Potential Impacts of Ocean Acidification on Some Harvested Species in the Salish Sea

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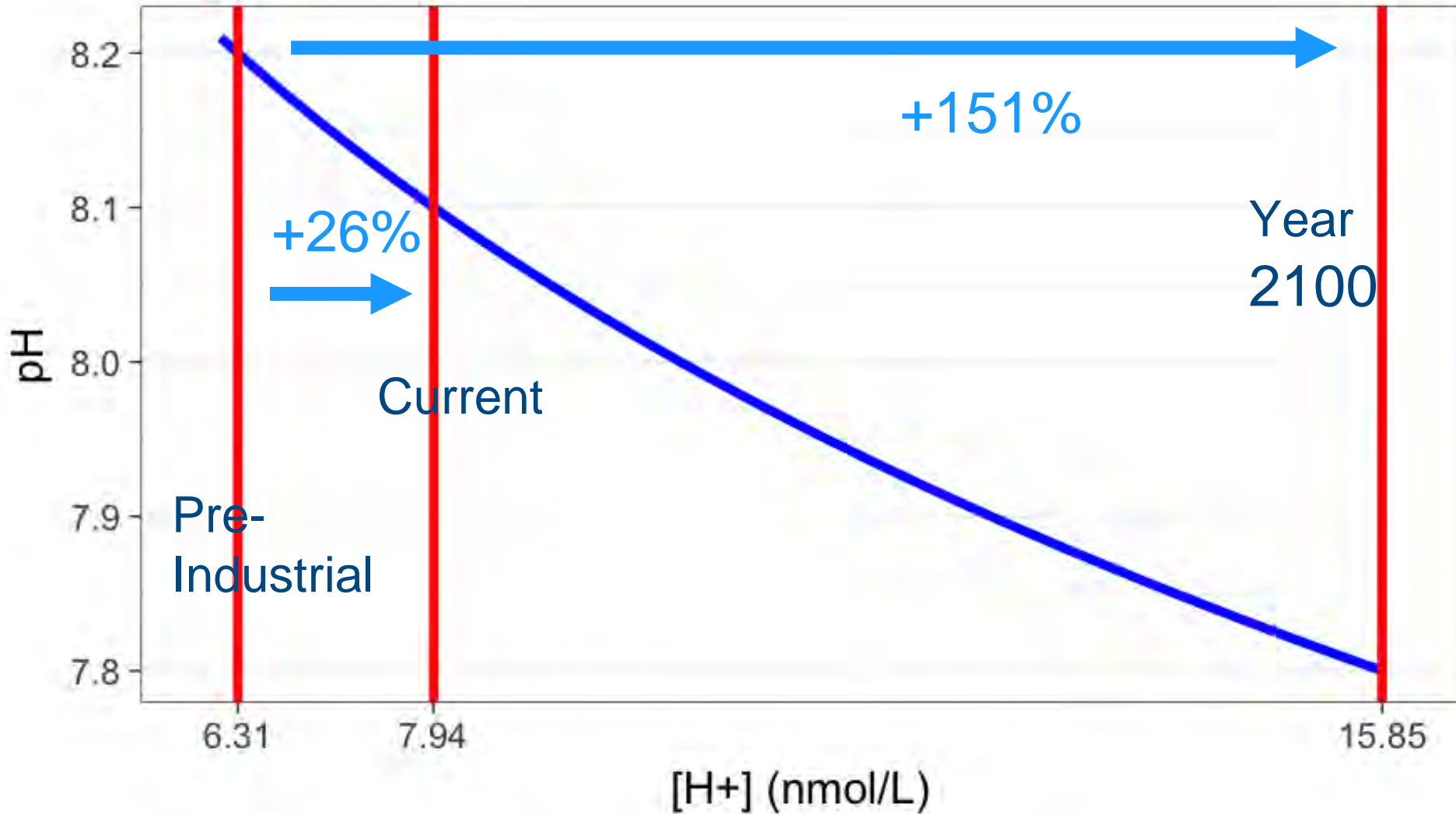# Ocean Acidification

Carbon Dioxide
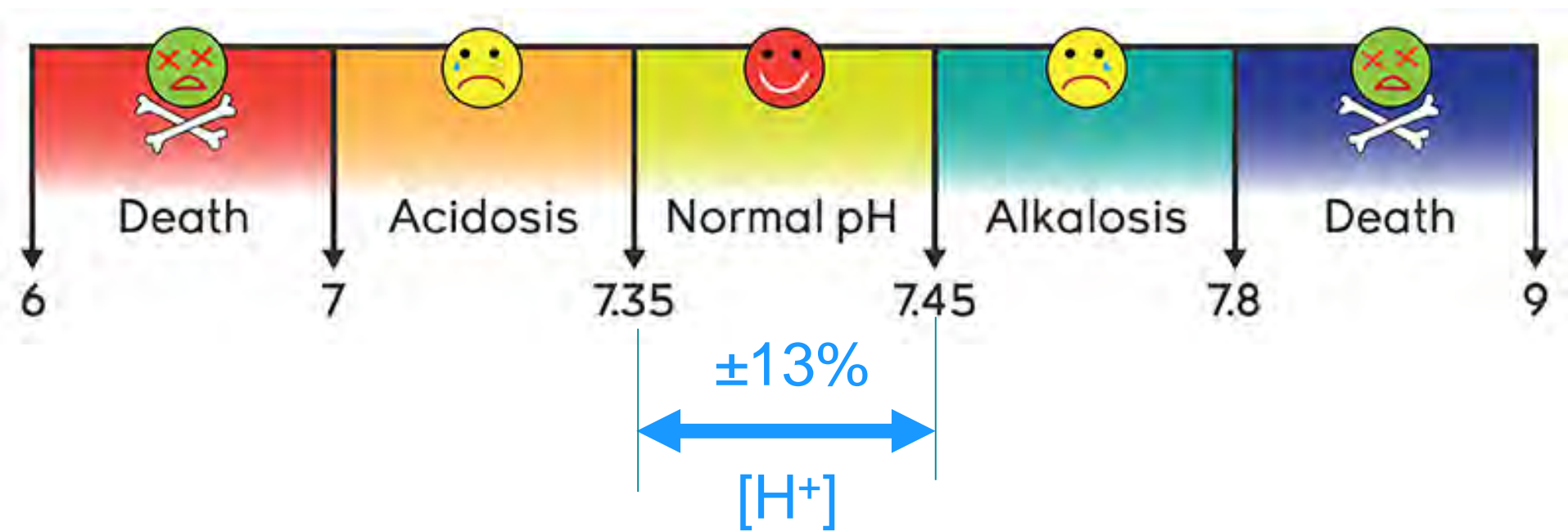

Acidification

Biological Impacts

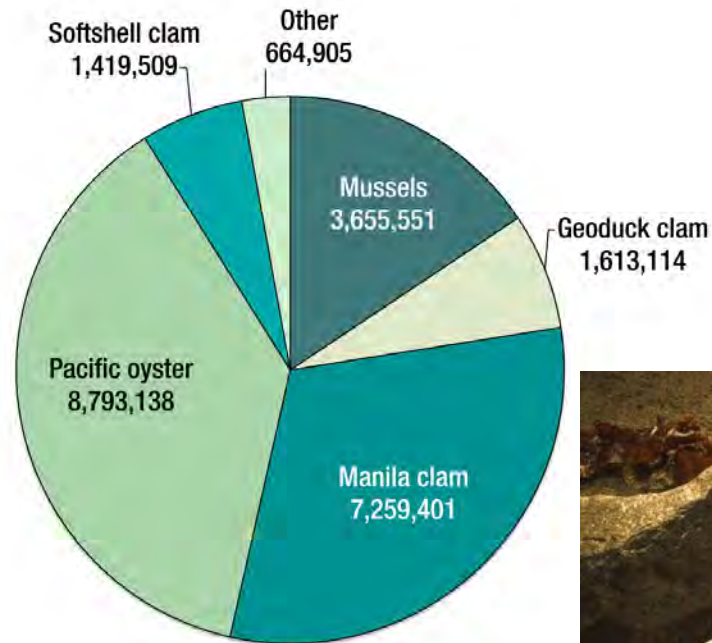# Hydrogen Ion Concentration

Biological sensitivity to [H+]

Human Blood pH levels
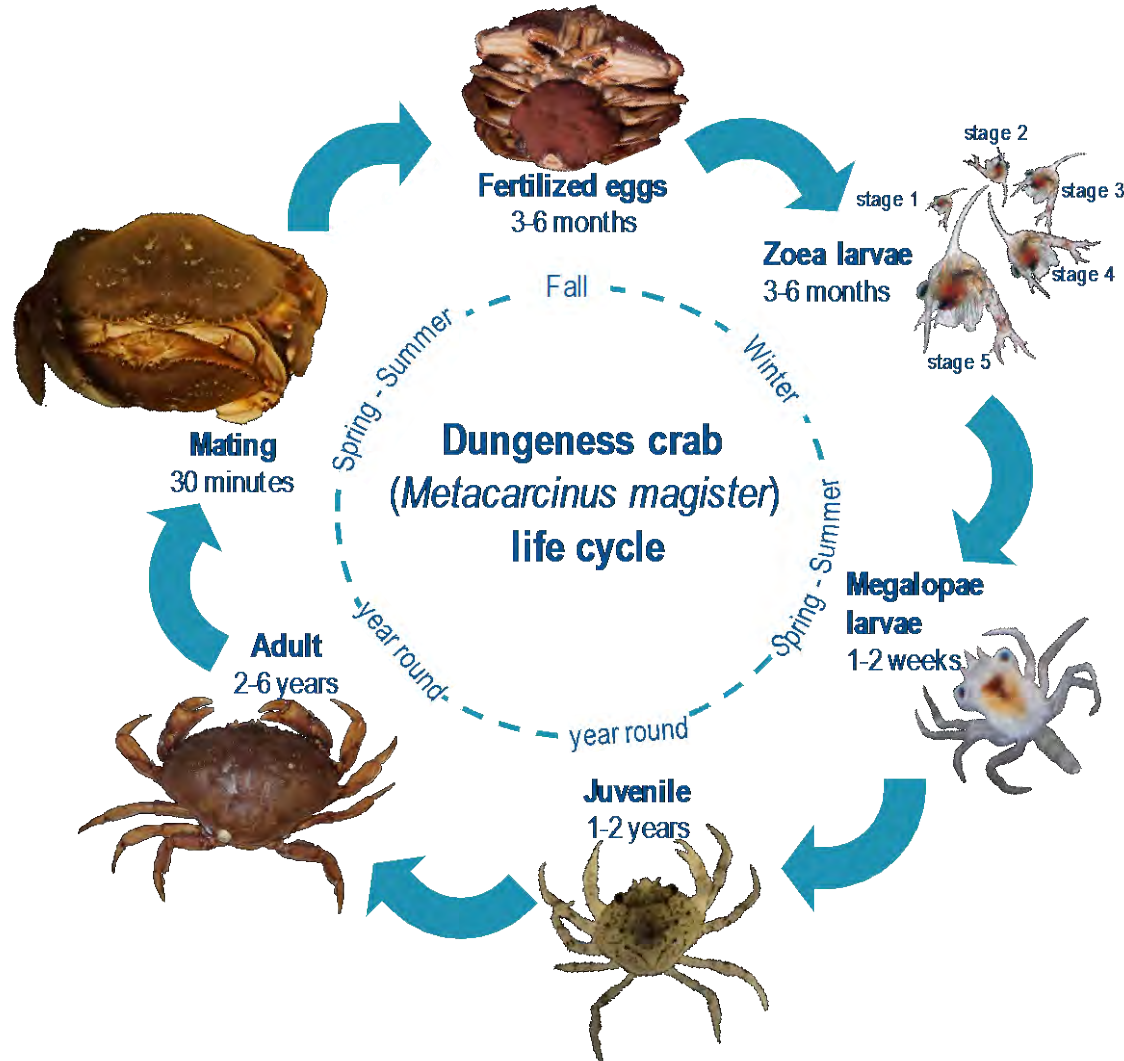
Top Harvested Species in Salish Sea

Washington State Shellfish Aquaculture Production by Species and Weight (lbs), 2013
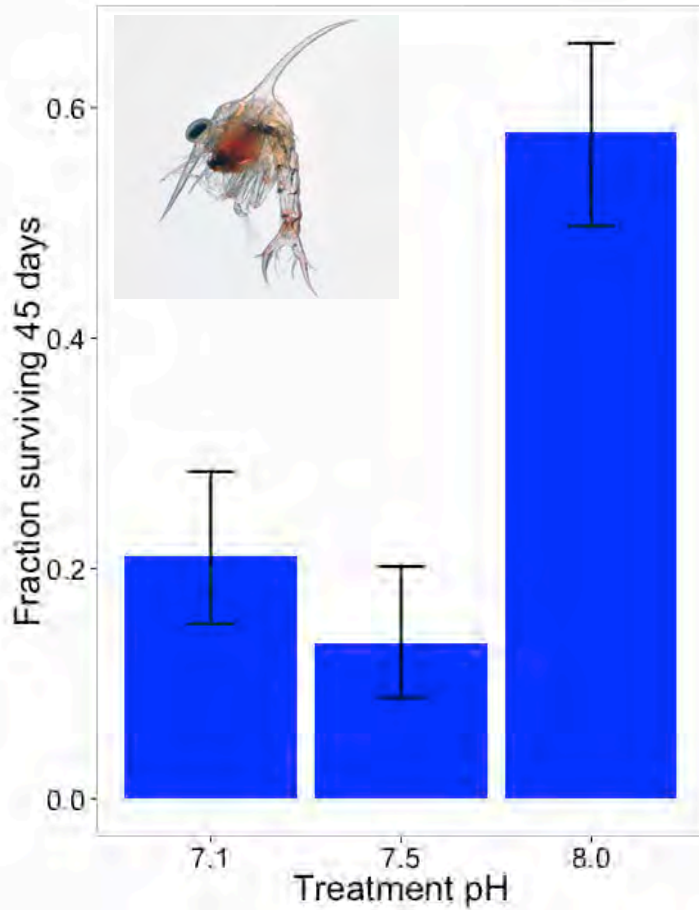
- Softshell clam 1,419,509
- Other 664,905
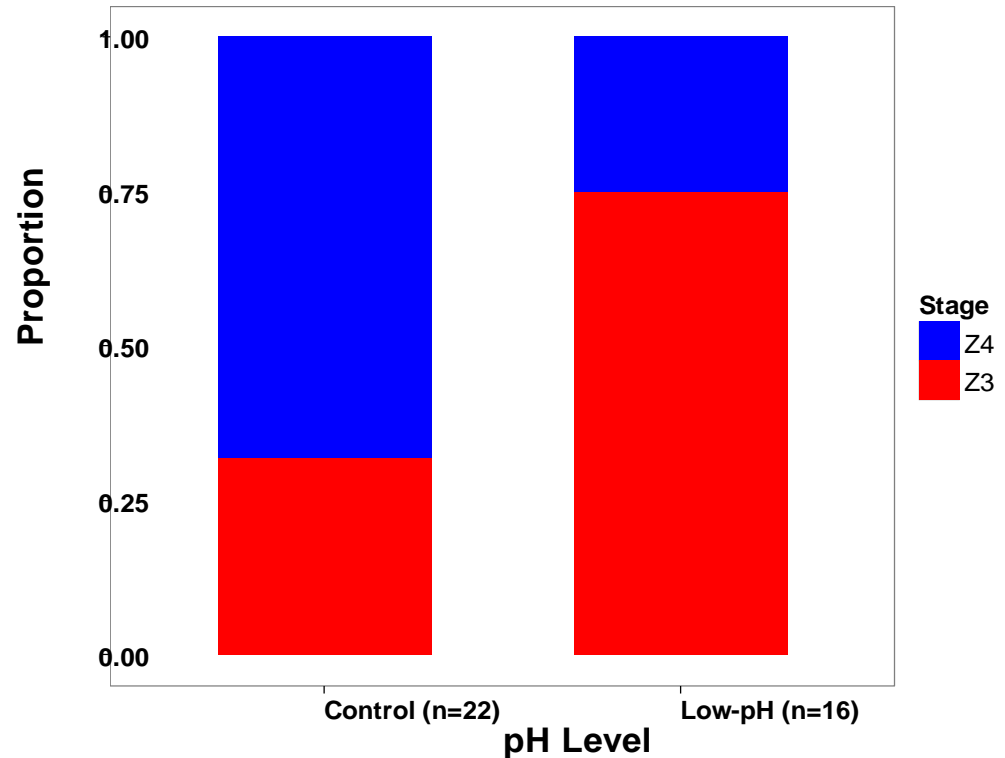- Mussels 3,655,551
- Geoduck clam 1,613,114
- Manila clam 7,259,401
- Pacific oyster 8,793,138

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Sensitivity to CO_2: Experimental System

McElhany, Maher, Miller. Ongoing

Ocean Acidification and Dungeness Crab

Dungeness crab (*Metacarcinus magister*) life cycle

Fertilized eggs
3–6 months

Zoea larvae
3–6 months

stage 1
stage 2
stage 3
stage 4
stage 5

Megalopae larvae
1–2 weeks

Juvenile
1–2 years

Adult
2–6 years

Mating
30 minutes

Fall
Winter
Spring – Summer
Spring – Summer
year round
year round

Diagram by S. Trigg, photos by NWFSC OA lab

Dungeness crab survival and development

Dungeness crab zoea

Miller, Maher, Bohaboy, Friedman, and McElhany. 2016 (Marine Biology)

Decreased survival at low oxygen but not pH

Other Dungness Crab Experiments

Photo by Paul McElhany

Megalops, 1.9 mm
Photo by Audrey Djunaedi

Photo by Melaina Dyck
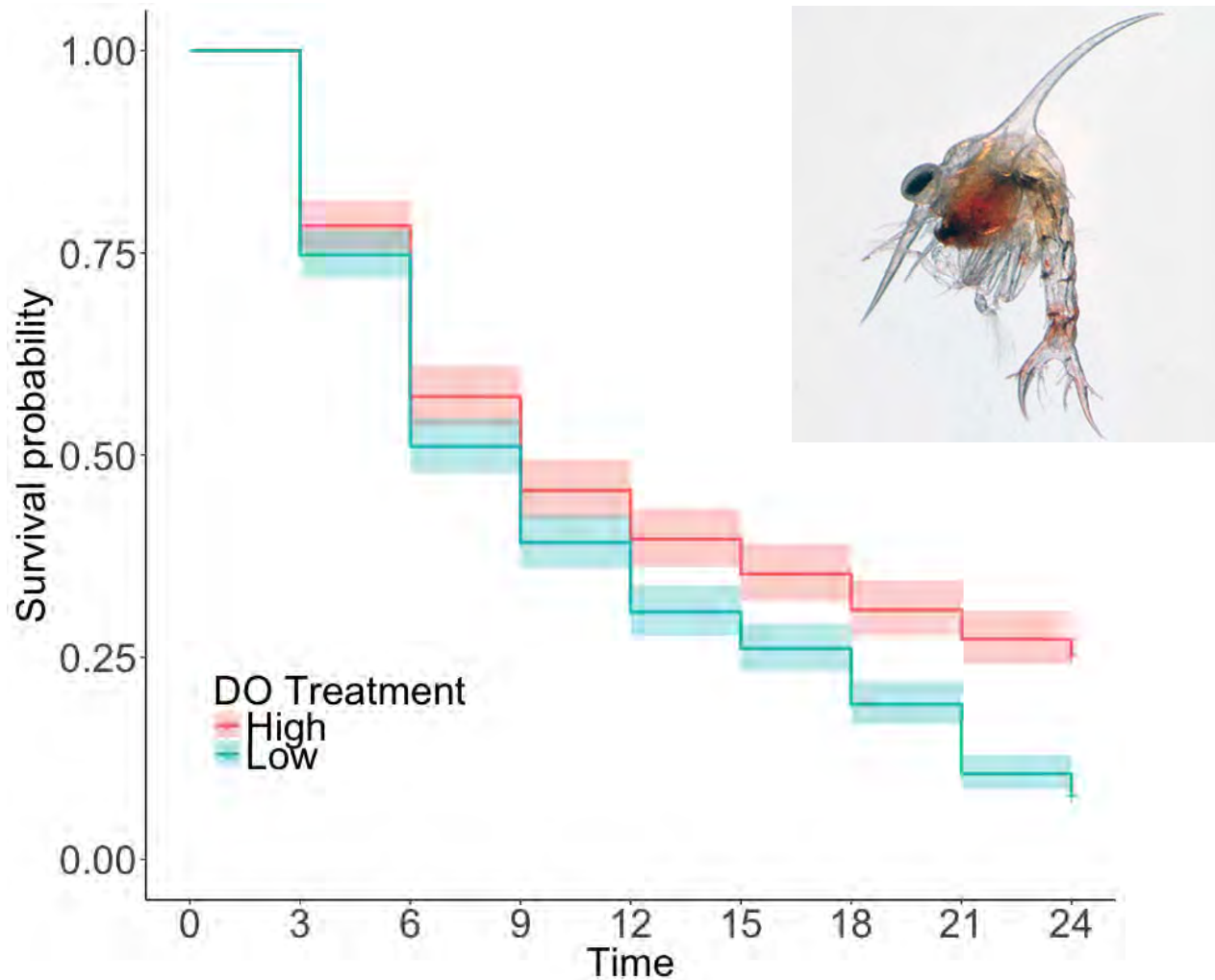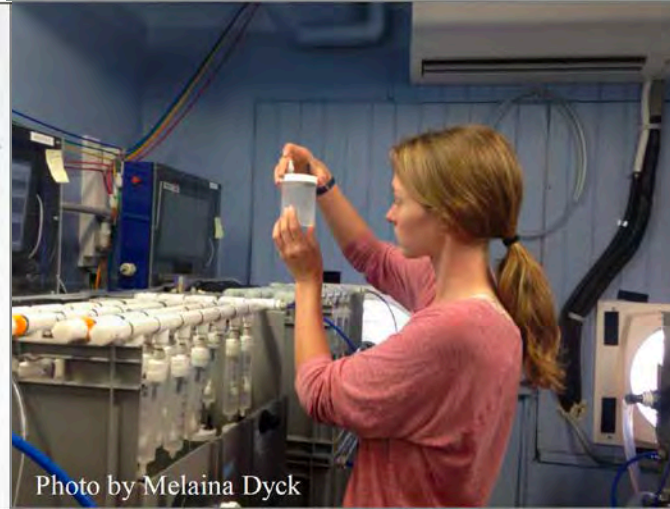
- Megalopae to juvenile stage
- pH x temperature, pH x oxygen
- Variable pH (daily fluctuations)
- Metabolomics, respirometry, spine strength
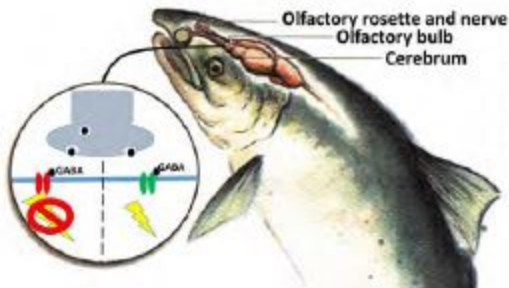
Next Experiment: Adaptation and Acclimation

Elevated CO_2 directly impacting Salmon?

What are we doing to investigate?

How?

Current evidence suggests that elevated CO_2 alters important neural signaling pathways in the brains of fish.

Olfactory rosette and nerve
Olfactory bulb
Cerebrum

GABA   GABA

Olfactory behavioral testing

Direct neural recording

The alarming outcome

Control fish: **20%**

VS.

High CO_2 fish: **50%**

What now?

We are investigating:

- Mechanisms of dysfunction

- Other critical behaviors

Chase Williams et al. in progress

Clarified Salmon Brain for Deep Neural Imaging

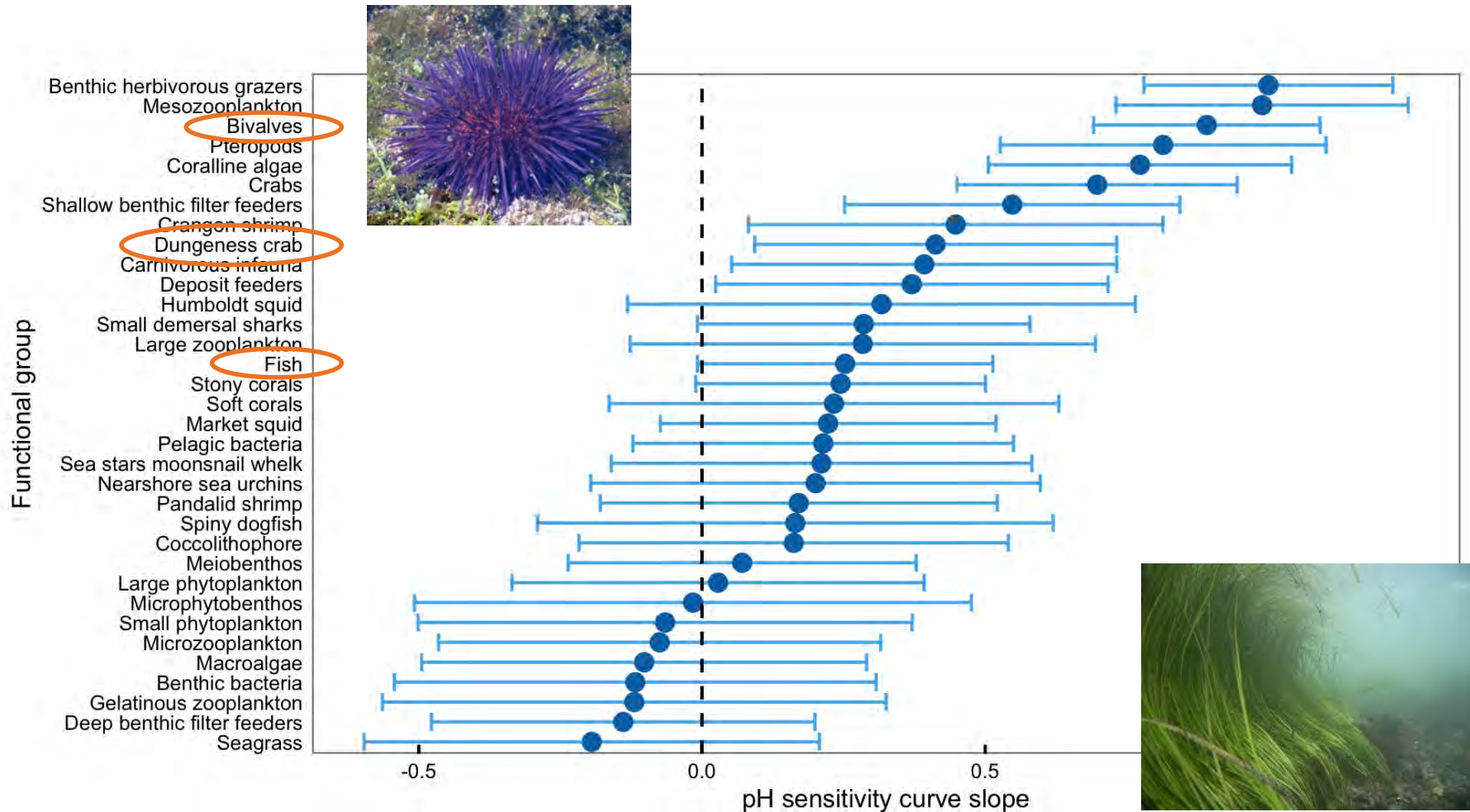Chase Williams et al. in progress
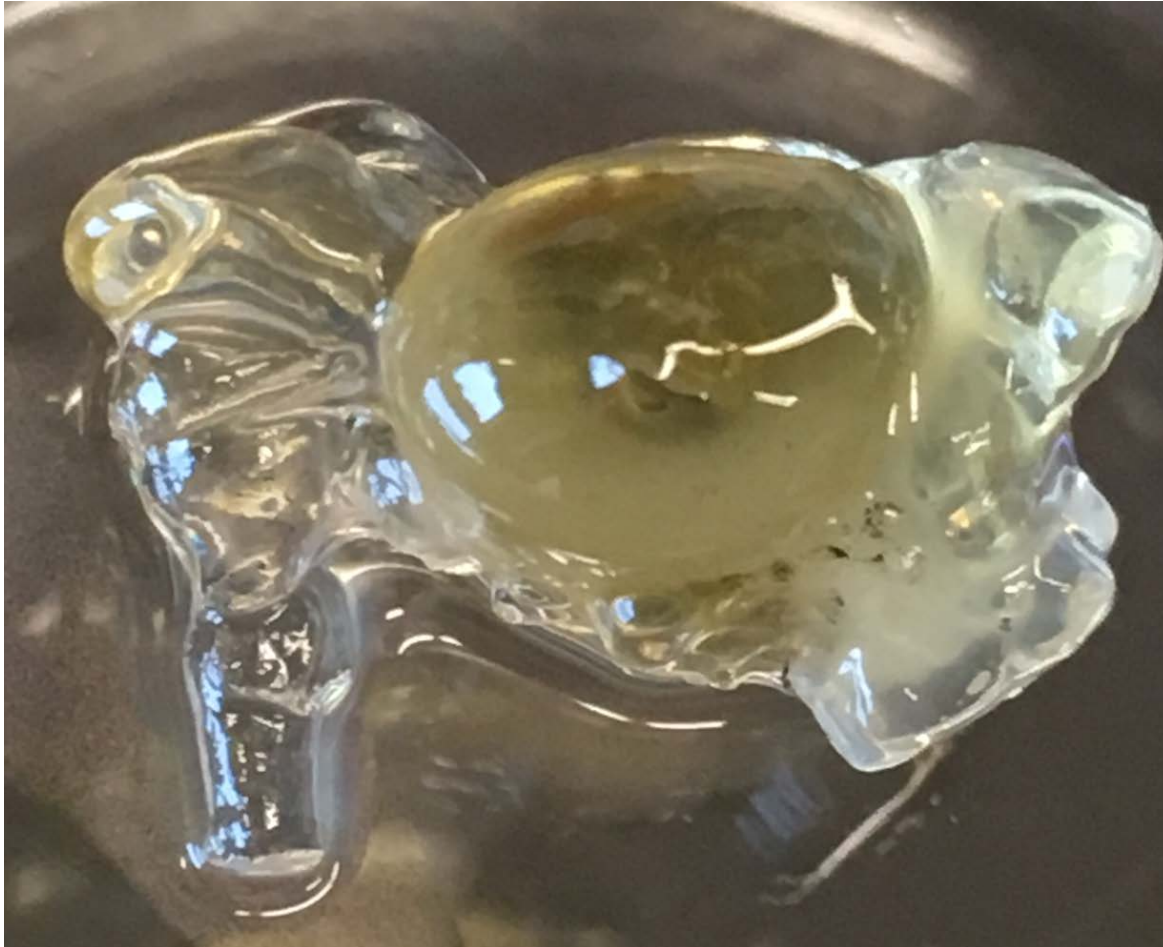
Geoduck Evolutionary Capacity

- Larval and juvenile geoduck clams were exposed to ambient and low pH seawater (pH 8.0, 7.4, 7.0) at the NOAA Kenneth K. Chew Center for Shellfish Research and Restoration, Manchester, WA

- Larvae had *higher survivorship and growth in lower pH* treatments (pH 7.4 and 7.0)

- Juvenile growth declined at pH 7.4 and 7.0 in the initial exposure, but when placed back in pH 8.0, resulted *in compensatory growth, larger shells, and resistance to repeat exposure*

- Epigenetic mechanisms such as *DNA methylation may provide environmental memory and acclimatization* to buffer effects of ocean change

See poster and https://safsoa.wordpress.com/ for data and more

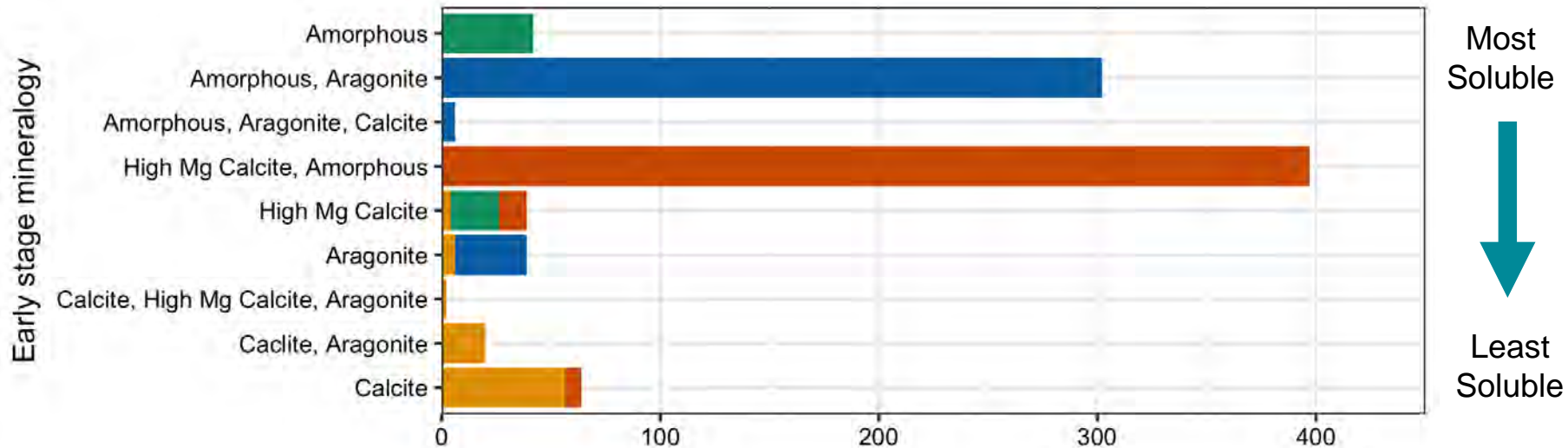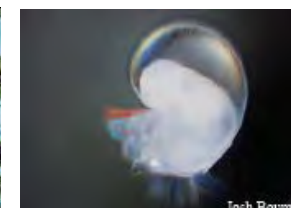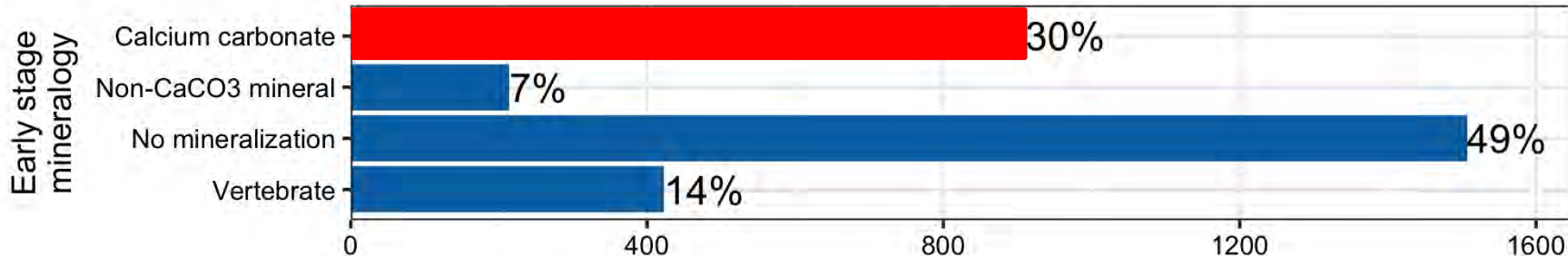Putnam, Spencer, Roberts, McElhany, Goetz. in progress

Relative pH Sensitivity:
Meta-analysis of ~400 OA Papers Relevant to California Current

Busch and McElhany. 2016 (PLOS)

Puget Sound Species Mineralogy

Total species in Puget Sound = 2,992

Busch and McElhany. In review

Food Web Effects – Puget Sound Ecopath

Busch, Harvey, and McElhany. 2013 (ICES)
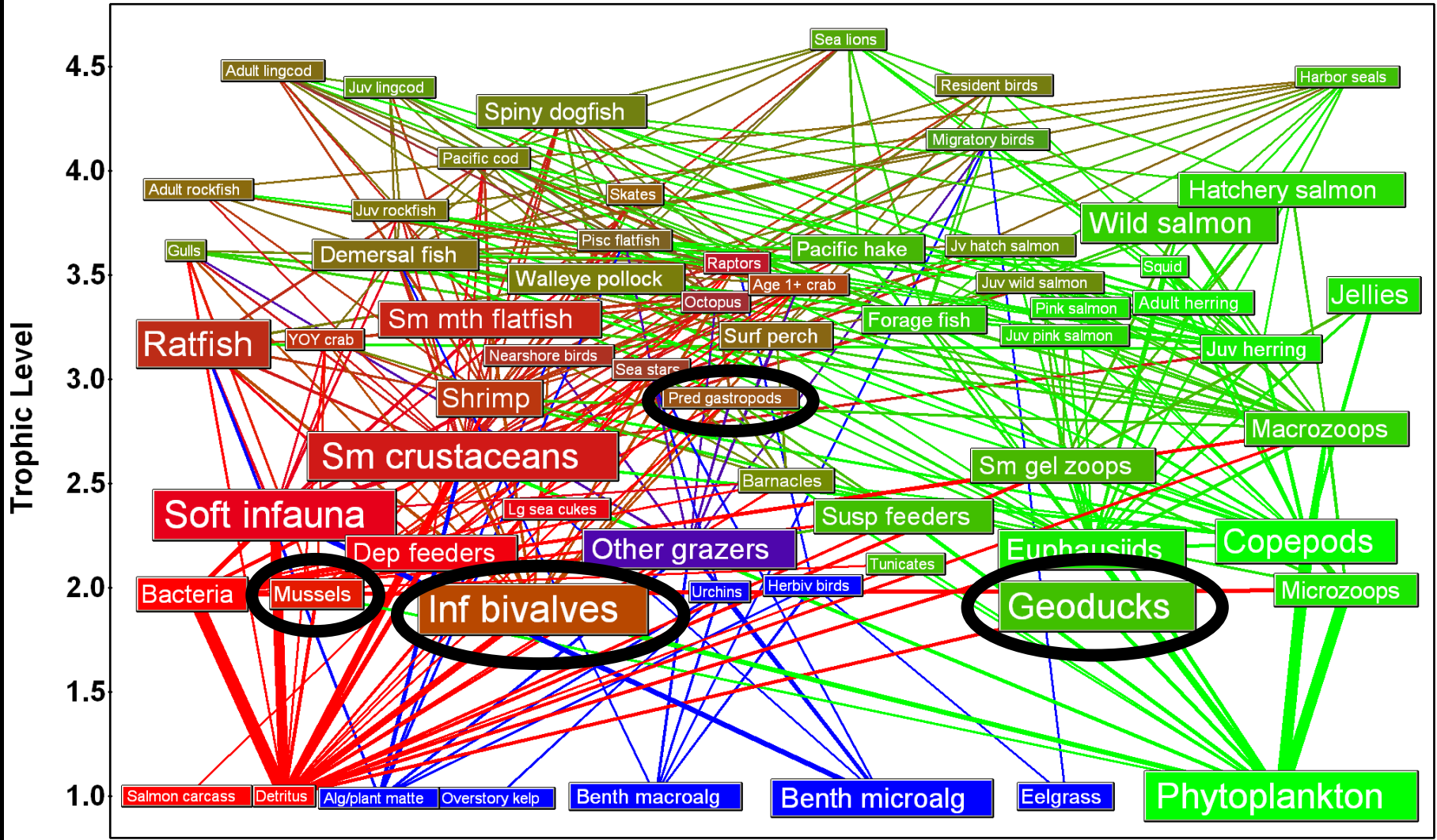
Change in harvest
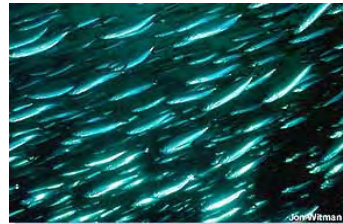
Percent change in fisheries yield (metric tons/ km²)/yr

Legend:
- 5% decline
- 15% decline
- 25% decline

Categories (x-axis):
Salmon*, Herring*, Lingcod, Rockfish, Flatfish, Squid & octopus, Shrimp, Cancer crab*, Urchin, Sea cuc., Bivalves*
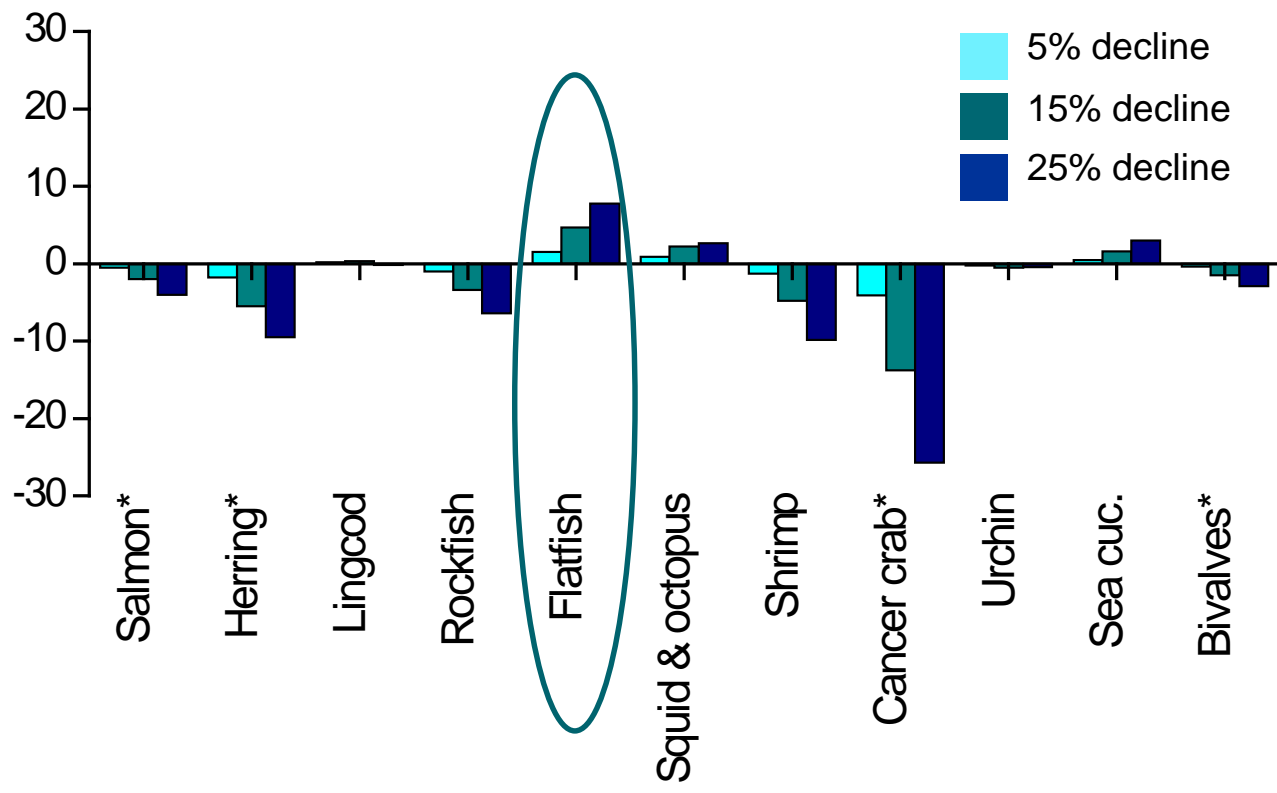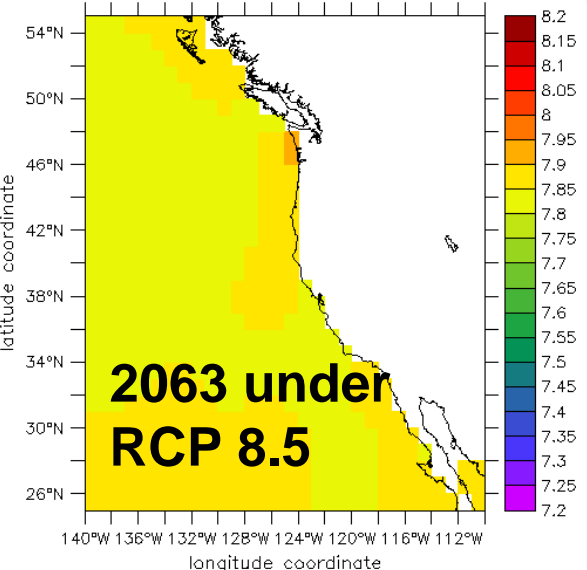
Indirect effects of scenarios

Direct effects of scenarios

Relative to baseline scenario

Busch et al. 2013

Food Web Effects – Atlantis

Oceanographic Model Predicts 2060s pH

2063 under RCP 8.5

Atlantis Ecosystem Model
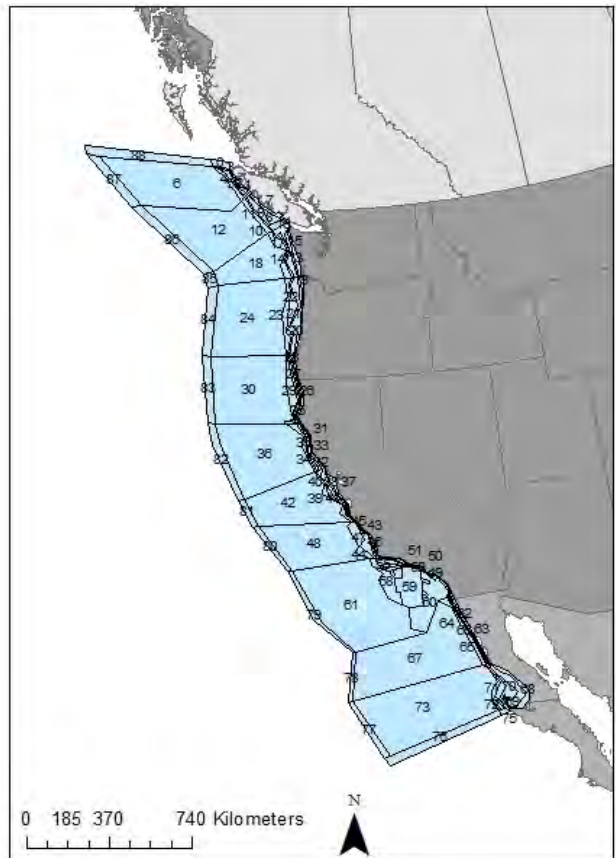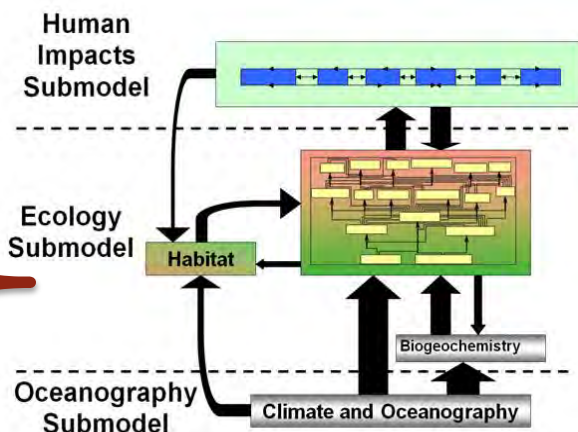
Literature Review of pH Sensitivity

Marshall, Kaplan, Hodgson, Hermann, Busch, McElhany, Essington, Harvey, Fulton. 2017. (Global Change Biololgy)

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Food web effects drive declines in crab, flatfish; large $ declines in state-managed fisheries

How might ocean acidification affect the West Coast food web and fisheries in 50 years?
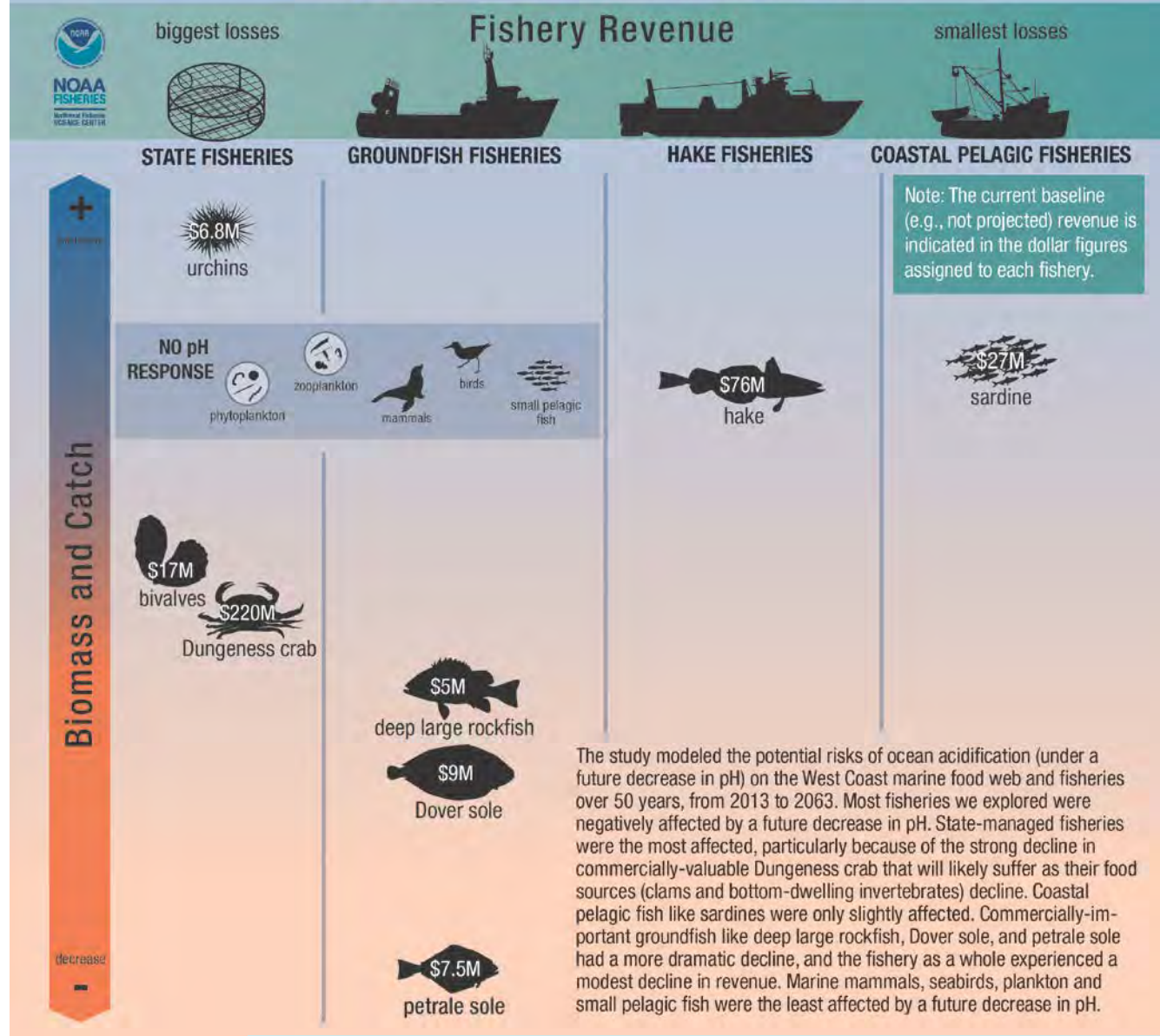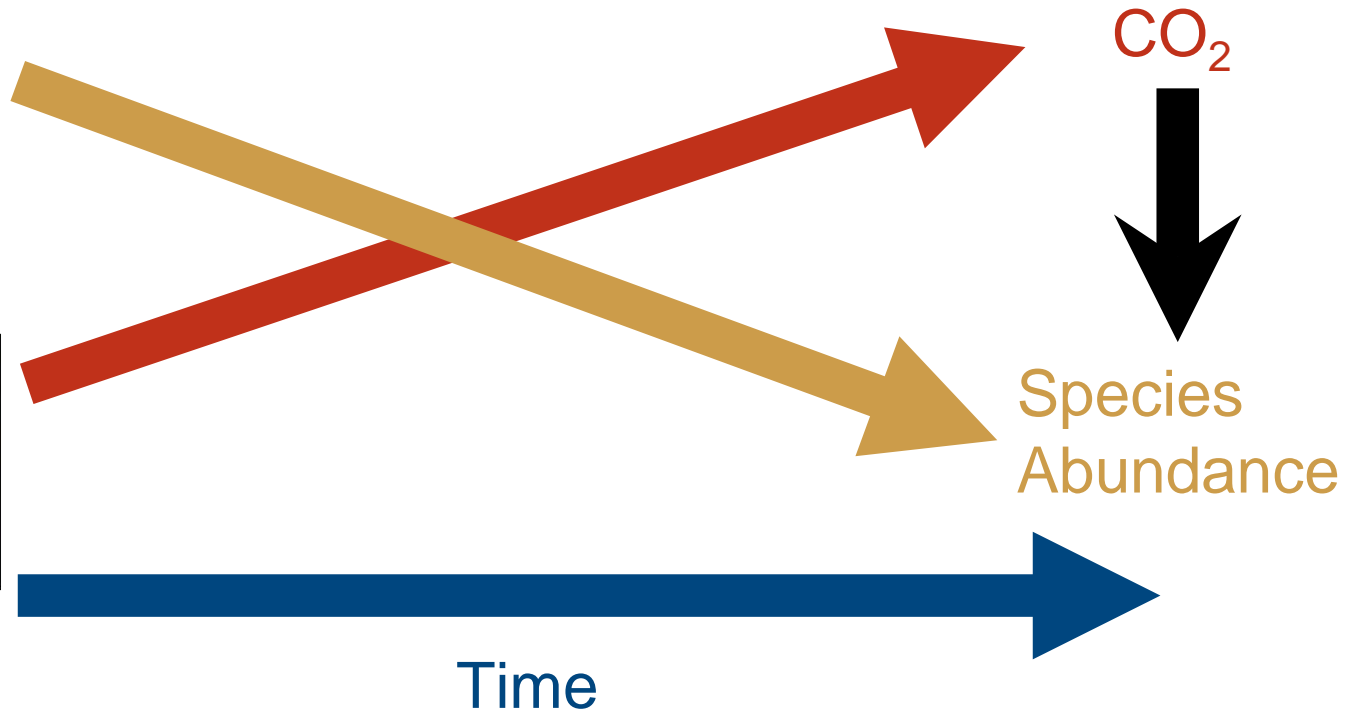
Marshall, Kaplan, Hodgson, Hermann, Busch, McElhany, Essington, Harvey, Fulton. 2017. (Global Change Biolology)

- The ocean is acidifying from burning fossil fuels
- Many organisms show negative effects when reared in low pH environments
- …But do we actually observe any effects of OA in the wild?

To show effect of OA...

CO$_2$

Species Abundance

Time

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Real Data are Messy
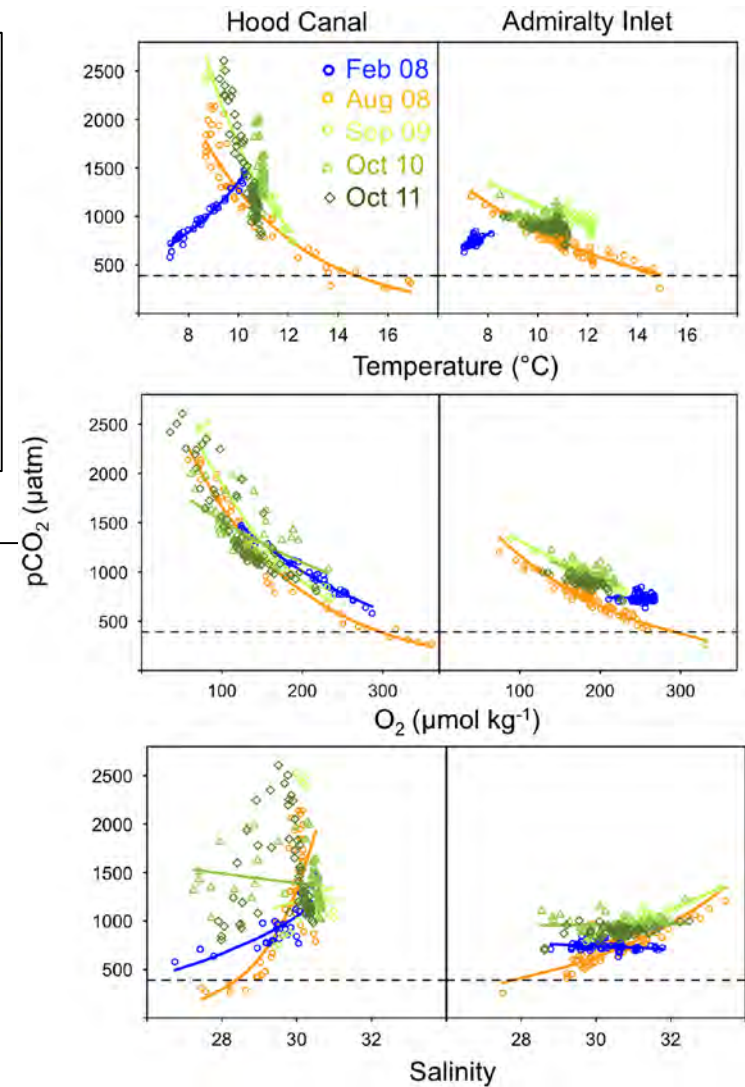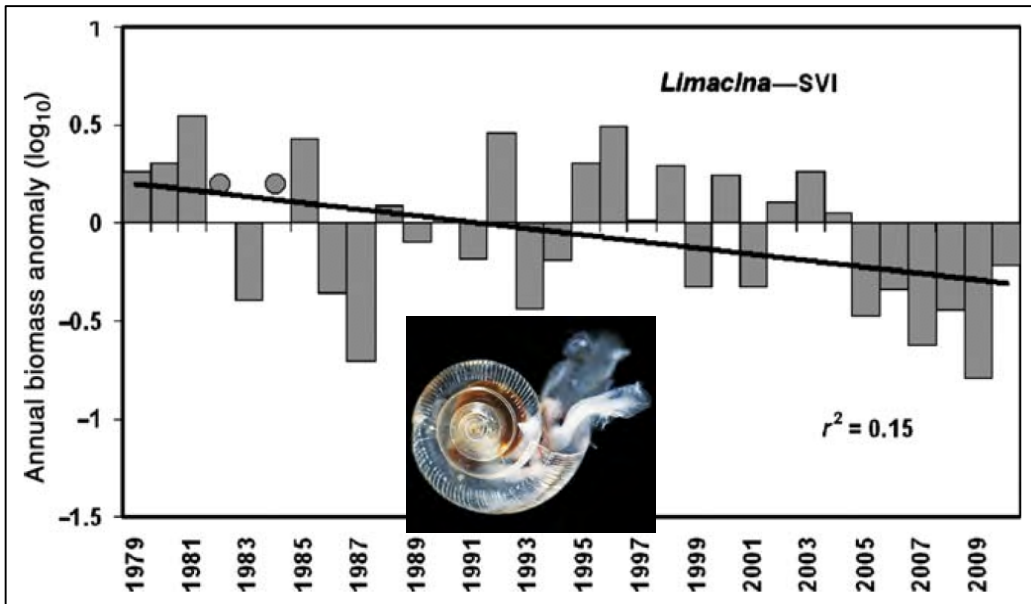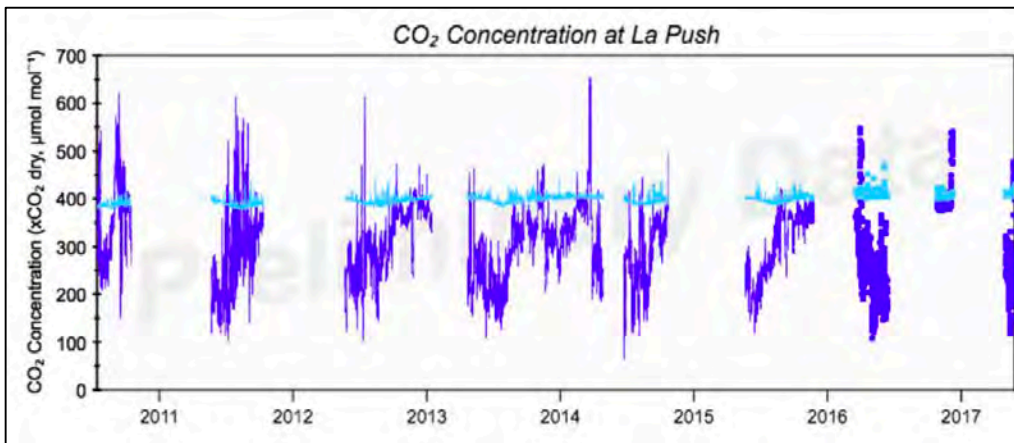
So…

- Have any effects on harvested species already occurred that we have not detected?
- How long until we see unambiguous evidence of OA effects?

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Searching for a metaphor…

Management Actions for OA

- Reduce CO_2
- Aquaculture control pH
- Small scale mitigation (oyster shells, kelp/eel grass)
- Reduce terrestrial nutrient input (biological pump)
- Reduce other stressors
- Develop CO_2 tolerant strains
- Develop tools for detection and prediction
- OA informed spatial planning
- REDUCE CO_2

Conclusions

Technically,
The Glass is Completely Full.

Pessimist

1. West Coast ecosystems likely affected by OA

2. Prediction of biological effects of OA is difficult

3. Detecting biological effects of OA is difficult

4. Management options are limited

Optimist

1. Some species and systems likely not affected

2. Experiments and modeling improving fast

3. Increased coupled pH and biological monitoring

4. There are some management options
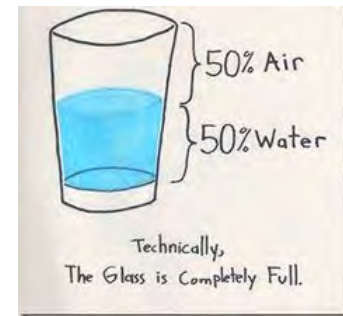
Cast of Thousands…

- Simone Alin
- Lindsay Alma
- Tori Bahe
- Katie Beaumont
- Eric Bjorkstedt
- Josh Bourma
- Shallin Busch
- Vathsala DeSilva
- Andy Dittman
- Audrey Djunaedi
- Melaina Dyck
- Andrea Fassbender
- Dick Feely
- Rick Geotz
- Jennifer Imm
- Pam Jensen

- Isaac Kaplan
- Julie Keister
- Cindy Kekeh
- Tarang Khangaonkar
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- Kaitlyn Lowder
- Mike Maher
- Gene McKeen
- Anna McLaskey
- Jason Miller
- Tori Monsaint-Queeney
- Mukilteo Field Station
- Krista Nichols

- Zoe Nichols
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