SCIENCE-DRIVEN FISHERIES DYNAMICS: WHAT'S IN OUR FUTURE?

UPDATE ON NEW SPECIES DEVELOPMENT AND THE ALASKA OCEAN ACIDIFICATION LABORATORY

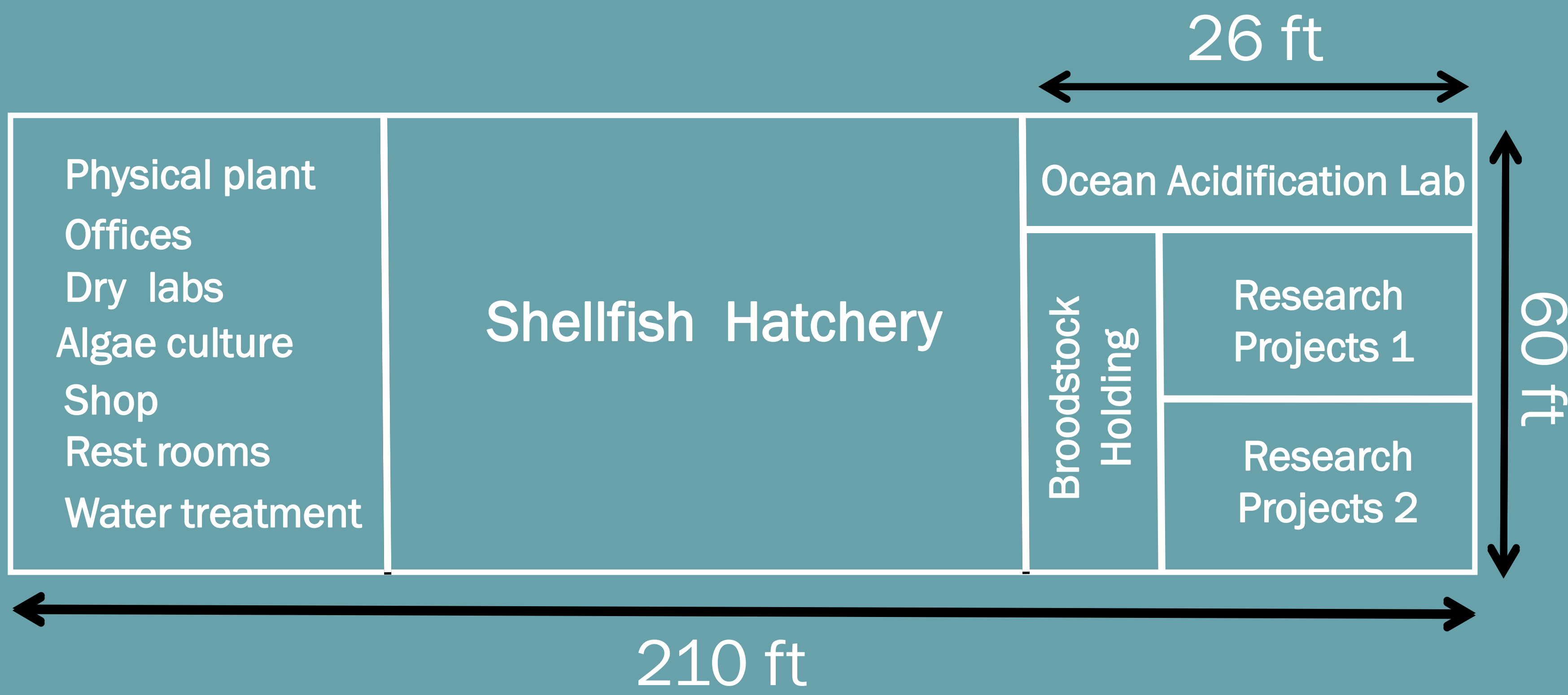
Southwest Alaska Municipal Conference March 6, 2020

Jeff Hetrick, Director
Alutiiq Pride Shellfish Hatchery

Alutiiq Pride Shellfish Hatchery

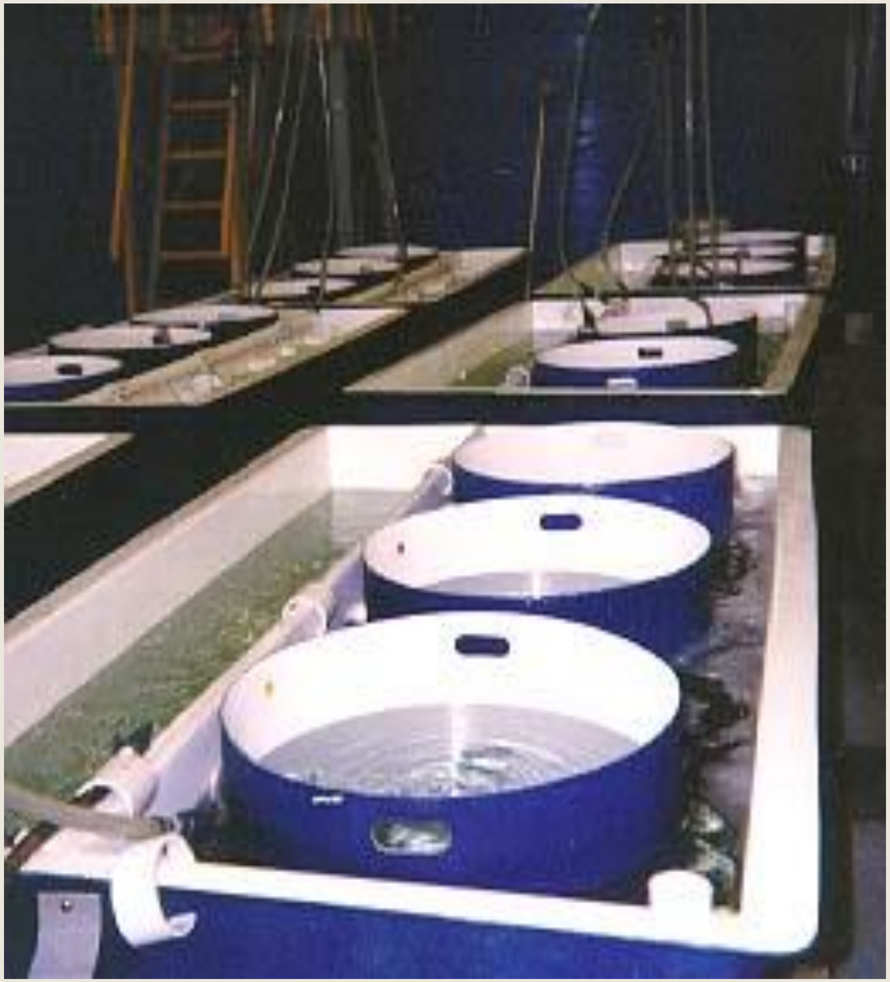
APSH in relation to Resurrection Bay

Hatchery Floor Plan



Algae Culture

Larva Setting & Nursery Culture



Aquatic Species grown at APSH:

Pacific oyster *Crassostrea gigas*
Geoduck clams *Panapea generosa*

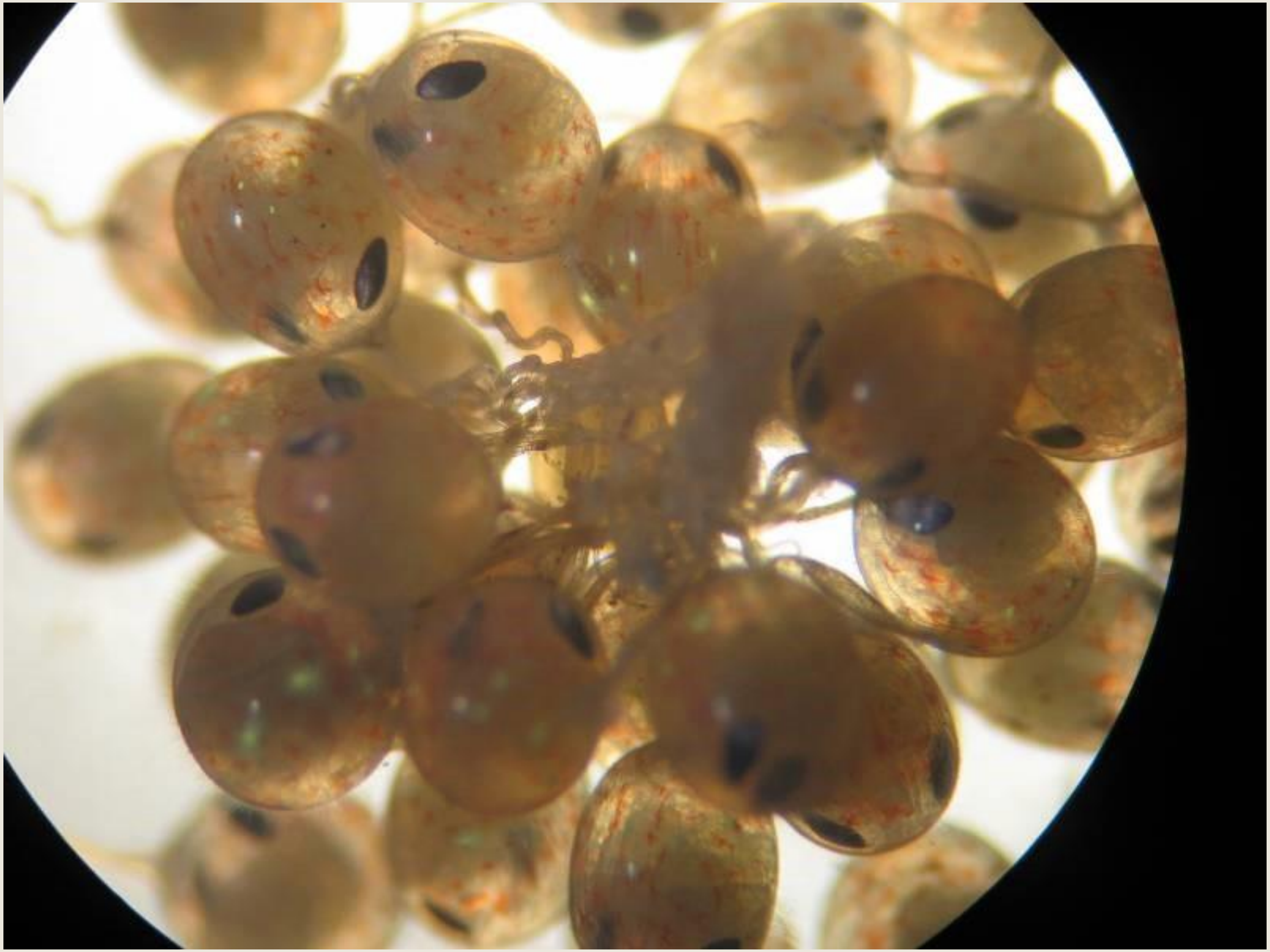
Basket cockle *Clinocardium nuttallii*
Pacific Razor clam *Siliqua patula*
Littleneck clam *Protothaca staminea*
Purple hinge rock scallop *Crassodoma gigantea*
Soft shell clam Mya arenaria

Blue King crab *Paralithodes platypus*
Red King crab *Paralithodes camtschaticus*

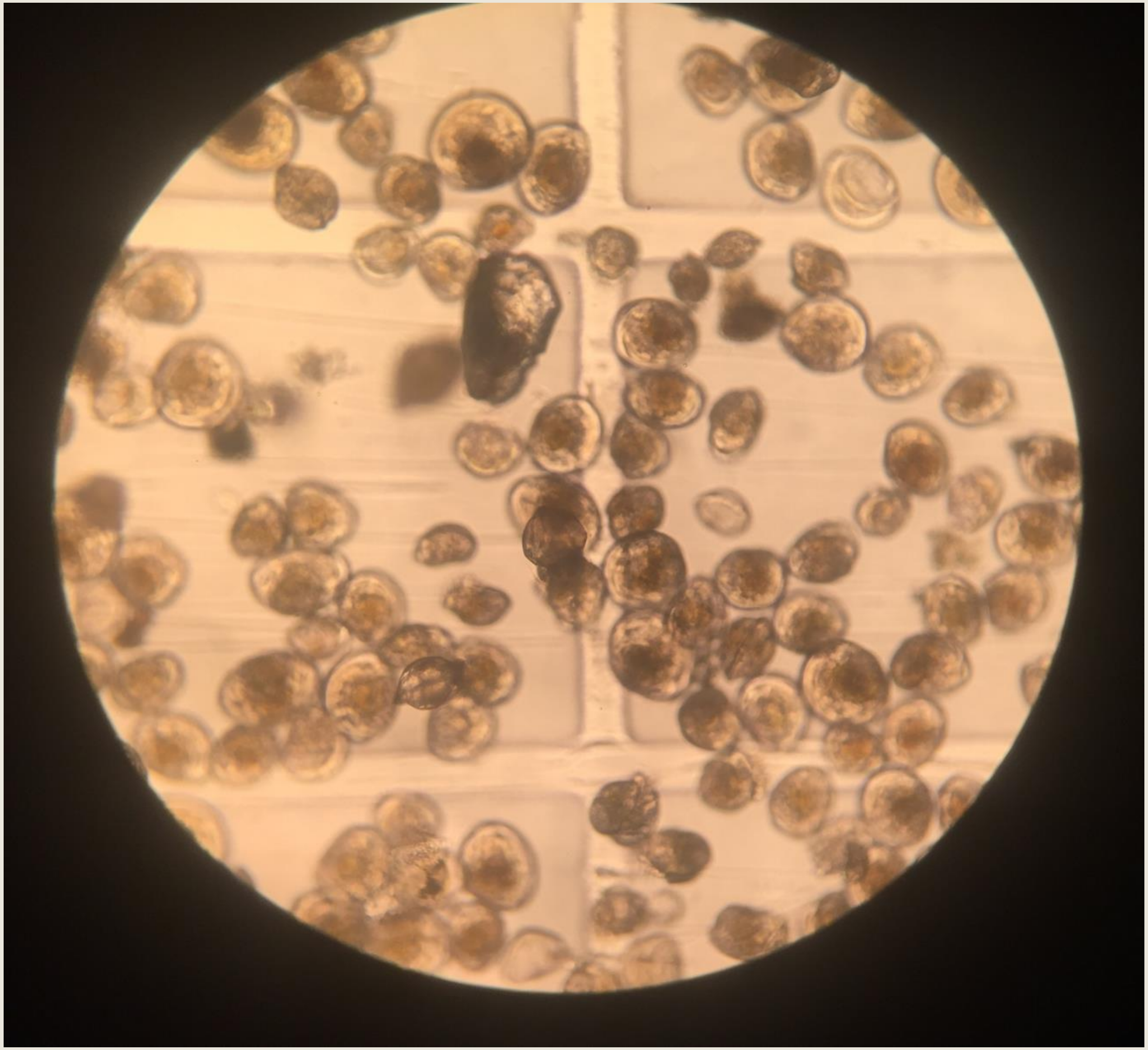
Purple hinge rock scallop *Crassodoma gigantea*
California sea cucumber *Parastichopus californicus*
Pinto Abalone *Haliotis kamtschatkana*`

Pacific Halibut *Hippoglossus stenolepis*
Giant Pacific Octopus *Eneroctopus dofleine*

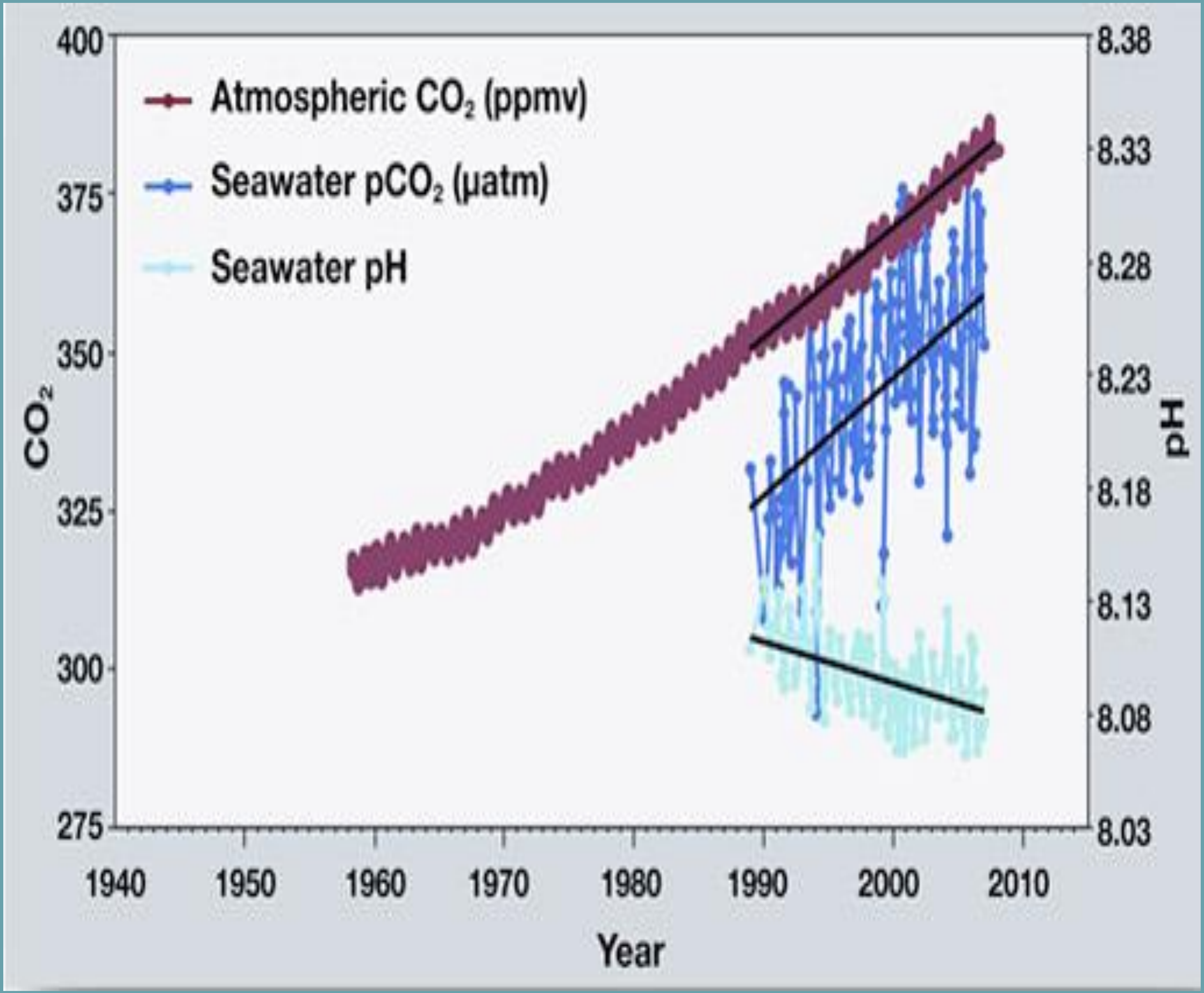
Red King crab larvae



Butter Clam spawn

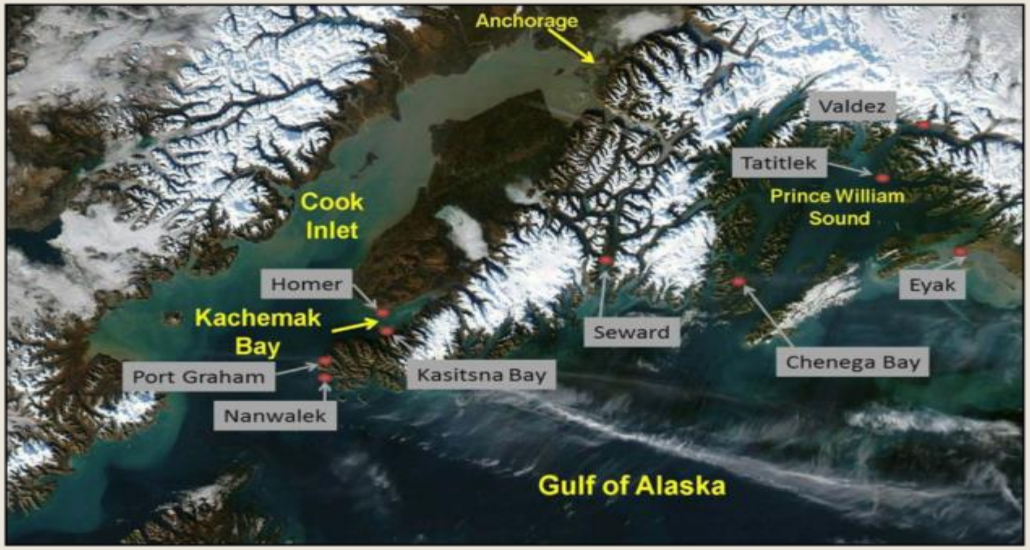


Ocean Acidification



Ocean Acidification & Shellfish Research Laboratory

Ocean Acidification & Shellfish Research Lab



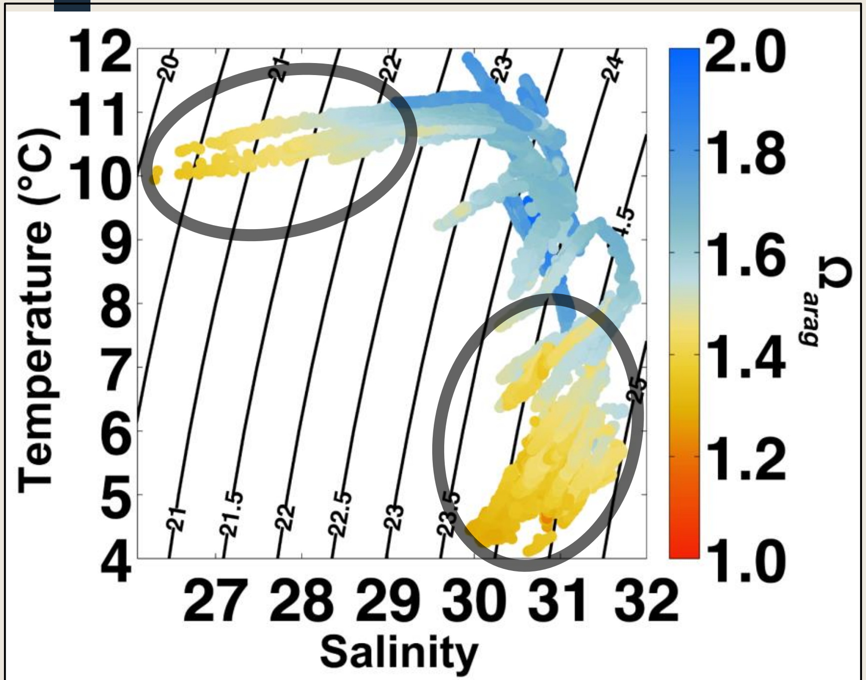
OA Sampling Sites on the Kenai Peninsula

Burke-o-lator

Invented by Burke Hales,
Oregon State University

Allows the hatchery to continuously monitor multiple ocean parameters, distribute that data in real time, test discreet samples, and dose the water tanks.

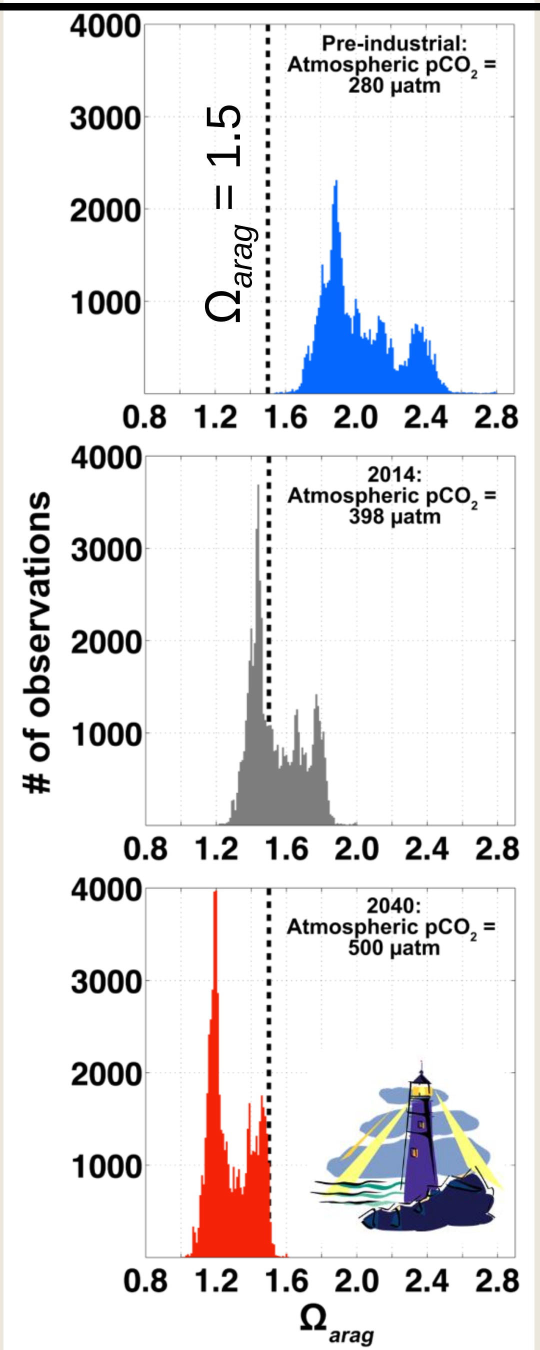
(1) Early data: October 2013 to August 2014



Two distinct stressful Ω water masses; autumn freshets and cold winter water

(−) anthroCO_2
(Harris et al. 2013)

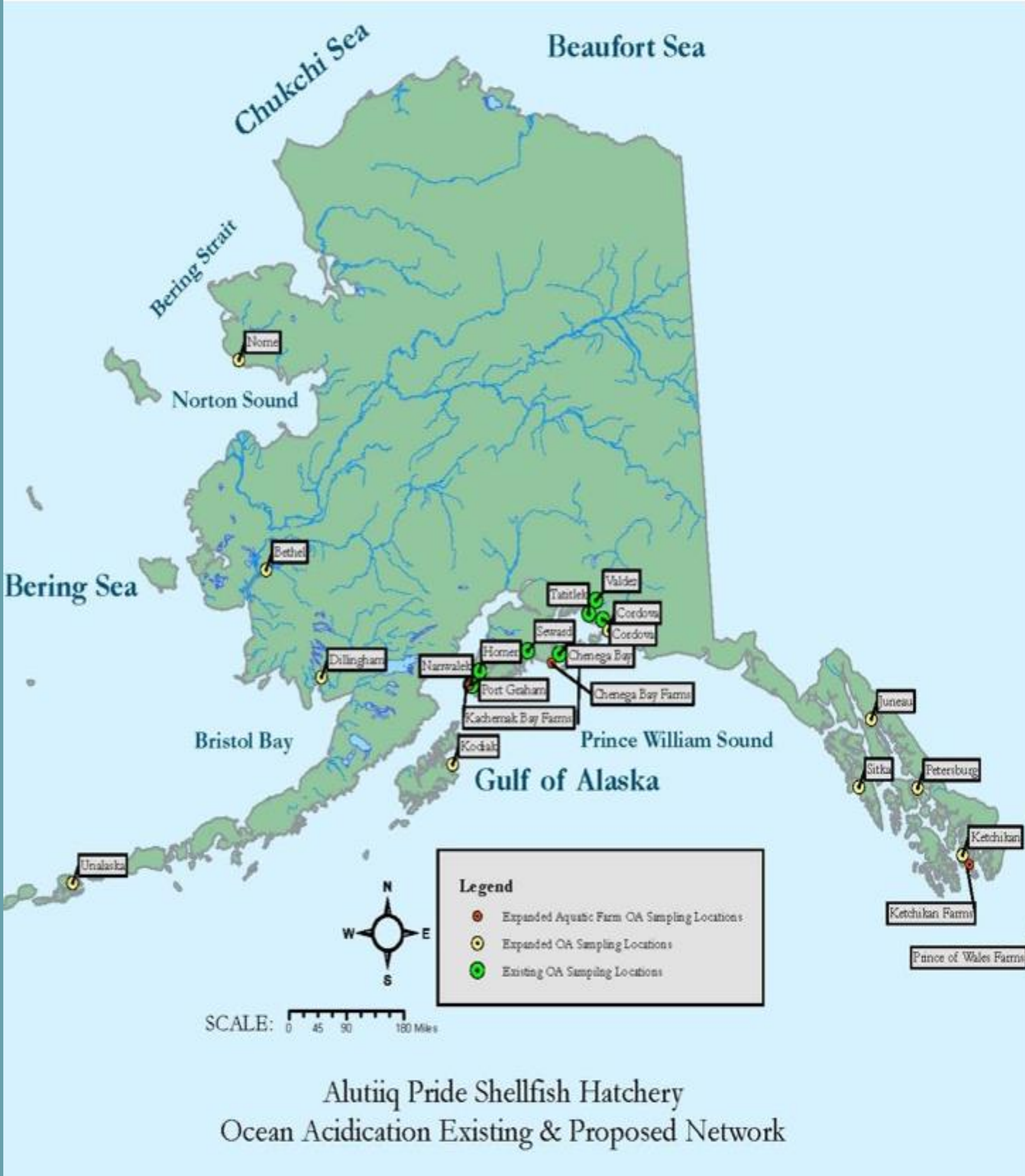
Average Ω_{arag} = 1.55 ± 0.15; 43% < Ω_{arag} = 1.5



Window of reprieve from stressful Ω_{arag} gone at $pCO_{2(atm)}$ = 500 µatm

IPCC RCP 8.5 predicts <u>*this level by 2040*</u>

<u>*Significant implication*</u> for growing Alaskan industry

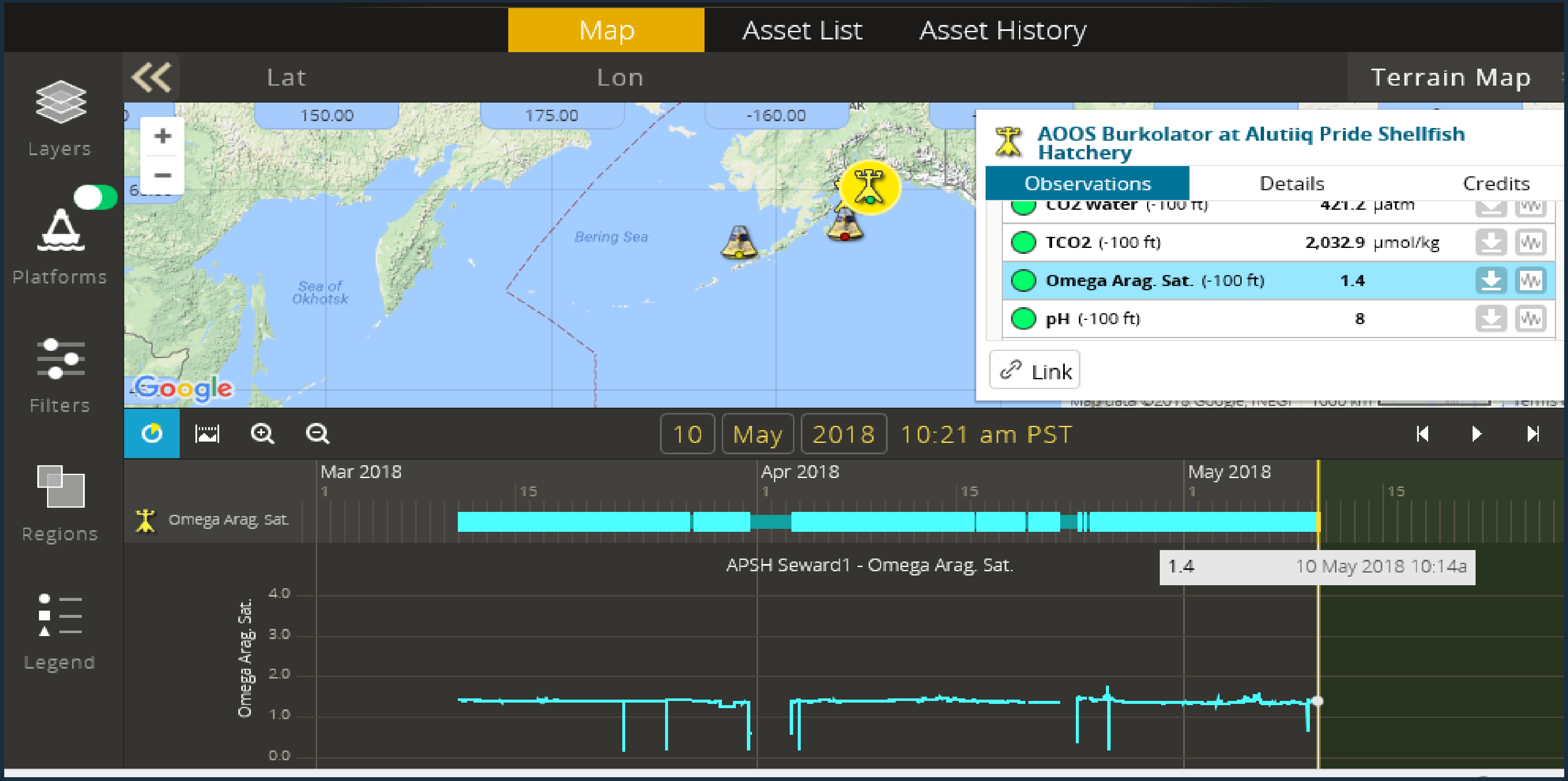


APSH is now processing seawater samples collected on a weekly basis by citizen scientists from Alaska Native communities around Southcentral Alaska following established protocols using APSH produced field kits.

Two Data Portals

1) https://portal.aoos.org/real-time-sensors.php

2) http://www.ipacoa.org/

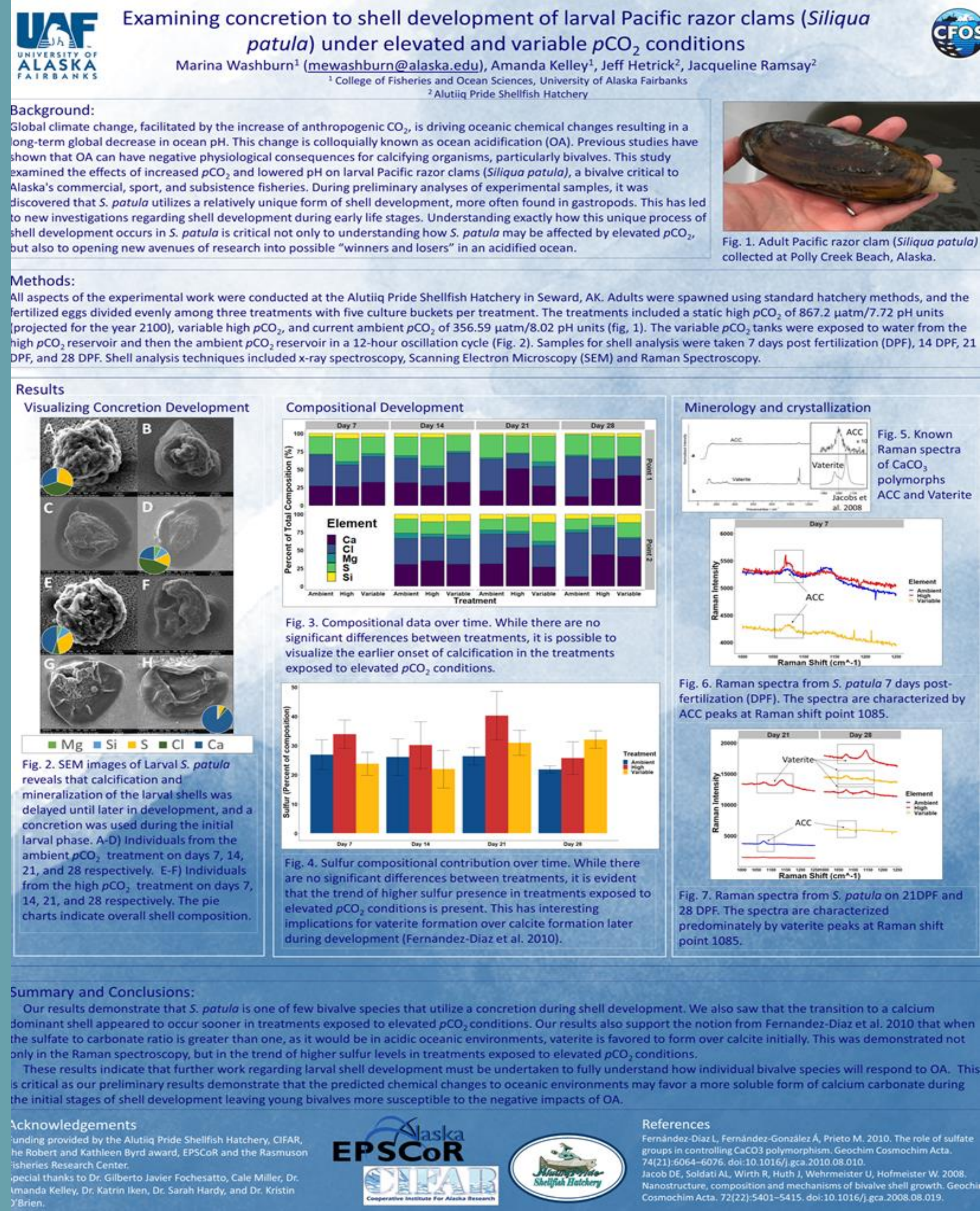


Examining concretion to shell development of larval Pacific razor clams *(Siliqua patula)* under elevated and variable *p*C02 conditions

Marina Washburn[1] (mewashburn@alaska.edu), Amanda Kelley[1], Jeff Hetrick[2], Jacqueline Ramsay[2]

[1] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks

[2] Alutiiq Pride Shellfish Hatchery



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CFOS

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Background:

Global climate change, facilitated by the increase of anthropogenic CO_2, is driving oceanic chemical changes resulting in a long-term global decrease in ocean pH. This change is colloquially known as ocean acidification (OA). Previous studies have shown that OA can have negative physiological consequences for calcifying organisms, particularly bivalves. This study examined the effects of increased pCO_2 and lowered pH on larval Pacific razor clams (*Siliqua patula)*, a bivalve critical to Alaska's commercial, sport, and subsistence fisheries. During preliminary analyses of experimental samples, it was discovered that *S. patula* utilizes a relatively unique form of shell development, more often found in gastropods. This has led to new investigations regarding shell development during early life stages. Understanding exactly how this unique process of shell development occurs in *S. patula* is critical not only to understanding how *S. patula* may be affected by elevated pCO_2, but also to opening new avenues of research into possible "winners and losers" in an acidified ocean.

Fig. 1. Adult Pacific razor clam (*Siliqua patula*) collected at Polly Creek Beach, Alaska.

Methods:

All aspects of the experimental work were conducted at the Alutiiq Pride Shellfish Hatchery in Seward, AK. Adults were spawned using standard hatchery methods, and the fertilized eggs divided evenly among three treatments with five culture buckets per treatment. The treatments included a static high pCO_2 of 867.2 µatm/7.72 pH units (projected for the year 2100), variable high pCO_2, and current ambient pCO_2 of 356.59 µatm/8.02 pH units (fig, 1). The variable pCO_2 tanks were exposed to water from the high pCO_2 reservoir and then the ambient pCO_2 reservoir in a 12-hour oscillation cycle (Fig. 2). Samples for shell analysis were taken 7 days post fertilization (DPF), 14 DPF, 21 DPF, and 28 DPF. Shell analysis techniques included x-ray spectroscopy, Scanning Electron Microscopy (SEM) and Raman Spectroscopy.

Results

Visualizing Concretion Development

A B C D E F G H

Mg Si S Cl Ca

Fig. 2. SEM images of Larval *S. patula* reveals that calcification and mineralization of the larval shells was delayed until later in development, and a concretion was used during the initial larval phase. A-D) Individuals from the ambient pCO_2 treatment on days 7, 14, 21, and 28 respectively. E-F) Individuals from the high pCO_2 treatment on days 7, 14, 21, and 28 respectively. The pie charts indicate overall shell composition.

Compositional Development

Day 7 Day 14 Day 21 Day 28

Percent of Total Composition (%)

Element: Ca, Cl, Mg, S, Si

Point 1 Point 2

Ambient High Variable

Treatment

Fig. 3. Compositional data over time. While there are no significant differences between treatments, it is possible to visualize the earlier onset of calcification in the treatments exposed to elevated pCO_2 conditions.

Sulfur (Percent of composition)

Treatment: Ambient, High, Variable

Day 7 Day 14 Day 21 Day 28

Fig. 4. Sulfur compositional contribution over time. While there are no significant differences between treatments, it is evident that the trend of higher sulfur presence in treatments exposed to elevated pCO_2 conditions is present. This has interesting implications for vaterite formation over calcite formation later during development (Fernandez-Diaz et al. 2010).

Minerology and crystallization

ACC Vaterite Jacobs et al. 2008

Fig. 5. Known Raman spectra of $CaCO_3$ polymorphs ACC and Vaterite

Day 7

Raman Intensity

ACC

Raman Shift (cm^-1)

Element: Ambient, High, Variable

Fig. 6. Raman spectra from *S. patula* 7 days post-fertilization (DPF). The spectra are characterized by ACC peaks at Raman shift point 1085.

Day 21 Day 28

Vaterite

ACC

Raman Intensity

Raman Shift (cm^-1)

Element: Ambient, High, Variable

Fig. 7. Raman spectra from *S. patula* on 21DPF and 28 DPF. The spectra are characterized predominately by vaterite peaks at Raman shift point 1085.

Summary and Conclusions:

Our results demonstrate that *S. patula* is one of few bivalve species that utilize a concretion during shell development. We also saw that the transition to a calcium dominant shell appeared to occur sooner in treatments exposed to elevated pCO_2 conditions. Our results also support the notion from Fernandez-Diaz et al. 2010 that when the sulfate to carbonate ratio is greater than one, as it would be in acidic oceanic environments, vaterite is favored to form over calcite initially. This was demonstrated not only in the Raman spectroscopy, but in the trend of higher sulfur levels in treatments exposed to elevated pCO_2 conditions.

These results indicate that further work regarding larval shell development must be undertaken to fully understand how individual bivalve species will respond to OA. This is critical as our preliminary results demonstrate that the predicted chemical changes to oceanic environments may favor a more soluble form of calcium carbonate during the initial stages of shell development leaving young bivalves more susceptible to the negative impacts of OA.

Acknowledgements

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Alaska EPSCoR CIFAR Cooperative Institute For Alaska Research Alutiiq Pride Shellfish Hatchery

References

Fernández-Díaz L, Fernández-González Á, Prieto M. 2010. The role of sulfate groups in controlling CaCO3 polymorphism. Geochim Cosmochim Acta. 74(21):6064–6076. doi:10.1016/j.gca.2010.08.010.

Jacob DE, Soldati AL, Wirth R, Huth J, Wehrmeister U, Hofmeister W. 2008. Nanostructure, composition and mechanisms of bivalve shell growth. Geochim Cosmochim Acta. 72(22):5401–5415. doi:10.1016/j.gca.2008.08.019.

Examining the effects of ocean acidification on a native Alaskan bivalve *Saxidomus gigantea*, the butter clam

Amanda L. Kelley, Cale A. Miller- Ocean Acidification Research Center, University of Alaska Fairbanks

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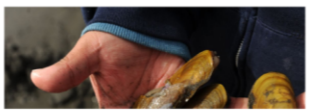
Introduction:

- Very little experimental work exists that characterizes the response of native Alaskan bivalves to conditions of ocean acidification or other anthropogenic stressors (increased temperature, hypoxia)
- Target species: *Saxidomus gigantea*, the butter clam, juvenile stage, ~5 months old, 3mm wide
- Important subsistence species for Alaska Natives and a recreational harvest species of interest
- Primarily used for 'clam chowder'
- Alaska clam populations are shrinking, with no known cause. Below, Alaska Dispatch News

Outdoors/Adventure
Clamming shut down again on Kenai Peninsula beaches 12/29/2016



- Preliminary ocean acidification experiment: Collaboration with UAF, Alutiiq Pride Shellfish Hatchery and the Hakai Institute, carried out September – October 2016 in Seward, Alaska

Research Question:

How will juvenile butter clams respond to ocean acidification?

Measurement variables:

- Calcification/growth/elemental analysis
- Cellular hallmarks of environmental stress

Approach:

- Juvenile butter clams (3mm) were reared in ambient and acidified conditions for 14 days
- Samples collection: day 1, 3, 5, 7,10 and 14
  - SEM, elemental analysis, molecular assays
  - Carbonate chemistry: Burke-o-Lator

Materials and Methods:

Target carbonate chemistry values based on previous Burk-O-Later measurements:

Ambient: 450 pCO_2; pH 7.97; Omega 1.7

IPCC prediction year 2100, RCP 8.5, -0.3 pH units
'Future scenario' Business as usual

Treatment: 1100 pCO_2; pH 7.67; Omega 0.86

5 replicate culture containers (n=5)

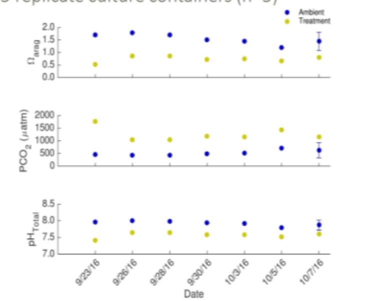


Figure 1 Carbonate chemistry parameters measured every 48 hours using Burke-o-Lator: (top) aragonite saturation state; (middle) µatm pCO_2; (bottom) pH; over two week experiment, error bars std.

Measured carbonate chemistry values:

Parameters:	pCO_2	DIC	TA	pH	Omega
Ambient (blue)	522.28	1895.21	2022.34	7.92	1.54
Treatment (yellow)	1247.80	2001.53	2023.61	7.57	0.74

Results:

Shell dissolution:

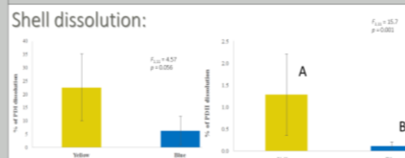


Figure 2 Area of dissolution expressed as a percent of total area of PDI (left) and PDII (right) (t-test). Yellow bars are the shells in acidified conditions and blue bars are shells in ambient conditions, 14 days. Error bars- std (n=5).

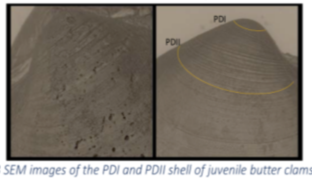


Figure 3 SEM images of the PDI and PDII shell of juvenile butter clams under acidified (left) and non-acidified (right) conditions.

Results continued:

Shell growth:

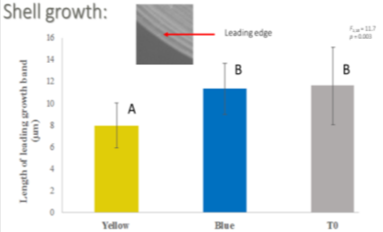


Figure 4 Length in microns of leading growth band at day 14 for juvenile butter clams reared in acidified (yellow) and non-acidified water (blue) (ANOVA). *Gray bar is the length of leading growth band at day zero, before exposed to treatments. Error bars are std,* (n=5).

Energy-dispersive X-ray spectroscopy

Component		Conc.	Units
Al_2O_3	Calc	1.761	wt.%
SiO_2	Calc	0.274	wt.%
K_2O	Calc	0.000	wt.%
CaO	Calc	87.217	wt.%
TiO_2	Calc	5.596	wt.%
Fe_2O_3	Calc	5.153	wt.%
		100.0	wt.%

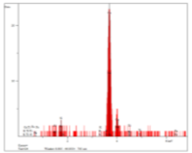
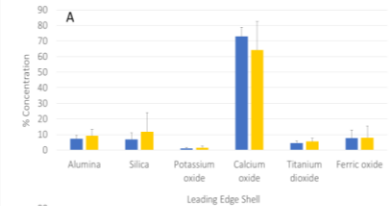


Figure 5 Example of shell constituents from shells sampled on day 14, expressed as % weight (left), histogram of shell elemental make-up (right).



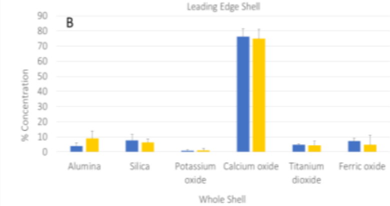


Figure 6 Mean and std shell constituents, blue- ambient, yellow- acidified conditions. (A) Leading band constituents. (B) Whole shell constituents. t-Test found no significant differences between ambient and treatment after 14 days

Future Work:

Conduct similar ecophysiological studies on other important native bivalve species~ *Clinocardium nuttallii* (Cockle), *Protothaca stamineais* (Little Neck Clams), February 2017.

Port Graham, Alaska

Thank you!

Jeff Hetrick

Director

Alutiiq Pride Shellfish Hatchery

jjh@seward.net

(C) 907-362-2378

alutiiqpridehatchery.com