Session 3: Spawning and Incubation

San Joaquin River Spawning Habitat Suitability

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The availability of spawning habitat within the San Joaquin River downstream of Friant Dam (Reach 1A) is crucial for successful reintroduction and sustained population of Chinook salmon. Multiple studies are underway or have been completed to help identify the quality of the river environment as it relates to successful spawning and fry emergence, including evaluations of water quality within the hyporheic zone (DO, water temperature, fine sediment accumulation), egg survival, meso-habitat, bed material size and mobility, scour and deposition, and channel morphology changes associated with alteration to the flow regime. In addition, bedload and suspended load monitoring have been conducted within the reach since 2010.

Critical to identification and quantification of potential spawning areas are the surface water temperature, bed material and hydraulic conditions within the reach during probable spawning periods of spring-run and fall-run Chinook salmon. The current study integrates bed material characterization with two-dimensional hydraulic modeling results to identify areas considered potentially suitable spawning habitat based upon depth and velocity requirements. The suitability of the potential spawning habitat is evaluated with GIS parameterization of substrate, meso-habitat and hydraulic conditions. Limitations of surface water temperature on spawning spring-run versus fall-run populations are also examined. Areas delineated as potentially suitable are analyzed for patterns of correlation and compared with mapped spawning redds within the reach over the past 2 years. This effort is part of a larger study to characterize suitability of spawning and incubation habitat based on physical, biological, and chemical criteria.

Chinook Salmon spawning within the San Joaquin River Restoration Area: A story of success?

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After the construction of Friant Dam in the 1940's, fall- and spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) were extirpated from the lower San Joaquin River upstream of the confluence with the Merced River. Currently, the San Joaquin River Restoration Program (Program) is working towards restoring the river, and maintaining naturally-producing and self-sustaining populations of Chinook Salmon. Although there is consensus among managers that the lack of river connectivity (i.e., flow) is a restoration priority, there is uncertainty regarding the existing quality and quantity of suitable salmon spawning habitat within the Restoration Area. Here, we evaluated the pre- and post-spawning mortality, spawning success, and habitat use of adult Fall-run Chinook Salmon translocated from upstream of Hills Ferry Barrier and associated sloughs into Reach 1 of the Restoration Area upstream of the Highway 99 bridge. We conducted redd and carcass surveys during the Fall and Winter for two consecutive years. During these surveys, environmental characteristics were measured at each redd, and carcasses were assessed for sex, length, spawning status, and origin (i.e., wild vs hatchery). Since there was a known number of salmon translocated into Reach 1, we implemented a pilot mark and recapture study of carcasses in the second year of the study to later assess the accuracy of different population estimators to inform future monitoring if they are needed. In 2013, a total of 68 redds were observed after translocating 364 (122 females) adult Chinook Salmon. Similarly, in 2014, a total of 81 redds were observed after 483 (118 females) were translocated. However, approximately 16% of the 2013 redds were partially dewatered in February after a decrease in river flows. A total of 33 and 99 salmon carcasses were detected during 2013 and 2014, respectively. During both years, approximately 43% of the carcasses observed were female. Assuming no redd superimposition and complete detection of redds, our preliminary results suggest that 55% of translocated females attempted to spawn in 2013 compared to 69% in 2014. Given the relatively low number of translocated fish being recaptured as carcasses, we recommend that the Program should adopt or continue the piloted mark-recapture methods to accurately estimate the number of adult salmon that return to the Restoration Area in future years. Information gathered during this study should be used to help plan fall-run reintroduction activities, future monitoring, and evaluate the utility of ongoing trap and haul techniques.

Egg Survival-to-emergence of fall-run Chinook salmon within the San Joaquin River Restoration Area

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Currently, the San Joaquin River Restoration Program is working towards restoring fish habitat in the San Joaquin River below Friant Dam to support self-sustaining populations of spring- and fall-run Chinook Salmon (*Onchorynchus tshawytscha*). However, there is considerable uncertainty regarding the quality of extant spawning habitat within the Restoration Area. As a result, the amount of spawning habitat restoration (e.g., gravel augmentation) required to achieve the Program's population targets is unknown. Here, we evaluated survival-to-emergence rates and the distribution of emerging fall-run Chinook Salmon translocated into the Restoration Area. Using emergence traps, emerging fry were collected at a total of fifteen natural redds during the winter for two consecutive years. We installed emergence traps on natural redds prior to predicted emergence. Redds were selected for sampling only if the emergence trap would cover their entire egg pocket. We hypothesized that the survival of eggs to emerging fry would be influenced by river flow, water velocity, hyporheic temperatures, dissolved oxygen, permeability, gravel quality and/or sedimentation accumulation. We used regression models to evaluate the relative support for particular environmental variables influencing survival-to-emergence. Preliminary results revealed that in 2014 emergence started earlier (636 ATUs) compared to 2013 emergence (832 ATUs). Although more fry emerged, on average, in 2014, there was considerable intra-annual variability during both years among sampled redds. Early emergence and fewer fish observed during 2013 may have been result of higher initial incubation temperatures and lower velocity in the hyporheic zone. Whereas the intra-annual variability in survival among sampled redds was likely the result of differences in geomorphology. Therefore, natural resource managers should consider the hydrogeomorphology within the Restoration Area when assessing spawning habitat quality and quantity. We believe that our results can be used to determine if reintroduced salmon can successfully spawn to sustain population targets, inform flow management decisions concerning habitat suitability, and guide potential habitat restoration.

Assessment of the incubation environment in Chinook salmon redds, San Joaquin River, California

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The salmon life-cycle is directly dependent on the hyporheic environment for spawning and egg incubation. A substantial quantity of research has focused on the interrelated abiotic factors affecting embryo survival-to-emergence (STE), which include intragravel flow (i.e., gravel permeability and hydraulic gradient), fine sediment concentration, gravel size, dissolved-oxygen (DO), and temperature. The percent of fine sediment observed within the redd incubation environment is contended to be the greatest factor affecting STE by contributing to both asphyxiation and entombment. For this reason, we assessed concentrations of fine sediment in Chinook salmon (*Oncorhynchus tschawytscha*) redds within the San Joaquin River in California to determine if it limits STE. Sampling of gravel permeability and fine sediment percentage occurred over two seasons (2013 and 2014) in natural redds after emergence was complete. These data were applied to peer-reviewed and unpublished regression-based indices used to predict STE. In addition, fifteen redds were capped with emergence traps to monitor observed STE directly, which allowed for comparison of observed versus predicted STE. Eleven of the fifteen redds were used in the analysis, because four had no measured emergence or biological indicators that eggs had been present. Although results show that observed STE was more closely predicted by gravel permeability than by fine sediment concentration, the small sample size of observed emergence (n=11) and high variability of the data does not allow statistically significant conclusions. All redds sampled (n=83) were ranked into three groups (low, medium, and high survival) based on their permeability (K) and calculated STE percent relative to their biological significance as per fisheries population objectives; where low survival (K < 2000 cm/hr; STE < 30%), medium survival (K = 2,000 to 7,500 cm/hr; 30% ≤ STE ≤ 50%), and high survival (K > 7,500 cm/hr; STE > 50%). This assessment provides a preliminary understanding of current spawning conditions in the San Joaquin River Restoration Area.

Physical factors and Chinook salmon egg survival: A study to determine the primary controls

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Chinook salmon egg survival is dependent on many physical factors that affect their incubation environment. These factors include water quality parameters, hydraulics, and sedimentary characteristics. Here we present findings from artificial redd experiments that monitored many physical factors simultaneously with USF&WS's egg survival study (#8). Five study sites were monitored along the uppermost 10 miles of Reach 1A thereby accounting for stream-wise variance in habitat. Water temperature, dissolved oxygen, flow rate, flow velocity, flow depth, sediment transport rate, sand accumulation, hydraulic conductivity, and grain size distribution metrics were all used to compare with the egg survival results. We also employed empirical models (from research literature) that predict egg survival to examine their predictive applicability to the San Joaquin River. Overall, the egg survival results indicate lowest survival at the study site midway within the study reach and increasing survival further upstream and downstream, and that the upstream sites tend to have the greatest survival. This pattern is in agreement with expectations from trends in abundance of sand within the bed's subsurface stratum and site specific transport rate functional exponents. Other physical factors produced spurious correlations. The Tappel and Bjornn [1983] predictive equation for percent egg survival as a function of percent of subsurface grain sizes less than 0.85 and 9.5 mm consistently overpredicts survival by about 15%. We will present the correlations that allow comparison of egg survival dependence on several physical factors and predictive models. These findings suggest (1) the ambient sedimentary environment acted as the primary control on egg survival; (2) a minor adjustment to the fine sediment based model will produce very reasonable river specific predictions of egg survival; (3) the bed's grain size composition controls 85% of egg survival; and (4) effort to enhance the incubation environment quality through fine sediment reduction within the bed substrate has the greatest potential to produce the most significant gains in egg survival.