The Effects of Ocean Acidification on Maternal Condition and Reproductive Success and Larval Condition and Survival of Tanner Crabs, *Chionoecetes bairdi*

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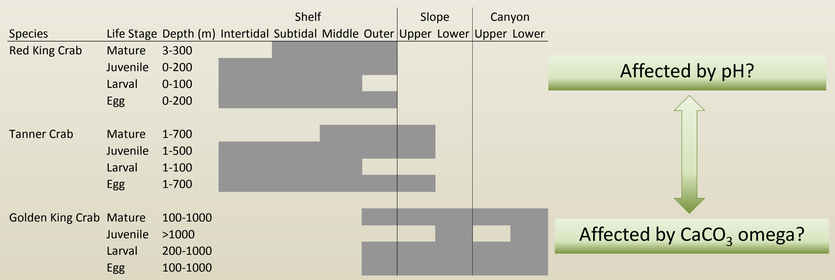
INTRODUCTION

- Dissolution of anthropogenic CO_2 has reduced global mean surface water 0.1 pH units below preindustrial levels, a 26% change (Caldeira & Wickett 2003, Orr et al. 2005).
- Deep oceanic waters are depleted in carbonate due to respiration in the benthos resulting in a saturation depth below which calcium carbonate dissolves.
- Decreased carbonate ion concentration hinders the formation of shells and support structures by some calcifying organisms (Feely et al. 2004).
- Unlike red king crab (*Paralithodes camtschaticus*) (shallower) and golden king crab (*Lithodes aequispinus*) (deeper), Tanner crab (*Chionoecetes bairdi*) inhabit depths from the subtidal to 700 m and are thus affected by both surface increases in CO_2 and by deep undersaturated waters.



As depth increases: (pressure increases, temperature decreases, and pH decreases) – all promoting $CaCO_3$ dissolution.

OBJECTIVES

Goal: to examine the effects of OA on aspects of the reproduction and larval development of Tanner crabs.

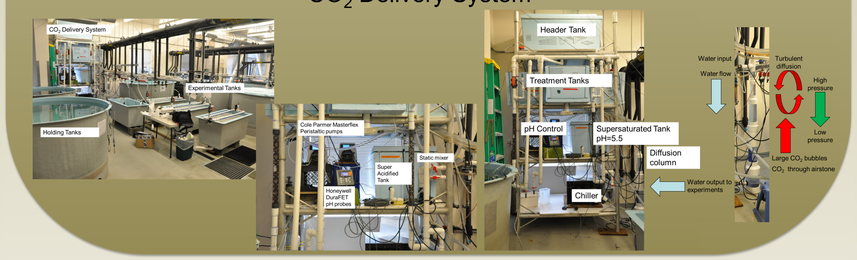
1. Effects of OA on brooding mothers, embryo viability, embryo development, hatching success, and fecundity:
We hypothesize that OA will lead to decreased fecundity, decreased embryo viability, increased embryo development time, altered embryo development, decreased embryo lipid and protein content (CHN), decreased hatching success, and decreased maternal condition.

2. Effects of OA on larval condition and mortality:
Ocean Acidification is likely to impose an energetic cost on developing larvae that would lead to a decrease in mass and changes in chemical composition. We hypothesize that OA will decrease larval survival, alter the morphology of larvae, decrease larval mass, and decrease larval CHN.

3. Effects of OA on juvenile condition and mortality:
We hypothesize that OA will decrease juvenile survival, decrease juvenile mass, and decrease juvenile CHN.

4. Effects of OA on calcification:
We hypothesize that OA will reduce calcification in adult females and in larvae.

CO_2 Delivery System



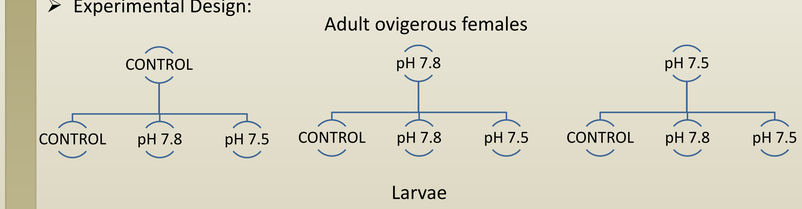
EXPERIMENTAL DESIGN/METHODS

Response variables to increased CO_2:

Life History Stage	Survival	Morphometry	Calcification	Condition	Other
Brooding females			√	√	Fecundity, hatch dynamics
Embryos		√		√	Development
Larvae (zoea)	√	√	√	√	Growth
Juveniles	√		√	√	Growth

Brooding females, embryo viability and development, hatching success, and fecundity:

- Experimental Design:



- Daily and weekly water samples are taken to measure pH, alkalinity, and dissolved inorganic carbon to monitor the carbonate water chemistry throughout the experiment.

- Embryo developmental stage will be determined for ten embryos monthly based on:
  - Embryo area; maximum, minimum and average diameter; yolk area; % yolk.
  - Eyespot area and maximum, minimum and average diameter.

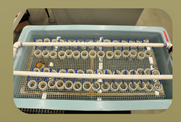
- Adult fecundity: the total number of zoea hatched.
- Condition: dried zoea (10 mg) from each female for CHN analysis.
- Incubation time and hatching success.
- Calcification and condition index (len and wt).

Larval condition and mortality:

- Larval mortality experiments: Twenty zoea / 1L beaker (n=15/experiment); three pH treatments.
- Larval condition experiments: Three hundred zoea / 2L beaker (3 maternal treatments x 3 zoea treatments x 5 replicates)
  - Baseline condition (morphology, dry mass, calcification, and CHN content)
  - Morphology (CW, lateral spine length and dorsal spine length).

Juvenile condition and mortality:

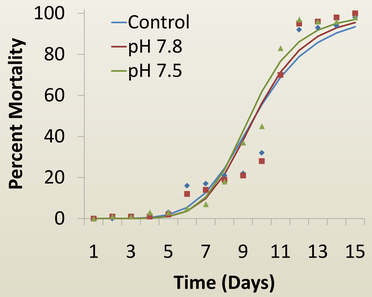
- Juvenile experiments: Thirty juveniles / treatment; three pH treatments.
  - Baseline condition (dry mass, calcification, and CHN content)
  - Survival measured over time.



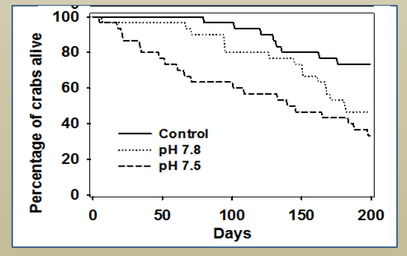
RESULTS

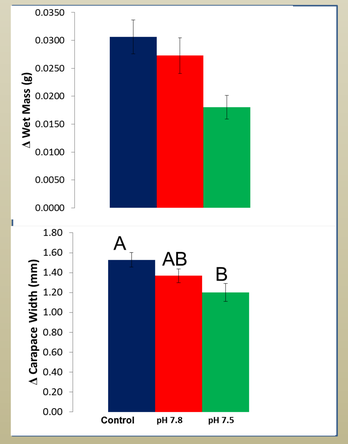
Tanner crab BROODING FEMALES and EMBRYOS: study currently underway. Hatching expected in April 2012.

Tanner crab LARVAE (2011 preliminary study)



Tanner crab JUVENILES (W. Christopher Long, Katherine M. Swiney, Caitlin Harris, Heather N. Page, Robert J. Foy. In review. Effects of ocean acidification on juvenile red king crab (*Paralithodes camtschaticus*) and Tanner crab (*Chionoecetes bairdi*). Global Change Biology.)





CONCLUSIONS

Initial response of increased CO_2 on Tanner crab :

- Higher mortality in larvae (although effect is slight)
- Juvenile weight and size decreased
- No change in time to first molt
- Higher mortality in juveniles

FUTURE CONSIDERATIONS

- Respirometry: measure oxygen consumption to assess basal metabolic condition.
- Intracellular hemocyte pH: measure pH to determine effect on calcium transport
- Genomics: Using RNA-sequencing to identify protein expression changes with OA.
- Population dynamics: increased mortality in size based models to predict OA implications.
- Multiple environmental stressors: crossed temperature and CO_2 experimental designs.
- Monitoring in situ variability: GOA and EBS shipboard and autonomous measurements.

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