Ocean Acidification:
What It Means To Alaska

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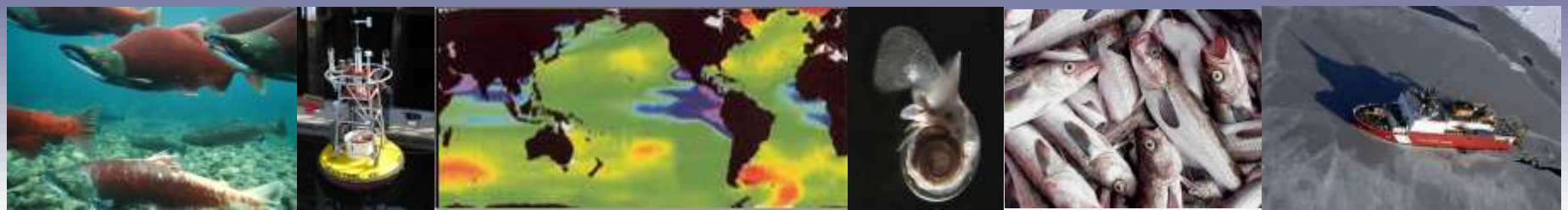
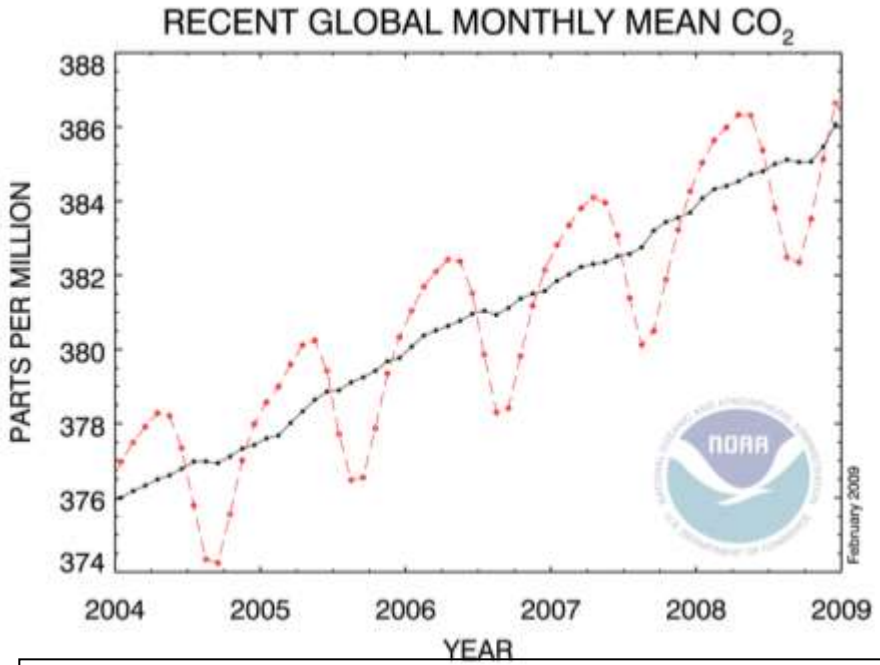


Outline

- Too Much CO_2
- What is ocean acidification?
- What do we currently know?
- What are the impacts on marine organisms?
- What studies are underway in Alaskan waters?
- How could it affect Alaskan ecosystems?

Atmospheric CO_2 Concentration



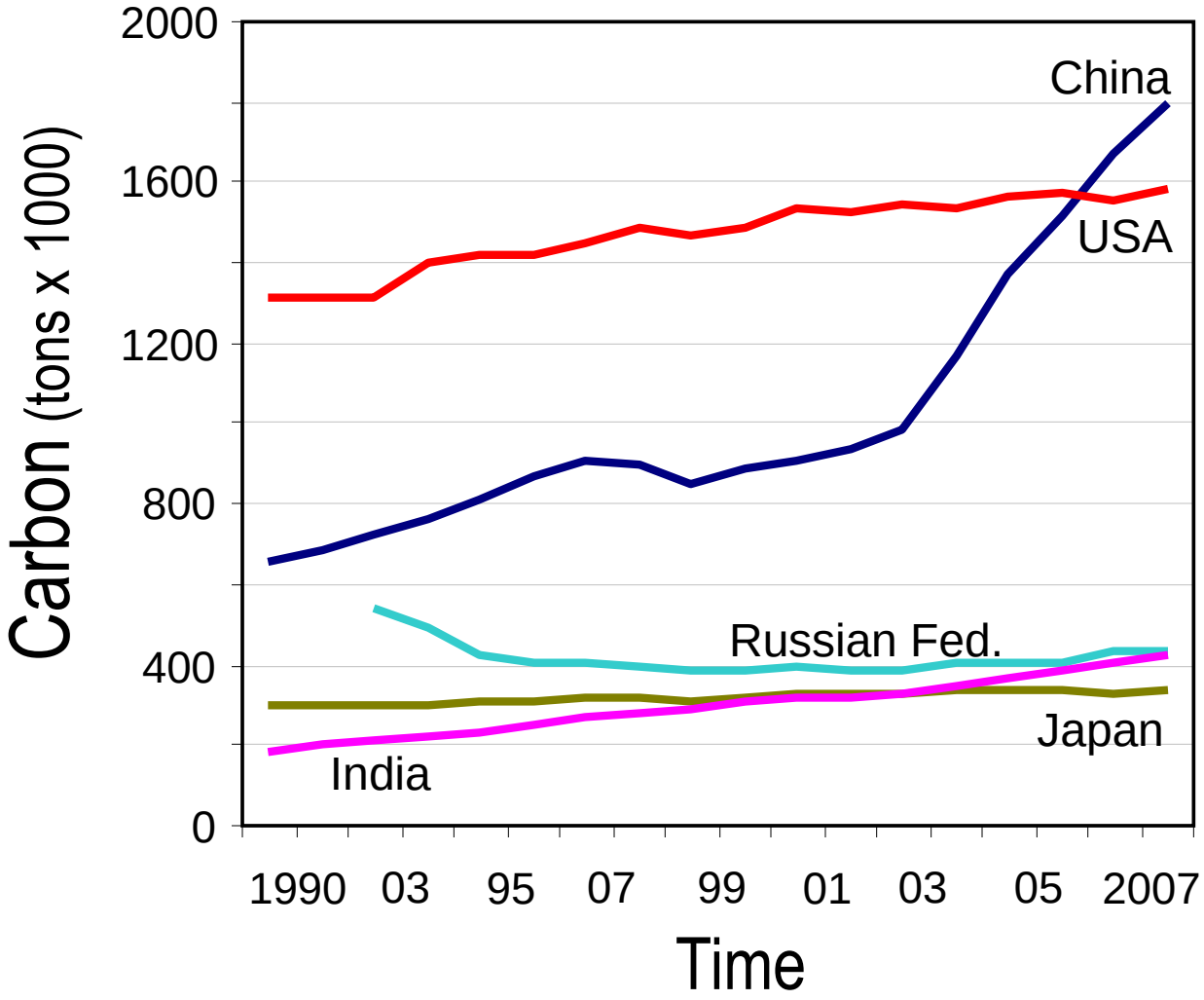
Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

1970 – 1979: 1.3 ppm y^{-1}
1980 – 1989: 1.6 ppm y^{1}
1990 – 1999: 1.5 ppm y^{-1}

2000 - 2008: 2.0 ppm y^{-1}
2008: 2.3 ppm y^{-1}

year	ppm y^{-1}
2000	1.24
2001	1.85
2002	2.39
2003	2.21
2004	1.61
2005	2.41
2006	1.79
2007	2.17
2008	**2.28**

Fossil Fuel Emissions: Top Emitters



Gregg Marland et al., CDIAC; Global Carbon Project 2009

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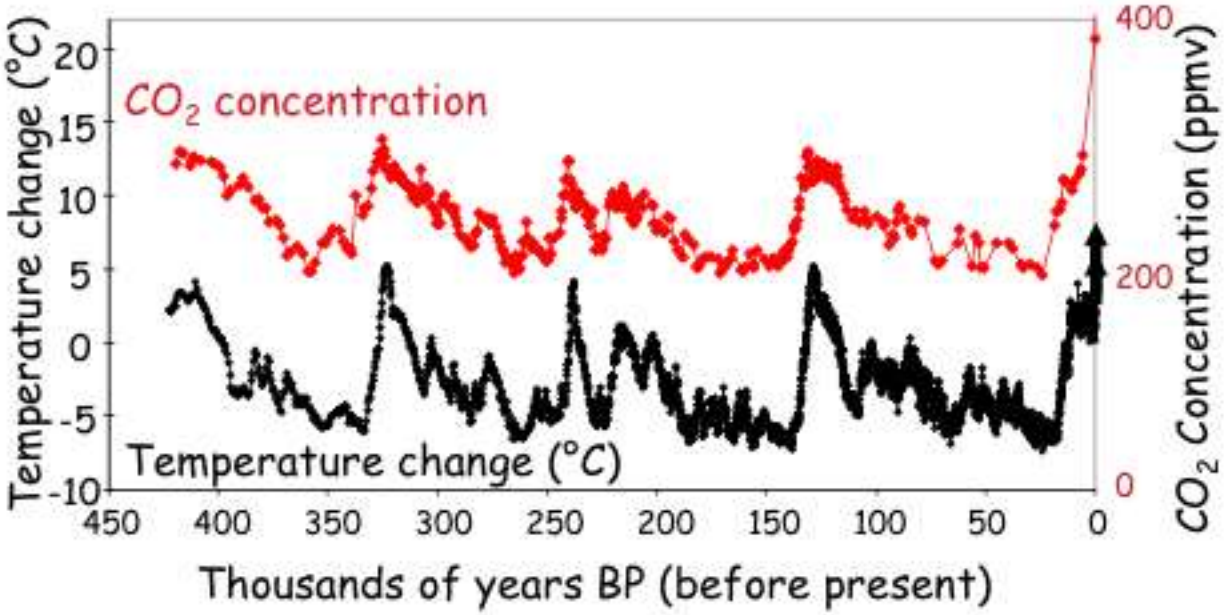
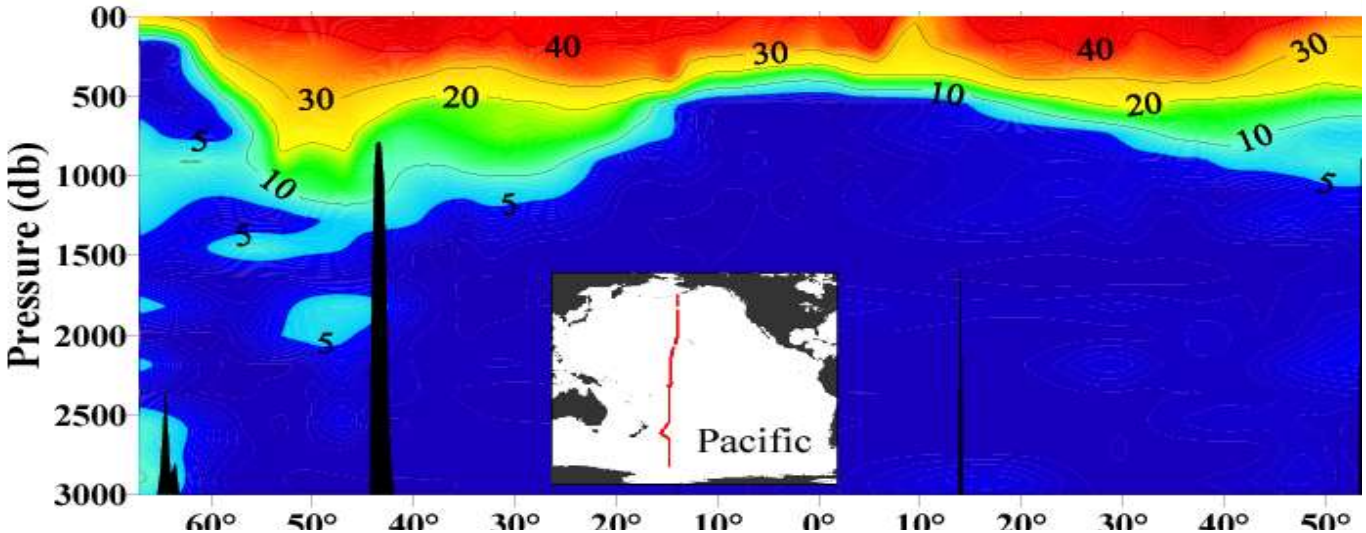
The CO_2 Problem



"It is very likely that [man-made] greenhouse gas increases caused most of the average temperature increase since the mid-20 century"
- *IPPC 4th Assessment Report*

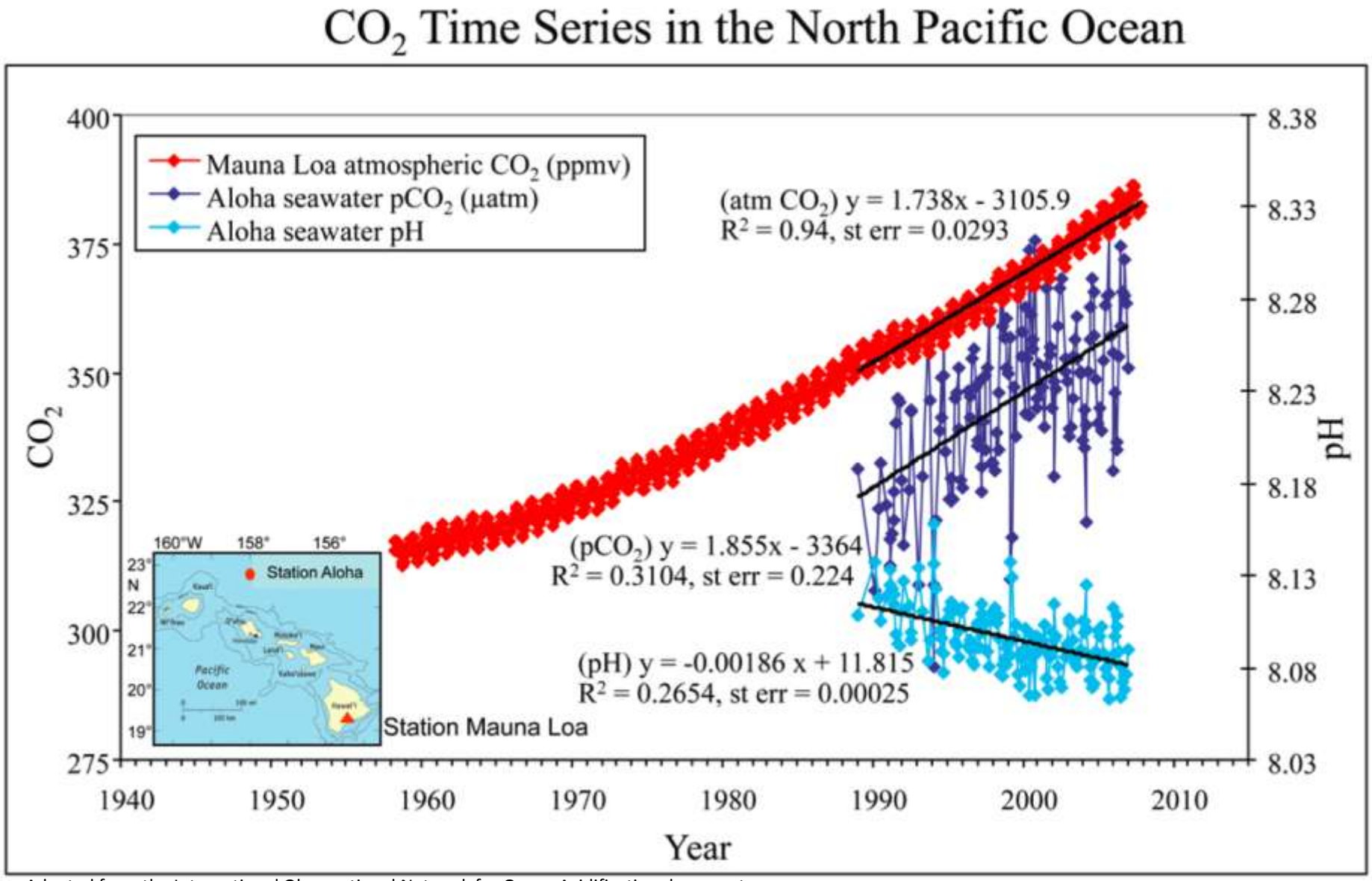
The ocean has taken up 1/3 to 1/2 of all anthropogenic CO_2 emissions.

However, since the ocean mixes slowly it is concentrated in the upper 10%.



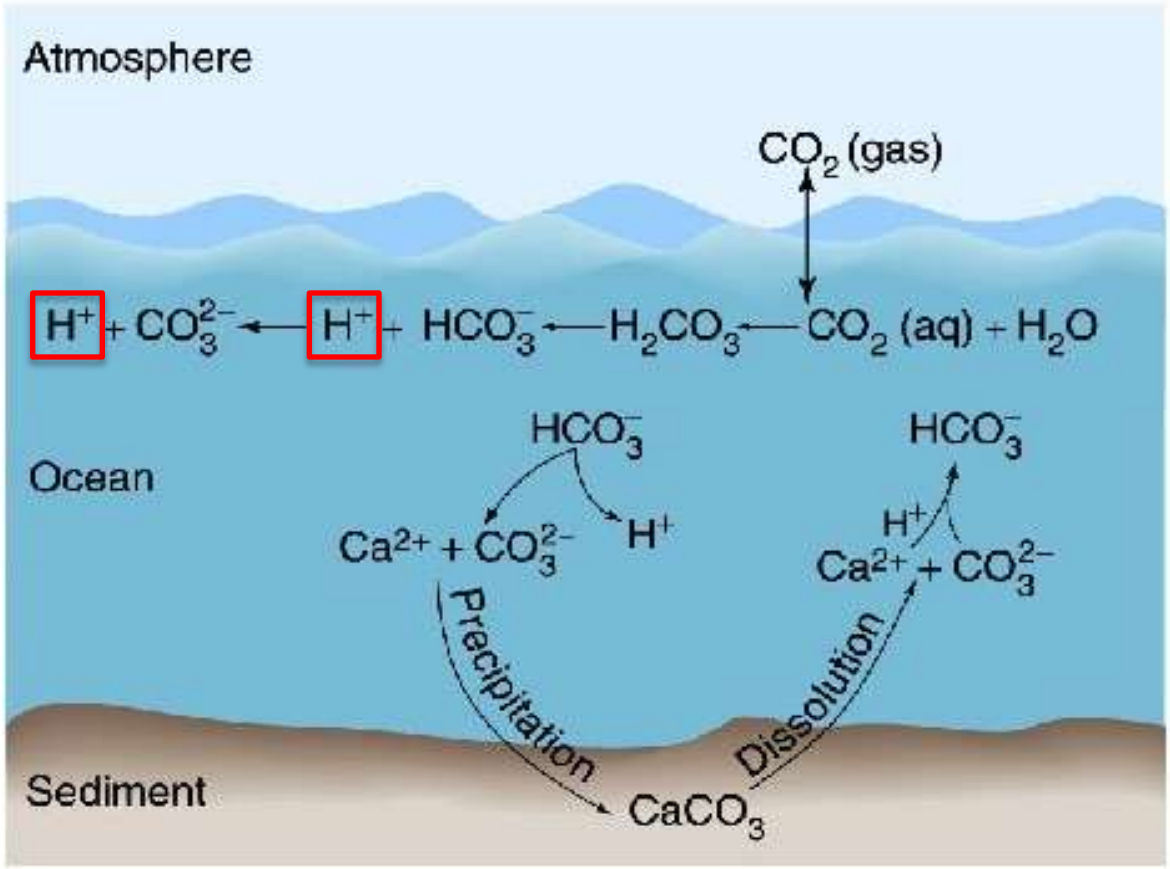
Sabine et al. Science (2004)

Creating A More Acidic Ocean



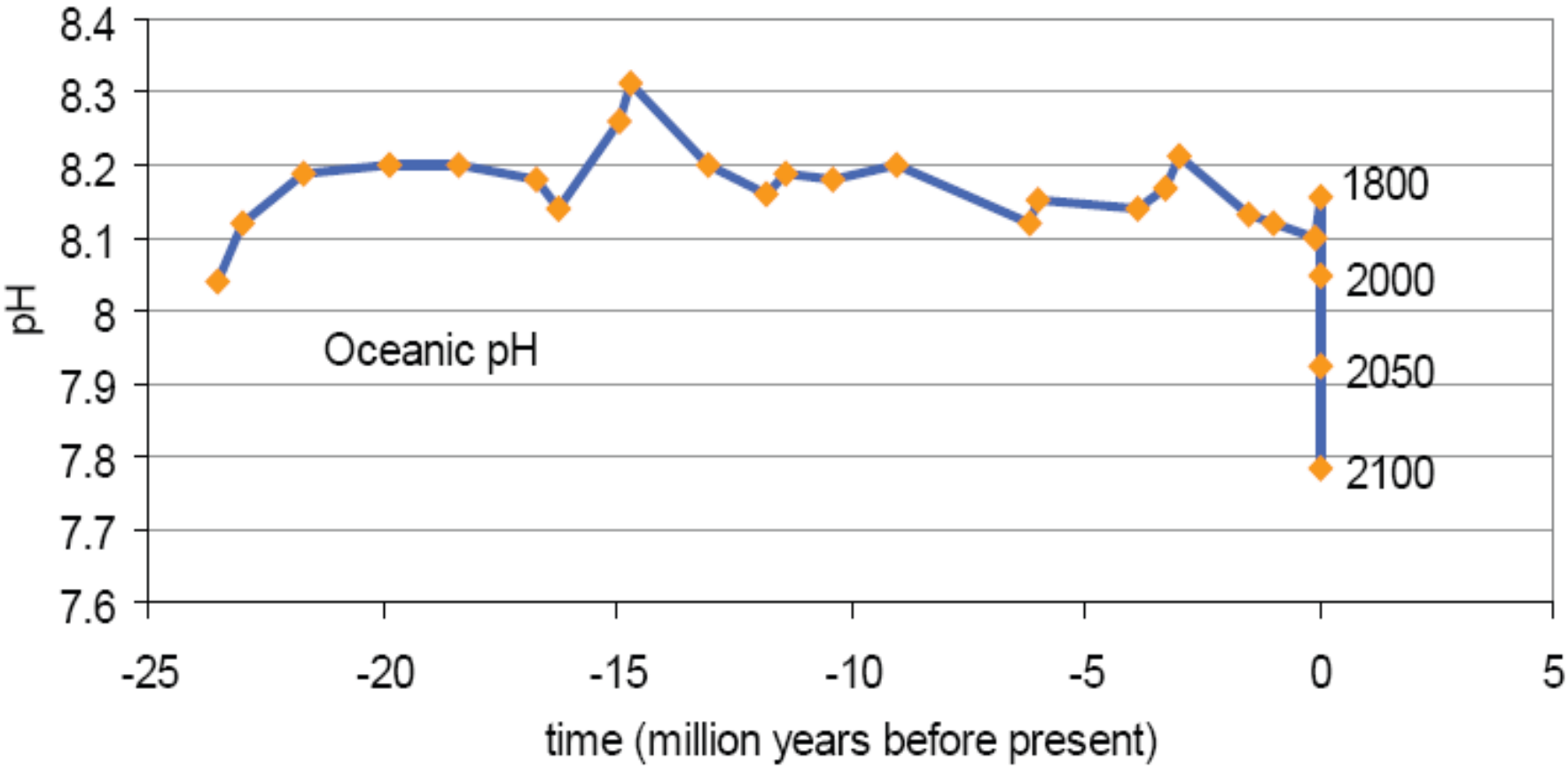
Adapted from the International Observational Network for Ocean Acidification document

What is Ocean Acidification?



- As more CO_2 dissolves into the ocean, more H^+ ions are given off.
- As the concentrations of H^+ ions increase, the pH of the water decreases.

Creating A More Acidic Ocean



Under the “Business-As-Usual” scenario, ocean acidity will likely increase rapidly over the next 25 years.

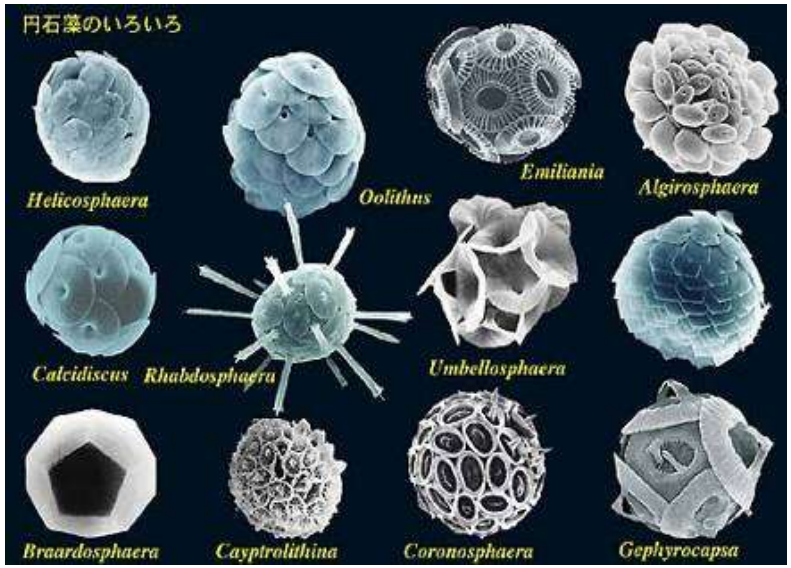
Ocean Acidification

Since the beginning of the industrial age, the pH and CO_2 chemistry of the oceans (ocean acidification) have been changing because of the uptake of anthropogenic CO_2 by the oceans.

- These changes in pH and carbonate chemistry may have serious impacts on open ocean and coastal marine ecosystems.
- 30% increase in acidity; decrease in carbonate ion of about 16%

Photo: Missouri Botanical Gardens

Corals

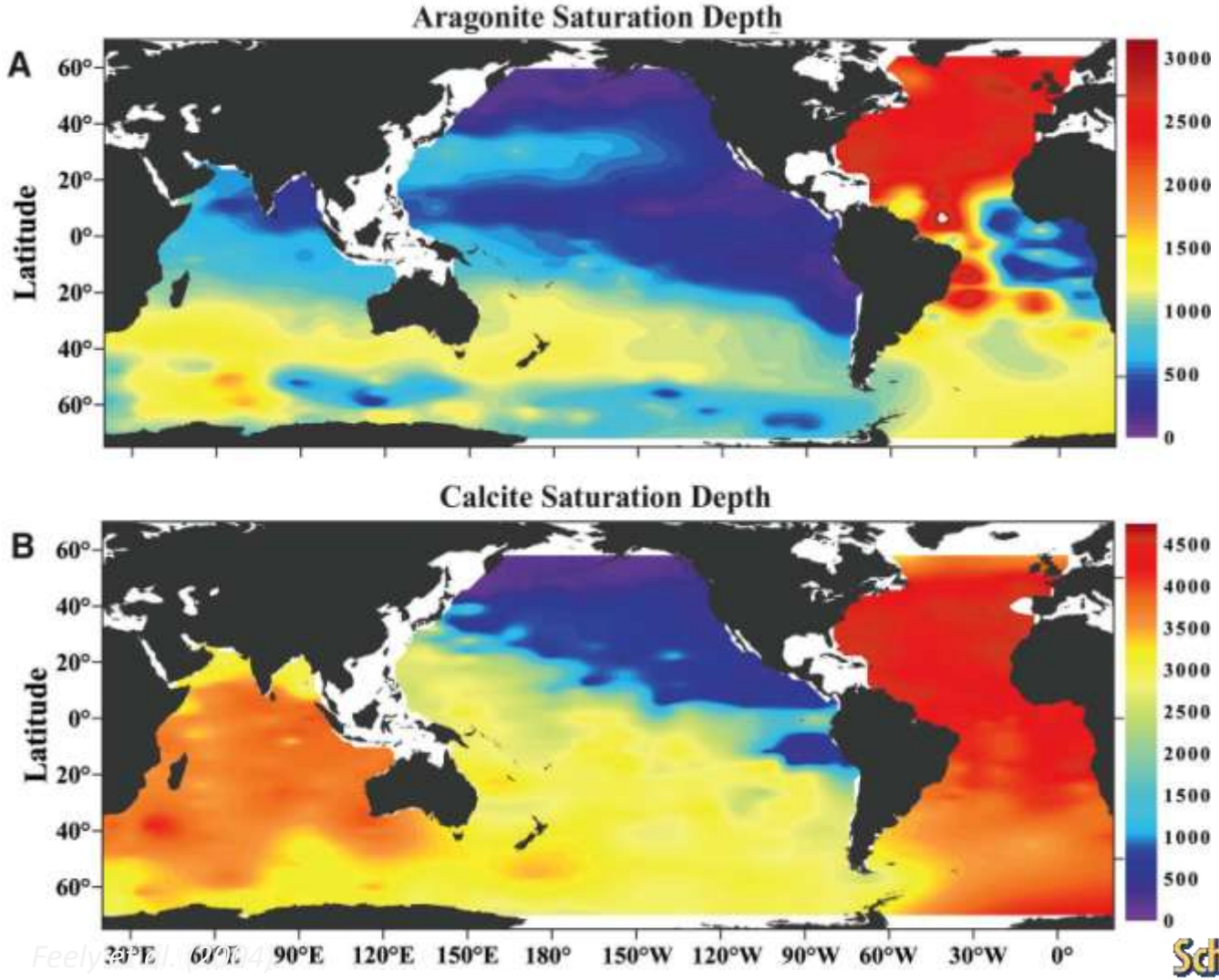


http://www.biol.tsukuba.ac.jp/~inouye

Calcareous Plankton

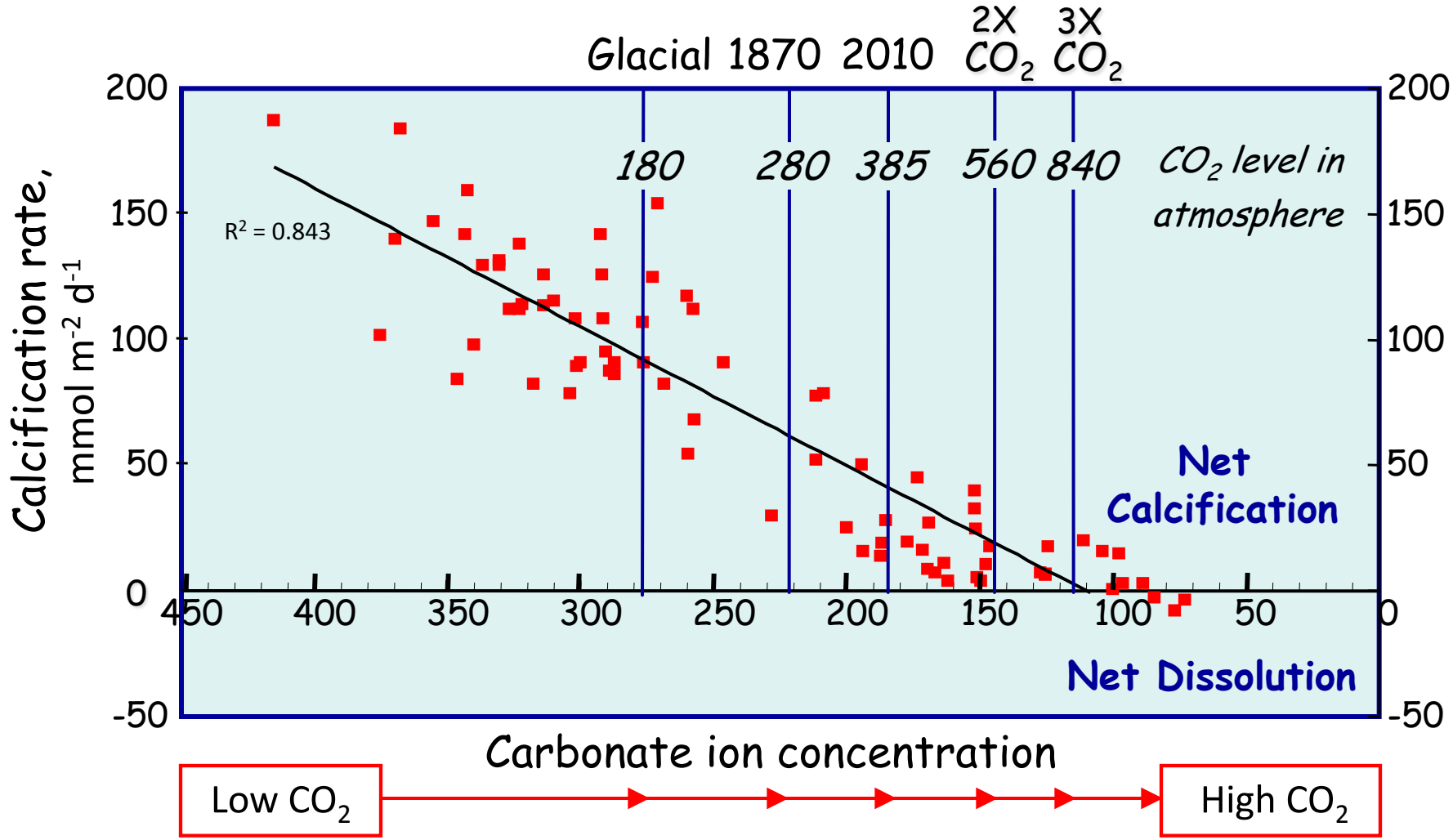
Carbonate Mineral Saturation Depth

Depth at which calcite and aragonite become undersaturated and potentially corrosive to shell building organisms



Saturation Depth:
The closer to the surface the saturation depth, the more likely organisms will be exposed to undersaturated waters

The impact of rising atmospheric CO_2 on ocean carbonate chemistry and potential impact on calcifiers

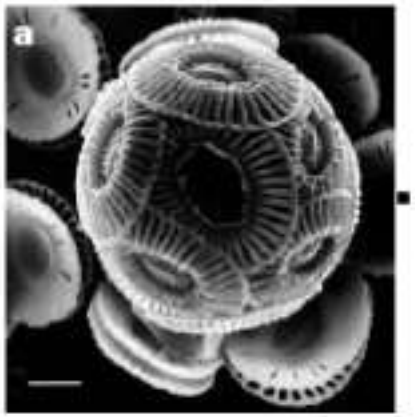


Biosphere 2 Results

Langdon & Atkinson, (2005)

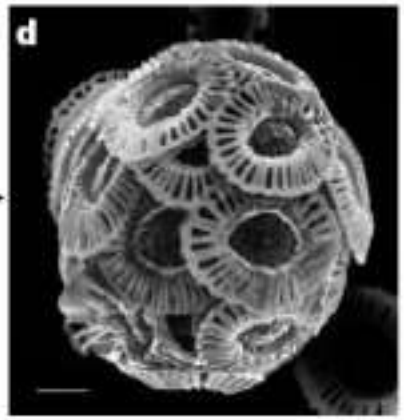
Coccolithophore (single celled algae)

pCO_2 280-380 ppmv



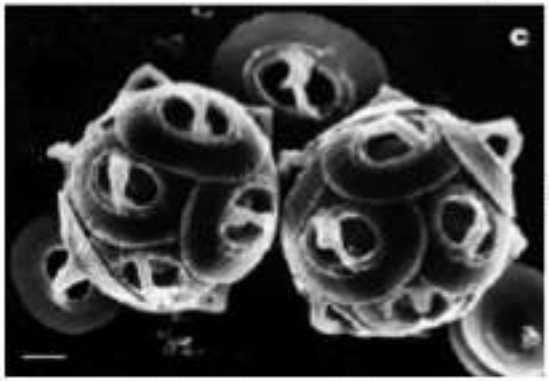
Emiliania huxleyi

pCO_2 780-850 ppmv

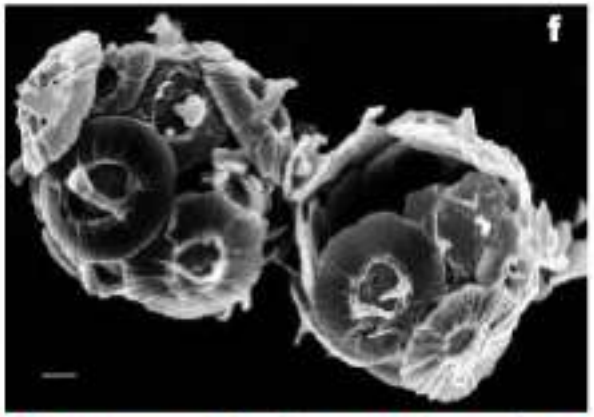


Calcification decreased

- 9 to 18%



Gephyrocapsa oceanica



- 45%

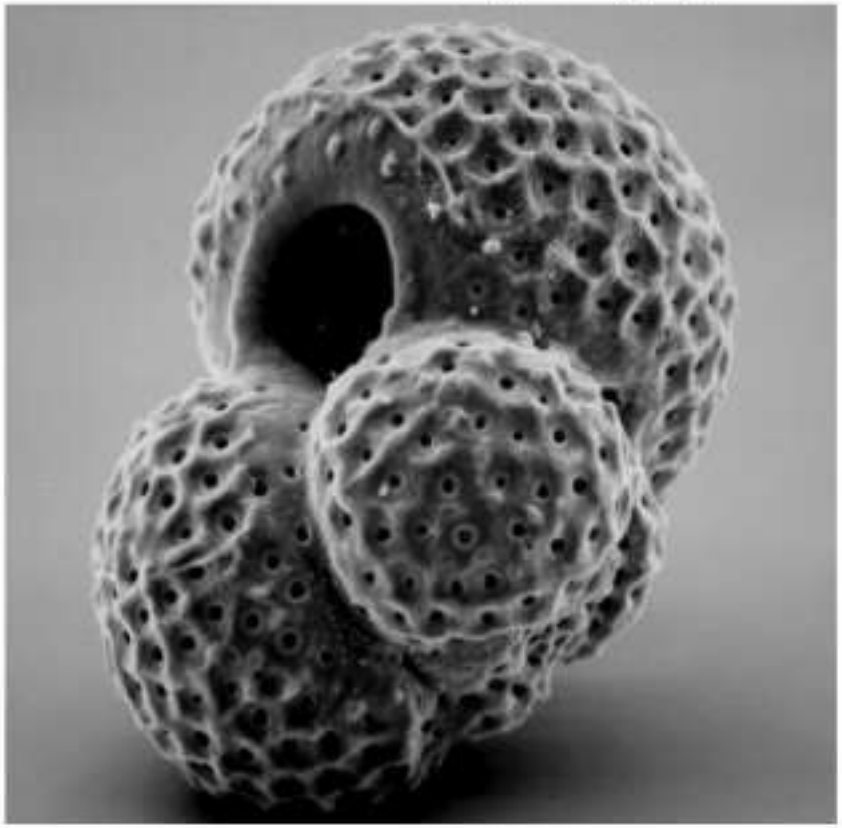
Malformed liths at high CO_2

Manipulation of CO_2 system by addition of HCl or NaOH

Riebesell et al.(2000); Zondervan et al.(2001)

Foraminifera (single-celled protists)

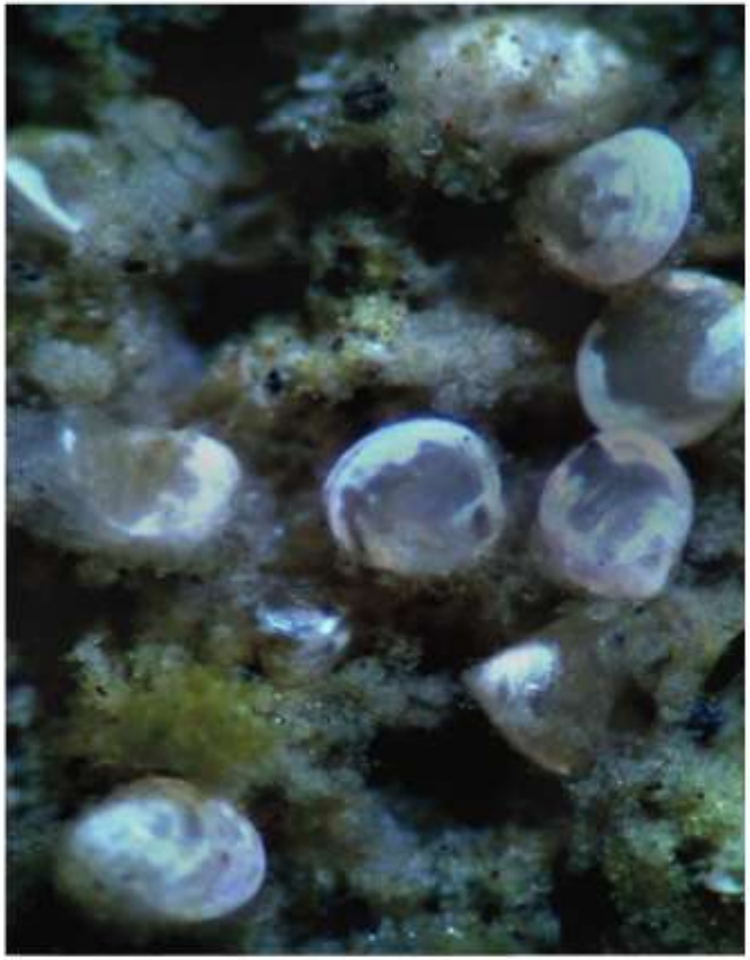
Shell mass is positively correlated with $[CO_3^{2-}]$



-4 to -8% decline in calcification at pCO_2= 560 ppm
-6 to -14% decline in calcification at pCO_2= 780 ppm

Bijma et al. (2002)

Bivalves (e.g. clams)



Hard shell clam *Mercenaria*

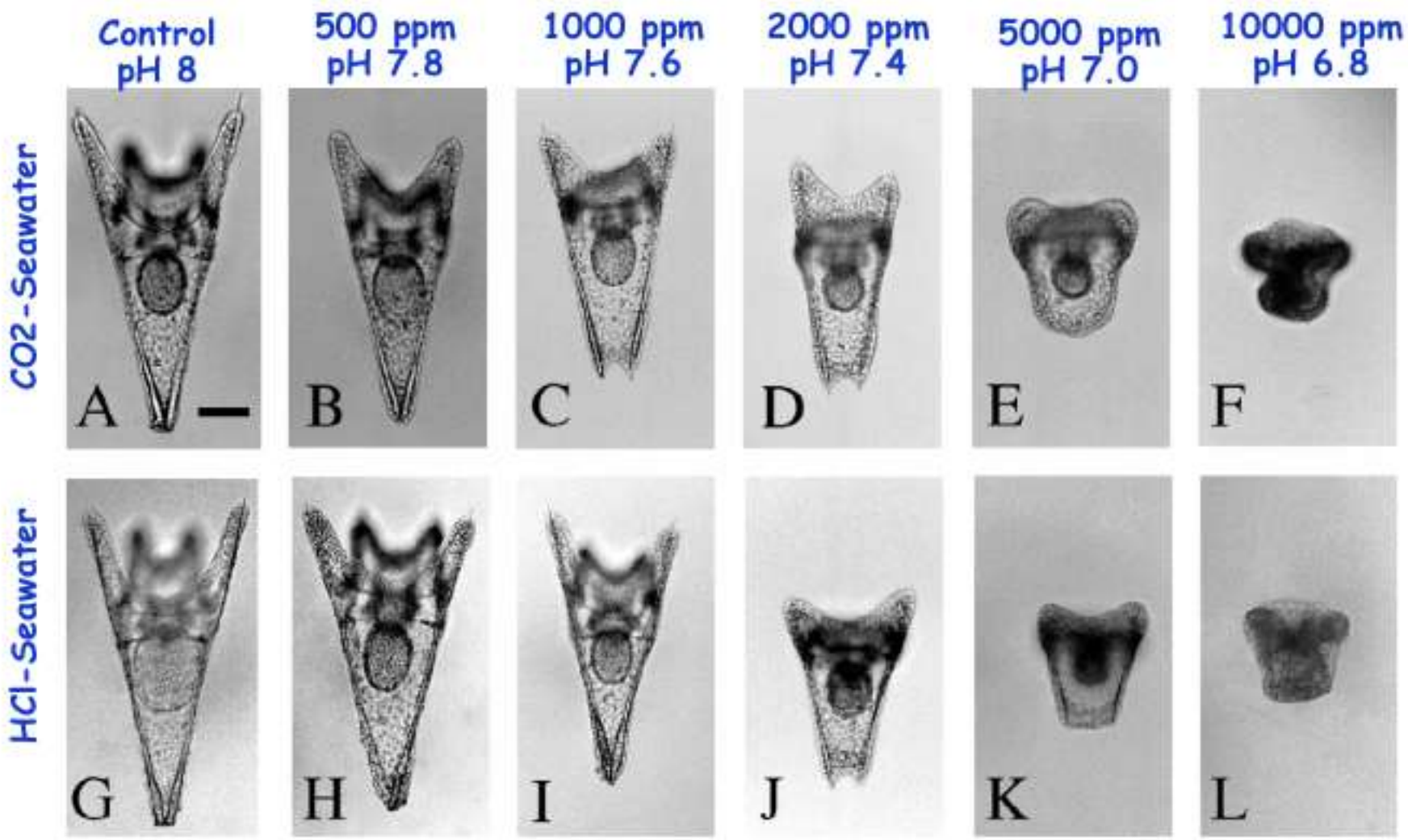
- Common in soft bottom habitats

Used newly settled clams

- Size 0.3 mm
- Massive dissolution within 24 hours in undersaturated water; shell gone within 2 weeks
- Dissolution is source of mortality in estuaries & coastal habitats

Green et al., 2004

Sea Urchins

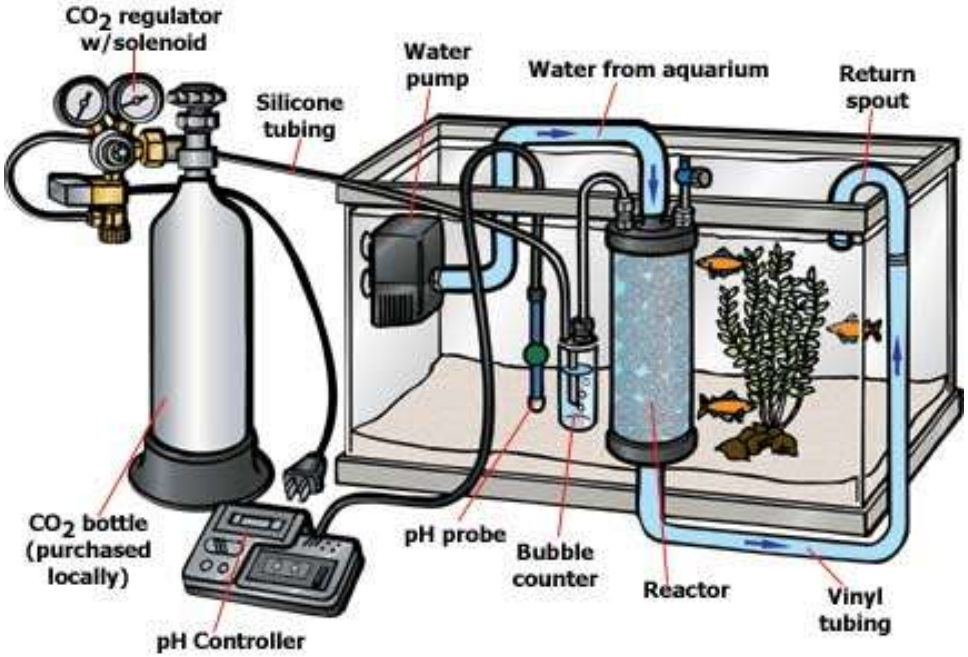


Kurihara & Shirayama., 2004

The effects of ocean acidification on age-0 and age-1 walleye Pollock physiology

- Hatching success, % mortality, growth rate, and body condition
- Metabolic enzyme activity in age-1 juveniles
- Analysis of stress hormones

- pH levels at 8.05, 7.85, 7.45, and 7.05
- Eggs hatched under these conditions



Potential Impacts on Food Webs

Coccolithophores

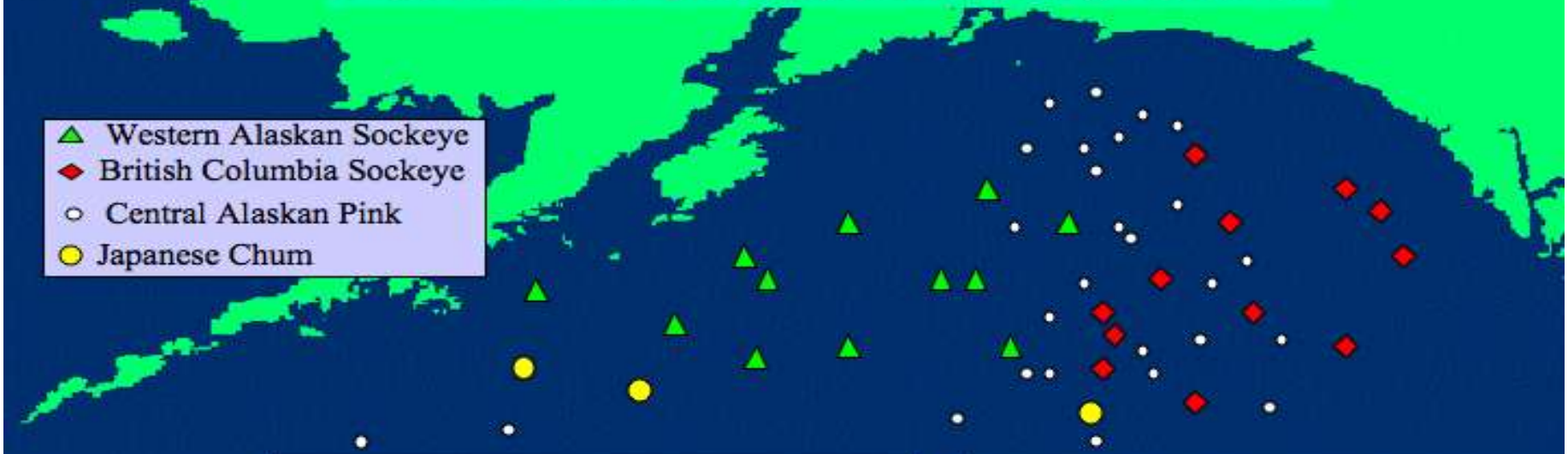
Copepods

Pteropods

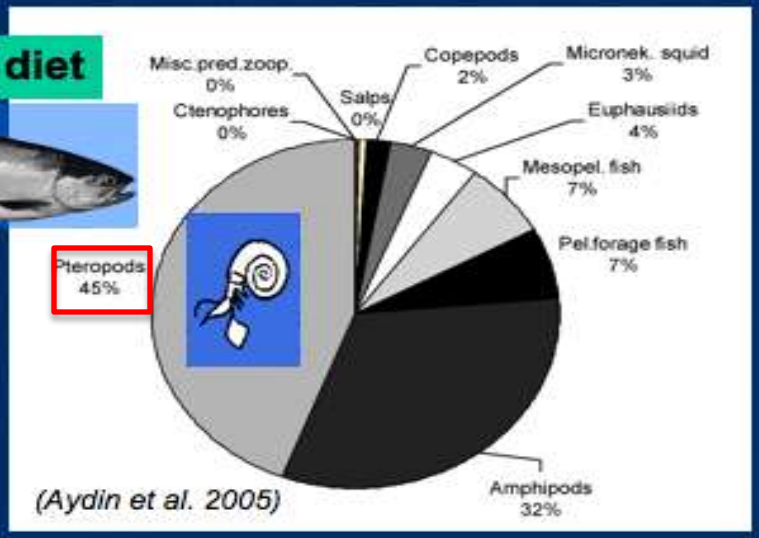
Pacific Salmon

Physiological Impacts of Ocean Acidification

Research on Impacts of OA on Pacific Salmon



Pink salmon diet

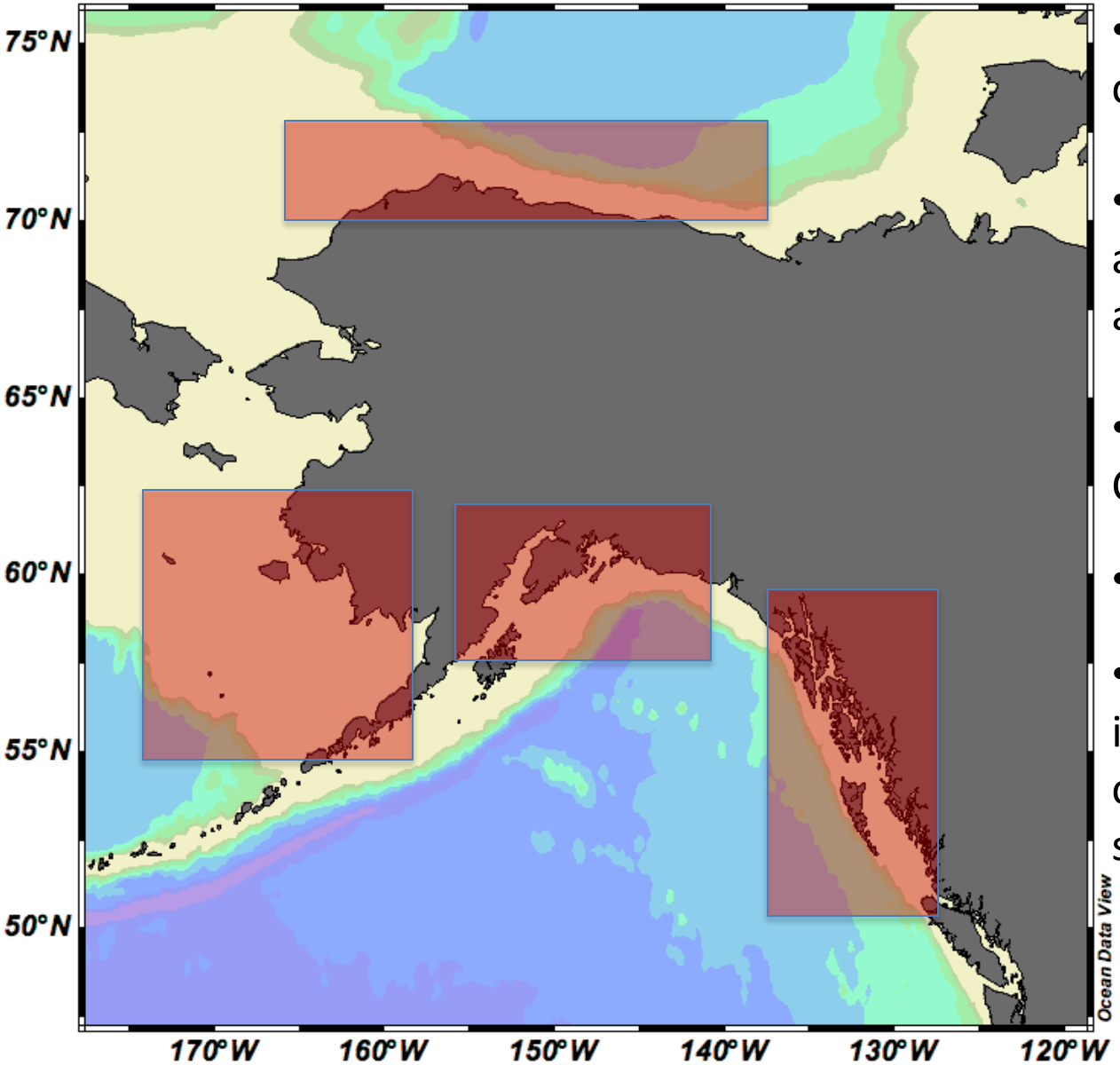


(Aydin et al. 2005)

Predicted effect of climate change on pink salmon growth:

- 10% increase in water temperature leads to 3% drop in mature salmon body weight (physiological effect).
- 10% decrease in pteropod production leads to 20% drop in mature salmon body weight (prey limitation).

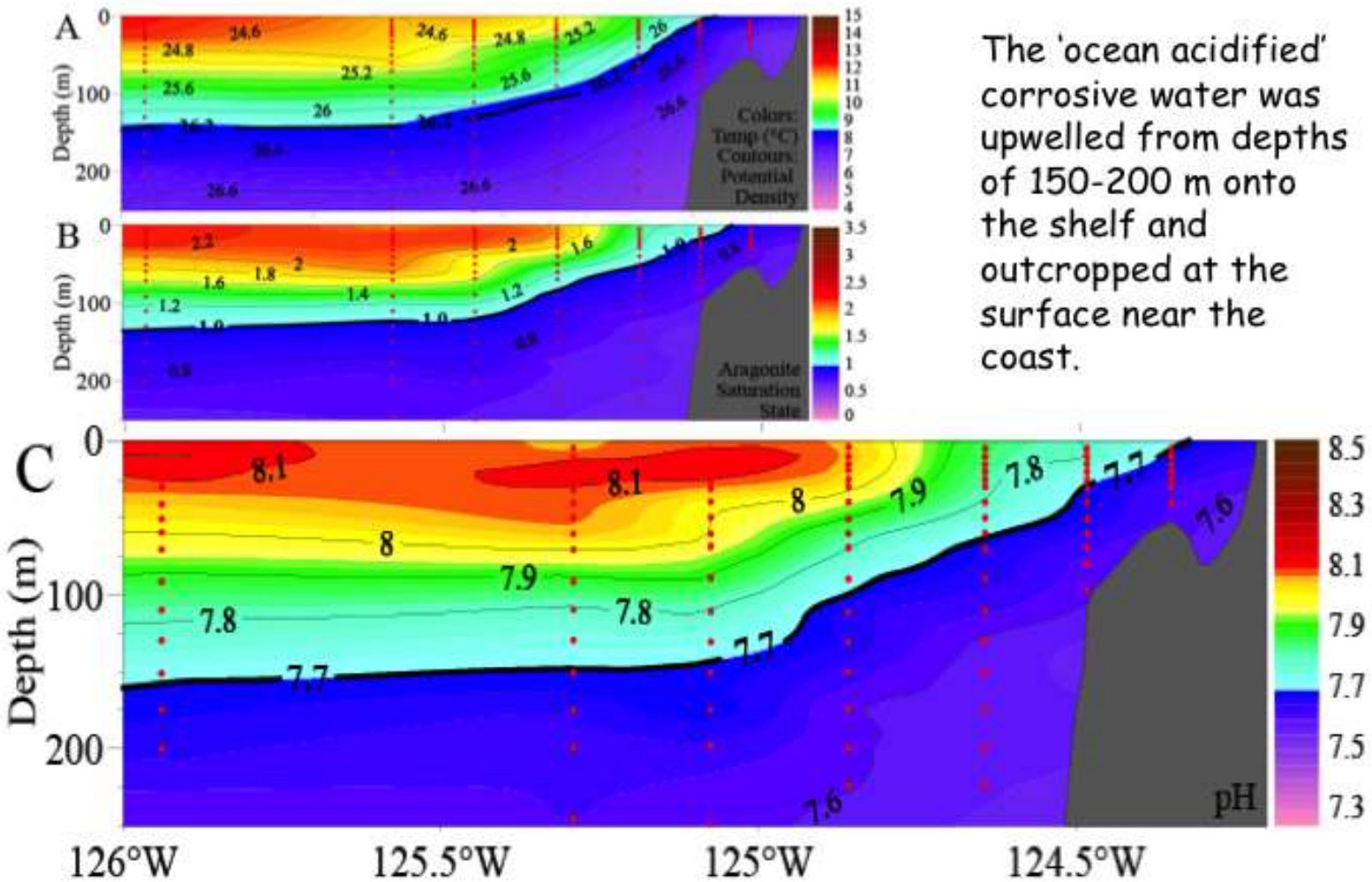
Coastal Zones At Risk From OA



- Alaskan coastal waters are cold and highly productive.
- Both of these increase the amount of CO_2 that is absorbed by the water.
- Upwelling also bring high CO_2 water to the surface
- More CO_2 = More Acidic
- Higher acidity has direct and indirect impacts on commercially important species.
  - Mineral saturations
  - Physiological response

West Coast of the US – A Proxy for SE Coastal Alaska?

NACP Coastal Survey Cruise: 11 May - 14 June 2007



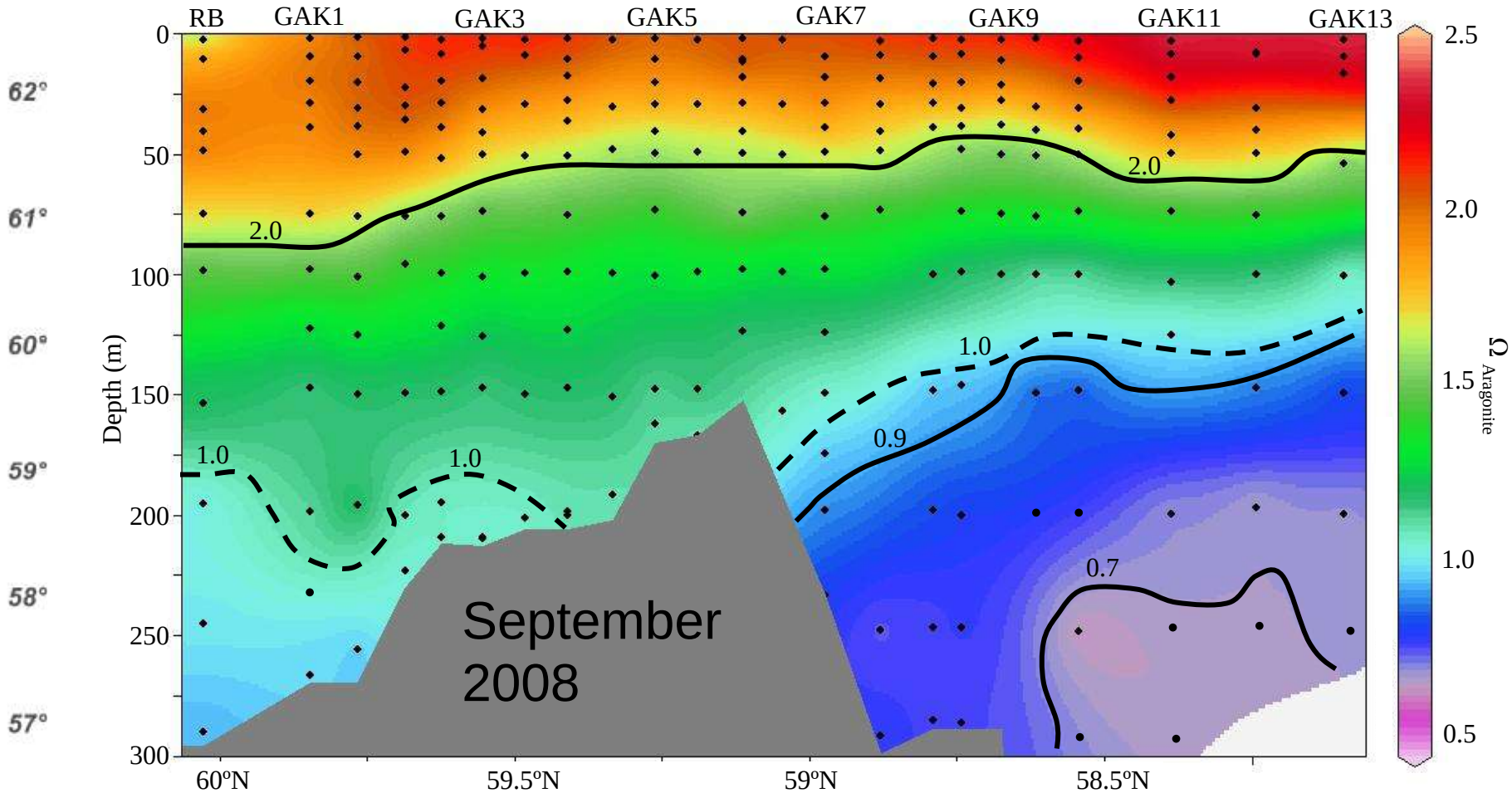
The 'ocean acidified' corrosive water was upwelled from depths of 150-200 m onto the shelf and outcropped at the surface near the coast.

Red dots represent sample locations.

Vertical sections from Line 5 (Pt. St. George, California)

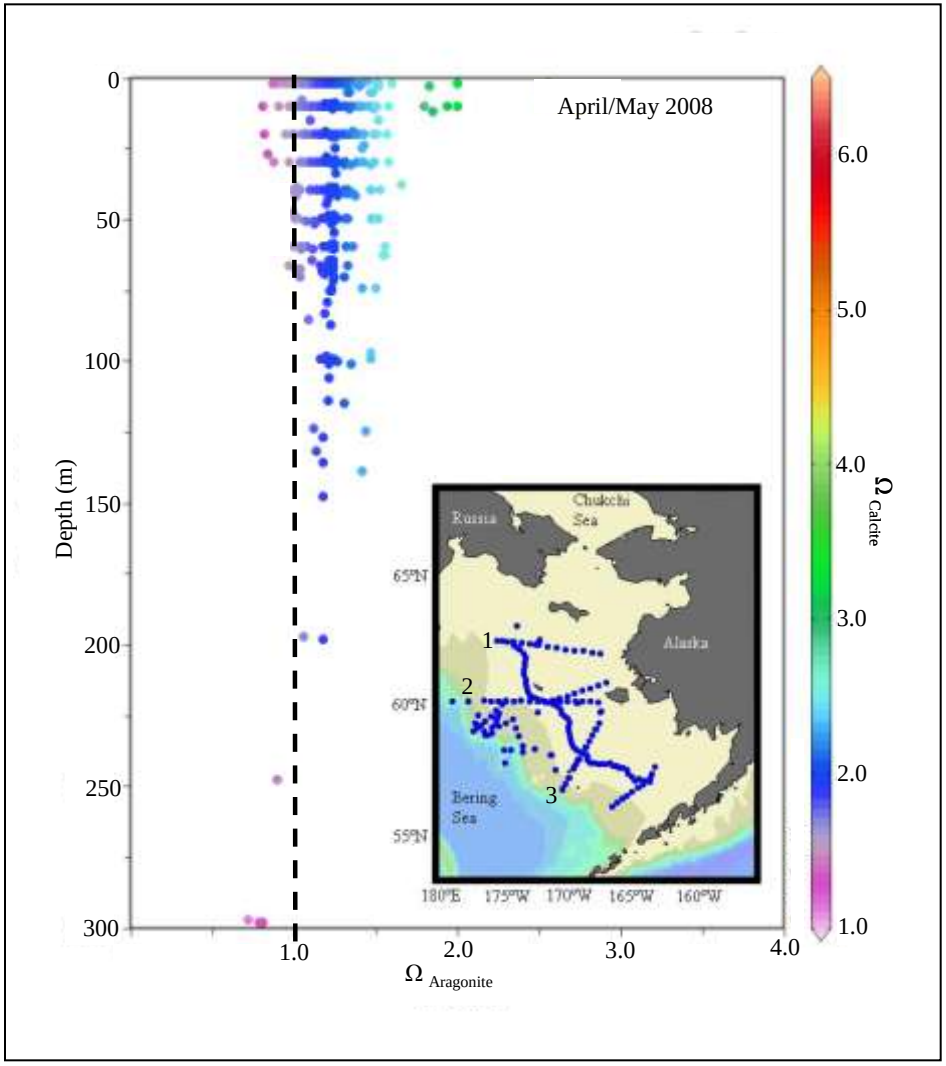
Feely et al. (2008)

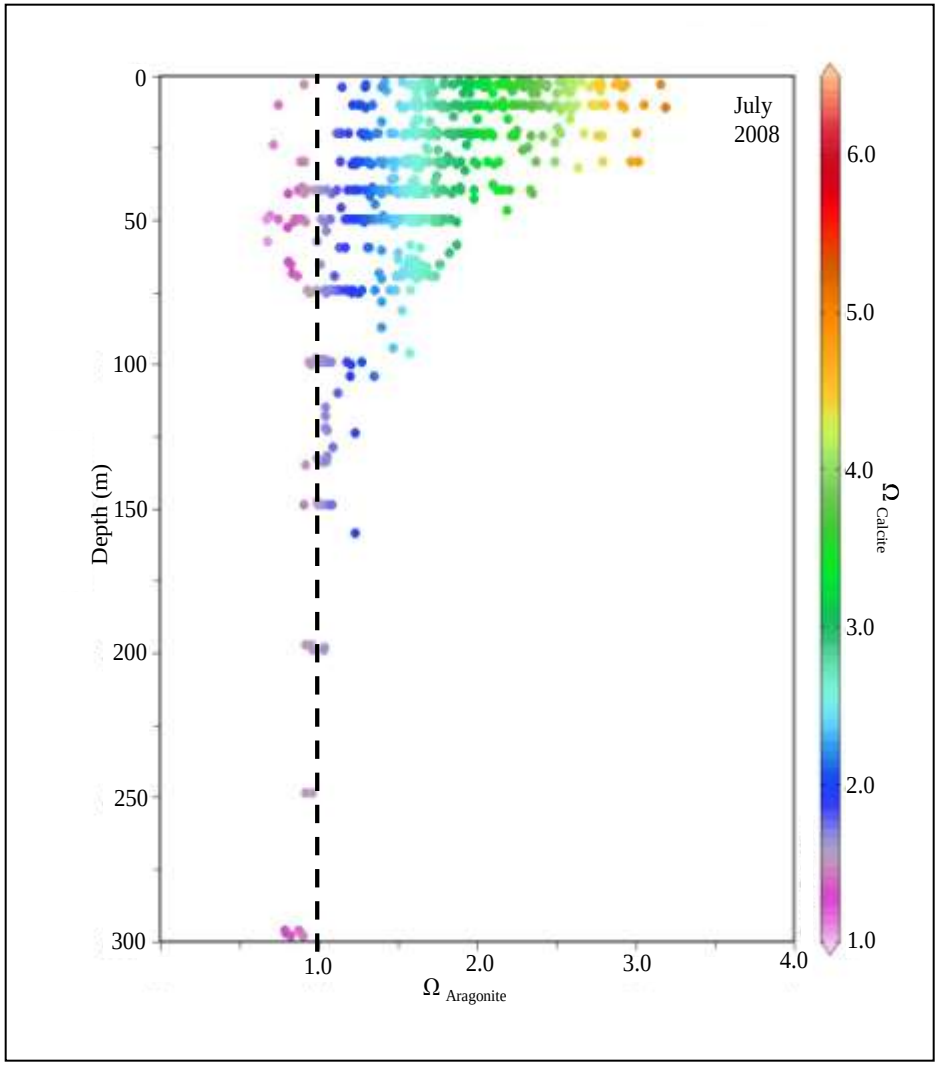
OA in the GOA



Mathis, J.T., Shake, K., Junanek, L., Feely, R.L., Carbon Biogeochemistry of the Northern Gulf of Alaska Part I: Seasonal Variability of Carbonate Mineral Saturation Sates (Continental Shelf Research, In Prep.)

OA in the Bering Sea

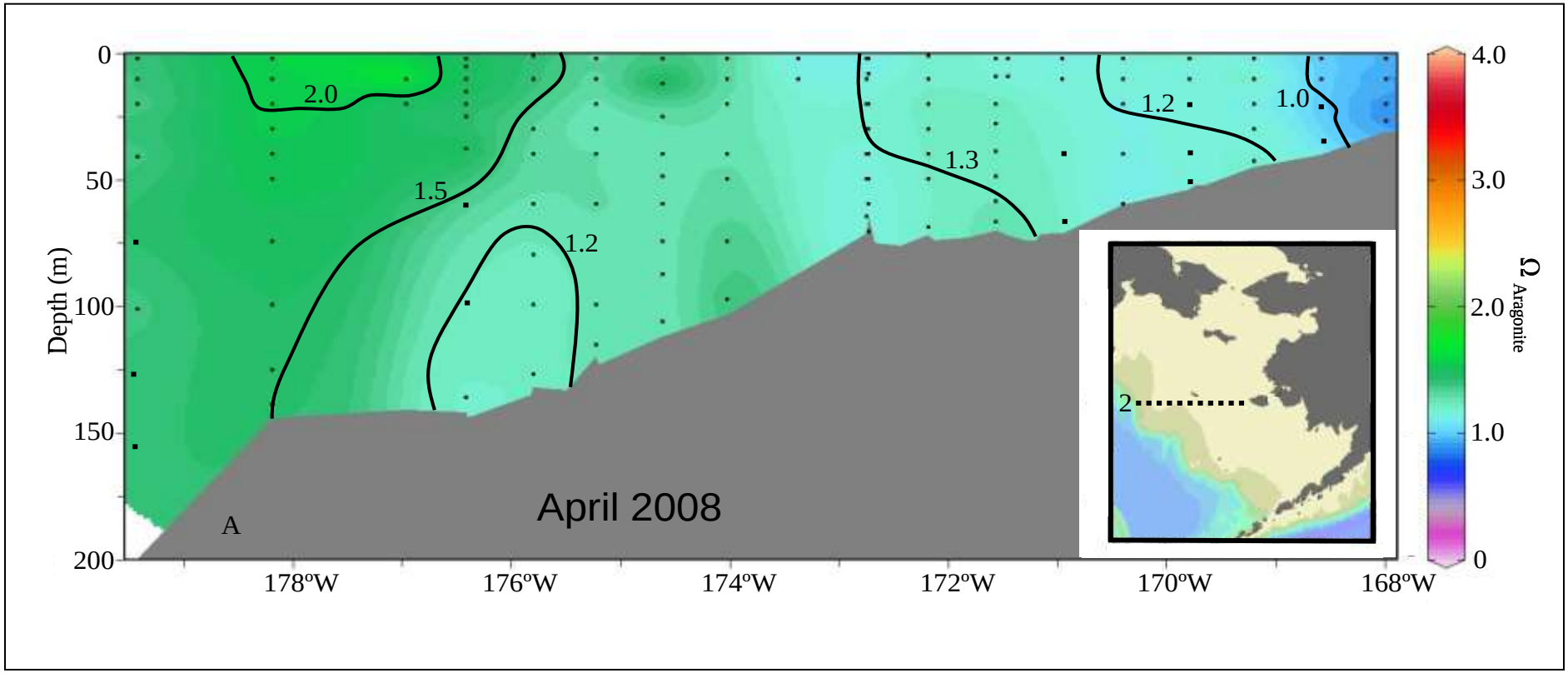




Mathis, J.T., Bates, N.R., Cross, J.N., Coupling Primary Production and Terrestrial Runoff to Ocean Acidification and Carbonate Mineral Suppression in the Eastern Bering Sea (Journal of Geophysical Research-Oceans, In Prep).

OA in the Bering Sea

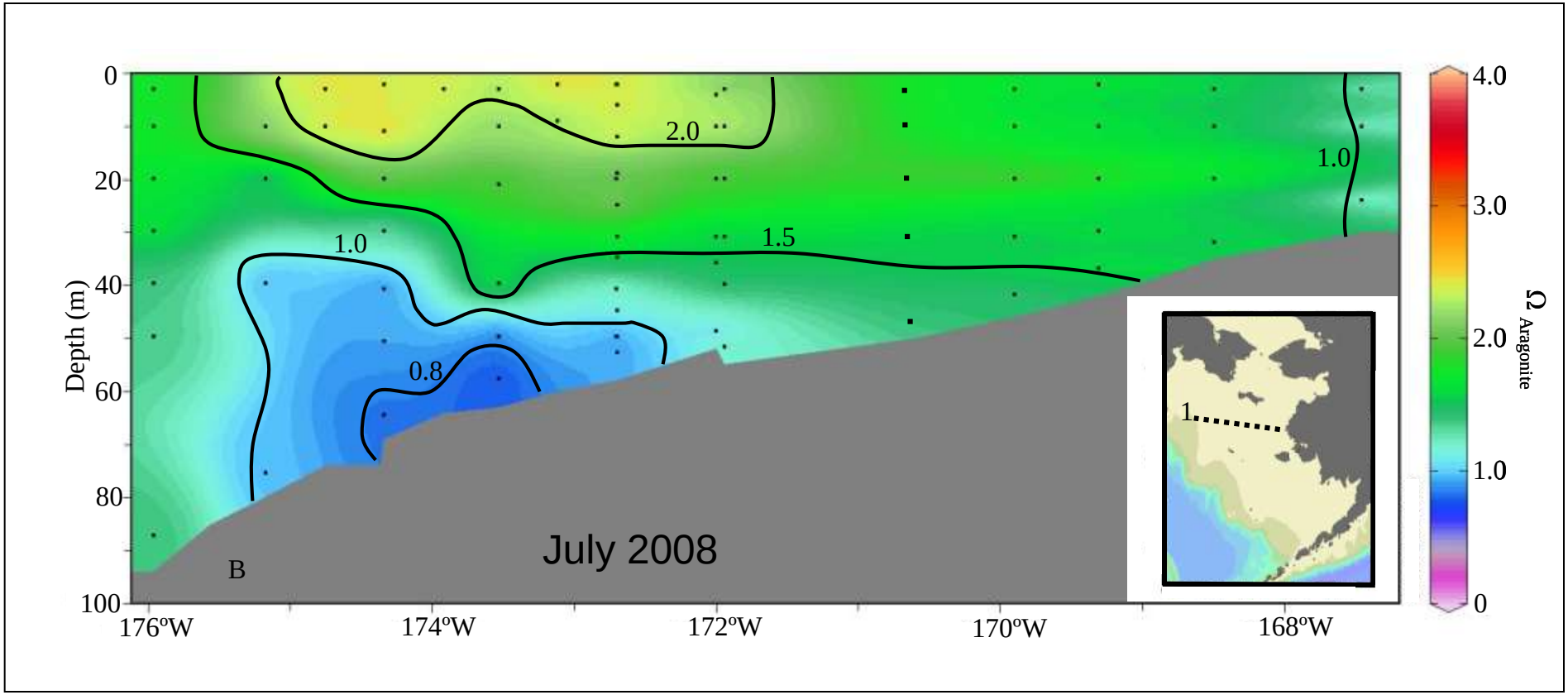
In spring, the discharge of low pH water from the Yukon and Kuskokwim Rivers causes aragonite saturation states to drop below 1.0



Mathis, J.T., Bates, N.R., Cross, J.N., Coupling Primary Production and Terrestrial Runoff to Ocean Acidification and Carbonate Mineral Suppression in the Eastern Bering Sea (Journal of Geophysical Research-Oceans, In Prep).

OA in the Bering Sea

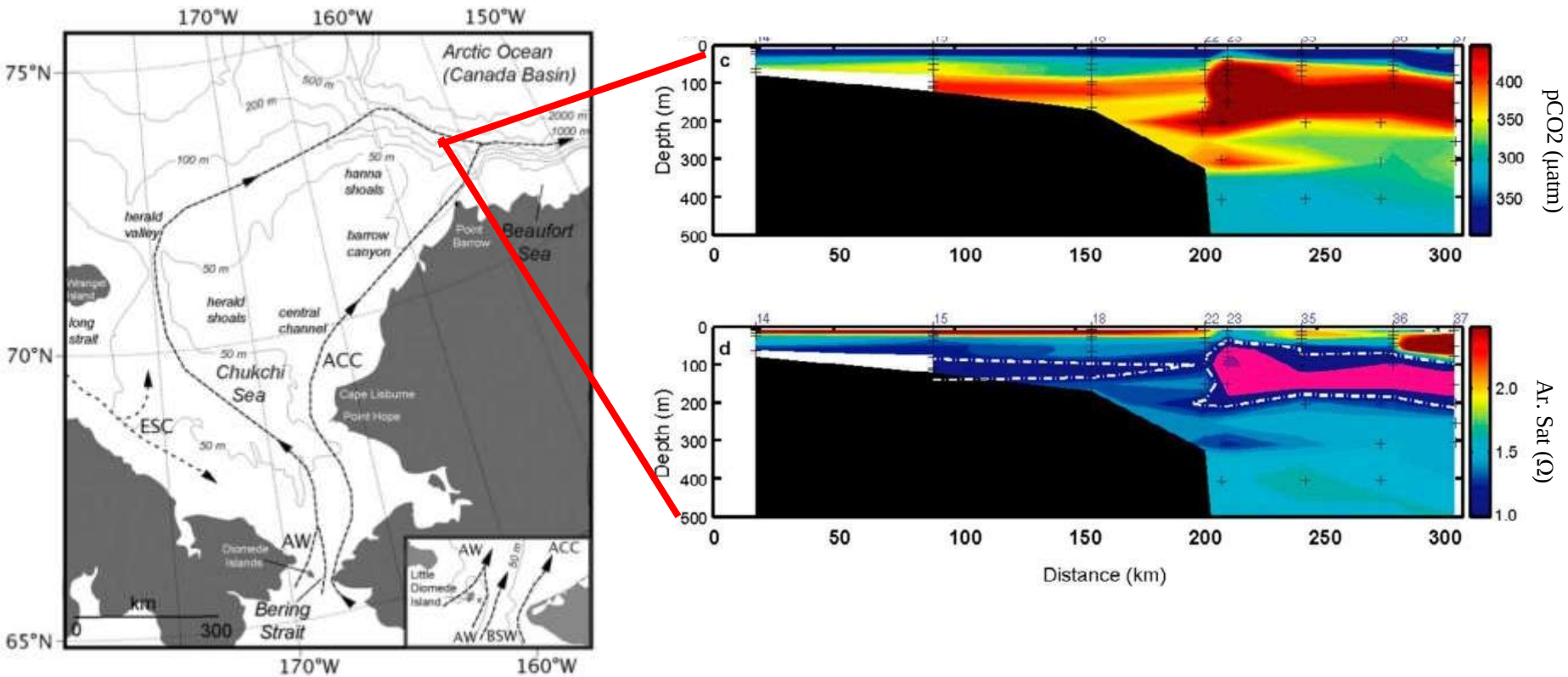
In summer, the remineralization of organic matter suppresses aragonite saturation states in the bottom waters of the shelf beneath the “green belt”.



Mathis, J.T., Bates, N.R., Cross, J.N., Coupling Primary Production and Terrestrial Runoff to Ocean Acidification and Carbonate Mineral Suppression in the Eastern Bering Sea (Journal of Geophysical Research-Oceans, In Prep).

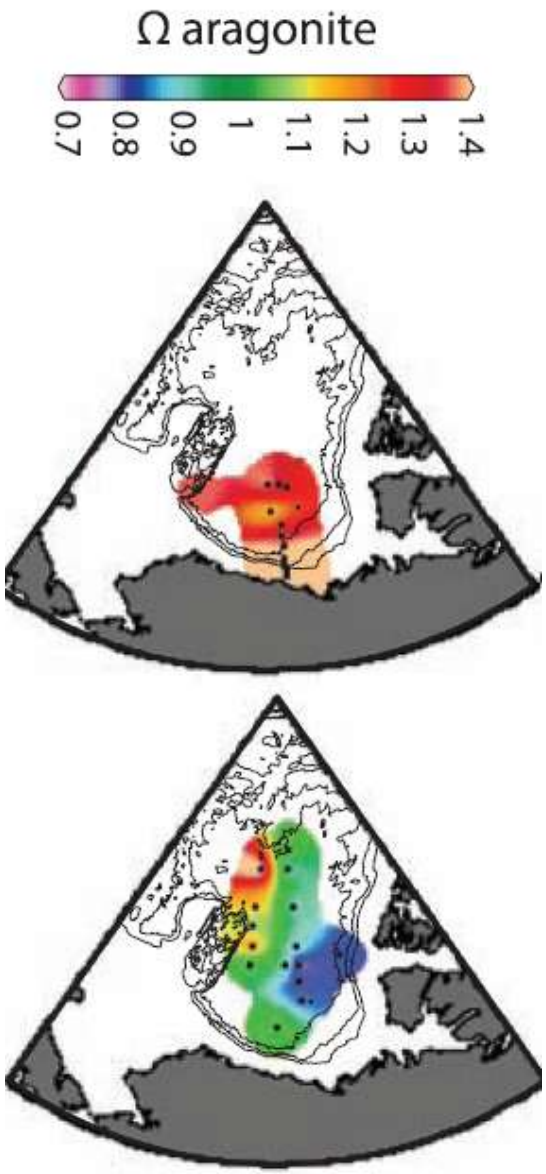
OA in the Chukchi Sea

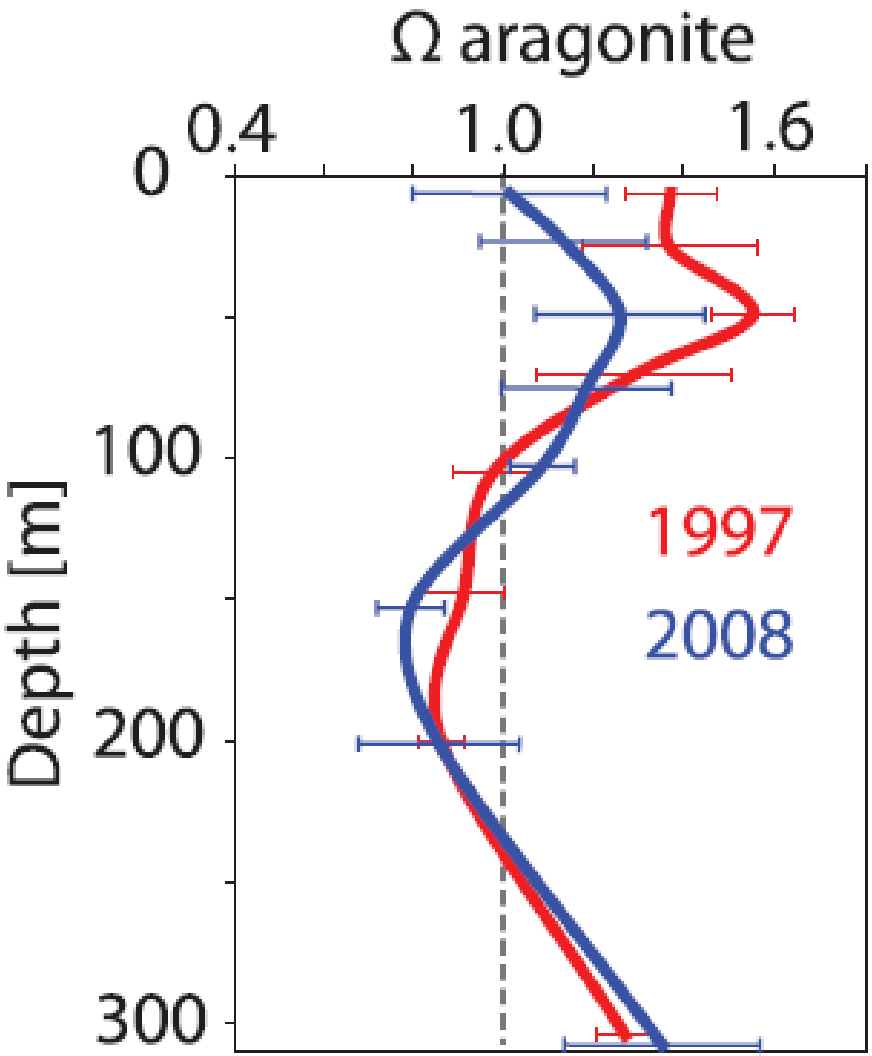
The remineralization of exported organic matter in the bottom waters creates a high pCO_2 environment that suppresses saturation states. These waters then condition the halocline of the Chukchi Sea.



Bates, N. R., J. T. Mathis, and L. W. Cooper (2009), Ocean acidification and biologically induced seasonality of carbonate mineral saturation states in the western Arctic Ocean, J. Geophys. Res., 114, C11007

OA in the Arctic Ocean





Yamamoto-Kawai, 2009

Conclusions

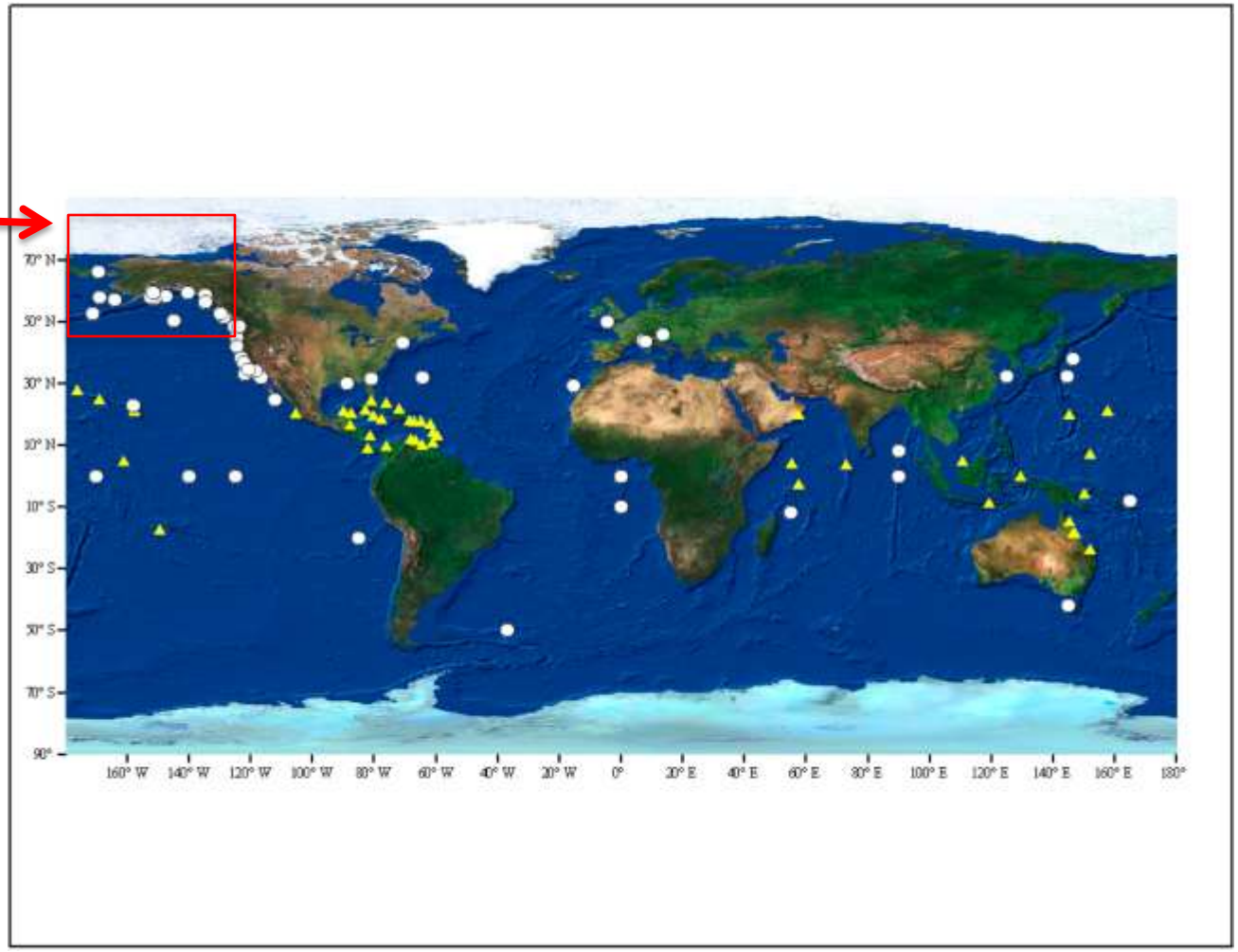
- Impacts of ocean acidification on marine ecosystems are largely unknown.

- Calcification in many planktonic organisms is reduced at elevated CO2, but the response is not uniform.

- Possible responses of ecosystem are speculative, but could involve changes in species composition and abundances – could affect food webs and biogeochemical cycles.

- Baseline data with sufficient resolution are lacking in some of the most sensitive regions (i.e. coastal Alaska).

OA Mooring Network



A network of moorings would allow us to obtain time series data to assess real time changes in ocean pH

Action Plan

- The root cause of this problem is excess CO_2 emissions.
  - H.R. 2454: American Clean Energy and Security Act of 2009 (Rep. Waxman).
  - As Alaskans, let's lead the way in the push for cleaner energy sources and better conservation

- We need more data about the rates of ocean acidification and the impacts on commercially viable species.

  - Ocean Acidification Research Center (UAF)
    - Request has been made for a Federal Initiative to support Alaska-centric OA research. (Contact Sen. Murkowski's office)

Thanks to my staff, colleagues and SFOS