Lower Mokelumne River Salmonid Redd Survey Report: October 2010 through March 2011

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, *Oncorhynchus mykiss*, redd survey, spawning, superimposition, gravel enhancement

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Abstract

Weekly fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and *Oncorhynchus mykiss* spawning surveys were conducted on the lower Mokelumne River from 22 October 2010 through 28 February 2011. Estimated total escapement during the 2010/2011 season was 7,196 Chinook salmon. The estimated number of in-river spawners was 1,920 Chinook salmon. The first salmon redd was detected on 22 October 2010. During the surveys, a total of 314 salmon redds were identified. Fourteen (4.5%) Chinook salmon redds were superimposed and 180 (57.3%) were located within gravel enhancement areas. The reach from Camanche Dam to Mackville Road (reach 6) contained 276 (87.9%) salmon redds and the reach from Mackville Road to Elliott Road (reach 5) contained 38 (12.1%) redds. The highest number (89) of Chinook salmon redd detections took place on 16 November 2010. The first *Oncorhynchus mykiss* redd was found on 2 November 2010. Fifty-three *O. mykiss* redds were identified, of which three were superimposed on four Chinook salmon redds. Thirty-two (60.3%) *O. mykiss* redds were located within gravel enhancement areas. Reach 6 contained 46 (86.8%) redds and reach 5 contained seven (13.2%) redds. The highest number of *O. mykiss* redds was detected on 31 January 2011.

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 defined as the approximate 103 kilometer (km) long portion of the Mokelumne River between Camanche Dam (the farthest downstream major impoundment) and the confluence with the San Joaquin River. Camanche Dam was completed in 1963 and blocked upstream passage of Chinook salmon and steelhead 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 (*Oncorhynchus tshawytscha*) and both resident and anadromous forms of *Oncorhynchus mykiss* (*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 construction of Camanche Dam and receives approximately 59% of the total run per year (1990-2009 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 monitor 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 2010/2011 salmonid redd surveys (referred to as the 2010 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 these two reaches. Specifically, surveys took place within a 13-km reach, from river km (Rkm) 103 (the base of Camanche Dam) downstream to Rkm 90 (Figure 1). Weekly redd surveys began on 22 October 2010 and were concluded on 28 February 2011. Both reaches were surveyed once per week when possible. However, due to high flows on the LMR, redd surveys during weeks 8-13 and 20-23 were cancelled. 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 surveyors between spawning areas and was also used to search for redds in areas that were not wadeable under high flow conditions.

In previous years, redd locations were marked with numbered cattle ear tags and/or colored bricks. However, with high resolution Global Positioning Systems (GPS)

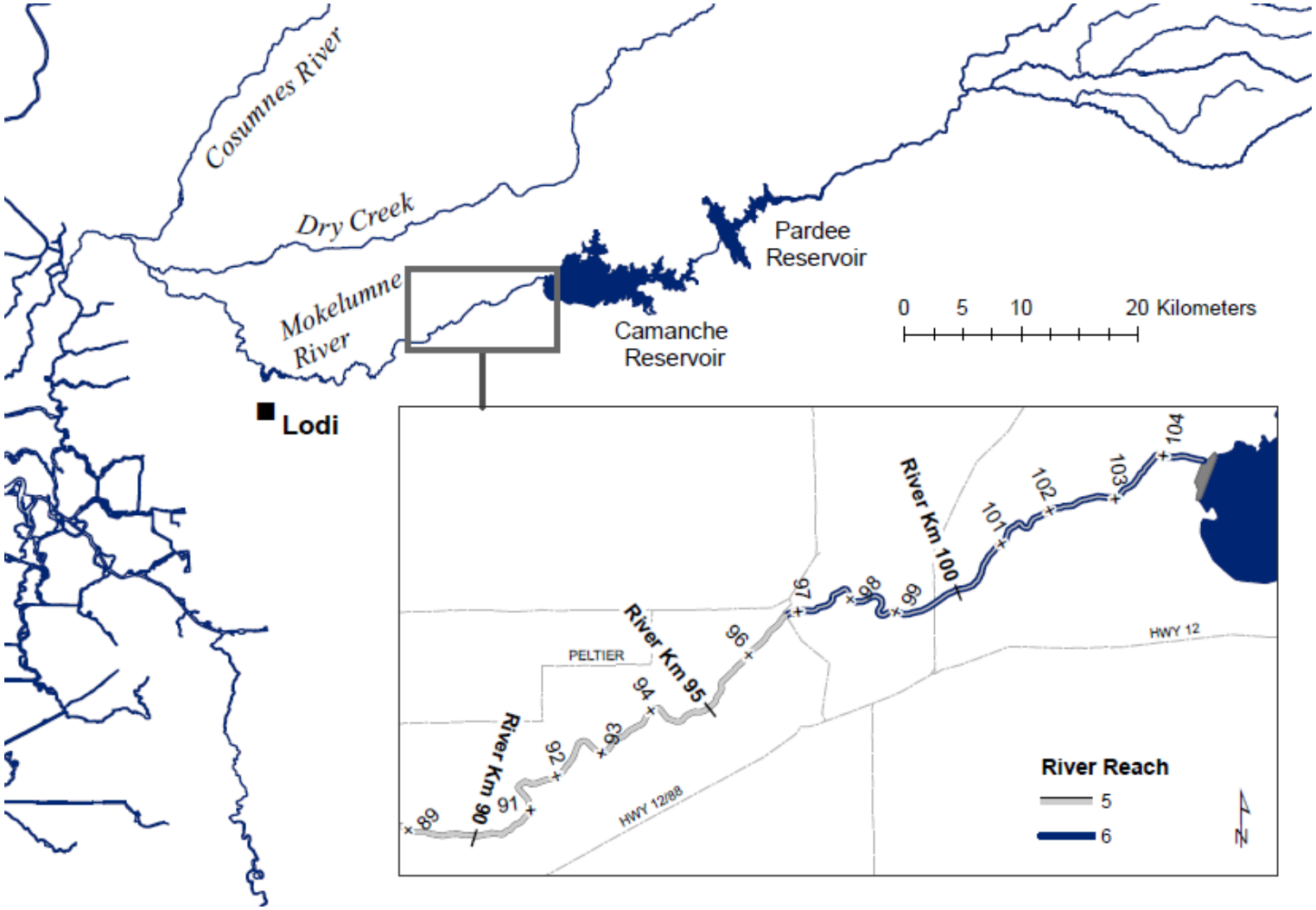

Figure 1. Mokelumne River watershed (extent) and salmonid redd survey reach (inset) locations.

technology available, locations were recorded using two Trimble Geo XH GPS units. The Trimble Geo XH GPS 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.

During weeks three and four of the 2010 redd survey, a subset of depth and velocity measurements was recorded just above the nose of Chinook salmon redds when releases from Camanche Dam were relatively low. Depth measurements were recorded to the nearest centimeter (cm) using a top-setting velocity 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). Surveyors determined if previously detected redds were superimposed based on the amount of time that had elapsed since a redd was first detected. All visible occurrences of redd superimposition were recorded. Water temperature and flow data were obtained from EBMUD's gauging stations at Camanche Dam (Rkm 103) and McIntire (Rkm 101).

Data Collection and Analysis

A minimum of ten points were collected for each redd and point data files were stored in the GPS unit using Terrasync 4.10 software. After field data were collected, information was downloaded and processed using GPS Pathfinder Office 4.20 software. Once downloaded, geographic positions were corrected using the nearest base data provider. The point data files were then imported to an ArcMAP 9.3 (ESRI) data base.

Data analyses were performed using ArcMAP 9.3 (Arc/Info (ESRI) systems), JMPIN 9.0.0 (Academic), Microsoft (MS) Access 2003 and MS Excel 2003. Mean values were reported with ± 1 standard deviation. A P-value ≤ 0.05 was considered statistically significant.

RESULTS

Environmental data

In 2010, three pulse flow events took place between 4 and 29 October 2010 (Figure 2). Average daily releases from Camanche Dam during the first pulse peaked at 1,417 cubic feet per second (cfs) on 6 October 2010. Average daily flow during the second pulse peaked at 2,399 cfs on 16 October 2010 and the third pulse peaked at 1,414 cfs on 26 October 2010. Shortly thereafter, several more large releases from Camanche Dam took place due to above average precipitation within the watershed.

During the redd survey period (22 October 2010 – 28 February 2011) average daily releases from Camanche Dam ranged from 596 to 2,992 cfs (Figure 2). The average daily flow during this time period was 1,143 cfs. The average daily flow from 22 October 2009 through 31 January 2011 (time period Chinook salmon redds were

detected) ranged from 596 to 2,992 cfs and averaged 1,291 cfs. The average daily flow from 2 November 2010 through 28 February 2011 (time period *O. mykiss* redds were detected) ranged from 596 cfs to 2,992 cfs and averaged 1,167 cfs. Average daily water temperature at the McIntire gauging station (Rkm 101, reach 6) ranged from 8.6°C to 16.0°C during the survey period (Figure 2). The average temperature during this time frame was 12.2°C. The average daily water temperatures from 22 October 2009 through 31 January 2011 (time period salmon redds were detected) ranged from 8.8°C to 16.0°C and averaged 13.0°C . The average daily water temperature during the time period when *O. mykiss* redds were detected ranged from 8.6°C to 16.0°C and averaged 11.9°C.

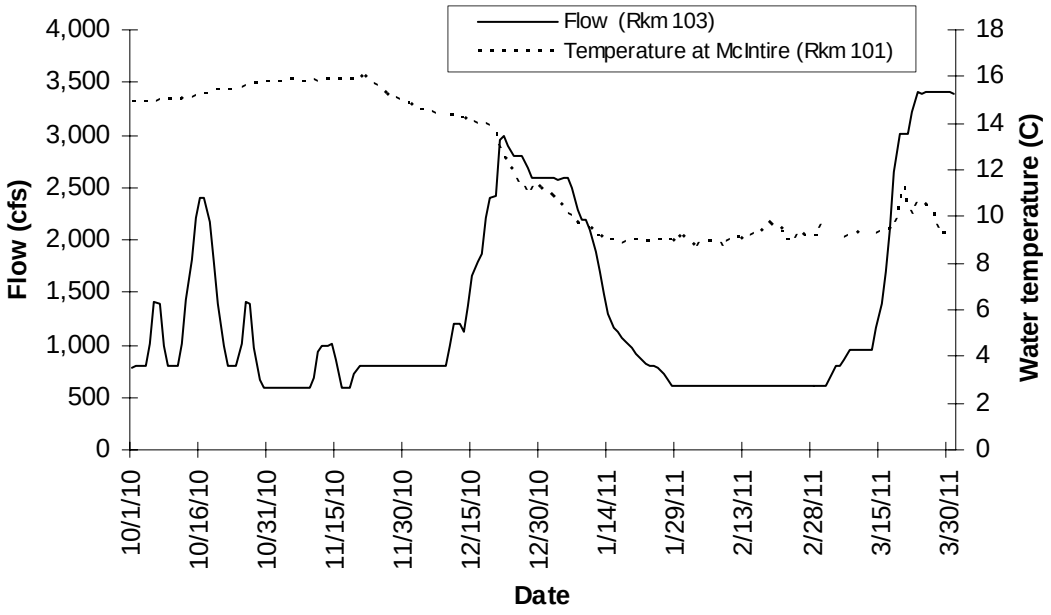

Figure 2. Average daily releases from Camanche Dam (Rkm 103) and water temperatures at the McIntire Station (Rkm 101) in the lower Mokelumne River during the 2010 salmonid redd surveys.

Chinook Salmon

Redd totals and Escapement

During the annual redd survey period, 314 Chinook salmon redds were detected. The first and last redd detections occurred on 22 October 2010 and 31 January 2011, respectively. The highest number of redds (89) was detected on 16 November 2010 (Figure 3). Reach 6 contained 276 redds (87.9%) and reach 5 contained 38 redds (12.1%). Survey weeks 8-13 were missed this season due to high flows (Figure 3). Based on redd counts during Julian weeks 50-52 and 1-3 (corresponding to survey weeks 8-13) from previous seasons (2000-2001, 2003-2009), it is estimated that an average of 16.5 ± 11.6% of the total number of redds were missed during this time frame (Figure 4). Therefore, it is possible that an additional 52 ± 36 salmon redds were constructed during the high flow period this season. However, there is a high degree of annual variability

associated with this estimate, as indicated by the large standard deviation around the mean.

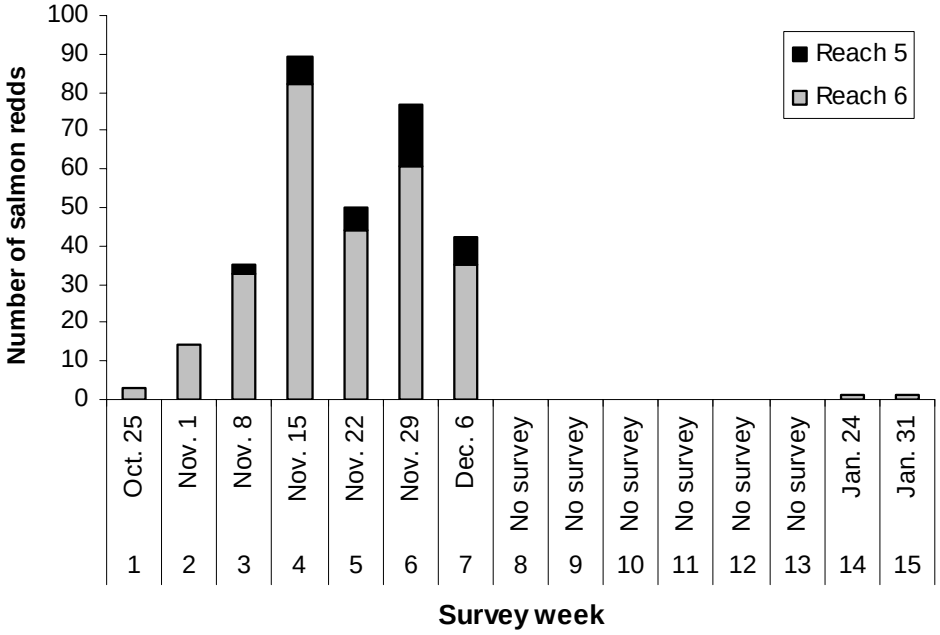

Figure 3. Chinook salmon weekly redd totals by reach on the lower Mokelumne River during the 2010 surveys.

The 2010 annual redd count was 57% below the long term average (1990-2009) of 730, 48% below the pre-Joint Settlement Agreement (JSA) average (1990-1997) of 625 and 61% below the post-JSA average (1998-2009) of 800 (Figure 5).

To estimate fall-run Chinook salmon escapement in the LMR during the 2010 season, video monitoring was conducted at WIDD from 1 August 2010 to 31 January 2011. During this time, 7,196 Chinook salmon were counted passing the fish ladders at WIDD. The total count of Chinook salmon hatchery spawners at the MRFI this season was 5,276. The LMR in-river escapement estimate of 1,920 fall-run Chinook salmon was calculated by subtracting the MRFI salmon count from the video monitoring count at WIDD. The in-river Chinook salmon escapement estimate consisted of 865 males, 1,050 females, and 5 unknown salmon.

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. An additional 3,361 cubic yards (yd^3) of gravel were placed in the SHIRA enhancement reach this season. This

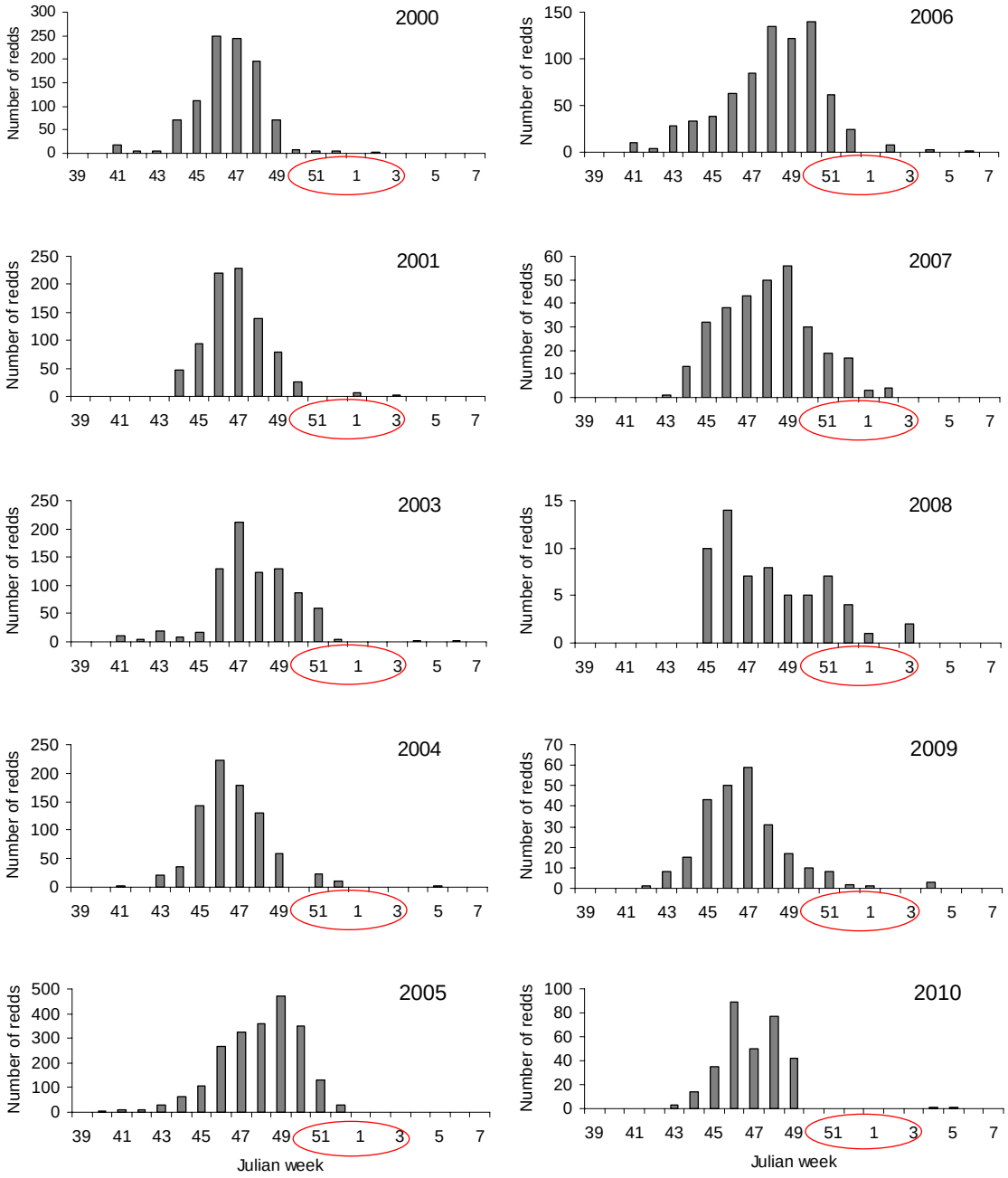

Figure 4. Comparisons of annual Chinook salmon redd timing during Julian calendar weeks 39 – 7 from 2000-2001 and 2003-2010. Survey weeks 50-52 and 1-3 were missed during the 2010 Chinook salmon redd survey season and are circled in red to highlight the annual temporal variation of redd construction during this time.

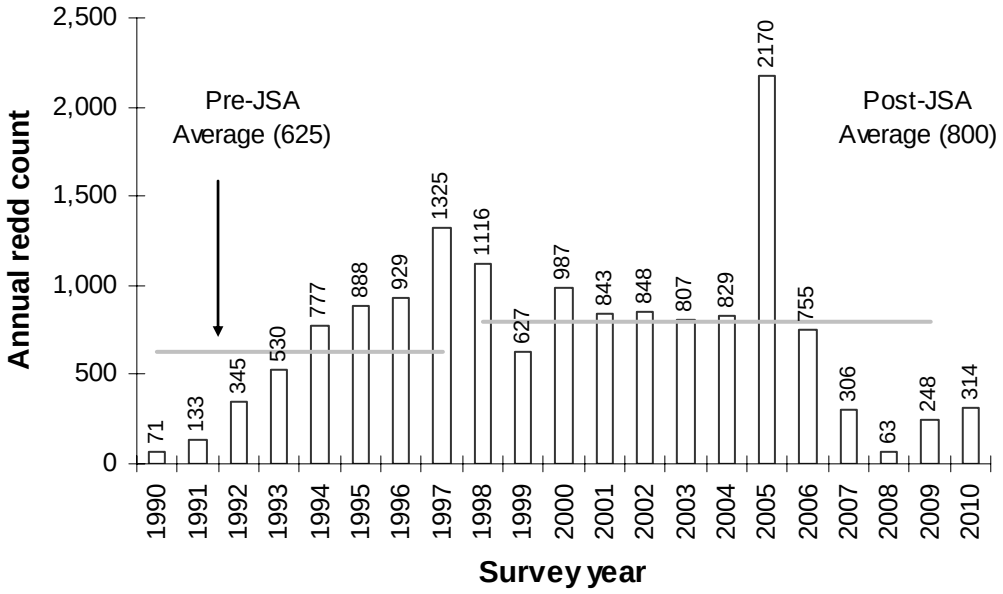

Figure 5. Chinook salmon redd totals on the lower Mokelumne River during pre-JSA flows (1990 – 1997) and post-JSA flows (1998 – 2009).

brings the total volume of gravel added to the reach to 17,377 yd^3 between 2007 and 2010. During the 2010 redd survey, 70 Chinook salmon redds were found within the SHIRA reach. This represents 22% of the total number of redds found during the survey season.

In 2010, 180 Chinook salmon redds, or 57% of the total number of redds detected (314), were constructed in gravel enhancement areas. Ninety-two percent (165) of redds constructed in enhancement areas were located in reach 6 and 8% (15) were located in reach 5.

There was a statistically significant relationship between the annual percentage of total redds found in gravel enhancement areas and the cumulative amount of gravel added to the LMR (Figure 6, Logistic regression: $F = 113.7041$; df = 1, 19; $P < 0.0001$). The natural logarithm of the total amount of gravel added to the LMR explained 86% of the variation in the annual percentage of redds found in gravel enhancement areas.

Superimposition

Fourteen salmon redds (4.5%) were superimposed during the 2010 redd survey season, all of which were found in reach 6. The superimposition (SI) rate was lower than the long-term average of 10.6% (1991-2009), the pre-JSA average of 9.0% (1991-1997) and the post-JSA average of 11.5% (1998-2009). There was a significant linear relationship between the annual redd count and the annual SI rate (Linear regression: $F = 23.5980$; df = 1, 18; $P = 0.0001$). The annual redd count explained 57% of the variation in annual SI rates.

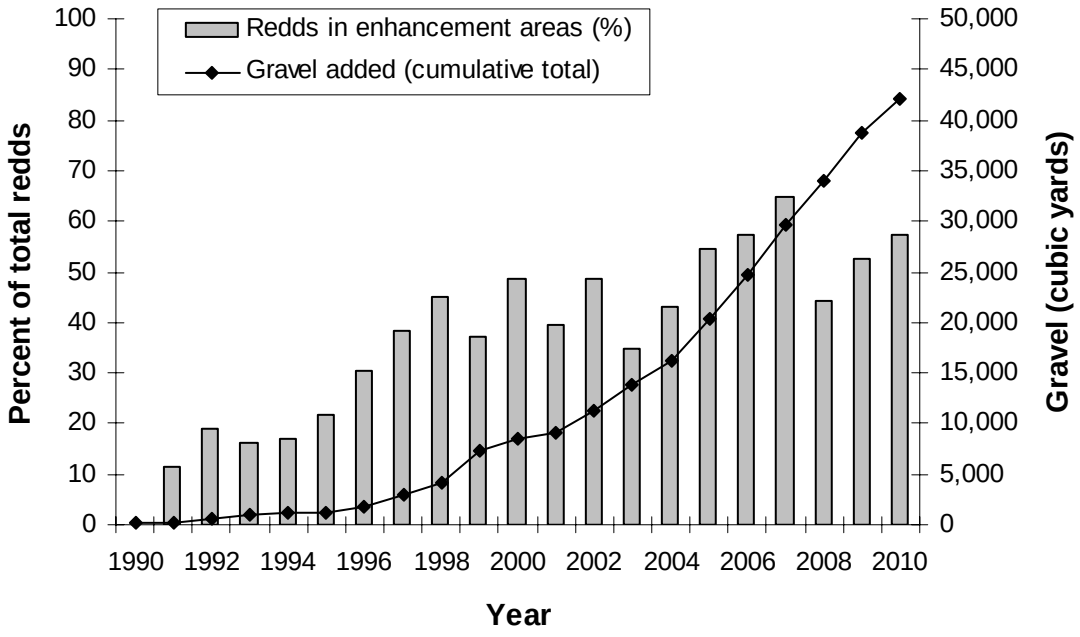

Figure 6. The relationship between the percentage of Chinook salmon redds constructed in gravel enhancement areas and the cumulative total amount of spawning gravel added to the lower Mokelumne River from 1990-2010.

Habitat Use - Depth and Velocity

A total of 30 depth measurements and velocity measurements were taken just above the nose of Chinook salmon redds on 9 and 16 November 2010, when water releases from Camanche Dam were relatively low (~600 cfs). Most of the measurements were taken within the uppermost spawning reaches of the river, just below Camanche Dam (Figure 7). Depths ranged from 16 to 90 cm and averaged 50 ± 18 cm. The central 50% of the depth measurements (between Q1 and Q3) occurred between 38 and 60 cm. Velocity measurements ranged from 0.20 m/s to 1.09 m/s and averaged 0.63 ± 0.22 m/s. The central 50% of the velocity measurements occurred between 0.49 and 0.76 m/s.

Oncorhynchus mykiss

Redd totals

Fifty-three *O. mykiss* redds were detected during the 2010 salmonid redd survey. The first and last detections occurred on 2 November 2010 and 28 February 2011, respectively. The largest number of *O. mykiss* redds (18) was detected on 31 January 2011 (Figure 8). Reach 6 contained 46 redds (87%) and reach 5 contained 7 redds (13%). Survey weeks 8-13 and 20-23 were missed this season due to high flows.

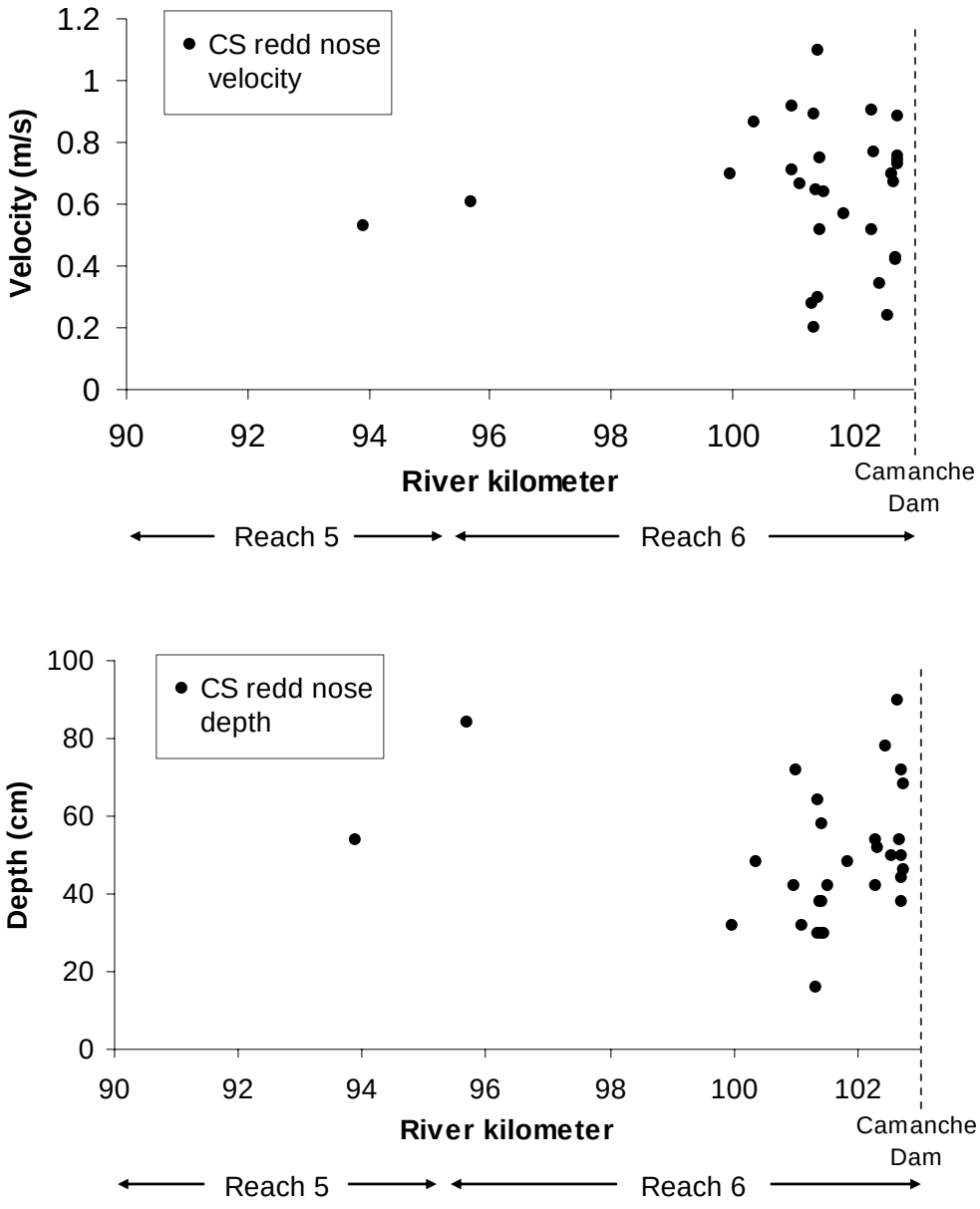

Figure 7. Water velocity (top) and depth (bottom) measurements taken just above the nose of Chinook salmon (CS) redds during survey weeks 3 and 4 of the 2010 spawning season. The x-axis depicts the river kilometer where the salmon redd was detected.

The 2010 annual redd count was 17.7% above the long-term (2000-2009) average of 45 (Figure 9). The *O. mykiss* redd count was relatively high when compared with previous *O. mykiss* surveys that were not conducted throughout the entire spawning season.

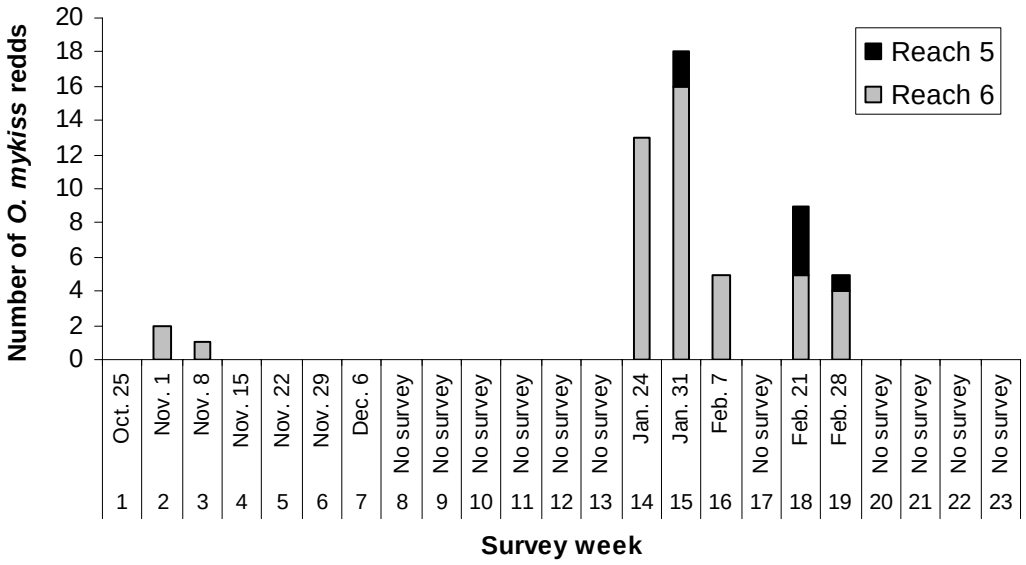

Figure 8. Weekly *O. mykiss* redd totals by reach on the lower Mokelumne River during the 2010 survey season.

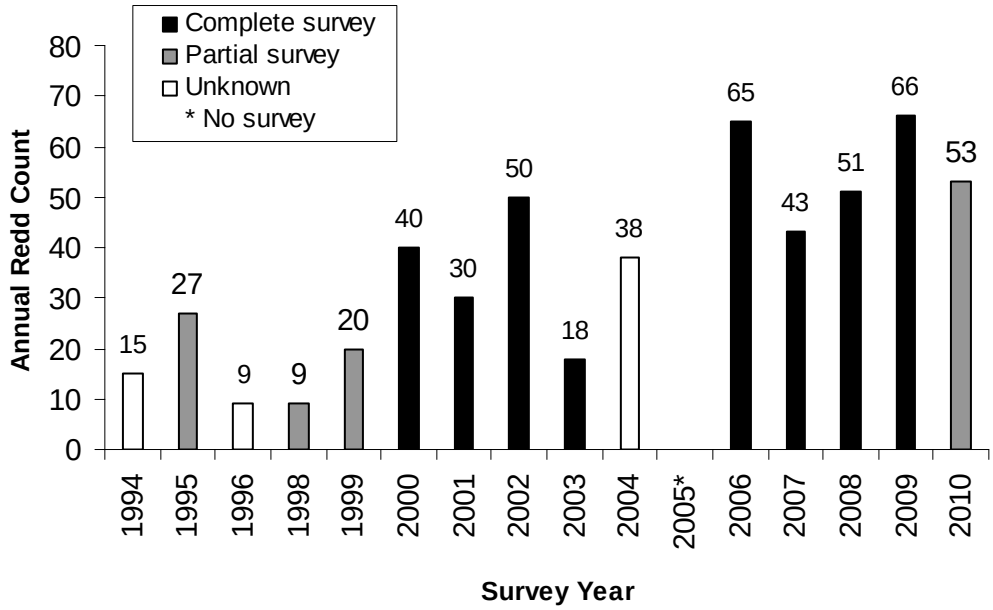

Figure 9. Annual *O. mykiss* redd totals on the lower Mokelumne River from 1994-2010.

Gravel Enhancement Area Usage

During the 2010 redd survey season, 21 (39.6%) *O. mykiss* redds were found within the SHIRA enhancement area. Overall, 32 *O. mykiss* redds, or 60.3% of the total number of redds detected (53), were constructed in gravel enhancement areas. Eight-eight percent

(28) of redds constructed in enhancement areas were located in reach 6 and 13% (4) were located in reach 5.

Superimposition

Three *O. mykiss* redds were superimposed on four Chinook salmon redds during the 2010 season, all of which occurred in the upper 1.5 km of reach 6.

DISCUSSION

Chinook Salmon

The 2010-2011 LMR Chinook salmon escapement estimate of 7,196 was 74% higher than the historical (1940-2009) average of 4,146, 109% higher than the pre-JSA (1940-1997) average of 3,439, and 1% lower than the post-JSA (1998-2009) average of 7,266 (Figure 10). Preliminary 2010 escapement data from GrandTab[1] indicate that a total of 163,190 fall-run Chinook salmon returned to the California Central Valley this season. This total was comprised of 152,832 salmon that returned to the Sacramento River system and 10,358 salmon that returned to the San Joaquin River system. This season, the LMR accounted for 69% 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 number of Chinook salmon redds detected during the 2010 salmonid redd surveys (314) likely represented the minimum number of redds constructed on the LMR this

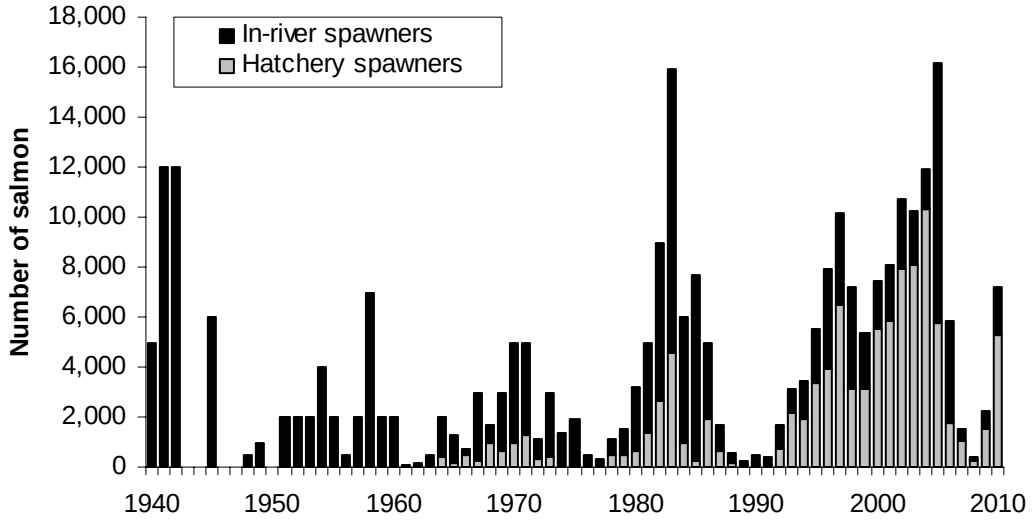

Figure 10. Estimated Chinook salmon escapement on the lower Mokelumne River from 1940 through 2010.

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

season. High flows prevented some Chinook salmon redds from being visible during the 2010 season, as the surveys were conducted at flows ranging between 600-1,000 cfs; roughly 200-600 cfs higher than conditions during a normal season. In addition, six survey weeks (8-13) were missed because flows on the LMR exceeded 1,000 cfs, which created unsafe wading conditions for surveyors and significantly reduced salmon redd visibility. The six survey weeks that were missed made up the second half of the spawning season and may have accounted for roughly 17% of the total number of Chinook salmon redds detected; although this estimate assumes that the salmon can successfully spawn during high flow conditions. Furthermore, there is a high degree of annual variation in redd timing on the LMR. While the 2010 Chinook salmon redd total was lower than the post-JSA average of 800, it was an improvement from the redd counts over the past three years (Pagliughi 2008; Del Real and Rible 2009; Bilski and Rible 2010).

Peak spawning on the LMR typically occurs sometime between the middle and the end of November, which was consistent with the spawning pattern observed this season. Average daily water temperatures ranged from 8.8 to16.0 °C during the time Chinook salmon redds were detected. While water temperatures fell outside of the range necessary for maximum embryo survival (5 to13 °C), a 50% survival rate (from fertilization to hatching) has been recorded for Chinook salmon embryos incubated at 16 °C (Moyle 2002; McCullough 1999). In addition, the 2010 water temperatures fell within the range recorded during previous spawning seasons on the LMR (Setka 2004).

The overall goal of EBMUD's spawning habitat improvement project is to supplement depleted coarse sediment with suitable-sized gravel in the LMR spawning habitat reaches to provide high quality spawning habitat for Chinook salmon and steelhead (Wheaton et al. 2004). As of 1990, EBMUD has completed 19 annual gravel enhancement projects in reaches 5 and 6 on the LMR in cooperation with federal and state agencies, local partnerships, and public organizations. The spawning habitat improvement project continues to provide high-quality spawning habitat as demonstrated by the large percentage of redds constructed within the enhancement areas (57% this season). This represents a population-scale impact by assisting to sustain and possibly expand the existing population of naturally spawning salmon in the LMR.

The logistic relationship between the cumulative amount of gravel added to the LMR and the percentage of redds found within gravel enhancement sites reflects the recent reach-scale rehabilitation efforts, which take geomorphic processes into consideration, requiring a large volume of gravel to re-initiate active bedload transport out of the reach over time.

The 2010 SI rate was approximately 6.1% lower than the long term average (1991-2008) of 10.6%. A number of factors may be used to explain annual SI rates. Spawning density (using annual redd counts) appears to have a large affect on the annual SI rate, explaining 57% of the variation in the data. In addition, spawning behavior (influenced by the sex ratio and grilse composition) may impact how spawning habitat is used on the LMR (Setka 1997). During the 2010 spawning season, the relatively low density of spawners (reflected by the redd count) may have influenced the SI rate. In addition, a

modified Beyond Before-After Control-Impact design was used to demonstrate that there has been a significant reduction in the clustering of Chinook salmon redds and a significant reduction in the SI rate within the SHIRA enhancement reach after implementation of the reach-scale project (EBMUD unpublished data). This season the SHIRA reach contained 25% of the total number of Chinook salmon redds and it is possible that the project also contributed to a low overall SI rate in 2010.

At 600 cfs, Chinook salmon redd depths and velocities on the LMR fell within the expected ranges for the species (Moyle 2002), however most of the measurements were taken within the upper 1.5 km of the river during the beginning of the spawning season. Unfortunately, it was not possible to take a random subsample of measurements when flows exceeded 800 cfs; however a two-dimensional (2D) hydrodynamic model within the upper 1-km of the LMR is currently beginning developed under a range of flows (Pasternack et al. 2004). The results of the model will allow for a better understanding of how changes in flow may affect spawning habitat availability and use within the reach.

O. mykiss

Fifty-three *O. mykiss* redds were observed during the 2010 season, which was a relatively high redd count given that 7 survey weeks were missed during the *O. mykiss* spawning season (January – March). It is possible that some of these redds were constructed by individuals from a group of 1,097 hatchery origin age 2+ *O. mykiss*, which were released just below Camanche Dam on 19 October 2010, two weeks before the first *O. mykiss* redd was detected. The in-river release of age 2+ *O. mykiss* just below Camanche Dam may also explain why an unusually large proportion of redds were found in reach 6, specifically within the SHIRA enhancement area, which overlapped with the release site.

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). While researchers in Oregon have been able to identify differences between the physical habitat of redds built by resident and anadromous forms of *O. mykiss*, this may not be possible in the Central Valley (Zimmerman and Reeves 2000). Temporal segregation of spawning between resident and anadromous *O. mykiss* has not been established on the lower Mokelumne River. Additionally, very few *O. mykiss* are observed constructing redds during the surveys.

MANAGEMENT IMPLICATIONS

The success of the adaptive management strategy for the lower Mokelumne River fisheries program in 2010 was due to several important actions. The series of flood-flow releases from Camanche Dam provided an attraction flow for adult spawners, as an estimated 7,196 Chinook salmon returned to the LMR, comprising 69% of the entire San Joaquin River system fall-run return. In addition, the closure of the Delta Cross Channel from 13 through 15 October 2010 may have reduced straying to other rivers for a short

period of time. Such efforts help diminish the mixing of different stocks, which may help to reduce the homogenization of California Central Valley fall-run Chinook salmon.

ACKNOWLEDGEMENTS

We would like to thank Jason Shillam, Matt Saldate, Charles Hunter, Casey Del Real, Steve Boyd and Jose Setka for their input, advice, and assistance with the surveys. Thanks to all EBMUD Lodi Fisheries and Wildlife staff for their contributions.

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