Lower Mokelumne River Salmonid Redd Survey Report:
October 2013 through March 2014

September 2014

Robyn Bilski and Ed Rible
East Bay Municipal Utility District, 1 Winemasters Way, Lodi, CA 95240

Key words: lower Mokelumne River, salmonid, fall-run Chinook salmon, steelhead, rainbow trout, redd survey, spawning, superimposition, gravel enhancement

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Abstract

Weekly fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and winter-run steelhead/rainbow trout (*O. mykiss)* spawning surveys were conducted on the lower Mokelumne River from 17 October 2013 through 3 March 2014. Estimated total escapement during the 2013/2014 season was 12,252 Chinook salmon. The estimated number of in-river spawners was 7,071 Chinook salmon. The first salmon redd was detected on 17 October 2013. During the surveys, 1,823 salmon redds were identified. Two hundred and sixty (14.3%) Chinook salmon redds were superimposed on other Chinook salmon redds and 1,044 (57.3%) redds were located within spawning habitat restoration sites. The reach from Camanche Dam to Mackville Road (reach 6) contained 1,548 (85%) salmon redds and the reach from Mackville Road to Elliott Road (reach 5) contained 275 (15%) salmon redds. The highest number of Chinook salmon redd detections (448) took place during survey week 6 on 19 and 20 November 2013. Sixty-eight *O. mykiss* redds were identified during the surveys. The first *O. mykiss* redd was found on 23 December 2013. Two *O. mykiss* redds were superimposed on other *O. mykiss* redds. Twenty-three (33.8%) *O. mykiss* redds were located within spawning habitat restoration sites. Reach 6 contained 44 (65.7%) *O. mykiss* redds and reach 5 contained 24 (35.3%) *O. mykiss* redds. The highest number of *O. mykiss* redds (13) was detected on 21 January 2014.

INTRODUCTION

The Mokelumne River is an east-Delta tributary that drains more than 1,642 square kilometers (600 square miles) of the western slope of the Sierra Nevada with headwaters at an elevation of 3,048 meters (10,000 feet) on the Sierra Nevada Crest (Jones and Stokes 1999). The Mokelumne River currently has 16 major water impoundments including Salt Springs Reservoir, Lower Bear River Reservoir, Pardee Reservoir and Camanche Reservoir. Water releases to the lower Mokelumne River (LMR) are controlled by Camanche Dam. The LMR is approximately 103 river kilometers (rkm) in length from the confluence with the San Joaquin River (rkm 0) and Camanche Dam (the first major impoundment and limit to anadromy, rkm 103). The construction of Camanche Dam was completed in 1963 and blocked upstream passage of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) to much of the available historical spawning habitat in the Mokelumne River. Most of the available spawning habitat in the LMR is now limited to the 15.8 km (9.8 mile) section of river directly downstream of Camanche Dam (Setka and Bishop 2003).

Pardee and Camanche reservoirs and associated power generating facilities are owned and operated by the East Bay Municipal Utility District (EBMUD) and regulated by the Federal Regulatory Energy Commission (FERC Project P-2916), which provides water for approximately 1.3 million customers in Alameda and Contra Costa counties. Additional reservoirs and power generation facilities are located upstream of Pardee Reservoir and are owned and operated by Pacific Gas & Electric Company (PG&E). Downstream of Camanche Dam, Woodbridge Irrigation District (WID) operates Woodbridge Irrigation District Dam (WIDD) and an associated system of irrigation canals near Lodi, CA.

The LMR is utilized for spawning and rearing by fall-run Chinook salmon and both resident and anadromous forms of *O. mykiss*. Adult Chinook salmon ascend the LMR as early as August and may begin spawning in early September. Spawning activity usually peaks in November and tapers off through the month of December (Hartwell 1996; Marine and Vogel 1994; Setka 1997). The Mokelumne River Fish Installation (MRFI) was constructed in 1964 to mitigate for spawning habitat lost during the construction of Camanche Dam and receives approximately 64% of the total run per year (1990-2012 average). EBMUD has conducted annual spawning surveys on the LMR since 1990 (Hagar 1991; Hartwell 1996; Setka 1997). EBMUD conducts video monitoring at WIDD to assess the upstream passage of anadromous fishes. Video monitoring provides an escapement estimate of the total number of Chinook salmon and steelhead returning to the LMR each season.

OBJECTIVES

The primary objective of the 2013/2014 salmonid redd surveys (referred to as the 2013 season) was to enumerate Chinook salmon and *O. mykiss* redds in the LMR. Additional objectives of the redd surveys included:

- Determine the spatial and temporal distribution of redds in the LMR;
- Enumerate redds impacted by superimposition; and
- Determine use of spawning habitat restoration (SHR) sites.

METHODS

Surveys

The LMR is divided into six reaches between Camanche Dam and the confluence with the San Joaquin River. Reach delineations are based on gradient, substrate, and tidal influence. The majority of salmonid spawning habitat on the LMR is available in reaches 5 and 6. Therefore, redd surveys were conducted within reaches 5 and 6. Specifically, the surveys took place within a 16-rkm reach, from rkm 103 (the base of Camanche Dam) downstream to rkm 87.4 (Figure 1). Weekly redd surveys began on 17 October 2013 and were concluded on 3 March 2014. Both reaches were surveyed once per week during this time frame. Surveys consisted of two to three individuals walking abreast downstream

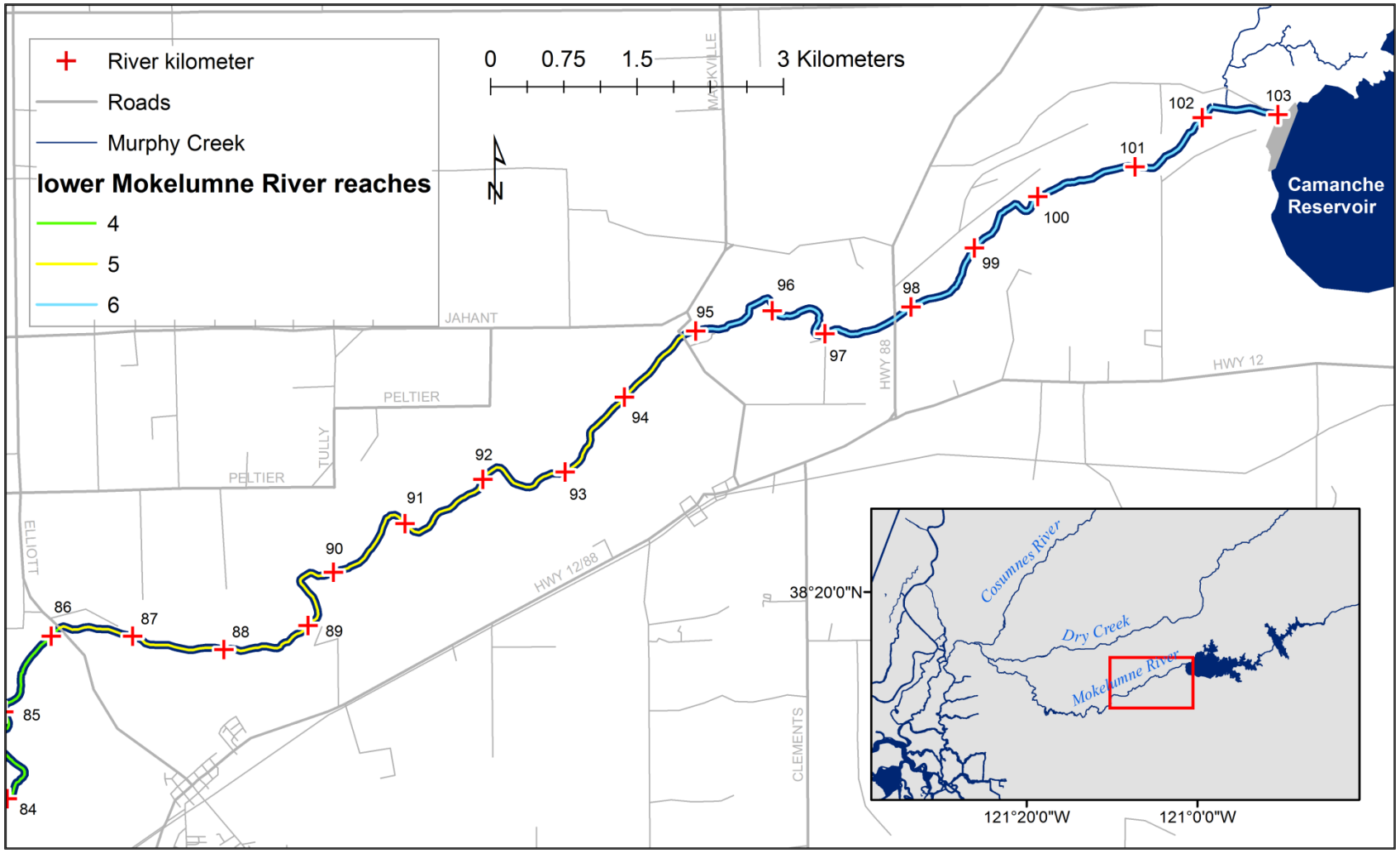

Figure 1. The location of river reaches 5 and 6 on the lower Mokelumne River, where salmonid redd surveys took place during the 2013 season.

(water depths up to 1.2 meters) searching for redds. This method has been used in past Mokelumne River spawning surveys and in other rivers and streams (Keefe et al. 1994; Fritsch 1995; Hartwell 1996; Setka 1997). A drift boat was used to transport surveyors between spawning areas and was also used to search for redds in areas that were not wadeable.

In previous years, redd locations were marked with numbered cattle ear tags and/or colored bricks. More recently, however, Global Navigation Satellite Systems (GNSS) have been used to mark salmonid redd locations. The Trimble Geo XH GNSS units record more accurate positions (<1 meter real-time) and have the capability to display previously recorded data in the field. The ability to see data from previous surveys eliminated the need to physically mark redds and reduced the potential of counting a redd more than once. Surveyors positioned themselves directly downstream of each redd and recorded the position of the tailspill. Care was taken to avoid impacting redds during the surveys.

Surveyors determined if previously detected redds were superimposed based on the amount of time that had elapsed since a redd was first detected. A 3-week (21 days) filter was used to help distinguish older redds from newly constructed redds. The filter was based on the estimated life of fall-run Chinook salmon redds (Gallagher et al. 2007). All visible occurrences of redd superimposition were recorded.

Throughout the 2013 salmonid redd surveys, a subset of water depth and velocity measurements was recorded just above the nose of Chinook salmon and *O. mykiss* redds. In an attempt to capture a random subsample of measurements accounting for spatial and temporal variability, water depth and velocity data were recorded from one of every ten Chinook salmon redds detected throughout the survey period. Because fewer *O. mykiss* redds are detected on an annual basis, water depths and velocities were measured at nearly all *O. mykiss* redds detected during the survey period. Water depth measurements were recorded to the nearest centimeter (cm) using a top-setting rod. Velocity measurements were taken using a Flo-Mate™ portable velocity meter (Marsh McBirney, Inc.) at 60% of the depth and were recorded in meters per second (m/s).

Surface water temperature and flow data were obtained from EBMUD gauging stations at Camanche Dam (rkm 103), McIntire (rkm 101), and Elliot Road (rkm 86). In addition, a total of sixteen StowAway Tidbit waterproof temperature loggers were buried below the gravel surface on 13 October 2013 to record subsurface water temperatures on an hourly basis. Two temperature loggers were buried at depths of 25 cm and 40 cm within eight spawning sites between Camanche Dam (rkm 103) and Elliot Road (rkm 86). A Trimble Geo XH GNSS unit was used to mark the burial locations of the temperature loggers. The temperature loggers were recovered from the gravel on 3 March 2014, after the majority of Chinook salmon fry were predicted to have emerged from their redds according to an egg model developed by Vogel (1993).

Data Collection and Analysis

Staff collected a minimum of ten points on the GNSS unit at each redd location and point data files were stored using Terrasync 5.21 software. After field data were collected, the data files were downloaded and processed using GPS Pathfinder Office 5.30 software. Once downloaded, geographic positions were corrected using the nearest base data providers. The point data files were then imported to an ArcMap 10 (ESRI) database.

Data analyses were performed using ArcMap 10 (Arc/Info (ESRI) systems), JMPIN 8.0.1 (Academic), Microsoft (MS) Access 2010 and MS Excel 2010. A P-value ≤ 0.05 was considered statistically significant.

RESULTS

Environmental Data

In 2013, a series of pulse flows were released throughout October and in the beginning of November (Figure 2). Average daily flow from Camanche Dam peaked at 472 cubic feet per second (cfs) on 8 October 2013, during the first pulse flow. Average daily flow peaked at roughly 400 cfs during the following four pulses (Figure 2).

During the redd survey period (17 October 2013 – 3 March 2014) average daily discharge from Camanche Dam ranged from 204 to 434 cfs (Figure 2). The average daily flow during this time period was 264 cfs. The average daily flow when Chinook salmon redds were detected (17 October 2013 through 13 January 2014) ranged from 254 to 434 cfs and averaged 271 cfs. The average daily flow when *O. mykiss* redds were detected (23 December 2013 through 3 March 2014) ranged from 204 cfs to 257 cfs and averaged 252 cfs.

Average daily surface water temperatures at the McIntire gauging station (rkm 101, reach 6) ranged from 10.2°C to 15.4°C during the survey period (Figure 2). The average temperature during this time frame was 12.2°C. The average daily water temperatures during the time period salmon redds were detected (17 October 2013 through 13 January 2014) ranged from 10.5°C to 15.4°C and averaged 13°C . The average daily water temperatures during the time period when *O. mykiss* redds were detected(23 December 2013 through 3 March 2014) ranged from 10.2°C to 11.6°C and averaged 10.7°C.

Twelve of the sixteen temperature loggers were recovered from below the gravel surface at burial depths of 25 cm and 40 cm on 3 March 2014. The remaining four temperature loggers, buried at rkm 101 and rkm 100.3, were unrecoverable. A comparison of maximum daily subsurface water temperatures recorded at burial depths of 25 and 40 cm and maximum daily surface water temperatures at the McIntire (rkm 101) and Elliot Road (rkm 86) gauging stations is presented graphically in Figure 3.

Maximum daily subsurface water temperatures recorded at 25 cm below the gravel surface during the first half of the incubation period for the majority of Chinook salmon

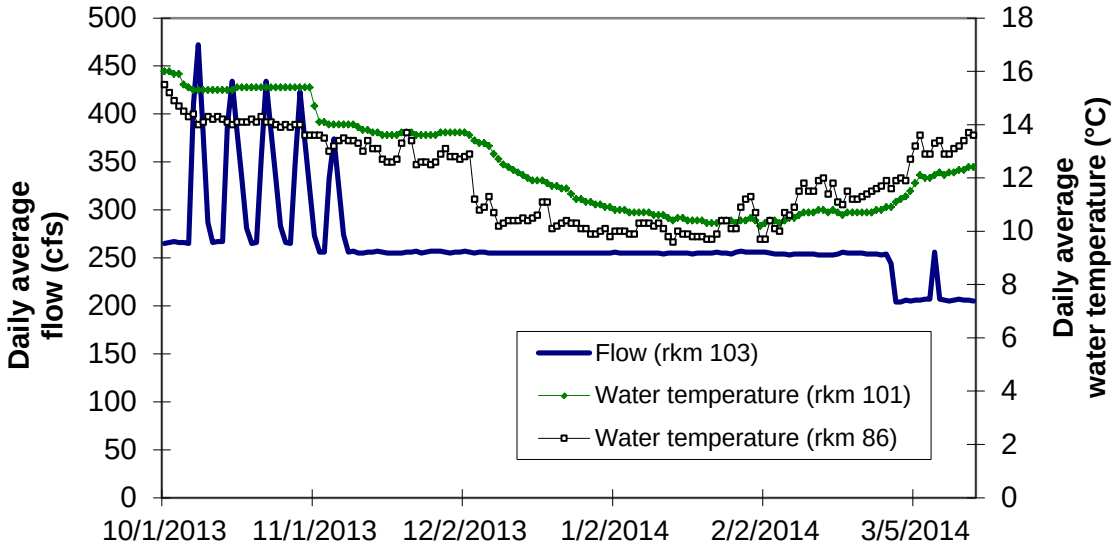

Figure 2. Average daily discharge from Camanche Dam (rkm 103) and surface water temperatures at the McIntire gauging station (rkm 101) and the Elliot Road gauging station (rkm 86) in the lower Mokelumne River during the 2013 salmonid redd surveys.

embryos (23 October 2013 through 1 January 2014) averaged 13.1°C and ranged between 10.5 and 15.2°C. During the same time frame, maximum daily subsurface water temperatures recorded at 40 cm below the gravel surface averaged 12.9°C and ranged between 10.5 and 15.0°C. Prior to 1 November 2013, daily maximum surface water temperatures at the McIntire gauge were higher than all daily maximum subsurface water temperatures, regardless of burial depth (Figure 3). However, between 1 November 2013 and 1 January 2014 daily maximum surface water temperatures at the McIntire gauge were similar to most daily maximum subsurface water temperatures recorded at 25 cm below the gravel surface. Daily maximum surface water temperatures recorded at the Elliot Road gauging station were generally lower than all daily maximum subsurface water temperatures recorded on or before 1 January 2014.

Maximum daily subsurface water temperatures recorded at 25 cm below the gravel surface during the second half of the incubation period for the majority of Chinook salmon embryos (2 January through 3 March 2014) averaged 11.3°C and ranged between 10.3 and 13.3°C. During the same time frame, maximum daily subsurface water temperatures recorded at 40 cm below the gravel surface averaged 11.0°C and ranged between 10.2 and 13.0°C. In general, daily maximum surface water temperatures at the McIntire gauge were similar to, or slightly lower than, most daily maximum subsurface water temperatures recorded during the second half of the incubation period. Daily maximum surface water temperatures recorded at the Elliot Road gauging station were more variable than water temperatures at the McIntire gauge, rising above and falling below daily maximum subsurface water temperatures.

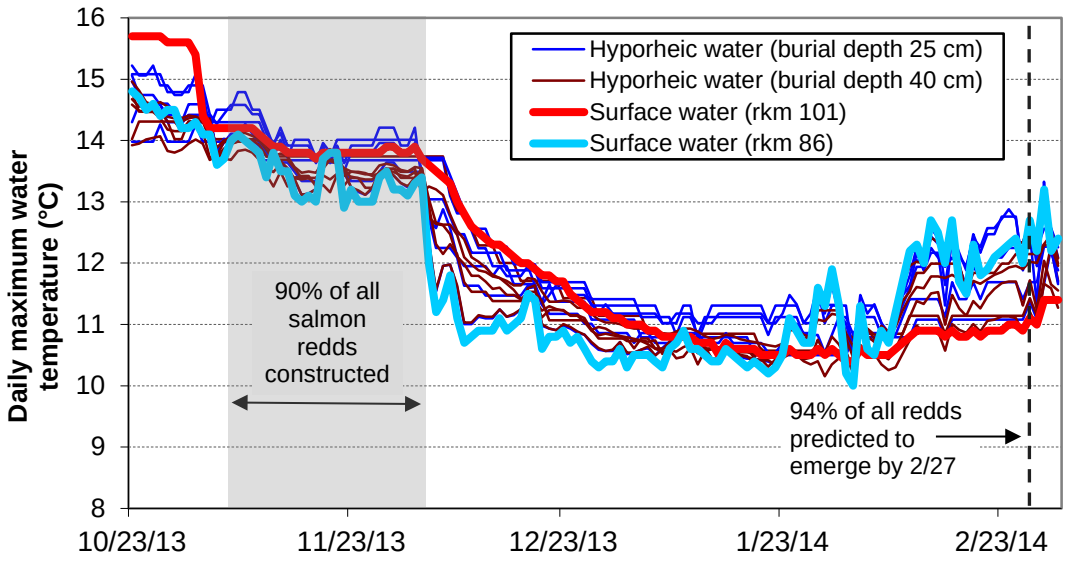

Figure 3. Maximum daily surface and subsurface (hyporheic) water temperatures recorded on the lower Mokelumne River during the 2013 redd survey season.

During the complete study time frame (23 October 2013 through 3 March 2014), maximum daily subsurface water temperature was not significantly different by site (two-way ANOVA: $F_{5, 1577} = 1.48$, $P = 0.193$), however, maximum daily subsurface water temperature was significantly different by burial depth (two-way ANOVA: $F_{1, 1577} = 12.20$, $P < 0.001$).

Chinook Salmon

Redd totals and escapement

During the 21 week redd survey period, 1,823 Chinook salmon redds were detected. The first and last redd detections occurred on 17 October 2013 and 13 January 2014, respectively. The highest number of redds (448) was detected during survey week 6 on 19 and 20 November 2013 (Figure 4). Reach 6 contained 1,548 redds (85%) and reach 5 contained 275 redds (15%). One weekly survey (week 12) was missed due to a staffing shortage and weekly surveys were scheduled to avoid storm events during the 2013 survey season, for improved water clarity and detection ability.

The 2013 annual redd count was 150% above the long term average (1990-2012) of 729, 192% above the pre-Joint Settlement Agreement (JSA) average (1990-1997) of 625, and 133% above the post-JSA average (1998-2012) of 784 (Figure 5).

To estimate fall-run Chinook salmon escapement in the LMR during the 2013 season, video monitoring was conducted at WIDD from 1 August 2013 to 31 March 2014.

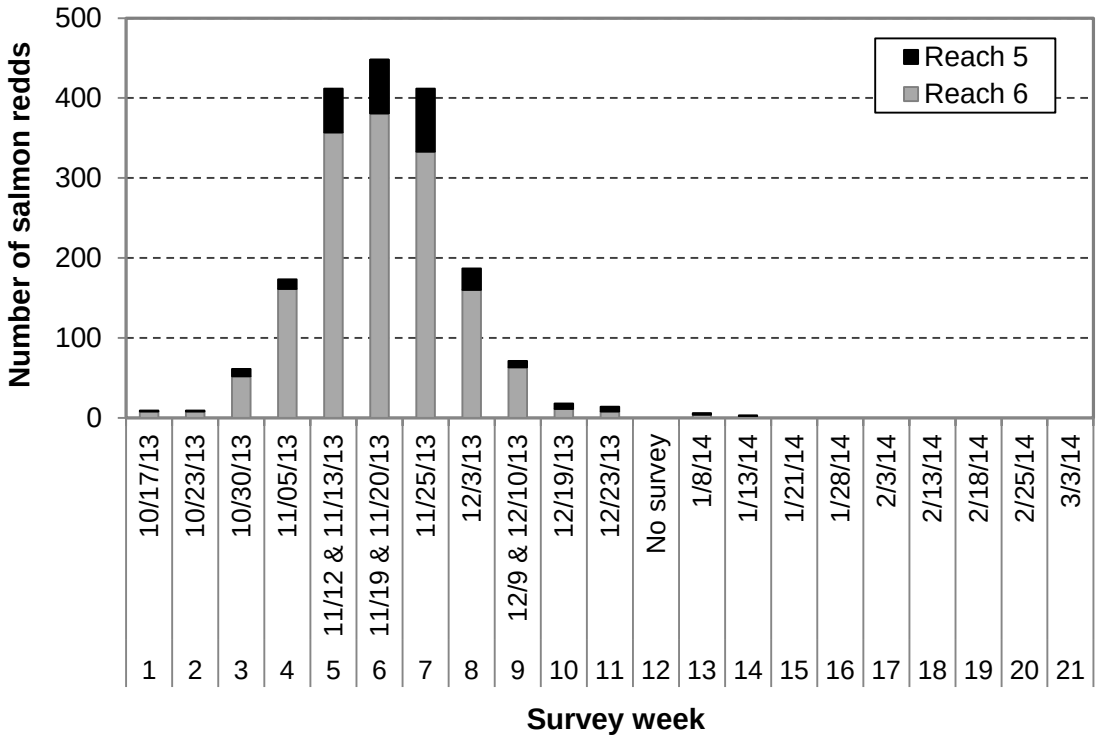

Figure 4. Weekly Chinook salmon redd totals by reach on the lower Mokelumne River during the 2013 surveys.

During this time, 12,252 Chinook salmon were counted passing the fish ladders at WIDD. The total count of Chinook salmon that entered the MRFI this season was 5,181.

The LMR in-river escapement estimate of 7,071 fall-run Chinook salmon was calculated by subtracting the MRFI salmon count from the video monitoring count at WIDD. Most of the Chinook salmon that returned to the LMR were classified as adults (9,499, 78%), while the remaining 22% (2,747) were classified as grilse, and less than 1% (6) could not be identified. Sexual composition of the run was, 54% (6,664) male, 46% (5,580) female, and less than 1% (8) could not be determined.

Spawning habitat restoration site usage

During the 2013 redd survey, 657 (36%) Chinook salmon redds were found within the restored upper 1-km reach, just below Camanche Dam (SHIRA reach). Overall, 1,044 (57.3%) Chinook salmon redds were constructed within SHR sites. In reach 6, 950 redds (91%) were constructed in SHR sites. Ninety-four salmon redds (9%) were constructed in SHR sites in reach 5.

Superimposition

Two hundred and sixty Chinook salmon redds (14.3%) were superimposed on other Chinook salmon redds during the 2013 redd survey season. Most of the superimposition took place in reach 6 (239 redds), while just 21 redds were superimposed in reach 5. The

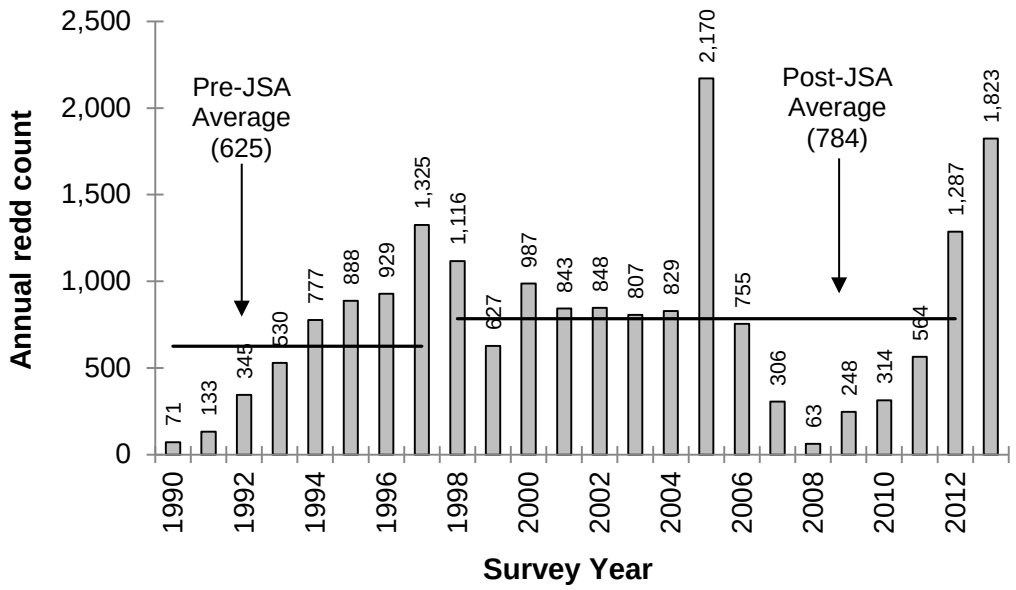

Figure 5. Chinook salmon redd totals on the lower Mokelumne River during pre-JSA flows (1990 – 1997), post-JSA flows (1998 – 2012), and for the 2013 survey season.

2013 superimposition rate was higher than the long-term average of 10.4% (1991-2012), the pre-JSA average of 9.0% (1991-1997) and the post-JSA average of 11% (1998-2012). There was a significant positive linear relationship between the annual red count and the annual superimposition rate (Linear regression: $F = 27.03$; df = 1, 21; $P < 0.001$). The annual redd count explained 56% of the variation in the annual superimposition rate.

Habitat use – water depth and velocity

One hundred and seventy-nine water depth measurements and 183 water velocity measurements were taken just above the nose of Chinook salmon redds from 17 October 2013 to 8 January 2014. During this time frame, average daily discharge from Camanche Dam ranged from 255 to 434 cfs, however discharge did not exceed 383 cfs on the dates the measurements were recorded. Chinook salmon redd water depths ranged from 22 to 110 cm and averaged 52 cm (SD = 18). The central 50% of measured redd depths (between Q1 and Q3) were between 38 and 66 cm. Water velocity measurements ranged from 0.04 to 1.24 m/s and averaged 0.56 m/s (SD = 0.21). The central 50% of measured redd velocities were between 0.41 and 0.68 m/s.

Overall, water depths and velocities just above the nose of Chinook salmon redds appeared similar between survey years and flow ranges (Figure 6). Survey year did not have a statistically significant effect on redd water velocity (two-way ANOVA: $F_{3, 405} = 1.57$, $P = 0.196$) or redd water depth (two-way ANOVA: $F_{3, 397} = 2.17$, $P = 0.091$). In addition, flow range did not have a statistically significant effect on redd water velocity (two-way ANOVA: $F_{2, 405} = 2.56$, $P = 0.079$) or redd water depth (two-way ANOVA: $F_{2, 397} = 0.29$, $P = 0.750$).

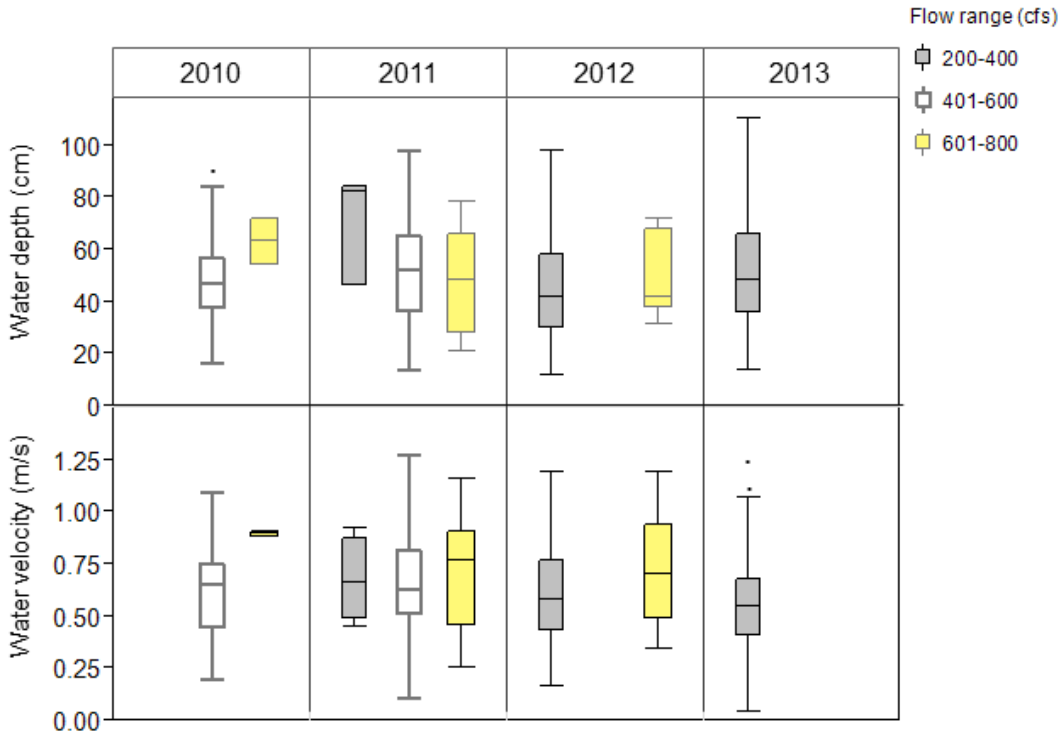

Figure 6. Boxplots of water depths and velocities measured just above the nose of Chinook salmon redds by survey year (2010-2013) and by flow range (200-400 cfs, 401-600 cfs, 601-800 cfs) on the lower Mokelumne River.

Oncorhynchus mykiss

Redd totals

Sixty-eight *O. mykiss* redds were detected during the 2013 salmonid redd survey. The first and last detections occurred on 23 December 2013 and 3 March 2014, respectively. The largest number of *O. mykiss* redds (13) was detected on 21 January 2014 (Figure 7). Reach 6 contained 44 redds (65.7%) and reach 5 contained 24 redds (35.3%). The 2013 annual redd count was 37.7% above the long-term (2000-2012) average of 49 (Figure 8).

Spawning habitat restoration site usage

During the 2013 redd survey, 13 (19.1 %) *O. mykiss* redds were found within the SHIRA reach. Overall, 23 *O. mykiss* redds, or 33.8% of the total number of redds detected (68), were constructed in SHR sites. Eighty percent (17) of redds constructed in SHR sites were located in reach 6 and 20% (6) were located in reach 5.

Superimposition

Two *O. mykiss* redds were superimposed on other *O. mykiss* redds and two were superimposed on Chinook redds during the 2013 season. Both incidents of

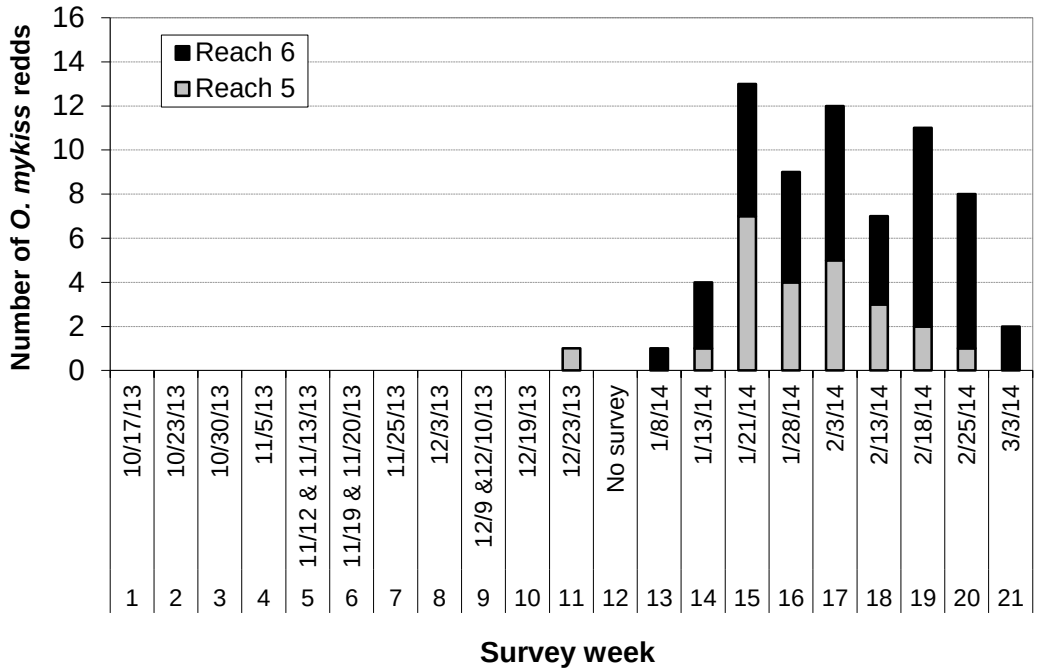

Figure 7. Weekly *O. mykiss* redd totals by reach on the lower Mokelumne River during the 2013 survey season.

superimposition on another *O. mykiss* redd took place above the MRFI barrier fence (rkm 103), where spawning habitat is limited.

Habitat use – water depth and velocity

Fifty-seven water depth and water velocity measurements were taken just above the nose of *O. mykiss* redds between 13 January 2014 and 3 March 2014. Discharge from Camanche Dam ranged from 204 to 257 cfs on the dates the measurements were taken. Water depths ranged from 18 to 114 cm and averaged 66 cm (SD = 21). The central 50% of measured *O. mykiss* redd depths (between Q1 and Q3) were between 52 and 82 cm. Water velocity measurements ranged from 0.11 m/s to 1.28 m/s and averaged 0.60 m/s (SD = 0.22). The central 50% of measured *O. mykiss* redd velocities were between 0.50 and 0.69 m/s.

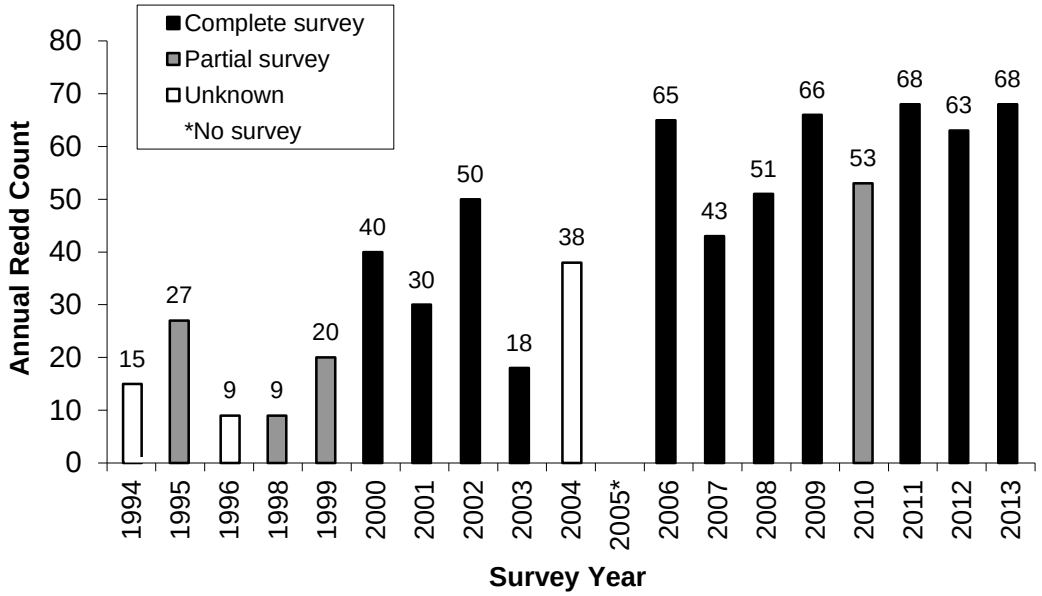

Figure 8. Annual *O. mykiss* redd totals on the lower Mokelumne River from 1994-2013.

DISCUSSION

Maximum daily subsurface water temperatures at 40 cm below the gravel surface were significantly higher than maximum daily subsurface water temperatures at 25 cm below the gravel surface during the Chinook salmon embryo incubation period. However, the majority of subsurface water temperatures at all burial depths fell between the maximum daily surface water temperatures recorded at the McIntire gauge and the Elliot road gauge during the first half of the incubation period. This time frame coincides with a critical period for incubating Chinook salmon embryos, as maximum daily water temperatures frequently fall outside of the range necessary for maximum embryo survival (5 to13°C) (McCullough 1999). Therefore, daily maximum surface water temperatures at the McIntire and Elliot Road gauging stations may provide a good general estimate of daily maximum subsurface water temperatures at a range of Chinook salmon embryo incubation depths (Devries 1997) from November through December. These data may be used to help manage water temperatures during the early stages of the Chinook salmon embryo incubation period. Still, more data are needed to provide a clear picture of how well surface water temperatures compare with subsurface water temperatures over several spawning seasons on the LMR.

The 2013 LMR Chinook salmon escapement estimate of 12,252 was 271% higher than the historical (1940-2012) average of 4,520, 356% higher than the pre-JSA (1940-1997) average of 3,439, and 147% higher than the post-JSA (1998-2012) average of 8,339. Preliminary 2013 escapement data from GrandTab[1] indicate that 447,728 fall-run Chinook salmon returned to the California Central Valley this season. This included

[1] California Department of Fish and Game - Fisheries Branch Anadromous Assessment, http://grandtab.calfish.org/GTFall4.aspx , accessed on 9/26/2014.

426,781 salmon that returned to the Sacramento River system and 20,947 salmon that returned to the San Joaquin River system. This season, the LMR accounted for 58% of the total return to the San Joaquin River system, which includes the Cosumnes River, the LMR, the Stanislaus River, the Tuolumne River, and the Merced River.

The 2013 Chinook salmon redd total was higher than the annual redd counts over the past six years. In addition, it was higher than the post-JSA average of 784. This may have been due, in part, to the large proportion of adult salmon returned to the LMR this season. Roughly 78% of the returning population were adult salmon. In addition, a smaller proportion (42%) of returning Chinook salmon was trapped at the hatchery when compared to 2012 (55%) and 2011 (86%). The other 58% of the population (7,071 salmon) remained in the LMR. Peak spawning on the LMR typically occurs between the middle and the end of November, which was consistent with the spawning pattern observed this season.

One of the primary objectives of EBMUD's ongoing spawning habitat rehabilitation projects is to supplement depleted coarse sediment with suitable-sized spawning gravel in the LMR. These projects are intended to improve and expand spawning habitat for adult Chinook salmon and steelhead in the LMR. As of 1990, EBMUD has completed 22 annual spawning habitat rehabilitation projects in reaches 5 and 6 of the LMR in cooperation with federal and state agencies, local partnerships, and public organizations. Since 2001, the Spawning Habitat Integrated Rehabilitation Approach (SHIRA) has been implemented to restore geomorphic processes and salmonid spawning habitat within the upper 1-km reach of the LMR, just below Camanche Dam (Pasternack et al. 2004). Since 1990, 46,677 yd^3 of gravel has been added to the LMR. These projects continue to provide high-quality spawning habitat as demonstrated by the large percentage of salmon redds constructed within the SHIRA reach (36% this season) and within all SHR sites (57.3% this season).

The 2013 Chinook salmon redd superimposition rate of 14.3% was higher than the long term average (1991-2012) of 10.4%. Spawning density (using annual redd counts) explained 56% of the variation in the annual salmon redd superimposition rate. During the 2013 spawning season, the Chinook salmon redd count was 150% above the long-term average, which may have contributed to the higher than average superimposition rate.

Most of the Chinook salmon redd water depths and velocities recorded this season fell within the expected ranges for the species (Moyle 2002) at discharge rates from 204-434 cfs. Survey year and discharge did not have a statistically significant effect on Chinook salmon redd water velocity or water depth from 2010-2013. These results suggest that the selection for several physical spawning habitat parameters (water depth and velocity) is relatively consistent between years, despite annual environmental variation and variation among brood stocks.

Sixty-eight *O. mykiss* redds were observed during the 2013 season, which was the highest redd count on record since 1994. However, this number may not necessarily be a reflection of a high steelhead escapement. The hatchery returns during 2013 were 226

adult *O. mykiss* (total length ≥ 16 in.), but adult *O. mykiss* counts at the hatchery have exceeded 200 adults six of eight previous seasons. In addition, redd survey frequency is dependent on a number of factors, including weather conditions, flows, and the number of staff available to conduct the surveys. This season, low flows, optimal weather, and adequate staffing allowed for weekly redd surveys to be conducted through early-March with just one weekly survey missed. It is also important to note that given the mixed life history of *O. mykiss* in Central Valley streams, the difference between resident rainbow trout redds and winter-run steelhead redds could not be distinguished during the spawning surveys (Zimmerman et al. 2009).

MANAGEMENT IMPLICATIONS

In 2013, EBMUD initiated an adaptive management strategy which included reserving 2,230 acre feet of water from the spring to save for shaping pulsed releases in the fall for adult salmonid attraction flows. In addition, Woodbridge Irrigation District (WID) worked collaboratively with EBMUD to coordinate changes in the water surface elevation at Lake Lodi during several of EBMUD's pulse flows. This action enhanced several of EBMUD's planned pulse flows by altering the timing of water releases at Woodbridge Dam, thereby increasing the magnitude of the flow peaks. The series of pulse flows from Camanche Dam and augmented pulse flows from Woodbridge Dam provided an attraction flow for adult spawners, as a large number (12,252) of Chinook salmon returned to the LMR, comprising 58% of the entire San Joaquin River system fall-run return. In addition, a smaller proportion (42%) of returning adult Chinook salmon was trapped at the hatchery this season. This provided an opportunity for the remaining 58% of the returning population to spawn naturally in the LMR. Consequently, a total of 1,823 Chinook salmon redds were constructed, the second highest annual redd total on record since 1990.

ACKNOWLEDGEMENTS

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