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

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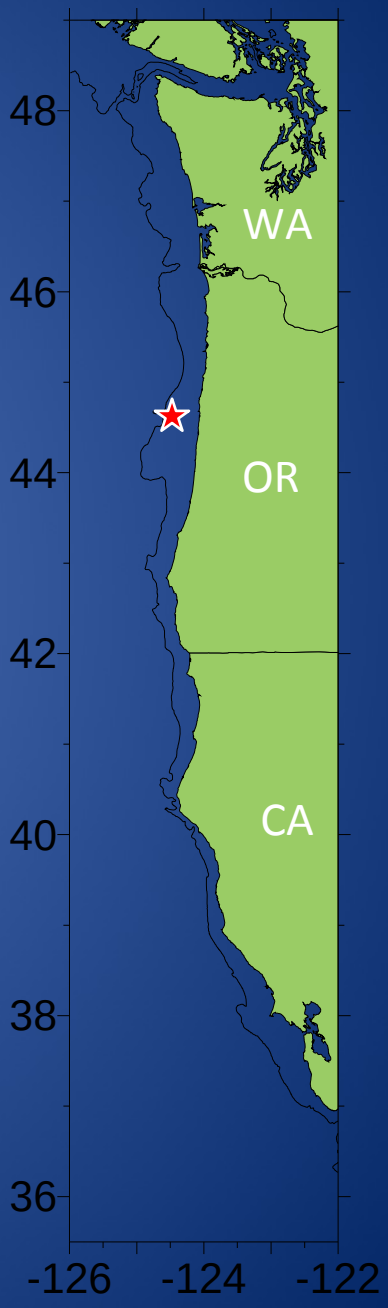
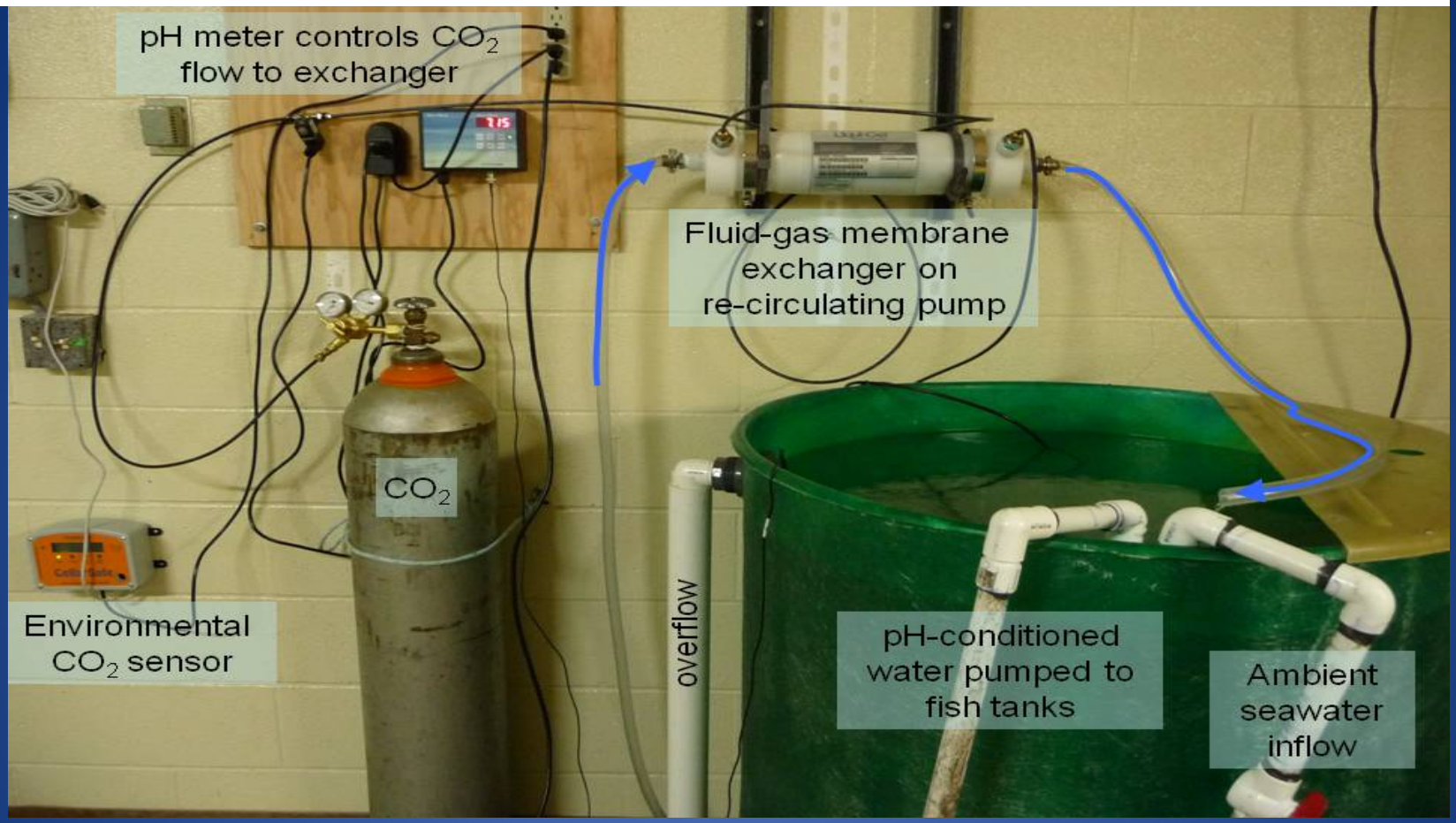
Introduction

- *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



Automated pH control system for *Euphausia pacifica* experiments

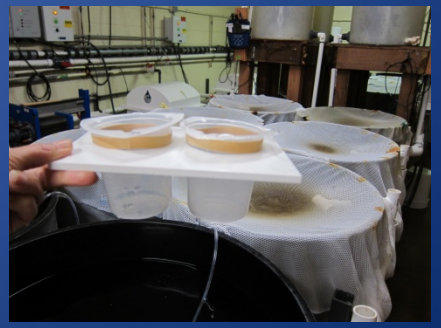


- The pH treatment tanks are managed using automated control of CO_2 injection into a water conditioning reservoir
- CO_2 is introduced by passing seawater through a gas-fluid membrane exchanger
- The pH of the reservoir is maintained at 7.05

- 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

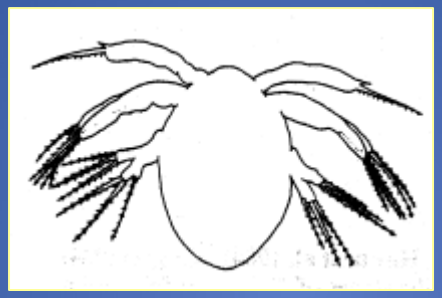
Methods for Experiments

- 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

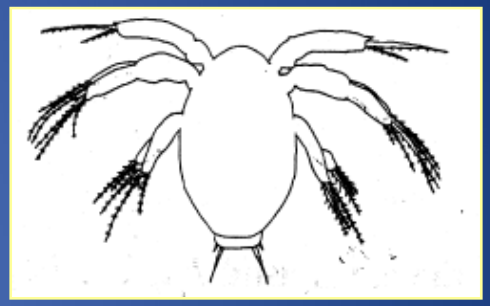


Will a decrease in pH decrease *Euphausia pacifica* hatching success?

Egg



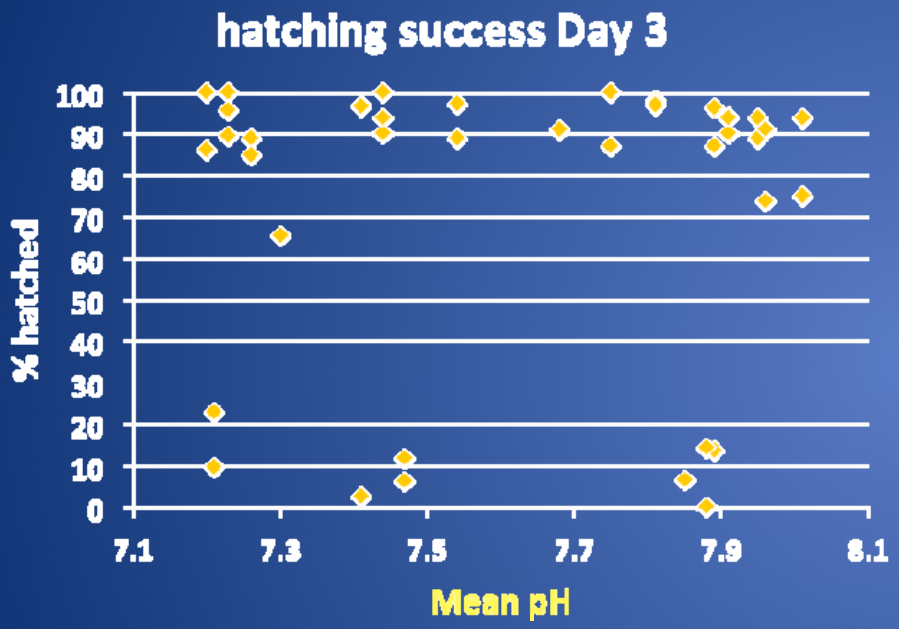
nauplius 1

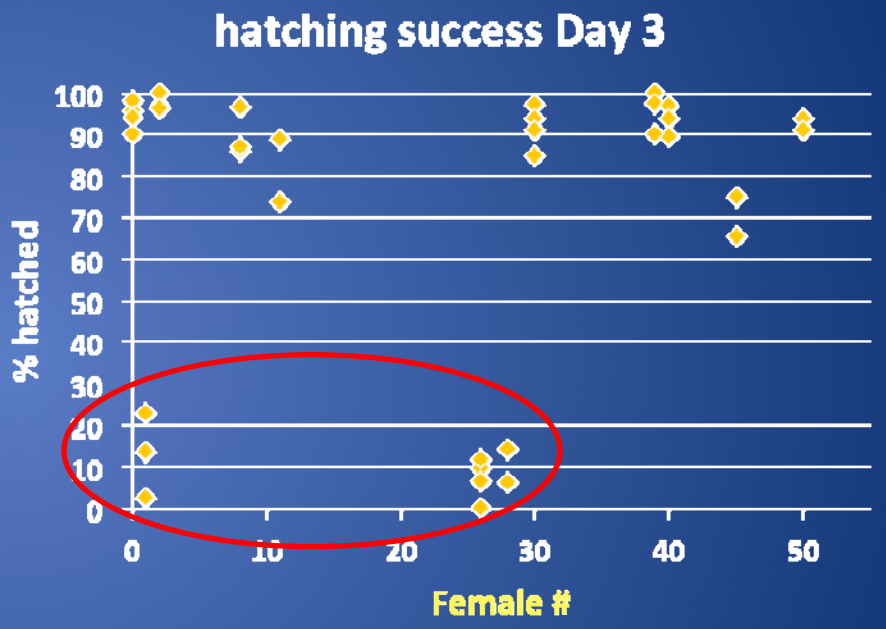


nauplius 2

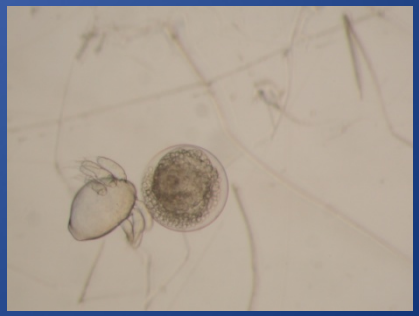
- Beakers sampled after 3 days
- By day 3 all normally developing eggs should have hatched
- Observed swimming behavior and deformities
- Counted and staged eggs and nauplii

Egg Hatching

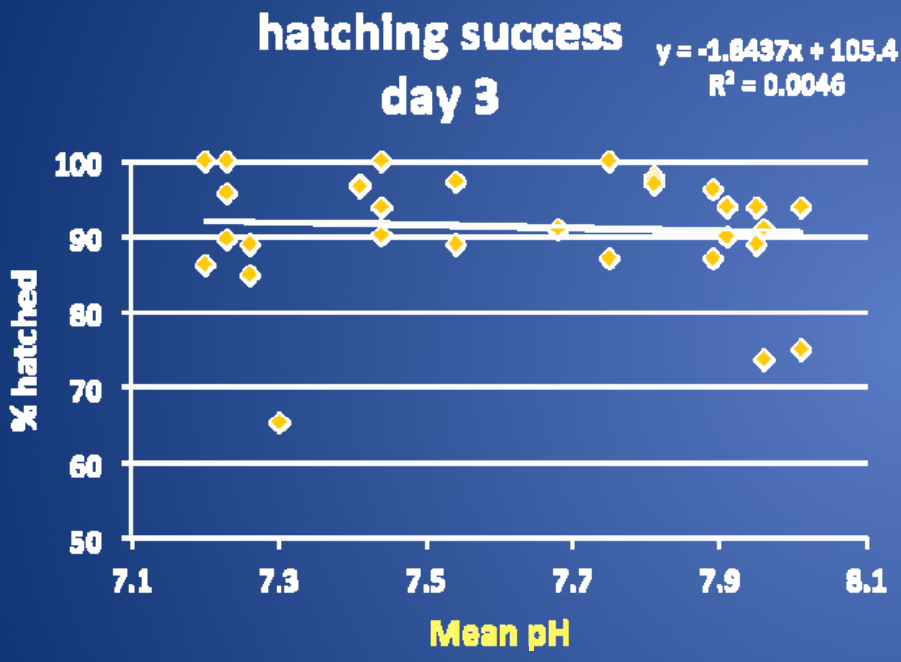


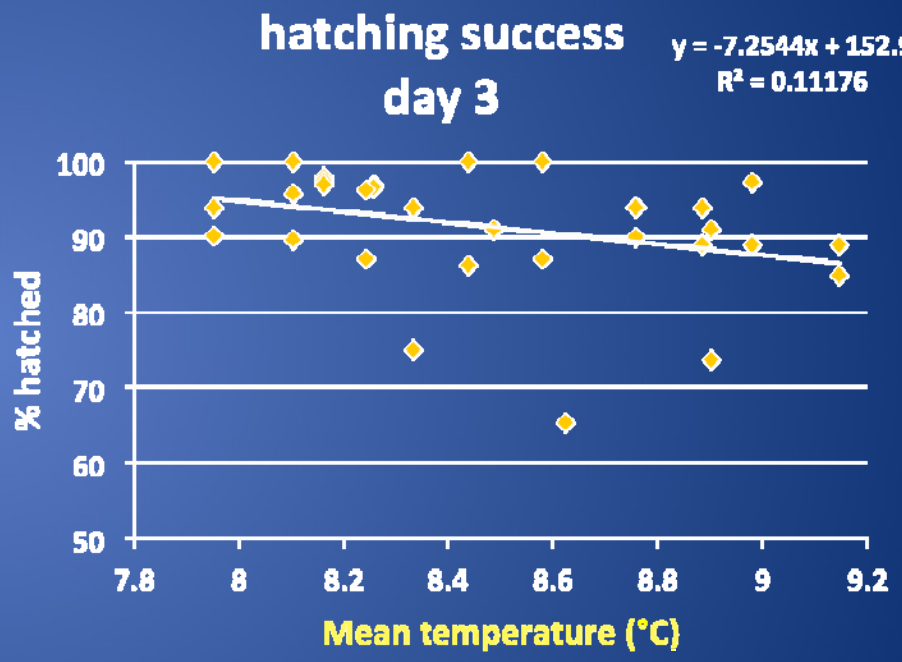


- Low hatching success not associated with lowered pH
- Hatching success is strongly linked to individual females



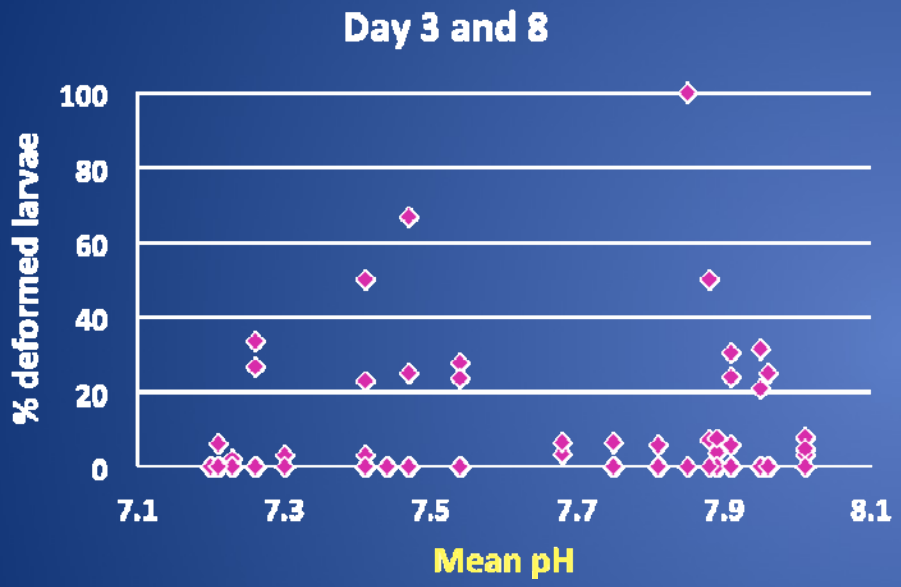
Egg Hatching

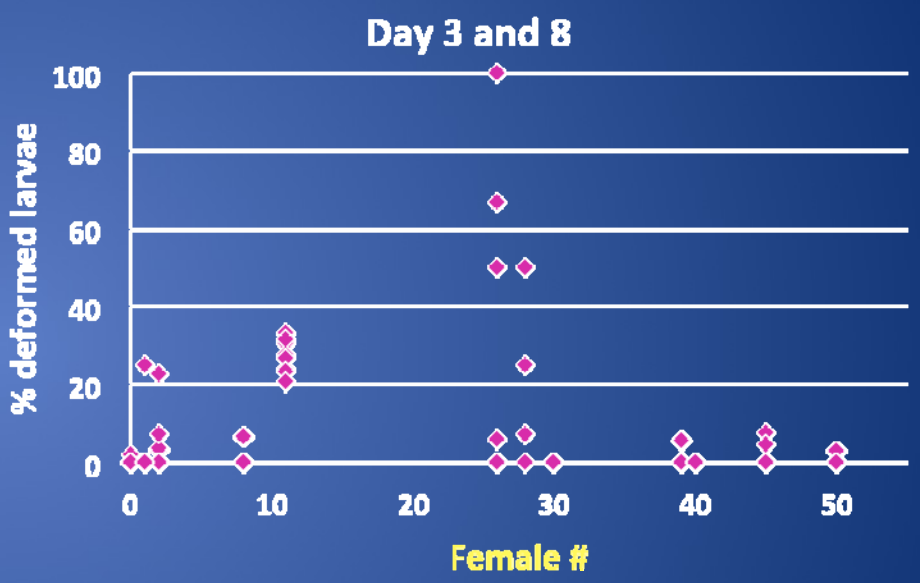




- After removal of bad broods, still no relationship with pH
- Variation in temperature only explained 11% of the variability

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

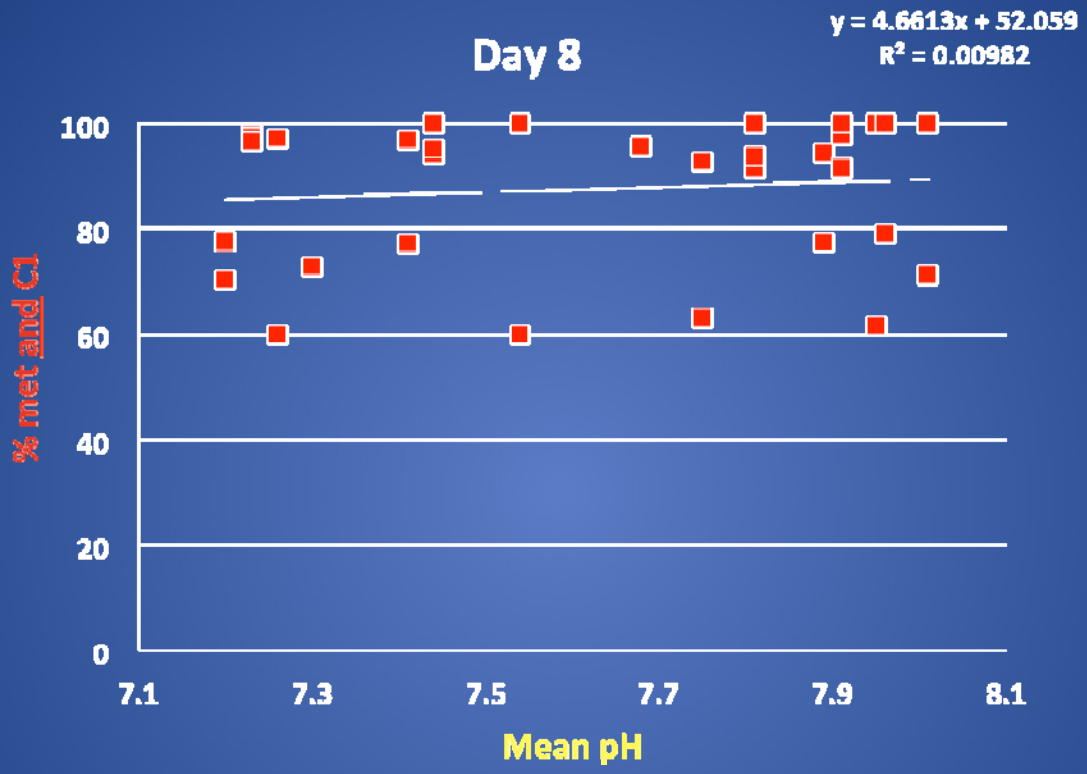
Will a decrease in pH slow *Euphausia pacifica* larval development?

metanauplius

calyptopis 1

- Beakers sampled after 8 days
- By day 8 all normally developing larvae should be to the metanauplius (met) or calyptopis 1 (C1) stages
  - Met is last non-feeding stage
- Observed swimming behavior and deformities
- Counted and staged eggs and larvae

Larval Development

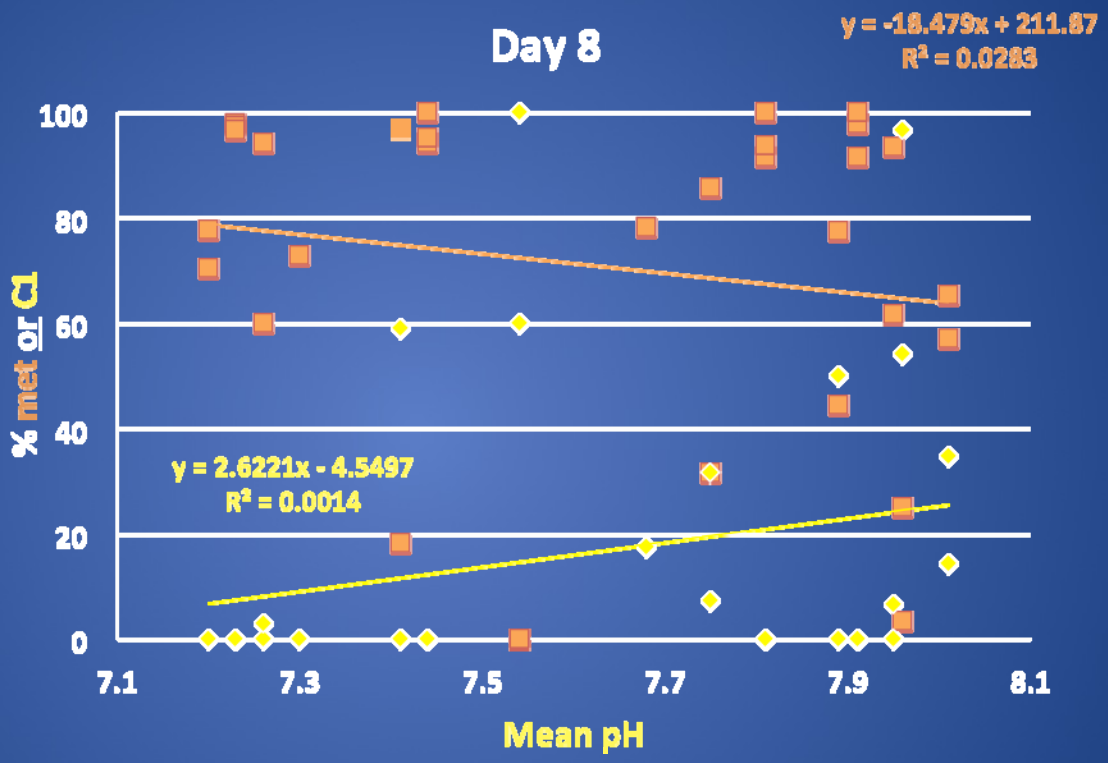


- Development by day 8 to met or C1 stages are both considered to be normal for 8° C
- Unhatched eggs account for the remaining % of the larvae, not nauplii
- At 8 days, there is no relationship between pH and the ability for larvae to develop normally
- Development based solely on visual observation of stage, not internal structures

Larval Development

metanauplius

calyptopis 1

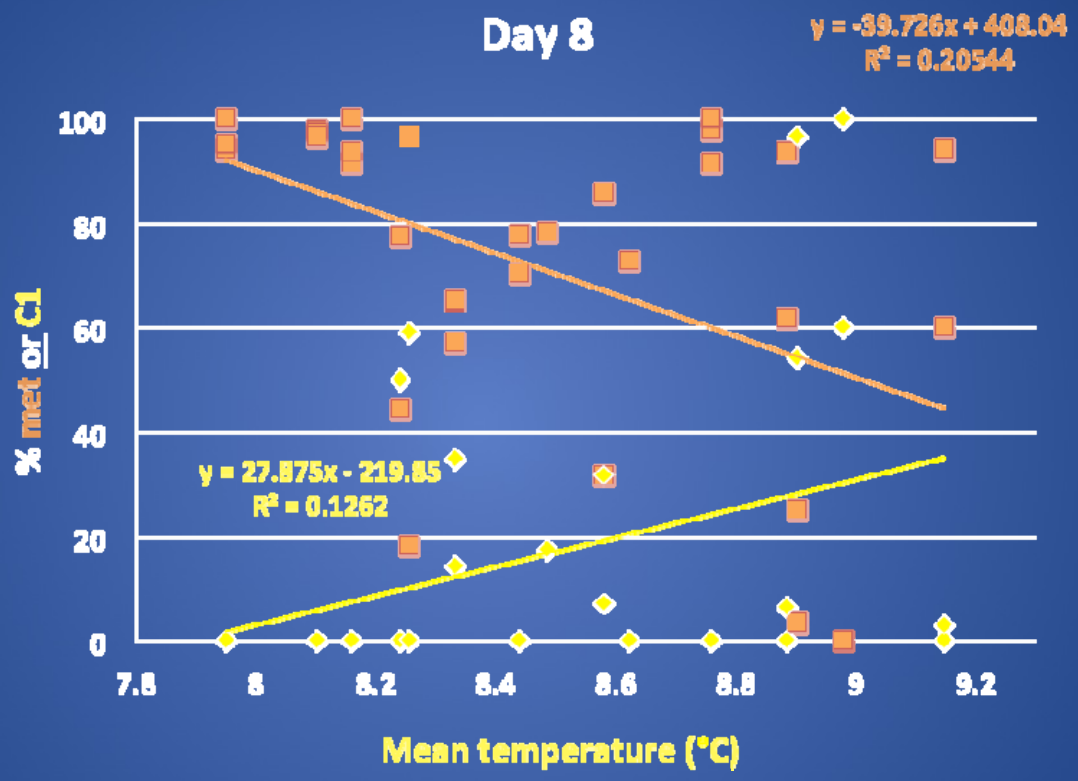


- Looked at the breakdown between met and C1 to see if there was a finer scale impact on development
- Larvae did not make it to C1 at lowest pH, but not a statistically significant relationship

Larval Development

metanauplius

calyptopis 1



- 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, O_2)
- 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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- Tom Hurst, NOAA-AFSC
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