Predicted Effects of Heat Stress on Chinook Salmon Abundance Regarding Juvenile Survivability and Body Length

BIOL*4110: Ecological Methods

Dr. Joey Bernhardt

Group 2

Hannah Bennett (1125667), Rose Brandt (1174398), Nora de Vos (1134440), Karleigh Fishback (1128401)

2024.10.10

Introduction

Chinook salmon (*Oncorhynchus tshawytscha*) are an important species of fish with a high cultural, economic, and environmental significance (State of Salmon, 2021). They have such a large implication due to their prevalence in a habitat range extending from the Monterey Bay of California up to the Chukchi Sea in Alaska, with substantial numbers living within the Yukon River in Alaska (DFO, 2019; NOAA, 2024). Chinook salmon hatch and remain in these freshwater ecosystems before migrating long distances out to saltwater, eventually returning to their natal rivers (DFO, 2019; NOAA, 2024). This migration puts great stress on migrating individuals (Twardeck et al., 2023). This stress is often compounded by increasing temperature stress as Chinook salmon are limited throughout various life stages and histories by narrow temperature tolerance ranges (Richter & Kolmes, 2005; Keefer et al., 2018). Annual average air temperatures from 1895 to 2011 rose 0.7°C in the Pacific Northwest, which raises concerns about water temperatures and, thus survivability and success of Chinook salmon (Crozier et al., 2014)

Adult Chinook salmon can tolerate temperatures between 12.8 and 17.8°C, with significant population declines observed at temperatures above 18°C (National Wildlife Federation, n.d.). The optimal growing temperature of juvenile Chinook salmon occurs at 15.6°C, while temperatures above this reduce growth and lead to increased mortality rates (Richter & Kolmes, 2005). Water temperatures that exceed the optimal range of Chinook salmon at each life stage can result in failed reproductive success or reduced egg viability (Richter & Kolmes, 2005). Moreover, even temperatures that are within the tolerable range but approaching their limits can cause stress, potentially impacting survivability (Myrek & Cech, n.d.).

Considering the large numbers of Chinook salmon that spawn in rivers within the Yukon River region (DFO, 2019) and their narrow temperature ranges, this proposal aims to address the knowledge gap regarding how rising water temperatures impact physiological and survival metrics across salmon life stages. Specifically, we hypothesize that temperatures exceeding or approaching thermal tolerance limits will impact body length and juvenile survivability, contributing to the well-observed decline in returning salmon to natal rivers. We predict that rising temperatures will increase physiological stress, reducing body length and survival of juveniles. The results of this study will provide insight into the future of Chinook Salmon populations in the Yukon River, possible adaptability to climate change, and allow predictions of broader ecological consequences.

Summary of Study Design and Methods

We will analyze how temperature fluctuations during spawning months correlate with escapement rates, juvenile productivity, and body length using linear regressions. Temperature data (2011-2022) will be averaged across spawning months (June-September) to assess the physiological impact of heat stress on salmon, with the advantage of high-resolution hourly data (Yukon River Panel, 2024). However, this dataset requires extensive cleaning to derive meaningful seasonal averages. We will also assess body condition by examining salmon length collected from Age, Sex, and Length (ASL) data (1979-2017) gathered by the DCFADFG (2021). This will then be compared with temperatures, using length as a proxy for body condition. We predict that as water temperatures rise above 18°C, there will be a significant decrease in salmon length, potentially due to increased thermal stress affecting their growth and body condition (Figure 1). The choice of length data offers a practical measure of body condition but may overlook other physiological stress indicators such as weight.

Finally, Juvenile productivity (the number of offspring that survive to be a juvenile) (2003-2021) will be examined against temperature data (2011-2022) to evaluate early-life-stage survival (Howard & von Biela, 2020). However, our data has a limited geographic and temporal scope. Statistical methods, including linear regression and correlation analysis, will be applied. We expect results to show a negative relationship between rising temperatures and juvenile survivability. This suggests that rising water temperatures negatively affect the reproductive viability of Chinook salmon, likely due to thermal stress impacting survival (Figure 2).

This study could have the potential outcome that rising water temperatures reduce Chinook salmon populations by negatively affecting body condition and juvenile survival. This has broader ecological implications, as reduced salmon populations will disrupt nutrient cycling and food chains in both freshwater and marine environments (Wainwright & Weitkamp, 2013). The significance extends beyond ecosystems, impacting fisheries and Indigenous communities that rely on salmon for economic and cultural practices (Oke et al., 2020). The novelty of this research lies in its integration of multiple life stages and environmental factors, providing a comprehensive view of how temperature stress affects both freshwater spawning and survival capabilities. As climate change continues to warm rivers, our research may inform conservation strategies aimed at mitigating the effects of climate change on vulnerable species. This study emphasizes the urgent need for adaptive management to protect temperature-sensitive species and the ecosystems and communities that depend on them.

Appendix

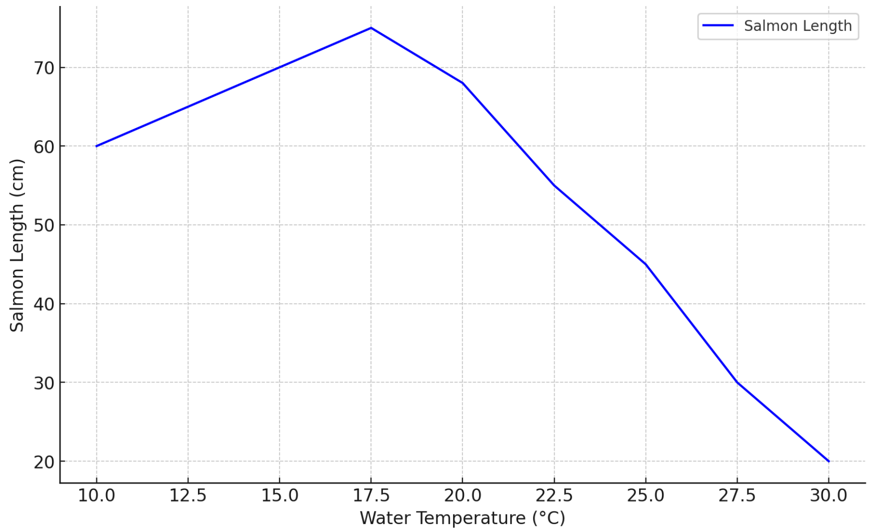

Figure 1: Predicted relationship between water temperature (°C) and Chinook salmon body length (cm). This graph demonstrates how increasing water temperatures impact salmon body size, with a peak length observed around 17.5°C. As water temperature rises beyond this point, a significant decrease in salmon length is predicted, potentially due to increased thermal stress affecting their growth and body condition.

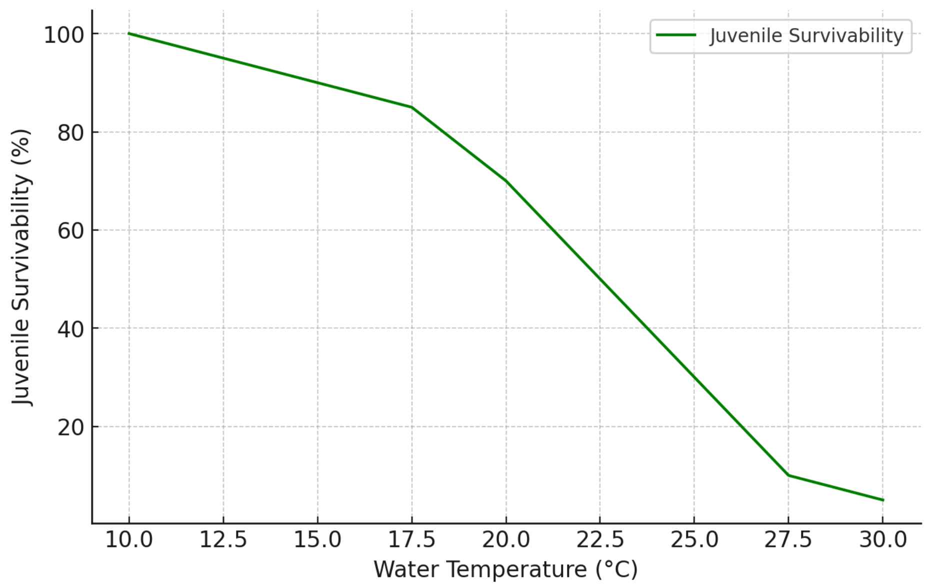

Figure 2: Predicted relationship between water temperature (°C) and juvenile survivability (%) of Chinook salmon. The graph demonstrates that juvenile survivability remains high and relatively stable up to 17.5°C. Beyond this temperature, there is a sharp decline in survivability with near-complete failure at temperatures approaching 30°C. This suggests that rising water temperatures negatively affect the reproductive viability of Chinook salmon, likely due to thermal stress impacting egg development and survival.

References

Alaska Department of Fish and Game. (n.d.). Commercial Fisheries News Release. Retrieved October 10, 2024, from https://www.adfg.alaska.gov/static/applications/dcfnewsrelease/1554859263.pdf

Division of Commercial Fisheries, Alaska Department of Fish and Game. (n.d.). Salmon age, sex, and length data from Westward and Southeast Alaska, 1979-2017. DataONE Data Repository. Retrieved October 10, 2024, from https://knb.ecoinformatics.org/view/doi%3A10.5063%2FJ38QX8

Fisheries and Oceans Canada (DFO). (2019, December 9). Information about pacific salmon. Pacific Region | Fisheries and Oceans Canada. https://www.pac.dfo-mpo.gc.ca/fm-gp/salmon-saumon/facts-infos-eng.html#

Howard, K. G., & von Biela, V. (2023). Adult spawners: a critical period for subarctic Chinook salmon in a changing climate. *Global Change Biology*, *29*(7), 1759-1773.

Keefer, M. L., Clabough, T. S., Jepson, M. A., Johnson, E. L., Peery, C. A., & Caudill, C. C. (2018). Thermal exposure of adult chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLOS ONE, 13(9). https://doi.org/10.1371/journal.pone.0204274

Myrick, C. A., & Cech, J. J. (n.d.). Temperature effects on Chinook salmon and Steelhead: a review focusing on California's Central Valley Populations. Colorado State University. https://www.cwemf.org/Pubs/TempReview.pdf

National Wildlife Federation. (n.d.). Chinook salmon. National Wildlife Federation. https://www.nwf.org/Educational-Resources/Wildlife-Guide/Fish/Chinook-Salmon

NOAA Fisheries. (2024, September 9). Chinook salmon. NOAA Fisheries. https://www.fisheries.noaa.gov/species/chinook-salmon#:~:text=Range,Chukchi%20Sea%20area%20of%20Alaska.

Oke, K. B., Cunningham, C. J., Westley, P. A. H., Baskett, M. L., Carlson, S. M., Clark, J., ... & Palkovacs, E. P. (2020). Recent declines in salmon body size impact ecosystems and fisheries. *Nature communications*, *11*(1), 4155.

Richter, A., & Kolmes, S. A. (2005). Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science, 13(1), 23–49. https://doi.org/10.1080/10641260590885861

State of Salmon. (2021, January 13). Salmon recovery 101. State of Salmon. https://stateofsalmon.wa.gov/salmon-101/

Twardek, W. M., Cooke, S. J., & Lapointe, N. W. R. (2023). Fishway performance of adult Chinook salmon completing one of the world's longest inland salmon migrations to the upper Yukon River. Ecological Engineering, 187, 106846. https://doi.org/10.1016/j.ecoleng.2022.106846

Wainwright, T. C., & Weitkamp, L. A. (2013). Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science, 87(3), 219-242.

Yukon River Panel. (n.d.). Data sets. Yukon River Panel. Retrieved October 10, 2024, from https://www.yukonriverpanel.com/publications/data-sets/