

Title: Causes and consequences of hypoxia and pH impacts on zooplankton: Linking movement behavior to vertical distribution.

Project Summary

Overview: Individual swimming behavior is a primary mechanism underlying patterns in zooplankton population distributions, used by most zooplankton species to select among water column positions that differ in biotic variables, such as predator and prey abundance, and abiotic variables such as light, oxygen concentration, and pH. Anthropogenic climate change and eutrophication are leading to declines in oxygen and pH throughout the world's oceans. Species-specific movement responses to de-oxygenation and acidification are likely mechanisms through which short-term, localized impacts of these stressful conditions on individual zooplankton will be magnified or suppressed as they propagate up to population, community, and ecosystem-level dynamics.

Studies of zooplankton behaviors in the ocean have mostly relied on measuring movement of centers of population abundances rather than direct observation of individual movements. Very few studies have quantified behaviors of zooplankton in the ocean on spatial scales relevant to individuals, primarily due to the technical difficulties in observing movements of individual organisms *in situ*. In particular, appropriate tools have been lacking to track individual organisms concurrent with information needed to characterize environmental conditions and taxonomic identities. Recently, significant advances in technologies that image individual zooplankton *in situ* enable much closer pairing of zooplankton abundance with environmental variables such as hypoxic and low pH layers, and now are at the stage where they can be used to quantify *in situ* zooplankton swimming behaviors within low oxygen and pH environments.

The proposed study quantifies key zooplankton responses to oxygen and pH using *in situ* video systems to quantify changes in individual behavior in hypoxic, low-pH versus well-oxygenated, high-pH regions of a seasonally hypoxic estuary. Distributions and movements of zooplankton within and across regions of low oxygen and pH will be quantified using three approaches: 1) an imaging system deployed *in situ* on a profiling mooring over two summers in a seasonally hypoxic system, 2) imagers deployed on Lagrangian drifters to sample simultaneously throughout the water column on research cruises, and 3) vertically-stratified pumps and net tows to verify species identification and video-based abundance estimates. Field observations will be combined with laboratory analysis of movements by focal zooplankton taxa in oxygen and pH gradients, and with spatially-explicit population-level models to predict how behavioral mechanisms modulate large-scale impacts of environmental stresses.

The field site is Hood Canal, a sub-estuary of Puget Sound, Washington that regularly experiences oxygen depletion and low pH in late summer and autumn. The zooplankton community in Hood Canal is composed of a diverse assemblage, including copepods, euphausiids and gelatinous species that are ecologically important throughout the coastal Northeast Pacific. Instruments will be mounted on Oceanic Remote Chemical Analyzer (ORCA) moorings that provide real-time water column profiles of temperature, salinity, and oxygen, allowing precise co-location of zooplankton with ambient environmental variables, and accurate estimates of abundances, taxonomic composition, and behaviors in relation to environmental gradients.

Intellectual Merit: The research tests a fundamental hypothesis of plankton ecology, that swimming behaviors determine how spatially variable environmental stressors like low O₂ and pH impact vertical distributions of zooplankton and key ecological functions such as predator avoidance. These observations will be the first to quantify behavioral responses to O₂ and pH *in situ*, with laboratory observations and predictive models translating the individual and population-level effects to coastal ecosystems more broadly.

Broader Impacts: The PIs will expand current ocean technology-based STEM outreach activities to include hands-on activities and curricular materials enabling K-12 students in under-served coastal communities to construct and deploy low-cost *in situ* plankton-monitoring cameras. Including zooplankton observations into existing oceanographic data streams would transform our ability to quantify the state of ocean biology and responses of key taxa to ocean change with unprecedented detail.