Monitoring Ecological Impacts of Ocean Acidification on Coral Reefs

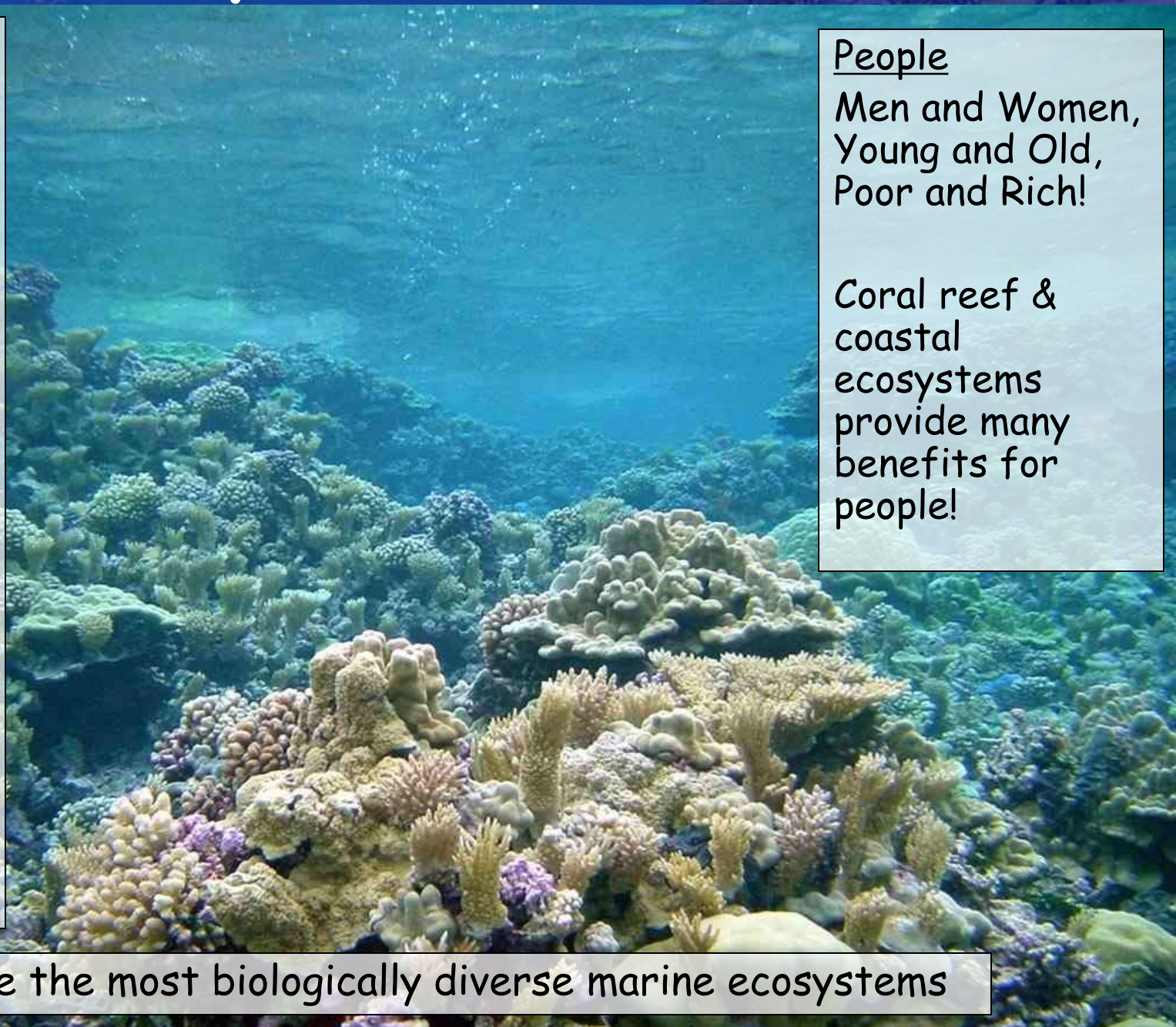
Rusty Brainard[1], C Young[2], M Timmers[2], R Feely[3], S Alin[3], A Sutton[3], A Cohen[4], T DeCarlo[4], N Price[5], J Smith[5], T Martz[5], A Andersson[5], N Knowlton[6], C Meyer[6], D Manzello[7], I Inochs[7], G Paulay[8], D Gledhill[9], L Jewitt[9], R Toonen[10], F Rohwer[11], S Khokiattiwong[12], A Chavanich[13], W Zhu[14], J Jompa[15], many others

1 NOAA Pacific Islands Fisheries Science Center, Honolulu
2 Joint Institute for Marine and Atmospheric Research, Honolulu
3 NOAA Pacific Marine Environmental Laboratory, Seattle
4 Woods Hole Oceanographic Institute, Woods Hole
5 Scripps Institution of Oceanography, Univ. California San Diego
6 National Museum of Natural History, Smithsonian Institution, Washington
7 NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami
8 Florida Museum of Natural History, University of Florida, Gainsville
9 NOAA Ocean Acidification Program, Silver Spring
10 UH-Hawaii Institute of Marine Biology, Kaneohe
11 San Diego State University, San Diego
12 Phuket Marine Biological Lab, Phuket,Thailand
13 Chulalongkorn Univ.Thailand
14 UNESCO IOC WESTPAC, Bangkok, Thailand
15 Hassanuddin Univ. Makassar, Indonesia

SIDS OA Workshop, Apia, Samoa, 28-29 Aug. 2014

Why Should We Care?

Coral reefs provide ecosystem services (**food security, livelihoods, coastal protection**, etc.) to many 100s of millions of people in the tropics worldwide, especially SIDS countries!



People

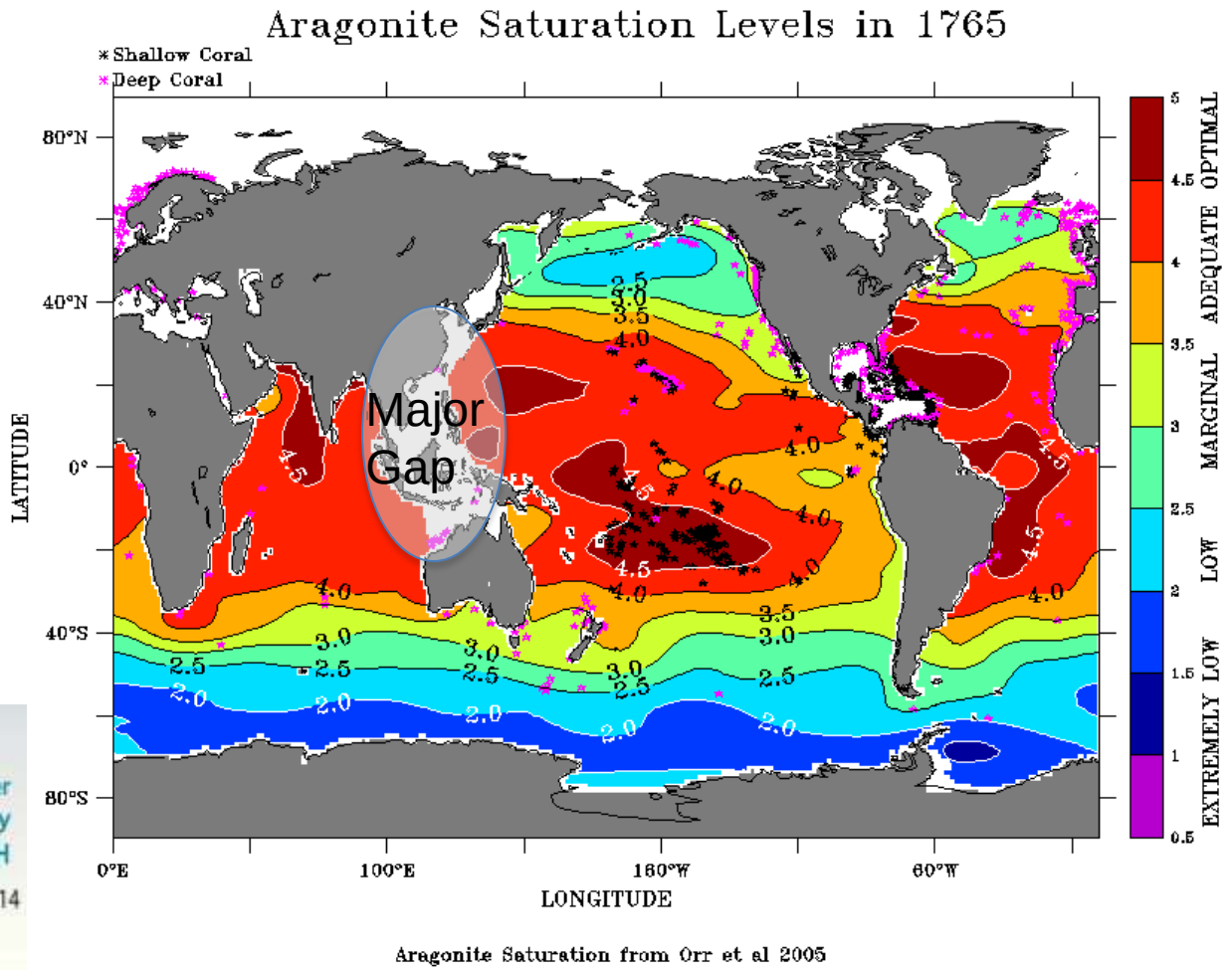
Men and Women, Young and Old, Poor and Rich!

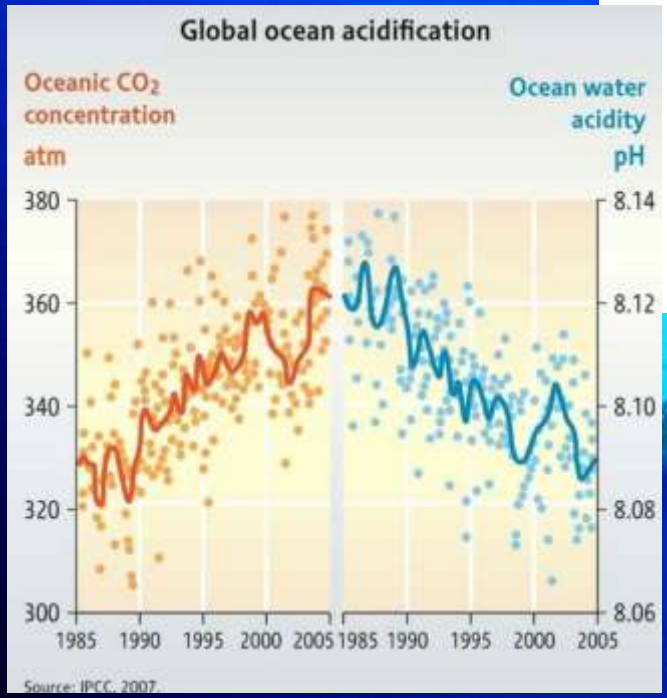
Coral reef & coastal ecosystems provide many benefits for people!

Coral reefs are the most biologically diverse marine ecosystems

Coral calcification

- 1765 **Adequate**
- 2000 **Marginal**
- 2100 **Low**



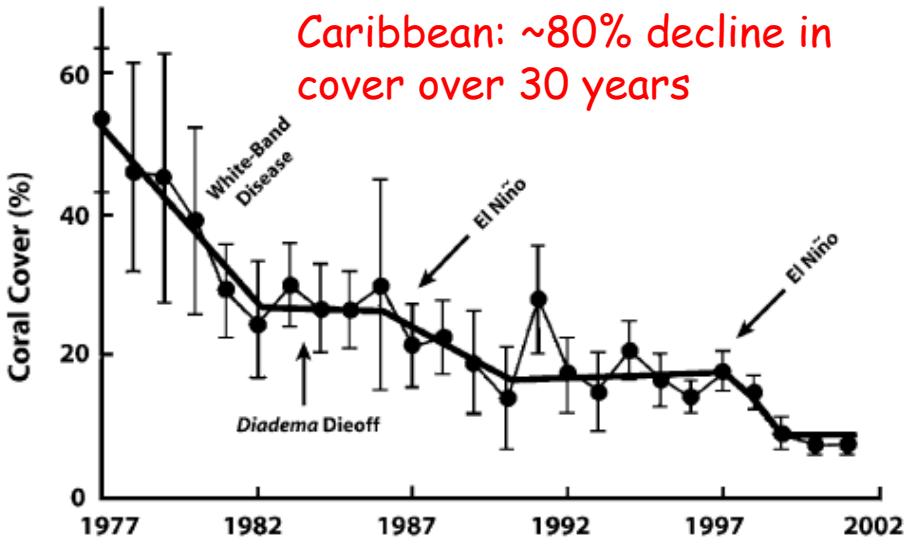


Ocean Acidification is not just a theory, it's happening now

Coral Reef Ecosystems

- Reef-building corals & calcareous algae provide the foundational 3-dimensional habitat structures supporting this rich biodiversity

- Coral reefs are declining worldwide due to multiple stressors, including warming, overfishing, pollution, disease, ocean acidification.



From Gardner et al. (2003)

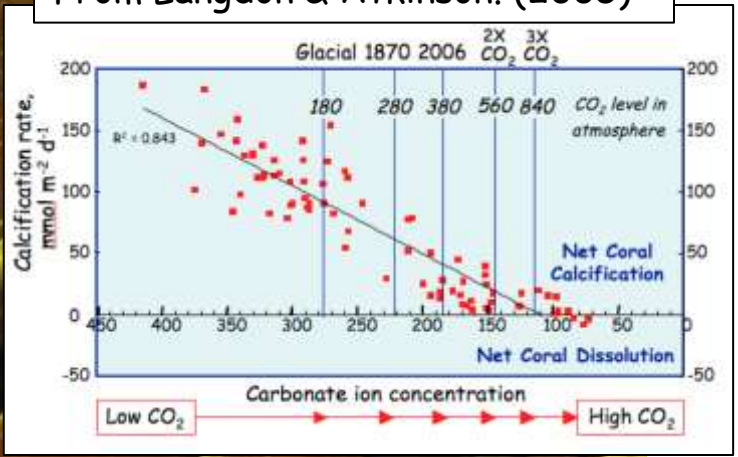
Great Barrier Reef – 50% decline in coral cover over the past 26 yrs.
De'ath et al. (2012)

Calcification/Recruitment

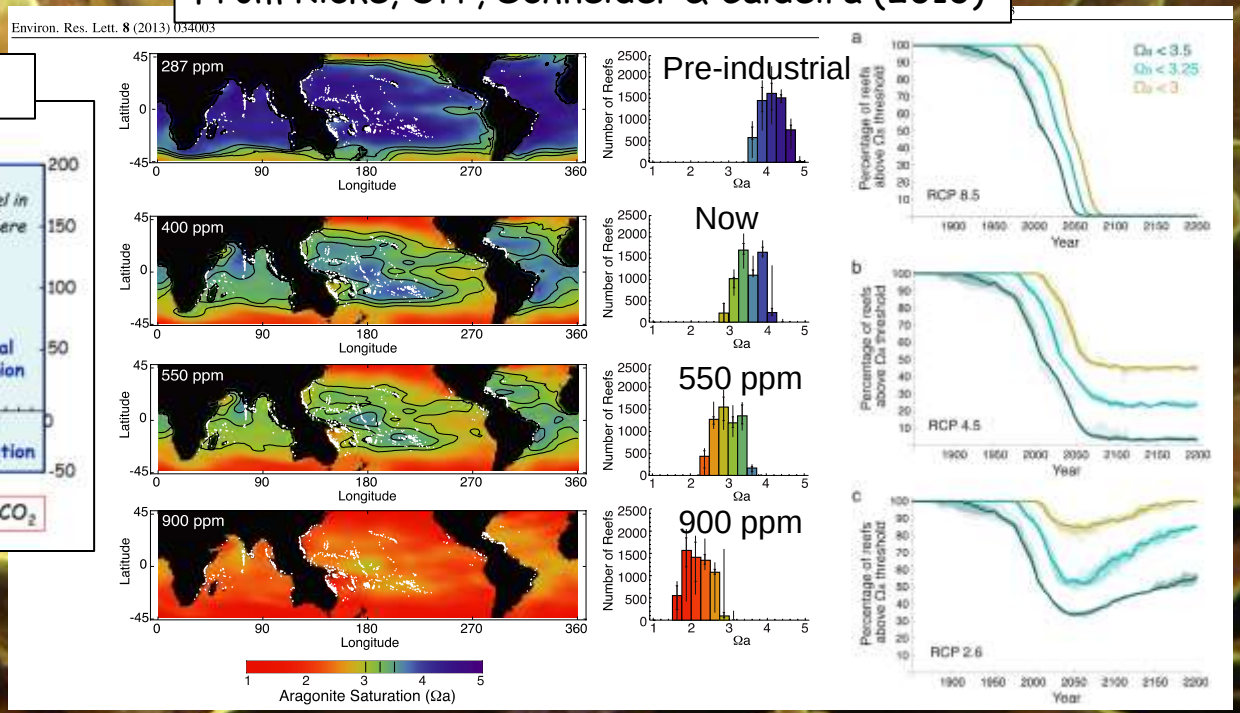
- Experiments/models have shown corals and reef-building crustose coralline algae are highly vulnerable to OA:
  - Reduced calcification/growth
  - Reduced settlement/recruitment

- Will this happen in nature? Or,, does nature provide more resilience? → need long-term global observations

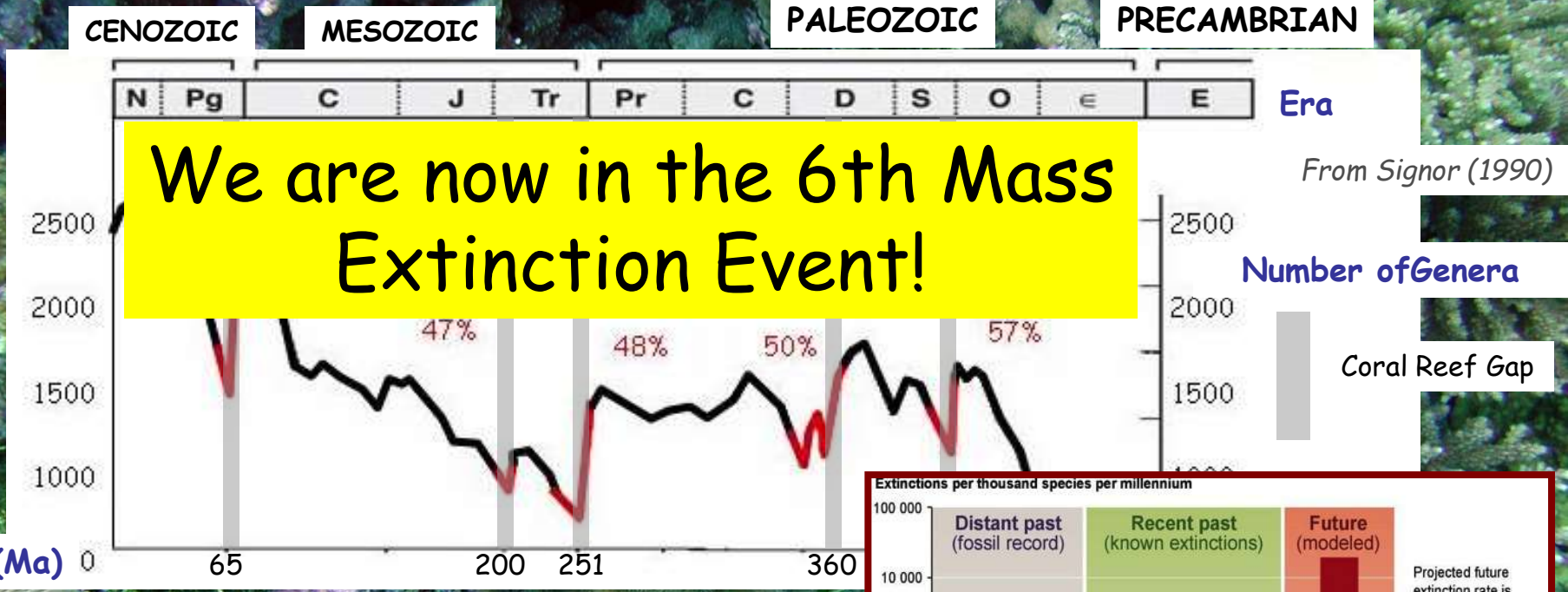
From Langdon & Atkinson. (2005)



From Ricke, Orr, Schneider & Caldeira (2013)



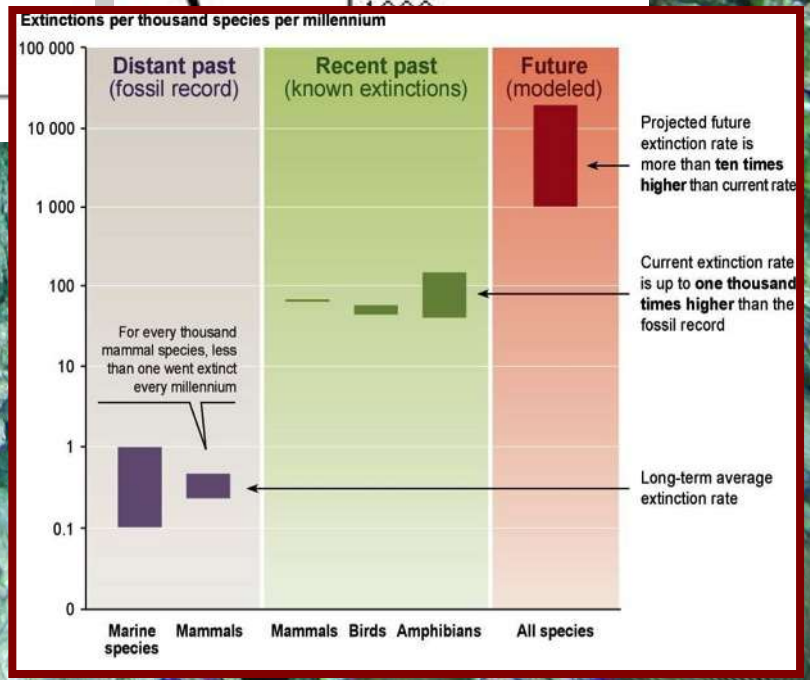
Biodiversity Loss



We are now in the 6th Mass Extinction Event!

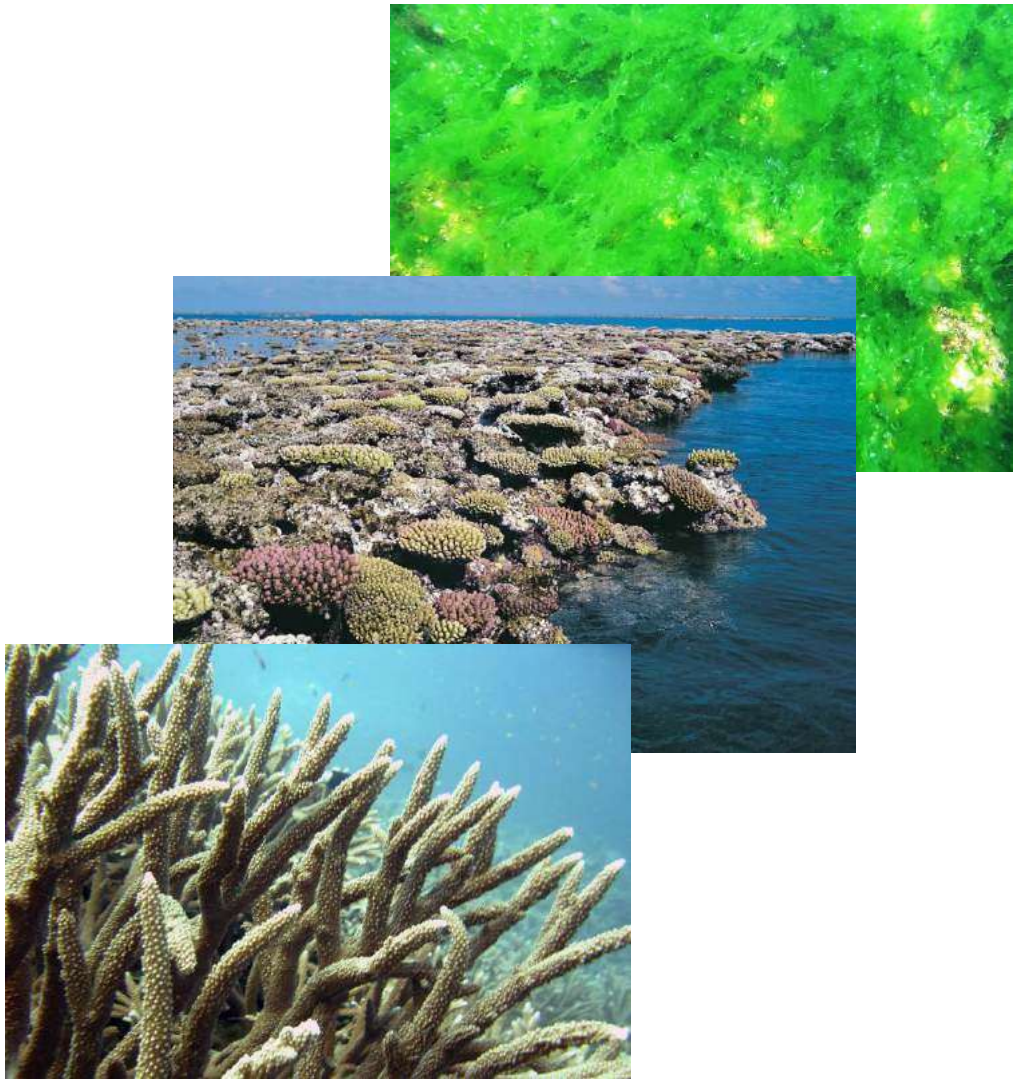
- Extinction rates have already increased ~100X
- Predicted to increase >100X over next century

→ Lost Resilience?
→ lost function?
→ lost ecosystem services?



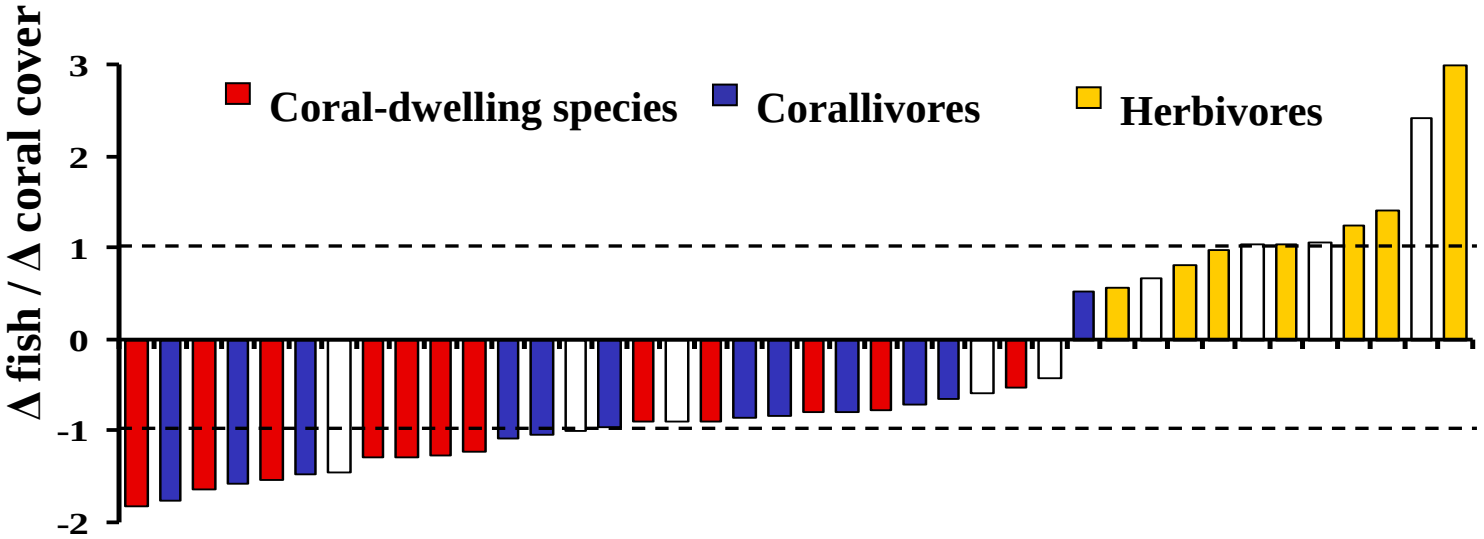
Who will be impacted?: *Not all species respond the same to reduced seawater pH*

- Species that are fleshy and CO_2 limited may **thrive**
- Species that currently live in highly variable environments may be **best adapted**
- Species that calcify, are sessile, and are taxonomically ‘simple’ may **not survive**



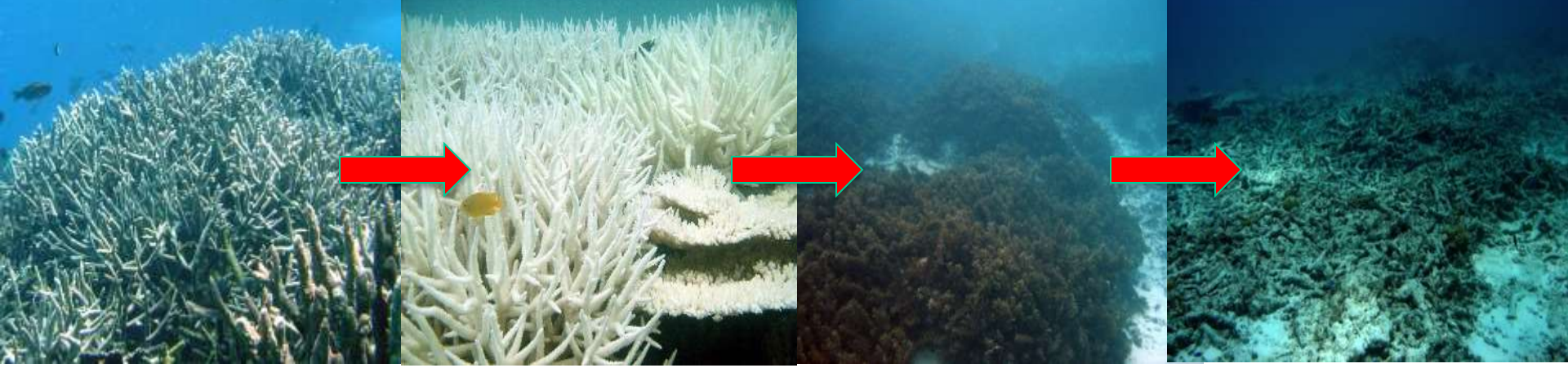
Coral loss

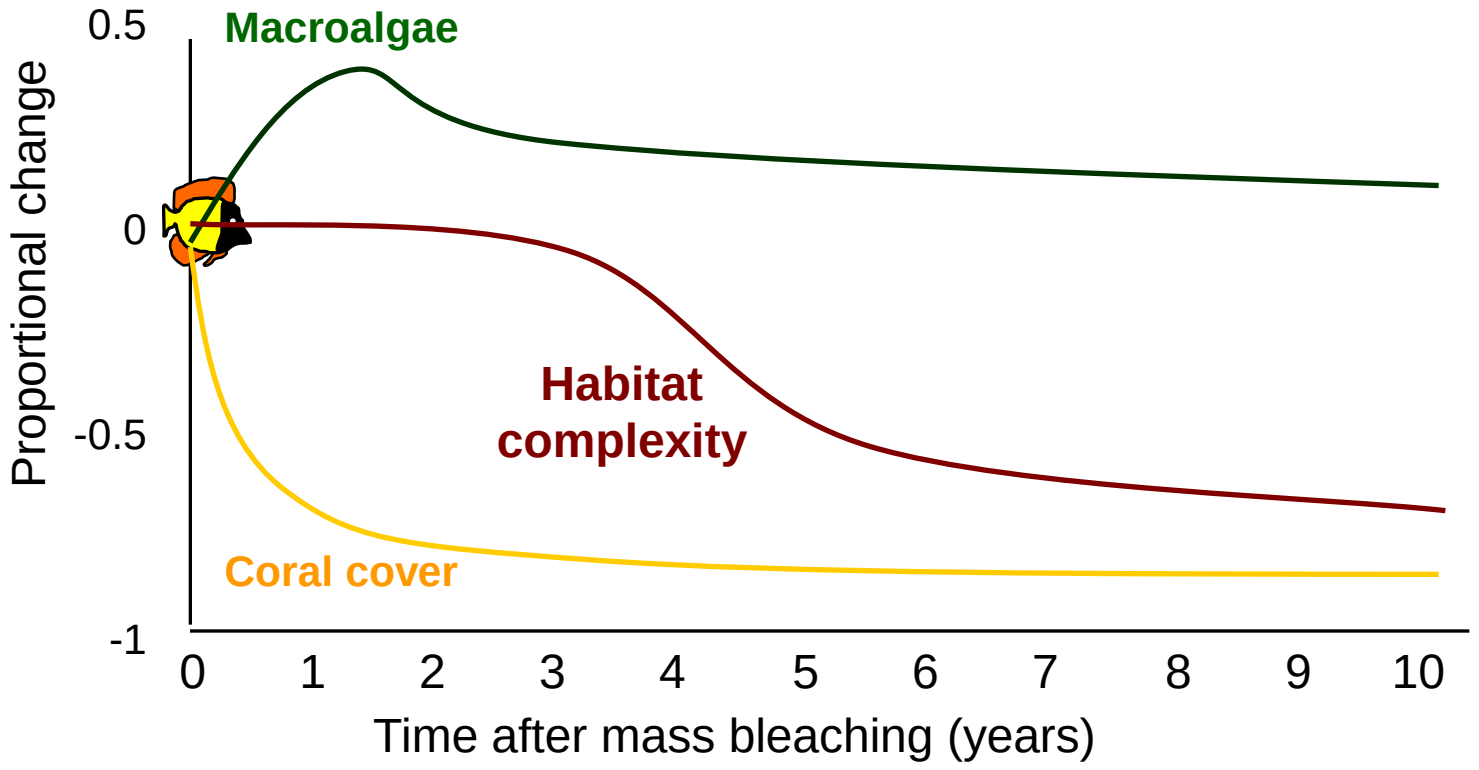
- 10 % of coral reef fishes are coral dependent, so directly affected by coral loss
- But, 75% of fish species declined following coral decline
- 50% of fish species declined by >50%



Slide courtesy Phil Munday

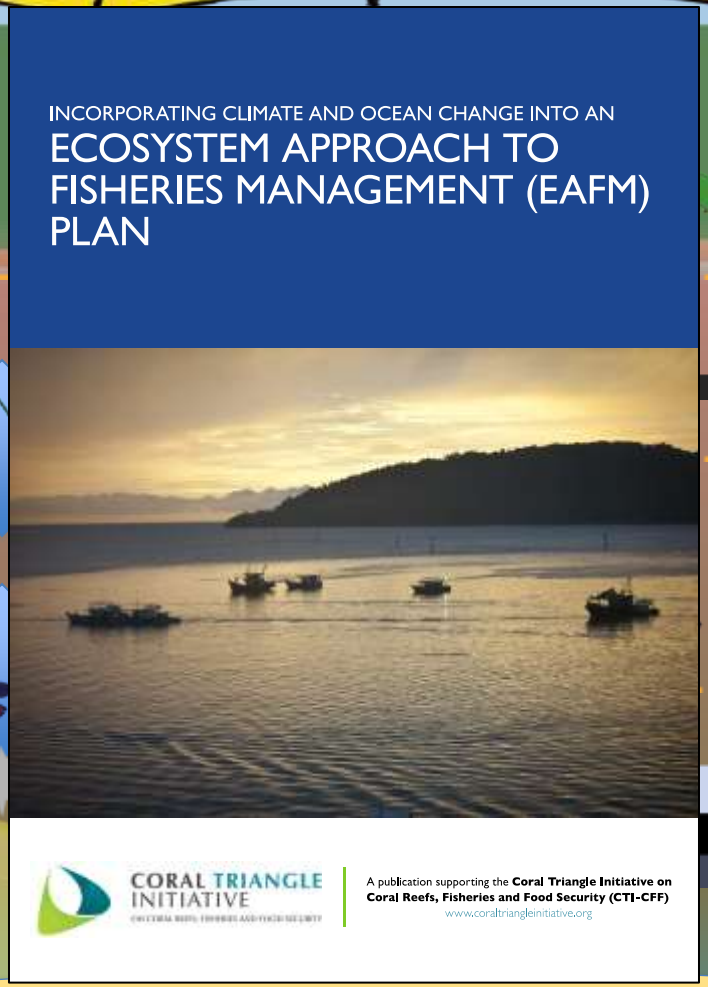
Wilson et al. 2006 Global Change Biology 12, 2220-2234





Slide courtesy Phil Munday

Example:
Ecosystem-Based Management (EBM) or EAFM



Vertical Integration

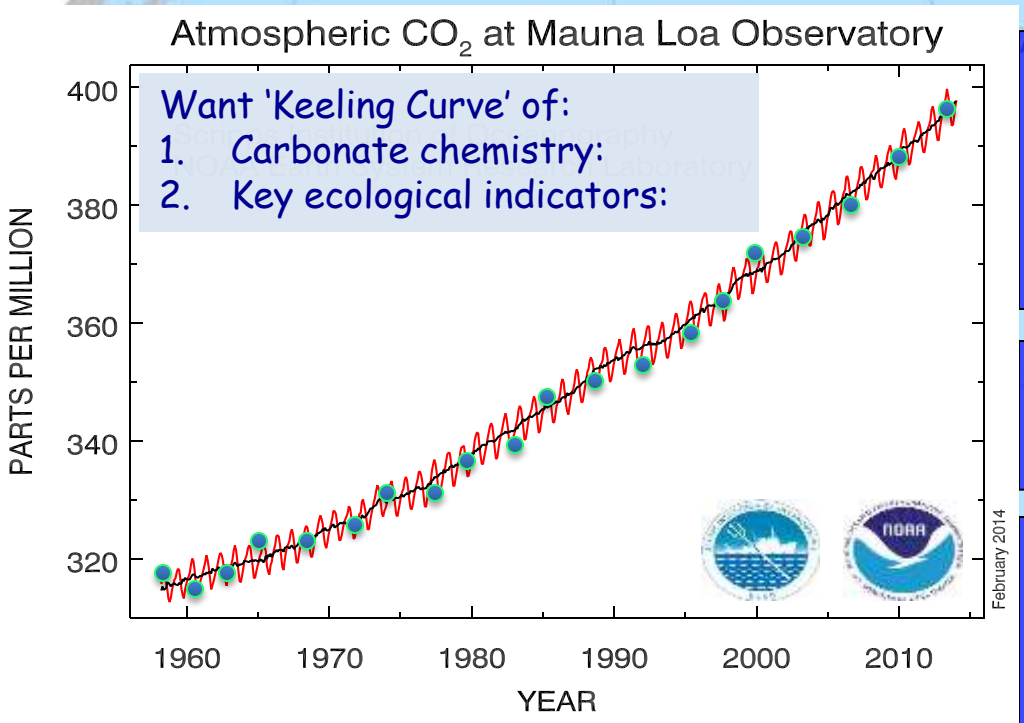
EAFM and EBM need to take into account ocean acidification (and climate change) because it will effect all aspects of the marine ecosytems.

Rusty Brainard - NOAA

Monitoring Ecological Impacts of OA Pacific RAMP

Establishing baseline observations to monitor long-term changes of:

- Carbonate chemistry DIC, TA, S → pH, Ω
- Calcification rates (Coring, CAUs)
- Bioerosion rates (BMUs)
- Crytobiota diversity (ARMS)

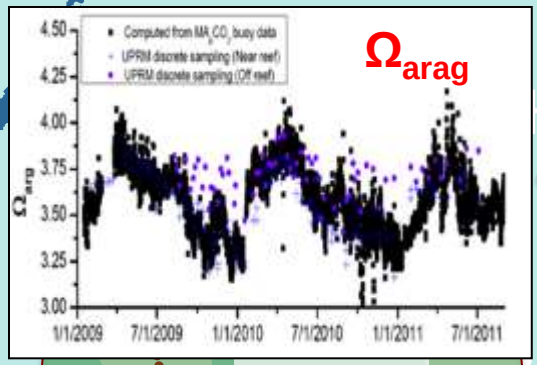


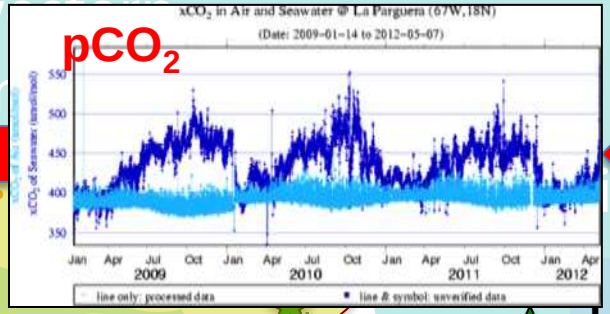
- Microbial diversity (environmental water sampling)
- Benthic rugosity
- Benthic & Fish diversity & abundance

→ Spatially distributed, consistent, repeatable, long-term observations of key indicators to robustly document changes in natural coral reefs attributable to OA

Pacific Reef Assessment & Monitoring Program (Pacific RAMP)

Broad spatial coverage (wide-but-thin) stratified random design





U. S.

Northwestern Hawaiian

Pacific Remote Island Areas

Philippines

Indonesia

Equator

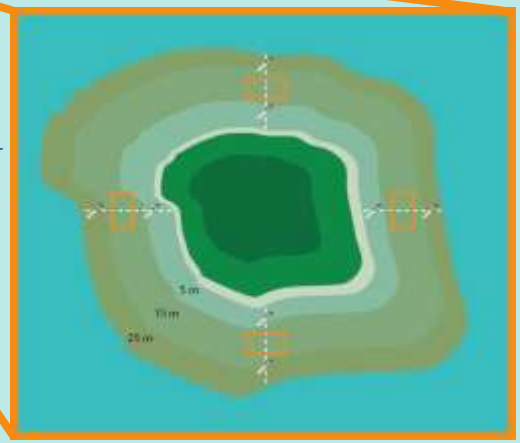
Papua New Guinea

Timor Leste

American Samoa

- Level 3 – MApCO2/Other
- Level 2 – Partial
- Level 1 – Partial

2015



Observing across gradients of environmental conditions, biodiversity, human impacts

Island-scale Survey Design

Sampling for DIC, TA, T, S, Chl *a*, nutrients, microbes.

- Surface & Reef
- Onshore-offshore
- 3-year sampling
- Derive pH, Ω, NEC, NEP

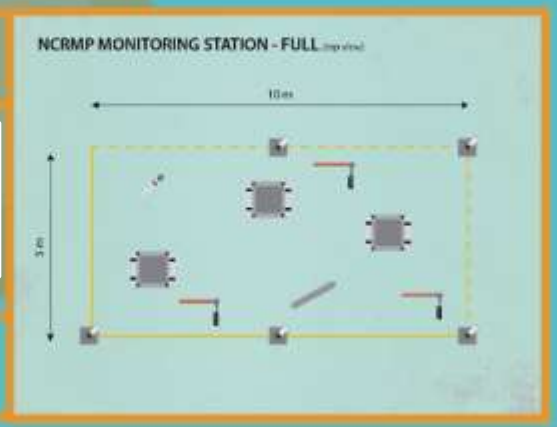
Upstream DIC/TA sampling

5 m

15 m

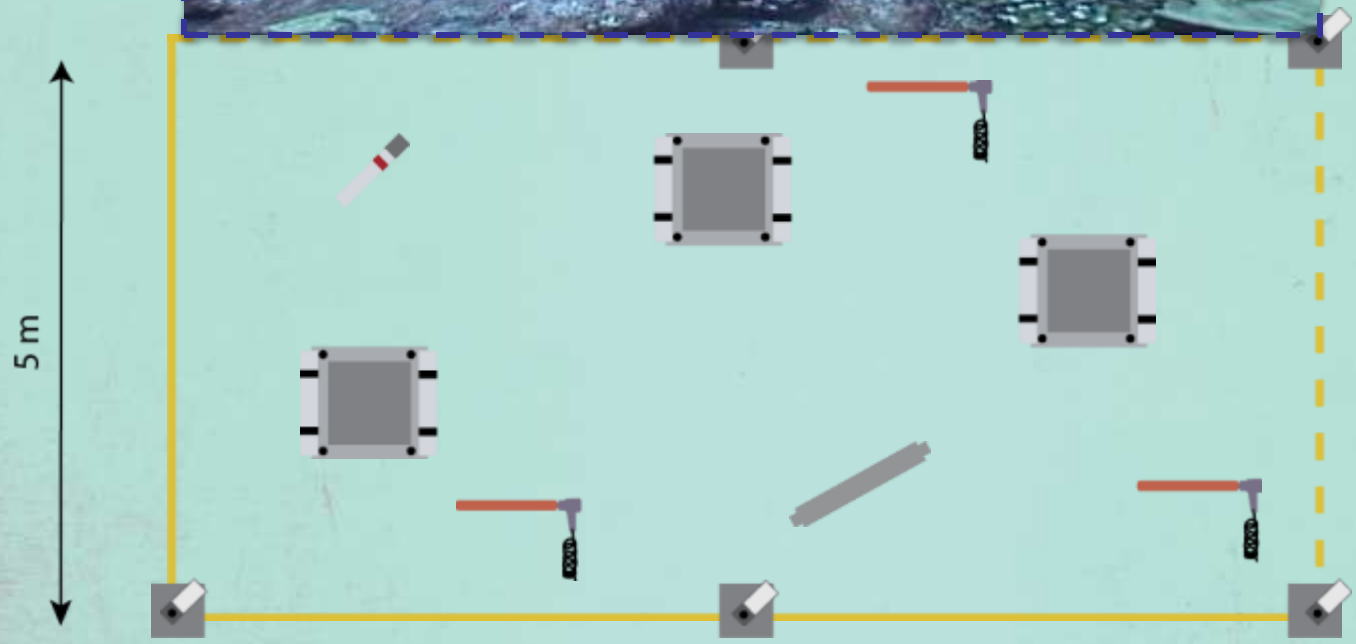
25 m

STR Transects



NCRMP Monitoring Station - Full

NCRMP



STR

ARMS

CAU

BMU

Photoquad

Topographic Complexity

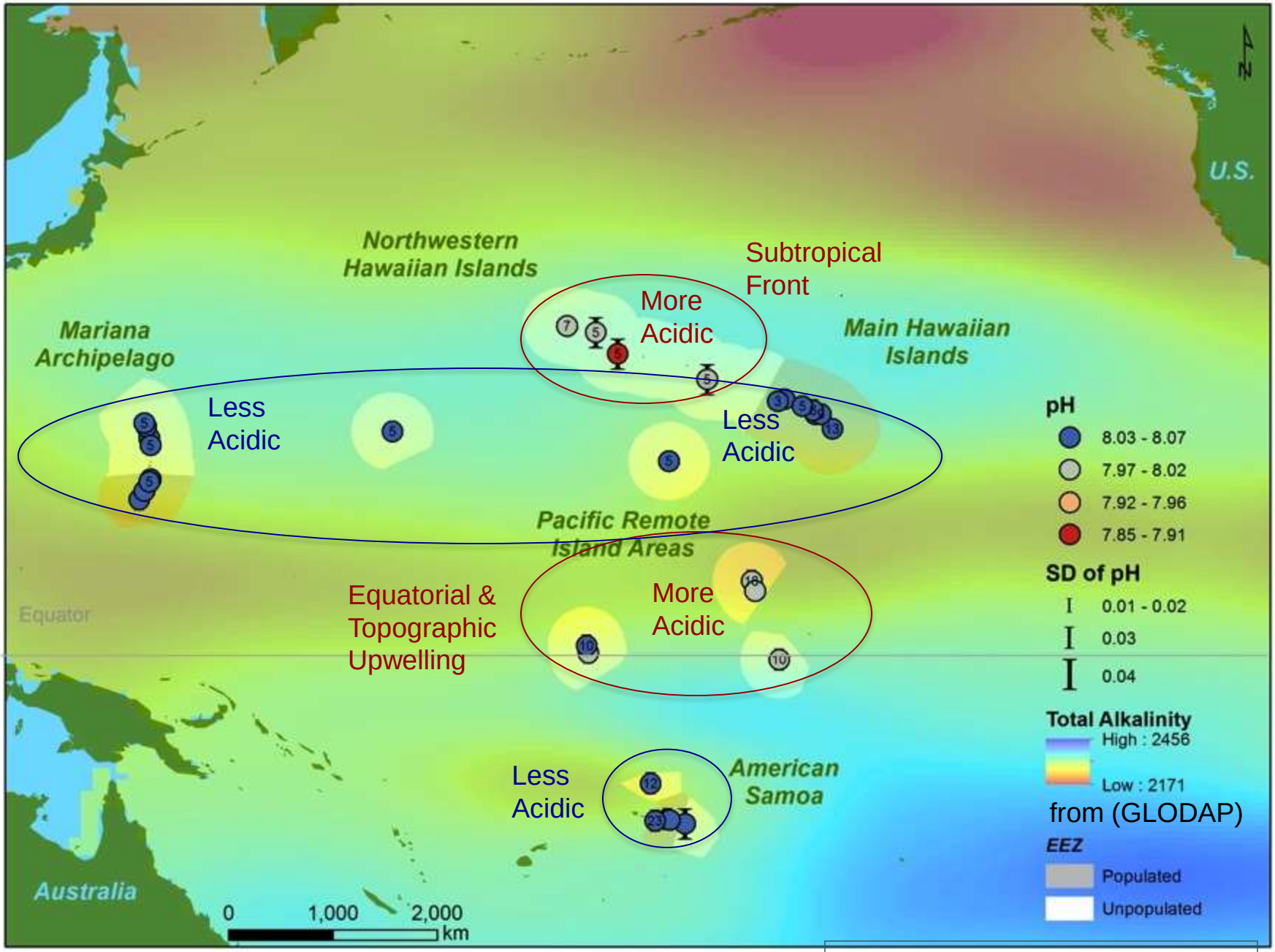
Water Sample

CTDs

Coral Coring

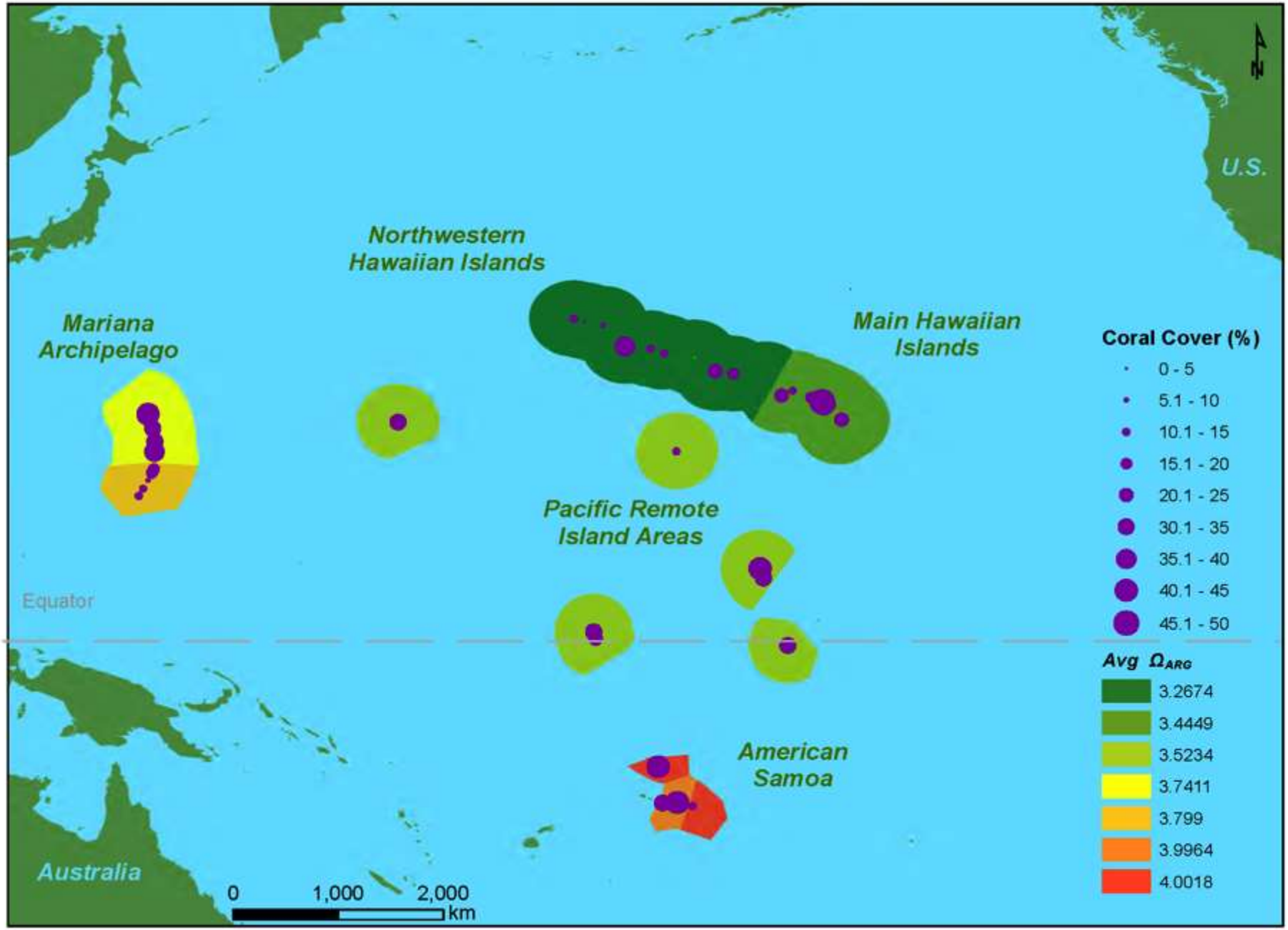
Site-scale Sampling Design

Mean Reef pH

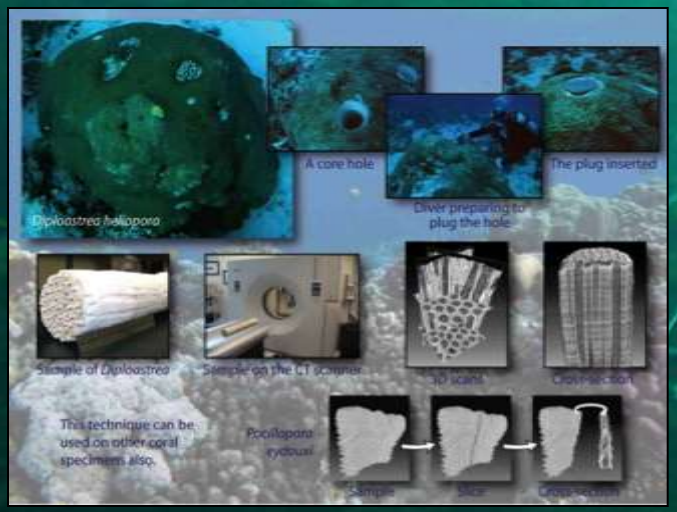


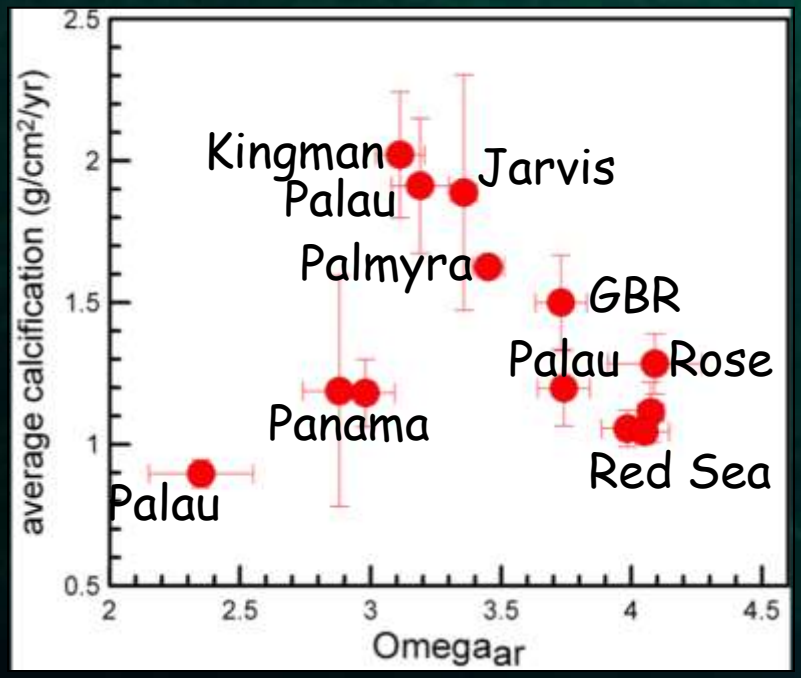
Chip Young et al. (in prep)

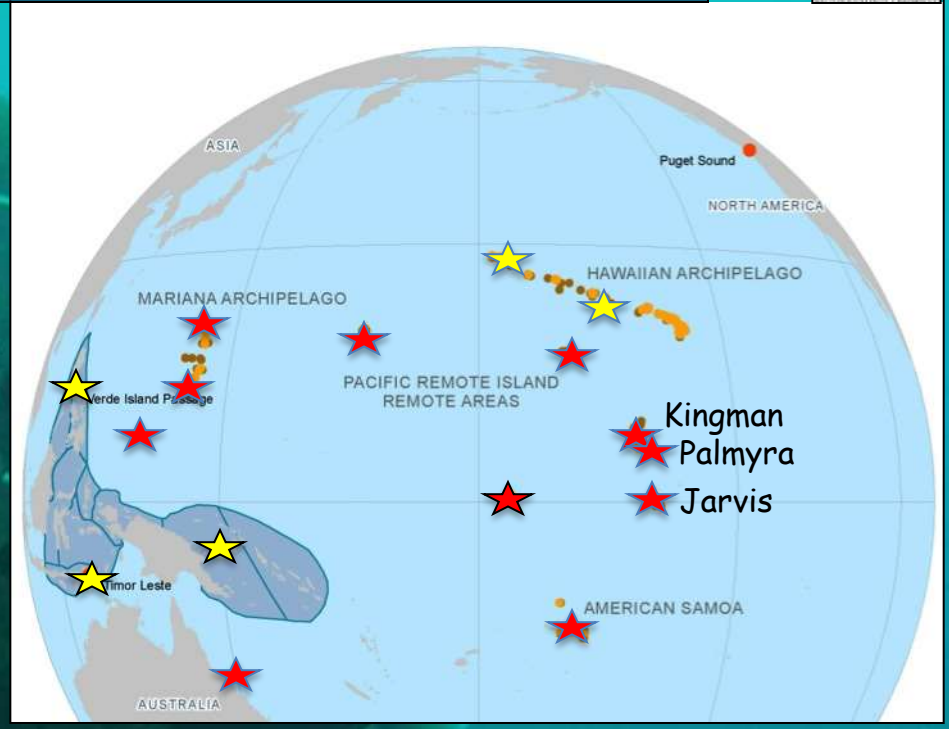
Coral Cover over Average Aragonite



Coral Calcification Rates





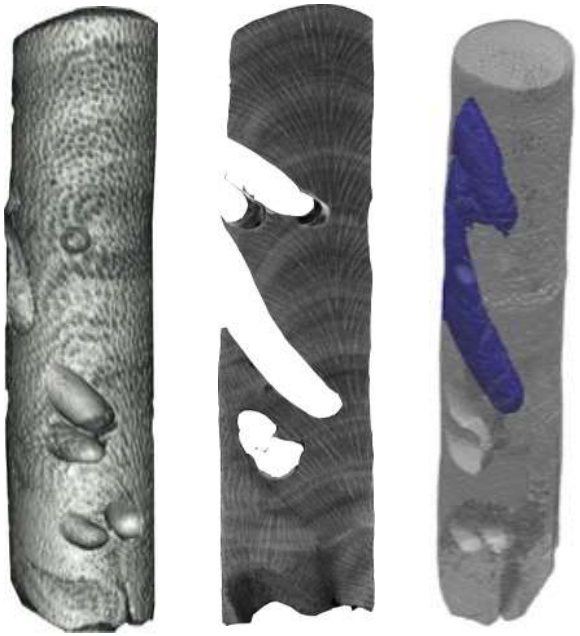


- Calcification rates of massive reef-building corals not a function only of saturation state.
- Also a function of food supply provided by upwelling.

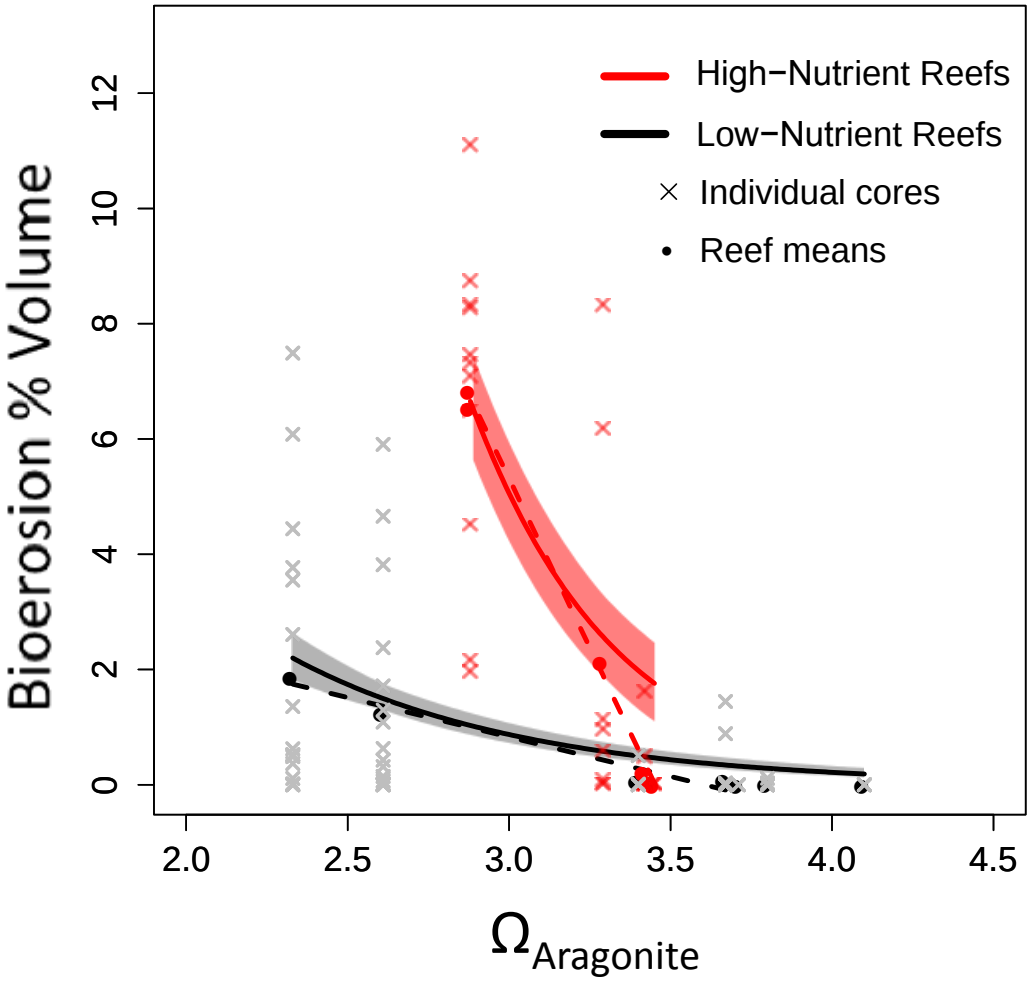
With Anne Cohen's Lab WHOI

Coral Bioerosion is Higher at Low Saturation State & High Nutrients

A core of skeleton is removed from a live coral (above) and CT scanned (below)



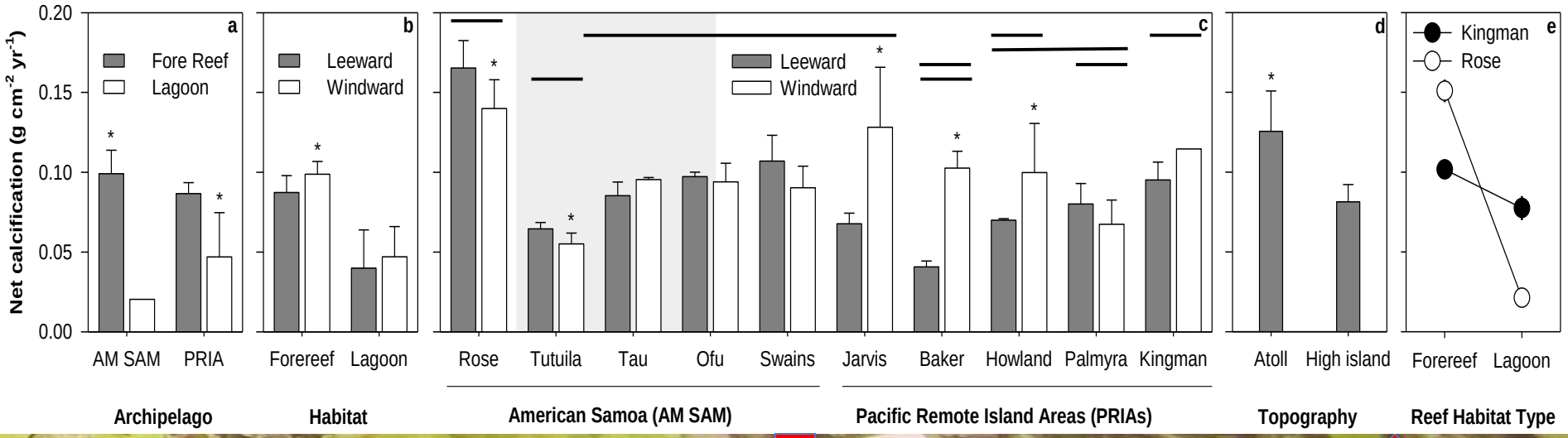
surface slab 3D

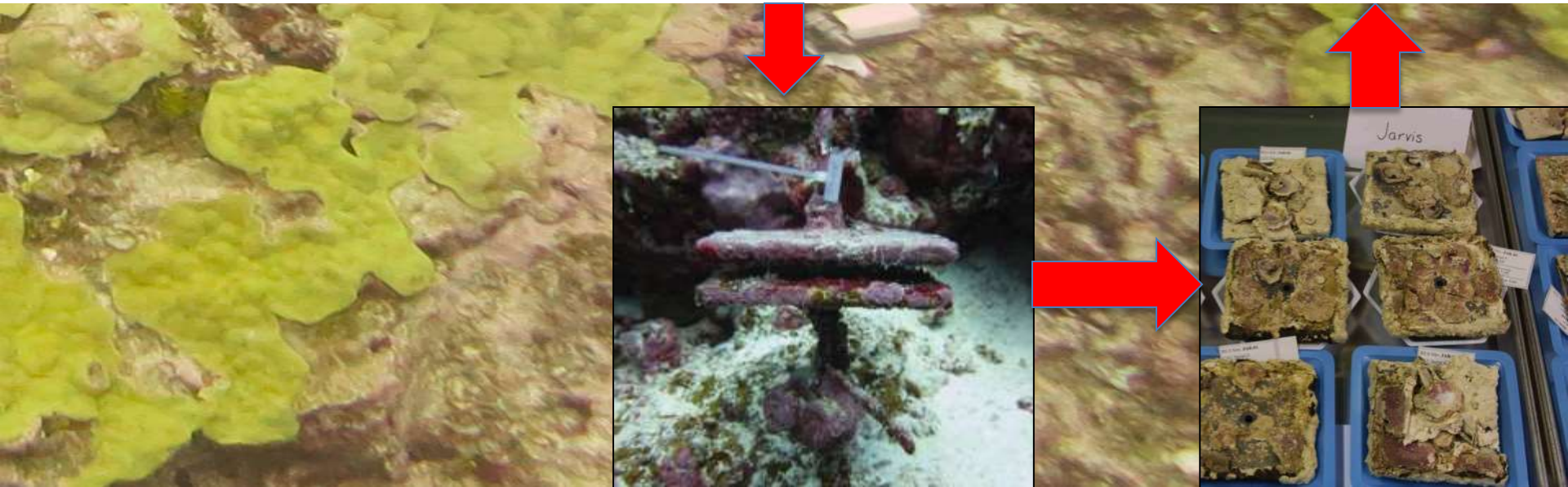


Cohen Lab, Woods Hole Oceanographic Institution

DeCarlo *et al.* (in review) *Nature Climate Change*

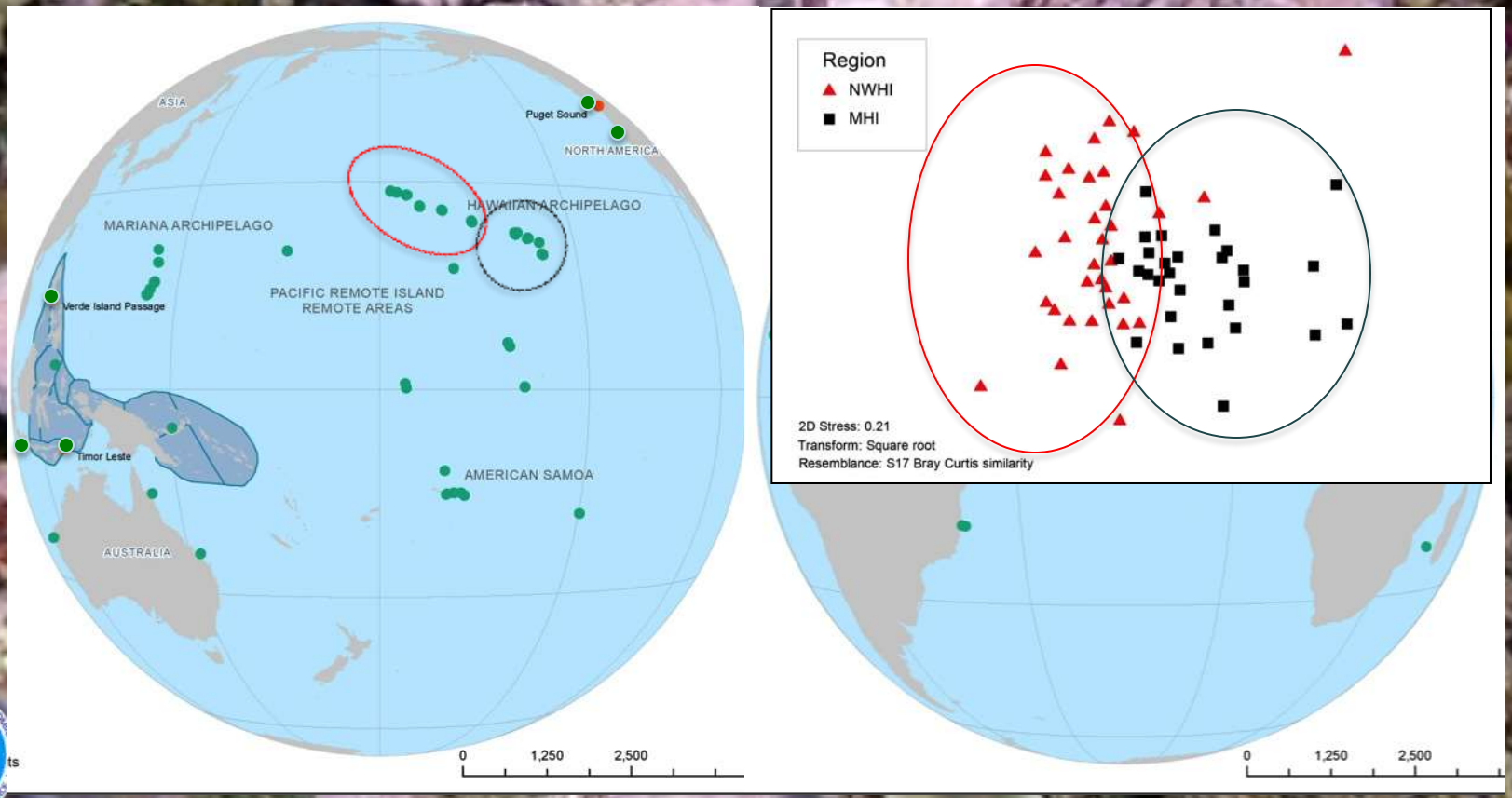
Calcification Accretion Units (CAUs)
Bioerosion Monitoring Units (BMUs)





Biodiversity Shifts: ARMS

Autonomous Reef Monitoring Structures (ARMS) are a systematic tool to assess and monitor changes in indices of biodiversity. On-going development of both taxonomic and genetic analytical approaches to robustly detect biodiversity shifts.



Conclusions

- Ocean Acidification will increasingly impact marine ecosystems, coral reefs, fisheries, coastal protection & communities in the SIDS countries!

- Need simple, consistent/systematic, **cost-effective** time series observations of both physical/chemical & key ecological parameters of coastal & coral reef ecosystems to inform policy & resource management decisions.

→Urge SIDS countries to collaborate and join GOA-ON to obtain standardized observations!

Rusty.Brainard@noaa.gov 808-725-5419