Lower Mokelumne River Salmonid Redd Survey Report:
October 2012 through March 2013

September 2013

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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 23 October 2012 through 12 March 2013. Estimated total escapement during the 2012/2013 season was 12,091 Chinook salmon. The estimated number of in-river spawners was 5,471 Chinook salmon. The first salmon redd was detected on 23 October 2012. During the surveys, a total of 1,287 salmon redds were identified. One hundred and ninety-four (15.1%) Chinook salmon redds were superimposed on other Chinook salmon redds and 808 (63%) redds were located within gravel enhancement areas. The reach from Camanche Dam to Mackville Road (reach 6) contained 1,142 (88.7%) salmon redds and the reach from Mackville Road to Elliott Road (reach 5) contained 145 (11.3%) salmon redds. The highest number of Chinook salmon redd detections (392) took place during survey week 6 on 26 and 27 November 2012. Sixty-three *O. mykiss* redds were identified during the surveys. The first *O. mykiss* redd was found on 19 December 2012. One *O. mykiss* redd was superimposed on another *O. mykiss* redd. Twenty-five (39.6%) *O. mykiss* redds were located within gravel enhancement areas. Reach 6 contained 34 (54%) *O. mykiss* redds and reach 5 contained 29 (46%) *O. mykiss* redds. The highest number of *O. mykiss* redds (16) was detected on 23 January 2013.

INTRODUCTION

The Mokelumne River is an east-Delta tributary that drains more than 1,642 square kilometers (600 square miles) of the eastern 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 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 and runs between Camanche Dam (the farthest downstream major impoundment, rkm 103) and the confluence with the San Joaquin River (rkm 0). 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 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 are owned and operated by the East Bay Municipal Utility District (EBMUD), 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 by fall-run Chinook salmon and both resident and anadromous forms of *O. mykiss* for spawning and rearing. 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 65% of the total run per year (1990-2011 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 returning to the LMR each season.

OBJECTIVES

The primary objective of the 2012/2013 salmonid redd surveys (referred to as the 2012 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 enhancement gravel areas.

METHODS

Surveys

The LMR is divided into 6 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 23 October 2012 and were concluded on 12 March 2013. Both reaches were surveyed once per week during this time frame. Surveys consisted of two to three individuals walking abreast downstream (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

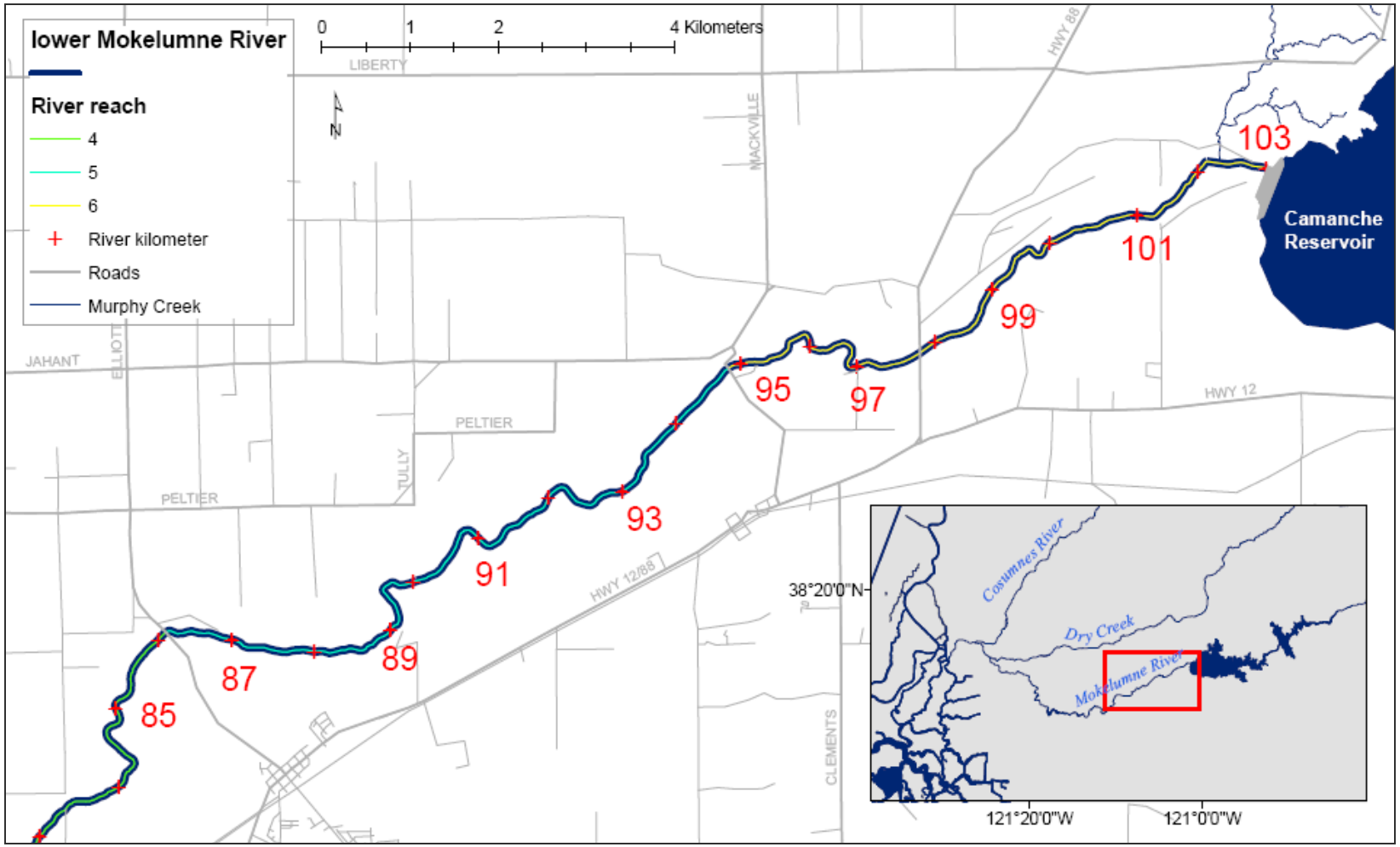

Figure 1. The location of river reaches 5 and 6 on the lower Mokelumne River, where salmonid redd surveys took place during the 2012/13 season.

surveyors between spawning areas and was also used to search for redds in areas that were not wadeable. In addition, the mainstem of Murphy Creek was surveyed by foot following a series of large rainfall events this season. Murphy Creek is a small tributary to the LMR, with its confluence located roughly 1-2 km below Camanche Dam (Figure 1). Three weekly surveys took place from 6 to 19 December 2012, coinciding with the time that adult Chinook salmon were present and spawning in Murphy Creek. The surveys took place from the confluence of Murphy Creek and the LMR and extended roughly 2.5 rkm upstream (1 rkm north of Liberty Road) to a waterfall (roughly 5 m tall) that appeared to block upstream passage for Chinook salmon.

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 one 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 survey.

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 2012 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 approximately one of every two *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 25 cm below the gravel surface on 30 October 2012 to record subsurface water temperatures on an hourly basis. Two temperature loggers were buried within eight spawning riffles located between Camanche Dam (rkm 103) and Elliot Road (rkm 86) on the LMR. 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 between 27 February

and 11 July 2013, after the majority of Chinook salmon fry were predicted to emerge from their redds according to an egg model developed by Vogel (1993).

Data Collection and Analysis

A minimum of ten points were collected at each redd location and point data files were stored in the GNSS unit using Terrasync 5.21 software. After field data were collected, the data files were downloaded and processed using GPS Pathfinder Office 5.20 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 9.0.0 (Academic), Microsoft (MS) Access 2003 and MS Excel 2003. A P-value ≤ 0.05 was considered statistically significant.

RESULTS

Environmental data

In 2012, a series of pulse flow events took place throughout October and in the beginning of November (Figure 2). Average daily releases from Camanche Dam peaked at 553 cubic feet per second (cfs) on 9 October 2012, during the first pulse. Average daily flow peaked at roughly 400 cfs during the following four pulses (Figure 2).

During the redd survey period (23 October 2012 – 12 March 2013) average daily releases from Camanche Dam ranged from 254 to 756 cfs (Figure 2). The average daily flow during this time period was 326 cfs. The average daily flow from 23 October 2012 through 8 January 2013 (time period Chinook salmon redds were detected) ranged from 254 to 756 cfs and averaged 366 cfs. The average daily flow from 19 December 2012 through 12 March 2013 (time period *O. mykiss* redds were detected) ranged from 255 cfs to 503 cfs and averaged 325 cfs.

Average daily surface water temperatures at the McIntire gauging station (rkm 101, reach 6) ranged from 8.6°C to 15.3°C during the survey period. The average temperature during this time frame was 11.6°C. The average daily water temperatures from 23 October 2012 through 8 January 2013 (time period salmon redds were detected) ranged from 10.3°C to 15.3°C and averaged 13.7°C . The average daily water temperatures during the time period when *O. mykiss* redds were detected ranged from 8.6°C to 12.8°C and averaged 9.6°C.

Thirteen of the sixteen temperature loggers were recovered from below the gravel surface at the same initial burial depth of 25 cm. These temperature loggers were recovered between 27 February and 11 July 2013. One temperature logger, which was located at rkm 100.3, was recovered at a burial depth of 15 cm on 5 March 2013. Another temperature logger, located at rkm 90.2, was found just downstream of its initial burial

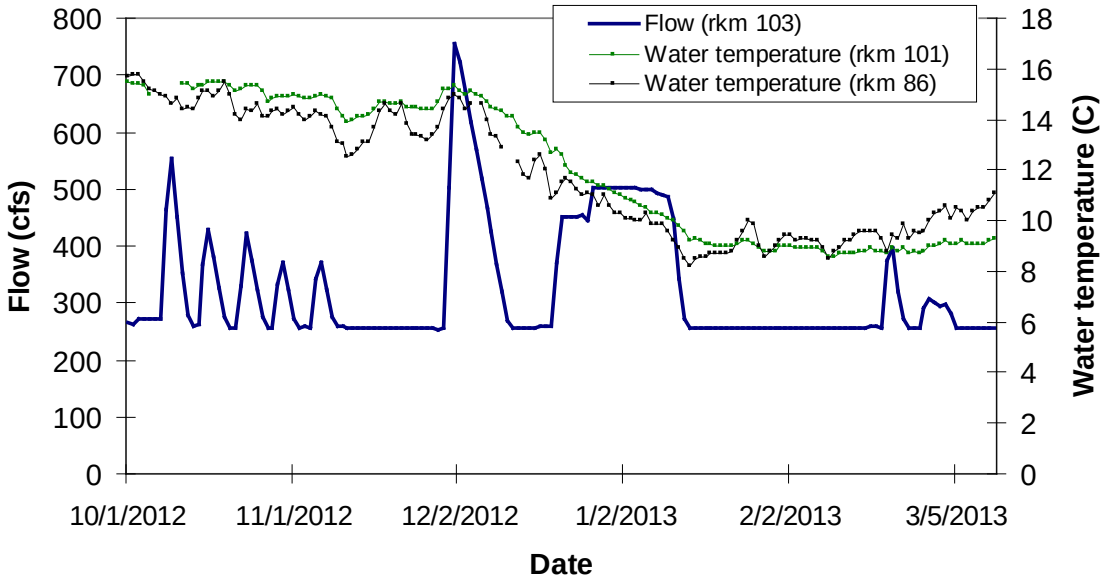

Figure 2. Average daily releases from Camanche Dam (rkm 103) and surface water temperatures at the McIntire gauging station (rkm 101) and the Elliot gauging station (rkm 86) in the lower Mokelumne River during the 2012 salmonid redd surveys.

location on the gravel surface on 26 November 2012. Water temperature data were not reported for that temperature logger. In addition, one of the two temperature loggers buried at rkm 97.3 was not recovered. A comparison of maximum daily subsurface water temperatures recorded in river reaches 5 (rkm 86-95) and 6 (rkm 95-103) and maximum daily surface water temperatures at the McIntire (rkm 101) and Elliot road (rkm 86) gauging stations is presented graphically in Figure 3.

From 31 October 2012 through 21 December 2012 maximum daily subsurface water temperatures recorded on the LMR ranged between 12.3 and 15.5°C (Figure 3). This time frame represented the beginning of the incubation period for the majority of Chinook salmon embryos. In general, daily maximum surface water temperatures at the McIntire gauge were slightly higher than or similar to all daily maximum subsurface water temperatures recorded on or before 21 December 2012. 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 21 December 2012.

From 22 December 2012 to 27 February 2013 maximum daily subsurface water temperatures recorded on the LMR ranged between 9.4 and 12.8°C (Figure 3). This time frame represented the middle and the end of the incubation period for the majority of Chinook salmon embryos. In general, daily maximum surface water temperatures recorded at the McIntire and Elliot Road gauges were lower than or similar to daily maximum subsurface water temperatures recorded between 22 December 2012 and 27 February 2013.

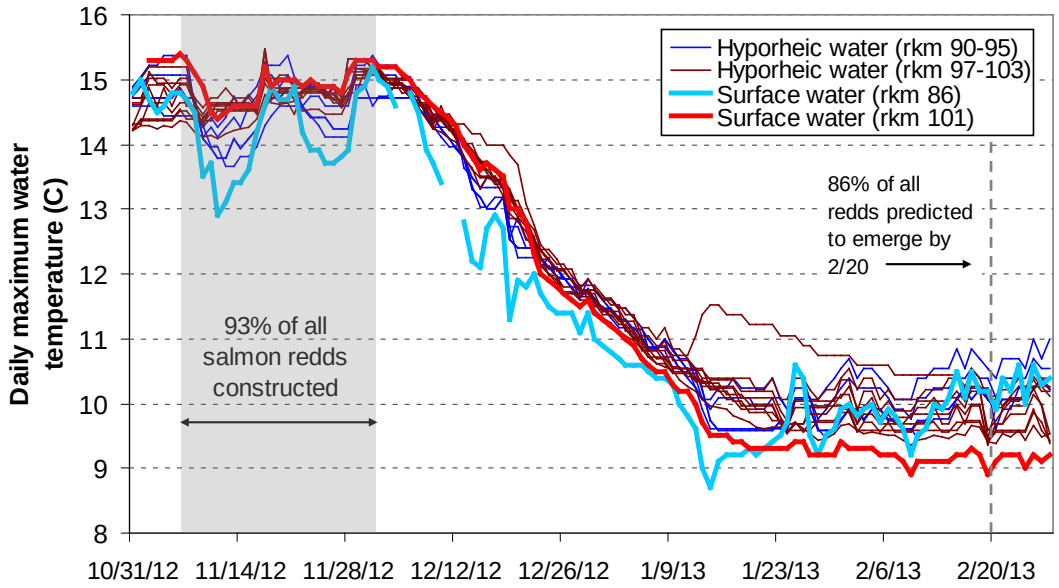

Figure 3. Maximum daily surface and subsurface water temperatures recorded on the lower Mokelumne River during the 2012/13 redd survey season. Subsurface (hyporheic) water temperatures were recorded at 25 cm below the gravel surface.

Chinook Salmon

Redd totals and Escapement

During the annual redd survey period, 1,287 Chinook salmon redds were detected. The first and last redd detections occurred on 23 October 2012 and 8 January 2013, respectively. The highest number of redds (392) was detected during survey week 6 on 26 and 27 November 2012 (Figure 4). Reach 6 contained 1,142 redds (88.7%) and reach 5 contained 145 redds (11.3%). No surveys were missed and no surveys were conducted during storm events this season.

The 2012 annual redd count was 83% above the long term average (1990-2011) of 703, 106% above the pre-Joint Settlement Agreement (JSA) average (1990-1997) of 625, and 72% above the post-JSA average (1998-2011) of 748 (Figure 5).

In Murphy Creek, three Chinook salmon redd surveys took place from 6 to 19 December 2012, coinciding with the time that adult Chinook salmon were present and spawning in the mainstem of the creek. The temporal distribution of Chinook salmon redds could not be determined because only some sections of the Murphy Creek mainstem were surveyed on a weekly basis. However, a total of 40 Chinook salmon redds were identified in the mainstem of Murphy Creek during the surveys. In addition, thirty-two of the Chinook salmon redds (80%) were found above a previously existing dam that was removed in 2003. The 2003 Murphy Creek dam removal site is located roughly 0.5 rkm below Liberty Road.

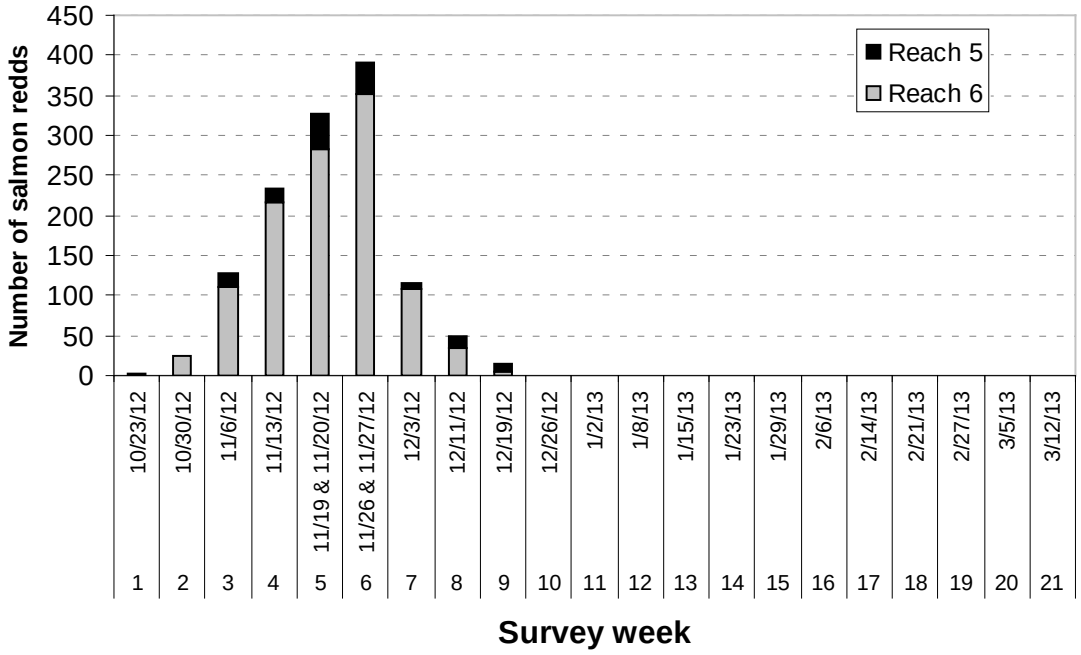

Figure 4. Weekly Chinook salmon redd totals by reach on the lower Mokelumne River during the 2012 surveys.

To estimate fall-run Chinook salmon escapement in the LMR during the 2012 season, video monitoring was conducted at WIDD from 1 August 2012 to 31 March 2013. During this time, 12,091 Chinook salmon were counted passing the fish ladders at WIDD. The total count of Chinook salmon that entered the MRFI this season was 6,620. The LMR in-river escapement estimate of 5,471 fall-run Chinook salmon was calculated by subtracting the MRFI salmon count from the video monitoring count at WIDD. The majority of the Chinook salmon that returned to the LMR was classified as adults (8,251, 68%), while the other 32% (3,840) was classified as grilse. Overall, 56% (6,727) of the Chinook salmon returning to the watershed this season were male, 44% (5,362) were female, and less than 1% (2) could not be identified.

Gravel enhancement area usage

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). An additional 2,457 cubic yards (yd^3) of gravel were placed in the SHIRA enhancement reach in August 2012. This brings the total volume of gravel added to the reach to 23,028 yd^3 between 2007 and 2012. During the 2012 redd surveys, 528 (41%) Chinook salmon redds were found within the SHIRA reach.

Overall, 808 Chinook salmon redds, or 63% of the total number of redds detected

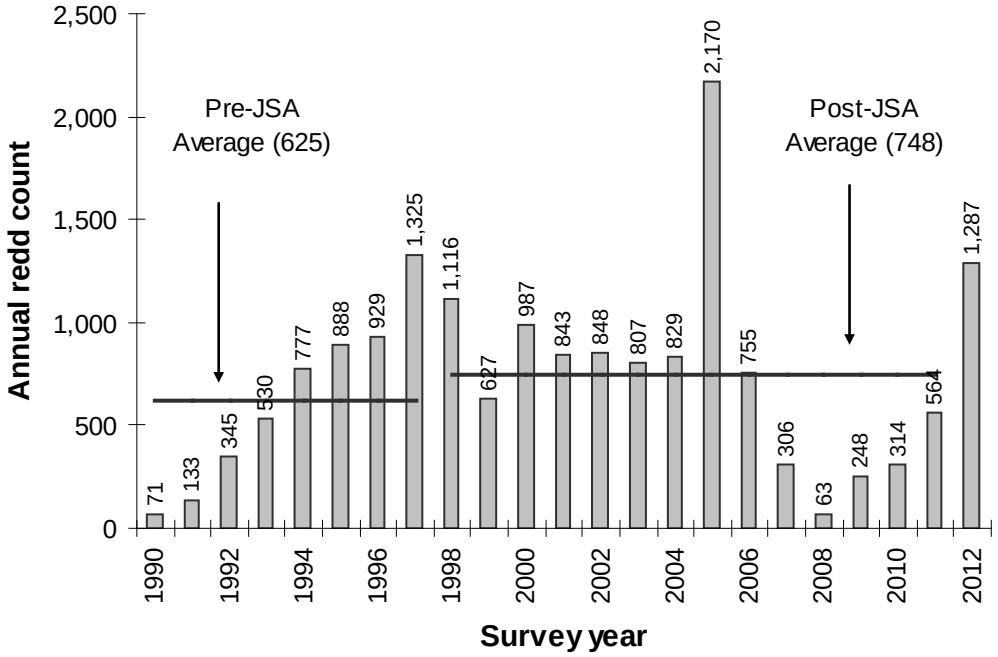

Figure 5. Chinook salmon redd totals on the lower Mokelumne River during pre-JSA flows (1990 – 1997), post-JSA flows (1998 – 2011), and for the 2012 survey season.

(1,287) were constructed within spawning habitat restoration (SHR) sites. A total of 756 redds (94%) were constructed in SHR sites located in reach 6. Fifty-two salmon redds (6%) were constructed in SHR sites located in reach 5.

Superimposition

One hundred and ninety-four Chinook salmon redds (15.1%) were superimposed on other Chinook salmon redds during the 2012 redd survey season. Most of the superimposition took place in reach 6 (182 redds), while just twelve redds were superimposed in reach 5. The 2012 superimposition rate was higher than the long-term average of 10.2% (1991-2011), the pre-JSA average of 9.0% (1991-1997) and the post-JSA average of 10.8% (1998-2011). There was a significant positive linear relationship between the annual redd count and the annual superimposition rate (Linear regression: $F = 28.68$; df = 1, 20; $P < 0.001$). The annual redd count explained 59% of the variation in annual superimposition rates.

Habitat Use – Water Depth and Velocity

A total of 119 water depth measurements and 121 water velocity measurements were taken just above the nose of Chinook salmon redds from 30 October to 19 December 2012. During this time frame, average daily releases from Camanche Dam ranged from 254 to 756 cfs, however releases did not exceed 672 cfs on the dates the measurements were recorded. Chinook salmon redd water depths ranged from 12 to 98 cm and averaged 46 cm (SD = 19). The central 50% of the depth measurements (between Q1 and Q3)

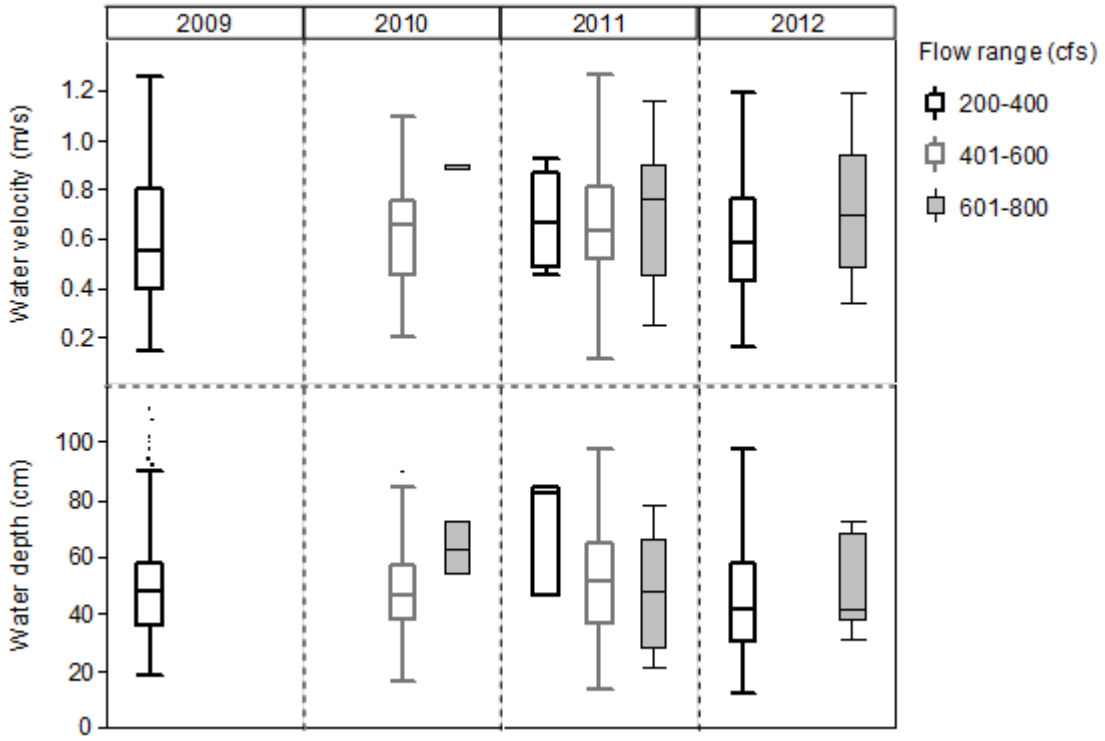

Figure 6. Boxplots of water depths and velocities measured just above the nose of Chinook salmon redds by survey year (2009-2012) and by flow range (200-400 cfs, 401-600 cfs, 601-800 cfs) on the lower Mokelumne River.

occurred between 31 and 58 cm. Water velocity measurements ranged from 0.16 to 1.19 m/s and averaged 0.62 m/s (SD = 0.23). The central 50% of the velocity measurements occurred between 0.44 and 0.78 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: $F_{3, 369} = 0.33$, $P = 0.801$) or redd water depth (two-way ANOVA: $F_{3, 366} = 1.79$, $P = 0.148$). In addition, flow did not have a statistically significant effect on redd water velocity (two-way ANOVA: $F_{2, 369} = 2.26$, $P = 0.106$) or redd water depth (two-way ANOVA: $F_{2, 366} = 0.28$, $P = 0.758$).

Oncorhynchus mykiss

Redd totals

Sixty-three *O. mykiss* redds were detected during the 2012 salmonid redd surveys. The first and last detections occurred on 19 December 2012 and 12 March 2013, respectively. The largest number of *O. mykiss* redds (16) was detected on 23 January 2013 (Figure 7). Reach 6 contained 34 redds (54%) and reach 5 contained 29 redds (46%). The 2012 annual redd count was 31.3% above the long-term (2000-2011) average of 48 (Figure 8).

Gravel Enhancement Area Usage

During the 2012 redd survey season, 14 (22.2 %) *O. mykiss* redds were found within the SHIRA enhancement area. Overall, 25 *O. mykiss* redds, or 39.6% of the total number of redds detected (63), were constructed in gravel enhancement areas. Eighty-four percent (21) of redds constructed in enhancement areas were located in reach 6 and 16% (4) were located in reach 5.

Superimposition

One *O. mykiss* redd was superimposed on another *O. mykiss* redd during the 2012 season. The only incident of superimposition took place above the MRFI barrier fence (rkm 103), where spawning habitat is limited.

Habitat Use – Water Depth and Velocity

A total of 31 water depth measurements and 31 water velocity measurements were taken just above the nose of *O. mykiss* redds between 26 December 2012 and 12 March 2013. Water releases from Camanche Dam ranged from 255 to 503 cfs on the dates the measurements were taken. Water depths ranged from 30 to 98 cm and averaged 61 cm (SD=18). The central 50% of the depth measurements (between Q1 and Q3) occurred between 48 and 75 cm. Water velocity measurements ranged from 0.28 m/s to 0.99 m/s and averaged 0.59 m/s (SD = 0.21). The central 50% of the velocity measurements occurred between 0.41 and 0.78 m/s.

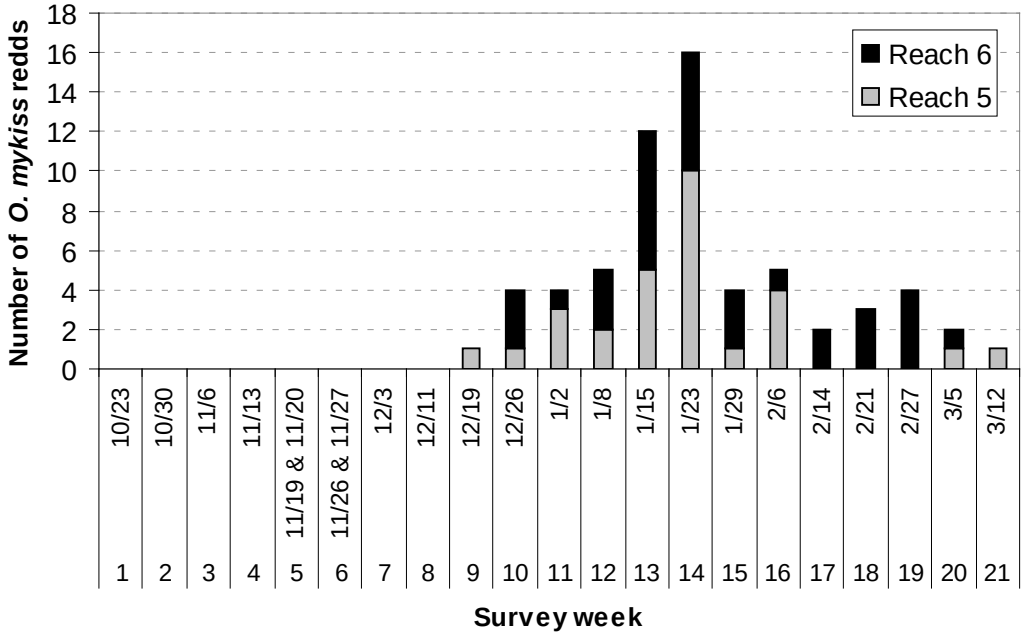

Figure 6. Weekly *O. mykiss* redd totals by reach on the lower Mokelumne River during the 2012 survey season.

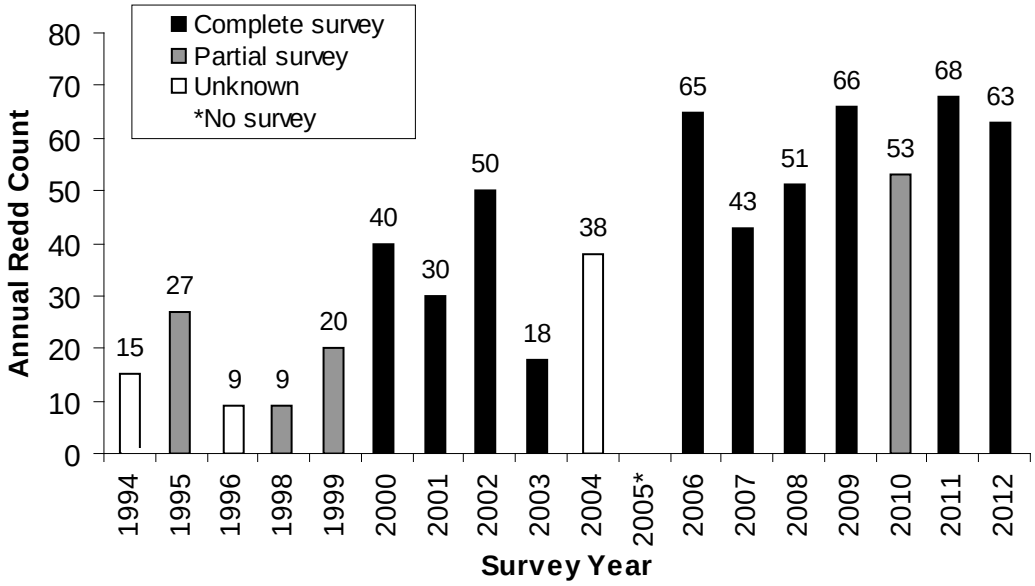

Figure 7. Annual *O. mykiss* redd totals on the lower Mokelumne River from 1994-2012.

DISCUSSION

The 2012-2013 LMR Chinook salmon escapement estimate of 12,091 was 274% higher than the historical (1940-2011) average of 4,407, 352% higher than the pre-JSA (1940-1997) average of 3,439, and 150% higher than the post-JSA (1998-2011) average of 8,071. Preliminary 2012 escapement data from GrandTab[1] indicate that a total of 341,759 fall-run Chinook salmon returned to the California Central Valley this season. This total was comprised of 320,861 salmon that returned to the Sacramento River system and 20,898 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 Stanislaus River, the Tuolumne River, the LMR, and the Merced River.

The 2012 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 748. This may have been due, in part, to the larger proportion of adult salmon returned to the LMR this season. Roughly 70% of the returning population was comprised of adult salmon, whereas, only 30% of the returning population was comprised of adults in 2011. In addition, a smaller proportion (55%) of returning Chinook salmon was trapped at the hatchery, when compared to 2011 (86%) and 2010 (73%). The other 45% of the population (5,471 salmon) remained in the LMR or traveled up Murphy Creek. 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.

[1] California Department of Fish and Game - Fisheries Branch Anadromous Assessment, http://beergarage.com/GrandTab/GTFallSum1.aspx, accessed on 9/24/2013.

A comparison of surface and subsurface water temperatures during the Chinook salmon embryo incubation period on the LMR indicated that daily maximum surface water temperatures at the McIntire gauge were slightly higher than or similar to all daily maximum subsurface water temperatures recorded until late December. 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 gauging station may provide a conservative estimate of daily maximum subsurface water temperatures at shallow or average embryo incubation depths (25 cm) (Devries 1997) from November through mid-December. These data may be used to help manage water temperatures during the early stages of the Chinook salmon embryo incubation period, as a 50% survival rate (from fertilization to hatching) has been recorded for Chinook salmon embryos incubated at 16°C (Moyle 2002; McCullough 1999).

However, more data are needed to provide a clear picture of how well surface water temperatures compare with subsurface water temperatures over a range of incubation depths and over several spawning seasons on the LMR. Future efforts may seek to expand the range of temperature logger burial depths over several seasons.

One of the primary objectives of EBMUD's ongoing spawning habitat improvement 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 gravel enhancement projects in reaches 5 and 6 of the LMR in cooperation with federal and state agencies, local partnerships, and public organizations. These projects continue to provide high-quality spawning habitat as demonstrated by the large percentage of redds constructed within the enhancement areas (63% this season).

The 2012 Chinook salmon redd superimposition rate of 15.1% was higher than the long term average (1991-2011) of 10.2%. Spawning density (using annual redd counts) explained 59% of the variation in annual salmon redd superimposition rates. During the 2012 spawning season, the Chinook salmon redd count was 83% 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 fell within the expected ranges for the species (Moyle 2002) at flows ranging from 254-756 cfs. Interestingly, survey year and flow did not have a statistically significant effect on Chinook salmon redd water velocity or water depth from 2009-2012. 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. All of the water depth and velocity measurements recorded at *O. mykiss* redds during the 2012 season fell within the ranges documented by Moyle (2002).

Sixty-three *O. mykiss* redds were observed during the 2012 season, which was the fourth highest redd count on record since 1994. However, this number was not necessarily a reflection of a high steelhead escapement. In fact, a relatively low number (131) of adult

O. mykiss (total length ≥ 16 in.) returned to the hatchery during the 2012 season, as adult *O. mykiss* counts at the hatchery exceeded 200 adults three of the four 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 mid-March with zero weekly surveys 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). This is a problem within many streams in the Central Valley that contain both resident and anadromous *O. mykiss* (Giovannetti and Brown 2007).

MANAGEMENT IMPLICATIONS

The success of the adaptive management strategy for the lower Mokelumne River fisheries program in 2012 was due to several actions. The series of water releases from Camanche Dam provided an attraction flow for adult spawners, as a large number (12,091) of Chinook salmon returned to the LMR, comprising 58% of the entire San Joaquin River system fall-run return. In addition, a smaller proportion (55%) of returning adult Chinook salmon was trapped at the hatchery this season. This provided an opportunity for the remaining 45% of the returning population to spawn naturally in the LMR. Consequently, a total of 1,287 Chinook salmon redds were constructed, the third highest annual redd total on record since 1990.

ACKNOWLEDGEMENTS

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