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Salmonid habitat availability in the lower Tuolumne River and the effect of water levels on spawning success

Introduction

The manipulation of water in California has been altered due to a variety of agricultural, urbanization, recreational, and environmental diversions. The construction of dams in our water systems altered the course of water to combat several of these issues. These dams have had major impacts on salmonid populations throughout California. More specifically, the construction of La Grange dam in 1883 initially disconnected salmonid juveniles from their historic habitat. Later on, Don Pedro, followed by New Don Pedro, was built and further fragmented the habitat. To preserve the diversity and integrity of the biotic community in the lower Tuolumne River, conservation goals should include maintaining historic native salmonid populations while also managing for agriculture, urbanization, and recreation. In order to do this, regulation of water levels from La Grange dam and New Don Pedro need to coincide with spawning habitat requirements. This paper will discuss the effects of water level manipulation on salmonid spawning habitat and the potential management actions on flow and sediment to improve spawning success.

Habitat needs for spawning success

The two native salmonid species in the Tuolumne River are Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*). These species are adapted to the Mediterranean climate in California through various physiological and behavioral adaptations. These adaptations reflect the species ability to survive in a region of extended droughts and massive floods (Moyle 2002). This has promoted many endemic species and has excluded non-natives because of the fluctuation in flow and turbidity throughout the year (Bjornn and Reiser 1991). It's important to retain this natural flow regime so that non-native species are excluded from historically native reaches of the Tuolumne River. In these areas, non-natives pose a threat to native fish species by out-competing them for resources or predating upon them. In order for salmonids to successfully reproduce, they require specific spawning habitats to ensure the survival of their offspring, the appropriate stream discharge, water temperatures, water quality (Bjornn and Reiser 1991), and sediment size during their migration season. Not only does this meet the physical needs for their spawning, but the coarse sediment also ensures a safe place for offspring to develop without the threat of predators.

First, it is important to have the available habitat for these species to migrate to, because without enough spawning habitat availability populations of salmonids would drastically decline or go extinct. For example, recent studies in the Tuolumne River have shown that Chinook spawning habitat availability has decreased 66%, however, there have been recent rebounds in Chinook salmon populations (Fryer).

Salmonid spawning habitat quality is assessed through water temperature, DO, sediment size, and water level. On the spawning grounds, salmonids need cold, well-oxygenated water--but as water temperatures increase, the waters' ability to hold oxygen decreases (Allan and Castillo 2007). Temperature is the main factor that influences these organisms' life cycle and therefore is critical for egg and juvenile growth (Réalis-Doyelle *et al* 2016). During egg development, the embryos are very sensitive and need specific levels of oxygen to be able to develop into the next stage (Réalis-Doyelle *et al* 2016). Chinook salmon have been observed to have delays in upstream migration because their natal streams temperatures were too high (Bjornn and Reiser 1996) and as a result, the streams had little oxygen. Sediment size is another important factor for spawning success. Very fine particles are detrimental to spawning sites since they increase the mortality of eggs, (Sear *et al* 2016) while gravel and cobble allow the eggs to aerate, from water being able to pass through and under the rocks (Schindler Wildhaber *et al* 2014). Another factor is the amount of stream discharge from La Grange dam; juvenile survival is poor in low water years. It has also been observed in Sacramento's River system that fish migrating during high flows have a higher chance of survival, and fish in deeper waters juveniles are able to avoid predators (Michel *et al* 2015). Low flows also affect salmonids by increasing the sediment deposition; lots of sediment particles will smother the spawning grounds and reduce spawning success (Louhi *et al* 2008). All these habitat requirements are necessary for the survival of salmonid juveniles in the lower Tuolumne River; increased juvenile survival could potentially increase the number of adults that return to spawn.

Effect of urbanization on flows and sediment

The constant fight for water in California has primarily altered the river flows to divert into urbanization. Societies rely on the constant accessibility to water. Dams have diminished the natural and variable flow regime in exchange for the constant water supply; reducing high winter flows and increasing summer and fall flows (Michel *et al* 2015). As a result, the surrounding ecosystem where the river is altered becomes homogenized, which is where we see a loss of biodiversity. Non-natives that once couldn't survive in the fluctuation of flows throughout the year now can (Confluence 2010). Native salmonids in the Tuolumne River have adapted through thousands of years in isolation (Moyle 2002) and now because of the decrease of variability in the river system we see an increase in non-native species abundance (Confluence 2010).

Dams also affect the sediment distribution along the river-- the stream power distributes different sizes of sediment. Most gravel-bed rivers are armored, which means that the bed surface has coarser grain size than the subsurface (Wilcock and DeTemple 2005). With an altered flow regime, the amount and size of sediment are changed, and different levels of water will transport different sizes of sediment (Wilcock and DeTemple 2005), which then affects salmonid egg mortality.

The lower Tuolumne River was historically a floodplain. It was later degraded from the mining for gold in the 1930s, and then in the 1960s, it was re-excavated to provide aggregate for the construction of New Don Pedro (Fryer). The Tuolumne River previously had an "unimpaired" flow regime, which provided a variation in the magnitude, timing, duration, and frequency of stream flows; however, the average annual water yield below La Grange Damn has been reduced from 1,906 million af (acre feet) to 719,000 af (McLain 2010). Almost the entire valuable floodplain habitat that is crucial for the survival of juveniles has been lost due to agriculture conversion (California Trout, Inc. 2018). Urbanization has impacted the flows and sediment distribution in the Tuolumne River and as a result, has reduced the return rate of spawning salmonids.

Current management strategies

A successful dam management strategy with salmonids was seen at Putah Creek in Solano County, CA. Salmon populations have increased from as little as eight salmon in 2013 to over 500 salmon from 2014-2017 (Chapman *et al* 2018). This was first possible from enhancing rearing habitats for juvenile salmon by exposing spawning gravel that had previously been buried and by releasing more water from the Putah Diversion Dam upstream at optimal times to maximize habitat quality (Chapman *et al* 2018). A high flow year in 2017 resulted in juveniles growing longer and plumper, averaging 97 millimeters in length and 11.4 grams in weight (Chapman *et al* 2018). The success of this project gives hope to future restoration projects that work on reestablishing spawning habitats and managing water levels from dams.

For the lower Tuolumne River, there is currently a management project to restore spawning habitat in the river below La Grange dam. The “Tuolumne River Sediment Acquisition and Spawning Gravel Transfusion Project” is a management project located from river mile 52 (below La Grange dam) to river mile 41 (Turlock Lake State Recreation Area) (Fryer). Planning is underway to add more gravel and cobble in order to restore the degraded lower Tuolumne River. The goal is to increase productivity and salmon spawning habitats of the river. This will also improve geomorphic processes and restore other wildlife habitats (Fryer); flow regimes modify entire food webs, not just single species (Poff *et al* 1997).

Conclusion

Chinook salmon and rainbow trout play an important role in the ecosystem of the Tuolumne River watershed. Their sensitivity to different factors can dramatically increase their mortality. Constructing dams in their historical spawning sites reduces the variability in the natural flow regime. Since the construction of La Grange dam in 1883, urbanization has posed a threat to native salmonid species in the lower Tuolumne River. We have the ability to restore this habitat and increase the amount of salmon that can return to their spawning grounds. With increased water flows during critical spawning times and restoration of gravel beds, we should see an increase in abundance and overall fitness of the species, as shown with the example from Putah Creek. The Tuolumne River Sediment Acquisition and Spawning Gravel Transfusion Project will create more successful spawning habitat, with the addition of coarser sediment reducing egg mortality. By reducing egg mortality, the number of salmonid juveniles migrating downstream (smolts) will increase and we will have a greater population returning to the Tuolumne River to spawn in the future. Management strategies like this are important for restoring the Tuolumne River watershed and increasing the native salmonids back to their historic populations.

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