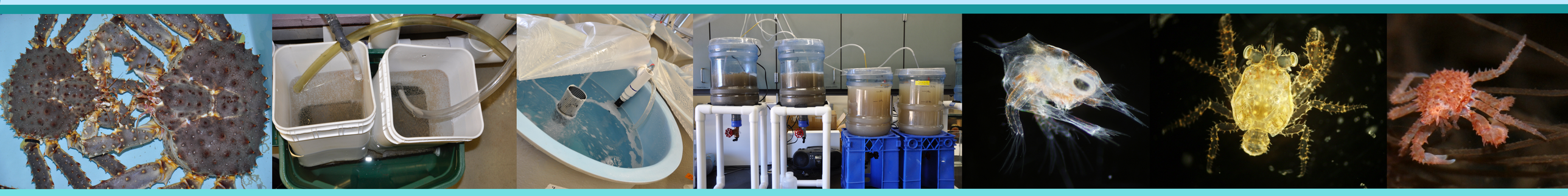
Effects of Ocean Acidification on Red King Crab Larval Development

W. Christopher Long, Allie Conrad, Jennifer Gardner, Robert J. Foy

Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA



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. Red king crab, *Paralithodes camtschatica* , juveniles are highly vulnerable to ocean acidification, but the effects on larval development are unknown

Objectives

Determine how ocean acidification affects red king crab larvae:

- Survival
- Growth
- Development
- Condition
- Calcification

Methods

Experimental setup

- Water acidified with CO_2
- Four pH treatments
  - Ambient (pH ~ 8.1)
  - Diel variation (mimics larval migration above and below the mixed layer)
  - pH 7.8 (Global pH predicted for c. 2100)
  - pH 7.5 (Global pH predicted for c. 2200)
- 5 replicates of each treatment combination run.

Animals

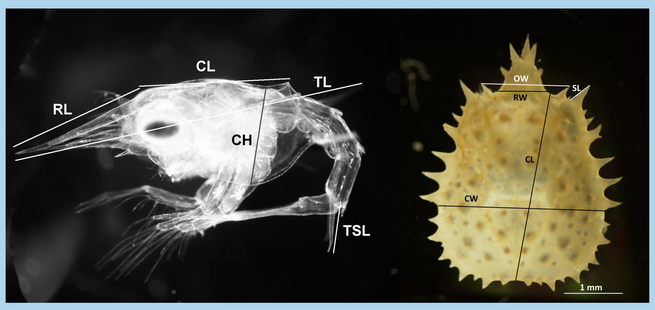
- Ovigerous females captured in Bering Sea
- Larvae collected at hatching and used to stock larval experiments

Rearing conditions

- 180 L conical bottomed tanks
- Larvae stocked at 50/L
- Fed on DHA enriched *Artemia* nauplii daily
- Water sieved (5 µl bag filter) and UV sterilized
- Flow 2L/min
- Reared at local ambient temperatures (range 4.6 – 10.1°C) and salinity
- Treated with EDTA daily
- Glaucothoe unfed and provided with structure
- Reared to the first crab stage (C1)

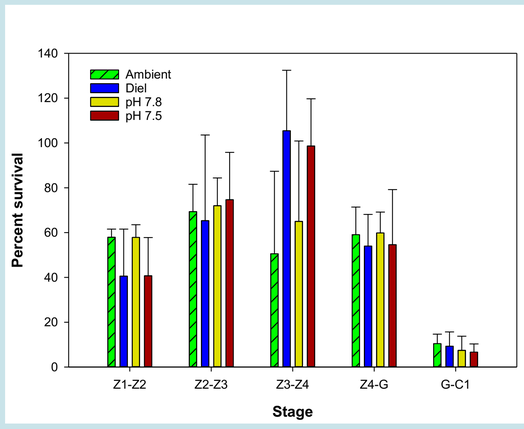
Data Collection

- Daily in each tank
  - pH and temperature measured
  - 5 larvae staged
- Weekly in each tank
  - Water sample taken
  - Analyzed for DIC and alkalinity
- After each molt in each tank
  - Tanks drained and sterilized
  - Larvae counted, survival calculated
  - Average dry mass determined (50 count)
  - 3 individuals imaged and morphometrics measured
  - Samples processed for Ca and Mg content
  - Samples analyzed for CHN content



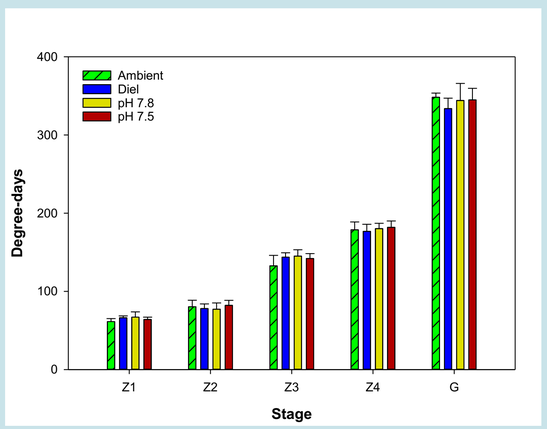
Morphometric measurements made on A) zoeal stages and B) Glaucothoe and crab stages. RL- rostrum length, CL- carapace length, CH- carapace height, TL- total length, TSL- telson spine length, OW- orbital width, RW- rostrum width, SL- 1st spine length, CW- carapace width

All figures are mean + standard deviation. Bars or treatments marked with different letters differ significantly (Tukey's test)



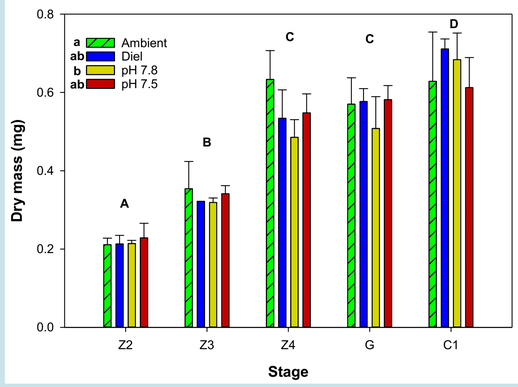
Survival

- No difference among treatments in survival at any stage
- No differences among treatments in cumulative survival (not shown).



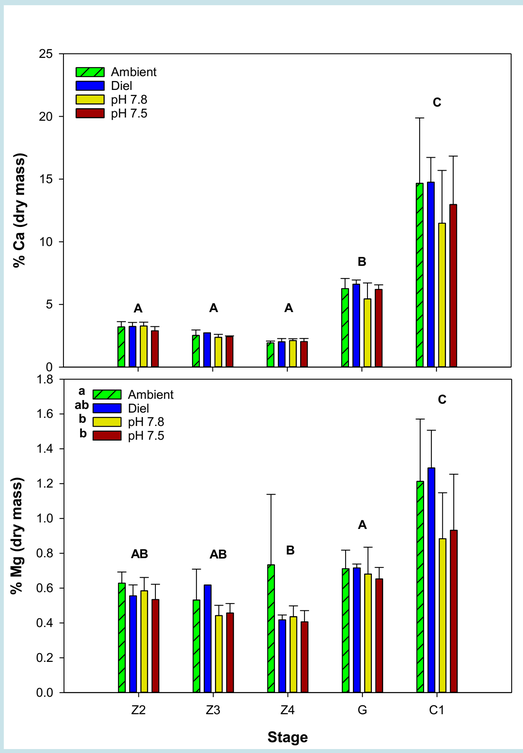
Developmental time

- No difference among treatments in duration of each stage
- No differences in cumulative development time at any stage (not shown)



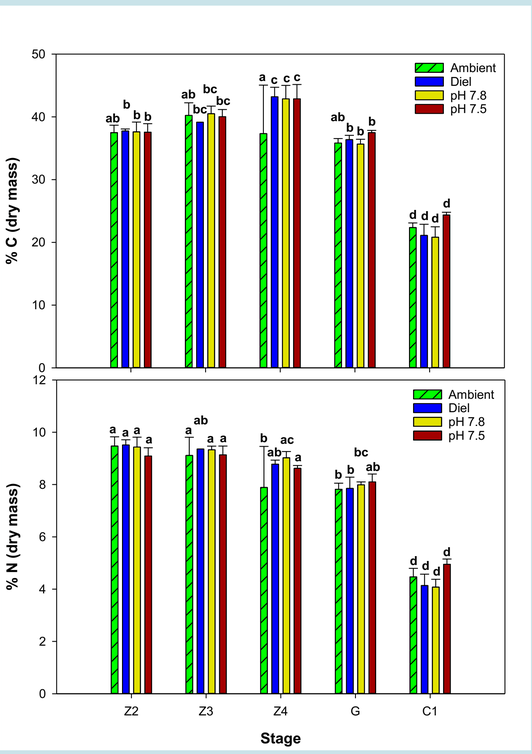
Dry mass

- Average dry mass generally increase with stage
- There was a small difference between the Ambient and pH 7.8 treatment
  - Small effect size pH 7.8 larvae were 7.8% smaller overall
  - But at the final stage (C1) the pH 7.8 larvae were 8.0% larger



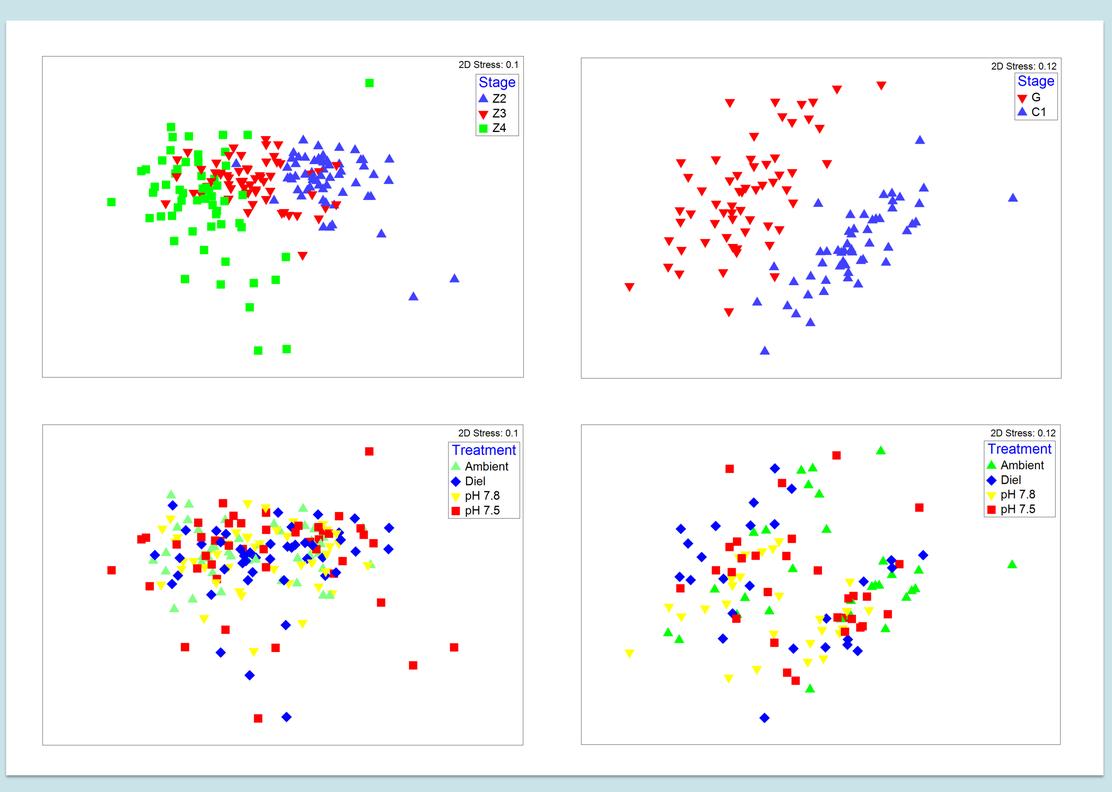
Calcium and magnesium content

- Ca content increased at the glaucothoe and first crab stage but no difference among treatments
- Mg increased at the first crab stage and the Ambient treatment had 20% higher Mg content than the pH 7.8 and 7.5 treatment



Carbon and nitrogen content

- Decrease in C and N at the glaucothoe and first crab stage
- Slightly lower C and N content in Ambient Z4 larvae but no difference at any other stage



Morphometrics

- No difference among treatments in zoeal stages
- pH 7.8 glaucothoe and 1st crab stage slightly smaller than Ambient

Results

Water chemistry parameters throughout experiment (mean ± SD).

	Ambient	Diel AM	Diel PM	pH 7.8	pH 7.5
Temperature	7.24 ± 1.40	7.22 ± 1.40		7.25 ± 1.40	7.23 ± 1.44
Salinity	31.267 ± 0.142	31.268 ± 0.133	31.317 ± 0.124	31.277 ± 0.149	31.288 ± 0.163
pH_T	8.05 ± 0.03	7.98 ± 0.10	8.06 ± 0.03	7.79 ± 0.05	7.50 ± 0.06
pCO_2 µatm	370.74 ± 26.92	467.73 ± 50.84	383.22 ± 23.62	703.89 ± 90.45	1414.71 ± 287.82
HCO_3^- mmol/kg	1.89 ± 0.08	1.96 ± 0.07	1.91 ± 0.08	1.96 ± 0.05	2.00 ± 0.04
CO_3^{-2} mmol/kg	0.11 ± 0.01	0.09 ± 0.01	0.11 ± 0.01	0.06 ± 0.01	0.03 ± 0.01
DIC mmol/kg	2.01 ± 0.08	2.04 ± 0.08	2.04 ± 0.09	2.06 ± 0.05	2.10 ± 0.05
Alkalinity mmol/kg	2.09 ± 0.08	2.08 ± 0.07	2.07 ± 0.08	2.10 ± 0.05	2.11 ± 0.04
$\Omega_{Aragonite}$	1.66 ± 0.09	1.41 ± 0.15	1.62 ± 0.08	0.96 ± 0.13	0.52 ± 0.19
$\Omega_{Calcite}$	2.65 ± 0.15	2.24 ± 0.24	2.58 ± 0.13	1.53 ± 0.21	0.83 ± 0.31

Conclusions

1) No differences among treatments in survival or developmental timing.
2) Effects on other parameters were small, often restricted to a single stage, and usually between the Ambient and pH 7.8 but not the more extreme pH 7.5.
3) Red king crab larvae appear to be tolerant of ocean acidification levels predicted for the next ~200 years.

Acknowledgements: *The authors thank the NOAA Ocean Acidification program for project funding and the staff and contractors of Kodiak Laboratory for help running the experiment.*