LOWER MOKELUMNE RIVER
UPSTREAM FISH MIGRATION MONITORING
Conducted at Woodbridge Irrigation District Dam
August 2013 through July 2014

August 2014

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***Abstract*: This report summarizes data collected below Woodbridge Irrigation District Dam (WIDD) on the lower Mokelumne River (LMR) from August 1, 2013 through July 31, 2014. An estimated 12,252 fall-run Chinook salmon (*Oncorhynchus tshawytscha*) passed the WIDD fish ladder between September 24, 2013 and January 21, 2014. Fifty percent of the run passed WIDD by November 6, 2013. Ninety percent of the run passed WIDD by November 22, 2013. Highest daily passage was 1,178 fish on October 23, 2013 which is the 2nd highest daily count of fish passage since video monitoring began. The sex and life stage was positively determined for 12,243 fish including 4,964 (41%) adult (≥70 cm FL) females, 4,534 (37%) adult males, 615 (5%) grilse (<70 cm FL) females, and 2,130 (17%) grilse males. Management actions, such as pulse flows and Delta Cross Channel closures, were followed by peaks in daily passage and contributed to high overall returns. One hundred and twenty-four adult steelhead (*O. mykiss*) passed WIDD between October 2013 and June 2014. Peak steelhead passage occurred in January (n=50).**

INTRODUCTION

East Bay Municipal Utility District (EBMUD) has been monitoring adult fall-run Chinook salmon (*Oncorhynchus tshawytscha*) escapement in the lower Mokelumne River (LMR) using video monitoring and trapping at the Woodbridge Irrigation District Dam (WIDD) at river kilometer (Rkm) 64 since fall 1990. In 1997, Woodbridge Irrigation District initiated a rebuild of the dam, fish ladders, and fish screening facilities on the LMR. Carcass surveys and video monitoring were conducted simultaneously in the fall of 2003 in order to determine the accuracy and precision of estimates generated by carcass survey versus video monitoring and trapping at WIDD (Workman 2004). During the fall of 2004, carcass surveys and video monitoring were again both completed successfully in order to estimate Chinook salmon escapement. Between 2005 and 2007, the LMR fall-run Chinook salmon escapement was estimated by conducting carcass surveys for in-river escapement and adding the salmon trapped at the Mokelumne River Fish Hatchery (MRFH) for a total Mokelumne River fall-run Chinook salmon escapement. Due to low

returns of Chinook salmon during 2008 and 2009, salmon per redd estimates were multiplied by the salmon redd counts to estimate in-river escapement. Beginning in 2010, through coordination between EBMUD and Woodbridge Irrigation District, Lodi Lake remained full of water throughout the Chinook salmon run which facilitated continuous video monitoring of Chinook salmon passage in the high stage ladder at WIDD. WIDD management remained the same during the upstream migration of fall-run Chinook salmon from 2010/2011 through 2013/2014. Therefore, total Mokelumne River fall-run Chinook salmon escapement during these years was based on video monitoring of fish passage at WIDD.

OBJECTIVES

The objectives of this study are to 1) develop an escapement estimate for fall-run Chinook salmon for the LMR, 2) summarize sex and age composition, run timing, and coded wire tag component of the 2013 fall-run Chinook salmon population on the LMR, 3) describe the relationship of fall-run Chinook salmon movements to environmental conditions and management actions on the LMR and in the Sacramento-San Joaquin Delta, and 4) monitor presence of native and non-native fishes in the WIDD high stage fish ladder.

METHODS

Video

EBMUD's video monitoring in the high stage ladder at WIDD is conducted year round, with the exception of a short period of time when the dam is lowered for annual maintenance. Woodbridge Irrigation District lowered the dam on February 5, 2014. As water was routed through the low stage ladder, video monitoring operations were suspended. After the air bladders of WIDD were reinflated on March 3, 2014, monitoring in the high stage ladder resumed and continued through July 31, 2014.

All other monitoring, data collection, and storage methods for video monitoring were consistent with prior year's monitoring efforts (Marine and Vogel 2000, Workman 2004).

RESULTS AND DISCUSSION

Chinook Salmon

The fall-run Chinook salmon escapement estimate in the LMR for 2013/2014 is 12,252 spawners entering the river between September 2013 and January 2014 (Figure 1). Fifty percent of the run passed WIDD by November 6th (Table 1). Highest daily passage of 1,178 fish occurred on October 23, 2013. This was the same day as the highest daily passage during the 2012/13 monitoring period. In addition, it was the second highest daily fish passage count since video monitoring began. The sex and life stage was positively determined for 12,243 fish including 4,964 (41%) adult (≥70 cm FL) females,

4,534 (37%) adult males, 615 (5%) grilse (<70 cm FL) females, and 2,130 (17%) grilse males (Figure 2).

Table 1. Dates when 10%, 50%, and 90% of fall-run Chinook salmon passed the Woodbridge Irrigation District Dam, 1990-2004; 2010-2013.

Year	10%	50%	90%
1990	Oct. 23	Nov. 18	Dec. 12
1991	n/a	n/a	n/a
1992	Oct. 28	Nov. 13	Dec. 2
1993	Oct. 22	Nov. 3	Nov. 21
1994	Oct. 21	Nov. 7	Dec. 2
1995	Sept. 28	Oct. 30	Nov. 23
1996	Oct. 18	Oct. 31	Nov. 20
1997	Oct. 15	Nov. 8	Nov. 22
1998	Oct. 11	Nov. 4	Nov. 24
1999	Oct. 16	Nov. 3	Nov. 20
2000	Oct. 12	Oct. 30	Nov. 16
2001	Oct. 29	Nov. 11	Nov. 25
2002	Oct. 24	Nov. 7	Nov. 24
2003	Sep. 4	Nov. 13	Dec. 4
2004	Oct. 23	Nov. 12	Nov. 29
2010	Oct. 9	Oct. 24	Nov. 24
2011	Oct. 9	Oct. 24	Nov. 13
2012	Oct. 17	Nov. 3	Nov. 22
2013	Oct. 23	Nov. 6	Nov. 22

From 1990 to 2003 and in 2010, approximately a 1:3 grilse to adult ratio was observed on the LMR. In 2004 and 2012, the grilse ratio was considerably higher with a grilse to adult ratio closer to 1:2. Conversely, the grilse to adult ratio in 2011 was reversed with an approximate adult to grilse ratio of 1:3. In 2013, the earlier, more common trend of approximately 1:3 grilse to adult ratio was observed (22% GR; 78% AD) (Figure 3).

In the 2013/2014 monitoring season, 72% of fish passed the video monitor during the day and 28% during the night. Day is defined as ½ hour before sunrise to ½ hour after sunset. Daytime passage has been consistently higher than nighttime passage (Table 2). Peak passage occurred between 0800hrs and 1000hrs. However, Chinook salmon passage times throughout the day were more variable than in previous years (Figure 4).

Table 2. Percent of annual fall-run Chinook salmon passing WIDD during day and night, 1990-2004; 2010-2013.

Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2010*	*2011*	*2012*	*2013*
Day	57	64	69	59	61	68	52	56	56	62	68	58	55	73	79	87	82	68	72
Night	43	36	31	41	39	32	48	44	44	38	32	42	45	27	21	13	18	32	28

Clipped adipose fins were evident on 3,587 (29%) of the observed fall-run Chinook salmon (Table 3). The sex and life stage were positively determined for all 3,587 adipose fin clipped fish. Of the fish identified with an adipose fin clip, 1,809 (50%) were adult (≥70 cm FL) females, 1,112 (31%) were adult males, 201 (6%) were grilse (<70 cm FL) females and 465 (13%) were grilse males. Thirty-six percent of the returning adult females were adipose fin clipped, 25% of the adult males were adipose fin clipped, 33% of the grilse females were adipose fin clipped, and 22% of the grilse males were adipose fin clipped. The increased percentage of adipose fin clipped adult Chinook salmon may be due to the increased rate of coded wire tagging of the returning 2009 broodyear fish. In 2008 and 2009, 100% of hatchery reared Chinook salmon at the MRFH were coded wire tagged and adclipped. In 2010 and 2011, approximately 25% of hatchery reared Chinook salmon at the MRFH were coded wire tagged and adclipped.

Table 3. Incidence of adipose fin clips on fall-run Chinook salmon passing Woodbridge Irrigation District Dam, 1992-2004; 2010-2013.

	Adults		Grilse	
Year	Number	Percent	Number	Percent
1992	10	1.4	35	3.8
1993	11	0.9	8	1.7
1994	244	10.3	22	4
1995	161	7.8	55	15.2
1996	169	9.2	47	3.5
1997/1998	152	2.9	7	1.7
1998/1999	427	7.4	175	12
1999/2000	327	10.8	139	6.1
2000/2001	225	4.0	83	8
2001/2002	326	8.5	188	18.6
2002/2003	1,228	14.4	363	16.2
2003/2004	996	13.4	319	12.7
2004/2005	614	9.7	129	3.7
2010/2011	1,978	38.3	1,708	84.1
2011/2012	3,508	80.1	13,449	94.6
2012/2013	7,656	92.8	1,152	30.0
2013/2014	2,921	30.8	666	24.2

During the 2013/2014 Chinook salmon migration period, Camanche Dam releases ranged from 240 – 472 cfs (Figure 5). Average flow was 278 cfs. Flow below WIDD ranged from 32 – 459 cfs and averaged 131 cfs (Figure 6). Water temperatures from the August through January monitoring period ranged from 10.3 – 16.2 C° at below Camanche Dam (Figure 7) and 7.9 – 22.7 C° at WIDD (Figure 8). Total rainfall, collected at the California Irrigation Management Information System's Lodi West station #166, was 2.03 inches (Figure 9). Peak daily rainfall was 0.78 inches. Turbidity in the LMR increases with rainfall, but was not recorded through the migration period.

River flow, temperature, and rainfall have been investigated for their relationship to salmon returns. Regression analyses comparing these factors to the number of fish on the ascending portion of the curve were run for the 2013/2014 escapement (Table 4). Flow

and temperature had a significant relationship with daily salmon passage. However, due to variability in the response of fish passage at WIDD to management actions and environmental variables, the relationship between flow, temperature, and fish counts do not signify a strong correlation.

Table 4. Relationship of environmental variables measured to the number of Chinook salmon passing Woodbridge Irrigation District Dam.

	Range	R^2	*P* value
Flow below Woodbridge (cfs)	34 – 459	0.19	0.0046
Temperature below Woodbridge (C°)	12.7 – 18.3	0.29	0.0004
Precipitation (in)	0	-	-

Expected flow below WIDD between April and September was based on the Joint Settlement Agreement Dry water year designation. Flow was increased below WIDD on September 30, 2013 in order to meet the October through March Below Normal water year flow schedule, which was determined by total Pardee and Camanche storage.

EBMUD conducted 5 planned pulse flow events during October and November. This was the fourth year in a row that EBMUD released fall attraction flows in the LMR. Woodbridge Irrigation District also supported the implementation of fall attraction flows by the re-regulation of Camanche Reservoir releases. Woodbridge Irrigation District was able to surcharge Lodi Lake by building up the lake elevation to approximately 40 feet and then dropping the lake level by 1 - 2 feet thereby augmenting 4 of the 5 EBMUD planned pulses (the 1st, 3rd, 4th, and 5th pulse flows). WIDD also conducted 2 additional pulses following the planned events. EBMUD did not release any additional water above and beyond typical flow releases in order to surcharge Lodi Lake. In addition to the pulse flow events, multiple Delta Cross Channel (DCC) closures occurred from October through January in order to meet Rio Vista flow standards and implement winter-run Chinook salmon protection measures (Figure 6).

As in previous years, peaks in Chinook salmon passage corresponded with the pulse flow events and DCC closures (Figure 6). The first pulse flow peaked on October 8th during a DCC closure on October 8th and 9th. The corresponding peak in passage was observed on October 10th. The 2nd pulse flow peaked on October 15th with a peak in passage on October 16th. The highest daily passage was observed one day after the 3rd pulse flow which peaked on October 22nd. The 4th pulse flow peaked on October 29th with a spike in passage observed 1 day later on October 30th. Both the 3rd and 4th pulse flow events occurred during a 10 day DCC closure. The 5th pulse flow peaked on November 5th with an increase in passage observed on November 6th. The attraction pulse on November 20th occurred during a 4 day DCC closure and 3 day rain event which resulted in 2,241 Chinook salmon passing WIDD between November 20th and 22nd. The attraction pulse on November 27th followed a 2 day DCC closure with a spike in passage observed that same day.

Steelhead

Steelhead have been observed since monitoring began in 1990 (Table 5). In all years prior to 1997, adult monitoring ended in December. Spawning, however, typically occurs between January and March for winter steelhead in the Central Valley (IEP Steelhead PWT 1999).

Table 5. Steelhead observed moving upstream during video monitoring at Woodbridge Irrigation District Dam.

Monitoring Period	*Number*	*Monitoring Period*	*Number*
Oct. - Dec. 1990	4	Aug. 2000 – Apr. 2001	48
Oct. - Dec. 1991	n/a	Aug. 2001 – July 2002	91
Oct. - Dec. 1992	7	Aug. 2002 – July 2003	62
Oct. - Dec. 1993	8	Aug. 2003 – July 2004	39
Oct. - Dec. 1994	19	Aug. 2004 – Apr. 2005	44
Sept. - Dec. 1995	76	Aug. 2010 – July 2011	100
Sept. - Dec. 1996	12	Aug. 2011 – July 2012	257*
Sept. 1997 – Feb. 1998	6	Aug. 2012 – March 2013	74
Aug. 1998 – Mar. 1999	12	Aug. 2013 – July 2014	124
Aug. 1999 – Mar. 2000	80		

* Count may include hatchery-origin Age 1+ steelhead released during the monitoring period at the Feist Ranch and/or New Hope.

One hundred and twenty-four adult steelhead (≥380 mm FL) were observed moving upstream through WIDD from October 5, 2013 through June 9, 2014. The highest monthly abundance of steelhead was in January (n=50). No video monitoring occurred between February 6th and March 2nd as fish passage at WIDD was diverted to the low stage ladder. Of the 124 fish observed, 24 were males, 21 were females, and 79 were not distinguishable to sex. Ninety-two percent (n=114) were adipose fin clipped (Table 6).

Table 6. Monthly sex composition and adipose fin clip totals of steelhead passing Woodbridge Irrigation District Dam, August 1, 2013 – July 31, 2014.

Monitoring Period	*Male Count*	*Female Count*	*Unknown Sex Count*	*Total Count*	*Adclip Total*
August	-	-	-	-	-
September	-	-	-	-	-
October	5	9	10	24	21
November	5	5	10	20	17
December	4	-	13	17	15
January	9	4	37	50	50
February	-	1	4	5	5
March	1	2	3	6	5
June	-	-	2	2	1
Totals	24	21	79	124	114

Yearling steelhead (FL <200mm) and subadult steelhead (FL ≤350mm) were not counted due to their ability to pass through the bars which guide fish in front of the video monitoring vault and their tendency to hold within the high stage ladder.

Incidental Species

Prior to the fall of 1996, adult Pacific lamprey observations at WIDD were not recorded. Numbers of adult lamprey observed during video monitoring on the LMR have been sporadic since recording began in 1996, from a high of 979 in fall 1999, to one recorded passing upstream during video monitoring in 2000/2001. The years 1996 and 1999 are the only years we saw more than 100 adult lamprey ascending the ladders at Woodbridge (Table 7). Pacific lamprey are in decline in the Columbia and Snake River Basins and the same may be true in the Central Valley (Close et al 1995; Brown and Moyle 1993). Since the WIDD rebuild, lamprey are not counted due to their ability to fit through the bars within the high stage ladder bypassing our video monitoring equipment, but observations are recorded (Table 8).

Table 7. Adult Pacific lamprey observed moving upstream during video monitoring at Woodbridge Irrigation District Dam, 1996-2004.

Year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1996	n/a	123	13	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1997	n/a	12	7	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1998	14	0	0	0	0	0	0	0	n/a	n/a	n/a	n/a
1999	323	606	50	0	0	0	0	0	n/a	n/a	n/a	n/a
2000	1	0	0	0	0	0	0	0	-1	n/a	n/a	n/a
2001	0	0	0	0	0	0	0	0	0	0	1	2
2002	0	0	0	0	1	0	1	1	0	2	0	8
2003	16	4	0	0	1	0	0	0	0	3	11	3
2004	2	0	0	0	0	0	0	0	1	n/a	n/a	0

Presence and absence data of native and non-native species is presented in Table 8. Native fishes observed using the ladder include hitch, Pacific lamprey, Sacramento pikeminnow, Sacramento sucker, and tule perch. In addition, 1 adult and 1 grilse Chinook salmon were observed moving upstream past WIDD between May 23, 2014 and May 29, 2014. Clipped adipose fins were evident on both of the observed Chinook salmon. Non-native fish using the fish ladders at WIDD include black bass, black crappie, bluegill, carp, goldfish, largemouth bass, redear sunfish, and other unidentified centrarchids.

Table 8. Native and non-native fish observed in the Woodbridge Irrigation District Dam fish ladder, August 1, 2013 - July 31, 2014. Species names in bold represent native species.

	August	September	October	November	December	January	February	March	April	May	June	July
Hitch										X		
Pacific Lamprey								X		X	X	
Sacramento Pikeminnow	X	X	X			X		X	X	X	X	X
Sacramento Sucker								X	X	X	X	X
Tule Perch											X	X
Chinook Salmon										X		
Black Bass	X	X							X	X	X	X
Black Crappie		X										
Bluegill										X	X	X
Common Carp									X	X	X	X
Goldfish										X		
Largemouth Bass									X	X	X	X
Redear Sunfish	X									X		X
Unidentified Centrarchid	X										X	X

Acknowledgements

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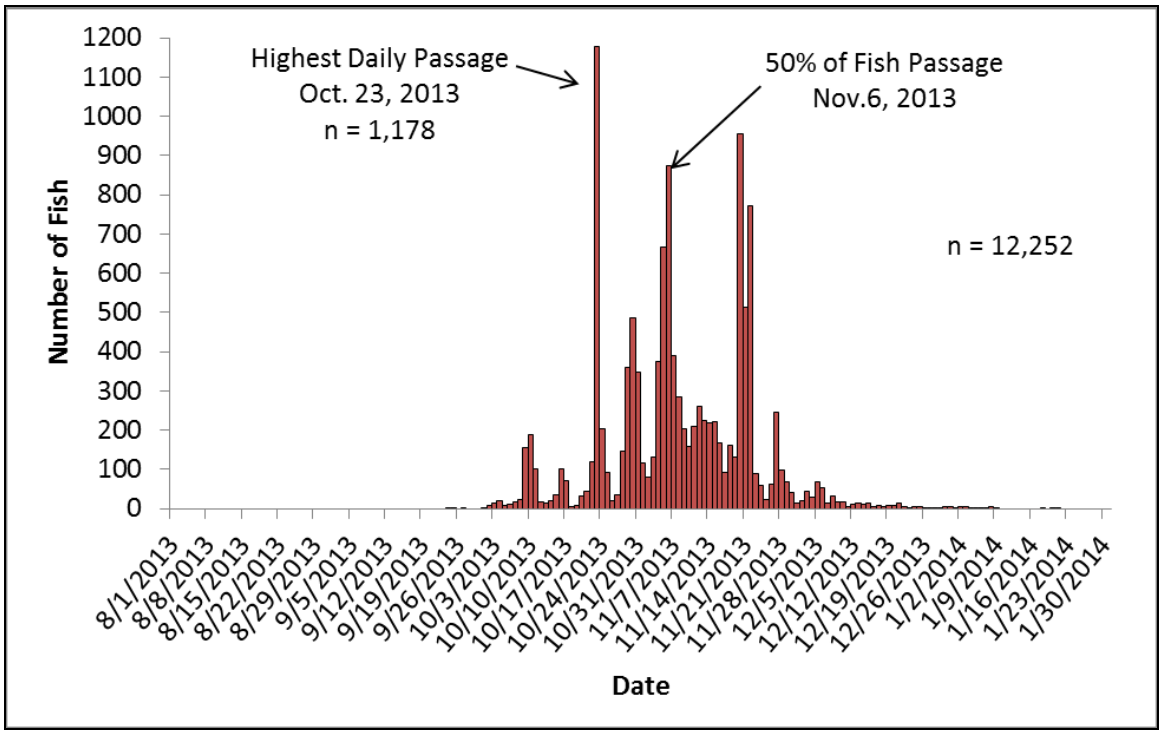

Figure 1. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD, August 1, 2013 – January 31, 2014.

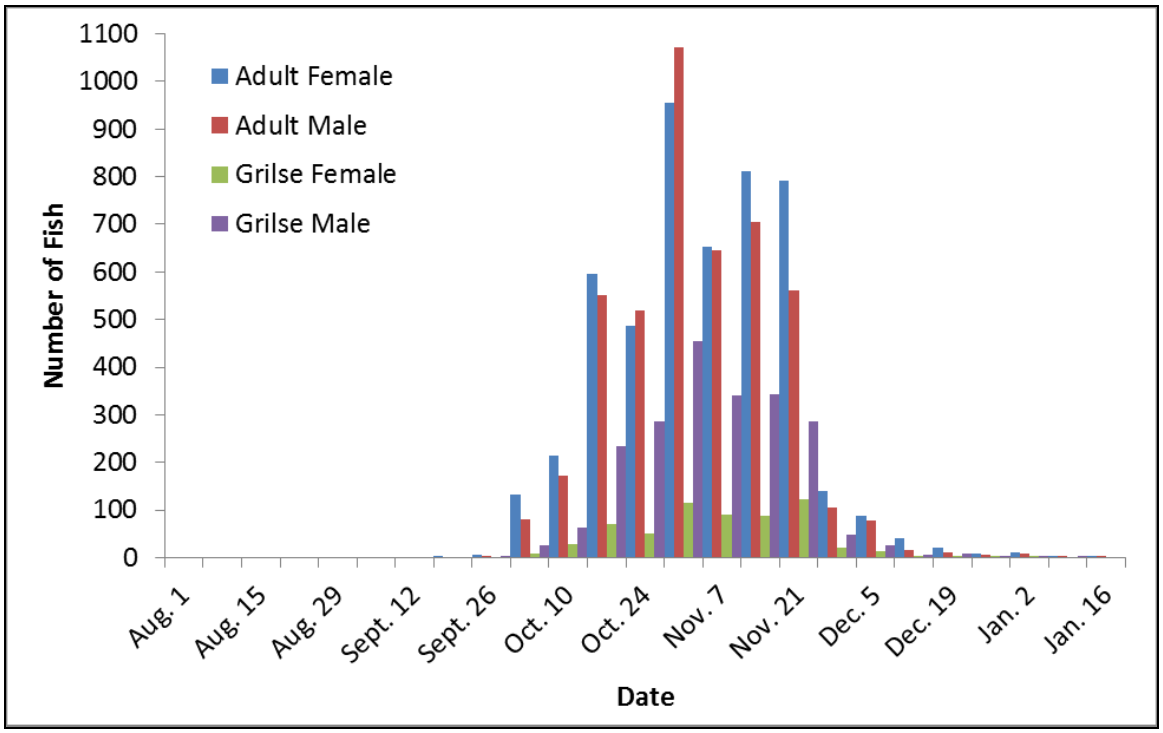

Figure 2. Weekly sex/age composition of fall-run Chinook salmon passing WIDD, August 1, 2013 – January 31, 2014.

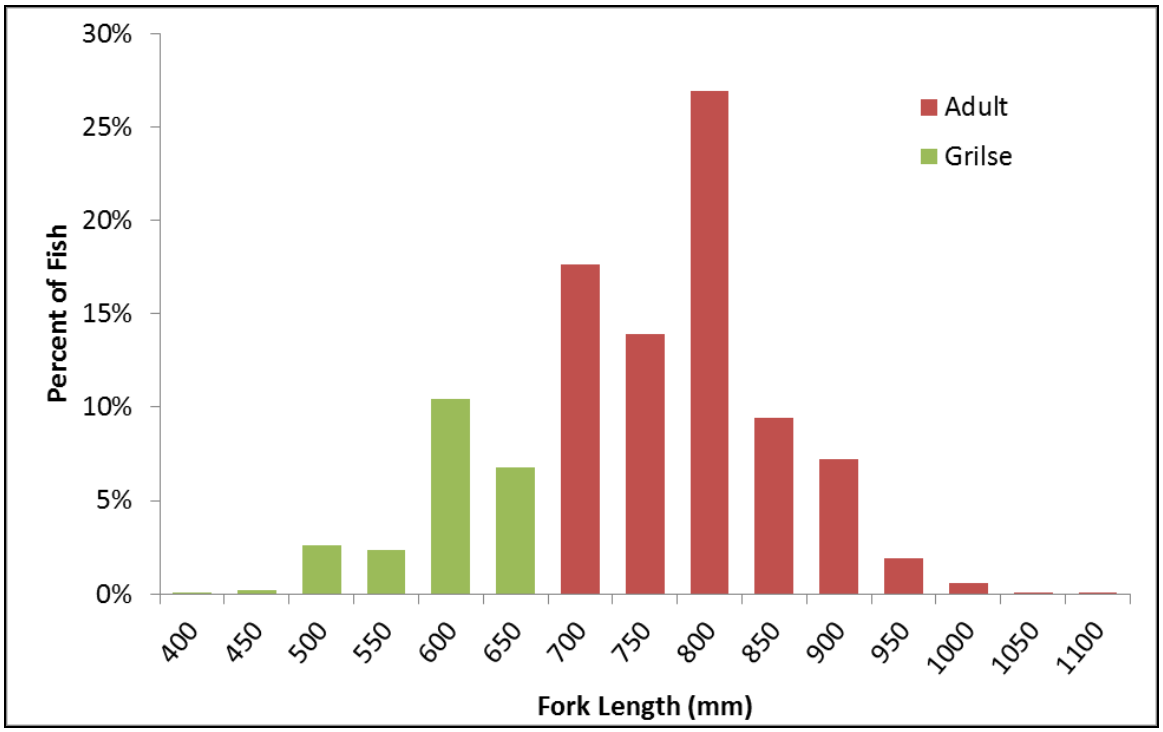

Figure 3. Length frequency of adult and grilse Chinook salmon (% by size class) passing WIDD, August 1, 2013 – January 31, 2014.

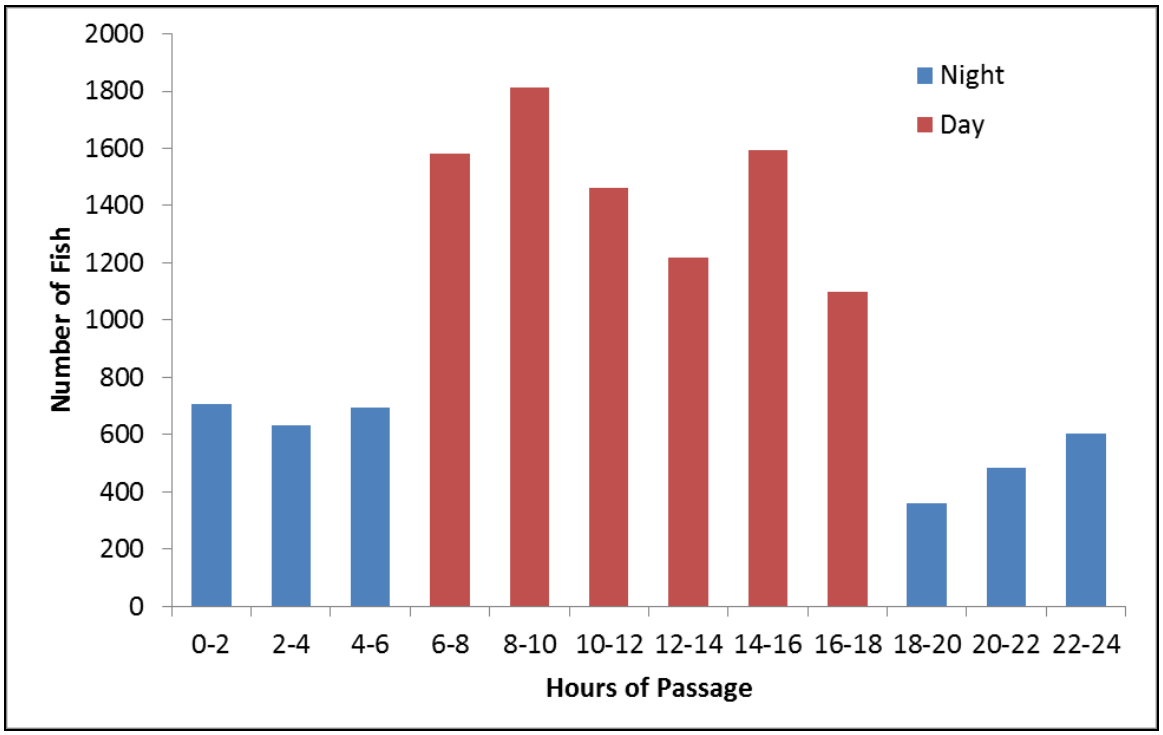

Figure 4. Chinook salmon passage (2 hour intervals) recorded from video monitoring at WIDD, August 1, 2013 – January 31, 2014.

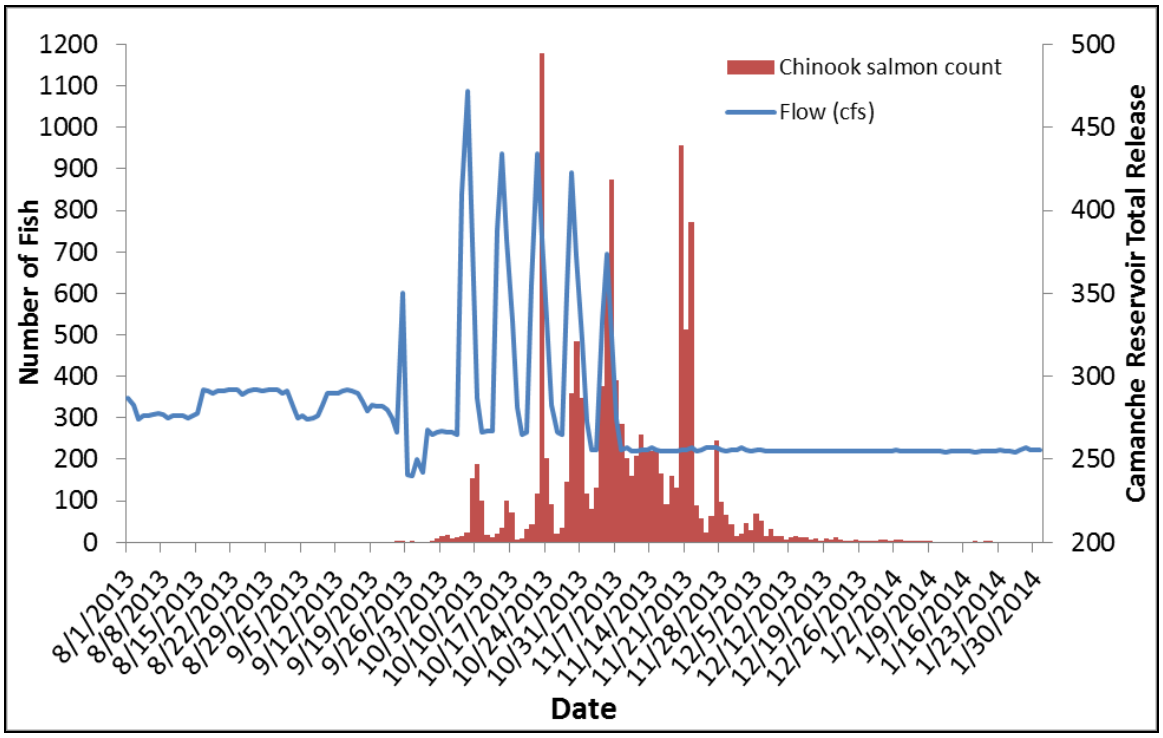

Figure 5. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to flow below Camanche Reservoir, August 1, 2013 - January 31, 2014. Flow data are preliminary and subject to change.

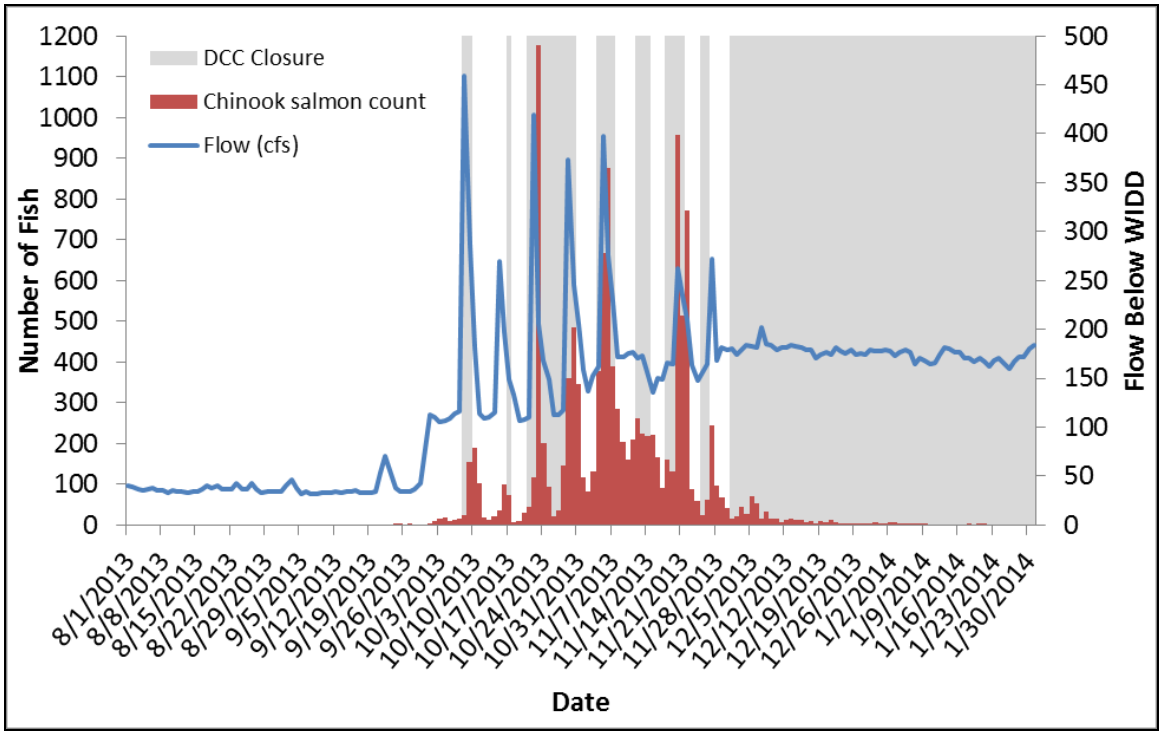

Figure 6. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to flow below WIDD and DCC closures, August 1, 2013 – January 31, 2014. Flow data are preliminary and subject to change.

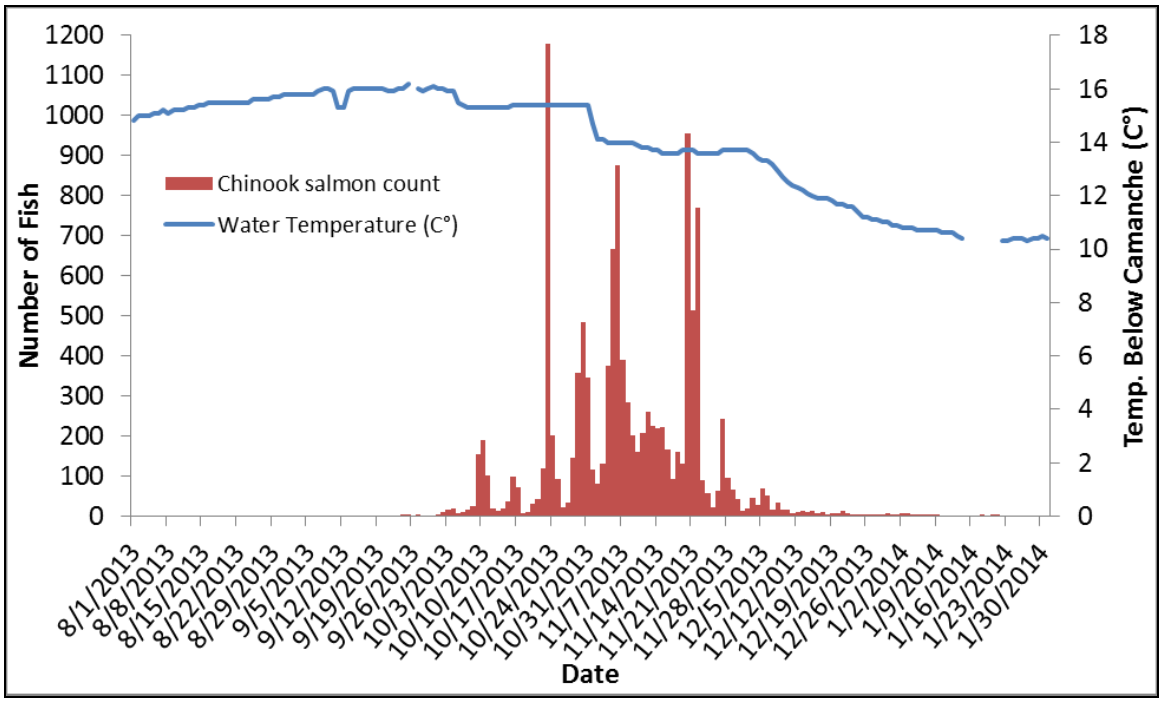

Figure 7. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below Camanche Reservoir, August 1, 2013 - January 31, 2014.

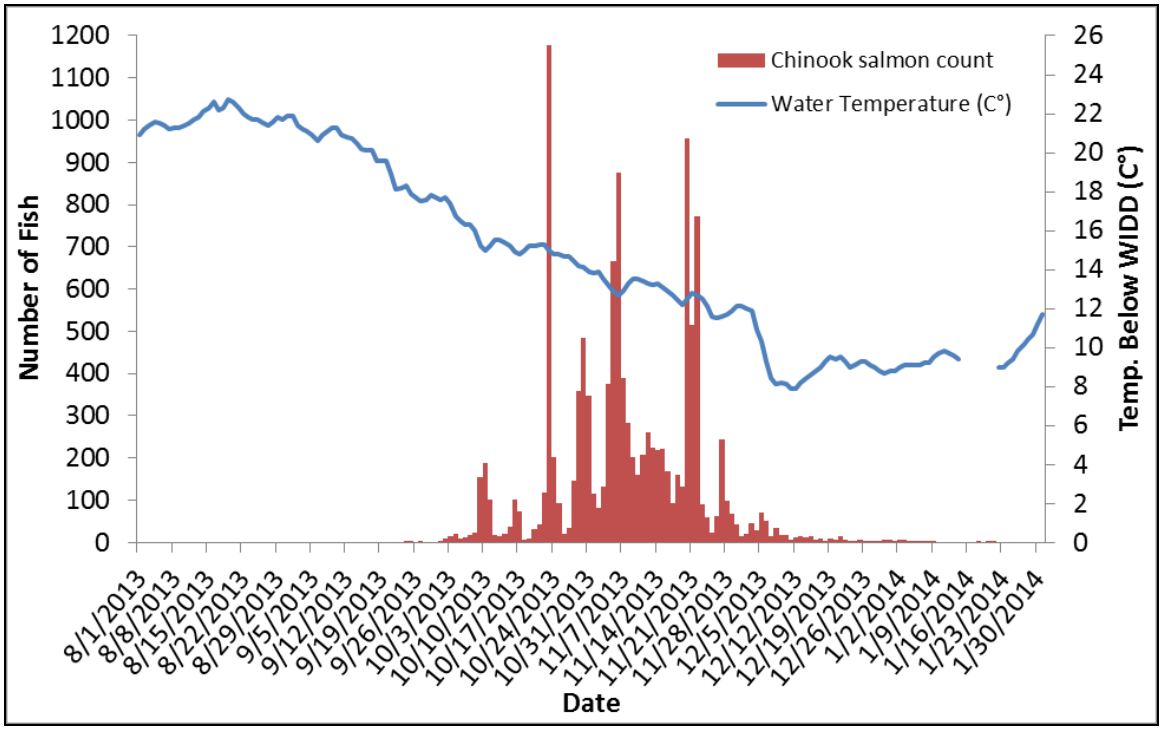

Figure 8. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below WIDD, August 1, 2013 - January 31, 2014.

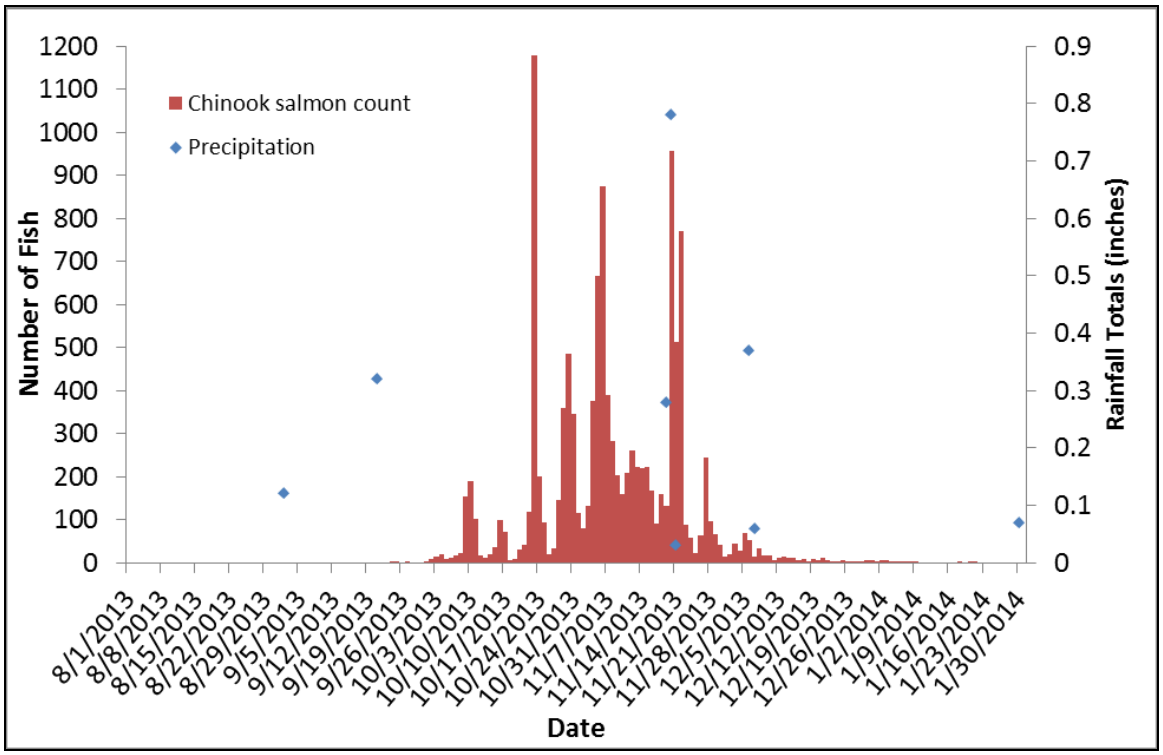

Figure 9. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to Lodi rainfall, August 1, 2013 - January 31, 2014.

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