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Ocean Acidification: Current & Planned Research at the AFSC

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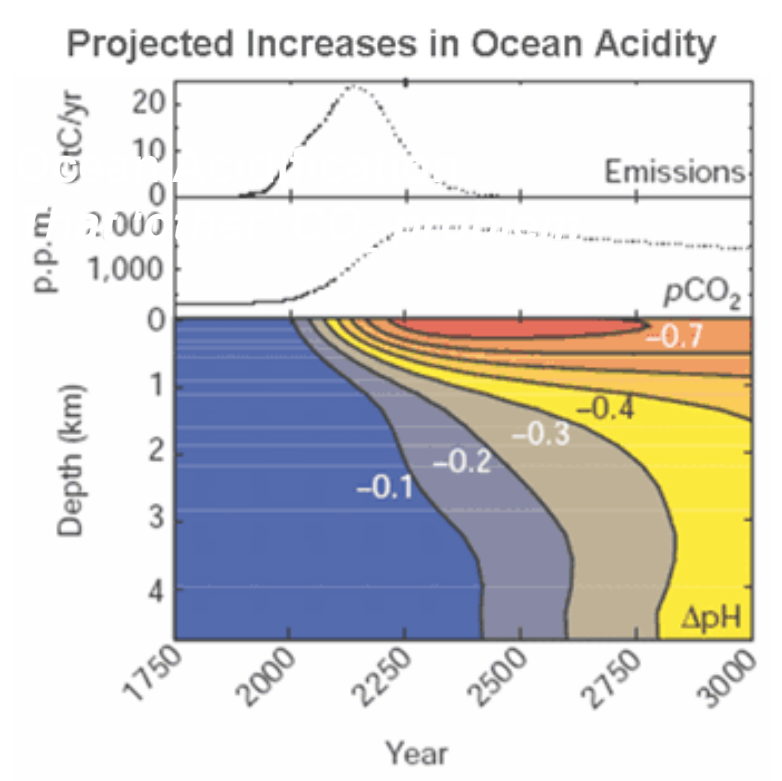
Ocean Acidification

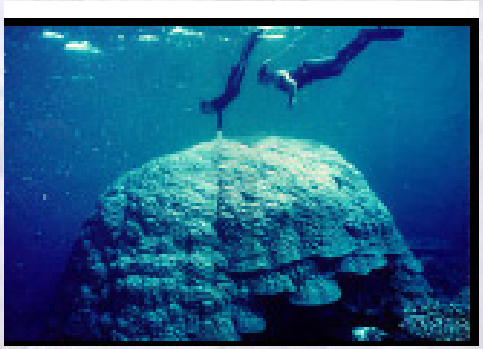
- Dissolving CO2 increases the hydrogen ion (H+) concentration in the ocean, and thus reduces ocean pH.
- The use of the term "ocean acidification" to describe this process was introduced in Caldeira and Wickett (2003).
- Since the industrial revolution began, ocean pH has dropped by approximately 0.1 units, and it is estimated that it will drop by a further 0.3 - 0.4 units by 2100 as the ocean absorbs more anthropogenic CO2 (Caldeira and Wickett, 2003; Orr *et al.*, 2005).

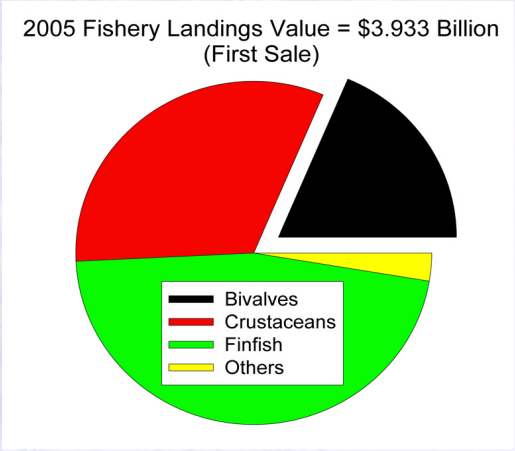
Ocean Acidification Issues

- We know the kinetics of OA pretty well
- Oversaturation is good! For aragonite, it is reduced with ↑depth, ↑pressure, ↓temperature, & ↓pH
- We know very little about how a given organism will "respond" to reductions in oversaturation of water with respect aragonite and calcite- need lab studies and field/process studies
- Ecosystem effects should be expected
- We need to deploy more sensors for routine monitoring

Ocean Acidification: A Consequence of Human Production of Greenhouse Gasses – Ocean Impacts







Value:
Bivalves: $732M ex-vessel commercial value
Crustaceans: $1,265M ex-vessel commercial value
Combined : $1,997M ex-vessel commercial value (51% of commercial catch by $)

As ocean calcium carbonate saturation state decreases, a concomitant reduction in calcification rates by marine organisms can occur.

- potential impacts on shelled plankton, coral reefs (shallow and deep), bivalves and crustaceans, and food chains

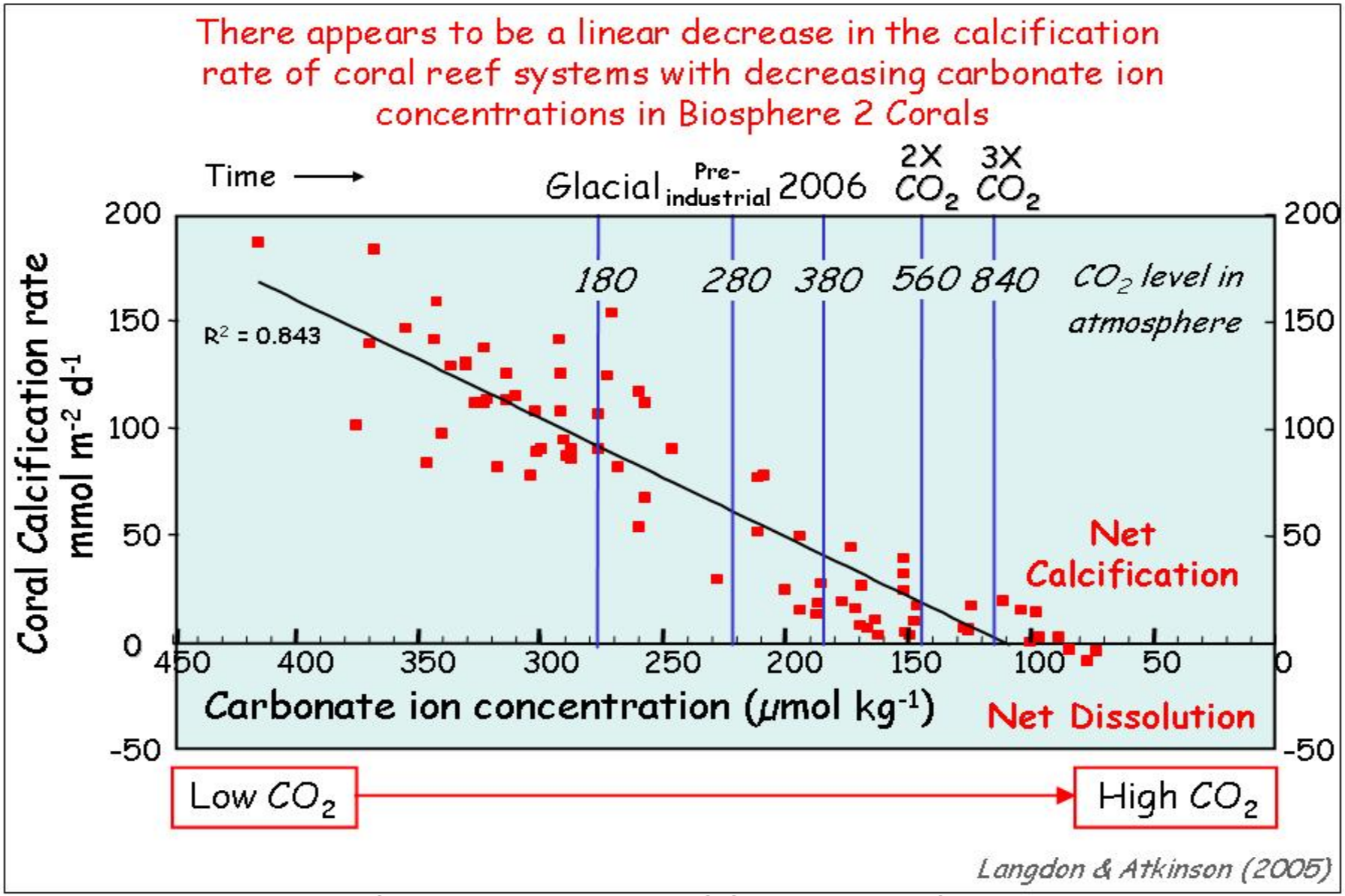
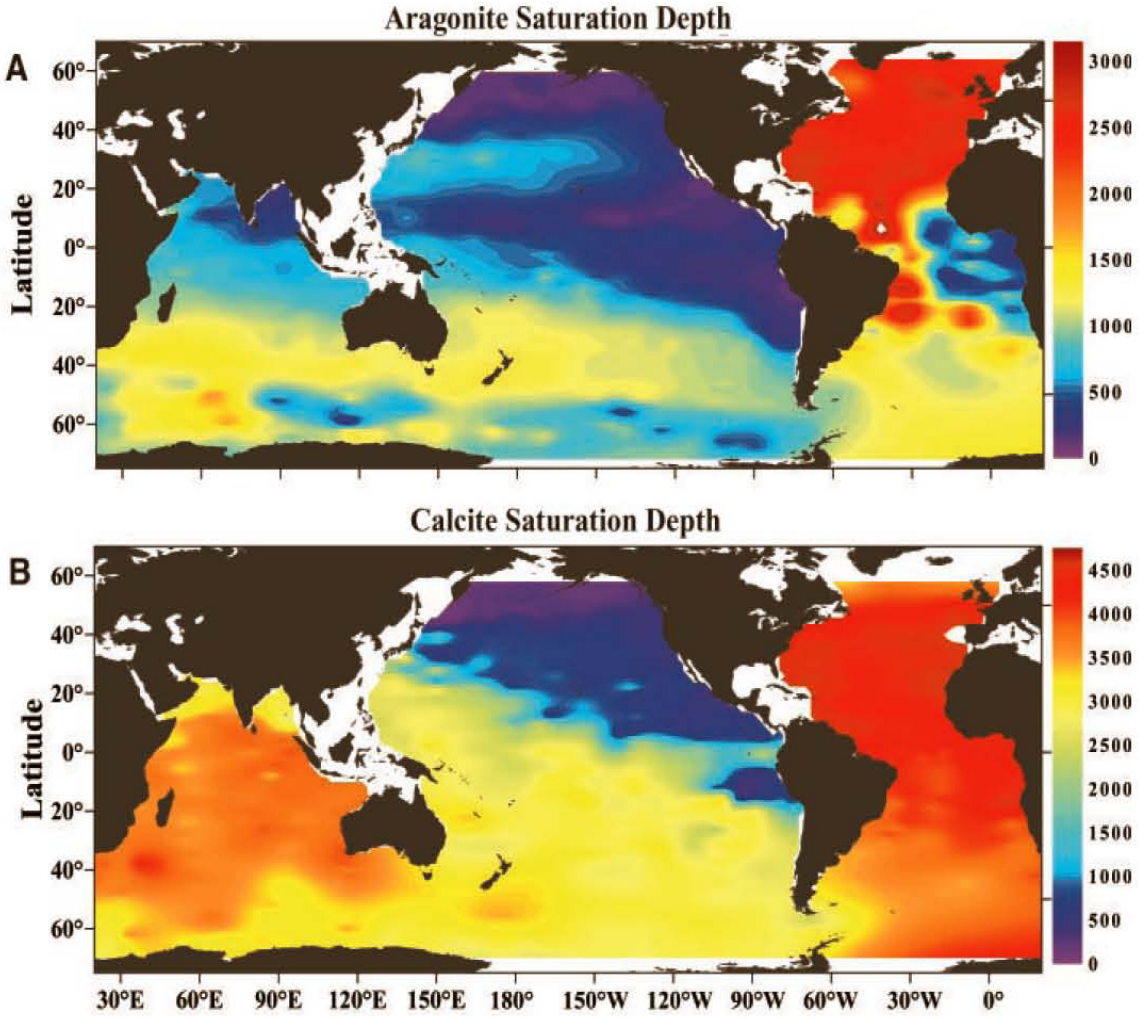
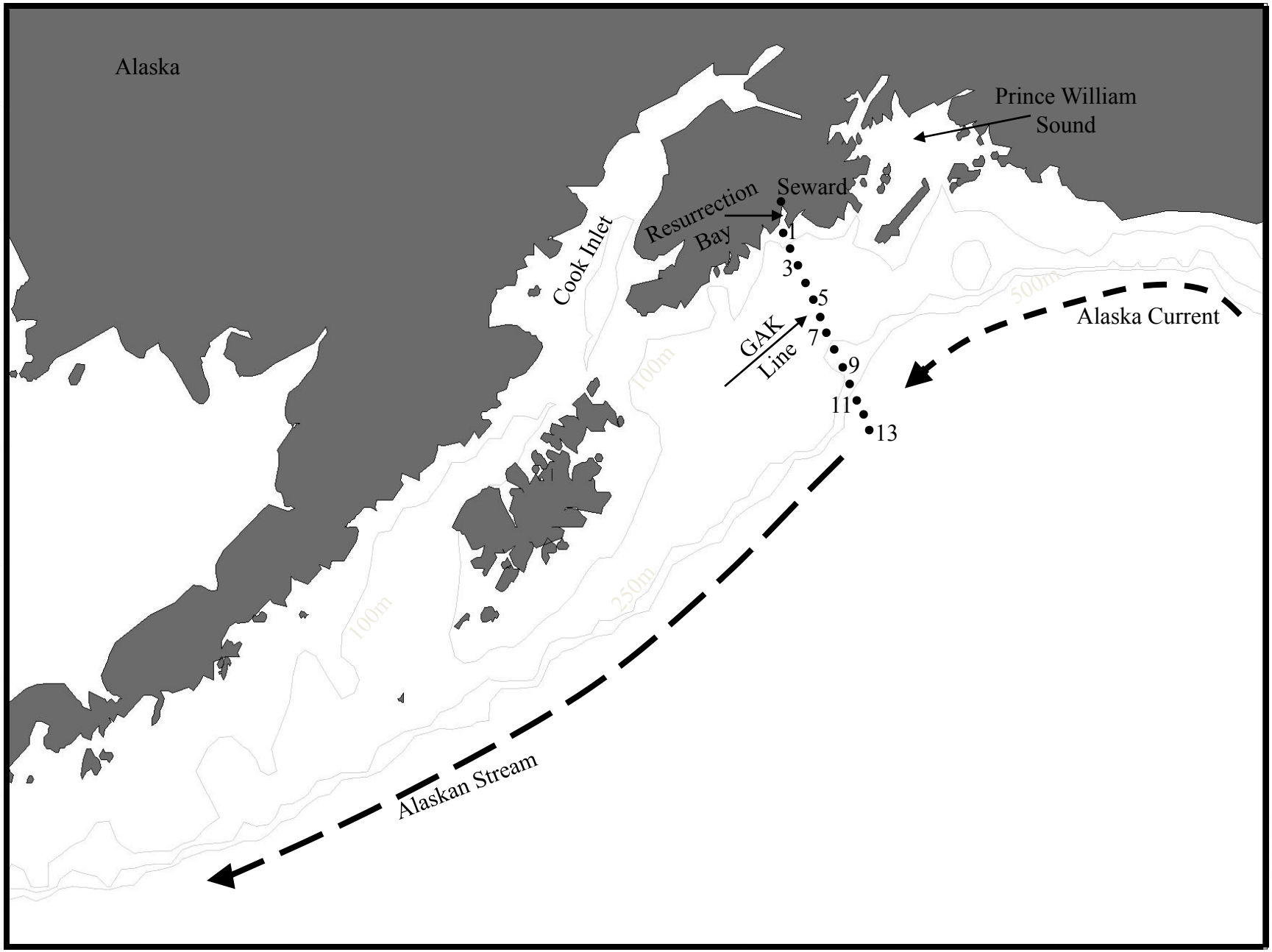


Figure 1: Impact of rising atmospheric CO_2 on the surface ocean carbonate chemistry and its potential impact on corals.

North Pacific fisheries are at risk because calcium carbonate saturation horizons are relatively shallow there.




Alaska
Prince William Sound
Seward
Resurrection Bay
Cook Inlet
1
3
5
7
9
11
13
GAK Line
Alaska Current
Alaskan Stream
500m
100m
250m
100m
60ºN
58ºN
56ºN
54ºN
160ºW
155ºW
150ºW
145ºW

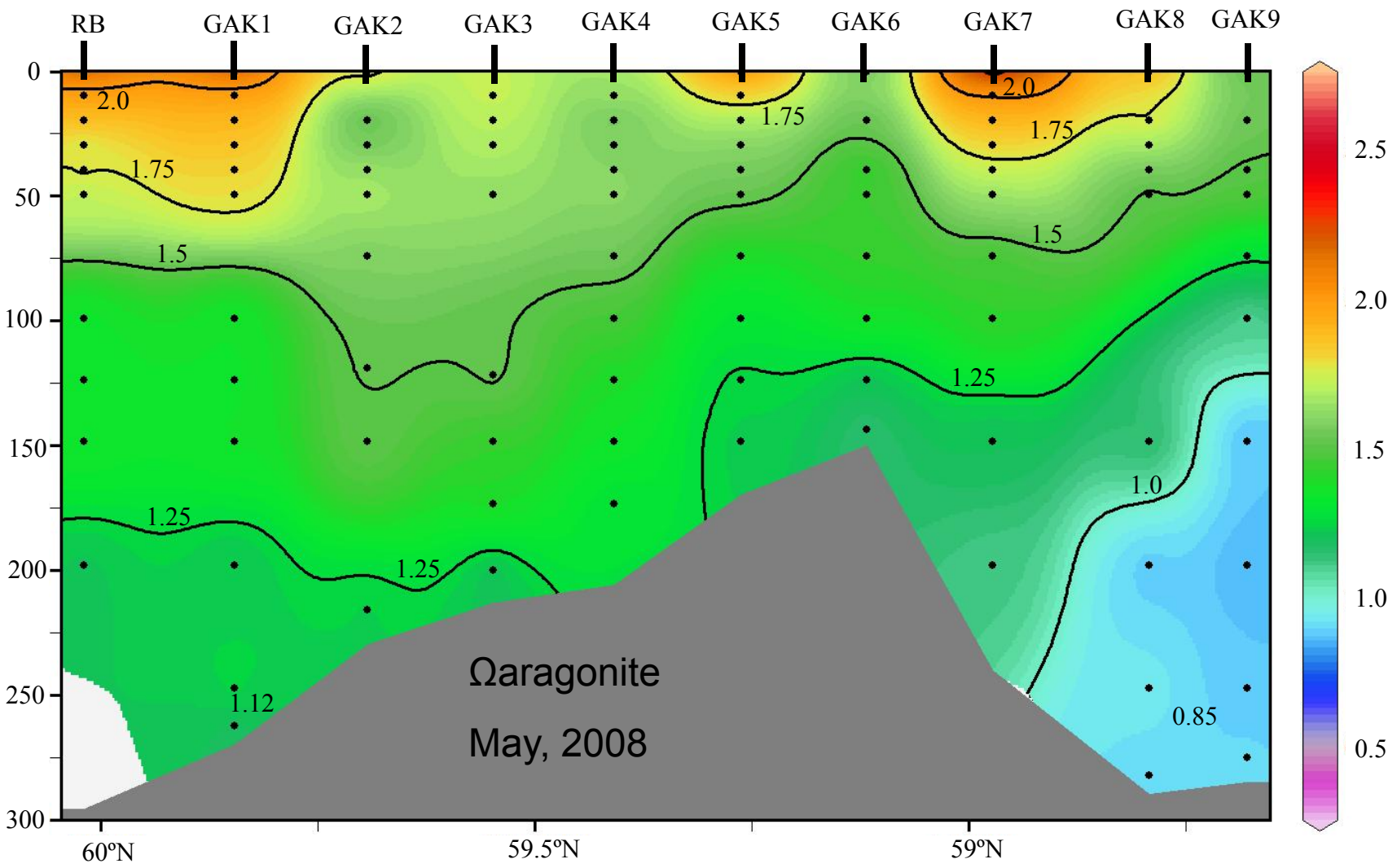
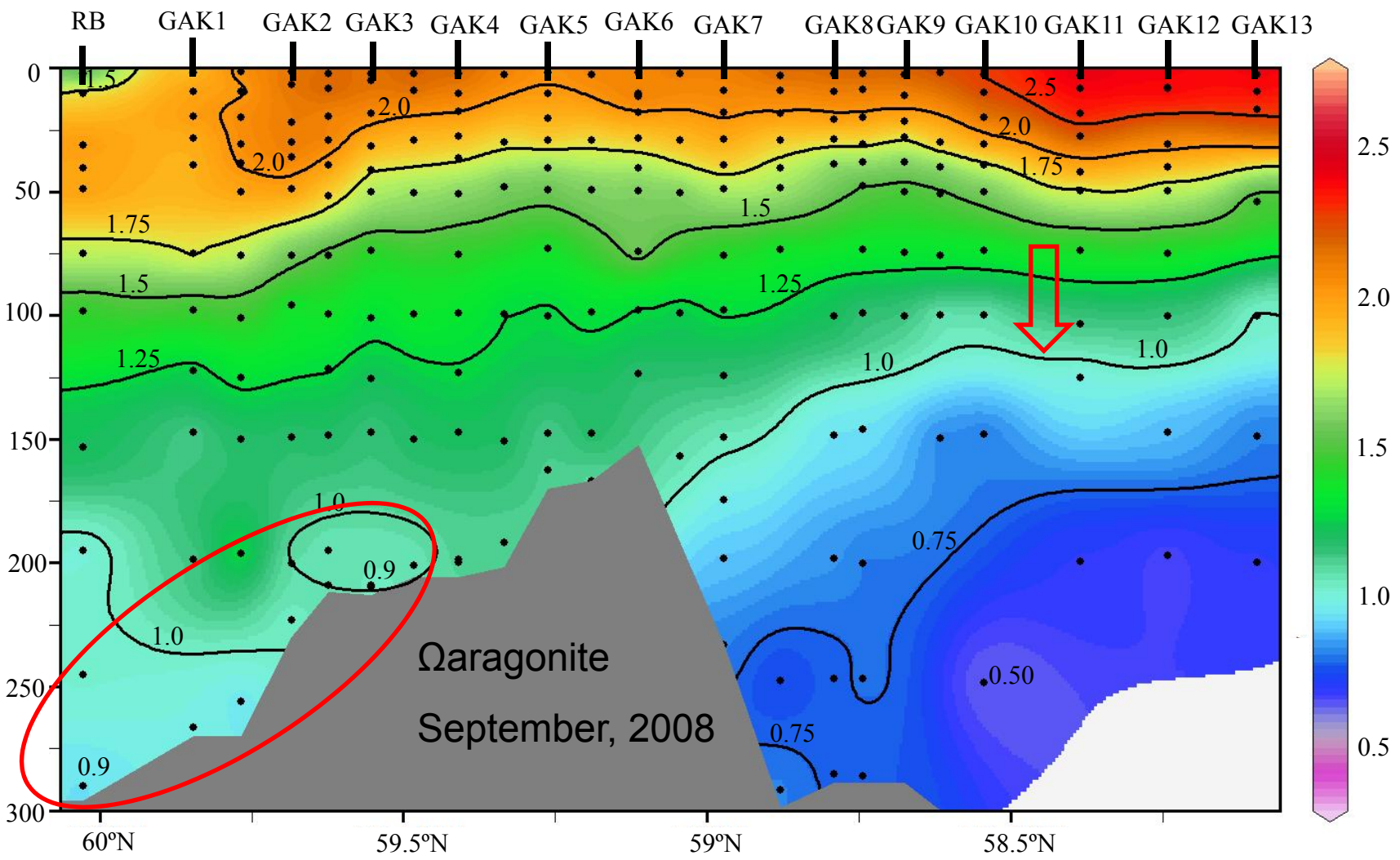

RB
GAK1
GAK2
GAK3
GAK4
GAK5
GAK6
GAK7
GAK8
GAK9
0
50
100
150
200
250
300
2.0
1.75
1.5
1.25
1.12
1.0
0.85
Ωaragonite
May, 2008
60ºN
59.5ºN
59ºN
2.5
2.0
1.5
1.0
0.5

Figure 2


RB
GAK1
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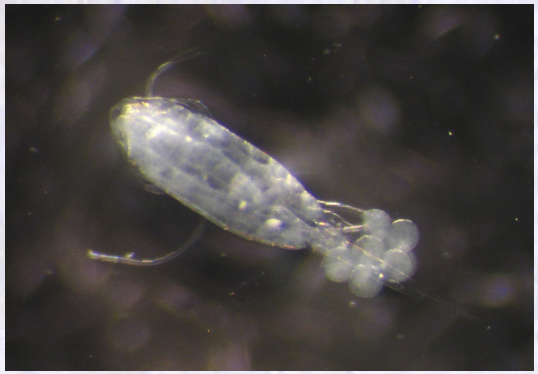
GAK10
GAK11
GAK12
GAK13
0
50
100
150
200
250
300
60ºN
59.5ºN
59ºN
58.5ºN
Ωaragonite
September, 2008
2.5
2.0
1.75
1.5
1.25
1.0
0.9
0.75
0.50
0.5

Goal: determine pH effects on plankton

Euphausiids *(Thysanoessa raschii)*

- **Early life stage metrics:**
  - Hatching success
  - Egg development
  - Molting
  - Progression from nauplii to calytopsis or furcilia
  - Respiration
  - Mortality

T. raschii



Psuedocalanus, photo by C. Sislak

- **Adult metrics:**
  - Growth
  - Reproduction
  - Molting
  - Respiration
  - Mortality
  - Lipids
  - Metals (Ca, Mg)
  - RNA/DNA

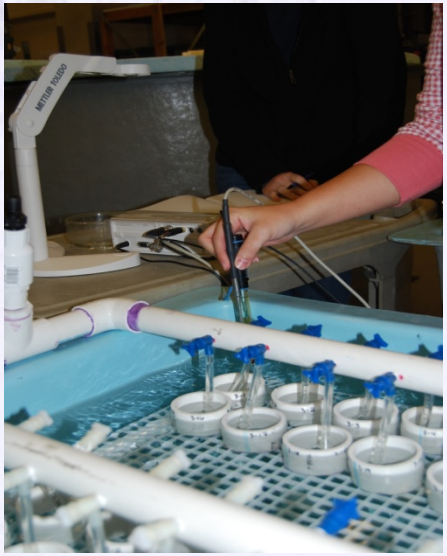
Copepod (Pseudocalanus) metrics:

- (Clutch size)
- Hatching success
- Molting
- Progression to N2 & N3
- Respiration
- Mortality

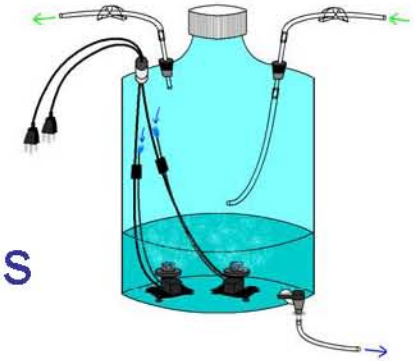
Ocean Acidification Effects on Crabs

NOAA Alaska Fisheries Science Center: Kodiak Laboratory

- Focus on king and Tanner crab.
- 2007-2008 pilot experiments and methods development
- 2009-2010 experimentation:
  - Red and Golden king crab adult molting (growth) slowed by increased CO_2
  - Red king crab larval growth and survival negatively impacted by increased CO_2
  - Tanner crab juveniles experience decreased survival, decreased mass, and decreased size with increased CO_2

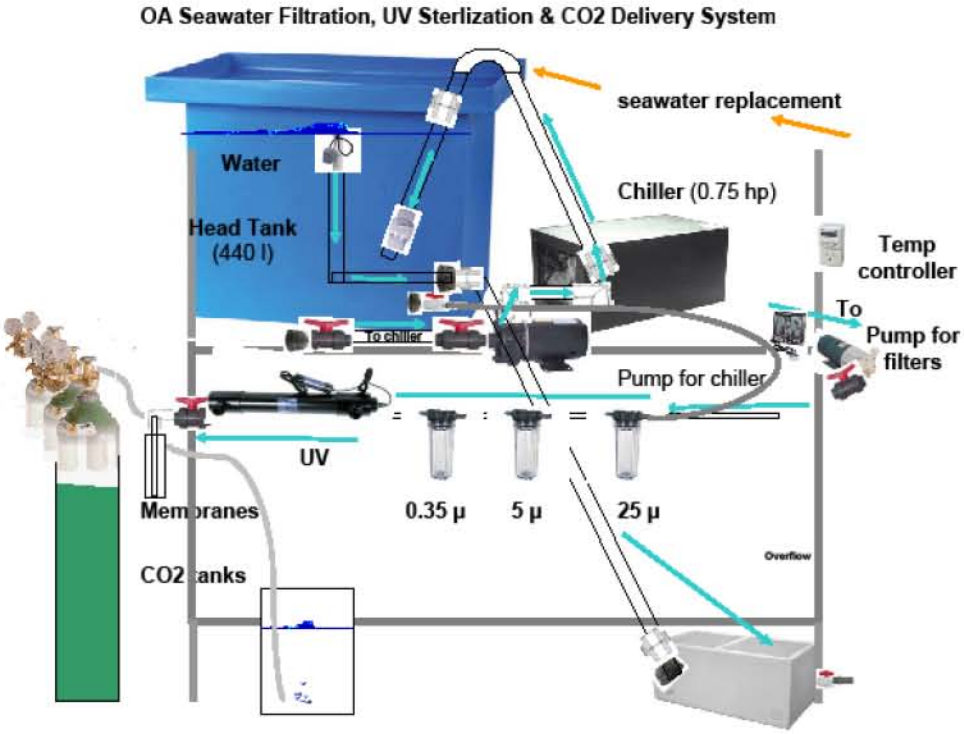


Ocean Acidification Effects on Alaska Crabs



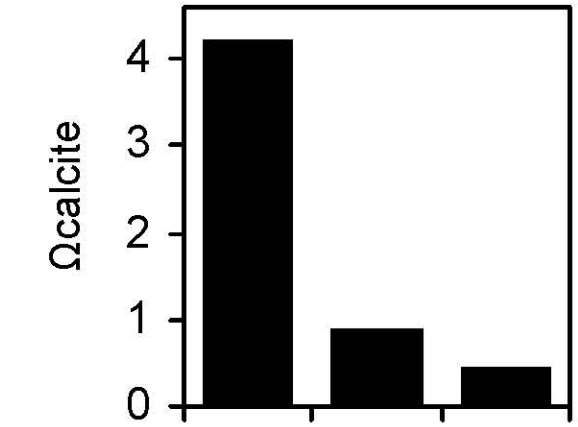
Successful development of CO_2 delivery systems

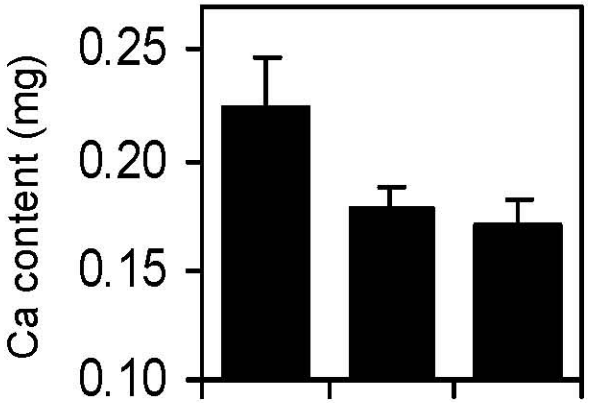
- Gas bubble microcosms
- Gas flow mesocosms

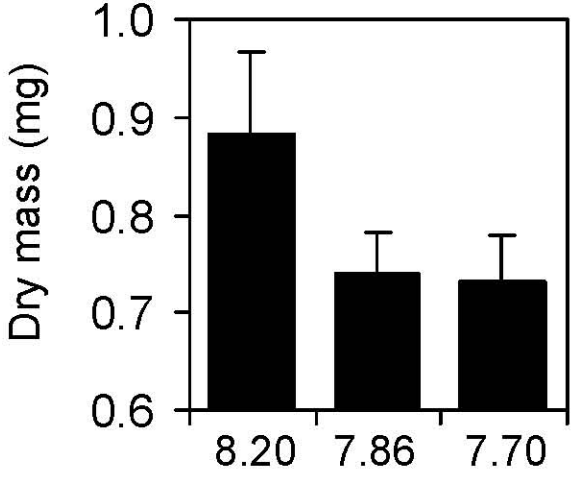


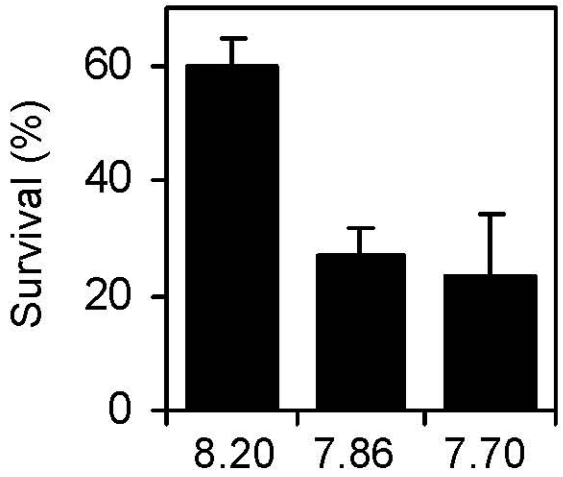
Ocean Acidification Effects on Alaska Crabs

Lower pH reduces larval mineral content, mass, and survival









pH

Ocean Acidification Effects on Alaskan Gadids

Fisheries Behavioral Ecology Program, Newport OR
w/ University of Alaska - Fairbanks

Focal species: walleye pollock and Pacific cod

Direct effect studies: Examine effects of early life stages to range of predicted pH in laboratory experiments.

Indirect effect studies: Examine influences OA-induced changes in prey abundance and nutritional content.

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

UAF University of Alaska Fairbanks

Pollock Conservation Cooperative Research Center

OSU Oregon State University

Ocean Acidification Effects on Alaskan Gadids

Experimental system for large-scale rearing of marine fish larvae and juveniles

- 4 pH treatments with 4 tank replication
- Automated pH regulation
- Independent pH control and monitoring
- Integrated temperature control

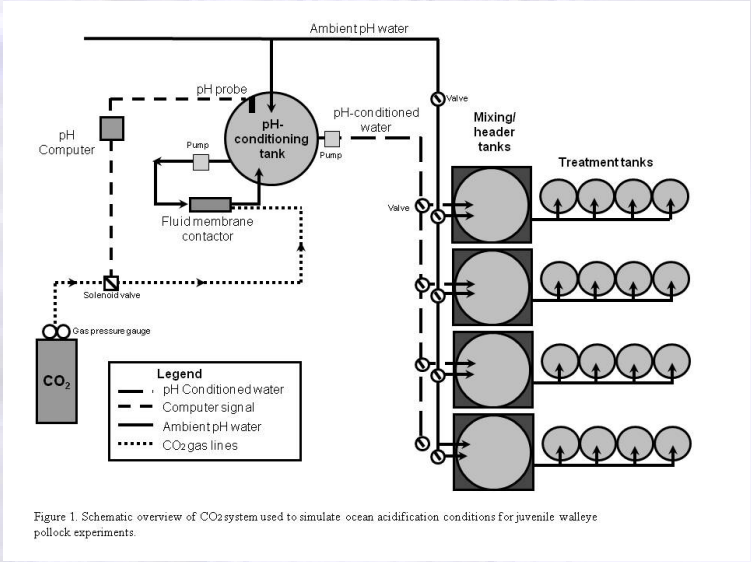


Figure 1. Schematic overview of CO_2 system used to simulate ocean acidification conditions for juvenile walleye pollock experiments.

Phase I experiments:

6-week exposure of juvenile walleye pollock at warm temperature

Metrics: Growth, condition, stress hormones, blood chemistry, otolith growth

Egg incubation trial with walleye pollock at warm temperature

Metrics: Hatch success, time to hatch, size at hatch, energy reserves at hatch

Phase II experiments:

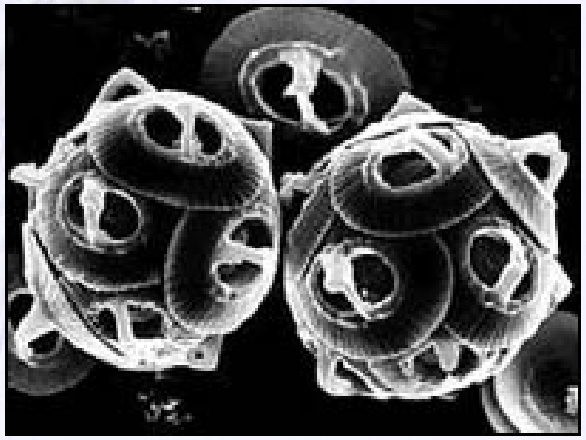
Larval rearing – hatch to 6 weeks post-hatch

Comparison with Pacific cod

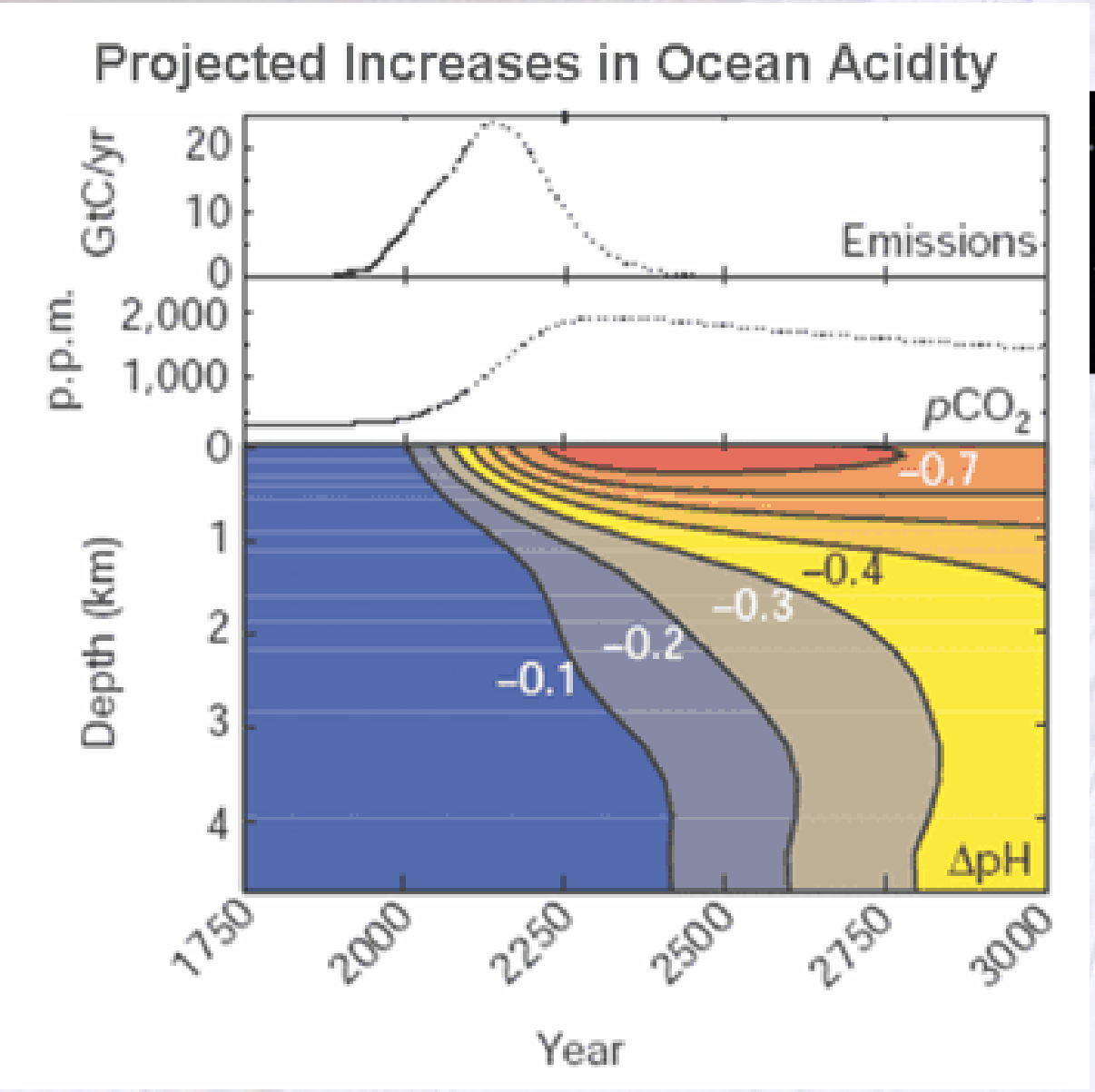
Ocean Acidification is a Serious Threat to Marine Ecosystems

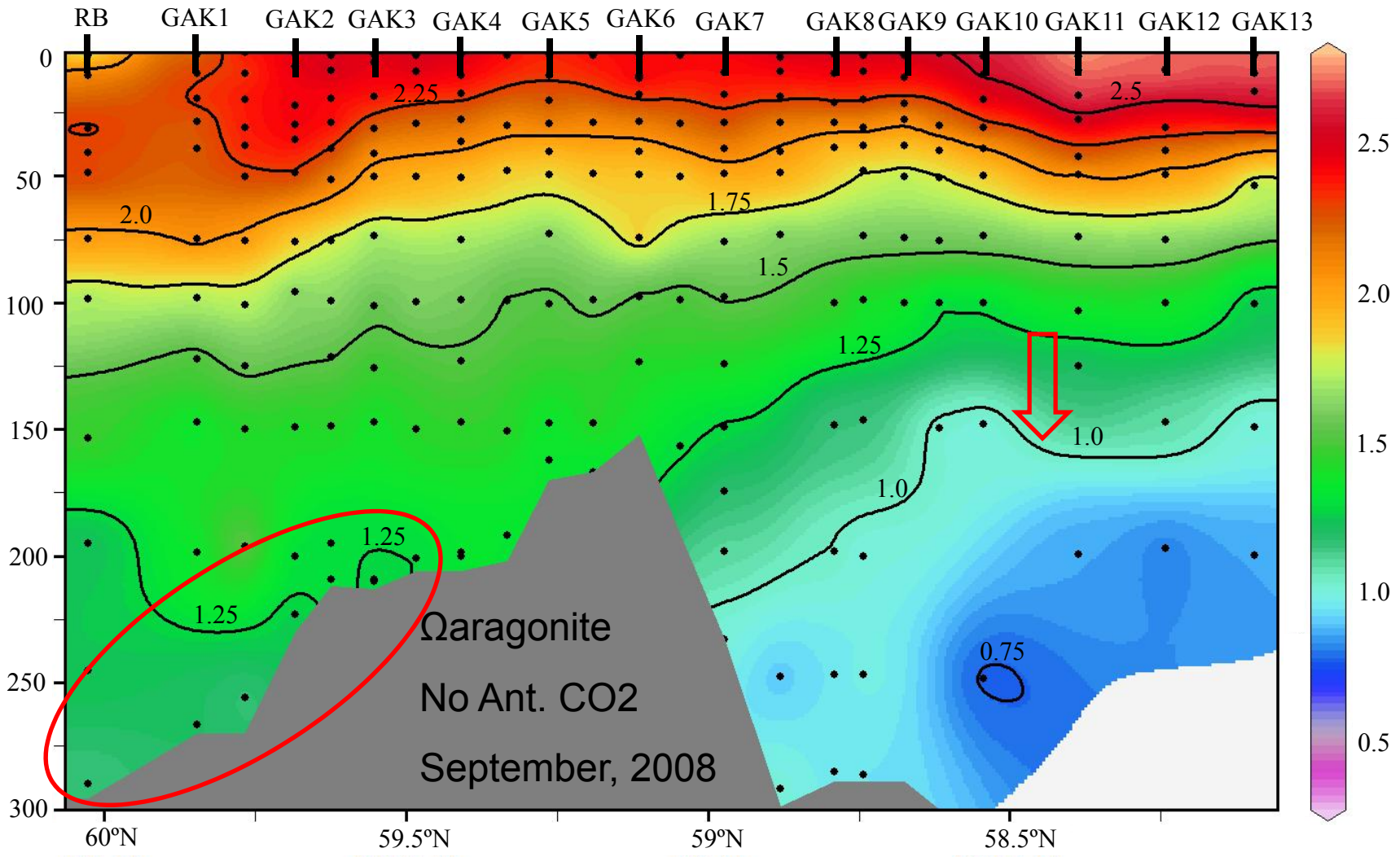
Marine species are under threat from rising levels of acidity in the oceans, says the UK's Royal Society.

1. Unless carbon dioxide emissions are cut, there could be irreversible damage to ecosystems
2. Failure to do so may mean that there is no place in the oceans of the future for many of the species and ecosystems that we know today



Questions?


Projected Increases in Ocean Acidity
GtC/yr
20
10
0
Emissions
p.p.m.
2,000
1,000
0
pCO_2
Depth (km)
1
2
3
4
−0.7
−0.4
−0.3
−0.2
−0.1
ΔpH
1750
2000
2250
2500
2750
3000
Year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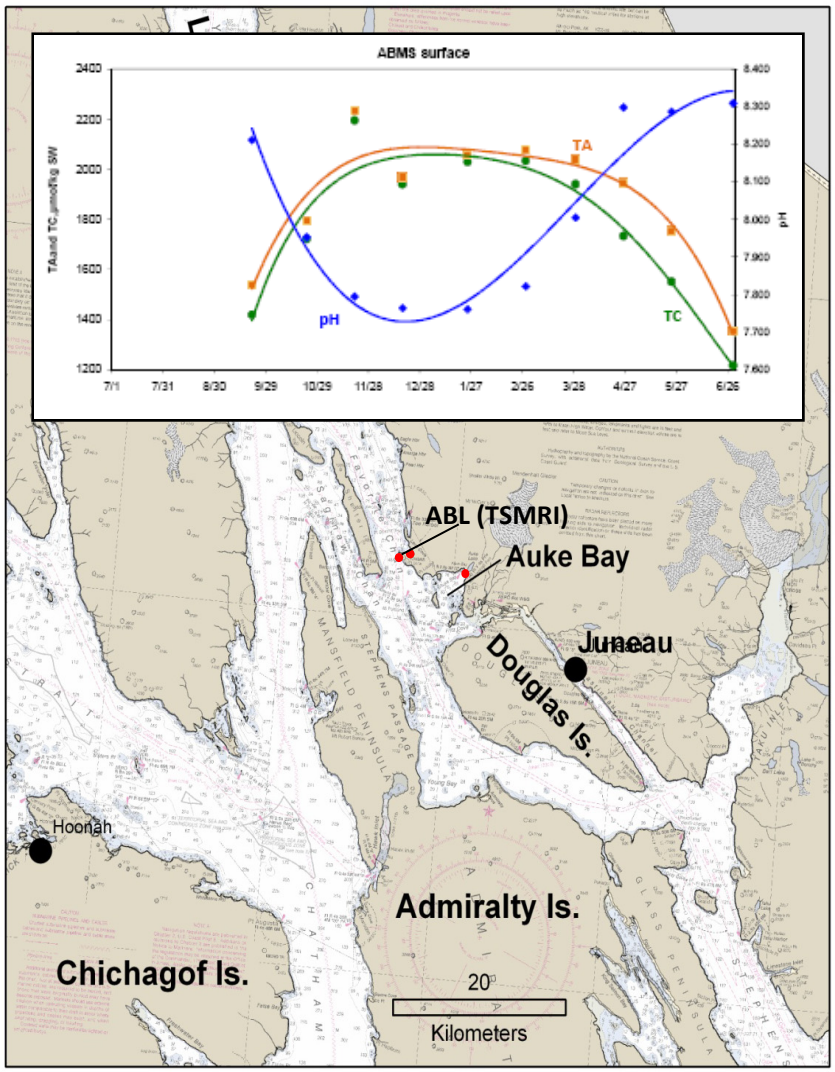
1.75
1.5
1.25
1.0
0.75
Ωaragonite
No Ant. CO2
September, 2008
60ºN
59.5ºN
59ºN
58.5ºN
2.5
2.0
1.5
1.0
0.5

Goal: understand carbon chemistry in Southeast Alaska



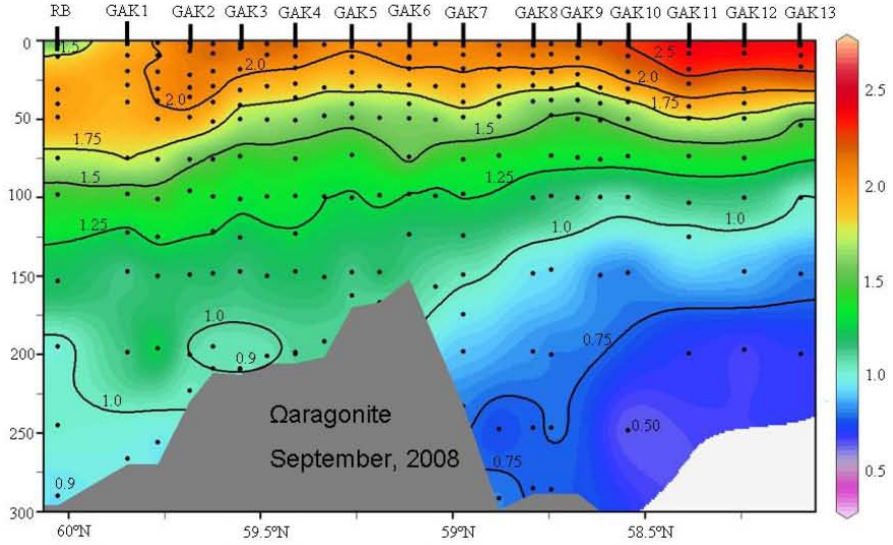
Goal: understand the local environment

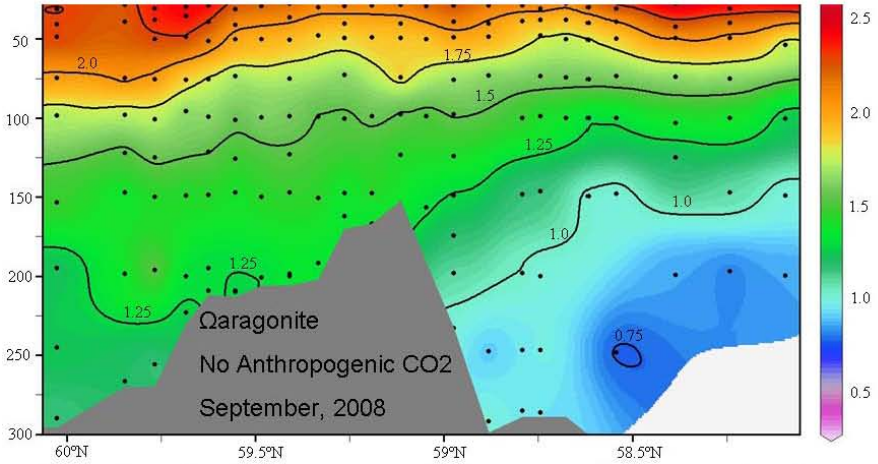
- Relate water chemistry to plankton biology
- Separate physical and biological influence on total alkalinity (TA), total dissolved inorganic carbon (TC), and pH

Metrics

- TA, TC, pH
- Phytoplankton biomass (chlorophyll a)
- Nutrients (nitrogen, silicate, phosphate)
- Depth profiles
  - Temperature
  - salinity
  - light

Gulf of Alaska

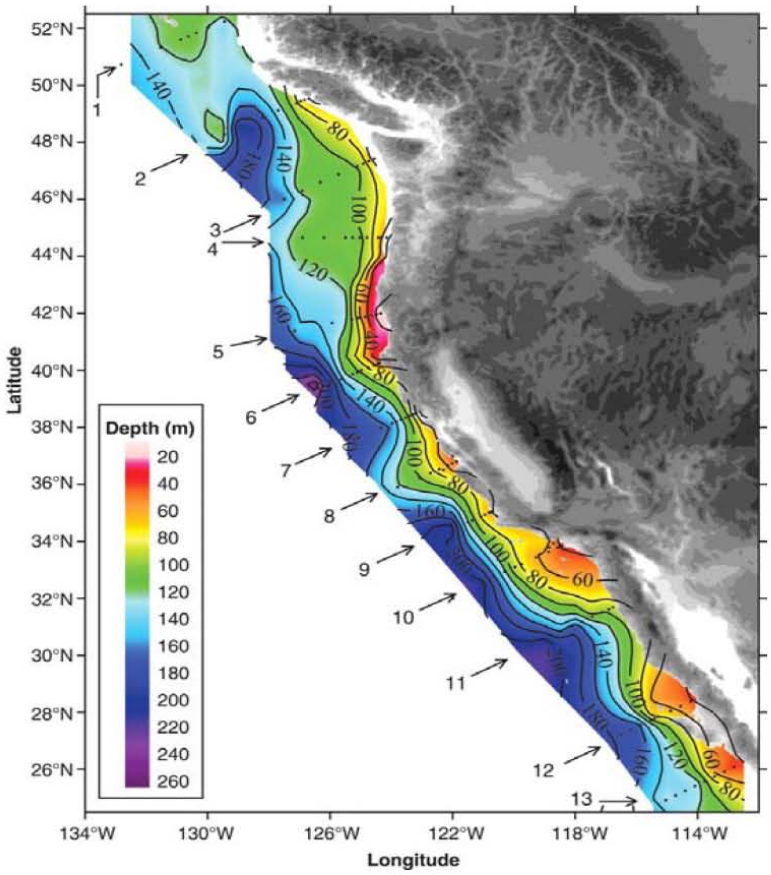




Depth of undersaturated waters (aragonite) at 147 Deg W *J. Mathis, Univ. Alaska*

Aragonite saturation horizons

West Coast



Depth of undersaturated waters (aragonite) on West Coast *Feely et al. 2008*

Known Locations of Deep Corals and Observed Aragonite Saturation Depths