State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2013-2014

by
Patrick Jarrett
Pacific States Marine Fisheries Commission
Red Bluff Fisheries Office

Douglas Killam
California Department of Fish and Wildlife-Northern Region
Red Bluff Fisheries Office

RBFO Technical Report No. 01-2014

State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2013-2014

1

Cover photo: PSMFC's Patrick Jarrett collecting redd data

Patrick Jarrett
Pacific States Marine Fisheries Commission
Red Bluff Fisheries Office

Douglas Killam
California Department of Fish and Wildlife-Northern Region
Red Bluff Fisheries Office

RBFO Technical Report No. 01-2014

1/ This is the fourth year of this study on Sacramento River redd dewatering. This report and work described herein is funded in part by: the Central Valley Improvement Act Anadromous Fish Restoration Program and by the Federal Aid in Sport Fish Restoration Act (SFRA). Activities described in this report were undertaken through cooperative efforts with the California Department of Fish and Wildlife, the Pacific States Marine Fisheries Commission (PSMFC), and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office (USFWS), and were supported by various funding sources including: a U.S. Bureau of Reclamation (USBR) contract with the PSMFC, and a USFWS **Anadromous Fisheries Restoration Program (AFRP) grant (Agreement #81330AJ366)** with the PSMFC.

TABLE OF CONTENTS

TABLES AND FIGURES

TABLES PAGE

FIGURES

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX F

SUMMARY

From the summer of 2013 to the spring of 2014 staff from the California Department of Fish and Wildlife (CDFW) and Pacific States Marine Fisheries Commission (PSMFC) working together from the CDFW's Red Bluff Fisheries Office (RBFO) conducted a fourth season of data collection to monitor redd dewatering and juvenile stranding- (second year) on the upper Sacramento River. Data on redd dewatering and juvenile stranding was collected from the city of Tehama at river mile (RM) 229 upstream to Keswick Dam (RM 302). This data provided information to fishery managers to guide management of flow releases from Keswick Dam to minimize impacts to Chinook salmon redds and juveniles in the Sacramento River.

During monitoring a combined 813 winter, spring, fall, and late-fall-run Chinook redds were marked and monitored. Of these, 573 (5-winter, 23-spring, 515-fall and 30-late-fall) were observed to be dewatered upon first observation or become dewatered as flows were reduced. An estimated 5,958 winter-run, 40,084 fall/spring-run mix, and 7,950 late-fall-run salmon spawned in the upper Sacramento River in 2013 into 2014. Based on these population estimates, about 0.2% winter, 3.1% fall/spring mixed, and 1.2% late-fall-run Chinook salmon redds were dewatered to various degrees. For the fall/spring mix large numbers of fish spawning over a period of months resulted in many fish likely spawning on or near the redds of earlier spawners. Individual redds are difficult to identify after multiple fish have spawned in close proximity. As a result, the combined fall and spring-run Chinook dewatered redd totals (538) observed this season represent only the actual marked and dewatered redds. The total number of redds dewatered was likely much higher but crews did not have opportunity to determine the amount of superimposition (multiple spawners at one site) that occurred and could only track the redds they actually marked.

Juvenile stranding surveys were implemented to observe and report on locations that could potentially contain stranded salmonids that were isolated to varying degrees by flow reductions. During monitoring, 188 stranding locations between the Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and the Tehama Bridge (a total of 73 river miles) were observed. Crews logged 375 site visits to selected locations to observe and record data at different flow levels. An estimated 6,360 naturally spawned Chinook juveniles including 2,143 winter-run were observed stranded in isolated sites. Of these, crews estimated that 179 winter-run and 232 fall-run juveniles were unlikely to survive their stranding due to environmental conditions. Crews were uncertain of the survival of the remaining fish. Rescue efforts were initiated beginning in January 2014 after CDFW rescue permitting was granted. Several thousand fish were successfully rescued including 6,551 juvenile Chinook salmon and rainbow trout/steelhead.

The nearly "real-time" reporting of redd dewatering provided fishery managers the ability to make management recommendations to prevent the dewatering of redds this season. Periodic meetings between fishery agencies and water agencies utilized the data generated by this survey to more effectively manage the limited water resources available.

INTRODUCTION

The Sacramento River is the largest river system in California, and yields 35% of the state's water supply. This river system supports the largest contiguous riverine and wetland ecosystem in the Central Valley. The Upper Sacramento River Basin (USRB) of California's Central Valley is unique worldwide because it has four separate spawning runs of Chinook salmon (*Oncorhynchus tshawytscha*) each year. Chinook salmon populations of the Sacramento River provide the majority of the state's sport and commercial catch (Killam, 2012). Each run of Chinook has adopted a different life history (spawning locations, and seasonal timing) that allows it to survive many different environmental conditions found over the course of a year in the USRB. Figure 1 shows the major spawning reaches of the Sacramento River, home to all four salmon runs.

Most of the Sacramento River flow is controlled by the U.S. Bureau of Reclamation's (USBR) operation of Shasta Dam, which stores up to 4.5 million acre-feet (maf) of water. The median historical unimpaired run-off above Red Bluff is 7.2 maf, with a range of 3.3-16.2 maf, (USFWS, 1995). Population levels of Chinook salmon in the upper Sacramento River reached historically low levels in the last five years (Killam, 2012). In addition California Central Valley steelhead (*Oncorhynchus Mykiss*) were listed as threatened under the Federal Endangered Species Act in 1998, and status was reaffirmed in 2006. The 2011 status review (Williams et al. 2011) for Central Valley steelhead indicates that their status has diminished since the 2005 status review (Good et al. 2005), with updated information indicating an increased risk of extinction.

The Anadromous Fish Restoration Program (AFRP) Final Restoration Plan (U.S. Fish and Wildlife Service (USFWS), 2001), recommended six specific actions to address the declines in anadromous fish that had been observed since 1970. Of specific relevance to this study is the need (as salmon population levels have continued to remain low in the years since the 2001 Plan) for river flows that support and restore salmon and steelhead populations. As outlined in the Final Restoration Plan:

> *Changes in the natural frequency, magnitude, and timing of flows - Reservoirs have changed the natural flow regimes of the Sacramento River by changing frequency, magnitude, and timing of flow. Flows need to be established that support the life history needs of all four races of salmon and steelhead: spawning flows, stable flows for early life stages, outmigration flows, and flushing flows for sediment transport.*

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs/larval fish may not survive. After emergence from their redd, juvenile salmon can become stranded in shallow isolated water and be exposed to the same poor environmental conditions as well as increased predation. For the eggs and juveniles to survive they need water, of a suitable temperature, velocity, and water quality, at all times.

Action (A2) from the Final Restoration Plan addresses the concerns regarding flow management:

> *Upper Sacramento River, Action 2: 2. Implement a schedule for flow changes that avoids, to the extent controllable, dewatering redds and isolating or stranding juvenile anadromous salmonids, consistent with SWRCB Order 90-5.*

Figure 1. Map of the Upper Sacramento River Basin with the river shown in blue from the Tehama Bridge to Keswick Dam (73 miles). River sections from study shown as labels and based on river miles and landmarks.

Relevant actions (Reasonable and Prudent Alternatives, or RPA's) found within the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central

Valley Project and the State Water Project (OCAP BO) (National Marine Fisheries Service, 2009) state the following:

> *Action I.2.2. November through February Keswick Release Schedule (Fall Actions). Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir. Action: Depending on EOS (End of September) carryover storage and hydrology, (Bureau of) Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

The OCAP BO identifies additional "sub" actions for implementation procedures when Shasta Reservoir has storage of various levels (2.4 million acre feet (maf) or higher, 1.9 maf to 2.4 maf, and below 1.9 maf, (Action I.2.2.A, B, and C respectively)). These actions include developing release criteria that addresses the need for stable Sacramento River level/stage in order to increase habitat for optimal spring-run and fall-run Chinook redds/egg incubation, and/or to minimize redd dewatering and juvenile stranding. Additional relevant excerpts from the OCAP BO are included in Appendix A.

In 2000, California Department of Fish and Wildlife (CDFW) staff collected data which when compared to the aerial redd survey counts, showed that 18 percent of the total fall-run Chinook salmon (fall-run) redds had been dewatered in December 2000 (CDFW, unpublished data). While this was not a comprehensive study, (aerial survey is not a total count of redds and effort varies annually) it should be considered a valuable "incidental observation", as it provides detail on the amount of redds that were dewatered in one year.

Redd dewatering and juvenile stranding relationships based on flow fluctuations for the thirty-one river miles between Battle Creek and Keswick Dam (Figure 1) are well described in a 2006 report by Dr. Mark Gard of the USFWS for the Instream Flow Investigations of the Central Valley Project Improvement Act (CVPIA), (USFWS, 2006). This report was part of a seven year investigation to describe instream flow needs of CVPIA managed streams for anadromous species. The report provides an in-depth analysis of Sacramento River salmon spawning habitats and stranding sites and their relationship to river flows. The relationships found in the report can be used to predict the consequences of flow fluctuations and their impact to spawning habitat, redd dewatering and juvenile stranding. An example table from Gard's 2006 report can be found in Appendix B. These tables can be used by resource managers to model impacts of proposed flow reductions to salmon populations. Data collection for the Gard study was from 1998 to 2001. While much of this information is dated, it is likely still relevant today. The study did not focus on the biological consequences or actual impacts of the dewatering or the stranding. In contrast the purpose of this current monitoring effort is to better determine the present day impacts to flow reductions on a relatively real time basis (weekly, or seasonal).

Real time monitoring of redd dewatering and stranding due to flow reductions is beneficial to managers to assist decision making based on actual conditions on the river. The timing of flow reductions can often be critical to the survival of large numbers of eggs or juveniles. Up-to-date information can provide fishery managers with the assurances they need to make decisions to mitigate flow changes, if the data shows that the biological consequences will be significant.

One source for flow reduction mitigation is to supplement Keswick Dam flows with water dedicated for environmental purposes. This "environmental water account" is commonly referred to as "the B2 water" and is part of the CVPIA, section 3406(b)(2). This directs the Secretary of the Interior to dedicate and manage annually 800,000 acre-feet of CVP water yield for the purpose of implementing the fish, wildlife, and habitat restoration purposes and measures as authorized by the CVPIA. Water from the B2 account can be used to supplement existing flows to prevent dewatering and stranding. This, in combination with up-to-date information on salmon in the river and close coordination between the different water and fishery agencies, can help reduce the impacts of flow management to salmon survival on the Sacramento River.

Winter-run Chinook salmon begin spawning in the upper reaches of the Sacramento River below Keswick from early May through August. Redd surveys are necessary beginning in August to locate and monitor possible dewatering during flow reductions in late summer. Fall-run Chinook salmon (and limited spring-run Chinook) begin spawning in the Sacramento River from the first week of September through mid-to-late November (Killam and Johnson 2013). Late-fall-run Chinook salmon (late-fall-run) spawning begins in early-December and peaks in mid-December to mid-January. Field surveys during the months of September through March provide opportunities to observe and collect data on current year fall and late-fall-run redds that are constructed in shallow water along the stream margins and in riffles. These surveys allow subsequent surveys to document dewatering with assurance that an active redd is being impacted. Dewatering can occur anytime a flow reduction is made. A typical reduction in flow, or "stepping down" of flow, occurs from September to November as less water is needed for agricultural purposes. When flow decreases coincide with large numbers of salmon spawning the impacts to spawning success can be significant. Figure 2 shows the stepping down of flow in the fall of 2013 and winter of 2014.

Redd dewatering on the Sacramento River can be observed anytime, but the biological significance of the dewatering depends on the timing of the flow decreases. When flows are increasing or maintained at a constant level there is minimal concern that new redds will be dewatered or juveniles stranded. Juvenile salmon will reside in the redd after hatching until their yolk sac is absorbed then "swim up" between the gravel and escape the redd structure into the water column. The development from egg to "swim up fry" depends on water temperature during development, (Beacham 1990), but can typically take up to100 days or more for water temperatures normal to the Sacramento River. Fall-run salmon spawning takes place in the fall when under natural conditions rainfall can be expected to maintain or increase natural flows. In the Sacramento River, under USBR managed Keswick Dam flow releases, this flow regime can be reversed (Figure 2) leading to decreased survival. Years in which flows are relatively high during the spawning season, and are then “stepped-down” as the season progresses can create conditions that result in high levels of redd dewatering for main stem spawning salmon.

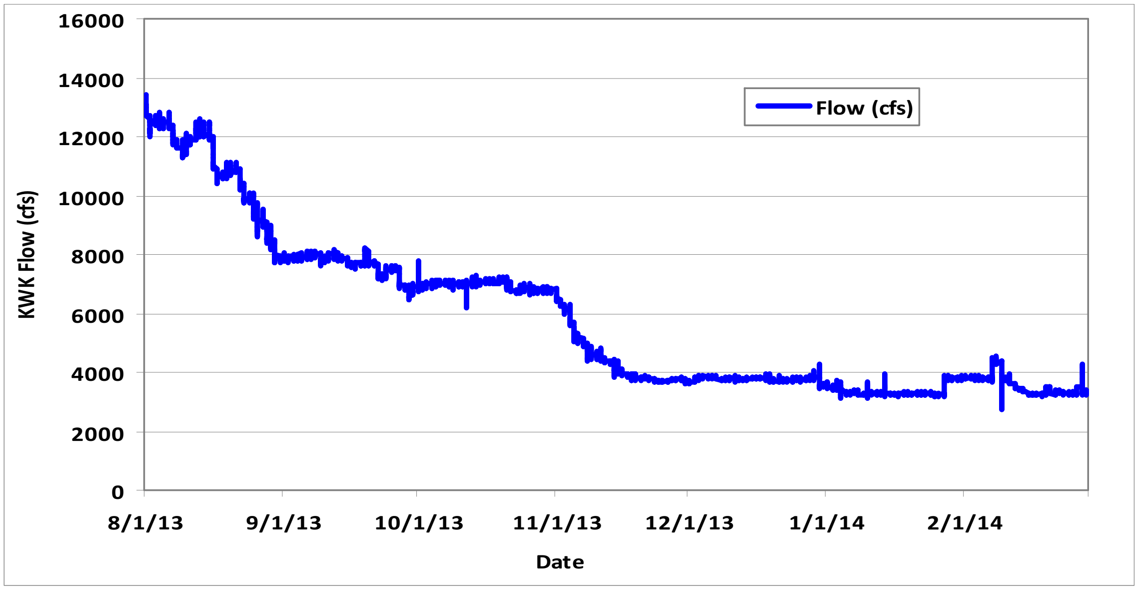


Figure 2. Flow releases from Keswick Dam on Sacramento River during selected periods in 2013 and 2014, from internet KWK-USGS gauge (CDEC 2014).

Stranding of juvenile salmonids can also occur as a result of flow reductions throughout the Sacramento River. These stranding events have the potential to affect all four runs of the Sacramento Chinook (fall, late-fall, winter and spring-run). The historical migration timing of all four adult Chinook salmon runs passing the Red Bluff Diversion Dam is provided in Appendix B. Table B2. Spawning and juvenile rearing occurs year round in the USRB with spawning peaks occurring in October through January (fall and late-fall-runs) and again in June and July (winter-run) (Killam 2012).

Redd dewatering assessment can be challenging. For example, if dewatered redds are first observed out of water, these redds may be ones that were made by salmon that spawned in earlier runs or previous years, and from which the juvenile fish have already vacated. This creates difficulty in verifying if a dewatered redd contains eggs or juveniles, or if it is an older, inactive redd from a previous salmon run. Another challenge is that storm events can cause flow fluctuations downstream of Keswick Dam. Storm inflow from the many tributary streams below Keswick Dam (Figure 1) has the potential to re-water redds for various periods of time. The larger tributaries (e.g. Cow and Cottonwood Creek(s)), can contribute flows that increase main stem flows for a much longer time period. Therefore, the best time to observe potential dewatered redds is immediately after Sacramento River flows are dropping, but prior to large storms.

Most redds in this study were marked before dewatering even occurred and while adult female salmon were observed actively guarding the redd from other females (e.g., Figure 3). This marking of active redds (still underwater) assures that crews will be positively able to identify these marked redds as redds with eggs in them from the current run of salmon and not redds from a previous run.

This was the fourth season of redd dewatering monitoring and the second year of juvenile stranding monitoring. Prior year reports from 2011, 2011-2012, and 2012-2013 studies are available online through the RBFO's CALFISH internet link at this address: http://www.calfish.org/Programs/CDFGUpperSacRiverBasinSalmonidMonitoring/tabid/222/Default.aspx) or by request from the authors.

Increased funding made the 2013-2014 survey monitoring possible. The data collected from this year's survey provided resource managers a more accurate understanding of the impacts of redd dewatering and frequency of juvenile stranding occurring during this period.

Figure 3. Spring-run Chinook guarding a marked redd (blue flagging), Sacramento River September 25, 2013. This site is located at RM 297 in Redding.

METHODS

Redd Dewatering Field Survey Methods

Redd dewatering survey efforts were conducted primarily by boat. Survey crews typically consisted of two staff members from the Red Bluff Fisheries Office (CDFW or PSMFC). Crews were instructed to collect data on both active underwater redds (adult fish recently present) or dewatered redds from the present salmon run. Crews recorded data onto a paper datasheet printed on both sides that represented data collected in a single section of river (Figure 1). Data categories included: date, river section, boat, water temperature, water clarity, weather, crew, and GPS model. The datasheet had three other redd specific sections and included sections on new redds observed, redds previously marked and redd measurements. Appendix C provides an example of field datasheets used by crews in the 2013-2014 surveys. A Microsoft Access database was also developed that allowed for further analysis of findings.

Chinook salmon redds are constructed by female fish using their tails to scour out a shallow pit from the streambed. Once the pit is made, the male (or multiple competing males) and female salmon deposit eggs and milt side by side into the lowest point and the fertilized eggs sink to the bottom. The female then immediately covers the eggs with new gravel from just upstream of the pit. The female continues this process until all her eggs are deposited, (may take days). As the eggs are covered in gravel a redd mound is created sheltering the eggs. When the female dies, the finished redd typically has an upstream pit (a.k.a. redd pot) that she has been using to cover her eggs located deep within the mound. This mound (called a tailspill) is the distinctive characteristic of salmon redds that the survey crews observed for dewatering and is shown in Figure 4 with other redd details.

During the study, each observed redd was classified in the database from a list of five dewatering descriptors ranging from “not dewatered” to “totally dry”. For the purposes of this study a dewatered redd was minimally identified as any active redd that had its highest section (the tailspill mound) exposed to the air. This would indicate that the river flow had decreased from the time when the redd was constructed and that impacts to egg or juvenile survival could be present. A small number of dewatered redds were excavated to observe if eggs or juveniles survived.

Active redds (underwater with recent activity or fish near them) were identified by boat crews while surveying from the Tehama Bridge (RM 229) upstream to Keswick Dam (RM 302) near Redding. Figure 1 shows an aerial view of the survey area including the landmarks and river miles dividing the river sections used in the survey. Table 1 lists the survey sections with corresponding river miles. Redd surveys were conducted after periods of Keswick flow decreases to allow crews to make observations of new redds and repeat observations of previously marked redds.

Active new redds were marked with round aluminum disc tags (1.25-inch diameter) attached by hog rings to an individual link of heavy steel chain placed underwater near the redd, (Figure 4). A short length of surveyors flagging tape was added to the tag to increase visibility. Flagging was color coded based on salmon “race” or run. Pink flagging was used during winter-run, blue for spring-run, and yellow for fall-run and late-fall-run. Blue disc tags were also used to increase visibility. Figures 3 and 4 show markers placed near active redds and the physical components of a finished redd. Occasionally crews encountered and marked redds that were not marked before they were dewatered but showed similar characteristics to actively marked redds (lack of algal growth on rocks in the redd).

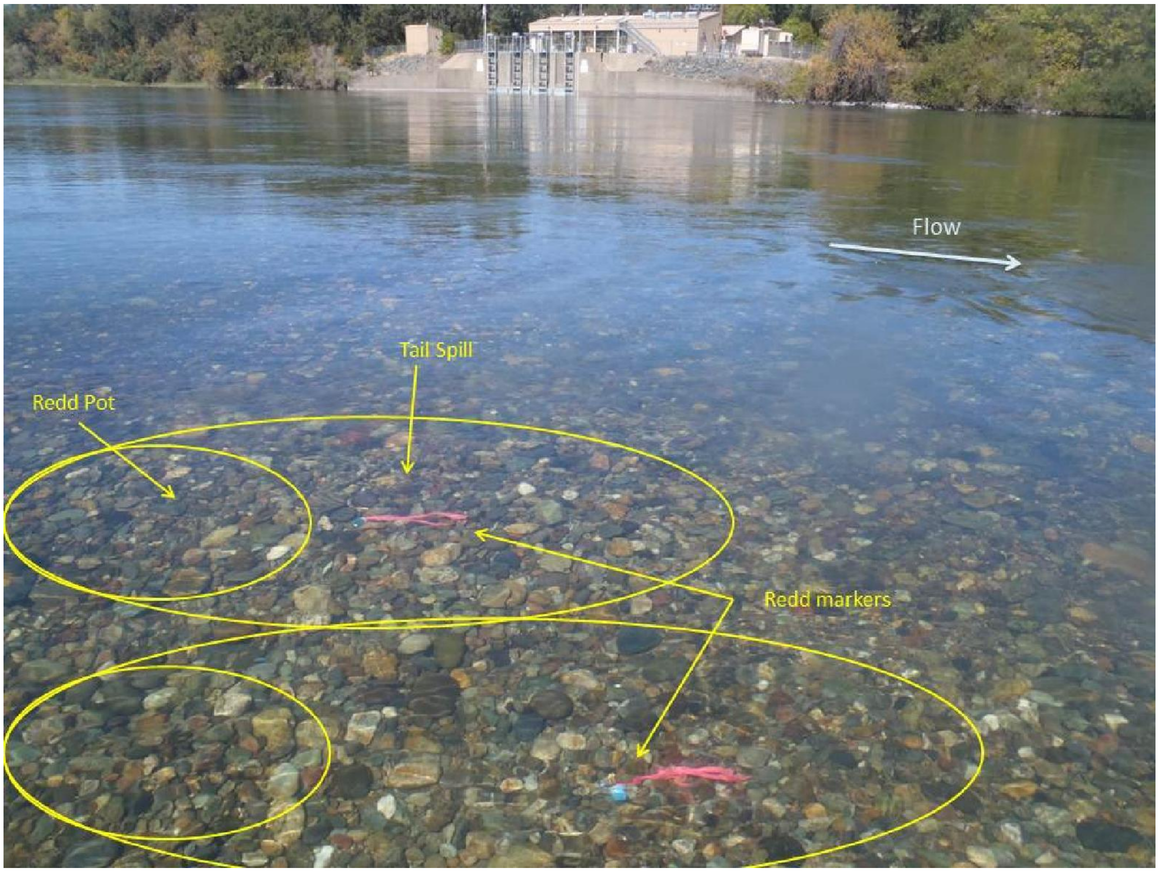


Figure 4. Winter-run Chinook redds marked during the 2013-2014 pilot study. Key identifying features of Chinook redds are illustrated in the diagram.

Survey Section	River Miles	Landmarks
1	302-298	Keswick Dam **to** ACID Dam in Redding, CA
2	298-296	ACID Dam **to** Turtle Bay Brg (Hwy 44) in Redding, CA
3	296-288	Turtle Bay Brg (Hwy 44) **to** just below Clear Creek mouth
4	288-276	Clear Creek **to** Balls Ferry Brg near Anderson, CA
5	276-271	Balls Ferry Brg **to** mouth of Battle Creek near Cottonwood, CA
6	271-266	Battle Creek **to** Jellys Ferry Brg near Red Bluff, CA
7	266-257	Jellys Ferry Brg **to** Bend Ferry Brg near Red Bluff, CA
8	257-242	Bend Ferry Brg **to** Red Bluff Diversion Dam in Red Bluff, CA
9	242-229	RBDD downstream **to** Tehama Brg in Los Molinos, CA

Table 1. Dewatered Redd Survey river section numbers by river miles and landmarks for the 2013-2014 survey season.

Active newly encountered redd locations were documented on the datasheet with a handheld Garmin GPS Map 76CSX. The status and current condition of each new redd was recorded. Redd data categories were as follows:

a.) **Disc (Redd) Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
b.) **Time:** This is the recorded military time a redd is marked and recorded.
c.) **River Mile:** Obtained from online Sacramento River map atlas and represents distance from Sacramento River mouth, near Antioch, CA. Used to assist locating redds during repeat observations.
d.) **Picture Number:** Photos are usually taken of each redd. These assist crews in determining the timeline of each redd's dewatering sequences.
e.) **Salmon Present:** This is a range of options to help crews identify active redds. The four choices include: none, fish on redd, fish observed nearby, or redd dewatered.
f.) **Dewatered:** This is a range of options describing the extent of dewatering for each new redd encountered. The five choices include: no, top only, mostly, pot still wet, and pot dry.
g.) **Sample Type:** This is a range of options to describe any actions taken at the redd location. The five choices include: marked and photo taken, measured, egg check, marked and measured, or all combined.
h.) **Depth:** This is a measurement in inches of water above the redd tail spill. Once a redd becomes "dewatered," a negative number is recorded.
i.) **Comments:** This allows crews to document any unusual qualities of each redd.

Once a new redd was marked, repeat trips to that redd were made after flow changes to document changes to the water conditions at the redd. These observations were made on the reverse side of the data sheet in the section labeled: Previously Marked Redds. Categories on the previously marked redds were as follows:

a.) **Redd Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
b.) **Time:** This is the recorded military time the redd was revisited.
c.) **Dewatering of Marked Redd:** This is a range of options describing the extent of dewatering for each new redd encountered. The five choices include: no, top only, mostly, pot still wet, and pot dry.
d.) **Action Taken:** This is a range of options to describe any actions taken at the redd location. The six choices include: none, photo taken, measured, egg check, marked and measured, marker rock placed, egg/fry check, or some combination of these. (Egg checks made on completely dewatered redds only, painted marker rocks are placed to avoid revisiting previously checked redds).
e.) **Depth:** This is the measurement in inches of water above the redd tailspill. Once the redd becomes "dewatered," a negative number is recorded.
f.) **Comments:** This allows crews to document any unusual qualities of each previously marked redd.

The depth of each redd was measured in inches from the top of the tailspill to the existing water level. Dewatered redds received a negative number which corresponded to the distance of the tailspill out of water. A hand held dumpy level and stadia rods were utilized to obtain depth measurements.

The datasheet also provided a Redd Measurement section to allow crews to document physical measurements of dewatered redds for future analysis. Dewatered redds were sub-sampled and the dimensions were measured with measuring tape that followed a standardized protocol. Categories for redd measurements were as follows:

a.) **Redd Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
b.) **Total Length:** This is the length of the disturbed area upstream near the pit to downstream edge of the redd.
c.) **Pot Length:** This is the length of the final digging pit (or pot) as it is commonly termed.
d.) **Pot Width:** This is width of pot.
e.) **Tail Width:** crews measure the mound (or redd tailspill) in two locations and average these measurements.
f.) **Flow Average:** This is the average water velocity measured in four locations around a redd.
g.) **Substrate:** This is a range of choices to describe the predominant streambed substrate in the redd. Choices include: cobble 3 to 5 inches, small gravel 1 to 3 inches, larger cobble 5 to 12 inches, or sandy gravels.
h.) **Pot Water Temperature:** This is water temperature of pot and is relevant for dewatered redds to indicate possible survival limitations from higher water temperatures.

Juvenile Stranding Field Survey Methods

Juvenile salmon can become stranded when decreasing river flows cause fish to become physically trapped in isolated pools or channels that at higher flows were previously connected (allowing free passage) to the Sacramento River. Stranding can lead to direct mortality when these areas drain or dry up. Indirect mortality can result through increased susceptibility to predators (otters, raccoons, birds, etc) or water quality deterioration in shallow or stagnant stranding locations.

A datasheet was developed for the "juvenile stranding study" effort in early 2013. The datasheet categories were developed by RBFO staff to describe the unique characteristics of each potential site and provide information on the site's potential for impacting juvenile salmon survival. New stranding site locations were recorded on a field data sheet and a handheld Garmin GPS 78 SC. Crews routinely carried both the Dewatered Redd datasheets and Stranding datasheets on surveys, completing the appropriate sheet if any observations were made. The Stranding datasheets included a similar river section to the one described for the Dewatered Redd sheet. Individual stranding sites were documented using the following categories:

a.) **Time:** This category allows determination of flows at the site by using a relationship between flow from Keswick Dam and the distance downstream.
b.) **Waypoint Number:** This is a number assigned to each potential stranding site using the GPS unit.
c.) **Picture Numbers:** These are photographs of the site for comparative purposes between visits.
d.) **River Mile:** Obtained from the online Sacramento River map atlas and represents distance from Sacramento River mouth, near Antioch, CA. Used to assist locating stranding sites during repeat observations and for flow calculations. (http://www.sacramentoriver.org/SRCAF/index.php?id=atlas)
e.) **Connection:** This is a range of choices determined by crews at each site and describes the connection of the stranding site to the nearest flowing water of the river. Choices include: site open both up and downstream (crews determine site likely to become dewatered), downstream open only, upstream open only, and isolated completely.
f.) **Winter-run Number:** This is the estimated number of winter-run sized salmon observed in the stranding site. Size cut-offs are determined by each specific date using a screw trap developed length cut off chart for the Upper Sacramento River (example: Appendix B. Table B3).
g.) **Fall-run Number:** This is same as winter-run above except for fall-run.
h.) **Late-fall-run Number:** This is same as winter-run above except for late-fall-run.
i.) **Habitat:** This is a range of choices describing the predominant habitat of the site and includes: pool, riffle, or combination.
j.) **Survival:** This a range of choices based on the crew's best judgment of the site and the knowledge of weather forecasts and future hydrological expectations based on the date and current environmental conditions. It describes the expectations for survival of salmon at the site and includes choices for: survival likely, death likely, and survival uncertain
k.) **Substrate:** This is a range of choices and describes the predominant substrate of the stranding site. Choices include: bedrock, cobble, small rock-sand, sand-silt-mud, or a combination of these.
l.) **Pool Temperature:** This is water temperature from a hand held thermometer or water quality meter.
m.) **Dissolved Oxygen:** This is dissolved oxygen level from a water quality meter.
n.) **Length:** Measured or estimated length of the stranding site.
o.) **Width:** Measured or estimated width of the stranding site.
p.) **Depth:** Measured or estimated depth of the stranding site.
q.) **Shelter:** This category describes the predominant type of shelter for stranded fish available in each site. It is a range of choices including: tree branches, submerged wood, aquatic vegetation, none, or combinations.
r.) **Reconnect:** This category describes a range of choices for the methods that could be used to reconnect the site to the river should that option be pursued. It is a simplified description of the type of work necessary to prevent stranding in future times at the site. Choices include: by hand, by power tools, by machinery, or not possible.

s.) **Rescue:** This category describes the level of effort (estimated by crews experienced in similar rescue efforts) that would be necessary to rescue the fish in the stranded site. Choices include: easy, moderate, difficult, or not possible.

t.) **Comments:** Allows crews to include other descriptions of each site.

Juvenile stranding events and stranding sites were observed while surveying the Sacramento River and side channels by boat and on foot. Efforts to locate and monitor stranding sites were conducted from the Tehama Bridge (RM 229) to Keswick Dam (RM 302). Isolated and partially or potentially isolated pools were observed and marked on a handheld GPS. All stranding sites observed were photographed. Fish present were enumerated and identified by visual observation, including underwater observation and underwater photography. Juvenile salmonids were identified by species, and juvenile Chinook were classified by run based on approximate fork length relative to date. This is accomplished using an electronic version of a Central Valley Chinook length-at-date fork length table, an example of which is located in Appendix B Figure B3. Prior to each field survey the fork length table was referenced and the size ranges of all present Chinook runs were recorded for classification in the field. Figure 5 provides an example photo of the different size (winter-run and fall-run fish) observed in the stranding locations. The site location and environmental conditions were also recorded. Some stranding pools were subsequently measured and environmental conditions such as temperature, dissolved oxygen levels, substrate, type of shelter present, etc., were recorded. Likelihood of juvenile survival was assessed at observed stranding pools and was based on current and expected environmental conditions (e.g., if site was isolated and drying up and warm dry weather forecasted, then survival was probably unlikely for that site).

The feasibility of juvenile fish rescue and removal from the observed stranding site was also evaluated. This was based on the size and substrate of the stranding site, as well as surrounding habitat. For example fish stranded in a wide, shallow pool with little aquatic vegetation, could be removed and relocated to adjacent flowing water easily using beach seines or other capture methods. Conversely, a deep bedrock pool with submerged debris such as downed logs or tree branches would be very difficult to effectively capture and remove juveniles for relocation.

In the spring of 2013 the CDFW developed a new fish rescue policy that directs all fish rescues made under CDFW authority go through a rigorous management level review process. As a result of this policy, crews were directed to “observe and report” fish presence in stranding pools and no rescue efforts were made until January of 2014 when juvenile rescues were authorized and became a drought related priority for the Sacramento River. Stranding sites suitable for rescues containing juvenile salmonids were identified and prioritized based on numbers of fish as well as accessibility. Rescues used seine nets of various lengths, dip nets and assorted tubs and buckets. Multiple passes were made with seine nets at each site and captured fish were transferred to buckets of water. Fish were then identified, tallied, and relocated to the nearest flowing river channel with minimal handling.

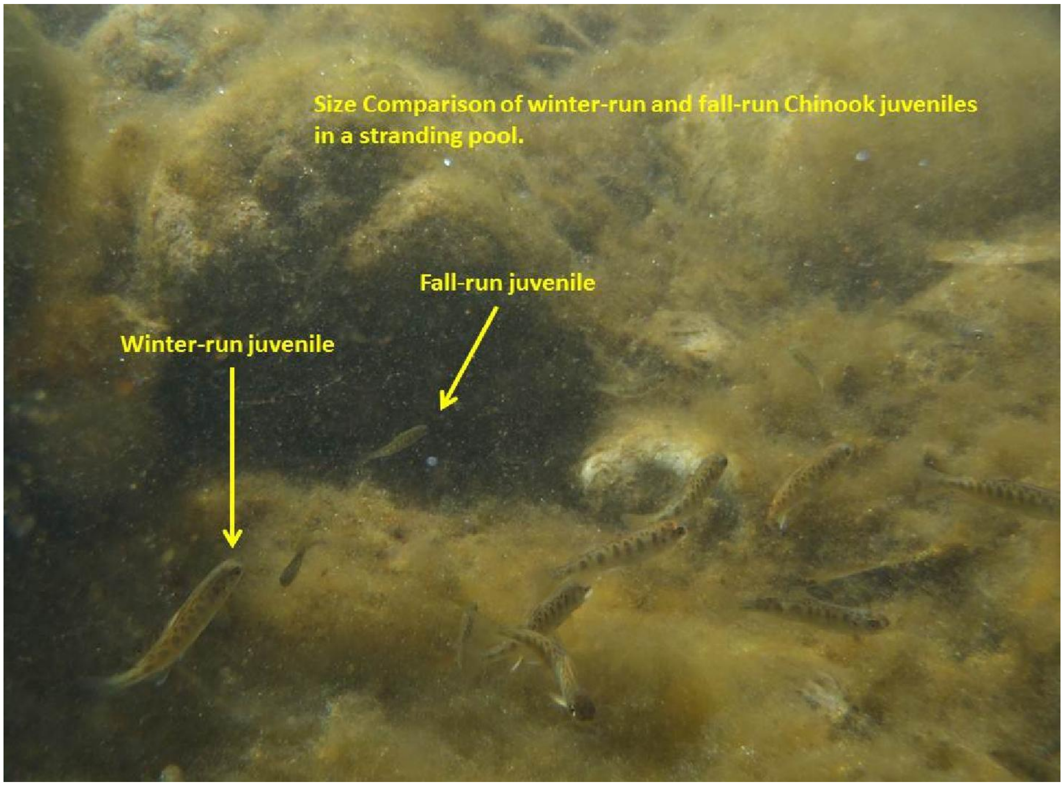


Figure 5. Underwater photo taken in February demonstrating the size difference between juvenile winter-run and fall-run Chinook stranded in an isolated pool.

Another characteristic assessed at each observed stranding site was the potential for reconnection. This was based on the substrate of the stranding site and the proximity to the nearest watered portion of Sacramento River. The feasibility of reconnection included the potential for use of hand tools (e.g., shovels), power tools (e.g., jack hammers) and more aggressive reconnection using machinery such as backhoes, etc. Both permanent and temporary reconnection techniques were considered during assessment. Documented stranding sites were regularly revisited as resources allowed throughout the survey season. The status of each stranding site was evaluated to determine if and when the location reconnected or disconnected to the main river system. Fish present were counted and identified to assess mortality of stranded juveniles over time.

RESULTS

Dewatered Redd Data Summary

One of California's driest years on record occurred in 2013 (CDWR, 2014). The 2013-2014 dewatered redd monitoring season began with the winter-run Chinook spawning season that occurs from May through August each year. Nearly 6,000 winter-run were estimated to have spawned in the Sacramento River in the summer of 2013. (Killam and Johnson, 2014). Many of these salmon spawned from mid-July to mid-August, somewhat later than typical compared to previous years (Killam and Johnson, 2013). These later spawning winter-run raised concerns with the fisheries agencies (CDFW, USFWS, and NMFS) that the redds of these (state and federally listed as Endangered) salmon would be dewatered with the typical flow reductions that occur in late August from Keswick Dam as agricultural water demands decrease. As a result, crews were tasked with monitoring shallow water winter-run redds in August and to report the results of this monitoring to the "B2" water project work team. The B2 team is comprised of members from both fisheries and water agencies and is tasked with managing the B2 water account (supplemental water reserved for beneficial environmental purposes) and the team is able to recommend on flow decisions made by water agencies.

A group of 30 winter-run redds were closely monitored from August 1, 2013 through November 1, 2013. Winter-run redds are first observed during helicopter aerial redd surveys conducted to develop population estimates. On August 26, 2013 boat crews using the aerial redd flight data were able to identify and mark 30 of the later spawning winter-run redds. Keswick flows remained around 7,000 cfs during this period at the request of the fisheries agencies to allow enough time (85 to 100 days) for fry emergence before fall flow reductions began.

A total of 62 dewatered redd surveys were conducted between August 1, 2013 and January 27, 2014. The Keswick (KWK-CDEC) flow gauge was used to determine flows in the 2013-2014 season. Flows remained relatively stable around 7,000 cfs from September 27 through November 1. Flows from Keswick Dam decreased to around 4,500 cfs from November 8 to November 14 and continued to decrease to 3,800 cfs from November 16 to January 3, 2014. State wide extreme drought conditions initiated further Keswick flow reductions to 3,250 cfs on January 4, 2014. Figure 6 provides a summary of Keswick Dam Flow releases for the entire survey season and compares to the number of dewatered redds observed. The last dewatered redd survey was conducted on January 27, 2014. A total of 818 active redds were marked during this 2013-2014 period, (examples of locations provided in Appendix D). Of the 818 redds marked, 573 (70%) were considered dewatered to different degrees. Dewatering was categorized into four different levels and all are considered to impact egg or fry survival. The four levels include: top only dewatering, most of redd dewatered, pot still wet, and pot completely dry. Of the 573 dewatered redds, 60 (10.5%) were top dewatered, 81 (14.1%) were mostly dewatered, 250 (43.6%) were pot wet (but tail spill mound dry), and 182 (31.8%) were pot dry (completely dry on all exposed areas). A total of **5** (0.8%) winter-run redds, **23** (4%) spring-run, **515** (90%) fall-run, and **30** (5%) late-fall-run redds were dewatered to various degrees. Redds were assigned to a salmon run based on time of year observed.

Figure 7 displays the number of dewatered redds marked per survey section. Most redd dewatering happened in three survey sections coincident with shallow areas of high density spawning (sections 2, 3, and 7- see Figure 1). These three sections contributed to 73.3 % (420 of the 573 redds) dewatered. Superimposition of redds by later arriving females spawning in same areas as previous spawners was observed at many different locations in these high density sites. This made enumerating the total number of redds at these sites difficult and likely resulted in an overall under estimation of redd dewatering for the study.

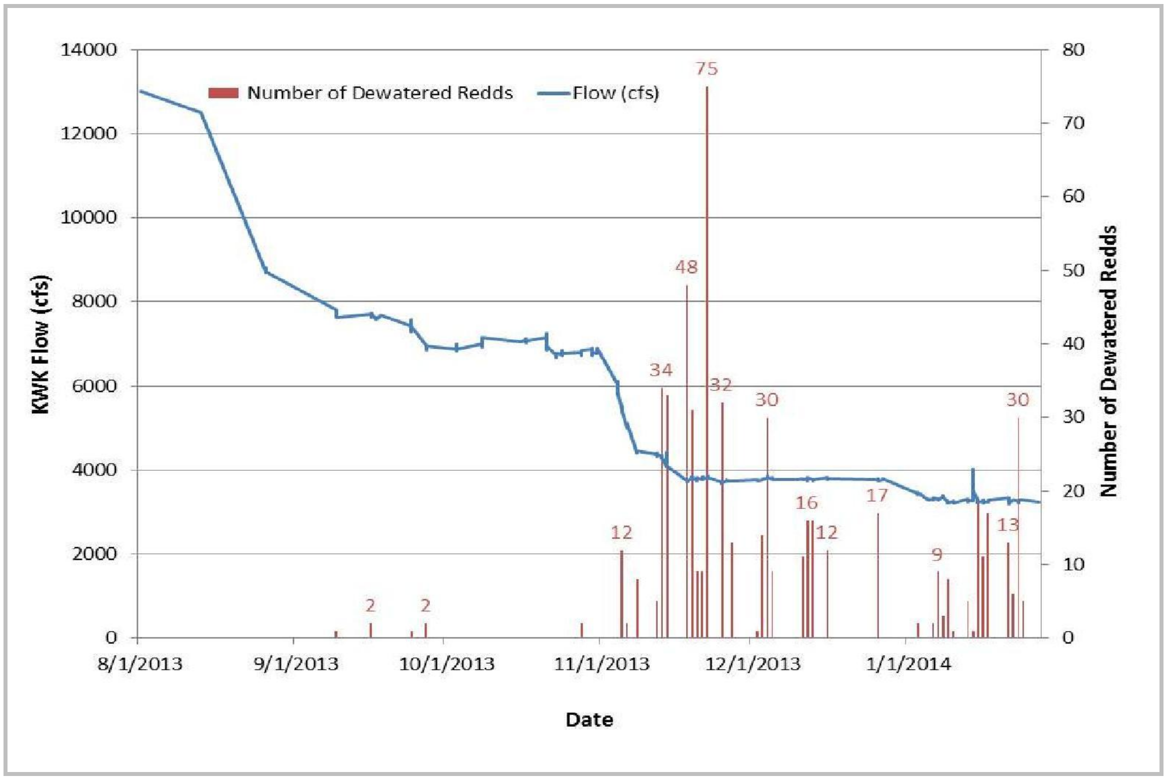


Figure 6. Graph comparing the number of dewatered redds to Sacramento River flow (obtained from the KWK gauge) by date for the 2013-2014 survey period.

The time of day was recorded for each redd observed. This allowed analysis of the flow at each marked redd based on redd's distance from Keswick Dam and the time it takes for flows to travel downstream. A multi-year time series of flow changes was analyzed using multiple linear regressions of flow changes coming from Keswick Dam and other points. Flows from Keswick Dam during periods of steady tributary inputs were compared with flows at other fixed monitoring stations along the river (CDEC: Bend station (BND), Red Bluff Diversion Dam (RDB), and Tehama Bridge (TEH)) to develop a relationship between time-distance and flows enabling crews to determine river flows at redds or stranding sites by recording time and the location during survey observations. Appendix F. Table F1 provides the results of this time-distance-flow relationship. Data from Appendix F. Table F1 was used to calculate the flow at each given redd or stranding site. This enables comparison between water depths at redds and stranding site inlets and outlets. This data can be useful in predicting at what flow a certain area can become dewatered or isolated. For this study the Sacramento River was divided into half-mile segments based on the river mile designations available in the online CDWR atlas at the following link: http://www.sacramentoriver.org/srcaf/index.php?id=atlas .

The depth of water over the highest point of the tail spill of the redd was measured for each redd (Figure 4 and 8). This provided data to compare water elevation at each redd with the flow in the river at each redd. This proves helpful in determining at what flow a certain area could be expected to be dewatered. For redds that had been dewatered the distance (elevation) from the redd's highest point to the nearest water surface was surveyed and reported as a negative number in the depth category for those dewatered redds.

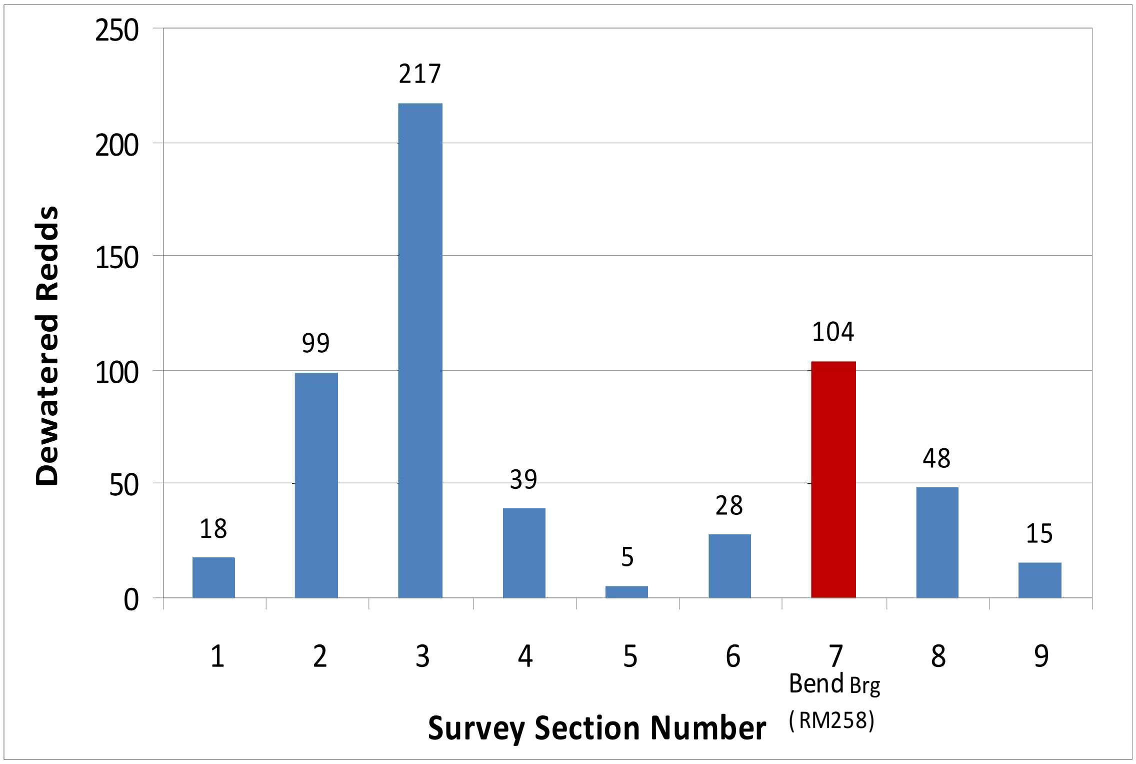


Figure 7. Dewatered redds by survey section. Section 7 is highlighted in red indicating that most of dewatered redds from that section were located in one area on a gravel bar just above Bend bridge (see Appendix D. Figure D3).

Redd dimensions were measured on 72 total redds throughout the entire study. The average area of measured redds was 97.4 ft² (9.05 m²) and the lengths, widths, and depths are displayed on the redd dimensions diagram in Figure 8. In addition to redd measurements, 16 dewatered redds were excavated for positive identification of egg presence. These egg checks resulted in 11 dewatered redds with decomposed eggs, alevins, or fry. A picture of excavated decomposed eggs can be seen in Appendix E. Figure E14. Trapped salmon fry were also found alive in three of five dewatered redds in which the pot was still wet (level three category redds).

Percentage of Redds Dewatered

To calculate an estimate of the percentage of each run that was impacted by dewatering the overall spawning female escapement estimate of each run was divided by the dewatered redds observed for that run. This methodology assumes for each spawning female there is a single redd. This method provides a minimal percentage dewatering estimate and this would increase if superimposition on the marked redds by other females occurred between survey visits by survey crew. This is most likely for the fall-run salmon that occur in large numbers during periods of reduced flows (less spawning area).

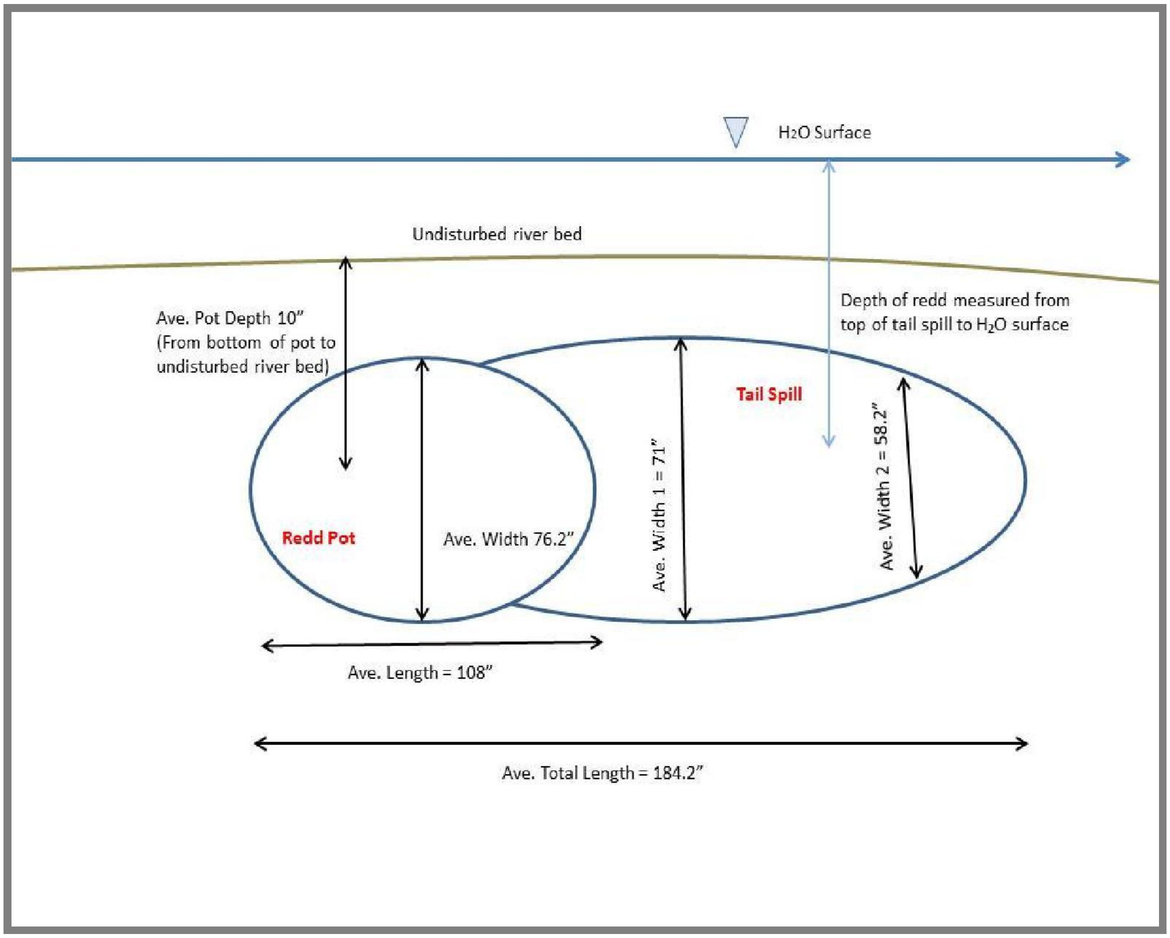


Figure 8. Diagram of the average redd dimensions measured from 72 different redds during the 2013-2014 survey period.

The 2013 winter-run Chinook estimate was 5,958 in-river salmon including 3,680 females (Killam and Johnson 2014). All of these spawners occurred within the boundaries of the dewatered redd survey. Additionally a 1.0% unspawned female rate was observed on the winter-run carcass survey and effectively reduces the number of females digging redds to 3,643. Five dewatered redds were observed for winter-run. A winter-run Chinook dewatered redd estimate of **0.13%** (5 / 3,463) was made. Redd superimposition at the site of the dewatered winter-run redds was not likely as most were in easily observable areas and redds did not appear to overlap at these sites.

The 2013 Sacramento River spring/fall-run Chinook escapement included 19,125 female salmon in the population (Killam and Johnson 2014). This estimate included both spring and fall-run Chinook since there was no attempt made to separate out the Sacramento River run of these two species due to overlap in spawning times and location, (authors note: funding for genetic separation of these runs is being sought, but at present time, spring-run numbers are thought to be very low). The 19,125 estimate was used as a starting point to quantify the number of total redds in the river based on the assumption that there was one redd per spawning female. This female estimate was developed using the annual fall-run mark-recapture carcass survey as well as the aerial redd survey results. To develop the total dewatered redd percentage the 8.2% of the aerial redds downstream of Tehama Bridge (123 downstream of a total 1,504 spring and fall-run redds observed) were removed from the 19,125 total system estimate, resulting in 17,561 females upstream of Tehama. Additionally the carcass survey reported a 1.1% unspawned female figure and this further reduces the females making redds in the dewatered redd survey area to 17,368 females. The combined 538 dewatered spring (23) and fall (515) redds are divided by 17,368 **resulting in a 3.1% rate of the spring and fall-run redds dewatered**. Appendix D shows examples of the marked redds and juvenile stranding sites observed in high density areas during the survey period in a series of images (from Google Earth) starting upstream and progressing downstream.

The 2013-2014, (2014) late-fall-run Sacramento River estimate was 7,950 Chinook, including 2,861 female salmon. Carcass survey crews noted a 1.1% unspawned female rate (i.e, 2,830 females spawned) and redd distributions from aerial flights indicated that 8.0% of all late-fall redds (N=14) were below Tehama Bridge. From this, an estimated 2,603 female late-fall-run made redds in the survey range. Crews noted 30 dewatered late-fall-run redds resulting in an estimate of **1.2% of the late-fall-run redds dewatered.**

Juvenile Stranding Data Summary

There were 70 surveys conducted from July 26, 2013 through February 21, 2014. Crews observed 188 potential unique stranding locations (examples shown in Appendix D) between the Tehama Bridge (RM 229) and the Keswick Dam (RM 302), a distance of 73 river miles. Of the 188 potential stranding sites, 30 were both completely isolated and contained juvenile salmonids (Figure 9). Many other sites contained unknown juvenile fishes. The number of juvenile Chinook stranded in these locations was estimated at 2,298 winter-run, 10,296 fall-run, and 263 late-fall-run for a total of 12,857 juveniles. Crews revisited these sites multiple times to observe and record data at different flows. Some locations containing juvenile salmon were visited up to six different times to monitor the connection status and fish health. An estimated 179 winter-run and 232 fall-run juveniles suffered mortality through either direct (stranding area drying up) or indirect means (predation, warm water, poor water quality).

Stranding locations are those in which crews observed that fish passage to the main river channel would be difficult or impossible (completely isolated) at current flows. Crews rated each stranding location by the degree of isolation to the nearest flowing channel. Ratings ranged from still connected (if flows dropped these sites would be disconnected), limited upstream or downstream connections, and completely isolated. There were three major stranding events (flow reductions) during the 2013-2014 juvenile stranding survey. On August 1, 2013 flows from Keswick Dam were reduced from 13,000 cfs to 9,000 by August 26, 2013 (Figure 10). This 31% flow reduction resulted in 284 stranded juvenile salmon, most of which were winter-run Chinook. The next flow reduction happened from

October 30 to November 16, when Keswick flows decreased from 6,900 cfs to 3,800 cfs. After this 45% flow decrease crews observed 1,793 juvenile Chinook salmon stranded at various locations. The last significant flow reduction was completed on January 5, 2014 when Keswick flows were decreased to 3,250 cfs and resulted in an estimated 10,858 stranded juvenile salmonids. These stranding events occurred in various habitat types (bedrock, riffles, side channels and eddies) along the entire length of the study (Keswick Dam to the Tehama Bridge).

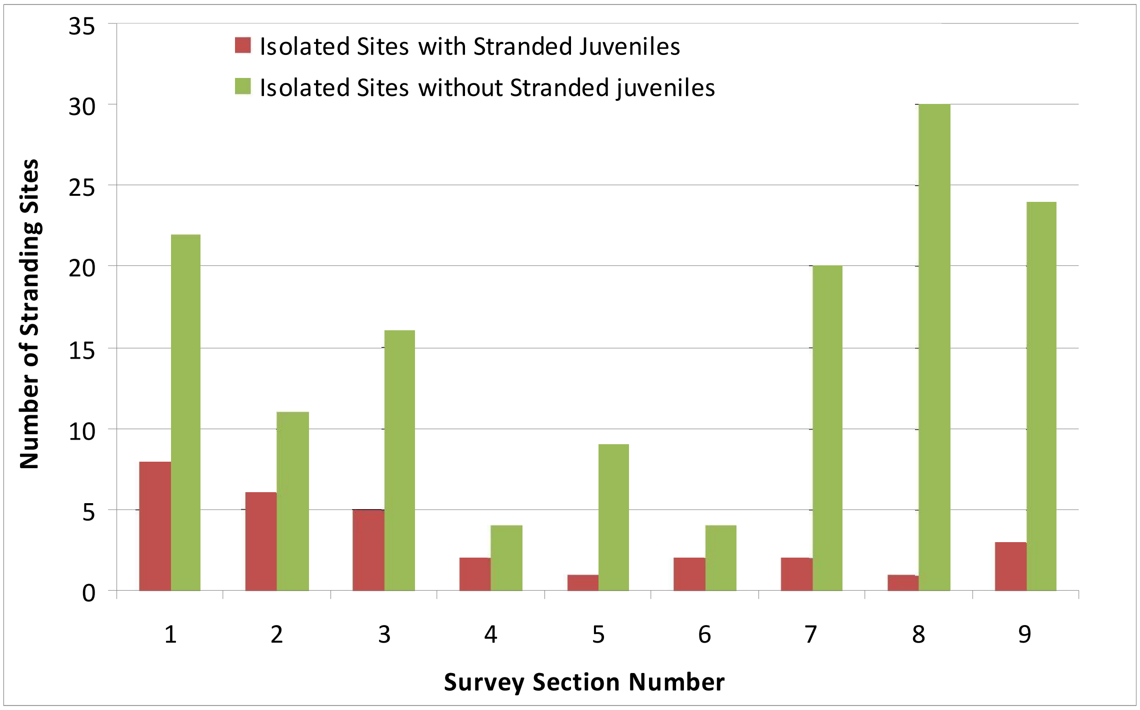


Figure 9. Number of isolated stranding sites with juvenile salmon compared to the number of stranding sites without juvenile salmon for each survey section during the 2013-2014 survey period.

Figure 9 reveals that the majority of observed juvenile stranding sites occurred in the upper most twelve miles of the river (sections 1, 2 and 3). In these three sections alone there were 19 stranding sites (63.3% of the 30 juvenile sites) containing live salmon

Crews recorded various data for each stranding site (see Appendix C. Figure C3.). Basic water quality measurements were taken including water temperature and dissolved oxygen. Many physical stream properties such as substrate size and natural stream shelter data were collected and used for prioritizing fish rescues. The dominate substrates found at all sites were cobble and multiple substrates that include all categories (sand, silt, cobble, gravel). Most sites had aquatic vegetation, tree branches or both for shelter. River discharge was calculated using the same procedure as the dewatered redds (Appendix F. Table F1.). This information was utilized to relate flow to the stage stranding sites become isolated and prevent fish passage. Resulting data from these monitoring efforts is available upon request please contact the authors at doug.killam@wildlife.ca.gov or pjarrett@psmfc.org .

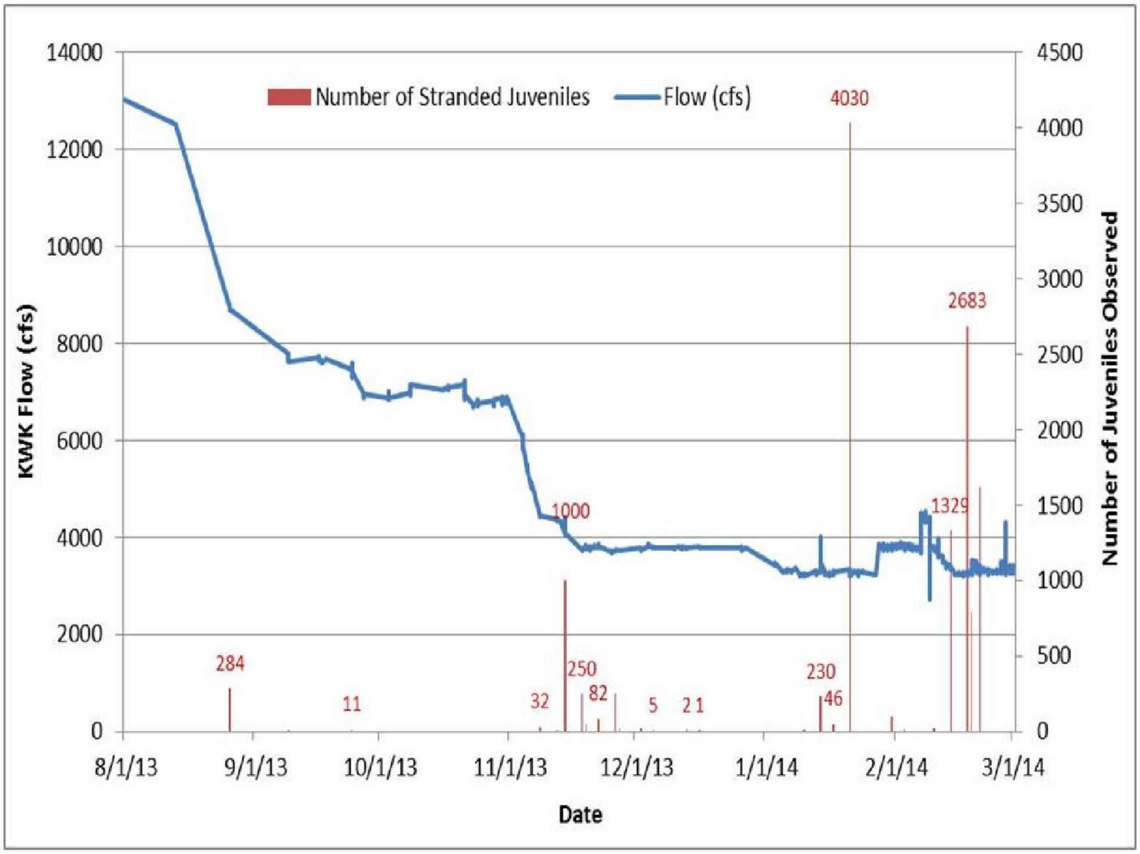


Figure 10. Graph comparing the number of stranded juvenile salmonids to Sacramento River flow (from the KWK gauge) by date for the 2013-2014 survey.

Fish Rescue Efforts

Stranded juvenile fish rescue efforts (example shown in Figure 11) using seine nets were conducted from January 31, through February 21, 2014. A total of 9,171 fish were observed and rescued from 21 stranding locations on the Sacramento River during this period. There were a total of 162 winter-run and 6,389 fall-run sized salmon (based on data in Appendix B. Table B3) and 153 rainbow trout (*Oncorhynchus mykiss*). Another 2,467 fish of other species were also rescued during salmonid rescues, (i.e. Cyprinidae, Cottidae, etc.). Beach seining proved very successful and safe during these rescue attempts. A small number (N= <10) of fish mortalities resulted from these rescues but for the most part a seine net proved effective at removing juvenile salmonids from most stranding sites.

DISCUSSION

The overall objective of this monitoring effort is to investigate and gain information on the extent and nature of impacts of river flow reductions and fluctuations to salmon populations in the upper Sacramento River. The monitoring effort provides data to water and fishery agency managers that allow them to better understand how flow changes affect salmonid resources. It also provides opportunities to protect these resources using real time information.

Figure 11. Stranding Survey crew seine a stranding pool to relocate juvenile salmon on February 14, 2014, on the Sacramento River at RM 280.

Readers should take note that in mid-2013 the "KES" CDEC gauge historically used to record Keswick Dam outflows for numerous databases, reports and studies malfunctioned and was not repaired (it continued reporting inaccurate readings) as of the time of this report. Fortunately three quarters of a mile downstream from Keswick Dam (see Appendix F. Table F1.) is the "KWK" CDEC gauge that records similar flow data. Readers interested in further analysis should use the KWK gauge for all flow related data needs, until such time that the KES and KWK gauges report similar results.

The 2013-2014 survey occurred during a period of extreme drought. Concern over diminishing water resources led to a significant increase in use by mangers of the data collected on the survey. Additionally the 2013-2014 survey began earlier than scheduled when concern over winter-run redd dewatering led to crews, for the first time, actively marking later spawning winter-run redds in August of 2013.

The 2013 winter-run spawning season experienced a surge in interest by agency managers when hundreds of adult winter-run spawners strayed and were trapped in the Colusa Basin Drain area that serves as a drainage system for the vast western side of the Northern Central Valley agricultural system. Some of these trapped winter-run adults were rescued while many others died as a result of high water temperatures and poor water quality, (CDFW 2014). This focused attention on winter-run escapement in the upper river and led to requests to begin the dewatered redd monitoring early to determine if later spawning winter-run redds made in late-July and August were going to be dewatered by flow reductions typical in August as agricultural needs decrease.

Survey crews identified some 30 winter-run redds that were thought to be susceptible to future dewatering before the eggs and juveniles within them had a chance to emerge from their redds. These redds were carefully monitored as seasonal flow reductions began to "top" dewater five of these winter-run redds later in August, (Figure 2). Managers met regularly (through the auspices of the B2IT conference calls) and decided to minimize further flow reductions until the end of October to allow these juvenile winter-run time to clear the redds. As a direct result of the monitoring from this survey, flows were stabilized for protection of these shallow winter-run redds.

All of these 30 winter-run redds were downsteam of the Anderson Cottonwood Irrigation District Dam (A.C.I.D) which creates a deep water pool in the Sacramento River in Redding (RM 298). Nearly 76 percent of the winter-run spawned upstream of the ACID based on aerial redds survey data in 2013. An additional management action taken to protect these upstream winter-run redds was to request that the A.C.I.D dam be kept in place until November 1, to prevent dewatering of those winter-run redds above the dam. The seasonal flashboard dam is normally taken out in October but by keeping the dam in place through October the redds upstream remained flooded, allowing winter-run juveniles the opportunity to emerge from the redds without problems. One management recommendation of this study for future years is to investigate regularly leaving the ACID dam in place until November during dry years when redd dewatering is predicted.

The California Department of Water Resources (CDWR) actively assisted in monitoring flows around the winter-run and other redds. The CDWR's Northern District staff is working to produce flow rating tables for selected high density spawning areas that will enable managers to determine at what flows specific areas will become dewatered. This project, when complete, will complement the real-time monitoring of this survey and allow flow reductions to be carefully adjusted ahead of time to prevent dewatering of active redds observed by this survey in areas with up to date flow rating tables.

The work done on the endangered winter-run salmon redds transitioned into monitoring dewatering of spring, fall and late-fall-run redds as flows decreased when winter-run redds had "expired" after November 1. Monitoring for these runs typically begins in

October, but stable flows through October in 2013 prevented dewatering. An unusually large number of spring-run adults were observed at the Keswick Dam trap in the spring of 2013. In most years the Sacramento River is thought to have a small number of adult spring-run “strays” from other waters (i.e, Feather River, Butte, Mill, Deer, Clear and Battle Creek(s)). The river is not known to have a distinct run of spring-run (Killam and Johnson 2013). The reason for this is unknown but it is postulated that the much larger fall-run (that spawn at the same time and location) interbreed with these stray spring-run and the resulting offspring become mixed-run fish that eventually become genetically similar to the much larger fall-run population.

No attempt was made to quantify the spring-run population in the Sacramento River (due to lack of funding for genetic testing). Some carcasses in early September were genetically tested to separate the later spawning winter-run from other populations (genetic analysis found winter, spring and fall-run fish) but fall and spring-run carcasses were not sampled for genetics after early September. The survey noted that 23 redds identified as spring-run based on their time of construction (September) became dewatered. Agency managers realized that the ESA threatened spring-run juveniles would require over 100 days (until January) to emerge from these redds. Winter-run redds were protected by decisions to hold flows at around 6 to 7 thousand cfs until November but the continuing extreme drought conditions forced mangers to drop the flows to the 3 to 4 thousand cfs range in November over concerns that no cold water would be available for the 2014 winter-run spawners. The lack of water in Shasta Lake essentially “pitted” the current and future needs of the endangered winter-run against the needs of an undocumented number of threatened spring-run redds. After discussion, the winter-run needs “trumped” the spring-run for fishery managers. In addition the ongoing drought conditions were raising alarms for future agricultural and urban needs that resulted in agreements to conserve water by reducing outflows from Lake Shasta after November 1 to absolute minimal needs.

Observations during the 2013-2014 and prior studies indicate that oscillating river flows have the potential to dewater redds and strand juvenile salmonids repeatedly in the same locations. Juvenile salmon naturally move between shallow slow moving waters to rest between venturing into swifter food carrying waters. This tendency makes them particularly susceptible to stranding as flows recede isolating the shallow river margin areas. Appendix E contains photographs of some of the different dewatered redd and stranding sites discussed in this report. During typical winter dry periods with steady or decreasing tributary inputs, small flow changes (up or down) from Keswick Dam can result in repeated flooding and dewatering of pool and side channels throughout the upper Sacramento River. Images of these areas are shown in Appendix E, and in Figure 12. This figure shows that stranding sites may occur in close proximity to spawning areas (the small pool of water in between redds that were dewatered in Figure 12) and to other stranding sites. During certain circumstances, recently emerged juvenile salmonids have been observed stranded in pools surrounding dewatered redds. These unfortunate fish survive redd dewatering but then become susceptible to stranding as juveniles.

The main objectives of the 2013-2014 juvenile stranding survey were to locate new stranding sites and to monitor the known sites for stranded juvenile salmonids. Later in the stranding season, fish rescues became the main priority. Future efforts will shift their focus towards monitoring, rescuing, and implementing preventive actions including possibly developing strategies for reconnecting stranding sites to the river.

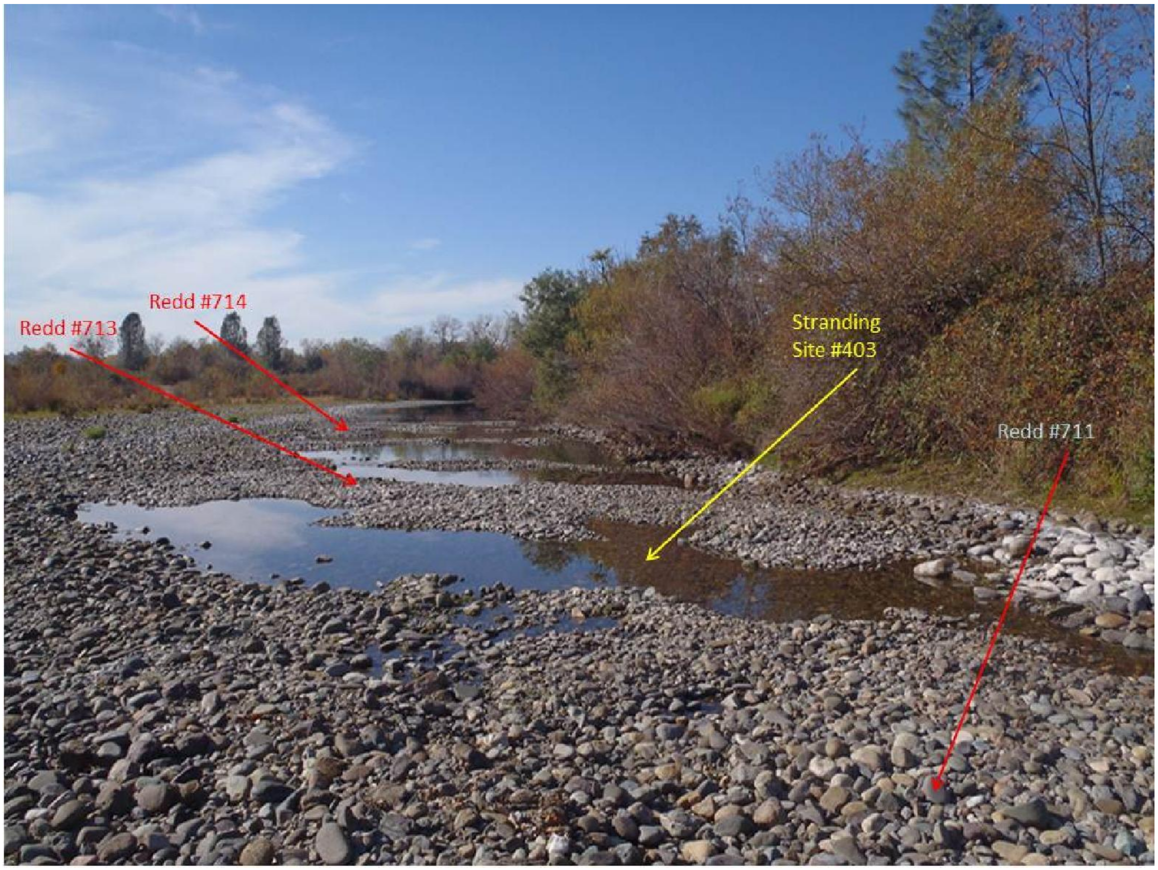


Figure 12. This photo shows a stranding site formed in between dewatered redds. Note: this site is located in the side channel just above the mouth of Clear Creek at a flow of 3,893 cfs on November 6, 2013.

Summary of Four Year Study and Future Plans

We know that constant river flows for a period of over 3 months following redd construction will prevent dewatering and stranding. During dry years it seems increasingly difficult to balance fisheries needs with the water needs of California's human population. A goal of this study was to provide information on the impacts that redd dewatering and juvenile stranding caused by flow changes can have on the early life stages of naturally produced Chinook salmon. The complexity of the Sacramento River below Keswick Dam makes determination of the impacts to juvenile salmon difficult to judge. Some of the issues this study is focused on are as follows:

a.) Determining the total percentage of redds dewatered and the impacts of superimposition to this percentage.
b.) Determining the impacts of salmon mortality from redd dewatering.
c.) Determining the survival of stranded juvenile Chinook in stranding sites.
d.) Determining the relationships between Keswick Dam flows and rain events that increase tributary flows and the impacts to stranding locations.

All of these will prove challenging to determine in future years. The total percentage of dewatered redds depends on the ability to monitor closely both the dewatered redds and the total number of redds. The CDFW aerial redd count survey was not designed to count all redds so another method was developed. During this year's survey, the 2013 (and early 2014) Sacramento River escapement survey results were utilized to obtain an estimated percentage dewatered for each salmon run. For the large fall-run numbers difficulties arose when unusually high spring-run numbers proved inseparable from the fall-run. Another difficulty was redd superimposition in areas of marked redds. We observed that in areas of high superimposition the later spawning fish would bury the existing redd markers and make it difficult to determine exact numbers of dewatered redds in those locations.

Superimposition was observed in a variety of different high density spawning locations throughout the entire survey reach. Redd superimposition occurs when early constructed redds are imposed upon by late spawning salmon that construct redds on top of or near the preexisting redds. This usually occurs in areas of high quality spawning habitat with adequate subsurface water flow and loose gravel provided by previous redds that are no longer guarded (S.J.R.P, 2008). Superimposition has been documented in many other streams and known to have negative effects on previously deposited eggs (Fukushima M, et.1998). Counting redds in these high density areas during this study season was problematic due to the common occurrence of superimposed redds. Many redds were constructed in close proximity to one another and difficult to distinguish. The redd survey crew was asked to be very conservative when marking and enumerating redds and was cautious not to overestimate redd counts.

Crews reported that the original redd markers were often missing from the redd locations on subsequent visits and had to rely on GPS to locate the original marked redd. This could happen when subsequent spawners kicked up new gravel that covered the marker, or by the public walking in the dewatered areas and removing them upon observation. If there was actually more than one redd for each marked redd location than the overall number of dewatered redds would increase. Crew ability to revisit marked redd sites was limited by staffing levels and the distance (73 miles) that redd dewatering occurred. The 3.1% redd dewatering estimate calculated using the fall/spring-run population escapement is the minimal percentage dewatered and is lower than the predicted 20-40% loss in total redd population derived from the dewatered redd calculation table in the USFWS 2006 Dewatered Redd Report (USFWS 2006). That report's dewatering percentages are limited to a single start flow and single ending flow for the entire season and are not suited to account for a series of flow reductions during the long spawning season. In any case, a 3.1% dewatered redd equates to an impact to 538 fall/spring redds containing up to 5,500 eggs each (Moyle 2002), or nearly 3 million juvenile salmon. Next year's dewatered redd survey (if conditions allow) will focus on obtaining near exact counts at selected high density sites. This will significantly aid in obtaining a total dewatered redd count and increase the accuracy of the impact on dewatering to the total redd numbers.

Salmon mortality in dewatered redds is variable and each redd is unique based on location and physical and environmental conditions around the redd. Dewatering of redds can occur due to small changes in flows and knowing the impacts (see Becker, et al., 1983) to the developing fish will need focused study. Determining what allows some salmon in dewatered redds to survive and others to perish will be a focus of future efforts. Water velocity reduction and temperature increases are key components to the risks of salmon in redds during dewatering. Salmonid redds have specific water velocity, dissolved oxygen, and temperature requirements for embryo survival. Intragravel water flow transports dissolved oxygen, a biological requirement for salmon embryo production, to the eggs while removing silt and metabolic waste (Cordone and Kelley 1961). The observed ideal velocity requirements for chinook salmon redds are 30-80 cm/sec (1-2.6 ft/sec) while optimal temperatures range from 5-13°C or 41-55°F (Moyle, 2002). Although surface water levels and velocities may fall well below these ranges, sub-surface flow in the hyporheic zone may (or may not) be sufficient in providing dissolved oxygen for egg incubation. During this year's study, 16 dewatered redds were excavated with a shovel for egg presence and condition. In most situations decomposed salmon eggs or fry were found in pot wet and pot totally dry (category 3 and 4) dewatered redds although live fry or alevins were found trapped in a few others. These findings display the variation and importance of subsurface flow to salmon redds. Further efforts to determine impacts to survival in the redds will focus on measurement of intragravel and surface water flows and water quality in and around dewatered redds.

Survival of juveniles in stranding sites depends on many factors. The connectivity to the river changes as Keswick Dam flows change or as tributary flows (e.g. Cow Creek) change so each stranding site is a dynamic balance of environmental inputs at any given time. The further upstream the site, the less likely that downstream tributary flows will contribute to connectivity changes. Fish in some stranding locations are not necessarily lost as many even completely isolated sites were large and deep enough to support fish life for weeks possibly months and eventually would reconnect as flows increase in the spring for agricultural purposes. While fish may survive in some stranding pools their growth and ability to migrate is impaired and may lead to further survival problems later in life due to reduced growth or migration delays. Stranding sites along river margins are a common natural occurrence and provide much needed rearing and resting habitat in the Sacramento River. They can become salmon death traps when conditions (flows) are managed opposite of the naturally occurring conditions. As natural flows increase from rainfall and flows from Keswick Dam are reduced, salmon in the upper river may become stranded and miss the opportunity to out migrate during peak flows. Salmon out-migration during peak flows assist in predator avoidance and ensure the salmon can find their way to the Ocean past the confusion of alternate pathways in the Sacramento-San Joaquin Delta. The majority of fall-run Central Valley hatchery salmon in early 2014 were trucked to the lower Delta to avoid such difficulties. Management options such as

Keswick pulse flows during dry years timed to rain events may trigger a migratory response in naturally spawned fish and allow stranded fish a chance to escape. Figure 13 compares the Keswick flows and the flows 42 miles downstream at the Bend site (Appendix F. Table F1.). Figure 13 reveals that even in a critically dry year like this 2013-2014 season there may be opportunities to help move juvenile salmon out of the stranding sites and upper river with a Keswick pulse flow that could be timed to naturally mimic the Bend gauge hydrograph shown in Figure 13.

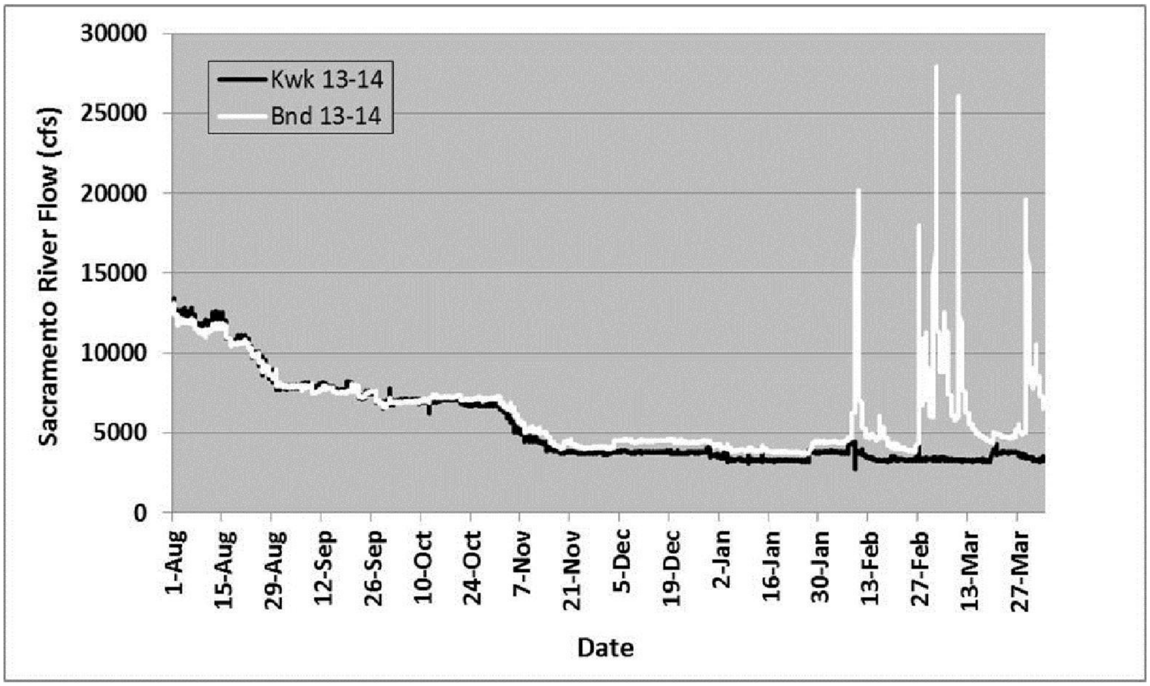


Figure 13. Graph of Sacramento River flow at KWK (below Keswick Dam) and at Bend Bridge (located 44 miles downstream of KWK) during study year 2013-2014.

Fish rescues are now a component to juvenile stranding surveys but are limited to staff time and resources. Rescues will be carried out after significant flow reductions from Keswick Dam if juvenile fish are observed stranded in disconnected pools and survival in these pools is unlikely due to dewatering or long term expected dry conditions. Rescuing every stranding site with juvenile salmon by hand is not a viable long-term solution. Other options should be investigated such as deepening connections to known stranding sites to allow connection with the main channel at the current (agency established) minimum low flow from Keswick Dam of 3,250 cfs.

The past four years of this study have demonstrated the need for flexibility and adaptability when studying the dewatering and stranding of redds and juveniles in the upper Sacramento River. Figure 14 shows the flow releases from Keswick Dam for all four study seasons. Figure 14 reveals the typical variability that occurs from year to year during the study period of interest. To continue this effort in future years, staff should be in place in late summer but because of rainfall variability the study may or may not be able to occur on any given year. Flow releases from Keswick Dam in year 2010-2011 jumped above 15,000 cfs in early-December, (Figure 14), thus effectively canceling the ability to conduct the study after early-December. In year 2011-2012 the steady flows from mid-October to mid-November resulted in few dewatering events, but this was not the case in 2012-2013 when flows were slightly decreasing but large numbers of salmon were spawning for long periods of time. The variability experienced each year points to the challenge of managing river flows, predicting precipitation timing, and staffing human resources for this project. In some future years crews will be busy all year (i.e., years similar to this dry 2013-14 season), while in others the river might be flooding for months and crews will have little opportunity to collect data. In many years natural rainfall can swell the tributaries downstream of Keswick Dam. These natural inflows raise and lower the river levels and can both prevent, and lead to, dewatering and juvenile stranding depending on timing and salmon numbers.

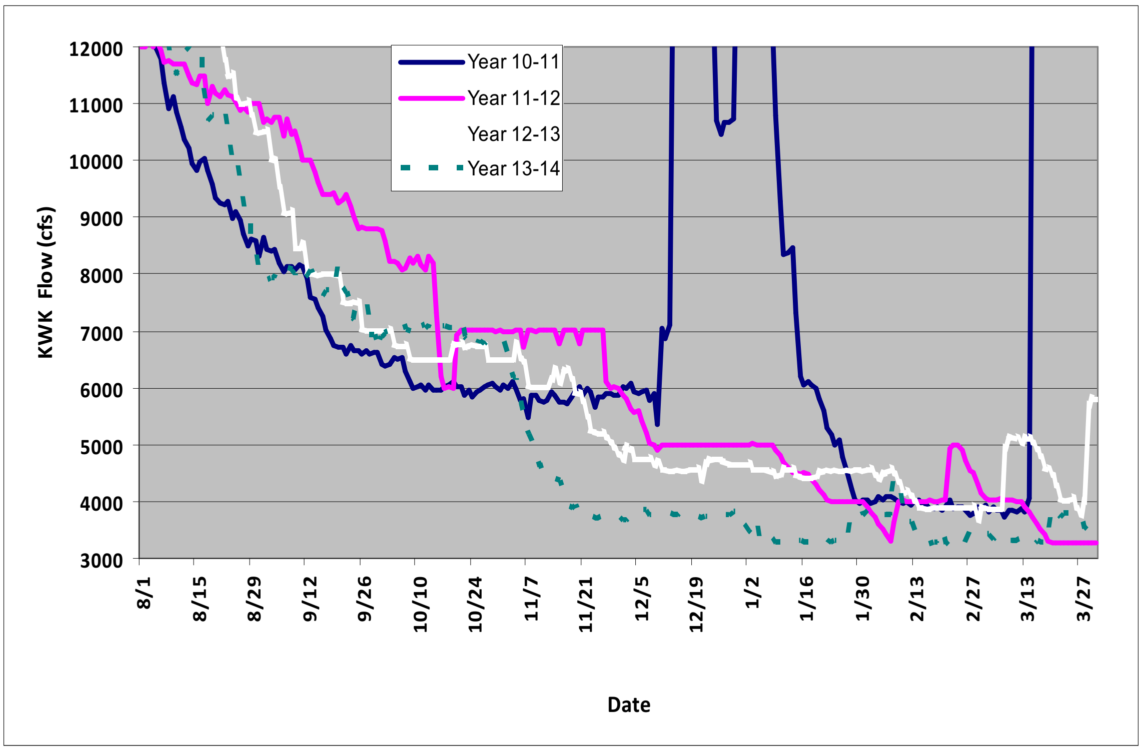


Figure 14. Graph of four years of Keswick Dam flows to the Sacramento River for the dates of interest to the dewatered redds and juvenile stranding pilot study. Year 2013-2014 uses the KWK flow gauge. Other years use KES.

This 2013-2014 study season was a very dry season. Keswick flows were reduced earlier than typical in the year despite being held around 7,000 cfs until the first of November. Without the study data on the winter-run redds, flows likely would have been dropped much sooner (in September or October) to conserve water storage in Shasta Lake. The absence of precipitation throughout most of the season resulted in limited hydrological influences from tributary streams except for some much needed, but short spanned, rain events in February of 2014 reflected on the BND trend line in the graph in Figure 13. These lower than usual flows resulted in dangerous conditions for navigating the river during surveys. The below average fall and winter flows (Figure 14) also led to the dewatering of many more redds than previously observed. The timing of flow reductions (end of October) occurred post peak spawn time of fall-run chinook which also contributed to the greater amount of dewatered redds and stranding events during this survey period.

The fourth year of the dewatered redd and juvenile stranding study made many improvements with this year's additional funding and resources. A fully funded and dedicated staff made it possible to increase the distance downstream the study could monitor and gain valuable data that normally is not available in these areas due to typical tributary high flows in winter. Additional data and measurements such as redd dimensions and egg checks were also conducted in response to the new resources. Crews were able to utilize and combine the field methods that were developed during the last three years of the pilot redd dewatering study with new techniques. The analysis and information in Appendix F. Table F1. made possible the ability to calculate flows at almost any site along the river.

Based on the data collected during this study, Sacramento River flow reductions and flow oscillations have the potential to increase the mortality of naturally produced salmonids by dewatering and/or stranding thousands of juvenile Chinook. It appears that the issue of stranding can affect juveniles of all runs, and can occur throughout the year at many different flows. It is now apparent that redd dewatering and stranding of juveniles impacts all types of habitat and has the potential of being a major impact for juvenile salmonid survival throughout the upper Sacramento River.

Future efforts will allow efficient and extensive coverage of the study areas as well as almost real-time reporting of redd dewatering and juvenile stranding. Most notably this includes further monitoring of juvenile stranding sites to provide insight on future fish rescues. Micro-habitat elements, such as hyporheic flow (intragravel flow) and water temperatures in and near redds and in stranding sites will be analyzed to gain a better understanding of egg, and juvenile survival during dewatering and stranding events. In addition, coordinating this study with other studies (such as gravel injections, habitat typing, restoration projects, CDWR efforts, etc.) will provide mutually beneficial data collection and management options. Future efforts will also begin to assess the presence of superimposition in high density spawning grounds and its impact on the total number of Chinook redds being dewatered, as a proportion of the entire spawning population. With the use of advanced technology, further studies will provide resource managers with real-time data to make educated decisions on future flow allocations and the impacts these decisions will have on Central Valley Chinook Salmon.

ACKNOWLEDGEMENTS

Many individuals participated in the data collection, project coordination and project administration efforts associated with this project, they include: Tricia Parker-Hamelberg, Valerie Emig, and Jim Smith (USFWS), Patricia Bratcher-CDFW, Stan Allen, Amy Roberts, Kat Gillies-Rector, Ryan Revnak, Darin Olsen, Byron Mache, Mike Memeo, Zach Sigler, and Tom Clifford (from the PSMFC). The authors wish to thank everyone who was involved with the data collection and administration of activities associated with this report.

LITERATURE CITED

Angilletta, M.J. Jr., E.A. Steel, K.K. Bartz, J.G. Kingsolver, M.D. Scheuerell, B.R. Beckman, and L.G. Crozier. 2008. Big dams and salmon evolution: changes in thermal regimes and their potential evolutionary consequences. Evolutionary Applications 1:286-299.

Anderson, J.J., R.T. Kneib, S.A. Luthy, and P.E. Smith. 2010. Report of the 2010 Independent Review Panel (IRP) on the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria And Plan (OCAP) for State/Federal Water Operations. Prepared for: Delta Stewardship Council, Delta Science Program. December 9. 39 pages.

Beacham, T.D. and C.B. Murray. 1990 Temperature, Egg Size, and Development of Embryos and Alevins of Five Species of Pacific Salmon: A Comparative Analysis, Transactions of the American Fisheries Society: 119:6, 927-945.

Becker, C.D., D.A. Neitzel, And C.S. Abernethy. 1983. Effects of Dewatering on Chinook Salmon Redds: Tolerance of Four Development Phases to One-Time Dewatering. North American Journal of Fisheries Management 3:373-382, 1983.

CDFW, 2014. Winter-run Chinook salmon escapement estimate for 2013. Letter from CDFW- Stafford Lehr to NMFS-Will Stelle dated January 7, 2014., 3p.

CDWR, 2013. Draft Progress Report: Investigations into Dewatered Fall-Run Chinook Salmon Redds in the Upper Sacramento River for 2010-2011. Northern Region Office, California Department of Water Resources, Red Bluff, CA. April 2013. 12p.

CDWR, 2014. Breaking Drought News. WRCC climate region dry years, ranked by inches of precipitation. Access May 06, 2014 at: http://www.water.ca.gov/waterconditions/

CDWR, 2014. California Data Exchange Center (CDEC), records of historical flow data, Keswick Reservoir. http://cdec.water.ca.gov/cgi-progs/queryF?s=kes

Cordone, Almo J.; Kelley, Don W. 1961. The Influences of inorganic sediment on the aquatic life of streams. California Fish and Game. 47(2): P. 189-228.

Fukushima M, Quinn TJ, Smoker WW.1998. Estimation of eggs lost from superimposed pink salmon (*Oncorhynchus gorbuscha*) redds. Can J Fish AquatSCi 55:618-25.

Good, T.P., R.S. Waples, and P. Adams. 2005. Updated status of federally listed ESUs of west coast salmon and steelhead. U.S. Department of Commerce. NOAA Tech. Memo. NMFS-NWFSC-66. 598 p.

Killam, D. 2012, Chinook Salmon Populations in the Upper Sacramento River Basin In 2011. CDFW-RBFO Tech. Report No.-03-2012.

Killam, D. and M. Johnson, 2013, Chinook Salmon Populations in the Upper Sacramento River Basin In 2012 CDFW-RBFO Tech. Report No. 02-2013.

Killam, D. and M. Johnson, 2014, Chinook Salmon Populations in the Upper Sacramento River Basin In 2013 CDFW-RBFO Tech. Report No. 02-2014. IN PROGRESS

Moyle, P.B 2002. Salmon and Trout, Salmonidae – Chinook Salmon, (*Oncorhynchus tshawytscha*) in Inland Fishes of California. Los Angeles, California: University of California press, 251-259.

National Marine Fisheries Service. 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. June 4, 2009. NMFS Southwest Regional Office. 844 pp. plus attachments.

National Marine Fisheries Service. 2011. Amendment to the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. June 4, 2009. NMFS Southwest Regional Office. 189 pp.

San Joanquin River Restoration Program. 2008. Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon. Redd Superimposition 4.1.3. February 7, 2008.

U.S. Fish and Wildlife Service. 1995. Working Paper: habitat restoration actions to double natural production of anadromous fish in Central Valley of California. Volume 2. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

U.S. Fish and Wildlife Service. 2001. Final Restoration Plan for the Anadromous Fish Restoration Program—A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California. Released as a Revised Draft on May 30, 1997 and Adopted as Final on January 9, 2001. 146 pp.

U.S. Fish and Wildlife Service. 2006. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook salmon and steelhead in the Sacramento River between Keswick Dam and Battle Creek. Stockton Fish and Wildlife Office. June 22, 2006. 87 pp.

U.S. Fish and Wildlife Service. 2011. Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California and Fisheries

Investigations, Annual Progress Report, Fiscal Year 2010. USFWS, Sacramento Fish and Wildlife Office, Sacramento, CA. 53 pp.

Williams, T.H., S.T. Lindley, B.C. Spence, and D.A. Boughton. 2011. Status review update for Pacific salmon listed under the Endangered Species Act: Southwest. 17 May 2001 – Update to 5 January 2001 report. National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA.

Yates, D. H. Galbraith, D. Purkey, A. Huber-Lee, J. West, S. Herrod-Julius, and B. Joyce. 2008. Climate warming, water storage, and Chinook Salmon in California's Sacramento Valley. Climate Change 91:335-350.

APPENDIX A

Relevant Excerpts from the National Marine Fisheries Service (NMFS)-Operations and Criteria Plan (OCAP) Biological Opinion.

Page 587: Project operations of the Sacramento River Division affect winter-run, spring-run, CV steelhead, the Southern DPS of green sturgeon. In addition, project operations affect fall-run, which are not listed. Fall-run salmon are considered in developing the actions as a prey base for Southern Residents. This Division section of the RPA includes actions related to minimizing adverse effects to spring-run and steelhead spawning and rearing in Clear Creek and all species in the main stem Sacramento River. Actions include those necessary to reduce the risk to temperature effects to egg incubation in the upper river, especially to winter-run and spring-run spawning below Shasta Dam.

Page 590: Action Suite I.2. Shasta Operations, Introduction to Shasta Operations: Maintaining suitable temperatures for egg incubation, fry emergence, and juvenile rearing in the Sacramento River is critically important for survival and recovery of the winter-run ESU. The winter-run ESU has been reduced to a single population, which has been blocked from its historical range above Shasta Dam. Consequently, suitable temperatures and habitat for this population must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summer. Maintaining optimum conditions for this species below Shasta is crucial until additional populations are established in other habitats or this population is restored to its historical range. Spring-run are also affected by temperature management actions from Shasta Reservoir.

The effects analysis in this Opinion highlights the very challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool. In most years, reservoir releases through the use of the TCD are a necessity in order to maintain the bare minimum population levels necessary for survival (Yates et al. 2008, Angilletta et al. 2008).

The effects analysis in this Opinion, and supplemental information provided by Reclamation, make it clear that despite Reclamation's best efforts, severe temperature-related effects cannot be avoided in some years. The RPA includes exception procedures to deal with this reality. Due to these unavoidable adverse effects, the RPA also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek that may be support a second population of winter-run, and a fish passage program at Keswick and Shasta dams to partially restore winter-run to their historical cold water habitat.

***Objectives**: The following objectives must be achieved to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:*

Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning between Balls Ferry and Bend Bridge in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.

Ensure suitable spring-run temperature regimes, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Residents.

Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.

Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.

Page 592: ***Action 1.2.1 Performance Measures.***

Objective*: To establish and operate to a set of performance measures for temperature compliance points and End-of-September (EOS) carryover storage, enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. Performance measures will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.*

Action: *The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (e.g., extended drought), then Reclamation shall reinitiate consultation with NMFS.*
Performance measures for EOS carryover storage at Shasta Reservoir:

87 percent of years: Minimum EOS storage of 2.2 MAF
82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)
40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:
Meet Clear Creek Compliance point 95 percent of time

Meet Balls Ferry Compliance point 85 percent of time
Meet Jelly's Ferry Compliance point 40 percent of time
Meet Bend Bridge Compliance point 15 percent of time

Rationale: *Evaluating long-term operations against a set of performance measures is the only way to determine the effectiveness of operations in preserving key aspects of life history and run time diversity. For example, maintaining suitable spawning temperatures down to Bend Bridge in years when this is feasible will help to preserve the part of winter-run distribution and run timing that relies on this habitat and spawning strategy. This will help to ensure that diversity is preserved when feasible. The percentages are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations.*

P 592: ***Action I.2.2*. *November through February Keswick Release Schedule (Fall Actions)***

Objective: *Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.*

Action*: Depending on EOS carryover storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

Action I.2.2.A Implementation Procedures for EOS Storage at 2.4 MAF and Above
If the EOS storage is at 2.4 MAF or above, by October 15, Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable process, to consider a range of fall actions. A written monthly average Keswick release schedule shall be developed and submitted to NMFS by November 1 of each year, based on the criteria below. The monthly release schedule shall be tracked through the work group. If there is any disagreement in the group, including NMFS technical staff, the issue/action shall be elevated to the WOMT for resolution per standard procedures.
The workgroup shall consider and the following criteria in developing a Keswick release schedule:

1) *Need for flood control space: A maximum 3.25 MAF end-of-November storage is necessary to maintain space in Shasta Reservoir for flood control.*

2) *Need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding.*

3) *Need/recommendation to implement USFWS' Delta smelt Fall X2 action as determined by the Habitat Study Group formed in accordance with the 2008 Delta smelt Opinion. NMFS will continue to participate in the Habitat Study Group (HSG) chartered through the 2008 Delta smelt biological opinion. If, through the HSG, a fall flow action is recommended that draws down fall storage significantly*

from historical patterns, then NMFS and USFWS will confer and recommend to Reclamation an optimal storage and fall flow pattern to address multiple species' needs.

If there is a disagreement at the workgroup level, actions may be elevated to NMFS Sacramento Area Office Supervisor and resolved through the WOMT's standard operating procedures.

Rationale: *2.2 MAF EOS storage is linked to the potential to provide sufficient cold water to meet the minimum Balls Ferry Compliance point in the following year, and it is achievable approximately 85 percent of the time. Based on historical patterns, EOS storage will be above 2.4 MAF 70 percent of the time. The 2.4 MAF storage value provides a reasonable margin above the 2.2 level to increase the likelihood that the Balls Ferry Compliance Point will be reached while also implementing fall releases to benefit other species and life stages. Therefore, in these circumstances, actions should target the fall life history stages of the species covered by this Opinion (i.e., spring-run spawning, winter-run emigration). The development of a Keswick release schedule is a direct method for controlling storage maintained in Shasta Reservoir. It allows Reclamation to operate in a predictable way, while meeting the biological requirements of the species. The B2IT workgroup has been used in the past to target actions to benefit fall-run during this time of year using b(2) resources, and, because of its expertise, may also be used by Reclamation to develop this flow schedule. In the past, the B2IT group has used the CVPIA AFRP guidelines to target reservoir releases. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.B Implementation Procedures for EOS Storage Above 1.9 MAF and Below 2.4 MAF

If EOS storage is between 1.9 and 2.4 MAF, then Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable workgroup, to consider a range of fall actions. Reclamation shall provide NMFS and the work group with storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February, and develop a monthly average Keswick release schedule based on the criteria below. The monthly release schedule shall be submitted to NMFS by November 1. Criteria for the release schedule shall include:

1) Maintain Keswick releases between 7000 cfs and 3250 cfs to reduce adverse effects on main stem spring-run and conserve storage for next year's cold water pool.

2) Consider fall-run needs per CVPIA AFRP guidelines, through January, including stabilizing flows to keep redds from de-watering.

3) Be more conservative in Keswick releases throughout fall and early winter if hydrology is dry, and release more water for other purposes if hydrology becomes wet. For example, release no more than 4,000 cfs if hydrology remains dry.

Reclamation, in coordination with the work group, shall review updated hydrology and choose a monthly average release for every month (November, December, January, February), based on the release schedule. In the event that the updated hydrology indicates a very dry pattern and consequent likely reduction in storage, the work group may advise Reclamation to take additional actions, including export curtailments, if necessary to conserve storage

If there is a disagreement at the work group level, actions may be elevated to NMFS and resolved through the WOMT's standard operating procedures.

***Rationale**: It is necessary to be reasonably conservative with fall releases to increase the likelihood of adequate storage in the following year to provide cold water releases for winter-run. This action is intended to reduce adverse effects on each species without compromising the ability to reduce adverse effects on another species. A work group with biologists from multiple agencies will refine the flow schedule, providing operational certainty while allowing for real-time operational changes based on updated hydrology. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:

> *1) In early October, reduce Keswick releases to 3,250 cfs as soon as possible, unless higher releases are necessary to meet temperature compliance points (see action I.2.3).*
>
> *2) Starting in early October, if cool weather prevails and temperature control does not mandate higher flows, curtail discretionary water deliveries (including, but not limited to agricultural rice decomposition deliveries) to the extent that these do not coincide with temperature management for the species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition, and any other discretionary purposes at this time of year, may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS, USFWS, and CDFG.*
>
> *3) By November 1, submit to NMFS storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February. In coordination with NMFS, Reclamation shall: (1) develop a monthly average Keswick release schedule similar in format to that in Action I.2.2.B, based on the criteria below and including actions specified below; and (2) review updated hydrology and choose a monthly average release for every month, based on the release schedule. November releases shall be based on a 90 percent hydrology estimate.*

Criteria and actions: 1) Keswick releases shall be managed to improve storage and maintained at 3,250 cfs unless hydrology improves. 2) November monthly releases will be based on 90 percent hydrology. 3) Consider fall-run needs through January as per CVPIA AFRP guidelines, including stabilizing flows to keep redds from dewatering. 4) Continue to curtail discretionary agricultural rice decomposition deliveries to the extent that these do not coincide with temperature management for the species, or impact other ESA-listed species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS. USFWS, and CDFG. 5) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then: a) CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick release (or other planned release based on biological needs of species); and b) if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom; and c) in general, Reclamation shall increase releases from Keswick as a last resort. d) Based on updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence. 6) If the hydrology and storage have not improved by January, additional restrictions apply – see Action I.2.4.

Rationale: *Per actions I.2.3 and I.2.4 below, Reclamation is required to meet 1.9 MAF EOS. The BA's CALSIM modeling shows that during a severe or extended drought, 1.9 EOS storage may not be achievable. In this circumstance, Reclamation should take additional steps in the fall and winter months to conserve Shasta storage to the maximum extent possible, in order to increase the probability of maintaining cold water supplies necessary for egg incubation for the following summer's cohort of winter-run. Assessment of the hydrologic record and CALSIM modeling shows that operational actions taken during the first year of a drought sequence are very important to providing adequate storage and operations in subsequent drought years. The biological effects of an extended drought are particularly severe for winter-run. Extended drought conditions are predicted to increase in the future in response to climate change. While it is not possible to predict the onset of a drought sequence, in order to ensure that project operations avoid jeopardizing listed species, Reclamation should operate in any year in which storage falls below 1.9 MAF EOS as potentially the first year of a drought sequence. The CVP storage system is likely to recover more quickly in the winter and spring months if additional storage conservation measures are taken in the fall and winter. The curtailments to discretionary rice decomposition deliveries and combined export curtailment of 2,000 cfs are necessary to conserve storage when EOS storage is low. These actions were developed through an exchange of information and expertise with Reclamation operators. This action is consistent with comments from the Calfed Science Peer Review panel. That panel recommended that Shasta be operated on a two-year (as opposed to single year) hydrologic planning cycle and that Reclamation take additional steps to incorporate planning for potential drought and extended drought into its operations.*

APPENDIX B

Reference Tables of Salmon Biological Life History Traits.

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.9%
9000																2.2%	5.5%
8000															2.6%	6.6%	11.5%
7500														0.8%	4.4%	9.1%	14.1%
7000													0.9%	2.0%	6.6%	11.8%	17.3%
6500												1.3%	2.6%	4.2%	9.8%	15.6%	21.1%
6000											1.2%	2.8%	4.6%	6.5%	12.9%	19.7%	25.8%
5500										1.4%	3.2%	5.4%	7.7%	10.3%	17.6%	24.9%	31.0%
5250									0.7%	2.1%	4.2%	6.8%	9.4%	12.3%	19.8%	27.2%	33.1%
5000								0.7%	1.3%	3.2%	5.6%	6.6%	11.6%	14.7%	22.6%	30.2%	36.0%
4750							0.8%	1.6%	2.5%	4.8%	7.6%	10.8%	14.2%	17.6%	25.8%	33.2%	38.8%
4500						0.8%	1.7%	2.8%	4.0%	6.9%	10.4%	14.2%	18.2%	22.1%	30.9%	38.8%	44.2%
4250					0.8%	1.6%	2.7%	4.0%	5.4%	8.9%	13.0%	17.2%	21.6%	25.8%	34.9%	42.8%	48.0%
4000				0.9%	1.7%	2.8%	4.1%	5.7%	7.3%	11.4%	15.8%	20.3%	24.8%	29.0%	38.0%	45.7%	50.7%
3750			0.9%	1.6%	2.6%	3.9%	5.5%	7.3%	9.2%	13.6%	18.4%	23.1%	28.0%	32.4%	41.5%	48.7%	53.6%
3500		1.0%	2.1%	3.2%	4.6%	6.2%	8.1%	10.1%	12.2%	17.0%	22.2%	27.4%	29.2%	37.0%	45.9%	52.8%	57.3%
3250	1.0%	2.0%	3.4%	4.8%	6.6%	8.4%	10.6%	12.9%	15.3%	20.6%	26.2%	31.7%	37.0%	41.5%	50.2%	56.3%	60.4%

USFWS, SFWO, Energy Planning and Instream Flow Branch
Sacramento River (Keswick Dam to Battle Creek) Redd Dewatering and Juvenile Stranding Final Report
June 22, 2006 55

Appendix B. Table B1. Example of a relationship table developed in Gard's USFWS 2006 report between salmon spawning flows and redd development flows shown in percentage of total redds dewatered, if development flows less than spawning flows.

Percentage and cumulative percentages

		Based on years--82-86		1970-1988		1970-1988		1970-1986		1970-1988	
		Winter Run		**Spring Run**		**Fall Run**		**Late-Fall**		**Steelhead**	
	Week	%	cum.%	%	cum.%	%	cum.%	%	cum.%	%	cum.%
	1	1.70	3.45					6.50	55.39	0.97	91.84
JAN	2	1.78	5.23					6.32	61.71	0.80	92.64
	3	0.35	5.57					3.07	64.77	0.61	93.25
	4	1.28	6.85					2.91	67.69	0.50	93.75
	5	2.38	9.23					3.58	71.26	0.29	94.05
FEB	6	3.12	12.35					4.08	75.34	0.45	94.50
	7	3.08	15.44					4.19	79.54	0.56	95.06
	8	0.97	16.41					4.38	83.91	0.53	95.59
	9	6.35	22.76					3.29	87.20	0.49	96.09
MAR	10	7.72	30.48					2.14	89.34	0.46	96.54
	11	9.23	39.70	start				1.74	91.08	0.38	96.92
	12	7.79	47.49	0.10	0.10			3.39	94.47	0.30	97.22
	13	4.91	52.40	0.25	0.35			2.08	96.55	0.28	97.50
	14	7.64	60.04	0.59	0.93			1.82	98.37	0.35	97.85
APR	15	8.26	68.29	0.96	1.89			1.39	99.76	0.28	98.12
	16	9.19	77.48	1.38	3.27			0.24	100.00	0.19	98.31
	17	3.47	80.95	1.63	4.90			end		0.17	98.48
	18	2.02	82.98	1.60	6.50					0.16	98.63
MAY	19	1.60	84.58	1.71	8.21					0.17	98.80
	20	2.17	86.75	2.16	10.37					0.23	99.03
	21	3.09	89.84	2.63	13.00	start				0.18	99.20
	22	2.03	91.87	2.86	15.86	0.01	0.01			0.20	99.40
JUN	23	1.63	93.50	2.61	18.47	0.00	0.02			0.13	99.54
	24	1.84	95.34	2.93	21.40	0.01	0.03			0.14	99.68
	25	0.51	95.85	3.50	24.89	0.03	0.06			0.15	99.82
	26	0.76	96.61	3.10	27.99	0.08	0.14			0.18	100.00
	27	1.60	98.20	3.67	31.66	0.10	0.24			0.13	0.13
JUL	28	0.31	98.52	6.02	37.68	0.29	0.53			0.18	0.31
	29	1.04	99.55	4.75	42.44	0.49	1.02			0.18	0.49
	30	0.44	99.99	3.21	45.65	0.70	1.72			0.22	0.72
	31	0.01	100.00	4.12	49.77	0.96	2.68			0.26	0.98
AUG	32	end		6.97	56.74	1.68	4.36			0.39	1.36
	33			6.07	62.81	2.95	7.31			0.68	2.04
	34			6.75	69.55	3.53	10.84			1.12	3.16
	35			5.74	75.29	3.91	14.75			2.36	5.52
	36			7.22	82.51	4.54	19.29			3.82	9.34
SEP	37			6.68	89.19	5.59	24.88			5.80	15.14
	38			5.23	94.42	8.58	33.46			7.54	22.67
	39			3.70	98.12	9.24	42.70			8.95	31.63
	40			1.19	99.31	10.49	53.19	start		11.75	43.37
OCT	41			0.69	100.00	10.59	63.78	0.26	0.26	11.27	54.65
	42			end		8.97	72.75	2.06	2.32	9.79	64.44
	43					6.99	79.74	2.33	4.65	6.51	70.95
	44					6.70	86.44	3.27	7.92	5.17	76.12
NOV	45					4.68	91.12	4.24	12.16	4.04	80.17
	46					2.71	93.83	3.42	15.58	2.44	82.61
	47					2.23	96.06	3.65	19.23	2.21	84.82
	48	start				1.68	97.74	5.37	24.60	2.05	86.87
DEC	49	0.17	0.17			0.90	98.64	5.27	29.87	1.44	88.31
	50	0.38	0.55			0.66	99.30	5.27	35.14	1.04	89.35
	51	0.49	1.04			0.51	99.81	6.94	42.08	0.69	90.04
	52	0.71	1.75			0.19	100.00	6.81	48.89	0.83	90.87

Appendix B. Table B2. Average migration timing for the various salmonid runs passing the Red Bluff Diversion Dam 1970-1988.

Fork Lengths by day sampled not SID

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Jan	0-41	42-55	56-111	112-202	203-270	1-Jan
2-Jan	0-41	42-55	56-112	113-230	231-270	2-Jan
3-Jan	0-41	42-56	57-112	113-205	206-270	3-Jan
4-Jan	0-41	42-56	57-113	114-206	207-270	4-Jan
5-Jan	0-42	43-56	57-114	115-207	208-270	5-Jan
6-Jan	0-42	43-57	58-115	116-209	210-270	6-Jan
7-Jan	0-42	43-57	58-115	116-210	211-270	7-Jan
8-Jan	0-43	44-58	59-116	117-211	212-270	8-Jan
9-Jan	0-43	44-58	59-117	118-213	214-270	9-Jan
10-Jan	0-43	44-58	59-118	119-214	215-270	10-Jan
11-Jan	0-43	44-59	60-119	120-216	217-270	11-Jan
12-Jan	0-44	45-59	60-119	120-217	218-270	12-Jan
13-Jan	0-44	45-59	60-120	121-218	219-270	13-Jan
14-Jan	0-44	45-60	61-121	122-220	221-270	14-Jan
15-Jan	0-45	46-60	61-122	123-221	222-270	15-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
16-Jan	0-45	46-61	62-123	124-223	224-270	16-Jan
17-Jan	0-45	46-61	62-123	124-224	225-270	17-Jan
18-Jan	0-45	46-61	62-124	125-226	227-270	18-Jan
19-Jan	0-46	47-62	63-125	126-227	228-270	19-Jan
20-Jan	0-46	47-62	63-126	127-229	230-270	20-Jan
21-Jan	0-46	47-63	64-127	128-230	231-270	21-Jan
22-Jan	0-47	48-63	64-127	128-232	233-270	22-Jan
23-Jan	0-47	48-64	65-128	129-233	234-270	23-Jan
24-Jan	0-47	48-64	65-129	130-235	236-270	24-Jan
25-Jan	0-48	49-64	65-130	131-236	237-270	25-Jan
26-Jan	0-48	49-65	66-131	132-238	239-270	26-Jan
27-Jan	0-48	49-65	66-132	133-239	240-270	27-Jan
28-Jan	0-49	50-66	67-133	134-241	242-270	28-Jan
29-Jan	0-49	50-66	67-133	134-243	244-270	29-Jan
30-Jan	0-49	50-67	68-134	135-244	245-270	30-Jan
31-Jan	0-50	51-67	68-135	136-246	247-270	31-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Feb	0-50	51-67	68-136	137-247	248-270	1-Feb
2-Feb	0-50	51-68	69-137	138-249	250-270	2-Feb
3-Feb	0-50	51-68	69-138	139-251	252-270	3-Feb
4-Feb	0-50	51-69	70-139	140-252	253-270	4-Feb

1

Appendix B. Table B3. Example of juvenile salmon fork length table allowing run classification by date and length developed for use in California Central Valley investigations.

APPENDIX C

Example of Field Datasheets used in 2013-2014 Redd Dewatering and Stranding Study.

SACRAMENTO RIVER REDD DEWATERING STUDY DATA SHEET

Date:_____/_____/_______ Water temp:_______ Weather:________ GPS #________

River Section ___________ USE NEW PAGE EACH SECTION 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow SURVEY ID# from computer_______

Boat __________ Water clarity:_______ (nearest 1/2 foot) Crew:_____,_____,_____ Agency (s)______________

carcass survey boat = 1 (and 2 if both doing redds), 3= specific boat redd survey, 4= redds only 2nd boat, 5= walking to redd areas

COMMENTS: take pic of marker number another of marker on the redd

NEW REDDS FIRST OBSERVED (not previously marked) Try to ensure Redd Tag Number and Waypoint similar

	DISC #	Time	Waypoint #	R-Mile	Pict #	Salmon Present	Dewatered	Sample Type	Depth "	Comments
1						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
2						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
3						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
4						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
5						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
6						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
7						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
8						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
9						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
10						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
11						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
12						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
13						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
14						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
15						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
16						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
17						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
18						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
19						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
20						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
21						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
22						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
23						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
24						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
25						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
26						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
27						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
28						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
29						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
30						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
31						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
32						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
33						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
34						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
35						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
36						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
37						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
38						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
39						0 1 2 3	0 1 2 3 4	0 1 2 3 4		
40						0 1 2 3	0 1 2 3 4	0 1 2 3 4		

Codes:

Redd # is the Disc Tag number- it helps if same as waypoint number

Salmon Present = **0**-none, **1**-on redd, **2**-seen in area, **3**-redd dewatered

Dewatered ? = **0**-No, **1**-Top only, **2**-Mostly, **3**-Pot still wet, **4**-Pot dry

Sample Type = **0**- marked + pic only, **1**-measured, **2**-egg check, **3**-Marked and Measured, **4**-All (use back if measuring)

River Sections- **1**= up from ACID, **2**= up from Hwy 44, **3**=up from Clear **4**=up from Balls, **5**=up from Battle, **6**=up from Jellys, **7**=up from Bend **8**=up from RBDD, **9**=up from Los Mo, **10**=all down from Los Mo

DEPTH is inches of H20 of top of redd, can be negative (-99 is dry)

Appendix C. Figure C1. Front side of redd dewatering field datasheet.

REVERSE SIDE of SACRAMENTO Dewatered REDD DATA SHEET DATE:____/____/____ Section_____ Boat # _________

REDDS PREVIOUSLY MARKED

	REDD #	Time	Picture #	Dewatering of Marked Redd	Action Taken	Depth "	Comments
1				0 1 2 3 4	0 1 2 3 4 5		
2				0 1 2 3 4	0 1 2 3 4 5		
3				0 1 2 3 4	0 1 2 3 4 5		
4				0 1 2 3 4	0 1 2 3 4 5		
5				0 1 2 3 4	0 1 2 3 4 5		
6				0 1 2 3 4	0 1 2 3 4 5		
7				0 1 2 3 4	0 1 2 3 4 5		
8				0 1 2 3 4	0 1 2 3 4 5		
9				0 1 2 3 4	0 1 2 3 4 5		
10				0 1 2 3 4	0 1 2 3 4 5		
11				0 1 2 3 4	0 1 2 3 4 5		
12				0 1 2 3 4	0 1 2 3 4 5		
13				0 1 2 3 4	0 1 2 3 4 5		
14				0 1 2 3 4	0 1 2 3 4 5		
15				0 1 2 3 4	0 1 2 3 4 5		
16				0 1 2 3 4	0 1 2 3 4 5		
17				0 1 2 3 4	0 1 2 3 4 5		
18				0 1 2 3 4	0 1 2 3 4 5		
19				0 1 2 3 4	0 1 2 3 4 5		
20				0 1 2 3 4	0 1 2 3 4 5		
21				0 1 2 3 4	0 1 2 3 4 5		
22				0 1 2 3 4	0 1 2 3 4 5		
23				0 1 2 3 4	0 1 2 3 4 5		
24				0 1 2 3 4	0 1 2 3 4 5		
25				0 1 2 3 4	0 1 2 3 4 5		
26				0 1 2 3 4	0 1 2 3 4 5		
27				0 1 2 3 4	0 1 2 3 4 5		
28				0 1 2 3 4	0 1 2 3 4 5		
29				0 1 2 3 4	0 1 2 3 4 5		
30				0 1 2 3 4	0 1 2 3 4 5		

Codes: Depth inches to highest point (-99 is dry)

Dewatering of Marked Redds: 0-No, 1-Top only, 2-Mostly, 3-Pot dewatered but still wet, 4-Pot dry

Action Taken: 0-None, 1-photo 2-Measured, 3-marker rock placed, 4-egg/fry check, 5-combination use comments

REDD MEASUREMENTS in feet (use for both new or previously marked redds)

	Redd #	Total length	Pot length	Pot wide	Pot Depth	Tail wide 1st-2nd	Flow avg (m/sec) (4spots = frt,side,side,back)	Substrate	H20 temp (f°) (pot)
1						,	, , , , avg =	1 2 3 4	
2						,	, , , , avg =	1 2 3 4	
3						,	, , , , avg =	1 2 3 4	
4						,	, , , , avg =	1 2 3 4	
5						,	, , , , avg =	1 2 3 4	
6						,	, , , , avg =	1 2 3 4	
7						,	, , , , avg =	1 2 3 4	
8						,	, , , , avg =	1 2 3 4	
9						,	, , , , avg =	1 2 3 4	
10						,	, , , , avg =	1 2 3 4	
11						,	, , , , avg =	1 2 3 4	
12						,	, , , , avg =	1 2 3 4	
13						,	, , , , avg =	1 2 3 4	
14						,	, , , , avg =	1 2 3 4	
15						,	, , , , avg =	1 2 3 4	
16						,	, , , , avg =	1 2 3 4	
17						,	, , , , avg =	1 2 3 4	
18						,	, , , , avg =	1 2 3 4	
19						,	, , , , avg =	1 2 3 4	
20						,	, , , , avg =	1 2 3 4	

Substrate codes (circle predominant): 1- normal spawn size (3-5") cobble; 2-smaller gravel (trout1-3"), 3-larger cobble- (5-12"), 4-sandy

Pot depth is to surrounding undistrubed river bed

Appendix C. Figure C2. Rear side of redd dewatering field datasheet.

SAC RIV JUVENILE FISH STRANDING SURVEY DATA USE NEW Pg per SECTION see reverse for more section codes, fish lengths

Date:_____/______/_______ **River temp:**________ **Weather:**__________ **GPS #**__________ SURVEY ID _________

River Section __________ 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow fill in at office

Boat _____________ **Water clarity:**_______ **Crew:**_____,_______,______ **Agency (s)**____________________

carcass survey boat = 1 (and 2 if both doing stranding), 3= specific boat stranding survey, 4= stranding only 2nd boat, 5= walking (no boat) to standing areas

COMMENTS: Fill out fish fork cutoffs before the survey based on date. Take pics of all stranding locations surveyed

	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				

CODES: Time:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle

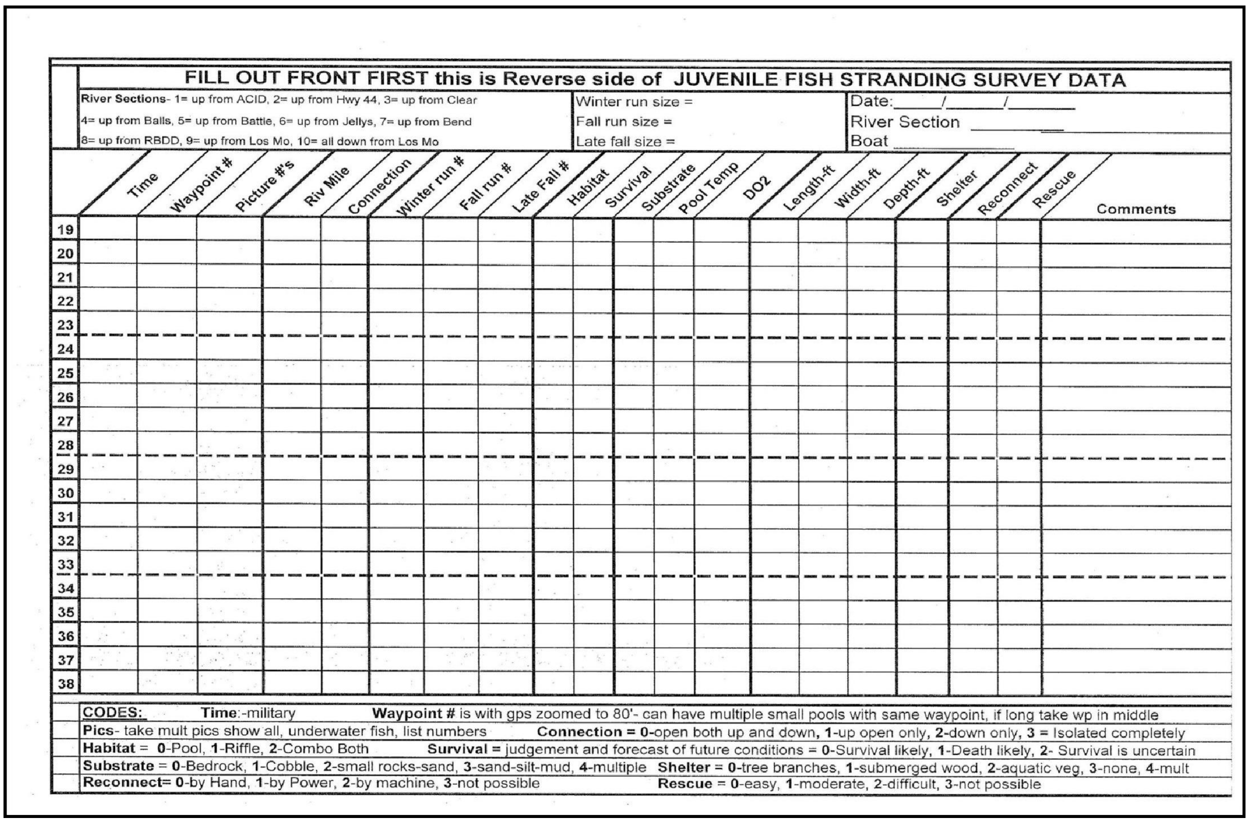
Pics- take mult pics show all, underwater fish, list numbers **Connection = 0**-open both up and down, **1**-up open only, **2**-down only, **3** = Isolated completely

Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival** = judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain

Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter** = **0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult

Reconnect= **0**-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

Appendix C. Figure C3. Front side of juvenile stranding field datasheet.



FILL OUT FRONT FIRST this is Reverse side of JUVENILE FISH STRANDING SURVEY DATA

River Sections- 1= up from ACID, 2= up from Hwy 44, 3= up from Clear
4= up from Balls, 5= up from Battle, 6= up from Jellys, 7= up from Bend
8= up from RBDD, 9= up from Los Mo, 10= all down from Los Mo

Winter run size =
Fall run size =
Late fall size =

Date:____/____/____
River Section ______
Boat ______

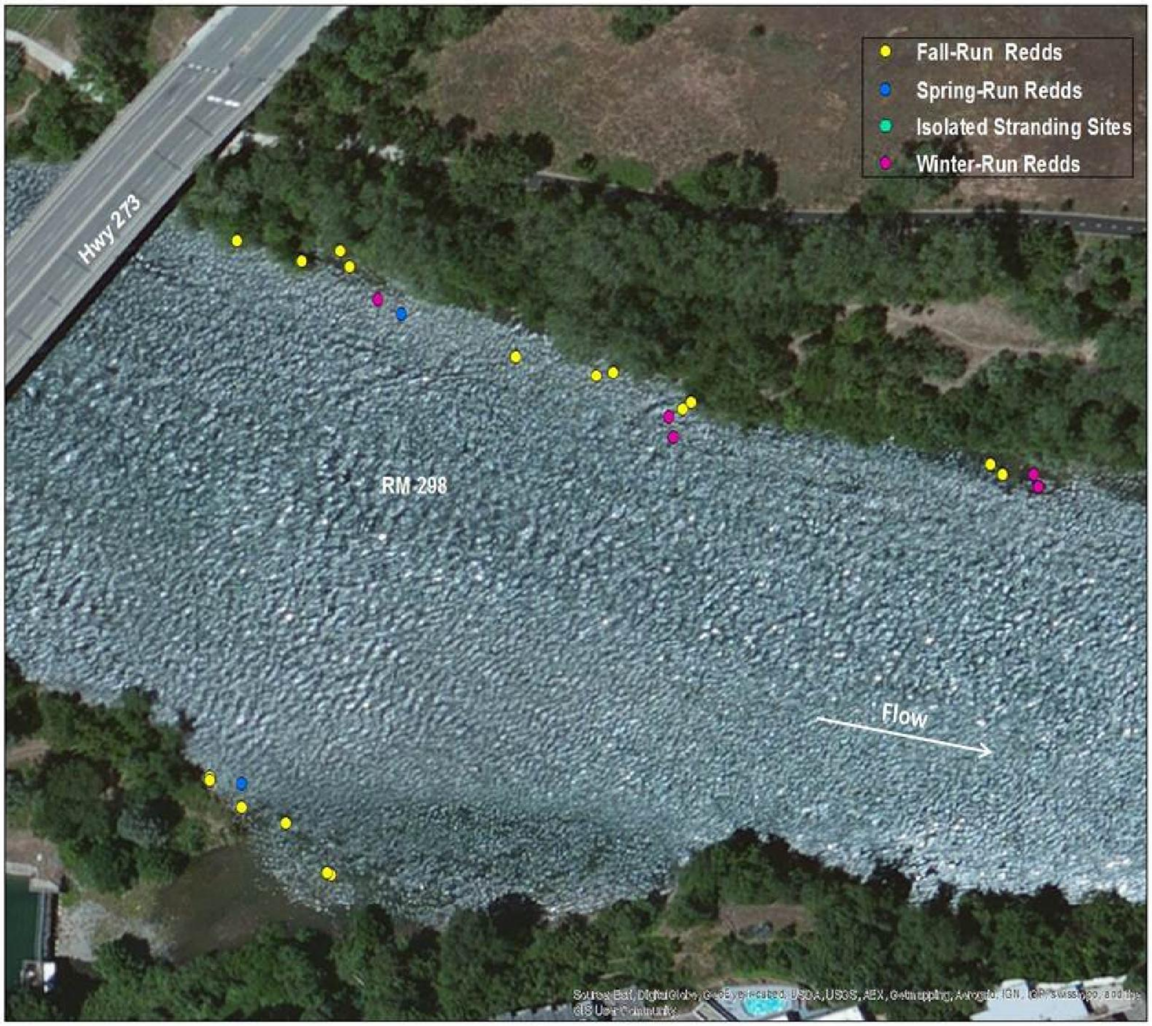
	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
32																				
33																				
34																				
35																				
36																				
37																				
38																				

CODES: **Time**:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle
Pics- take mult pics show all, underwater fish, list numbers **Connection = 0**-open both up and down, **1**-up open only, **2**-down only, **3** = Isolated completely
Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival =** judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain
Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter = 0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult
Reconnect= 0-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

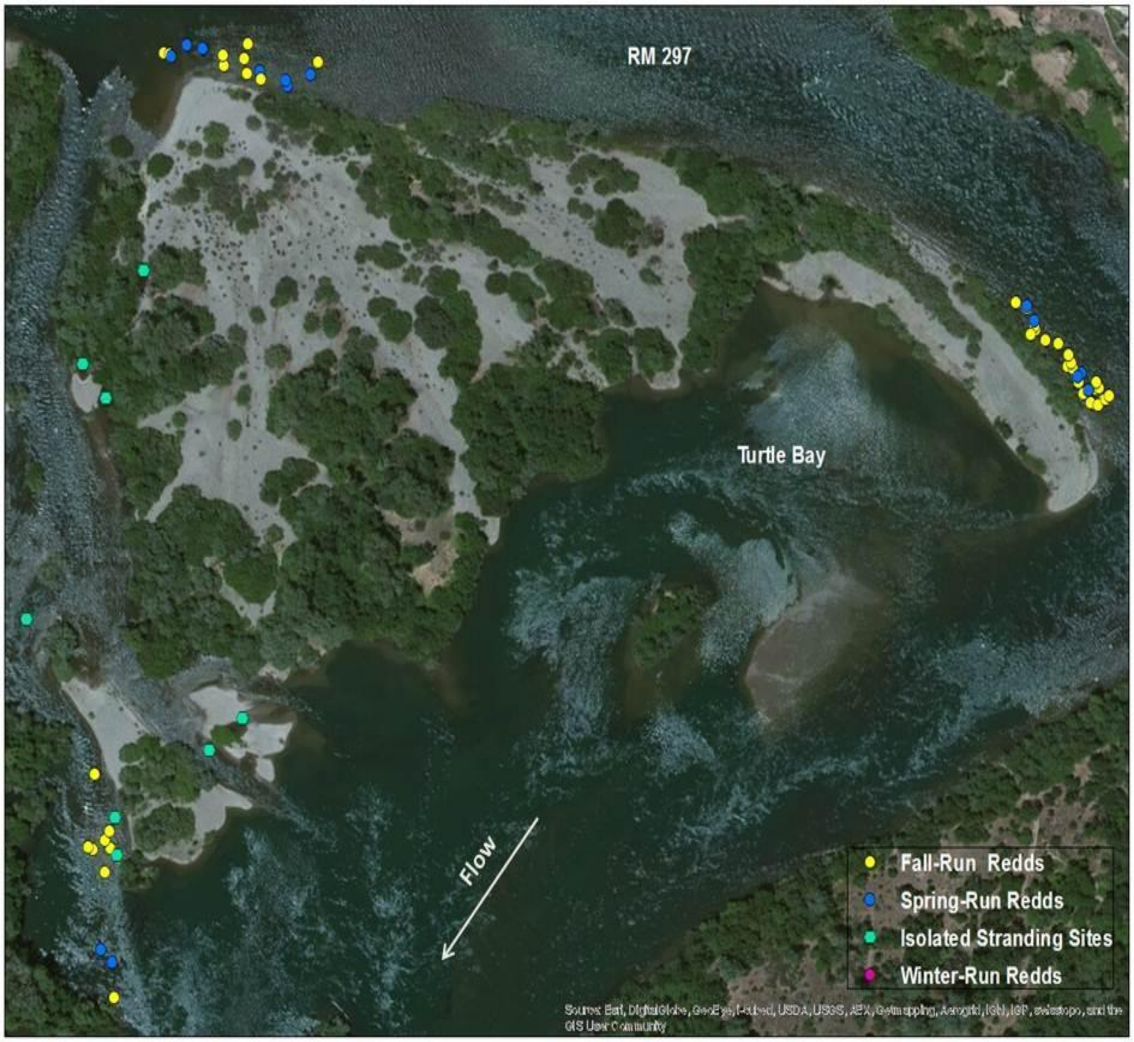
Appendix C. Figure C4. Rear side of juvenile stranding field datasheet.

APPENDIX D

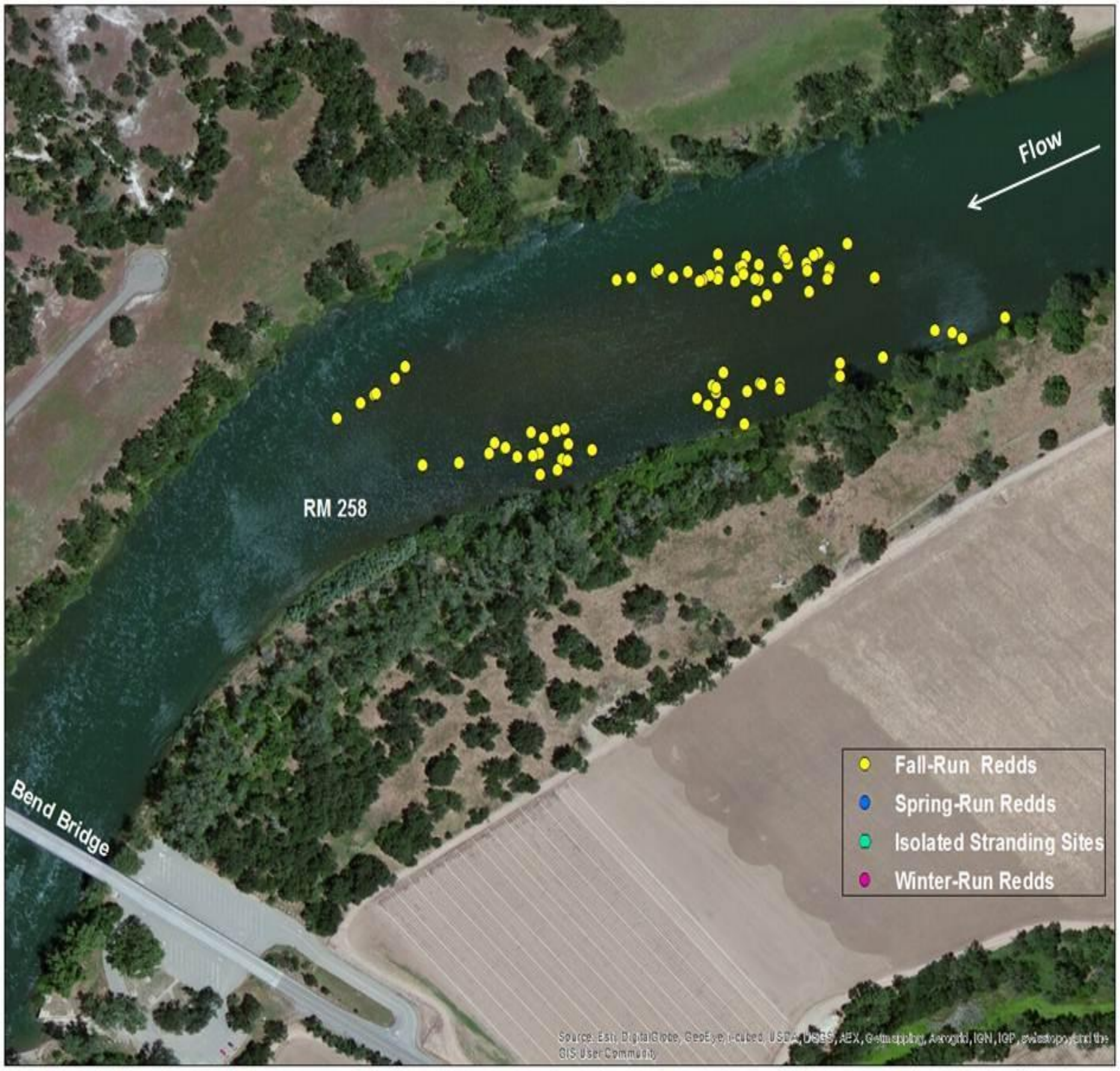
Example locations of Stranding Sites and Chinook Redds Marked During the 2013-2014 Monitoring Season. Maps and site locations for entire river survey reach are available upon request.



Appendix D. Figure D1. Location of dewatered redds at river mile 298 in Redding. Includes fall, spring and winter-run Chinook redds dewatered at various times during the 2013-2014 survey.



Appendix D. Figure D2. Dewatered redds and stranding sites at river mile 297 in Redding, CA. Several stranding sites contained winter-run Chinook juveniles.



Appendix D. Figure D3. Dewatered fall-run Chinook redds above Bend Bridge near Red Bluff, CA.

APPENDIX E

Photographs of Redd Dewatering and Juvenile Stranding from the 2013-2014 Study on the Sacramento River.

Appendix E. Figure E1. Juvenile winter-run Chinook in a stranding pool on the Sacramento River, November 22, 2013. Keswick Dam flow: 3,850 cfs.

Appendix E. Figure E2. Bedrock and cobble stranding pool, Sacramento River, September 20, 2013. Keswick Dam flow: 4,472 cfs.

Appendix E. Figure E3. Exposed cobble stranding pool, Sacramento River, September 20, 2013. Keswick Dam flow: 3,893 cfs.

Appendix E. Figure E4. Stranding pool containing winter-run Chinook. Sacramento River, November 26, 2013. Keswick Dam flow: 3,893 cfs.

Appendix E. Figure E5. Stranding site #401, located in side channel below Hwy 44 bridge. Contained an estimated 50 juvenile salmonids on November 19, 2013. Photo taken January 21, 2014. Keswick Dam flow: 3,260 cfs.

Appendix E. Figure E6. Stranding site containing juvenile winter-run Chinook, Sacramento River, November 15, 2013. Keswick Dam flow 3,893 cfs.

Appendix E. Figure E7. Dewatered Chinook redd being marked during survey, Sacramento River, December 12, 2013. Keswick Dam flow: 3,887 cfs.

Appendix E. Figure E8. Dewatered Chinook redd (top only dewatering), Sacramento River, November 14, 2013. Keswick Dam flow: 3,887 cfs.

Appendix E. Figure E9. Dewatered fall-run Chinook redd (mostly dewatered), Sacramento River November 27, 2013.

Appendix E. Figure E10. Dewatered fall-run Chinook redd (pot still wet), Sacramento River January 13, 2014.

Appendix E. Figure E11. Dewatered fall-run Chinook redd (completely dry), Sacramento River near Bend Bridge (RM 258) January 13, 2014.

Appendix E. Figure E12. Dewatered fall-run Chinook redds, Sacramento River near Riverview Country Club golf course in Redding (RM 292).

Appendix E. Figure E13. Decomposed Chinook eggs excavated from dewatered redd, Sacramento River December 3, 2013.

APPENDIX F

Relationship between Distance and Time and Flows for the Sacramento River between Keswick Dam (RM 302) and Tehama Bridge (RM 229).

Note to use this table: use recorded time of day and the river mile of your point of interest (redd, stranding site, etc). River miles are divided into half miles and segments begin at downstream edge. Subtract the time from this table from the actual time at site location. Compare this calculated time to the closest (15 minute) corresponding KWK or KES gauge time and use CDEC site to obtain a river flow value for the calculated time. This flow value is the actual flow at your point of interest, minus any tributary inputs.

Appendix F. Table F1. Times for Sacramento River flows to travel downstream from Keswick Dam to Tehama CA. by half-river miles (RM). Green highlight indicates locations with flow measuring sites.

Miles	RM	KES Time	KWK Time	Location
0.0	302	0:00		KESWICK DAM (KES Gauge)
0.5	301.5	0:06		
1.0	301	0:11	0:02	KWK Gauge is 0.75 miles downstream
1.5	300.5	0:17	0:08	
2.0	300	0:23	0:14	
2.5	299.5	0:28	0:20	
3.0	299	0:34	0:25	Diestelhorst Bridge-Redding CA
3.5	298.5	0:40	0:31	
4.0	298	0:46	0:37	
4.5	297.5	0:51	0:43	
5.0	297	0:57	0:49	Turtle Bay-Redding CA
5.5	296.5	1:03	0:54	
6.0	296	1:09	1:00	
6.5	295.5	1:15	1:06	
7.0	295	1:20	1:12	Cypress Street Bridge-Redding CA
7.5	294.5	1:26	1:17	
8.0	294	1:32	1:23	
8.5	293.5	1:38	1:29	
9.0	293	1:43	1:35	
9.5	292.5	1:49	1:40	
10.0	292	1:55	1:46	Bonnyview Bridge-Redding CA
10.5	291.5	2:01	1:52	
11.0	291	2:06	1:58	
11.5	290.5	2:12	2:04	
12.0	290	2:18	2:09	
12.5	289.5	2:24	2:15	
13.0	289	2:30	2:21	Clear Creek mouth
13.5	288.5	2:35	2:27	
14.0	288	2:41	2:32	
14.5	287.5	2:47	2:38	
15.0	287	2:53	2:44	I5 close below Burbon Island

Appendix F. Table F1. Continued:

Miles	RM	KES Time	KWK Time	Location
15.5	286.5	2:58	2:50	
16.0	286	3:04	2:55	
16.5	285.5	3:10	3:01	
17.0	285	3:16	3:07	I5 Bridge-Anderson CA
17.5	284.5	3:21	3:13	
18.0	284	3:27	3:19	Airport Road Bridge- Anderson CA
18.5	283.5	3:33	3:24	
19.0	283	3:39	3:30	
19.5	282.5	3:45	3:36	
20.0	282	3:50	3:42	
20.5	281.5	3:56	3:47	
21.0	281	4:02	3:53	Deschutes Road Bridge-
21.5	280.5	4:08	3:59	
22.0	280	4:13	4:05	Cow Creek mouth
22.5	279.5	4:19	4:10	
23.0	279	4:25	4:16	
23.5	278.5	4:31	4:22	
24.0	278	4:36	4:28	
24.5	277.5	4:42	4:34	
25.0	277	4:48	4:39	Ash Creek-Mouth
25.5	276.5	4:54	4:45	
26.0	276	5:00	4:51	Balls Ferry Bridge-Cottonwood CA
26.5	275.5	5:05	4:57	
27.0	275	5:11	5:02	
27.5	274.5	5:17	5:08	
28.0	274	5:23	5:14	
28.5	273.5	5:28	5:20	
29.0	273	5:34	5:25	Cottonwood Creek mouth
29.5	272.5	5:40	5:31	
30.0	272	5:46	5:37	
30.5	271.5	5:51	5:43	
31.0	271	5:57	5:49	Battle Creek mouth
31.5	270.5	6:03	5:54	
32.0	270	6:09	6:00	Barge Hole Fishing Access
32.5	269.5	6:15	6:06	
33.0	269	6:20	6:12	Lake California Area side channel
33.5	268.5	6:26	6:17	
34.0	268	6:32	6:23	
34.5	257.5	6:38	6:29	
35.0	267	6:43	6:35	Jellys Ferry Road Bridge
35.5	266.5	6:49	6:40	
36.0	266	6:55	6:46	
36.5	265.5	7:01	6:52	
37.0	265	7:06	6:58	
37.5	264.5	7:12	7:04	
38.0	264	7:18	7:09	Inks Creek mouth
38.5	263.5	7:24	7:15	

Appendix F. Table F1. Continued:

Miles	RM	KES Time	KWK Time	Location
39.0	263	7:30	7:21	Massacre Flat BLM camp
39.5	262.5	7:35	7:27	
40.0	262	7:41	7:32	
40.5	261.5	7:47	7:38	
41.0	261	7:53	7:44	
41.5	260.5	7:58	7:50	BEND Gauge is at RM 260.4
42.0	260	8:05	7:57	
42.5	259.5	8:12	8:03	
43.0	259	8:19	8:10	
43.5	258.5	8:26	8:17	
44.0	258	8:33	8:24	Bend District Road Bridge
44.5	257.5	8:39	8:31	
45.0	257	8:46	8:38	
45.5	256.5	8:53	8:45	
46.0	256	9:00	8:51	
46.5	255.5	9:07	8:58	
47.0	255	9:14	9:05	China Rapids
47.5	254.5	9:21	9:12	
48.0	254	9:27	9:19	
48.5	253.5	9:34	9:26	
49.0	253	9:41	9:33	Paynes Creek mouth
49.5	252.5	9:48	9:39	
50.0	252	9:55	9:46	
50.5	251.5	10:02	9:53	
51.0	251	10:09	10:00	
51.5	250.5	10:15	10:07	
52.0	250	10:22	10:14	Powerlines in Iron Canyon
52.5	249.5	10:29	10:21	
53.0	249	10:36	10:27	
53.5	248.5	10:43	10:34	
54.0	248	10:50	10:41	
54.5	247.5	10:57	10:48	
55.0	247	11:03	10:55	Dibble Creek mouth
55.5	246.5	11:10	11:02	
56.0	246	11:17	11:09	
56.5	245.5	11:24	11:15	
57.0	245	11:31	11:22	Antelope Ave. Bridge-Red Bluff CA
57.5	244.5	11:38	11:29	
58.0	244	11:45	11:36	
58.5	243.5	11:51	11:43	Red Bank Creek mouth
59.0	243	11:59	11:51	RBD Gauge is at RM 242.9
59.5	242.5	12:07	11:58	
60.0	242	12:15	12:06	
60.5	241.5	12:22	12:14	
61.0	241	12:30	12:21	
61.5	240.5	12:38	12:29	
62.0	240	12:46	12:37	mouth of Salt Creek

Appendix F. Table F1. Continued:

Miles	RM	KES Time	KWK Time	Location
62.5	239.5	12:53	12:45	
63.0	239	13:01	12:52	mouth of Craig Creek
63.5	238.5	13:09	13:00	
64.0	238	13:16	13:08	
64.5	237.5	13:24	13:15	
65.0	237	13:32	13:23	
65.5	236.5	13:40	13:31	
66.0	236	13:47	13:39	
66.5	235.5	13:55	13:46	Butler Slough mouth
67.0	235	14:03	13:54	
67.5	234.5	14:10	14:02	
68.0	234	14:18	14:10	Antelope Creek mouth
68.5	233.5	14:26	14:17	
69.0	233	14:34	14:25	Coyote Creek mouth
69.5	232.5	14:41	14:33	
70.0	232	14:49	14:40	Dye Creek mouth
70.5	231.5	14:57	14:48	
71.0	231	15:05	14:56	
71.5	230.5	15:12	15:04	Elder Creek mouth
72.0	230	15:20	15:11	Mill Creek mouth
72.5	229.5	15:28	15:19	TEH Gauge is at RM 229.3
73.0	229	15:35	15:27	Tehama CA