Gore, Joni
Hildeburn, Chase
Ekasumara, Natasha
Saron, Gabriel
WFC 102 Final Paper ΔΣP

Evaluation of Trap and Hauling Fall-Run Chinook on the Tuolumne

Introduction

This paper analyzes the feasibility of using trap and haul to reintroduce fall-run Chinook salmon in the main stem Tuolumne River between New Don Pedro Reservoir and Preston Falls. If enacted, this plan would involve trapping adult spawning California Chinook salmon (*Oncorhynchus thawytscha)* below La Grange Dam and releasing them above New Don Pedro Reservoir. Additionally, juveniles would be trapped at the upstream mouth of New Don Pedro Reservoir and hauled to below La Grange Dam, where they would out-migrate to the sea (Perales et al. 2015). Our analysis uses geomorphic, hydrologic, and ecological conditions to examine the feasibility of salmon success at five life history junctures, which would determine the practicality of such a program.

Feasibility of Fall-Run Adult Chinook Migration and Trap and Haul from La Grange Dam

For trapping and hauling salmon above La Grange Dam to be successful, a viable adult population must to present at the trapping site. For this population to be present, salmon must receive a hydrologic cue to initiate their upstream migration (Thorpe 1988). Yet since most of the remaining Chinook salmon in the Tuolumne watershed are hatchery-raised, these migrating adult fish may take multiple years to use hydrologic cues to become self-sustaining and genetically competent. This is because hatchery fish populations tend to exhibit genetic

homogenization and are susceptible to die offs (Williamson and May 2005). In addition to a genetically competent population, truck and hauling is feasible if adult salmon migrate in water below their incipient lethal temperature of 21˚C (Mosser et al. 2012). Despite these necessities, these conditions may not be met due to managed flows upstream of La Grange Dam. Managed flows out of La Grange may alter subtle chemical and temperature related cues, thus affecting the timing of upstream migration (Thorpe 1988, Brown and Ford 2002).

After migrating to the base of La Grange Dam, salmon will be hauled to the upstream mouth of New Don Pedro Reservoir (Perales et al. 2015). The handling associated with trapping and hauling imposes significant amounts of stress on salmonids (Barton et al. 2011), and studies have shown a correlation between stress and mortality (Fagerlund 1967). Additionally, rapid temperature changes between the transport tank and the destination stream may be a source of physiological stress. These considerations must be minimized to reduce mortality of adult salmon during trapping and hauling on the Tuolumne River (Mosser et al. 2012). Well-designed environmental flow regimes from La Grange Dam as well as proper handling techniques could maximize the success of a trap and haul program.

Feasibility of Fall-Run Adult Chinook Spawning in Main Stem Tuolumne River

For the trap and haul process to be worthwhile, Chinook salmon must be able to build redds and spawn in the middle reaches of the Tuolumne River. Hydrological, geomorphic, and ecological factors determine if spawning Chinook can successfully spawn. Even slight differences in these characteristics will adversely affect the success of reproduction.

Hamilton and Buell found that hydropeaking flows significantly affect the behavior of female Chinook salmon as they build redds. Female salmon exhibit disorientation and confusion in response to pulsed flows, forming incomplete redds and later abandoning them (Hamilton and Buell 1976). This results in decreased reproductive success due to untimely release of eggs and improper fertilization (Hamilton and Buell 1976).

Spawning success is also dependent on appropriate grain size. Sediment tends to be coarser as a result of high flows and finer as a result of low flows. In a hydropeaking flow regime, both extremes in sediment size occur throughout the watershed. Dams alter watersheds by preventing the replenishment of scoured sediment downstream of the structure, leading to the substrate being too large for female salmon to move (Zeug et al. 2014). Optimal sediment size for spawning Chinook salmon ranges between 6-102 mm and $D_{50=}$24 mm (Zeug et al. 2014). Although UC Davis Ecogeomorphology students performed pebble counts in 2014, 2015, and 2016, these counts were not available along the main stem Tuolumne, and thus a conclusion cannot be drawn as to whether the substrate is viable for spawning.

Appropriate dissolved oxygen levels are also required for successful spawning. Moir and Pasternack (2008) found that the optimal dissolved oxygen level for spawning is 76% oxygen saturation at 16˚C, with a rapidly increasing demand for oxygen as temperature rises (Moir and Pasternack 2008). If levels of dissolved oxygen are not within this range, successful spawning rates significantly decrease. Levels of dissolved oxygen ranged between 93-96% saturation at about 20˚C in the main stem Tuolumne River below Preston Falls, according to data collected by Ecogeomorphology students in 2015.

Feasibility of Juvenile Chinook Migration to New Don Pedro Reservoir

The population size and vitality of out-migrating juveniles must be considered for the viability of a Chinook salmon truck and haul program. Similar to their adult forms, juvenile Chinook require certain hydrologic conditions to successfully migrate downstream (Armstrong et al. 1998). If conditions are not met or the juvenile Chinook population is not viable, then a truck and haul program may not be advantageous to maintain fall-run Chinook salmon populations.

Hydropeaking flows in the main stem Tuolumne River may laterally displace fry and increase their risk of stranding and predation (Hamilton and Buell 1976, Bauersfeld 1978). When flows are peaking, the banks of the river may become inundated, and juveniles may move out of the wetted channel; though when flows decrease, juveniles may become stranded on dry land as the water resides. This may desiccate fish or expose them to predators, both of which increase the mortality of juveniles.

Feasibility of Trucking Juvenile Salmon Downstream from New Don Pedro Dam to Below La Grange Dam

The crux of a hypothetical trap and haul operation on the Tuolumne River is the capture of out-migrating juvenile salmon at the mouth of New Don Pedro Reservoir. Juvenile salmon pose a challenge to trap and haul because of their small size, fragile physiology, and high abundance relative to the adults. Multiple studies have shown juvenile salmon trapping to be extremely inefficient. Trapping and hauling juvenile fish on the Columbia River exhibited

capture efficiencies ranging from 2.5 to 5.7% (Ebel and Park 1973). On tributaries of the Williamette River, capture efficiencies ranged from 3.91 to 12.5% above the reservoirs. Among the uncaptured fish, the majority did not survive the passage over the dam (Keefer et al. 2012). In both instances, capture efficiencies increased with overall discharge from upstream dams. These studies indicate that there is potentially very high mortality of juvenile Chinook. More research is needed to determine if a minimum viable population could be retained in juvenile Chinook released on the Tuolumne River.

Feasibility of Juvenile Salmon Out-Migration Below La Grange Dam

Another issue with the feasibility of trap and haul is whether juvenile salmon can navigate downstream to rearing waters after they are trucked below La Grange Dam. Due to the agricultural nature of the San Joaquin Valley, there are countless diversions and pumping stations removing water from the river. For out-migrating fish, this can be a physical barrier that disorients juveniles leading them into stray canals or sucks them up fish at screen-less pump intakes.

Juvenile salmon have specific rearing habitat requirements in order to grow large enough to migrate out to sea. Anadromous fish require aquatic macrophytes to provide insects, shade, and refuge from predation during their younger years (Goertler et al. 2016). It has been observed that juvenile salmon rearing in slow and warm off-channel habitats generally grow at a higher rate than juveniles in fast and cool habitats (Jeffres et al. 2008). Off-channel habitats can be scarce along the lower Tuolumne River and San Joaquin River due to highly regulated flows. River banks and channel structure in the Central Valley have been heavily altered from its

historical floodplain configuration, resulting in a steady decline in optimal rearing habitat. These conditions may ultimately decrease the possibility of a successful trap and haul program (Williamson and May 2005).

Final Remarks

Our analysis suggests several challenges exist to the success of a proposed trap and haul program for salmon at multiple life junctures in the Tuolumne River Watershed. Adult salmon may encounter pre-spawning stressors and resulting mortality as the result of poorly timed releases from La Grange Dam. These releases may, in turn, alter the cues needed for adult salmon to initiate upstream migration. Fish may be exposed to additional stress and consequent mortality due to handling during the trap and haul process. Upstream of New Don Pedro Reservoir, the spawning success of fall-run Chinook depends upon flow regime and channel bed grain size. Hydropeaking flows may reduce spawning success by disorienting females and creating coarser bed material. The juvenile recruitment is adversely affected by the current hydropeaking flow regime in the middle main-stem Tuolumne, potentially exposing them to desiccation and predators. Furthermore, juveniles are very vulnerable during the out-migrating trapping and hauling process. As the frequency of wet years is predicted to decrease due to climate change, so too might the viability of a trap and haul program to restore a fall-run Chinook population above New Don Pedro Dam (Null et al. 2010).

Works Cited

Armstrong, J. D., V. A. Braithwaite, and M. Fox. 1998. The response of wild Atlantic salmon parr to acute reductions in water flow. Journal of Animal Ecology **67**:292-297.

Barton, B. A., A. H. Haukenes, B. G. Parsons, and J. R. Reed. 2011. Plasma Cortisol and Chloride Stress Responses in Juvenile Walleyes during Capture, Transport, and Stocking Procedures. North American Journal of Aquaculture **65**:210-219.

Bauersfeld, K. 1978. Stranding of juvenile salmon by flow reductions at Mayfield Dam on the Cowlitz River, 1976.

Brown, L. R., and T. Ford. 2002. Effects of flow on the fish communities of a regulated California river: implications for managing native fishes. River Research and Applications **18**:331-342.

Ebel, W. J., and D. L. Park. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull **71**:549-563.

Fagerlund, U. 1967. Plasma cortisol concentration in relation to stress in adult sockeye salmon during the freshwater stage of their life cycle. General and Comparative Endocrinology **8**:197-207.

Goertler, P. A. L., C. A. Simenstad, D. L. Bottom, S. Hinton, and L. Stamatiou. 2016. Estuarine Habitat and Demographic Factors Affect Juvenile Chinook (Oncorhynchus tshawytscha) Growth Variability in a Large Freshwater Tidal Estuary. Estuaries and Coasts **39**:542-559.

Hamilton, R. E., and J. Buell. 1976. Effects of modified hydrology on Campbell River salmonids. Department of the Environment, Fisheries and Marine Service, Habitat Protection Directorate.

Jeffres, C. A., J. J. Opperman, and P. B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes **83**:449-458.

Keefer, M. L., G. A. Taylor, D. F. Garletts, C. K. Helms, G. A. Gauthier, T. M. Pierce, and C. C. Caudill. 2012. Reservoir entrapment and dam passage mortality of juvenile Chinook salmon in the Middle Fork Willamette River. Ecology of Freshwater Fish **21**:222-234.

Moir, H. J., and G. B. Pasternack. 2008. Relationships between mesoscale morphological units, stream hydraulics and Chinook salmon (Oncorhynchus tshawytscha) spawning habitat on the Lower Yuba River, California. Geomorphology **100**:527-548.

Mosser, C. M., L. C. Thompson, and J. S. Strange. 2012. Survival of captured and relocated adult spring-run Chinook salmon Oncorhynchus tshawytscha in a Sacramento River tributary after cessation of migration. Environmental Biology of Fishes **96**:405-417.

Null, S. E., J. H. Viers, and J. F. Mount. 2010. Hydrologic Response and Watershed Sensitivity to Climate Warming in California's Sierra Nevada. PLoS One **5**:e9932.

Perales, K. M., J. Rowan, and P. B. Moyle. 2015. Evidence of Landlocked Chinook Salmon Populations in California. North American Journal of Fisheries Management **35**:1101-1105.

Thorpe, J. E. 1988. Salmon Migration. Science Progress **72**:345-379.

Williamson, K. S., and B. May. 2005. Homogenization of fall-run Chinook salmon gene pools in the Central Valley of California, USA. North American Journal of Fisheries Management **25**:993-1009.

Zeug, S. C., K. Sellheim, C. Watry, B. Rook, J. Hannon, J. Zimmerman, D. Cox, and J. Merz. 2014. GRAVEL AUGMENTATION INCREASES SPAWNING UTILIZATION BY ANADROMOUS SALMONIDS: A CASE STUDY FROM CALIFORNIA, USA. River Research and Applications **30**:707-718.