LOWER MOKELUMNE RIVER
UPSTREAM FISH MIGRATION MONITORING
Conducted at Woodbridge Irrigation District Dam
August 2015 through May 2016

June 2016

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Key words: lower Mokelumne River, fall-run Chinook salmon, steelhead, escapement

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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, 2015 through May 31, 2016. An estimated 12,879 fall-run Chinook salmon (*Oncorhynchus tshawytscha*) passed the WIDD fish ladder between October 17, 2015 and January 21, 2016. Fifty percent of the run passed WIDD by November 23, 2015. Ninety percent of the run passed WIDD by December 12, 2015. Highest daily passage was 1,493 Chinook salmon on November 24, 2015 which is the highest daily count of Chinook salmon passage since video monitoring began. The sex and life stage was positively determined for 12,877 fish including 4,127 (32%) adult females, 4,109 (32%) adult males, 1,367 (11%) grilse females, and 3,274 (25%) grilse males. Management actions, such as pulse flows and Delta Cross Channel closures, were followed by peaks in daily passage and contributed to the high overall returns. Sixteen adult steelhead (*O. mykiss*) passed WIDD between November 2015 and April 2016. Peak steelhead passage occurred in January (n=10).**

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. Beginning in 2010, through coordination between EBMUD and Woodbridge Irrigation District, Lodi Lake remained full of water throughout the Chinook salmon run. This facilitated continuous video monitoring of Chinook salmon passage in the high stage ladder at WIDD. WIDD operations remained the same during the upstream migration of fall-run Chinook salmon from 2010/2011 through 2015/2016. 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 in the LMR, 2) summarize sex and age composition, run timing, and coded wire tag component of the 2015 LMR fall-run Chinook salmon population, 3) describe the relationship of fall-run Chinook salmon movements to environmental conditions and management actions in the LMR and Sacramento-San Joaquin Delta, 4) enumerate steelhead passage, and 5) 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 typically conducted year round, with the exception of a short period of time when the dam is lowered for annual maintenance. Video monitoring was also temporarily halted for the month of September as conditions below WIDD were unsuitable for Chinook salmon passage due to the ongoing drought and Critically Dry Water Year. Woodbridge Irrigation District lowered the dam on January 25, 2016. As water was routed through the low stage ladder, video monitoring operations were suspended. After the air bladders of WIDD were reinflated on March 5, 2016, monitoring in the high stage ladder resumed and continued through May 31, 2016.

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

Fall-Run Chinook Salmon

The fall-run Chinook salmon escapement estimate in the LMR for 2015/2016 is 12,879 spawners entering the river between October 2015 and January 2016 (Figure 1). Fifty percent of the run passed WIDD by November 23rd (Table 1). Highest daily passage of 1,493 fish occurred on November 24, 2015. This was the highest daily Chinook salmon passage count since video monitoring began. Sex and life stage were positively determined for 12,877 fish including 4,127 (32%) adult (≥70 cm FL) females, 4,109 (32%) adult males, 1,367 (11%) grilse (<70 cm FL) females, and 3,274 (25%) grilse males (Figure 2). In 2015, approximately a 1:2 grilse to adult ratio was observed on the LMR (36% GR; 64% AD) (Figure 3).

Table 1. Dates when 10%, 50%, and 90% of fall-run Chinook salmon passed the Woodbridge Irrigation District Dam, 1990-2004; 2010-2015.

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[1]	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
2014	Oct. 22	Nov. 11	Dec. 2
2015	Oct. 26	Nov. 23	Dec. 12

[1]Between 2005 and 2009, Lodi Lake was drained during the LMR Chinook salmon run suspending video monitoring operations in the high stage ladder. Therefore, fish passage data was not collected at WIDD for the entire run of salmon during these years.

In the 2015/2016 monitoring season, 65% of fish passed the video monitor during the day and 35% 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 800hrs and 1000hrs (Figure 4).

Table 2. Percent of annual fall-run Chinook salmon passing WIDD during day and night, 1990-2004; 2010-2015.

Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Day	57	64	69	59	61	68	52	56	56	62	68	58	55	73	79	87	82	68	72	72	65
Night	43	36	31	41	39	32	48	44	44	38	32	42	45	27	21	13	18	32	28	28	35

Clipped adipose fins were evident on 3,456 (27%) of the observed fall-run Chinook salmon (Table 3). The sex and life stage were positively determined for all adipose fin clipped fish. Of the fish identified with an adipose fin clip, 1,070 (31%) were adult (≥70 cm FL) females, 1,038 (30%) were adult males, 420 (12%) were grilse (<70 cm FL) females, and 928 (27%) were grilse males. Twenty-six percent of the returning adult females were adipose fin clipped, 25% of the adult males were adipose fin clipped, 31%

of the grilse females were adipose fin clipped, and 28% of the grilse males were adipose fin clipped. Between 2011 and 2013, approximately 25% of hatchery reared Chinook salmon at the Mokelumne River Fish Hatchery 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; 2010-2015.

	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
2014/2015	1,543	24.1	1,347	23.5
2015/2016	2,108	25.6	1,348	29.0

Mokelumne River Flow, Water Temperature, and Rainfall

During the 2015/2016 Chinook salmon migration period, Camanche Dam daily average releases ranged from 105 – 416 cfs (Figure 5). Average daily flow was 188 cfs. Average daily flow below WIDD ranged from 17 – 340 cfs and averaged 83 cfs (Figure 6). Daily average water temperatures from August through January ranged from 9.6 – 18.8 C° below Camanche Dam (Figure 7) and 6.8 – 24.7 C° below WIDD (Figure 8). Total rainfall, collected at the Camp Pardee station, was 13.9 inches (Figure 9). Peak daily rainfall was 1.48 inches.

River flow, temperature, and rainfall have been investigated for their relationship to salmon returns. Regression analyses comparing these factors to the number of fish that passed WIDD were run for the 2015/2016 escapement. Flow ($P<0.001$) and temperature ($P=0.018$) had a significant relationship with daily salmon passage. However, due to variability in the response timing of fish passage at WIDD to management actions and environmental variables, the relationship between flow, temperature, and fish counts do not represent a strong correlation.

Management Actions and Migration Response

Expected flow below WIDD from August through March was based on the Joint Settlement Agreement (JSA) Critically Dry water year type for both the April to September and October to March periods. This was the first JSA Critically Dry designation on record and, in accordance with the October through March JSA water year type, flow was increased below WIDD on October 15, 2015 in order to maintain the minimum JSA flow requirement of 75 cfs. This increase in flow corresponded with the first Chinook salmon observed moving passed WIDD on October 17, 2015.

EBMUD conducted 7 planned pulse flow events from October through December. This was the sixth 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 5 of the EBMUD planned pulses. WIDD also conducted 3 additional pulses which extended attraction flow events into January. January pulse flow events were implemented to promote steelhead passage. 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 May in order to meet Delta salinity levels, Rio Vista flow standards, and implement winter-run Chinook salmon protection measures.

As in previous years, peaks in Chinook salmon passage corresponded with pulse flow events and DCC closures (Figure 6). Table 4 summarizes each pulse flow event and concurrent DCC closure conducted during the immigration of fall-run Chinook salmon to the Mokelumne River.

Table 4 Summary of management actions, including pulse flow events and corresponding DCC closures, implemented during the 2015/2016 Mokelumne River Chinook salmon run.

Pulse Flow	Date of Peak Flow	Peak Flow (cfs)[1]	Peak Passage Event	Daily Passage Total[2]	DCC Operations
1	10/17/2015	318 cfs	10/20/2015	156 CS	Open
2	10/28/2015	735 cfs	10/29/2015	411 CS	Closed[5]
3	11/4/2015	343 cfs	11/5/2015	322 CS	Open
4	11/11/2015	690 cfs	11/10/2015	444 CS	Closed[5]
5	11/24/2015	730 cfs	11/24/2015	1493 CS[3]	Open
6	12/1/2015	710 cfs	12/2/2015	438 CS	Closed
7	12/9/2015	766 cfs	12/9/2015	464 CS	Open
8	12/14/2015	662 cfs	12/14/2015	227 CS	Open
9	1/8/2016	683 cfs	1/9/2016	-2 STH[4]	Closed
10	1/20/2016	694 cfs	1/20/2016 1/21/2016	9 STH	Closed

[1]Flow is based on raw 15 minute instantaneous measurements recorded at the Golf gauge located downstream of WIDD. Flow data are preliminary and subject to change.
[2] CS = Chinook salmon; STH = steelhead.
[3]Highest daily passage of fall-run Chinook salmon recorded during the 2015/2016 monitoring period.
[4]Negative numbers represent downstream passage.
[5]DCC was closed on final day of pulse flow event.

Steelhead

Steelhead (*O. mykiss*) 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. 2001 – July 2002	91
Oct. - Dec. 1991	n/a	Aug. 2002 – July 2003	62
Oct. - Dec. 1992	7	Aug. 2003 – July 2004	39
Oct. - Dec. 1993	8	Aug. 2004 – Apr. 2005	44
Oct. - Dec. 1994	19	Aug. 2010 – July 2011	100
Sept. - Dec. 1995	76	Aug. 2011 – July 2012	257[1]
Sept. - Dec. 1996	12	Aug. 2012 – March 2013	74
Sept. 1997 – Feb. 1998	6	Aug. 2013 – July 2014	124
Aug. 1998 – Mar. 1999	12	Aug. 2014 – July 2015	152
Aug. 1999 – Mar. 2000	80	Aug. 2015 – May 2016	16
Aug. 2000 – Apr. 2001	48		

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

Sixteen adult steelhead (≥380 mm FL) were observed moving through WIDD from November 24, 2015 through April 4, 2016. The highest monthly abundance of steelhead was in January (n=10). Of the 16 fish observed, 1 was male, 6 were females, and 9 were not distinguishable to sex. One-hundred percent (n=16) 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, 2015 – May 31, 2016.

Monitoring Period	*Female Count*	*Male Count*	*Unknown Sex Count*	*Total Count*
August				
September				
October				
November	1			1
December	1		2	3
January[1]	4	1	5	10
February[1]				
March[1]			3	3
April			-1	-1
Totals	6	1	9	16

[1] No video monitoring occurred between January 26, 2016 and March 4, 2016 as fish passage at WIDD was diverted to the low stage ladder.

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

Presence and absence data for native and non-native species are presented in Table 7. Native fishes observed using the ladder include Pacific lamprey, prickly sculpin, Sacramento pikeminnow, Sacramento sucker, and tule perch. Non-native fish using the fish ladders at WIDD include black bass, bluegill, carp, channel catfish, goldfish, largemouth bass, redear sunfish, striped bass, and unidentified centrarchids.

Table 7. Native and non-native fish observed in the Woodbridge Irrigation District Dam fish ladder, August 1, 2015 - May 31, 2016. Species names in bold represent native species.

	August	September[1]	October	November	December	January	February[1]	March	April	May
Pacific Lamprey			X			X		X	X	X
Prickly Sculpin									X	
Sacramento Pikeminnow			X			X		X	X	X
Sacramento Sucker			X	X	X	X		X	X	X
Tule Perch				X	X			X	X	X
Black Bass			X					X	X	
Bluegill			X							
Common Carp				X				X	X	
Channel Catfish				X						
Goldfish								X	X	X
Largemouth Bass			X	X		X		X	X	X
Redear Sunfish			X							X
Striped Bass	X		X							
Unidentified Centrarchid			X	X		X		X	X	X

[1]Video monitoring was suspended during September and February.

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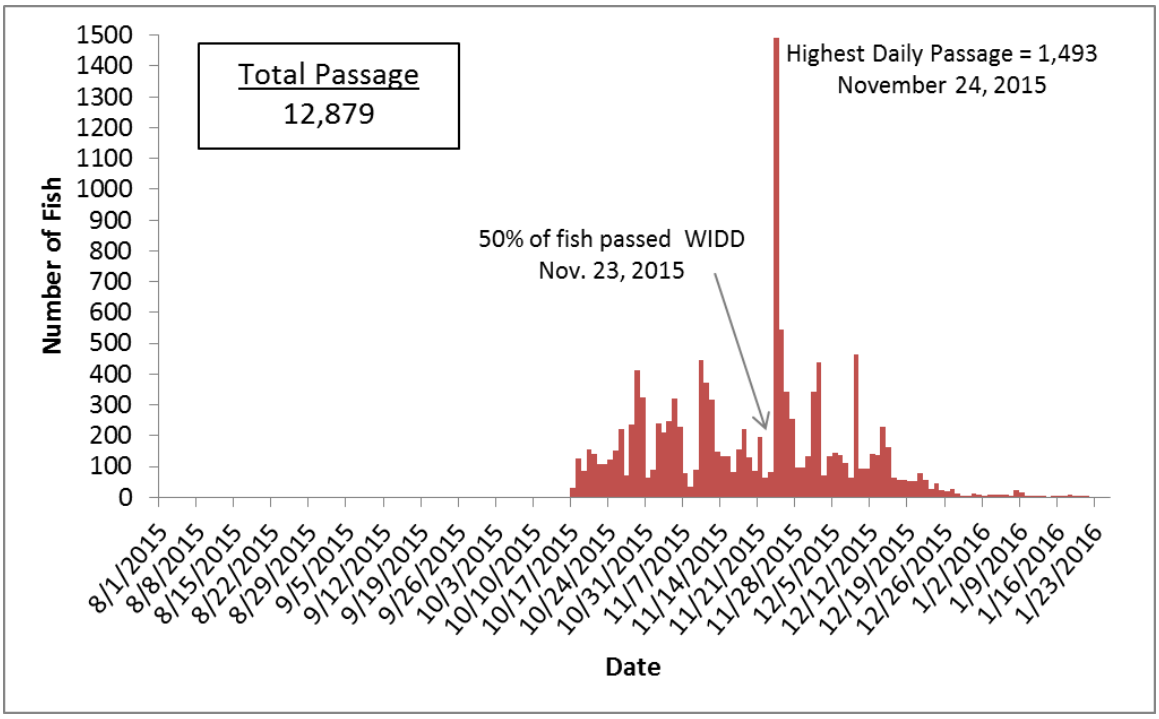

Figure 1. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD, August 1, 2015 – January 25, 2016.

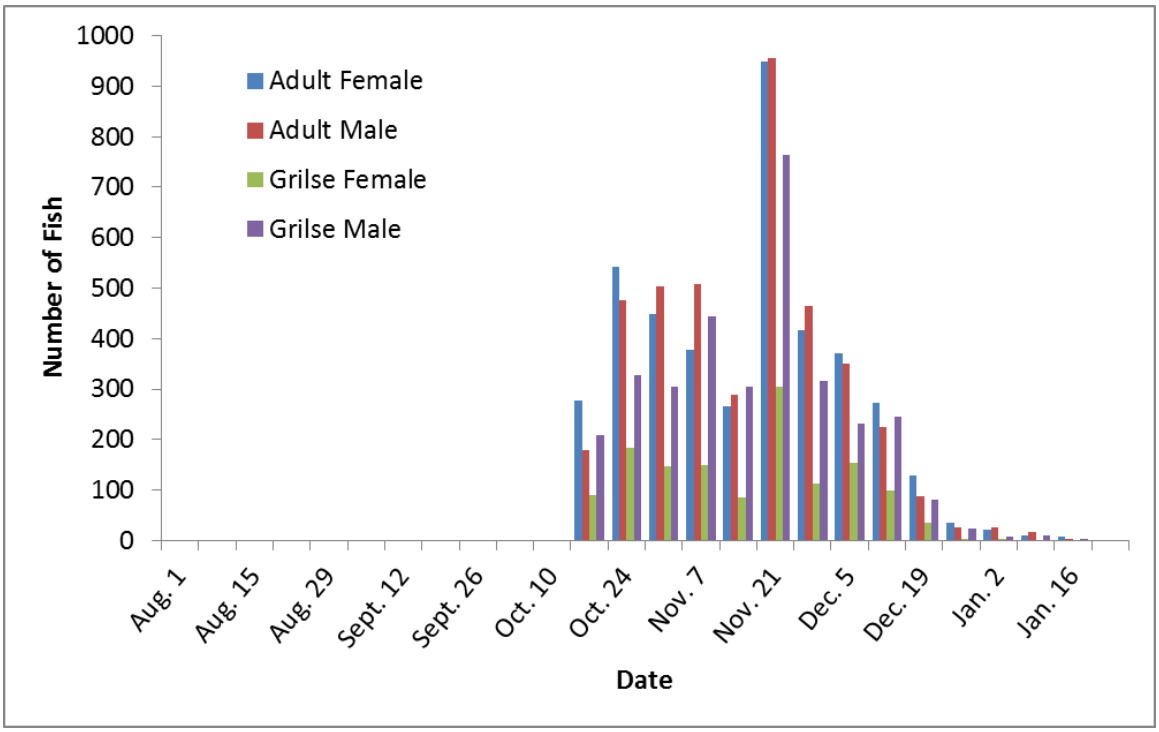

Figure 2. Weekly sex/age composition of fall-run Chinook salmon passing WIDD, August 1, 2015 – January 25, 2016.

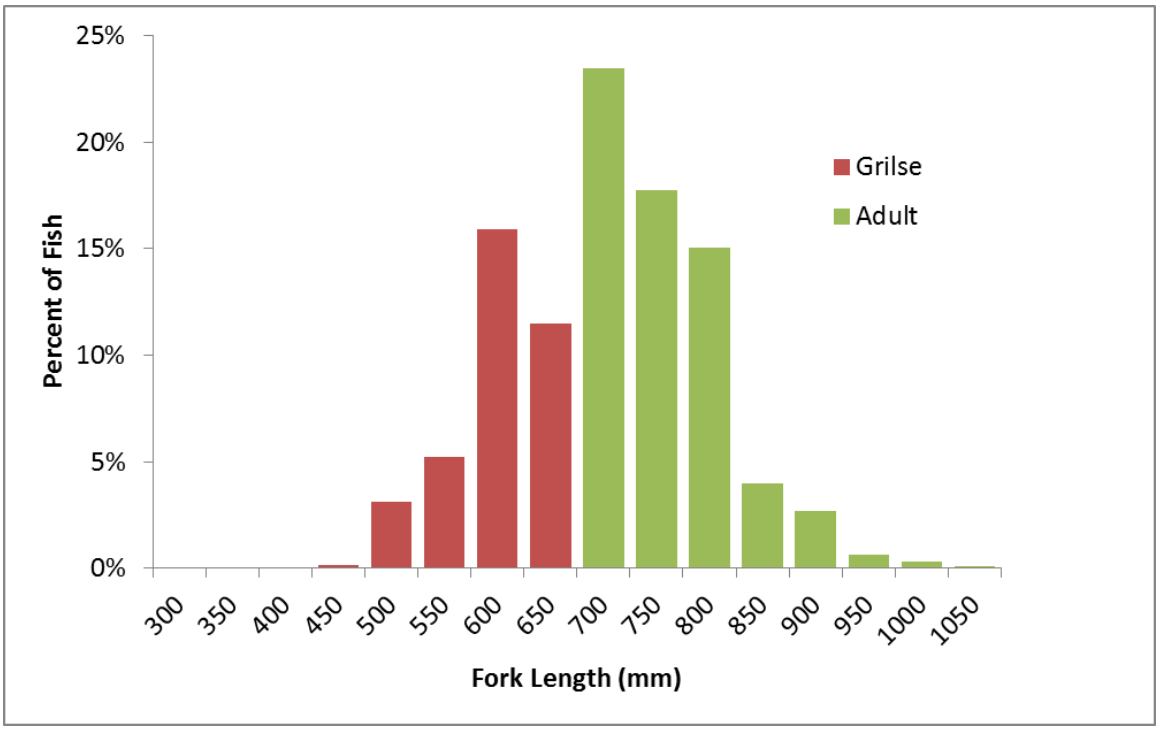

Figure 3. Length frequency of adult and grilse Chinook salmon (% by size class) passing WIDD, August 1, 2015 – January 25, 2016.

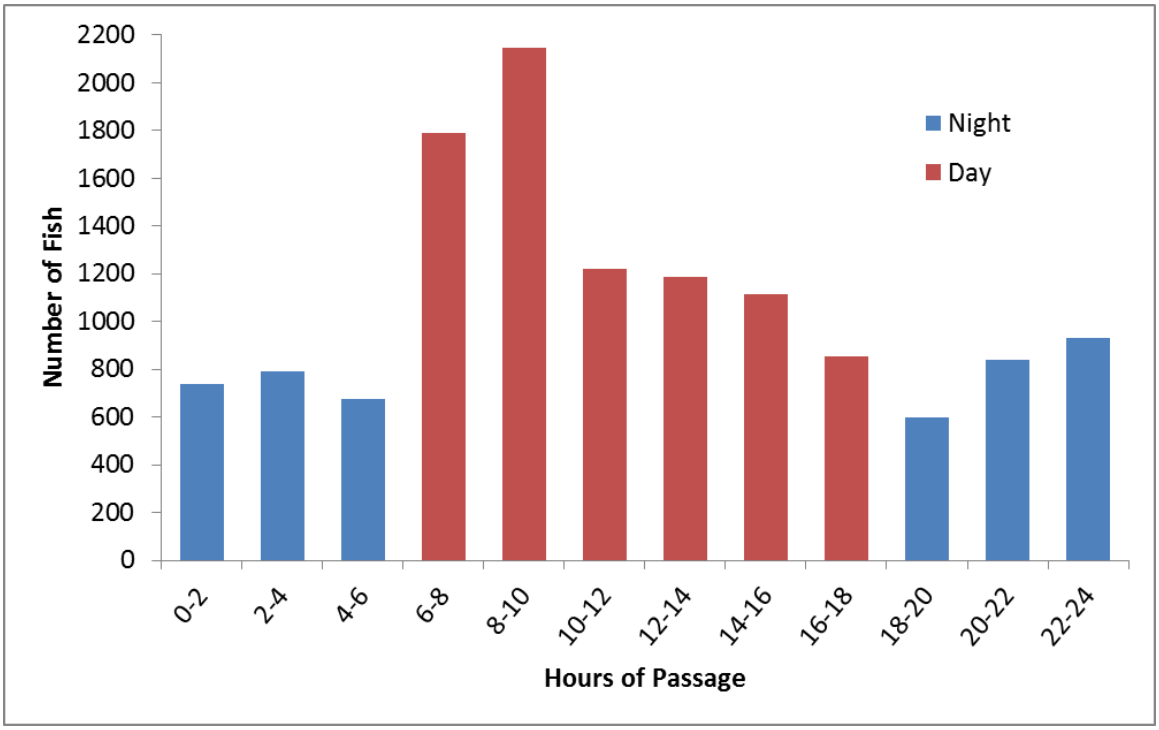

Figure 4. Chinook salmon passage (2 hour intervals) recorded from video monitoring at WIDD, August 1, 2015 – January 25, 2016.

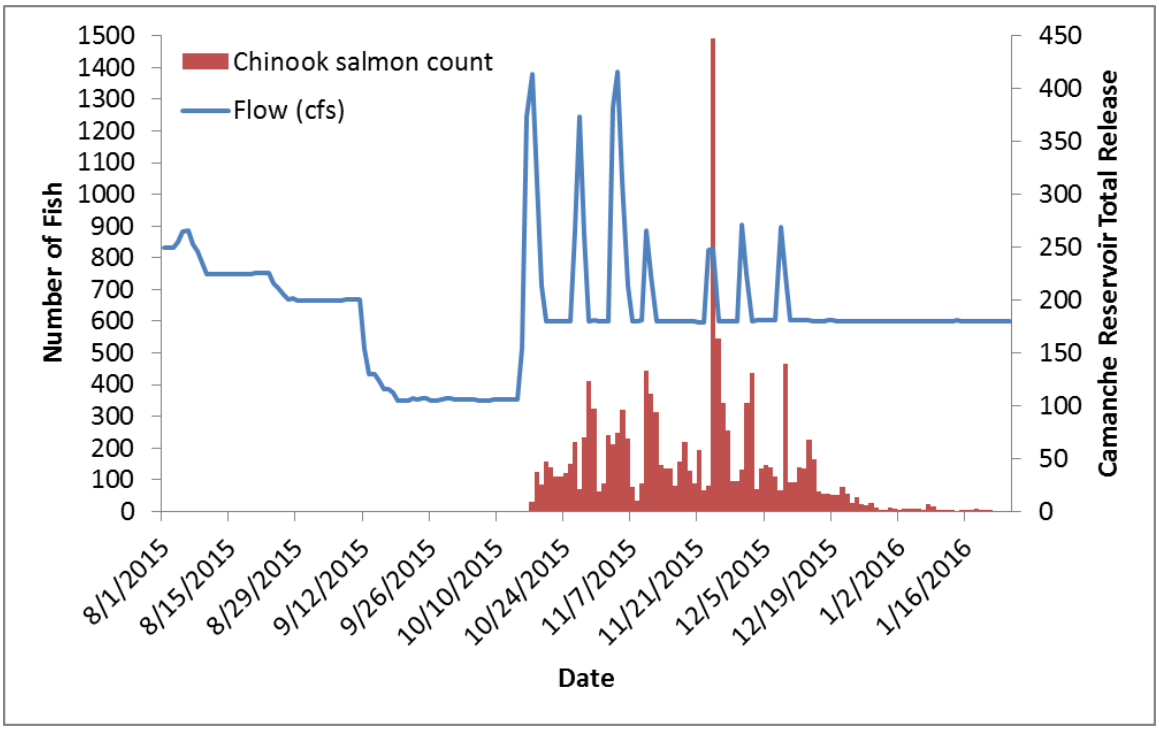

Figure 5. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to flow below Camanche Reservoir, August 1, 2015 – January 25, 2016. Flow data are preliminary and subject to change.

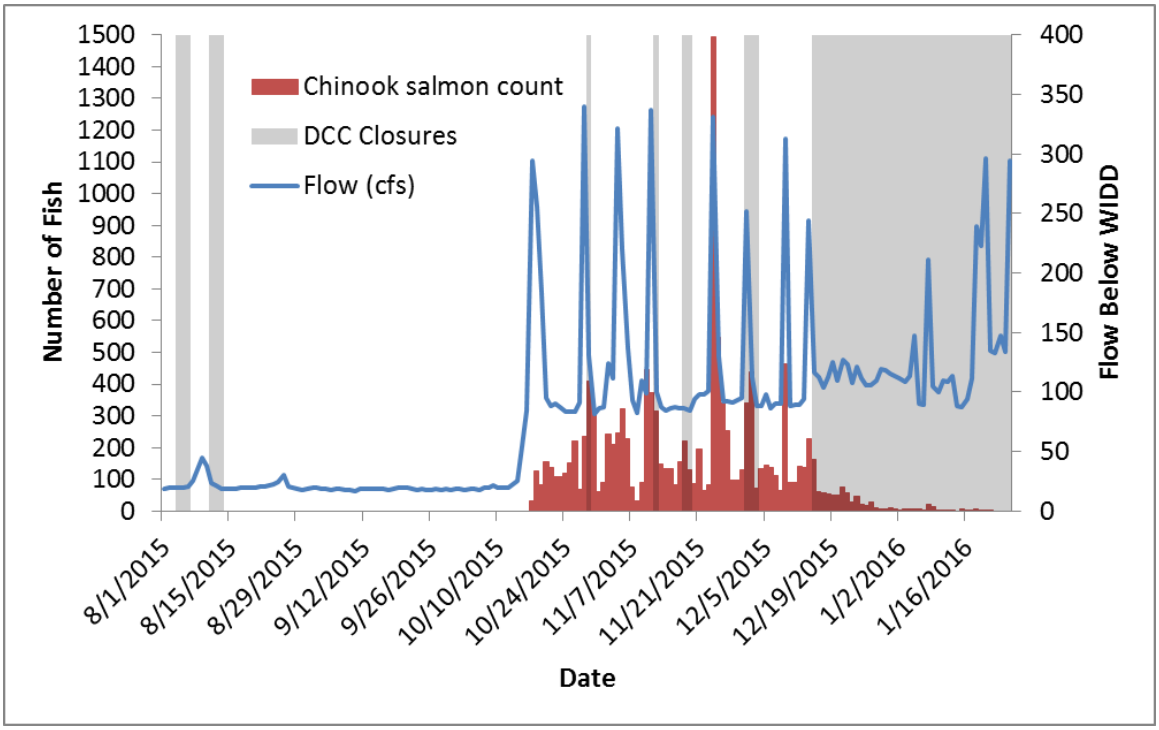

Figure 6. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to flow below WIDD and DCC closures, August 1, 2015 – January 25, 2016. Flow data are preliminary and subject to change.

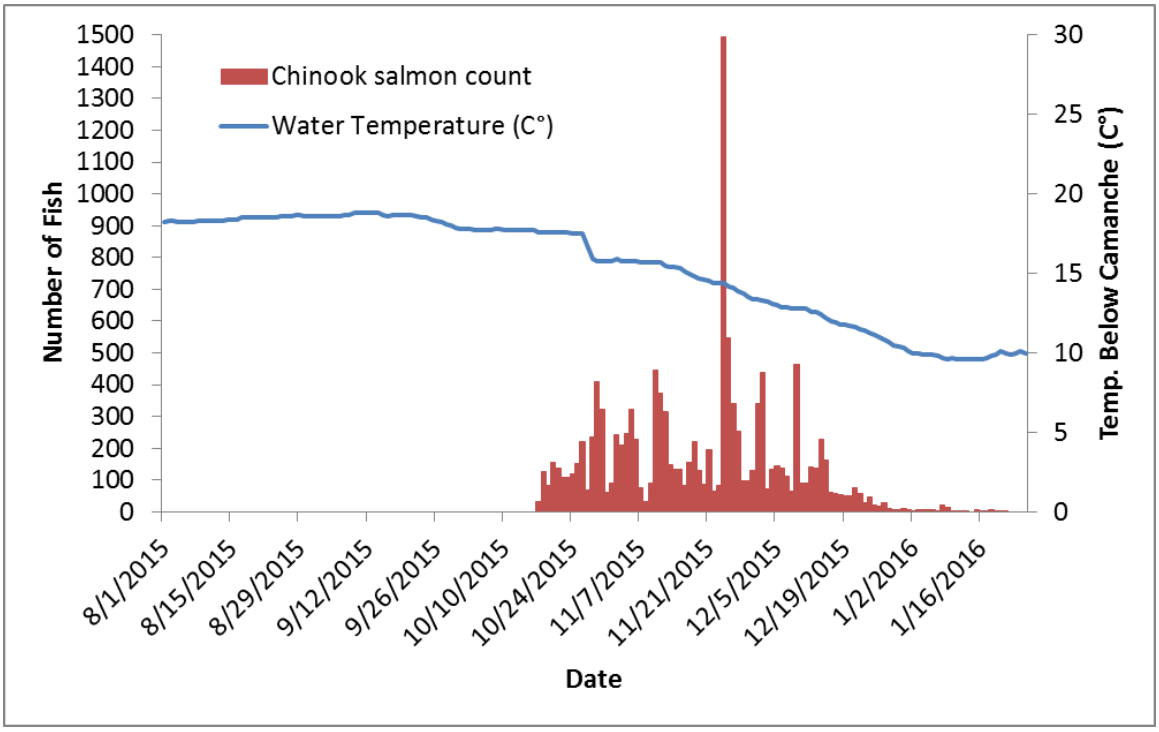

Figure 7. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below Camanche Reservoir, August 1, 2015 – January 25, 2016. Temperature data are preliminary and subject to change.

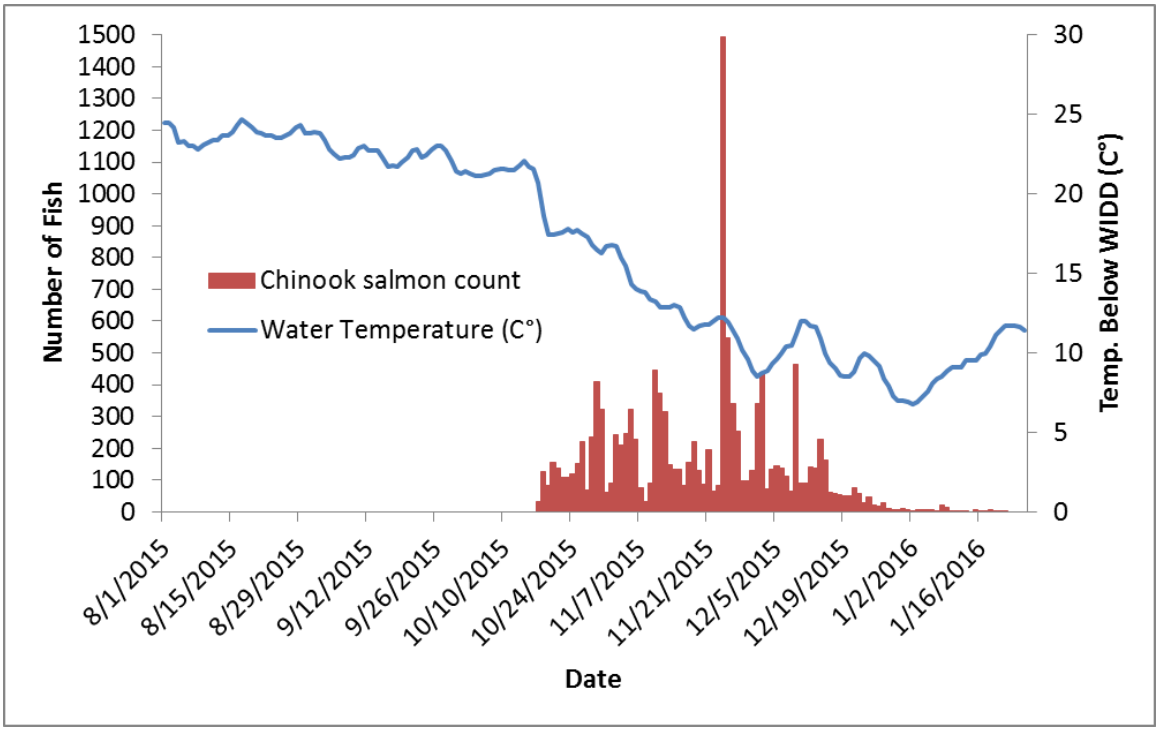

Figure 8. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below WIDD, August 1, 2015 – January 25, 2016. Temperature data are preliminary and subject to change.

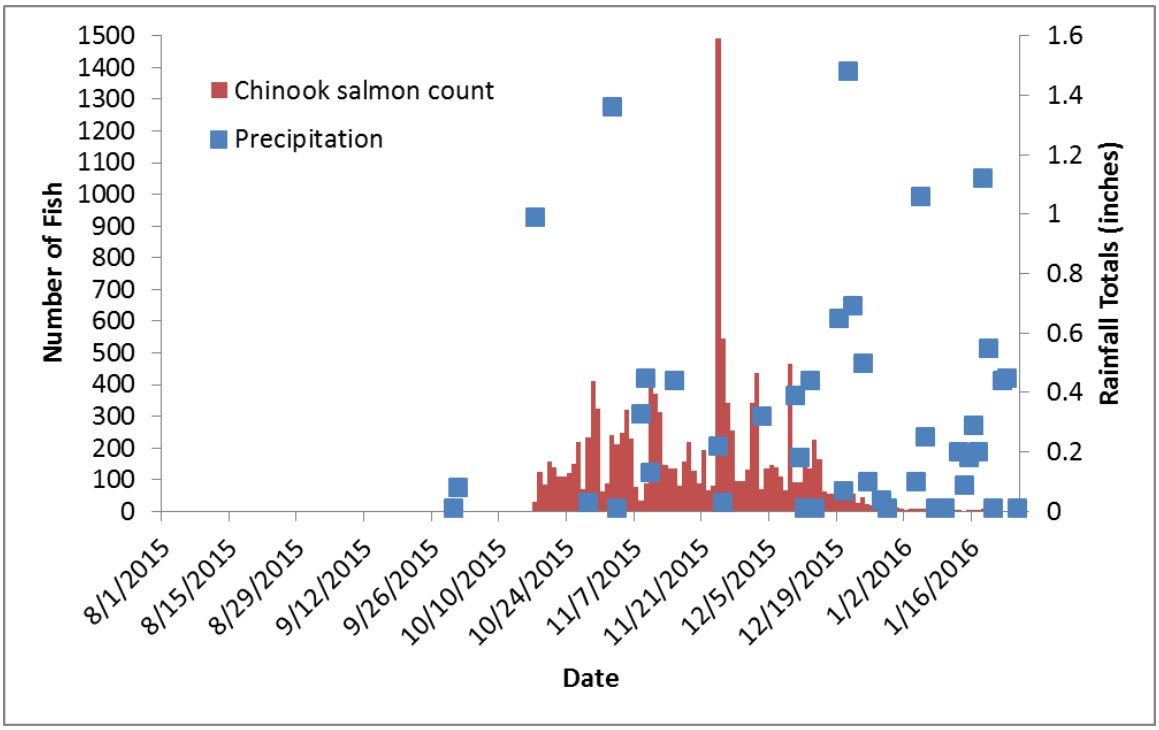

Figure 9. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to rainfall recorded near Pardee Reservoir, August 1, 2015 – January 25, 2016. Precipitation data are preliminary and subject to change.

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