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Alaska
Fisheries
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Ocean Acidification: what is it and how will it affect coastal Alaska communities

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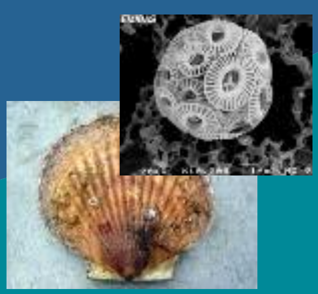
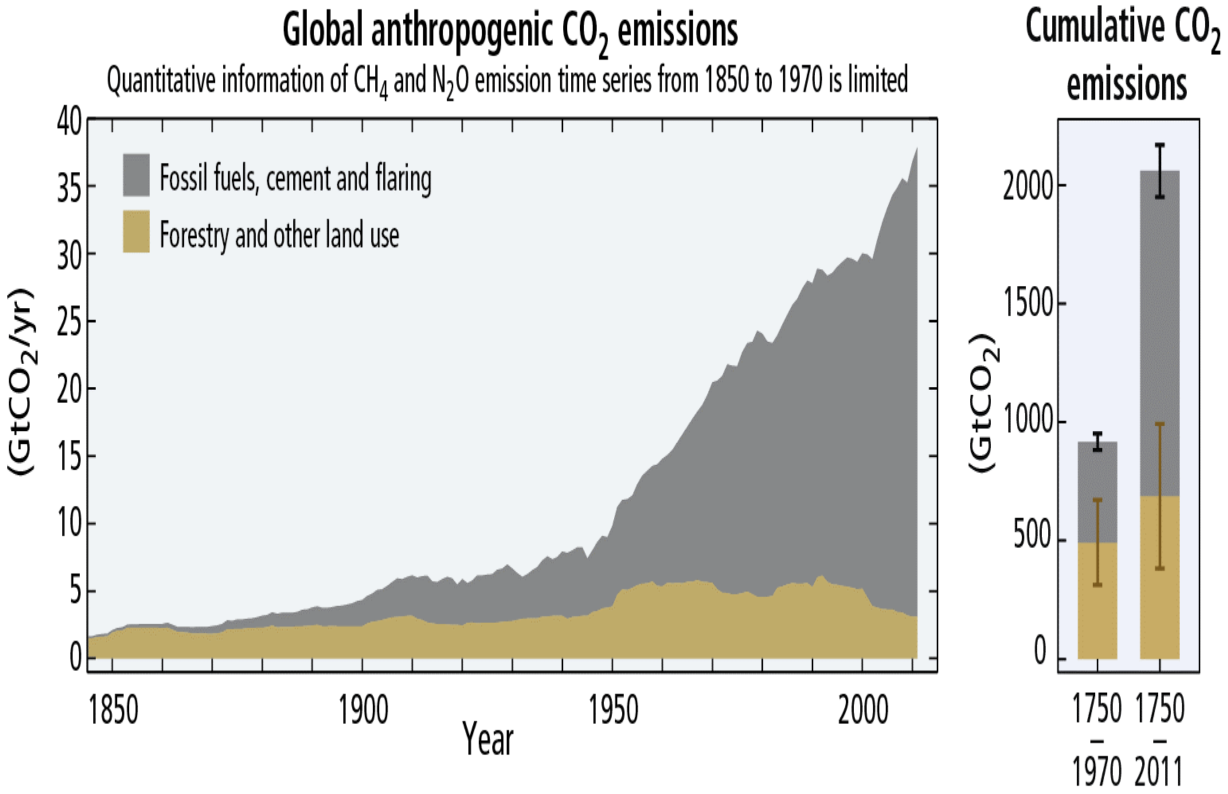
2016 LEO webinar

August 23, 2016



Outline

- What is OA?
- Why is Alaska at risk?
- How will fisheries be affected?



IPCC 2014

Ocean Acidification

observed decrease in ocean pH resulting from increasing concentrations of CO_2

- 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
- North Atlantic and North Pacific (pH decreasing -0.0015 to -0.0024 per year)

Ocean Acidification: is it the carbonate or the pH?

$$CO_2 + CO_3^{2-} + H_2O \leftrightarrow 2HCO_3^-$$

Carbonate used up if CO_2 added to water

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

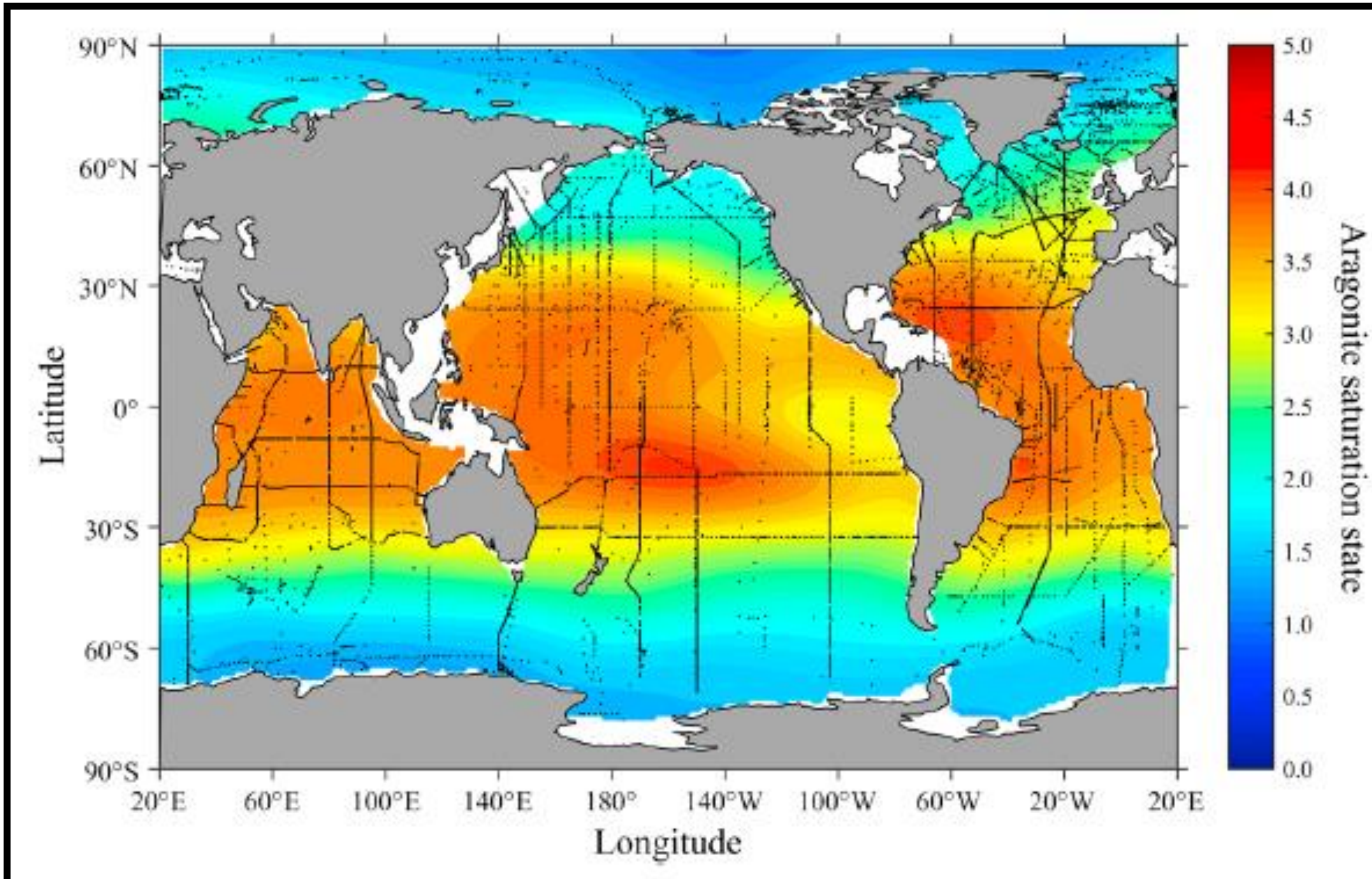
Shellfish and corals *need* carbonate (inorganic carbonate)

$CaCO_3$ supersaturated (precipitation) at surface

$CaCO_3$ undersaturated (dissolution) at depth

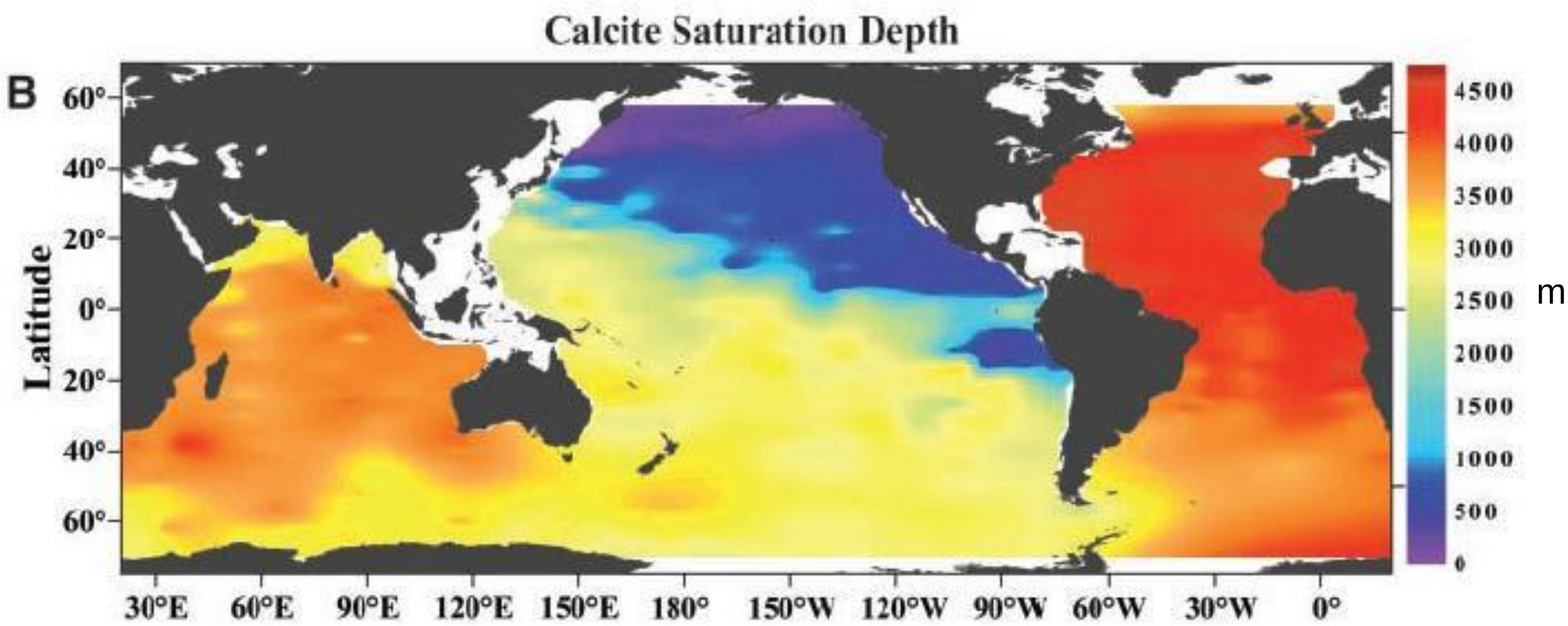
However, some corals and coccolithophores *can use* bicarbonate (organic carbonate)

Ocean Acidification: the global surface picture



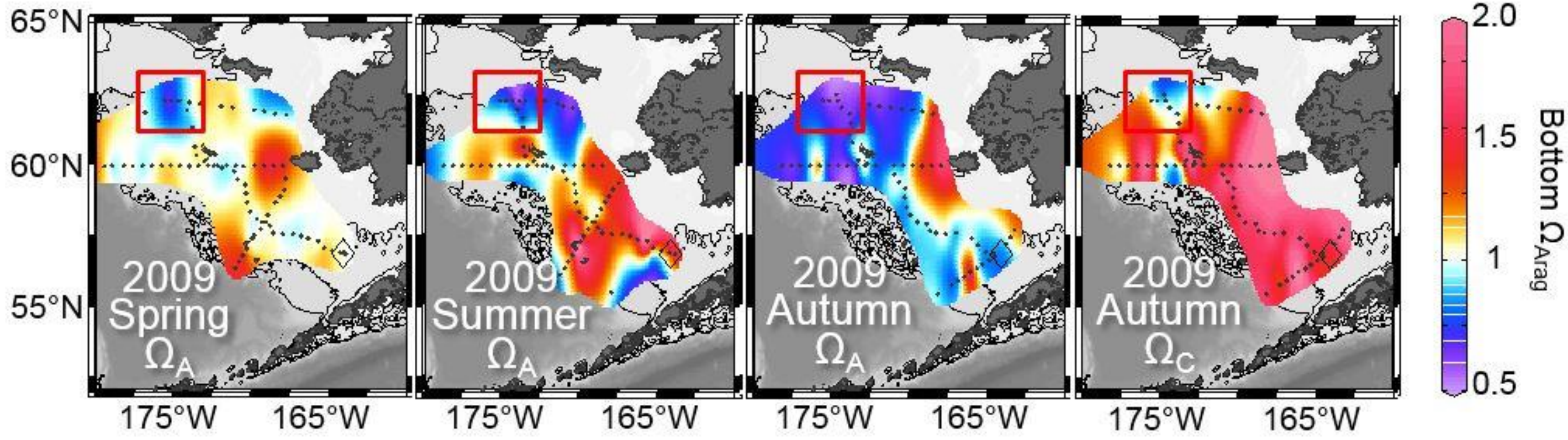
Jiang et al., 2015

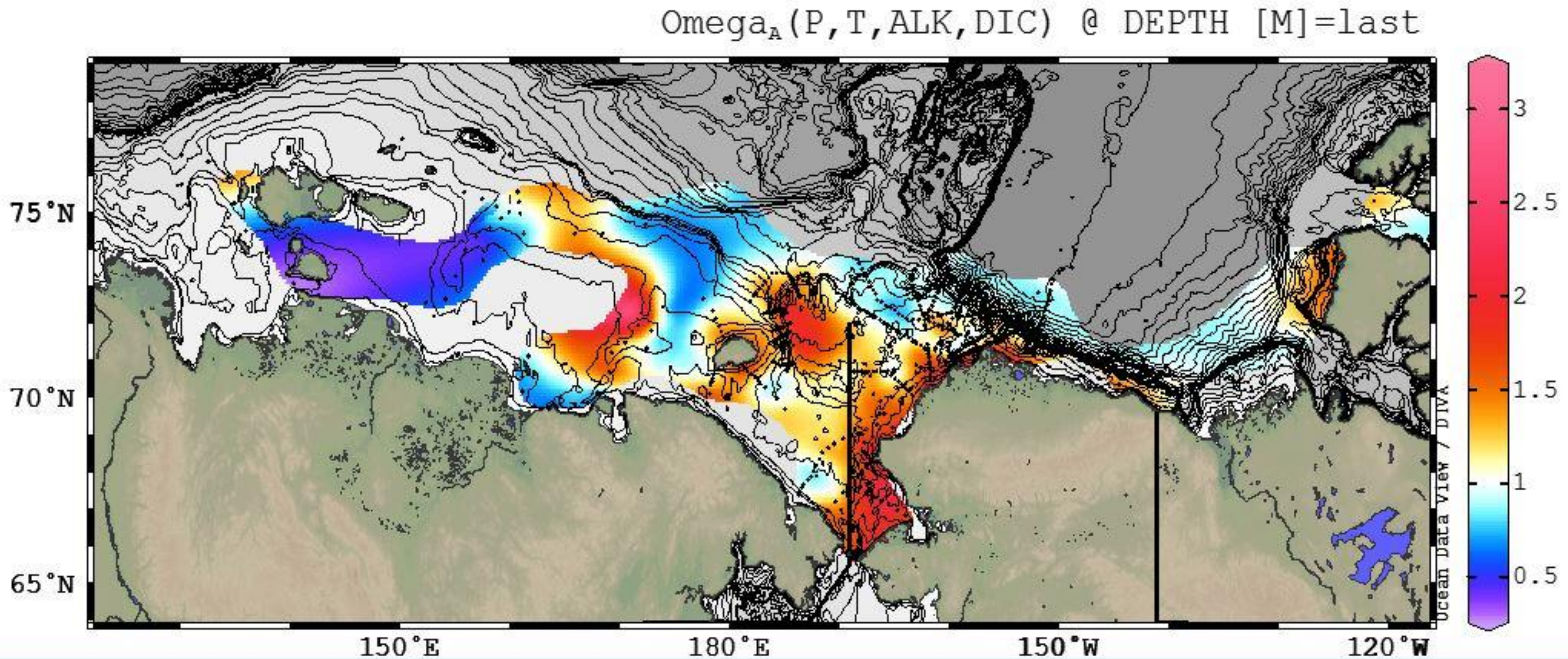
Ocean Acidification: the global depth picture



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

Calcite saturation horizon ~ 300 m in the North Pacific compared to ~ 4,000 m in the North Atlantic.





Cross et al., In Prep

NOAA Alaska Fisheries Science Center Research Approach

Focal species groups

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

Objectives

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

So how do we measure effects of climate change and ocean acidification….

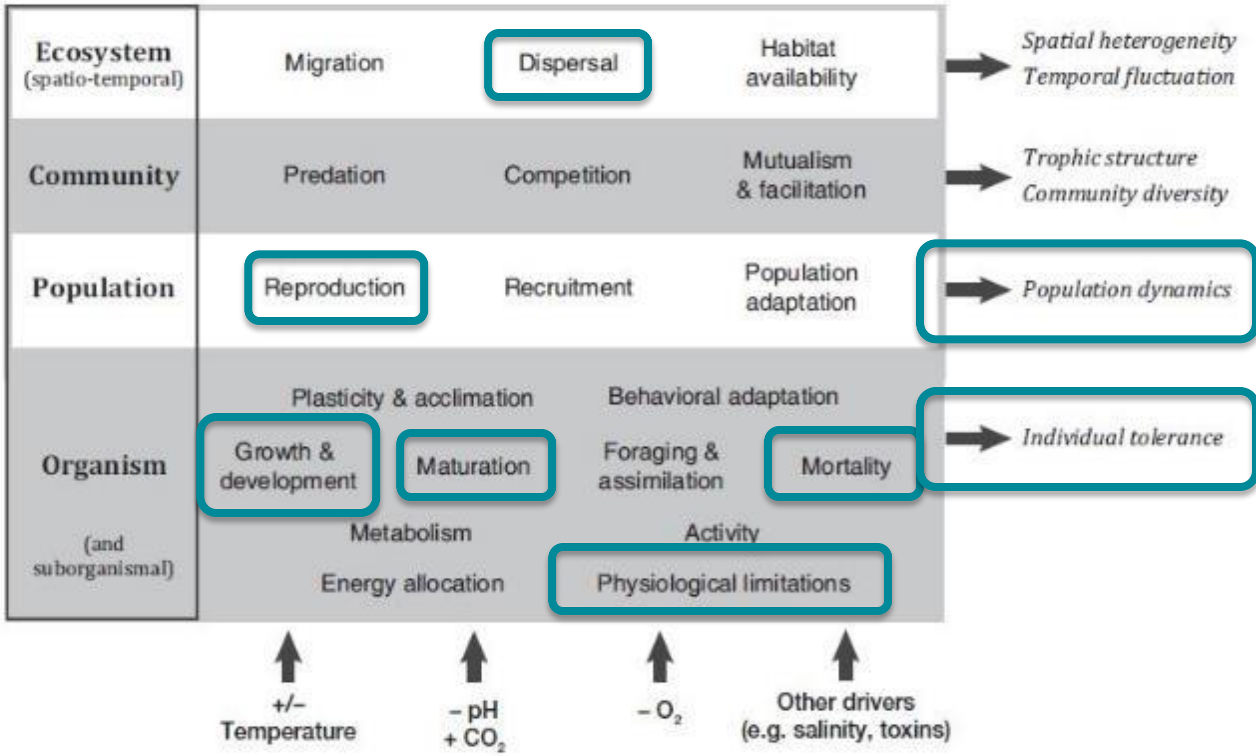
Climate Change

1. Range expansion
2. Change life history
   - Growth
   - Reproductive timing
   - Habitat availability
   - Species interactions
   - Larval drift

Ocean Acidification

1. Increased Mortality…recruitment
2. Growth change
3. Calcification
4. Behavioral changes

Framework to assess environmental effects



modified Koenigstein et al. 2016

Crab life cycle and depth distributions

			Shelf				Slope		Canyon	
	Life Stage	Depth (m)	Inter-tidal	Sub-tidal	Middle	Outer	Upper	Lower	Upper	Lower
Red king crab	Mature	3-300		■	■	■				
	Juvenile	0-200	■	■	■	■				
	Larvae	0-100	■	■	■	■				
Blue king crab	Mature	0-200		■	■	■				
	Juvenile	0-200	■	■	■	■				
	Larvae	0-100	■	■	■	■				
Golden king crab	Mature	100-1000				■	■	■	■	■
	Juvenile							■	■	■
	Larvae	100-1000				■	■	■	■	■

ΔpH more important? More resilient?

$\Delta CaCO_3$ saturation state more important?

As depth increases: (pressure increases, temperature decreases, and pH decreases) – all of which promote the dissolution of CaCO3.

Crab life cycle and depth distributions

			Shelf				Slope		Canyon	
	Life Stage	Depth (m)	Inter-tidal	Sub-tidal	Middle	Outer	Upper	Lower	Upper	Lower
Southern Tanner crab	Mature	1-500			■	■				
	Juvenile	1-500	■	■	■	■				
	Larvae	1-100	■	■	■					
Snow crab	Mature	1-200			■	■				
	Juvenile	1-1			■	■				
	Larvae	1-100			■	■				

ΔpH more important? More resilient range?

$\Delta CaCO_3$ saturation state more important?

King and Tanner crab lab research

Treatment system: (2006-2007)

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

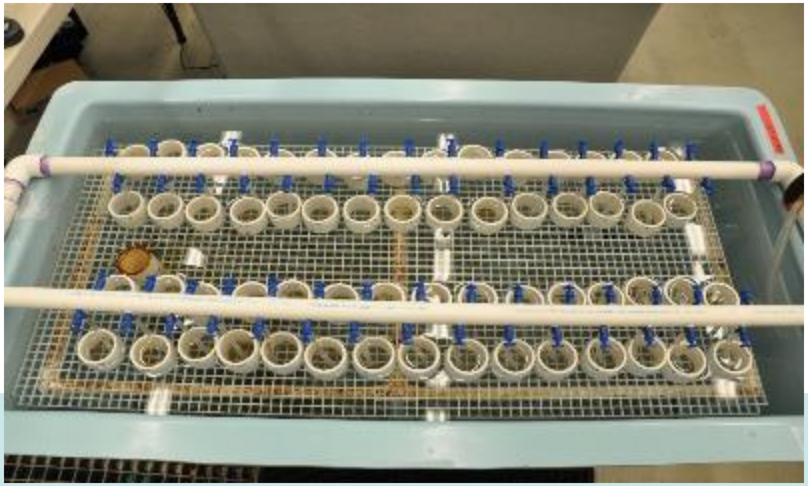
King and Tanner crab lab research

Experiments: (2010-2016)

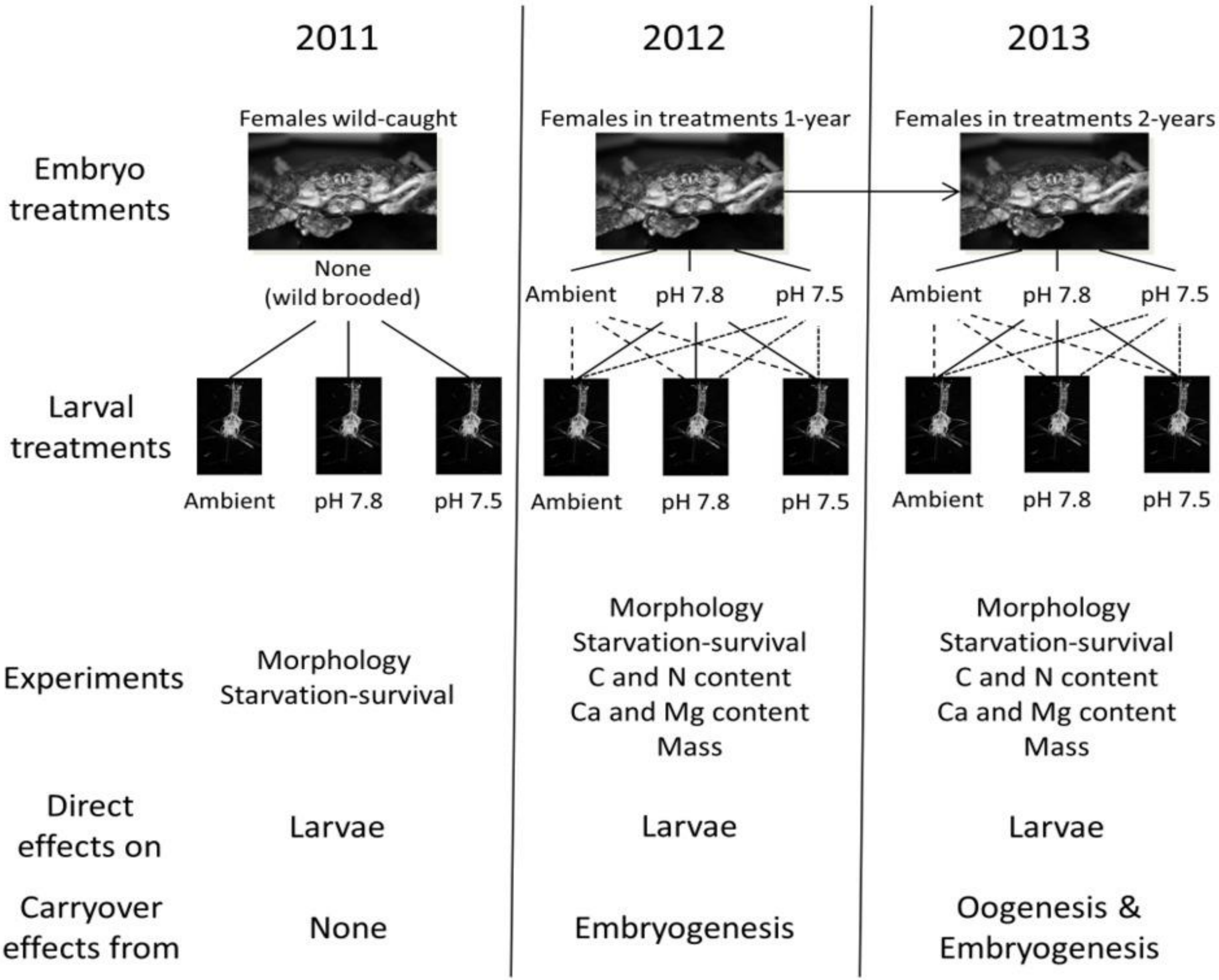
- Red king crab adult females
  - Red king crab embryos and larvae
  - Red king crab juveniles
- southernTanner crab juveniles
- Golden king crab adults
- Snow crab adults

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

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



Ocean Acidification: *Tanner crab*



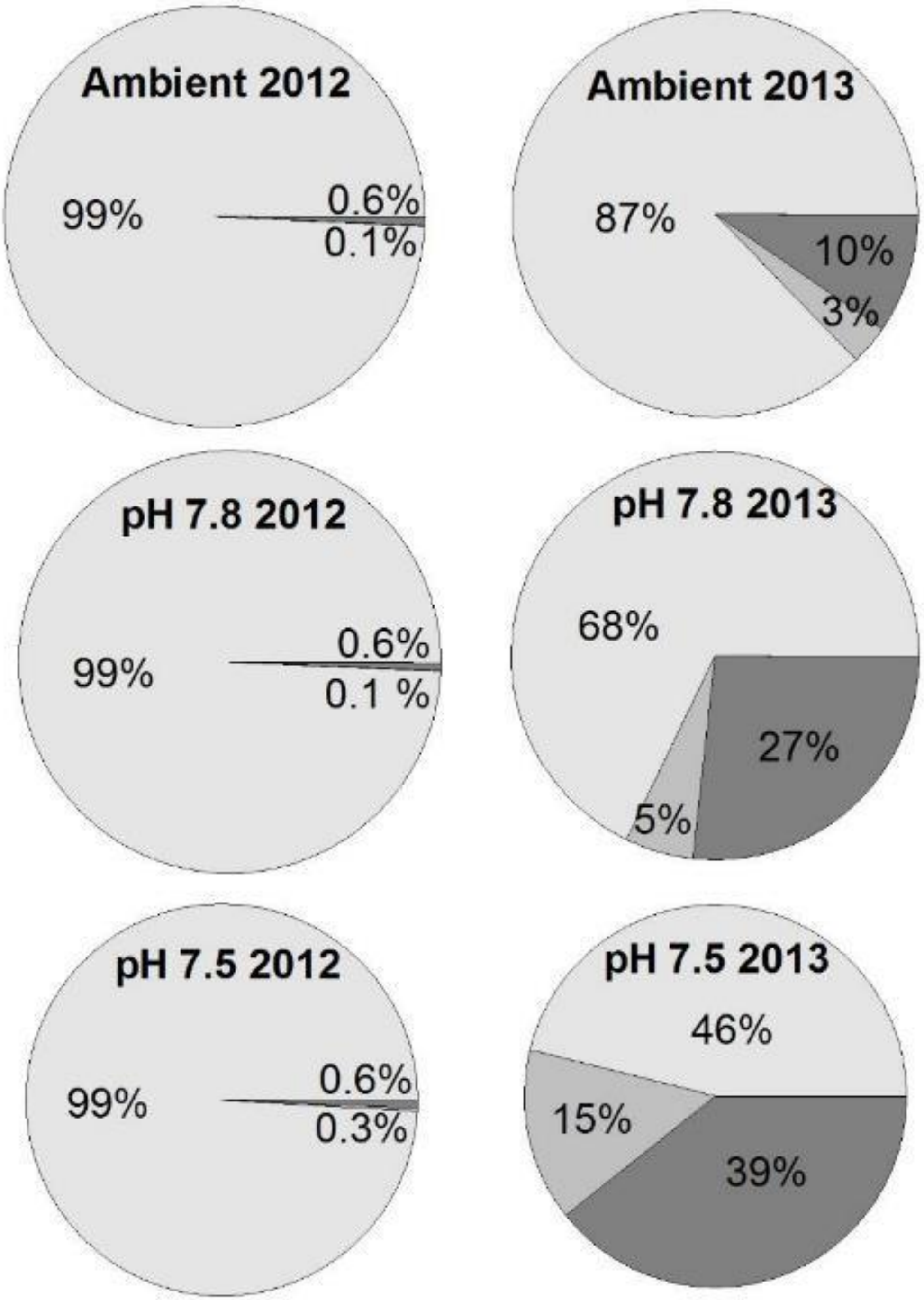
Swiney, K., C. Long, R.J. Foy. 2016. Ocean acidification alters embryo development and reduces hatching success and calcification in Tanner crab, Chionoecetes bairdi. For ICES Journal Marine Science.

Long, C., K. Swiney, R.J. Foy. 2016. Effects of ocean acidification on Tanner crab larvae. For ICES Journal Marine Science.

Meseck, S., J. Alix, G. Wikfors, and R.J. Foy. 2016. Ocean acidification affects hemocyte physiology in the Tanner crab (Chionoecetes bairdi). PLoS ONE.

What Happened to Tanner crab?

Hatching success was lower in year 2 than year 1- carryover effect

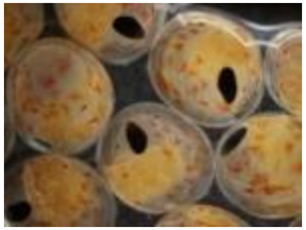


Viable larvae hatched

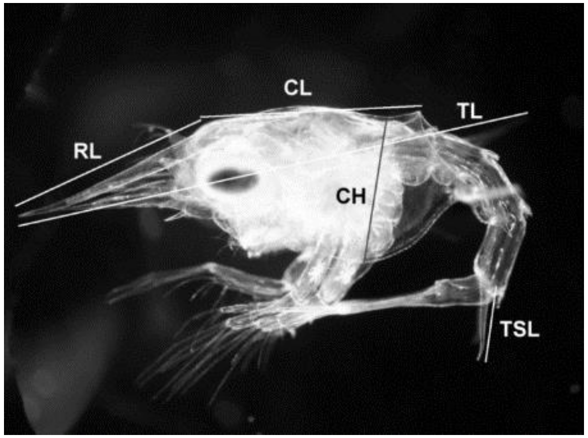
Non-viable hatched larvae

Eggs that did not hatch

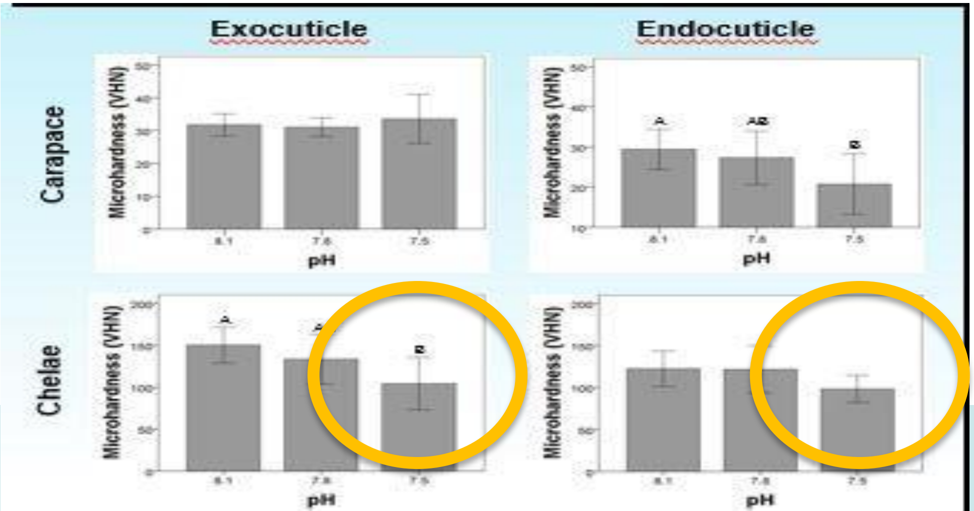
Red King Individual and Population Effects



- Decreased pH associated with smaller eggs and embryos and larger yolks.
- Larval calcification increased
- Larval morphometrics varied
- Survival decreased
- Juv growth (length and mass) reduced
- Juv calcium content did not change
- Survival decreased with decreasing pH

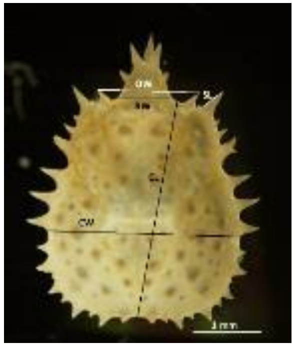


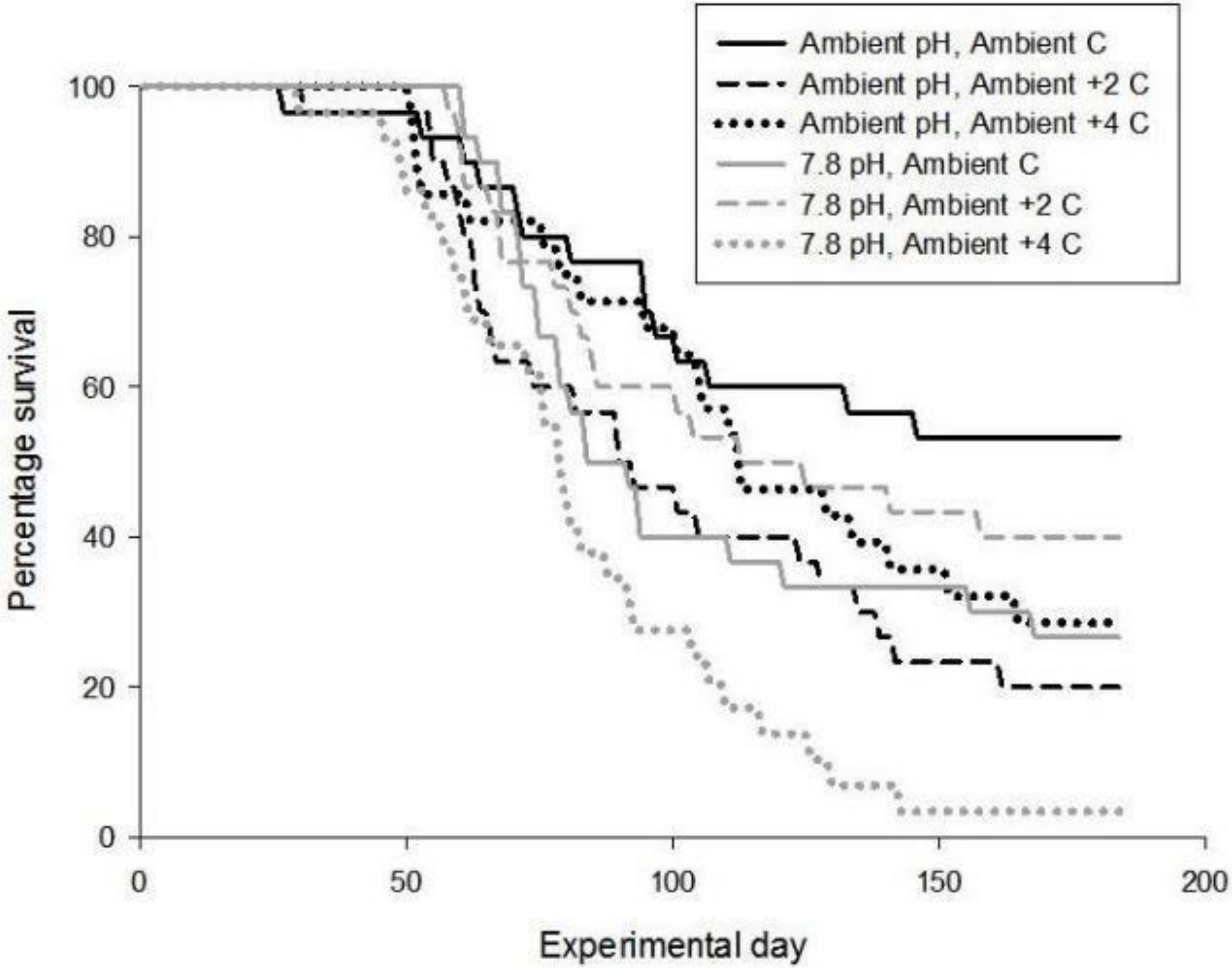
Shell hardness



Red King Crab OA and Climate Effects

-multiple stressors





Temperature and pH increase mortality

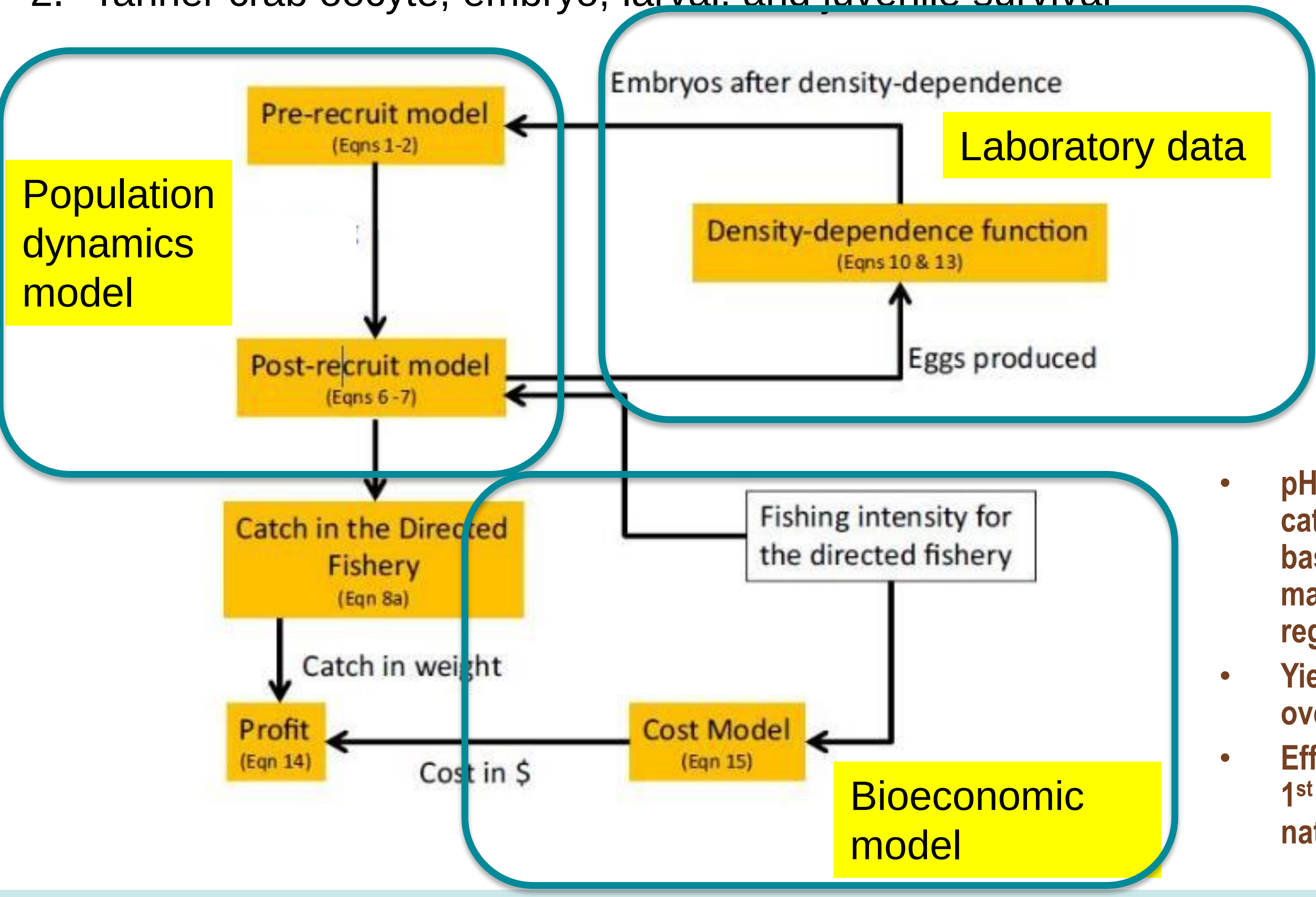
- 184 day study with juveniles
- Survival, growth, mortality
- No change in growth or morphology
- Survival decreased with increased temp and lower pH

Katherine M. Swiney, W. Christopher Long, and Robert J. Foy. 2016. Ocean acidification and increased temperatures reduce young of the year red king crab (*Paralithodes camtschaticus*) survival but not growth or morphology. ICES

Fisheries population effects

Experimental results were used to inform pre-recruitment model

1. red king crab juvenile survival during each stage
2. Tanner crab oocyte, embryo, larval, and juvenile survival



- **pH 7.8: stocks and catches (effort) decline based on current management regulations**
- **Yield and profit decline over 100 yrs**
- **Effects muted during 1st 20 years due to natural mortality**

André E. Punt, R. J. Foy, M. G. Dalton, W. Long, and K. M. Swiney. 2016. Effects of long term exposure to ocean acidification on future southern Tanner crab (Chionoecetes) fisheries management. For ICES Journal Marine Science.

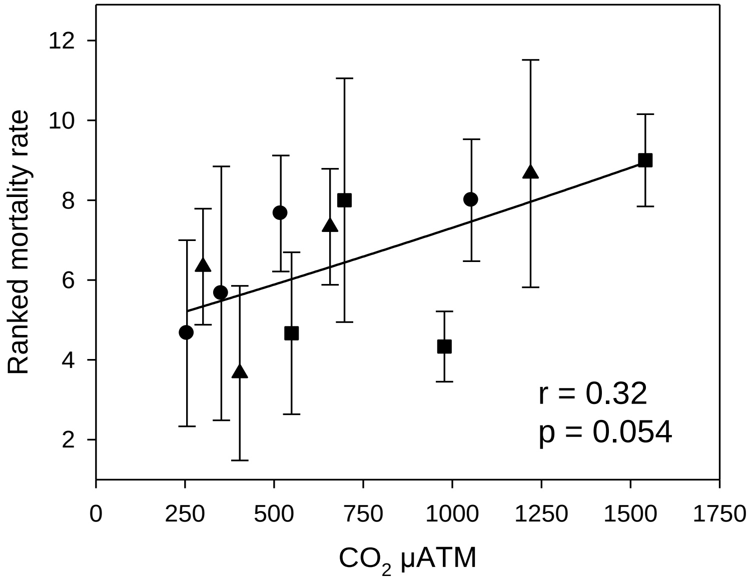
Alaska groundfish studies

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.

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Conclusions

- Climate and environmental perturbations: how uncertain are we in the North Pacific?
  - Changes are coming…but which ones will be more significant?
- The biology of it all…
  - Crab are sensitive to temperature, pH, and $CaCO_3$ saturation
  - Groundfish behavior may be affected
- Are shellfish fisheries sustainable?
  - Can crab and fish resources (and fisheries…and communities) acclimate or adapt….? (e.g. Dungeness)

Descoteaux, Raphaelle. 2014. Effects of ocean acidification on development of Alaskan crab larvae. University of Alaska M.S. thesis. 71 pages.

Current/Future OA Research at AFSC

Crab Aquaculture: Alutiiq Pride Shellfish Hatchery OA monitoring

Red king crab genetics · Jonathon Stillman, Scott Fay, Kathy Swiney, and Robert Foy. In Prep. Transcriptomic Response of Juvenile Red King Crab, Paralithodes Camtschaticus, to the Interactive Effects of Ocean Acidification and Warming.

Snow crab (*Chionoecetes opilio*): embryological, larval effects.

Red tree coral (*Primnoa resedaeformis)*: ecologically important 125-400 m, WA to EBS, EFH for commercial fish.

Walleye pollock: prey scent detection, multiple stressors

Red king crab (*Paralithodes camtschaticus*): effects of diurnal and seasonal variability.

Thank you!

- Chris Long
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- Alaska Fisheries Science Center Research Staff