Interactive effects of ocean acidification and ocean warming on Pacific herring (Clupea pallasi) early life stages

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Seasonal upwelling gives us a glimpse of future ocean acidity
Pacific herring spawning stocks in Puget Sound are predisposed to low ocean acidity levels.
Responses to acidification are species-specific

Impairs olfactory senses

Orange Clownfish (Munday et al. 2008. *PNAS*)

Reduces growth and survival


No sperm motility effects


No embryonic or hatch rate effects

Atlantic Herring (Franke & Clemmesen 2011. *Biogeosci.*)
Organisms are bombarded by multiple environmental stressors.

- Human activities
- Increased greenhouse gas concentrations
  - Increased UV
  - Increased air temperature
  - Intensified atmospheric pressure gradients
  - Increased storm frequency
  - Intensified upwelling (?)
  - Increased CO₂
  - Increased water temperature
  - Decreased pH

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“Bigger may not be Better”

- Warmer temperatures accelerate growth
- Gill and muscle deformities
- Increases energetic needs for survival – reduced aerobic scopes and swimming performances

How are Pacific herring embryos affected by pCO$_2$ and temperature changes?
Herring Collections

1. Quilcene, WA
   • March 2016

1. Craig, AK
   • March 2016

2. Cherry Point, WA
   • May 2016
Fertilization Success

Hatching Success

Larval Weight, Length

Respiration
## Hypotheses

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<td>Low survivorship</td>
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Shorter larvae observed in the warmer temperature
Experimental Tanks
Red = 19 C; Blue = 13 C

Storage Tank

pCO₂ mixing tanks

1700 ppm
400 ppm
400 ppm
1700 ppm
400 ppm
1700 ppm
1700 ppm
400 ppm

Experimental Tanks
Red = 19 C; Blue = 13 C

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Spawning biomass at Cherry Point, WA decreased from 15,000 tons in 1973 to 1,700 tons in 2004.
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