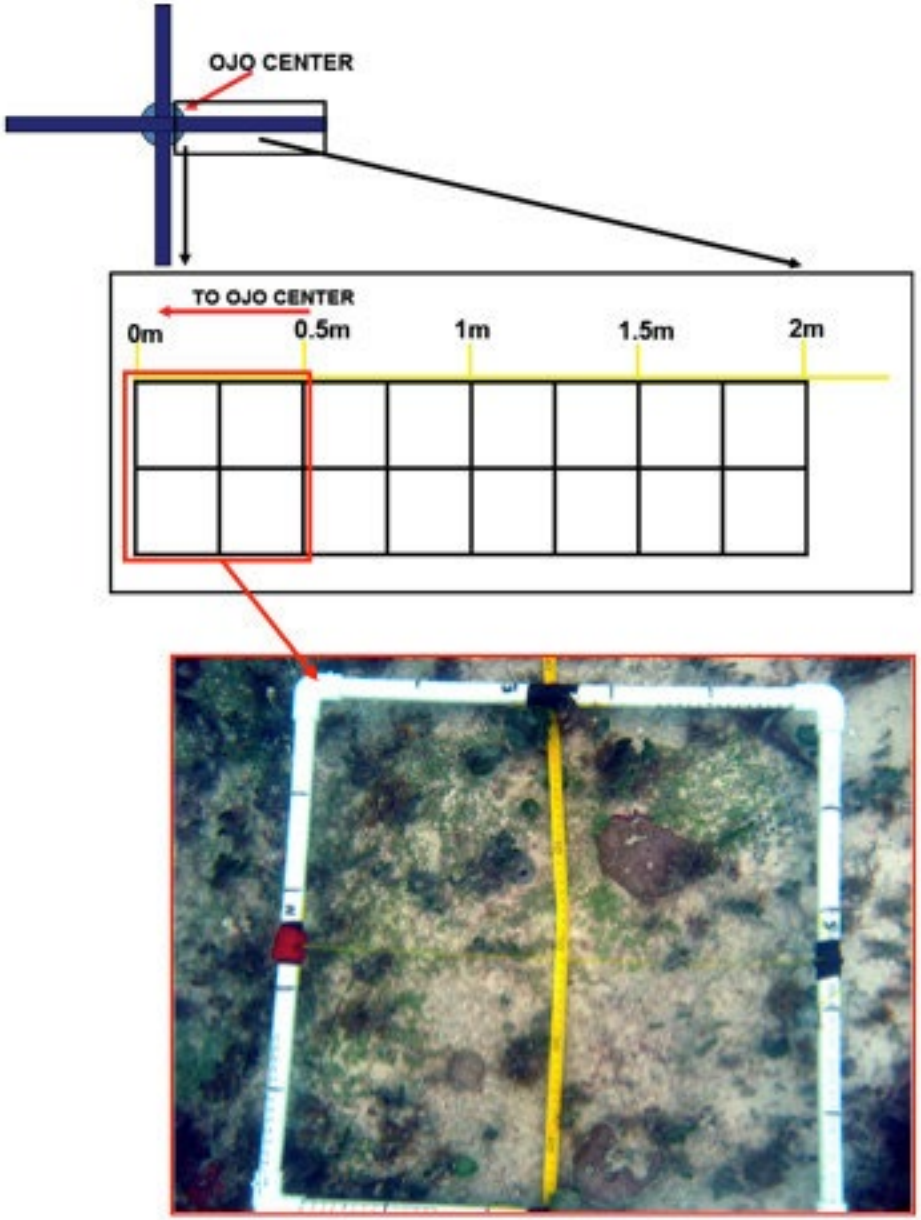

A


B

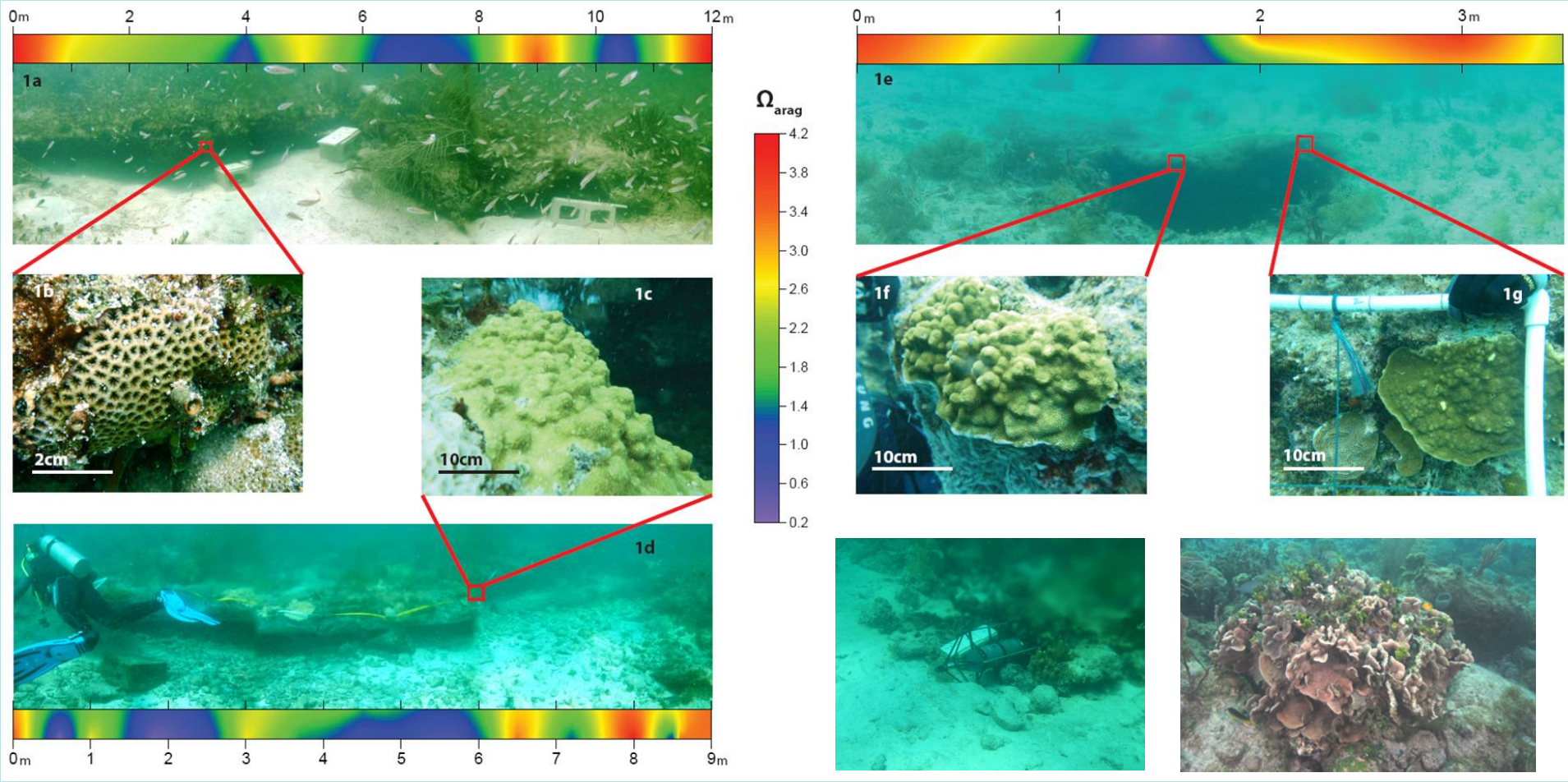

Ca2+ vs Salinity
Ca2+ (mM)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
25
27
29
31
33
35


DIC vs. TA
y = 0.6255x + 1096.8
R2 = 0.8595
TA µmol/kg
DIC µmol/kg
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1500
2000
2500
3000
3500
4000
4500
5000
5500




OJO CENTER
TO OJO CENTER
0m
0.5m
1m
1.5m
2m

Ecosystem Response – Field experiments to investigate community and ecosystem responses and adaptation over long scales

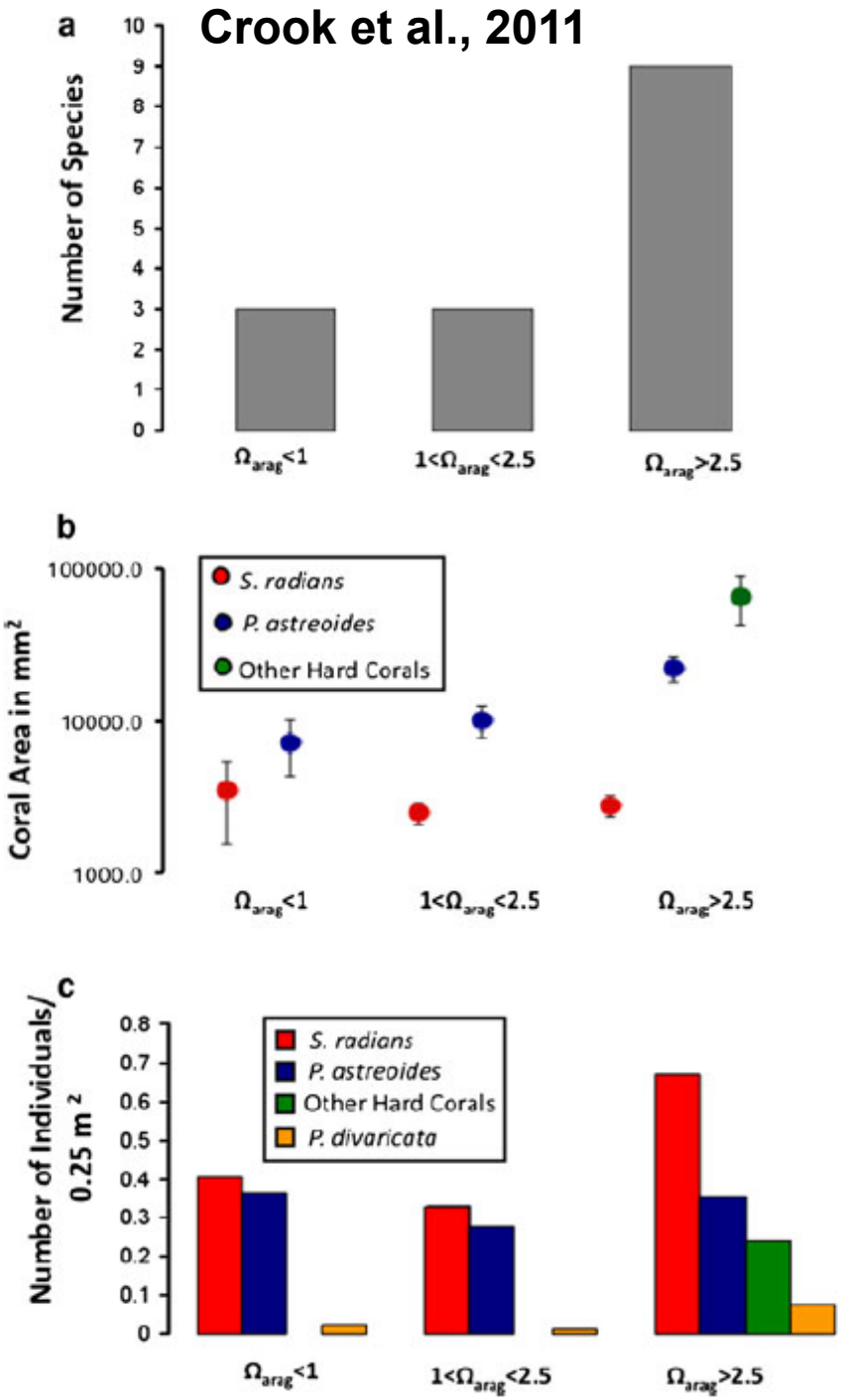


* 3 calcifying corals species settled, grew and calcified under low pH low saturation (10 outside).

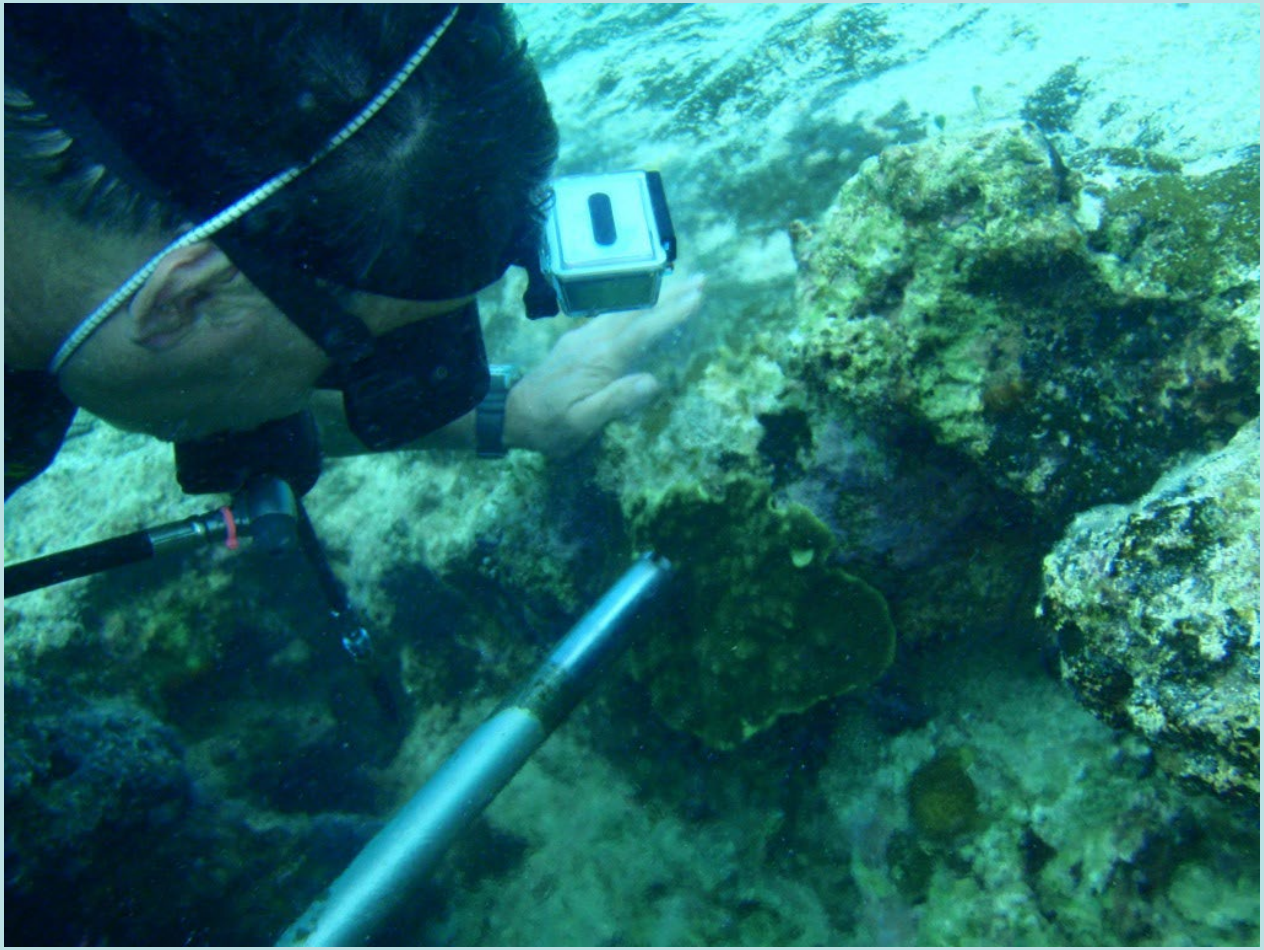
* These species (*Porites astreoides, P. divaricata, and Siderastrea radians*) are not major contributors to reef framework.

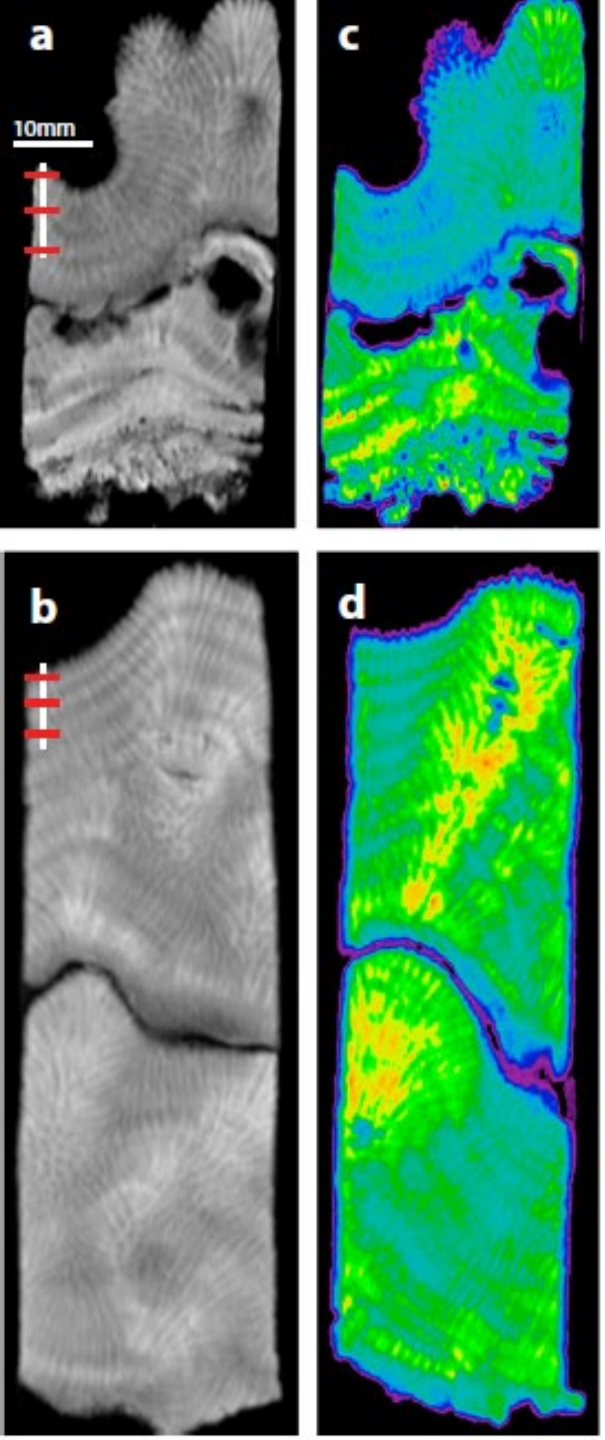
* Coral species richness & coral colony size decline in proximity to low-saturation.

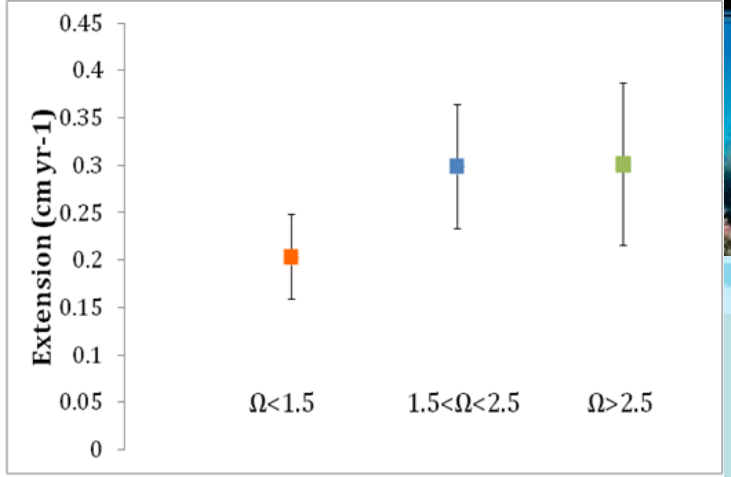
* Response to ocean acidification is likely to vary across species and environments.

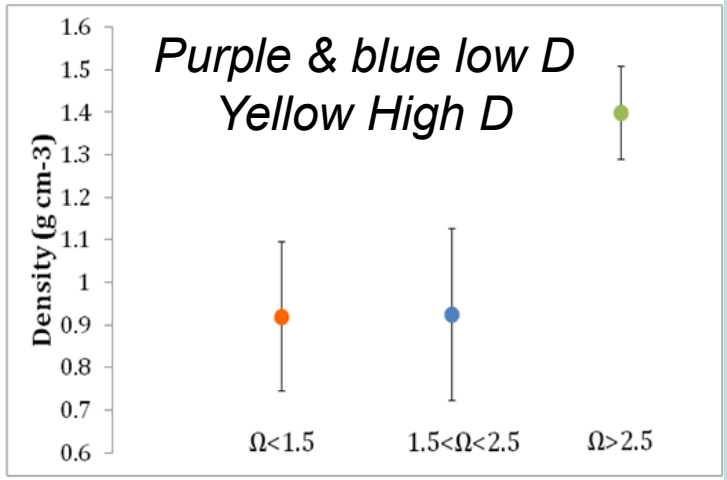


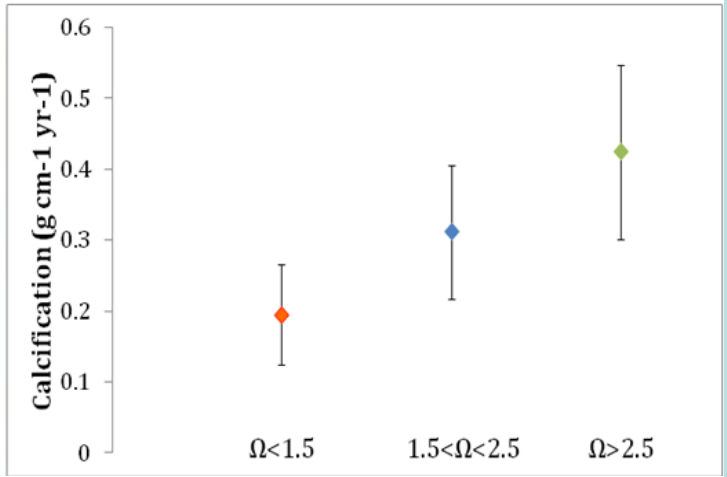
Impact on coral physiology – calcification rate and other coral health parameters (symbionts, tissue thickness and protein content)









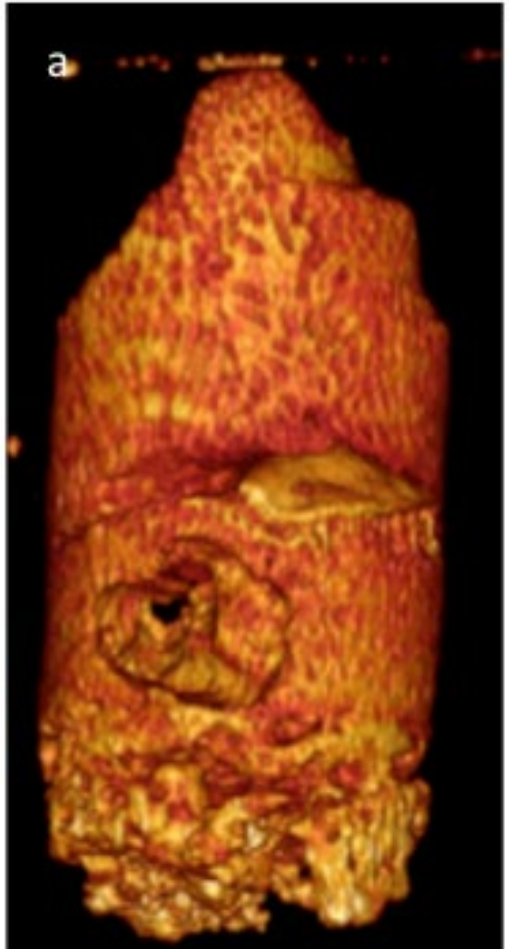


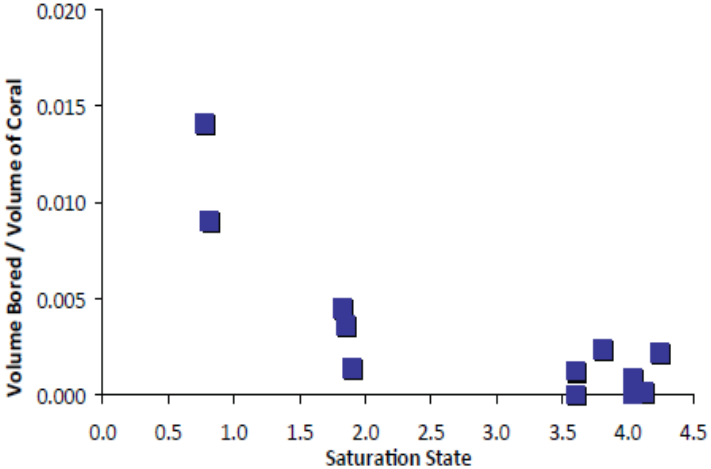
Extension – Distance between annual growth bands.

Density – How much aragonite in each volume of skeleton.

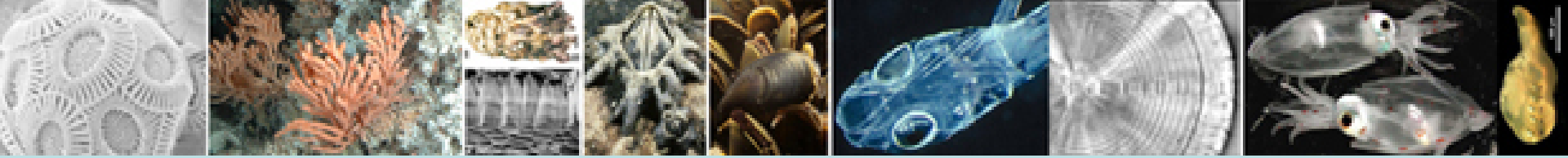
Calcification – Product of extension and density.

Cores were scanned intact with a Siemens Volume Zoom Spiral Computerized Tomography (CT) scanner.





Two pairs of Porites cores of equal size from ojos center (a & c - pH 7.6) and control (b & d - pH 8.1) showing differential degrees of boring.



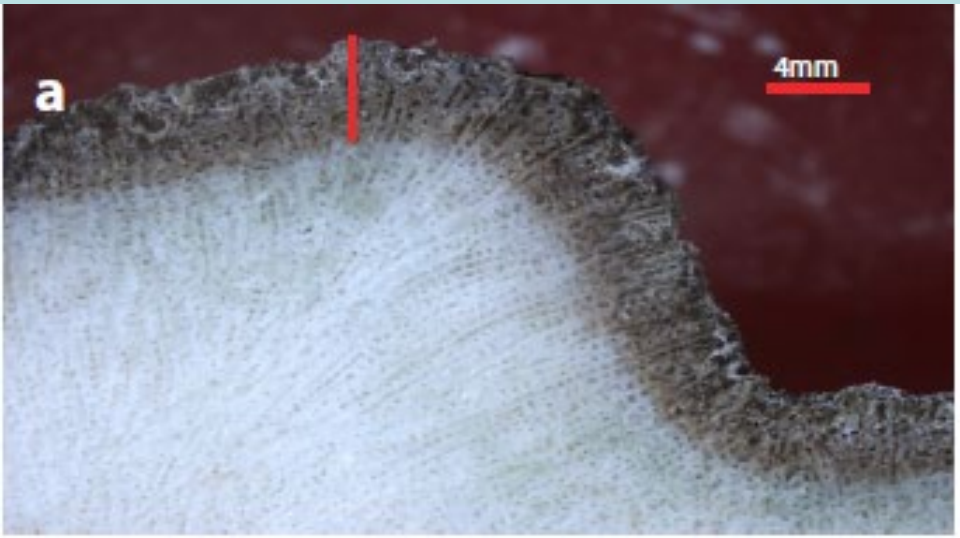
Mechanisms for Acclimation

Tissue thickness – increase to compensate for calcification at low pH

Symbiont clades – May be different symbionts are more adapted?

Symbiont density – More symbionts more resources ?

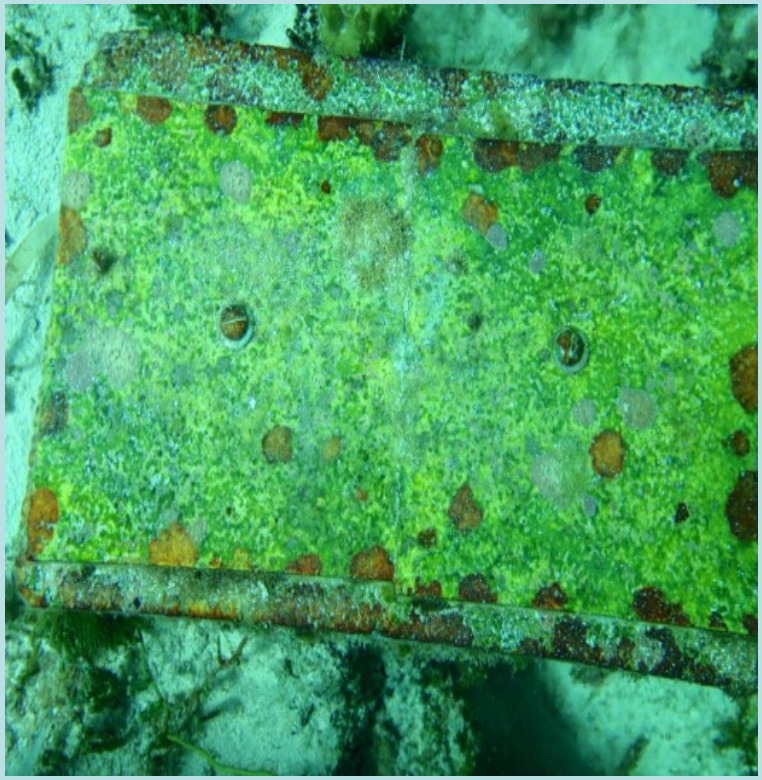
Nutrient levels – Higher nutrients more energy for calcification ?



Recruitment

Largest effect on algae

Control

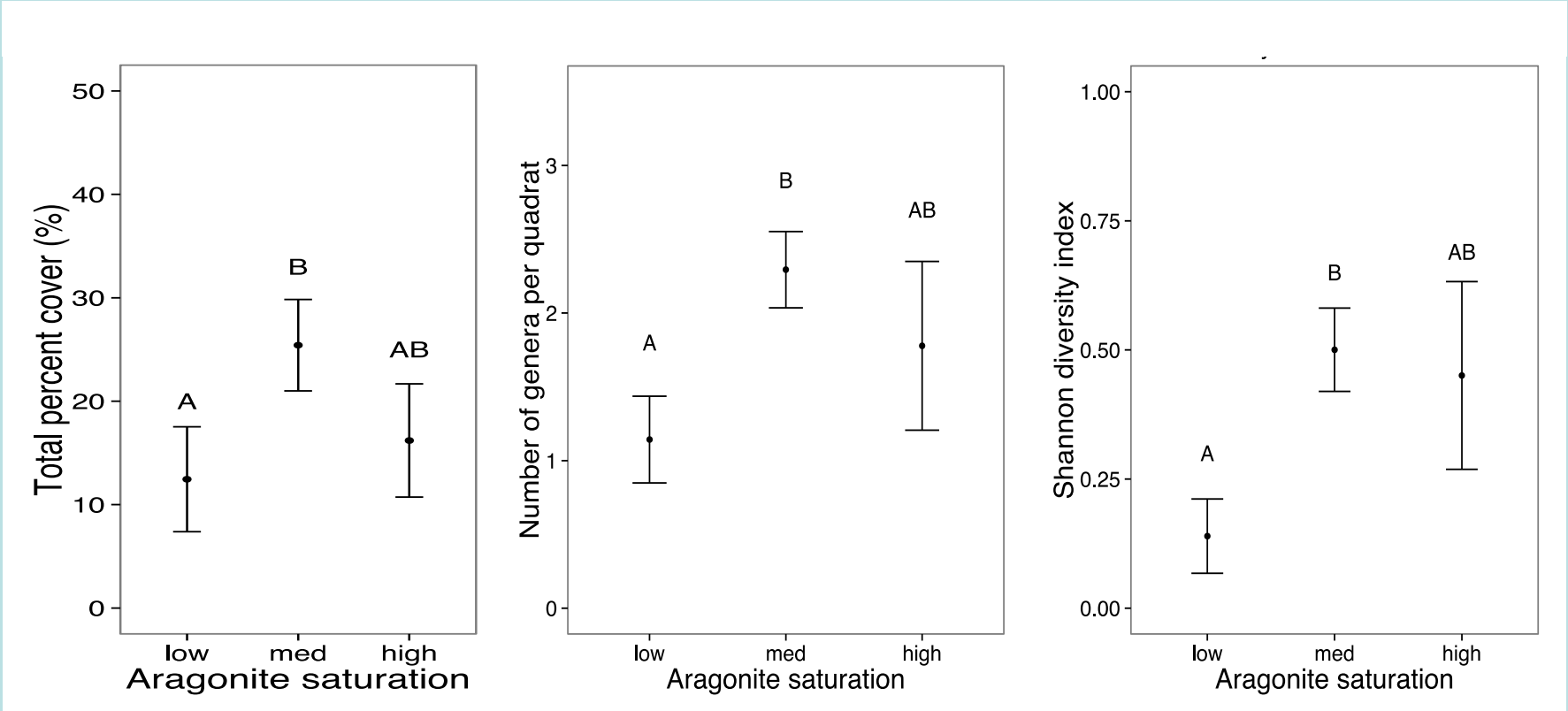


Low pH

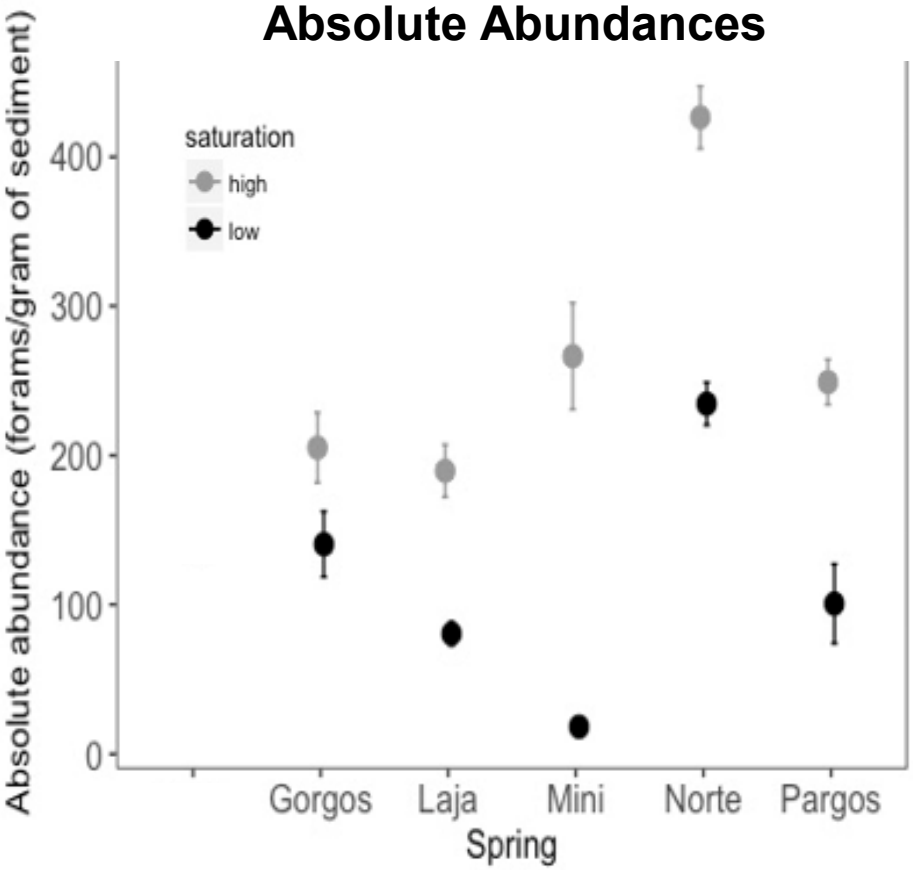
Coraline Algae

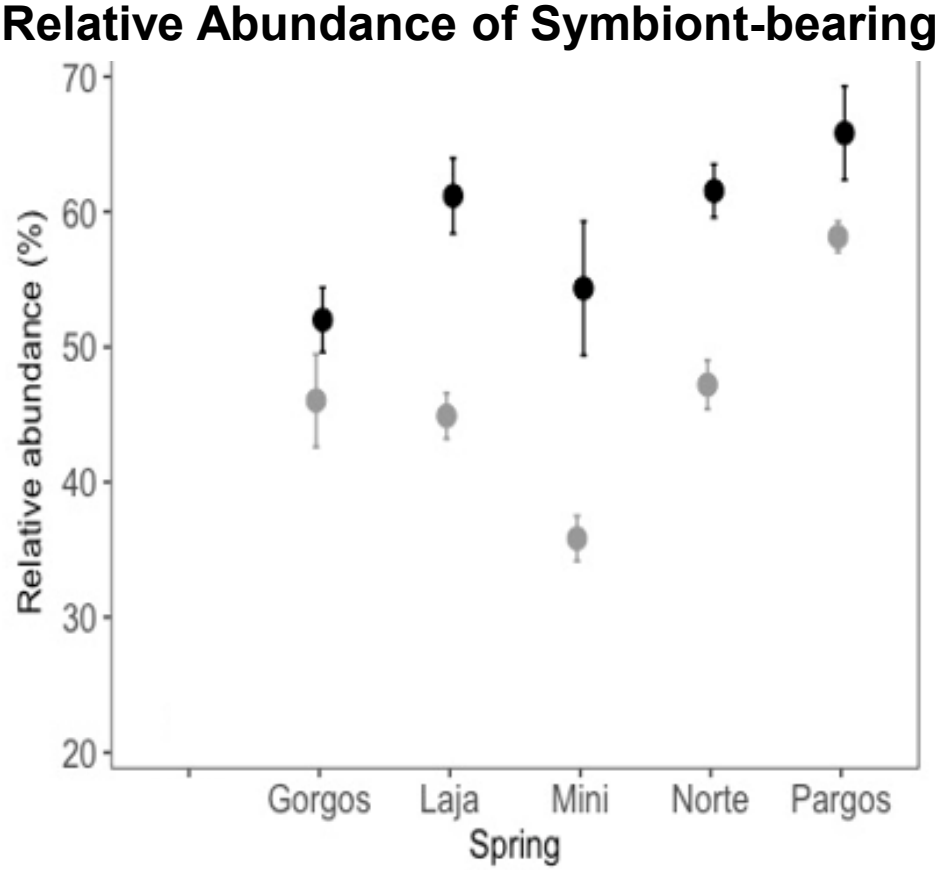
<u>Field survey</u>: underwater transects @ 5 ojos

Measured percent cover of all calcifying algae & identified to species/genus, (richness, diversity, composition and structure)



Foraminifera

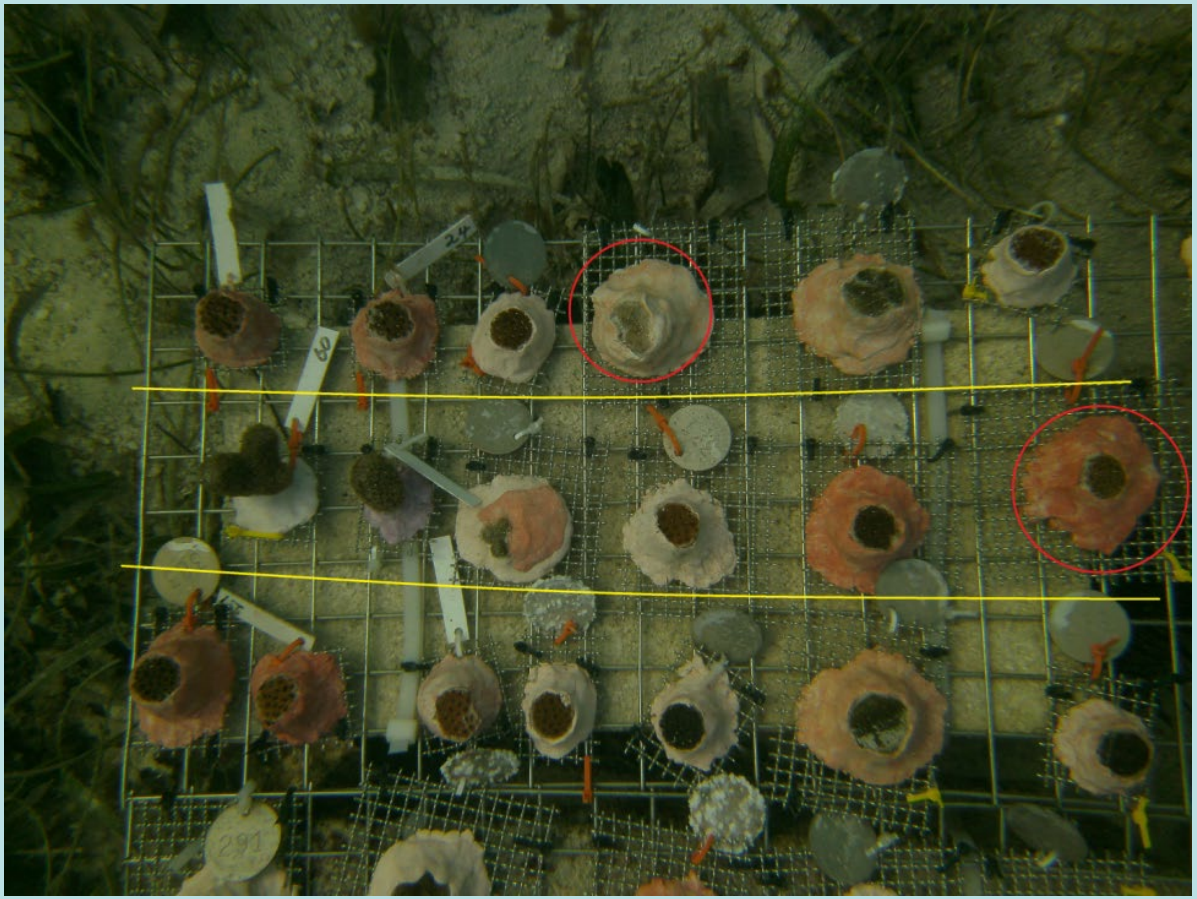


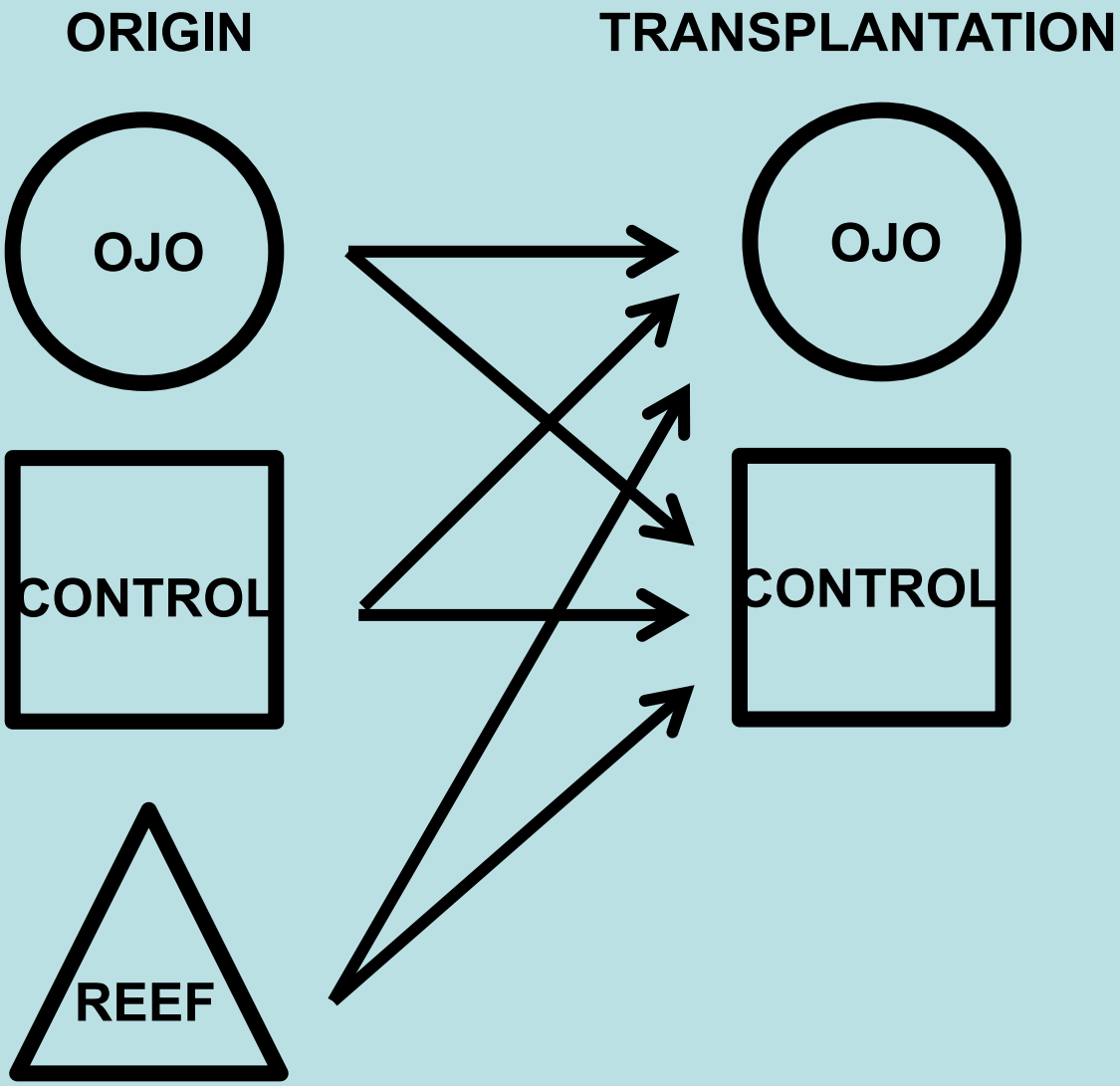


Ongoing Research

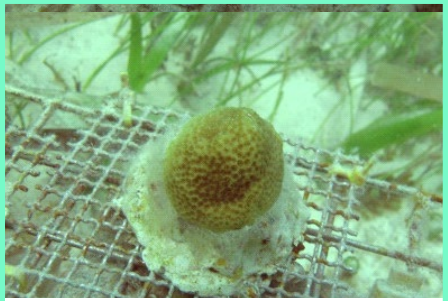
Response to ocean acidification is likely to vary across species and environments. Need to understand genetic mechanisms for calcification.

What are the prospects for adaptation?



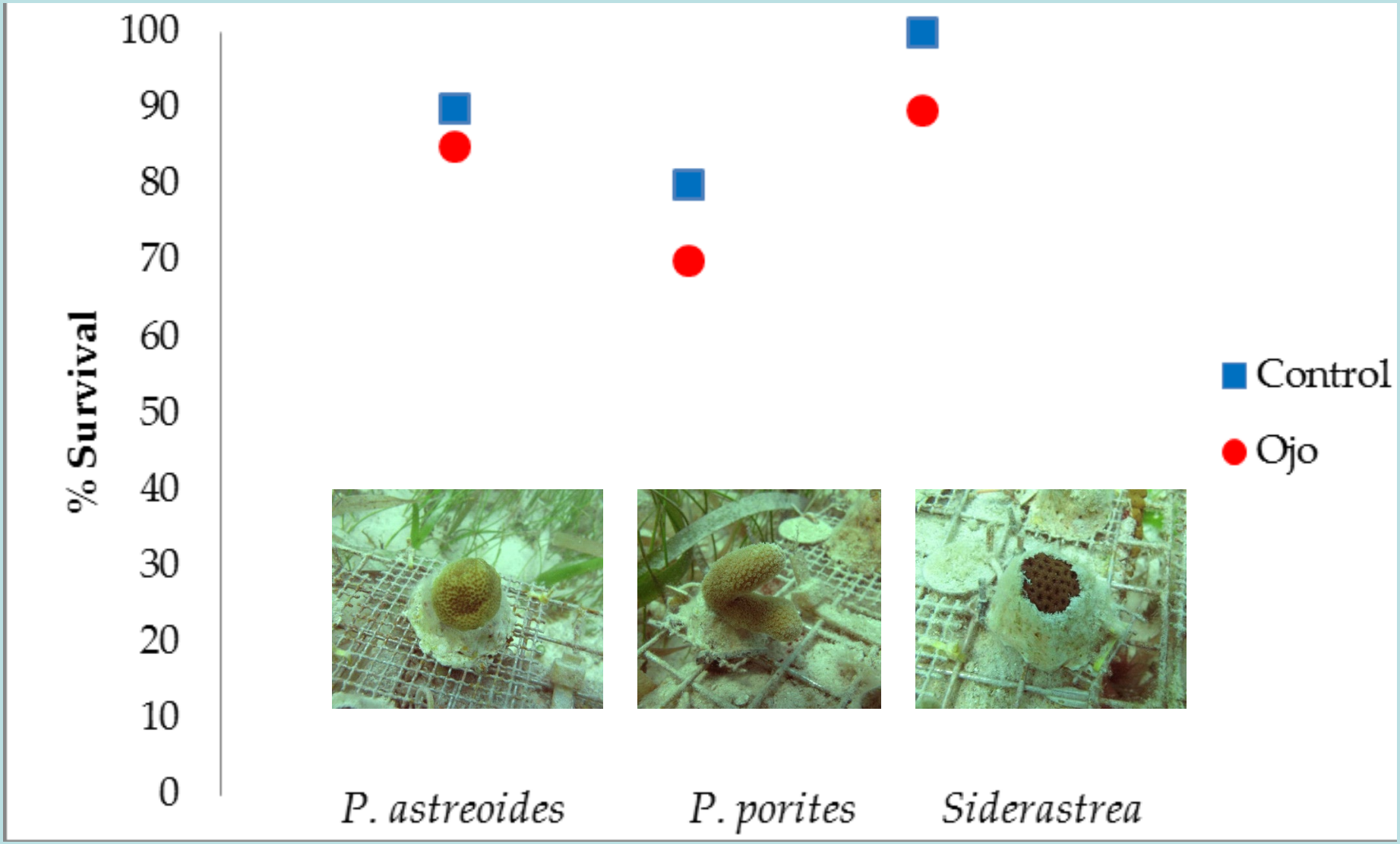


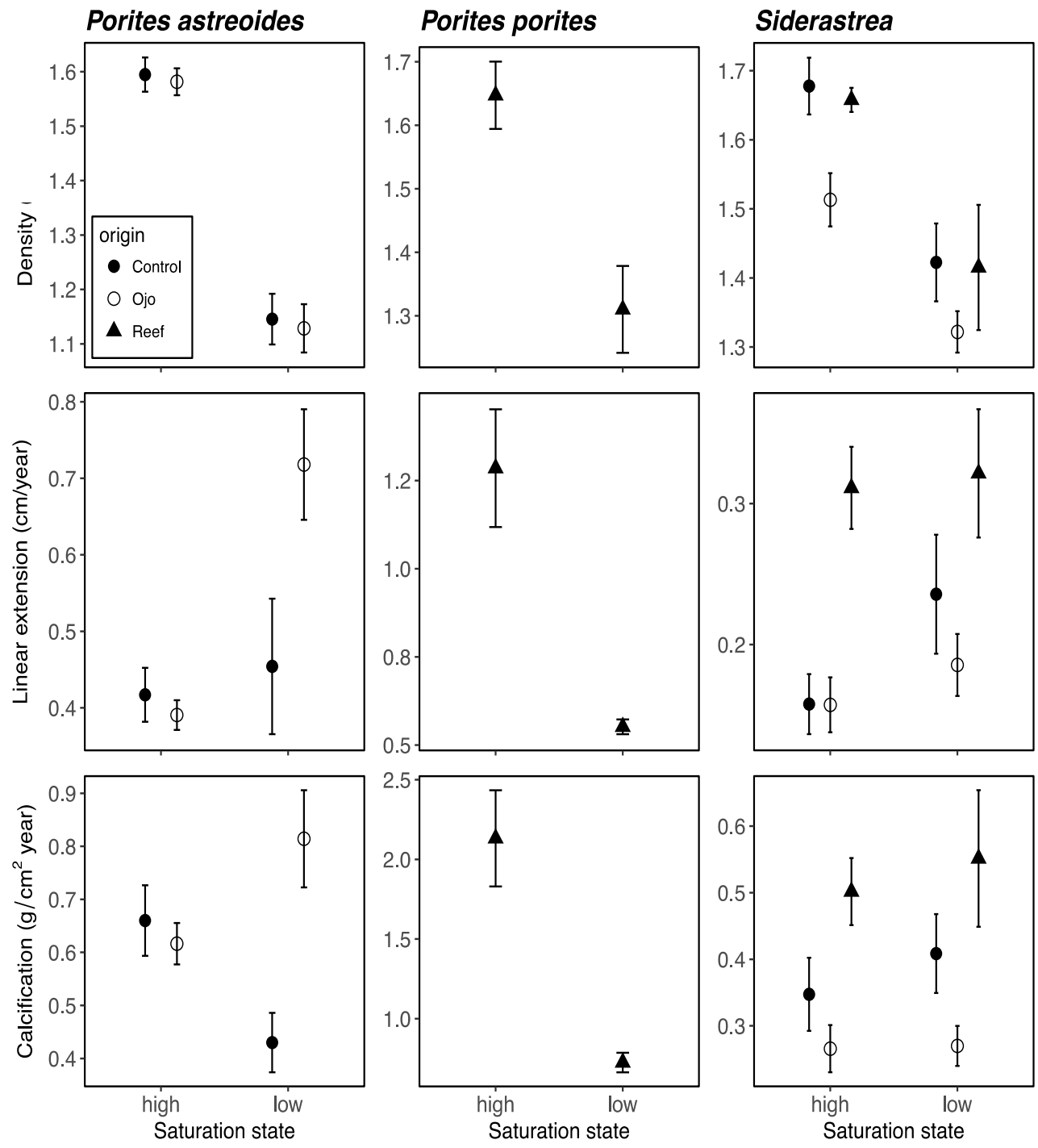
Porites porites



Porites astreoides

Siderastrea Radians

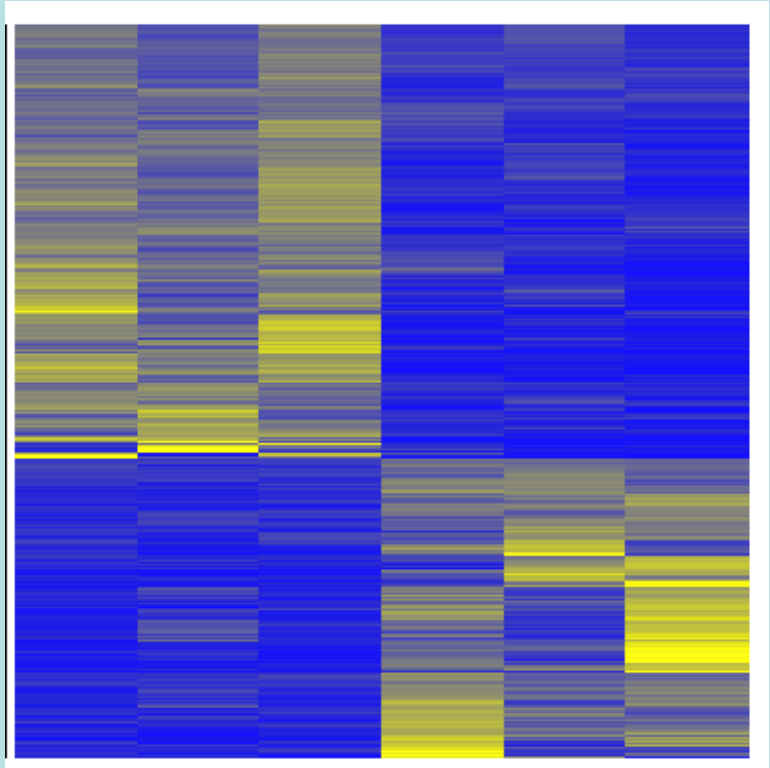

100
90
80
70
60
50
40
30
20
10
0
% Survival
Control
Ojo
P. astreoides
P. porites
Siderastrea



More symbionts
More chlorophyll
More protein

Siderastrea

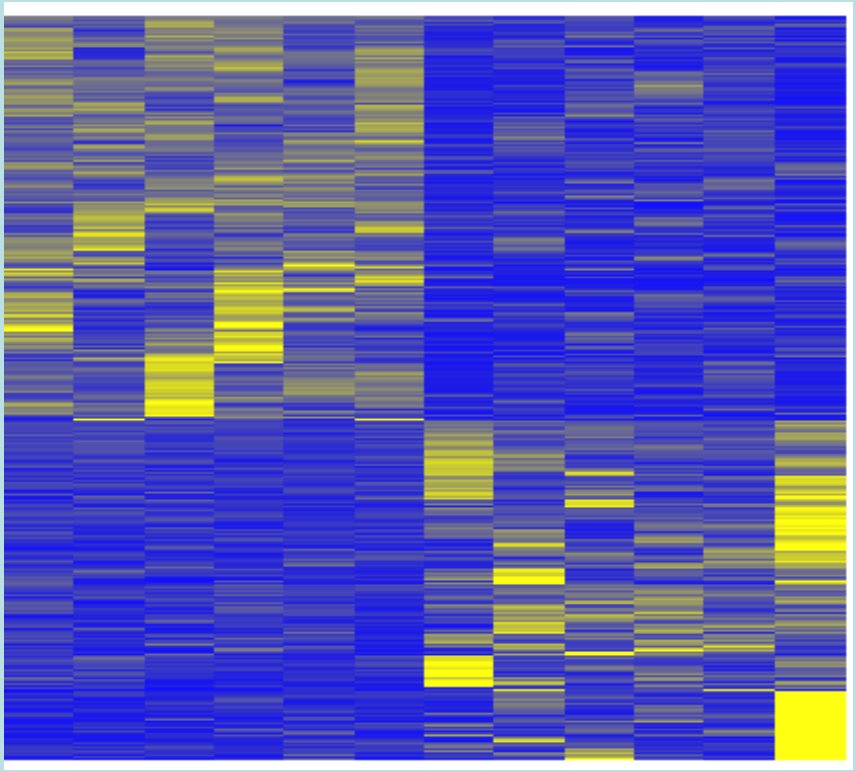
There is a significant difference in gene expression due to coral origin.



Origin Control | **Origin Ojo**

P. astreoides

There is a significant difference due to transplantation effect.



Transplantation Control | **Transplantation Ojo**

Technology

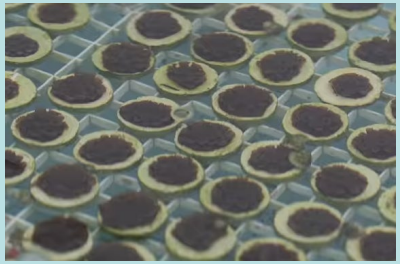
Credit: COURTESY O AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Breeding - "assisted evolution." Cross-breeding organisms for desirable traits

Hybridized - manually breeding "supercorals" capable of living in the increasingly inhospitable sea

Manipulate the bacteria and algae that live within coral

Genetic modification - Crisper



Mitigation, Conservation and Protection, Elimination of Invasive Species Enhancement by Transplantation

Value the ocean
It's the only one we have.

We were life Aquatic