4TH ANNUAL CAPE COASTAL CONFERENCE

Acidification impacts on larval shellfish

Daniel C. McCorkle
Senior Scientist
Department of Geology and Geophysics
Woods Hole Oceanographic Institution

4TH ANNUAL CAPE COASTAL CONFERENCE

Daniel C. McCorkle
Anne L. Cohen (WHOI)
Lisa M. Milke (NOAA-NMFS Milford CT)

Meredith White (WHOI,Mook Sea Farm)
Lauren Mullineaux (WHOI)

Ryan Petit
Cailan Sugano
Gabrielle Fignar

Scott Lindell (MBL)

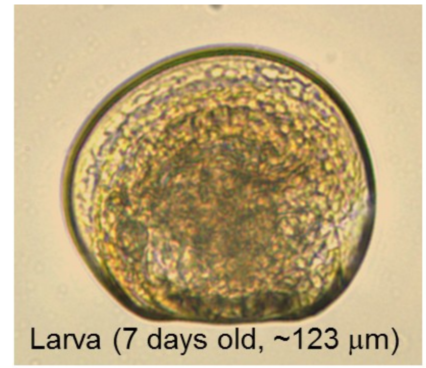
Woods Hole Sea Grant

NOAA — National Oceanic and Atmospheric Administration — U.S. Department of Commerce

Woods Hole Oceanographic Institution 1930

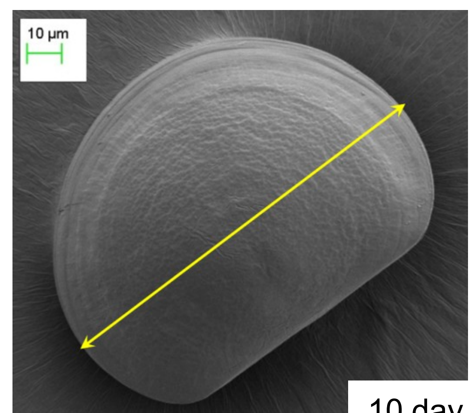
Ocean acidification culture experiments at WHOI

larval bay scallops (*Argopecten irradians*)



Larva (7 days old, ~123 µm)

larval sea scallops (*Placopecten magellanicus*)



10 day, 100 µm

Why do we care?

National - fisheries managers use quantitative models to help set appropriate harvest levels – models which include linked environmental, biological, and economic components.

Local - Coastal managers need to understand the impacts of changes in coastal water quality on coastal ecosystems (e.g., nutrient pollution (eutrophication), which can drive acidification of estuaries).

Broad questions:

Are shellfish vulnerable to ocean acidification, and if so, over what range of pH?

Are particular life stages more/less vulnerable?

Are particular species more/less vulnerable?

Does food availability influence the impact of acidification?

Today: Laboratory culture experiments at WHOI to assess bay scallop and sea scallop larval sensitivity to acidification.

Two treatments in each experiment:

- acidification (elevated carbon dioxide)
- feeding rate

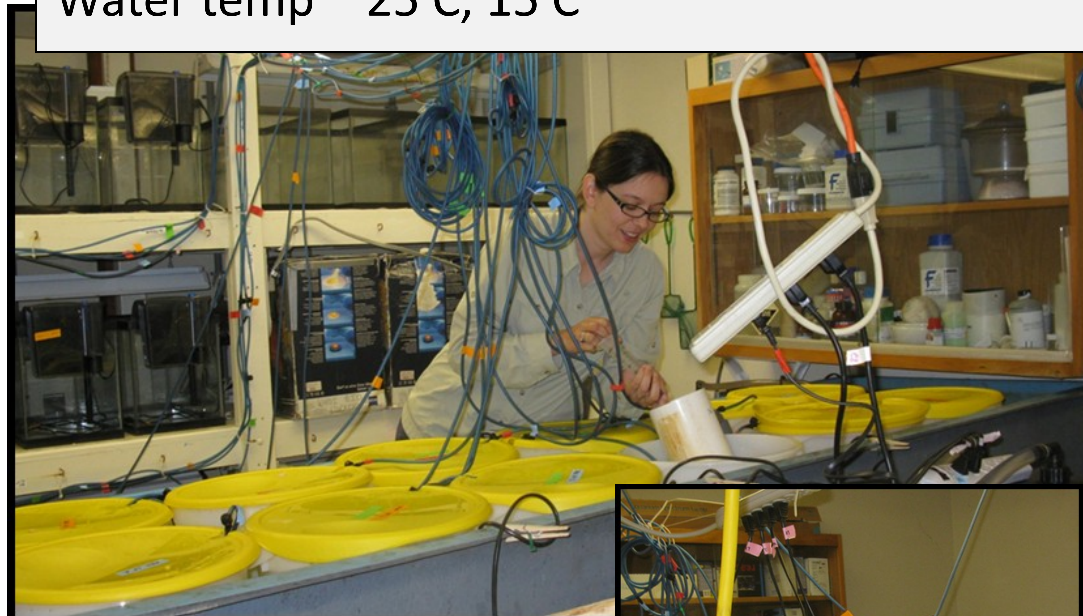
Two metrics to assess impacts:

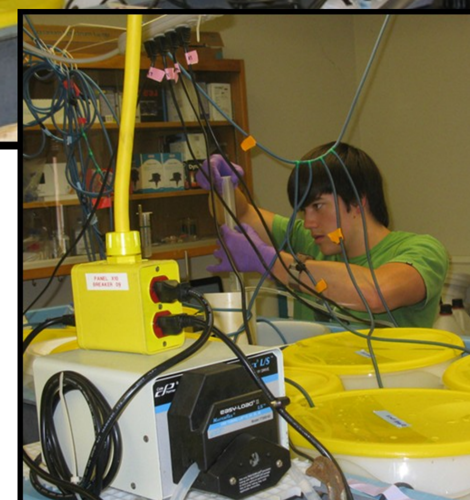
- survival
- frequency of shell deformities

Elevated carbon dioxide levels – acidification – has negative impacts on larval survival, and on the frequency of shell-shape abnormalities (deformities).

Triplicate 15 L buckets
Initial stocking density = 10 - 30 embryos / mL
Water temp ~ 25 C, 15 C

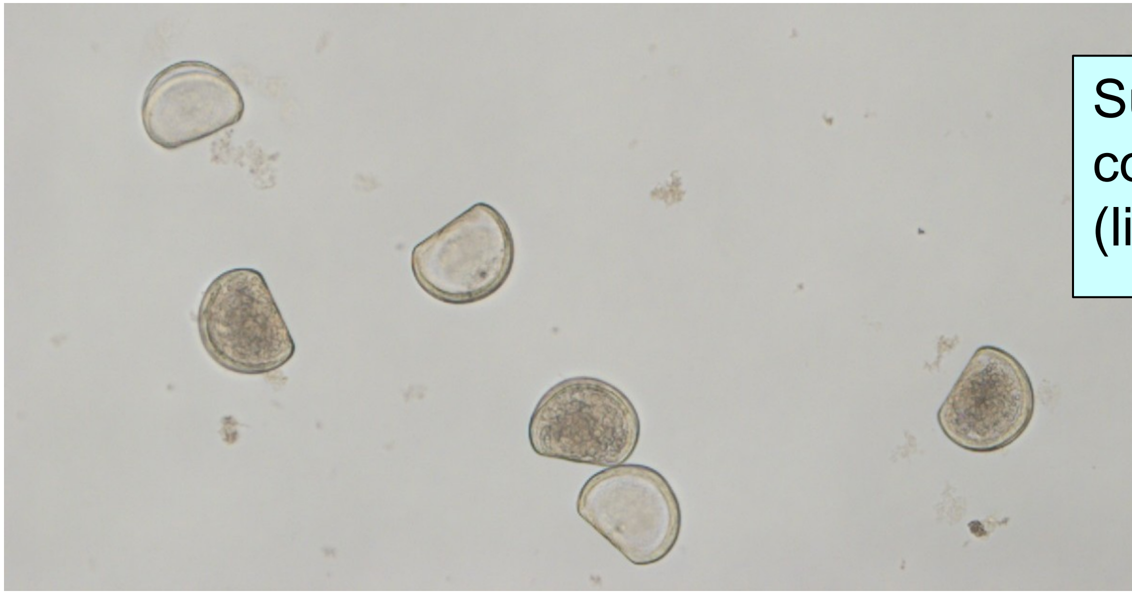
Sea scallop broodstock from Cape Cod bay (12 males, 12 females)





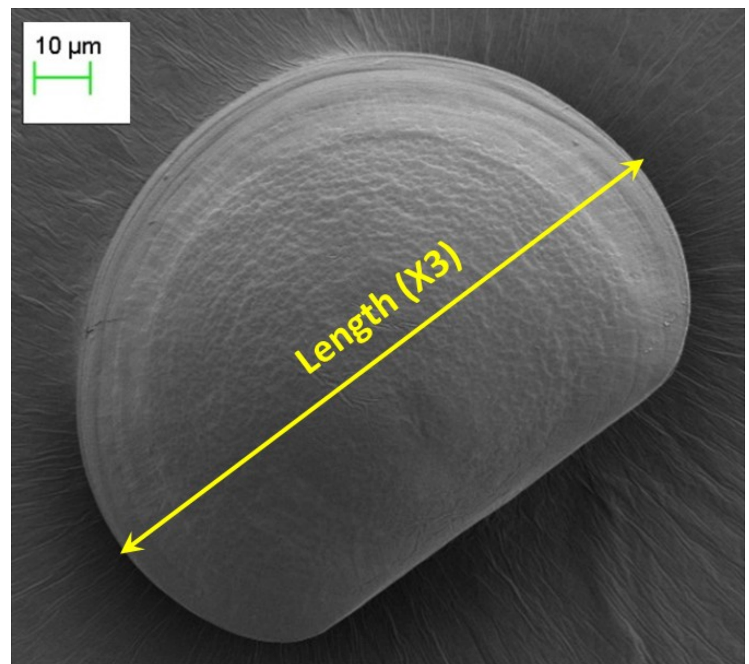
2 – 3 carbon dioxide levels
(high CO_2 = low pH)

Daily feeding at two rates

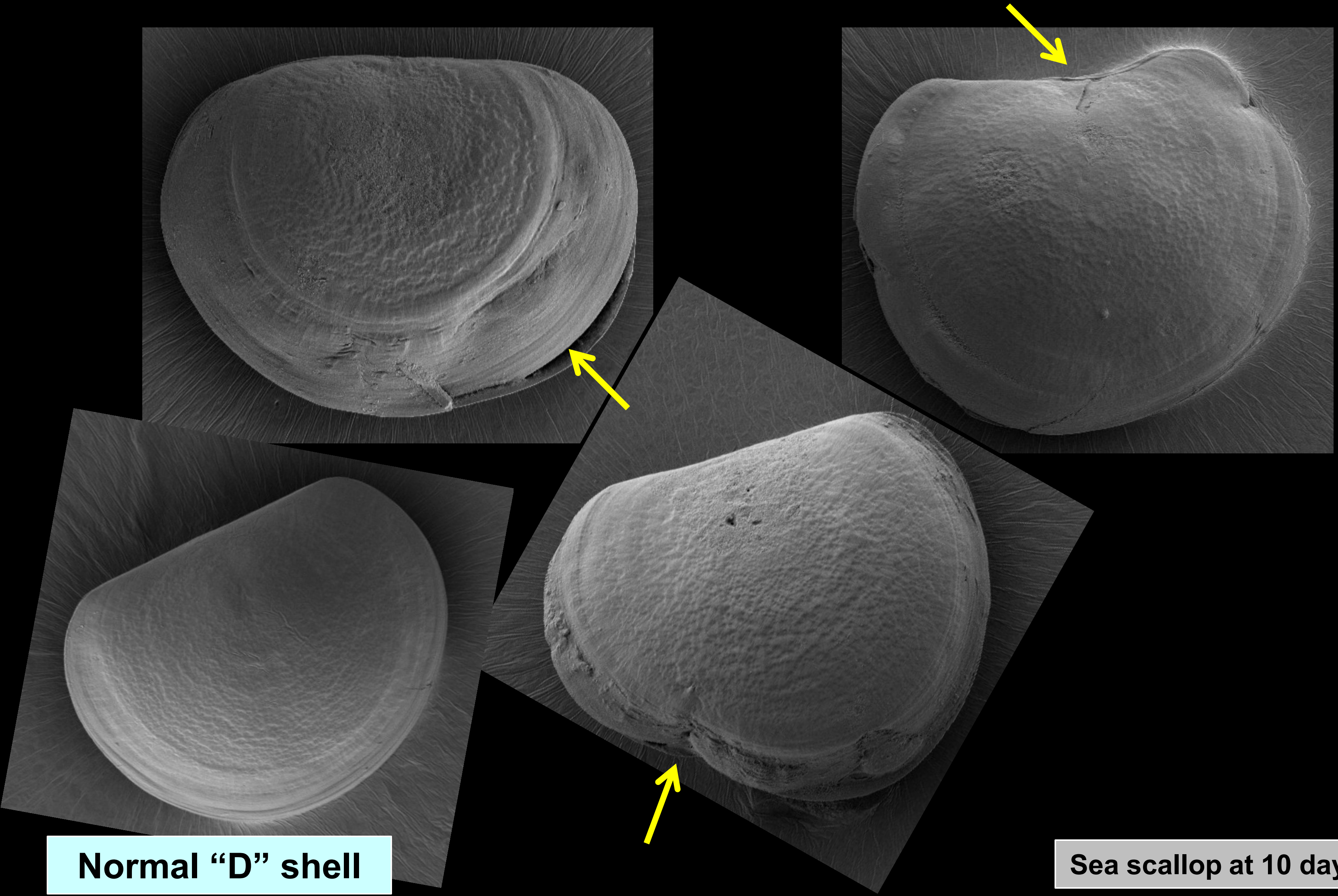


Survival – light microscopy to count shells with protoplasm (live) and without (dead)

Scanning electron microscope imaging (Marine Biological Laboratory) to determine shell size and to quantify shell shape abnormalities.



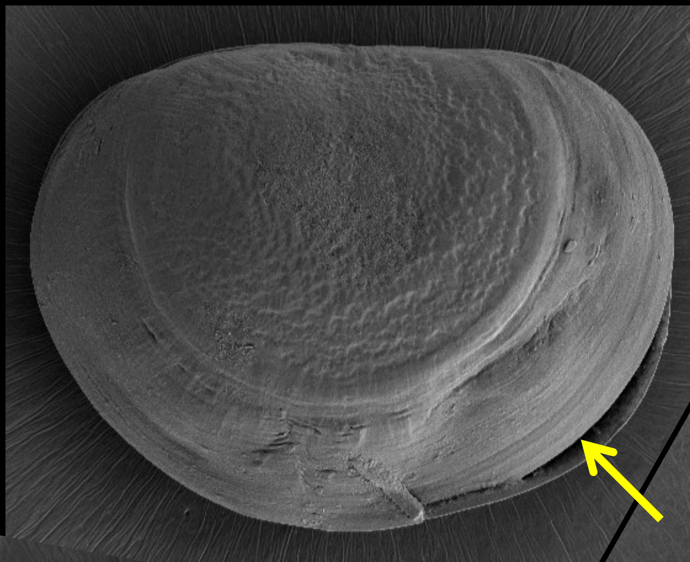
Types of Shell Deformities

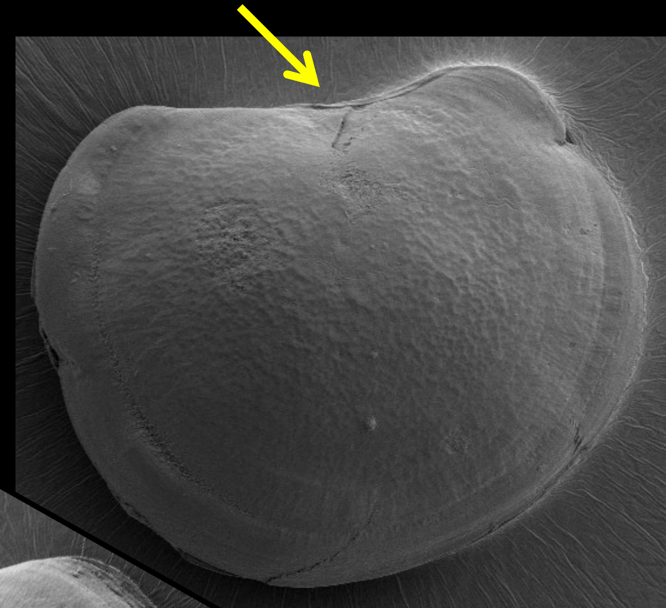


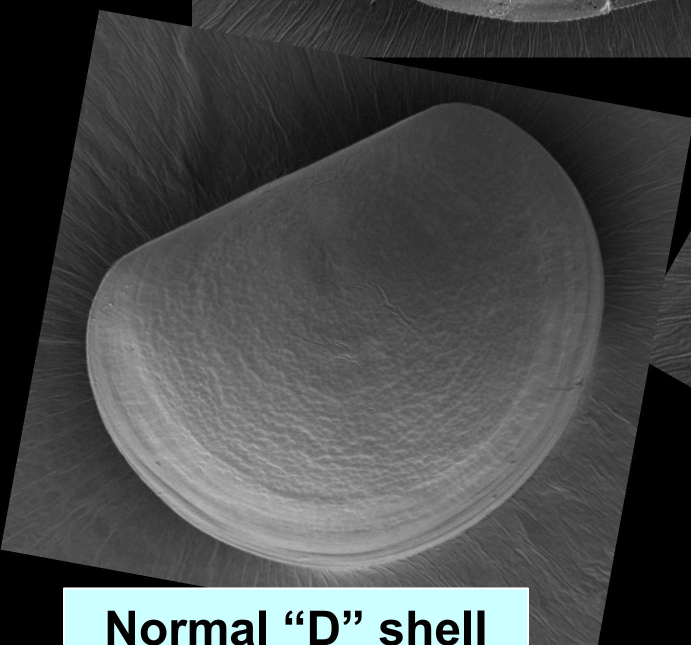
Normal "D" shell

Sea scallop at 10 days

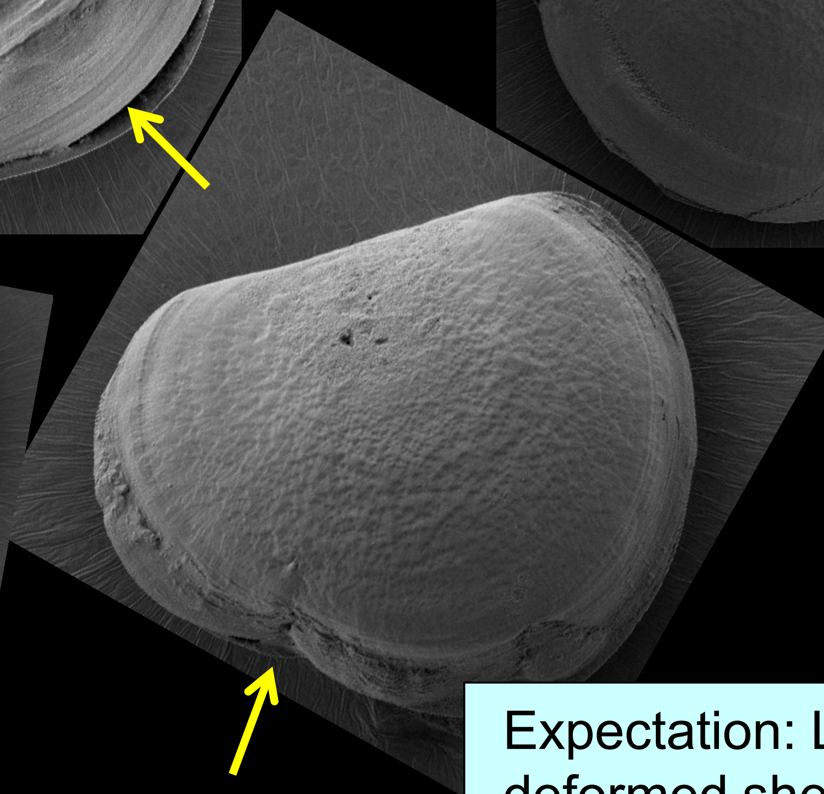
Types of Shell Deformities





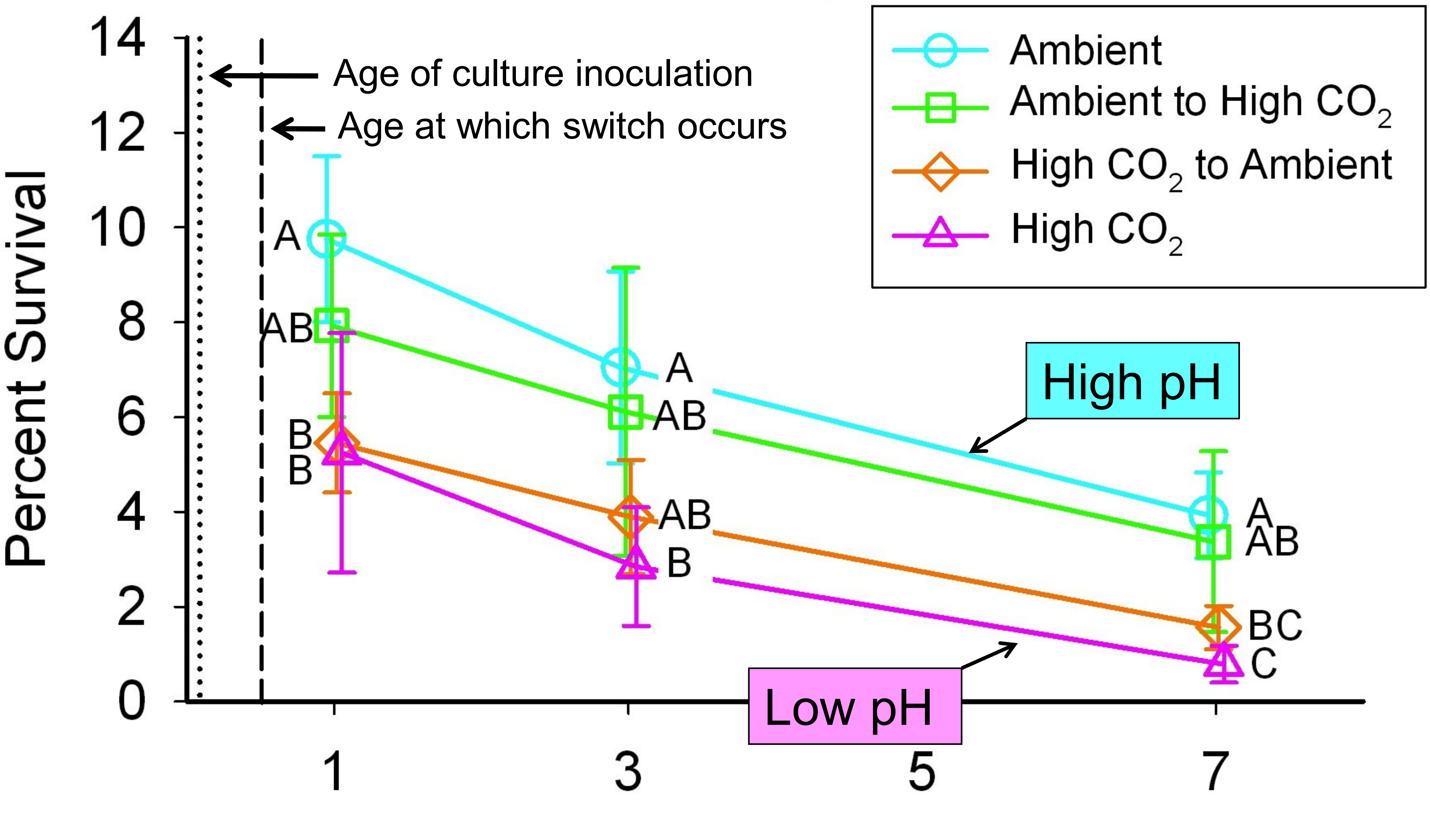


Normal "D" shell



Expectation: Larvae with deformed shells don't survive.

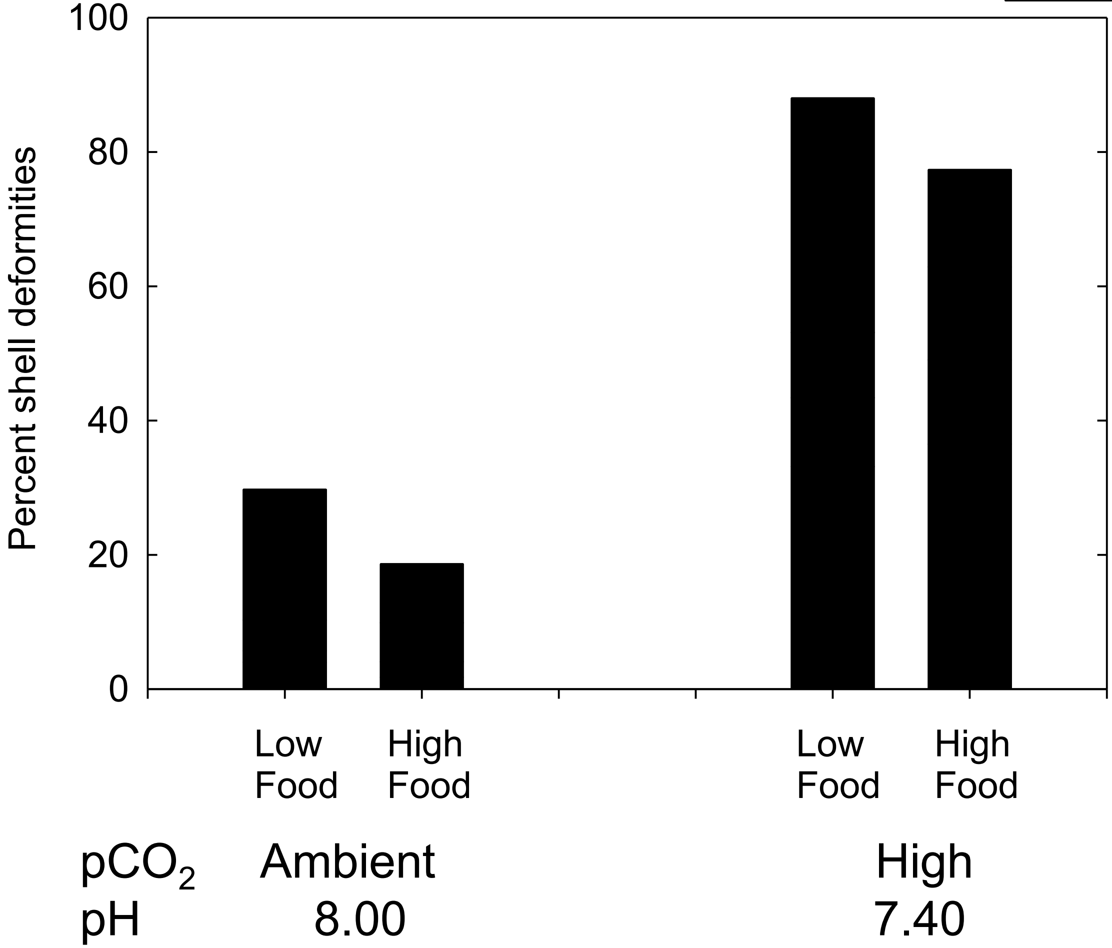
Exposure to high CO_2 (= low pH) reduces survival of larval bay scallops



White et al. (submitted)

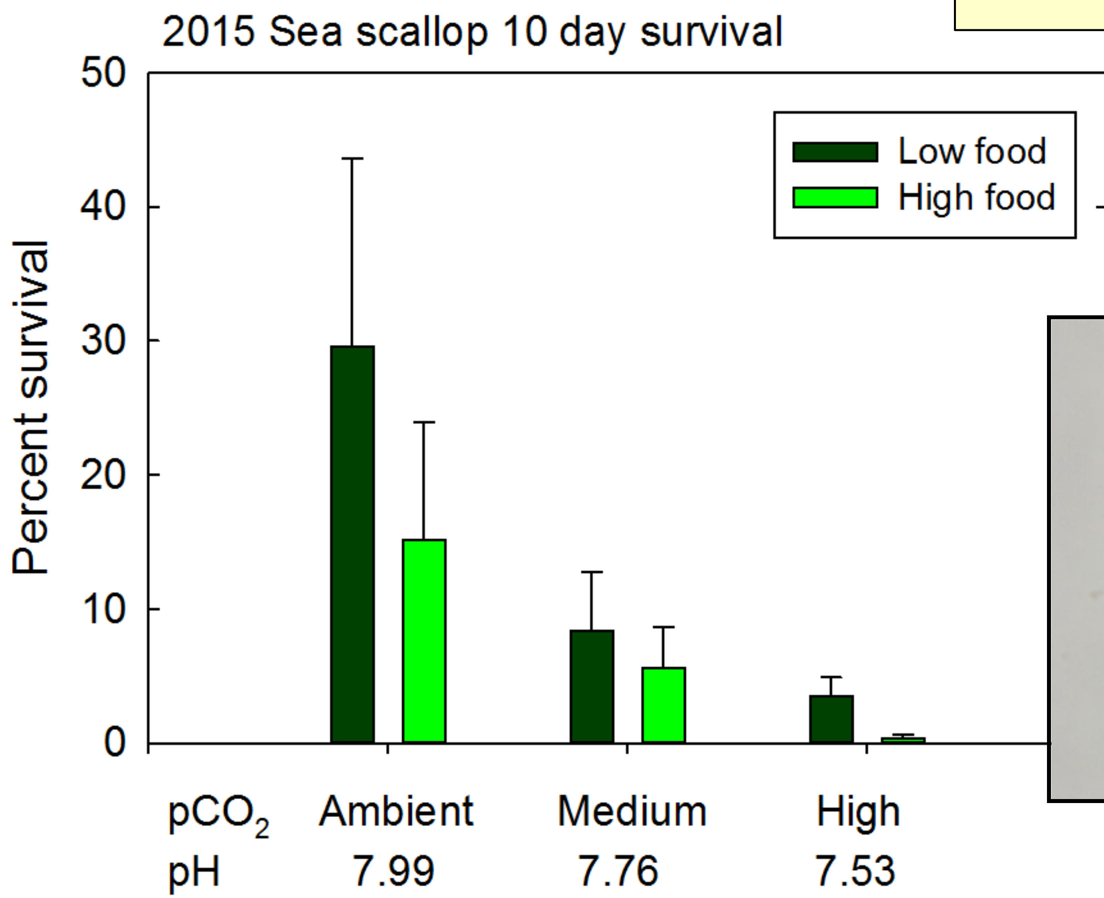
2014 Bay Scallop Shell Deformities

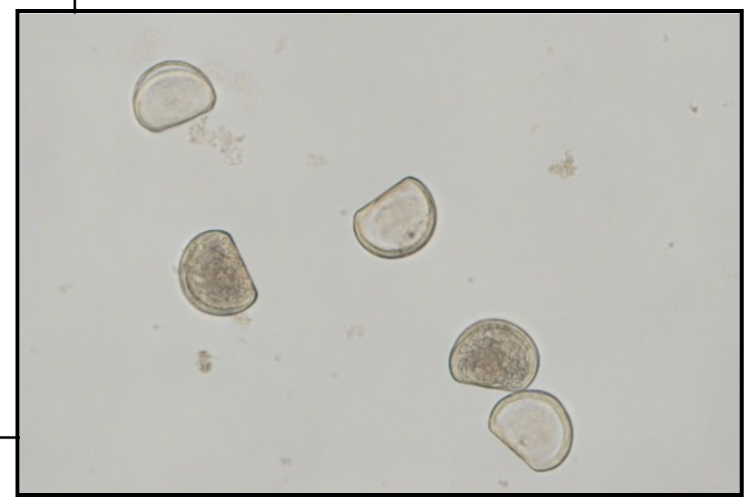
Exposure to high CO_2 (= low pH) increases the frequency of larval bay scallop shell deformities



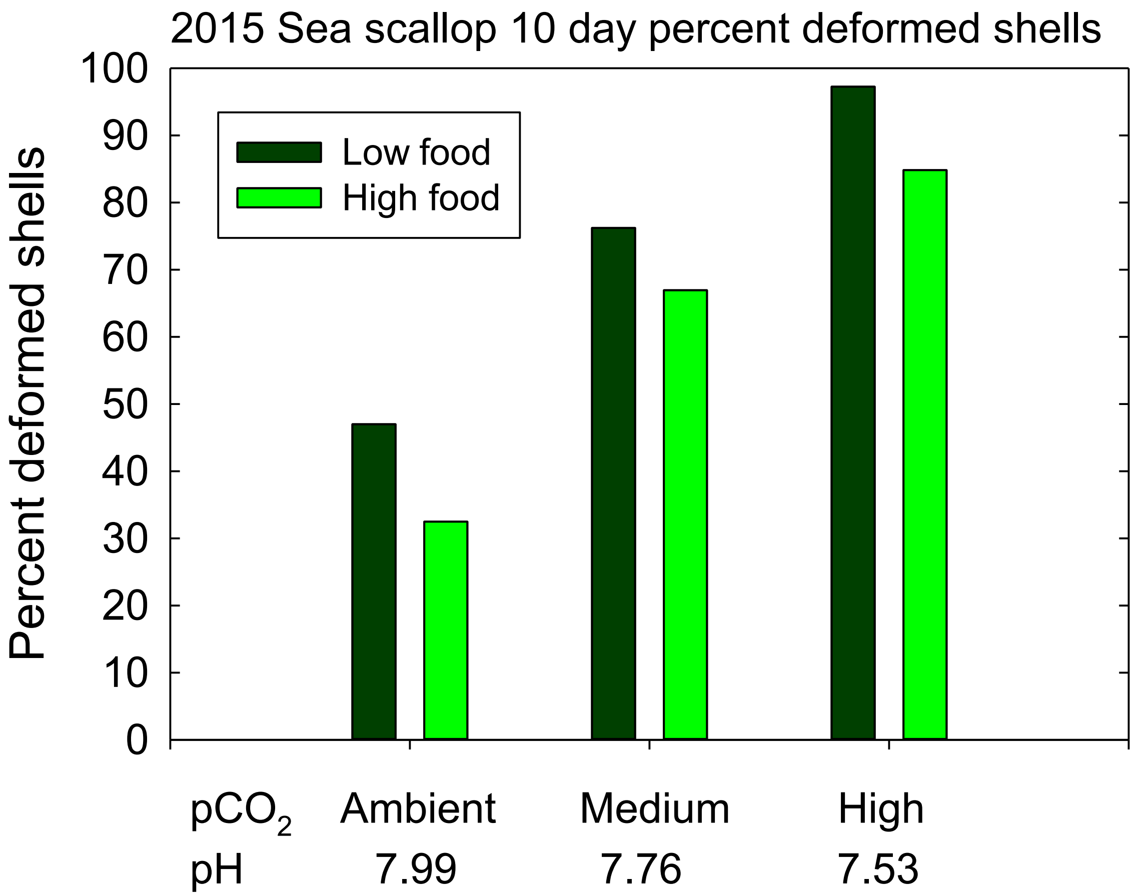
Sugano et al. (2015)

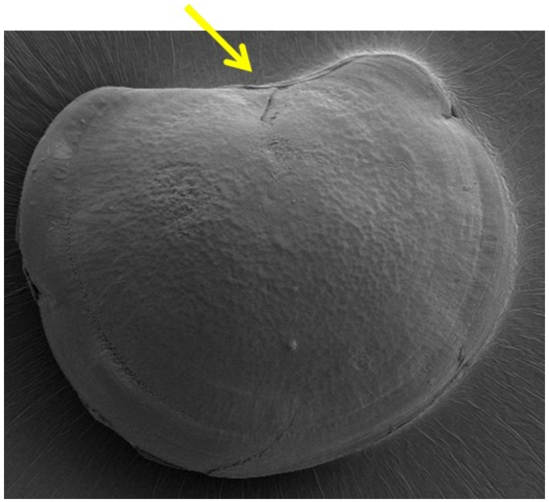
Exposure to high CO_2 reduces survival of larval sea scallops





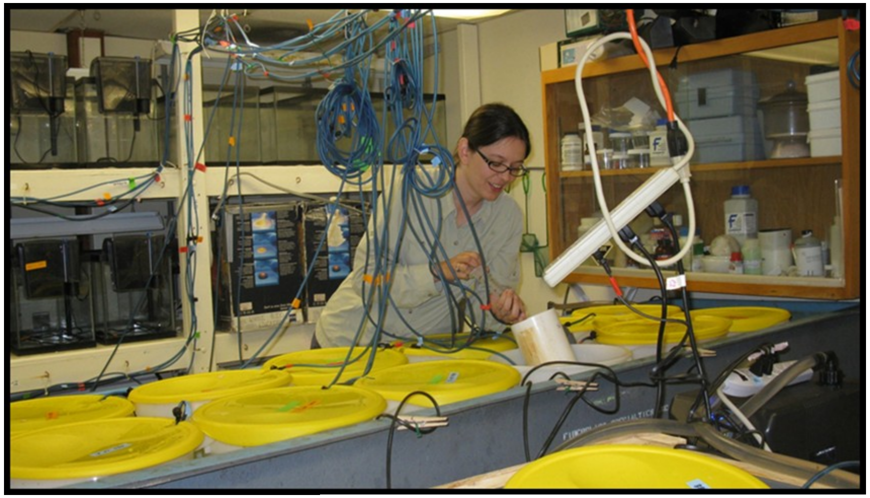
Exposure to high CO_2 increases the frequency of larval bay scallop shell deformities

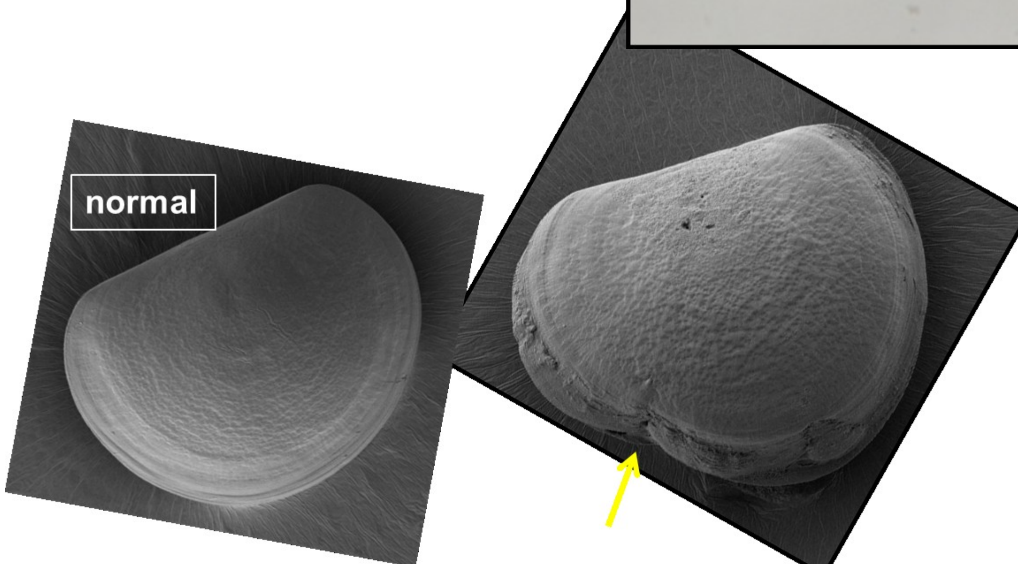




Assumption: Larvae with deformed shells don’t survive.

Elevated carbon dioxide levels – acidification – has negative impacts on larval survival, and on the frequency of shell deformities.





Some outstanding questions, in order to use these results in fisheries models:

Do larval shell deformities actually lead to mortality?

Is the adult population (fishery resource) sensitive to larval mortality?

Not necessarily, under current conditions.

But what if larval mortality increases dramatically?

Can high food availability offset negative impacts of elevated carbon dioxide?

Would reduced food availability exacerbate acidification impacts?

Future culture studies (WHOI / NMFS):

Are there ‘parental’ influences on acidification impacts on bivalves?

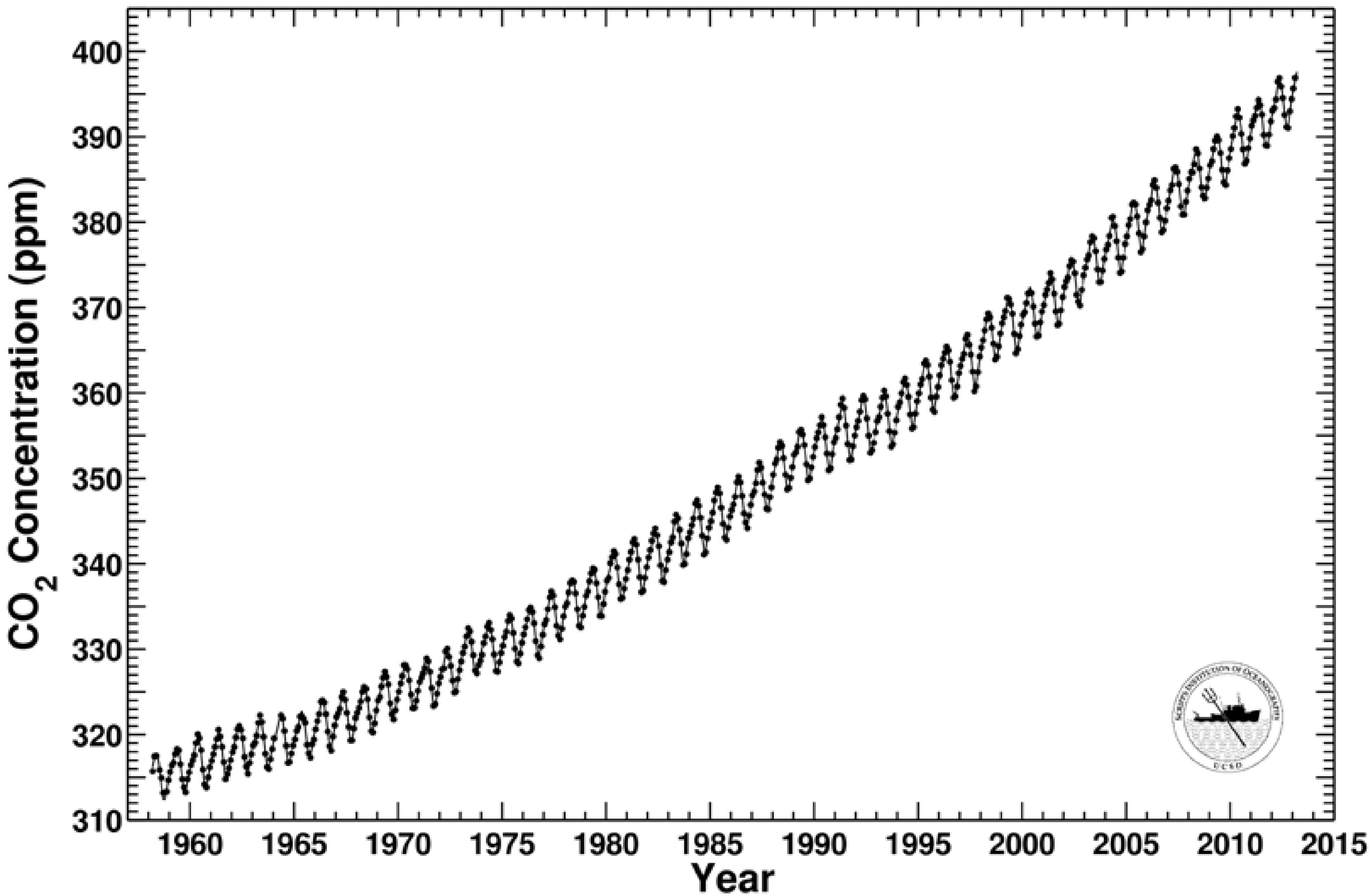
If so, what is the natural range of sensitivity to acidification?

Is this variability genetic, or linked to parental nutrition, or…?

Does this variability offer the prospect of adaptation, or breeding (for hatchery species)?

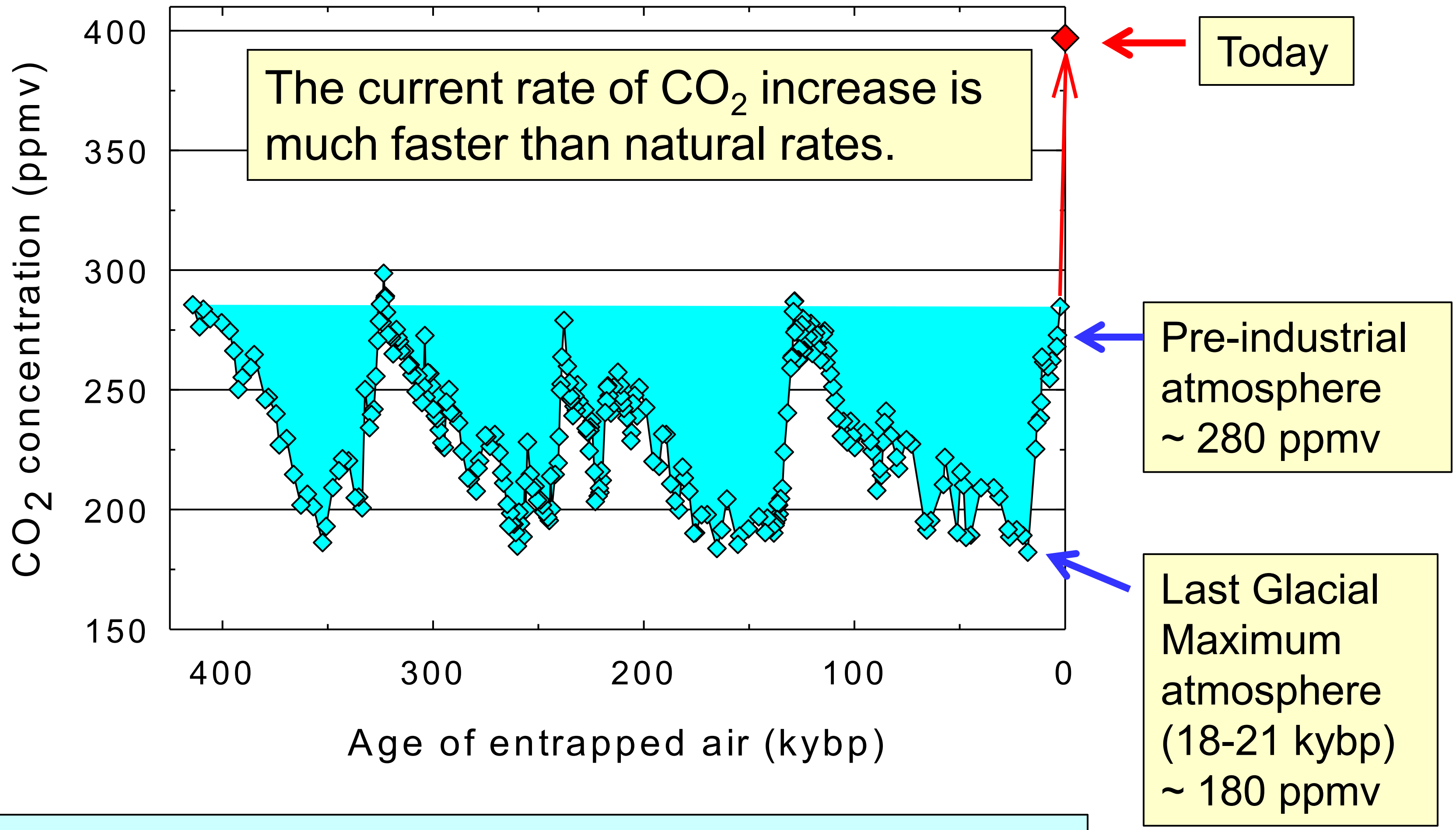
An introduction to ocean acidification

Carbon dioxide in the atmosphere (Mauna Loa, HI)



http://scrippsco2.ucsd.edu mauna_loa_record

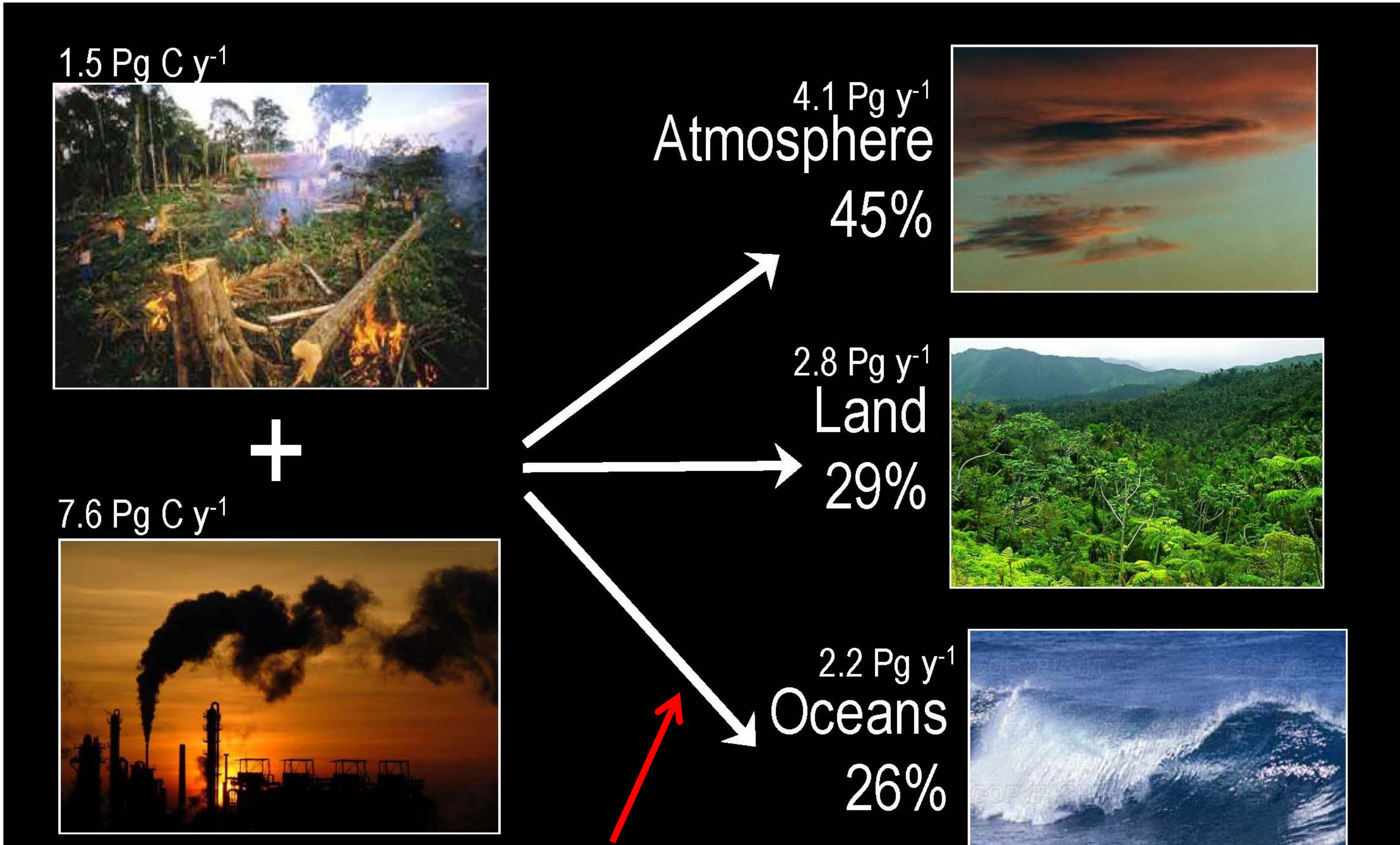
400,000-year Antarctic ice core record of atmospheric CO_2



Natural cycles in atmospheric carbon dioxide
+ fossil fuel combustion, deforestation,…

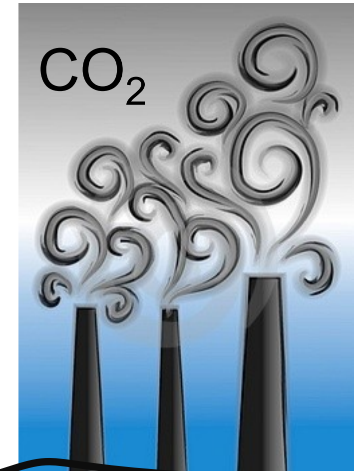
Barnola et al., 1999

Current budget for CO_2 from human activities



Removal of CO_2 from the atmosphere is good, but addition to the ocean is not…

Ocean acidification – the chemistry of carbon dioxide in seawater



Atmosphere

$CO_{2(g)}$

$\uparrow\downarrow$

Ocean

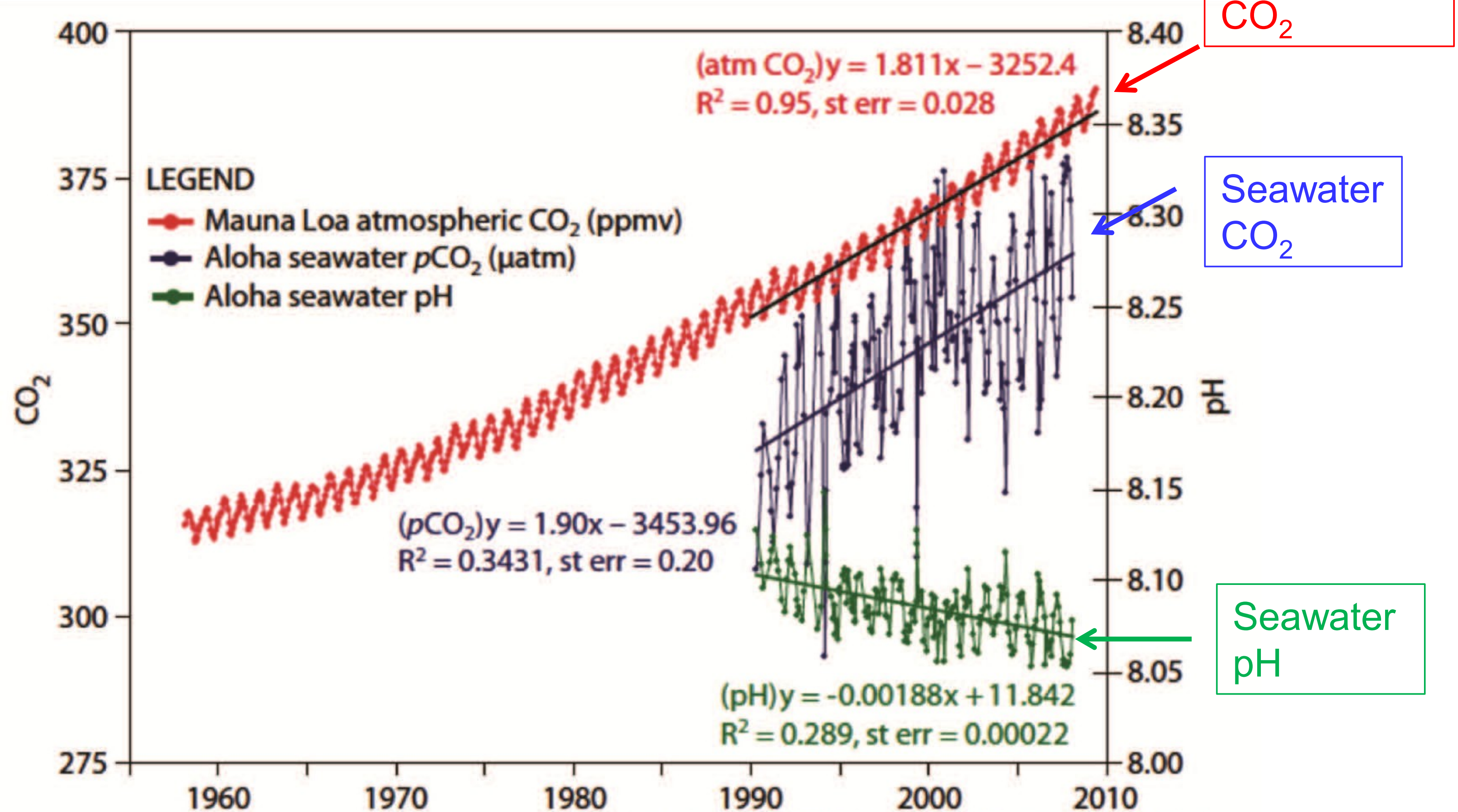
$$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_3$$

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \uparrow$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$$

As CO_2 is added to water, H^+ is produced: pH decreases (= acidification), and CO_3^{-2} (carbonate ion) decreases

Ocean Acidification is observable - the pH of the surface ocean is dropping.



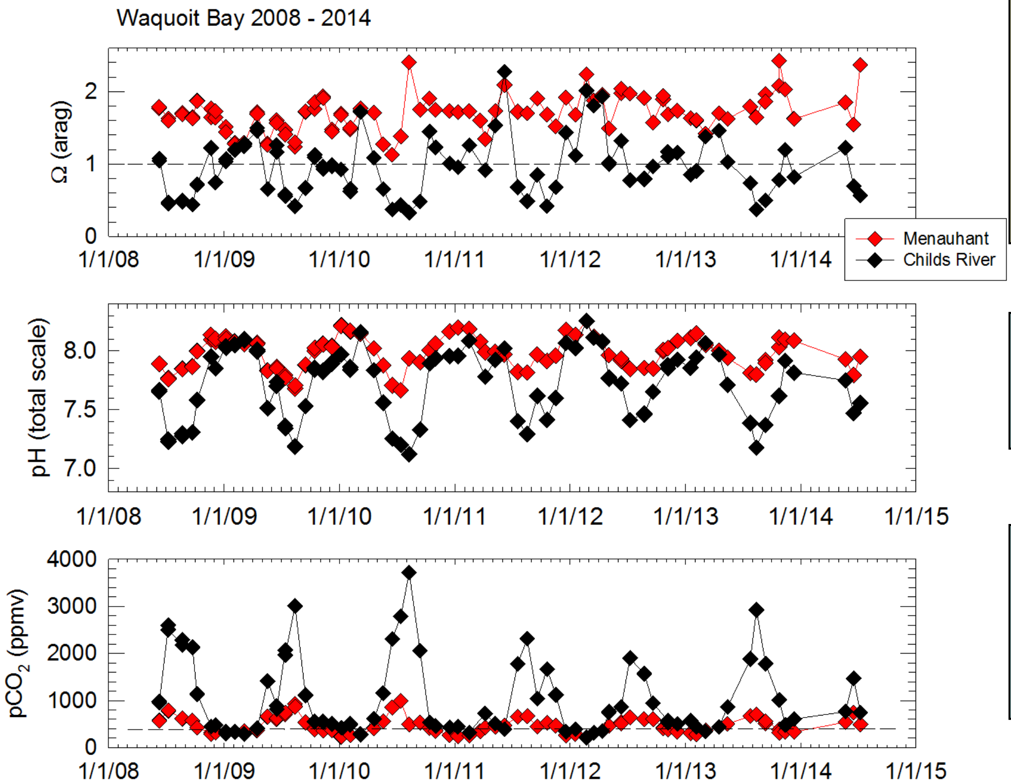
Feely et al. 2009 / NOAA, Pacific Ocean near Hawaii

Open Pacific: 20-year decrease, and annual cycle in pH, less than 0.05 units

Monthly discrete samples just before low tide from 4 stations
(NERR system-wide monitoring program (SWMP))

O_2 data from continuous monitoring stations
(NERR CDMO – Centralized Data Management Office)

Focus on:
Menauhant (most like inflow water)
Childs River (most strongly modified).



- Strong seasonality of pH, pCO_2.

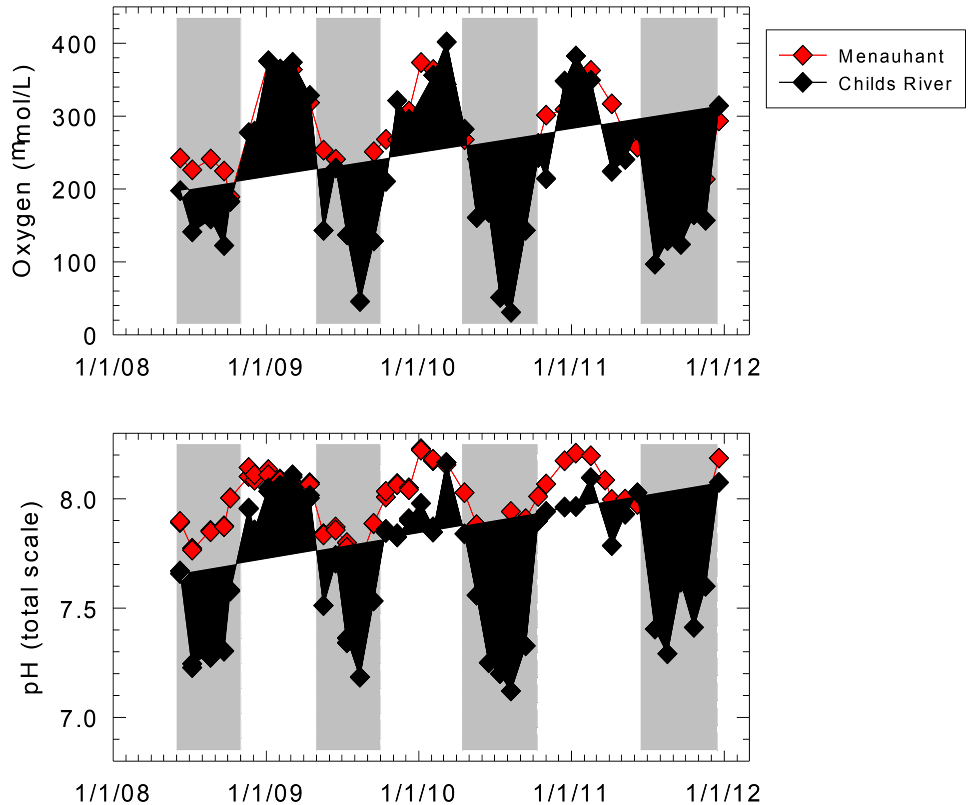
- Most extreme in Childs River:
  Low (volume)/(bottom area)
  Low flushing rate

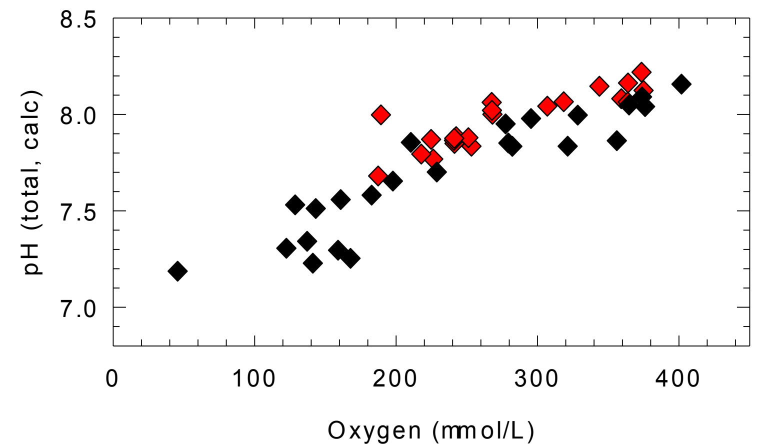
pH(total) values well below 7.5
(all sites below 7.8)

Childs River summer:
pCO_2 above 2000 ppmv
(all sites 100s of ppm above atm)

Calculated Ω, pH and pCO_2, from measured Alkalinity and DIC and temperature

Larvae affected by multiple stressors.





Low pH and high pCO_2 linked to low dissolved oxygen.

Driven by organic matter decomposition in sediments (which produces CO_2, and groundwater discharge.

Natural and anthropogenic contributions to both processes (e.g., eutrophication).

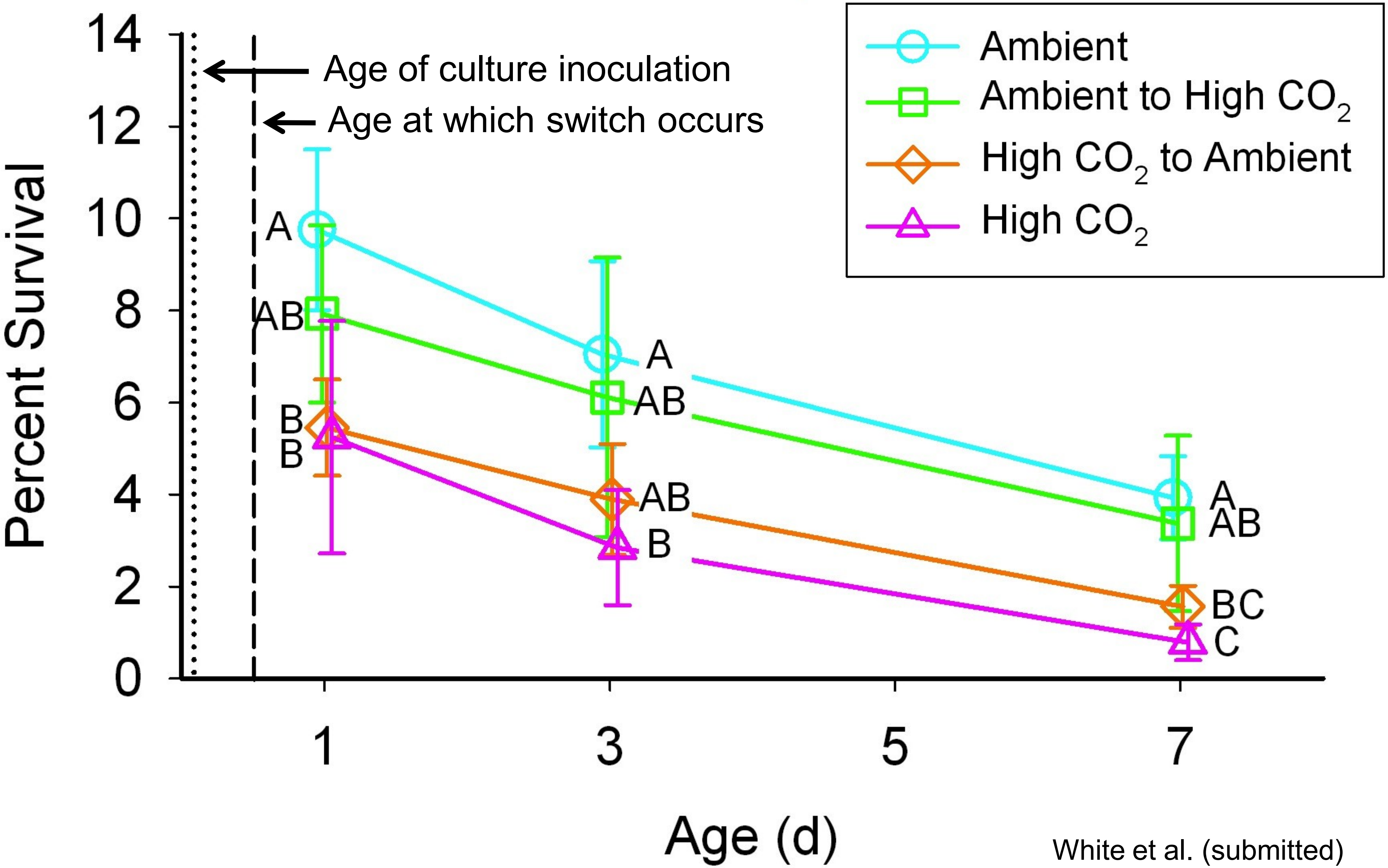
As atmospheric pCO_2 increases, the pH and Ω(ar) at a given oxygen concentration will drop.

Is acidification the biggest threat to shellfish health (recruitment and growth)?
Or low oxygen?
Or combined impacts…?

O_2 data from WBNERR continuous monitoring stations (NERR CDMO – Centralized Data Management Office)

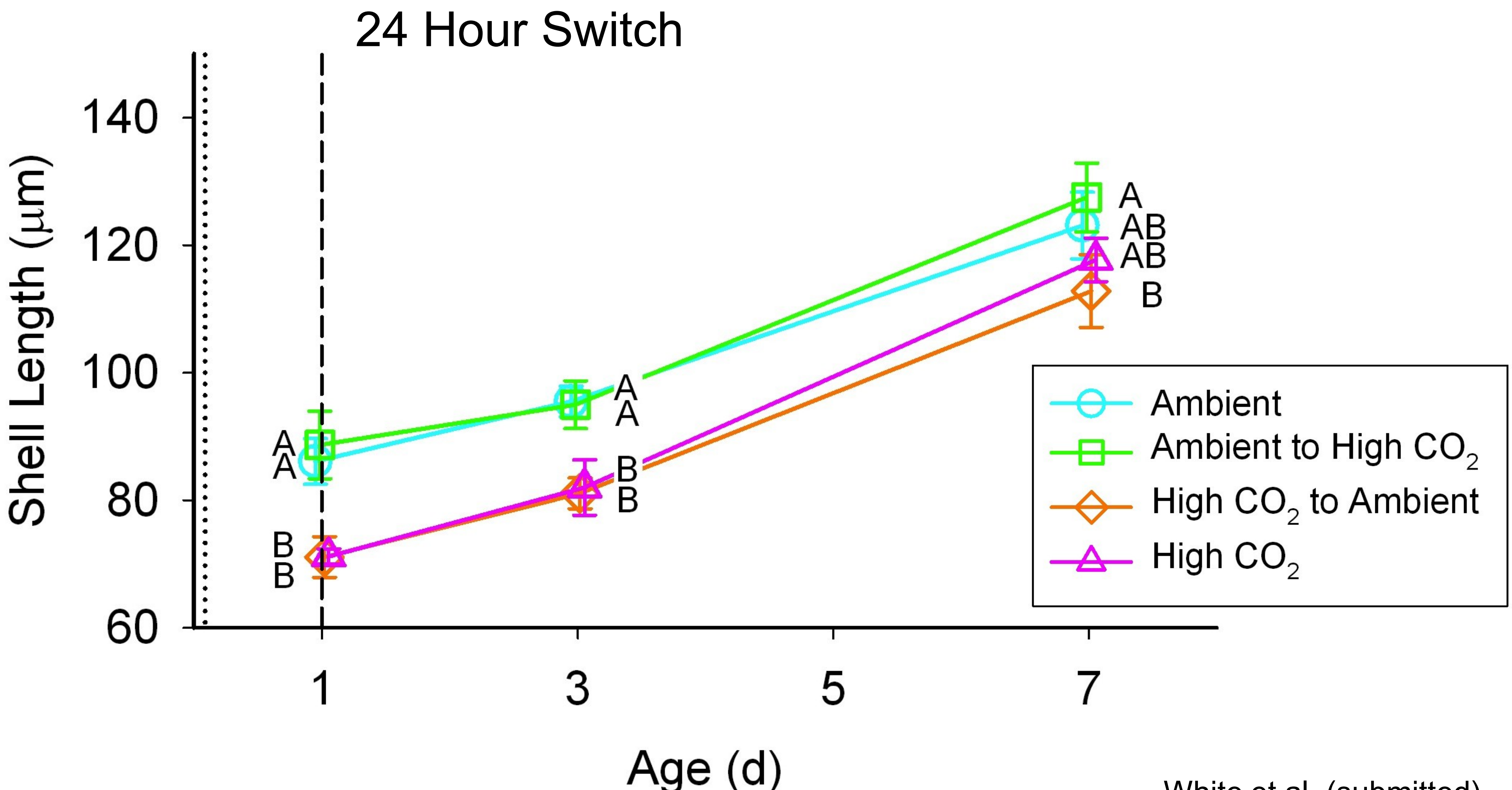
Exposure to high CO_2 reduces survival

12 hour switch



White et al. (submitted)

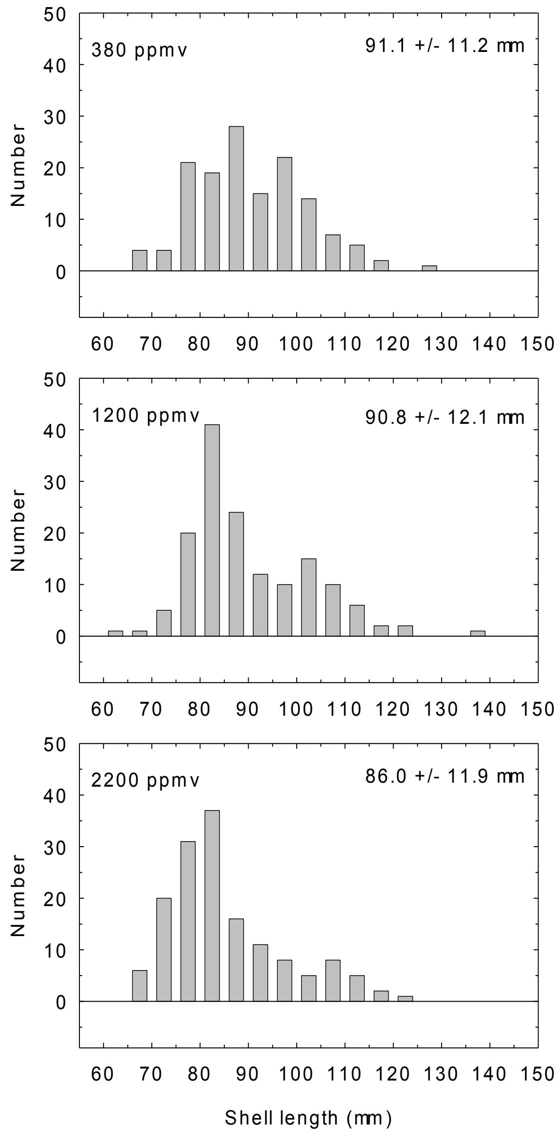
Shell size impacted by CO_2 level during the initial calcification (12-24 hr).
They don't catch up.



White et al. (submitted)

2011 surf clam experiment, day 6

Shell length histograms reveal a range of responses for each treatment (each CO_2 level)



Average size decreases as CO_2 increases, but even the high-CO_2 treatments include some large individuals.

Suggests possibility of selection for CO_2 tolerance:

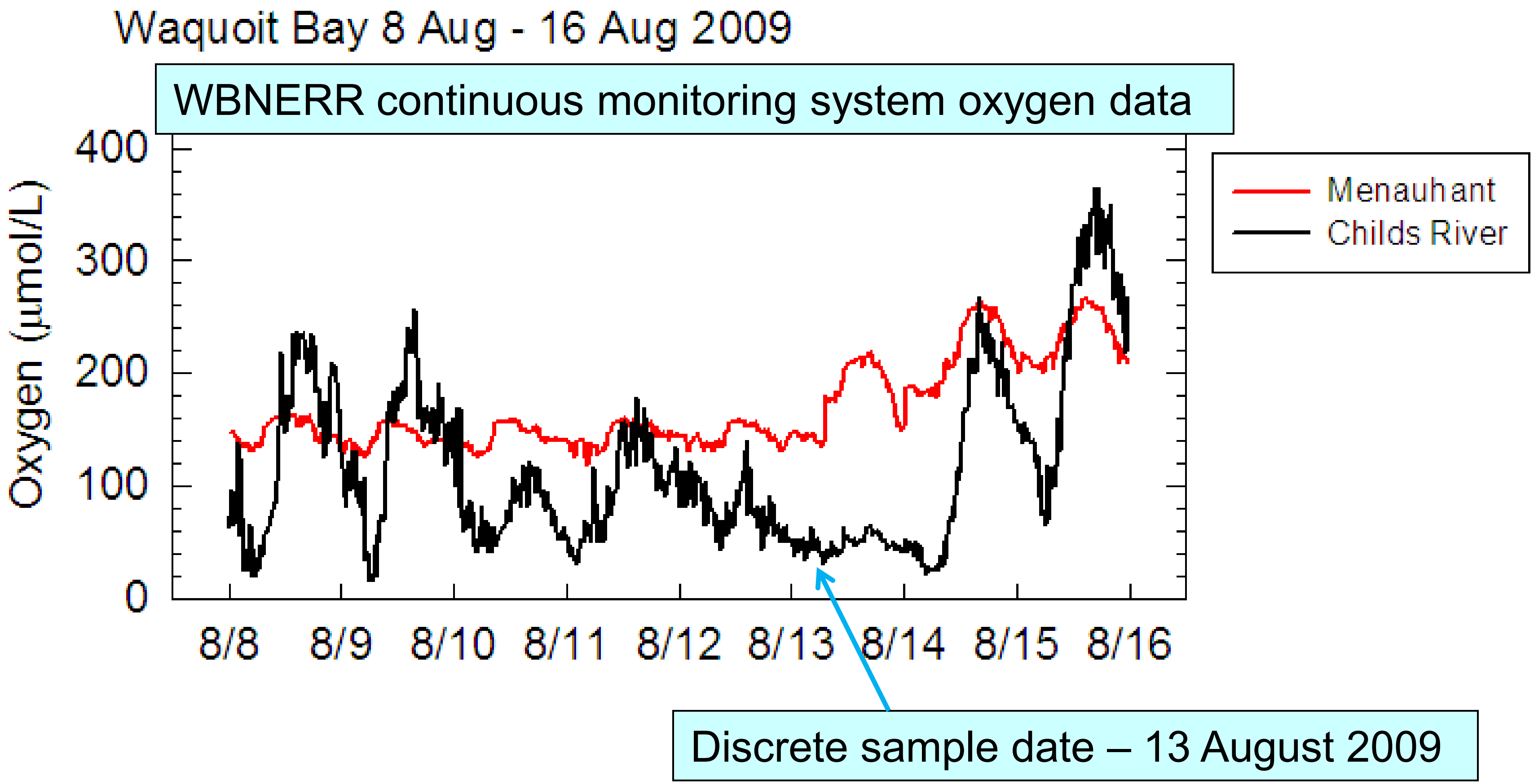
Natural selection (in the field) likely to be too slow. (rate of CO_2 increase)

Active selection (in hatcheries) may help commercial species. (but not whole ecosystems)

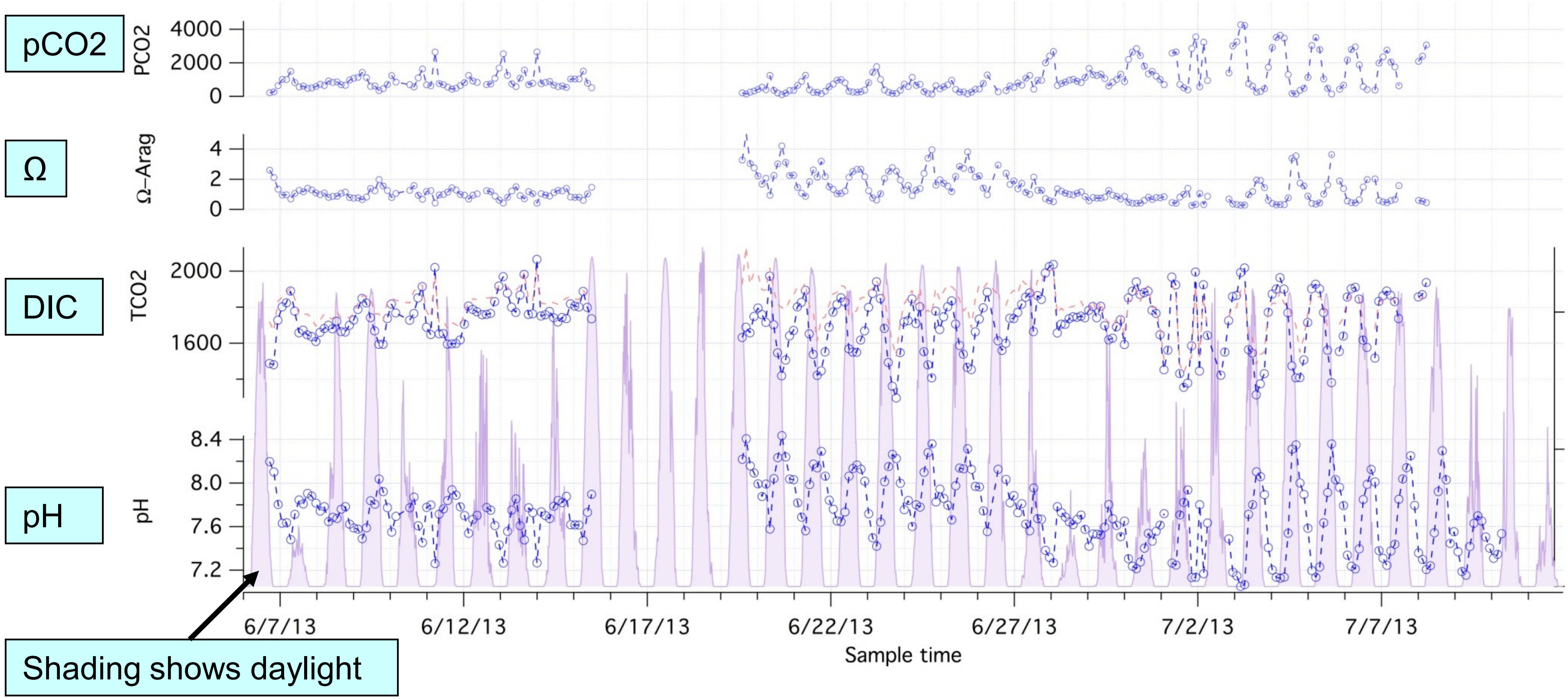
Most fundamental solutions are to cut CO_2 emissions, and reduce nutrient pollution!

McCorkle and Cohen (WHOI), Milke and Widman (NOAA/NMFS)

The variability is not just seasonal.
WBNERR dissolved oxygen data show strong daily cycles.
Since $[O_2]$ and pH are linked, this suggests that we're missing a lot with only monthly sample resolution for carbonate chemistry.



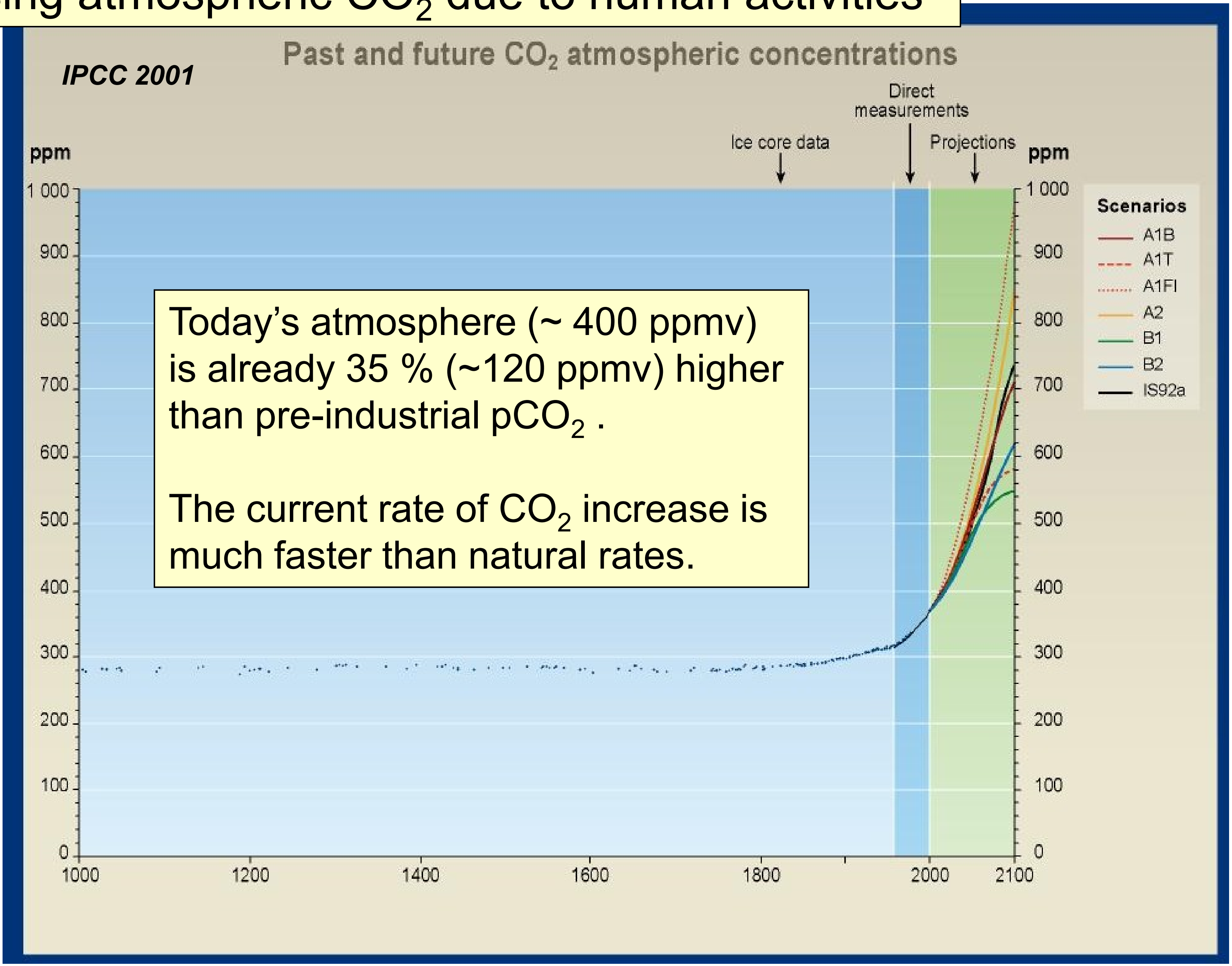
Automated in situ pH and DIC analyses show daily cycles as large as the season cycles. (Martin, Sayles, McCorkle, & Weidman)



We've missed a lot with monthly sample resolution for carbonate chemistry!

What factors are most important to the health of the bay, or its shellfish?
Minimum values (pH, O_2); sustained values; variability…

Rising atmospheric CO_2 due to human activities



Today's atmosphere (~ 400 ppmv) is already 35 % (~120 ppmv) higher than pre-industrial pCO_2 .

The current rate of CO_2 increase is much faster than natural rates.