Critical Windows in Chinook Salmon Development: Differential Sensitivity to Warming and Hypoxia During Early Development

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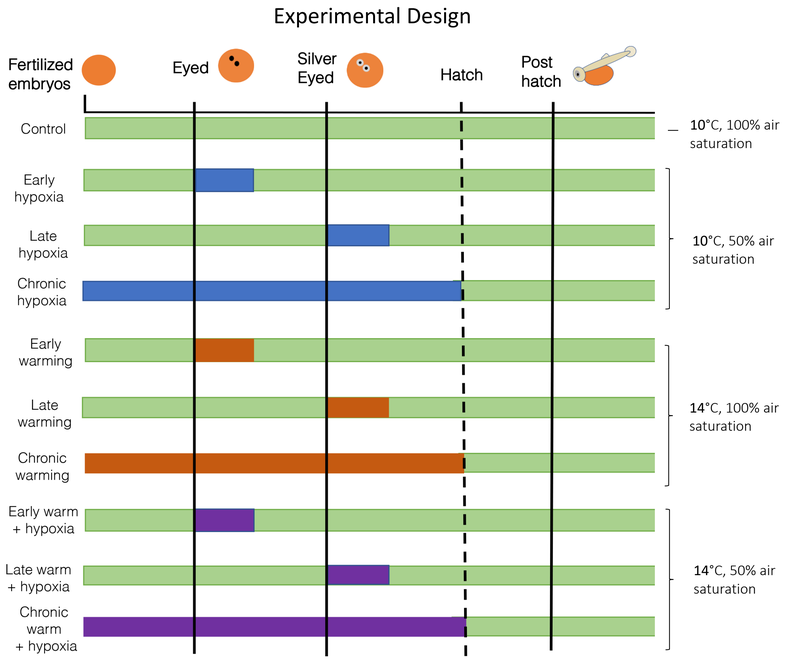
INTRODUCTION

- Chinook salmon populations in California are declining due to climate change, drought, and numerous anthropogenic impacts on habitat quality
- Warming and hypoxia (low dissolved oxygen) are two common stressors within the rearing environment of salmon redds
- Freshwater early life stages of salmon are particularly vulnerable to climate change stressors because they can't move to avoid poor water quality
- Early life stages have to rely on physiology to cope with stressors present
- We previously found that the interaction between warming and hypoxia caused significant effects on hatching success, growth, thermal tolerance, and hypoxia tolerance during chronic exposures (Del Rio et al. 2019)
- Here we investigated how the type of stressor as well as the timing of the exposure to stressors affected salmon embryo survival and development

METHODS

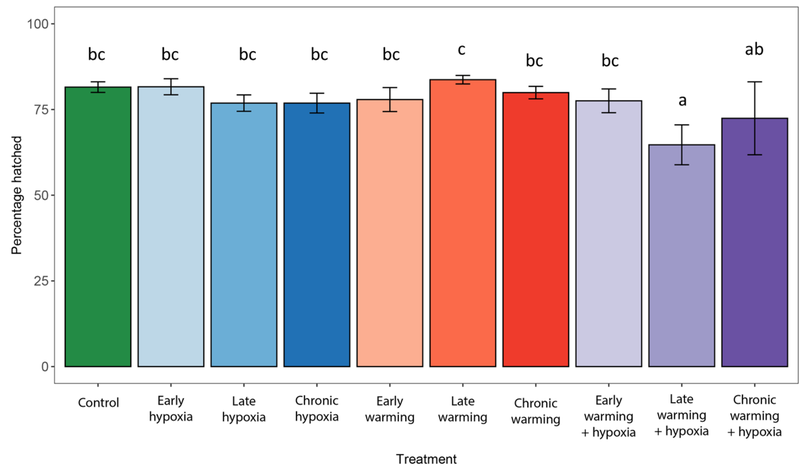
- Reared 3,330 late fall-run Chinook salmon embryos from Coleman National Fish Hatchery at the UC Davis Center for Aquatic Biology and Aquaculture
- Embryos were from 6 families, evenly distributed across treatments
- 10 Treatments varied in temperature (10° or 14°C), dissolved oxygen (100 or 50% air saturation) and timing of exposure (early, late or chronic)
  - Short term exposures were for 5 days at the eyed stage (early) or silver eyed stage (late)
  - Chronic exposures were from fertilization through hatching
  - 3 replicate culture buckets per treatment
- Each treatment was transferred to control conditions after hatching
- Measured hatching success as percentage hatched, hatch window as the number of days between the first and last embryo hatched, and percentage of body tissue 5 days post-hatch as the percentage of body tissue dry mass compared to the total dry mass in dissected alevins

Experimental Design

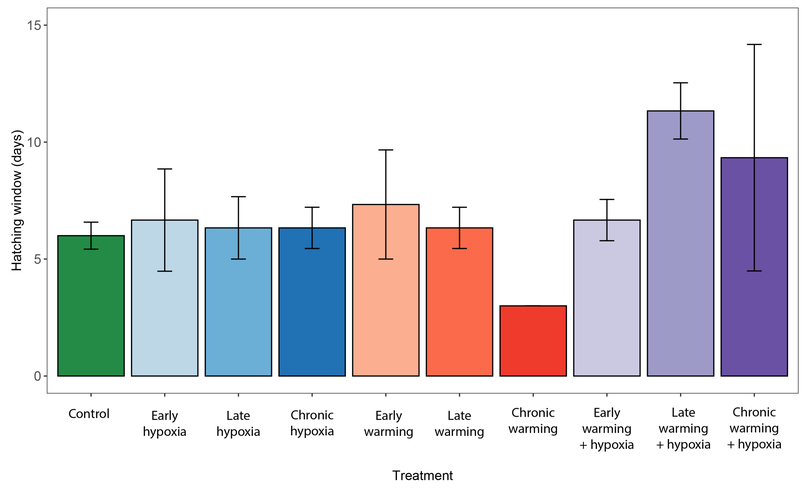


RESULTS

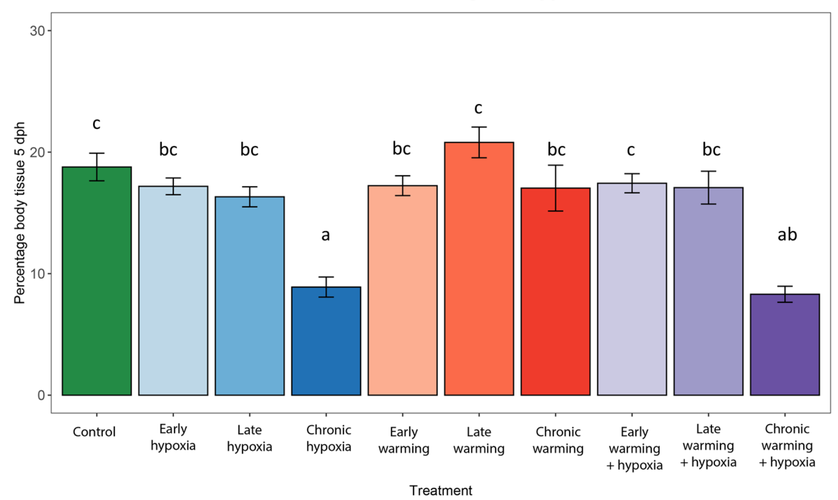
Significantly lower hatching success with exposure to multiple stressors late in embryonic development



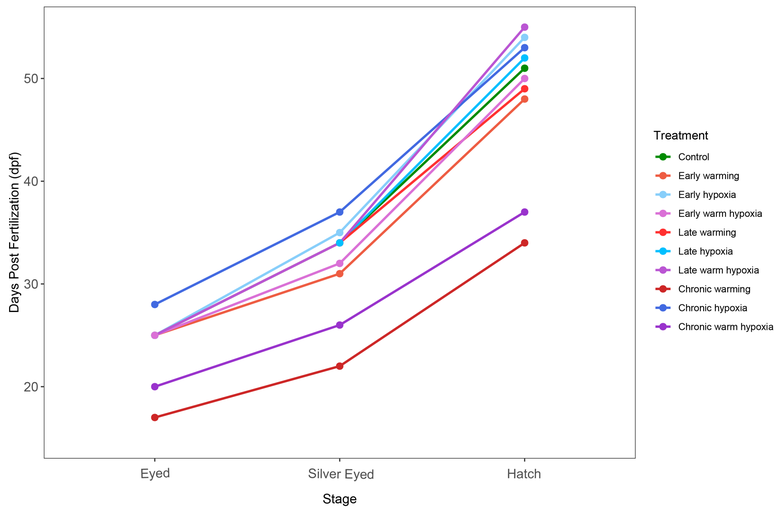
No significant differences in timing between first and last embryo hatched



Lowest body tissue mass 5 days post-hatch with chronic rearing in hypoxia or chronic warming and hypoxia

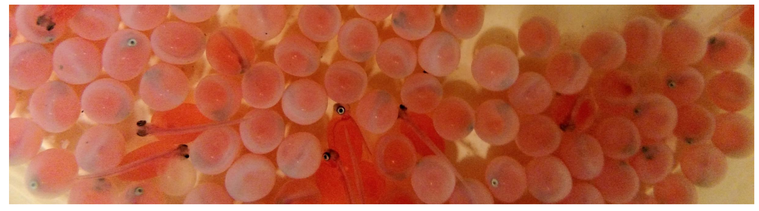


Type of stressor and timing of stressor affects developmental timing



DISCUSSION

- The multiple stressor treatments had the lowest hatching success and took longer to hatch, although the difference in hatching window was not significant
- Lowest hatching success and longest hatching window both occurred in the late warming and hypoxia treatment, suggesting sensitivity to both stressors increases later in embryonic development
- Exposure to chronic hypoxia and chronic warming and hypoxia resulted in smaller alevins that converted less yolk to body tissue shortly after hatch
- Growth is often linked to survival in small fishes so fish reared in chronic hypoxia or hypoxia and warming may be more vulnerable to predation at that stage
- Developmental rate increases with warming and decreases with hypoxia exposure, which could have larger impacts on the phenology of salmon development
- Chronic exposures caused the greatest changes in developmental timing, but even 5-day exposures caused lasting changes in the time until hatching



FUTURE DIRECTIONS

- The study continued through the fry stage to look at carryover effects of early developmental exposure on the physiology and behavior later in development
- There were carryover effects of developmental stress exposure on developmental timing, metabolic rate, and acute stress tolerance
- We are conducting a field study in the American River, analyzing water quality within artificial redds to learn how variations in water quality contribute to salmon embryo survival and physiology in a more natural environment

ACKNOWLEDGMENTS

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