San Joaquin River Restoration: Floodplain Production Study Statement of Work
Draft design plan and methods for 2014 season. Proposed by the California State University Fresno and Cramer Fish Sciences Team (31 December 2013).

Background

The Stipulation of Settlement in *NRDC, et al. v. Kirk Rodgers, et al.* (Settlement) established a Restoration Goal 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." To achieve the Restoration Goal the Settlement calls for channel and structural improvements in Paragraph 9, and releases of water from Friant Dam in Paragraph 13. The Floodplain Production Study developed based on the following Settlement and San Joaquin River Restoration Settlement Act provisions:

- *Design and construct channel and structural improvements as described in paragraph 11 of the Settlement… [Section 10004(a)(1)]*
- *Modifications in channel capacity (incorporating new floodplain and related riparian habitat) to ensure conveyance of at least 4,500 cfs in Reach 2B between the Chowchilla Bifurcation Structure and the new Mendota Pool bypass. [Paragraph 11(a)(2)]*
- *Modifications in San Joaquin River channel capacity (incorporating new floodplain and related riparian habitat) to ensure conveyance of at least 4,500 cfs through Reach 4B, unless the Secretary, in consultation with the Restoration Administrator and with the concurrence of the National Marine Fisheries Service (the "NMFS) and the Fish and Wildlife Service (the "FWS") determines that such modifications would not substantially enhance achievement of the Restoration Goal. [Paragraph 11(b)(1)]*
- *Likely additional channel or structural improvements (including, for example, additional fish screening, restoration of side channel habitat and augmentation of spawning gravel) that may further enhance the success of achieving the Restoration Goal. The Restoration Administrator shall identify and recommend to the Secretary such additional improvements and potential measures. [Paragraph 12]*
- *Modify Friant Dam operations so as to provide Restoration Flows and Interim Flows. [10004(a)(2)]*

The SJRRP Program Environmental Impact Statement/ Report and Record of Decision (ROD) for the release of water from Friant Dam provides Alternative C1 as the Preferred Alternative. The Alternative C1 project description included in the ROD identifies Common Restoration actions that are potential physical actions common to all action alternatives in order to achieve the Restoration Goal. The ROD states:

- *Site-specific studies and subsequent implementation of future potential Restoration actions under Paragraph 12 of the Settlement would be based on information collected through monitoring, as identified in the Physical Monitoring and Management Plan (Appendix D of the Draft PEIS/R) during implementation of Settlement-stipulated actions. (Attachment A, p.26)*
- *Create and/or enhance additional floodplain habitat outside of Reaches 2B and 4B1 to accommodate variable life history strategies of future salmon populations, which may vary spatially and temporally.*

The SJRRP Framework for Implementation (Framework, June 2012) identified Floodplain Improvements (Grading and Vegetation) as a Secondary Channel and Structural Improvement Action. The Implementing Agencies identified Secondary Actions in the Framework because they may improve the effectiveness of Core Channel and Structural Improvement Actions and Fish Reintroduction. Much of the historic Central Valley floodplain of the Sacramento San Joaquin River System was decoupled or converted long before monitoring was instigated and significant study must be undertaken to identify how and where investments in Floodplain Improvements would contribute to Program success. These studies should build on the most current and relevant information known about floodplains and floodplain function to support implementation of the SJRRP.

For floodplains to provide a productive rearing environment, flow pulse timing must coincide with appropriate physiological drivers (e.g., temperatures, primary productivity) and fish life stages (Junk et al. 1989; Bayley 1991). If flows are decoupled from fish life cycles and physiological drivers, the advantage of floodplain inundation is largely lost (King et al. 2003). Juvenile Central Valley fall-run Chinook salmon rear from approximately January until the smolt physiological transformation occurs (late-June). For spring-run, this may shift approximately 1-2 months earlier with a small percentage (estimated 10%) remaining in the upper reaches and migrating as yearlings the following year. Historically, these life stages coincided with storm and snowmelt-driven flood pulses, which inundated thousands of Central Valley floodplain acres. The timing and magnitude of flood occurrences depended on precipitation events, weather patterns, and time of year (Gasith and Resh 1999). Below we describe three core floodplain variables that will influence the value of these habitats for juvenile Chinook salmon. It is important to note that in recent years, anthropogenic stressors such as alien predator introduction and chemical pollutants may also have significant implications for floodplain function. However, the key goal of this initial undertaking is the assessment of bioenergetics as they relate to the early life stages of juvenile Chinook salmon production.

(1) Early –late floodplain inundation

Flood pulses early in the rearing period may provide opportunities for the greatest number of rearing juveniles; however, temperatures may be too low to provide a direct growth advantage (Figure 1). Temperatures later in this period may be better for growth; however, once juveniles smolt, behaviors change from rearing to active emigration toward the ocean and floodplain inundation during this period may be of less utility. Furthermore, temperature within the lower San Joaquin River may be a limiting factor by mid-April in some years, compressing the rearing period for what is acknowledged in typical Central Valley streams. Thus, it is essential to quantify tradeoffs in floodplain inundation timing throughout the rearing period as they relate to floodplain productivity and physiological responses of juvenile salmon (Figure 1).

(2) High-low productivity

The location of seasonal floodplain habitat along the river continuum will also have significant implications for when and how such environments benefit rearing salmon.

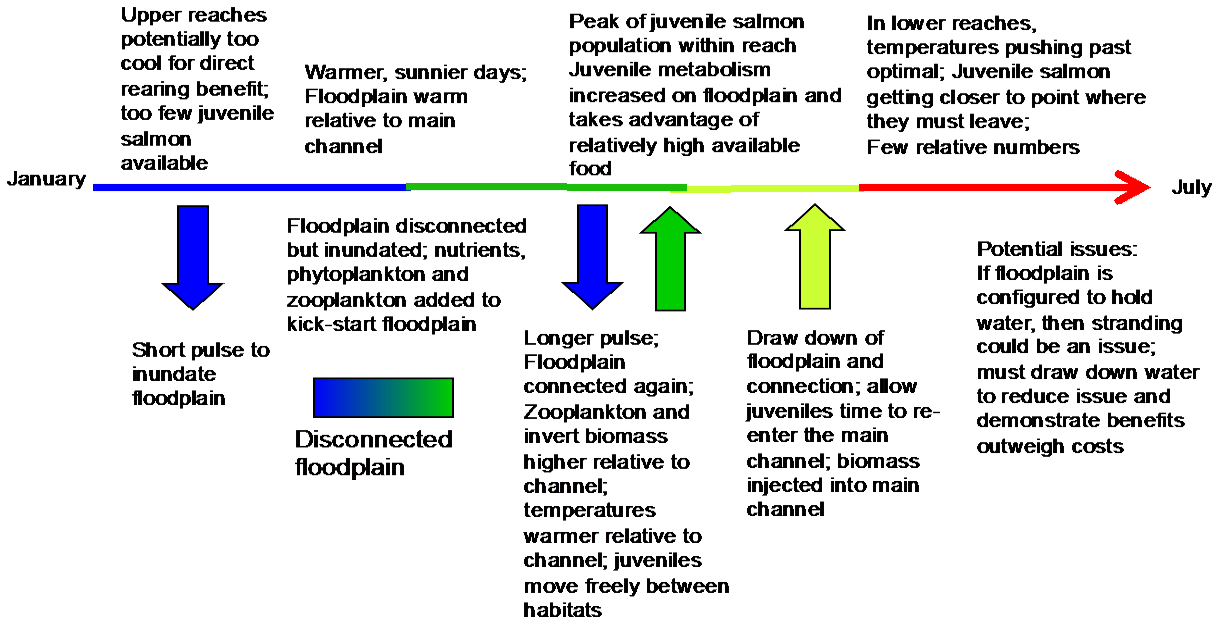

Figure 1. Conceptual direct and indirect benefits of floodplain inundation to juvenile salmon related to season and river reach. Concepts from Sommers et al. (2001), Moyle et al (2003; 2004), and Ahearn et al. (2006).

Typically, locations within the upper river reaches are characterized by relatively high velocity and energy, with short water residence time, low turbidity and temperature, and are often supported by terrestrial (allochthonous) production and aquatic insects (Figure 2). Whereas, lower gradient reaches support lower velocity habitats, and thus demonstrate greater water residence times and temperatures, relatively high turbidity and are primarily supported by autochthonous productivity and planktonic prey items (zooplankton). Upon project completion, the SJRRP below Friant Dam will be the southern-most Chinook salmon population in the Northern Hemisphere, suggesting these hypotheses must be vetted within the restoration project footprint. Therefore, it is essential to quantify floodplain productivity, sources of organic matter, and physiological responses of juvenile salmon as floodplain inundation transitions from high to low-gradient reaches.

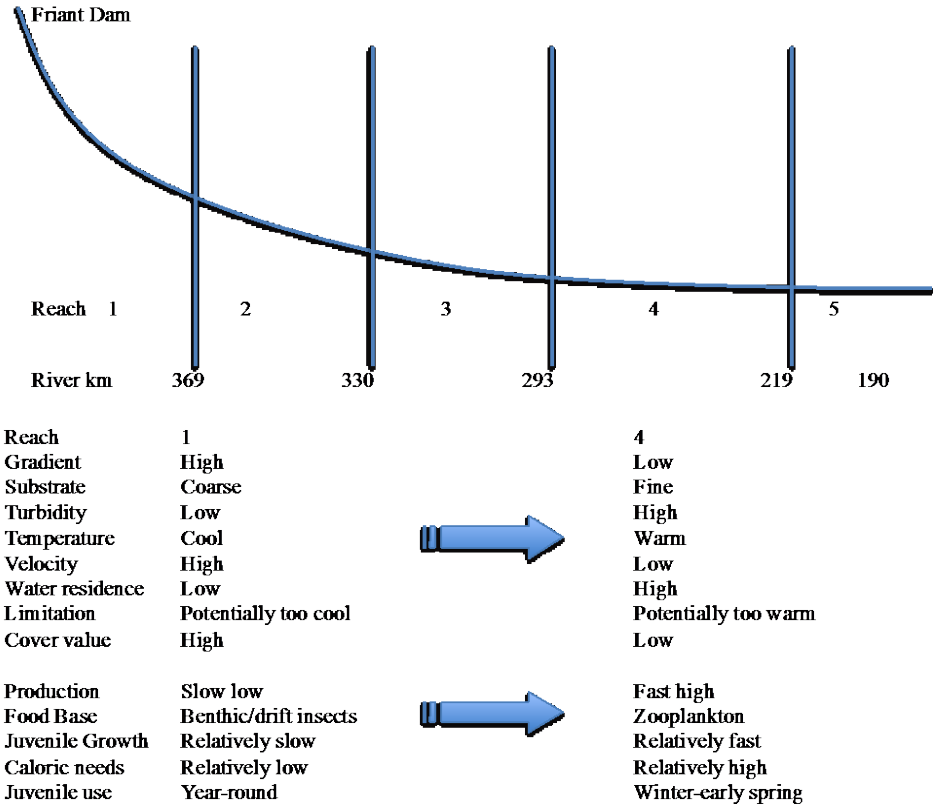

Figure 2. Hypothesized relative responses of physical and biological parameters along the river continuum.

(3) Simple-Complex Cover

Cover is a ubiquitous term used to define physical structure within the river channel, including substrate pore spaces, boulders, snags, over-hanging vegetation, root wads, under-cut banks, young trees, grasses and gravel interstices that may be used by salmonids to optimize growth and/or survival. Specifically, cover may create flow breaks that allow juveniles to remain in relatively high velocity areas to take advantage of drifting prey or compensate for reduced swimming performance when temperatures are low. Cover may also offer visual buffers that reduce predation risk, temperature stress (shade or freezing) or conflict among competitors. Therefore, cover is critical for protection from predation, flow displacement, temperature stress, and the optimization of caloric needs essential to future survival and health. However, as gradient and mean pose spaces within the substrate decrease and turbidity increases along the stream continuum, cover availability and its effect of cover on the physical responses of juvenile salmon may shift or change. Furthermore, as juveniles transition to the smolt stage, they tend to abandon feeding territories, taking on a more schooling and pelagic strategy, potentially altering the way in which cover benefits rearing salmon. Thus, it is essential to quantify and qualify cover and physiological responses of juvenile salmon to cover as they transition from high to low-gradient stream reaches (Figure 2).

To support the understanding of these key issues as they relate to the goal of restoring Chinook salmon populations to the lower San Joaquin River, the Floodplain Evaluation

Team, lead by California State University Fresno and Cramer Fish Sciences, will undertake three Tasks during the 2014 rearing period. **These tasks will provide a benchmark for floodplain design and construction under 2014 flow schedules and help inform subsequent study years that will support the overall goals of the San Joaquin River Restoration Program**. Each task will be designed to provide: (a) **descriptive information** about form and function of seasonal rearing habitat specifically associated within the San Joaquin River Restoration Program footprint and (b) **test key hypotheses** or assumptions about how these habitats may function along the river's gradient. The three tasks will evaluate (1) **Physical** (2) **Food Web** and (3) **Juvenile Salmon Response** to floodplain inundation along the San Joaquin River corridor. The information acquired from these tasks will provide an understanding of how bioenergetic-based variables differ among locations progressively through the course of the rearing period. The tasks will also advance the understanding of Chinook salmon responses to habitat changes as they evolve with flow restoration.

Task 1: Compare and contrast off-channel (floodplain) **physical properties** throughout the expected Chinook salmon rearing period along the river corridor.

Task 2: Describe development of off-channel **food webs** throughout the expected rearing period and variable complexity along the river corridor.

Task 3: Compare and contrast juvenile **Chinook salmon growth, behavior and survival** throughout the expected rearing period and habitat complexity along the river corridor.

GENERAL METHODS

The San Joaquin Restoration Program has designated five Reaches of the lower San Joaquin River (Figure 1). The tasks will be implemented at ~ three study sites located within reaches 1- 4 of the Restoration Area and monitored over the ~February to June rearing period. This geographic region and time period are meant to encompass the range of physical and biological variance expected along the stream continuum and over seasonal variability of flow, weather and solar inputs along the lower San Joaquin River. Within each site, a series of net pens will be installed to contain juvenile Chinook salmon of size ranges expected to use seasonal habitats. In conjunction with the net pen experiments, physical and biological responses to inundation will be monitored over the rearing period. It is important to note that the 2014 study period may only provide for a short-duration flood pulse within the ~5-month study window. Even so, this will provide a baseline for all of us to learn from and develop future hypotheses in upcoming study periods.

Study Sites

We will work with the BOR, USFWS, and CDFW to identify 2-4 potential sites among 2-3 reaches, focusing on Reaches 1 and 4 and excluding Reach 5. In particular, we will utilize GIS data layers to identify key parameters needed to successfully test our hypotheses (see below). These parameters include, but are not limited to: willing landowner participation, site accessibility, floodplain inundation during scheduled flows under the Agreement, areas large enough to maintain net pens and support biological succession and microhabitat diversity (at least 10,000 ft^2), substrates that will maintain surface water for weeks to

months after inundation, sites that have a reduced opportunity for vandalism or other disturbance, and sites that may facilitate manipulation or containment of flow. Once 10-15 candidate sites are identified, we will undertake field reconnaissance to choose 2-4 sites with the greatest potential to support task completion. We will also seek collaboration with other studies carried out within the watershed to enhance our understanding of San Joaquin River ecology and system management and improve cost efficiency (e.g. SJRRP Study 31: Riparian Microclimate Study). Landowner agreement would be obtained before our team would access any site (e.g., Coordinated by Craig Moyle, SJRRP).

Habitat Inundation

The selected sites will be those that are expected to inundate under the available flow regime and rearing period to facilitate the study, including replication and/or patterns for testing hypotheses. To improve our overall chances of success, we will work with our collaborators to develop a range of actions that would allow for artificial creation of "test floodplains". Such actions may include, but are not limited to: (1) identifying depressions on adjacent floodplains large enough to hold water and inundating them with portable pumps (2) Hand-grubbing soils on natural or artificial levees or berms, allowing water access to acceptable low areas (3) the use of inflatable or temporary coffer dams to control water movement on to and off acceptable floodplain shelves or (4) The use of earthmoving equipment to create acceptable test habitat. Several of these actions might require state and/or federal permits. Working with the Reach 4B wildlife refuge, lands already impacted by levee seepage in Reaches 2-3 and pre-existing channels near the Reach 1 hatchery facility are location examples that might facilitate this work with relatively little manipulation.

Data analyses and hypothesis testing

Several generalized hypotheses are included for each task outlined below. The inclusion and replicability of independent variables will be contingent on site selection and hydrology. Therefore, specific hypotheses and models will be developed as the environmental conditions of the first study year become apparent. The current plan is to explore sources of variation and pattern in the data using suitable methods such as ordination and regression trees. These exploratory methods will allow for the treatment of issues such as collinearity and autocorrelation that will greatly improve our ability to construct a viable set of models that can be evaluated with model comparison approaches.

The tasks include variables that are not necessarily independent (e.g. water depth & velocity) or univariate. In these cases, we will apply multivariate analyses such as constrained ordination ('response' variables with 'environmental' variables) and Mantel tests, which would apply to how food web structure varies with environmental variables for example.

Task 1: Floodplain habitat attributes -Morphological, physical, and structural complexity

Flow management has disrupted the relationship between the natural flow regime and juvenile salmonid habitat requirements (Nislow and Armstrong 2012). Numerous studies

illustrate off-channel habitats (i.e., floodplains and side channels) as productive foraging areas for rearing compared to main river channels, as they tend to support more optimal conditions for growth and survival (Grosholz and Gallo 2006; Jeffres et al. 2008; Bellmore et al. 2013). Off-channel habitat inundated at appropriate times of year promote conditions that may enhance juvenile salmonid growth and survival if water temperatures, prey biomass, and velocities are more favorable compared to main channel habitats during the rearing period (Kjelson et al. 1981; Swales et al. 1986; Ahearn et al. 2006). As a result, reconnecting off-channel habitat under lower flow conditions may be an effective juvenile salmonid habitat enhancement method because it can restore natural ecological processes, enhance productivity, and optimize several physical habitat parameters (e.g., depth, velocity, substrate, vegetative cover) (Merz et al. 2006; Gorski et al. 2011; Sellheim et al., in Press).

Rearing habitat must meet specific physical parameters to support and maintain juvenile Chinook salmon. Depth, velocity, temperature, dissolved oxygen, substrate and cover are all examples of key physical parameters shown to influence growth, health, and survival of juvenile salmon. The purpose of Task 1 is to compare and contrast off-channel (floodplain) and main channel physical properties over time along the river corridor. To do this, we will collect a suite of physical measurements, including the development of 2D flow models at each of the sites, to compare habitat as it develops on floodplains to the adjacent main channel.

Morphology

Topographic Channel bathymetry

We will use a combination of light and radar (LiDAR) remote sensing data from the BOR and bathymetric surveys collected by our team. A Trimble R8 RTK GPS system along with a Leica robotic total station will be used to record an estimated 800-1500 bed points at each project site. LiDAR data will be merged with points to generate a TIN surface with a vertical accuracy of 0.05 - 0.5 meters. Average point densities across the site will range between 0.5 - 2.0 m depending on topographic complexity.

Hydrodynamic model development

A two-dimensional depth averaged model of river hydrodynamics will be developed at the study sites following the methods described in Steffler and Blackburn (2002). This will allow us to estimate the percent of channel meeting juvenile salmon rearing habitat requirements and model depths and velocities at each site over a range of flows. Furthermore, the two-dimensional models will help inform us of water residence time on floodplains and main channel sites along the stream corridor and over a range of flows.

Consolidated topographic data sets will be inputs to the bed file creation and substrate attributes collected via pebble counts (see below) will be converted to roughness values as described by Gard (2006). We will use water surface elevations and flow transects (see below) to calibrate the model and river hydrodynamics will be simulated for a range of inundation under hypothesized restoration flow conditions. For the analysis, we will select three flow levels (i.e., low, moderate, and high relative to mean depths and velocities) to

evaluate changes in juvenile rearing habitat conditions within the main channel and floodplains from February through June.

Physical

Substrate characterization

Surface Samples

Pebble counts will be collected at 4 – 5 randomly selected transects (~100 samples per transect) at each site using methods similar to those of Bauer and Burton (1993). Surveyors will collect substrate samples by hand every 1 ft (~0.3 m) along transects and use a template to measure substrate size (Figure 3). Substrate from pebble counts will be categorized into 12 sizes: <8.0 mm, 8.0 mm, 16.0 mm, 22.2 mm, 31.8 mm, 44.5 mm, 63.5 mm, 89.0 mm, 127.0 mm, 177.8 mm, 254.0 mm, and >254.0 mm, based on the largest slot (round hole with specified diameter) through which an individual pebble could not be passed (Merz et al. 2006). Transect measurements will also include percent cover (e.g. as vegetation, logs, etc.).

Figure 3. Surface pebble counts.

Fine Sediment

At each site, 3 – 4 subsurface (core) samples will be collected using a McNeil core sampler (Figure 4; St-Hilaire et al. 1997). In the field, substrates will be sieved through screens of the following sizes: 9.5 mm; 12.7 mm; 16.0 mm; 22.2 mm; 31.8 mm; 44.5 mm; 63.5 mm; 88.9 mm; 127.0 mm; 177.8 mm; and, 254.0 mm. Each size-class will be weighed and data recorded. Material smaller than 9.5 mm and residual water will be retained, and transported to the lab for further analysis. Transported material will be sorted into further size classes, dried at 70°C for 24 h, weighed and data recorded.

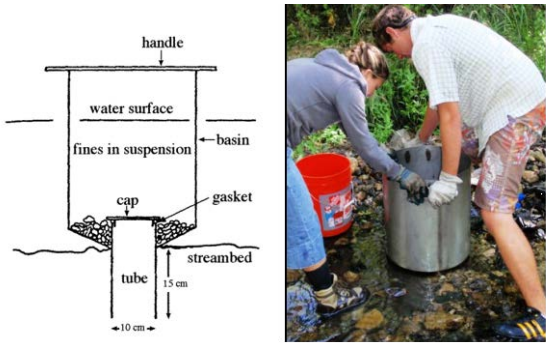

Figure 4. Core samples.

Hydrology

River Discharge and Flooding Inundation

We will use discharge data from USGS and DWR gauges in conjunction with stage data from pressure transducers placed in the channel and floodplain of each study site to determine flooding inundation in terms of flow duration and magnitude.

Flooding Inundation (i.e., Duration and Magnitude) – a series of continually recording in-channel and floodplain pressure transducers (e.g., Onset Computer Corporation; HOBO® 30-Foot Depth Data Logger) will be deployed to determine magnitude and duration of inundation. Loggers will be downloaded monthly and data summarized to evaluate

flooding inundation. Locations of all pressure transducers will be recorded with sub-meter accuracy GPS.

Pressure transducers will be installed and topographically tied into 3-4 surveyed and monitored cross-sections amongst the study sites. Installation of pressure transducers will be according to the manufacturer's specifications and downloads will occur periodically (monthly), or as necessary.

Water Velocity/Depth
Depth and water velocity will be measured at each sampling location at regular intervals and over variable flows to calibrate hydro models. A Marsh-McBirney flowmeter (Flo-Mate Model 2000; Hatch Company) will be used for taking water velocity measurements at each site. The unit uses an electromagnetic sensor to measure the velocity in a conductive liquid such as water. The velocity is in one direction and displayed on a digital display as feet per second (ft/s) or meters per second (m/s). The device measures water velocity using Fixed Point Averaging (FPA), which is defined as: average velocity measured over a fixed period of time (CFS uses a 30 second interval). At each site the depth of the velocity measurement varies depending on water depth. For depths less than 2.0 ft (0.6 m), water velocity is taken at 60% of depth (measured from water's surface). For depths greater than 2.0 ft (0.6 m), water velocity is taken at 20% and 60% of depth and averaged. For each site, total water depth and average velocity will be recorded.

Flow Transects
Specific sites will be selected to perform flow transect measurements to determine localized river discharge and floodplain flow-through. A rope or cable will be secured to the opposing banks perpendicular to the flow approximately 1-2 ft (0.3-0.6 m) above the water surface. The rope or cable will be pulled taught using a come-along or similar mechanical device. A measuring tape will be attached to the rope or cable using large binder clips at regular intervals (Figure 3). If the channels are too deep to wade, a small boat will be used. Water velocity is measured at 0.5-m stations across the entire channel using a flow meter.

Discharge (Q) is then calculated using the following formula:
$Q = \sum (V*D*W \text{ at each station})$
where, V= average velocity, D=depth, W=width of station

Water quality
Temperature- To measure water temperature in floodplain and main channel habitats, we will install Hobo® Pendant and Water Level loggers to monitor temperature continuously through time. We will also take point measurements of temperature, dissolved oxygen (DO), and turbidity each time we visited each site. We would also access databases that collect continuous measurement of DO and turbidity to strengthen our analyses (e.g. http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=FWQ).

Dissolved Oxygen- During seasonal field trips, dissolved oxygen data will be collected from each sampling location monthly using an YSI Handheld Dissolved Oxygen (DO) Instrument

(YSI; Model 550A). These spot measures are designed to determine if minimum criteria for water quality are met, and to meet effectiveness of monitoring objectives by determining if performance criteria for DO are met. If equipment is available, we will also deploy DO loggers to track continuous measurements over the study period.

Turbidity- During seasonal field trips, instantaneous turbidity will be measured in Nephelometric Turbidity Units (NTU) using a turbidity meter (LaMott Company; Model 2020). These spot measures are also designed to determine if minimum water quality criteria are met, and to meet effectiveness monitoring program guidelines. We will also install an automated water sampler to collect hourly turbidity measurements at the sites.

Key Hypotheses Tested in Task 1

H_1: Physical parameters, including depth, velocity and water quality (e.g., turbidity, temperature, dissolved oxygen) differ between main and off-channel habitats of the San Joaquin River.

H_2: Off channel physical parameters, including depth, velocity, substrate and water quality differ along the stream corridor.

H_3: Off channel physical parameters, including depth, velocity, substrate and water quality change over the rearing period.

How will Task 1 inform SJRRP management? – The timing and duration of floodplain inundation will likely require some alteration to SJRRP flow management. SJRRP water releases serve multiple purposes and impact many stakeholders. A major objective of this study is to maximize the efficacy of water releases stipulated in the Settlement Agreement to maximize juvenile Chinook salmon survival and growth by providing high-quality floodplain habitat and provide strong scientific information to support adaptive management. Physical data collected during this preliminary study will provide comparative descriptions of key environmental parameters such as water temperature, dissolved oxygen and turbidity on the floodplain and main channel and how these parameters change over the rearing period and along the stream corridor.

Task 2: Floodplain Food Webs

Background

The organic matter sources and storages in floodplains are likely to differ based on variables such as existing terrestrial vegetation, substrate composition, inundation depth, water velocity and clarity and flooding duration. Organic matter retention, production, and consumption in floodplains are also likely to be affected by connectivity with the main river channel. This task aims to inventory floodplain organic matter sources, consumers, and their trophic connections to juvenile Chinook salmon. Sampling and analyses will be conducted to best determine whether food web constituents are ‘autochthonous’ versus ‘allochthonous’. Autochthonous organic matter is produced within the activated floodplain, such as periphyton and seston. Allochthonous organic matter will be considered as material that is imported to the floodplain from the adjacent riparian/terrestrial habitat and the river main channel while hydrologically connected.

Efficient floodplain management and juvenile Chinook salmon production may be intricately linked through food web structure and fish energy budgets. Prior research demonstrates that juvenile salmonids can survive and grow better in floodplains compared to river main channels (Jeffres 2008, Bellmore et al. 2013). However, much less is known about the factors, which link floodplain hydrology and physical factors with juvenile salmonid production. Food web composition and trophic efficiencies are the factors linking floodplain attributes (Task 1) with juvenile salmon production (Task 3). Complex floodplain habitat (e.g. cover/vegetation) and inundation duration in concert with higher water temperatures can also foster increased prey abundance and production. These core variables act directly on the energy balance of fish.

Warmer floodplain temperatures (up to a point) relative to the river main channel allow more efficient fish metabolism, and reduced water currents alleviate the energy needed to maintain position or navigate compared to main channel flows. In this project we therefore advocate a bioenergetics-based approach to estimate the influence of these core floodplain variables on juvenile Chinook salmon survival and growth.

The primary objectives of this task (and links with Tasks 1 & 3) include measuring abundances of food web components, their rates of gain or loss (production), and determining pathways to juvenile Chinook salmon production. Specifically, data collected here (physical conditions, invertebrates/productivity, and fish growth), along with information collected in subsequent studies, will be used to populate a future bioenergetics model for the different habitat types. This will allow us to use field data to explore how growth could be modified in different areas via habitat manipulations such as temperature modification, or lowering juvenile Chinook activity through re-vegetation, etc.

Methods

We plan to collect organic matter samples and invertebrates every other week during floodplain inundation. This periodicity is a balance between detecting meaningful rates of change and the logistics of field collection and laboratory processing.

Organic matter **(FBOM, Seston, Periphyton)**

Fine particulate organic matter (FPOM) includes particles in the size range of 0.45µm (the pore size of a GF-F filter) to 1.0 mm. FPOM fractions can be distinguished by whether they are suspended in the water column as seston or deposited as FBOM (benthic). Periphyton is the attached, generally living organic material such as algae, bacteria, fungi, and microzoans on stream substrates.

These three forms of organic material comprise the majority of biomass at the base of river and stream food webs. Terrestrial (allochthonous) organic material may be introduced to low-order streams with dense riparian canopies. However, this source of organic material is integrated into lotic food webs upon breakdown to FPOM or through update mineralized N and/or P by autochthonous producers in the system. We focus on sampling protocols for FBOM, seston, and periphyton since terrestrial organic material is ultimately (if at all) incorporated into the organic matter biomass sampled by standard methods. For the methods described below, one field duplicate will be taken per sample event on each floodplain to assess the precision of field collection methods.

FBOM

Deposited fine organic matter will be sampled using a bottomless five-gallon bucket. To account for random and systematic (i.e. due to depth or velocity history) variation in FBOM, sampling will be done along three transects across the floodplain. Transects will be perpendicular with the longest axis of the floodplain, and will taken near the head, mid-point, and tail of each floodplain. Within each transect samples will be taken at points representing 25%, 50%, and 75% of the wetted width.

The bucket is placed down in the riffle substrate, large cobbles > 100mm are removed, and the water depth inside the bucket is recorded. Next, the fine sediment is suspended inside the cylinder for approximately one minute by digging and spinning the top five centimeters of substrate. Immediately after suspension of the fine sediment, a 500 ml grab sample is taken in a pre-labeled Whirl-Pak bag. In the lab, 100 ml of the samples is re-suspended and filtered through a 1mm sieve. The solution passing the sieve is filtered onto pre-ashed Whatman GF/F glass fiber filters (pore size = 0.7 µm), dried at 70°C for at least 24 hours, cooled in a desiccator and weighed to the nearest 0.1 mg. The samples are then placed in a muffle furnace at 500°C for at least one hour, cooled, rewetted, dried at70°C for at least 24 hours, and reweighed in order to determine % organic matter from loss of mass by ignition. The amount (mg/cm^2) of fine sediment (organic & inorganic) is calculated using the area enclosed by the bucket (531 cm^2), the water depth inside the bucket, the filtered volume (100 ml), and the dry weight of the filters.

Seston

The method and equipment for seston collection will depend on water velocity (+/0) and depth. A plankton net (86µm mesh) equipped with a flow meter will be used for floodplain habitats with deeper flowing water,. At least three samples will be taken from each floodplain per sample event to reflect variation in floodplain variation in velocity and depth. 20L grab samples will be used to collect seston in situations where floodplain water is not flowing and too shallow to use a plankton net. Grab samples will be filtered through the plankton net.

Once the water sample is collected the net will be washed down with tap water from Nalgene squirt bottles and the resulting concentrated sample (several 100ml) will be kept in a pre-labeled Whirl-Pak bag. In the laboratory, the sample will be split into two aliquots with a plankton splitter. One aliquot will be examined for micro- and macroinvertebrates (including zooplankton) with a stereo dissecting microscope. Invertebrates will be identified using keys in Thorp and Covich (2009) and measured using an ocular micrometer. Invertebrate lengths will be converted to dry weights using equations in Watkins et al. (2011) and converted to mg/L for each taxa. The density (mg/L) of non-animal detritus and phytoplankton will be processed using the filtration and drying methods described above for FBOM. Seston primary production and respiration will be estimated using clear and dark BOD bottles at representative habitat conditions including depth, temperature, and light.

Periphyton

Periphyton is the organic matter attached to lotic substrates as opposed to FBOM, which is merely deposited material, and it is used by specific functional feeding groups of consumers such as scrapers. The quality of either periphyton or FBOM for lotic consumers can be roughly

discriminated by how much of the fraction is organic. For periphyton, the 'autotrophic index' (AI) is a measure of the quality as a food resource, which is simply the ratio of total biomass to chlorophyll *a*. A low AI would indicate a healthy and actively growing organic matter source (living algae) as opposed to a sample dominated by potentially recalcitrant detritus.

As with seston, the periphyton sampling method is dependent upon features of the habitat. For floodplains with fine substrates (such as sand or pebble), periphyton is indistinguishable from FBOM, since these small substrates are easily disturbed and do not offer a quality substrate for attached algae. In these cases, another 500ml grab sample will be taken using the open bucket method for FBOM. In cobble-dominated floodplains, at least three individual cobbles will be randomly selected at each transect. Cobbles will be placed in plastic pans with water and scrubbed with a hard-bristled toothbrush to remove periphyton. The resulting slurry will be stored in a pre-labeled Whirl-Pak bag and kept dark and cool. The area of the cobble exposed to light will be determined using a common estimation method in which aluminum foil is covered over the area and trimmed with scissors. The resulting piece of foil is weighted and converted to area using a predetermined mass/area relationship.

Periphyton may also be estimated by measuring its accumulation on artificial substrates such as clay tiles. This method is particularly informative when lotic substrates are comprised of very fine particles. In these settings, periphyton production and accumulation may be limited by suitable (i.e. non-disturbed) substrate sizes, rather than other potentially limiting factors such as inorganic nutrients (N, P) or light. We will deploy fixed racks of 56cm^2 clay tiles for at least three weeks to test for periphyton accrual, which removes the influence of substrate composition. Tile racks will be arrayed to represent the range of water depths and light regimes in the floodplain. The clay tiles have been acid washed in a 2N H_2SO_4 solution for at least 48 hrs to remove potentially labile phosphate. Tiles will be placed in pre-labeled Whirl-Pak bags, and kept cool and dark until processing in the laboratory. Lab processing is similar to the field methods for periphyton collection from cobbles. The resulting slurry is processed for chlorophyll *a* as described below. However, half of the tile replicates will be used to determine periphyton biomass, such that the AI can be compared between artificial and natural substrates.

For all periphyton collection methods the samples will be processed in the laboratory for mg/cm^2 of chlorophyll *a* and phaeophytin using EPA Method 446.0, except that the pigments will be extracted with 95% EtOH at 80^oC which has a much greater extraction efficiency than 90% acetone (Wasmund et al. 2006). Periphyton primary production and respiration will be estimated using clear and dark enclosed chambers at representative habitat conditions including depth, temperature, and light.

Invertebrates

A recent bioassessment of the lower San Joaquin River as part of the SJRRP demonstrated relatively low diversity and quality of San Joaquin River invertebrates and their habitats (SJRRP 2012), largely due to limitations of homogenous, small sized river bed substrates. Floodplain invertebrate assemblages can be temporally and spatially dynamic, and can often support relatively higher levels of invertebrate diversity and abundance (Opperman 2012) due to habitat heterogeneity (Barnes et al. 2013) and variation in flood pulses (Ballinger et al. 2005, Robinson 2012). We expect that flooding duration and floodplain habitat heterogeneity will influence

whether SJR floodplain invertebrates merely reflect what is imported from the river main stem or develop unique assemblages as expected with longer inundation periods. Floodplain invertebrate assemblages will be compared across floodplains as well as between floodplains and the adjacent river main channels using ANOSIM and indirect gradient ordination procedures.

Invertebrates will be collected concurrently with organic matter. Invertebrates will be sampled with combinations of drift and plankton nets, and D-frame nets and/or modified Hess samplers for the benthos. D-frame nets are the most commonly used gear for lotic macroinvertebrates across U.S. state monitoring agencies (Carter and Resh 2001). However, we will ultimately use the gear appropriate to the conditions of depth, velocity, and substrate (Lenat 1988, Moulton et al. 2002, Hauer and Resh 2006, Merritt et al. 2008). All benthic collections and density data will be standardized to an areal basis (m^{-2}) and drift and plankton samples will be calculated per unit volume (e.g. Smock 2006). As with FPOM samples, three transects across each floodplain will be established to represent the upper, mid, and lower sections of the floodplain with respect to the orientation of the long axis of the floodplain. Samples will be taken at distances of 25%, 50%, and 75% of the wetted width with a 30.5 cm D-frame kicknet with 250 μm mesh. D-frame net capture methods will be through either current delivery or active sweeps of substrates. Both conditions will produce a $1ft^2$ sample area of the surface substrates.

The three transect samples then formed a composite sample with a total sample area of 0.3 m^2 per floodplain. Samples will be brought back to the laboratory, placed in 95% EtOH (to account for dilution from residual sample water), and subsequently sorted for organisms. Invertebrates will be identified to genus or lowest possible taxonomic level using Merritt and Cummins (1996). Chironomidae will be identified to the subfamily level, and non-insects to family or order. An ocular micrometer will be used to measure all body lengths to the nearest 0.1 mm. Macroinvertebrate biomass will be determined using length-mass regression equations from Benke et al. (1999). Oligochaete biomass will be separately determined using regression constants calculated from individuals representative of the size range of those collected. Total benthic macroinvertebrate biomass as well as distribution among taxa will be compared across sampling events and floodplains.

The import of river invertebrates to floodplains will be assessed with drift nets placed at water inputs to floodplains. Nets will be placed prior to dusk and collected after dawn, since most invertebrate drift occurs between these diel periods (Statzner and Mogel 1985). However, debris load and net function under specific conditions will determine set duration. Drift density (#/100 m^3 of water) will be determined as a function of net opening (18" x 12") and water velocity. Nets will be supported 2cm off the floodplain substrate to prevent capture of walking macroinvertebrates. Prior drift sampling in SJRRP Reach 1A and1B habitats found significant differences in invertebrate drift abundance and composition among riffle versus run habitats. Thus, the reach type and substrate composition of adjacent river main stem habitats will be incorporated into analyses.

Trophic efficiency between fish and invertebrate prey can be influenced by factors such as the distribution of prey sizes in addition to overall prey biomass and taxonomic composition for example. We will therefore analyze the size distribution of all invertebrate prey across sample

events and floodplains using normalized size spectra (Blumenshine et al. 2000) and the Pareto distribution (Moore 2011).

Invertebrate Secondary production (invertebrates)
Invertebrate production is the linchpin linking 'floodplain production' to juvenile salmon survival and growth through an overall food web analysis (sensu Benke and Huryn 2010). Secondary production by invertebrates will be estimated from data produced by invertebrate sample analyses and water temperature measurements. Identification of invertebrate taxa, body size, and temperature are sufficient variables to estimate production rates (Benke and Huryn 2006). Production rate estimates will be improved by using cohort-summation or size-frequency methods over multiple sample events. Samples from drift nets to quantify the import of drifting invertebrates will be calculated separately as allochthonous sources of floodplain production. Terrestrial insects that alight on floodplain surface waters may also be considered potential prey for fish, which will be quantified with pan traps. Terrestrial insects captured in drift nets will be distinguished from insects (e.g. immature forms) that are clearly representing autochthonous production.

Food Web Resolution
The methods above are primarily for the generation of biomass estimates and production, or the change in biomass over time. Resolving floodplain food webs will rely on several lines of evidence and data.

First, the known natural history of invertebrate taxa is quite informative of the types of organic material ingested by particular taxa. Invertebrate composition in the SJRRP study area is quite low and dominated by common taxa. Invertebrate functional feeding groups (FFG) are based on organic matter sources, and are thus ideal in identifying the organic matter source pool supporting the production of consumer taxa.

Second, Task 3 methods describe the deployment of video cameras in net pens that will be used to contain juvenile Chinook salmon in floodplains. The behavior data taken from video footage will help to determine if the fish are feeding on invertebrates vertically distributed as neuston, suspended/drifting, or benthic. With the exception of drifting invertebrates, the strata of salmon prey selection is indicative of food web sources and connections. While hatchery salmon may initially feed differently than natural salmon (Merz and Workman 2008), they begin to feed on prey items from the stream within 24 hours of release. We will also sacrifice some net pen salmon for a number of analyses including diet composition to confirm video evidence of feeding behavior.

Third, we will use stable isotope ratio analyses of carbon and nitrogen and a fish bioenergetics model to track the flow of energy and elements though the floodplain food webs. Resolving food webs from stable isotope signatures relies upon the ability to discriminate organic matter sources based on the ratios of ^{13}C:^{12}C and ^{15}N:^{14}N ($\delta^{13}C$ & $\delta^{15}N$ respectively). Recent sampling from SJRRP Reach 1A-B has shown us that periphyton, seston, FBOM, and CPOM have very distinct $\delta^{13}C$ and $\delta^{15}N$ signatures. Initially, floodplain organic matter may reflect the influence of C and N stable isotope ratios imported from the river as seston and inorganic C and N. Longer periods of floodplain inundation will likely

cause divergence in the stable isotope signatures of organic matter, as floodplain organic matter decomposes and liberates terrestrially-derived C and N, and as autochthonous periphyton and phytoplankton develop in the floodplains. Therefore, organic matter samples will be taken at early and late periods of floodplain inundation. Additional interim sampling may be included depending on resources and logistical constraints.

Juvenile Chinook Salmon

The position of juvenile Chinook salmon in floodplain food webs can be determined through diet analysis and/or stable isotope signatures of fast-turnover tissue such as blood plasma or fins (Heady and Moore 2012). Since juvenile salmon for net pen studies will be obtained from a local state hatchery, we will sacrifice a number of these fish to establish baseline C and N stable isotope signatures. Secondary samples will be taken after fish have resided in floodplains for at least 30 days or a doubling of biomass, whichever occurs first. Otherwise, diet and tissue samples will be taken from juvenile Chinook salmon used in cage experiments as described in Task 3. We will store otoliths from study fish to establish chemical signatures for different habitat types to be used to ID fish by rearing locations in future studies.

Juvenile Chinook salmon production

The measurements and estimates of floodplain habitat variables in this task and Task 1 will allow for calculations of the production potential of juvenile Chinook salmon. These calculations will be estimated from a combination of fish bioenergetics and habitat models. These estimates can be compared to actual juvenile Chinook salmon growth from those used in net-pen experiments described in Task 3. In future studies, data from free ranging fish will be used.

Key Hypotheses Tested in Task 2

H_1: What are the relationships and temporal dynamics of among floodplain food web biomass, production, and pathways and along the San Joaquin River corridor?

H_2: The floodplain food web, including key Chinook salmon prey species, is supported by allochtonous and autochthonous inputs.

H_3: Juvenile Chinook salmon in San Joaquin River floodplains preferentially feed on invertebrates vertically distributed as neuston, suspended/drifting, or on the benthos.

H_4: Pathways of energy and elements through floodplain food webs, including juvenile Chinook biomass, differ among sites and across times.

How will Task 2 inform SJRRP management?

A food web and bioenergetics approach aims to characterize the mechanistic links between floodplain management and juvenile Chinook salmon production. Management of floodplain hydrology and physical attributes will alter floodplain habitats leading to variation in organic matter and invertebrate consumer assemblages. It is likely that there will be an interaction such that alterations to the physical habitat (such as grading for depth variation and adding vegetation) will produce stronger effects over longer versus shorter inundation periods. Furthermore, floodplain production will develop differently along the channel gradient due to a variety of physical and biological differences. However, monitoring and experiments are needed to best quantify the variables accounting for increased secondary production and thus prey for juvenile salmon and how this changes along the river and through the juvenile salmon rearing period.

Information gathered hear will provide guidance to future channel restoration and flow management.

Task 3: Juvenile Salmon Biological Response to floodplain inundation

Modeling
The measurements and estimates of floodplain habitat variables in this and prior tasks will allow for calculations of the production potential of juvenile Chinook salmon. These calculations will be estimated from a combination of fish bioenergetics and habitat models such as inSTREAM (http://www.humboldt.edu/ecomodel/instream.htm) calibrated for juvenile Chinook salmon. These estimates can be compared to actual juvenile Chinook salmon growth from those used in net-pen experiments described below.

Common Garden Experiment
Through a series of otolith microstructure (see Limm and Marchetti 2009), and underwater video experiments (Sub-tasks 3.1-3.3), we will track responses such as behavior, feeding, and growth of juvenile Chinook salmon in floodplain habitats along the river gradient of the SJRRP. Up to two trials will be performed in the designated "early" through "late" periods (Figure 1) to identify trade-offs in growth, survival and habitat inundation timing as it relates to time of year and distance downstream from the dam.

To perform this task, CFS will set up net pens, and video equipment within the floodplain selected sites of the restoration study area. Results of this preliminary work will guide future experiments using PIT tags and receivers and other potential tracking devices. Crews will transport salmon, operate video cameras, and perform snorkel surveys to track fish behavior within each of the study sites. Study fish will be measured, weighed and otoliths removed at the end of each test trial to compare juvenile growth and development within floodplains throughout the study period.

Net Pens
Each Task will require the ability to contain a cohort of juvenile Chinook salmon (~32mm – 100mm) within the test floodplains while allowing water and prey to move freely through each site. It will be important for physical and biological succession to take place and for test fish to be exposed to this changing environment. Recent research on the Cosumnes River, Yolo Bypass, and lower American and Stanislaus rivers has provided a strong foundation for successful deployment of net pens and monitoring equipment to track juvenile Chinook response to off-channel habitat. Under mentorship of UC Davis and Cramer Fish Sciences, we will construct and deploy 4-8 net pens per study location (Figure 5). Pens will be constructed of 6-mm (1/4 inch) polypropylene aquaculture mesh (Memphis Net and Twine Co., Memphis, TN) affixed to metal t-posts and will measure ~ 122cm x 61 cm x 61 cm (L x W x H; 454 L). Nets will be affixed to the substrate using sandbags (The Sand Bag Store, Las Vegas, NV) that will ensure juvenile salmon will have free contact with the floodplain bed while not being able to escape the pen. This same pen design was used successfully to examine natural diet and growth rates of juvenile salmon on the Cosumnes and Yolo floodplains (Jeffres et al 2008; Jeffres and Katz Pers. Comm.) and long-term monitoring of mosquito fish mercury exposure on Yolo Bypass floodplains

(Ackerman and Eagles-Smith 2010). We will place net pens near the floodplain inlet, mid-floodplain and near the exit to expose juveniles to a range of water quality, flows and food productivity succession. The top of the net pens will be positioned about 15 cm above the water surface (see Ackerman and Eagles-Smith 2010) and larger sized nylon fish netting may be used to reduce predation potential while allowing solar exposure and terrestrial inputs. Open pens will allow for manipulation of habitat complexity throughout the study period to test the effects of cover complexity on juvenile response. Debris racks consisting of Protex® Safety/Barrier fence (NorPlex, Inc., Auburn, WA) will be deployed at the upstream side of net pens to reduce collapse potential during high debris loads. All enclosures will be equipped with temperature data loggers and if possible, DO loggers will be deployed with each net pen group.

Figure 5. Net pens from Yolo Bypass study. Photo from the Randal Benton.

Chinook salmon

Juvenile Chinook salmon will be acquired from one of several state hatcheries. Our first choice will be the San Joaquin River Fish Hatchery, follow by, in order of request, the Feather, Merced, Mokelumne, and Nimbus fish hatcheries. We will make a request for approximately 4000 Chinook (2000 fry acquired in February; 2000 parr acquired in April). This will allow us to replenish net pens if habitat inundation cannot be maintained for the entire study period or early fish must be replaced for late rearing (see below). Within each pen we will place ~30 juvenile Chinook salmon. Each floodplain will have 4-8 net pens; thus, we will introduce up to a total of 24 fish cages (720 total fish) into ~3 study sites. Our goal is to support a density of approximately 0.07 fry/L, or 0.11 g of fish/L, which is much lower than most caging experiments (see review by Oikari 2006). All fish will be euthanized following net pen experiments.

Otoliths

Otoliths have been successfully used to track juvenile Chinook salmon growth, life history and habitat use (Nielson and Green 1982; Kennedy et al. 2002). We will use otolith microstructures to test several hypotheses about the effect of inundation timing, duration and habitat complexity on juvenile Chinook growth along the river corridor under Task 3.1-3.3 (see below). Fish mass and standard length will be measured prior to otolith removal (Limm and Marchetti 2009). We will follow the methods of Secor et al. (1992) for otolith preparation. Right side otoliths will be mounted on microscope slides in Crystalbond™ (Aremco, Valley Cottage, NY) with the sulcus acousticus facing down. The otolith will then be polished using 600 wet grit sand paper followed by alumina micropolish (0.05 µm grit, Buehler ltd.). Polishing will continued until central primordia and daily increments are clearly visible using light microscopy. The left otolith will be used if the right otolith is in the vaterite form rather than the more common aragonite form.

Each mounted otolith will be assigned a random number to prevent bias during later analysis. We will photograph otoliths at 400X using a digital camera mounted to a compound microscope. Daily increment widths will be measured using Metamorph® (Molecular Devices Corp, Downington, PA) imaging analysis software and an average daily increment width (here after referred to as increment width) will be calculated for each fish. Two independent researchers will count the number of increments to avoid reader bias in the otolith analysis. We will then measure the ten most recently accreted daily increment widths to characterize growth for each fish at each site. All measurements will be made at a 45° angle to the longitudinal axis at the posterior end, ventral side.

Statistical Analyses

We will compare otolith increment width to the various environmental parameters associated with Tasks 3.1-3.3 using a generalized linear mixed model (GLMM).

Video

We have successfully used video imaging to monitor behavior of juvenile Chinook salmon on several Central Valley rivers (CFS 2013a; CFS 2013b). We will use video observations to test several hypotheses about the effect of inundation timing, duration and habitat complexity on juvenile Chinook growth along the river corridor under Task 3.1-3.3 (see below). Video observations will be performed in net pens containing a range of habitat conditions (e.g., depth and velocity) that juvenile Chinook salmon have been associated with (Beakes et al. 2012). We will conduct two separate experiments to test for cover density effects on juvenile salmonid behavior in the presence of two- and three-dimensional structures at each of the net pen sites to help evaluate key hypotheses within each of Tasks 3.1-3.3. Three cover treatments (low, medium, and high) will be constructed using a single row of 2.54-cm diameter bamboo poles attached to a willow frame. Bamboo poles will be used to mimic stems of young riparian trees such as willow (*Salix* spp.) and cottonwood (*Populus fremontii*), and because it provides a relatively easy way to index cover complexity. A "no cover" control will also be included, consisting of only the willow frame (bamboo poles not included). Each frame will be affixed to the channel bed by attaching it to a T-post driven into the substrate. Another T-post with a camera mount will be placed 1 m to the side of the structure perpendicular to flow, so the camera records an area that includes structure and an approximately 1-m x 1-m area adjacent to the structure. To determine the effectiveness of the velocity break created by each cover treatment, five measurements of depth and velocity will be recorded

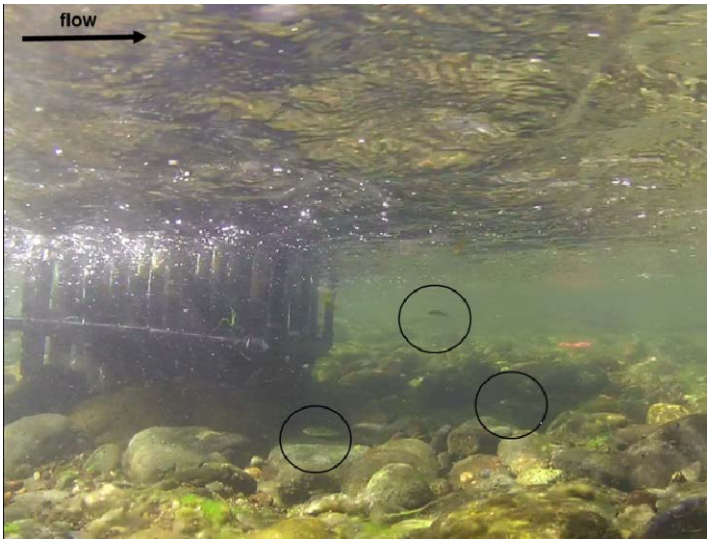

Figure 6. Still shot of high-definition video taken behind a high-density structure treatment. Circles demonstrate three juveniles using the structure as a velocity break

in front of and behind each structure, and a percent reduction in velocity will be calculated by subtracting the average velocity behind the cover feature from the average velocity in front of the cover feature, and dividing this value by the average velocity in front of the feature.

The three-dimensional (3-D) structure experiment will be conducted soon after the 2-D experiment. For this experiment, we will fabricate three cover treatments (low, medium, and high) from 2.54-cm diameter bamboo poles attached with wire to a 60-cm x 60-m polyvinyl chloride (PVC) frame that was painted black. The bamboo poles will be spaced at three different intervals to create three levels of cover density: low, medium, and high. We will also include a "no cover" control treatment consisting of a PVC frame without bamboo poles. Structures will be placed at floodplain net pens following the same procedures as above.

After the structure is installed, it will be left undisturbed for at least 15 minutes (Sellheim et al. 2013). A GoPro Hero 2 HD camera will then placed on the camera mount and turned on. Video of the structure and the area behind it will be recorded for 40 minutes. This process will be repeated until at least three replicate videos of each treatment are recorded at each of the sites. The video reviewer will enumerate fish by fork length (FL), document behaviors (aggressive, foraging), and estimate territory size based on multiple observations of individual fish movement. A behavior will be categorized as "aggressive" if it is clearly directed toward another juvenile, such as nipping and chasing. A behavior will be categorized as "foraging" if the fish darted forward or laterally with its mouth open.

Statistical Analyses

Prior to analysis of the video data, all raw counts of fish abundance will be converted to number of fish•minute^{-1} to account for differences in video duration. Similarly, all behavioral observations will be converted from raw counts to number of behaviors•fish^{-1}•minute^{-1}. Territory size will be calculated for individual fish as the average distance travelled during foraging or aggressive behavioral events across all observations for that fish.

Generalized linear mixed models will then be used to test for an effect of treatment on fish density, foraging and aggressive behavior, and territory size. All response variables will be log-transformed prior to analysis, and "site" will be included as a random effect. Statistical significance will be evaluated at $P < 0.05$. Most data analyses will be performed using the R statistical program with the package "nlme."

Adaptive Management

Video has been a very successful tool in tracking juvenile salmonid behavior on the American and Stanislaus rivers (CFS unpublished data). However, we expect turbidity to increase with distance from Friant Dam, which may hinder the use of this technique in some areas. To corroborate video assessment, we will 1) Assume that benefits of physical structure will be realized in the form of better growth and use the otolith data to examine growth difference in different structure treatments, and 2) Run controlled tank experiments within a laboratory at the Long Marine Lab, Santa Cruz.

SUB-TASK 3.1

Early Inundation - Establishing 'early' floodplain habitats. Tests the assumption that juvenile Chinook salmon will use and benefit from floodplain habitats (set up territories, feed, grow) as soon as they are available (e.g. February).

Late Inundation - Establish 'late' floodplain habitats. Allows for semi-independent assessment of whether juvenile Chinook salmon benefit from floodplain habitats based on timing (when available) and/or duration of inundation.

While logistically tenuous during this first season, our goal is to determine when the growth and survival benefits will be greatest in habitats at different points along the river continuum. At a minimum, we hope to at least have "bookends" of early and late effects for this first deployment.

Key Hypotheses Tested in Task 3.1

The following hypotheses are an overall study goal for the long-term work plan. However, for this initial stage of the study, are primary goal is to observe and describe baseline behavior, survival and growth of juvenile Chinook salmon along the SJRRP continuum.

H_1: Juvenile fry, early in the rearing period, set up territories, utilize cover (predator refuge), and survive at higher rates on SJRRP floodplains than in main channel habitats. However, there will be no significant difference in their growth rates.

H_2: As time progresses, juvenile feeding and growth rates will become significantly greater on SJRRP floodplains than in main channel habitats. Larger juveniles will also set up territories, utilize cover, and survive at higher rates on SJRRP floodplains than in main channel habitats.

H_3: Juvenile salmon on SJRRP floodplains behave differently and grow at different rates along the river corridor. Growth will be faster in downstream reaches than in upstream reaches due to lower gradients, warmer temperatures, and a less dense riparian canopy in the downstream reaches.

How will Sub-Task 3.1 inform SJRRP management? – The timing and duration of floodplain inundation will likely require some alteration to SJRRP flow management. SJRRP water releases serve multiple purposes and impact many stakeholders. A major objective of this study is to maximize the efficacy of water releases stipulated in the Settlement Agreement to maximize juvenile Chinook salmon survival and growth by providing high-quality floodplain habitat and provide strong scientific information to support adaptive management.

SUB-TASK 3.2. Periodicity of Floodplain Hydrology

Background

Duration- To maximize the benefit of floodplain inundation with limited water resources, it is essential to understand the duration of flooding required to provide growth and survival benefits. If inundation is too short, there is insufficient time for productive floodplain food webs to develop and little benefit is achieved (Humphries et al. 1999). However, prolonged

inundation can result in diminishing returns for the amount of water needed to maintain floodplain connectivity. Additionally, water quality problems can develop when extended inundation coincides with high temperatures. Estimating optimum flood duration is needed for the San Joaquin River to provide benefits for Chinook salmon with finite water resources.

Pulsing- Reconnecting floodplain habitat in a regulated watershed presents unique challenges for creating conditions similar to natural systems, especially with limited water resources. To obtain benefits of floodplain rearing for Chinook salmon while minimizing water use, it may be possible to use pulsed rather than constant floodplain connectivity (Ahearn et al. 2006). This strategy would use an initial, early pulse to inundate floodplains. Flows would then be reduced and standing water would be allowed to initiate primary and secondary production on the disconnected but inundated floodplain. A second pulse would then be used to reconnect the floodplain, allowing juvenile salmon to access the productive waters of the floodplain. During the receding hydrograph, juveniles would return to the channel to complete their migration, along with productive waters from the receding floodplain. However, with little data to support this strategy, direct quantitative evidence is needed prior to implementation.

Methods

Through a series of net pen, otolith microstructure, tagging, and underwater video experiments, we will track growth, survival, behavior and use of floodplains by juvenile Chinook salmon under pulsed versus sustained water deliveries. Several trials will be performed at sites inundated under the different hydrological regimes to identify trade-offs in growth and survival. If flows are not available to inundate each of our study plots under the available habitat configurations (see "Study Sites"), inundation may be truncated to manually flooding sites by pump or diversion at set intervals under this preliminary study (see "Habitat Inundation").

Key Hypotheses Tested in Task 3.2

H_1: Juvenile Chinook salmon can survive and grow in connected and disconnected San Joaquin River floodplains.

H_2: Growth and survival benefits will be significantly different under connected and disconnected conditions on the San Joaquin River.

How will Sub-Task 3.2 inform SJRRP management?

SJRRP water releases serve multiple purposes and impact many stakeholders. Furthermore, the water available and the temperature regime expected will greatly influence the ability to successfully create viable floodplain habitat. A major objective of this study is to optimize water releases that maximize juvenile Chinook salmon benefits from floodplain habitat and provide strong scientific information to support adaptive management.

SUB-TASK 3.3. Floodplain habitat attributes -Morphological, physical, and structural complexity

Background
Floodplains are diverse ecosystems composed of a patchwork of different substrate and habitat types (Amoros and Bornette 2002). Understanding how juvenile Chinook salmon growth and survival are related to floodplain habitat type is needed to guide land acquisition and habitat restoration and enhancement. We know that cover (e.g., woody debris, undercut banks, vegetation), water depth, and velocity are important components of overall juvenile salmon rearing habitat quality and carrying capacity (Bjornn and Reiser 1991). Unfortunately, most studies informing our understanding of habitat attributes come from mainstem environments in relatively high gradient, alluvial streams. It is unclear how well these parameters translate to low-gradient, floodplain habitat.

Methods
Physical habitat- Test floodplains will be identified (see "Study Sites") that inundate at varying depths (see Keeley and Slaney 1996 for acceptable ranges) during scheduled flood releases and populated with a range of cover types (see "video"). During inundation periods, water velocity and depth in test floodplains will be measured across no less than three transects perpendicular to flow (see Morphology section under Task 1). Flow and depth patterns will be re-assessed with each change in floodplain hydrology, and compared to discharge patterns in the adjacent river main channel (see "Water Velocity/Depth" under "Physical").

Floodplain water temperatures will be obtained from continuously deployed HOBO Tidbit temperature loggers. Prior experience has demonstrated strong vertical temperature gradients (especially in low-flow habitats). Therefore temperature loggers will be placed at floodplain surface and bottom positions using floats and anchors.

Fish habitat preferences- Through a series of common garden experiments using net pens, otolith microstructure, snorkeling and underwater video experiments, we will track juvenile Chinook salmon growth, survival and preferential use (behavior, feeding, growth) of floodplain habitats that demonstrate variable habitat complexity along the stream corridor. Observations and experiments will target physical habitat differences within floodplains (e.g. depth, flow, structure) to identify trade-offs in growth, survival and habitat use. This preliminary work in 2014 will help guide more specific study comparing floodplains to main channel habitats in future seasons (see time table in appendix).

Key Hypotheses Tested in Task 3.3

H_1: Habitat complexity, including cover, has a significant effect on juvenile Chinook behavior and growth on San Joaquin River floodplains.
H_2: Stream gradient has a significant effect on how juvenile Chinook utilize cover.
H_3: Water velocity and quality, including temperature and turbidity, have significant effects on how juvenile Chinook salmon utilize cover on San Joaquin River floodplains.

How will Sub-Task 3.3 inform adaptive management? –It is hypothesized that habitat quality (e.g., complexity, heterogeneity) has a strong influence on habitat carrying capacity and

therefore the area required to support a given population of fish. This has significant implications for habitat management and overall costs of long-term habitat development, maintenance, and management, including multiple land-use scenarios for future floodplains.

SCHEDULE AND DELIVERABLES

The following table outlines the objectives for project initiation, completing the three defined tasks, as well as presentation of results and feedback.

Annual reports are scheduled after the initial project year. Reporting will also include presentations of preliminary results, Restoration Goal Technical Feedback Annual Reports and a final comprehensive report.

Other results-oriented products may be produced as opportunities arise. We will provide documentation of project results developed as:

- *Presentation citations & abstracts*
- *Student products (Independent Study reports, Theses)*
- *Publications in peer-reviewed journals*

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	2013				2014				2015				2016				2017	
OBJECTIVE	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Kick off meeting																		
Reconnaissance/ Preparation																		
Identify potential floodplains																		
Permit acquisition																		
Floodplain manipulation																		
TASK 1. Floodplain habitat attributes																		
Obtain fish																		
Field preparation																		
Run experiment																		
Data analysis and reporting																		
TASK 2. Floodplain Food Webs																		
Field preparation																		
Run experiment																		
Data analysis and reporting																		
TASK 5. Floodplain Production																		
Field preparation																		
Run experiment																		
Data analysis and reporting																		
Presentation of Preliminary Results																		
Technical Feedback																		
Annual Reports																		
Final Comprehensive Report																		
Publications																		