Impacts of ocean acidification on the hatching success and larval development of *Euphausia pacifica*

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Introduction

• *Euphausia pacifica* is the dominant euphausiid species in the northern California Current
• There is great interest in predicting their responses to climate changes since they are a prominent link between primary producers and many commercial fish species, seabirds and marine mammals
• Eastern boundary upwelling systems like the California Current are especially vulnerable to ocean acidification and already experience seasonal under-saturation of aragonite
• Kawaguchi et al. (2010) found no hatching at a pH of ~7.4 for *E. superba* eggs
The pH treatment tanks are managed using automated control of CO₂ injection into a water conditioning reservoir.

CO₂ is introduced by passing seawater through a gas-fluid membrane exchanger.

The pH of the reservoir is maintained at 7.05.
• This acidified water is mixed with ambient seawater in the header tanks to make the different treatments and then piped into the treatment tanks

• The control tank is comprised solely of ambient seawater
Methods for Experiments

- 5 experiments during 2010 spawning season, 2,922 eggs
- Collected gravid females offshore, at night
- Incubated in dark 10.5°C cold room, 1L bottles
- Collected and counted eggs next morning
- Used large, healthy looking broods (>120 eggs)
- Split eggs between ambient pH and up to 3 treatments
- Target pH of treatments: 8.1(A), 7.9, 7.6, 7.2 and 8°C
- Eggs (~30 each) placed in 200µm mesh-bottomed 250ml beakers and floated in treatment tanks
Will a decrease in pH decrease *Euphausia pacifica* hatching success?

- Beakers sampled after 3 days
- By day 3 all normally developing eggs should have hatched
- Observed swimming behavior and deformities
- Counted and staged eggs and nauplii
Egg Hatching

- Low hatching success not associated with lowered pH
- Hatching success is strongly linked to individual females
After removal of bad broods, still no relationship with pH
Variation in temperature only explained 11% of the variability
Deformed Nauplii

- No trend towards increased rate of deformity with lowered pH
- High rates of deformity were better associated with individual females
- Deformed nauplii almost always reached the expected developmental stage
Will a decrease in pH slow *Euphausia pacifica* larval development?

- Beakers sampled after 8 days
- By day 8 all normally developing larvae should be to the metanauplii (met) or calyptopis 1 (C1) stages
  - Met is last non-feeding stage
- Observed swimming behavior and deformities
- Counted and staged eggs and larvae
• Development by day 8 to met or C1 stages are both considered to be normal for 8°C
• Unhatched eggs account for the remaining % of the larvae, not nauplii
• At 8 days, there is no relationship between pH and the ability for larvae to develop normally
• Development based solely on visual observation of stage, not internal structures
Larval Development

• Looked at the breakdown between met and C1 to see if there was a finer scale impact on development
• Larvae did not make it to C1 at lowest pH, but not a statistically significant relationship
• Fluctuations in experimental temperature explained more of the variability, but still not highly significant
• larval development experiments suggest that median time to C1 at 8°C is 8 days
  • standardized lab conditions 50% of larvae take > 8days
Preliminary Conclusions

• Lowered pH does not appear to impact hatching success of *E. pacifica*
• Lowered pH does not appear to slow early larval development of *E. pacifica*
• Maternal influences have greatest impact on hatching and presence of deformities
• Slight fluctuations in experimental temperatures had a greater impact on development rate than changes in pH
Discussion

• Collaboration is the only way to make these experiments work, and to make sense of the results
  – Chemists
  – Ecologists
  – Physiologists
• Why do *E. superba* eggs fail to hatch when little impact is observed for *E. pacifica* eggs?
  – *E. pacifica* is adapted to an upwelling region where currently pH can get down to 7.9...do they see more natural variability in pH?
  – Calcite saturation?
Future Work

• Continue (repeat) experiments on hatching success and larval development of *E. pacifica*, *Calanus marshallae* and *C. pacificus*
  – 8° C, 3 & 9 day experiments
• Improve OA experimental system to allow for more consistent conditions (temp, pH, O₂)
• Longer incubations through feeding stages in order to better assess impacts on development and survival
  – Develop appropriate methods for adequate feeding, while maintaining experimental conditions
• Define better metrics for assessing impacts on larval development
  – Confocal laser scanning microscope to look at internal structures and analysis of symmetry?
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