Lower Mokelumne River Salmonid Redd Survey Report:
October 2011 through February 2012

June 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 19 October 2011 through 28 February 2012. Estimated total escapement during the 2011/2012 season was 18,596 Chinook salmon. The estimated number of in-river spawners was 2,674 Chinook salmon. The first salmon redd was detected on 19 October 2011. During the surveys, a total of 564 salmon redds were identified. Forty-three (7.6%) Chinook salmon redds were superimposed by other Chinook salmon redds and 336 (59.6%) redds were located within gravel enhancement areas. The reach from Camanche Dam to Mackville Road (reach 6) contained 512 (90.2%) salmon redds and the reach from Mackville Road to Elliott Road (reach 5) contained 52 (9.8%) salmon redds. The highest number of Chinook salmon redd detections (161) took place on 22 November 2011. The first *O. mykiss* redd was found on 22 November 2011. Sixty-eight *O. mykiss* redds were identified. Nine *O. mykiss* redds were superimposed on Chinook salmon redds and one *O. mykiss* redd was superimposed on another *O. mykiss* redd. Thirty-one (45.6%) *O. mykiss* redds were located within gravel enhancement areas. Reach 6 contained 51 (75%) redds and reach 5 contained 17 (25%) redds. The highest number of *O. mykiss* redds (18) was detected on 1 February 2012.

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 construction of Camanche Dam and receives approximately 61% of the total run per year (1990-2010 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 2011/2012 salmonid redd surveys (referred to as the 2011 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 19 October 2011 and were concluded on 28 February 2012. Both reaches were surveyed once per week, when possible. However, due to rain and limited visibility, the redd survey during week 17 (7 February 2012) was 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

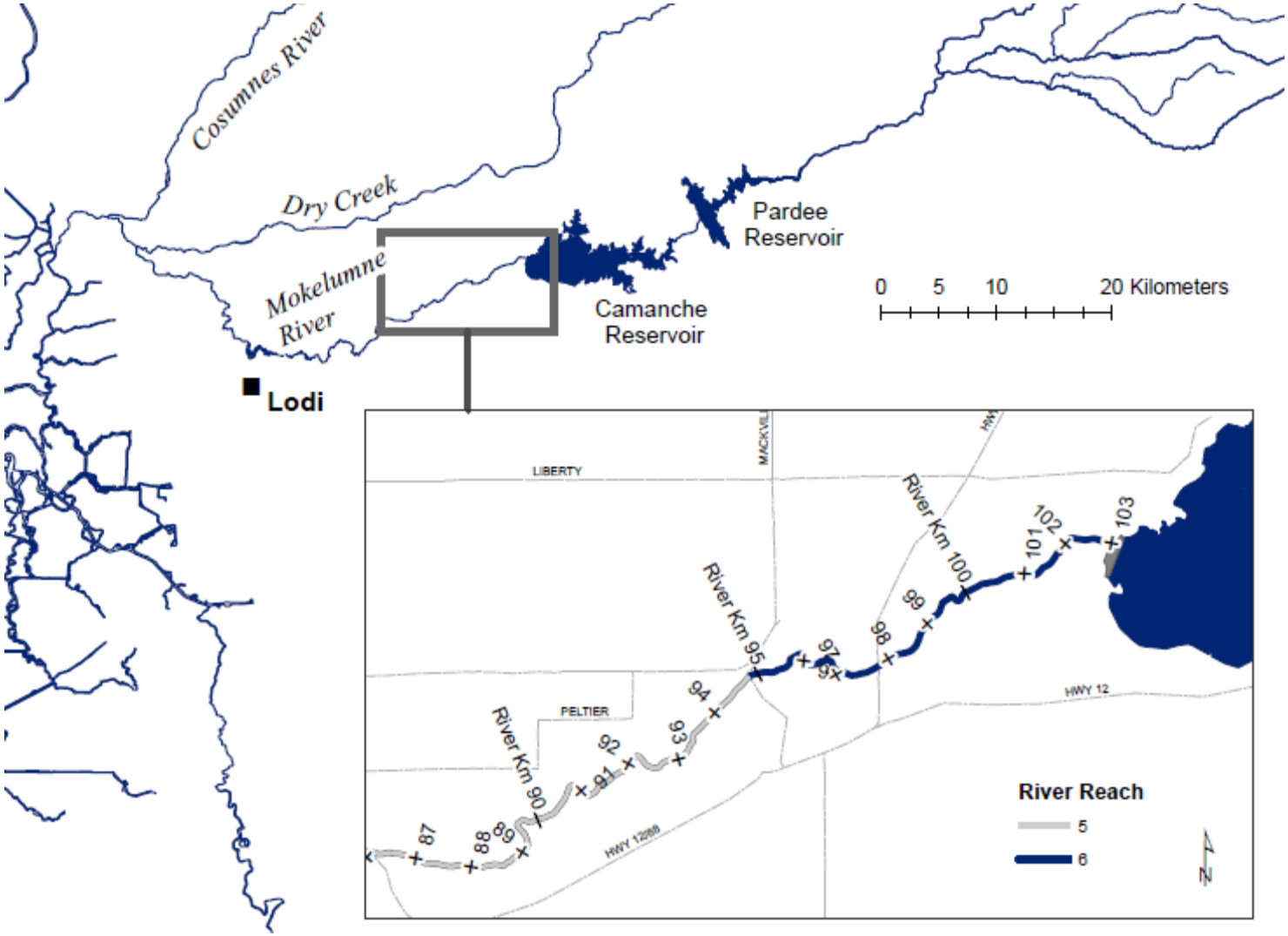

Figure 1. Mokelumne River watershed (extent) and salmonid redd survey reach (inset) locations.

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. However, with high resolution Global Positioning Systems (GPS) 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.

Throughout the 2011 salmonid redd surveys, a subset of 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, 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, depths and velocities were measured at approximately one of every two *O. mykiss* redds detected during the survey period. 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. 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. 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, the data files were downloaded and processed using GPS Pathfinder Office 4.20 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 2011, 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 1,802 cubic feet per second (cfs) on 8 October 2011, during the first pulse. Average daily flow peaked at roughly 1,600 cfs during the following three pulses (Figure 2).

During the redd survey period (19 October 2011 – 28 February 2012) average daily releases from Camanche Dam ranged from 300 to 1,598 cfs (Figure 2). The average daily flow during this time period was 469 cfs. The average daily flow from 19 October 2011 through 15 February 2012 (time period Chinook salmon redds were detected) ranged from 329 to 1,598 cfs and averaged 487 cfs. The average daily flow from 22 November 2011 through 21 February 2012 (time period *O. mykiss* redds were detected) ranged from 329 cfs to 404 cfs and averaged 340 cfs. Average daily water temperature at the McIntire gauging station (rkm 101, reach 6) ranged from 9.4°C to 16.3°C during the survey period. The average temperature during this time frame was 12.1°C. The average daily water temperatures from 19 October 2011 through 15 February 2012 (time period salmon redds were detected) ranged from 9.4°C to 16.3°C and averaged 12.4°C . The average daily water temperatures during the time period when *O. mykiss* redds were detected ranged from 9.4°C to 15.1°C and averaged 10.9°C.

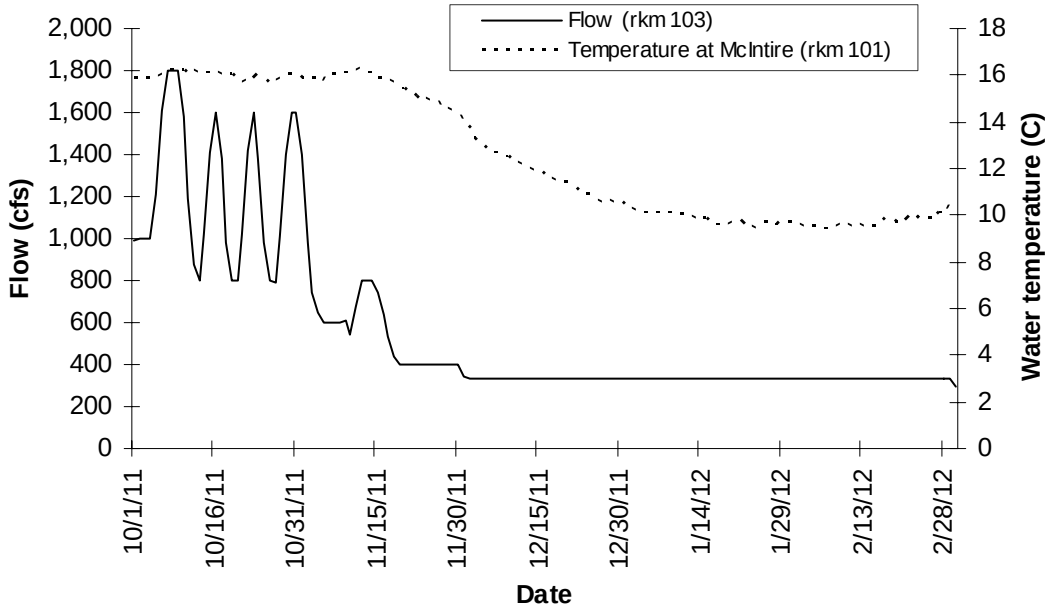

Figure 2. Average daily releases from Camanche Dam (rkm 103) and water temperatures at the McIntire Station (rkm 101) in the lower Mokelumne River during the 2011 salmonid redd surveys.

Chinook Salmon

Redd totals and Escapement

During the annual redd survey period 564 Chinook salmon redds were detected. The first and last redd detections occurred on 19 October 2011 and 15 February 2012, respectively. The highest number of redds (161) was detected the week of 20 November 2011 (Figure 3). Reach 6 contained 512 redds (90.8%) and reach 5 contained 52 redds

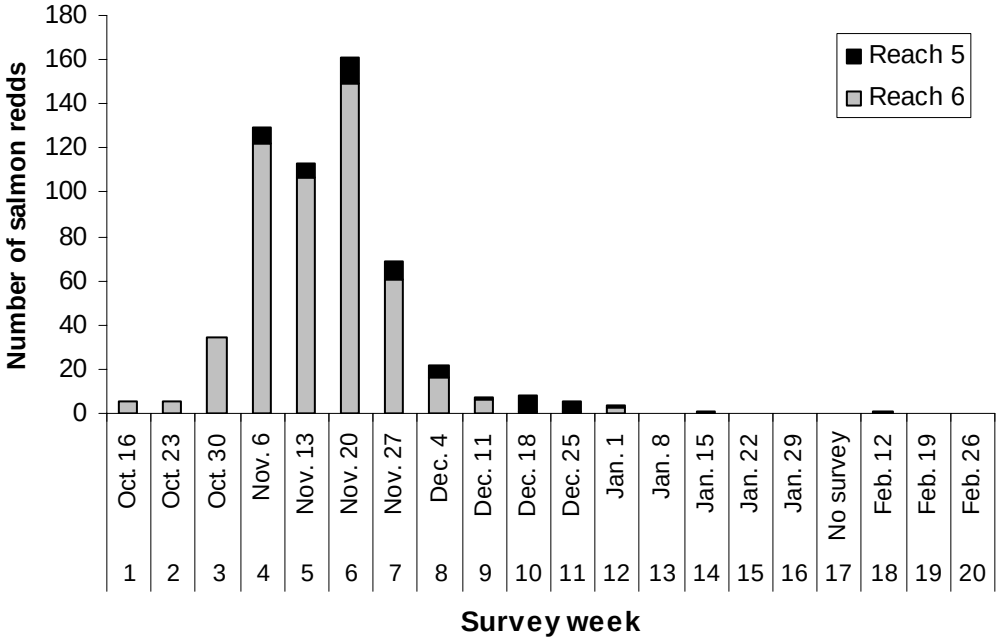

Figure 3. Weekly Chinook salmon redd totals by reach on the lower Mokelumne River during the 2011 surveys.

(9.2%). Survey week 17 was missed this season due to poor survey conditions and limited visibility caused by rain (Figure 3).

The 2011 annual redd count was 21% below the long term average (1990-2010) of 710, 10% below the pre-Joint Settlement Agreement (JSA) average (1990-1997) of 625, and 25% below the post-JSA average (1998-2010) of 748 (Figure 4).

To estimate fall-run Chinook salmon escapement in the LMR during the 2011 season, video monitoring was conducted at WIDD from 1 August 2011 to 31 January 2012. During this time 18,596 Chinook salmon were counted passing the fish ladders at WIDD. The total count of Chinook salmon that entered the MRFI this season was 15,922. The LMR in-river escapement estimate of 2,674 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 entered the MRFI was classified as grilse (13,513, 85%), while the other 15% (2,409) were classified as adults. In contrast, it was estimated

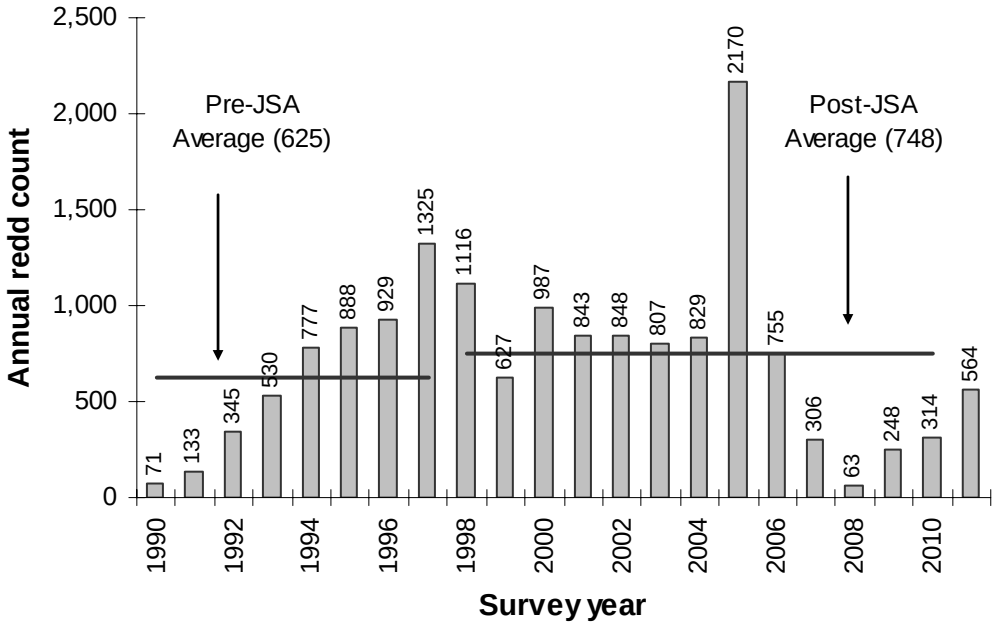

Figure 4. Chinook salmon redd totals on the lower Mokelumne River during pre-JSA flows (1990 – 1997) and post-JSA flows (1998 – 2010).

that 26% (704) of the adult Chinook salmon that remained in the river were classified as grilse and the other 74% (1,970) of in-river Chinook salmon were classified as adults. Overall, 70% (12,951) of the Chinook salmon returning to the watershed this season were male, 30% (5,616) were female, and less than 1% (29) 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 3,188 cubic yards (yd^3) of gravel were placed in the SHIRA enhancement reach in September 2011. This brings the total volume of gravel added to the reach to 20,565 yd^3 between 2007 and 2011. During the 2011 redd survey, 203 (36%) Chinook salmon redds were found within the SHIRA reach.

Overall, 336 Chinook salmon redds, or 60% of the total number of redds detected (564), were constructed within spawning habitat restoration (SHR) sites. In addition, one salmon redd was found within a restored side channel, which was constructed in 2005 and intended to expand juvenile salmonid rearing habitat. Ninety-four percent (316) of redds constructed in SHR sites were located in reach 6 and 6% (20) were located in reach 5.

Superimposition

Forty-three Chinook salmon redds (7.6%) were superimposed by other Chinook salmon redds during the 2011 redd survey season. Most of the superimposition took place in reach 6 (41 redds), while two redds were superimposed in reach 5. The 2011 superimposition rate was lower than the long-term average of 10.3% (1991-2010), the pre-JSA average of 9.0% (1991-1997) and the post-JSA average of 11.0% (1998-2010). There was a significant linear relationship between the annual redd count and the annual superimposition rate (Linear regression: $F = 25.39$; df = 1, 19; $P < 0.001$). The annual redd count explained 57% of the variation in annual superimposition rates.

Habitat Use – Water Depth and Velocity

A total of 75 water depth measurements and 77 water velocity measurements were taken just above the nose of Chinook salmon redds from 19 October to 14 December 2011. During that time frame average daily releases from Camanche Dam ranged from 330 to 1,598 cfs, however releases did not exceed 798 cfs on the actual dates the measurements were recorded (Figure 5). Chinook salmon redd water depths ranged from 14 to 98 cm and averaged 53 cm (SD = 21, Figure 5). The central 50% of the depth measurements (between Q1 and Q3) occurred between 37 and 66 cm. Water velocity measurements ranged from 0.11 to 1.27 m/s and averaged 0.66 m/s (SD = 0.24, Figure 5). The central 50% of the velocity measurements occurred between 0.53 and 0.81 m/s.

Oncorhynchus mykiss

Redd totals

Sixty-eight *O. mykiss* redds were detected during the 2011 salmonid redd survey. The first and last detections occurred on 22 November 2011 and 21 February 2011, respectively. The largest number of *O. mykiss* redds (18) was detected on 1 February 2012 (Figure 6). Reach 6 contained 51 redds (75%) and reach 5 contained 17 redds (25%). The 2011 annual redd count was 51.1% above the long-term (2000-2010) average of 45 (Figure 7).

Gravel Enhancement Area Usage

During the 2011 redd survey season, 15 (22.1 %) *O. mykiss* redds were found within the SHIRA enhancement area. Overall, 31 *O. mykiss* redds, or 45.6% of the total number of redds detected (68), were constructed in gravel enhancement areas. Ninety-four percent (29) of redds constructed in enhancement areas were located in reach 6 and 6% (2) were located in reach 5.

Superimposition

Nine *O. mykiss* redds were superimposed on Chinook salmon redds and one *O. mykiss* redd was superimposed on another *O. mykiss* redd during the 2011 season. All incidents of superimposition took place in the upper 2.5 rkm of reach 6. Four of the superimposed redds were located above the MRFI barrier fence, where spawning habitat is limited.

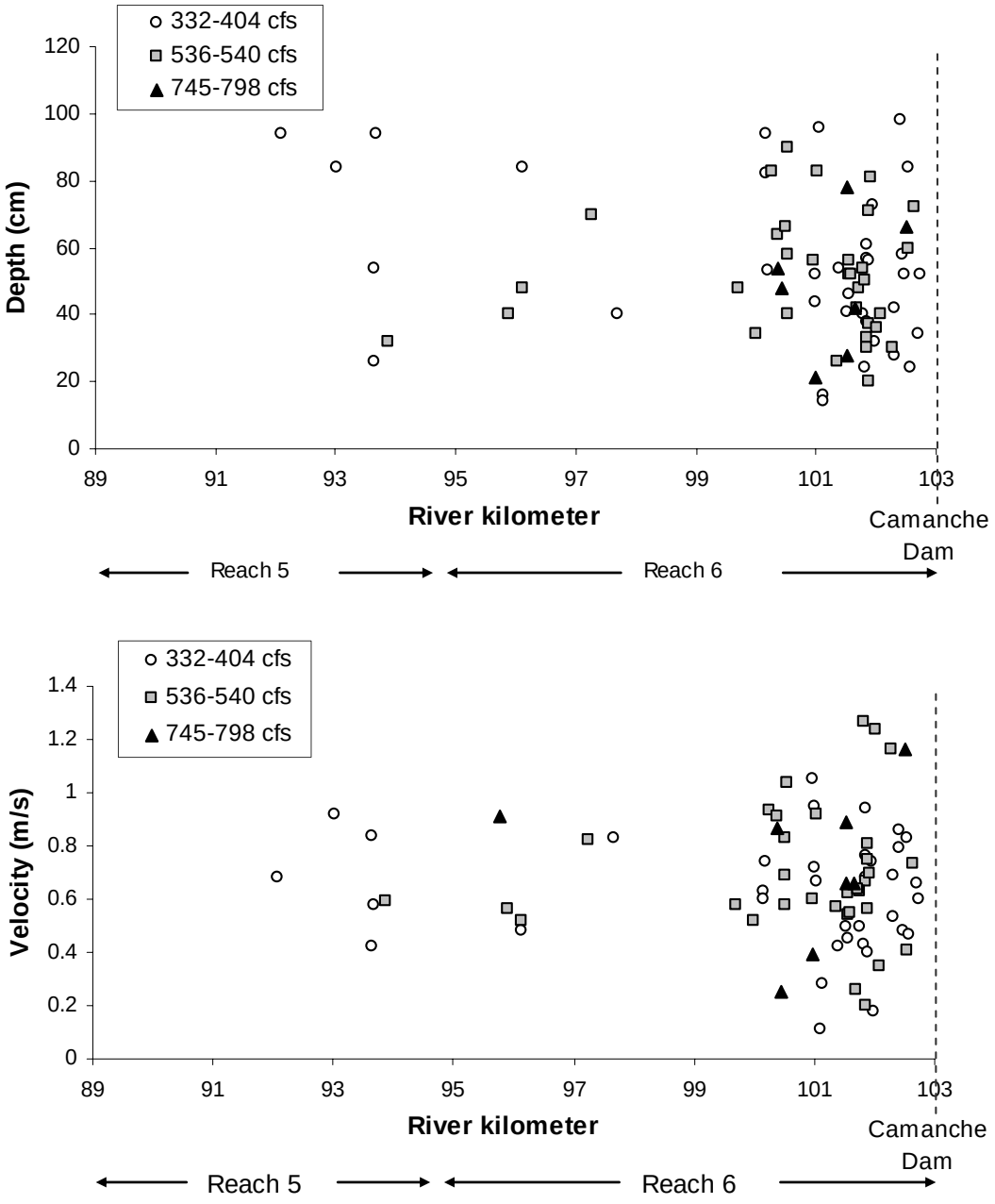

Figure 5. Water depth (top) and velocity (bottom) measurements taken just above the nose of Chinook salmon redds during the 2011/2012 annual survey on the lower Mokelumne River.

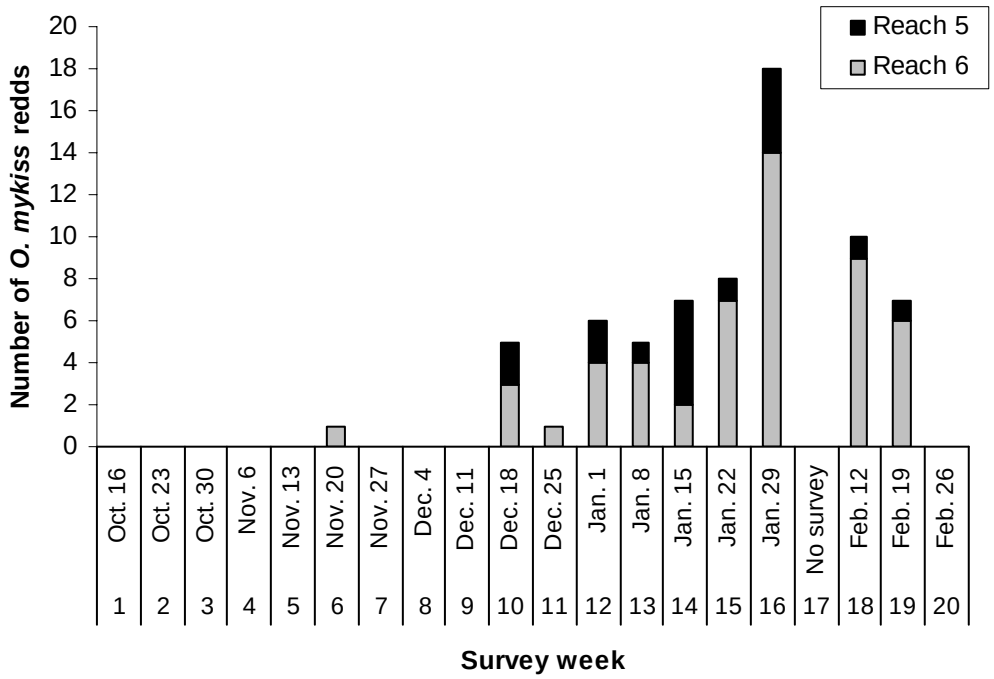

Figure 6. Weekly *O. mykiss* redd totals by reach on the lower Mokelumne River during the 2011 survey season.

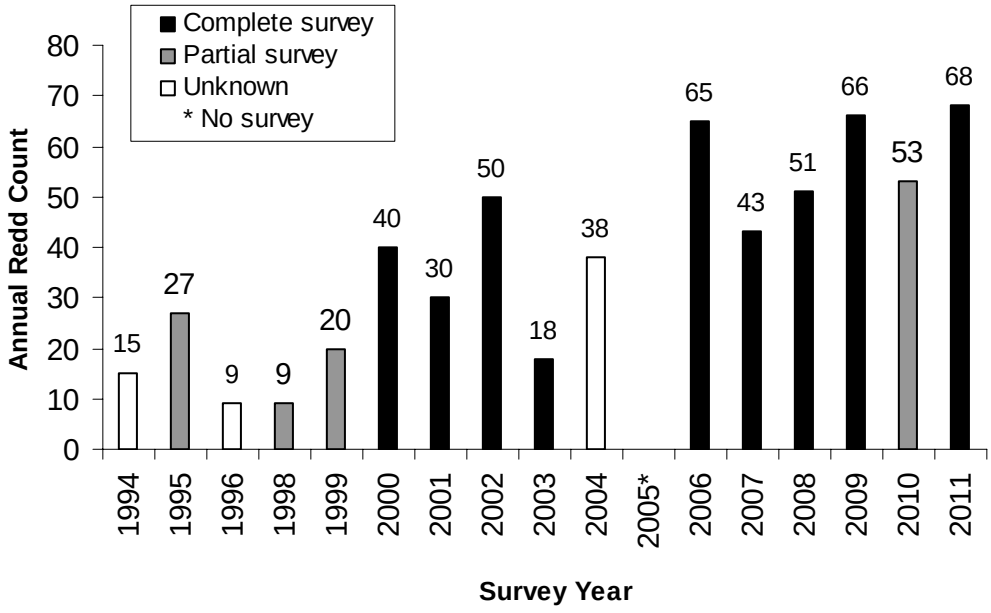

Figure 7. Annual *O. mykiss* redd totals on the lower Mokelumne River from 1994-2011.

Habitat Use – Water Depth and Velocity

A total of 36 water depth measurements and 36 water velocity measurements were taken just above the nose of *O. mykiss* redds between 22 December 2011 and 21 February 2012, when water releases from Camanche Dam were relatively low (~330 cfs). Most of the measurements were taken within the uppermost spawning reaches of the river, just below Camanche Dam. Water depths ranged from 26 to 94 cm and averaged 57 cm (SD =19). The central 50% of the depth measurements (between Q1 and Q3) occurred between 42 and 75 cm. Water velocity measurements ranged from 0.34 m/s to 1.12 m/s and averaged 0.68 m/s (SD = 0.20). The central 50% of the velocity measurements occurred between 0.52 and 0.83 m/s.

DISCUSSION

The 2011-2012 LMR Chinook salmon escapement estimate of 18,596 was 344% higher than the historical (1940-2010) average of 4,192, 441% higher than the pre-JSA (1940-1997) average of 3,439, and 156% higher than the post-JSA (1998-2010) average of 7,261. Preliminary 2011 escapement data from GrandTab[1] indicate that a total of 227,889 fall-run Chinook salmon returned to the California Central Valley this season. This total was comprised of 205,096 salmon that returned to the Sacramento River system and 22,793 salmon that returned to the San Joaquin River system. This season, the LMR accounted for 82% 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.

Although the 2011 Chinook salmon redd total was an improvement from the redd counts over the past four years (Bilski and Rible 2010), it was lower than the post-JSA average of 748. This was due in part, to the large number of grilse salmon that returned to the LMR this season, which comprised over 70% of the returning population. In addition, a large proportion (86%) of returning Chinook salmon was trapped at the hatchery. The other 14% of the population (2,674 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. Average daily water temperatures ranged from 9.4 to16.3°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 2011 water temperatures fell within the range recorded during previous spawning seasons on the LMR (Setka 2004).

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 21

[1] California Department of Fish and Game - Fisheries Branch Anadromous Assessment, http://beergarage.com/GrandTab/GTFallSum1.aspx, accessed on 10/11/2012.

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 (60% this season).

The 2011 Chinook salmon redd superimposition rate of 7.6% was lower than the long term average (1991-2010) of 10.3%. A number of factors may be used to explain annual superimposition rates. Spawning density (using annual redd counts) explained 57% of the variation in annual salmon redd superimposition rates. 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 2011 spawning season, the Chinook salmon redd count was 21% below the long-term average, which may have contributed to the low superimposition rate. Also, the large number of gravel augmentation projects on the LMR has expanded the amount of high quality spawning habitat available to adult Chinook salmon. This season 60% of the total number of Chinook salmon redds was located within SHR sites and it is possible that these projects also contributed to the low overall redd superimposition rate in 2011.

Most of the Chinook salmon redd water depths and velocities fell within the expected ranges for the species (Moyle 2002) at flows ranging from 332-798 cfs. However, there were a few redds identified in shallow habitats with slow surface water velocities just above the nose. This may have been due to the flood flow release that occurred between 10 November and 19 November 2011, as all of these redds were identified in mid to late November. All of the water depth and velocity measurements recorded at *O. mykiss* redds during the 2011 season fell within the ranges documented by Moyle (2002).

Sixty-eight *O. mykiss* redds were observed during the 2011 season, which was the highest redd count on record since 1994. However, this number was not necessarily a reflection of an unusually high steelhead escapement. In fact, an average number (246) of adult *O. mykiss* (total length ≥ 16 in.) returned to the hatchery during the 2011 season, as adult *O. mykiss* counts at the hatchery exceeded 200 adults three of the five 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 February with only one weekly survey missed. Finally, it is possible that some of these redds were constructed by individuals from a group of 997 hatchery-origin age 2+ *O. mykiss*. Over half of these fish (499) were released just below Camanche Dam (rkm 103) on 28 September 2011, while the other 498 were released at Feist Ranch (rkm 47) on 28 September 2011.

It is 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). 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 2011 was due to several actions. The series of water releases from Camanche Dam provided an attraction flow for adult spawners, as a record number (18,596) of Chinook salmon returned to the LMR, comprising 82% of the entire San Joaquin River system fall-run return. In addition, a 10-day closure of the Delta Cross Channel from 4 through 14 October 2011 may have reduced straying to other rivers for a short period of time.

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