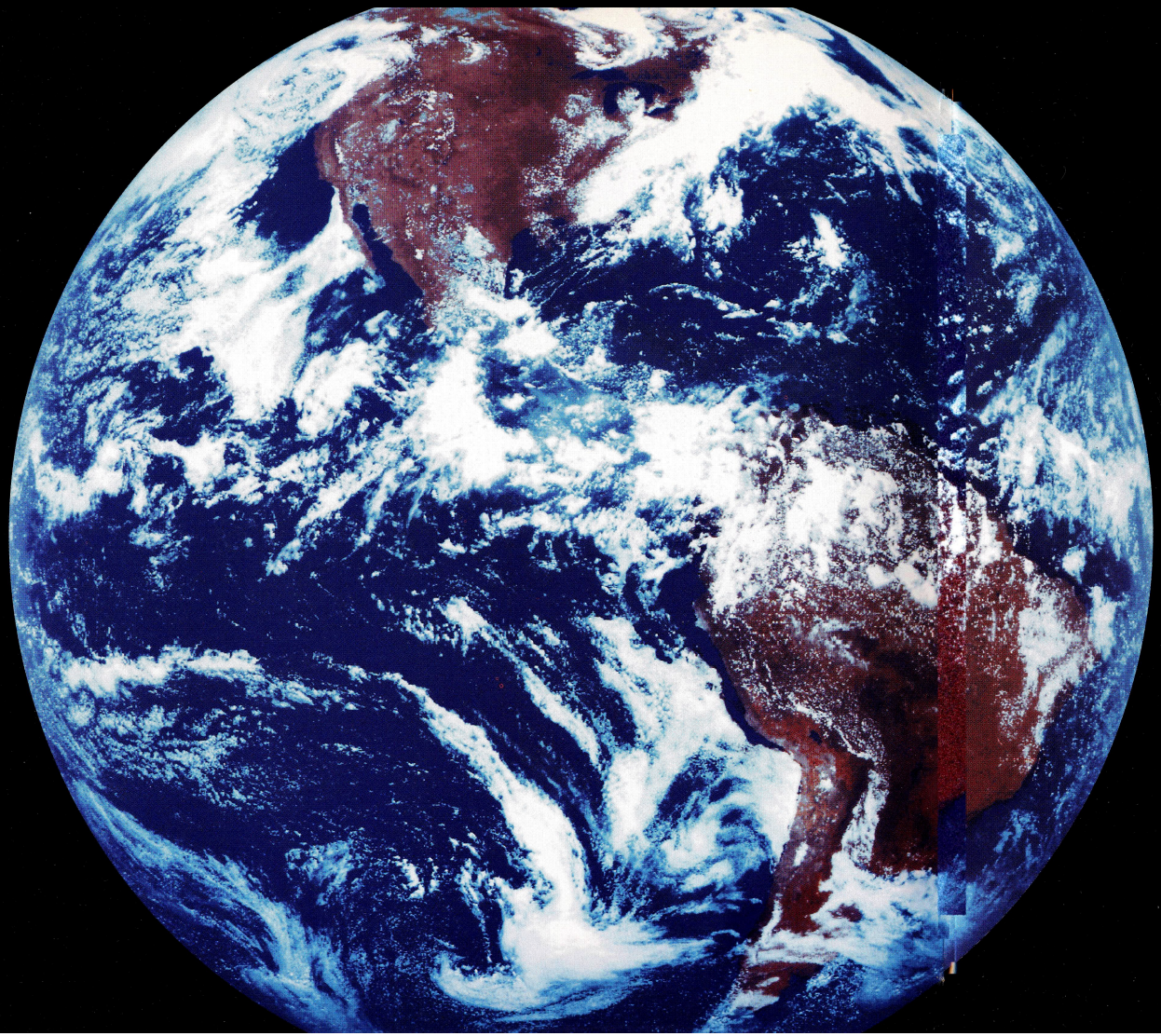
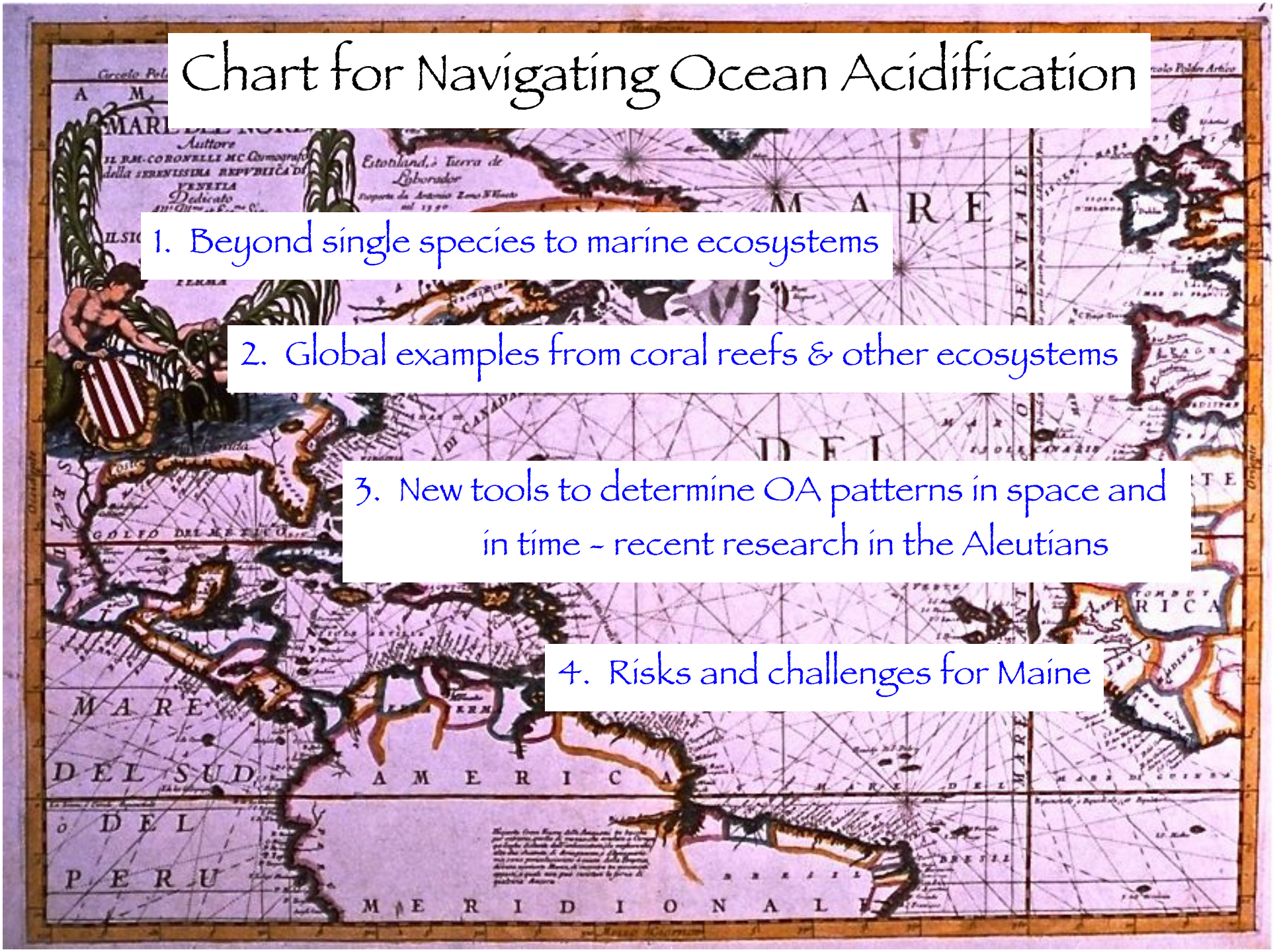
Ocean Acidification: Ecosystem Effects and Challenges for Maine



Bob Steneck
University of Maine
School of Marine Sciences

Chart for Navigating Ocean Acidification

1. Beyond single species to marine ecosystems
2. Global examples from coral reefs & other ecosystems
3. New tools to determine OA patterns in space and in time - recent research in the Aleutians
4. Risks and challenges for Maine



Going beyond single species to secondary and tertiary effects…

How does ocean acidification affect the structure and function of marine ecosystems?

Ecosystem structure (what's there).

- Dominant species
- Abundance of species
- Species diversity

Ecosystem function (how does it work?)

- How do species interactions change with OA?
  - Reproduction
  - Growth
  - Competition
  - Predation

What's so bad about a little acid?

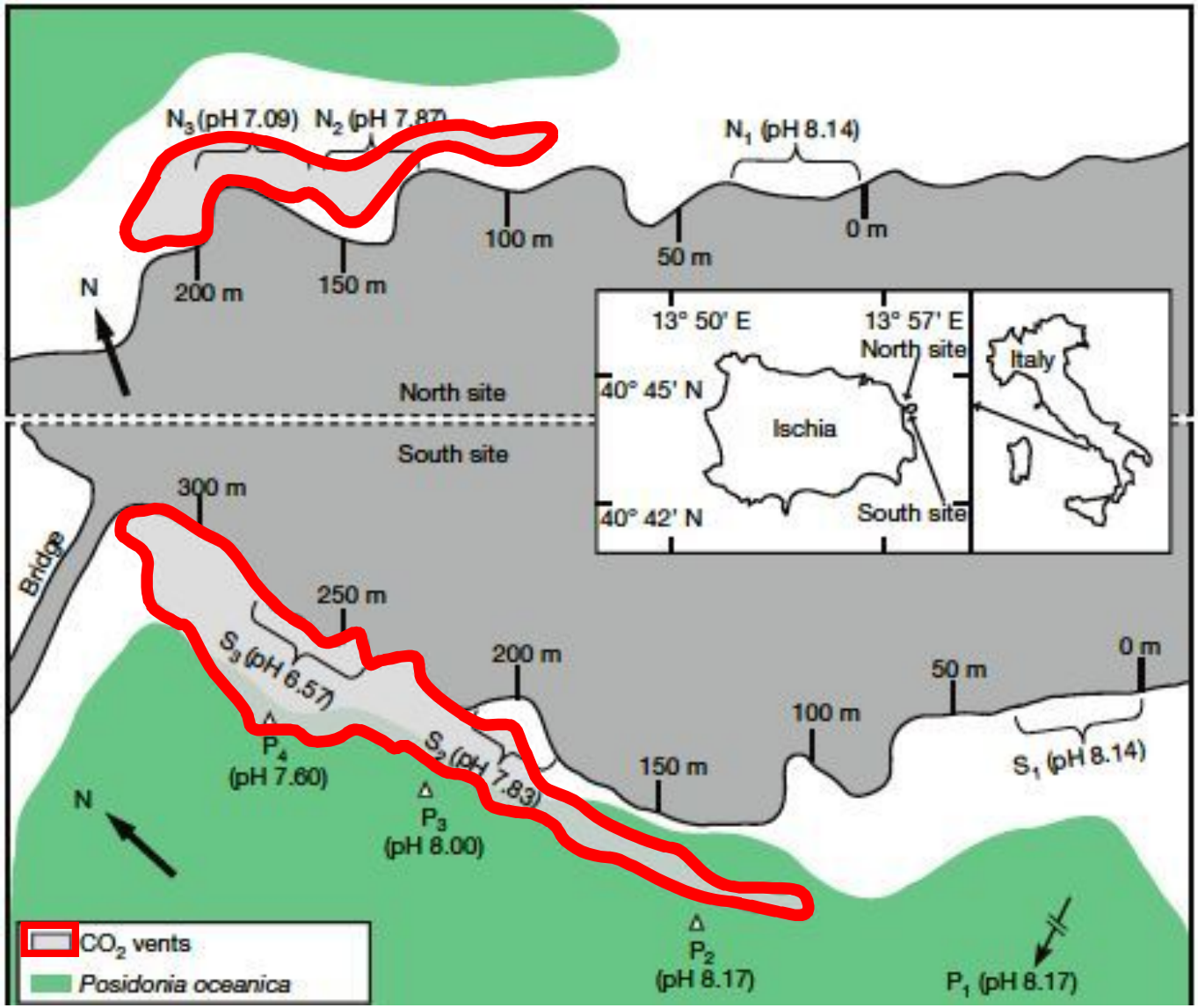
Let's go to the Mediterranean

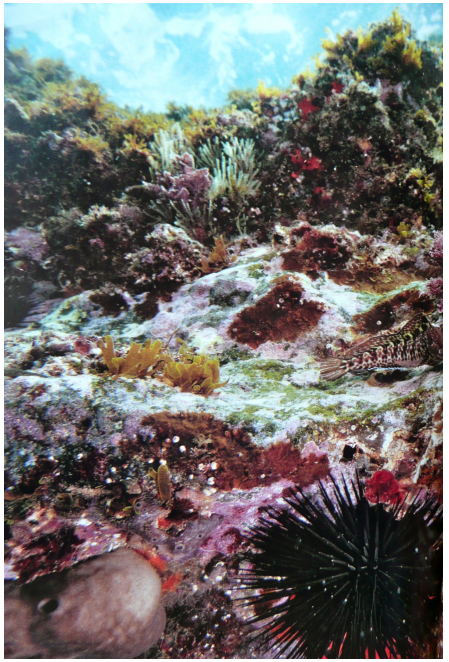
To see a "natural ecosystem-scale experiment"

Volcanic carbon dioxide vents show ecosystem effects of ocean acidification

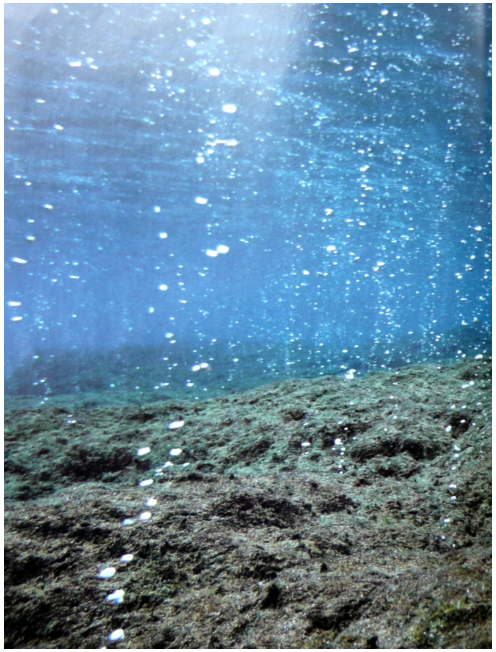
Jason M. Hall-Spencer[1], Riccardo Rodolfo-Metalpa[1], Sophie Martin[2], Emma Ransome[1], Maoz Fine[3,4], Suzanne M. Turner[5], Sonia J. Rowley[1], Dario Tedesco[6,7] & Maria-Cristina Buia[8]

NATURE|Vol 454|3 July 2008



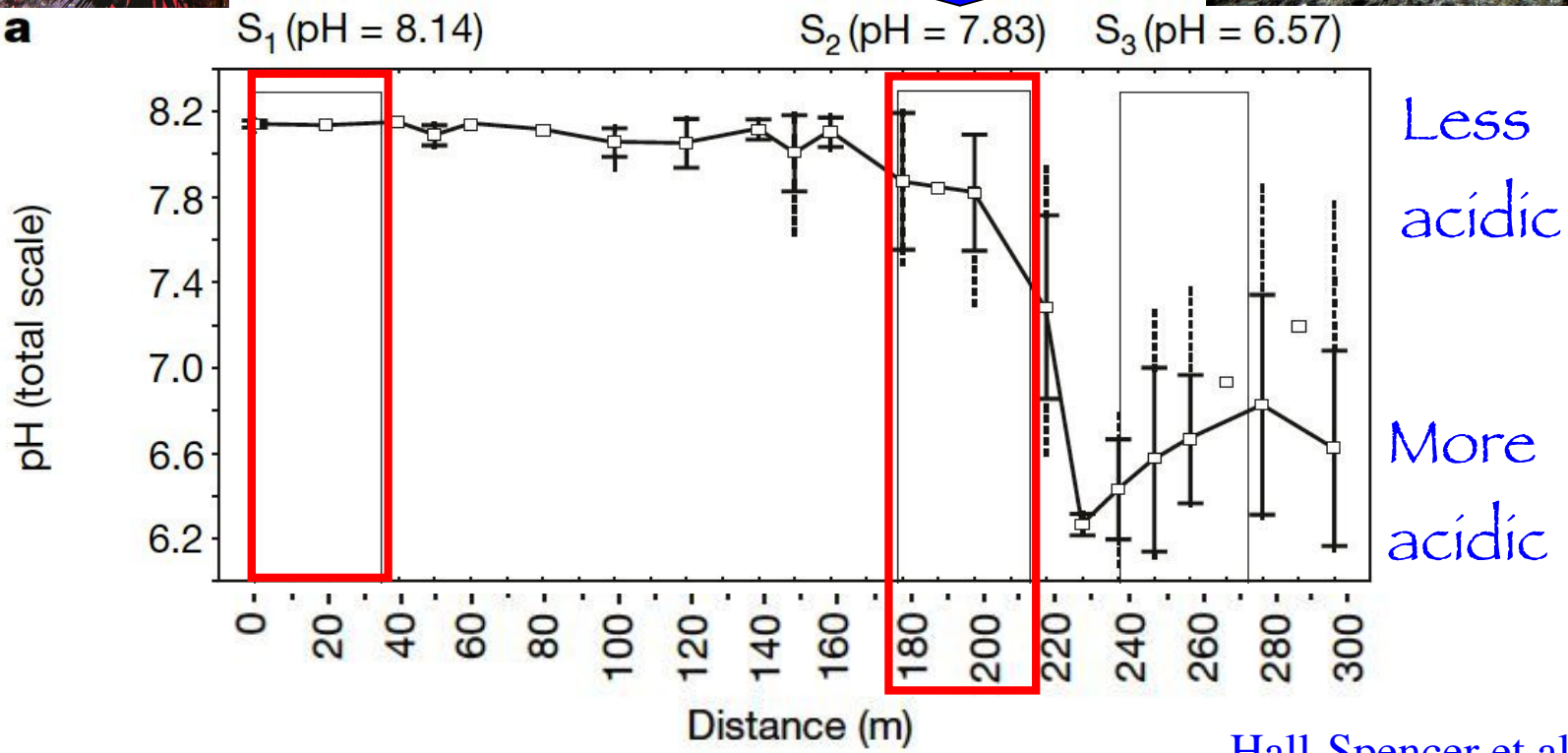


Towards acid oceans

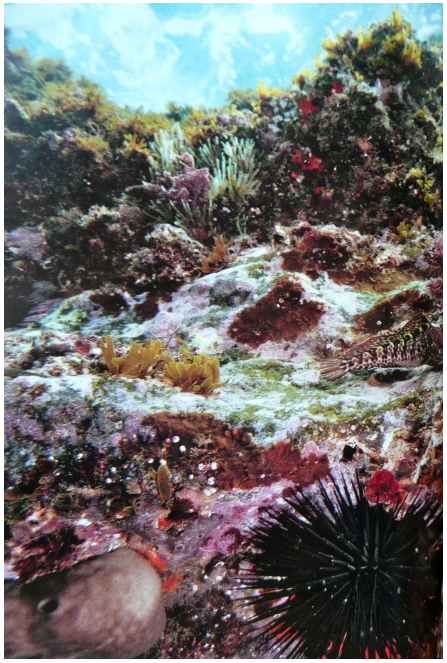


Today's Seas

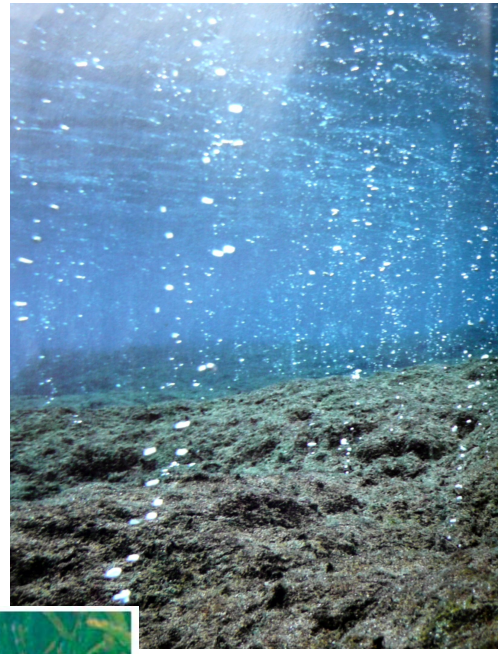
Seas Projected For 2100



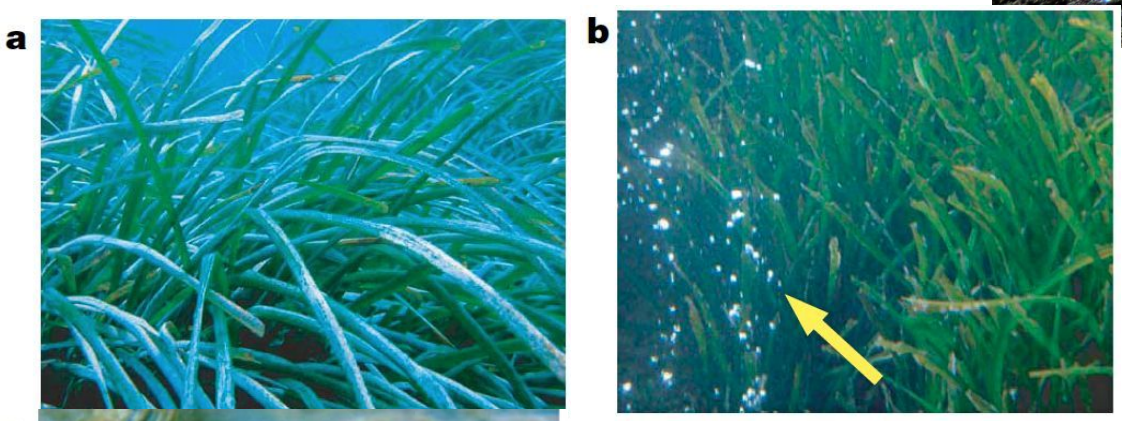
Hall-Spencer et al 2008



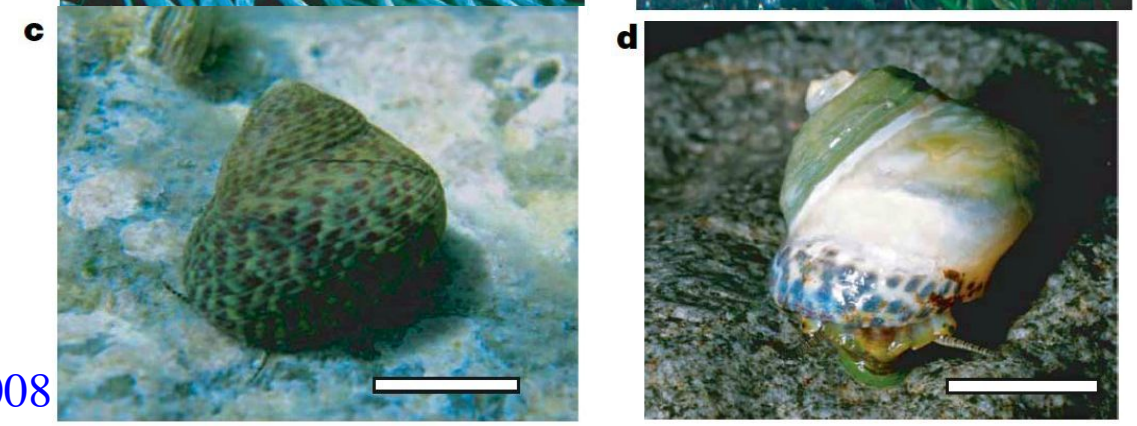
Towards acid oceans



Sea Grass

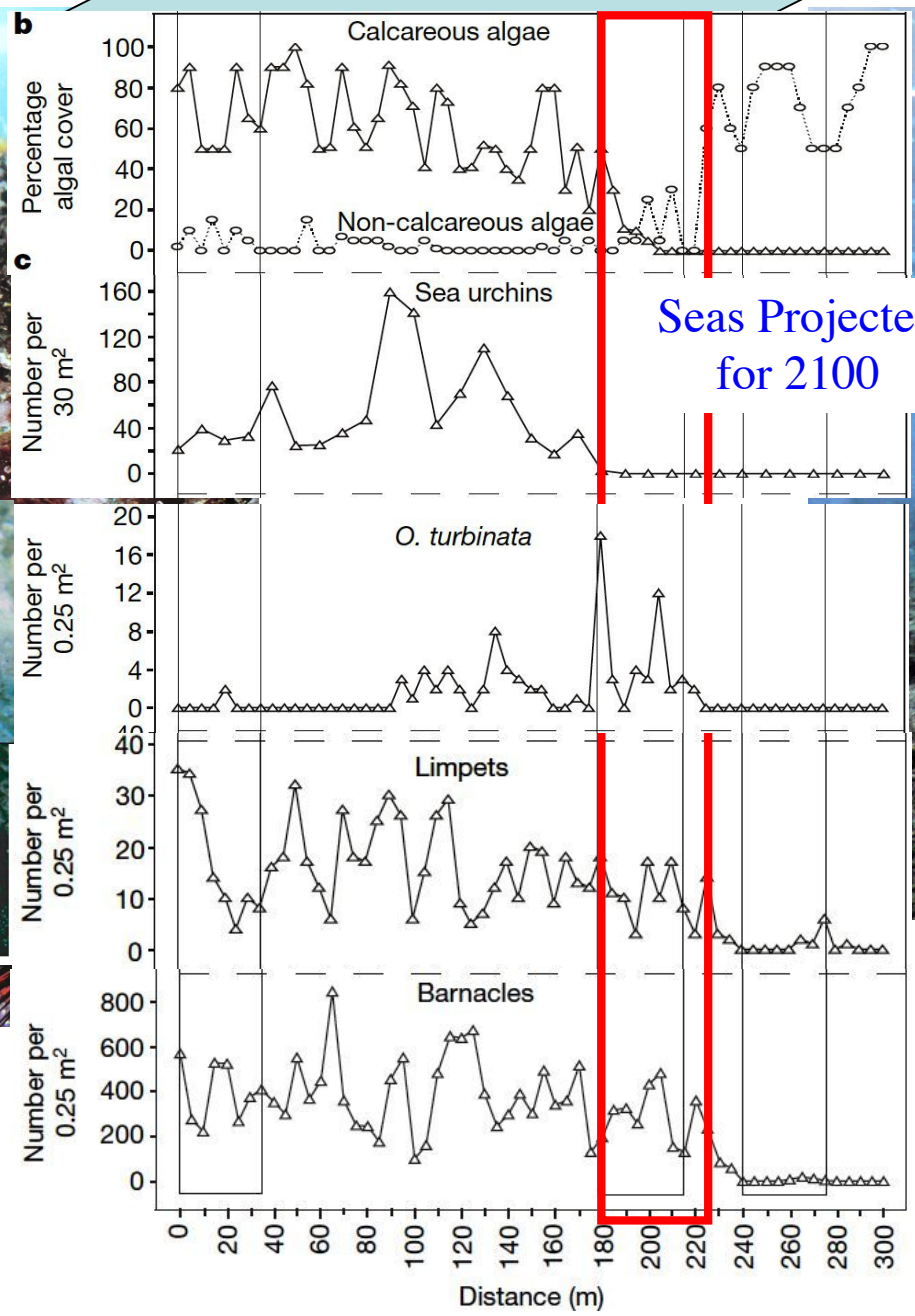


Snails

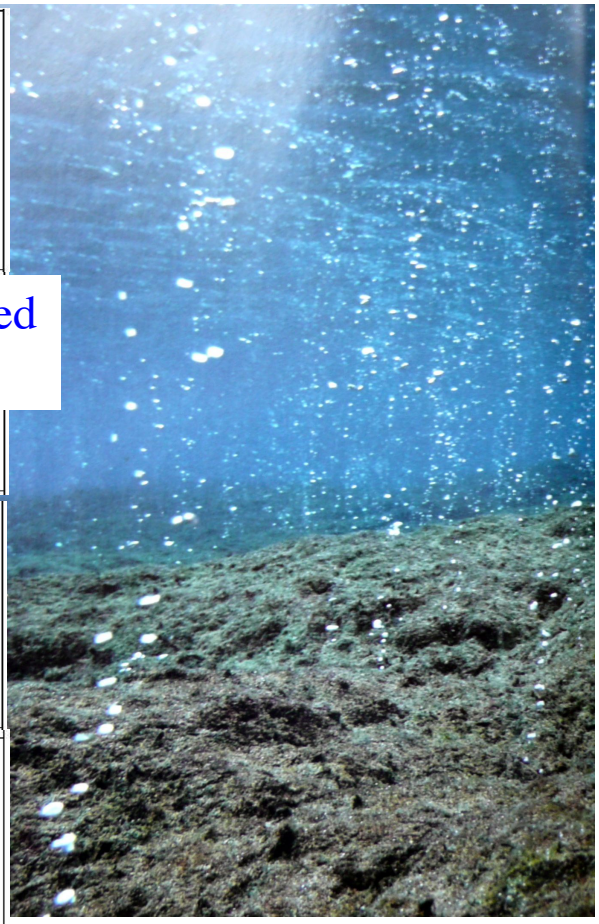


Hall-Spencer et al 2008

Towards acid oceans



Seas Projected for 2100



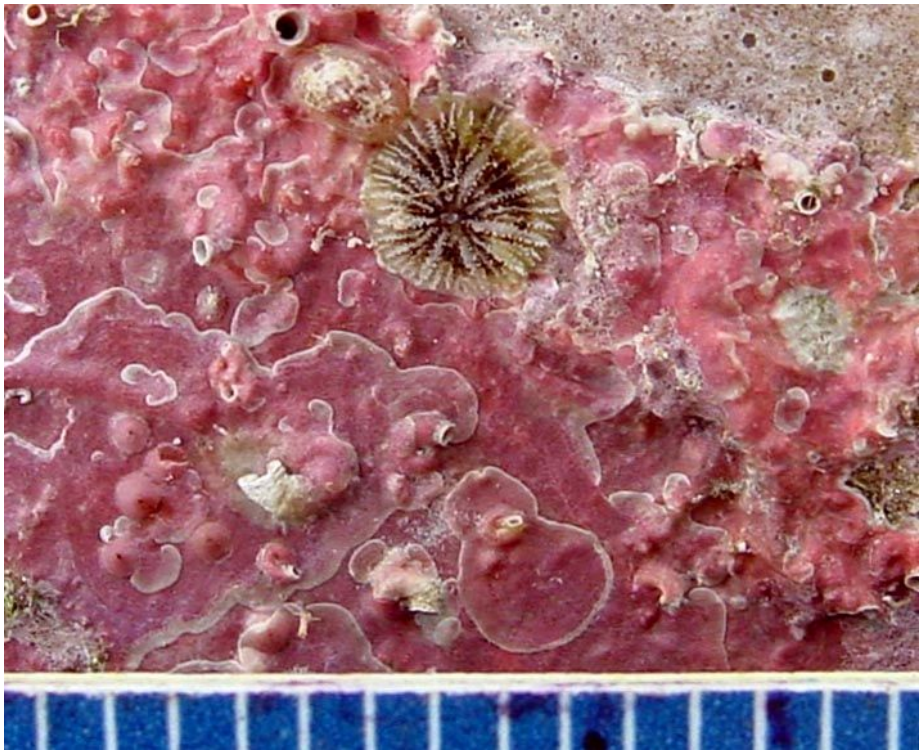
Hall-Spencer et al 2008

Clear changes to ecosystem *structure* (with extreme pH change)

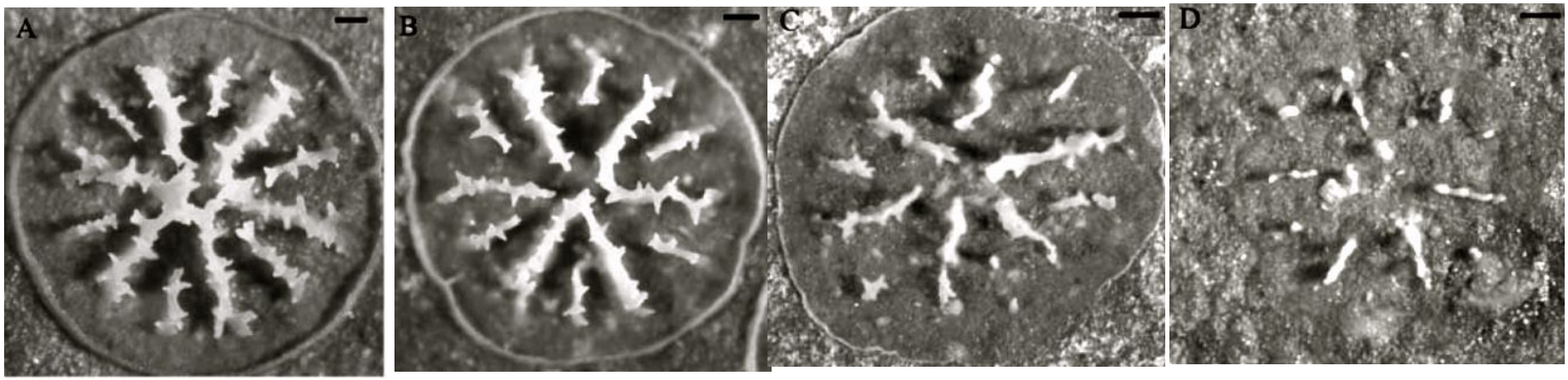
What about ecosystem *function?*

This is more like injury from a blunt instrument…

Disruption to reproduction, growth, competition and predation

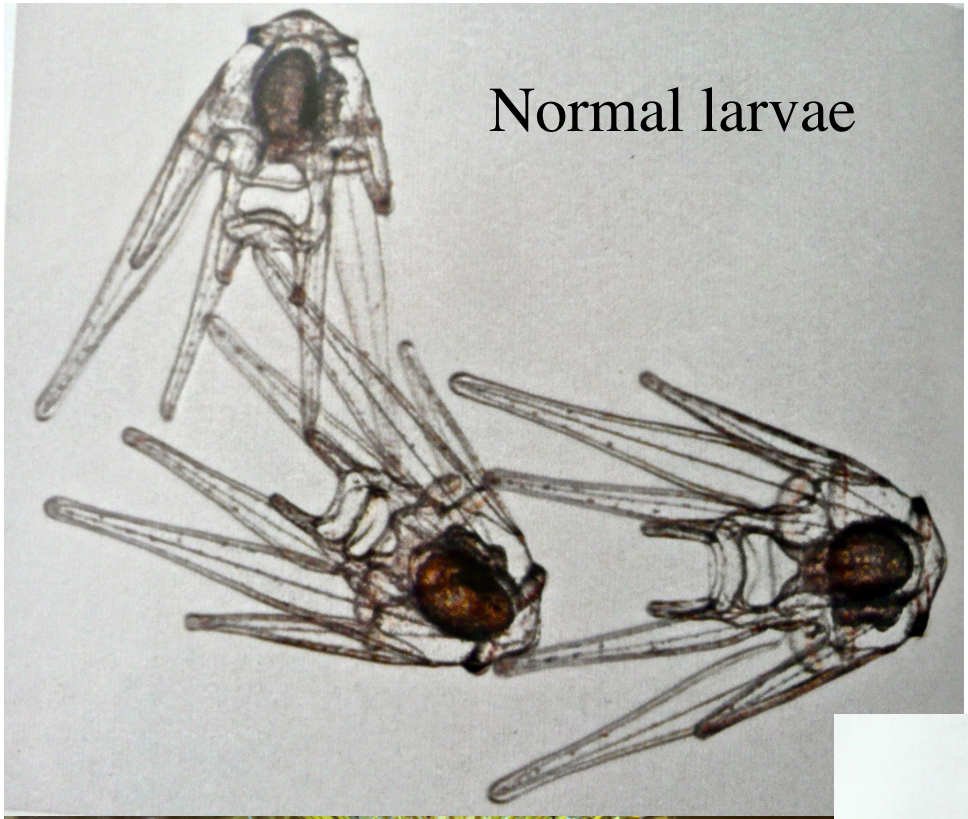


Baby Corals on Acid
(studies from the laboratory)



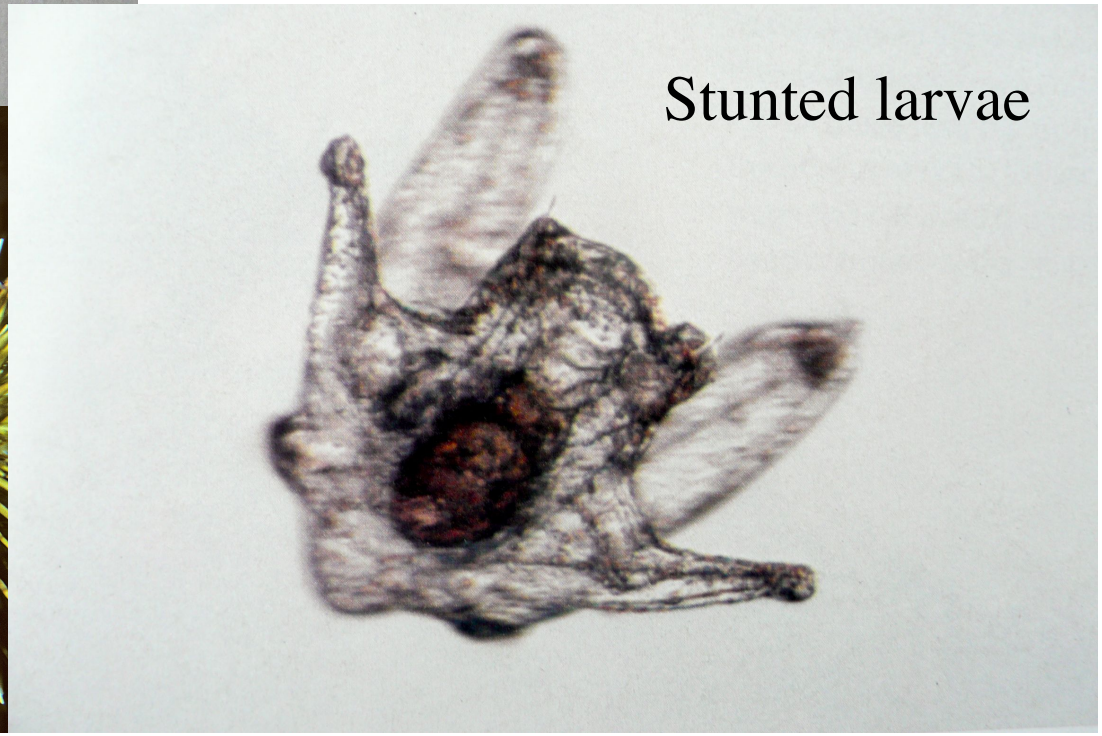
Normal Sea water → Increasing acidity

From Cohen et al., 2009

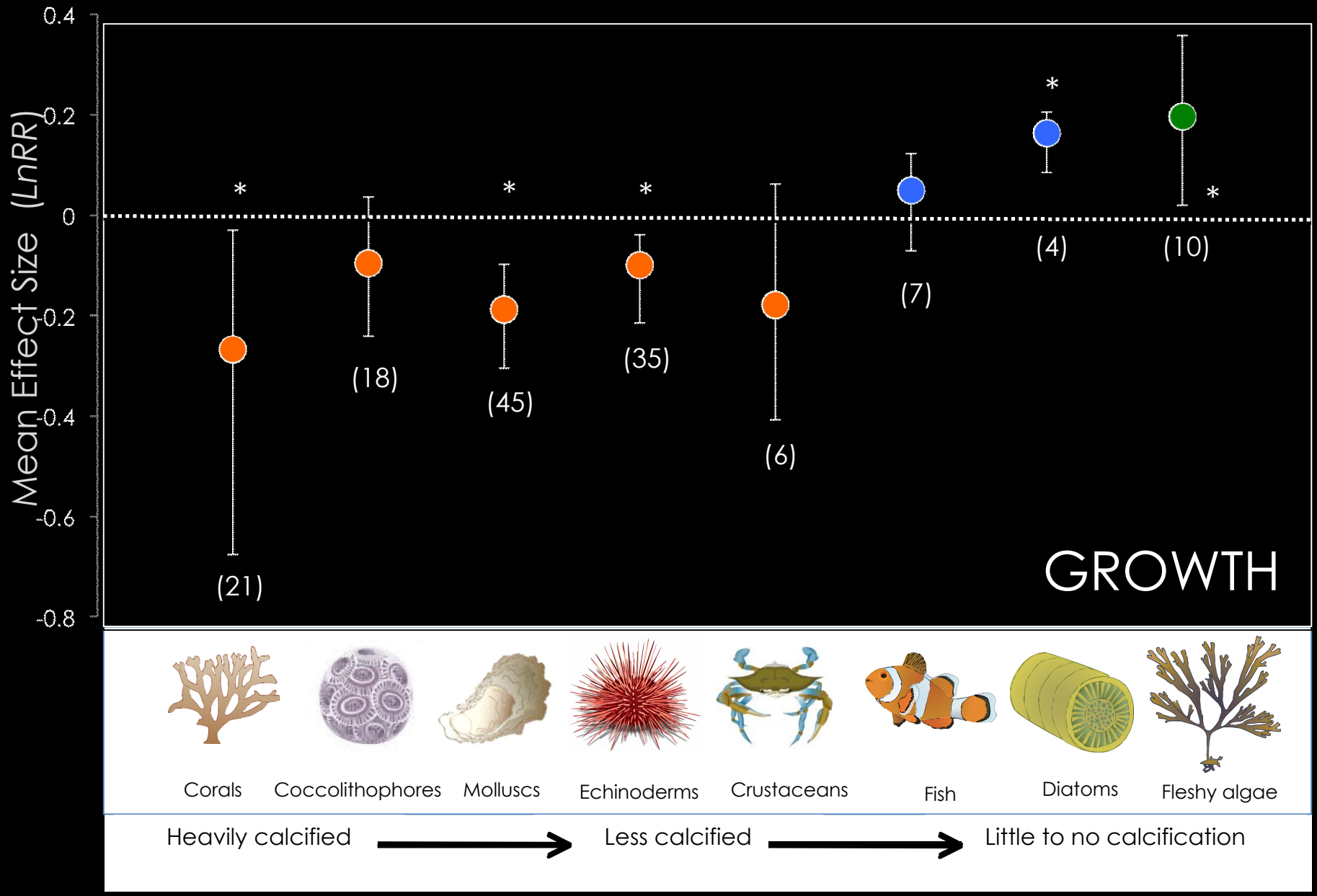


Sea urchin larvae on acid

But these were only single studies!



Growth rates decline with OA

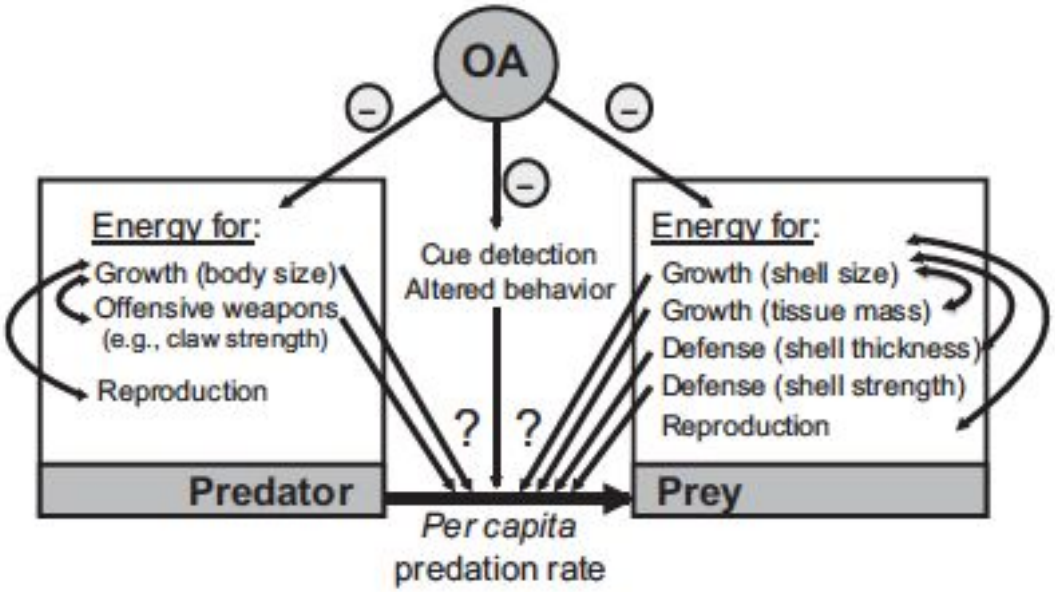


N = 146 published studies

Kroeker et al. 2010 *Ecol Letts*, Kroeker *et al. 2013 Global Change Biology*

Predicting the Effects of Ocean Acidification on Predator-Prey Interactions: A Conceptual Framework Based on Coastal Molluscs

K. J. KROEKER *ET AL.*



Species		Shell thickness or strength	Shell size	Energetic content	Adaptive Behavior	Predation pressure	Reference
Ostrea lurida		=	↓			↑	Sanford *et al.* (2014)
Mercenaria mercenaria		↓	↑	↑			Dickinson *et al.* (2013)
Mytilus edulis		=	=	=			Hiebenthal *et al.* (2013)
Arctica islandica		=	=	=			
Concholepas concholepas		=			↑		Manriquez *et al.* (2013)
Littorina littorea		↓	=				Metalunan *et al.* (2013)
Saccostrea glomerata		↓				↑	Amaral
Bembicium auratum		↓	=				(2012)
Mytilus californianus	*	↓	↓	↓			Gaylord *et al.* (2011)
Crassostrea virginica		↓		↓			Beniash *et al.* (2010)
Argopecten irradians	*		=	=			Talmage and Gobler (2010)
Crassostrea virginica	*		↓	=			
Mercenaria mercenaria	*		=	=			
Littorina littorea		↓			↑		Bibby *et al.* (2007)

It is metabolically expensive to calcify at lower pH

This can affect predator prey dynamics

Fish behavior:

Larval fish cannot sense and find their nursery habitats

Altered predator prey interactions

nature climate change

LETTERS

PUBLISHED ONLINE: 13 APRIL 2014 | DOI: 10.1038/NCLIMATE2195

Behavioural impairment in reef fishes caused by ocean acidification at CO_2 seeps

Philip L. Munday[1,2*], Alistair J. Cheal[3], Danielle L. Dixson[4], Jodie L. Rummer[1] and Katharina E. Fabricius[3]

nature climate change

LETTERS

PUBLISHED ONLINE: 15 JANUARY 2012 | DOI: 10.1038/NCLIMATE1352

Near-future carbon dioxide levels alter fish behaviour by interfering with neurotransmitter function

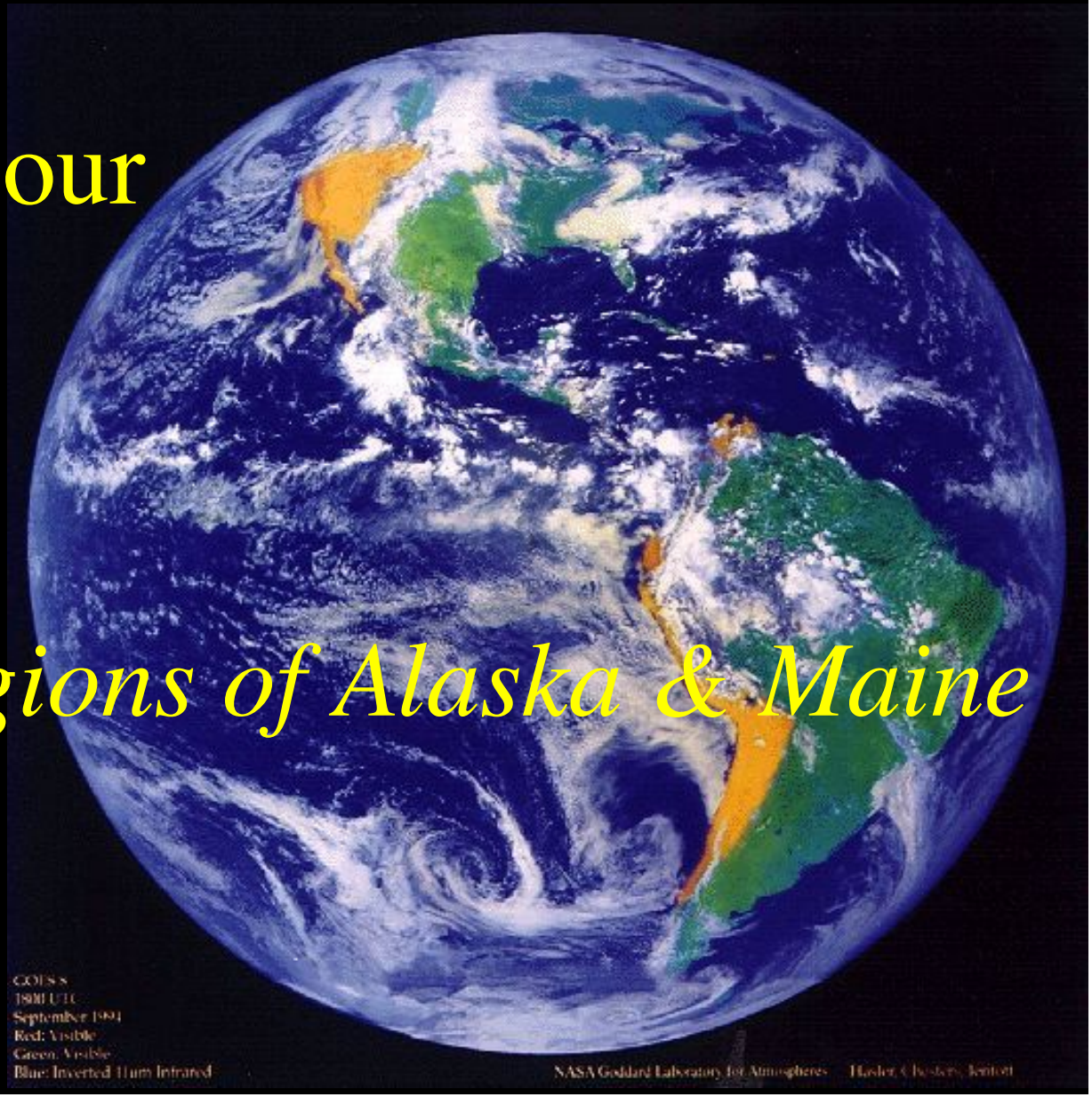
Göran E. Nilsson[1*], Danielle L. Dixson[2], Paolo Domenici[3], Mark I. McCormick[2], Christina Sørensen[1], Sue-Ann Watson[2] and Philip L. Munday[2]

Ecosystem effects

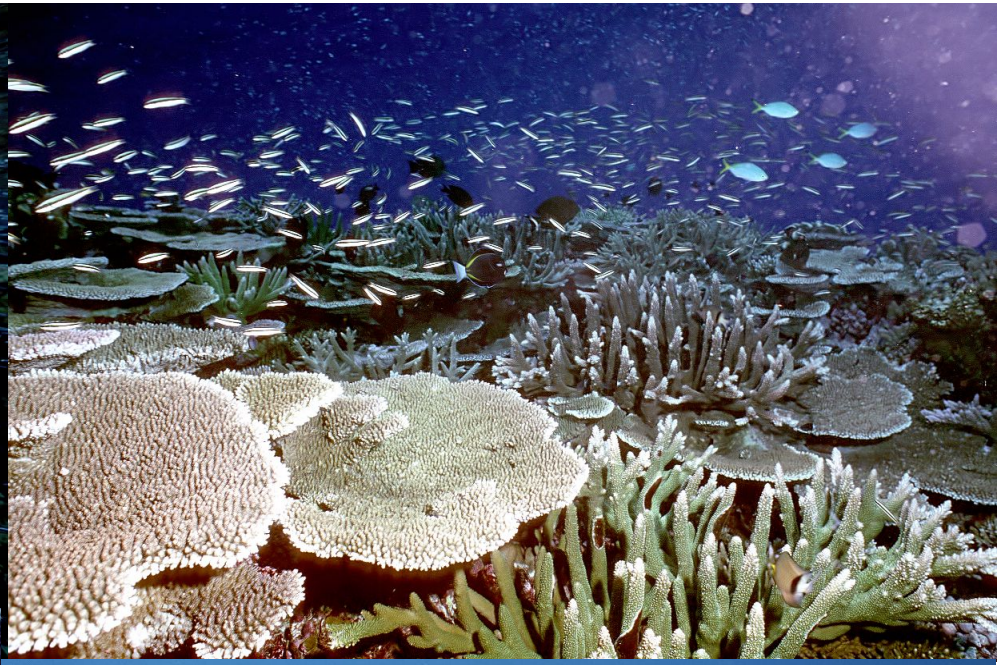
Lessons from our blue planet

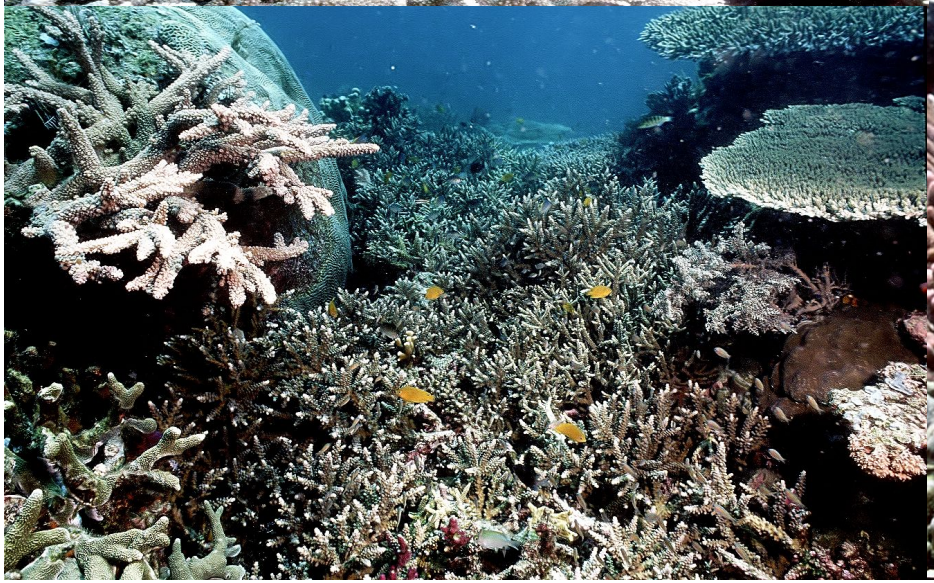
Coral Reefs

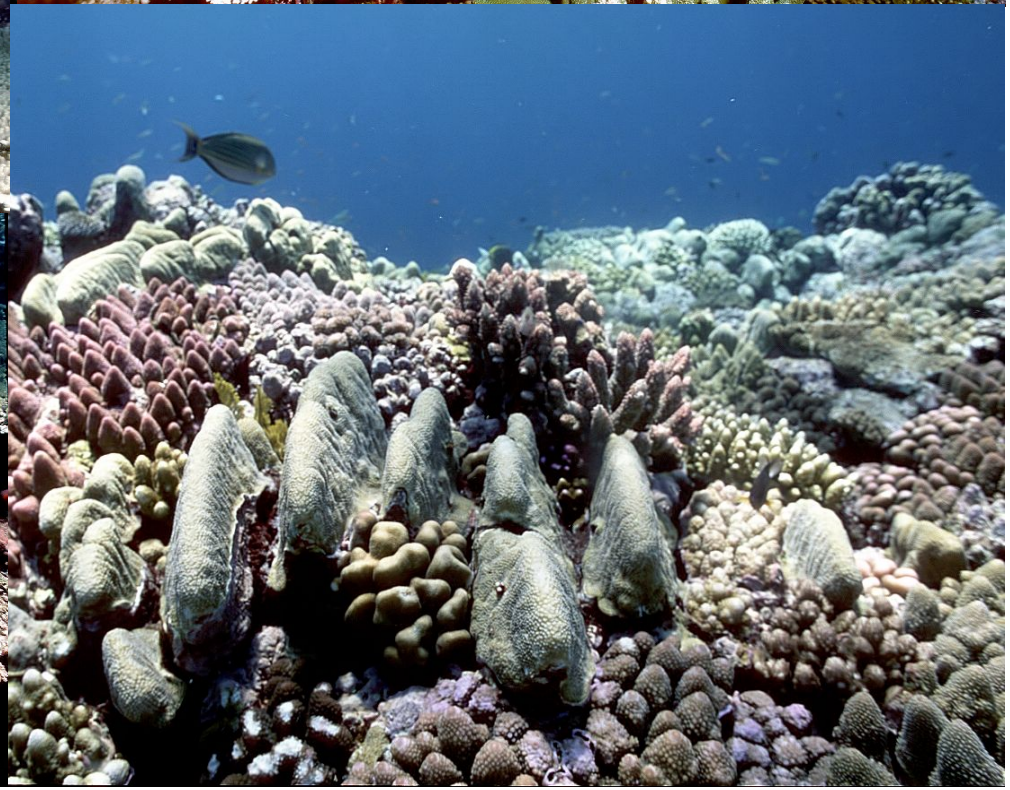
Coldwater regions of Alaska & Maine



Coral Reefs







Coral Reefs Under Rapid Climate Change and Ocean Acidification

O. Hoegh-Guldberg,[1*] P. J. Mumby,[2] A. J. Hooten,[3] R. S. Steneck,[4] P. Greenfield,[5] E. Gomez,[6] C. D. Harvell,[7] P. F. Sale,[8] A. J. Edwards,[9] K. Caldeira,[10] N. Knowlton,[11] C. M. Eakin,[12] R. Iglesias-Prieto,[13] N. Muthiga,[14] R. H. Bradbury,[15] A. Dubi,[16] M. E. Hatziolos[17]

SCIENCE VOL 318 14 DECEMBER 2007

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Projected changes to coral reefs

Today

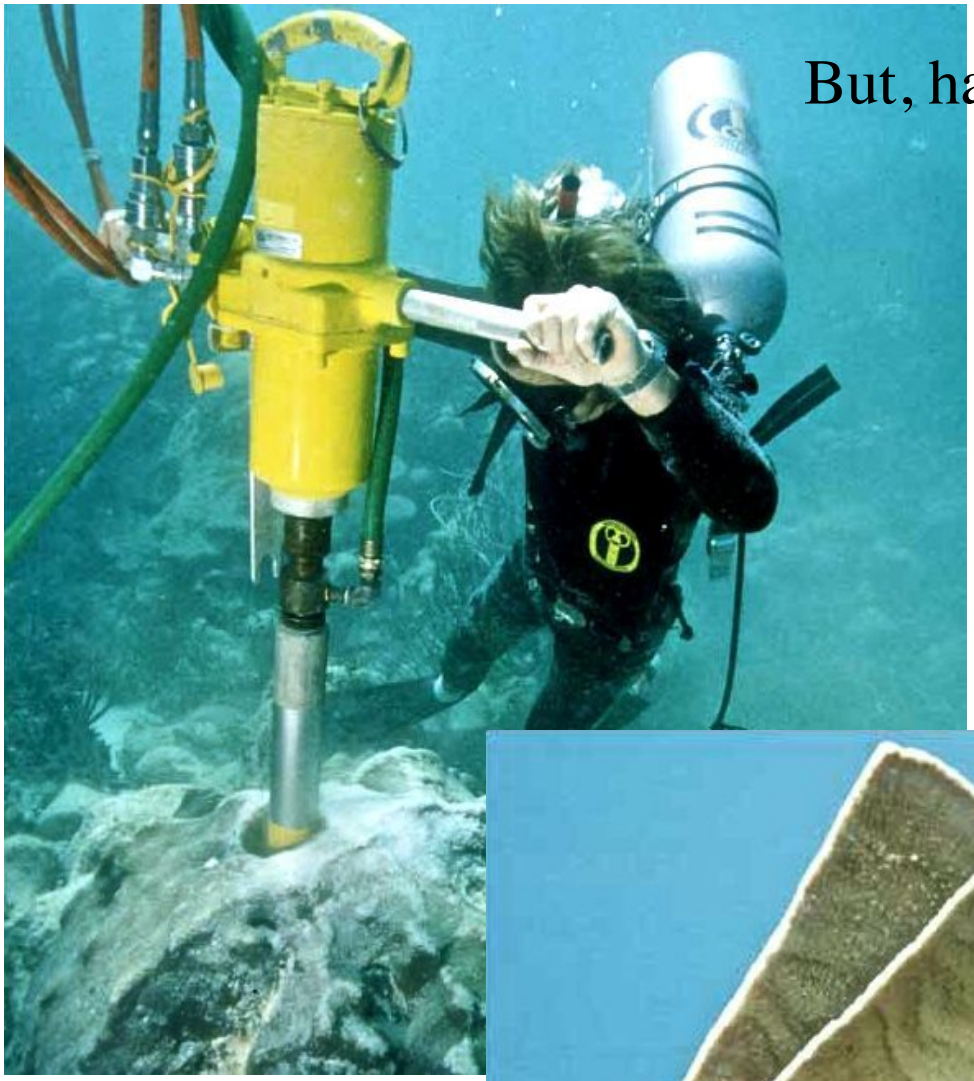
2025

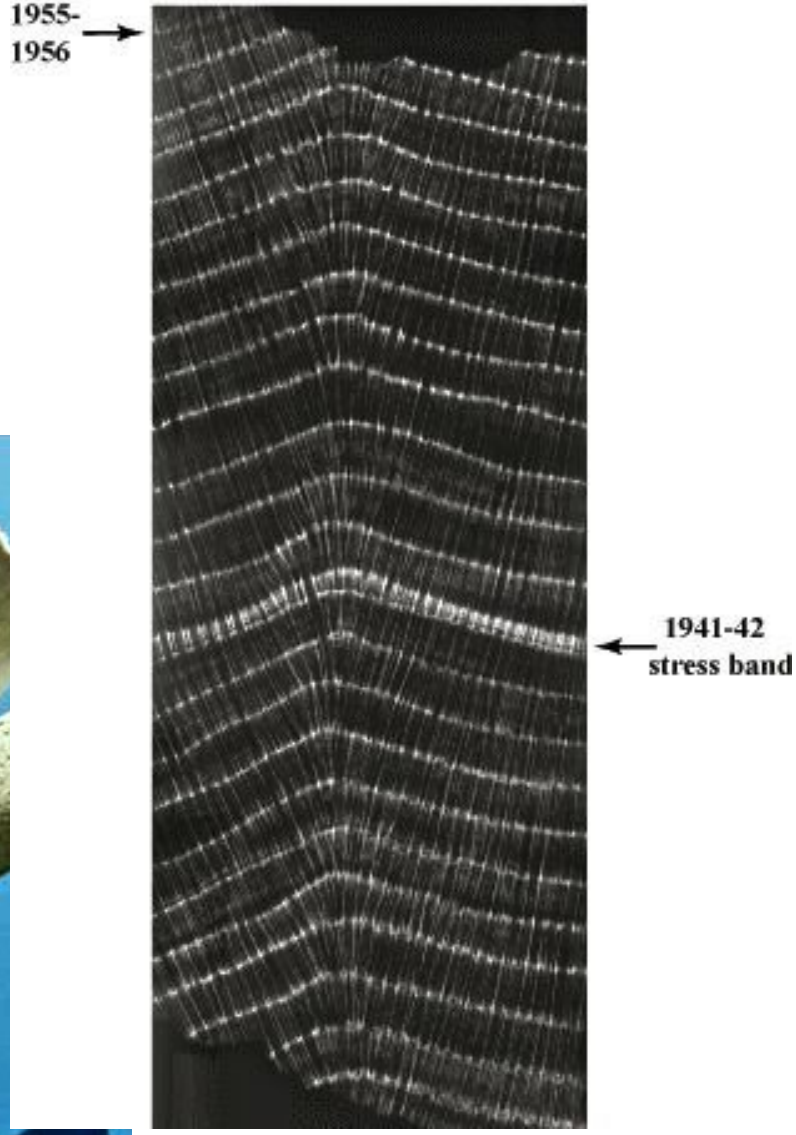
2050

Shift in *competitive* dominance from coral to seaweed

But, has calcification declined over time?

Study growth band and $CaCO_3$ density over time



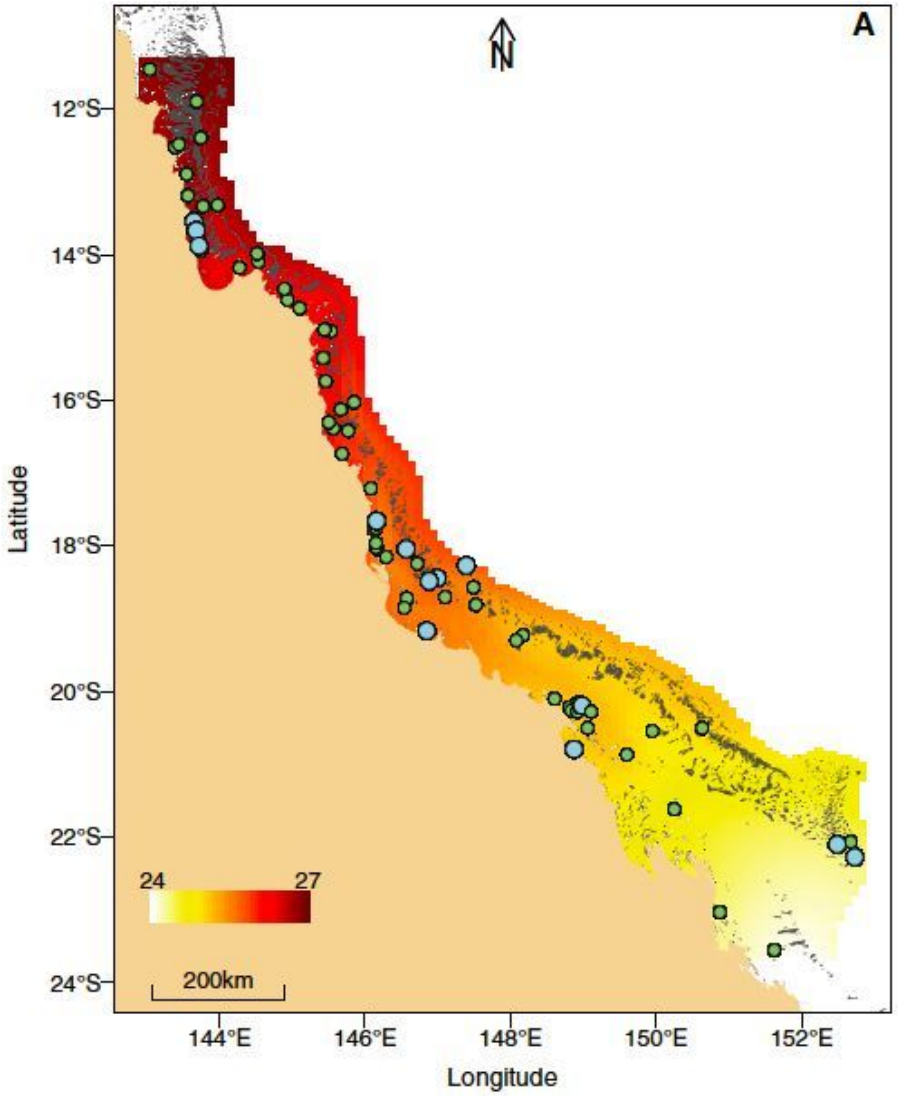


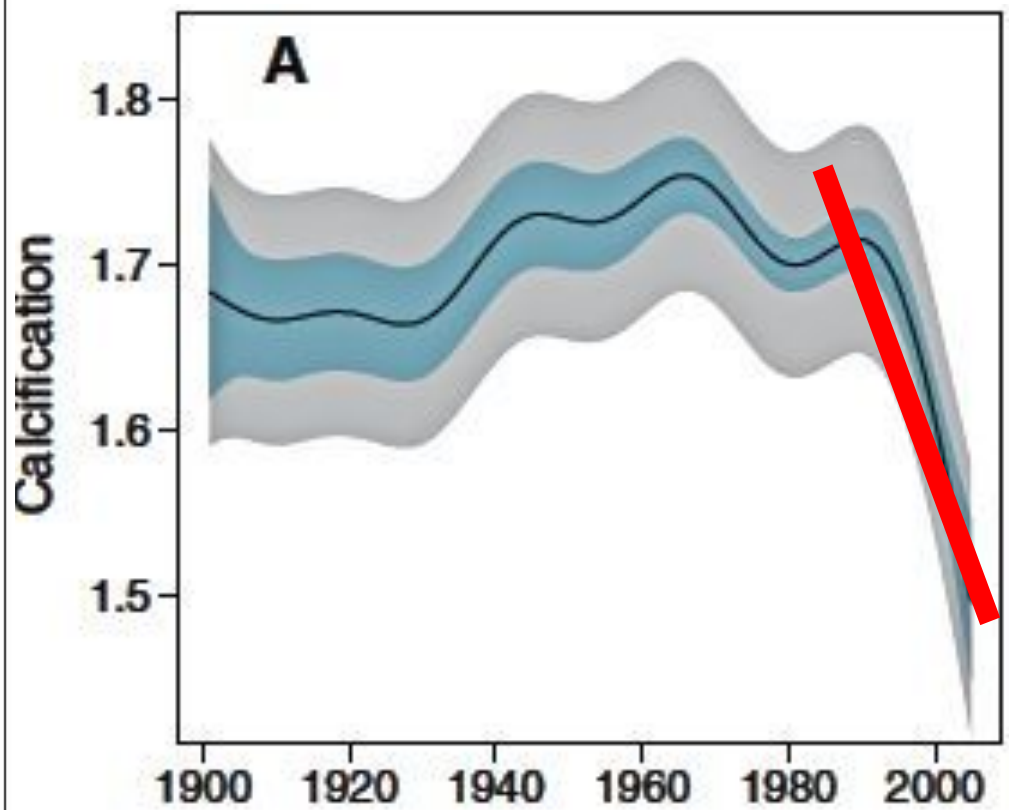
Declining Coral Calcification on the Great Barrier Reef

Glenn De'ath,* Janice M. Lough, Katharina E. Fabricius

2 JANUARY 2009 VOL 323 SCIENCE

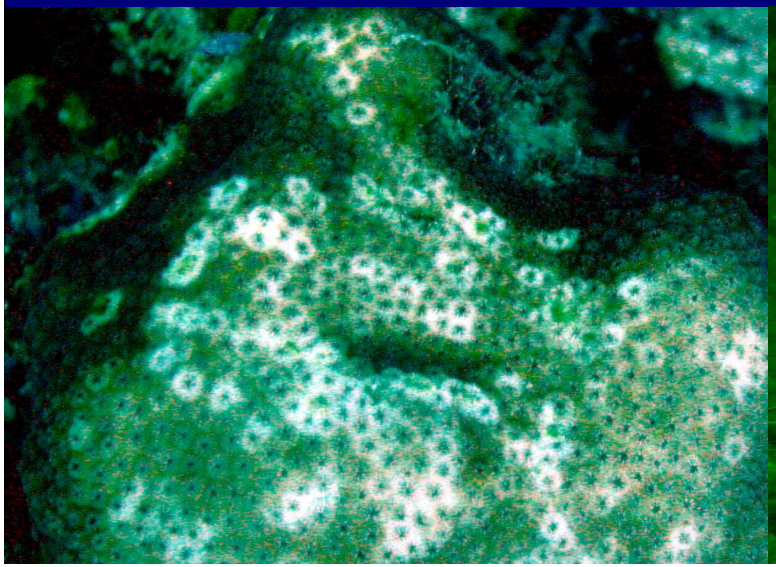
So, corals may be less dense and more prone to break

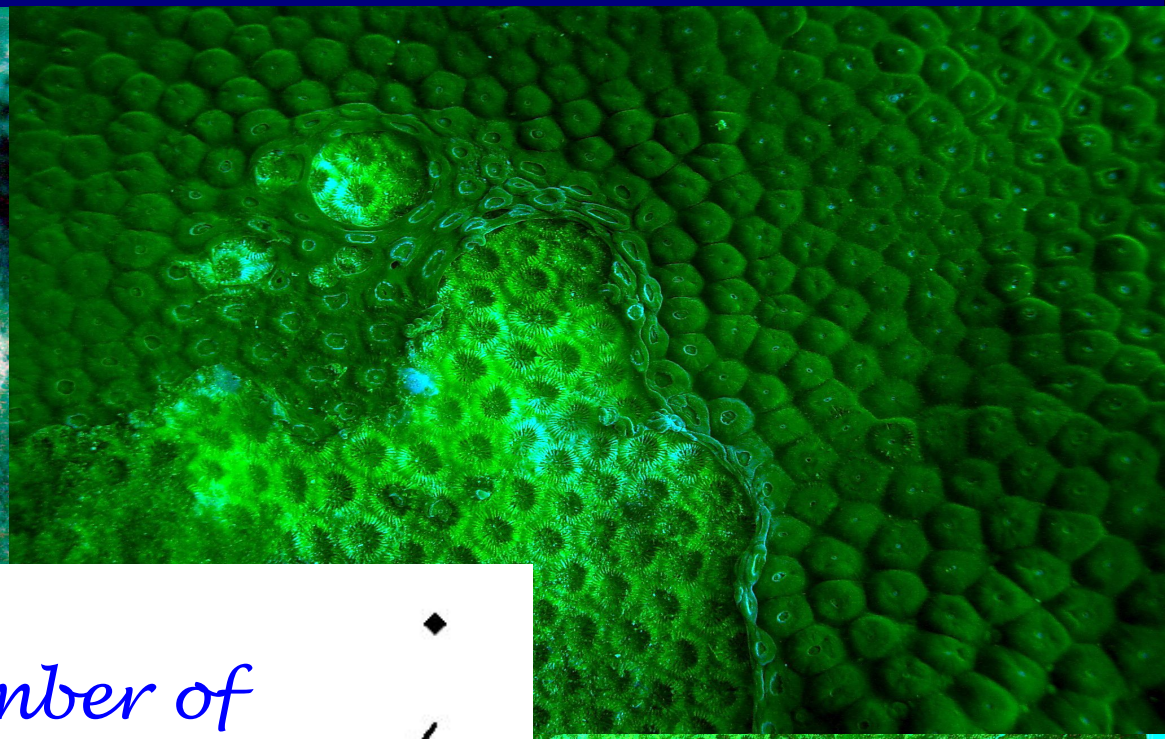


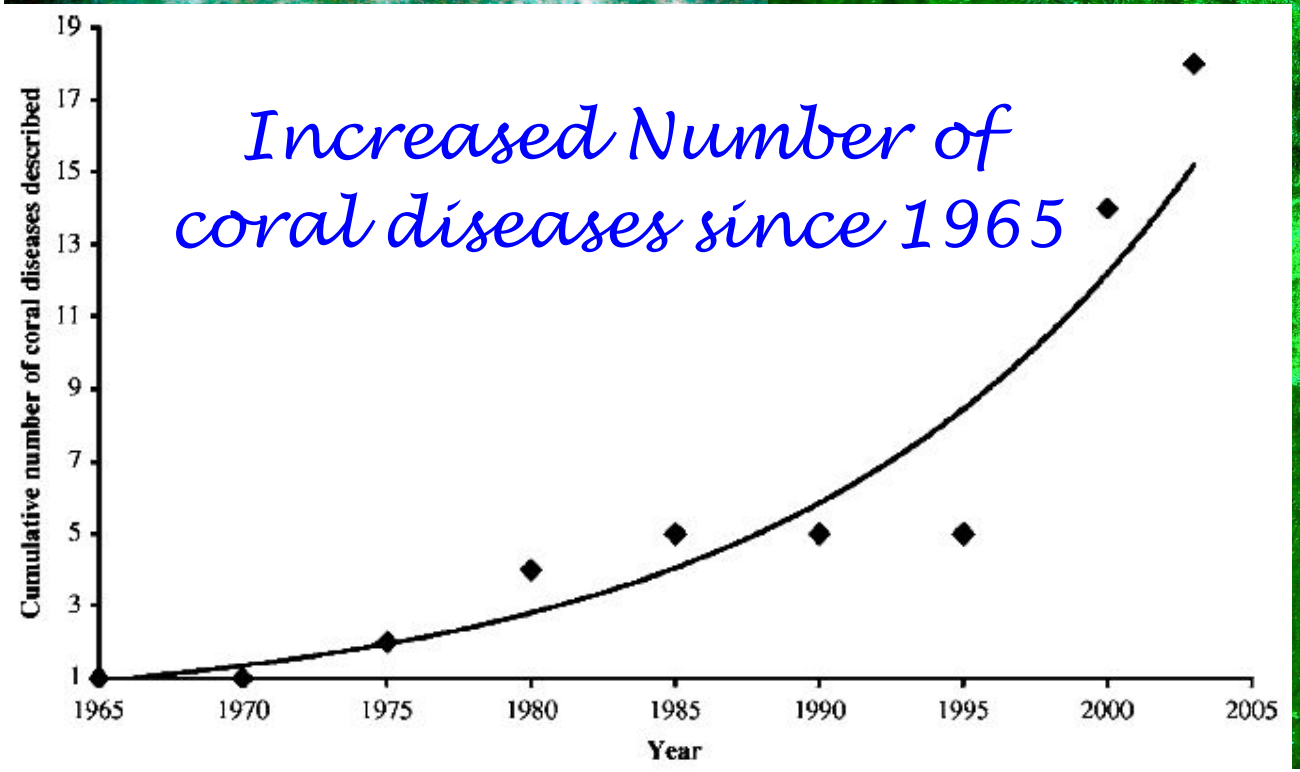


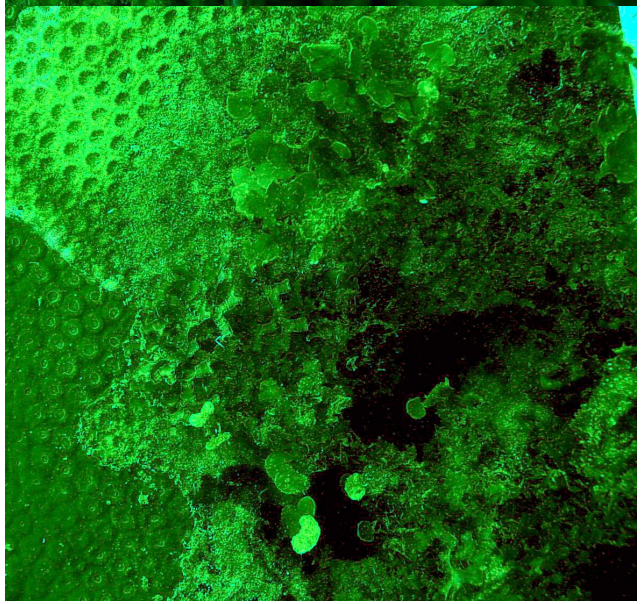
Maybe they will erode faster grazed by parrotfish

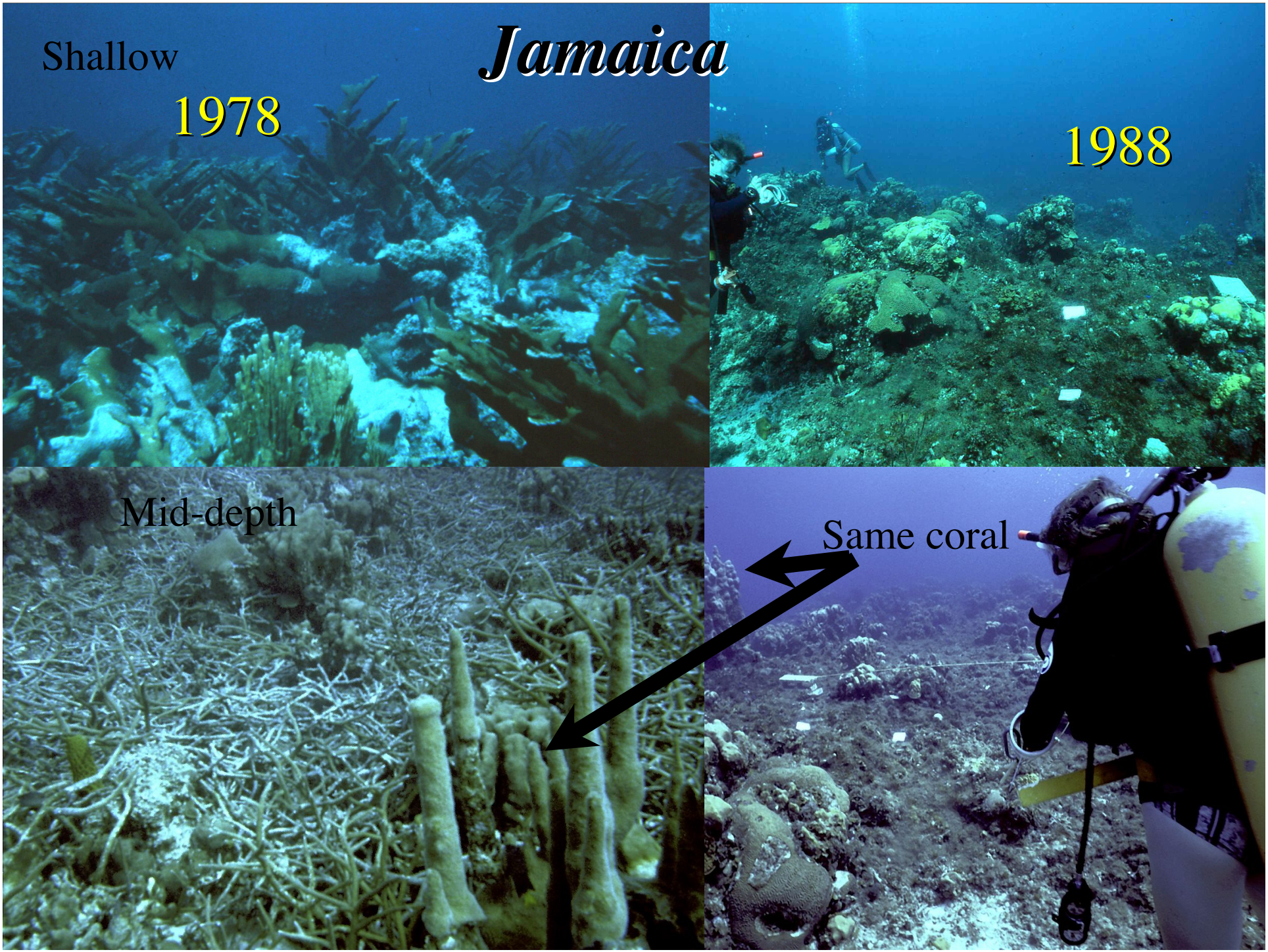
Acidification stresses corals and could compromise their immune system









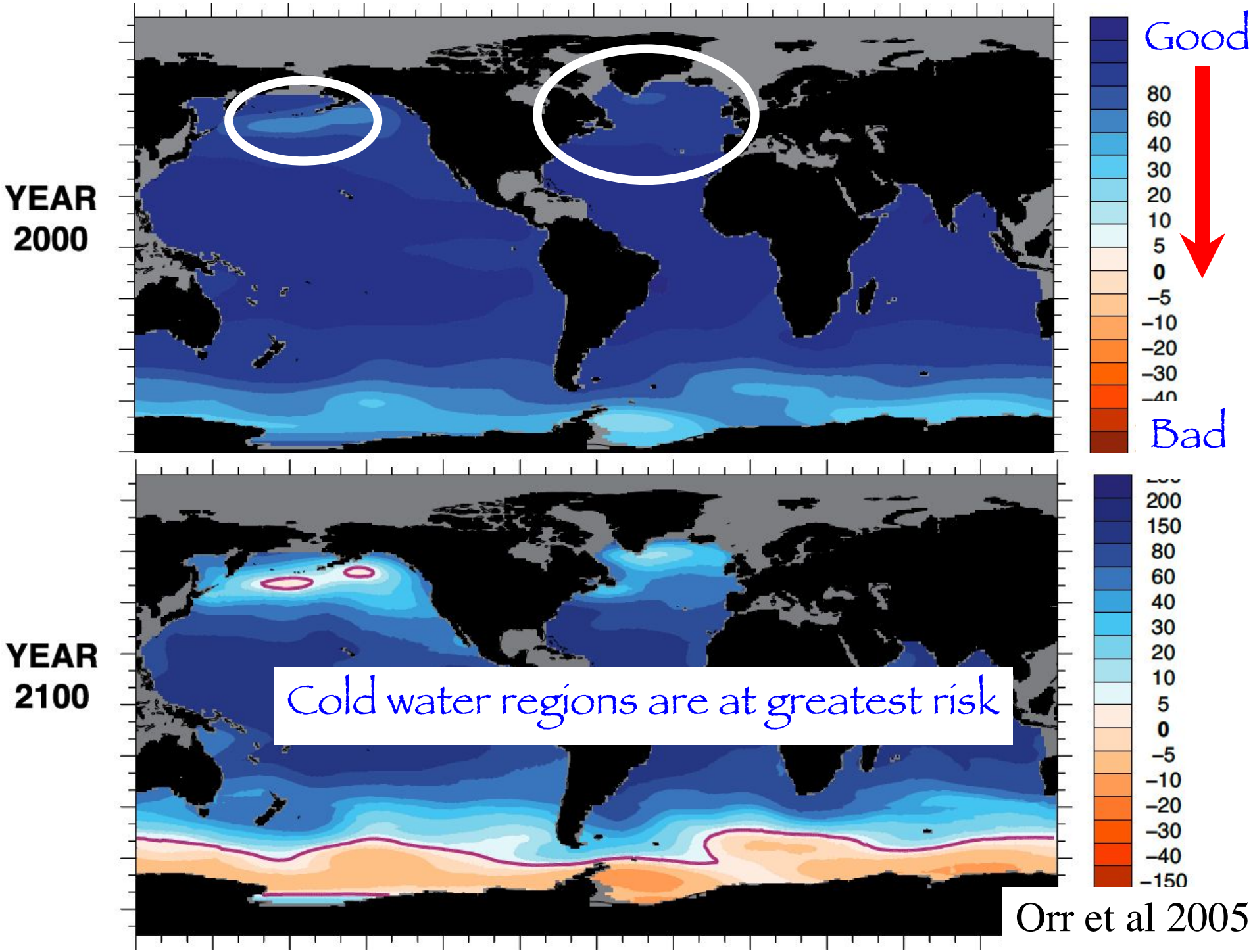

Jamaica
Shallow
1978
1988
Mid-depth
Same coral

Coralline Lethal Orange Disease (CLOD) Littler et al 2003

Diseases among calcareous organisms have increased in recent decades.

This was the most abundant coralline in the Caribbean in the 1970s but today it is rare.

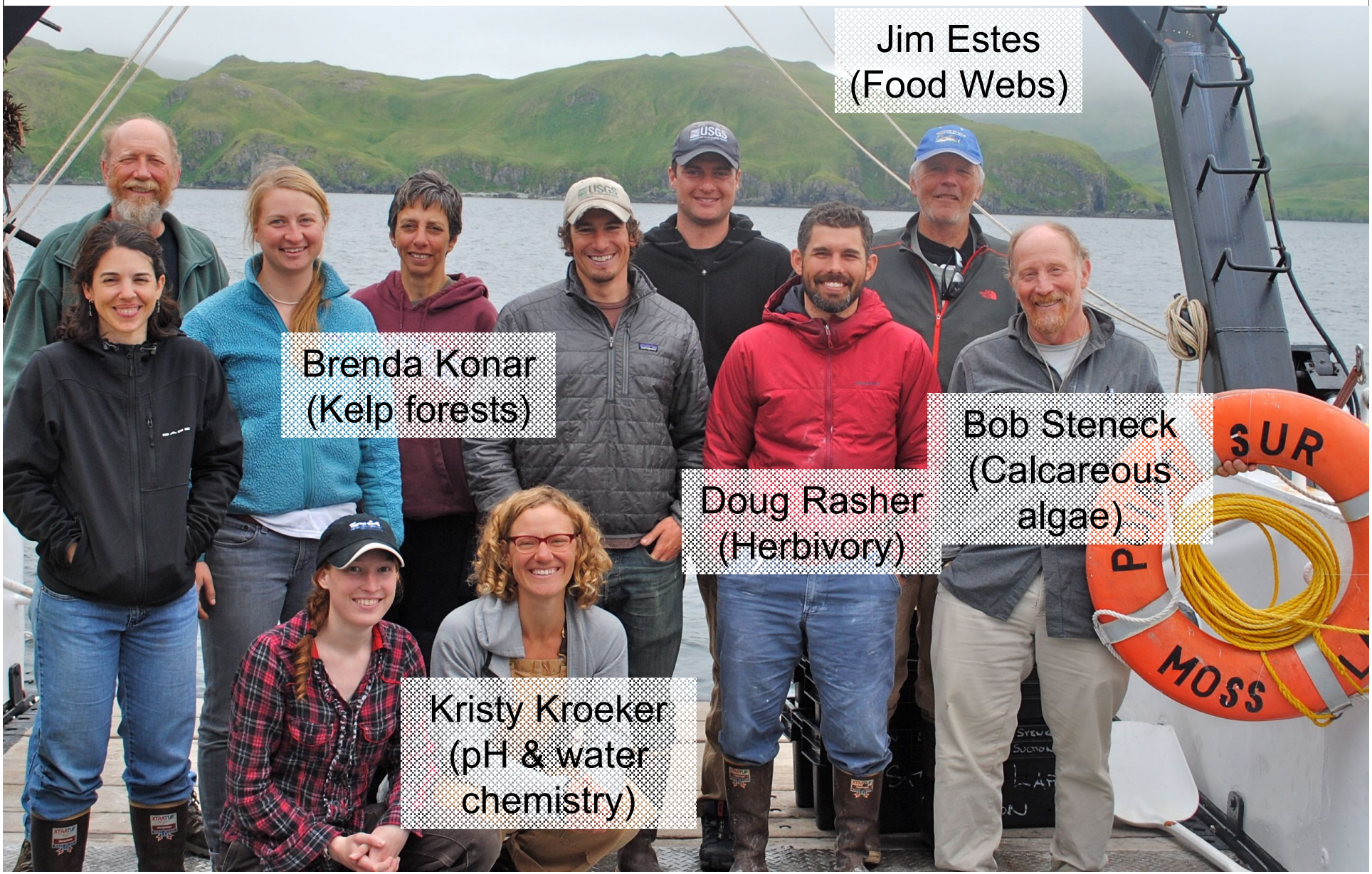
But, I live in Maine!
Should I be
concerned?
Colder water, bigger problem

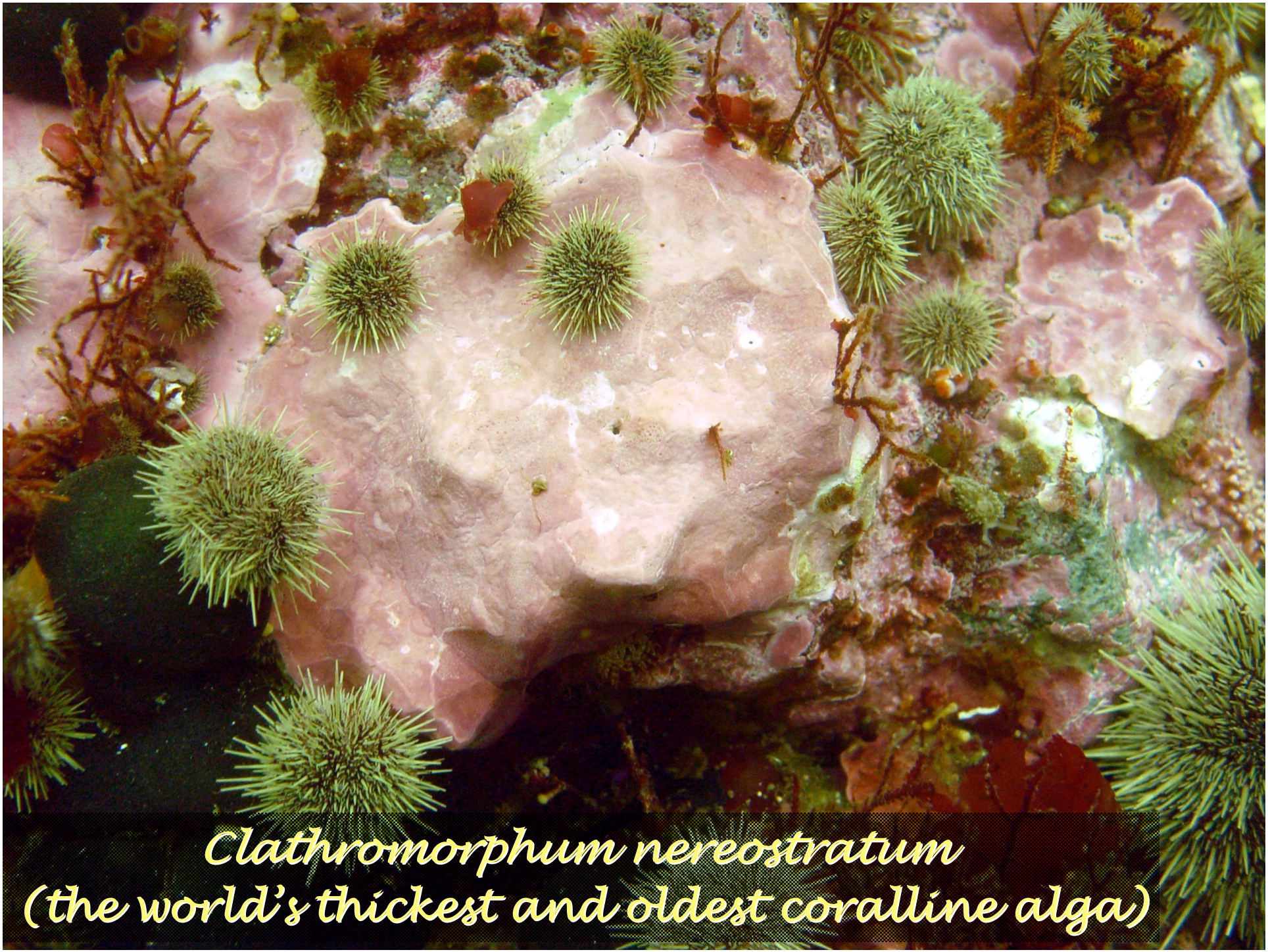


Orr et al 2005

The search for climate & OA "flight recorders" in cold oceans

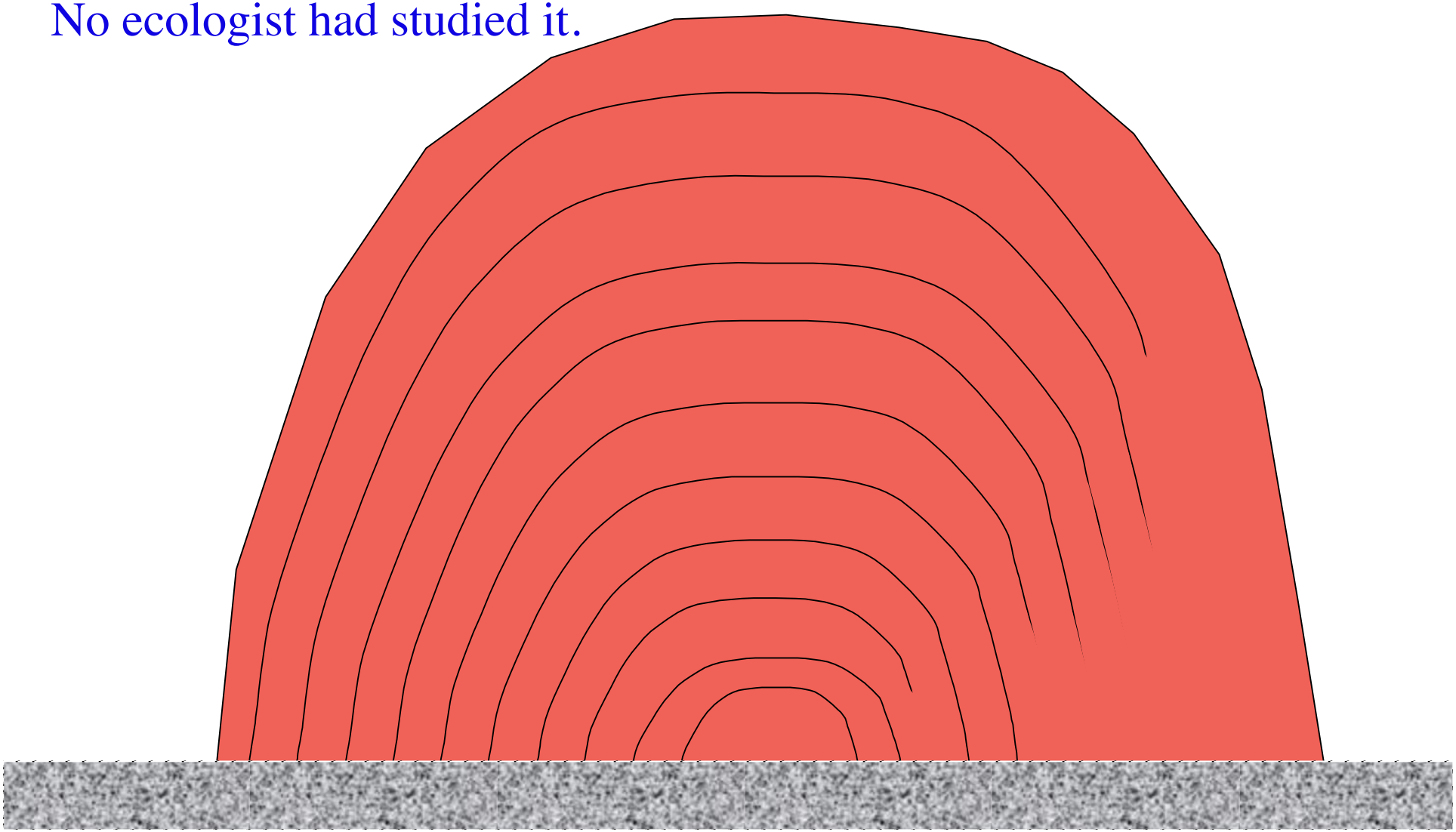
Ocean Acidification:
Century Scale Impacts to Ecosystem Structure and Function of Aleutian Kelp Forests



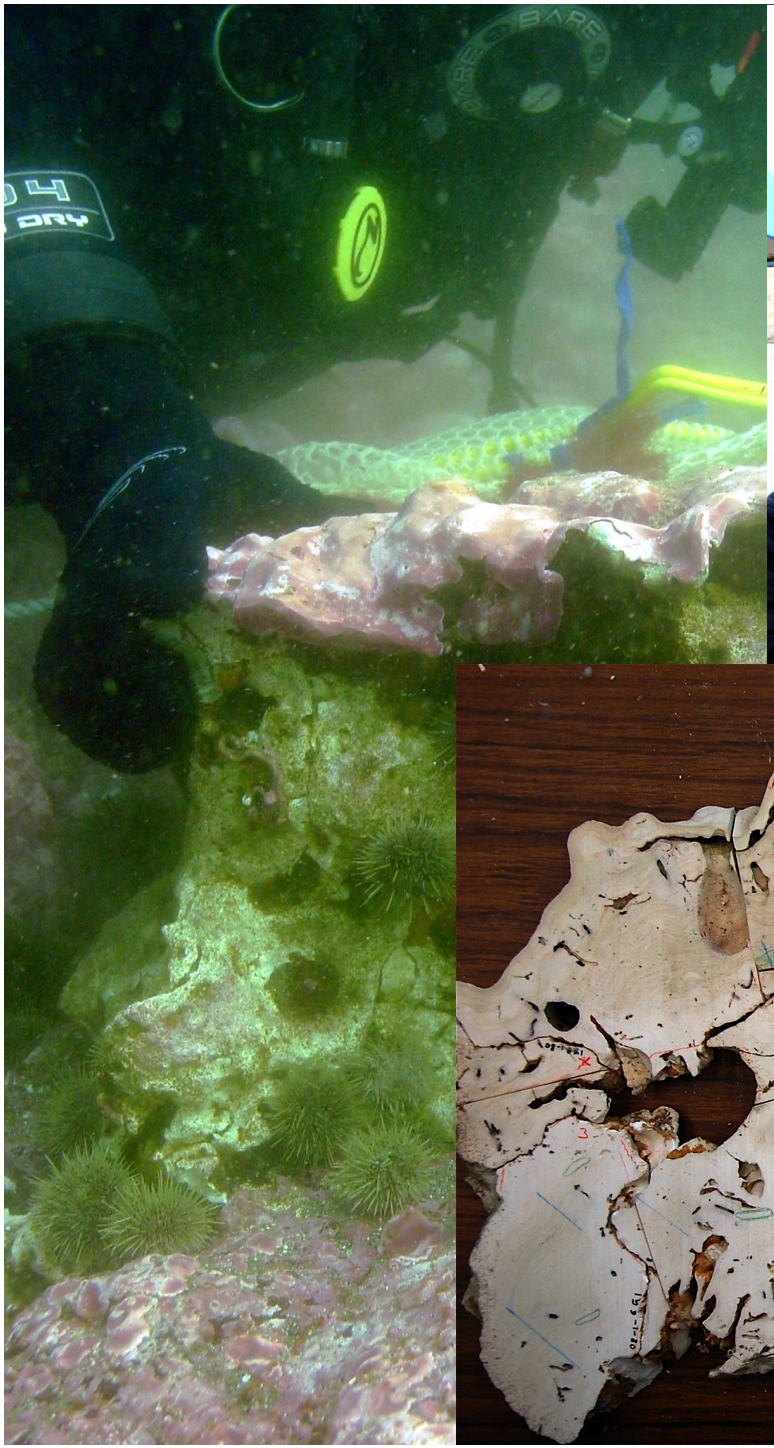

Clathromorphum nereostratum
(the world's thickest and oldest coralline alga)

Clathromorphum nereostratum: Indeterminate vertical growth

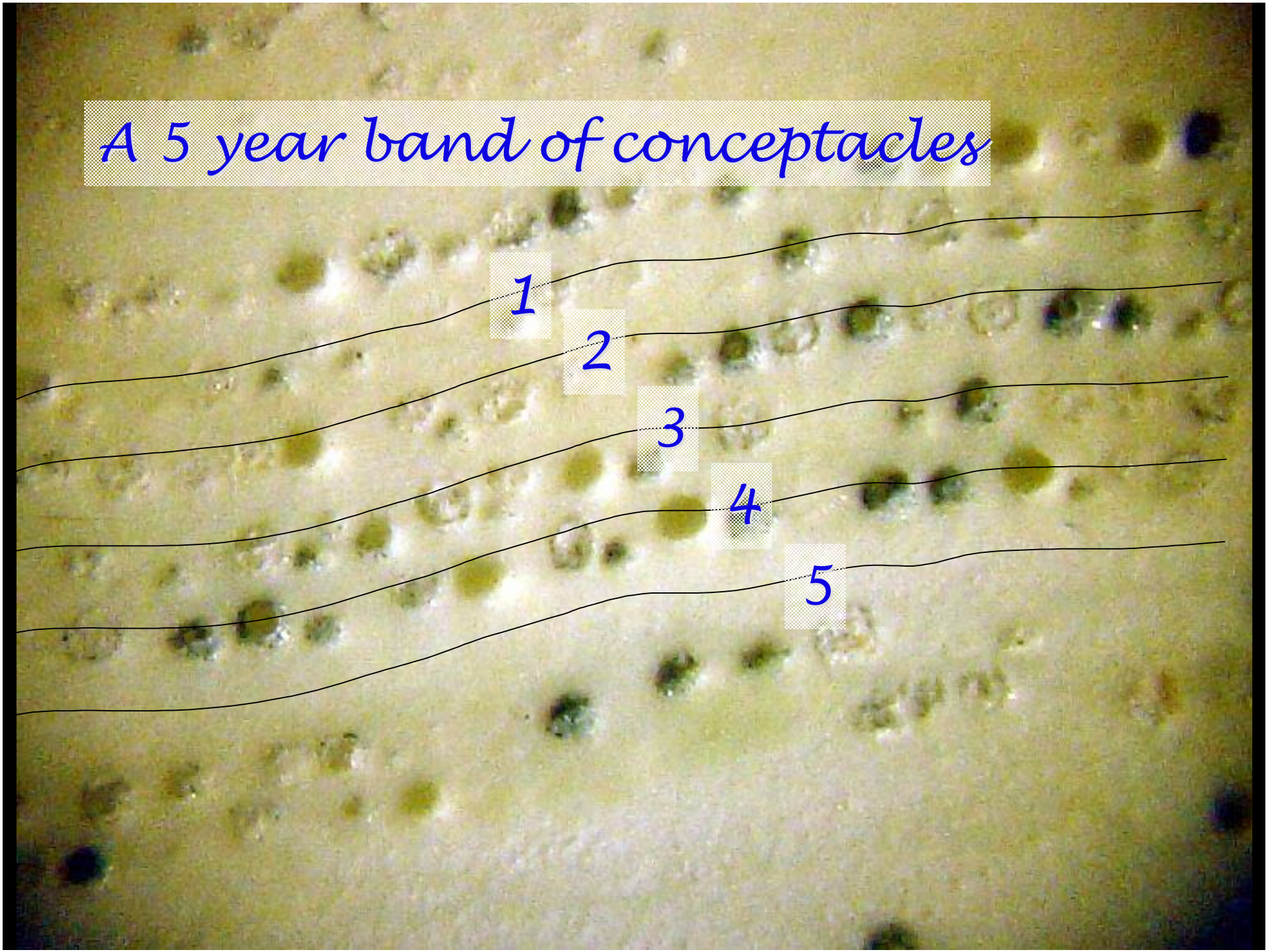
It grows upward: 1 mm/ 3yrs
It has been found nearly 1 meter thick!
No ecologist had studied it.



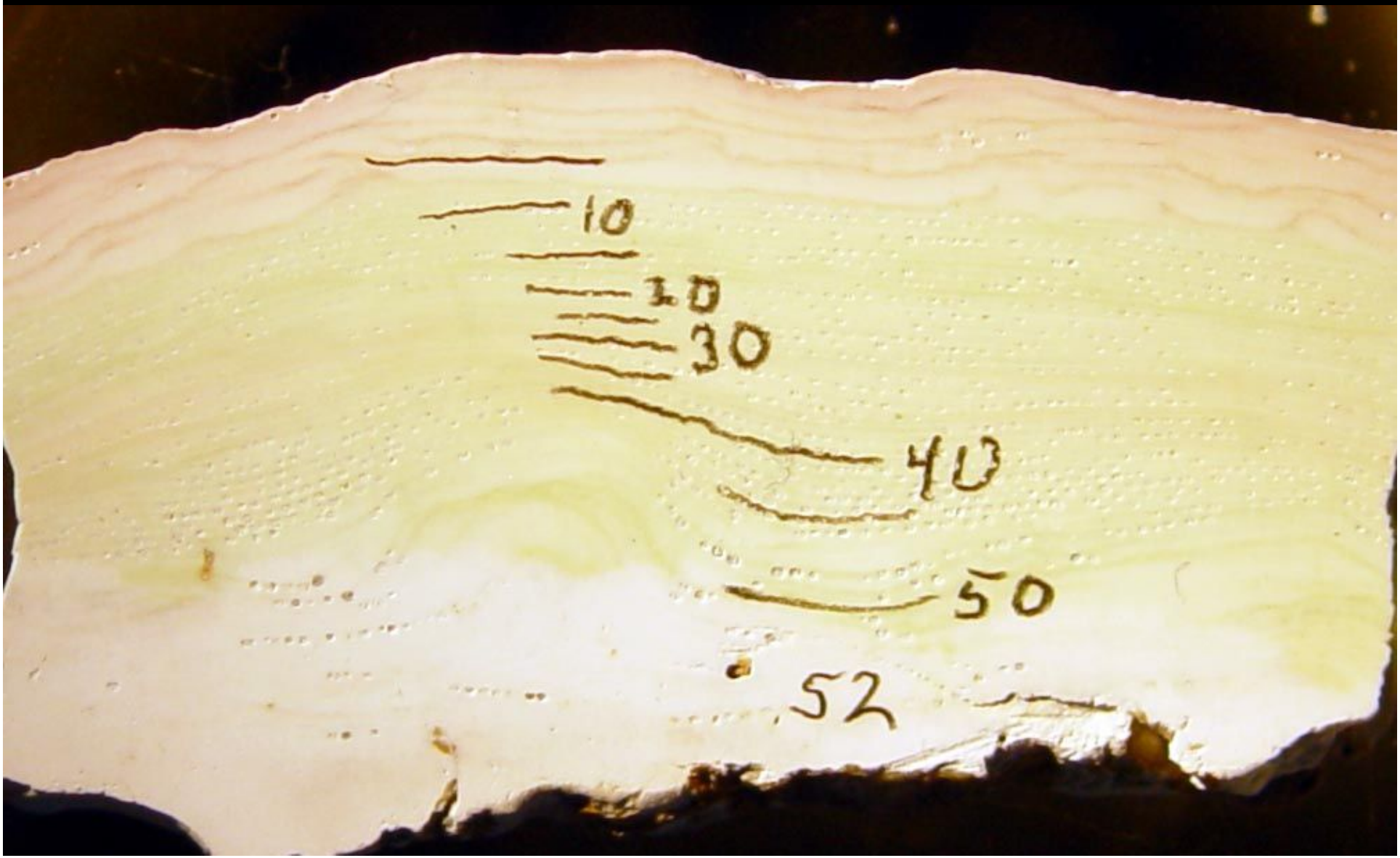
Looking for millennial scale patterns



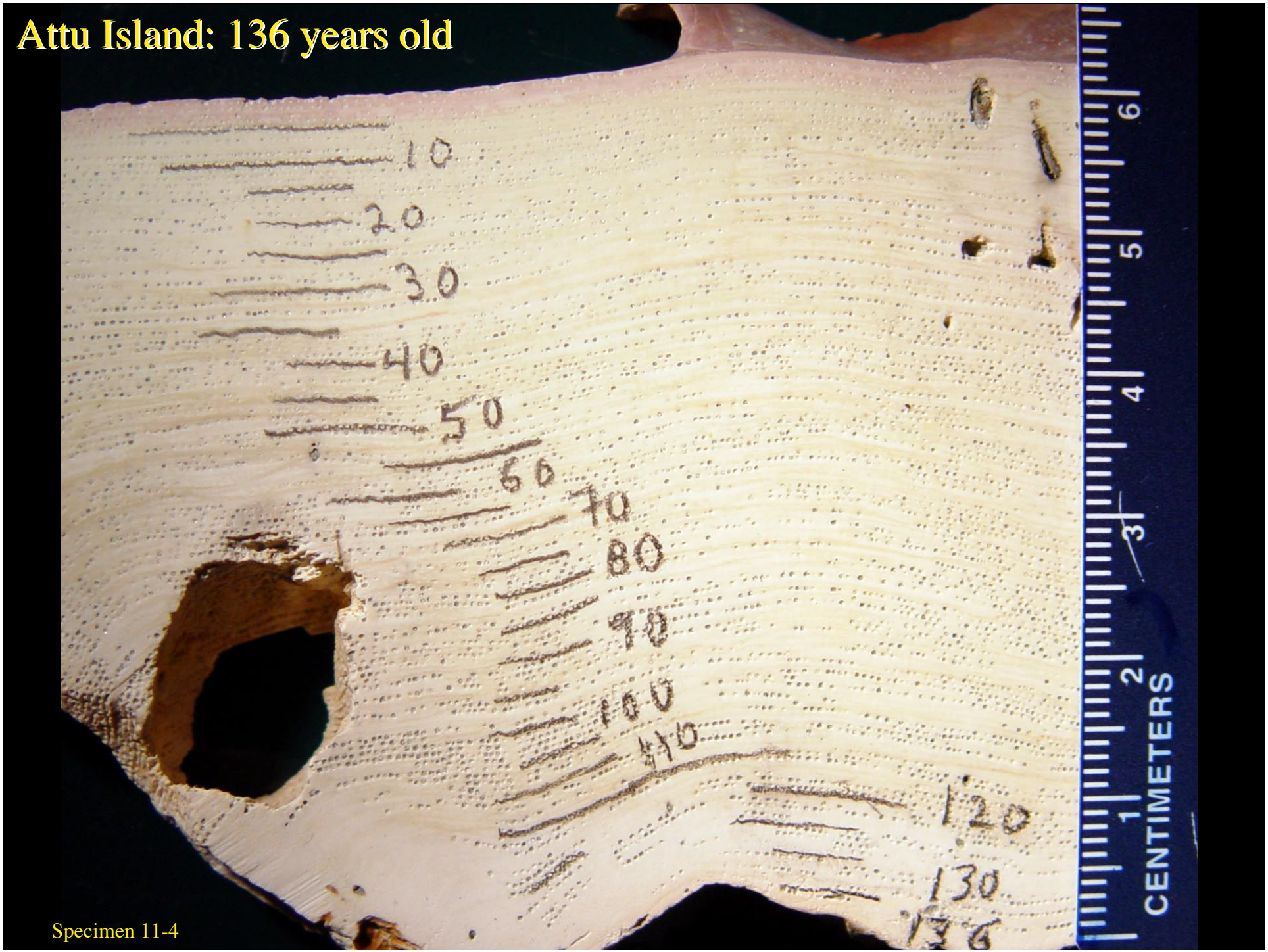
CENTIMETERS
Cat. No. 09-016
Fisher
Scientific
PRINTED IN U.S.A.
INCHES


A 5 year band of conceptacles
1
2
3
4
5

A 52 year old *C. nereostratum*



Attu Island: 136 years old

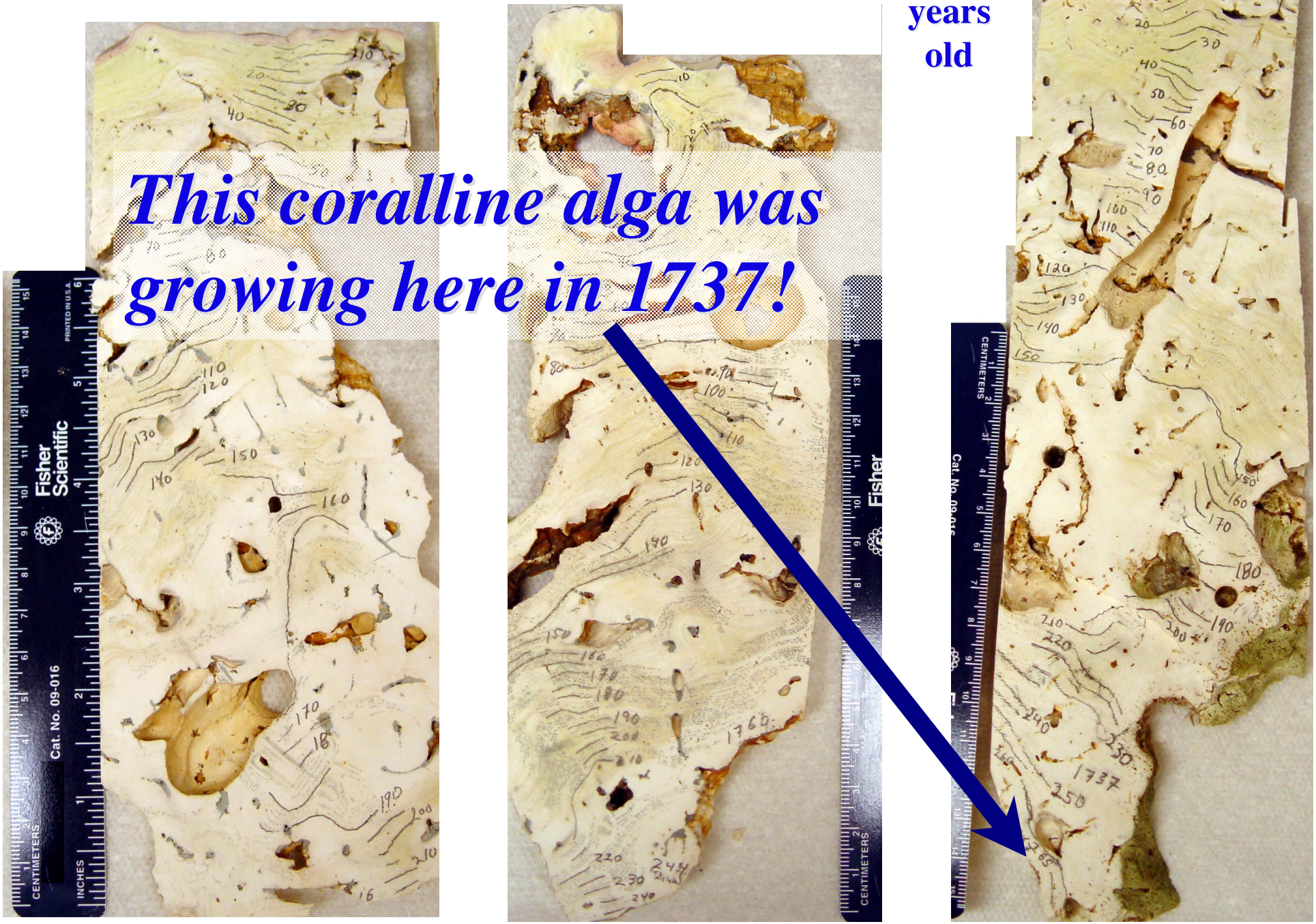


Specimen 11-4

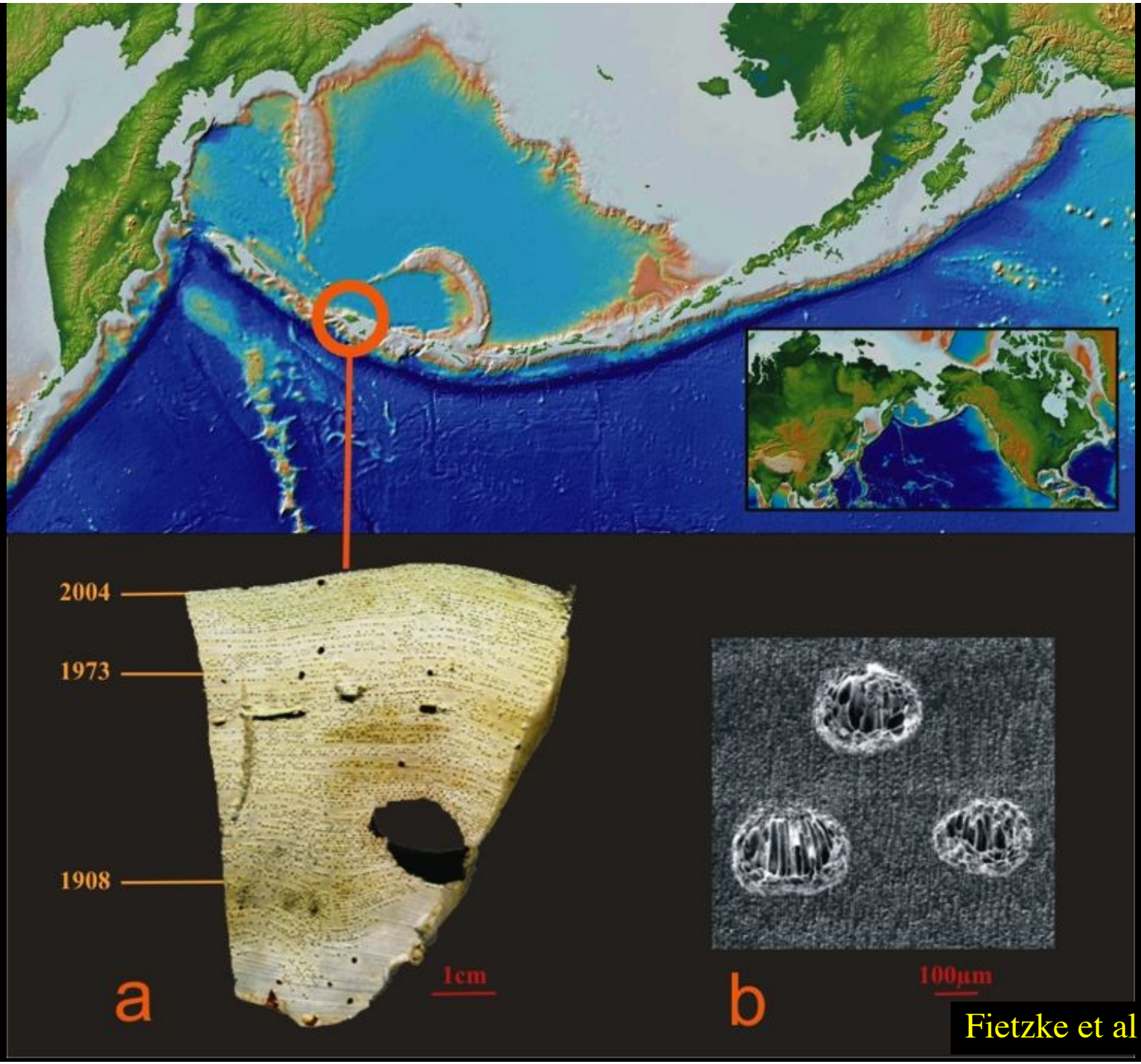
216 years old

244 years old

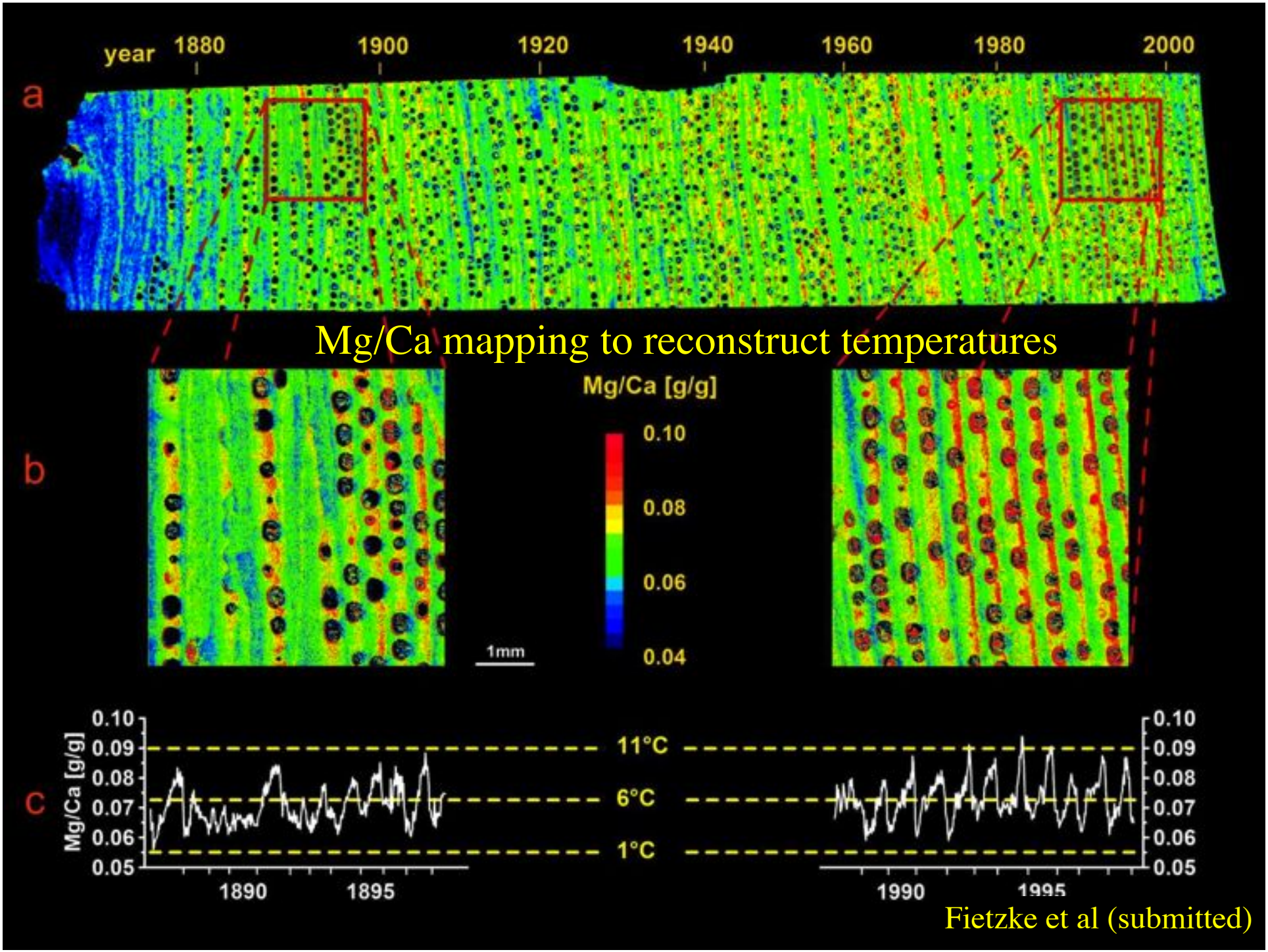
267 years old

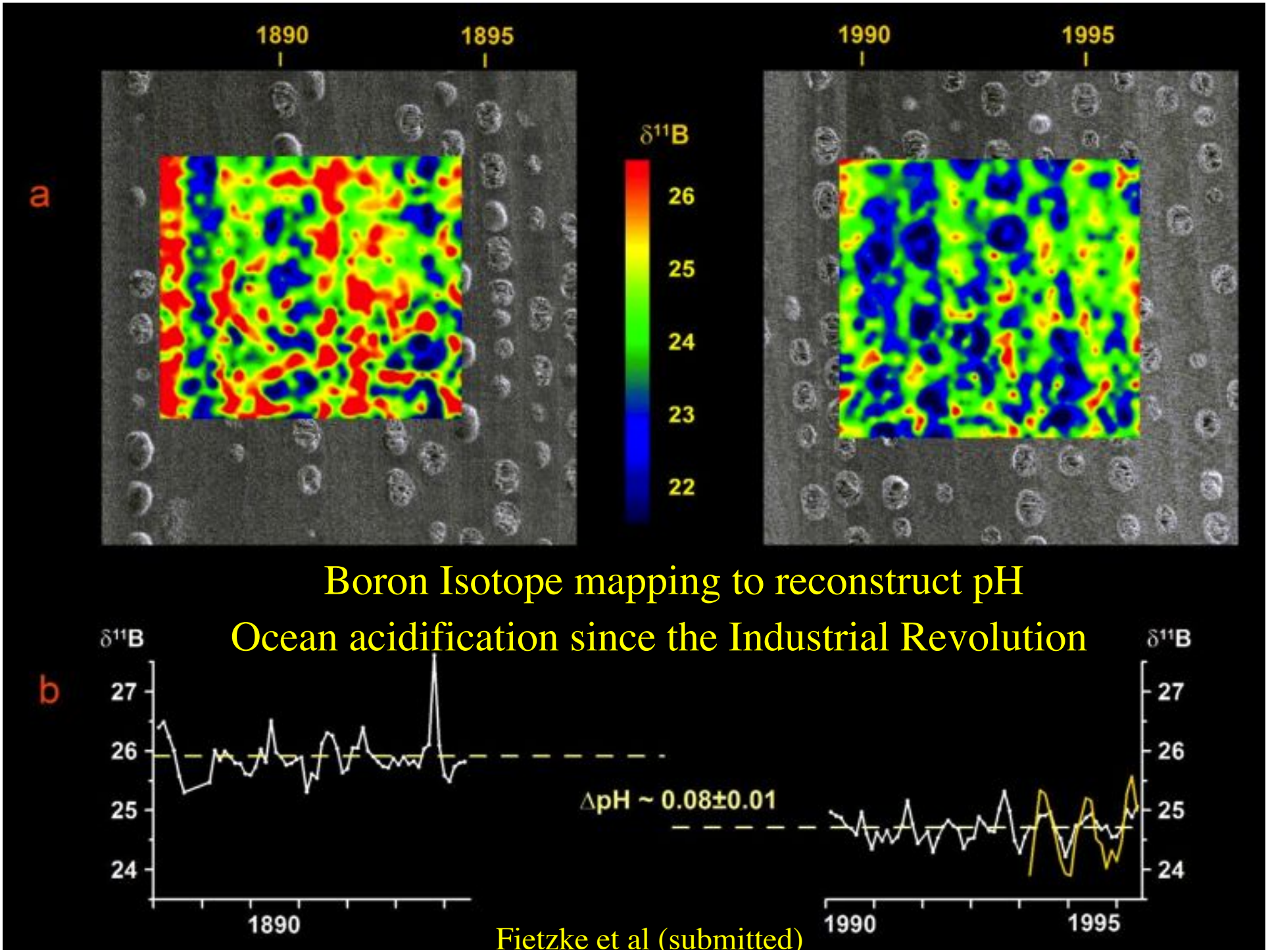


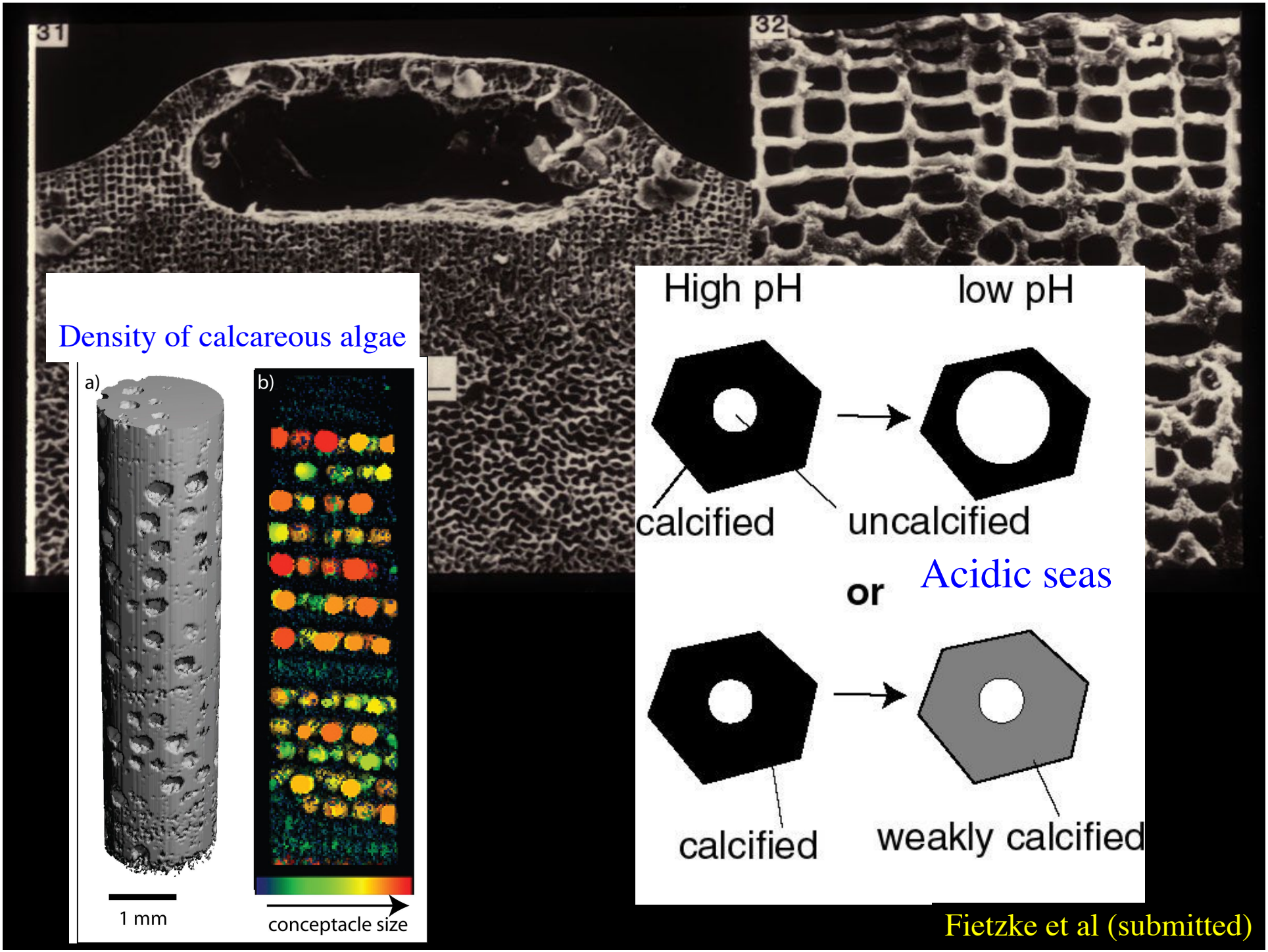
This coralline alga was growing here in 1737!



Fietzke et al (submitted)


Mg/Ca mapping to reconstruct temperatures
year
1880
1900
1920
1940
1960
1980
2000
a
b
c
Mg/Ca [g/g]
0.10
0.08
0.06
0.04
1mm
Mg/Ca [g/g]
0.10
0.09
0.08
0.07
0.06
0.05
11°C
6°C
1°C
1890
1895
1990
1995
Fietzke et al (submitted)


1890
1895
1990
1995
a
δ11B
26
25
24
23
22
Boron Isotope mapping to reconstruct pH
Ocean acidification since the Industrial Revolution
δ11B
b
27
26
25
24
ΔpH ~ 0.08±0.01
1890
1990
1995
Fietzke et al (submitted)

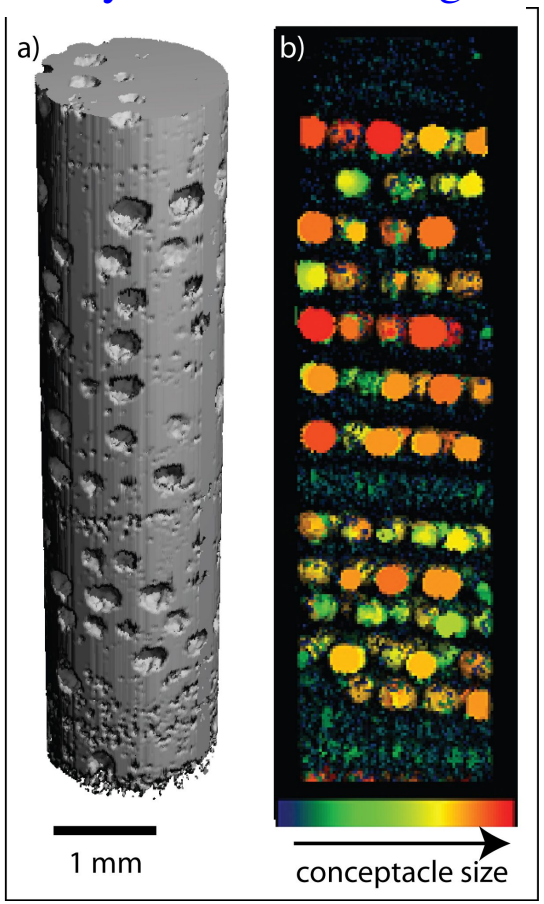

31
32
Density of calcareous algae
a)
b)
1 mm
conceptacle size
High pH
low pH
calcified
uncalcified
Acidic seas
or
calcified
weakly calcified
Fietzke et al (submitted)

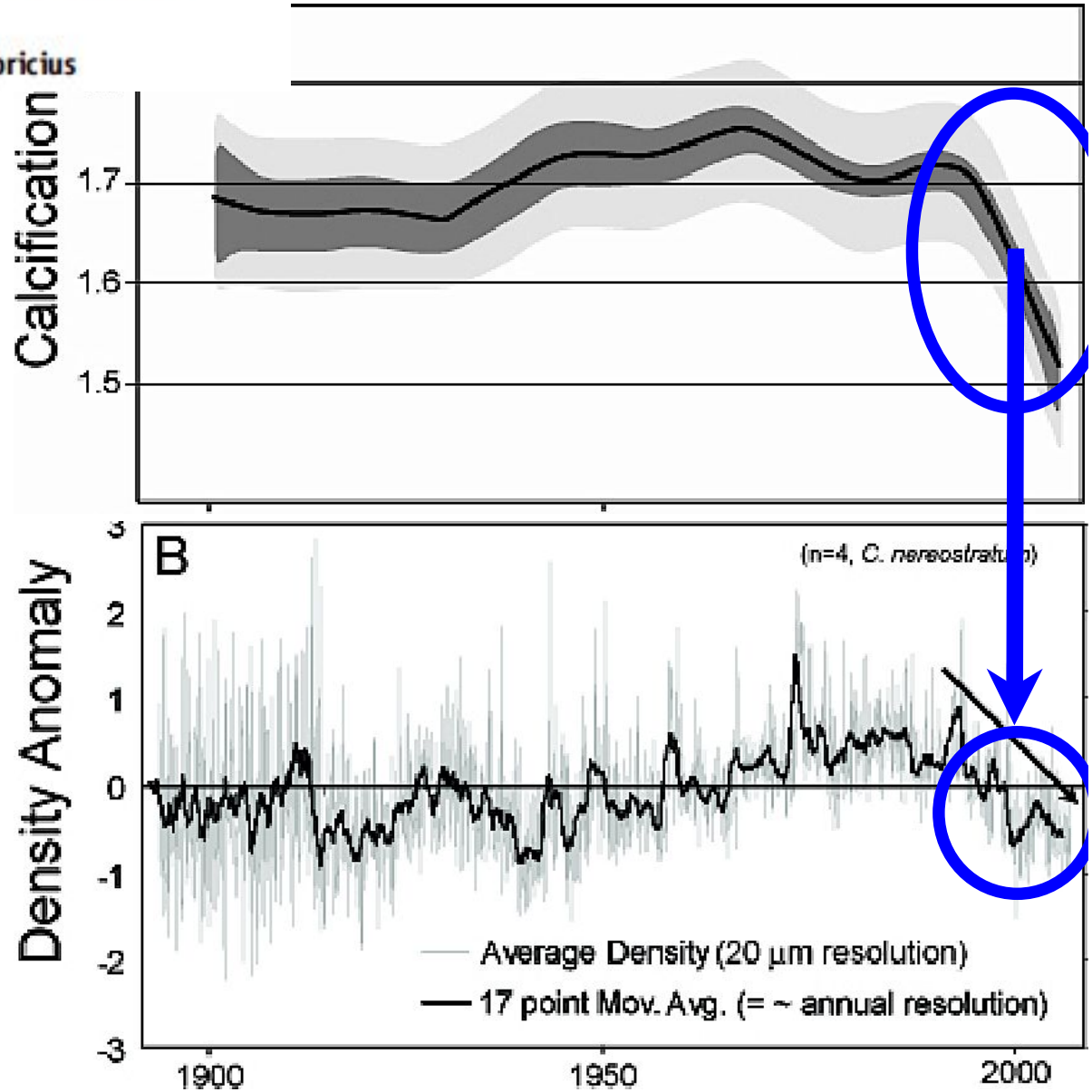
Declining Coral Calcification on the Great Barrier Reef

Glenn De'ath,* Janice M. Lough, Katharina E. Fabricius

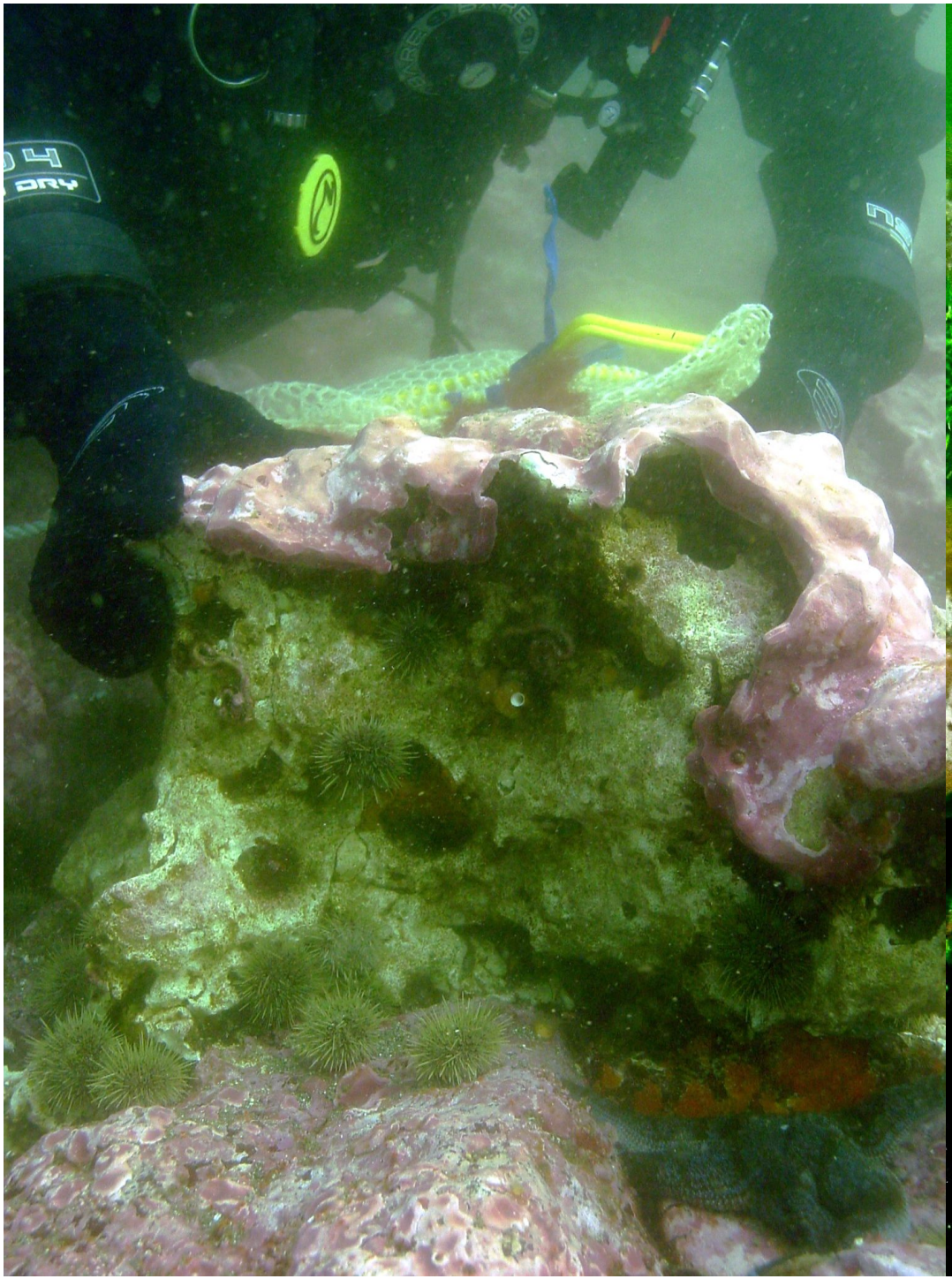
So what?

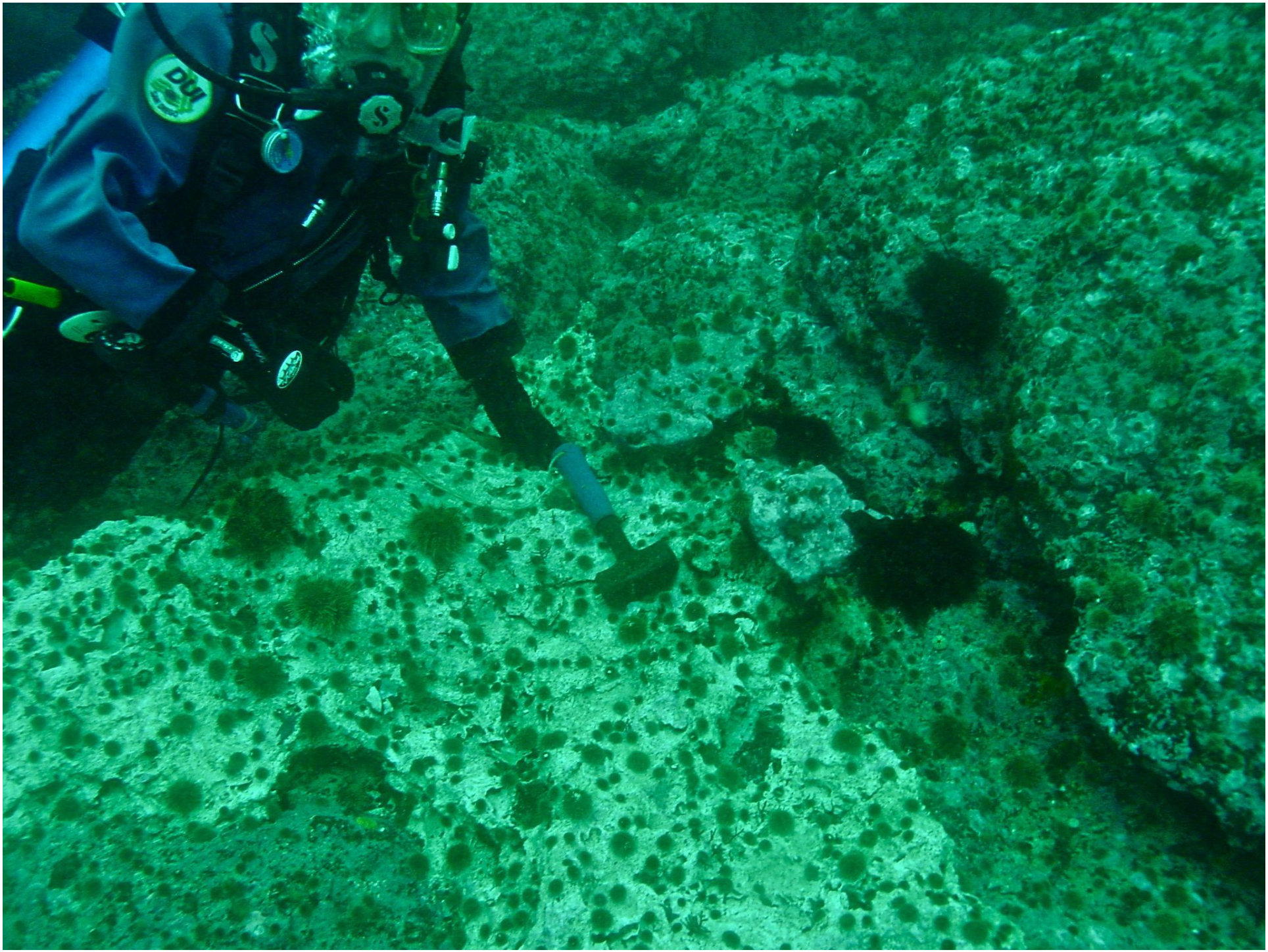
Density of calcareous algae

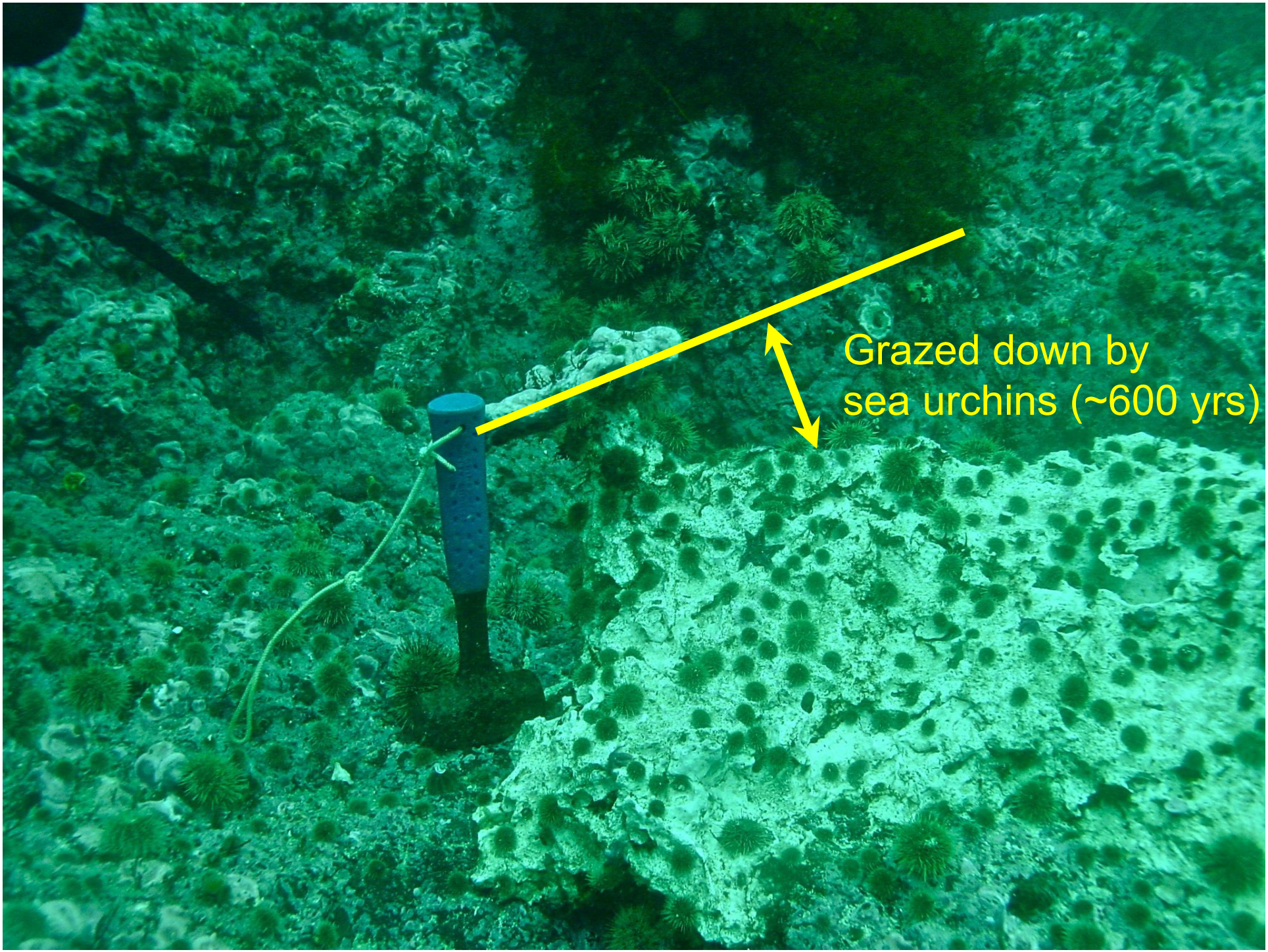


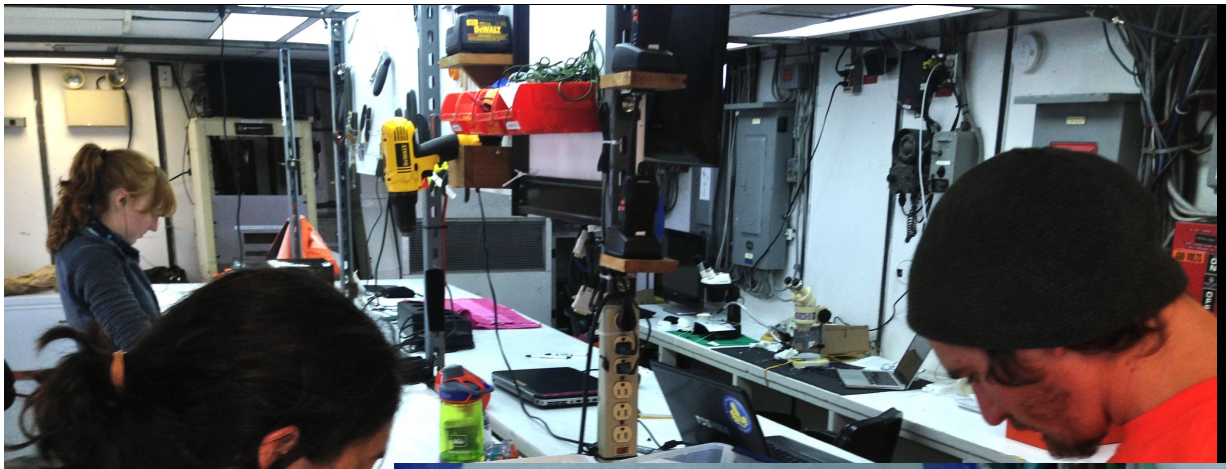


Halfar and Steneck in prep.




DUI


Grazed down by
sea urchins (~600 yrs)

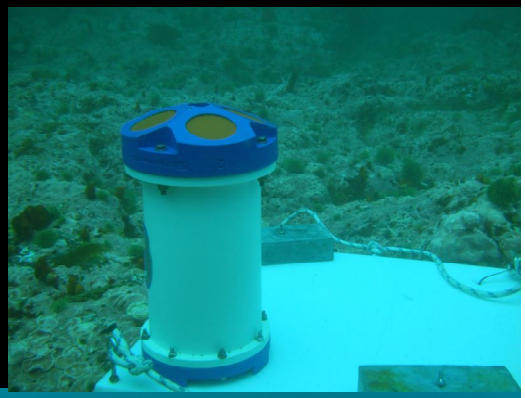


Collateral Damage

Diverse fauna depends on these reefs.

Considerable work left to do but it is possible that OA weakens the architectural strength of dominant reef builder

Local community dynamics matter



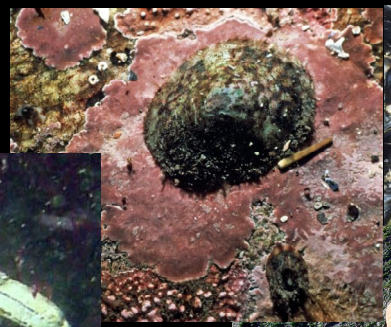
4. Risks & Challenges for Maine

Maine is at risk because calcareous organisms are important to our cold-water marine ecosystem and to our economy.

Many animals on the coast of Maine use limestone

Lobster

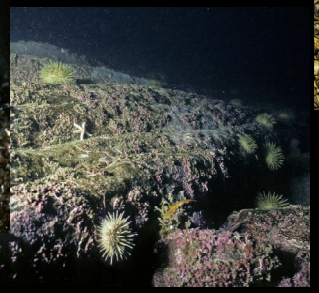
Crabs



Snails

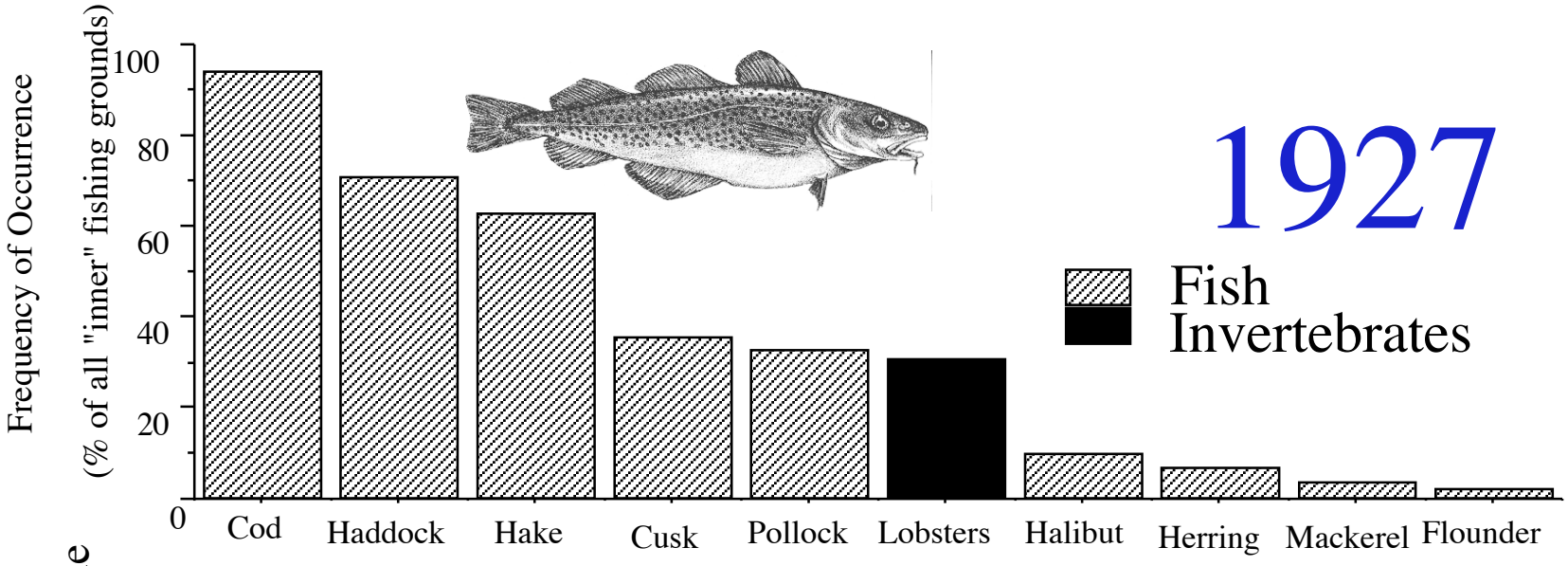
Mussels & Clams

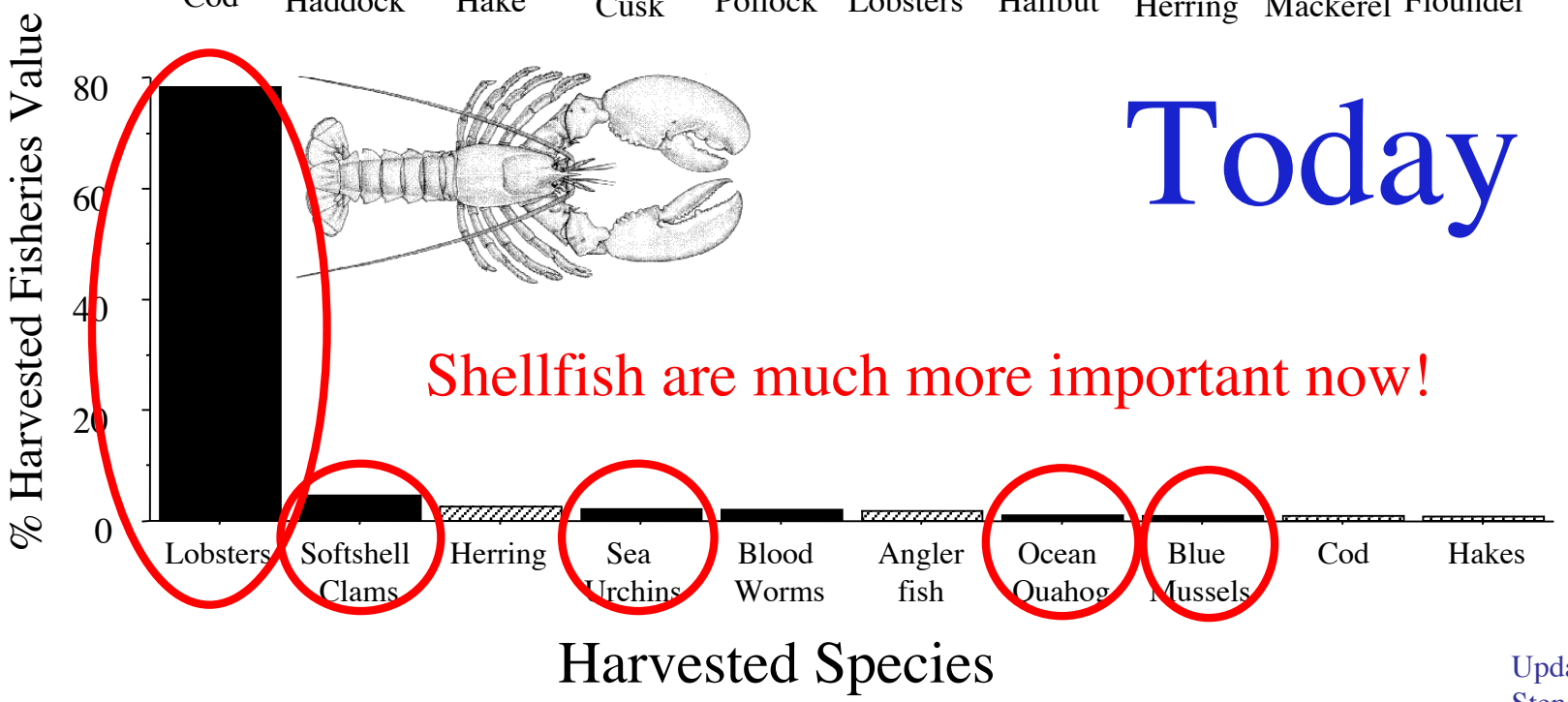
Sea urchins



Barnacles

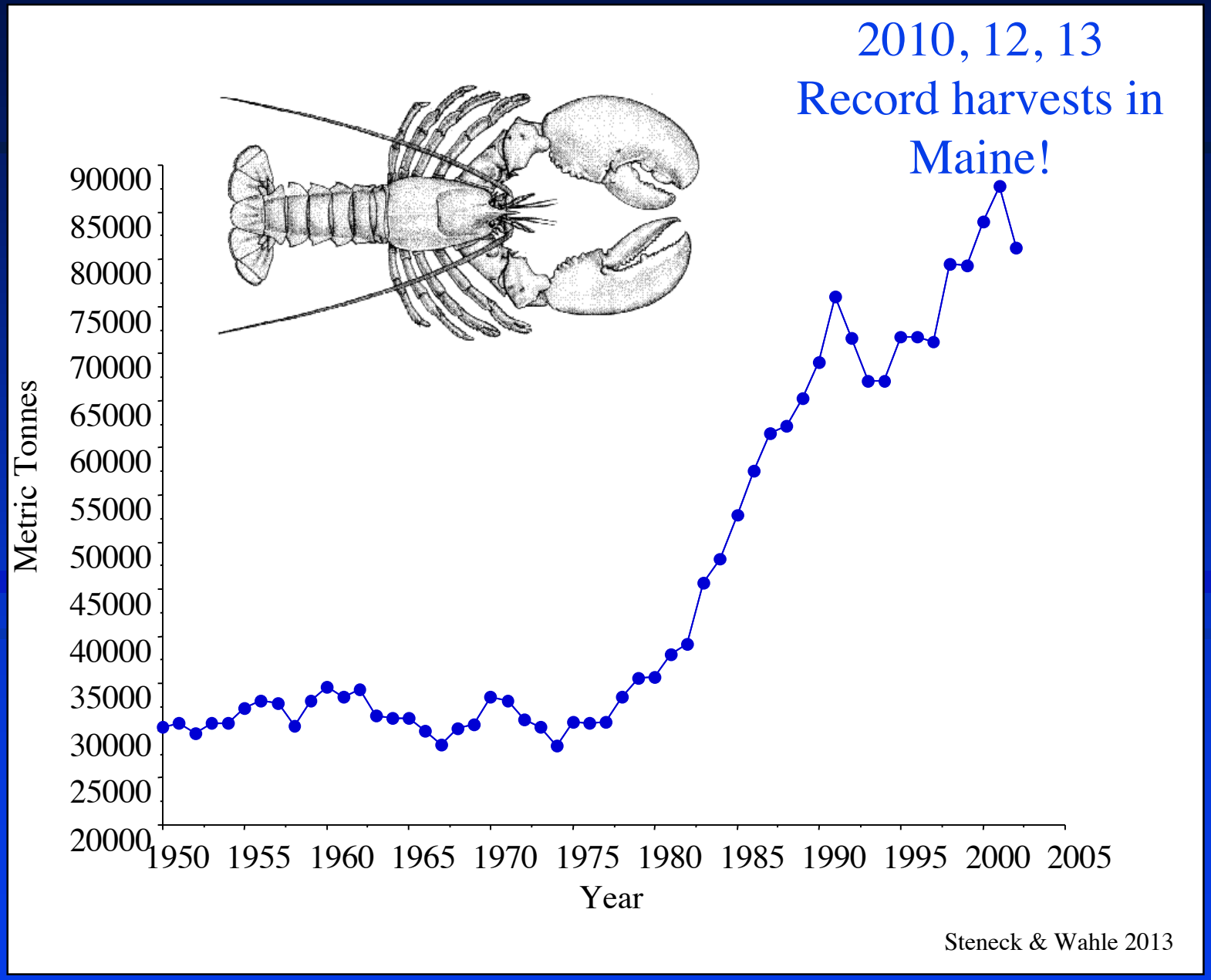
Coastal Fisheries of Maine





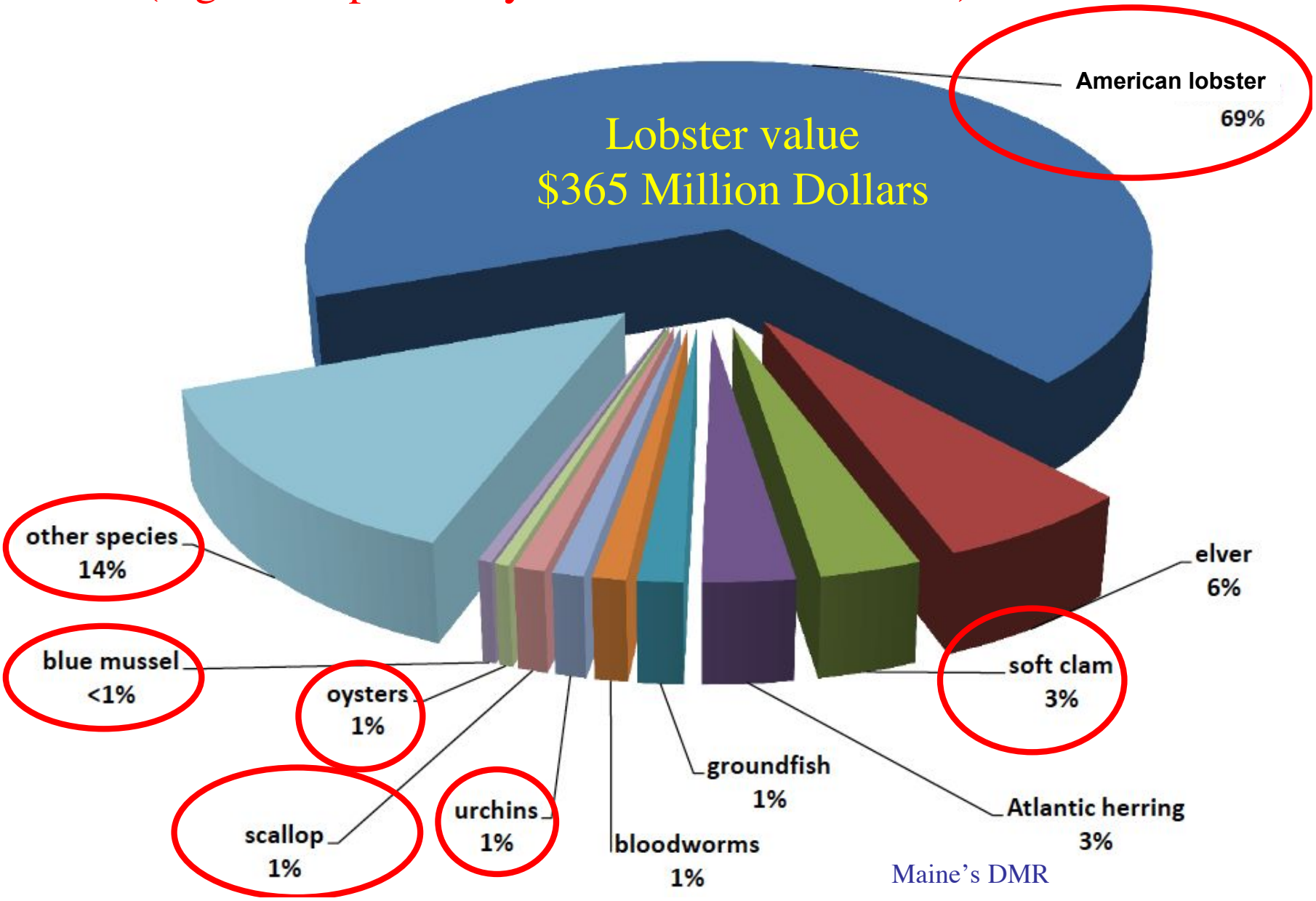
Updated from Steneck 1997

Lobster Landings: W. North Atlantic



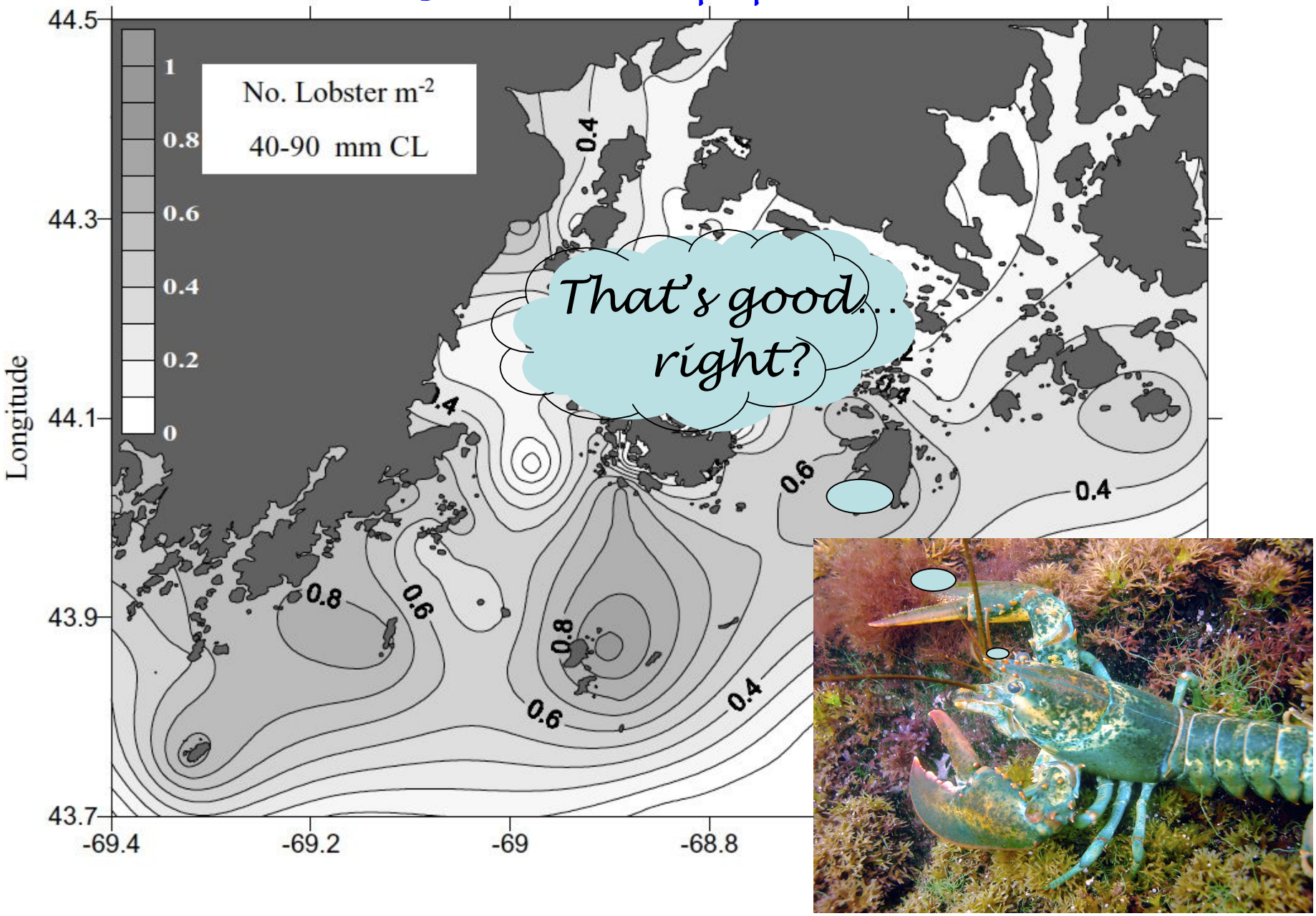
Maine's marine resource value: shellfish comprise over 75%

(highest dependency on shellfish in the US!)



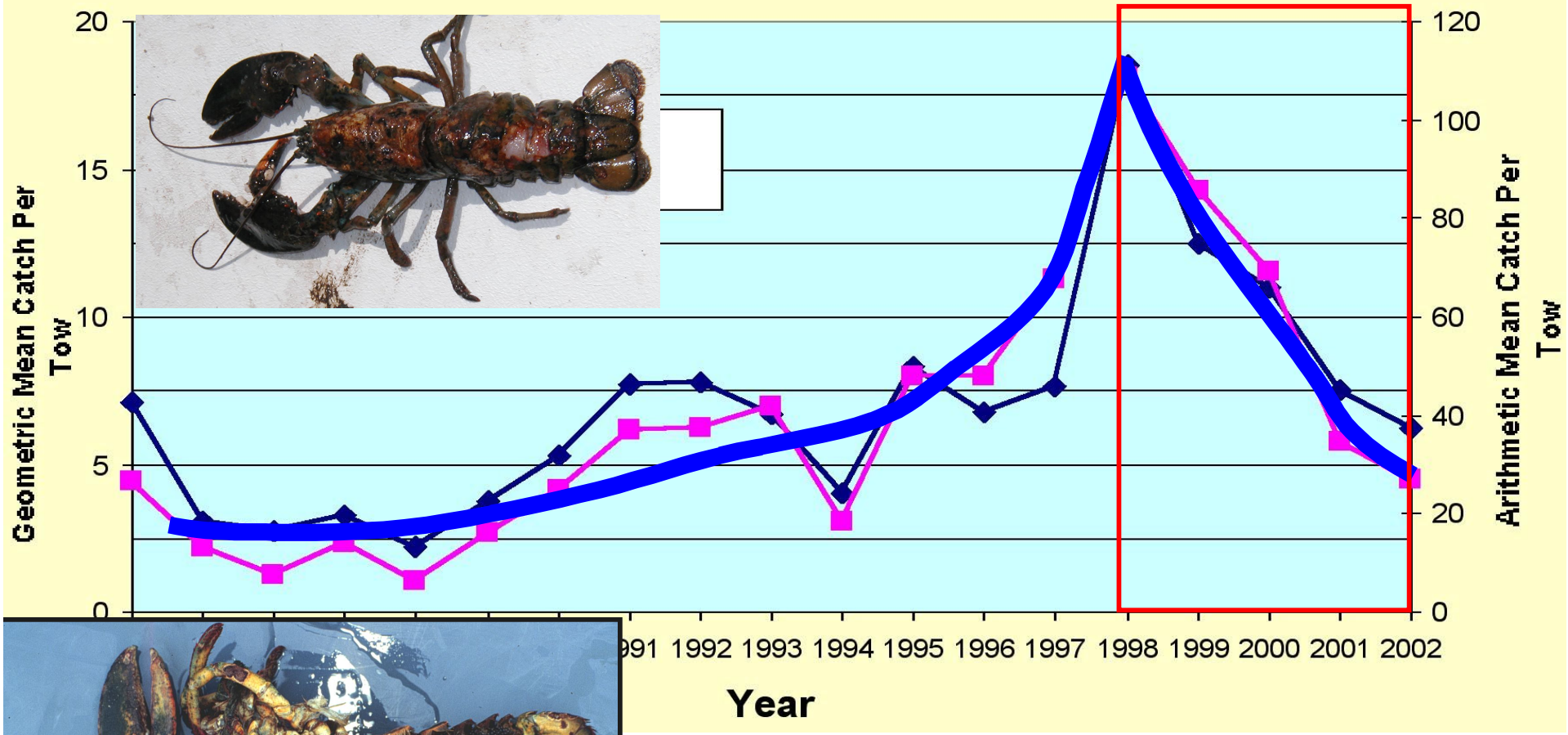
Maine's DMR

Maine has the highest lobster population densities in the world



Steneck & Wilson (2001)

Lobster Abundance in Long Island Sound



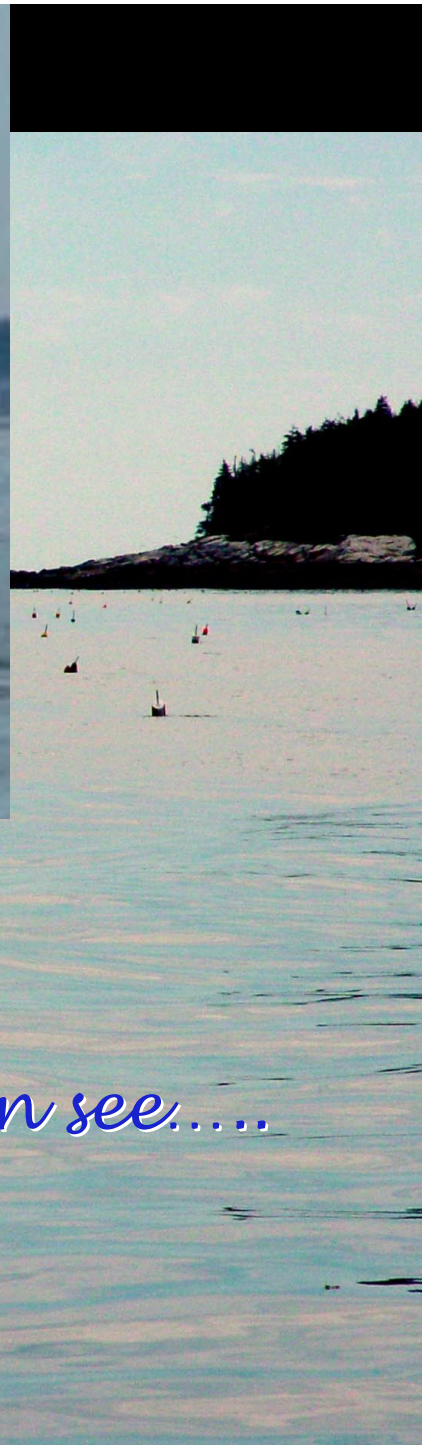
Shell Disease

Likely triggered by cumulative stresses

Castro et al 2006

6000 lobstermen depend on this one species

A socio-economic Time Bomb?



Only lobster traps as far as the eye can see…..

My intention is not to be alarmist but…..

1. Maine has always been a difficult place for shellfish to live
2. Ocean acidification makes the cost of doing business for shellfish greater (more stressful)
3. Hyperabundances of lobsters with acidification and warming puts them at greater risk of disease
4. If we lose Maine's lucrative monoculture, our coastal zone and maritime way of life will be at risk

This is one of Maine's biggest risks and biggest challenge

In Conclusion: ***Ocean Acidification: Ecosystem Effects and Challenges for Maine***

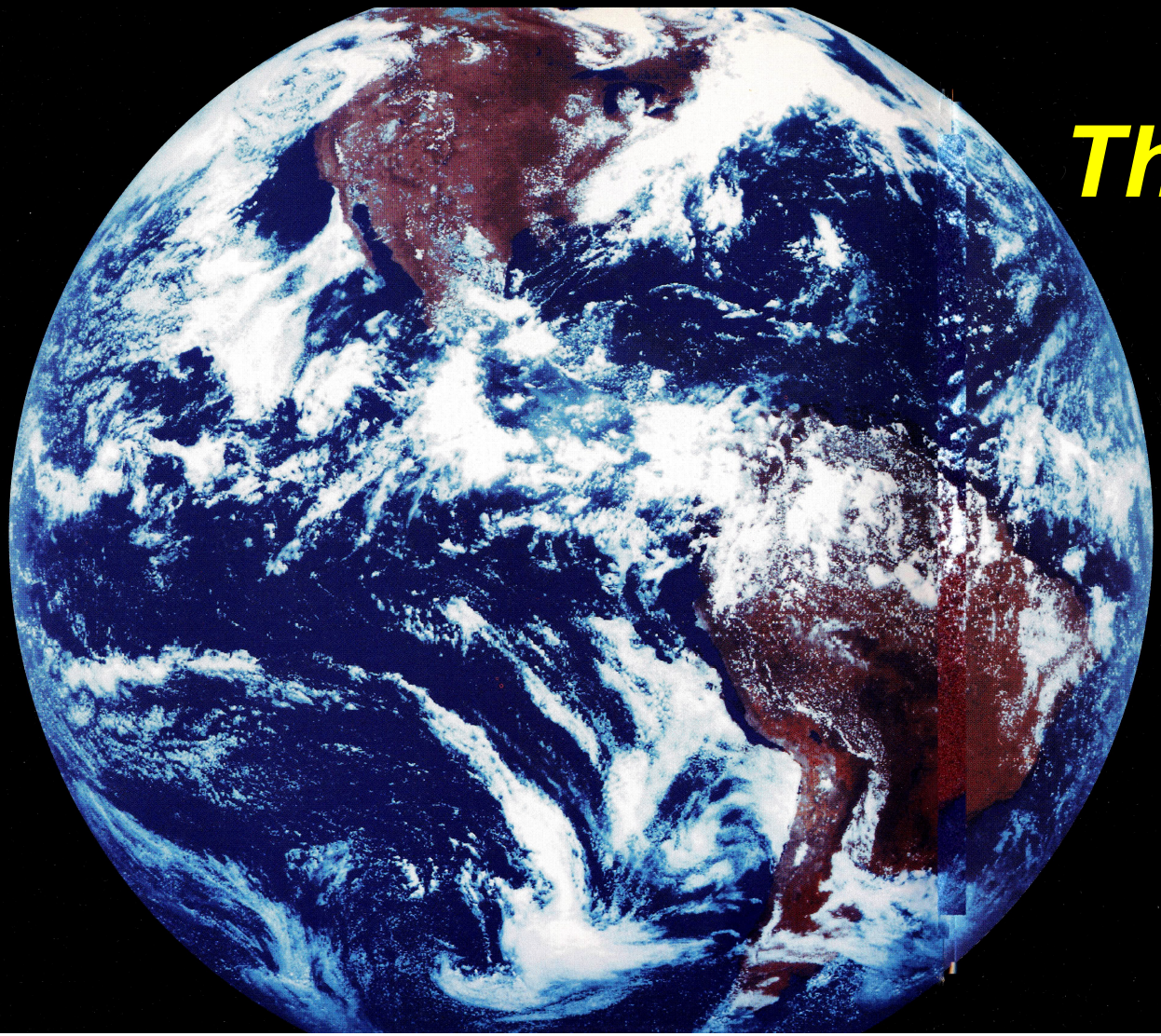
1. We must go beyond the study of single species.

2. We need to consider how OA affects the *structure* and *functioning* of our marine ecosystem

3. We should new apply tools to determine OA patterns in space and in time. There may be local 'hot-spots' and 'cold-spots' that could guide us for future planning.

4. Maine's low diversity but high value of calcified marine organisms puts our state at high risk for effects from OA.

Ocean Acidification: Ecosystem Effects and Challenges for Maine



Thank you!