The Effects of Climate Change on Salmonids

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Introduction

Two factors that affects the life cycle of the salmonid are temperature and flow. Recent climate change is affecting these two factors and therefore affecting the life cycle of the salmonid. Salmonids are stenothermic, anadromous fishes that rely on certain habitat requirements to fulfill their life cycles. Salmon spawn in freshwater systems such as streams, but live most of their lives in the ocean where they feed and grow to adulthood. The migration from oceans to streams is called a salmon run, and it occurs every year.

Water temperature is especially important because it influences the movement and behavior of the fish (Beitinger and Fitzpatrick 1979). Salmon are cold-blooded—their body temperature is the same as that of the environment—and thus the environment influences their behavior in water. Adult salmon require a certain temperature range to travel upstream to spawn, and juveniles require a certain temperature range to travel downstream to the ocean. Even though salmon need certain temperatures to fulfill their migration pattern, some salmon can withstand a wider range of temperature compared to others (Javaid and Anderson 1967). For example, steelhead, Chinook, and sockeye are more stenothermic compared to other salmonids, meaning they are more sensitive to changes that might occur in the environment (Mantua et al. 2010). The juveniles of those species might migrate earlier to the sea depending on the temperature of the water.

Water temperature has been increasing due to climate change; in some salmonid streams, air temperatures are predicted to increase by two, four, or even six degrees Celsius (Null, 2010). When air temperature increases, water temperature will also increase. Climate change is also affecting the flow patterns of different watersheds; the annual flow of many watersheds is decreasing (Medellín-Azuara et al. 2008). The changes that occur because of climate change will affect the conditions that are needed for salmonids to complete their life cycle. This paper will cover changes in water temperature and flow due to climate change and how these changes are affecting the migration pattern of salmonids.

Water Temperature Change

The temperature of water is important to the migration of juvenile and adult salmon. As water temperature increases, the timing for migration for spawning adults shifts. There have been delays in migration due to the temperature being too cold or too warm (Bjornn and Reiser 1991). Some studies have shown that a shift in the migration pattern of salmonids would affect the survival of juvenile salmon (Carter 2005). If adult salmon migrate too early or too late in the season, the timing of when the eggs hatch and the survival of the juveniles is affected (Jonsson and Jonsson 2009). If the juveniles hatch too early or too late, there might not be enough insects or small fish for the juveniles to eat and survive.

Change in temperature also affects when juveniles outmigrate to the ocean. For example, juvenile Chinook salmon move out to sea earlier when water temperature is higher(Achord et al. 2007). According to Jonsson (2009), “Smolt migration appears not to be triggered by a specific water temperature or a specific number of degree-day during spring, but is controlled by a combination of the actual temperature and temperature increase in the water during spring.” This means when water temperature increases, smolt migration patterns change affecting the overall populations migration timeline.

Adult salmon also require a certain temperature to spawn. For most salmonids, temperatures should not exceed 13°C for spawning, egg incubation, and fry emergence (Carter

2005). An increase in temperature will create an unsuitable spawning habitat for salmonids. There is a negative correlation between water temperature and longevity; as water temperature increases, there is a decrease in longevity and fecundity of salmonids (Jonsson and Jonsson 2009).

Stream Flow Change

Flow conditions strongly influence the migration of salmonids. With a change in climate, there is predicted to be correlative changes in flow. In some areas, a reduction in snowpack and a more rapid snowmelt runoff is predicted, while in others an overall decrease in annual flow is predicted (Null et al. 2010). Overall trends of reduced mean annual flow or MAF are predicted because of higher evapotranspiration rates as the climate becomes warmer (Null et al. 2010). For example, with an average increase in 2°C of air temperature, there could be a total reduction of about 700 million cubic meters in the mean annual flow in the Sierra Nevada region (Null et al. 2010). There may also be a decrease in inflow to the primary Sacramento and San Joaquin watershed reservoirs by 5% by 2025 (Brekke et al. 2004).

Reductions in flow may reduce sediment movement through the watershed, potentially decreasing available sediment for salmon spawning and rearing habitat. Ficklin et al. (2013) showed larger river outlets (Sacramento, American and San Joaquin) exported less sediment under predicted climate change conditions (Ficklin et al. 2013). They found a decrease in sediment transport by 8.9% in the Sacramento River, 9.7% in the American River, and 0.3% in the San Joaquin River. This is especially important for spawning salmonids that use medium-sized rocks or gravel to spawn.

Water flow regimes influence the ability for adult salmon to move upstream to the spawning habitat (Jonsson and Jonsson 2009). Adults require certain flow conditions for upstream migration to the spawning habitats, and juveniles require certain flows to support their outmigration downstream to the ocean (Jonsson and Jonsson 2009). If stream flows are too low, the upstream migration of salmonids might be delayed (Solomon and Sambrook 2004). For example, when freshwater levels were low, the Atlantic salmon of South West England remained in the estuary or returned to sea for several months until conditions improved, but most did not make it to the spawning reaches. The altered migration timing was found to correlate with increased water temperatures due to climate change (Solomon and Sambrook 2004).

Juveniles rely on appropriate flow conditions to outmigrate to the ocean. After eggs hatch, the juveniles tend to remain in the shallow riffles of their spawning habitat. They require a certain amount of flow to successfully get out of the shallow riffles, which if not achieved during a low flow season can be fatal (Armstrong et al. 1998). Waiting for flow increases also creates risk for juveniles. There is a higher chance of predation from terrestrial predators if the juveniles cannot outmigrate. Changes in climate may have large effect on stream flows creating difficulties for salmonids to migrate upstream and downstream.

Discussion and Conclusion

Many salmonids are anadromous and require migration from the ocean to fresh water during their adult stage, and from fresh water to the ocean during their juvenile stage to complete their life cycle. To migrate successfully, most salmonids have certain requirements for temperature and flow conditions. Salmonids are stenothermic and can only survive a narrow range of temperature change. They require enough flow to be able to migrate, and flow conditions affect the quality of spawning and rearing habitat. If temperature or flow conditions are inadequate, adult and juvenile salmon migration can be delayed or not occur.

Climate change is a big factor affecting salmonid migration upstream into fresh water and downstream towards the ocean. As climate changes, water temperatures are increasing, creating warmer stream habitats. Salmonids require colder water to migrate, so increased water temperatures can shift their migration patterns and affect the life cycle of the next generation. If juvenile salmon migrate later than usual, food availability might be low and water conditions may be unsuitable. Annual flow from many watersheds is predicted to be lower due to climate change, affecting sediment transport and habitat conditions for spawning and rearing. Reduced annual flows may also affect migration patterns for adults and juveniles, increasing stranding during outmigration or delaying migration for spawning.

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