Alaska Ocean Acidification Network update

Alaska Fisheries Science Center

Robert Foy, Darcy Dugan, Jessica Cross, Chris Long, Kathy Swiney, Tom Hurst

Alaska Ocean Acidification Network

AOOS
Alaska Ocean Observing System

Connecting Scientists and Stakeholders

The mission of the Alaska Ocean Acidification Network is to engage with scientists and stakeholders to expand the understanding of OA processes and consequences in Alaska, as well as potential adaptation strategies.

Activities:

- Provide relevant information to, and hear from, the fishing and aquaculture industries, policy makers, Tribes, coastal communities and the general public with regard to OA.
- Work with scientists and stakeholder communities to identify knowledge gaps and information needs, and recommend regional priorities for monitoring, research & modeling in both the natural and social sciences.
- Share best practices for monitoring as well as promote the development of synthesis materials, and devise strategies to ensure funding is available to support these efforts.
- Promote data sharing and act as a resource hub for OA information in Alaska for researchers, stakeholders and the general public, leveraging the AOOS data portal as needed.

The network was established in 2016 and is coordinated by the Alaska Ocean Observing System.

Alaska Ocean Acidification Network

AOOS
Alaska Ocean Observing System

Connecting Scientists and Stakeholders

About the Network | About OA | Monitoring | Biological Impacts | Data | Resources & Links

Alaska Ocean Acidification Network

Alaska Ocean Acidification 'State of the Science' workshops delivers latest findings

The Alaska Ocean Acidification Network hosted a workshop in Anchorage on Nov 30-Dec 1, inviting a broad audience to discuss the latest monitoring, research, impacts to species, and ideas for community engagement.

1 2 3 4

Alaska Ocean Acidification Network News Features archive

Scientist Interview

Meet Jeff Hetrick, the director of the Alutiiq Pride Shellfish Hatchery in Seward. Jeff has 30 years of experience in the Alaska aquaculture industry and formerly operated a shellfish farm in Prince William Sound. He has been the director of Alutiiq

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News feed

NOVEMBER 7, 2016

A Swell to Quell the Dissolution of Sh

This article describes 5 ways the Hak
ocean acidification in the North Pacifi
Network is involved in several of thes
O-Lators to a new ferry project.

OCTOBER 4, 2016

Ocean Acidification Kiosk to move to

An interactive kiosk, aimed at commu
ocean acidification to residents and v
coastal communities, is about to mov

SEPTEMBER 28, 2016

Why the EPA Doesn't Regulate Ocean

The Center for Biological Diversity re
over regulating OA under the Clean V
in the Atlantic explains why the EPA d

Network Coordinator: Darcy Dugan, Alaska Ocean Observing System

- **Shallin Busch** (NOAA OA Program)
- **Tina Buxbaum** (AK Center for Climate Assessment & Policy)
- **Dorothy Childers** (AK Marine Conservation Council)
- **Bob Foy** (NOAA AFSC)
- **Gary Freitag** (AK Sea Grant – Ketchikan)
- **Davin Holen** (AK Center for Climate Assessment & Policy)
- **Jeff Hetrick** (Alutiiq Pride Shellfish Hatchery)
- **Tahzay Jones** (National Park Service)
- **John Kiser** (AK Shellfish Growers Assoc.)
- **Michael Kohan** (Alaska Seafood Marketing Institute)
- **Melissa Good** (AK Sea Grant – Unalaska)
- **Mia Heavener** (Alaska Native Tribal Health Consortium)
- **Mike Miller** (Sitka Tribe/IPCoMM)
- **Molly McCammon** (AOOS)
- **Natalie Monacci** and **Jeremy Mathis** (UAF OA Research Center)
- **Ruth Christiansen** (Alaska Bering Sea Crabbers)

Alaska Ocean Acidification Network

AOOS
Alaska Ocean Observing System

Fishing Community Engagement

Members: Dorothy Childers (Alaska Marine Conservation Council), Lindsey Bloom (United Fishermen of Alaska), Bob Foy (NOAA AFSC Kodiak Lab), Theresa Peterson (North Pacific Fisheries Management Council), Tyson Fick (Alaska Bering Sea Crabbers), Chris Long (NOAA AFSC Kodiak Lab), Melissa Good (Alaska Sea Grant – Dutch Harbor), Chip Treinen (United Fishermen of Alaska), Darcy Dugan (Alaska Ocean Observing System), Marc Carrell (Cordova fisherman), Clayton Hamilton (Juneau fisherman).

Provide 2-way communication with Alaska fishermen and the seafood industry on the topics of OA research, forecasts, concerns, and ideas for collaboration.

Activities

- Identify key information pathways to engage fishermen on the topic of OA
- Hold roundtable Q&A sessions with fishermen and coastal communities
- Produce tailored outreach material including brochures, info sheets, and a website Q&A page
- Discuss partnerships for research and monitoring

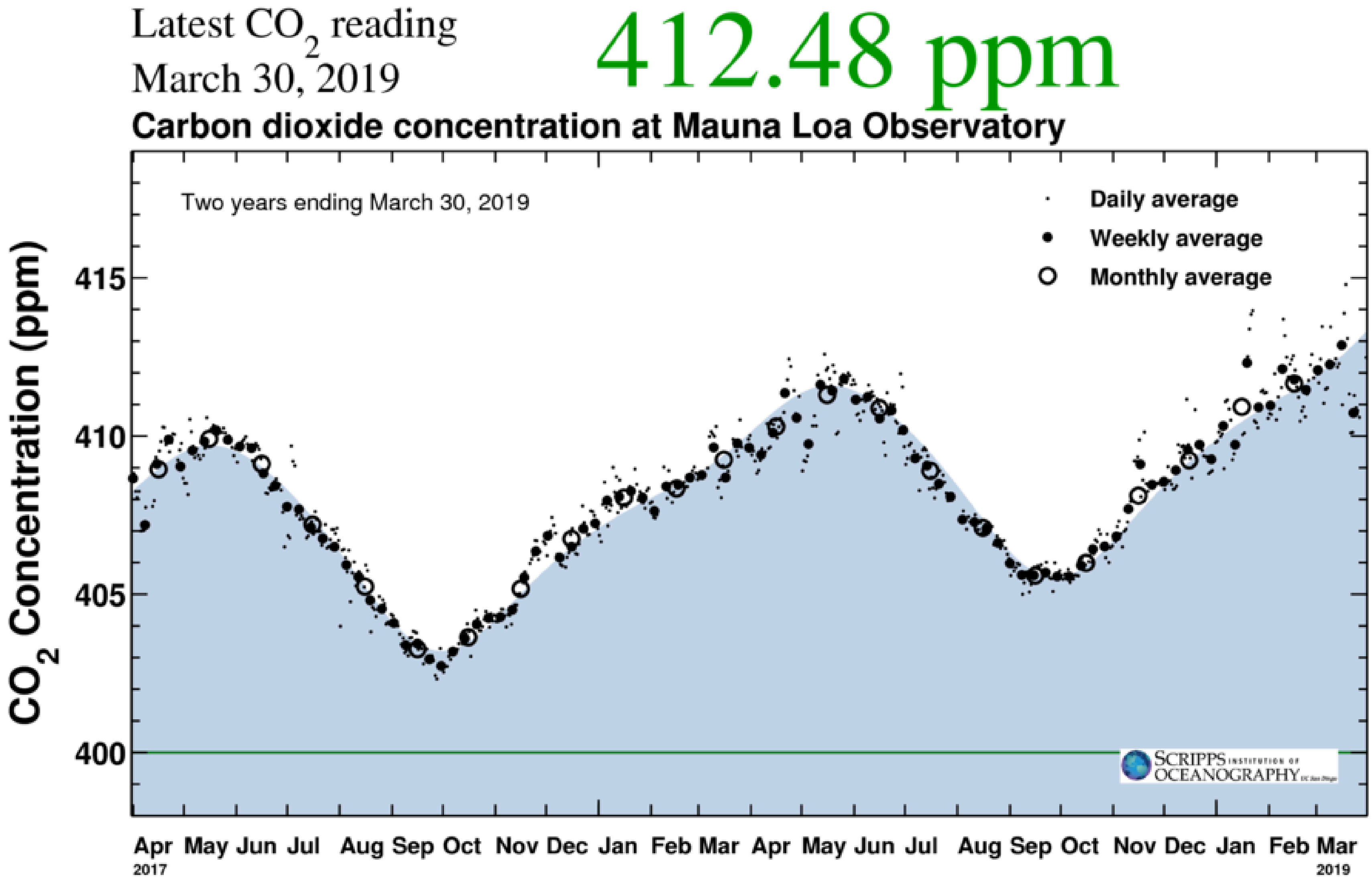
Global CO_2 Levels Continue to Rise

22 tons CO_2 every day

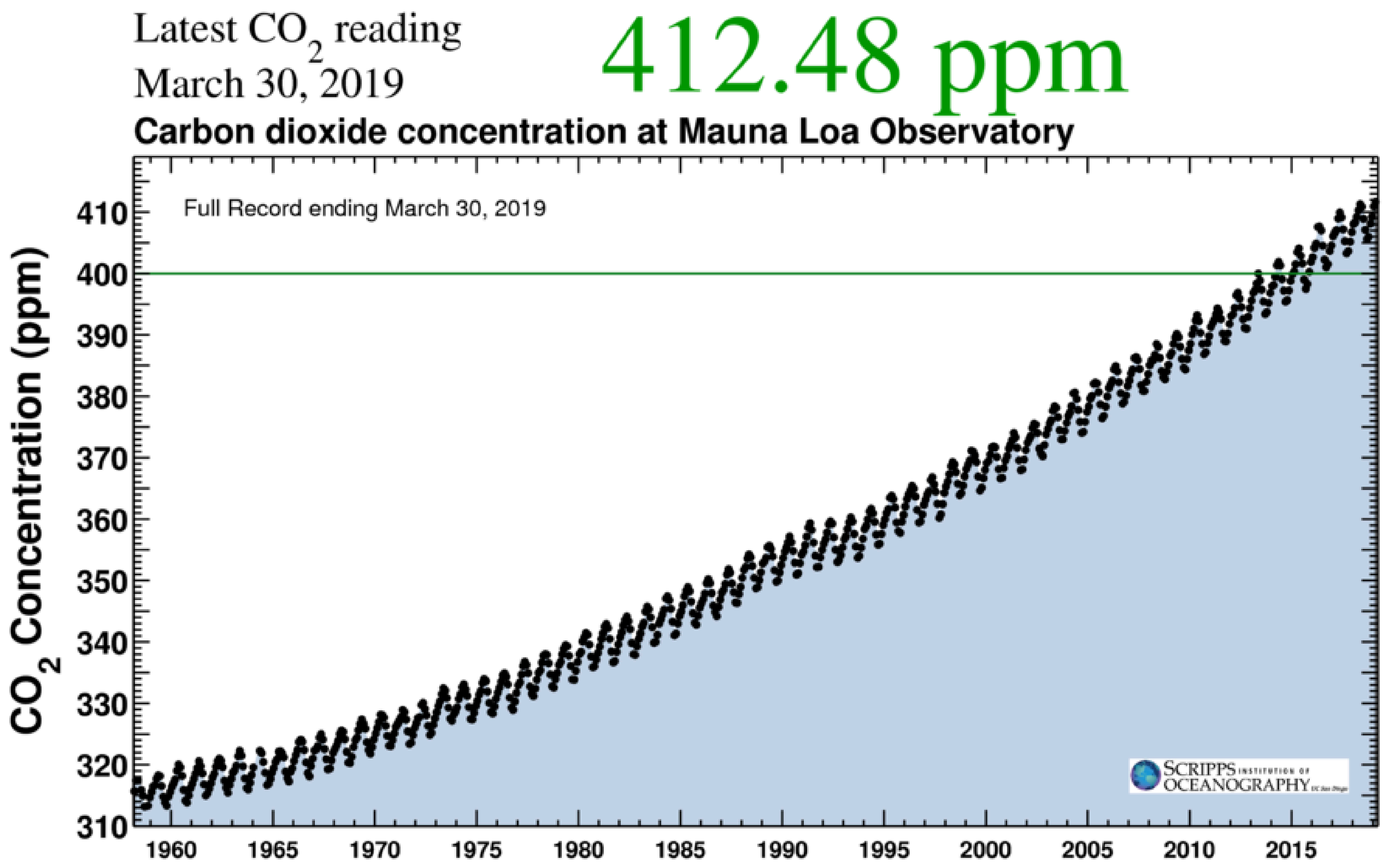
1/3 absorbed by ocean

Alaskan waters naturally high in CO_2

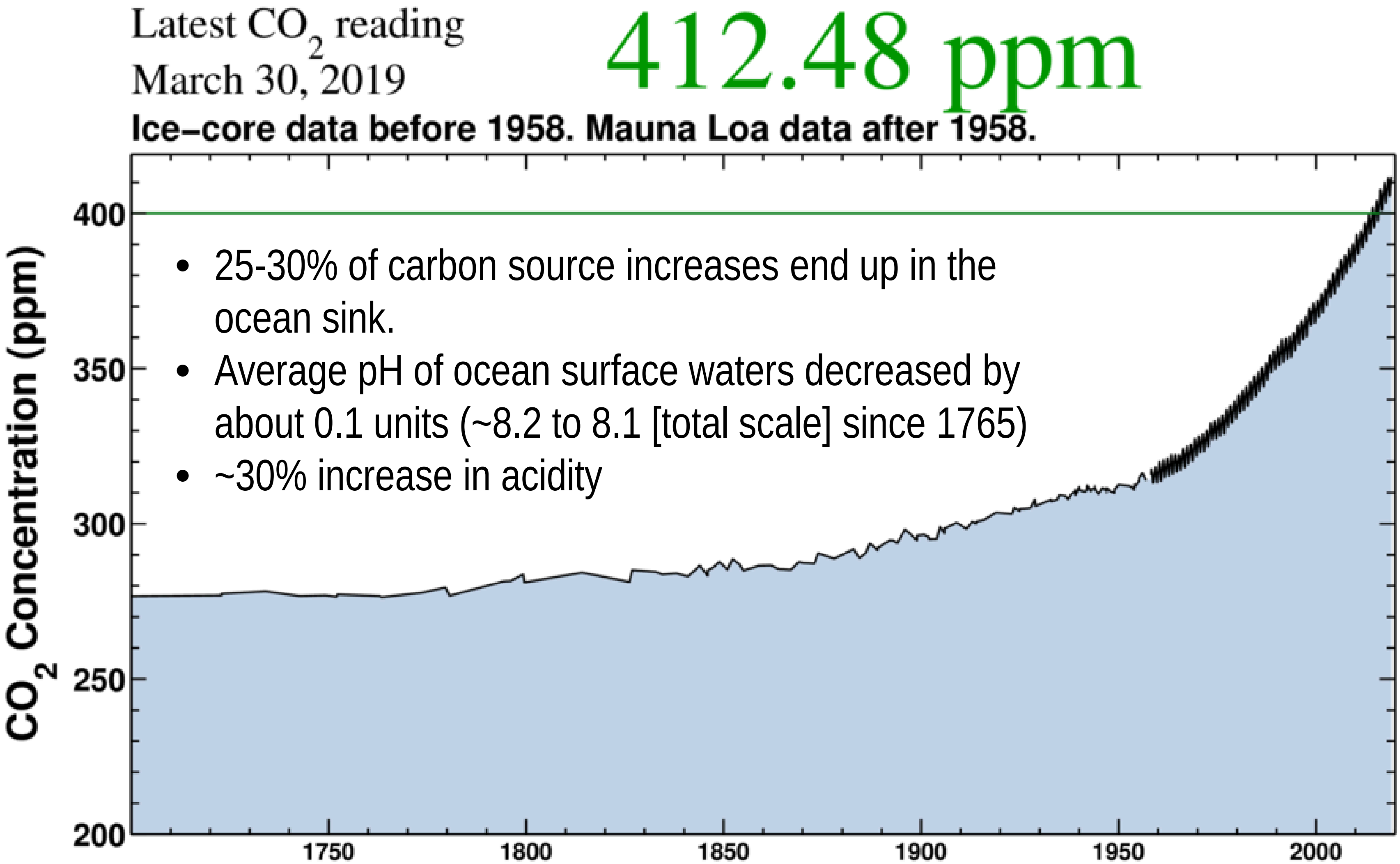
Global CO_2 Levels Continue to Rise



Global CO_2 Levels Continue to Rise

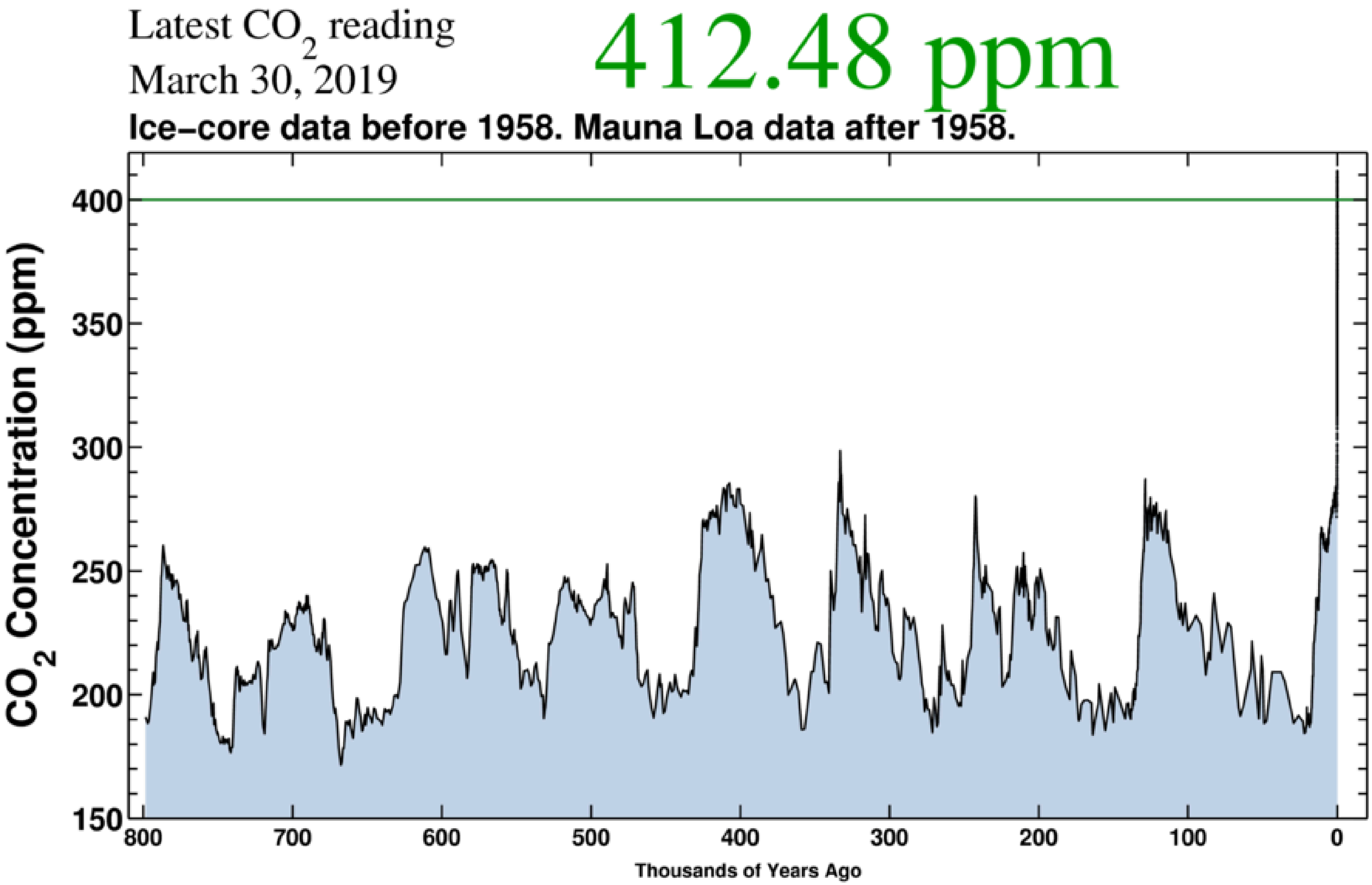


Global CO_2 Levels Continue to Rise



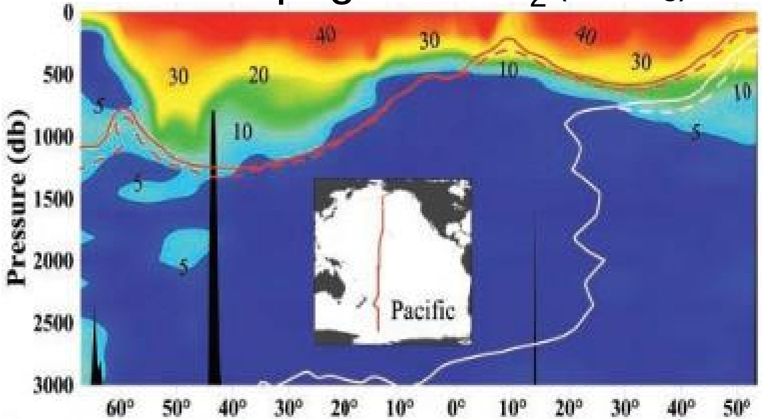
- 25-30% of carbon source increases end up in the ocean sink.
- Average pH of ocean surface waters decreased by about 0.1 units (~8.2 to 8.1 [total scale] since 1765)
- ~30% increase in acidity

Global CO_2 Levels Continue to Rise

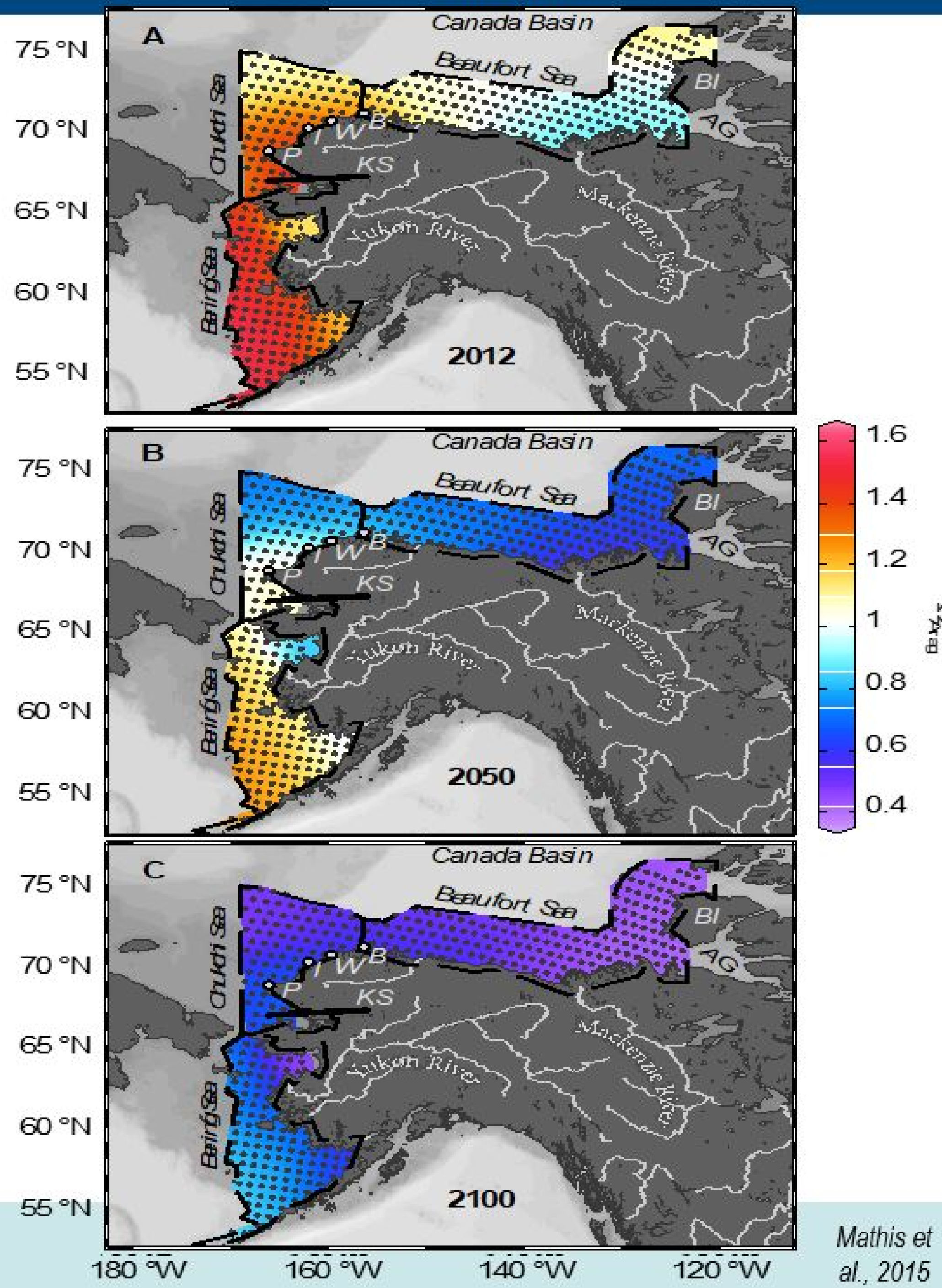


Ocean Acidification: Alaska's problem

Anthropogenic CO_2 (umol/kg)



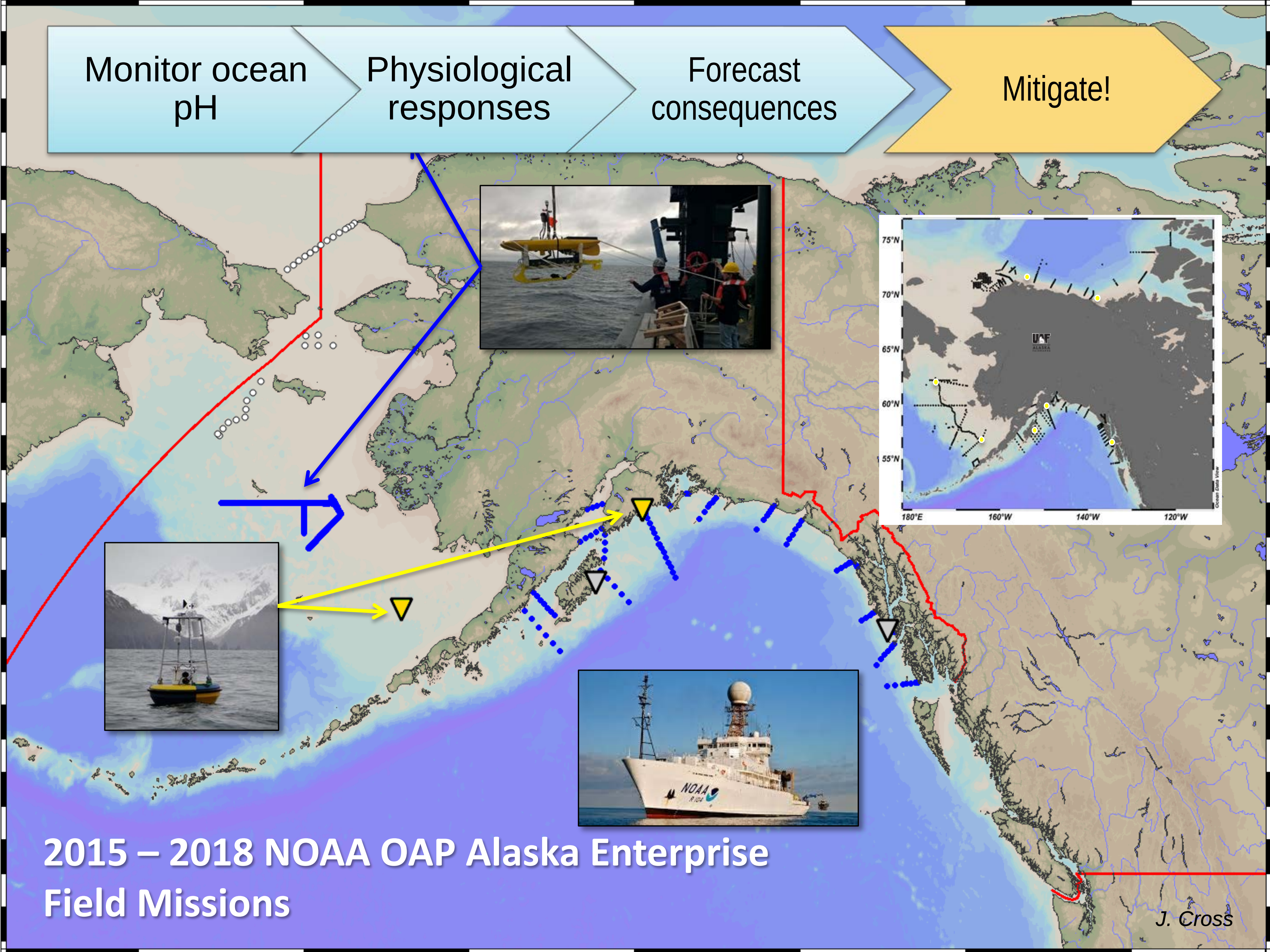
Feely et al., 2004



Mathis et al., 2015

North Pacific Ocean reductions in $CaCO_3$ saturation greater due to respiration along the deep ocean water.

Upward migration of calcite saturation horizon from 40 to100 m from pre-industrial times to the present.


Monitor ocean pH
Physiological responses
Forecast consequences
Mitigate!
75°N
70°N
65°N
60°N
55°N
180°E
160°W
140°W
120°W
NOAA
2015 – 2018 NOAA OAP Alaska Enterprise Field Missions
J. Cross

NOAA Alaska Fisheries Science Center

Research Approach—5 Large Marine Ecosystems!

Focal species groups

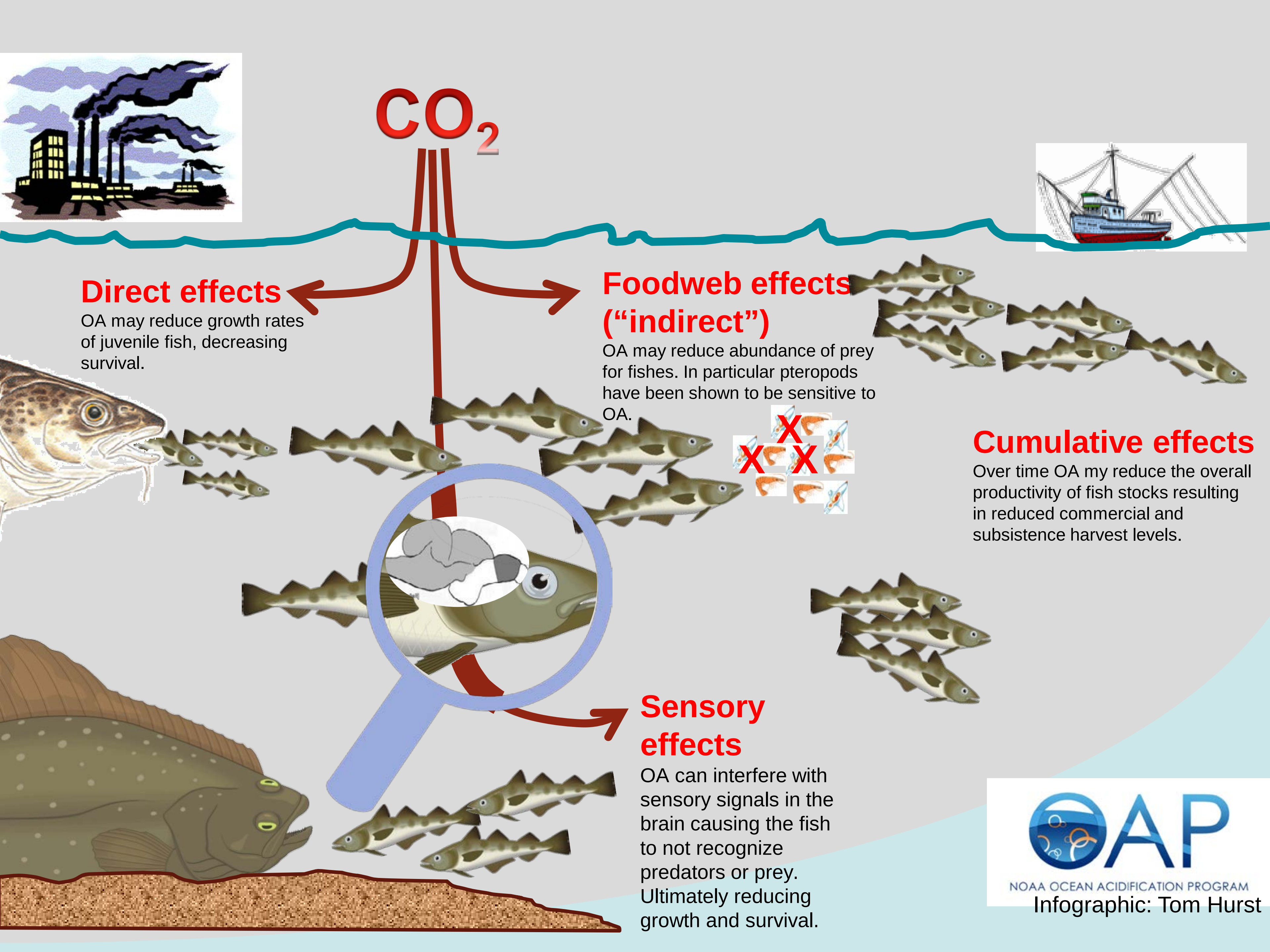
- Commercially important fish and shellfish species;
- Their prey (calcareous plankton);
- And shelter (corals).

Objectives

- Support ocean pH monitoring;
- Understand species-specific physiological responses;
- Forecast population impacts and economic consequences.

FY18-20 Assessing potential for adaptation

- Build on infrastructure and initial physiological work done from FY12-14; physiology/modeling FY15-17.
- 16 publications, 40+ presentations.



CO2
Direct effects
OA may reduce growth rates of juvenile fish, decreasing survival.
Foodweb effects ("indirect")
OA may reduce abundance of prey for fishes. In particular pteropods have been shown to be sensitive to OA.
X X X
Cumulative effects
Over time OA my reduce the overall productivity of fish stocks resulting in reduced commercial and subsistence harvest levels.
Sensory effects
OA can interfere with sensory signals in the brain causing the fish to not recognize predators or prey. Ultimately reducing growth and survival.
OAP
NOAA OCEAN ACIDIFICATION PROGRAM
Infographic: Tom Hurst

Framework to assess climate change and OA

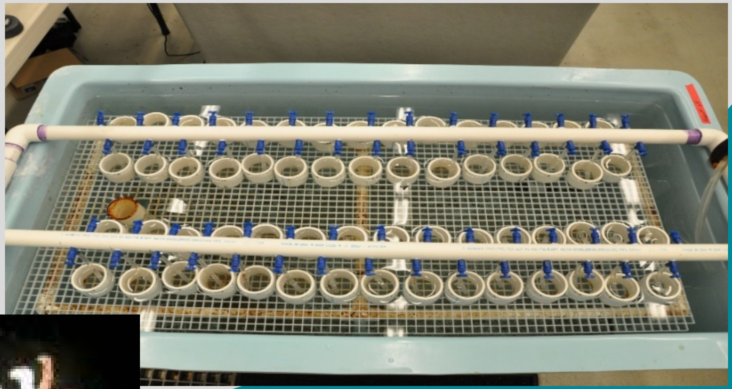
Organismal (individual tolerance), population, and ecosystem level response

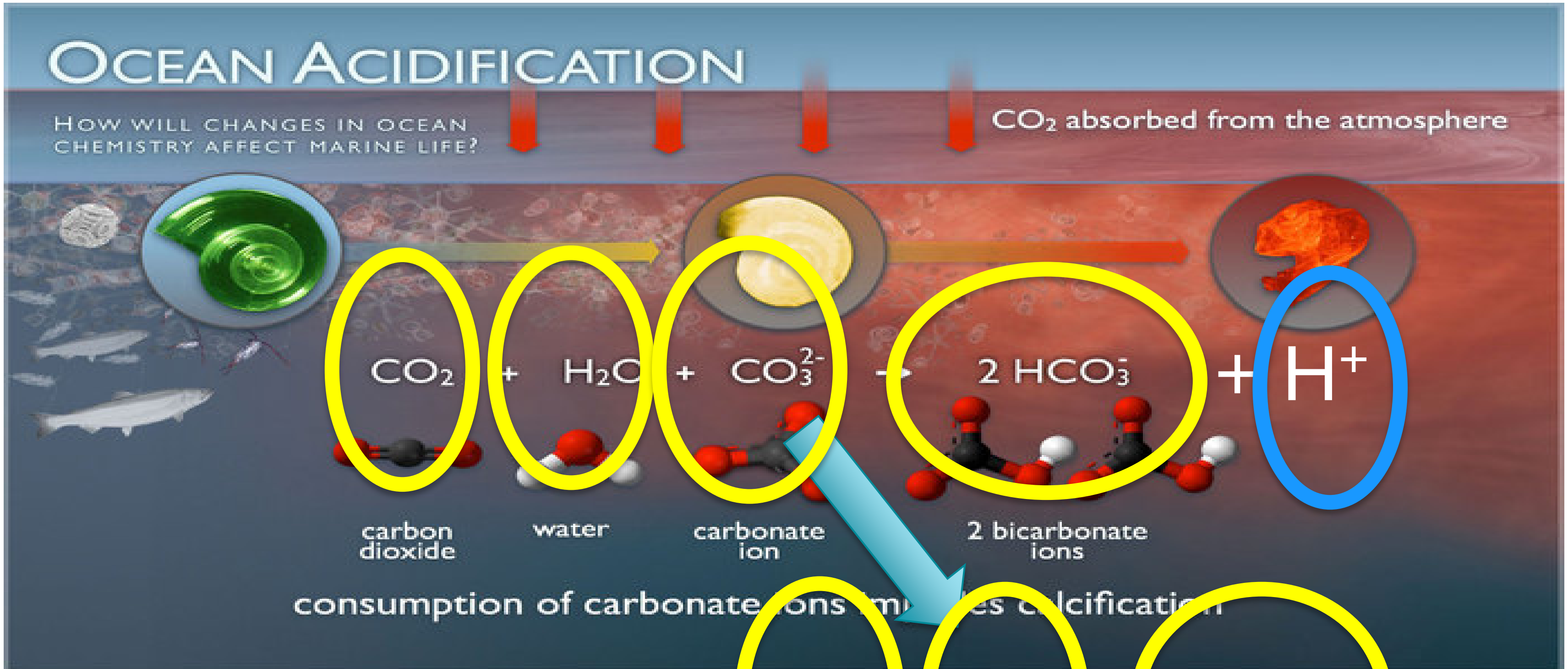
Experiments: (2010-2019)

- Red king crab
- SouthernTanner crab
- Golden king crab
- Snow crab

Life Stages: oocyte, embryo, larvae, juvenile

Response variables: Survival, fecundity, morphometrics, growth, calcification, hemocyte function, genetics (protein expression), and mechanics.





Shellfish and corals *need* carbonate (inorganic carbonate)

$$Ca^{2+} + CO_3^{2-} \leftrightarrow CaCO_3$$

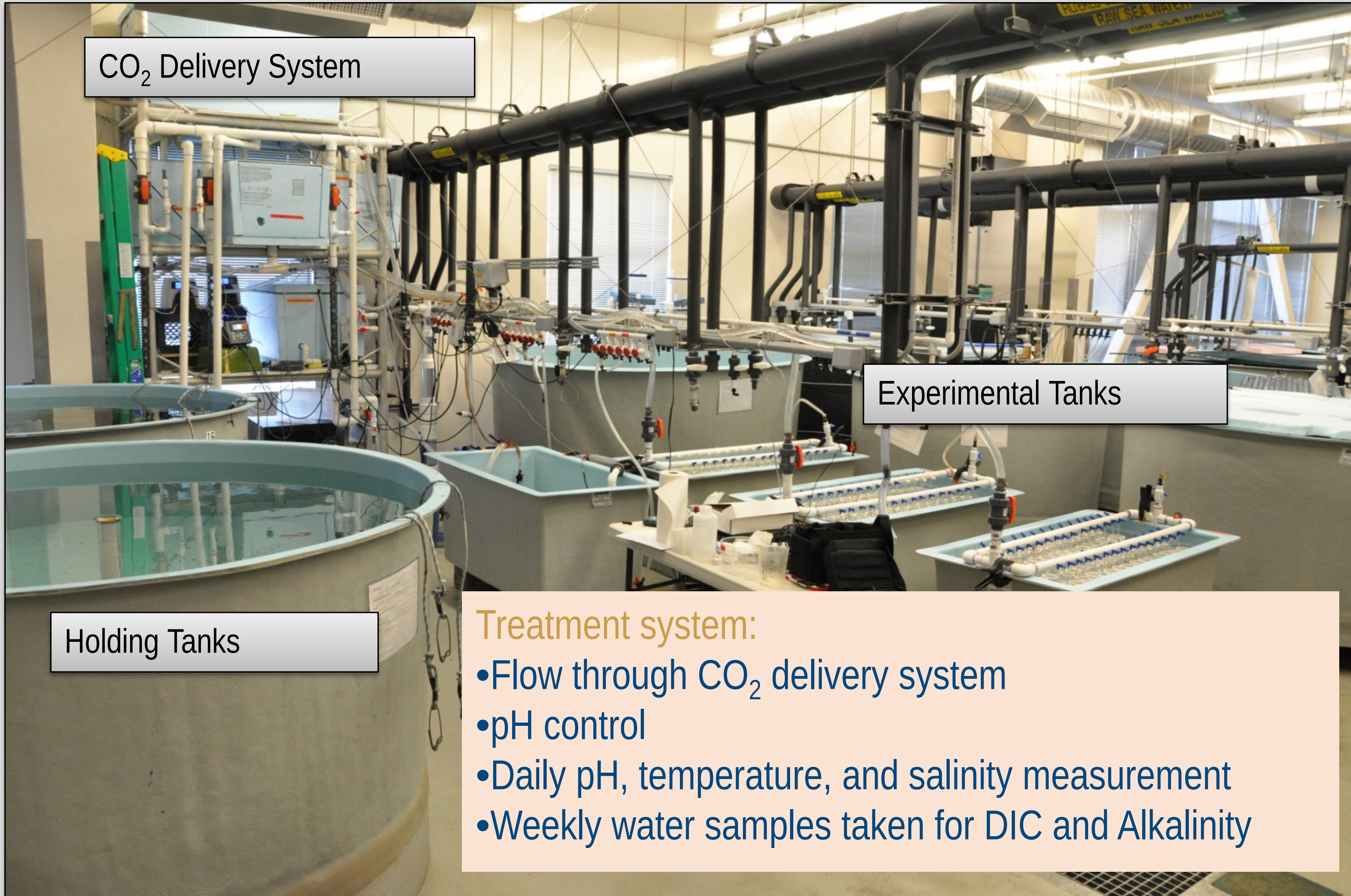
Calcium + Carbonate = Calcium Carbonate shell

Changes found in many calcifying organisms

- Changes in respiration rate
- Changes in aerobic metabolism
- Greater energy in shell maintenance
- Less energy in reproduction and growth
- Changes in stress tolerance

https://www.pmel.noaa.gov

Kodiak Ocean Acidification research laboratory

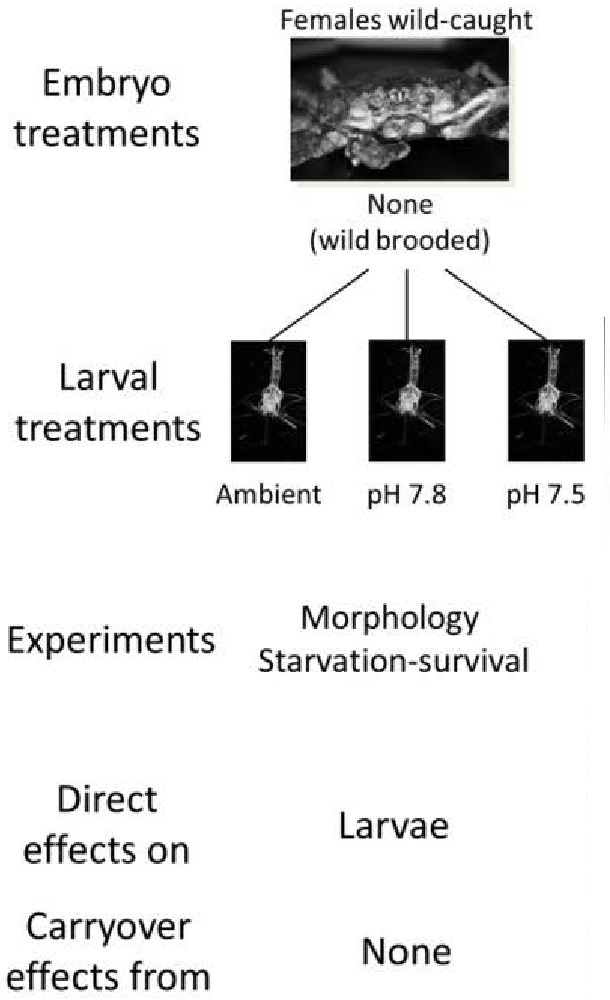


Treatment system:

- Flow through CO_2 delivery system
- pH control
- Daily pH, temperature, and salinity measurement
- Weekly water samples taken for DIC and Alkalinity

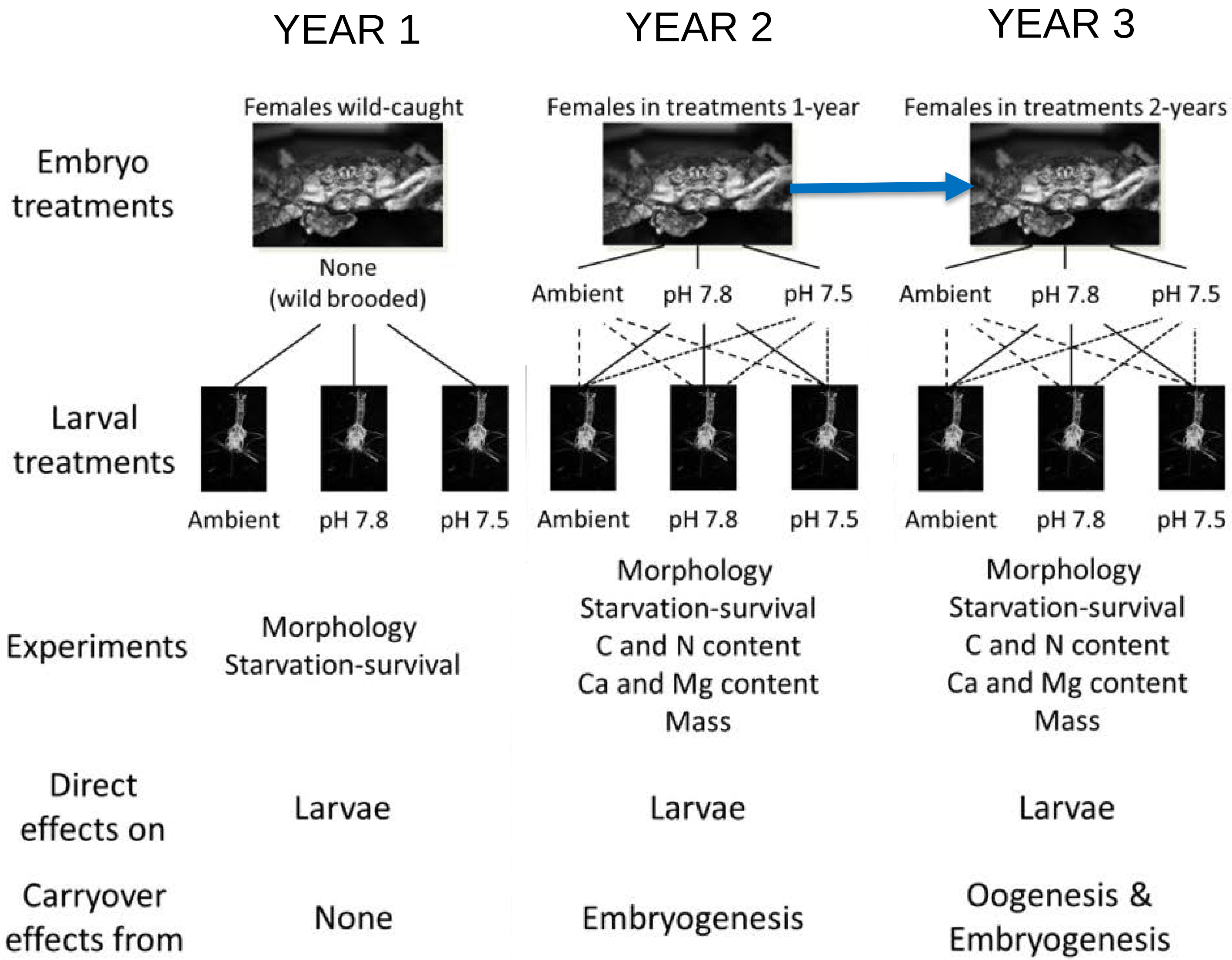
Multi-year lab experiment

YEAR 1



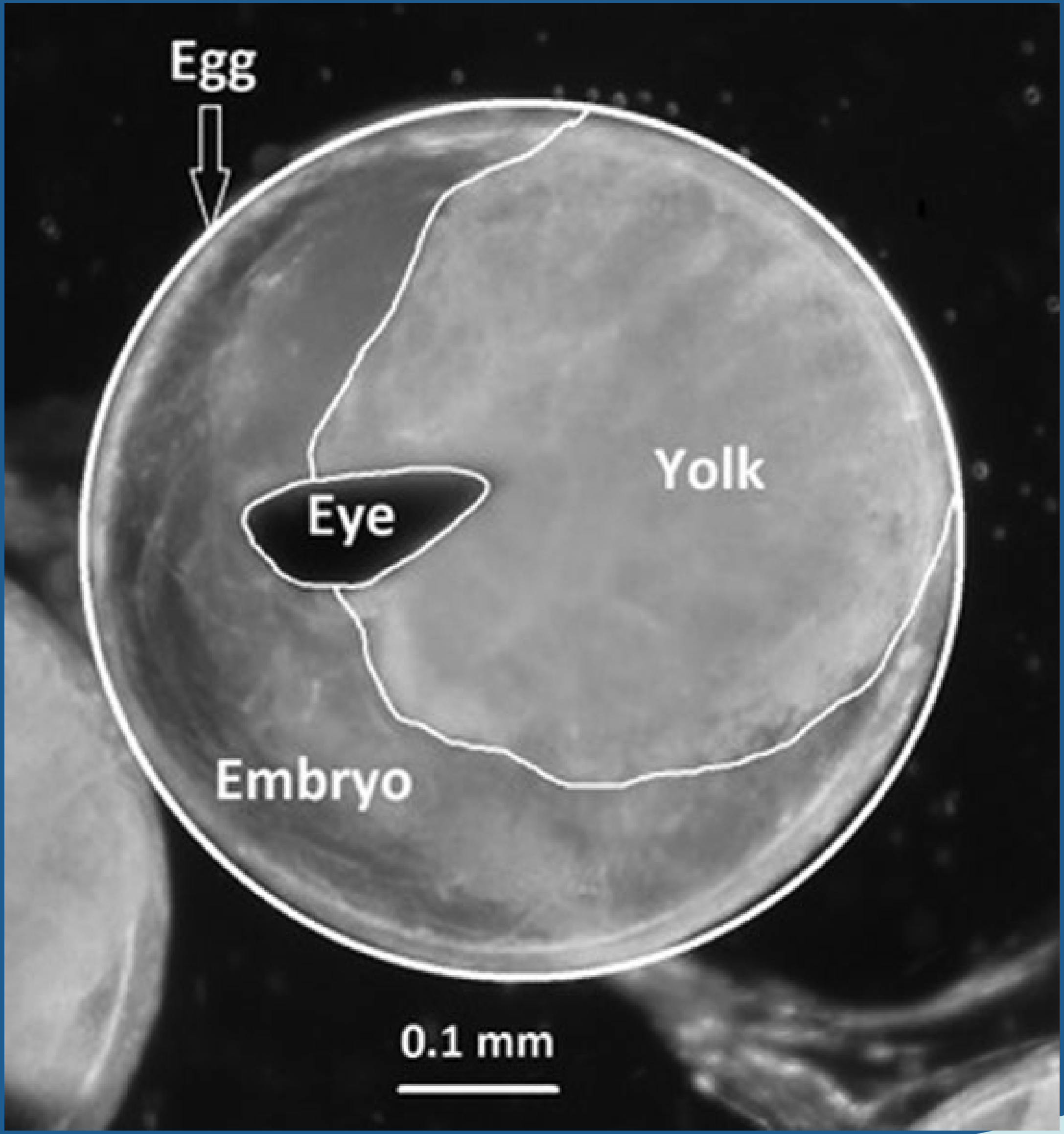
Swiney et al. 2016   *Long et al. 2016*

Multi-year lab experiment



Swiney et al. 2016 *Long et al. 2016*

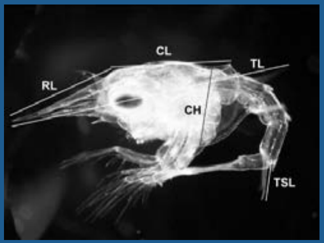
Tanner crab embryo



- pH 7.5: 10% larger yolks and 6% smaller embryos (slower development)

Tanner crab larvae hatching success

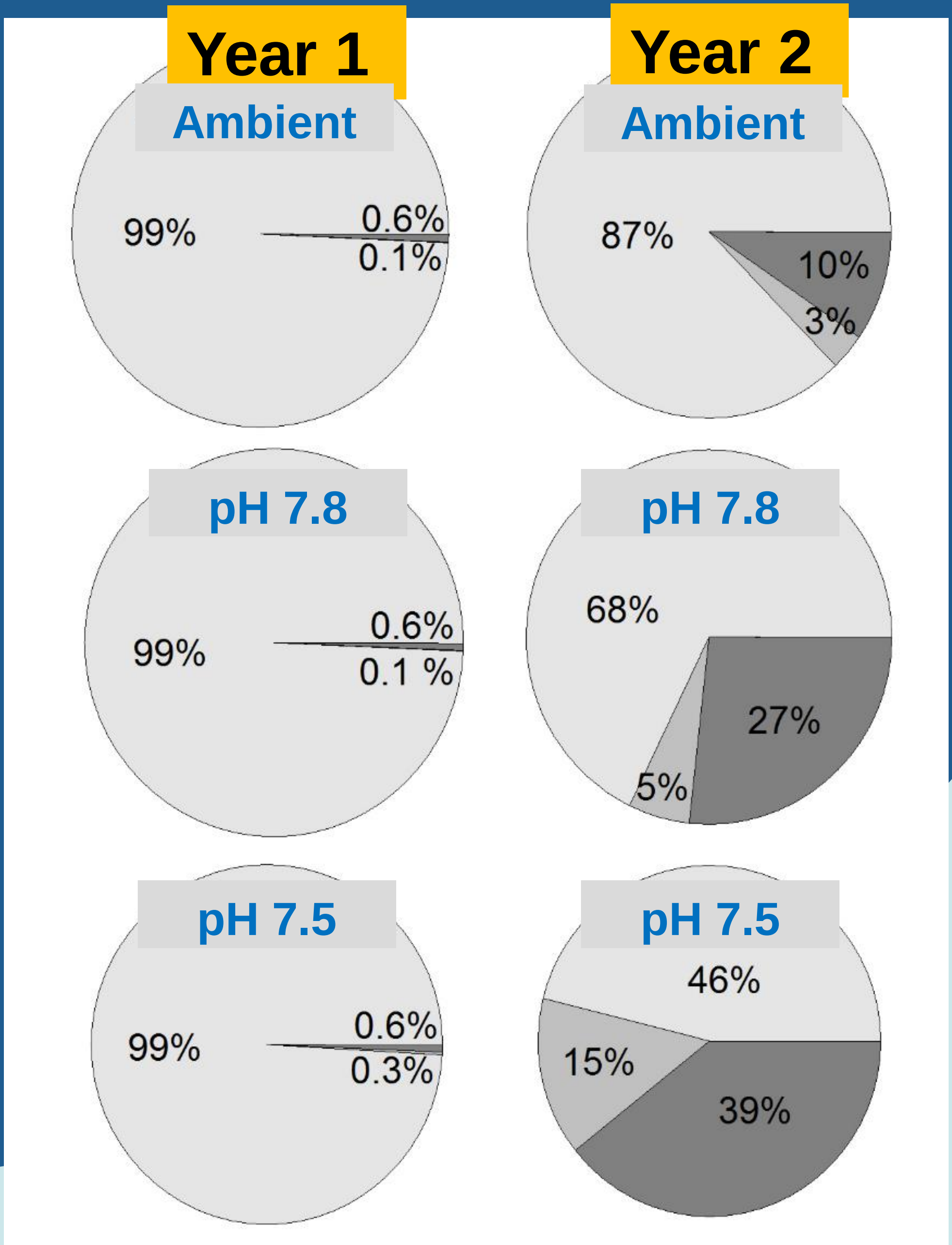
- Hatching success lower in year 2 than year 1-carryover effect
- Larvae 10% smaller in pH7.5
- Larvae that survived lived longer in year 2 (acclimation?)
  - Decreased metabolism OR higher energy reserves
- Adaptation due to variable environment?



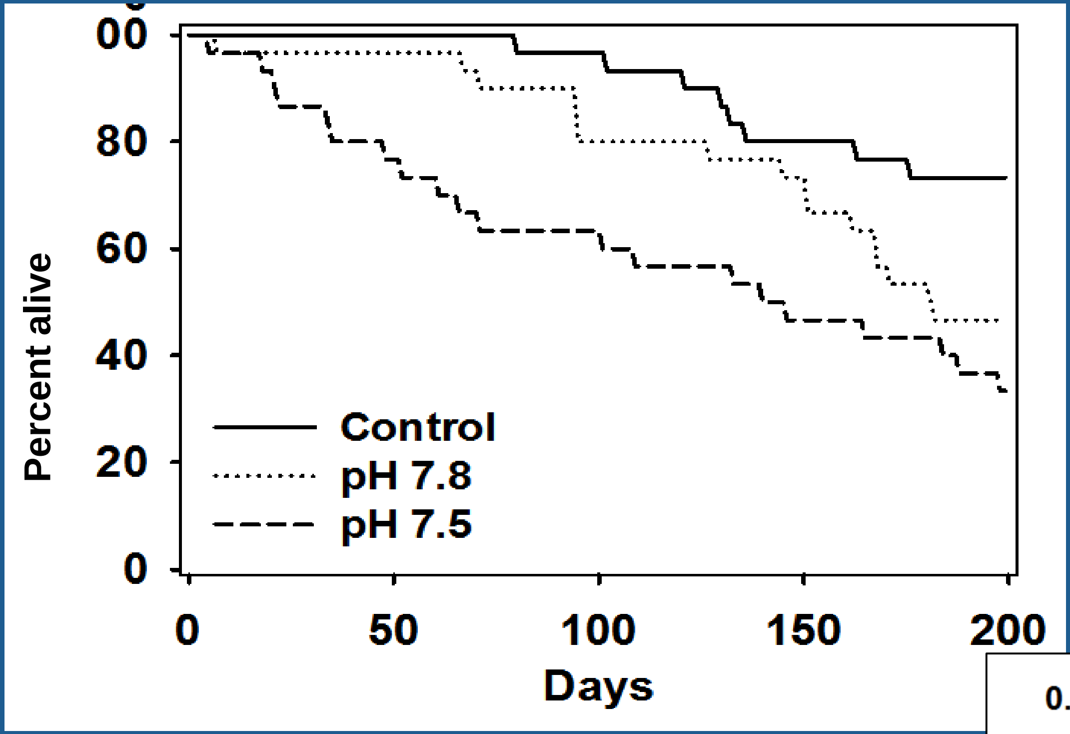
Viable larvae hatched

Non-viable hatched larvae

Eggs that did not hatch



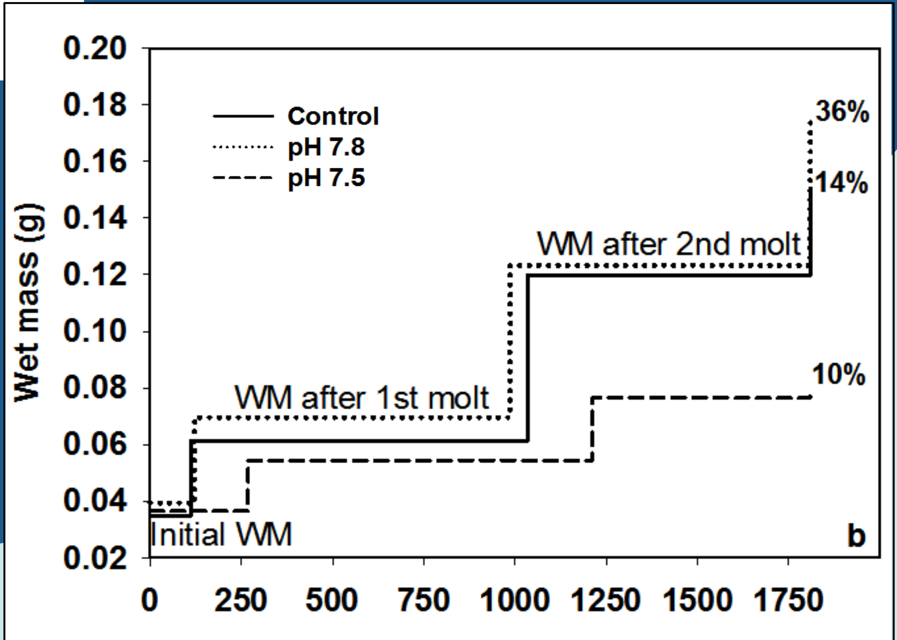
Juvenile crab mortality and growth



Juvenile stage is very susceptible to negative OA effects.

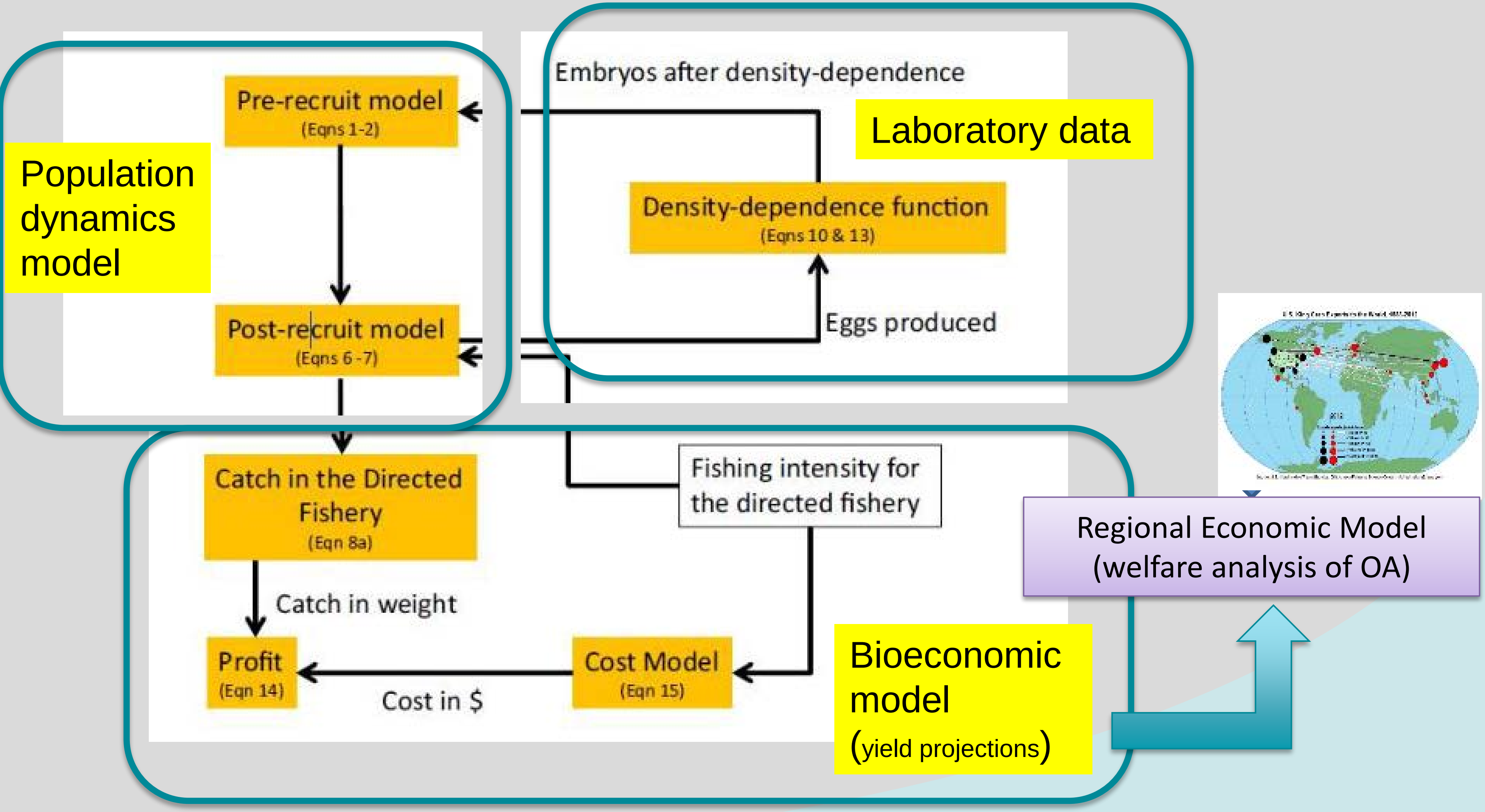
- Lower survival
- Slower growth

Energetic trade-off between condition and calcification?



Forecasting fisheries population effects

Experimental results were used to inform population and economics models



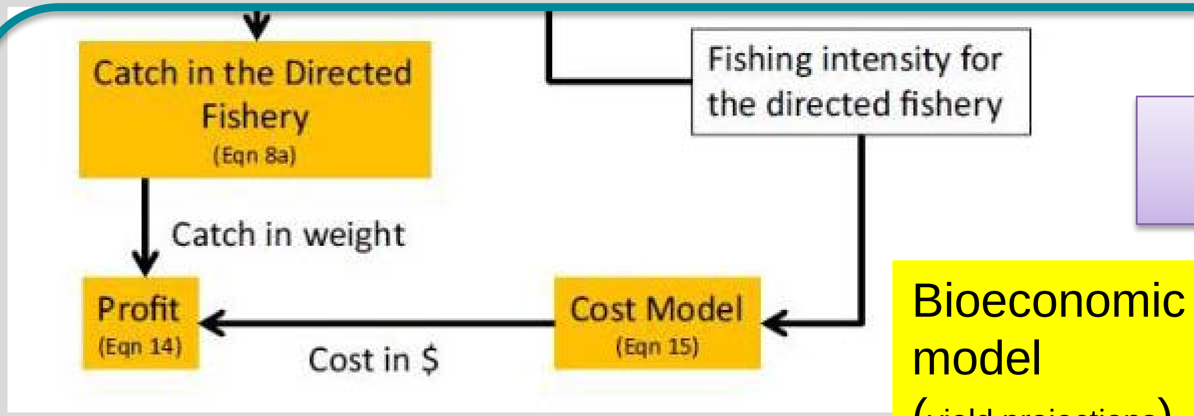
Seung et al. (2015); Punt et al. 2014 & 2016

Forecasting fisheries population effects

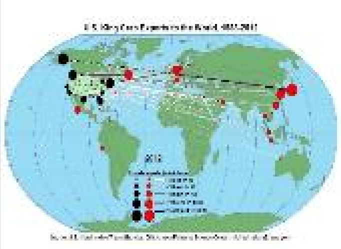
Experimental Tanner crab results were used to inform population and economics models

- Proportion larvae hatching that survive to juvenile stage C8 could decline by 25% over 100 y.
- >50% decrease in catch and profits within 20 years of EBS acidifying to 7.8
- Only significant when oocyte development is included in survival estimates
- $500 million - $1 billion welfare loss to Alaska households

Snow Crab Story Better!



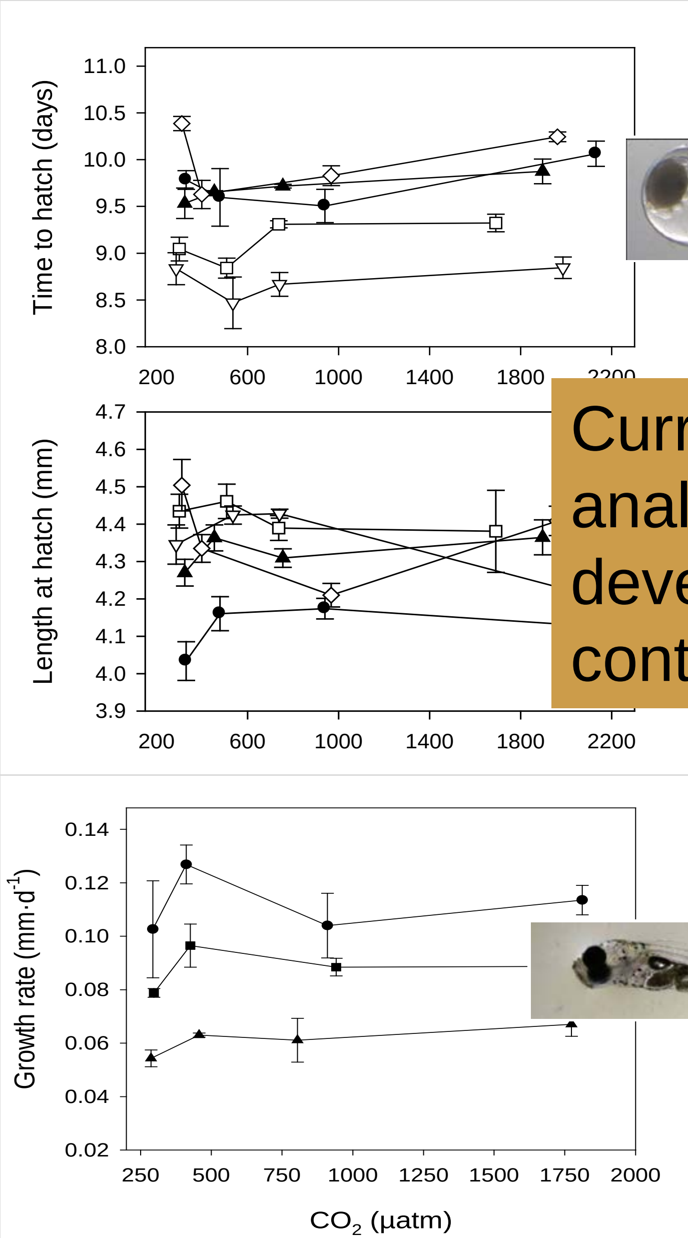
Bioeconomic model
(yield projections)



Regional Economic Model
(welfare analysis of OA)

Seung et al. (2015); Punt et al. 2014 & 2016

Pollock eggs & early larvae appear robust to OA



Hurst et al. (2013)

5 Independent batches of eggs incubated 250 to 1000 µATM CO_2

No reduction in hatch rate or size at hatch

Current: Additional analyses of organ development and energy content in larvae.

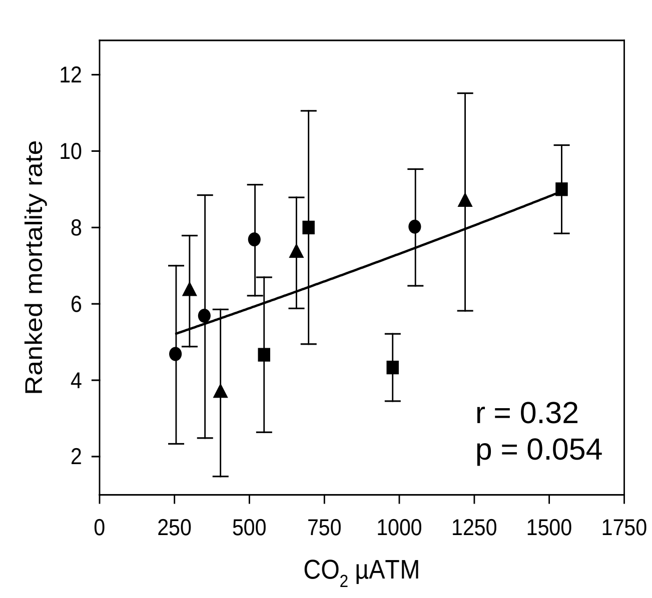
nt experiments

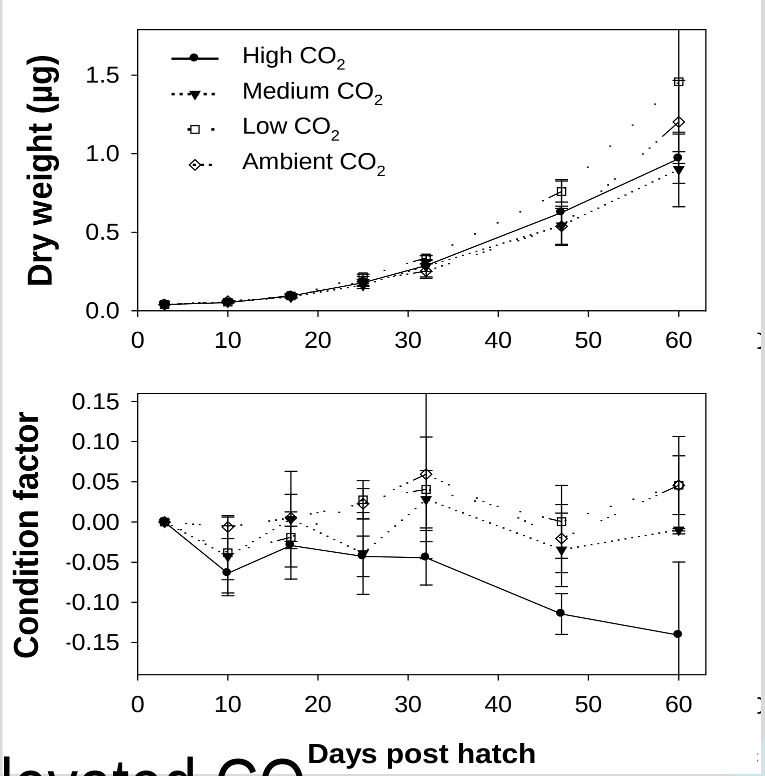
No evidence of negative effects on growth

Trend toward faster growth at slightly elevated CO_2

These effects smaller than effects of temperature

Northern rock sole appear more sensitive to OA





Trend toward higher mortality rates at elevated CO_2

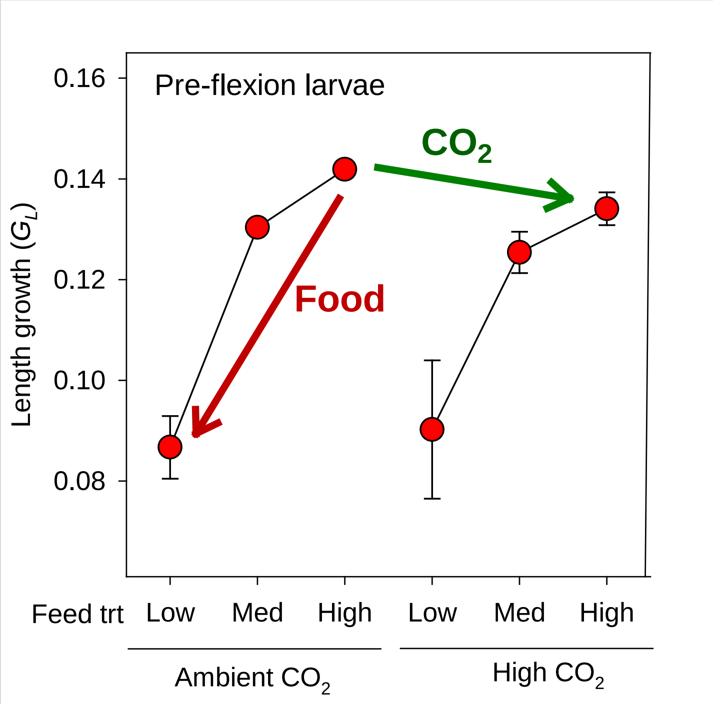
Lower growth rates and condition factors observed at high CO_2 levels.

Hurst et al. (2015)

OA Foodweb effects on rock sole

OA may cause reductions in prey availability / quality for fish.
Low prey availability may make fish more vulnerable to OA effects.

Northern rock sole larvae

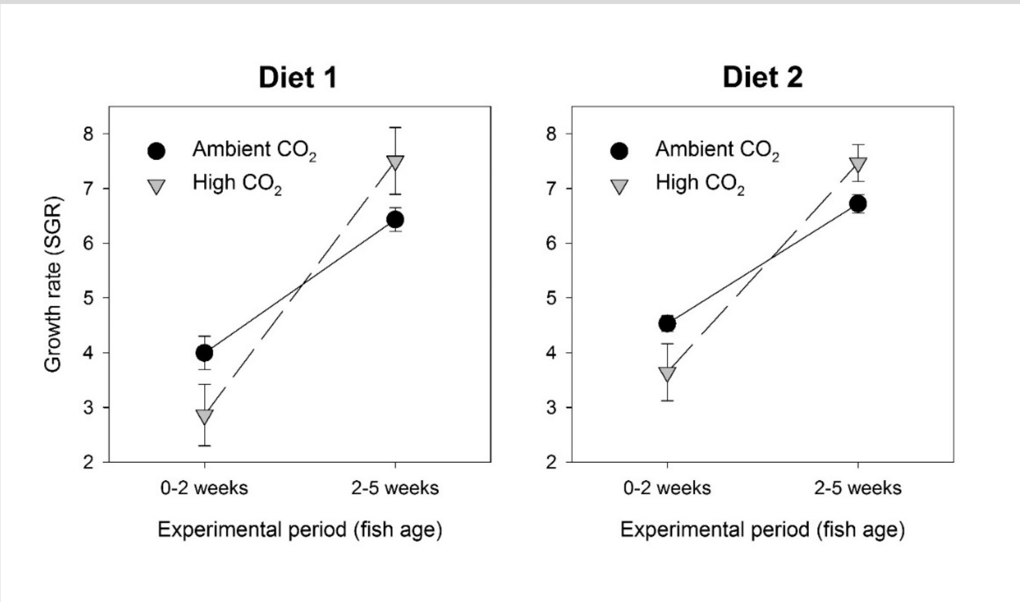


Larval growth was impacted by both OA and reduced prey availability.

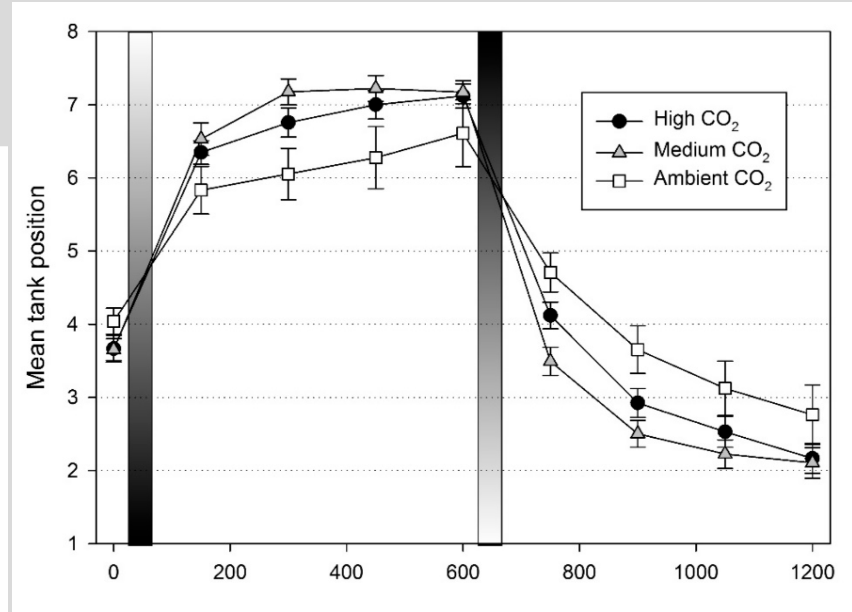
But, larvae were more sensitive to prey limitation that could be caused by OA effects on their zooplankton prey than they were to the direct effects of OA.

Hurst et al. 2016

OA effects on Pacific cod larvae - growth & behavior



OA reduced growth rates during the first 2 weeks of life, but fish compensated by 5 weeks.



High CO_2 also changed fish behavior by increasing their activity in a light gradient. This may have implications for feeding in the wild.

Hurst et al. 2019

- NOAA Ocean Acidification Program
- AOOS Ocean Acidification Network
- UAF Ocean Acidification Research Center
- Pacific Marine Environmental Lab
- Alaska Fisheries Science Center Kodiak Laboratory Research Staff

Thank you!

http://www.afsc.noaa.gov/RACE/shellfish/oceanAcid/oceanAcidCurrent_HOME.php

Ocean Acidification Research Center
AT THE UNIVERSITY OF ALASKA FAIRBANKS

AOOS Alaska Ocean Observing System

Alutiiq Pride Shellfish Hatchery

Hakai Science on the Coastal Margin

NOAA

NOAA FISHERIES

Evidence for ability to acclimate or adapt?

Effects at <u>oocyte</u> and <u>embryo</u> stage significant

Effects at <u>larval</u> stage minimal (no effect on mortality)

- Decreased metabolism?
- Larvae that survived may be acclimating?
- Adaptation due to variable environmental conditions?

Effects at <u>juvenile</u> stage significant

- Calcification vs condition tradeoff?

<u>Adult</u> crab maintain hemolymph pH

- Energy spent maintaining cell pH and immunological function…effects development during oogenesis

What's next?

Physiological Effects

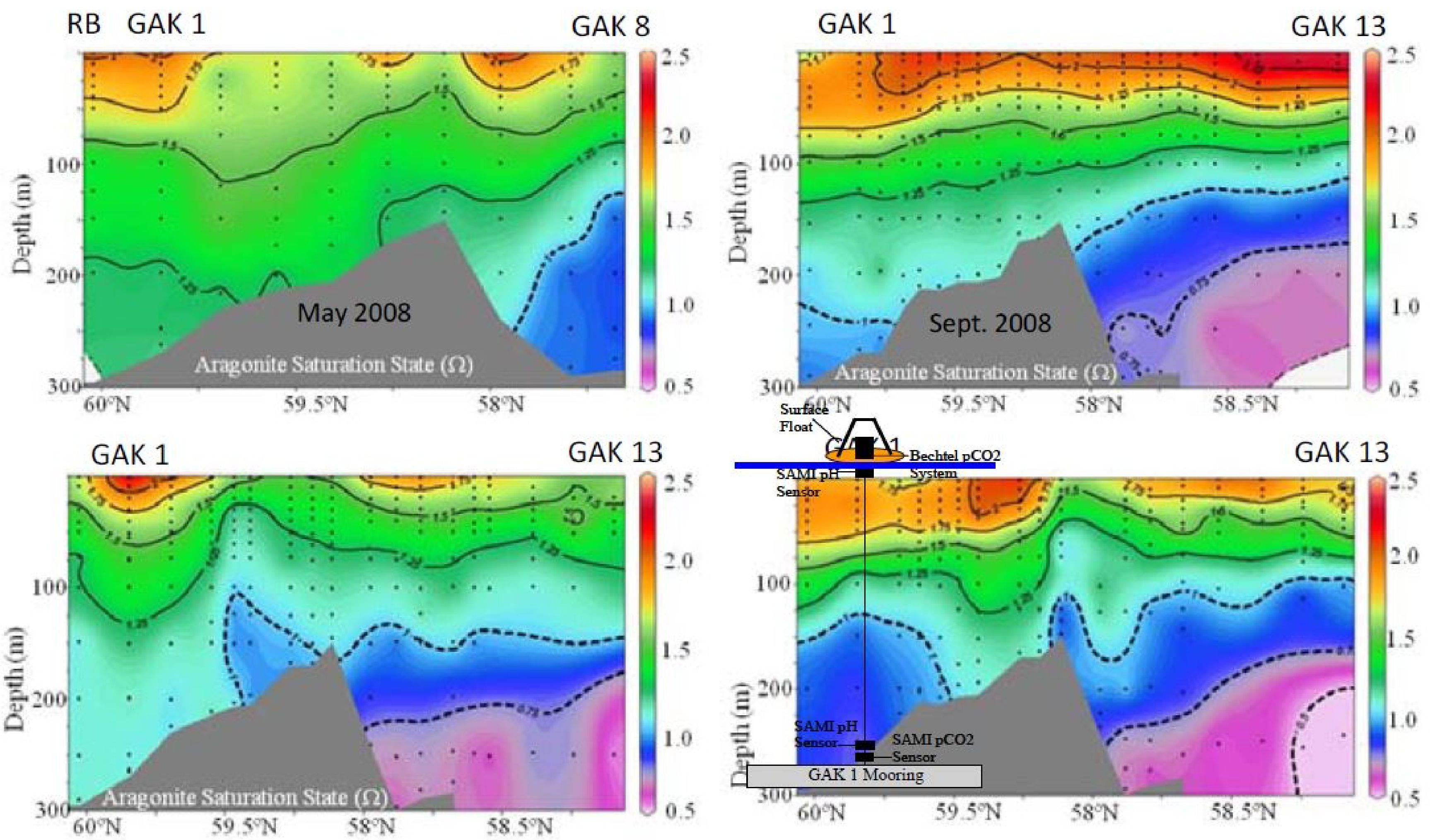
- Fish: continue to develop ecosystem and behavioral responses
- Coral: assess differences in skeletal components of Primnoa. Look at process(es) of mineralogy
- Crab: need to consider portions of stock that survive (acclimation!)
    - Assess energetic response (consumption)
    - Hemocytes: focus on molting processes, calcium transport (bicarbonate or carbonate)
- Additional spp.: pteropods in Alaska, salmon (subsistence species), shellfish (mariculture)
- Support for coastal monitoring

➢ Need to measure *in situ* variability

Economic Effects

- AK economic growth model development: multiple species, forward looking (fishermen will respond), better than economic yield, relaxed assumptions (e.g., constant ex-vessel price)
- Extend to gadids and rock sole

Aragonite Saturation States on the GOA Shelf



Mathis and Cross; Ocean Acidification Research Center

Alutiiq Pride Shellfish Hatchery

OceansAlaska
KETCHIKAN SHELLFISH HATCHERY

Major Marine Tours
(907)-274-7300

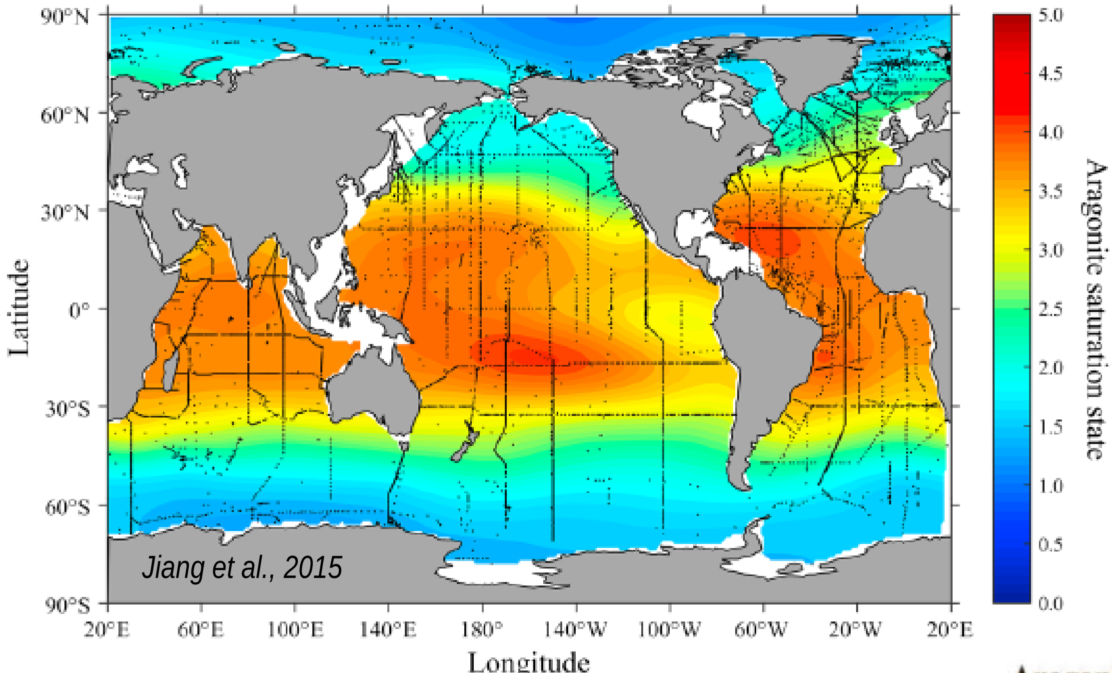
Hakai
Science on the Coastal Margin

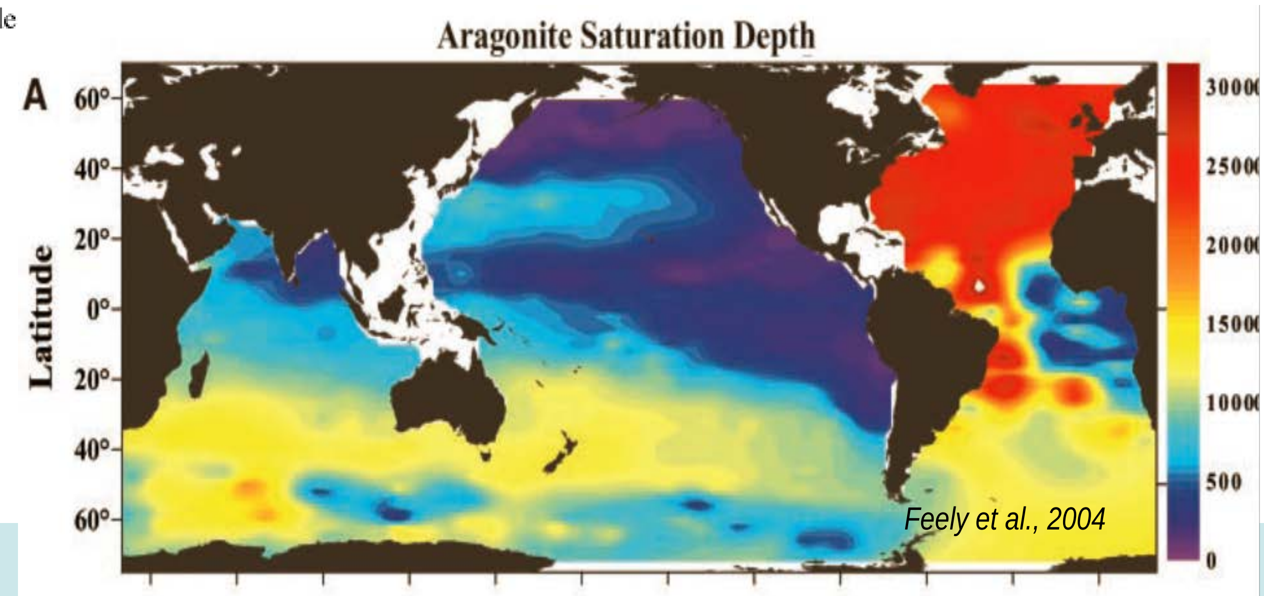
AOOS
Alaska Ocean Observing System

Ocean Acidification Research Center
AT THE UNIVERSITY OF ALASKA FAIRBANKS

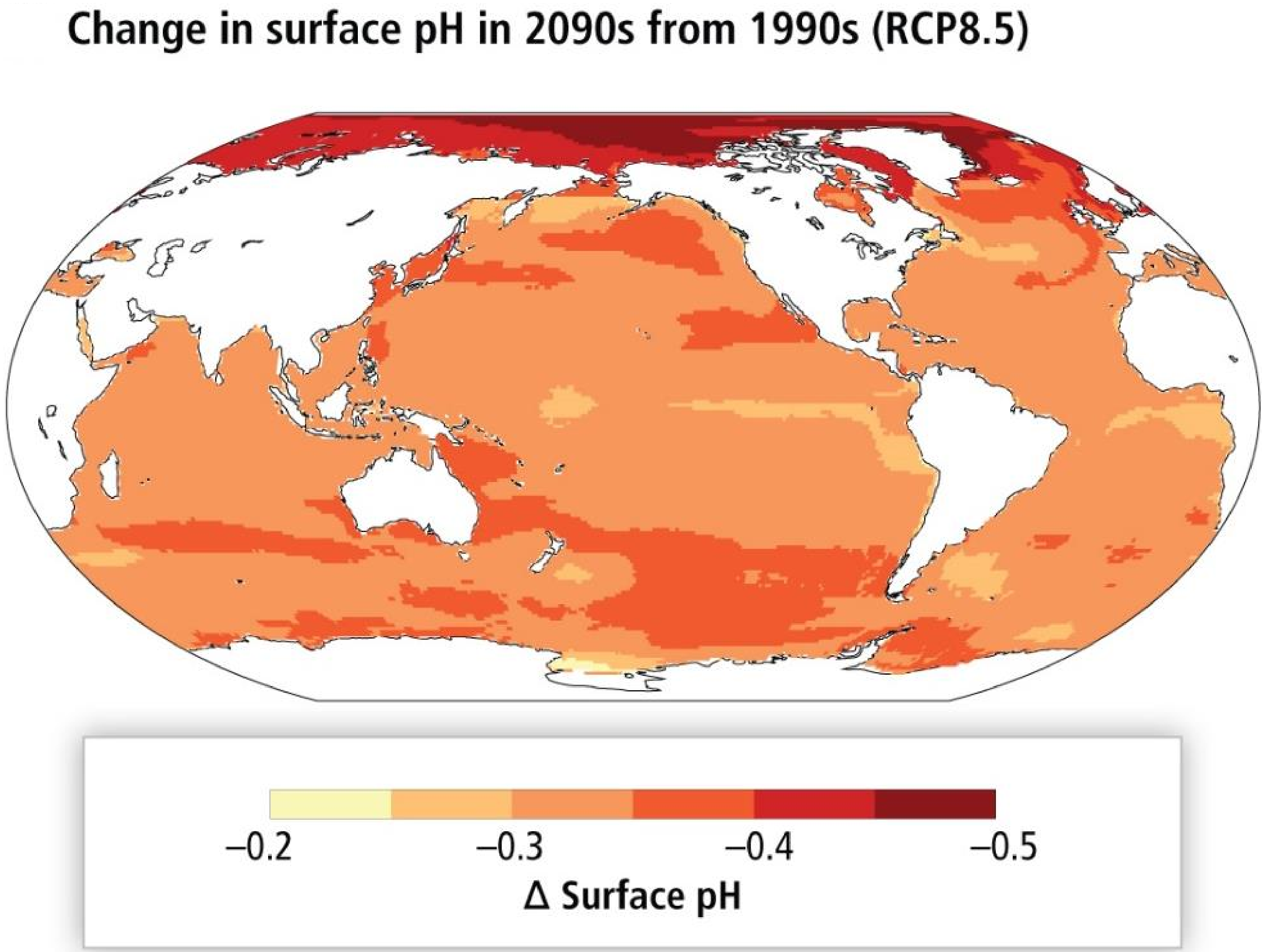
CIFAR
Cooperative Institute For Alaska Research

Ocean Acidification: this matters in Alaska!



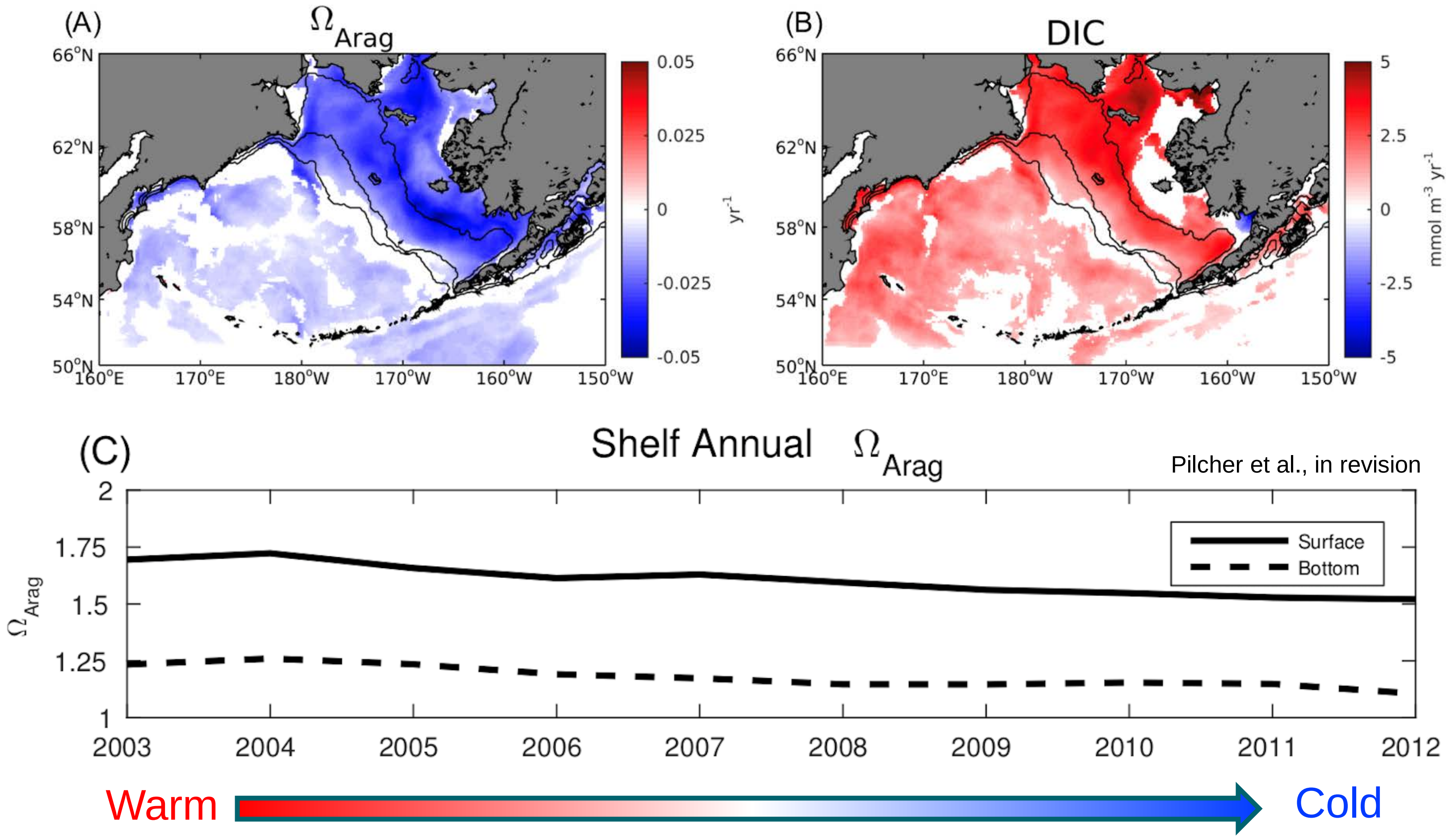


Ocean Acidification:predictions



IPCC 2014

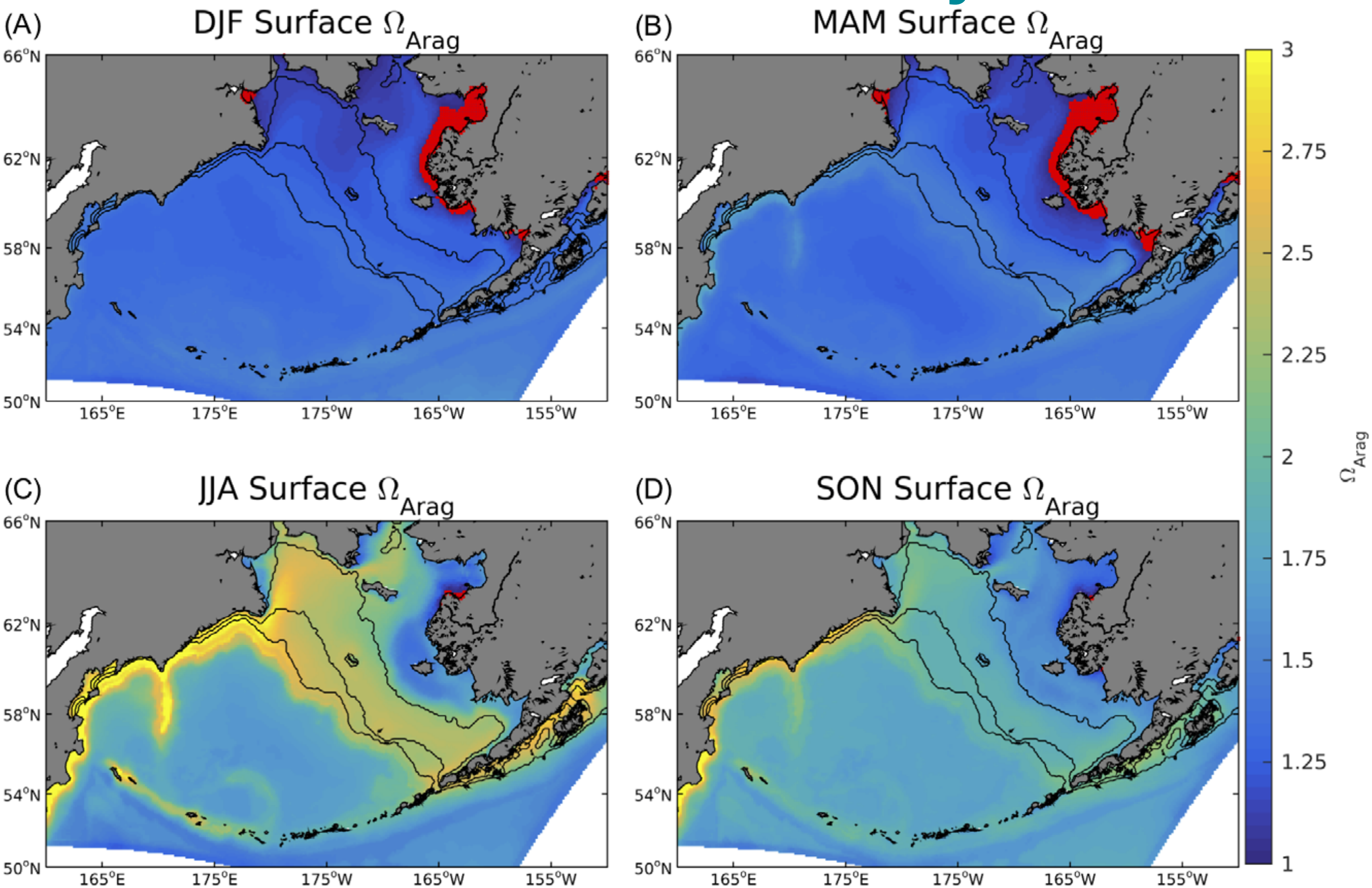
2003-2012 Trends



Annual surface Ω_{Arag} decreases by 0.025-0.04 units/year, however trends impacted by transition from warm to cold temperature regime

Pilcher, D.J.,D.M. Naiman, J.N. Cross, A.J. Hermann, S.A. Siedlecki, G.A. Gibson, and J.T. Mathis, Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea, Frontiers in Marine Science, in revision.

Seasonal Variability

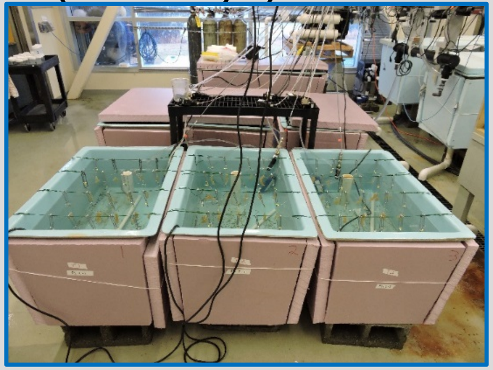


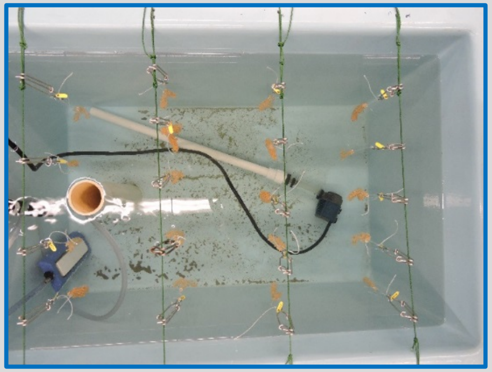
Pilcher et al. (in revision) Frontiers in Marine Science.

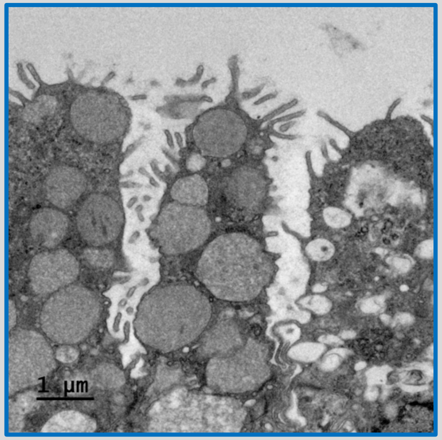
Physiological Response of the Red Tree Coral (*Primnoa pacifica*) to Low pH Scenarios in the Laboratory

(R. Stone, R. Foy, R. Waller, I. Enochs, S. Cairns)

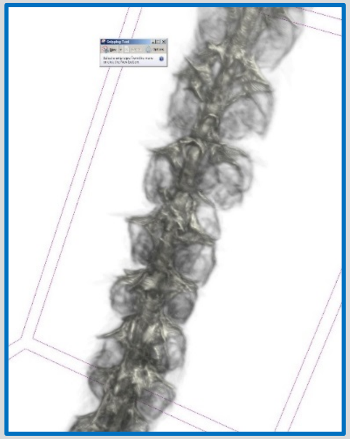
- Two treatments: pH 7.75 (current at 200 m depth GOA) and pH 7.55 (projected Year 2100).
- Snips from 54 colonies. 2 Treatments X 3 Tanks X 18 snips (plus 54 snips Day-0).
- January 15 to September 22, 2016 (252 days), except 1/3 of samples 21 June 2016 (159 days).



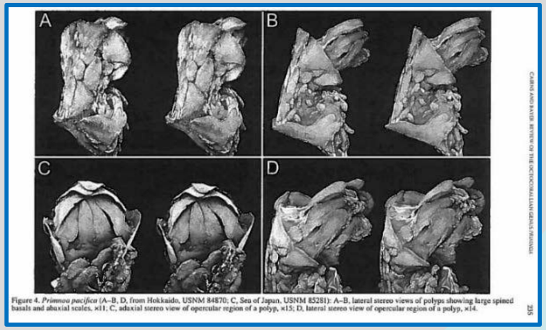




Fecundity and oocyte/ spermatocyst development



Micro-CT scans of skeletal density/growth



SEM scans of sclerites morphology

Ocean Acidification outreach

Kodiak Fisheries Research Center Ocean Science Discovery Lab

- NMFS and Kodiak Island Borough School District collaboration
- Goal: to improve Ocean Science Literacy in grades K -12

- Middle School: What is OA? How do you measure ocean pH?
  - Intro to pH scale and ocean chemistry
  - Algal growth and plankton exposure experiments
- High School: HS Oceanography class
  - Local OA background
  - Global OA implications
  - Climate change

Effects of Ocean Acidification on Alaskan Groundfishes

Research projects

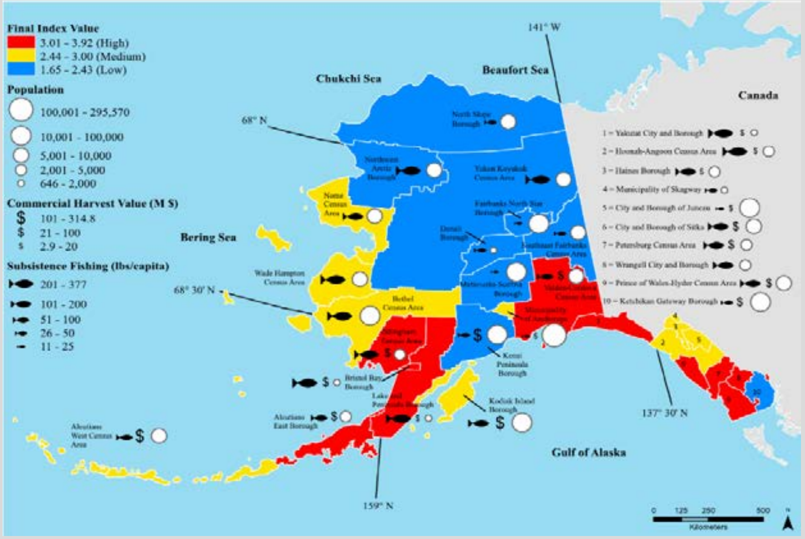
1. Direct effect studies on Alaskan fishes

- Walleye pollock juveniles & larvae
- Northern rock sole larvae
- Pacific cod larvae

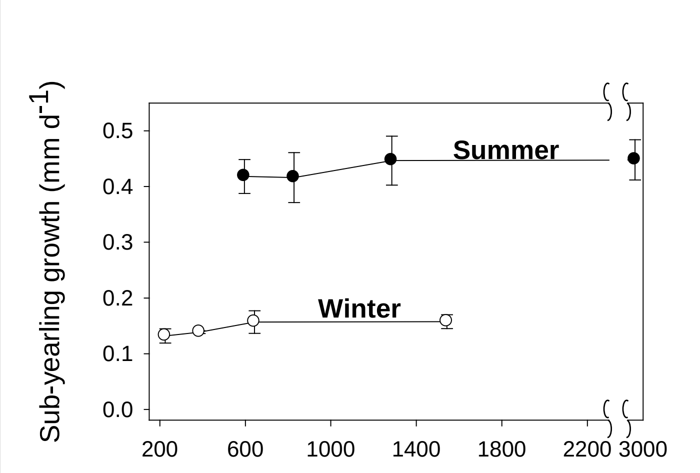
2. Indirect "food web" effects

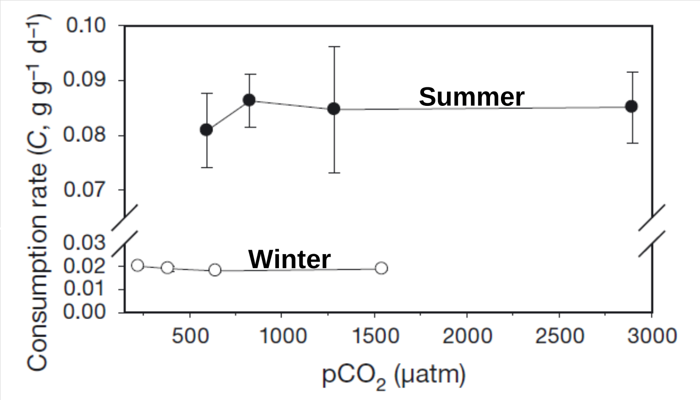
3. Sensory / behavioral effects

4. Alaskan community vulnerability index



Juvenile walleye pollock resilient to direct OA effects





Hurst et al. (2012)

No negative effects of OA in short (6 week) or long (6 month) exposures with juveniles.

There was no effect on consumption rate,
i.e. fish didn't consume more to maintain 'normal' growth rates.

Otolith development was affected as seen in other fish species.

AFSC Ocean Acidification Research

NOAA Alaska Fisheries Science Center focused on commercially important fish and shellfish, their prey, and shelter (coral).

Since 2007: assess physiological response of commercial crab species: red, blue, and golden king crab, Tanner crab, and snow crab; commercial fish species: walleye pollock and northern rock sole; important shelter: red tree coral.

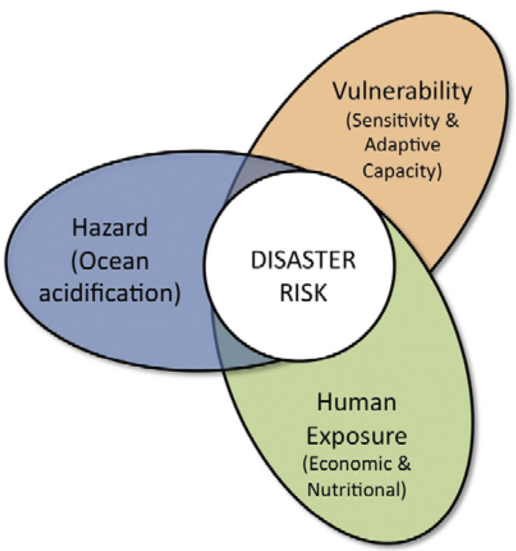
- Effects at <u>oocyte</u> and <u>embryo</u> stage significant
- Effects at <u>larval</u> stage minimal (no effect on mortality)
  - Decreased metabolism?
  - Larvae that survived may be acclimating?
  - Adaptation due to variable environmental conditions?
- Effects at <u>juvenile</u> stage significant
  - Calcification vs condition tradeoff?
- <u>Adult</u> crab maintain hemolymph pH
  - Energy spent maintaining cell pH and immunological function…effects development during oogenesis

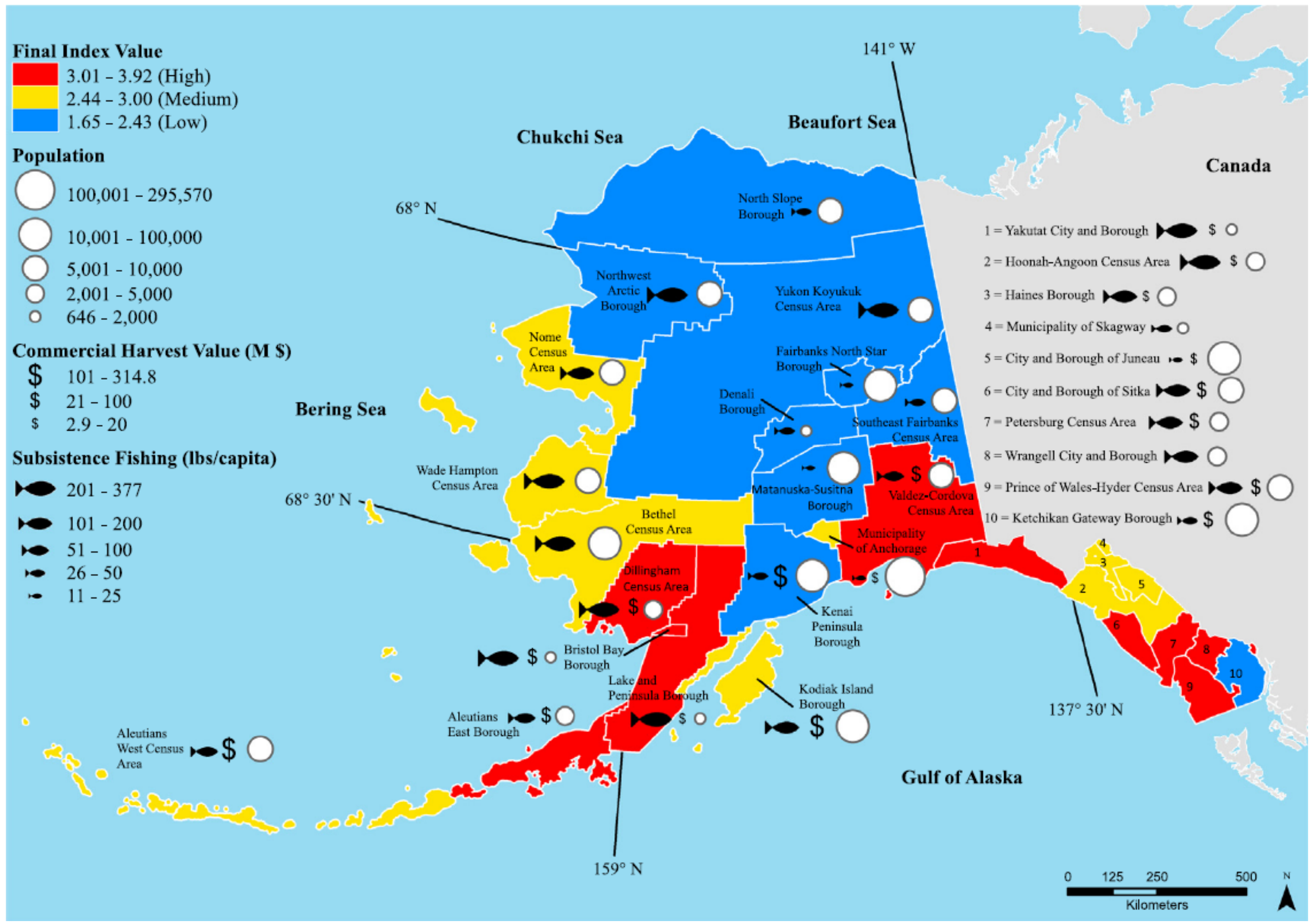
>50% decrease in catch and profits within 20 years?

Sustainability of commercial fisheries uncertain….but there is hope.

Alaska OA Risk Study

The physiological experimental studies are used as the basis for broader evaluations of the impacts of OA on fisheries, ecosystems, and communities.



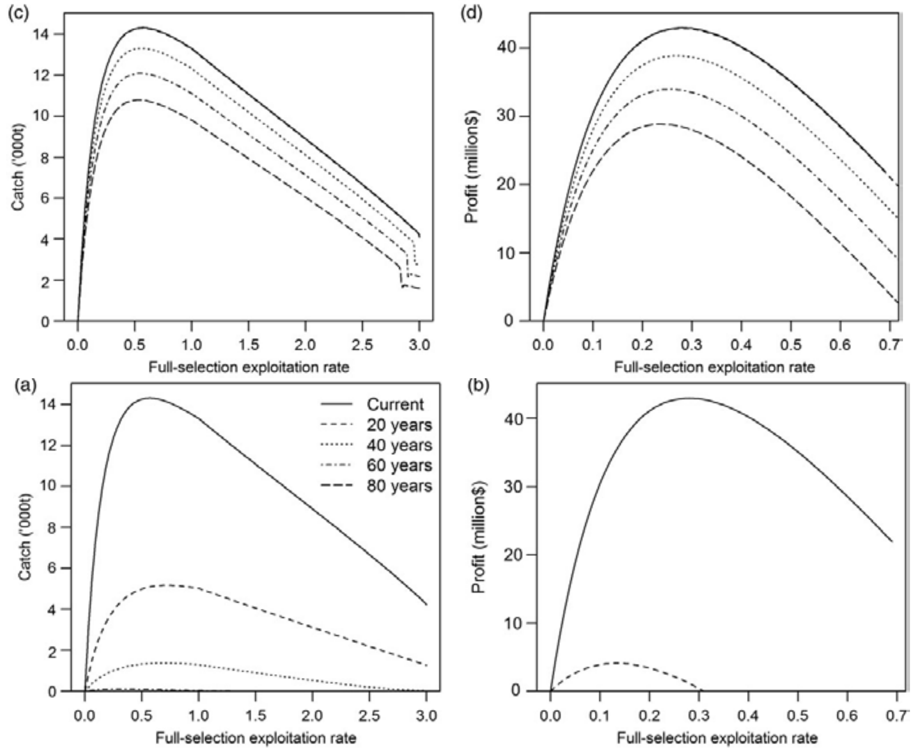


Mathis et al. 2015. Progress in Oceanography

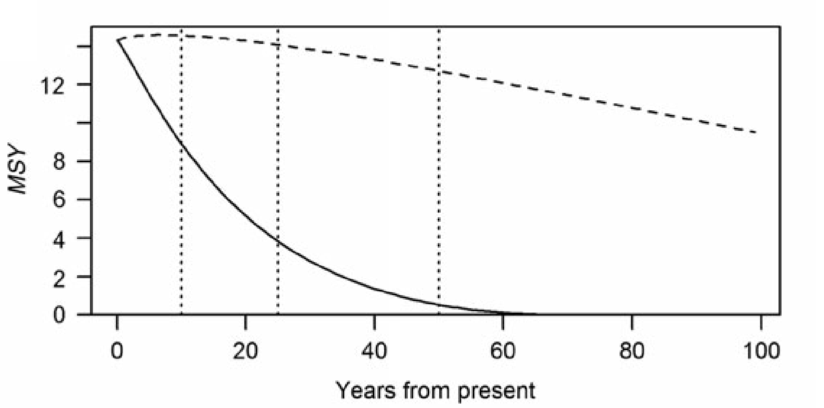
C. Bairdi Population Effects: *without acclimation*

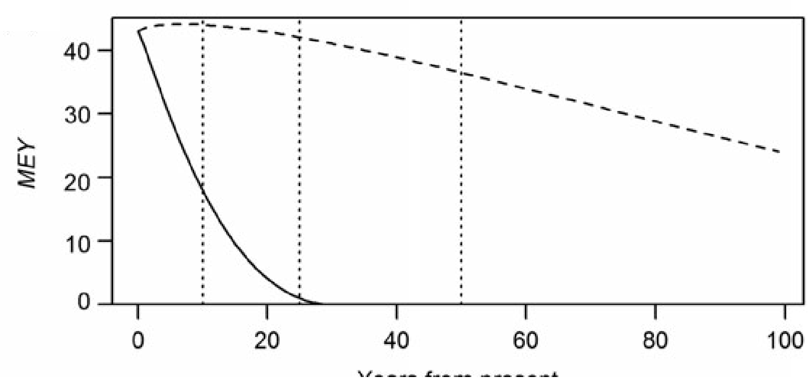
Without OA

With OA



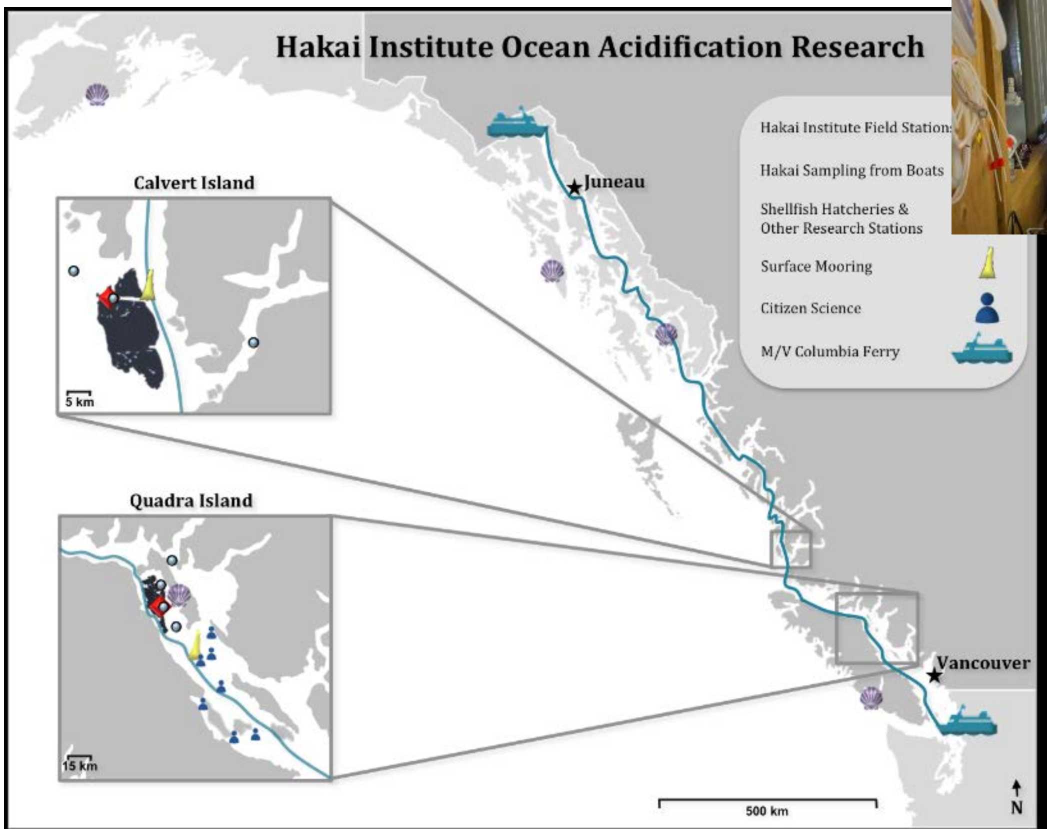
- Proportion larvae hatching that survive to juvenile stage C8 could decline by 25% over 100 y.
- >50% decrease in catch and profits within 20 years
- Only significant when oocyte development is included in survival estimates
- $500 million - $1 billion welfare loss to Alaska households

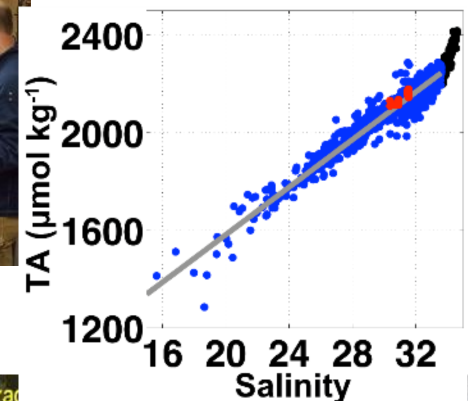


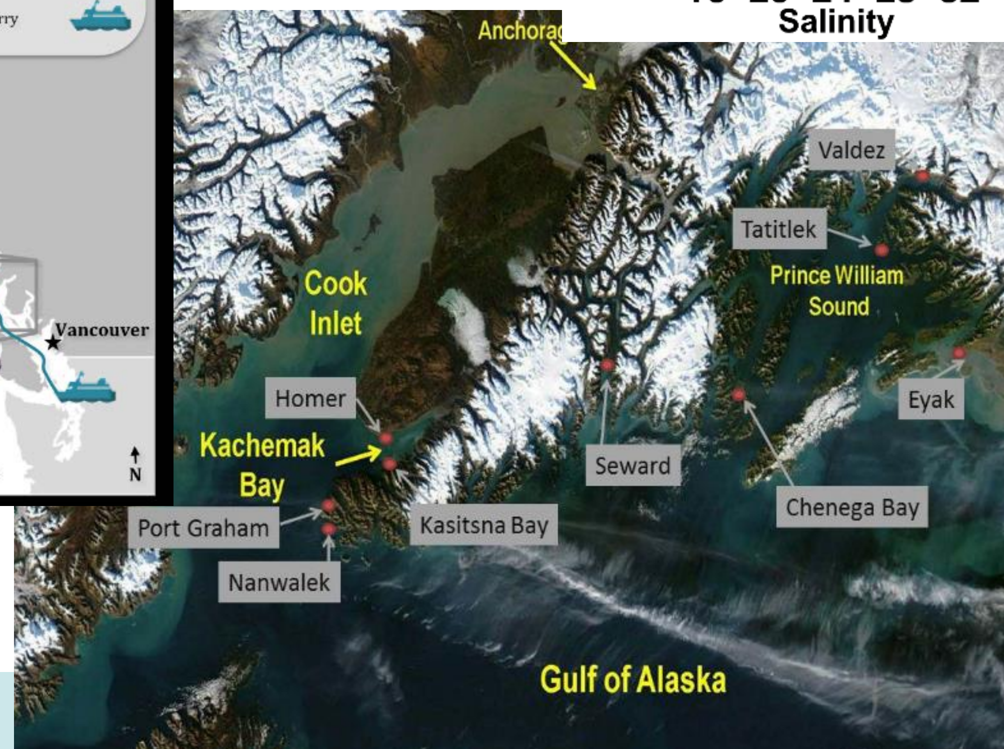


Punt et al. 2016

Ocean Acidification: what can communities do?

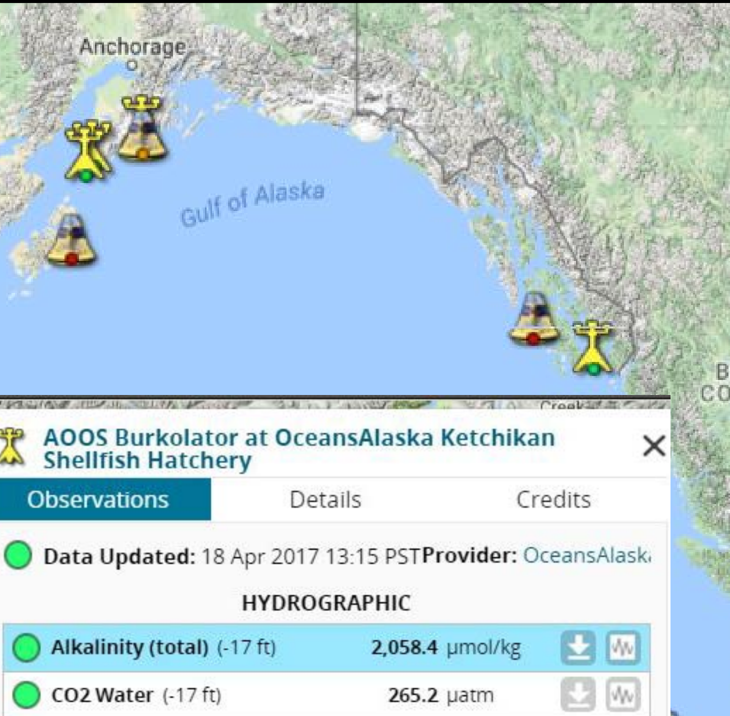






Evans; Hakai Institute

Ocean monitoring Kodiak 2018



AOOS Burkolator at OceansAlaska Ketchikan Shellfish Hatchery

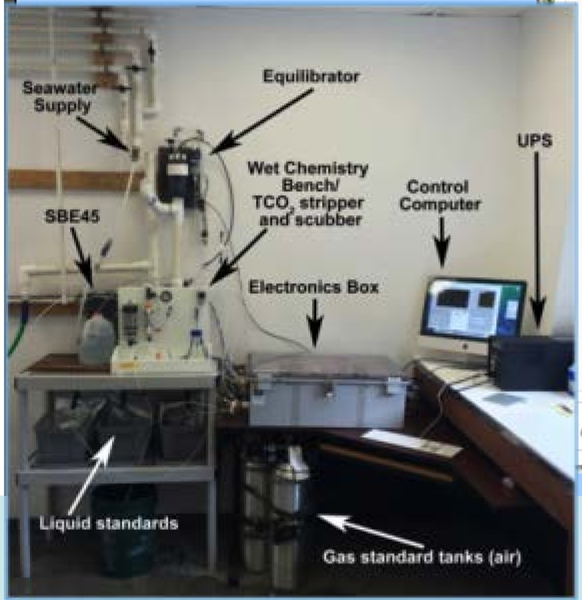
Observations | Details | Credits

Data Updated: 18 Apr 2017 13:15 PST **Provider:** OceansAlask

HYDROGRAPHIC

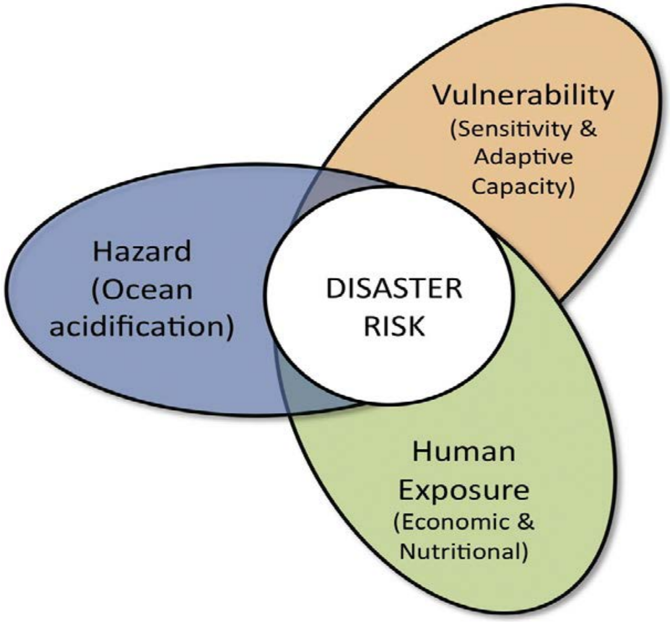
Alkalinity (total) (-17 ft)	**2,058.4** μmol/kg
CO2 Water (-17 ft)	**265.2** μatm
TCO2 (-17 ft)	**1,884.8** μmol/kg
Omega Arag. Sat. (-17 ft)	**2**
pH (-17 ft)	**8.2**
Salinity (-17 ft)	**29.8** PSU
Water Temperature (-17 ft)	**45** °F

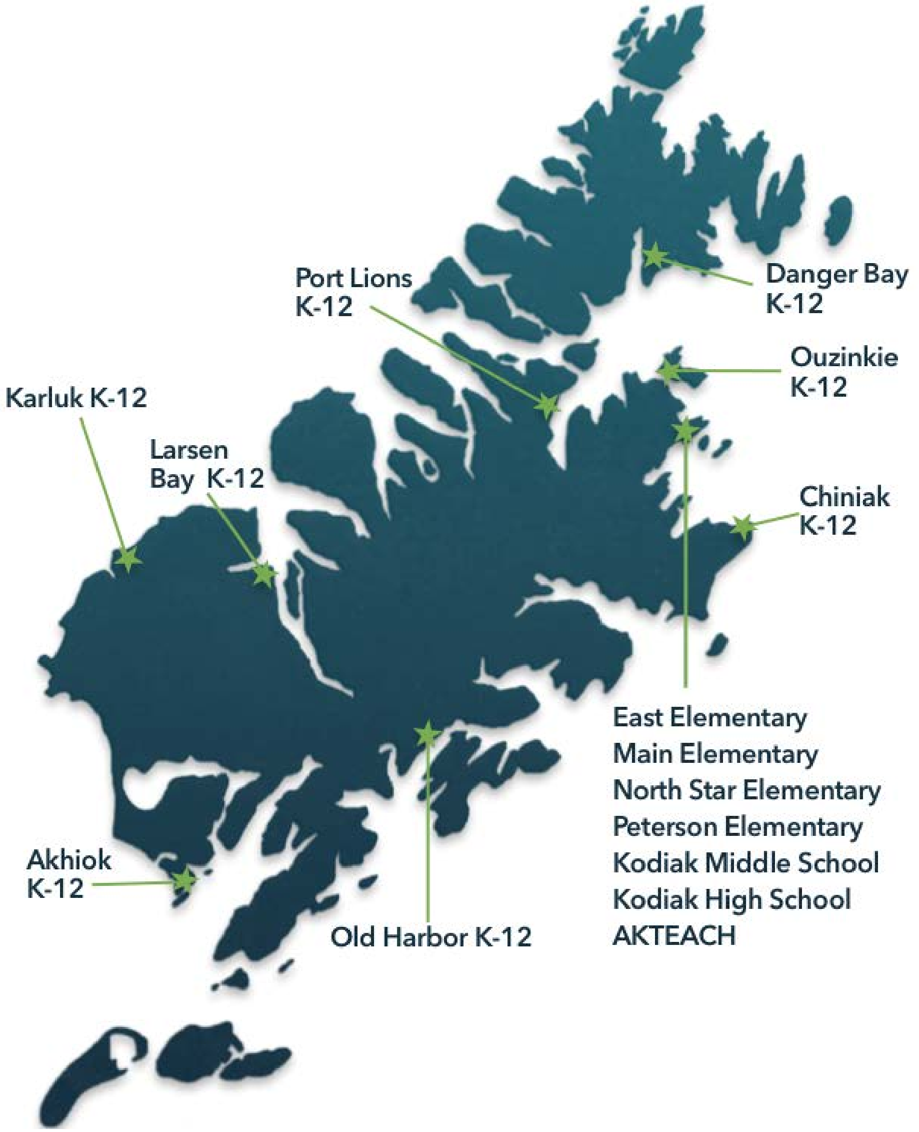
Link



Ocean monitoring Kodiak 2018

- What is the risk to the Kodiak Archipelago?
- Stakeholder identification
  - Coastal communities in Kodiak
- Educational opportunities (place based science)
- Community based collections?
- Leverage agency research
- Establish baseline
- Detect variability



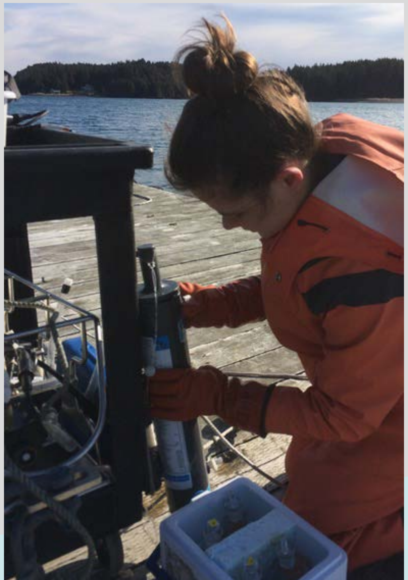


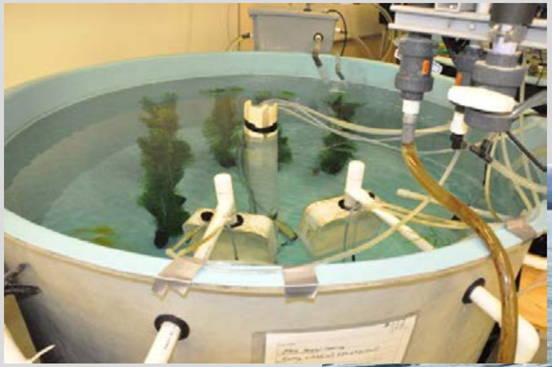
NOAA FISHERIES

Mathis et al. 2015. Progress in Oceanography

Kodiak Mariculture and Environmental Monitoring

- 2018 water quality monitoring program developed with Kodiak Area Native Association
- 2019 research
  - Assess affect of and potential for mitigation of ocean acidification on macroalgae growth
  - Measure growth and quality relative to environmental conditions

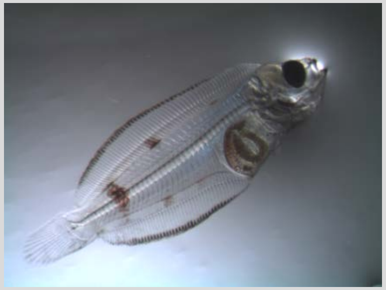




Alaska groundfish studies

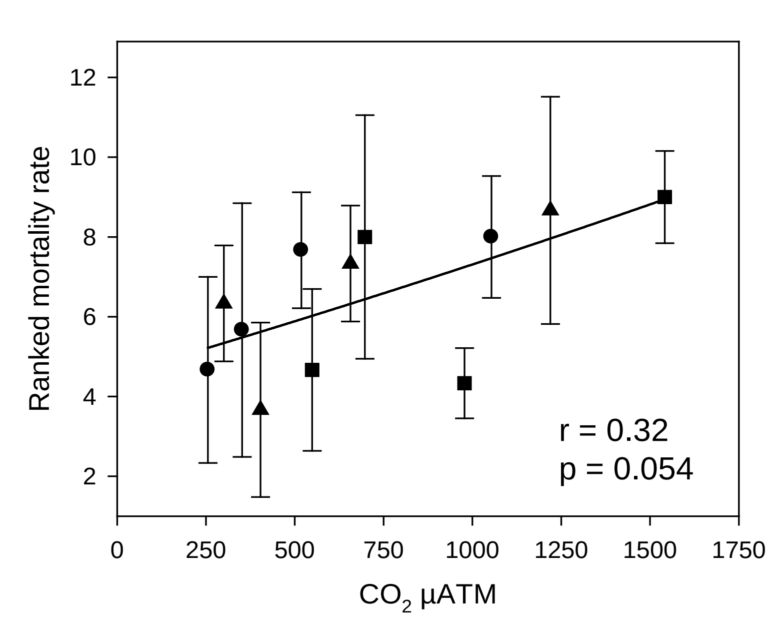
Based on laboratory experiments exposing eggs and larvae to elevated CO_2 in laboratory experiments.

Northern rock sole



More sensitive

- To 1600 µatm CO_2 ; to 60 days post hatch
- No effect on hatch success or size at hatch
- Reduced growth and condition in post-flexion fish
- Trend toward higher mortality at high CO_2 levels



Walleye pollock

Resilient

- To 2100 µatm CO_2 ; to 28 days
- No effect on survival to hatch
- Slight growth improvement at intermediate CO_2
- No CO_2 effect on survival

HURST, T. P., E. R. FERNANDEZ, and J. T. MATHIS. 2013. Effects of ocean acidification on hatch size and larval growth of walleye pollock (Theragra chalcogramma). ICES J. Mar. Sci. 70(4):812-822.

Hurst, T. P., Laurel, B. J., Mathis, J. T., and Tobosa, L. R. 2015. Effects of elevated CO2 levels on eggs and larvae of a North Pacific flatfish. ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv050.