Krill (Euphausia pacifica) Development in the Laboratory is Impaired at Currently Observed pCO₂ Levels

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Background

Euphausia pacifica is a dominant euphausiid and important prey species throughout the North Pacific. Despite the importance of euphausiids in marine ecosystems around the world there has been limited ocean acidification (OA) research on them. Previous studies have found that Antarctic krill, Euphausia superba, have reduced hatching at 1250 μatm pCO₂ (pH 7.50) and complete hatching failure at 3000 μatm pCO₂ (pH 7.36-7.40); however, larvae have only been monitored to three days post hatch (Kawaguchi et al. 2011, 2013). Subadults of the north Atlantic krill, Nyctiphanes couchii, have reduced survival at pCO₂ concentrations between 1100 and 1700 μatm pCO₂ (pH 7.63 and 7.47), but other life stages have not been tested (Sperfield et al. 2014).

Puget Sound is a large estuary connected to the California Current System (CCS), an upwelling system that has low and declining pH throughout the water column. Within the estuary, OA is exacerbated by freshwater runoff and the respiration of organic matter. The vertical distribution of E. pacifica larval stages is an important determinant of their exposure to low pH waters but is poorly characterized, and their response to OA has not been tested in the lab.

Methods

Field Exposure: We characterized the pH environment experienced by E. pacifica eggs and larvae with depth stratified net tows and carbonate chemistry measurements at two stations in the northern and of Hood Canal in Puget Sound, WA during April and June 2012.

Laboratory Experiments: We collected adult females and spawned them under a wide range of pCO₂ conditions in the laboratory, tracking hatching success, larval development, and survival. Two sets of experiments (8 experimental trials total) were done in two separate experimental systems.

During the first set of experiments, eggs were raised to five days post hatch inside sealed 500 mL jars of pCO₂ equilibrated seawater, with water changes and chemistry monitored every two days. Equilibrated seawater was generated by bubbling with CO₂ and CO₂-free air while monitoring pH.

During the second set of experiments, krill were raised to the Calyptopis 2 stage (18-21 days post hatch) in open dishes held inside sealed boxes with atmospheric gas of treatment pCO₂ levels. Air with precise pCO₂ concentrations was mixed with mass flow controllers.

Conclusions:

E. pacifica larval stages, particularly the Nauplius 2 and Metanauplius stages, were found throughout the water column (20-180m), where they were exposed to pH 7.8-7.5. In the laboratory, E. pacifica hatching was robust to a wide range of pH levels, but larval development and survival were reduced at lower pH. Development to the Calyptopis 1 stage was slowed at low pH. Survival from three days post hatch to the Calyptopis 2 stage was reduced by an average of 20% at pH 7.69 compared to pH 7.96. E. pacifica may be living near the limits of its pH tolerance and continued OA could push these organisms past their threshold, with negative consequences for their populations and higher trophic levels.