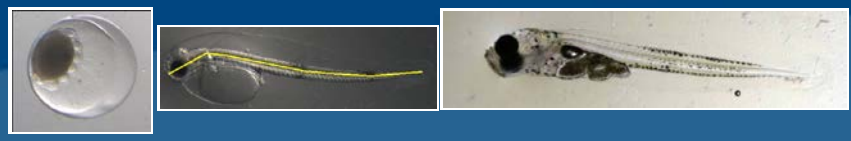
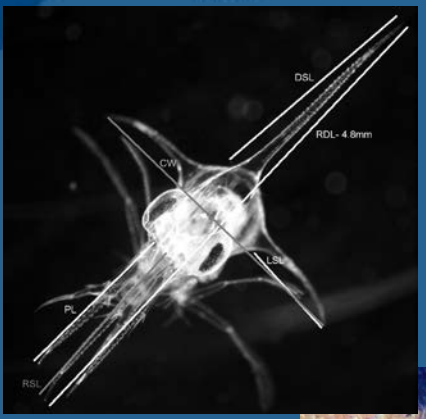
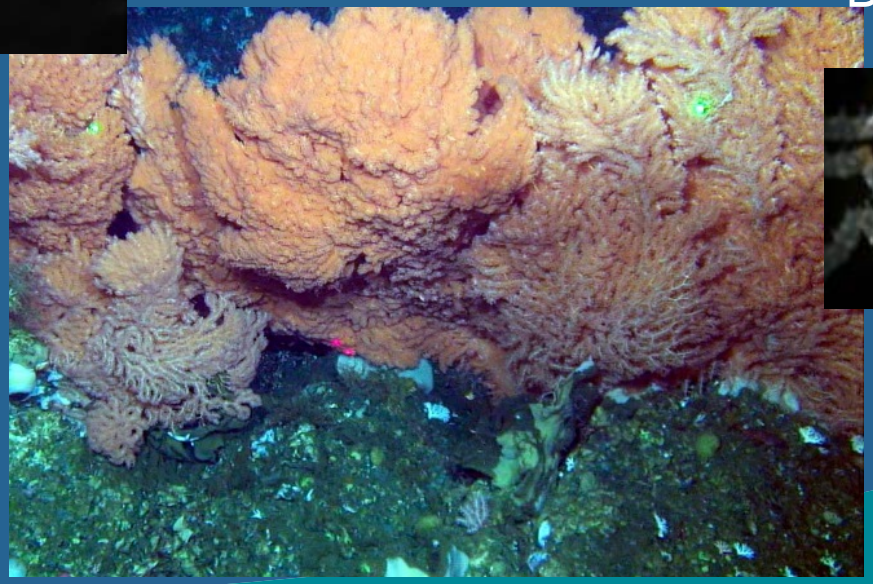


Research update on OAP funded biological and modeling research in Alaska

Robert Foy, Michael Dalton, Tom Hurst, W. Christopher Long, Shannon Meseck, Andre Punt, Bob Stone, Katherine Swiney

2017 OAP PI Meeting





January 4, 2017

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

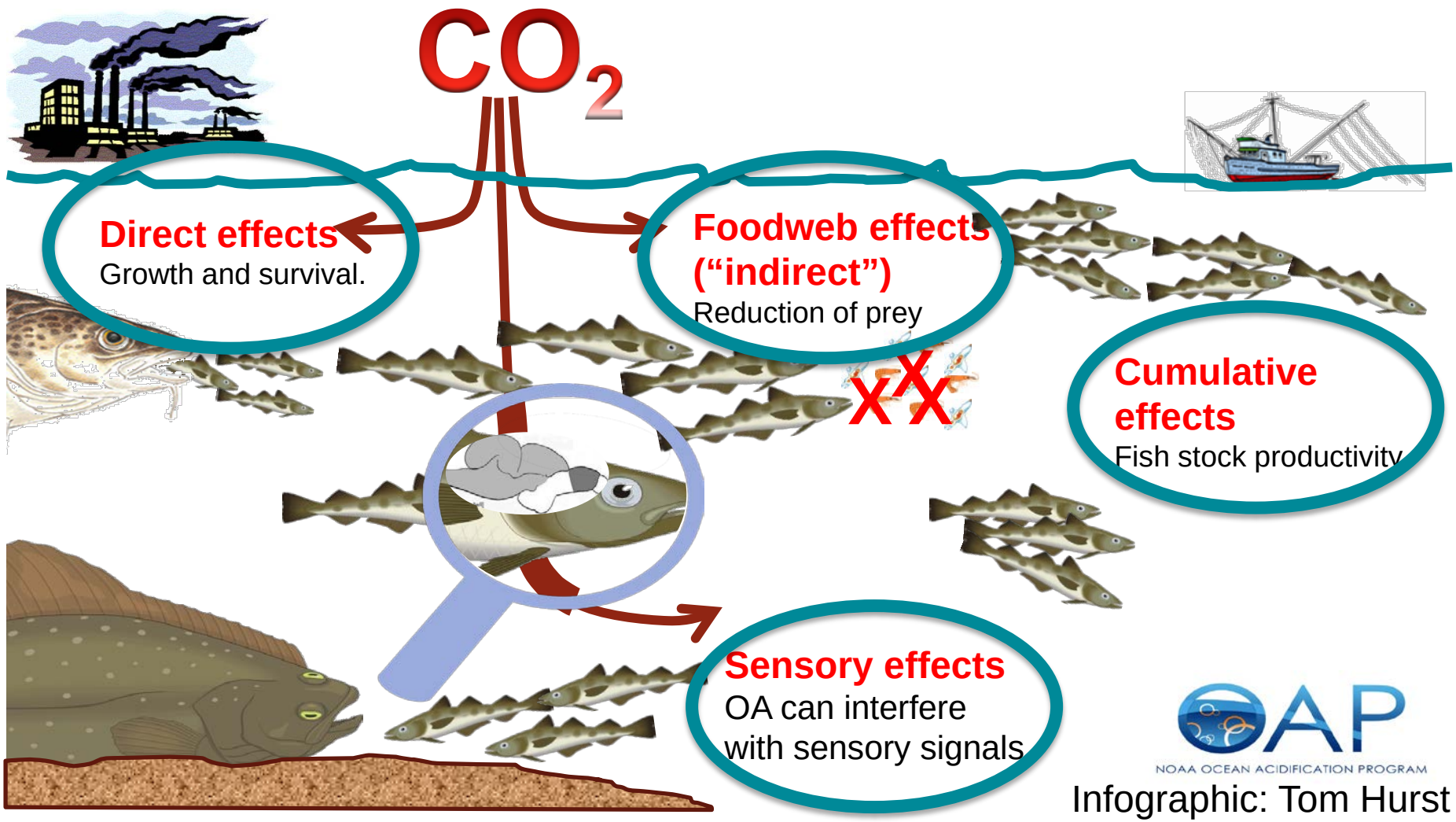
- Support ocean pH monitoring;
- Understand species-specific physiological responses;
- Forecast population impacts and economic consequences.

FY15-17 physiology/modeling studies

- Build on infrastructure and initial physiological work done from FY12-14;
- 16 publications, 30+ presentations.

Effects of OA on Alaskan groundfishes

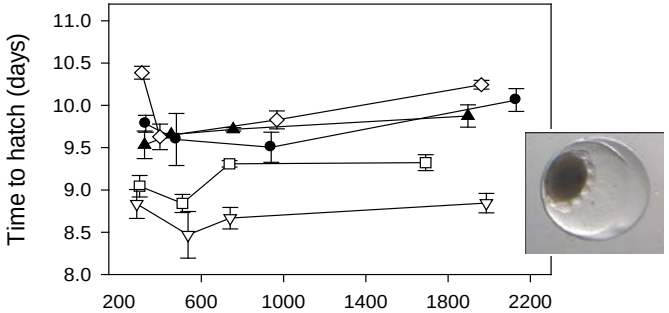
Tom Hurst



NOAA OCEAN ACIDIFICATION PROGRAM

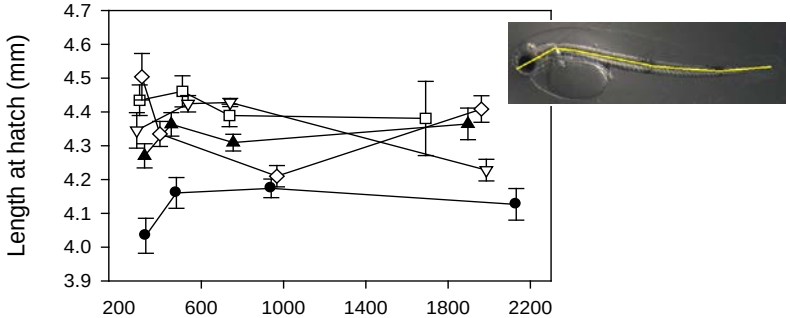
Infographic: Tom Hurst

Pollock eggs & early larvae appear robust to OA



5 Independent batches of eggs incubated 250 to 1000 µATM CO_2

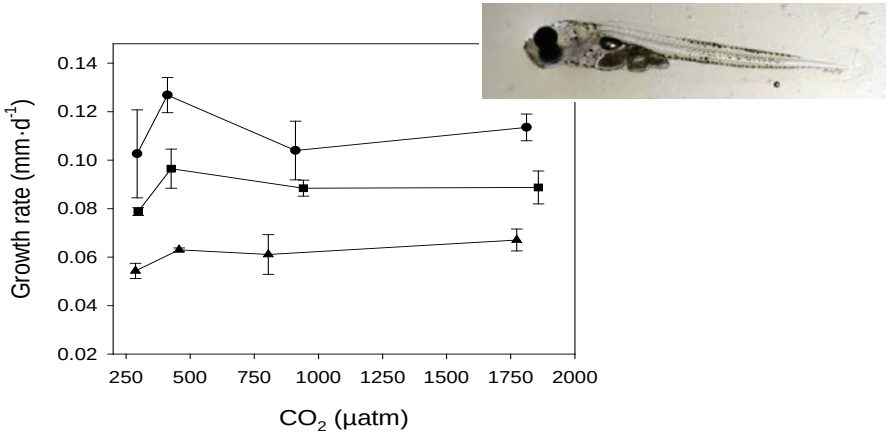
No reduction in hatch rate or size at hatch



3 independent experiments with larvae

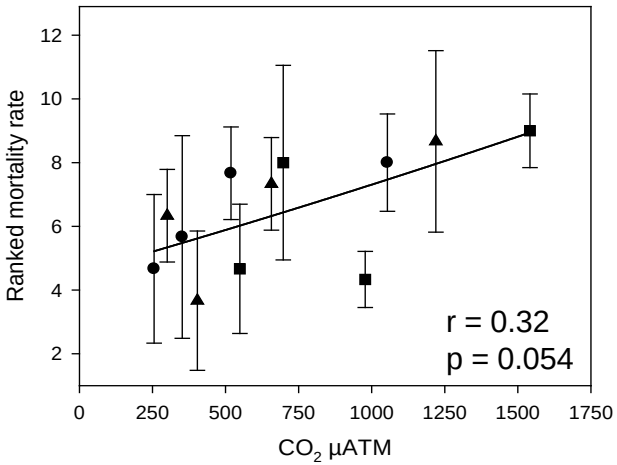
No evidence of negative effects on growth
Trend toward faster growth at slightly elevated CO_2

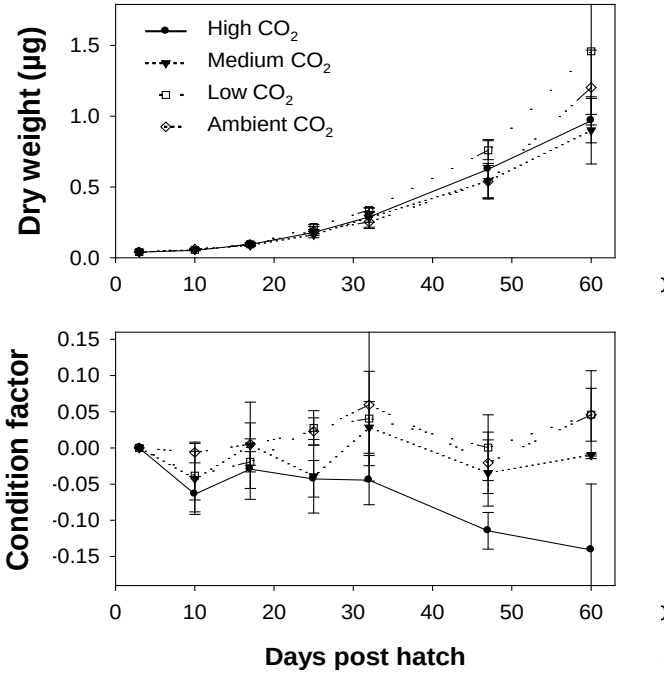
These effects smaller than effects of temperature



Hurst et al. (2013)

Northern rock sole appear more sensitive to OA





Trend toward higher mortality rates at elevated CO_2

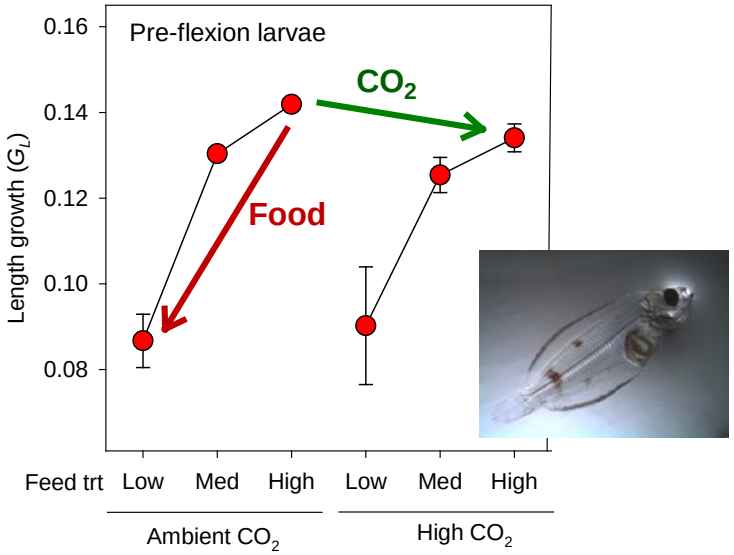
Lower growth rates and condition factors observed at high CO_2 levels.

Hurst et al. (2015)

OA Foodweb effects study

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



Hurst et al. *in press*.

As predicted, larvae were more sensitive to prey limitation that could be caused by OA effects on their zooplankton prey.

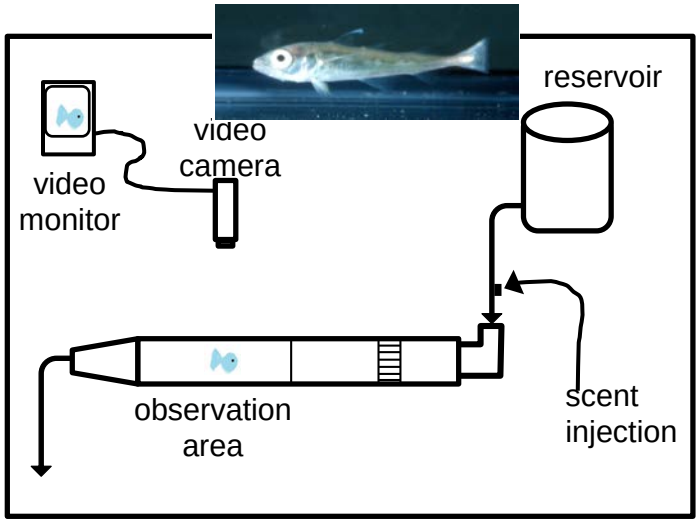
Fortunately, there did not appear to be interactive effects.
i.e. OA did not make the effects of prey shortage worse.

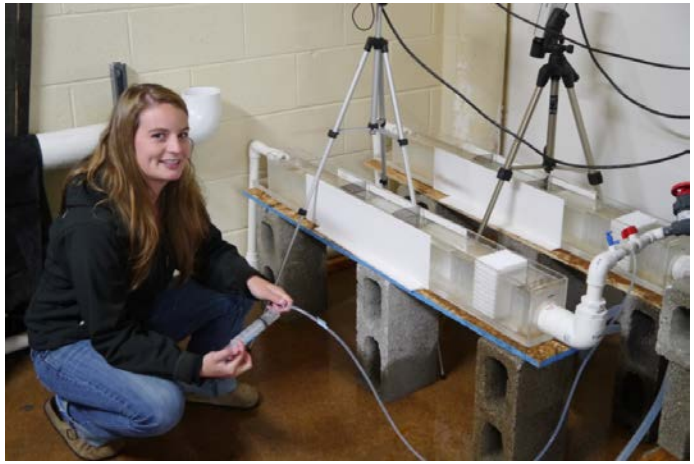
Currently doing similar experiment with Pacific cod larvae.

Sensory and behavioral effects of OA

Do OA effects observed in coral reef fishes extend to temperate and boreal fishery species?

Walleye pollock – response to prey scent

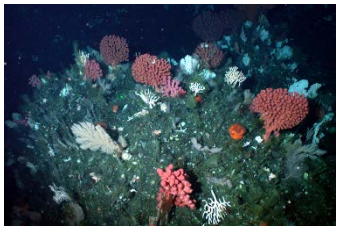




Preliminary data suggests that these effects do occur in walleye pollock – they were less likely to recognize the scent of their prey under OA conditions.

Alaska Fisheries Science Center

Deep-sea (Cold-water) Corals



- Alaska's ecologically most important coral (*Primnoa pacifica*) is most at risk to potential effects of OA given its highly soluble skeleton, depth distribution, and observed propensity for tissue loss from contact with fishing gear and predation.
- Most coral taxa live at least partially below the current saturation horizons so may be physiologically compensating for OA effects via important life-history trade-offs.

Potential Effects of OA on Alaskan Corals Based on Calcium Carbonate Mineralogy and Other Factors

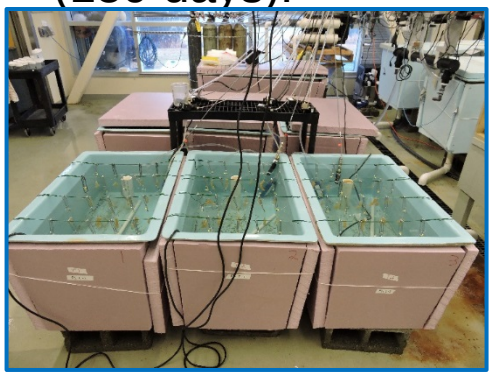
(R. Stone, J. Guinotte, A. Helbling, A. Cohen, S. Cairns, J. Cross)

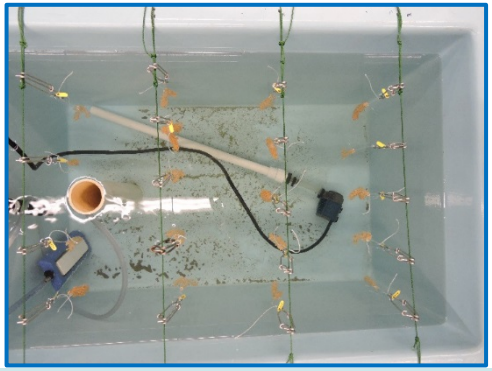
- XRD and full-pattern Rietveld data refinement to precisely determine the skeletal composition of 62 species of Alaskan corals – the most comprehensive cold-water coral dataset for any region in the world.
- No Alaskan corals are at risk for skeletal dissolution based on present-day carbonate chemistry conditions…chemistry of a few taxa may approach estimated dissolution points…based on high Mg Calcite forms of calcium carbonate.
- Evidence of mineral-switching related to depth distribution or broad-scale biogeography. A high percentage of taxa are slightly polymorphic (high-Mg calcite and aragonite.)

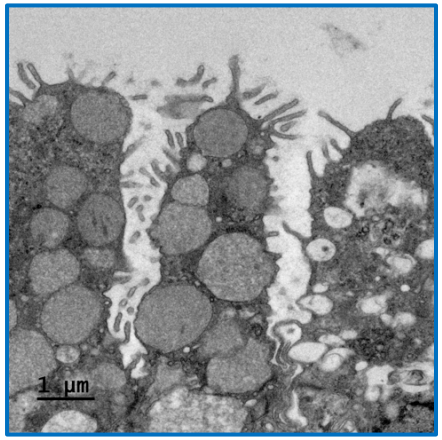
Physiological Response of the Red Tree Coral (*Primnoa pacifica*) to Low pH Scenarios in the Laboratory

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

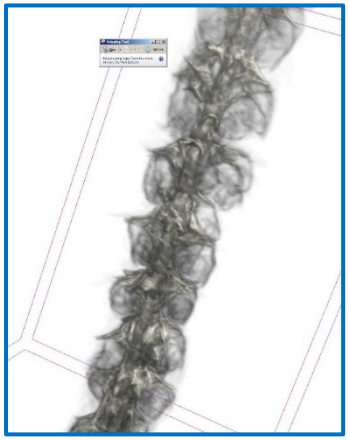
- Two treatments: pH 7.75 (current at 200 m depth GOA) and pH 7.55 (projected Year 2100).
- Snips from 54 colonies. 2 Treatments X 3 Tanks X 18 snips (plus 54 snips Day-0).
- January 15 to September 22, 2016 (252 days), except 1/3 of samples 21 June 2016 (159 days).



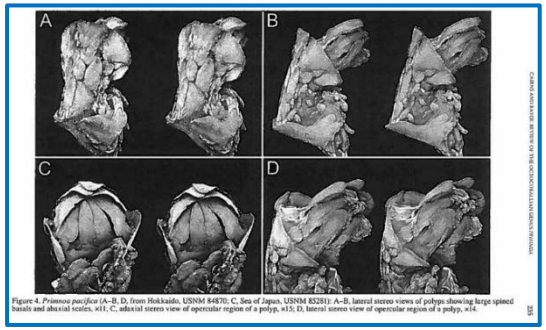




Fecundity and oocyte/ spermatocyst development



Micro-CT scans of skeletal density/growth



SEM scans of sclerites morphology

King and Tanner crab lab research

Framework for assessment of climate change and OA:
Organismal (individual tolerance), population, and ecosystem level response

Experiments: (2010-2016)

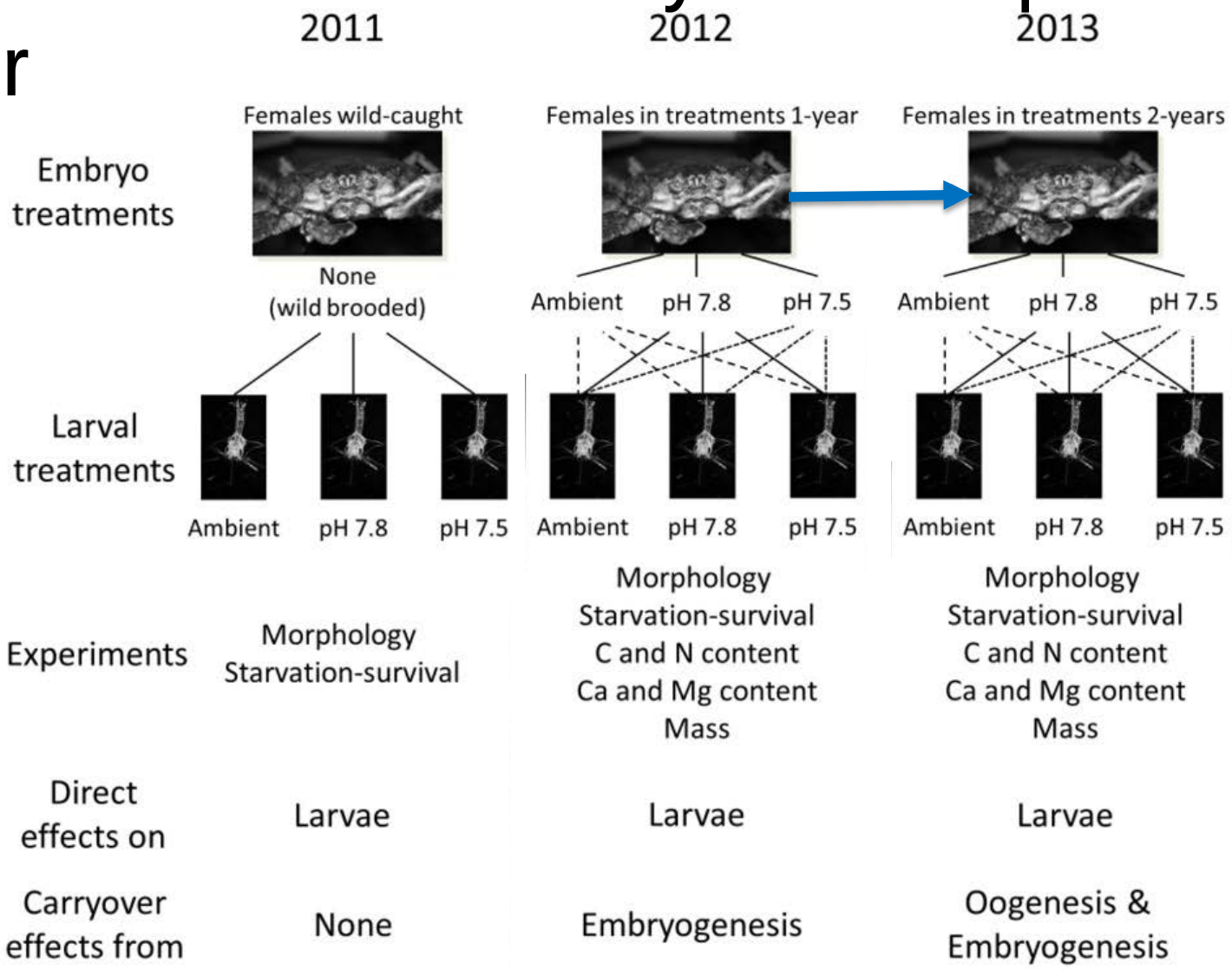
- Red king crab (*Paralithodes camtschaticus*) embryos, larvae, juveniles
  - CO_2 and temperature concurrent effects (Swiney et al. 2016)
  - Genomics: protien expression to support cuticle development (Jonathon Stillman UC Berkeley, 2017)
  - Shell mechanics (claw vs carapace) (Gary Dickinson, College of New Jersey 2016)
- Blue king crab (*Paralithodes platypus)* juveniles
- southernTanner crab (*Chionoecetes bairdi*) embryos, larvae, juveniles
- Golden king crab (*Lithodes aequispinus*) adults
- Snow crab (*Chionoecetes opilio*) embryos, larvae, juveniles

Response variables: Survival, fecundity, morphometrics (image analysis), growth (width and wet mass), calcification

Collaborations: Hemocyte function, genetics (protein expression), mechanics, population dynamics, bioeconomics

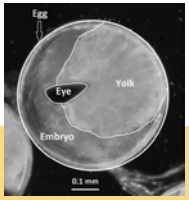
Chionoecetes bairdi multi-year lab experiment

Tanner crab



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

Embryo response



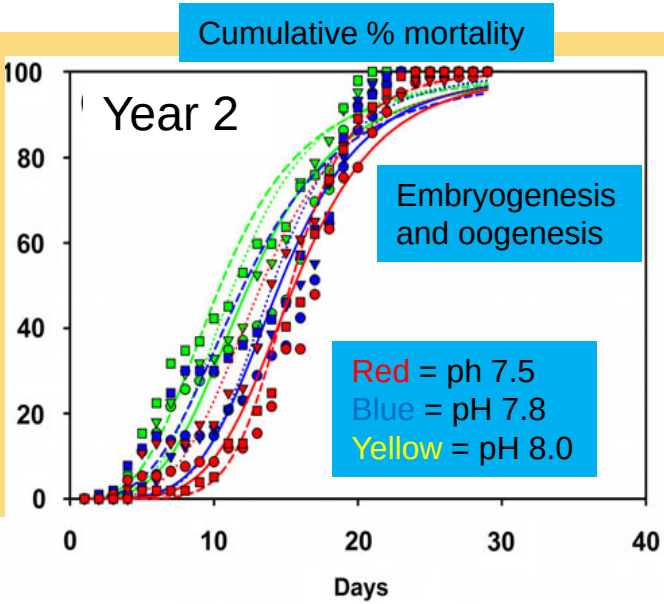
- pH 7.5: 10% larger yolks and 6% smaller embryos (slower development)

Embryo → larvae carryover

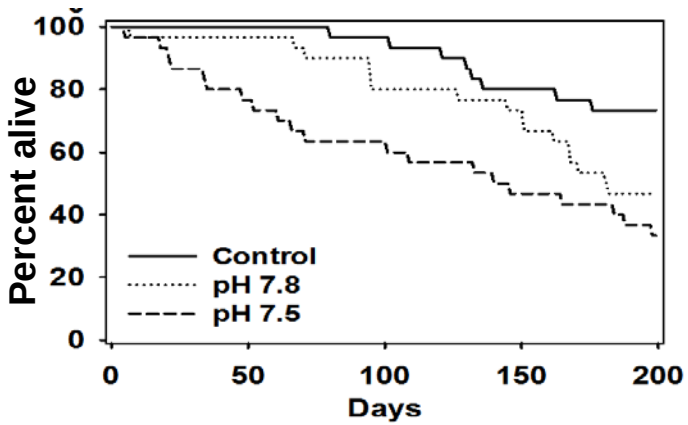
- Year 1: no significant difference in # hatched
- Year 2: 48-83% fewer larvae hatched
- Year 2: 71% fewer viable larvae hatched at pH 7.5

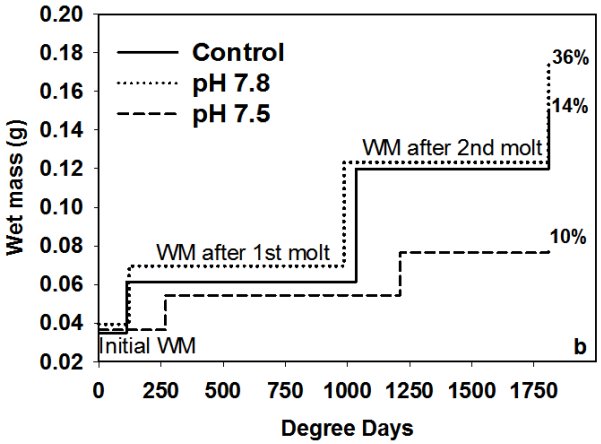
Larval survival: starvation experiments

- Embryo treatment affected larval morphometrics
- However, minimal effect on survival
- In year 2
  - 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?



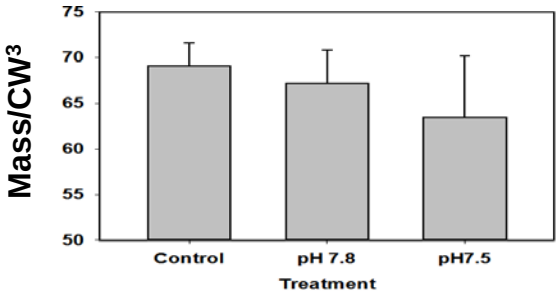
Juvenile crab mortality and growth

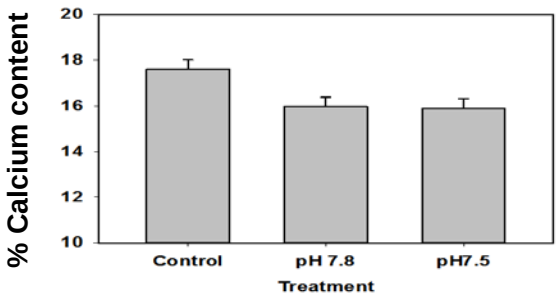




Juvenile stage is very susceptible to negative OA effects.

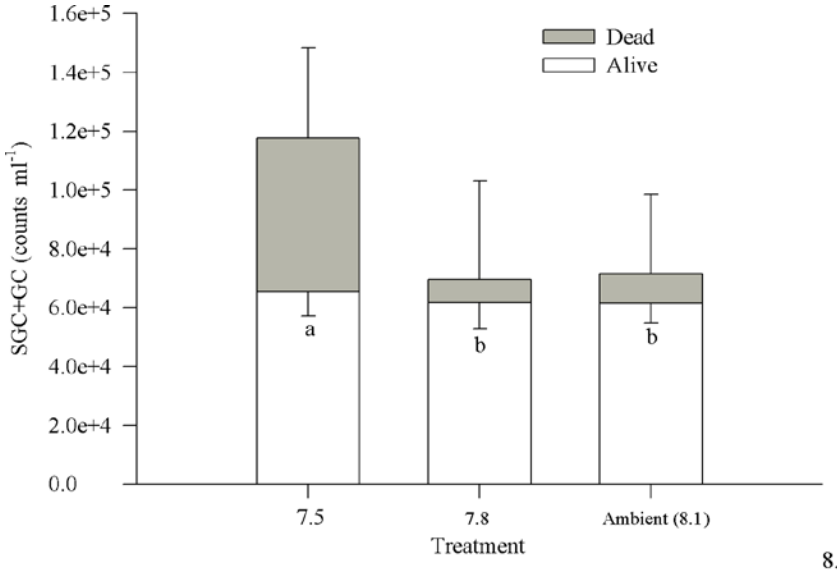
Adult condition and calcification





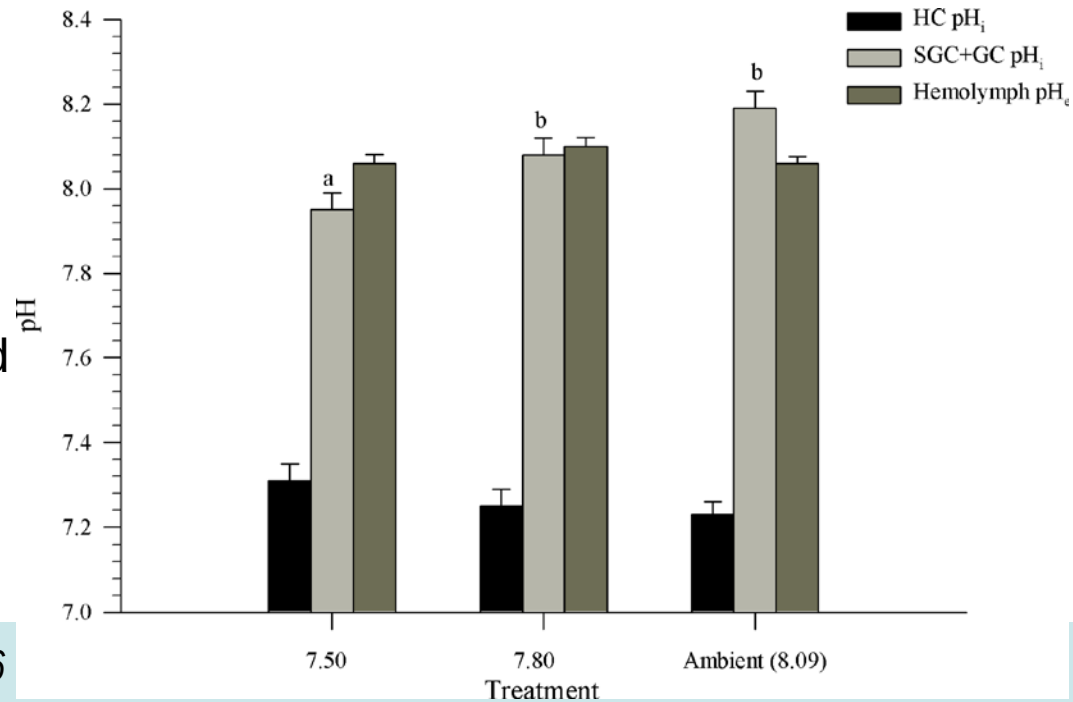
Energetic trade-off between condition and calcification?

Adult hemocytes (semi- and granular cells)



- Flow cytometer
- Total hemocyte count did not change
- More dead cells & phagocytosis increased at pH 7.5
  - Cells dying faster (turnover) than can be removed
- Different effect in snow crab

- Internal pH no different among treatments
- Energetic costs to maintain pH and maintain defense mechanisms
- Similar effects in snow crab



Meseck et al. 2016

Evidence for phenotypic plasticity?

Effects at oocyte and embryo stage significant

Effects at larval stage minimal (no effect on mortality)

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

Effects at juvenile stage significant

- Calcification vs condition tradeoff?

Adult crab maintain hemolymph pH

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

NOAA Alaska Fisheries Science Center

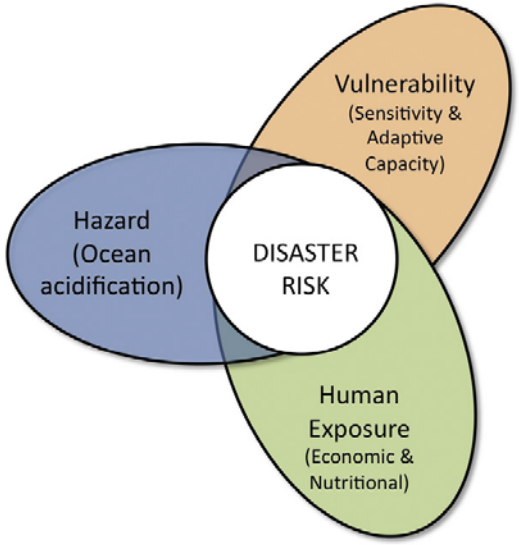
Research Approach

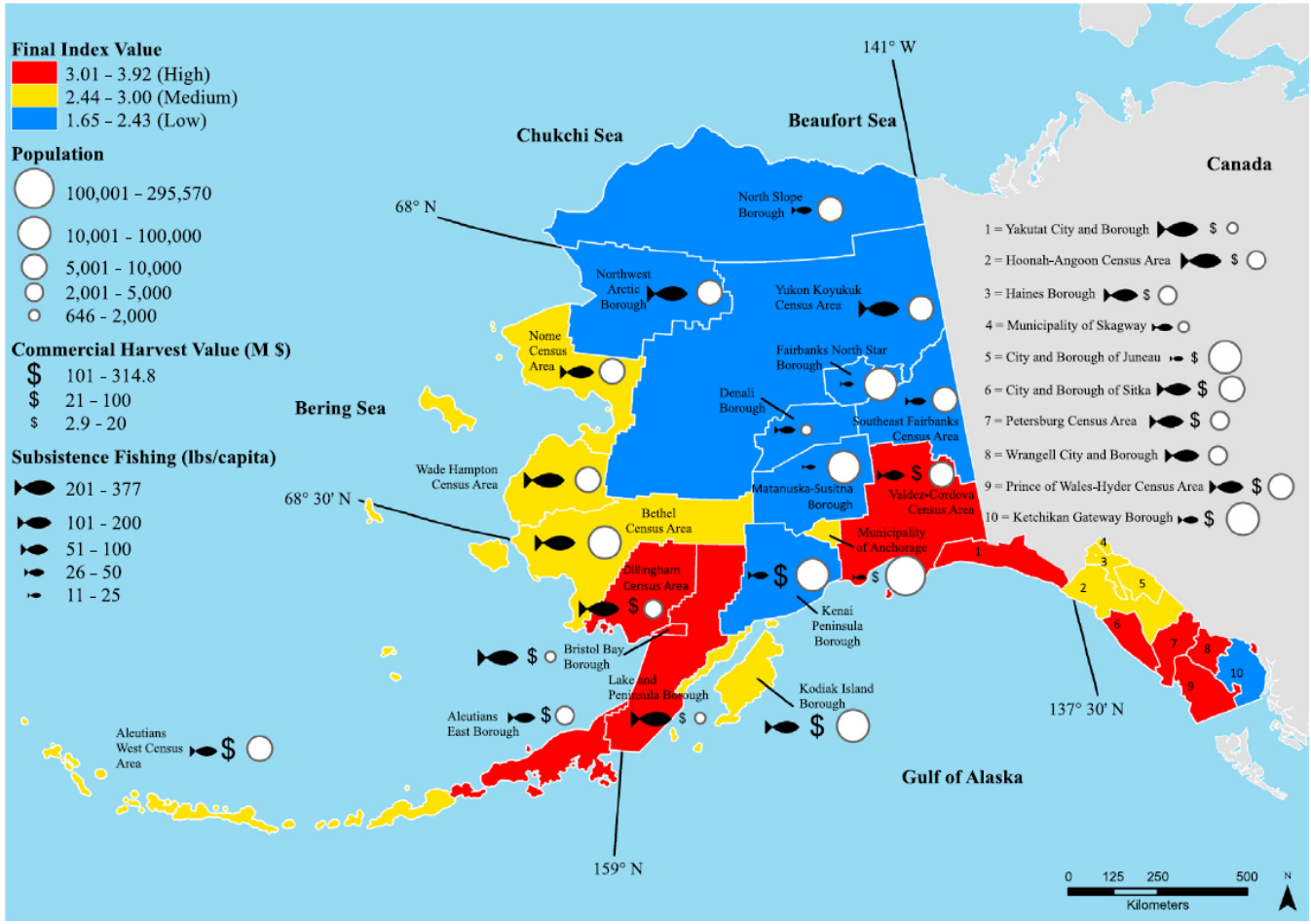
1. Understand species-specific physiological responses

2. **Forecast population impacts and economic consequences**

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.

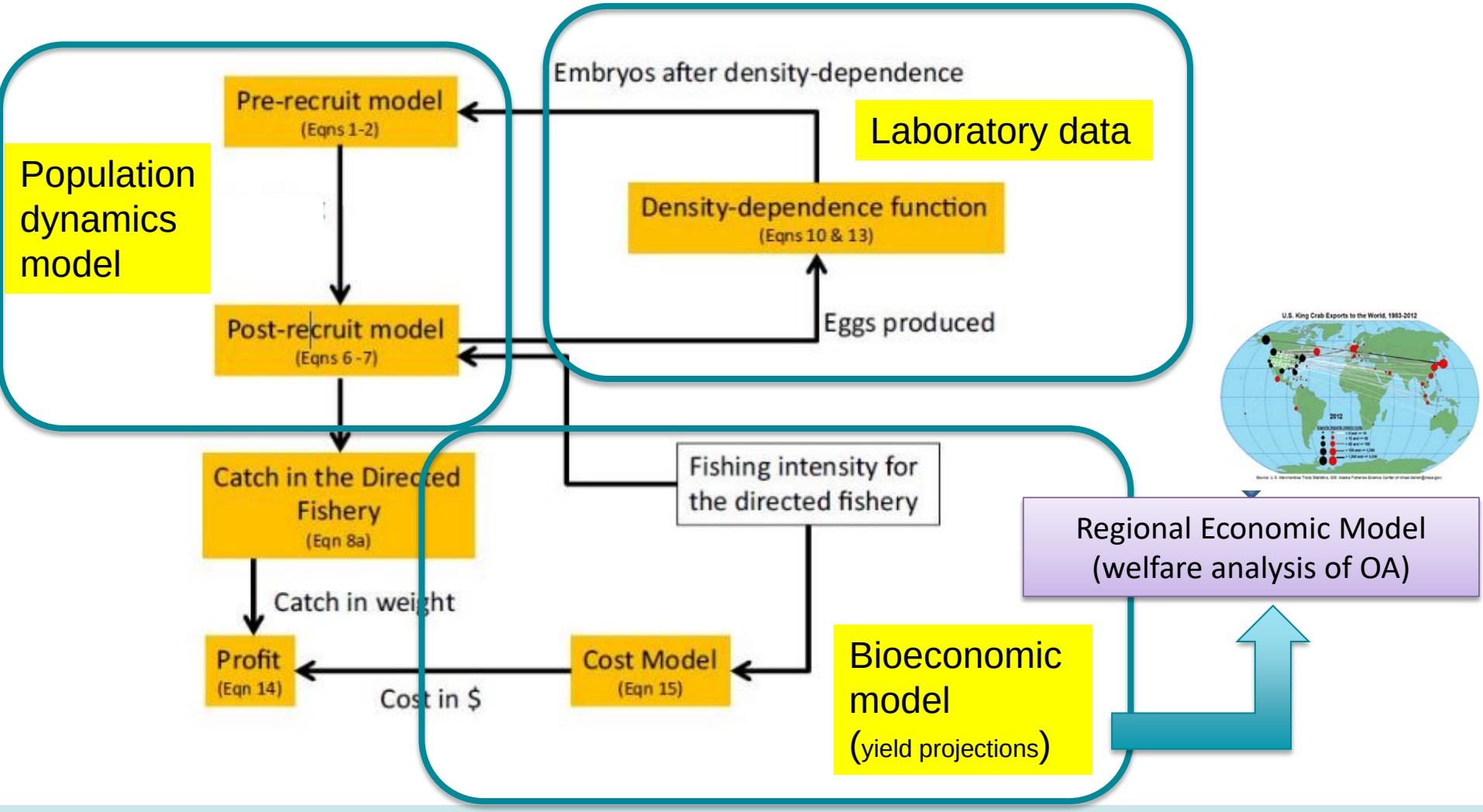




Mathis et al. 2015. Progress in Oceanography

Forecasting fisheries population effects

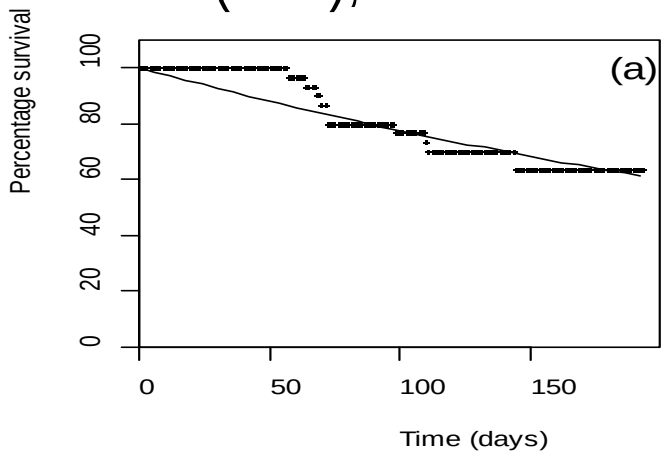
Experimental results were used to inform pre-recruitment model
-Tanner crab oocyte, embryo, larval, and juvenile survival

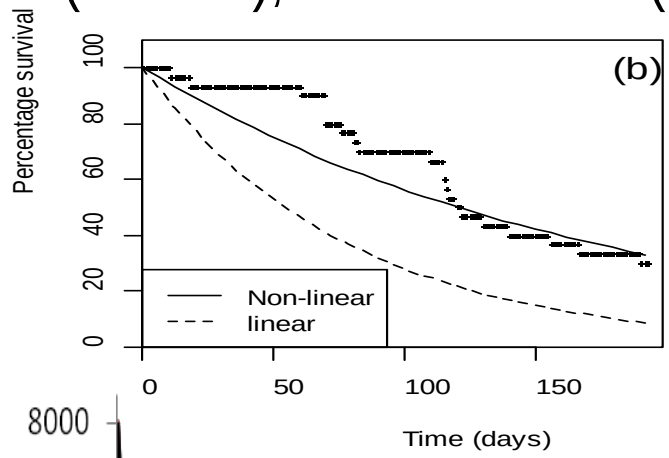


Punt et al. 2014 & 2016

Juvenile king crab survival model fits and yield projections

observed (dots), best-linear model (dashed), best-nonlinear (solid)

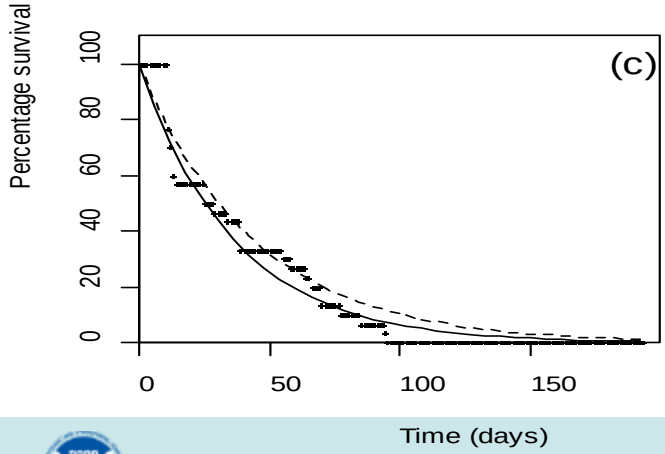


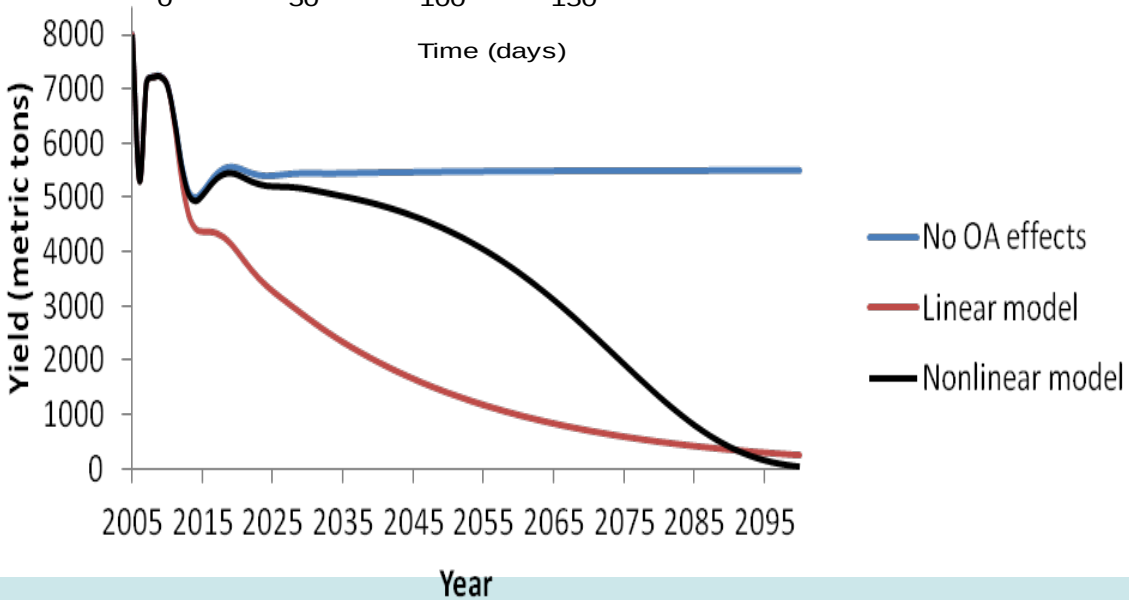


(a) pH = 8.0

(b) pH = 7.8

(c) pH = 7.5





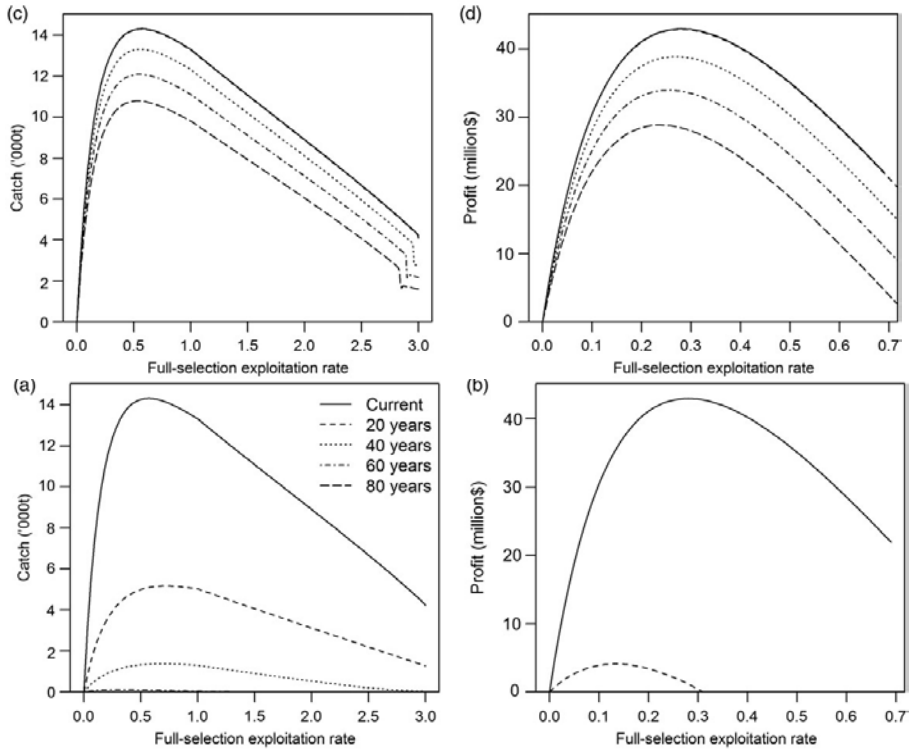
NOAA FISHERIES

Punt et al. (2014) survival plots; Seung et al. (2015) yields

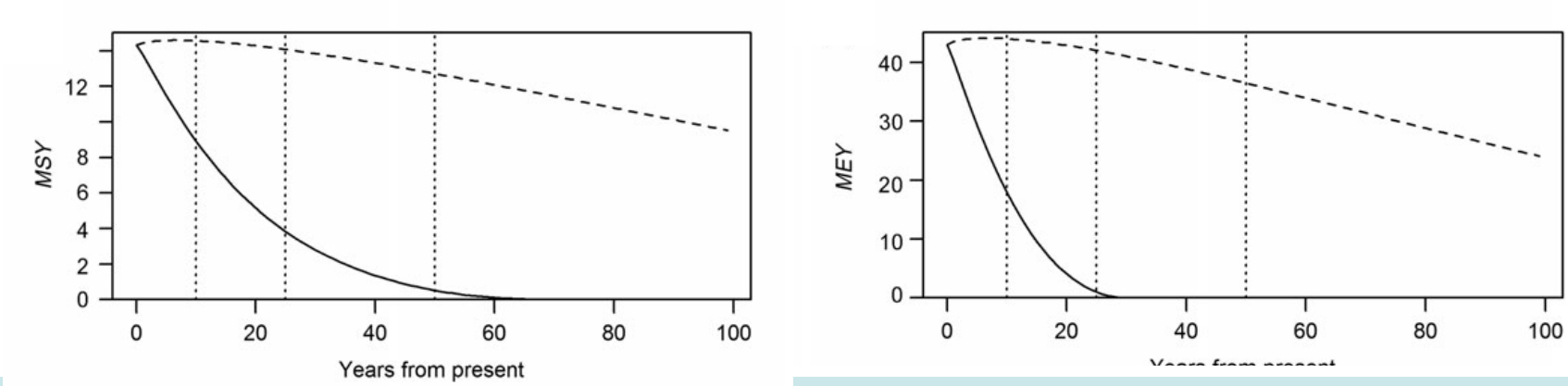
C. Bairdi Population Effects: *without acclimation*

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



NOAA FISHERIES

Punt et al. 2016

What's next?

Physiological Effects

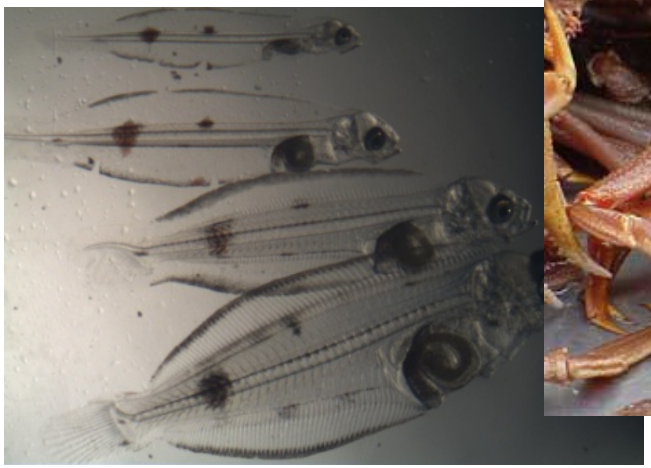
- Fish: continue to develop ecosystem and behavioral responses
- Coral: assess differences in skeletal components of Primnoa. Look at process(es) of mineralogy
- Crab: need to consider portions of stock that survive (acclimation!)
    - Assess energetic response (consumption)
    - Hemocytes: focus on 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

- Alaska Fisheries Science Center Research Staff
- Northeast Fisheries Science Center Research Staff
- University of Washington, College of New Jersey, UC Berkeley labs
- NOAA Ocean Acidification Program



Thank you!

Ocean Acidification: is it the carbonate or the pH?

Treatment	pH	pCO_2 uatm	HCO_3^- mmol/kg	CO_3^{-2} mmol/kg	DIC mmol/kg	ALK mmol/kg	Ω_{Ar}	Ω_{Ca}
Ambient	8.09 (0.07)	391.90 (65.59)	1.90 (0.04)	0.09 (0.02)	2.01 (0.04)	2.13 (0.06)	1.44 (0.25)	2.31 (0.40)
pH 7.8	7.80 (0.03)	781.17 (31.13)	1.99 (0.04)	0.05 (0.00)	2.08 (0.04)	2.13 (0.06)	0.78 (0.05)	1.24 (0.07)
pH 7.5	7.50 (0.03)	1597.15 (62.76)	2.05 (0.04)	0.03 (0.00)	2.16 (0.04)	2.13 (0.04)	0.40 (0.02)	0.64 (0.04)

- pH and temperature measured daily (n=316 in year 1; n=412 in year 2)
- DIC, salinity, alkalinity measured weekly
- HCO_3 and CO_3 and omega calculated

Do Tanner crab respond to lower pH or lower saturation state?

- relatively shallow & more variable environment
- can Tanner crab regulate pH?

$$Ca^{2+} + HCO_3^{2-} \leftrightarrow$$

Future Research on hemolymph chemistry

occolithophores, and
aceans can transport bicarbonate
(organic carbonate) to site of mineralization