Ocean acidification driven changes in pH exposure of zooplankton: projections from the Salish Sea model

Paul McElhany
Northwest Fisheries Science Ctr., United States, paul.mcelhany@noaa.gov

Vathsala DeSilva
Vicuna, Inc., United States, vaths@vicunainc.com

Tarang Khangaonkar
Pacific Northwest National Lab., United States, tarang.khangaonkar@pnnl.gov

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Ocean Acidification Driven Changes in pH Exposure of Zooplankton: Projections from the Salish Sea Model

(But really, what about Dungeness crab…)

Paul McElhany¹, Vathsala DeSilva², Tarang Khangaonkar³

¹ NOAA Northwest Fisheries Science Center Mukilteo Field Station
² Vicuna Inc., Seattle, WA
³ Pacific Northwest National Laboratory

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Ocean Acidification

Carbon Dioxide

Acidification
Ocean Acidification and Dungeness Crab

Dungeness crab (Metacarcinus magister) life cycle

- **Fertilized eggs**: 3-6 months
- **Zoea larvae**: 3-6 months
- **Megalopae larvae**: 1-2 weeks
- **Juvenile**: 1-2 years
- **Adult**: year round
- **Mating**: 30 minutes

Seasons:
- **Spring - Summer**: year round
- **Winter**: year round
- **Fall**: 3-6 months
Vulnerability Framework

1. Highly Vulnerable
   - At greatest risk
   - Specific research needed
   - Interventions generally needed

2. Potential Adapters
   - May be at risk
   - Monitor and support adaptive responses

3. Potential Persisters
   - May not be at risk
   - Monitor population trends

4. High Latent Risk
   - Not currently at risk
   - Monitor environment
Ocean Time Machine
Dungeness crab survival and development

![Graph showing survival and development of Dungeness crab under different pH levels.]

- **Control (n=22)**
  - Z4 stage: 0.75 proportion
  - Z3 stage: 0.25 proportion

- **Low-pH (n=16)**
  - Z4 stage: 0.50 proportion
  - Z3 stage: 0.50 proportion

*Miller, Maher, Bohaboy, Friedman, and McElhany. 2016 (Marine Biology)*
Relative pH Sensitivity: Meta-analysis of ~400 OA Papers Relevant to California Current

Busch and McElhany. 2016 (PLOS)
Pacific Northwest National Laboratory (PNNL) Circulation Model
Carbonate Chemistry Proxies

Carbonate Parameter = $f(\text{temperature, salinity, oxygen})$

Puget Sound Carbonate Cruise 2008 (Feb and Aug)

Feely et al. 2010
Explicit Carbonate Chemistry

Puget Sound pH March to July 2014
Puget Sound Cruises 2014 (June-July) & (Sept.-Oct)
### Simulation Parameters
- Circulation model input
- Number of trajectories
- Starting locations

### Horizontal Movement
- Stochastic
- Current-driven
- Environment-driven
- Combination

### Vertical Movement
- Surface only
- Daily Vertical Migrations (DVM)
  - Current-drive
  - Environment-driven
  - Combination

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**Plankton Movement Program (PMP)**

Java program implements individually-based movement simulation
Trajectories

Current-driven (2008)

Current-driven (2100)

Seeking high pH with DVM (2008)

Seeking high pH with DVM (2100)
Dispersal from Ship Harbor
Crab Zoea on Edmunds Beach April 2017

Photo by Paul Briggs, City of Edmunds
Daily Range in $[\text{H}^+]$

Hydrogen Ion Concentration

$\text{pH} = 8.0$  $\text{pH} = 7.72$  $\text{pH} = 7.55$

$\text{Pink} = \text{Daily Min}$  $\text{Pink} = \text{Daily Mean}$  $\text{Pink} = \text{Daily Max}$
Experimental Fluctuating pH
Fluctuating pH Experiment

Photo by Melaina Dyck

Megalops, 1.9 mm
Zoea Development Stage in Fluctuating pH
SSM and Vulnerability Framework
Next Steps…

• Improved validation/tuning of carbonate chemistry
• Explicit forcing with future carbon
• Include more complex behavior (e.g. vertical decision making)
• User interface for plankton tracking