



SAINT JOSEPH'S
COLLEGE

Ocean Acidification: An Overview

Mark A. Green
Jan. 30, 2020



National Science Foundation
WHERE DISCOVERIES BEGIN



The burning of fossil fuels releases
9 BILLION TONS
of carbon dioxide into the atmosphere
every year.

The carbon put into the atmosphere
each year is enough to fill a string of
coal cars 159,000 miles in length.
This would wrap around the world almost
7X.

<http://www.climateshifts.org/?p=4647>

8.3±0.4 PgC/yr 90%



1.0±0.5 PgC/yr 10%



+

4.3±0.1 PgC/yr
46%



2.6±0.8 PgC/yr
28%

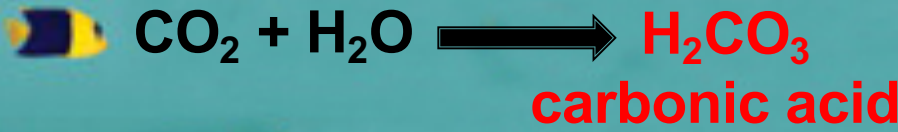


Calculated as the residual
of all other flux components

2.5±0.5 PgC/yr
26%



CO₂



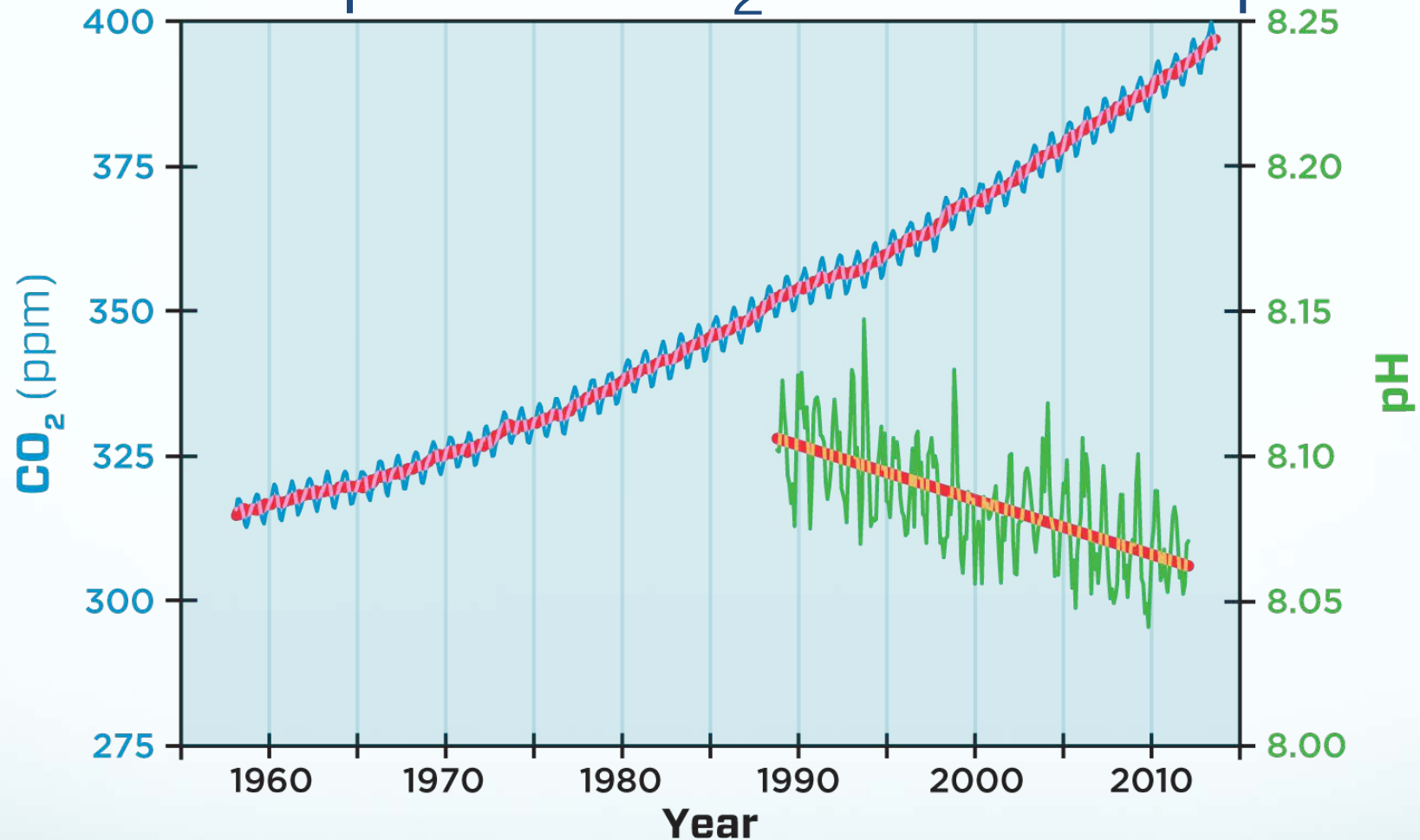
Carbonic acid reduces ocean pH.



The concentration of carbonate ions decreases.



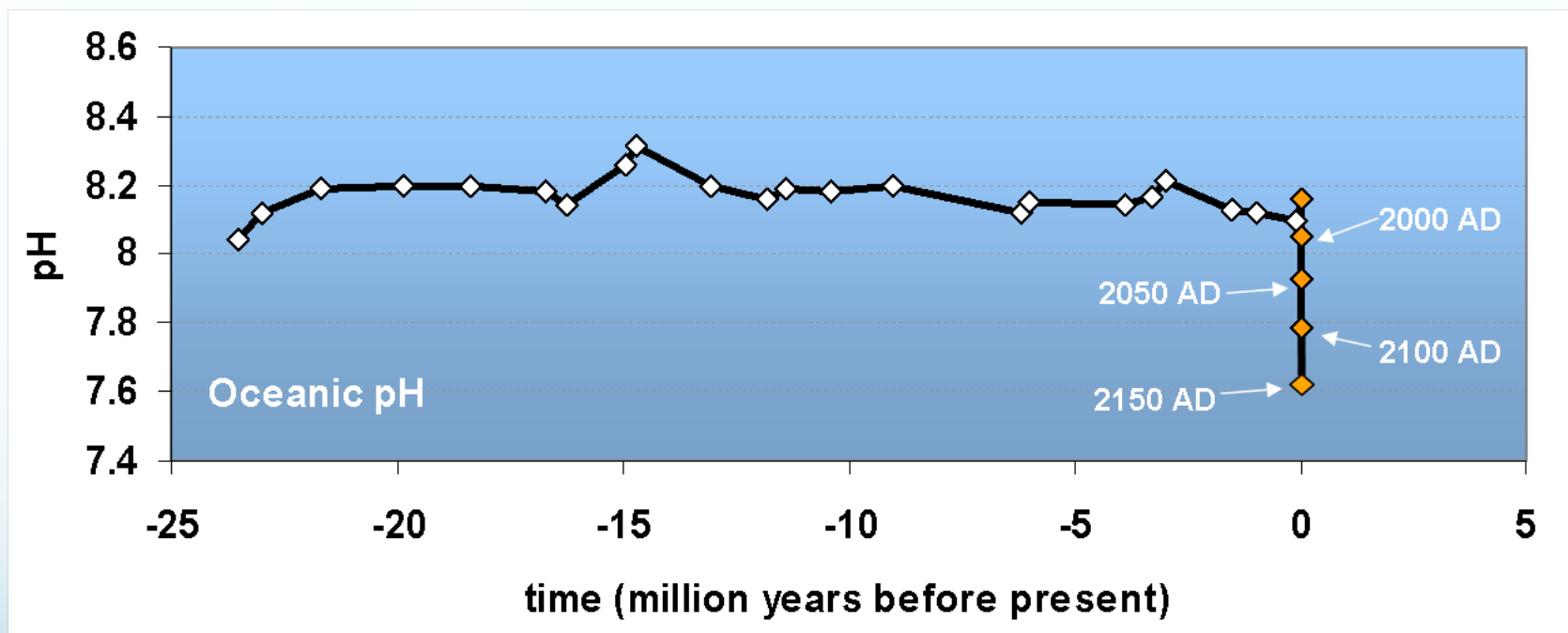
Atmospheric CO₂ and ocean pH



Anthropogenic ocean acidification is currently in progress and is measurable [VERY HIGH CONFIDENCE]

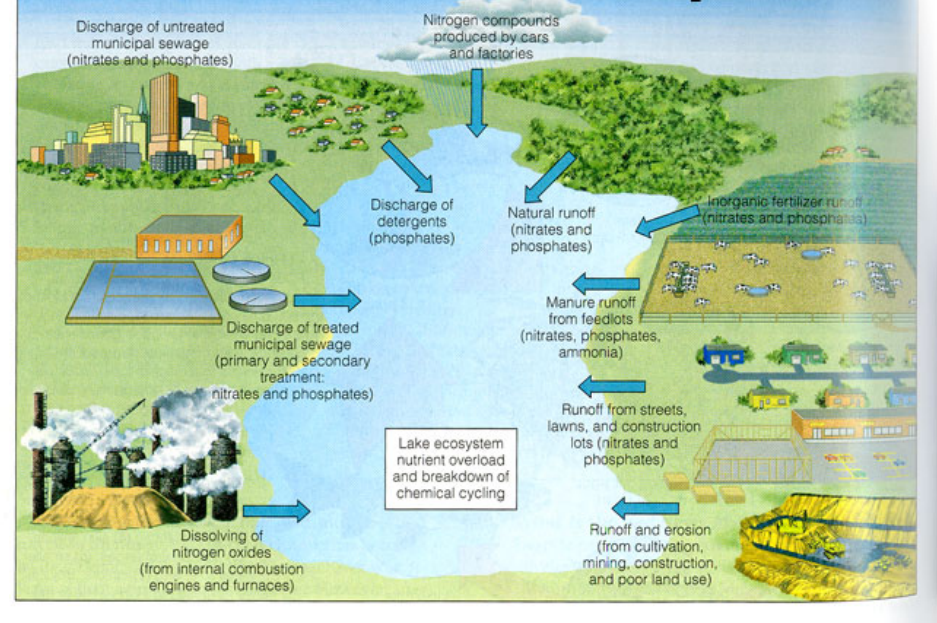
Rapid ocean acidification

H The ocean is acidifying more rapidly than it has in millions of years [HIGH CONFIDENCE]



CO₂ from fossil fuels or CO₂ from Phytoplankton...
at the end of the day it is all acid and it is produced in both the overlying water and the underlying sediments.

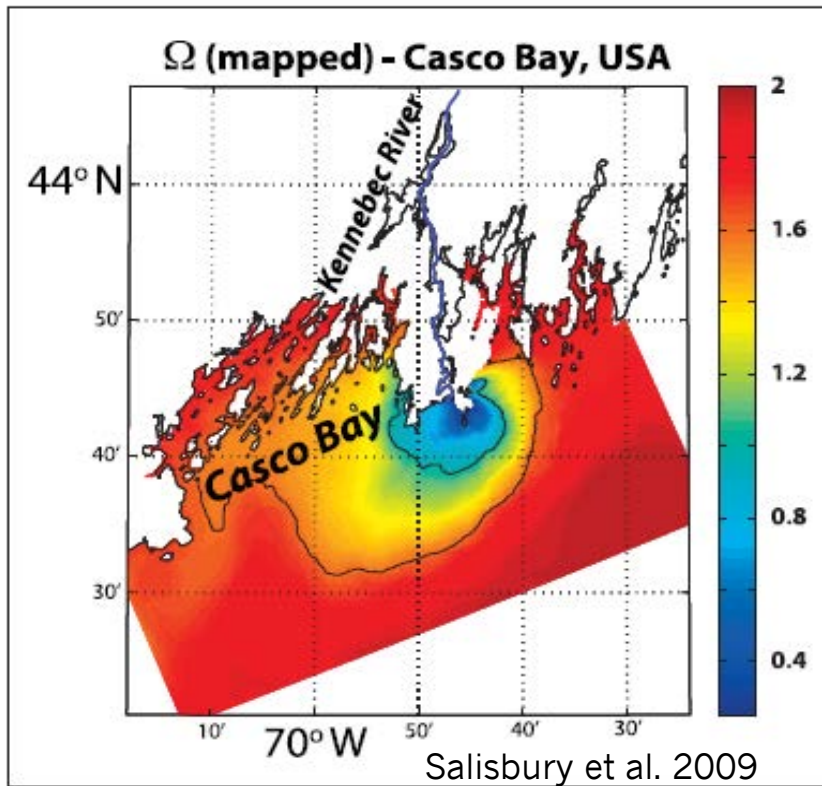
Sources of Cultural Eutrophication



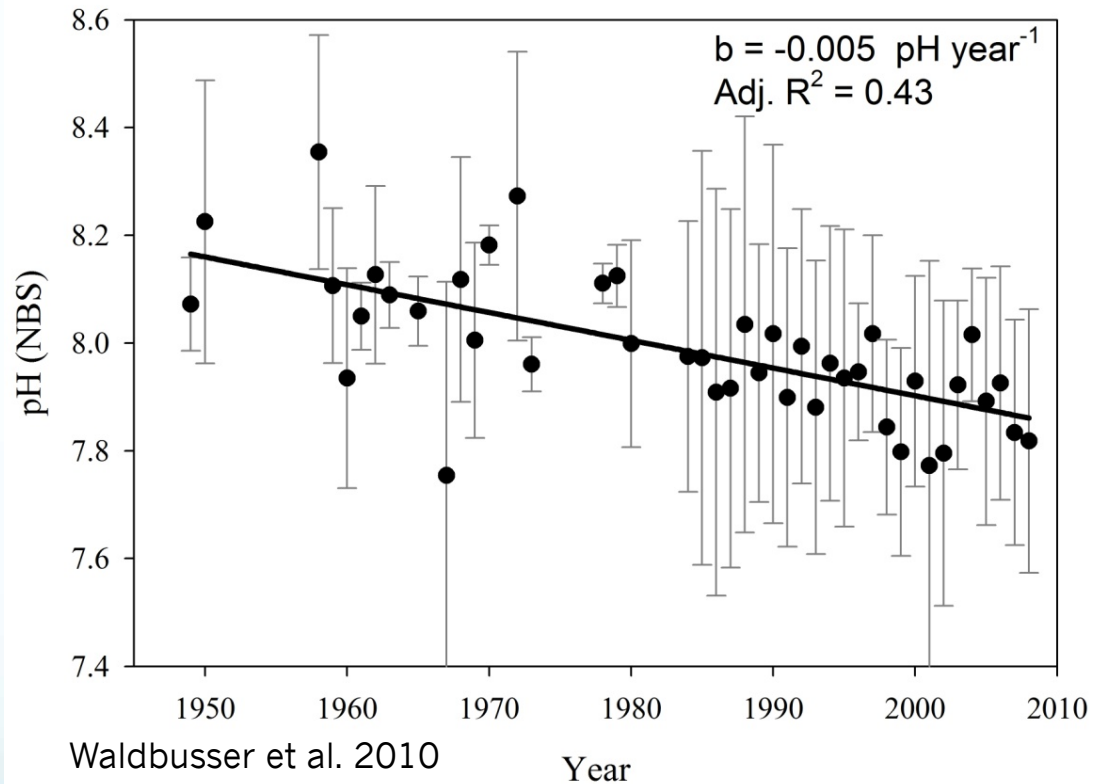
Coastal and Estuarine Acidification - Examples

Rivers lower available CO_3

Estuaries also show evidence of acidification



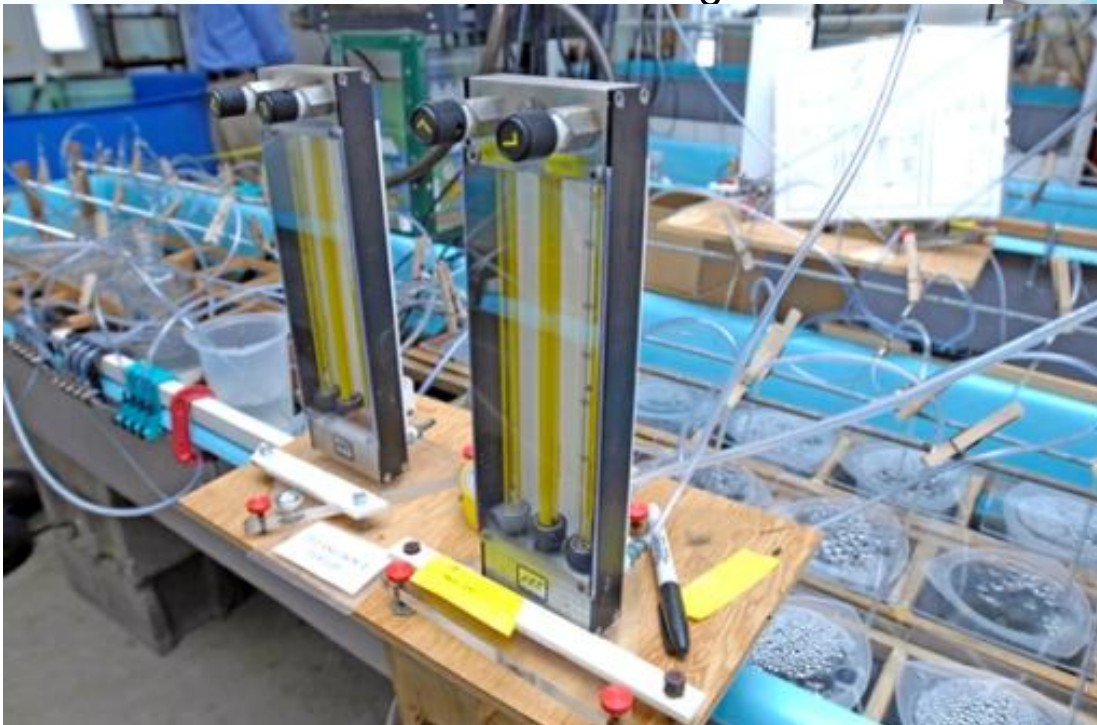
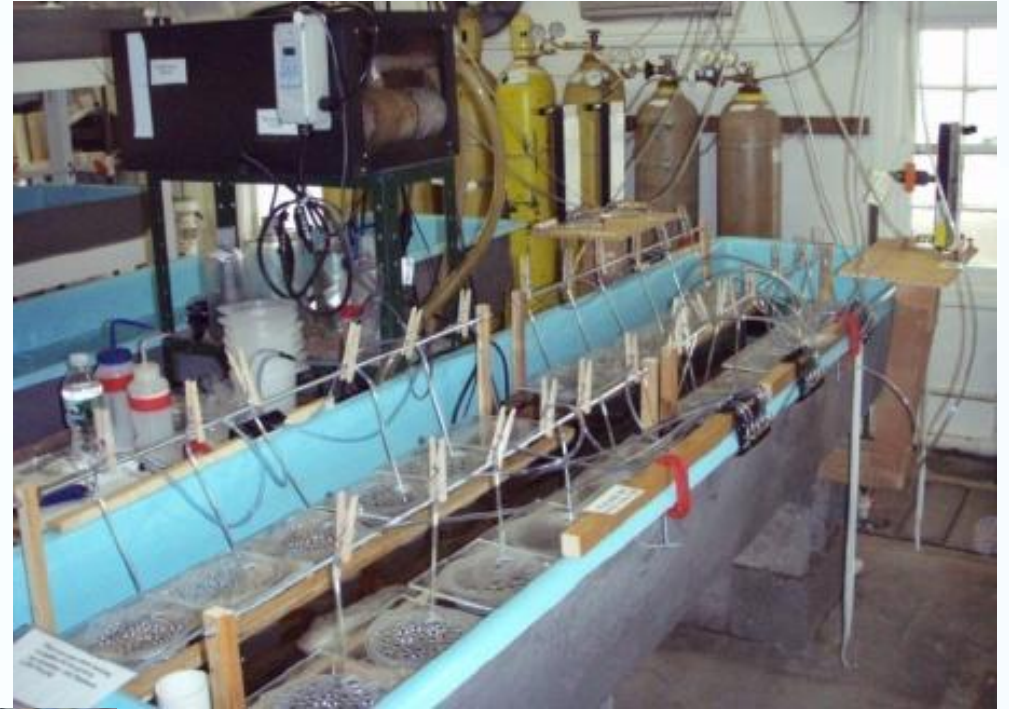
Chesapeake Bay pH Summer, Salinity > 20



Coastal acidification threatens all commercially and ecologically important calcifying organisms

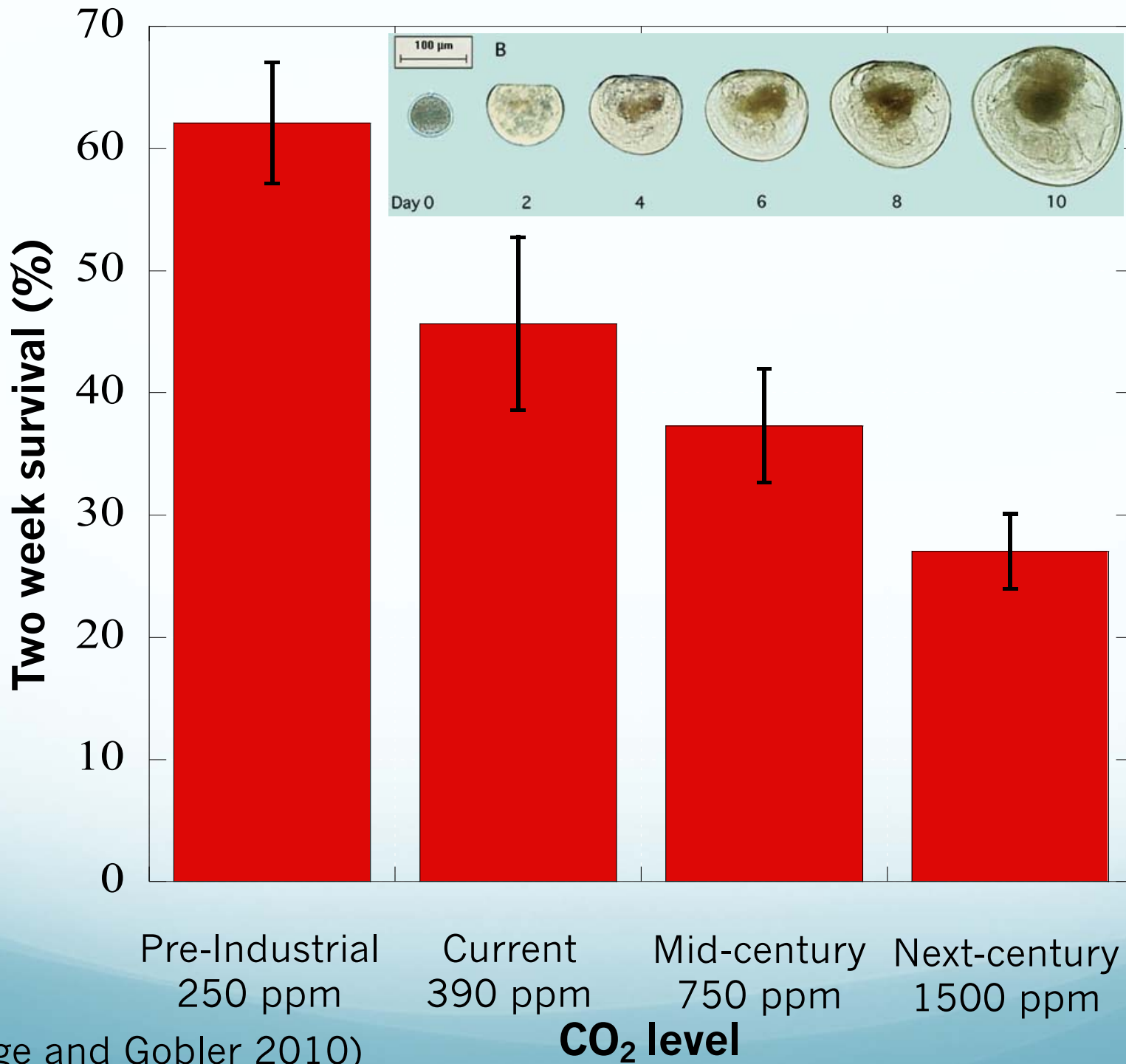
Methods: CO₂ treatments

- CO₂ / air mixed in gas proportionator to desired flow rates
- Experiments replicated with pre-mixed gases
- Desired CO₂ levels bubbled into replicated treatment vessels
- Constant temperature is maintained via circulating water bath



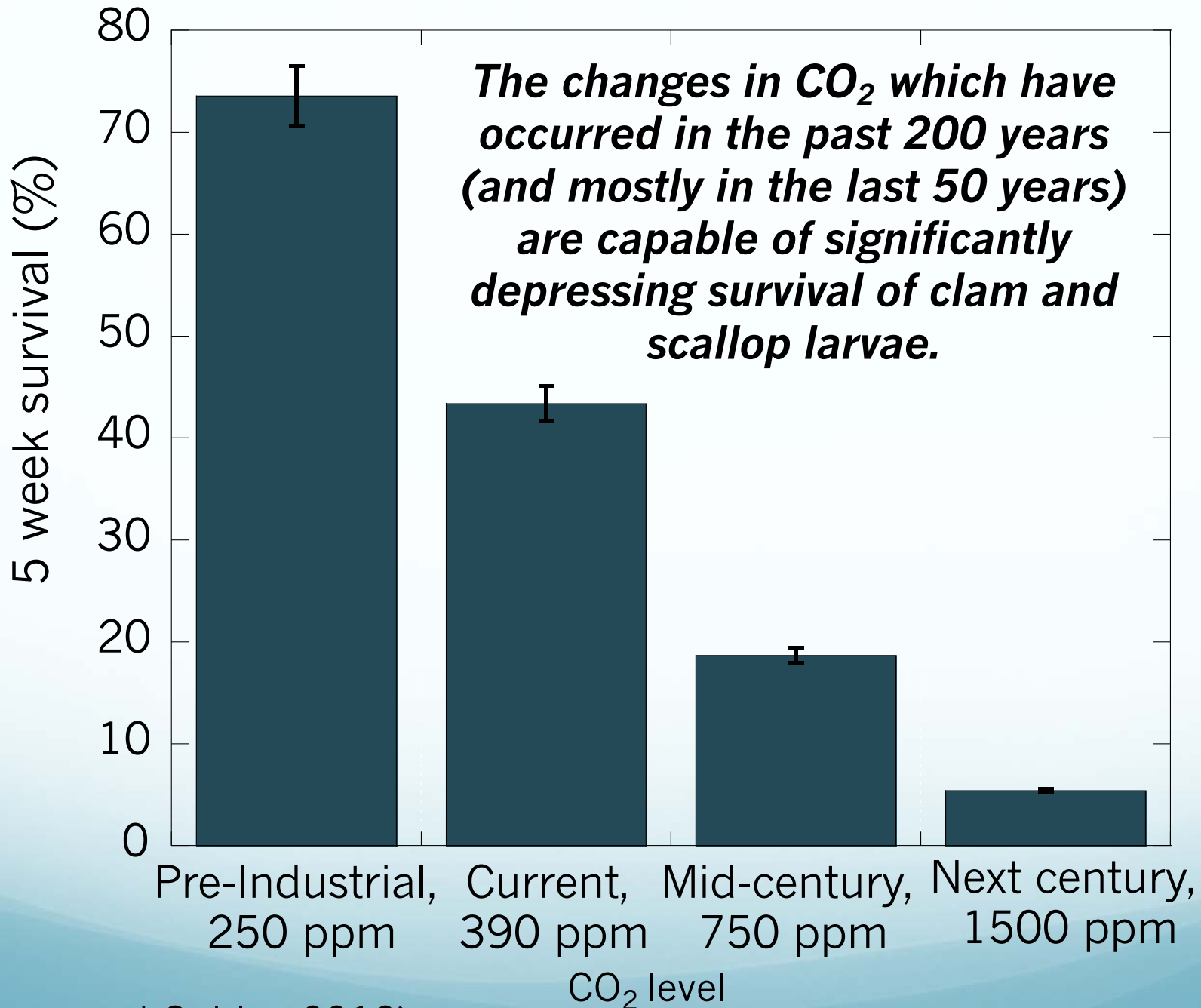
Mercenaria mercenaria larvae survival under past, present and future CO₂ levels

Past, Present, and Future CO₂



(Talmage and Gobler 2010)

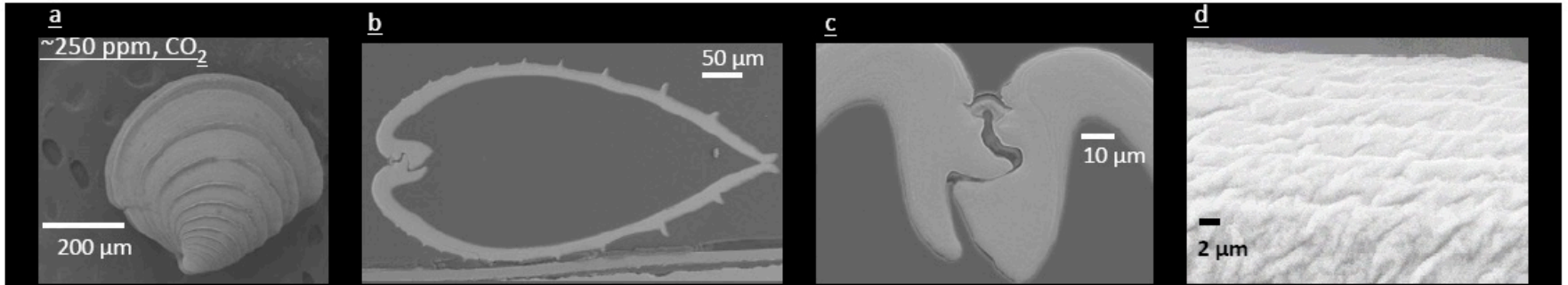
Argopecten irradians survival under past, present and future CO₂ levels



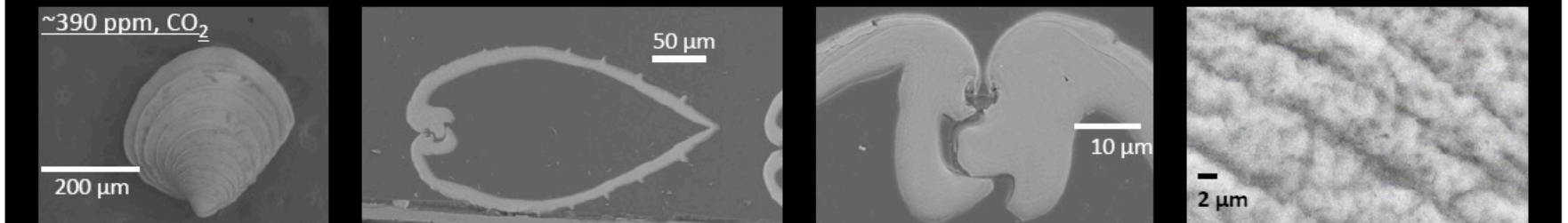
(Talmage and Gobler, 2010)

Mercenaria mercenaria, 36 day old juvenile scanning electron microscopy images

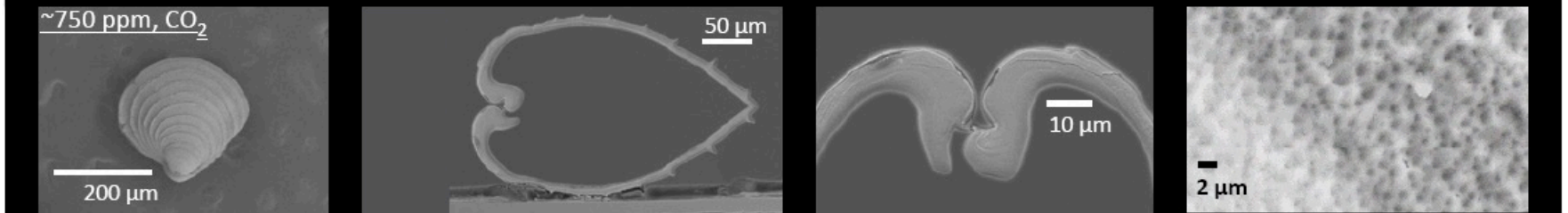
Pre-Industrial



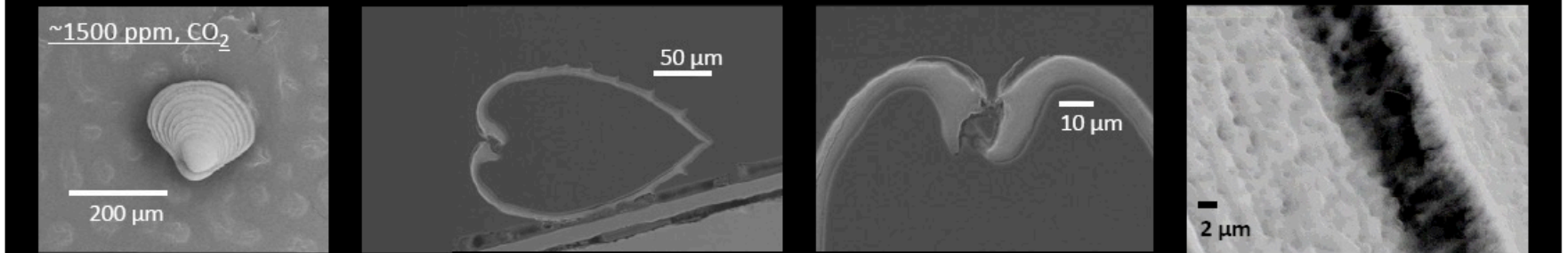
Present



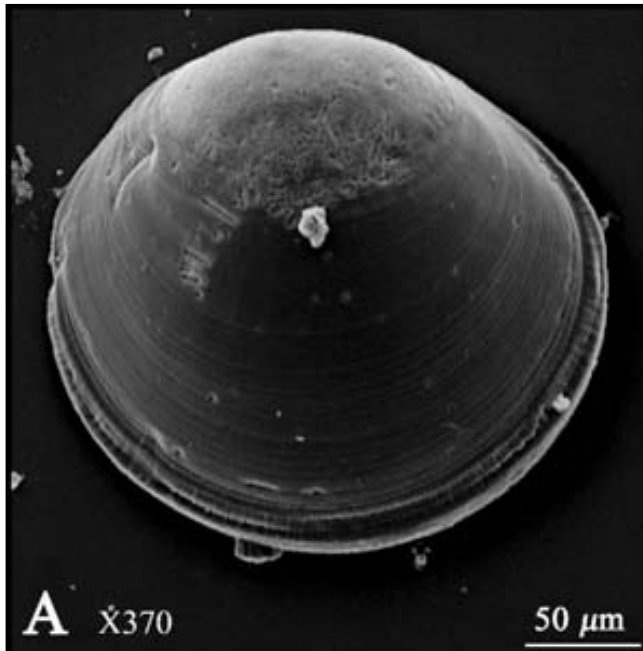
Mid Century



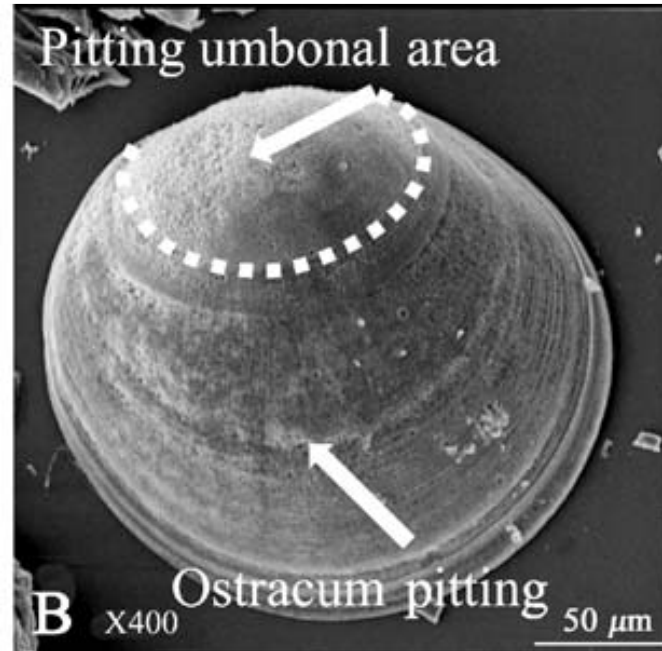
Next century



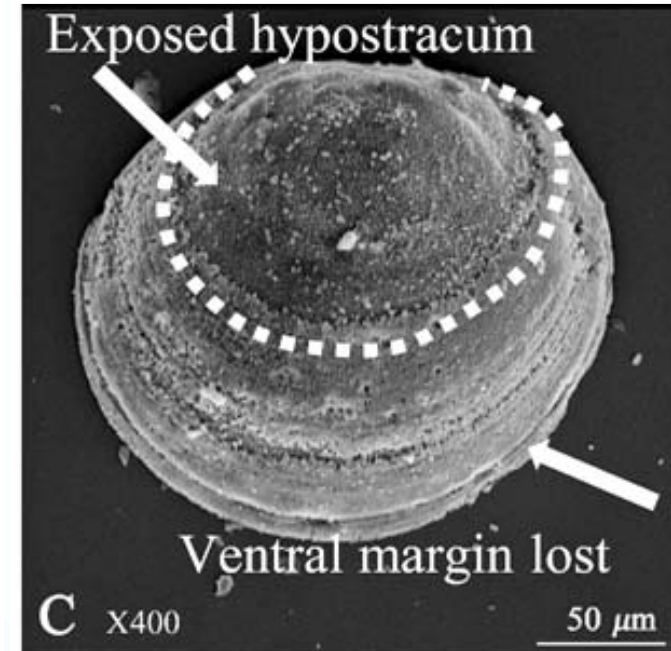
Mortality (Death by Dissolution)



Day 0



Day 4



Day 7

Representative clams from 0.2 mm size class at 0.6 Ω

Notice area near umbonal is the remnant of the larval shell

(Green et al. 2009; 2013)



STEVE RINGMAN / THE SEATTLE TIMES

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Oysters in deep trouble: Is Pacific Ocean's chemistry killing sea life?

Oysters' failure to reproduce will lead workers like Northern Oyster Co.'s Gildardo Mendoza to collect far more of their product from a state "oyster preserve" in Willapa Bay. Pacific oysters haven't successfully reproduced in the wild since 2004.

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The Seattle Times

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Foodwebs at risk

Acidification already eating away at tiny creatures along our coast

'JUST AMAZING' | Scientists are startled by new research showing how quickly pteropods – a potentially important link in the marine food web – are dissolving.



HOW CARBON DIOXIDE DAMAGES SEA SNAILS



PHOTOS BY STEVE RINGMAN / THE SEATTLE TIMES

A HEALTHY PTEROPOD: Tiny, translucent snails, also known as sea butterflies, provide food for salmon, herring and other fish. Seen under a microscope, this one's shell is smooth.

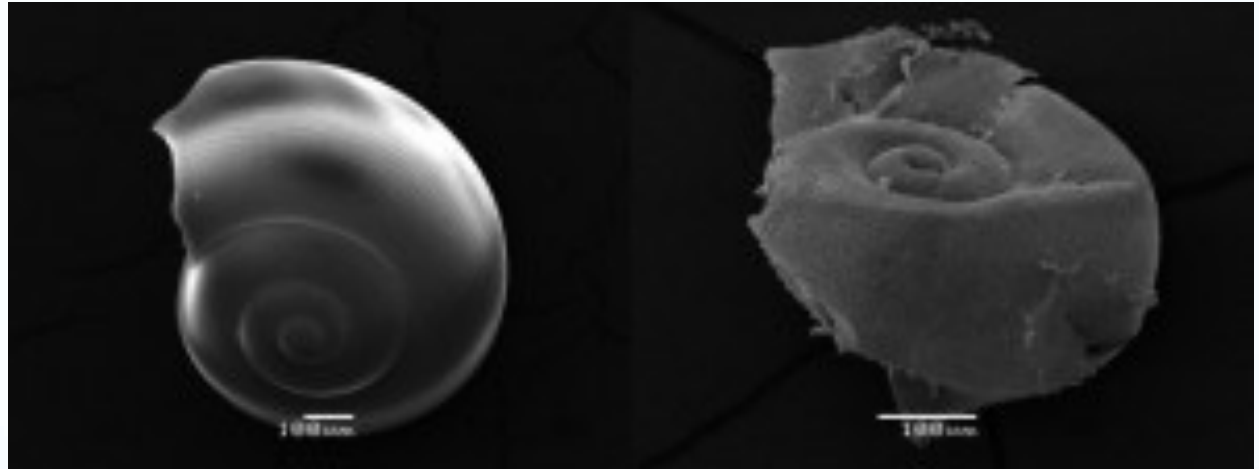
By CRAIG WELCH
Seattle Times environment reporter

Seattle Times
April 30, 2014

Nature Geoscience | Letter

**Extensive dissolution of live pteropods
in the Southern Ocean (2012)**

(N. Bednarsek)



Effect of CO₂-related acidification on aspects of the larval development of the European lobster, *Homarus gammarus* (L.)

K. E. Arnold¹, H. S. Findlay², J. I. Spicer³, C. L. Daniels^{1,3}, and D. Boothroyd¹

¹National Lobster Hatchery, South Quay, Padstow, Cornwall, PL28 8BL, UK

²Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, Devon, PL1 3DH, UK

³Marine Biology and Ecology Research Centre, School of Biological Sciences, University of Plymouth, Plymouth, Devon, PL4 8AA, UK

Received: 20 February 2009 – Published in Biogeosciences Discuss.: 18 March 2009

Revised: 8 July 2009 – Accepted: 20 July 2009 – Published: 24 August 2009



THE PLANET

Ocean Acidification is Hurting Maine's Lobster Economy

by *Dana Driskill*

Where have Maine's mussels gone?

Scientists and environmentalists are working to find out why the once plentiful 'people's seafood' has practically vanished from our rocky shores.

BY MARY POLS STAFF WRITER

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No One Can Explain the Steep Decline in Maine's Casco Bay Wild Mussel Population

SEAFOODNEWS.COM [The Forecaster] By Peter L. McGuire - January 26, 2015

BRUNSWICK — It used to be common to lift up thick mats of seaweed on the shores of Casco Bay and uncover thousands of dark blue mussels nestled among the rocks.

But over the last few years, people who harvest and work to conserve the mollusk say areas that used to be full of thriving...



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Bangor Daily News

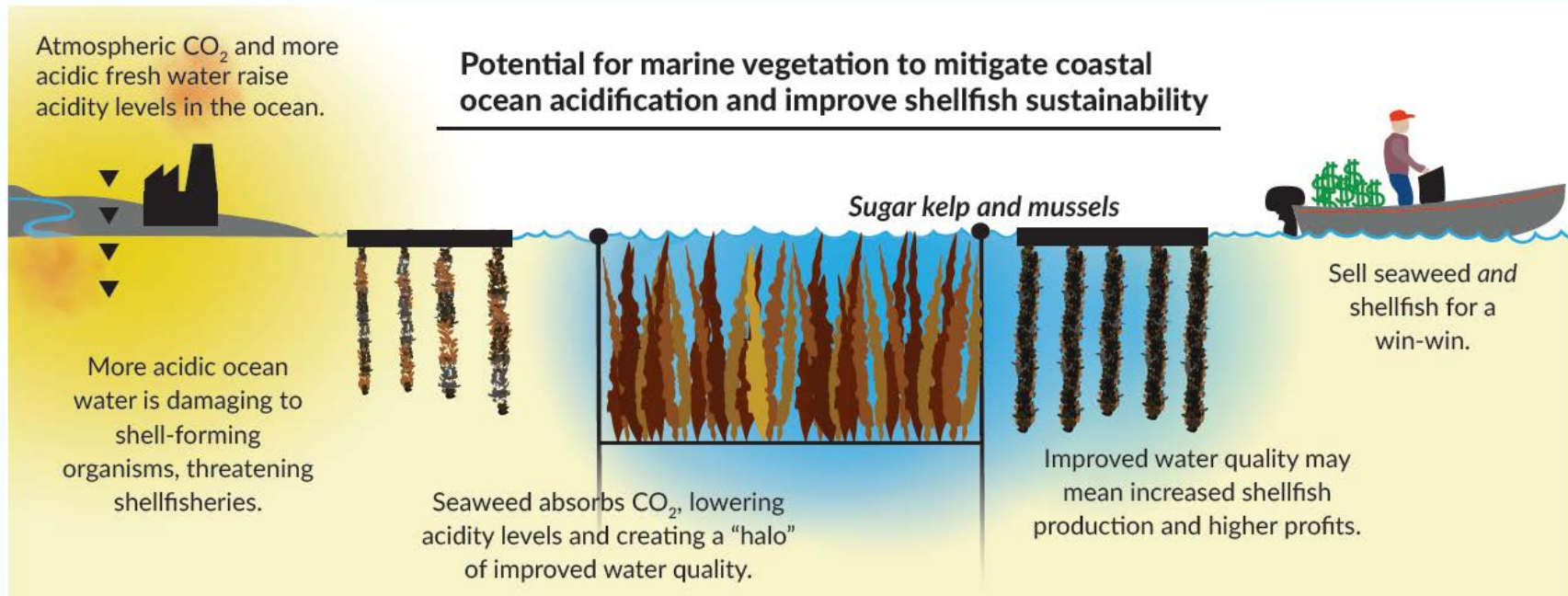
Sunday, April 24, 2016 Last update: 3:46 p.m.

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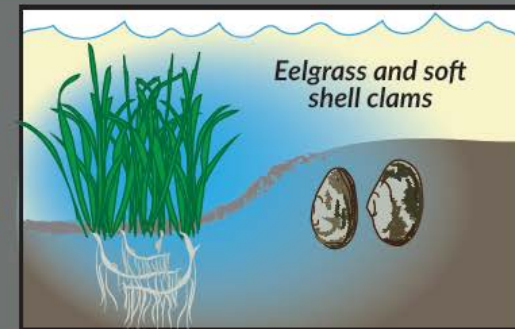
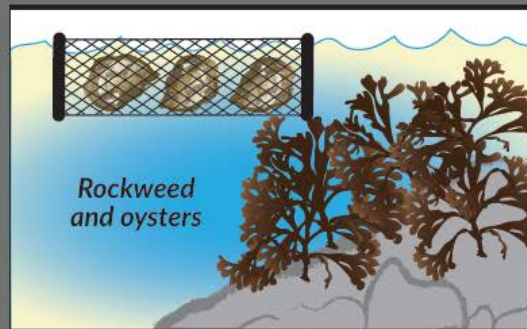
Shellfish harvesters plagued by acidic 'dead muds'

“Phytoremediation” as an adaptation strategy

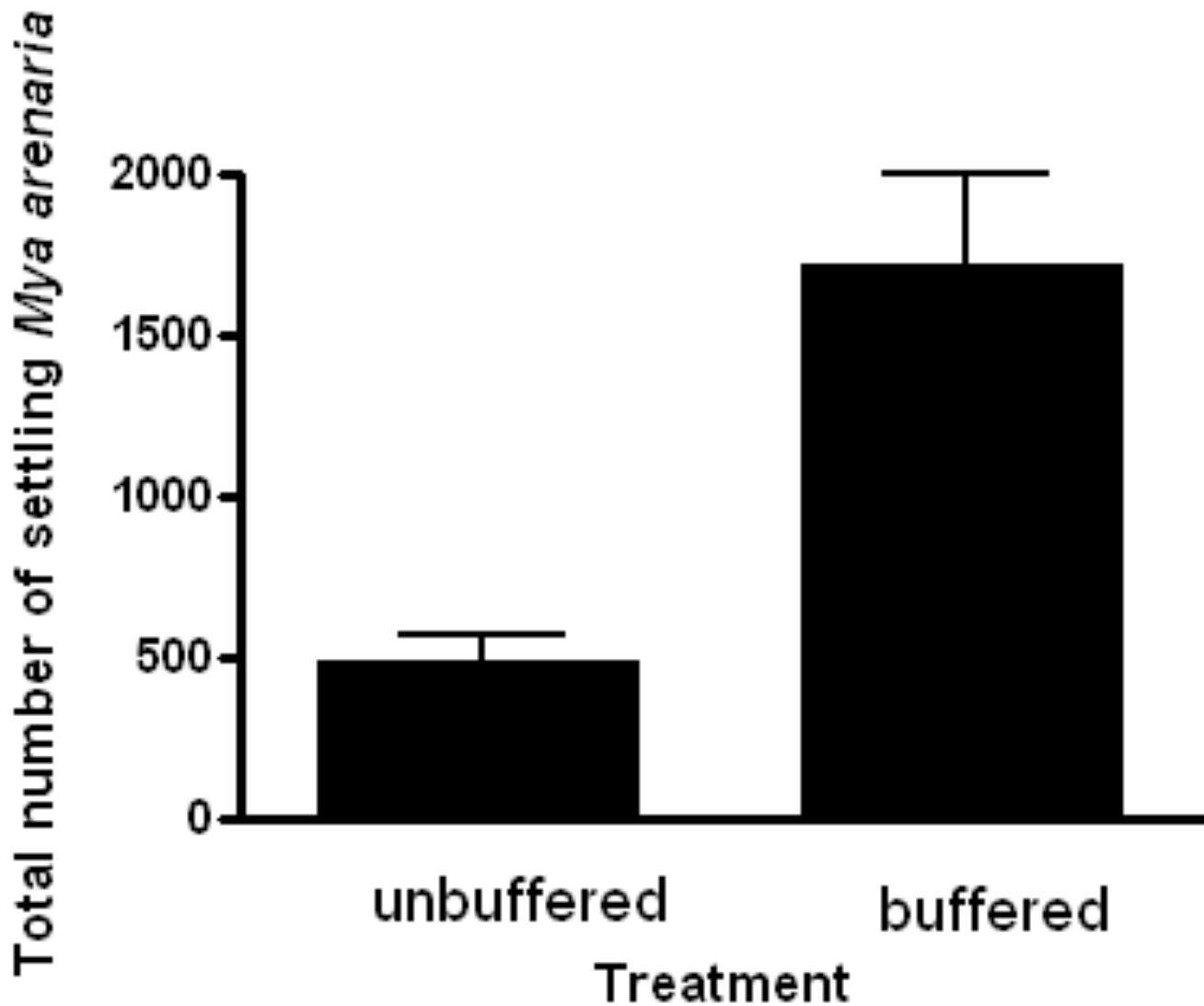


IN ADDITION to sugar kelp and mussels (above), two other natural pairings will be studied for potential benefits (at right).

Scale: $\mu\text{atm CO}_2$ in seawater	
280	1,100
pre-industrial	year 2100 (est.)



It works in the lab (and in the field)...



Conclusions

1. Increasing atmospheric carbon dioxide is causing the surface ocean to become more acidic.
2. There has been a significant increase in acid (decrease in pH) in your lifetime and it is changing faster than at any time during the last 60,000,000 years (at least).
3. The coastal ocean is acidifying even faster and represents a look into the future. Maine is particularly vulnerable.
4. It's getting more difficult for some marine organisms to make shell material (but it's not all about clams) and the cascade effect through marine ecosystems could be severe.
5. The window of conditions sufficient for natural bivalve larvae will continue to close. Recruitment will become less and less predictable.
6. Multi-trophic farms and hatcheries and buffering (seaweeds and shells) can mitigate poor water chemistry on a VERY small local level.
7. The slow and relentless increase in atmospheric and surface ocean CO₂ continues. There is only one real solution to overcome the looming disaster that is OA....