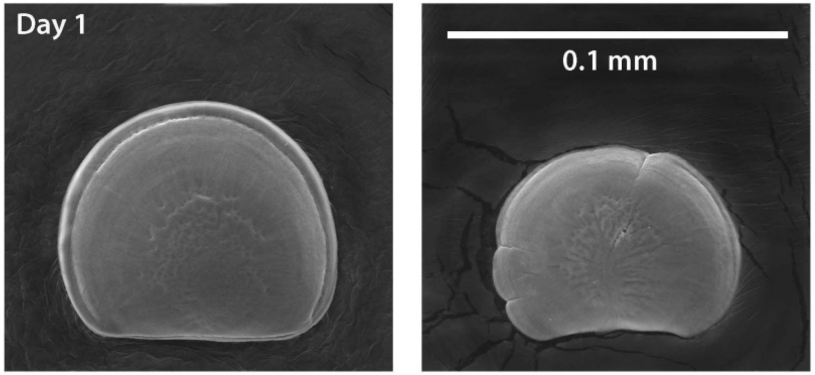
Oregon State University | College of Earth, Ocean, and Atmospheric Sciences

Impacts of ocean acidification on bivalve production in the U.S. Pacific Northwest

George G. Waldbusser and many others…



Oregon State University Hatfield Marine Science Center, Newport, Oregon

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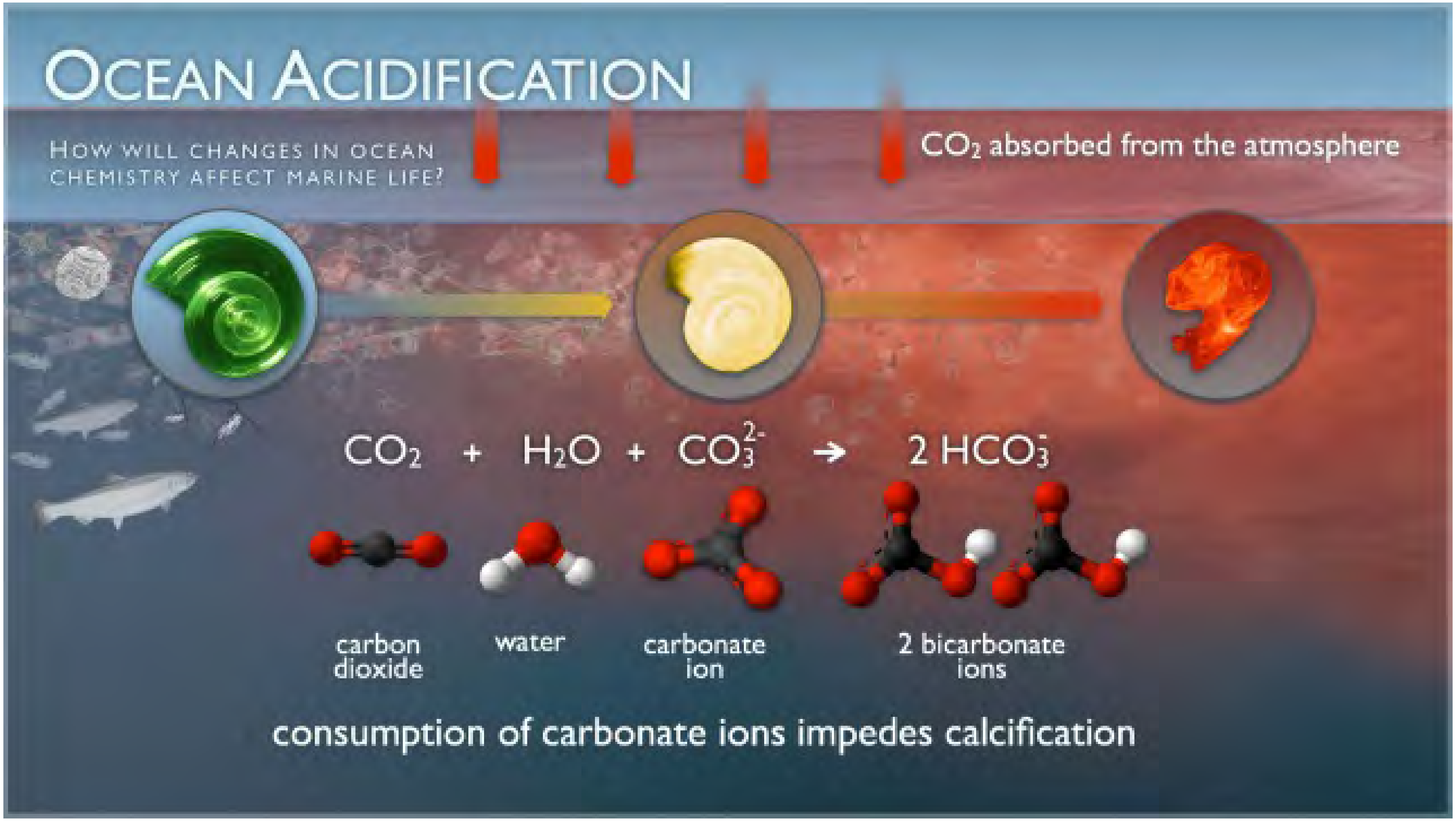
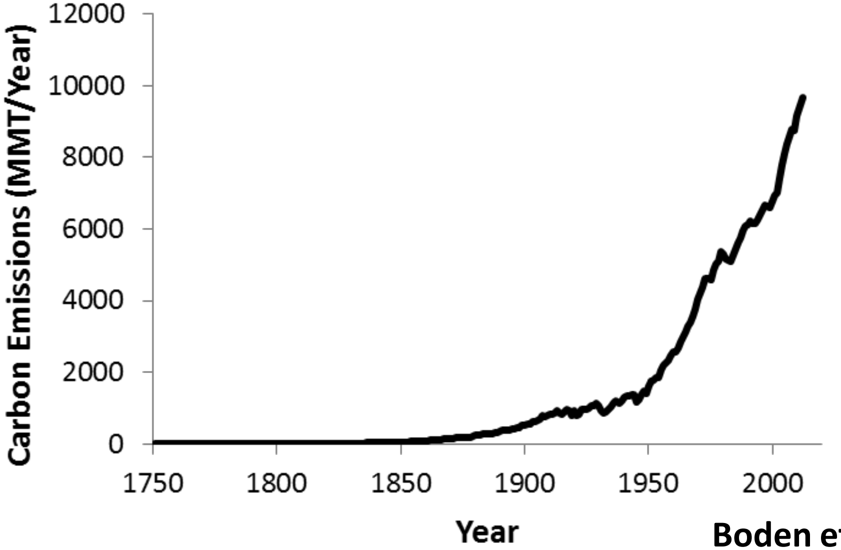
Definitions and Carbonate Chemistry Primer

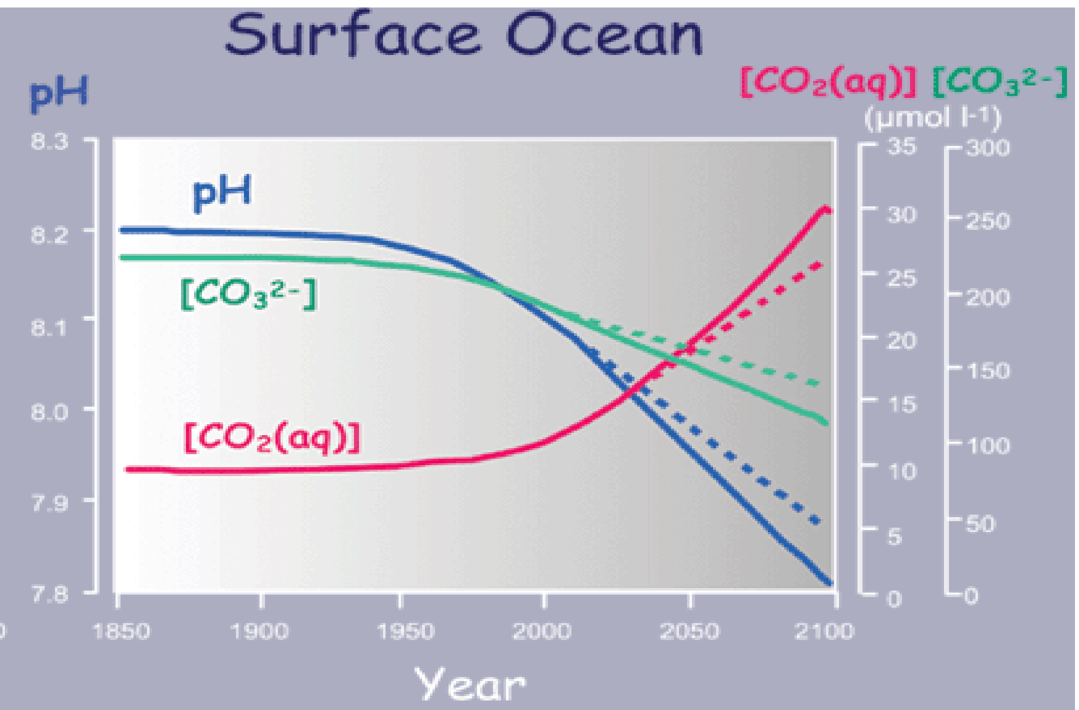


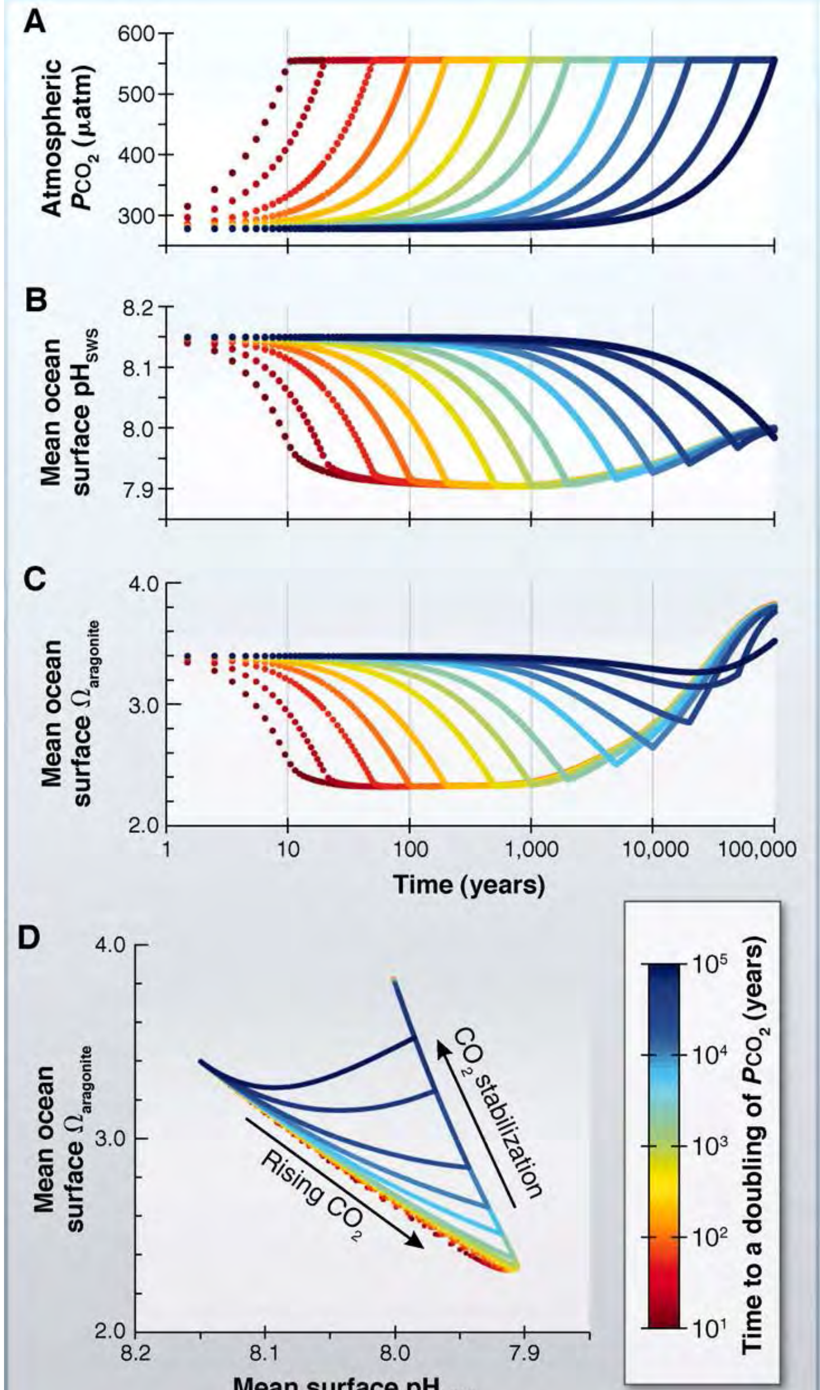
$$\sim pH = -Log_{10}\left(\sqrt{K_1 * K_2 * \frac{[CO_2^*]}{[CO_3^{2-}]}}\right) \qquad \Omega CaCO_3 = \frac{[Ca^{2+}][CO_3^{\ 2-}]}{K^*_{sp-CaCO_3}}$$

What is Ocean Acidification



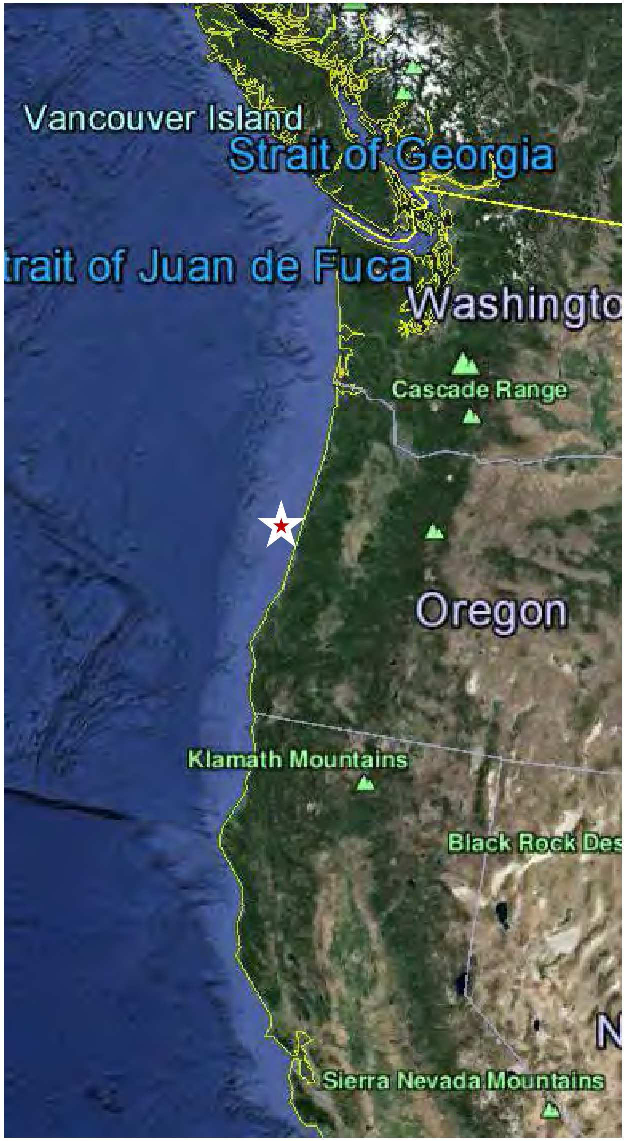
Boden et al. 2013

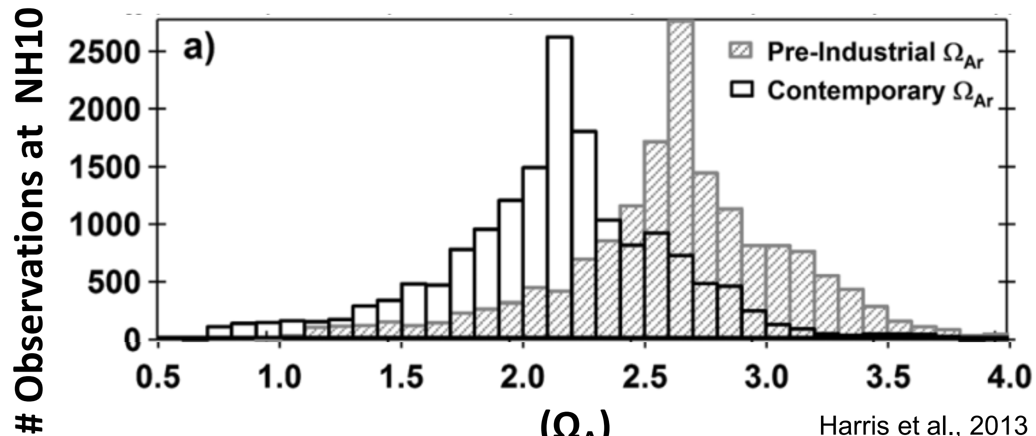




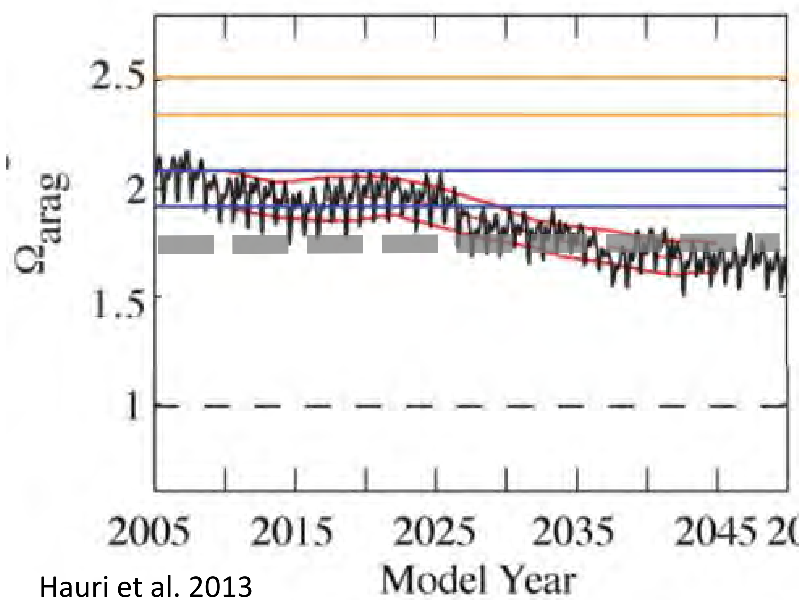
Hönisch et al. 2012

California Current: Acidification Hot Spot





Harris et al., 2013



280 ppm CO_2

400 ppm CO_2

550 ppm CO_2

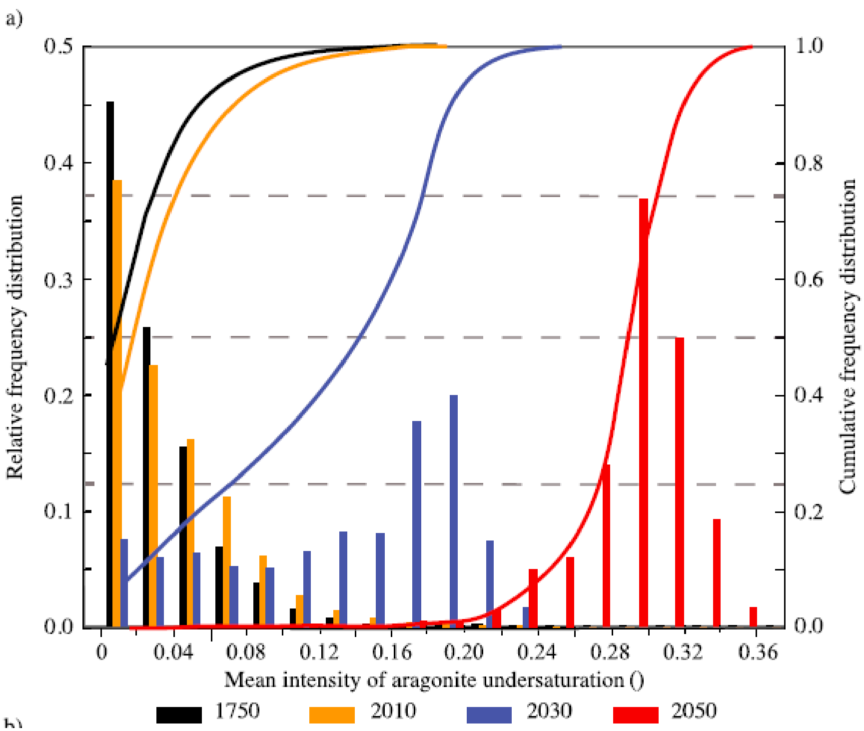
550 ppm is the low emissions scenario for 2100

Hauri et al. 2013

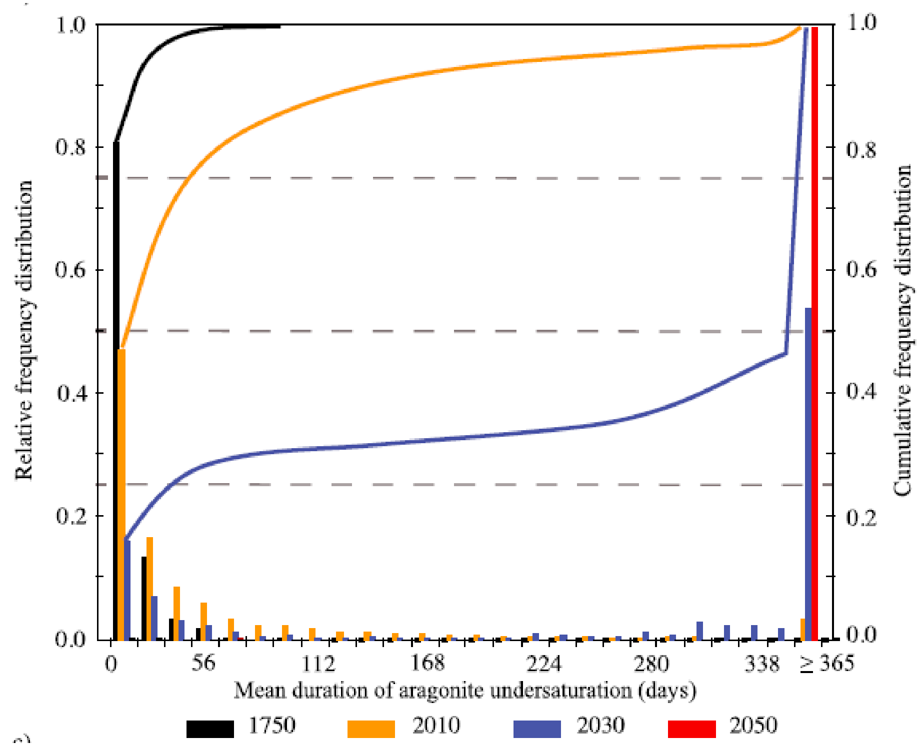
Intensity and Duration of Under-saturation in the CCE (Hauri et al. 2013)

- ROMS-Ecosystem Model, 2 day mean interval, bottom shelf waters
- Ω Threshold = 1

Intensity = Threshold - Ωmean

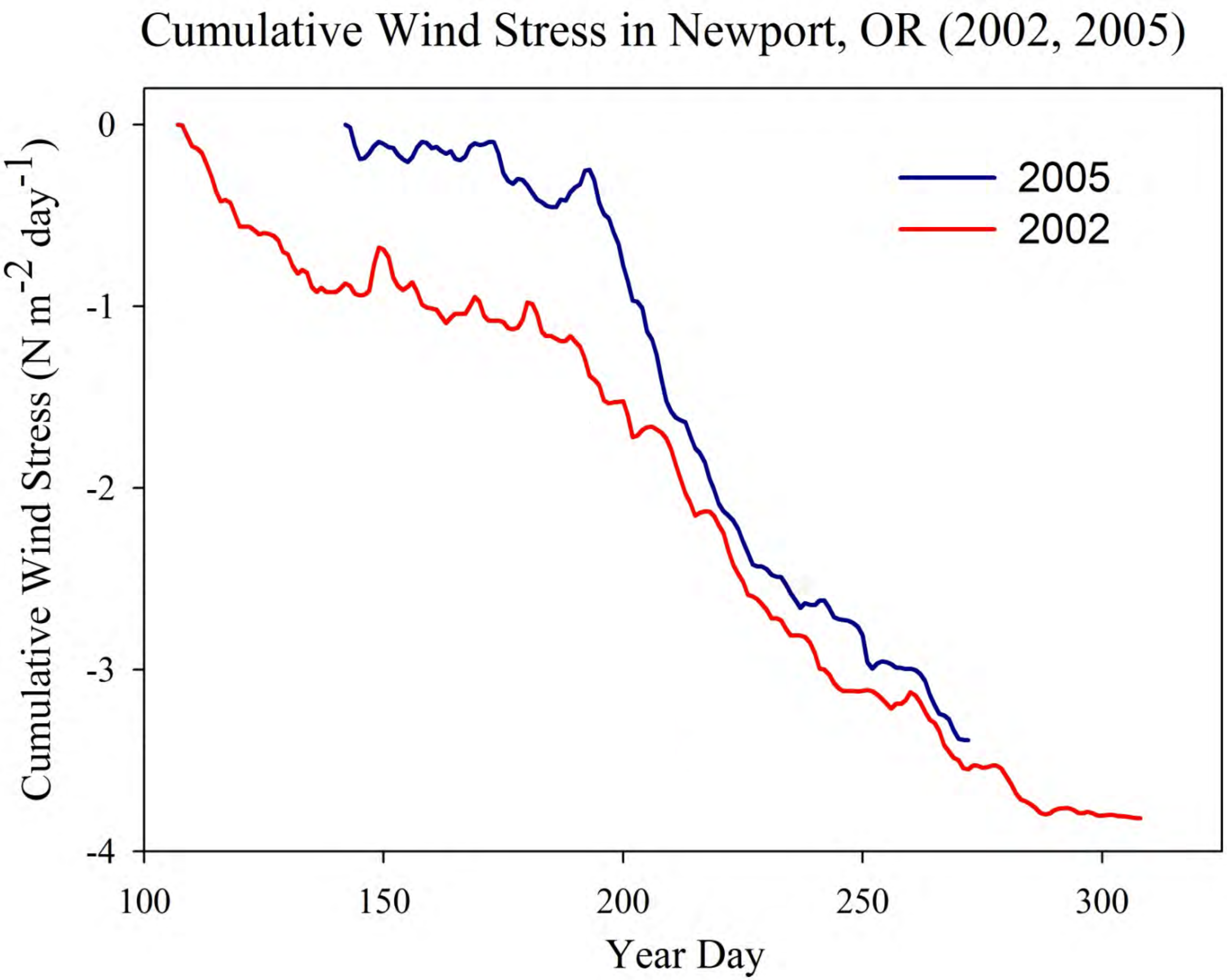


Duration = Days > Threshold



- Increasing $CO_{2(atm)}$ increases <u>Intensity</u> and <u>Duration</u> of extreme events
- System is beginning to change more rapidly, and will accelerate
- Adjusting the thresholds to biological (bivalve larval) relevance (~2.0)?

Oregon Estuaries pH- Connection to upwelling



2002 earlier spring transition or stronger upwelling

2005 later spring transition or weaker upwelling

Wind data from OrCOOS- NDBC 46050, pH from South Slough NERR

What does this mean for bivalves in these habitats and the people dependent on them for a living?

Pacific Northwest Oyster Seed Crisis

nature International weekly journal of science

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NATURE | NEWS

US state declares war on acid waters

Washington announces science-based plan to tackle ocean acidification.

Virginia Gewin

27 November 2012

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The New York Times
Monday, October 1, 2012

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Study Links Raised Carbon Dioxide Levels to Oyster Die-Offs

By LESLIE KAUFMAN

Forbes

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I write at the intersection of energy, climate and business.
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Originally published June 21, 2012 at 9:24 PM | Page modified June 22, 2012 at 1:34 PM

Willapa Bay oyster grower sounds alarm, starts hatchery in Hawaii

A Willapa Bay shellfish company is shifting some of its business to Hawaii because of ocean acidification that scientists believe is killing tiny oyster larvae in shellfish farms along Washington's coast.

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Originally published April 11, 2012 at 9:10 PM | Page modified April 12, 2012 at 5:54 AM

Acidity in ocean killed NW oysters, new study says

Researchers said Wednesday they have conclusive evidence that ocean acidification is at least partly responsible for killing oysters on the West Coast.

By Craig Welch
Seattle Times environment reporter

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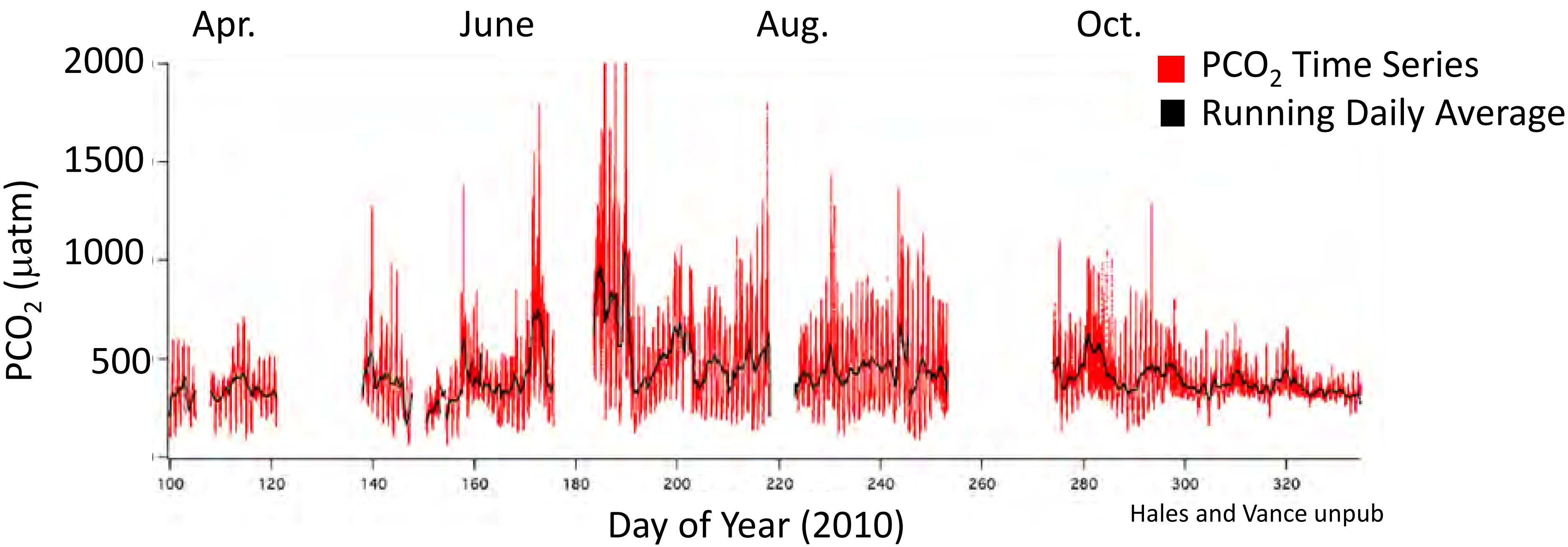
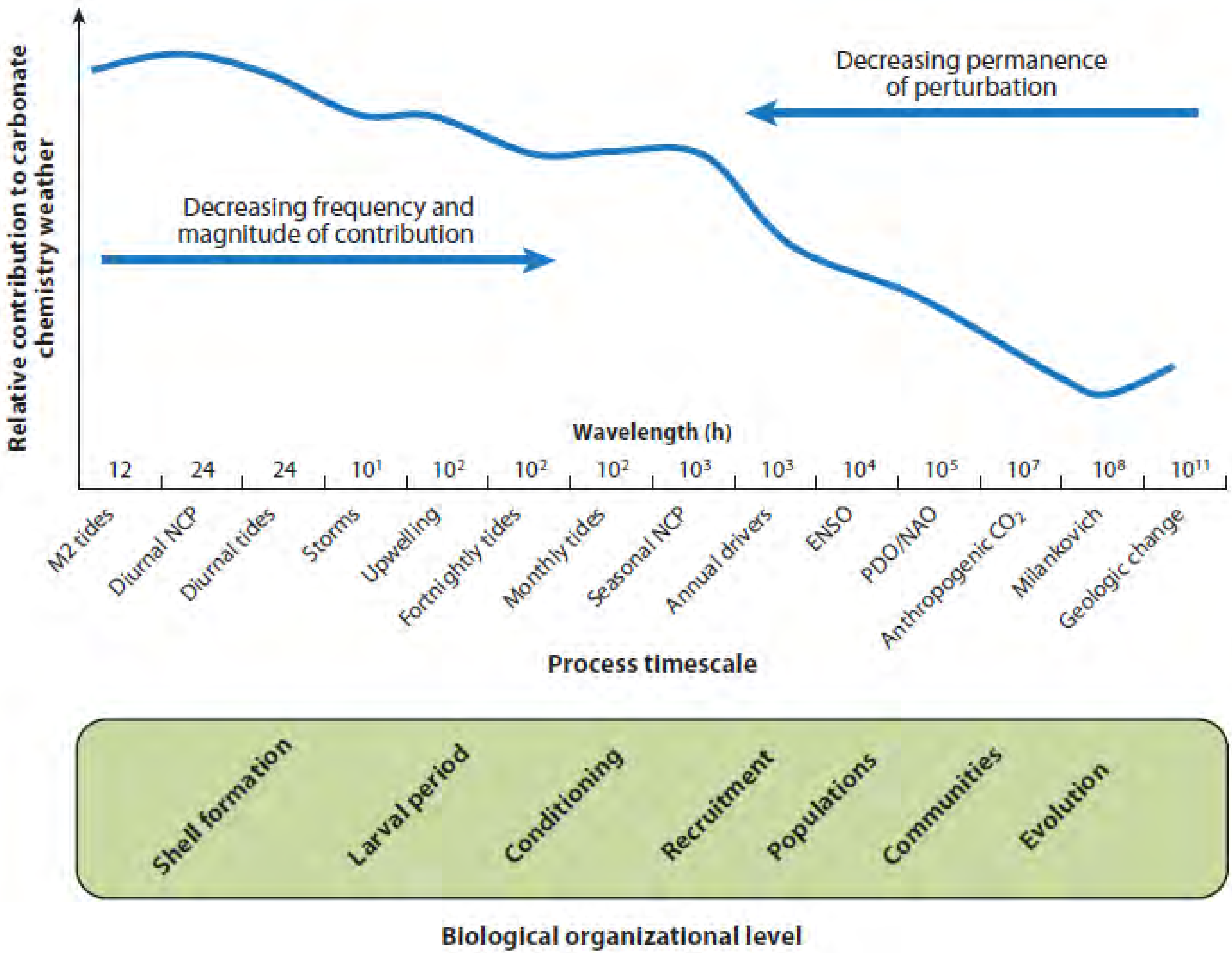
OBSERVATORY

Oyster Shells Are an Antacid to the Oceans

Whiskey Creek Shellfish Hatchery

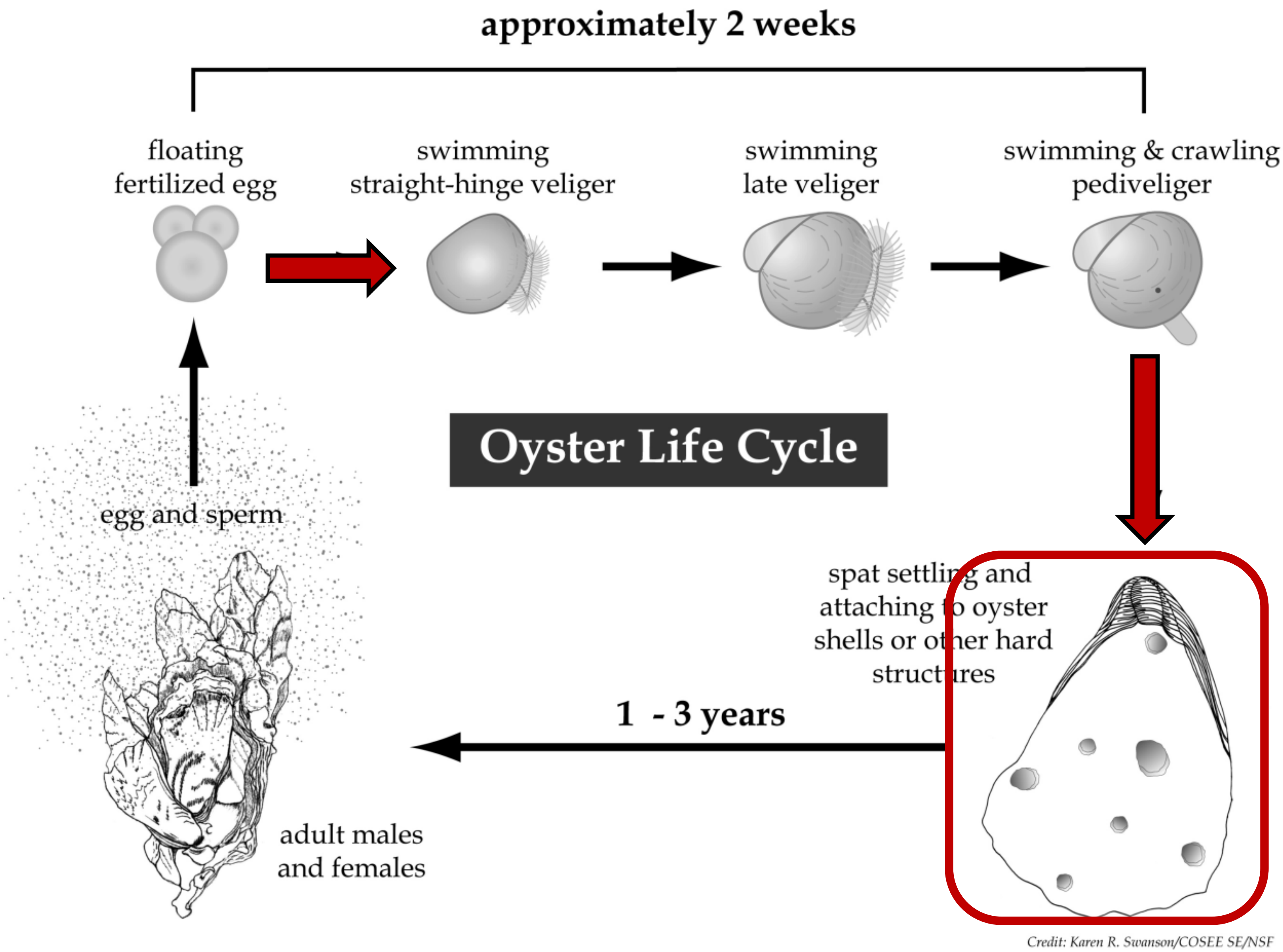


Carbonate Chemistry, Frequency, and Biology



Waldbusser and Salisbury 2014

Bivalve Life History and Bottlenecks



Optimal Physical Conditions for Larval Development in Willapa Bay (Hales et al. in review)

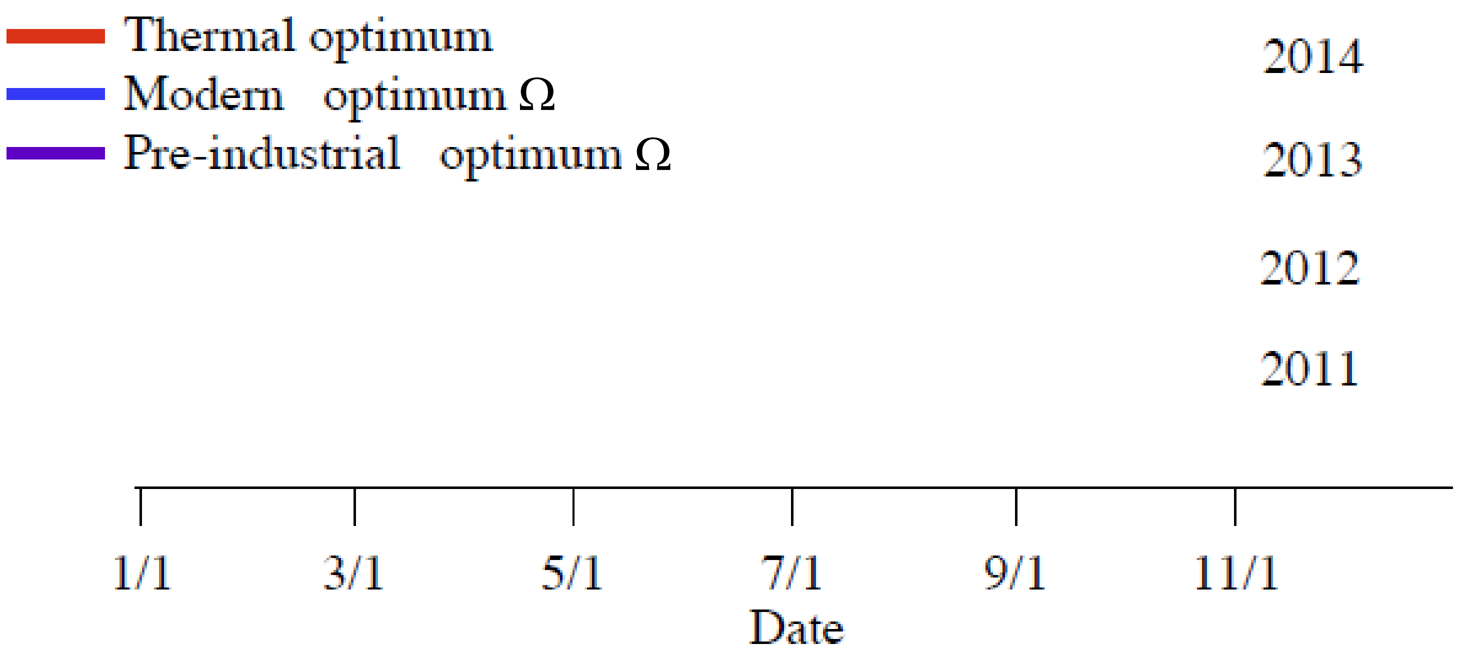
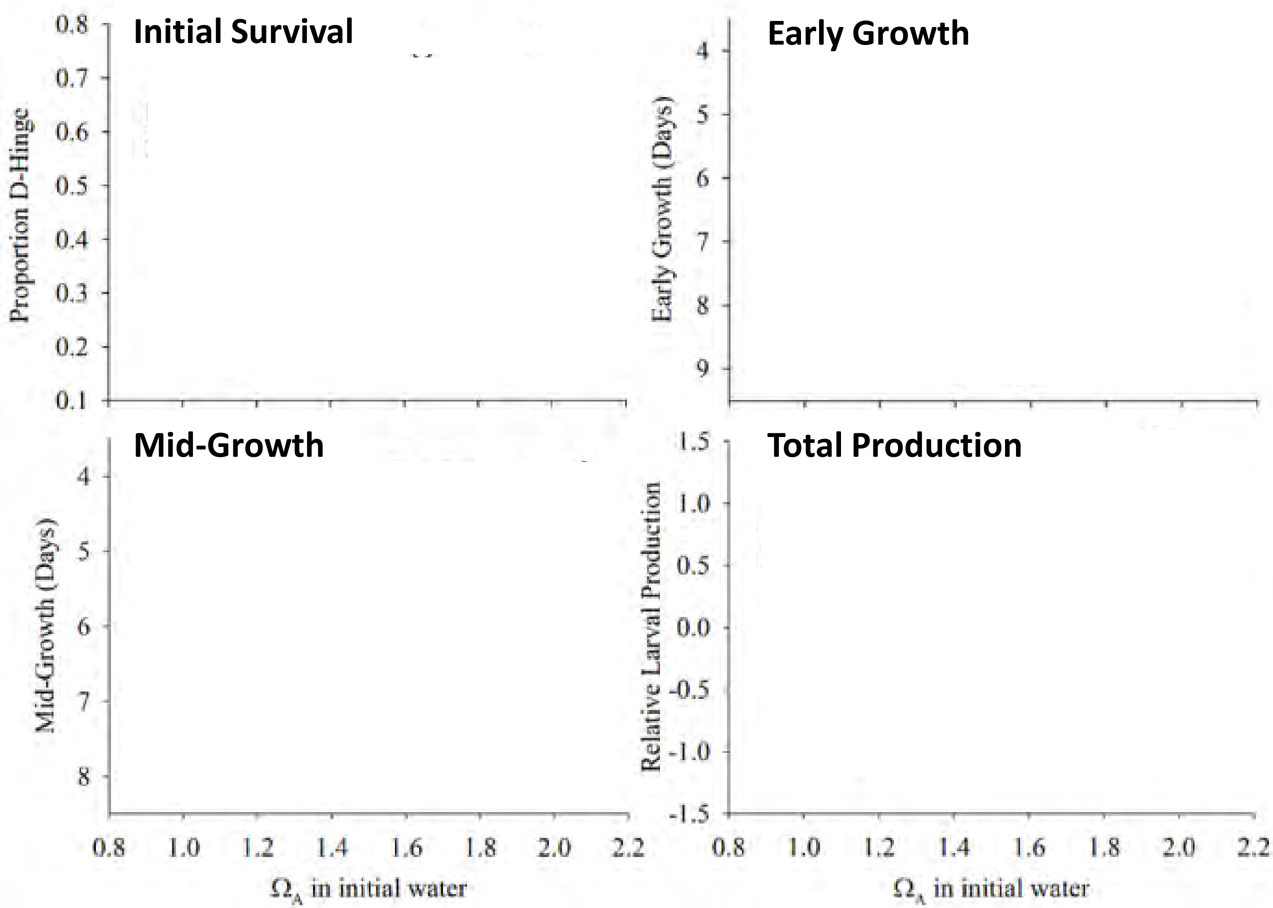


Figure 6. Intervals of thermal (red bars) and Ω_{ar} optimum conditions, for both modern (blue bars) and estimated pre-industrial conditions (purple bars; See Figure 7).

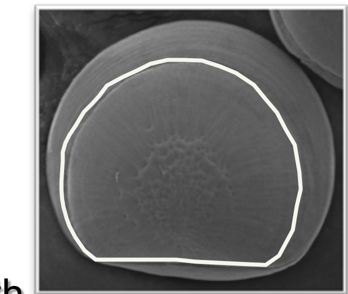
Anthropogenic CO_2 has in some years shorted the "Ω window of opportunity" for natural oyster reproduction, and in other years it hasn't had any impact…

Ocean Acidification impacts manifest later…

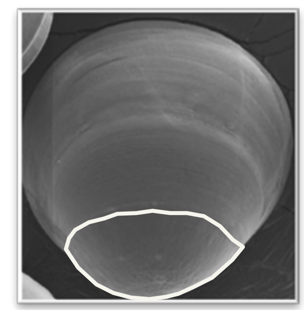


Barton et al., 2012

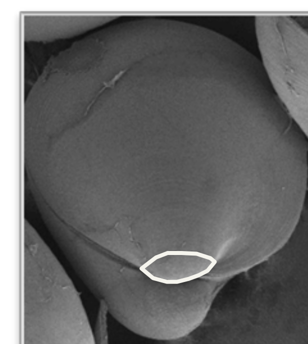
Initial Survival



Early Growth

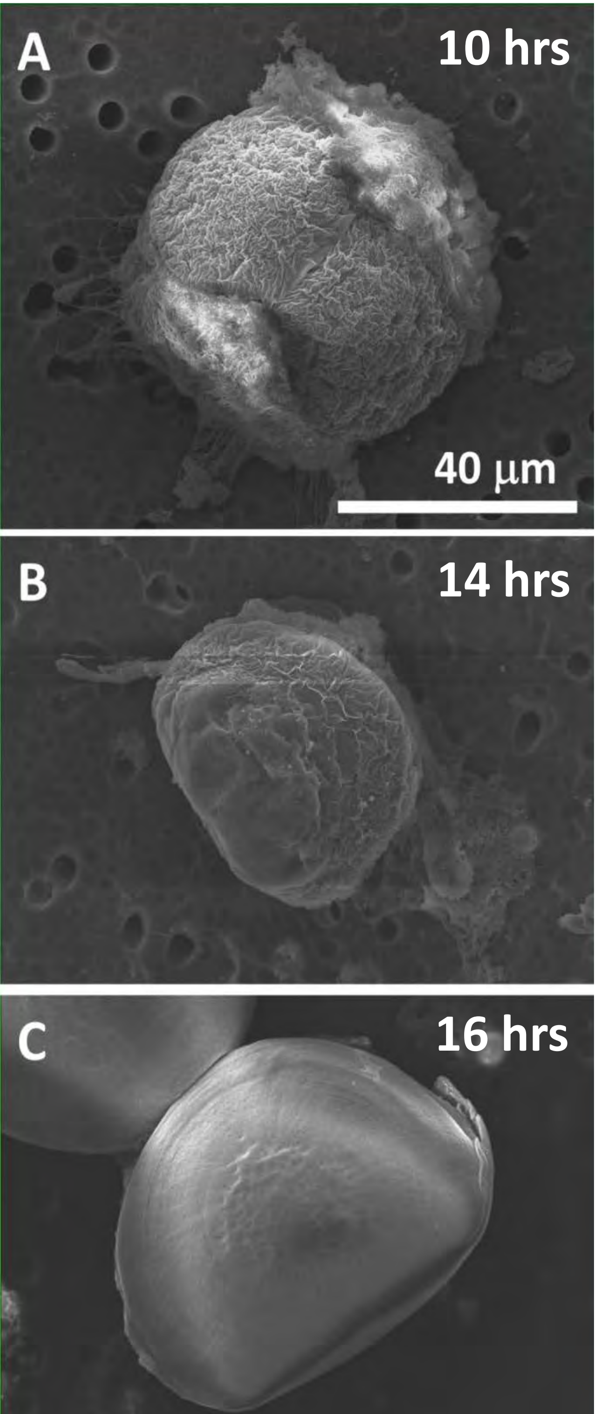


Mid-Growth

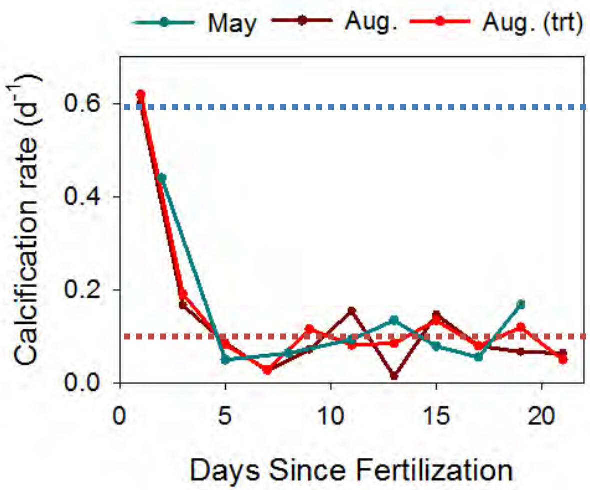


$$$

Over 50% of the hatchery production is explained by Ω_A in the first 48 hours!



Why Saturation State Should Matter…



Brunner et al. in prep

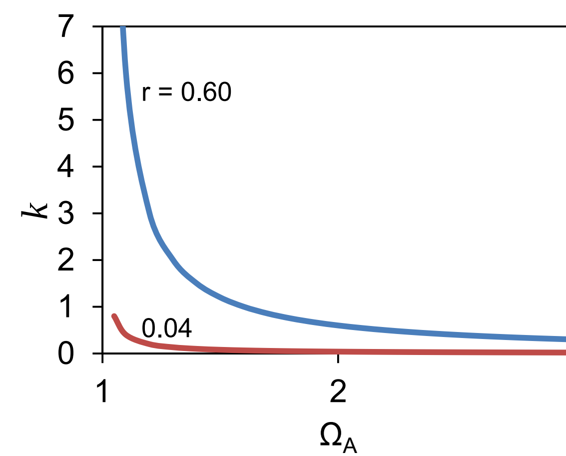
1) Within 48 hours, 80-90% of body weight is added as $CaCO_3$

2) Calcification surfaces more "exposed".

3) Until this, feeding not possible, and energy is limited.

$$r = k(\Omega - 1)^n$$

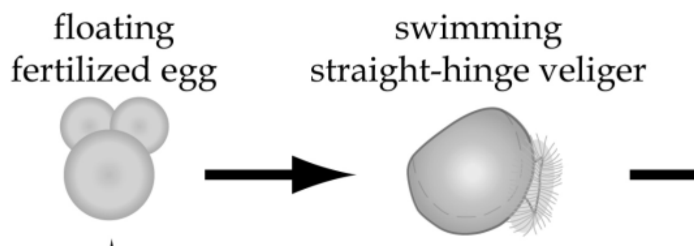
r = calcification rate
k = rate constant
Ω = saturation state
n = rate order (1)



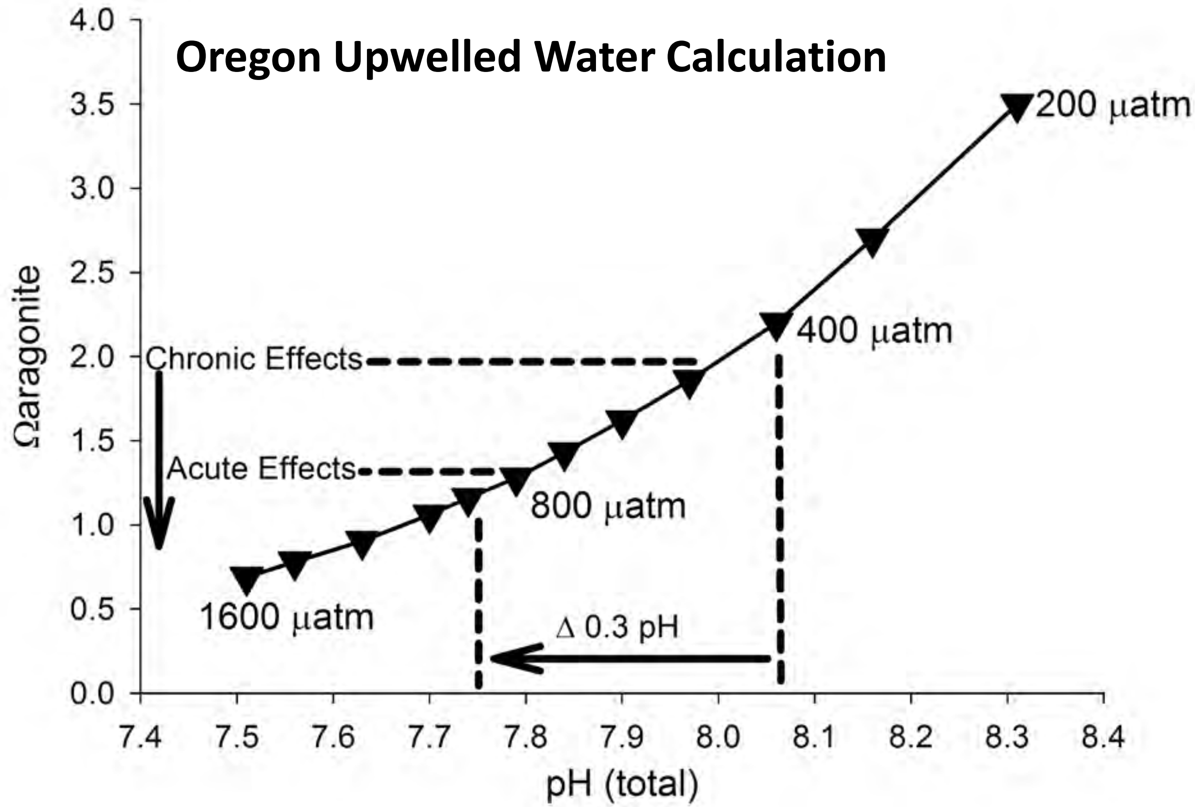
1) Rate of Calcification!

Waldbusser et al., 2013

Decoupling Carbonate Parameters to Understand Larval Bivalve Responses

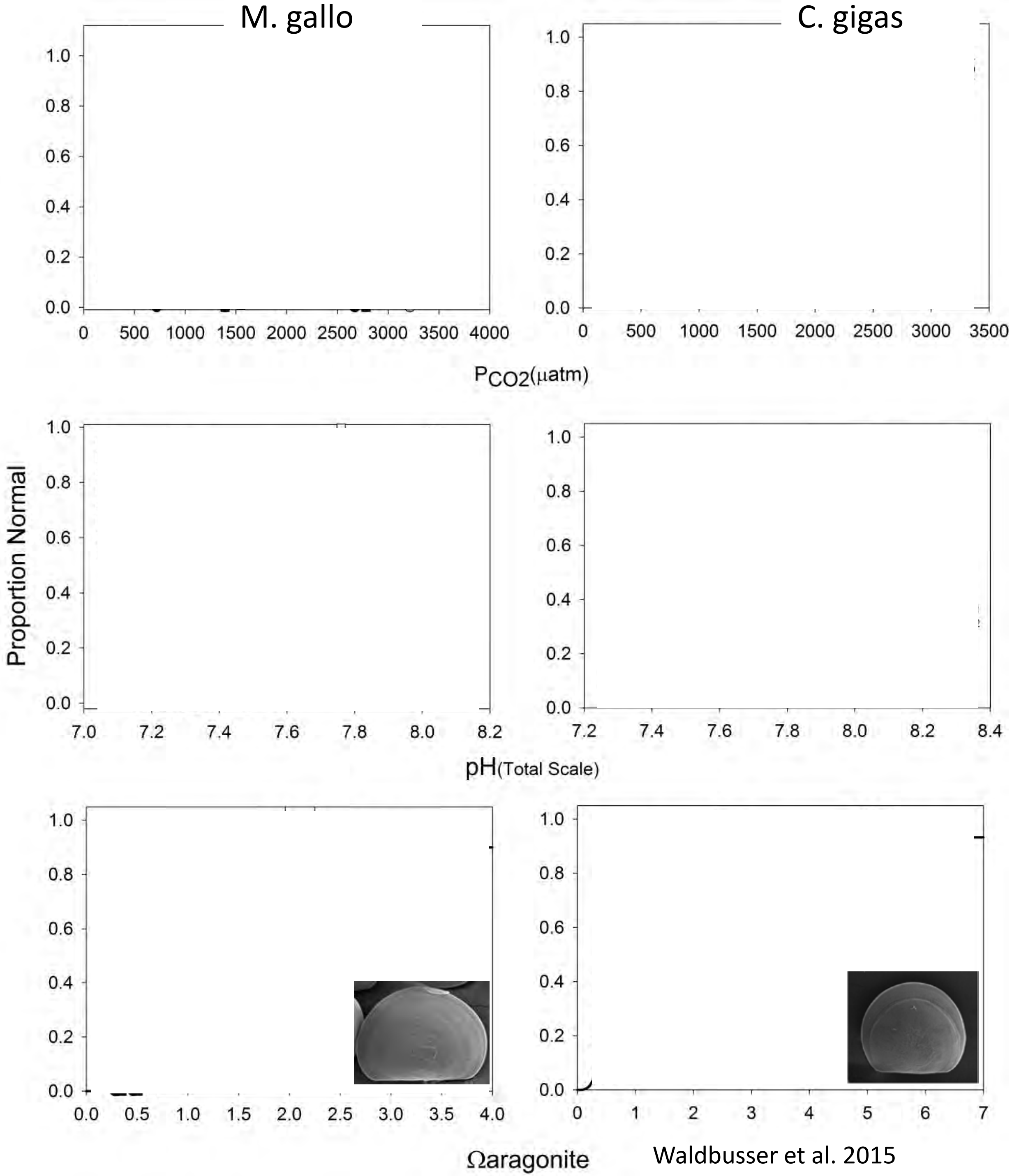


Environmental Relevance

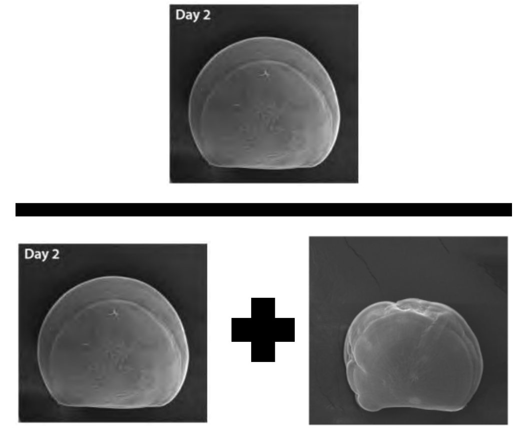


- Saturation state changes more quickly than pH
- Closer to saturation state thresholds

Proportion Normal



Waldbusser et al. 2015



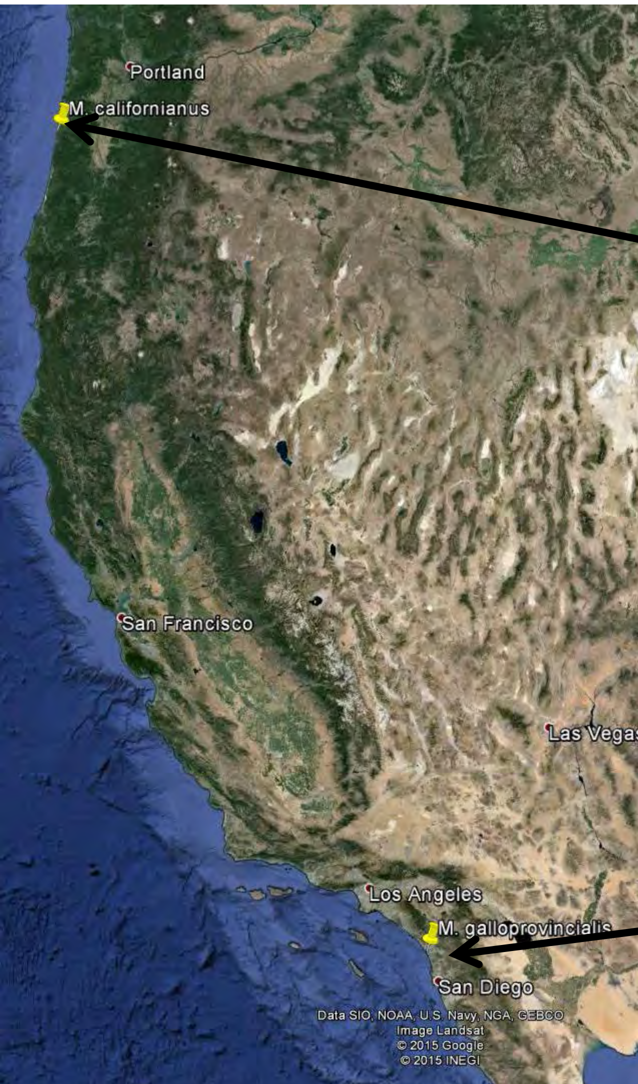
Saturation state is the primary variable of importance for these larvae.

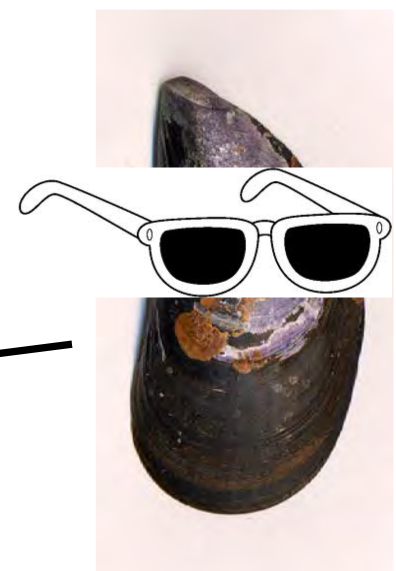
Little to no pH impact until very low values, and only in undersaturated conditions.

Same pattern in shell length of NORMAL larvae.

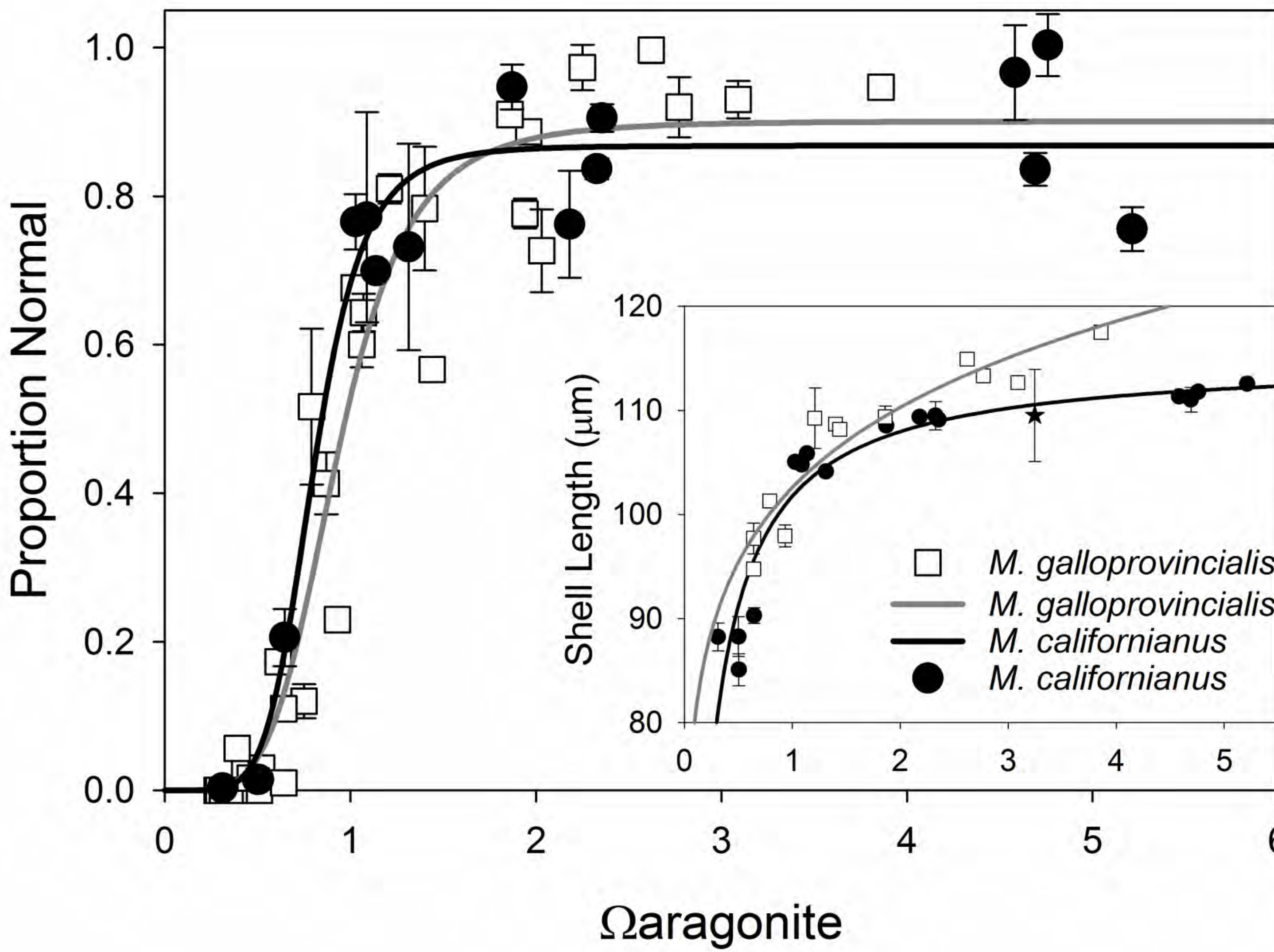
Comparison of Native and Non-native Mussel Larvae

M. californianus versus M. galloprovincialis





Comparison of Native and Non-native Mussel Larvae

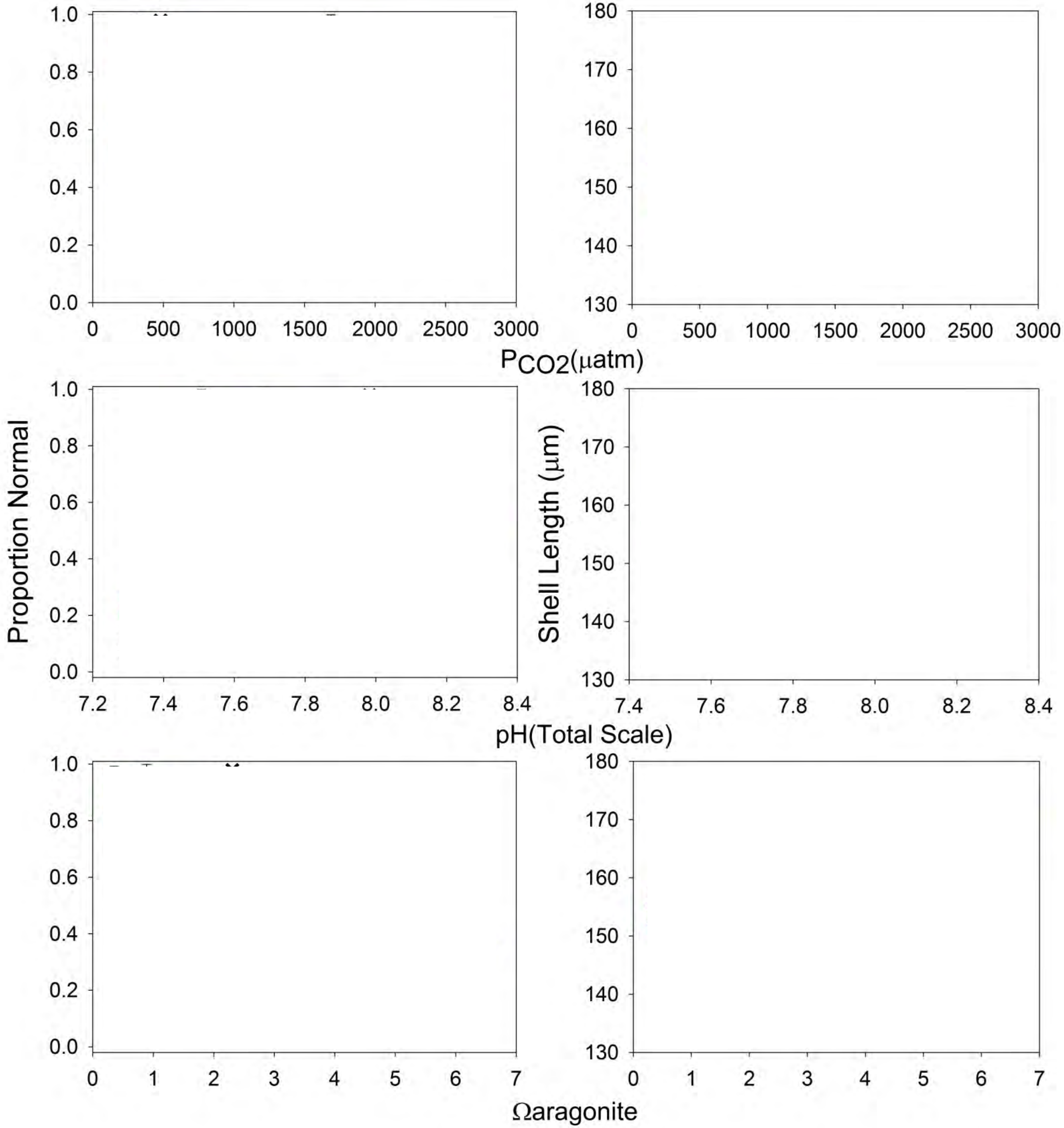


Hanging out in a OA Hot-spot doesn't seem to help *M. californianus*

Waldbusser et al. 2015b

What about Native Oysters?

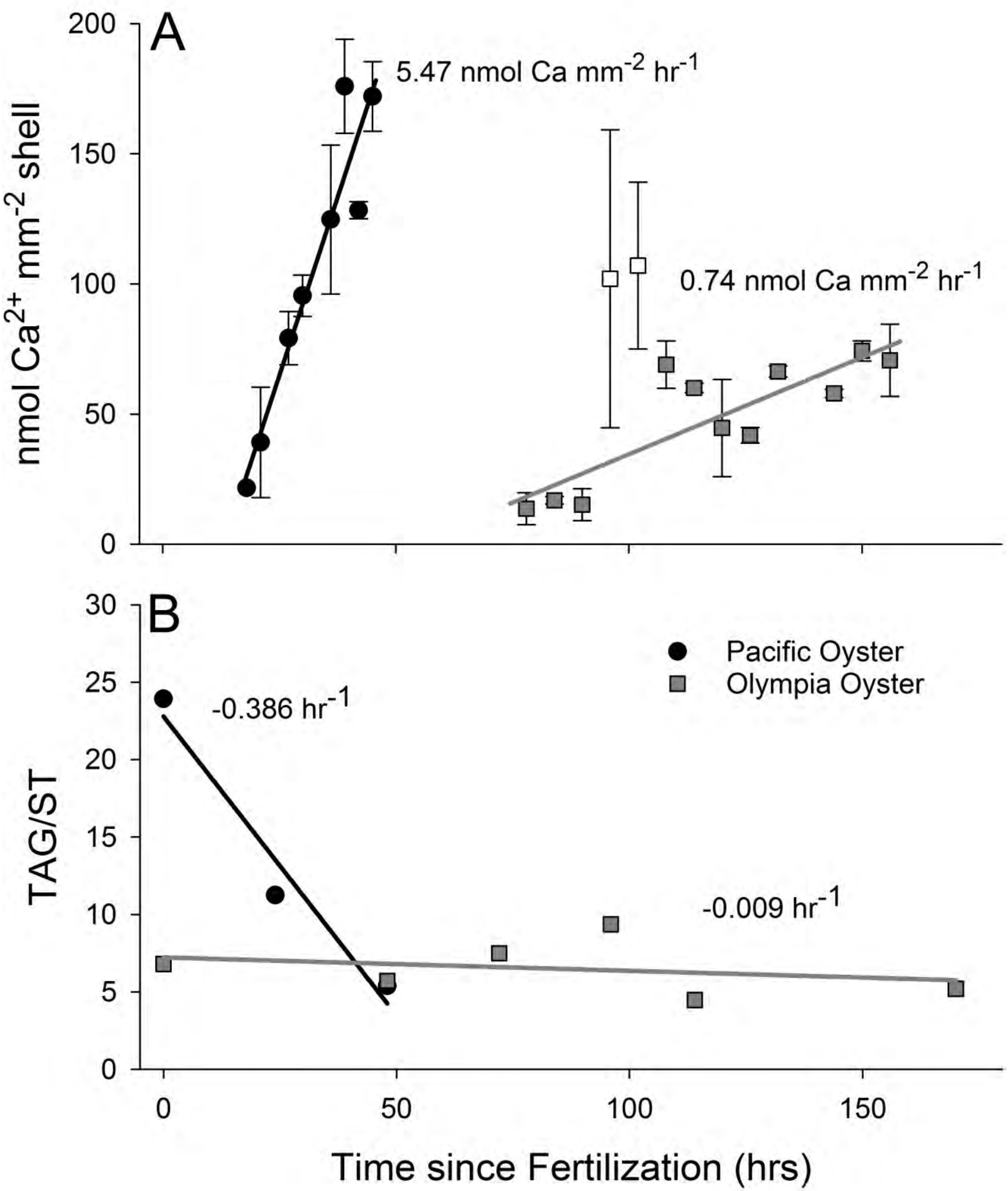
O. lurida



This doesn't mean O. lurida are impervious to OA, excellent work on chronic/carry-over effects by Hettinger et al.

Waldbusser et al. in prep

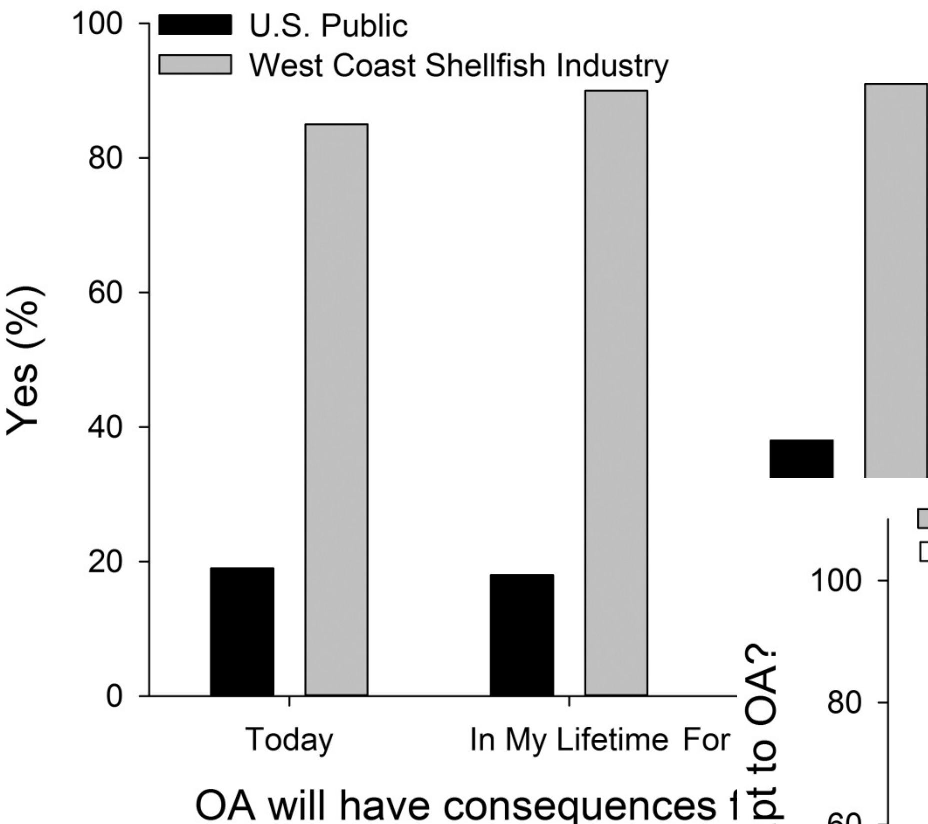
Calcification Rates



O. lurida **calcification rate is > 7x slower during the same development stage!!!**

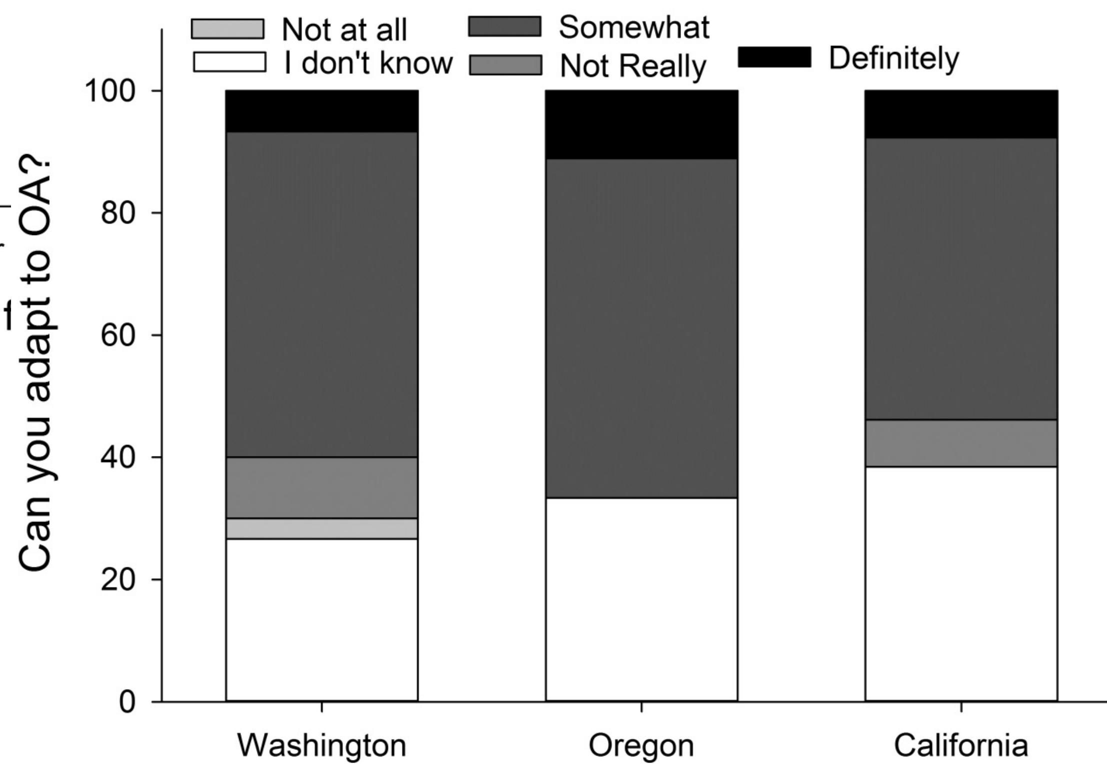
Waldbusser et al. in review

Back to the Human Dimension of Ocean Acidification



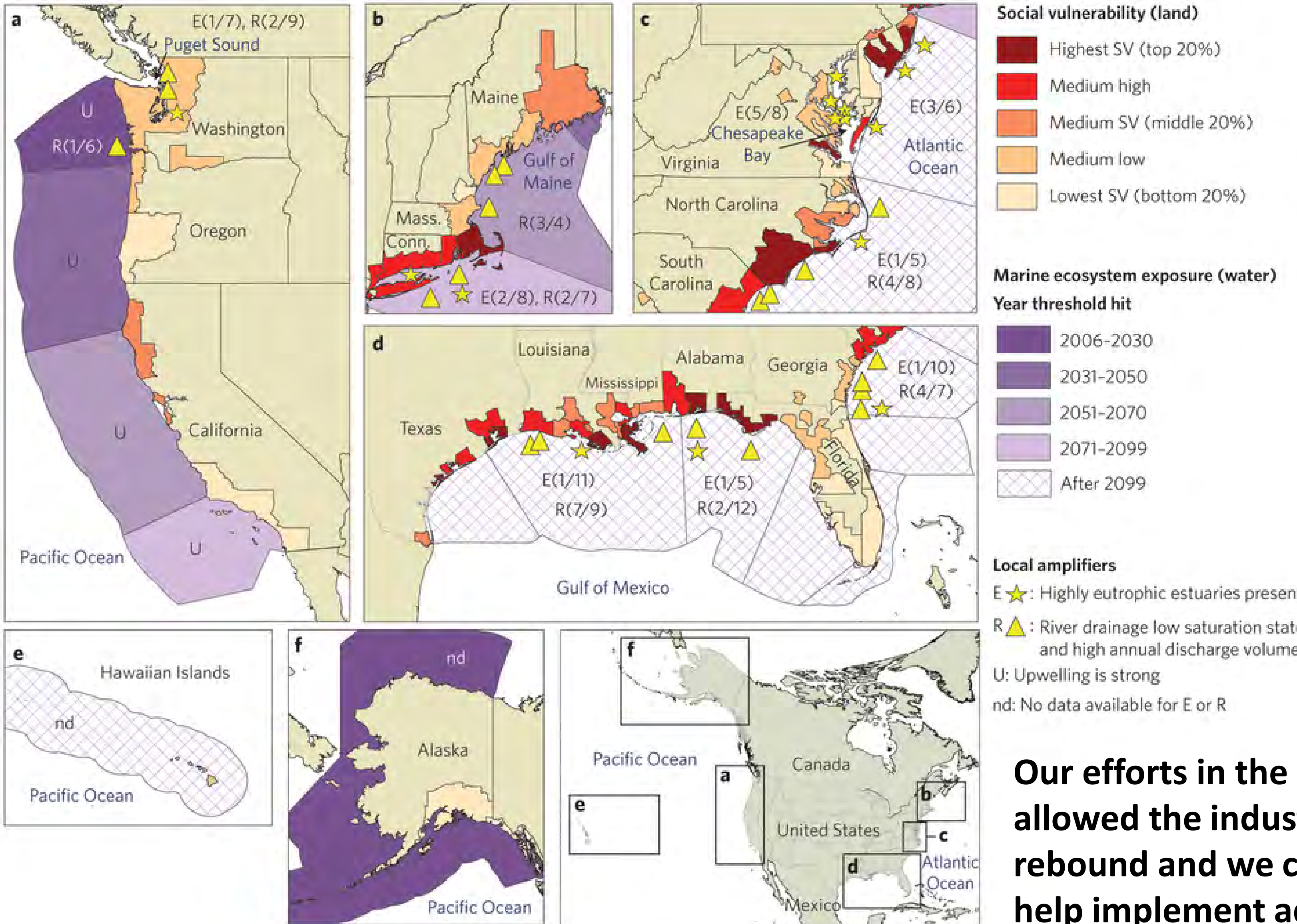
The U.S. West Coast Shellfish Industry:

1) Believes OA is happening
2) Have felt the impacts of OA
3) Believes they can adapt
4) Looks to take the lead in adapting



Mabardy et al. 2015

Although we are seeing OA effects on the oyster industry in the PNW, it may not be the most vulnerable to OA impacts on industry…

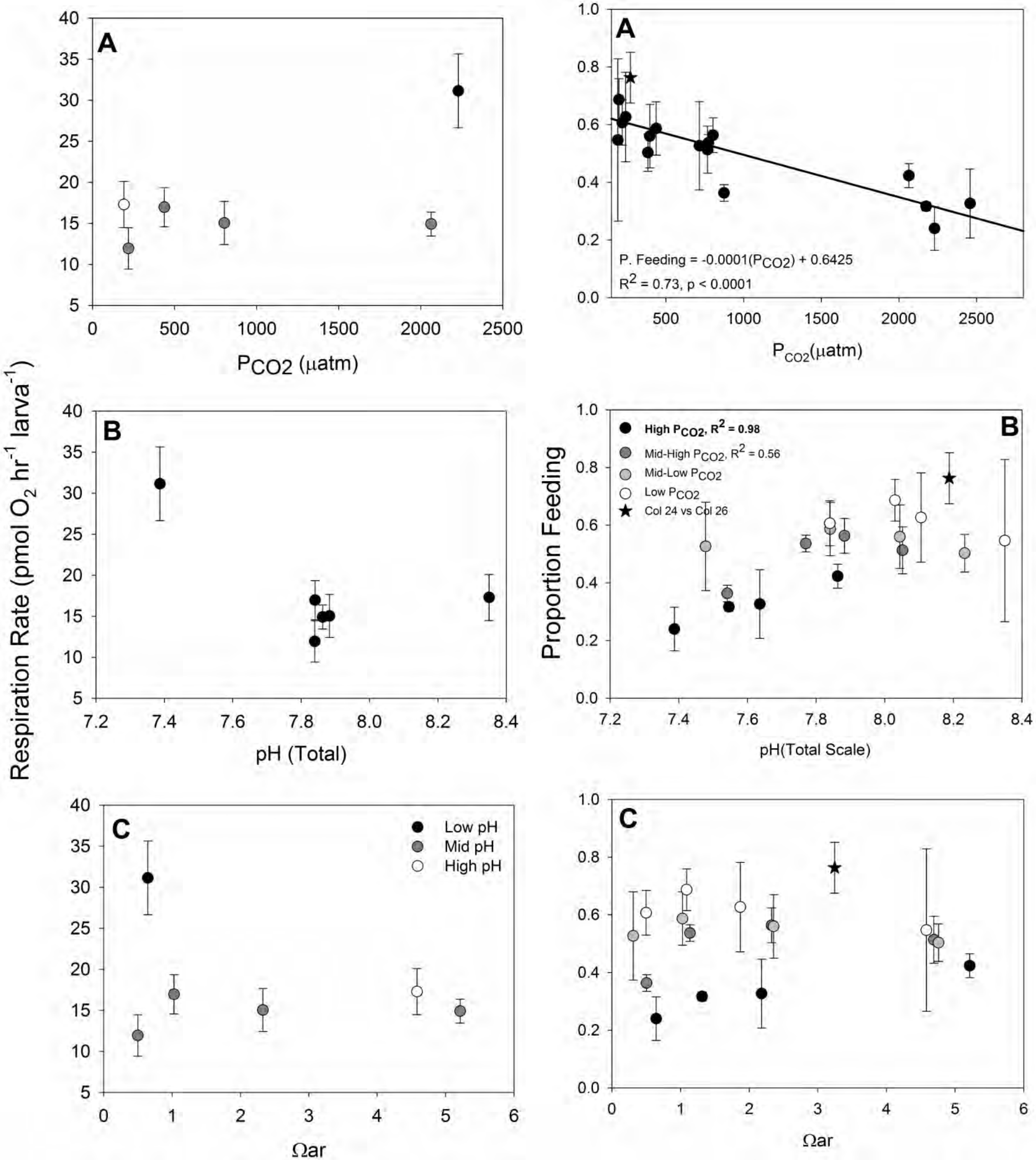


Our efforts in the PNW have allowed the industry to rebound and we continue to help implement adaptation strategies.

Ekstrom et al. 2015, Nature Climate Change

OA as a Multiple Stressor

Same experiments looking at respiration rates and a feeding metric in *M. californianus*



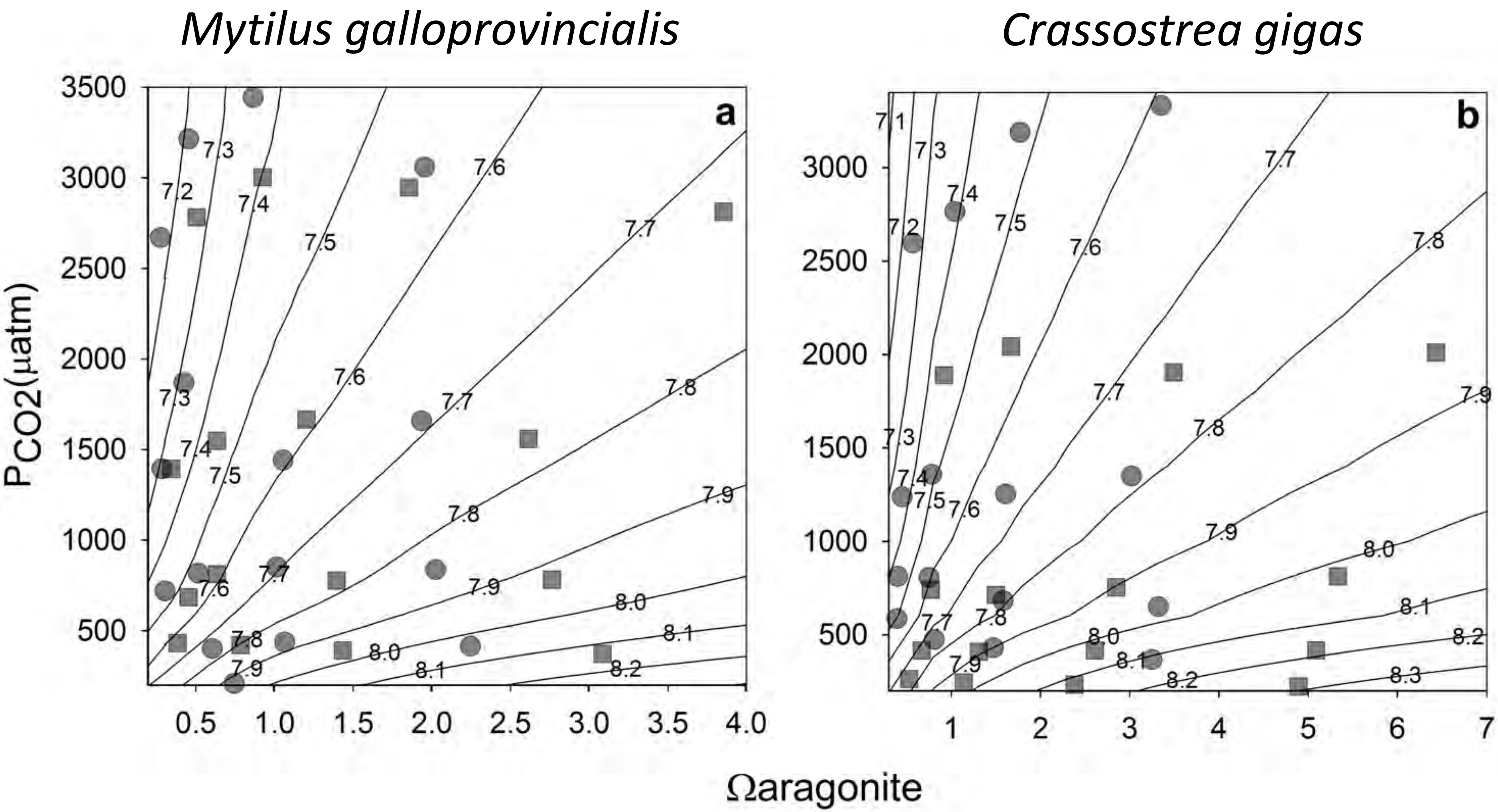
OA as a Multiple Stressor

Respiration Rate responds to pH (as expected).

Proportion Feeding to P_{CO_2}.

Waldbusser et al. 2015b

Methods (decoupling carbonate variables)



Manipulating DIC and Total Alkalinity to "decouple" carbonate system parameters.

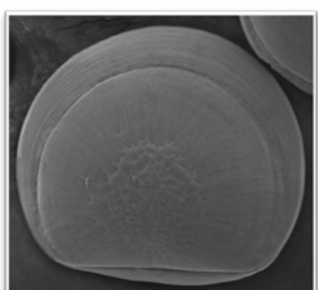
Methods

Closed Bottle Incubations (500 ml BOD bottles)

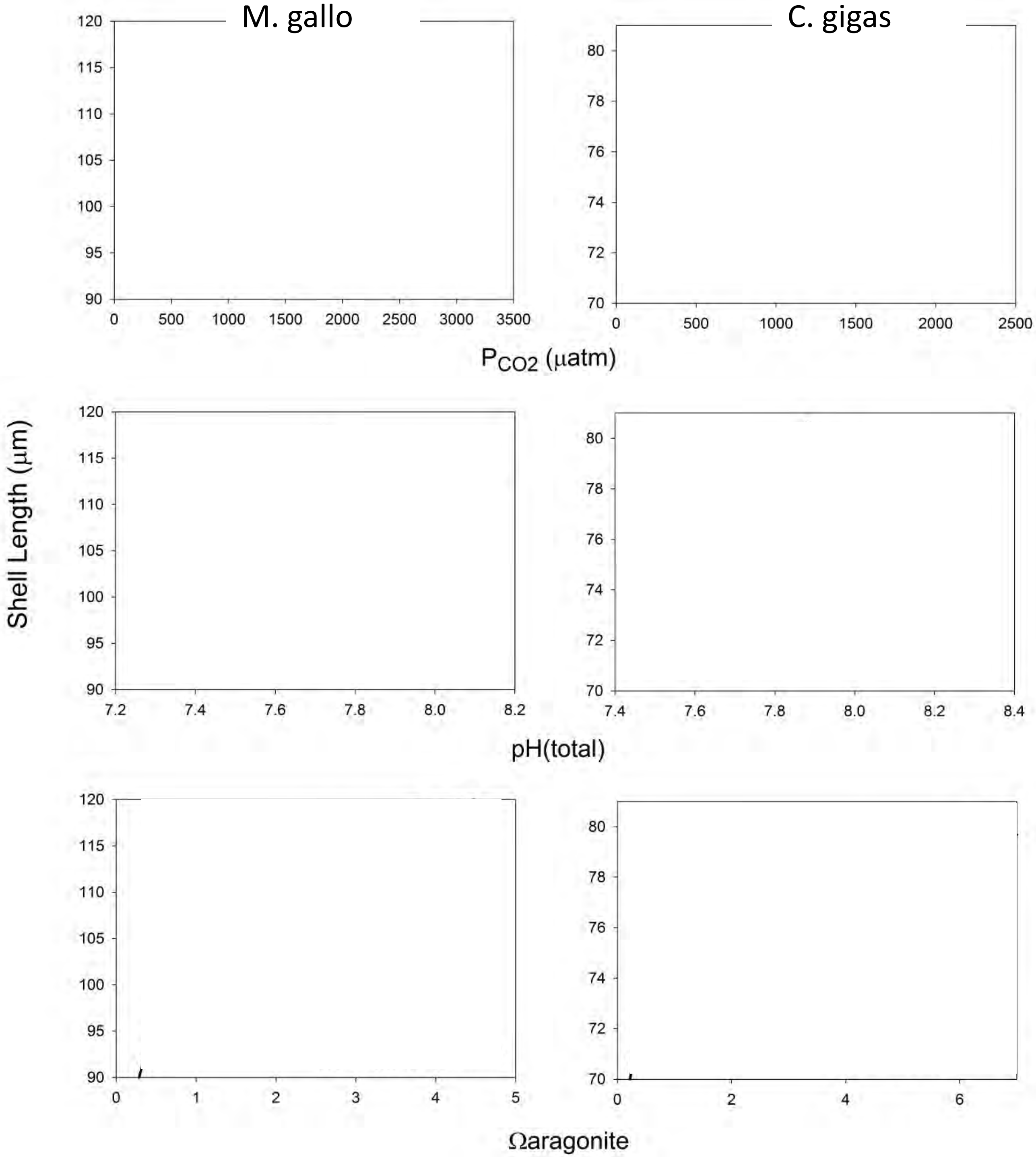
Shell Development and Length of Normal Shells
    48 hrs and 120 hrs

16 chemistry treatments, with 3 replicates each + several controls
    Triplicate counts for development
    Measured shell length of all “Normal” larvae

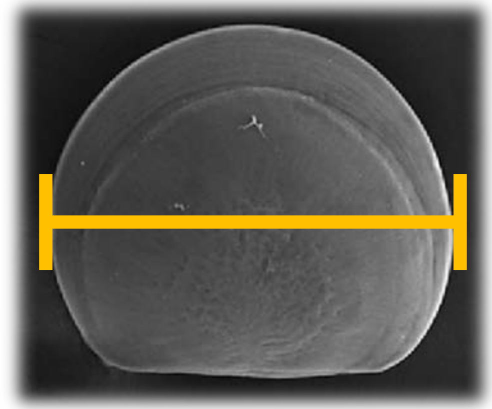
End up scoring ~100 larvae per sub-replicate, and have ~60 BOD bottles…



Only Acute Effects



Shell Length Normal

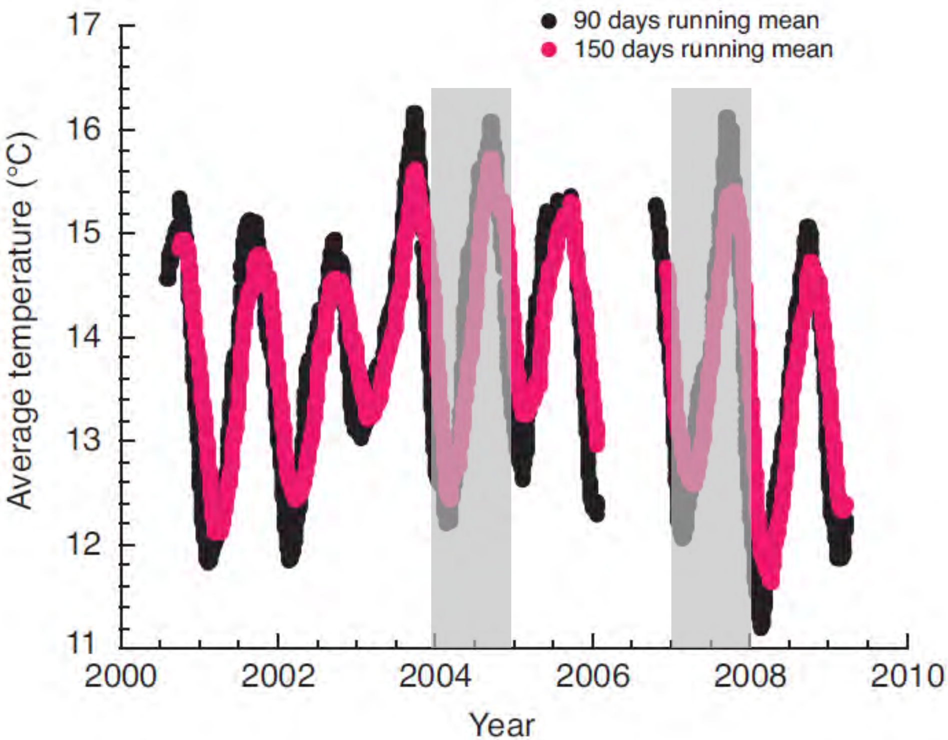


For the normally developed larvae, decreases in saturation state make smaller larvae.

Smaller scope for growth means making shell is more expensive, or something else is requiring more energy.

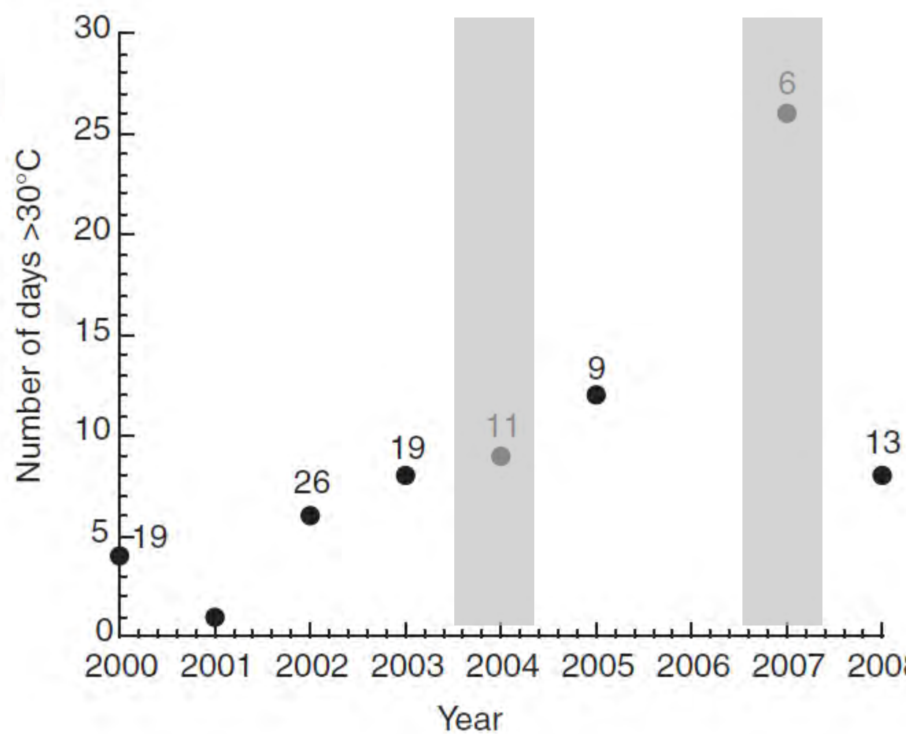
Waldbusser et al. 2015

Mussel Body Temperature in the Intertidal Helmuth et al. (2010)



Average Temperatures

Extreme Events



While climate change is a global phenomenon, to an organism, all relevant environmental changes are very local as the organism moves through space and time. (Helmuth et al. 2010)