SAN JOAQUIN RIVER RESTORATION PROGRAM

ABSTRACT BOOK

2016 SCIENCE MEETING

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SESSION ONE

Reintroduction of Spring-Run Chinook Salmon to the San Joaquin River: Management, Methods, and Evaluating Success

Chair: John Netto, US Fish and Wildlife Service

REINTRODUCTION CONJUNCTION: RESTORING SPRING-RUN CHINOOK SALMON IN CALIFORNIA'S CENTRAL VALLEY

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Historically, salmon in California's Central Valley basin had four distinct modal migration patterns, with fish entering freshwater at different times, utilizing distinct spawning and rearing habitat in the streams draining the Sierra Nevada and Cascade ranges. Spring-run populations were likely the numerically largest of these, using their unique life-history to access upstream habitat that is currently blocked by the Central Valley rim dams. This habitat loss has relegated spring-run to a handful of relictual naturally spawning populations and one hatchery stock (the Feather River), and led to ESA listing for the Central Valley spring-run Evolutionarily Significant Unit (ESU). With such protection comes the mandate to actively recover and restore this ESU, but starting from a fraction of the historical complement of populations, and with those remaining severely impacted and at small size. Here, we describe how genetic data and analyses are contributing to efforts to scale up from these small spring-run populations to the large and resilient basin-wide metapopulation that likely existed prior to dam construction. Initial efforts have focused on the San Joaquin River, as the legal-binding agreement to reintroduce salmon to this sub-basin provides a powerful impetus for grappling with many of the difficult issues associated with large-scale restoration of Chinook salmon. We describe the recovery efforts of spring-run Chinook salmon in the Central Valley and how genetic data are being used to decide how to select donor stock from fish in Mill, Deer and Butte Creeks and the Feather River Hatchery, which has a stock that is introgressed with fall-run, but retains the spring-run phenotype. We will also discuss how we use a combination of large-scale parentage inference and genetic stock identification to understand migration, connectivity and adaptation in this initial reintroduction effort and in natural recolonizations in Clear and Battle Creeks.

THE 5-YEAR STATUS REVIEW: IMPLICATIONS FOR THE EXPERIMENTAL POPULATION AND WILD BROODSTOCK COLLECTION OF CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

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The Endangered Species Act requires that NMFS conduct a status review every 5 years for all listed species under its responsibility. That process includes an assessment of the status of the Central Valley (CV) spring-run Chinook salmon population reintroduced to the San Joaquin River. The information developed is also used to determine if any changes to the experimental population designation may be warranted. If necessary, any revision to the regulation through Federal the rulemaking process. This ensures that the reintroduction of spring-run Chinook salmon to the San Joaquin River is providing for the conservation of the species as expected, and that the determination that the experimental population is not essential to the continued survival of the species in the wild is still appropriate.

The regulation designating the San Joaquin River experimental population also identifies that the optimal, and intended, founding stock would include the range of genetic diversity represented by the genetically distinct populations in Butte, Mill, and Deer creeks, in the Feather River. Collection of individuals from threatened source populations is to be done with great care and consideration of the status of potential source stocks. With completion of the long-term Salmon Conservation and Research Facility, it will be feasible to expand from a Feather River genetic group to include other genetic groups in the founding broodstock, provided that source population viability is not jeopardized. The 5 year status review by NMFS in 2011 considered the Butte Creek CV spring-run Chinook salmon population to be at a low risk of extinction and had the largest run size of the three major CV spring-run Chinook salmon populations in the Central Valley. Has four years of drought changed this status?

NMFS recently has completed a 5 year status review for CV spring-run Chinook salmon. This presentation will discuss the outcomes of the viability analysis for the species and the assessment of the current populations as they may affect potential broodstock collections for the SJRRP. Based on these reviews, NMFS has concluded that no change in the SJR experimental population rule is warranted at this time. The viability analysis and other information will be used by NMFS in determining whether to authorize collections from any stock pursuant to a section 10(a)(1)(A) Enhancement of the Species permit application.

INTERIM SALMON AND CONSERVATION AND RESEARCH FACILITY OPERATIONS FOR THE SJRRP

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The San Joaquin River Restoration Program (Program) is working to reintroduce a self-sustaining population of spring-run Chinook Salmon to the San Joaquin River. However, the ESA designation of Central Valley spring-run populations necessitates judicious selection of donor fish to establish a new population. In order to produce sufficient numbers of fish for reintroduction without adversely impacting donor populations, a captive broodstock program was initiated. The captive broodstock program allows collection of relatively small numbers of fish from wild populations. The Program then raises its broodstock to adulthood, spawns them and releases their offspring to the San Joaquin River. The Program is currently developing a full scale, one million-smolt capacity Salmon Conservation and Research Facility (SCARF), which is anticipated to be completed by the end of 2017. In the interim, CDFW is conducting hatchery operations from a small-scale facility that began operation in 2010.

The interim SCARF (Interim Facility) was developed to provide small-scale smolt production in pursuit of Program restoration objectives, to perform program-related fisheries research, and to study captive-rearing techniques. During fall of 2010, fall-run Chinook Salmon were collected from Merced River Hatchery to be used as experimental broodstock to test salmon-rearing practices for the Program. A total of 550 eyed-eggs were collected from 55 mated pairs, quarantined, reared to adulthood, and spawned at the Interim Facility, producing over 86,000 juveniles for release to the San Joaquin River during the spring of 2014.

Fisheries research at the Interim Facility has included both fall-run and spring-run Chinook broodstock for the following: surgically implanting acoustic tags for telemetry studies, cryopreserving salmon sperm for potential gene banking, using ultrasound to assess gonadal development prior to spawning, analyzing conservation hatchery techniques for egg incubation, using natural feed during rearing, modulating growth rates to control early male maturation, installing and applying water recirculation technology to ameliorate high water temperatures associated with the ongoing drought, and releasing adult broodstock to the San Joaquin River for an adult holding and spawning study.

The Interim Facility has also enabled the Program to pursue restoration objectives. In 2012, the Program began rearing spring-run Chinook Salmon broodstock from Feather River Hatchery using the methods refined from rearing experimental fall-run broodstock. From 2012 to 2015, a total of 560 – 1,935 eggs were collected annually. Each year, eggs were hatched and quarantined at the CDFW Silverado Fisheries Base in Yountville, California. Juveniles were coded-wire tagged and transferred to the Interim Facility where they were PIT tagged and tissue sampled for genetic analysis and sex identification. In the fall of 2015, brood year 2012 spring-run were spawned, and over 48,000 spring-run Chinook juveniles were released to the San Joaquin River in the spring of 2016. The Interim Facility continues to rear broodstock from the 2012-2015 brood years and anticipates releasing over 100,000 juveniles to the river in the spring of 2017.

MANAGING PRECOCIOUS MATURATION IN CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA) CAPTIVE BROODSTOCK

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The San Joaquin River Restoration Program (SJRRP) is tasked with restoring Central Valley spring-run Chinook Salmon to the San Joaquin River and has chosen a conservation hatchery as the primary strategy for reintroduction. Currently, CDFW operates a small-scale facility (Interim Facility) to provide practical experience rearing Chinook Salmon to adulthood in captivity and to allow early phase reintroductions while a full-scale Conservation Facility is under development. One of the challenges with raising Chinook salmon in a captive rearing facility is increased incidence of early maturation, particularly in males. Because the SJRRP seeks to maximize genetic diversity of its reintroduced population, CDFW is exploring ways to reduce the rate of early maturation in its broodstock. The ability to control early maturation to a manageable level would enable managers to include these fish during spawning while reducing concern for the trait being inherited by subsequent generations.

In an experimental group of 2010 brood year (BY) fall-run Chinook Salmon reared at the facility, early maturation occurred in 15% of the yearling males, 84% of age-two males, and in 10% of age-two females. Because of the high level of precocity that was observed, CDFW initiated a growth modulation strategy, which included limiting feed, beginning with BY 2012. Despite early attempts using this technique, precocity increased to 33% in the 2012 BY spring-run Chinook yearling males. In response, a more aggressive feed reduction schedule was implemented, particularly between the months of September and January, which is considered a maturation "decision window." Chillers were also installed to reduce high water temperatures associated with the current drought period. With the more aggressive growth modulation strategy, the percentage of age-two precocious 2012 BY males was reduced from 84% to 26%. In addition, precocity was reduced to just 7% in the 2013 BY males, nearly one-fifth of the precocious yearlings observed the previous year.

The observed reduction in early maturation in yearlings appears to be due to the aggressive reduction in feed rates and lowering of the rearing temperatures during incubation and early rearing. A current study of the 2014 BY males will attempt to further define the decision window for Central Valley Chinook Salmon by exploring the starting and end points of the window. Narrowing the decision window should produce fish closer in size to natural-origin Chinook while maintaining the natural 3-5 year lifespan of the population. As part of this study, the 2015 BY males were identified and separated randomly into six tanks. Each tank was then randomly assigned one of six different feeding regimes. Fish will be weighed once a month, checked for precocity and then finally analyzed for significant effects. The study will be ongoing until the BY 2015 males reach age-2/3; therefore results of the study are expected to be available in late 2017.

NEAR-TERM SPRING-RUN MANAGEMENT AND MONITORING PLANNING USING A STRUCTURED DECISION MAKING APPROACH

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Fishery management decisions for the San Joaquin River Restoration Program are complicated by high levels of uncertainty, limited management resources, and the need to overcome delays in the completion of channel and structural improvement projects within the Restoration Area. To address this complexity and the uncertainty, we developed a Structured Decision Making Framework to transparently and comprehensively evaluate spring-run Chinook Salmon management and monitoring alternatives for the Program in the near-term (i.e., 2016-2019). We developed a dynamic Bayesian Belief Network using the software program Netica version 5.12. The BBN consisted of 54 components (nodes) representing a total of six decisions, incorporated statistical uncertainty, and represented the effect of management and monitoring alternatives on our means objectives. Our mean objectives included maximizing our ability to learn, likelihood for building a self-sustaining population, ability to meet compliance requirements, and the feasibility of our actions in the near-term. Conversely, we also attempted to minimize financial cost, failure to meet prior programmatic commitments, and stakeholder burden. We determined the optimal management and monitoring alternatives by assessing which alternatives had the highest utility or value for each decision. We also conducted two one-way sensitivity analyses by varying one independent component at a time to determine their effects on the dependent component(s) of interest. The sensitivity analysis suggested that the Program's ability to learn is most sensitive to the Program's ability to detect or count returning adult spring-run salmon returning the Restoration Area. In addition, the model suggested that the ability to build a self-sustaining spring-run salmon population is most sensitive to water year type followed by juvenile survival throughout the Restoration Area. The results of this modeling exercise recommended that the Program allocate resources necessary to implement the monitoring of spring-run adults returning to Reach 5. Further, if returning adult spring-run salmon are detected, the Program should consider implementing adult translocation activities, expanding the CA Department of Fish and Wildlife's Acoustic Telemetry Study to accommodate translocated adult spring-run salmon, and conducting a redd and carcass survey along with juvenile monitoring to evaluate spawning and production. These management and monitoring alternatives would meet all spring-run associated permitting requirements and ultimately provide valuable information that can be used to adaptively manage the reintroduction of spring-run Chinook Salmon in the San Joaquin River.

ADULT SPRING-RUN CHINOOK SALMON RETURN MONITORING

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To facilitate the reestablishment of spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) into the San Joaquin River, the San Joaquin River Restoration Program implemented direct releases of approximately 54,000 juvenile spring-run Chinook Salmon from Feather River hatchery stock into the San Joaquin River beginning in 2014. The efficacy of implementing direct juvenile salmon releases from donor stocks into the San Joaquin River will be evaluated by monitoring these fish at various life-stages and detecting their contribution to future generations. The Program hypothesized that a total of 21 (±4) adult spring-run salmon would return to the Restoration Area during the spring of 2016 based on the numbers of juveniles released and historical hatchery fish return data. Because fish passage barriers still exist within the Restoration Area, we conducted real-time adult spring-run salmon monitoring during 2016 to inform a variety of critical adaptive fishery management decisions and fulfill the monitoring and management requirements associated with the Program's Section 10(a)(l)(A) Permit authorizing the reintroduction of spring-run Chinook Salmon into the Restoration Area. We passively monitored returning adult spring-run salmon using a Vaki Riverwatcher Fish Counter paired with a V-shaped net weir from March through June at Hills Ferry located within Reach 5 near Newman, CA. The Vaki Riverwatcher Fish Counter consisted of two infrared scanner plates and produced at least one silhouette image of each passing fish with a body depth greater than or equal to 4cm. The Vaki Riverwatcher Fish Counter and net weir were checked 3-5 times each week throughout the sampling period to ensure stability and proper function. More than 1,500 fish were scanned during the sampling period, but no Chinook Salmon were detected. To ensure that salmon were not misidentified, we evaluated the identification accuracy of our observers using Vaki Riverwatcher Fish Counter silhouettes of known fish species collected in other rivers within the Central Valley. In addition, our identification of fish using silhouette data was verified by local Vaki Riverwatcher Fish Counter experts and users. In general, our lack of adult spring-run salmon detections may be the result of poor survival during the early life-stages, poor ocean survival, adult straying within the Central Valley, and/or incomplete gear efficiency. We recommend that the Program continue monitoring returning adult spring-run salmon in subsequent years using our methods along with gear efficiency calibration tests.

SESSION TWO

Spawning and Incubation Habitat

Chair: Erica Meyers, California Department of Fish and Wildlife

CHINOOK SALMON SPAWNING WITHIN THE SAN JOAQUIN RIVER RESTORATION AREA

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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 (SJRRP) is working towards restoring the river, and maintaining naturally-reproducing 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 and the value of translocation (i.e., trap-and-haul) techniques within the Restoration Area to meet SJRRP restoration goals. Here, we evaluated the spawning success of adult fall-run Chinook Salmon translocated from upstream of Hills Ferry Barrier and associated sloughs to Reach 1 of the Restoration Area upstream of the Highway 99 bridge. We conducted a redd and carcass visual observation survey in Reach 1 to assess the spawning success of translocated salmon during the 2015 (October 2015 to March 2016) spawning season. We also assessed the number of fry emerging from a total of fifteen detected redds using emergence traps. Our results revealed that the spawning success of translocated females was 82%. We estimated that approximately 460 of the 929 adult translocated salmon were available for spawning and projected that a total of 217 translocated females had the potential to spawn (i.e., escaped), which is consistent with the number of redds detected (n= 202). We observed, on average, approximately 1,300 salmon fry emerge from the monitored redds. The Fisheries Management Plan set restoration targets of no more than 15% pre-spawn mortality and a minimum of 2,100 fry produced per redd. Our study revealed that the spawning success of translocated Chinook Salmon in Reach 1 of the Restoration Area during 2015 was near the SJRRP 85% target. However, the number of fry produced from their redds was below the SJRRP target of 2,100 fry per redd. Therefore, this study provides evidence that the quality of extant salmon spawning habitat within the Restoration Area or the effectiveness of adult translocation activities may be inadequate for achieving the Chinook Salmon reproduction targets at least during below normal water years. Although further research is needed, the information gathered during this study can be used to help inform fall-run and spring-run reintroduction activities, inform flow management decisions concerning habitat suitability, guide potential habitat restoration, and evaluate the effectiveness of ongoing trap and haul translocation activities.

ASSESSING SPAWNING GRAVEL QUALITY WITHIN FALL-RUN 2013-2015 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 and intragravel flow in Chinook salmon (Oncorhynchus tschawytscha) redds within the San Joaquin River in California to determine if it limits STE.

Sampling of gravel permeability and hydraulic gradient (n>100) and fine sediment concentration (n>40) occurred over a three year period (spring 2014, 2015, and 2016) in natural redds after fry emergence was complete. These data were applied to peer-reviewed and unpublished regression-based indices used to predict STE. Additionally, a subset of samples was collected within the ambient streambed adjacent to the above sampled redds. This allowed for comparison of both the pre-spawn (i.e. ambient) and post-spawn (i.e. redd) incubation environment.

Over the three sampling years, a total of twenty-five redds were capped with emergence traps to monitor observed STE directly. Not all capped redds were sampled or used in the analysis due to no measured emergence nor biological indicators that eggs had been present and/or sampling equipment limitations under high flows. Estimating STE in capped redds allowed for comparisons of observed versus predicted STE. Moreover, relating observed STE to abiotic factors has allowed us to begin developing specific regression-based indices useful for rapid gravel quality assessment of spawning habitat within the San Joaquin River. Although occurring during severe drought conditions, this three year assessment provides a preliminary understanding of current spawning gravel quality in the San Joaquin River Restoration Area.

OBSERVATIONS OF BEDLOAD TRANSPORT IN A GRAVEL BED REACH OF THE SAN JOAQUIN RIVER USING NEW METHODS, AND THEIR IMPLICATIONS TO PERMEABILITY AND HYPORHEIC FLOW

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The question: "how does a streambed change over a flood" does not have a clear answer due to lack of measurement methods during high flows, yet it strongly influences the morphology and permeability of the streambed, mediates the hyporheic exchange of water between flow and bed, and maintains salmon spawning habitat. We conducted two studies along Reach 1a of the San Joaquin River: one on bedload transport, and another on hyporheic exchange.

In the bedload transport study, we investigated bedload transport and disentrainment during a 1.5-year recurrence interval flood by linking high-resolution field measurements using fiber optic distributed temperature sensing (DTS) cable together with sediment transport formulae and an existing analytical solution to predict sediment deposition from temperature amplitude and phase information. In our field investigation, we deployed 2-km of fiber-optic DTS cable directly on top of the riverbed over three pool-riffle sequences each with a different degree of bed mobility. The method facilitated the study of gravel transport by using near-bed temperature time series to estimate rates of sediment deposition continuously over the duration of a 10-day sediment-mobilizing flow. The observations indicated that gravel and cobble particles were transported along the riffle at a relatively low Shields Number for the median particle size, and were re-deposited on the lee side of the bar at rates that varied over time during a constant 700 cfs flow. Approximately 3–40% of the bed was predicted to be mobile during a flood with a 1.5-year recurrence interval, indicating that large inactive regions of the bed, particularly between riffles, persist on an annual basis despite field observations of narrow zones of local transport and bar growth on the order of ~3–5 times the d50 particle size. In contrast, during a hypothetical 7-year flood approximately 35–85% of the bed was predicted to become mobile, suggesting that the continuous along-stream mobility required to mobilize coarse gravel through long pools and downstream to the next riffle is infrequent.

In the hyporheic flow study, we developed an analytical bedform-infiltration relation to illustrate the conditions required for infiltration and exfiltration of flow between a stream and its bed, and used it in conjunction with our own measurements of permeability and a 2D groundwater model to investigate the factors that affect paths and residence times of hyporheic flow along the length of two riffles in Reach 1a. It is shown that asymmetry of bar morphology is a first-order control on the extent and magnitude of infiltration, which would otherwise produce equal areas of infiltration and exfiltration under the assumption of sinusoidal bedforms. Hydraulic conductivity varied by orders of magnitude due to fine sediment accumulation and downstream coarsening related to the process of bar evolution. This systematic variability not only controls the magnitude of infiltration, but also the residence time of flow through the bed. The lowest hydraulic conductivity along the reach occurred where infiltration fluxes would otherwise be greatest into a bed of homogenous gravel, indicating the importance of managing sand supply to maintain the ventilation and flow through salmon spawning riffles.

BED MOBILITY MEASUREMENT AND FLOW EFFECTIVENESS

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Spring-run Chinook salmon spawning habitat is limited relative to the SJRRP Fisheries Management Plan (2010) stated requirements. Those locations where they are anticipated to spawn indicate incubation habitat quality will not meet fry production targets as set in the FMP. Studies have found the ambient bed and its provision of hyporheic flow impose a primary control on the incubation habitat quality. Explanation for the dominance of the ambient bed on incubation success is suggested to result from a low disturbance regime whereas low frequency of flood flows, insufficient supplies of large woody debris or sediment influx, and the absence of other bed disturbance instigators (e.g., high density salmon spawning by multiple runs per annum) over the past 70 years has resulted in a tightly packed bed with low permeability and a stagnant hyporheic environment. On the San Joaquin River's Reach 1A such a condition is suggested to occur at the pool-tailout zones, which is a critical zone for downwelling flow that drives hyporheic flow through the downstream riffle bed where salmon are anticipated to spawn. DWR measured the hydraulic forces necessary to initiate gravel-cobble entrainment using tracers. These results were used to calibrate force gauge measurements on the bed surface grains. Force gauge surveys were performed at two other spawning beds and the inference from the calibration suggests good agreement between the beds' mobility. These measurements were then applied to hydraulic model output to determine the location and extent of bed material entrainment at differing flow levels. The value of these results to the SJRRP is that by determining the flow releases capable of flushing the pool-tailout's bed of its pore space clogging fine sediments management is able to prescribe flows that provide this beneficial habitat maintenance process. By taking advantage of this process, surface water downwelling though the spawning gravels will reduce a dominant control against incubation habitat quality and enhance fry production.

SESSION THREE

Physical Processes Affecting River Restoration

Chair: Alexis Phillips-Dowell, California Department of Water Resources

ASSESSING THE IMPACTS OF ABANDONED GRAVEL MINING PITS ON PEAK DISCHARGE

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In support of the San Joaquin River Restoration Program, prioritization of future actions for potentially separating abandoned gravel pits in Reach 1 from the active channel to improve habitat and predation impacts is one of the factors identified in the Predation, Spawning and Incubation Group (SIG) draft Pit Prioritization Process document. Gravel pit impacts on low- to moderate-magnitude peak flows has been identified as one of the key factors in the California Department of Water Resources (DWR) Gravel Pit Prioritization Data Collection proposal.

DWR and Tetra Tech previously developed a one-dimensional, unsteady routing model to assess flow attenuation along the river. The model was used to assess the impact of removing various combinations of the pits on attenuation of pulse flows of various sizes. Both off-channel pits and pits that intersect with the main channel (in-channel pits) were considered in the analysis. In-channel pits were removed by imposing a series of idealized cross-sections through the affected area with shape and size similar to the existing river in areas not impacted by the pits to simulate a restored river channel. The results of the analysis indicate that removing the pits would reduce the attenuation of typical restoration pulses. The primary conclusion is that, while removal of the gravel pits would have an impact on the magnitude of a downstream peak discharge if the pulse duration is relatively short, most of the recently released restoration pulses were of sufficient duration to achieve the target downstream flow regardless of the presence of the gravel pits. Removal or isolation of the pits does, however, cause the target maximum flow to be reached sooner than with the pits in-place, potentially either saving water if the full duration is not required to achieve the physical objective or providing a longer duration for the flows to do the desired work on the channel. In addition, results identified the degree to which individual gravel pits contribute to these effects.

MECHANICS OF THE ENERGY BALANCE AND TEMPERATURE REGIME IN LOWLAND RIVERS, AND WHY THE BED MATTERS

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In many rivers dams trap sediment and water released downstream of the dams is clear. Downstream of the dam, temperature variability along the river is controlled by climate that warms or cools the water, flow of the water released from the dam, and the spectral (wavelength-dependent) properties of the water and the river's bed. We developed a physically-based, numerical fluvial energy balance model that, without calibration, couples a full spectrum solar radiation balance with turbulent heat fluxes, bed conduction, and a 1D hydraulic model employed over the length of a 150-km reach of the San Joaquin River downstream of Friant Dam to predict alongstream changes in the energy balance and river temperature. We paid detailed attention to the radiative heat transfer and the changes in temperature resulting from flow releases and bed composition because these distinctive features can be specified directly from field measurements. We show that variations in the river's temperature are sensitive to the albedo of the sediment on the bed, especially at shallow depths and smaller discharges. However, absorption of about half the solar radiation lies in a spectral range where absorption is independent of depth, explaining why flow releases of cold water may have limited influence to temperatures beyond tens of kilometers downstream of a dam. The results are relevant to understanding the spatial patterns of temperature at various places along the river and to assessing the value of management for regulating water temperatures.

MODELING INTERACTIONS OF FLOW, VEGETATION, AND SEDIMENT FOR IMPROVED RIVERINE SYSTEM MANAGEMENT

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Understanding sediment transport processes within vegetated flow conditions is a growing challenge due to the increasing priority of maintaining ecosystem function while sustaining water supply and providing flood protection. We present a quantitative two-dimensional model for predicting the effects of flow, sediment, and vegetation interactions that is currently under development at USBR. The model is based upon the SRH-2D package, which contains a two-dimensional flow and mobile bed sediment transport model. The new package incorporates a module that simulates the effect of vegetation on river and floodplain hydraulics through spatially distributed, dynamic roughness. Additionally, a roughness partitioning scheme has been introduced that allows for dynamic decoupling of sediment capacity predictions from the hydraulic solver. A primary motivation for the work is to enable more realistic simulation of sediment transport, erosion, and deposition for use in river restoration design where vegetated conditions are important. We present initial simulation results from application to simple case studies and discuss the utility of expanding the predictive capabilities for application within more complex systems. Results from the model will aid the science, economics, and policy of establishing environmental flows by addressing questions regarding the physical and biological interaction of flow, sediment, and vegetation in rivers and floodplains.

LONG-TERM DECLINE OF GROUNDWATER ACCRETIONS AND INCIPIENT SEEPAGE LOSSES FROM THE LOWER SAN JOAQUIN RIVER

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The goal of the San Joaquin River Restoration Program is to establish a continuous flowing river from Friant Dam to Merced River and restore the river's Chinook Salmon fishery, but this assumes that the lower San Joaquin River provides continuous flow down to the Delta. In the winter of 2015-2016, measured inflow to the lower San Joaquin River from its tributaries was greater than the measured outflow from the river to the Delta at Vernalis, suggesting seepage loss to groundwater were occurring along the river. An analysis of measured flow data was performed to ascertain if there is a long-term decline of accretions to the lower San Joaquin River from groundwater or if the apparent losses were an artifact of prolonged drought conditions. Groundwater accretions were calculated as the difference between the sum of measured tributary inflows to the San Joaquin River and the measured outflow from the San Joaquin River at Vernalis. Daily flow data was collected for 1985-2016 for the gages on the San Joaquin River near Stevinson, Salt Slough, Mud Slough, Orestimba Creek, Del Puerto Creek, Merced River, Tuolumne River, and Stanislaus River and were added together to get total daily inflow. In the late 1990's groundwater accretions were estimated to provide over 600 cfs of flow to the San Joaquin River, but since then there has been a persistent downward trend leading to approximately zero net groundwater accretions in 2015 and net seepage loss from the river in 2016. This trend is similar between the irrigation season, when there are substantial diversions from the river, and non-irrigation season. A continuation of this trend may result in sections of the river running dry with increasing frequency. This could have profound impacts on regional water users and the effort to restore Chinook Salmon to the San Joaquin River.

SESSION FOUR

Production, Survival, and Movement of Juvenile Chinook Salmon in a Newly Wetted River: Addressing Information Needs for River Restoration

Chair: Donald E. Portz, Bureau of Reclamation

CHINOOK SALMON EMIGRATION STRATEGIES DIVERSITY AND ESTIMATING EMIGRANT PRODUCTION AND SURVIVAL; EXAMPLES FROM THE SAN JOAQUIN RIVER BASIN

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Restoring Central Valley Chinook salmon populations in the San Joaquin River relies on discharge (e.g., dam releases) and non-discharge (e.g., channel rehabilitation, screening etc.) actions that will improve success of each life stage that misses its production target. Success of this approach requires a clear understanding of the various strategies employed by each life stage, accurate survival estimation from one life stage to the next and an understanding of how measureable environmental drivers influence successful life stage transition. This presentation will focus on juvenile Chinook Salmon emigration from two San Joaquin River tributaries; the Stanislaus and Mokelumne rivers. The spatial proximity of these systems to the San Joaquin provides a realistic approximation of salmon behavior in the restoration area. We will first describe observed phenotypic variation in juvenile migratory behavior. We will then discuss how well rotary screw trap monitoring data tracks timing and abundance estimates for juvenile emigrants. Finally, we will present results from a generalized life stage model that describes how well environmental drivers explain variation in transitions rates. Results from this approach suggest a potential framework for tracking success of actions meant to improve survival for a given life-stage within the San Joaquin River Restoration Program footprint and determining how successive stages respond to these changes. While examples are provided for CV Chinook salmon, these concepts can be applied wherever migratory salmonid populations and associated environmental data are adequately monitored.

JUVENILE CHINOOK SALMON TRAP AND TRANSPORT, SAN JOAQUIN RIVER, CALIFORNIA

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The anadromous life-cycle of Chinook salmon requires successful emigration of the juvenile life stage from natal spawning and rearing areas in freshwater to marine habitats to allow rearing to adulthood. Factors determining successful emigration include, but are not limited to, suitable water temperatures, adequate and timely flow for downstream movement, and a passable watercourse. None of which are currently available downriver of the San Joaquin River Restoration Program's (Program) Reach 1 during Critical low and high hydrologic water-year types and when Restoration flows are absent. Low water conditions and water temperatures exceeding salmon thermal tolerance limits create physical, environmental, and physiological barriers to downstream migration and result in lower salmon survival if no management actions are taken. The purpose of this study is to support the Settlement Restoration Goal by taking an adaptive management action to assess the feasibility of trapping and moving of Chinook salmon in response to unsuitable environmental and passage conditions. Due to poor hydrologic conditions in the spring of 2014–2016, the Program conducted a trap and transport effort to capture and move juvenile fall-run Chinook salmon from rearing areas in Reach 1, past dry river sections, to a downstream release location in Reach 5 where they could continue their migration. Temporary fence weirs were installed at three locations in Reach 1 between Highway 41 and Skaggs Bridge to facilitate fish capture. Weirs were constructed from bank to bank in a V-shaped configuration using wire mesh panels and supporting metal posts with A-frames leading to a set of tandem collection boxes. Fish enter the collection boxes through a chevron screen passageway, and a dewatering chute in 2016, intended to inhibit exit. Collection boxes were checked for fish and weirs cleaned of debris at least once daily. Length, weight, and juvenile life stage development were measured before transporting to a release site upstream of the Merced River confluence. Site-specific water quality was collected daily, and velocity profiles and 24-h post-transport survival assessments were completed weekly. Weir capture efficiency were completed at each location with up- and downstream passive integrated transponder (PIT) antennas using a mark-recapture evaluation. A total of 2,010 wild salmon were captured in 2016, surpassing capture and transport totals of wild salmon in 2014 (n =1,188) and 2015 (n =625). Non-salmonid weir bycatch numbered 22,872 and 35,101 for 2014 and 2015, respectively. Preliminary data suggests 24–48 h pulse flows (from "typical" 255–292 cfs to "pulse" 443–530 cfs) corresponded to increased capture success of juvenile Chinook salmon. Survival of salmon following capture, transport, and 24-h post-transport holding in Reach 5 were > 90% in all years. Additionally, weir and capture-box efficiencies suggest capture improvements could be made by determining methods to better retain salmon once captured. This effort continues to investigate effective and acceptable practices for collecting and translocating juvenile Chinook salmon during low flow years when the San Joaquin River may not be contiguous throughout the Restoration Area, as well as investigating the utility of pulsed water releases to facilitate downstream movement.

JUVENILE SALMON SURVIVAL IN THE SACRAMENTO-SAN JOAQUIN DELTA

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Juvenile salmon survival in the Sacramento-San Joaquin Delta has been estimated for fall run Chinook salmon smolts originating from the San Joaquin River basin since the mid-1980's. Hatchery fish were marked with coded wire tags and more recently with acoustic tags to estimate survival in different routes and to determine the benefits of increased flow with a physical barrier installed at the head of Old River (HORB) during the spring outmigration period. Juvenile salmon survival studies in the south Delta have also been conducted to assess the potential reduction in survival due to the absence of a HORB. In 1994, we began measuring survival through the Delta, from Mossdale to Jersey Point or Chipps Island for juvenile fall run salmon. In all years since 1994, survival has been below 0.20 for most releases in most years, with the exception of a few high flow years (1995, 1997 – 1999), or medium flow years with the HORB installed (first of two releases in 2000 and 2001). Survival since 2002 has generally been even lower with most values less than 0.10 (early May release in 2006 was an exception). To assess relative mortality between reaches of the Delta, we compared survival per km in various reaches. In the San Joaquin River, the highest mortality was in the lower reaches, between MacDonald and Medford Islands and between Medford Island and Jersey Point; survival from Turner Cut to Jersey Point through the Interior Delta was consistently 0. In the Old River route, the highest mortality was from the Clifton Court Forebay to Chipps Island via the SWP. Average survival per km must be at least 0.99 to obtain levels of survival through the Delta of 0.40 or above. Many factors are hypothesized to be responsible for the poor survival. Results of recent studies suggest that juvenile Chinook salmon survival was higher in some parts of the San Joaquin River with the HORB in place in 2012 relative to 2013, but there was no apparent difference in overall survival to Chipps Island. The potential benefit of the HORB may depend on flow; at Vernalis flows < 2500 cfs, survival to Jersey Point was estimated to be 0 even with a HORB. Results of a multi-year analysis (2010-2013) are pending and may shed further light on the factors influencing through-Delta and reach survival and route selection. Identifying mechanisms that influence reach-specific survival is critical for improving conditions in the Delta for this life stage of salmon. Additional juvenile fall run and spring run studies are planned for the spring of 2017.

CHANGING NEEDS: COVER REQUIREMENTS, ONTOGENY, AND THE STREAM CONTINUUM

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Successful restoration strategies rely on accurate knowledge of the relationships between individual organisms and their physical environment. Juvenile Chinook salmon utilize diverse habitats, from high velocity mountain streams to turbid slow moving deltas and floodplains, encountering a wide range of abiotic variables along the stream continuum. As they move throughout this gradient, juvenile Chinook mature and trigger ontogenic changes in growth and behavior. These changing habitat variables, behaviors, and life stages create dynamic habitat needs that must be well understood to implement successful restoration practices. My study seeks to investigate how cover (e.g., vegetation, woody debris, coarse substrate) requirements fluctuate across the stream continuum and juvenile life stages of Chinook salmon, and how individual behavior varies in response. To test this, I have set up net pens in different locations on the San Joaquin River that were stocked with fry and pre-smolt Chinook. With the use of video monitoring, I have been tracking cover use to determine the strength of which velocity and turbidity influence associations with cover and fish behavior. In this presentation, I will discuss the methods, preliminary results, and potential benefits of habitat complexity to successful restoration of the San Joaquin River.

RETHINKING TEMPERATURE REGIMES REQUIRED FOR SAN JOAQUIN RIVER CHINOOK SALMON: EVIDENCE FOR A 'NEW-NORMAL'

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Recent research suggests that concerns about the capacity of San Joaquin River thermal regimes to support juvenile Chinook Salmon (JCS) growth and development may be unfounded. The growth of juvenile salmonids is a critical variable affecting survival and recruitment to successive life history stages, essentially affecting the strength of subsequent cohorts. Consumption and temperature are key variables affecting growth for fishes in general. Temperature dictates the metabolic efficiency of prey conversion to production, and is thus a primary variable affecting growth. However, temperature optima and thresholds are variable for Pacific salmon populations. Yet many researchers using bioenergetic approaches to understand growth use temperature-dependent equations and coefficients for Chinook Salmon published in Steward & Ibarra (1991) which is based on adults from Lake Michigan, and uses coefficients from other salmonid species. To address this problem we are using an approach using several lines of evidence to better understand relationships between temperature and key bioenergetic functions. We focus this effort on JCS used in the San Joaquin River Restoration Program, which seeks to restore the southern-most run in North America. Our approach includes growth simulation using coefficients from different literature sources, simulations with inSTREAM and bioenergetics models, and field data, and hatchery sources. All evidence suggests that the growth rates of river-born JCS in the San Joaquin River are relatively high. Independent evidence from the neighboring Merced River supports this pattern as well, suggesting that the growth rates of JCS in the southern end of the range may actually be accelerated and not constrained by relatively high water temperatures. A broader objective to this work is to generate population and habitat specific bioenergetics algorithms and encourage a broader use of population-specific relationships of temperature and growth rate.

SESSION FIVE

Multi-Benefit Projects on Floodplains: Incorporating Ecological and Economic Benefits

Chair: Katrina Harrison, Bureau of Reclamation

MULTI-BENEFIT WEED CONTROL: THE SAN JOAQUIN RIVER INVASIVE SPECIES MANAGEMENT AND JOBS CREATION PROJECT

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In 2010, River Partners, the San Joaquin River Parkway and Conservation Trust, and The Nature Conservancy received funding from the Bureau of Reclamation to conduct broad-scale, multi-benefit invasive species monitoring and management in the San Joaquin Valley in support of the San Joaquin River Restoration Program. Initial project phases focused on planning, permits, and negotiations with landowners for site access. Mapping of invasive species began in 2011, and to date over 5000 acres of the SJRRP Program Area have been mapped to date including the San Luis and Merced NWRs, Great Valley Grasslands State Park, Hatfield State Recreation Area, Riverbottom Park, Scout Island, Sycamore Island, Spano River West, Van Buren Unit and eight private inholdings along the San Joaquin River. Focal invasives have included perennial pepperweed (*Lepidium latifolium*), giant reed (*Arundo donax*), red sesbania (*Sesbania punicea*), edible fig (*Ficus carica*), salt cedar (*Tamarix sp.*), Himalayan blackberry (*Rubus armeniacus*), yellow starthistle (*Centaurea solstitialis*), and tree tobacco (*Nicotiana glauca*). Treatments began in 2013 and will continue as funds allow. Site prioritization was required due to factors such as contract labor availability, site access, and optimal timing of treatments including biomass removal, herbicide application and retreatment as required. To date, over 1,000 acres of invasives have been treated, including >800 acres of *L. latifolium*, 160 acres of *S. punicea*, 30 acres of *A. donax*, and smaller extents of other species. In addition to funding permanent restoration staff and seasonal interns, the project has provided temporary positions for >75 California Conservation Corps members, >250 Fresno Local Conservation Corps members, and 90 agriculture labor crewmembers, all of whom have received job training related to riparian restoration and invasive species control. In addition, outreach activities have included presentations, publications, newspaper articles, and meetings with landowners and managers.

NITRATE TRANSFORMATIONS DURING SIMULATED FLOODING OF RESTORED FLOODPLAIN SOILS

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Throughout the United States and many parts of the world, rivers have been systematically replumbed and disconnected from their natural floodplains, thus fundamentally limiting potential biogemochemical processing of riverine nutrient loads when floodwaters infiltrate through floodplain soils. One of the many benefits of restoration projects that restore floodplain connectivity, may be changes in downstream water quality due to soil microbial metabolic pathways such as denitrification, anaerobic ammonium oxidation (anammox), and dissimilatory nitrate reduction to ammonium (DNRA), that transform nitrate under saturated soil conditions. However, few studies have quantified the contribution of all three pathways to nitrate retention in freshwater systems, and specifically in restored floodplains. Additionally, very little is known about how the rates of these microbial nitrate transformations during floods are impacted by periods of drought. This goal of this study is to demonstrate the relative importance of various nitrogen transformation pathways to total nitrate removal and retention in restored floodplains and to characterize the hydrologic conditions most favorable to each pathway.

To test how flood duration impacts nitrogen cycling we added 15N-enriched tracer to soil mesocosms to measure denitrification, anammox, and DNRA transformation rates. In July 2015, we extracted soil mesocosms from the floodplain and riverbed of the Lower Cosumnes River. Cosumnes River water enriched with 15NO3- tracer was pumped into each mesocosm at a constant rate simulating flood durations of 20 h, 30 h, and 96 h. Samples were collected from the surface water and pore water for NO3-, NO2-, and NH4+ using nested lysimeters. A second set of samples was collected from the surface water and transferred to a gastight vial for N2 and N2O isotope analyses. Sediment and drain water was sampled following completion of the flooding simulations and analyzed for grain size, NO3-, NO2-, and sorbed NH4+. Preliminary results indicate that multiple N transformation processes occur simultaneously in the restored floodplain soils, with greater N removal during longer duration flood events.

CHINOOK SALMON REARING: VARIATION IN GROWTH RELATED TO HABITAT TYPE ALONG THE LOWER SAN JOAQUIN RIVER

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In order to restore self-sustaining runs of Chinook Salmon (*Oncorhynchus tschawytscha*) in the San Joaquin River below Friant Dam, a suitable amount of rearing habitat must be rehabilitated, including seasonal floodplains. Unfortunately, most historic Central Valley floodplains were decoupled from the main channel or converted to other land uses long before monitoring was initiated. Therefore, studies are needed to determine how and where floodplain restoration on the San Joaquin River below Friant Dam could support juvenile Chinook Salmon; specifically in relation to inundation timing and juvenile growth and survival rates. To explore potential juvenile salmon growth benefits on San Joaquin River floodplains, we used net pen enclosures to rear juveniles in off-channel and main channel habitats between February and May of 2015 and 2016. Three paired study sites included a continuum from relatively high gradient alluvial habitat to meandering lowland reaches. These sites represent longitudinal changes in physical habitat that are encountered by juvenile salmon during different periods of their development and emigration. Chinook Salmon juveniles from the Mokelumne River Hatchery were stocked into net pens and subsamples were collected at weekly intervals to understand how growth varied with time at each location. A sub-set was allowed to range freely at the Merced National Wildlife Refuge and was re-captured at the end of the study. Additionally, key water quality parameters were monitored to link growth rates with environmental conditions at each site. Significant differences in water quality, food availability and salmon growth were observed during the first trial in 2015. We will present preliminary results from the second year of this study and potential management implications.

FURS, FEATHERS, FINS AND FLOODS: MULTI-BENEFIT RESTORATION DESIGNS ALONG THE SAN JOAQUIN RIVER

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The Floodplain Expansion and Ecosystem Restoration Project at Dos Rios Ranch has been designed to restore ecological processes and native riparian vegetation on approximately 1000 acres of the 2,100-acre Dos Rios Ranch (Stanislaus County, CA). The primary goals of the Project are to restore this acreage to native habitat types for the benefit of terrestrial and aquatic wildlife including threatened and endangered species such as the riparian brush rabbit (*Sylvilagus bachmani riparius*), San Joaquin riparian woodrat (*Neotoma fuscipes riparia*), valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), least Bell's vireo (*Vireo bellii pusillus*), Western yellow-billed cuckoo (*Coccycus americanus occidentalis*), Swainson's hawk (*Buteo swainsoni*), bank swallow (*Riparia riparia*), little willow flycatcher (*Empidonax traillii brewsteri*), tricolored blackbird (*Agelaius tricolor*), and Chinook salmon (*Oncorhynchus tshawytscha*). In addition, the Project is designed to reconnect historic floodplains to the San Joaquin and Tuolumne rivers to which will allow flooding for habitat benefits, as well as promote physical river processes of scour and deposition along eight river miles, increase transient floodwater storage and ground water recharge, and provide additional flood protection benefits to neighboring farms and communities. The Project location at the confluence of the Tuolumne and San Joaquin rivers is a critically important ecological area in a region of near-total conversion of natural habitats due to agricultural and urban development. Restoration of the Project site will also lead to the permanent retirement of thousands of acre-feet of water presently used on irrigated farmland, increasing regional water supply availability.

This presentation will discuss specific project design elements in regards to project goals based on River Partners' 15 years of experience conducting riparian restoration, the ecological site assessment, and the associated hydraulic and sediment transport modeling.

MULTI-BENEFIT FLOOD PLANNING IN FIREBAUGH

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Located on the western side of the San Joaquin River, the small community of Firebaugh is susceptible to frequent flooding. Under the SJRRP Seepage Management Program, several landowners in the Firebaugh area had expressed interest in potential realty actions, such as easements or acquisitions as part of SJRRP seepage mitigation. Under the San Joaquin River Basin-wide Feasibility Study, a supporting effort to the 2017 Central Valley Flood Protection Plan (CVFPP), DWR studied potential opportunities for a multi-benefit flood management/ecosystem restoration project with local stakeholders and in coordination with SJRRP and the U.S. Army Corps of Engineers. In addition to providing background on the CVFPP, this presentation will discuss integrated flood/ecosystem planning of several alternatives, multi-benefit alternative evaluations (including flood risk analysis, floodplain inundation analysis and quantification of ecosystem metrics from the draft Central Valley Flood System Conservation Strategy), stakeholder engagement, and coordination with SJRRP and U.S. Army Corps of Engineers.

THE KNAGGS RANCH STUDIES – REARING SALMON ON AN EXPERIMENTAL AGRICULTURAL FLOODPLAIN IN THE YOLO BYPASS

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Floodplains have been shown to provide high quality rearing habitat, but due to difficulty in sampling, very few studies have been able to directly compare water quality, food resources and growth of juvenile salmon between river and floodplain habitats. From 2012 to 2016 juvenile fall run Chinook salmon have been reared in flooded rice fields on the Yolo Bypass showing prolific growth rates. To look at a direct comparison between riverine and flooded agriculture lands, in the winter of 2016, juvenile Chinook salmon were reared across a transect of the Yolo Bypass, Toe Drain, and Sacramento River to compare water quality, food resources and growth rates between the habitats. Water temperatures were warmer on the rice fields and Toe Drain compared to the river site for lower flows, but during a storm the last week of the study water temperature were similar. Food resources (invertebrates and zooplankton) were 130 times more abundant in the flooded agricultural fields than in the river habitat. Fish were placed in cages within all three habitats for a total of three weeks. During the three-week period growth rates diverged greatly between the habitats. Growth rates were five times and three times higher in the flooded rice fields compared to the Sacramento River location and Toe Drain respectively. This direct comparison of food resources and individually marked fish allows for a better understanding of the potential benefits of juvenile salmon rearing on flooded agricultural habitats.

POSTER SESSION

SJR TEMPERATURE MONITORING PROGRAM: INVESTIGATING A LIMITING FACTOR

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Stream temperature is a critical factor for survival of Chinook salmon (*Oncorhynchus tschawytscha*), and temperatures considered necessary to survival vary based on each life-stage of salmonid development (i.e., migration, holding, spawning, incubation, rearing, and out-migration). The San Joaquin River (SJR) runs through California's Central valley where it is subject to extreme environmental (e.g., long lasting summer heat, idle or slow moving side channels and backwater, and recent drought) and anthropogenic (e.g., agricultural and mining run-off, in-channel and off-channel pits from historical gravel mining) influences that during portions of the year leave stream temperatures near or above critical levels for salmonid survival.

In order to develop a better understanding of each of these influences on stream temperature, the California Department of Fish & Wildlife (CDFW) began a temperature monitoring program on the SJR in 2002. Currently, more than 50 temperature loggers are strategically deployed from the base of Friant Dam to the confluence of the Merced River, each recording hourly temperature data. Field staff download and service equipment monthly to quarterly depending on the season and site location. Data are reviewed for quality to identify erroneous records (e.g., equipment malfunction, exposure to air, near surface solar heating) and maintained in a Microsoft Access database.

Much of the monitoring effort focuses on the Reach 1 of the SJR (from Friant Dam to Gravelly Ford), which is identified as the primary holding, spawning, incubation, and early life-stage rearing habitat for spring- and fall-run Chinook Salmon. Data collected from Reach 1 are being used to determine the influence of flow-through gravel pits and side channels on SJR temperatures, as well as the effects of magnitude, timing, and duration of water releases from Friant Dam. When river connectivity is restored to the Merced River confluence, downstream temperature sites will provide additional insight to the impact of agricultural diversions and run-off, tributary inputs, and/or changing flow. CDFW's SJR Temperature Monitoring Program allows SJRRP scientists to more accurately model SJR stream temperature and offers information regarding the influential factors driving temperatures during critical periods. This ongoing monitoring program aids SJRRP managers in determining appropriate actions to maintain appropriate stream temperatures spatially and temporally in support of salmonid life-stage temperature objectives.

SALMON INCUBATION AND REARING FACILITY (SIRF)

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The temporary Friant Satellite Incubation and Rearing Facility (Friant SIRF) is located on U.S. Bureau of Reclamation (USBR) property off Millerton Road on a bluff above the San Joaquin River, approximately 1,000 feet downstream of Friant Dam and 0.75 miles upstream of the Interim Salmon Conservation and Research Facility (Interim Facility) and San Joaquin Trout Hatchery. , Beginning with the 2012-2013 season, adult salmon captured during the San Joaquin River Restoration Program (SJRRP) Trap and Haul program were spawned and their eggs incubated at the trailer. That first season, two pairs were spawned, providing proof of concept and supplying a limited number of juveniles for studies. During the following 2013-2014 season, the mobile trailer provided 38,000 juveniles for various studies within the SJRRP. Throughout 2014, water temperatures were the highest on record at the San Joaquin Trout Hatchery, the Interim Facility, and the Friant SIRF, which all receive water from Friant Dam. Drought-related factors contributing to high water temperatures include low water levels in Millerton Lake, reduced cold-water inflow to the reservoir, relatively warm winter conditions during the winter of 2013-2014, and reduction of the cold-water pool due to large water deliveries downstream to Mendota Pool. In August 2014, water temperatures at the facilities exceeded the target range for adult holding and egg incubation, and temperatures peaked at over 70 degrees Fahrenheit (°F) in early October. CDFW was not able to utilize the Friant SIRF until water temperatures dropped below 60°F in mid-December, over six weeks after trap and haul efforts began, reducing the number of and delaying the availability of juveniles for studies in spring of 2015. As a long-term solution to prevent periodic high temperatures at the facility from impacting salmon reintroduction activities, CDFW utilized emergency drought funding to install water recirculation and chiller equipment at the Friant SIRF. The equipment allows CDFW to maintain suitable temperatures at the site year-round under drought conditions and also increases the rearing capacity of the facility without significantly increasing water use. First year data from operations indicate good success. Beginning in 2016, the SJRRP intends to also use the Friant SIRF to incubate and rear spring-run Chinook salmon eggs translocated from Feather River Fish Hatchery.

VARIATION IN JUVENILE CHINOOK SALMON INVERTEBRATE PREY ABUNDANCE AND COMPOSITION IN THE SAN JOAQUIN RESTORATION AREA

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A critical part of the SJRRP is estimation of the carrying capacity or production of early life history stages of Chinook Salmon rearing in the San Joaquin River. In cooperation with Cramer Fish Sciences, Juvenile Chinook Salmon net pens were installed at Scout Island (SI), Gravelly Ford (GF), and the Mendota Wildlife Refuge (MWR) to support a floodplain production study. Four pens were placed at each site with two positioned in a main stem area of the river and two in flood plain areas. Macroinvertebrate samples were taken every two weeks from February 2016 through April 2016 using drift and kick sampling methods outside and inside each net pen. Samples were brought back to the CSU Fresno lab for invertebrate identification and counting. Invertebrate abundances varied through an interaction between sites and sample location (in or out of the net pen). Invertebrate abundances from the downriver MWR sites were ca. 2-10x greater than SI and GF respectively. Variation in invertebrate samples taken inside and outside of net pens could be indicative of the effects of JCS predation on invertebrates inside net pens. However, we only observed differences in these sample types at GF, where prey abundances were relatively low and fish growth was correspondingly slow. The three main sites also varied greatly in invertebrate taxonomic assemblages, which is also affects the growth potential of JCS rearing in various reaches of the restoration area. Overall, prey abundance and composition can be coupled with information on water velocity and temperature as well as disturbance to help to establish realistic goals for the potential production of JCS cohorts.

VARIATION IN DAILY GROWTH RATES IN JUVENILE CHINOOK SALMON

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The Aquatic Ecology lab at California State University Fresno has worked in coordination with the San Joaquin River Restoration Project (SJRRP) to determine the success of juvenile Chinook Salmon (JCS; *Oncorhynchus tshawytscha*) development in the waterway. This study investigates the average daily growth rates of JCS born in the river, and determines if that rate varies by week. Daily growth rates can be reasonably extrapolated through measurements taken from otoliths, or ear bones, of salmon. High-powered microscopy allows us to measure ring distances on the order of micrometers. Salmon lay a new ring of calcified tissue on each otolith for each day of feeding, much like tree rings. The distance between each ring corresponds positively with the amount of daily growth of the fish. We analyzed growth rings on otoliths from river born fish caught as mortalities in 2014 in weirs operated by the U.S. Bureau of Reclamation. In general, growth rates of juvenile fish tend to be allometric and decline exponentially with size. The rising temperatures of the San Joaquin River over time, however, may complicate this usually observed pattern of growth. After analyzing the images of 19 separate otoliths, the data show a significantly consistent linear decline in weekly growth rates. Interestingly, the variation in growth rates among the examined fish also significantly decreases over weeks, suggesting convergence of JCS growth rates over the first eight weeks of exogenous feeding. Our estimated growth rate patterns can help to determine if allometric or thermal controls on growth are predominant in this cohort.

DOES ETHANOL PRESERVATION AFFECT STABLE ISOTOPE RATIOS OF FRESHWATER INVERTEBRATES?

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An important aspect of the San Joaquin River Restoration Program is the survival and growth of river-born juvenile Chinook Salmon (JCS). Documenting the invertebrate prey base for JCS is necessary to estimate the production potential of Chinook Salmon cohorts and the viability of re-establishing a self-sustaining population. Stable isotope analysis (SIA) of carbon (C) and nitrogen (N) in organisms can be used to determine the prey used by predators (such as JCS) by resolving the pathways and sources of organic matter to predators.

However, the processing of invertebrate samples from the San Joaquin River can take multiple weeks to sort, identify, and prepare for SIA. Preservation of samples (e.g. in ethanol) to avoid decomposition can add a bias to SIA because ethanol (a C-based organic solvent) may be incorporated into the tissue and extract lipids, which are particularly carbon-rich.

We conducted an experiment to examine the potential effects of ethanol on C and N stable isotope ratios in common invertebrate prey over time. We compared differences in C and N stable isotope ratios over time (2-60 days) in three distinct types of invertebrates that are consumed by juvenile Chinook Salmon in the San Joaquin River. We used *Daphnia* (chitin-rich crustacean), mosquito larvae (dipteran insect and surrogate for Chironomid larvae), and Oligochaetes (protein-rich annelids) and stored them in 70% ethanol for increments of 2, 5, 10, 20, and 60 days. Overall we found no significant effect on stable isotope ratios for either C or N in over a 20-day period, but there was variation in the precision of stable isotope ratios between taxa and elements. In *Daphnia* there was very little variation in C and N signatures, while there was high variation in Oligochaete C and N ratios, and mosquito larvae N ratios.

These findings show that potential ethanol effects are absent or not detectable compared to inter-sample variablility, and likely need no adjustment for current SIA data from the SJR samples. This study will also guide future invertebrate processing protocols.

USE OF STABLE ISOTOPES OF OXYGEN AND HYDROGEN TO TRACE WATER IN THE SAN JOAQUIN RIVER

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Typically, flow on the San Joaquin River changes dramatically with season. There is also commensurate seasonal variation in water temperature, which affects both evaporation and the solubility of oxygen and its evasion from the river. These dynamics between river flow, temperature, and oxygen are important for several reasons. First, oxygen is critical for organisms in the river such as fish. Second, oxygen solubility in water decreases with temperature, but ironically organisms' metabolic need for oxygen increases with temperature. Third, these dynamics can be revealed by examining the stable isotope ratios of oxygen and hydrogen in the water. Finally, these chemical 'signatures' (δ18O & δ2H) can be used to track fish movements and ranges, because water and gas with 'light' isotopes will preferentially evaporate or evade with higher temperatures. My research focuses on how flow rates can affect how dissolved oxygen concentrations and δ18O levels differ over space and time.

San Joaquin River water was sampled during July, August, and December 2015 in order to generate data to relate the effects of flow rates to variation in chemical tracers along the river course. Samples were taken from five different sites along ~25 miles of the San Joaquin River from just below Friant Dam. Water temperatures (°C) and oxygen concentrations (mg/L) were recorded using a dissolved oxygen (DO) meter. In July, water temperatures increased dramatically from 14.5 °C at the base of the dam to 29.8°C 25 miles downstream (+0.57°C/mile), and dissolved oxygen saturation decreased from 70.5% to 64.9%. Toward the end of July, large water releases from Friant Dam changed the characteristics of the river. Water ranged from 17.1°C at the base of the dam to 21.2°C downstream (+0.16°C/mile). Dissolved oxygen decreased from 103.7% at the base of the dam to 85.5% downstream. Sampling in December, with lower flow rates and air temperatures resulted in changes of 15.0°C to 8.7°C (-0.25°C/mile) and dissolved oxygen changed from 109.2% to 103.8% downriver. Water samples were analyzed for δ18O and δ2H at the UC Davis Stable Isotope Facility. As expected, July had the lowest levels of δ18O, followed by December. August exhibited the highest levels of δ18O, possibly resulting from high levels of water releases from Friant Dam during the entire month of July. These data show how water quality can dramatically change with seasonal variations and as it flows downstream, changing the stable isotope signatures of the stream.

These results can help us determine fish ranges by comparing stable isotope signatures in the tissues to the isotopes in the water. Additionally, stable isotope values in fish tissues are direct reflections of the water in their environment.

EFFECTS OF WATER TEMPERATURE VARIABILITY AND RANGES ON CENTRAL VALLEY CHINOOK SALMON SURVIVAL AND DEVELOPMENT

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Pacific Salmon species and their historical distributions are tied intrinsically to water temperatures at the local level. During the incubation stage of development, Chinook Salmon are more stenothermic, making them more susceptible to water temperature variability and ranges. Consequently, the success of restoring native fish populations in habitats that have been dramatically altered might hinge on the restoration of water temperature regimes. Altered water temperature variation and ranges could potentially complicate restoration efforts if not considered. In order to understand how Central Valley Chinook Salmon will respond developmentally and how well they will survive through the incubation stage, we incubated late migrating fall-run Chinook in three different temperature variations and ranges; Treatment A, a ramping down temperature profile (13.4°C-9.9°C), Treatment B, a constant temperature profile (11.7°C-13.1°C), and Treatment C a ramping up temperature profile (11.9°C-17.8°C). Treatments were chosen based on the temperature objectives set by the SJRRP. Each treatment had five genetically distinct crosses in which survival and rate of development was assessed from spawn to eyed egg, eyed egg to hatch, and hatch to ‘emergence’. Overall survival across the three treatments varied from a high of 96% to a low of 40%. Treatment A ranged from 95%-87%, Treatment B ranged from 96%-93%, and Treatment C ranged from 85%-40%. Rate of development was most accelerated in Treatment C, as was expected. Survival was most impacted from the hatch to ‘emergence’ stage in Treatment C. Treatment A and B did not appear to have a distinct stage of development that survival was impacted more than another. During water years when the Sierras are deficient in snow pack to maintain suitable water temperatures in the SJR, Central Valley Chinook Salmon in the SJR could experience temperatures similar to those used in this study. These findings can inform water management by increasing understanding of the potential magnitude of egg mortality under different temperature regimes.

ANALYZING GROWTH RATE VARIATIONS AMONG JUVENILE CHINOOK SALMON POPULATIONS

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The aim of the San Joaquin River Restoration Program (SJRRP) is to restore flows into San Joaquin River in order to re-establish a self-sustaining Chinook Salmon population. The success of the restoration will rely on sustained recruitment of juveniles. Growth rate of juveniles is an ideal measure of habitat suitability, because it integrates multiple sources of energy gains and losses. Although the growth rates of early San Joaquin River born cohorts is high, how does this compare to juveniles from other Chinook Salmon populations? We are conducting this comparison by performing literature meta-analysis of previous studies and comparing the growth rate values from these studies to our juvenile growth rate data from the San Joaquin River. Based on our current research we observe a high degree of variation in growth rates across diverse river ecosystems. Additionally, Chinook Salmon juveniles in the San Joaquin and Merced Rivers have relatively higher growth rates compared to those in northern California and other Pacific rivers. This project will also examine the underlying environmental sources of juvenile growth rate variation across Chinook Salmon populations. The results from this study will aid in determining the feasibility of SJRRP’s salmon restoration goals.

SEDIMENT TRANSPORT IN TRIBUTARY CREEKS OF THE SAN JOAQUIN RIVER

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Two large tributaries, Cottonwood Creek (CTK) and Little Dry Creek (LDC), enter the San Joaquin River below Friant Dam. These two tributaries are thought to be the only substantially sources of sediment other than the streambed and river banks of the mainstem San Joaquin River, yet there is little known about the sediment supply from them. One of the main concerns with respect to tributary sediments on the San Joaquin River downstream from Friant Dam is the potential adverse effect on salmonids. The effects of fine sediment supply on salmonids depend primarily on the size of the sediment and the timing of its delivery to the channel. To address this knowledge gap, the USGS began monitoring sediment in water year (WY) 2012. Monitoring included four automatic pump samplers, two hydrophone monitoring systems (to record sounds of gravel and cobble-size bedload transport), water-level loggers, terrestrial LiDAR, and GPS-surveying. Suspended-sediment samples were collected during storm events and analyzed. In addition, field observations over the last five years at Little Dry Creek have helped to understand the complex hydraulics in this heavily altered channel system.

Annual discharge on these creeks is highly variable and low or no flow can occur for multiple consecutive years on these tributary creeks. Discharge during most of the study period (WY2012 to present) has been very low. However, during the last winter, several small storms occurred in both watersheds. Maximum discharge reached 270 cfs (7.65 m^3/s) on CTK and 445 cfs (12.60 m^3/s) on LDC. In over 29 years of records, the highest discharge recorded on these creeks was 1,004 and 5,000 cfs, respectively, so the recent storms were relatively mild.

During the recent storm events, approximately 56 suspended-sediment-concentration (SSC) samples were collected from LDC, 53 from the LDC canal, and 32 from CTK using ISCO automatic pump samplers. Samples were analyzed for SSC, particle-size distribution (PSD), and loss on ignition. Two methods were used to determine SSC: filtration and decanting. PSD was determined by using a laser-diffraction particle size analyzer. Of those samples collected, D_{50} ranged from 0.01 to 0.10 mm on LDC canal and 0.01 to 0.04 mm on CTK.

Analysis of the audio data recorded by using the hydrophones suggested that coarse (gravel and cobble) bedload was not mobilized at either creek. At CTK, only small patches of sand were observed following storm events indicating that at those flows, low rates of bedload transport occurred. At LDC, however, fresh sand deposits were observed in much of the reach. Channel modifications and abandoned gravel pits near the LDC reach, which is downstream of the streamgage, substantially alters the hydrology and sediment transport—particularly after consecutive dry years. It appears that one of the abandoned gravel pits diverted a large portion of water (approximately 700 ac-ft) and sediment during the first storm of the season. This could reduce the overall contribution of fine sediment to the mainstem; however, the overall impact the channel modifications have on sediment dynamics has yet to be determined.

BANK EROSION MONITORING

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SJRRP Restoration flow releases may cause bank erosion thereby impacting communities, property, and infrastructure adjacent to the channel, as well as in-channel habitat (e.g., quarry pit separation, fine sediment deposition). As a first step towards a proactive monitoring program, DWR performed a pilot study at two sites to investigate remote sensing methods detection of bank erosion. The first site was the largest known bank erosion site (Reach 1A, at RM 262); and the second was a five mile subreach through the community of Firebaugh (Reach 3, at RM 196 – 191) with unknown erosion occurrence. Two remote sensing methods were tried at both sites. The first method compared sequential aerial photography (1998 and 2007 or 2008 with 2015) to determine differences in the locations of channel margins. The second method compared sequential LiDAR surveys (2008 with 2015) to detect changes in land surface elevations. At both sites lateral bank erosion was detected using both methods. Three sites directly east of Firebaugh and one site downstream of Firebaugh revealed substantial bank erosion and were marked as significant areas due to apparent erosion hazard to nearby infrastructure (aerial method). Site visits confirmed the detections in the Firebaugh subreach. Both methods detected sediment deposition and vegetation encroachment. The LiDAR data allows computation of volumetric change, which may be important for evaluating controls on lateral erosion rates. Because either method involves data storage in spatial GIS files, a record of channel morphology and sequential erosion is preserved thereby allowing rapid comparison with future datasets. The developed methodology will be extended throughout the Restoration reach of the San Joaquin River and the relevant bypasses and applied as frequently as necessary. Future monitoring will take advantage of the most current aerial photography and LiDAR survey datasets to document lateral erosion in the Channel Capacity Report. The value provided to the SJRRP from this effort is reduced liability that results from Restoration flow impacts to surrounding areas by using an efficient yet effective technique to monitor 150 miles of channel.

PARTNERING WITH A 21ST CENTURY SERVICE CORPS PROGRAM FOR CONSERVATION PROJECTS

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On January 12th, 2016 the USBR selected American Conservation Experience (ACE), and 15 other local, regional, and national 21 Century Service Corps (21CSC), as part of a new national agreement. This new agreement, as defined by the Secretary of the Interior, is an effort to build upon existing partnerships with youth conservation corps to assist young people; including divers low-income, underserved at-risk youth, and returning veterans; in gaining training and work experience while completing conservation & restoration projects within our public trust.

ACE would like to present how youth crew (R16-FOA-DO-002) and youth interns (R16-FOA-DO-001) can contribute people, work, expertise and diversity to each of the six themes mentioned as the corps focus of this years conference. Many new 21CSC partners are unfamiliar with the capacity to provide young talented and motivated individuals to work in every facet of conservation work. We stabilize riparian areas, build and plant wetlands, seed uplands, survey fisheries, author environmental documents, engineer structures, build trails, survey flora & fauna, and much more.

KANGAROO RAT AND THE SAN JOAQUIN RIVER RESTORATION PROGRAM: A CASE STUDY

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The San Joaquin River Restoration Program preformed surveys for Fresno kangaroo rat (*Dipodomys nitratoides exilis*) in the spring/summer of 2016. The surveys were conducted to determine the presence of Fresno kangaroo rat, a subspecies of the San Joaquin kangaroo rat, in Reach 4A of the San Joaquin River and a portion of the Eastside Bypass just north of Reach 4A.

Live trapping was carried out within seven locations as determined by the presence of potential kangaroo rat burrows and other kangaroo rat signs observed during burrow surveys directed by Reclamation. Each location was trapped for five consecutive nights. All animals trapped were identified to species, measured, weighed, marked, and their sex and reproduction condition recorded on a data sheet. The data collected during the trapping effort was analyzed in a variety of ways in order to establish baseline data which could be referenced in future studies.

RESTORATION FLOW CAPACITY IN THE EASTSIDE BYPASS WITH RESPECT TO LEVEE FRAGILITY

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Although the Eastside Bypass was constructed to convey approximately 16,500-cfs in flood flows (with excess freeboard), the infrastructure requires structural improvements before it can adequately pass the first phase of SJRRP fishery restoration flows of only 1,300-cfs. As fishery flows increase to 2,500- and then 4,500-cfs, even more improvements may be required. Why does there exist such a large variance in flow capacity? The answer lies in determining an acceptable level of risk versus performance versus capacity (a trifecta, of sorts).

In 2007, California Senate Bill 17 enacted the requirement for the Central Valley Flood Protection Board (Board) with the technical assistance of the California Department of Water Resources (DWR) to establish "…standards for levee construction, operation and maintenance." [§8726.(c)] Thus, the Board and DWR developed design standards for expected levee performance based on results from extensive geotechnical levee evaluations encompassing the entire State Plan of Flood Control system throughout the Central Valley.

The relationship of flood risk to levee performance is as follows. As flood flows rise and floodwater are detained and directed by levees (and other flood management devices), they impart a hydraulic loading against the levee prism (the main body of the levee). The higher the floodwater against the levee, the larger the hydrostatic loading and hydrodynamic stresses induced on the levee. With increased loading comes an increased risk of degraded performance which can be measured in terms of the levee's probability of failure for a variety of hydraulic loads ranging from water just against the toe of the levee all the way to flood elevations at the very crest of the levee. Levee failure modes are predominantly associated with five conditions: through-seepage, under-seepage, levee stability, erosion and overtopping. And, failure probabilities can range from 0-100% for any individual, or a combination of failure modes. A levee's performance (or risk of not performing) can be deduced for each of these failure modes, and then statistically combined to derive a composite performance versus risk relationship.

This presentation discusses how a 16,000+ cfs constructed capacity facility ends up with a derived acceptable capacity of only 500±cfs. It combines geotechnical performance expectations, design criteria and failure risk determination to guide how we rectify this capacity deficiency to regain the originally constructed capacity, and at what risk of failure can we, as owners, users, maintainers and regulators accept.

ADULT FALL-RUN CHINOOK SALMON TRAP AND HAUL, SAN JOAQUIN RIVER, CALIFORNIA

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A primary goal of the San Joaquin River Restoration Program is to reintroduce a naturally-reproducing, self-sustaining population of Chinook Salmon (*Oncorhynchus tshawytscha*) to the upper San Joaquin River in accordance with the Settlement. Current river conditions and in-river obstacles do not support anadromy and salmon must be provided assistance to circumvent these barriers. Fall-run Chinook Salmon passing Hills Ferry Barrier near the confluence of the San Joaquin River and Merced River were captured and translocated from the furthermost downstream end of the Restoration Area (Reach 5) to the uppermost section (Reach 1) near Fresno, California to study behavior and spawning site preference prior to reintroduction. Adult fall-run Chinook Salmon were captured using fyke nets in the mainstem San Joaquin River, Mud and Salt Slough, and near the confluence of the San Joaquin River and Eastside Bypass, and using dip nets at the terminal end of irrigation canals. Once captured, length, gender, reproductive stage, photographs, and a tissue sample for genetic analysis were collected. Salmon were marked with external tags denoting gender, month of capture, and individual fish number for identification during mobile tracking and post-spawning carcass surveys. A portion of female salmon were intragastrically implanted with acoustic transmitters to facilitate post-release tracking and monitoring. Following capture, the majority of individuals were truck-transported upriver from Hills Ferry Barrier (Approx. river mile 119) to Camp Pashayan (Approx. river mile 243) for release. The remainder of adult salmon (< 19 male-female pairs, 3.5 % across all years) were retained for artificial spawning and incubation, as a means to supplement juvenile habitat use, survival, and emigration studies. Post-release monitoring efforts included evaluations of environmental effects (i.e., water quality, temperature, and flow) and temporal variation in preferred spawning areas and salmon movements/distribution. From 2012-2015, the Bureau of Reclamation and California Department of Fish and Wildlife captured and truck transported 119 (16 acoustically tagged females, 18 Males), 367 (52 tagged females), 510 (111 tagged females), and 933 (198 tagged females) adult fall-run Chinook salmon, respectively. Across all years of sampling, males were smaller on average and outnumbered females at a ratio of 2.7:1. Most productive site(s) and method of capture varied across years of sampling. However, the peak of capture in 2013, 14, and 15 was generally consistent and near the first week of December. Across all years, survival of transported fish ranged from 93.0 – 99.7%.

MERCED RIVER RANCH SCREENING OPERATION

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Salmonid habitat projects need spawning-sized gravels as well as larger cobble. Construction aggregates use the same material. Ongoing mining operations on the San Joaquin System have created localized material scarcity. Processing alluvial materials for construction aggregate and its consistent demand has resulted in a long-standing and well-established economic driver. The habitat restoration market presents less demand, so producers are geared toward construction, not habitat. These conditions make habitat materials more expensive, and less available, driving up costs for restoration projects.

The California Department of Fish & Wildlife (CDFW) previously identified need for over 260,000 cubic yards of spawning gravel and cobble on the San Joaquin tributaries. Its earlier purchase of the Merced River Ranch (MRR), a 318 acre property 30 minutes north of Merced near Snelling, provided an opportunity for a restoration gravel source, though the MRR's primary acquisition purpose was protecting, enhancing, and restoring its habitat. MRR's gold dredge gravel tailings contain upwards of 1.2 million cubic yards (2.1 million tons) of alluvial materials, with an estimated 75-80% of this being spawning gravel-sized material.

During spring 2016, DWR assisted CDFW in acquiring a Maximus 516 Vibrating Scalper – a portable screening plant – and a loader. The plant separates material into stockpiles of coarse (>5″ or cobble), medium (5″ to ½″ or spawning gravel), and fine grains (<½″). The acquisition was funded by the Delta Fish Agreement (DFA) between the California Department of Water Resources (DWR) and CDFW to offset fish losses caused by water diversion at DWR's San Joaquin River delta Harvey O. Banks Delta Pumping Plant. DWR planned and designed MRR site improvements for DFW, including future floodplain, terrace, and side channel features within 13 acres of the site, and funded DFW's work in obtaining necessary permits to do this initial phase of the project. Work was complete and the plant became operational in May 2016.

This project has laid the groundwork for many years of future salmonid habitat improvement work along the Merced River and other San Joaquin River tributaries, and may provide opportunities for the San Joaquin River Restoration Program as well if alluvial materials continue to become scarcer and more expensive in coming years.

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