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## The Effects of Ocean Acidification and Temperature Rise on the Thermal Tolerance and Critical Thermal Limit of Pacific Herring (*Clupea pallasii*)

Nicole Singh  
*Western Washington University*

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# The Effects of Ocean Acidification and Temperature Rise on the Thermal Tolerance and Critical Thermal Limits of Pacific Herring (*Clupea pallasii*)

Western Washington University

Nicole Singh, Dr. Brooke Love, Dr. Christopher Murray

[Singhn5@wwu.edu](mailto:Singhn5@wwu.edu)

Will embryos reared at elevated temperatures and pCO<sub>2</sub> levels have higher mortality than those reared at ambient temperature and pCO<sub>2</sub> when exposed to a simulated heatwave event (CT<sub>max</sub>)?

## What is Critical Thermal Maximum (CT<sub>max</sub>)?

CT<sub>max</sub> is the thermal temperature at which an animal can no longer support physiological activity and mortality rate increases to near 100%

Differences in CT<sub>max</sub> can indicate potential future resilience to heatwave scenarios in embryos reared under different temperature and CO<sub>2</sub> conditions

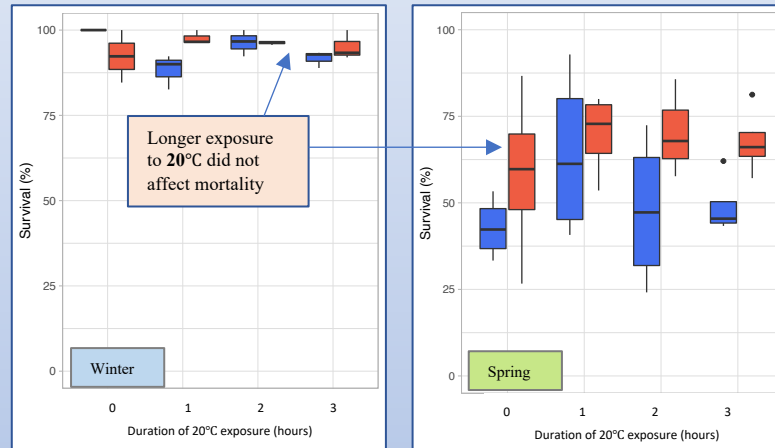
## CT<sub>max</sub> Protocol

- Embryos held at 10°C and 16°C were exposed to increasing temperature up to a maximum of either 20°C or 25°C
- Embryos were kept at 20°C or 25°C for either 1, 2, or 3 duration hours
- Mortality was assessed 24 hours after CT<sub>max</sub> trials

## Incubation Conditions

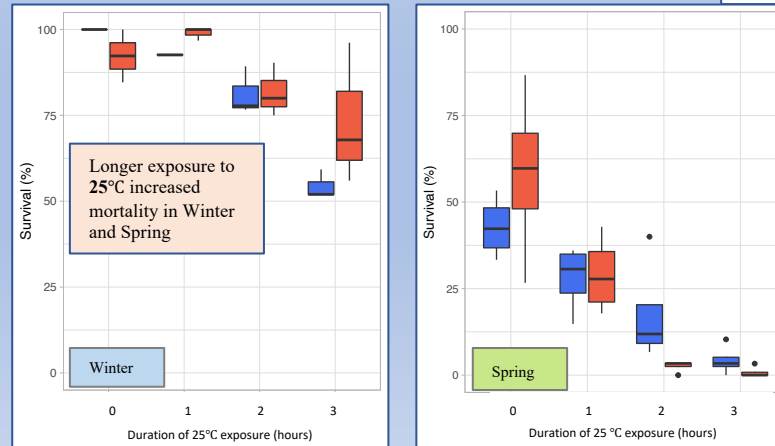
- Winter experiment:** Embryos were incubated at 4 temperature levels (10°C, 12°C, 14°C, 16°C) and 2 pCO<sub>2</sub> levels (~500 μatm, ~2000 μatm)
- Spring experiment:** Embryos were incubated at 2 temperature levels (10°C, 16°C) and 2 pCO<sub>2</sub> levels (~500 μatm, ~2000 μatm)

Embryos reared at differing temperature and pCO<sub>2</sub> levels did not show any significant differences in survival. Longer exposure at 25°C increased mortality in Winter and Spring embryos



Winter embryos had higher survival rates than spring embryos across rearing temperature and pCO<sub>2</sub> treatments

CO<sub>2</sub> (μatm)  
■ 500  
■ 2000



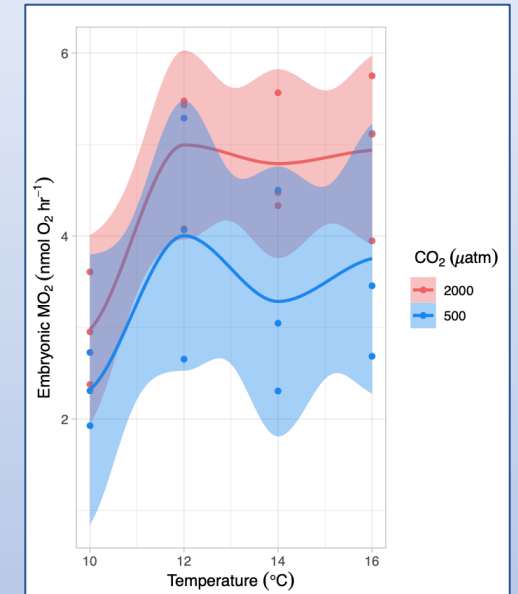
Will embryos reared at elevated temperatures and pCO<sub>2</sub> levels have higher oxygen consumption rates (MO<sub>2</sub>)?

## MO<sub>2</sub> Protocol

- O<sub>2</sub> levels were evaluated at embryo incubation temperature of 10°C, 12°C, 14°C, 16°C
- Water temperature was increased to 20°C and O<sub>2</sub> was measured

MO<sub>2</sub> was not assessed in spring due to logistical constraints

- Elevated incubation temperature was significant in increasing MO<sub>2</sub> but reached a plateau above 12°C.
- Elevated pCO<sub>2</sub> significantly increased MO<sub>2</sub>



## Conclusions

- These results help elucidate the capacity of herring to acclimatize to a warming ocean and increased acidification, and the impact of early life stage physiological stress on growth and survival
- Results suggest that spring embryos have increased stress spawning at heightened temperatures
- Embryonic herring were resilient to heat waves for a few hours, but mortality mounted at very high temperatures and was extreme when high heat lasted for 2-3 hours
- Elevated temperature is known to increase MO<sub>2</sub>, but the effect of pCO<sub>2</sub> is relatively novel and should be investigated further

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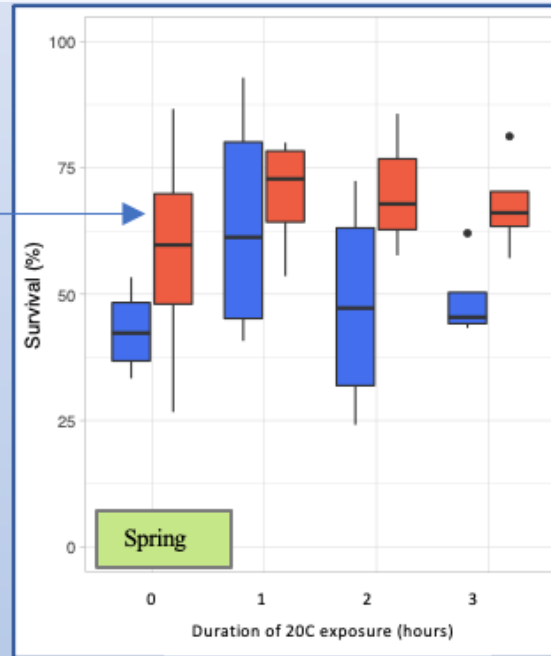
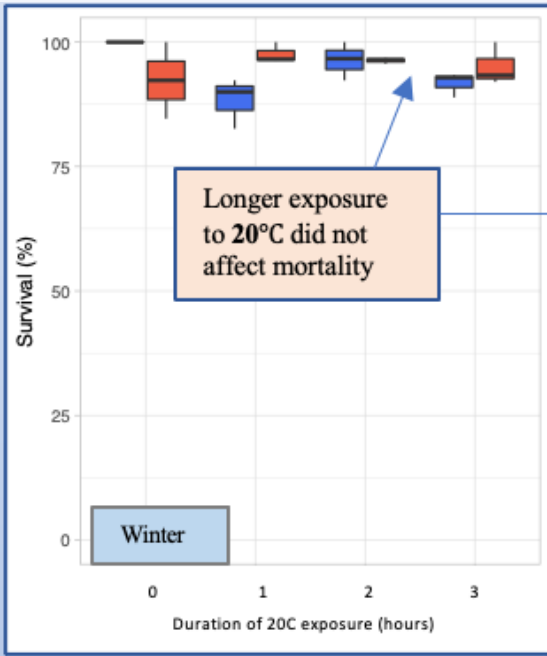
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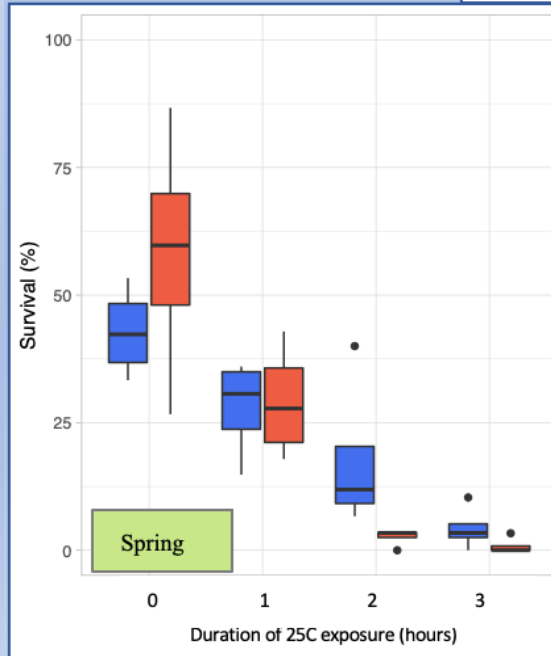
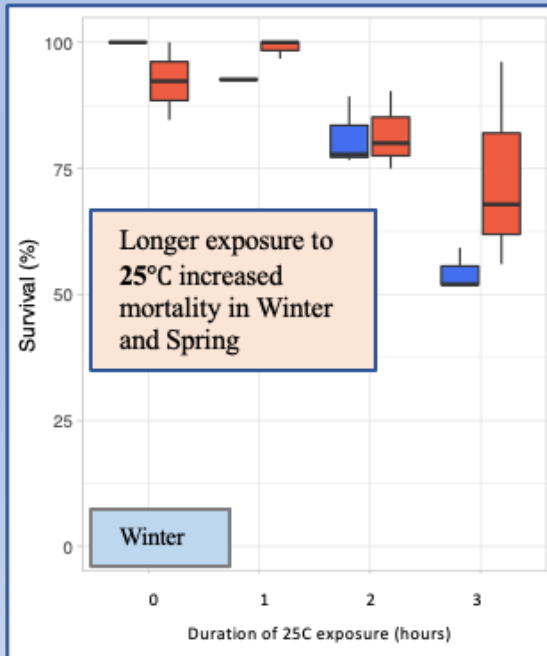
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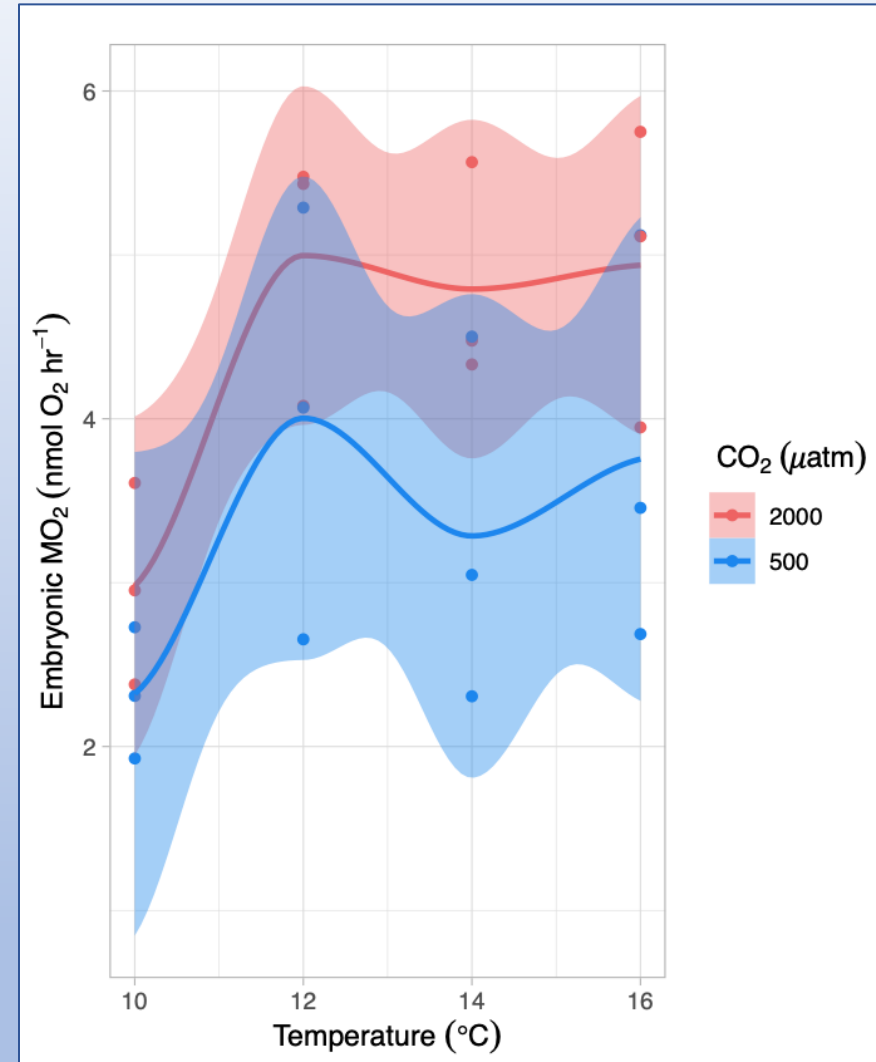
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