Study 30

San Joaquin River Spawning Habitat Assessment – Incubation Environment

Final
2014 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

November 2013

San Joaquin River Spawning Habitat Assessment – Incubation Environment

Scope of Work

<u>Spawning & Incubation Group Study Workplan</u>

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Introduction

The San Joaquin River Restoration Program (SJRRP) Restoration Goal is to "restore and maintain fish populations in good condition in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of salmon and other fish." The SJRRP Fisheries Management Plan identifies spawning and incubation as a life stage to be supported for successful completion of the salmon life cycle.

SJRRP's current understanding of the system is that sufficient availability and quality of spawning habitat within Reach 1 of the San Joaquin River is imperative to sustaining a population of Chinook salmon. For the purposes of this workplan spawning habitat is defined as habitat that will produce the desired outcome from spawning, with the desired outcome being a large proportion of the fertilized eggs will survive and add to the out-migrating cohort. This includes the allowance of the successful completion of spawning, redd construction, egg incubation, and fry emergence. Successful egg survival-to-emergence is often dependent upon the physical habitat quality of the incubation environment, as determined by limits to gravel size and the presence and accumulation of fine sediment, which directly affect gravel permeability, intragravel flow (i.e., apparent velocity and vertical hydraulic gradient (VHG)), and hyporheic water quality parameters (e.g. DO, temperature, etc.) at the egg pocket (Kondolf et al., 2008).

As per the *Restoration Objectives for the San Joaquin River* (Stillwater Sciences, 2003), the objective designed to support successful salmon egg incubation and fry emergence was to "maintain average gravel permeability rates of approximately 2,000 cm/hr (or higher) in spawning areas to support at least 30% survival-to-emergence rates." This objective is based on a highly significant relationship of gravel permeability rates with survival-to-emergence ratios per Tagart (1976) and McCuddin (1977). Their empirical predictions were applied to the average permeability at two potential spawning riffles in uppermost Reach 1 and resulted in predictions of 43% and 17% egg survival-to-emergence (Stillwater Sciences, 2003). Using a salmon population model Stillwater Sciences tested the sensitivity by adjusting the percentage of egg survival-to-emergence and determined that even modest reductions in survival-to-emergence can have serious consequences for the salmon population. With a survival-to-emergence ratio reduced to 15%, neither fall-run nor spring-run salmon populations will be self-sustaining. Three other potential spawning riffle sites were sampled downstream with resulting survival-to-emergence ratios of 20%, 21% and 12%, respectively.

Recent results from several studies confirm that fine sediment (transport and deposition) increases downstream, and also suggest local sources of sand supply, a translating sand pulse, and/or differential sand storage with the channel (SJRRP, 2012; Tetra Tech, 2012a, 2012b; USBR, in press). As sand is transported and subsequently deposited, this fine sediment accumulation clogs gravel interstitial spaces thereby reducing gravel permeability, intragravel flow, and, as a consequence, reducing hyporheic water quality. As found during the USF&WS and DWR's collaborative egg survival and sand accumulation studies, the amount of sand being transported and deposited in the spawning reach is sufficient to inhibit egg survival (SJRRP, 2012).

Based on the results that fine sediment accumulation of sand increases downstream and can inhibit egg survival on the San Joaquin River (SJRRP, 2012), and Stillwater (2003) gravel permeability rates are all well below the restoration objective except for the most upstream site, significant uncertainties persist as to the suitability of the existing streambed incubation environment within the spawning reach.

(1) What are the magnitudes, variability, and extent of adequate gravel permeability and intragravel flow in the existing streambed incubation environment of the San Joaquin River?
   - Where does the existing streambed allow for sufficient gravel permeability (i.e. 2,000 cm/hr or greater) that will maintain and support a critical threshold (30% or greater survival-to-emergence ratio) for a self-sustaining salmon population?

(2) What are the existing conditions of gravel permeability and intragravel flow within the incubation environment of natural and simulated redds created as a result of Reclamation's Fall 2013 Trap-and-Haul adult Chinook salmon transport study and USFWS' Egg Survival and Emergence study (see 2014 MAP)?
   - Do salmon select sites in areas we predict them to and, if so or if not, how do their selected sites perform?
   - How do the site characteristics and performance metrics compare with
      i. empirical predictions?
      ii. other systems?
   - Which processes appear to be limiting their performance, and do those adverse processes occur throughout or locally?

Insight provided by answering these questions will provide the ability to quantify potential spawning habitat using a habitat suitability index (HSI) approach as well as for enhancing spawning area quantity and quality. Comparison of gravel permeability and intragravel flow criteria within the scientific literature will allow us to develop reasonable expectations for spawning survival-to-emergence success with and without management actions (e.g. ripping, gravel augmentation, gravel cleaning, etc.), thereby allowing prediction of net benefit gained for an incurred cost. Finally, studying naturally selected and simulated redds will provide a method of validating the spawning habitat delineating methodology and the HSI.

The work Reclamation proposes within this scope of work seeks to answer these critical uncertainties of the incubation environment within Reach 1. Mapping salmon incubation habitat quality characteristics from measurements of gravel permeability, intragravel flow, fine sediment bedload, and percent of fines in bed material will provide insight to whether predicted spawning habitat will meet the restoration objective of 30% or greater survival-to-emergence, and what factors inhibit suitable incubation environment quality and quantity (e.g. low permeability). Gravel permeability and intragravel flow have demonstrated to be accurate (highly significant) and cost-effective predictors of Chinook salmon (*Oncorhynchus tshawytscha*) egg emergence success (Barnard and McBain, 1994; McBain and Trush, 2001; Stillwater, 2007). Furthermore, there are many permeability and intragravel flow studies throughout the Central Valley to compare the salmon incubation environment with the quality found on the San Joaquin River.

Purpose

The work Reclamation proposes within this scope seeks to answer critical uncertainties (see above Introduction questions) related to the incubation environment within Reach 1. These uncertainties will be investigated by directly measuring gravel permeability, intragravel flow, fine sediment transport as bedload, and percent of fines in bed material at naturally created and simulated Chinook salmon redds and their surrounding areas of potential spawning habitat. Insight provided will include whether or not the incubation environment meets the restoration objective of 30% or greater survival-to-emergence. Understanding the processes that limit survival-to-emergence will provide options for enhancing spawning through emergence area quantity and quality. Comparison of gravel permeability and intragravel flow criteria with the scientific literature will allow us to develop reasonable expectations for spawning survival-to-emergence success with and without management actions (e.g. ripping, gravel augmentation, gravel cleaning, etc.), thereby allowing prediction of net benefit gained for an incurred cost. Finally, by taking advantage of the naturally created fall 2013 redds and the simulated redds from the USFWS' Fall 2013 Egg Survival and Emergence Study (see 2014 MAP), empirical predictions for survival-to-emergence, and the HSI can be validated and customized to the San Joaquin River's spawnable reach.

Goals

The Spawning & Incubation Group identified task elements of investigating gravel permeability, intragravel flow, hyporheic water quality parameters, sediment (i.e. fine sediment accumulation and percent fines in bed material) at and near natural redds as essential for delineating suitable spawning habitat on the San Joaquin River. The goal of this study is to determine the survival-to-emergence success for natural and simulated redds in Reach 1 by using the highly significant relationships of gravel permeability and intragravel flow to predict survival-to-emergence ratios derived from Tagart (1976), McCuddin (1977), and Stillwater (2007), as well as determine factors (e.g. accumulation of fine sediment and percent fines in bed material) that may limit self-sustaining salmon populations by resulting in a survival-to-emergence less than the restoration objective of 30%. Incubation habitat quality parameter maps resulting from this study will be used in providing quantitative measures as first-order data layers that are critical to SJRRP's immediate need of quantifying potential spawning habitat (see SJRRP – Spawning and Incubation Group Process Document, in press).

Objectives

The Reach 1 salmon incubation environment quality and quantity will be investigated by directly measuring gravel permeability, intragravel flow, fine sediment bedload, and percent of fines in bed material at natural redds and their surrounding areas of potential spawning habitat to:

(1) Determine fine sediment transport at the fall 2013 natural and simulated redds by measuring bedload transport at the leading faces of each redd.
(2) Predict survival-to-emergence for fall 2013 natural and simulated redds from published indices by measuring gravel permeability, intragravel flow, and sampling redd bed material to the mean egg pocket depth immediately post-emergence of fry.
(3) Create San Joaquin River specific survival-to-emergence indices with determined survival-to-emergence rates from the USFWS's natural and simulated emergence trap study and the measured gravel permeability, intragravel flow, and bed material samples.
(4) Establish baseline data of the magnitudes, variability, and extent of post-disturbance gravel permeability for potential spawning gravel areas around the fall 2013 natural redds in relation to the restoration objective (i.e. 2,000 cm/hr or greater permeability). Establishing initial conditions will allow for detecting trends/relationships and changes that occur within a site, or between sites (e.g. comparing data measured at similar geomorphic features), and establish a baseline for monitoring these attributes through time.
(5) Develop incubation habitat quality parameter maps from gravel permeability and intragravel flow data for use in providing quantitative measures in the layered HSI approach to quantify spawning habitat. These first-order data layers are critical to SJRRP's immediate need to quantify potential spawning habitat (see Spawning and Incubation Group's Process Document, in press).

Study Design

The incubation environment investigation is contingent on the success of Reclamation's fall 2013 Trap-and-Haul Study, and the USFWS' Fall 2013 Egg Survival and Emergence Study (see 2014 MAP). These studies are tasked in locating natural redds, and for constructing up to ten simulated redds, with a known number of eggs, alongside the natural redds. Both the natural and simulated redds will be capped with an emergence trap.

DATA COLLECTION

A. <u>Natural Redds (with emergence trap)</u>

(1) <u>Pre-emergence</u>
   a. Bedload transport and velocity/depth will be measured, prior to emergence, at the leading face of each redd. Additional measurements will be collected if flow levels change prior to emergence.

(2) <u>Post-emergence</u>
   a. Immediately after emergence and prior to redd excavation for egg counts, gravel permeability will be measured at the mean egg pocket depth by advancing a temporary

stainless steel standpipe piezometer into the streambed. An electric vacuum pump will be used to extract a flux (volume/time) from the standpipe that will be converted to gravel permeability (Barnard and McBain, 1994; McBain and Trush, 2001; Stillwater, 2003, 2007; and Terhune, 1958).

b. VHG data will be collected by manually measuring the difference in water levels, if large enough, from the top of the temporary standpipe and the depth-to-water both inside and outside the standpipe.

c. Before and after the gravel permeability is measured, continuous pressure sensors will be temporarily placed inside the temporary standpipe piezometer at the middle of the perforated band and attached to the outside of the temporary piezometer at the stream bed surface elevation.

    i. VHG will be measured by the differences in hydraulic pressures at mean egg pocket depth relative to the bed surface. This pressure difference will be recorded at a finer resolution than a manual measurement. Sensors will record at 5-second intervals with 0.015-ft accuracy for 3 to 5 minutes at each deployment.

d. If possible, natural redd bed material will be collected, during excavation, to assess salmon preferred sediment gradations, as well as to determine the percent fines within each redd.

B. <u>Simulated Redds (with emergence trap)</u>

(1) <u>Construction</u>

a. A temporary standpipe piezometer will be placed within the simulated redd during construction where the middle of the perforation band is located at the mean egg pocket depth and the top is approximately 6-inches above the streambed surface.

b. Intragravel flow data will be measured at the mean egg pocket depth using continuous pressure/temperature sensors placed inside the in-pace temporary standpipe piezometer at the middle of the perforated band and attached to the outside of the temporary piezometer at the stream bed surface elevation. Sensors will record at 1-hour intervals with an accuracy of ± 0.015-ft; ± 0.05-C.

    i. Apparent velocity will be estimated by differences in diel temperature at the egg pocket depth relative to the streambed surface and time lags between minimum and maximums.

    ii. VHG will be measured by the differences in hydraulic pressures at mean egg pocket depth relative to the bed surface. This pressure difference will be recorded continuously thereby providing continuous VHG data (similar to differences in measured water levels) from inside and outside the standpipe, but at a finer resolution.

(2) <u>Pre-emergence</u>

a. Bedload transport and velocity/depth will be measured, prior to emergence, at the leading face of each redd. Additional measurements will be collected if flow levels change prior to emergence.

(3) Post-emergence

a. Immediately after emergence and prior to redd excavation for egg counts, gravel permeability will be measured immediately post-emergence at the mean egg pocket depth from the temporary in-place standpipe piezometer. An electric vacuum pump will be used to extract a flux (volume/time) from the standpipe that will be converted to gravel permeability (Barnard and McBain, 1994; McBain and Trush, 2001; Stillwater, 2003, 2007; and Terhune, 1958).

C. Natural Redds (without emergence trap) nearby Natural Redds (with emergence trap)

(1) Pre-emergence

a. Bedload transport and velocity will be measured, prior to emergence, at the leading face of each redd. Additional measurements will be collected if flow levels change prior to emergence.

(2) Post-emergence

a. Immediately after emergence, gravel permeability will be measured at the mean egg pocket depth by advancing a temporary stainless steel standpipe piezometer into the streambed. An electric vacuum pump will be used to extract a flux (volume/time) from the standpipe that will be converted to gravel permeability (Barnard and McBain, 1994; McBain and Trush, 2001; Stillwater, 2003, 2007; and Terhune, 1958).

b. Intragravel flow data will be measured at the mean egg pocket depth using continuous pressure/temperature sensors placed inside a temporary piezometer at the middle of the perforated band and attached to the outside of the temporary piezometer at the stream bed surface elevation. Each natural redd will contain a temporary piezometer with sensors for a minimum of 72 hours. Sensors will record at 1-hour intervals with an accuracy of ± 0.015-ft; ± 0.05-C.

    i. Apparent velocity will be estimated by differences in diel temperature at the egg pocket depth relative to the streambed surface and time lags between minimum and maximums.

    ii. VHG will be measured by the differences in hydraulic pressures at mean egg pocket depth relative to the bed surface. This pressure difference will be recorded continuously thereby providing continuous VHG data (similar to differences in measured water levels) from inside and outside the standpipe, but at a finer resolution.

c. Natural redd bed material will be collected to assess salmon preferred sediment gradations, as well as to determine the percent fines within each redd.

DATA PROCESSING & ANALYSIS

(1) Formulate critical San Joaquin River specific survival-to-emergence indices with gravel permeability, apparent velocity, and bed material data and the emergence rates from natural and simulated redd counts. This analysis and result relies upon the successful emergence trapping rates from natural and simulated redds as in the proposed USFWS' Fall 2013 Egg Survival and Emergence Study (see 2014 MAP).

(2) Egg survival-to-emergence ratios calculated from the fall 2013 natural and simulated redds will be derived from the highly significant relationships with gravel permeability from the indices of Tagart (1976) and McCuddin (1977).

(3) Egg survival-to-emergence ratios calculated from the fall 2013 natural and simulated redds will be derived from the highly significant relationships with apparent velocity as identified by Stillwater (2007) in an artificial redd study on the nearby Tuolumne River, Central California.
   - Intragravel flow is influenced by the magnitude of the downwelling VHG if gravel permeability is held constant. In contrast, a changing gravel permeability (i.e. from accumulation of fine sediment) will affect apparent velocity if VHG is held constant as generally observed on the San Joaquin River due to long regulated release flow bench periods.

(4) Egg survival-to-emergence ratios calculated from fall 2013 natural redds will be derived from the highly significant relationships with natural redd bed material gradation data from the index of Tappel and Bjornn (1983).

(5) Adjacent natural redds, if any, that are not capped and not excavated post-emergence, will allow for the measurement of gravel permeability, intragravel flow, and bed material collection. In addition to applying these data to published survival-to-emergence indices, these data and their close location from trapped redd emergence counts will further permit refining survival-to-emergence relationships specific to the San Joaquin River. This is built on the assumption that emergence rates will not significantly change within a small distance.

(6) Develop incubation habitat quality parameter maps from gravel permeability, intragravel flow, and bed material data for use in providing quantitative measures in the layered HSI approach to quantifying existing spawning habitat.
   - These first-order data layers are critical to SJRRP's immediate need of quantifying potential spawning habitat (see SJRRP – Spawning & Incubation Group's Process Document, in press).

Deliverables

Deliverables for this effort will consist of a preliminary Technical Memorandum (TM) and final TM as well as ATR updates documenting methods utilized to complete the aforementioned tasks. In addition, a geodatabase compiling GIS layers (vector and raster) of raw and interpolated distributions for each incubation habitat quality parameter will be provided for quantitative measures in the layered habitat suitability index (HSI) approach to quantifying existing spawning habitat. These layers include, but are not limited to the: (1) gravel permeability, (2) vertical apparent velocity,(3) vertical conductivity, (4) vertical/horizontal hydraulic conductivity anisotropy ratios, (5) redd bed material data of redds, and (6) survival-to-emergence derived from incubation quality parameters.

Schedule

Implementation of field work will begin mid to late September 2013 and end in winter 2014. Initial scope of data analysis will begin in late fall to early winter 2013 and will be completed in spring 2014. A draft TM and GIS geodatabase will be provided for comments in May 2014, with final deliverables completed no later than June 30, 2014.

Budget

GRAND TOTAL = $37,856.

(1) Equipment – EXISTING (expected cost = **$0.00**)
  a. McBain Modified Electric Vacuum Pump (CA DWR)
  b. Slide Hammer (USBR)
  c. GPS/Compass (USBR)
  d. 14’ Aluminum Jon Boat/Trailer/Oars/PFD (USBR/SJRRP/TSC)
  e. Vehicle w/ tow-hitch (USBR)
  f. Temporary standpipe piezometers for deploying continuous sensors (USBR/CA DWR)
  g. Pressure/Temperature sensors for measuring intragravel flow (USBR)
  h. Helley-Smith hand-held bedload sampler (CA DWR)
  i. Course and fine material sieves for bed material sample processing (CA DWR)
  j. Water level meter (USBR/CA DWR)

(2) Equipment – NEW (expected cost = **$280.00**)
  a. Modified Terhune Standpipe
  b. Helley-Smith hand-held bedload sampler baseplate.

(3) Staff Time –TSC daily rate ($488) (expected cost = **$37,576.00**)
  a. USBR/SJRRP lead staff (≤ 55 days x $488/day = $26,840)
    i. Gravel permeability (≤ 11 days)
    ii. Intragravel flow (≤ 6 days)
    iii. Bed material sampling (≤ 11 days)
    iv. Bed material processing (≤ 7 days)
    v. Data processing & Analysis/Deliverables (≤ 20 days)
  b. Staff Assistant (USBR/CA DWR/CA DFW) (≤ 22 days x $488/day = $10,736)
    i. Gravel permeability (≤ 11 days)
    ii. Bed material sampling (≤ 11 days)

(4) Travel/Hotel/Meals & Incidentals (expected cost = **$0.00**)

Point of Contact/Agency & Responsibilities

(1) Andy J. Shriver (USBR / SJRRP): Principal Investigator, Project Planning, Field Deployment, Data Collection, Data Processing & Analysis, and Reporting. (ashriver@usbr.gov)

(2) Erica Meyers (CA DFW): Co-PI, Assisting in the implementation of study.

(3) Matthew Meyers, P.G. (CA DWR): Co-PI, Assisting in the implementation of study.

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