Effects of ocean acidification on snow crab larvae: Carryover effects from embryogenesis and oogenesis reduce direct effects on larval survival

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Introduction

Ocean acidification is a decrease in pH caused by dissolution of anthropogenic CO_2 in the oceans. The chemical changes, including a decrease in the saturation states of calcium carbonate, can have physiological effects on marine organisms. Calcified organisms, including crabs, are thought to be particularly vulnerable. The Bearing Sea stock of snow crab, Chionoecetes opilio, is the largest crustacean fishery in the world. However, there has been no research on the effects of ocean acidification on this species.

Objectives

- Determine how ocean acidification affects snow crab larvae:
  - Survival
  - Condition
  - Calcification
- Determine if the response is affect by carryover effects from
  - Oogenesis
  - Embryogenesis

Experimental Overview

- Ovigerous females captured in Bering Sea
  - Exposed to experimental conditions for 1 y
  - Larval experiments performed
  - Direct effects on just larval stage and carryover effects from embryogenesis
- Mated in the lab
  - Exposed to experimental conditions for 2nd y
  - Larval experiments performed
  - Carryover effects from embryogenesis and oogenesis

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Methods

Experimental setup

- Water acidified with CO_2
- Three treatments in both embryo and larval exposures
  - Ambient (pH ~ 8.1)
  - pH 7.8 (Global pH predicted for c. 2100)
  - pH 7.5 (Global pH predicted for c. 2200)
- All larval experiments fully crossed embryo pH treatment with larval pH treatment
- 5 replicates of each treatment combination run in each experiment

Animals

- Ovigerous females captured in Bering Sea
- Larvae collected at hatching and used to stock larval experiments

Starvation-survival

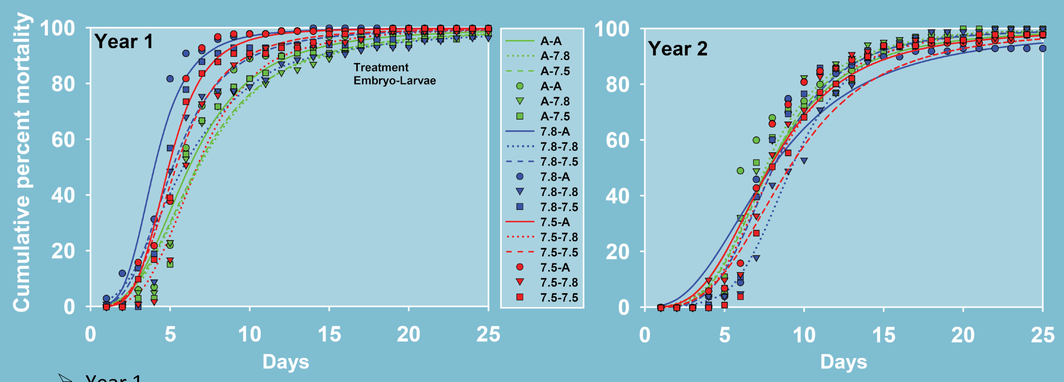
- 20 larvae in each replicate
- Larvae checked daily for 7 weeks
- Dead larvae recoded and removed

Calcification and condition

- 200 larvae in each replicate
- Larvae checked daily for 7 days
- Dead larvae recoded and removed
- Samples processed for Ca and Mg content
- Samples analyzed for CHN content
- Dry weight of 50 larvae determined
- Samples of larvae taken at hatching before stocking the experiments for comparison

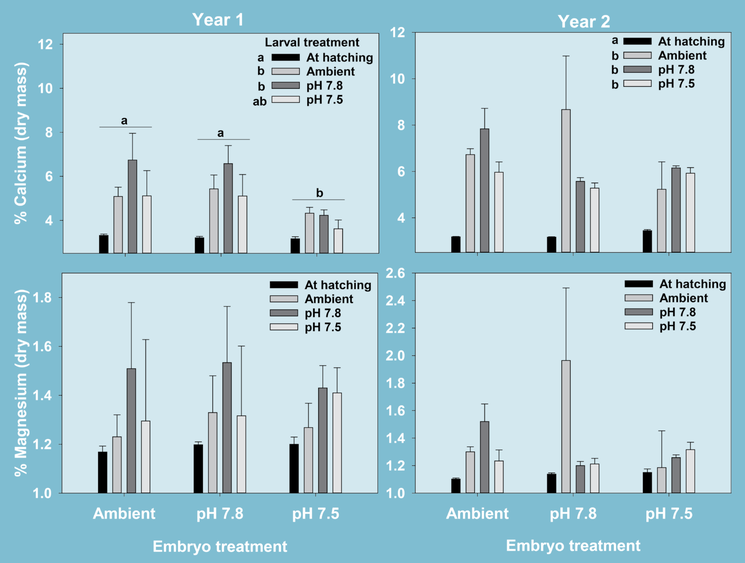
Results

Larval starvation-survival results. Points are the mean mortality within each treatment on each day. Lines are the best-fit logistic regression curves.



- Year 1
  - Exposure to low pH as embryos decreased larval survival times
  - Larval pH had a very small affect on survival times
  - Exposure to low pH as embryos had a positive carry-over effect when larvae were also reared at low pH
- Year 2
  - Exposure to low pH as embryos did not affect larval survival times
  - Larval did not affect survival times
  - Exposure to low pH as embryos had a positive carry-over effect when larvae were also reared at low pH

Larval dry mass, Ca, Mg, C, N, and C:N ratios all analyzed with a 2-way ANOVA with embryo and larval treatments as factors. Figures all show mean + SE. Significant post-hoc differences (Tukey's test) are indicated with different letters.



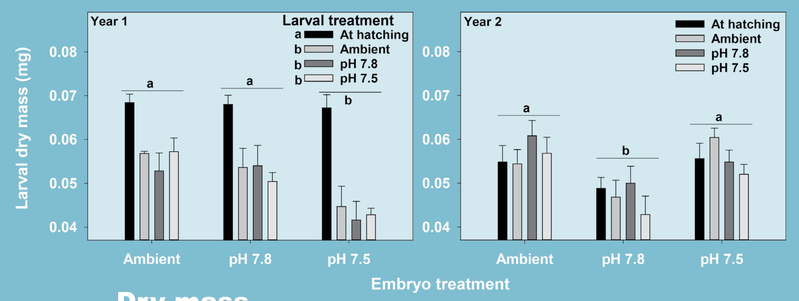
Calcium and magnesium content

- Ca content increased between hatching and day 7
- Less calcium uptake for embryos held at pH 7.5 in year 1, but not year 2
- No effect of larval pH treatment
- No differences among treatment in Mg content

Starvation-survival

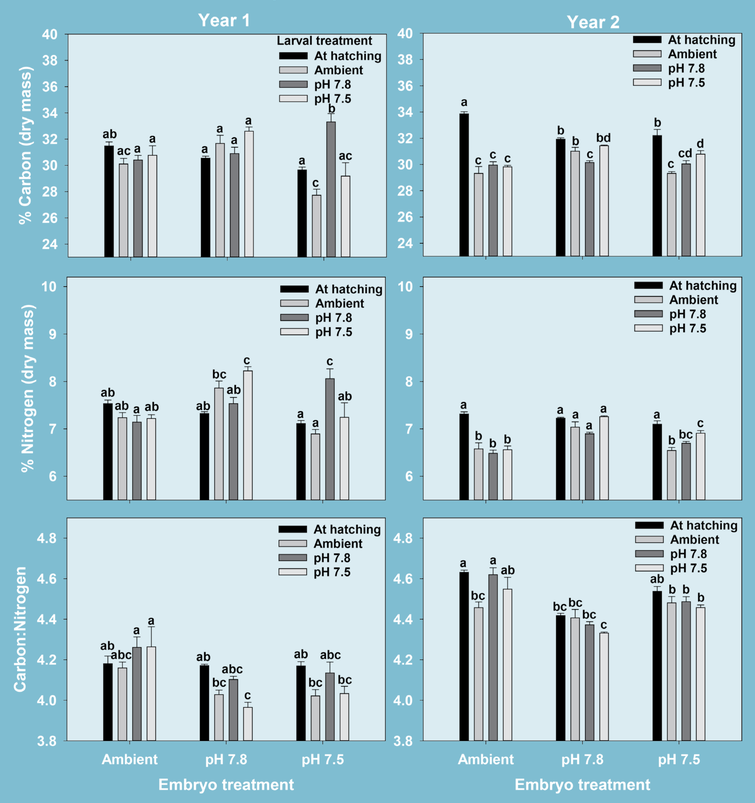
	Embryo treatment		Larval Treatment		Interactive Treatments			
	pH 7.8	pH 7.5	pH 7.8	pH 7.5	7.8*7.8	7.8*7.5	7.5*7.8	7.5*7.5
Year 1	-2.19	-1.30	0.55	0.49	1.29	0.65	1.04	-0.03
Year 2	0.20	0.07	-0.10	0.06	1.42	0.04	0.44	1.16

Effect of embryo and larval pH treatments and their interactions on the LT-50 (time to 50% mortality) estimated via maximum likelihood. All units are in days and are the effect size of that treatment as compared to the Ambient-Ambient treatment. Positive numbers indicate a increase in survival times and negative numbers a decrease.



Dry mass

- Mass decreased between hatching and day 7
- Small effect of embryo treatments both years, but only at pH 7.5 in year 1 and pH 7.8 in year 2
- No effect of larval pH treatment



Carbon and nitrogen content

- Significant interactive effects for all variables in all years
- No clear patterns among treatments
- Effect sizes small

Conclusions

1) Exposure to low pH as embryos can reduced larval survival, calcification, and mass, but exposure during oogenesis and embryogenesis reduces or eliminates the effects
2) Positive carry-over effects from earlier life-history stages suggest snow crab can acclimate to low pH conditions
3) Snow crab larvae appear to be tolerant of ocean acidification levels predicted for the next 200 years
4) Other life history stages need to be tested to predicted population-level effects.