Title: How will climate change affect the spawning habitat of Pacific Salmon in the Columbia River watershed?

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Introduction

Three species of Pacific salmon (chinook, coho, and sockeye) return to the Columbia River watershed to spawn each year, dying soon after[1]. Their offspring then swim out to sea, returning in the spring and summer months, as adults, to spawn the next generation of salmon. However, as these anadromous fish prefer cold freshwater and require specific temperature conditions to thrive, fluctuations in these freshwater conditions can influence their population levels[2].

The migratory cycle and life history of these Pacific salmon populations heavily depend on particular water conditions, including water temperature and the timing and volume of riverflow. These two conditions influence the timing of salmon's return to spawn more than air temperature or long-term natural climate fluctuations[3]. As climate change slowly warms the planet, temperatures will rise, precipitation patterns will change, and the timing and temperature of Columbia River flow will change, significantly affecting the future health of salmon populations spawning in the Columbia River. Indeed, in recent decades, Pacific salmon populations have declined, which has been closely linked to climate variability[2].

Salmon need specific water conditions to survive

Salmon thrive in cold water and will avoid warm patches of water to maintain their body temperature[4]. The optimal water temperature for salmon to thrive is 12-14°C[5]. Swimming in

warmer water requires salmon to expend additional energy to thermoregulate, reducing their fat stores and depleting the energy reserves needed to reach their spawning grounds. When water temperatures exceed a certain threshold, salmon will seek patches of colder water, and cannot tolerate temperatures exceeding 25°C[5]. This suggests that if temperatures in the Columbia River approach or exceed this threshold, the salmon population could be unable to reach their spawning grounds, thus limiting their ability to reproduce.

Furthermore, juvenile salmon are extremely sensitive to mortality threats, including predation and environmental stressors. Varying temperatures of river water can affect the timing at which juveniles leave their freshwater environment for the ocean, potentially subjecting them to altered levels of predation[6]. These juveniles typically return at the same time each year, as adults, to spawn, and rely on predictable temperatures to effectively swim upstream to their spawning grounds.

Climate change is affecting the water conditions

Over the past few centuries, humans have significantly influenced the hydrologic cycle of the Columbia River. Water has been diverted for irrigation purposes, river flows have been altered, dams have been constructed for power and reservoirs, and the surrounding landscape has been deforested. All of these changes drastically affect the natural flow of water in the Columbia River and upend the cycling of sediments and nutrients[7]. However, more than any of these anthropogenic stressors, climate change stands to most significantly disturb the timing, flow, and temperature of the Columbia River.

The Columbia is one of the largest rivers in the world and supplies the most water to the Pacific Ocean of any river in North or South America[8]. Its basin covers approximately 75% of the Pacific Northwest[8], and its mountains receive 100-200 inches of snow each year[9]. Much of its flow comes from melting snowpack, which accumulates through the winter and gradually melts

in the spring. Yet Cohen et al. (2009) have determined that these spring flows have decreased 11% since 1858 due to climate change[10].

These changes are primarily due to two factors: increased winter precipitation and warming temperatures[11]. Water flow in the Columbia River basin is primarily fed by melting snowpack. that slowly melts throughout spring, typically peaking in June. A warming climate results in increased temperatures and precipitation[12], which means that more precipitation will fall as rain instead of snow. This rain flows straight into the Columbia River during the winter months and increases the rate at which existing snowpack melts. These altered precipitation patterns will affect water flow in the Columbia River basin, and peak flow could occur earlier in the season[10]. Total annual flow and minimum flow could also both decrease[10].

Climate change could increase the frequency and severity of droughts, possibly impacting the flow of the Columbia River downstream from its major dams. Additionally, the Columbia River is an important source of water and is sensitive to climate variability relating to drought.[8] During drought conditions, water resource managers could keep a higher percentage of water in existing reservoirs, decreasing the allocated flow in the lower Columbia River, further decreasing water flow and increasing its temperature, since weaker downstream flows warm water more quickly.

Altered water conditions affect salmon populations

This problem is not unique to the Columbia River basin: all around the world, humans are stressing water basins and making them increasingly susceptible to climate change[13]. Even if climate variations produce few differences in winter precipitation, changes in temperature patterns will shift summer streamflow earlier in the season[14]. Bryant et al. (2009) have demonstrated that “increased winter precipitation may lead to more scouring and loss of

spawning habitat in redd-spawning salmonids"[15], and that higher river temperatures might cause juvenile fish to prematurely return to the ocean at a time when food resources are scarce[15].

If salmon arrive to find warmer, weaker-flowing water, they will be stressed as they swim upstream to their spawning grounds, significantly decreasing their ability to reproduce. Fewer salmon successfully returning to their spawning grounds each year will severely threaten the ability of Pacific salmon species to survive. Additionally, unstable river conditions that cause juvenile salmon to enter the ocean at inopportune times could increase their mortality, further eroding the resilience of these species. Therefore, additional fluctuations in temperature and water flow make the future of these salmon populations extremely uncertain.

Conclusion

Climate change will impact the timing, temperature, and volume of water in the Columbia River basin. Salmon rely on these habitats to spawn their next generation of fish. While it is difficult to say exactly how these salmon populations will be affected by changing water conditions, predicting the life cycle, migratory patterns, and future growth of these species is extremely uncertain under variable future conditions[16]—which spells trouble for the three species of Pacific Salmon that spawn in the Columbia River watershed. Salmon can tolerate a range of temperature and water conditions, however, they prefer colder, faster-flowing waters. Human disturbances including the erection of dams and the clear-cutting of forests have already negatively impacted salmon habitat and life cycle and additional fluctuations in temperature and water flow due to climate change make the future viability of these salmon populations even more uncertain. However, considering that these temperature and flow conditions vary widely across the Columbia River watershed, additional study is needed to better understand the future effects of climate change on these salmon populations.

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