LOWER MOKELUMNE RIVER
UPSTREAM FISH MIGRATION MONITORING
Conducted at Woodbridge Irrigation District Dam
August 2017 through May 2018

August 2018

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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, 2017 through May 12, 2018. An estimated 19,963 fall-run Chinook salmon (*Oncorhynchus tshawytscha*) passed the WIDD fish ladder between August 1, 2017 and January 24, 2018. This is the largest count of fall-run Chinook salmon ever recorded on the LMR. Fifty percent of the run passed WIDD by October 26, 2017. Ninety percent of the run passed WIDD by November 27, 2017. Highest daily passage was 945 Chinook salmon on October 20, 2017. The sex and life stage was positively determined for 19,960 fish including 4,793 (24%) adult females, 4,483 (22%) adult males, 2,583 (13%) grilse females, and 8,101(41%) grilse males. Managed pulse flows and DCC closures were followed by peaks in daily passage and contributed to the high overall returns.**

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 2017/2018. 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 2017 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 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 typically conducted year round, with the exception of a short period of time when the dam is lowered for annual maintenance. During the 2017 run, Woodbridge Irrigation District lowered the dam on February 2, 2018. As water was routed through the low stage ladder, video monitoring operations were suspended. After the air bladders of WIDD were reinflated on March 6, 2018, monitoring in the high stage ladder resumed and continued until May 12, 2018 when a camera malfunction ended video monitoring for the remainder of the season.

All other monitoring, data collection, and storage methods for video monitoring were consistent with prior years' monitoring efforts (Marine and Vogel 2000, Workman 2004). For day and night passage designations, the NOAA Solar Calculator (NOAA n.d.) was used to estimate apparent sunrise and sunset. Apparent sunrise and sunset are a result of atmospheric refraction. Atmospheric refraction causes apparent sunrise to occur shortly before the sun crests the horizon and apparent sunset to extend beyond the actual sunset.

Migration Response

Generalized additive models (GAM) were used to identify the influential variables that promote fish passage in the LMR at WIDD. GAMs allow flexibility in the dependency of a response to the covariates by defining the model in terms of smooth functions and not detailed parametric models (Wood 2017). This allows the linear predictor to predict a smooth monotonic function while the response can follow any exponential family distribution.

Covariates used to investigate the relationship between daily salmon counts were average daily flow below WIDD, change in average daily flow below WIDD, Sacramento River daily average flow at Rio Vista, San Joaquin River daily average flow near Vernalis, water temperature, and precipitation. In addition, pulse flows and Delta Cross Channel (DCC) operations were categorized as binary variables and treated as factors with the GAMs in order to denote pulse flow events and DCC closures. Covariates were lagged up to seven days in order to investigate delayed responses to each variable. Akaike Information Criterion (AIC) was used to select the best models. All data analyses were performed in the R programming package mgcv.

RESULTS AND DISCUSSION

Fall-Run Chinook Salmon

The fall-run Chinook salmon escapement estimate in the LMR for 2017/2018 is 19,963 spawners entering the river between August 2017 and January 2018 (Figure 1). The highest daily passage of 945 salmon occurred on October 20, 2017. Based on years with continuous salmon passage monitoring at WIDD, fifty percent of Chinook salmon migrated past WIDD between October 24th and November 23th. During the 2017 run, 10% of Chinook salmon passed WIDD by October 7th, 50% passed WIDD by October 26th, and 90% passed WIDD by November 27th (Figure 2).

Sex and life stage were positively determined for 19,960 fish. This includes 4,793 (24%) adult (≥70 cm FL) females, 4,483 (22%) adult males, 2,583 (13%) grilse (<70 cm FL) females, and 8,101 (41%) grilse males. Grilse males had the greatest proportion of fish passage during 13 of the 26 weekly fish counts, including 12 consecutive weeks from September 26th through December 12th (Figure 3). In 2017, approximately a 1:1 grilse to adult ratio was observed on the LMR (54% GR; 46% AD) (Figure 4).

In the 2017/2018 monitoring season, 79% of fish passed the video monitor during the day and 21% during the night. Following relatively consistent hourly passage rates at night, Chinook salmon passage spiked with the onset of sunrise (Figure 5). Peak passage occurred from 0800 hrs to 0900 hrs. Passage continued throughout the day at elevated rates, then decreased following sunset. This trend is consistent with historic passage rates with daytime passage on the Mokelumne River consistently higher than nighttime passage.

Clipped adipose fins were evident on 7,065 (35%) of the observed fall-run Chinook salmon. The sex and life stage were positively determined for 7,064 (2,687 adult and 4,377 grilse) adipose fin clipped fish. Of the fish identified with an adipose fin clip, 1,296 (18%) were adult (≥70 cm FL) females, 1,391 (20%) were adult males, 1,130 (16%) were grilse (<70 cm FL) females, and 3,247 (46%) were grilse males. Twenty-seven percent of the returning adult females were adipose fin clipped, 31% of the adult males were adipose fin clipped, 44% of the grilse females were adipose fin clipped, and 40% of the grilse males were adipose fin clipped.

Mokelumne River Flow, Water Temperature, and Rainfall

During the 2017/2018 Chinook salmon migration period, Camanche Dam daily average releases ranged from 333 – 1,948 cfs (Figure 6). Average daily flow was 640 cfs. Average daily flow below WIDD ranged from 96 – 1,541 cfs and averaged 445 cfs (Figure 6). Daily average water temperatures from August through January ranged from 10.6 – 18.3 C° below Camanche Dam (Figure 7) and 10.2 – 21.9 C° below WIDD (Figure 8). Total rainfall, collected at the Pardee Reservoir station, was 9.03 inches (Figure 9). Peak daily rainfall was 1.78 inches.

Management Actions and Migration Response

Expected flow below WIDD during August and September was based on the Joint Settlement Agreement (JSA) Normal & Above water year type. Elevated water flows in August corresponded with the first Chinook salmon observed moving passed WIDD at the start of our fall-run upstream monitoring on August 1st. The final water year designation for October through March was also Normal and Above.

EBMUD conducted 6 planned pulse flow events from September through October, through increased releases from Camanche Reservoir. This was the eighth year in a row that EBMUD released fall attraction flows in the LMR. Sixty-one percent of Chinook salmon passage occurred during pulse flow events. 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 creating downstream pulses. 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, weekly DCC closures occurred beginning September 18th and continued through November 17th. Closures occurred on Mondays and gates were reopened on Fridays for weekend operations. Weekly closures were a result of a California Department of Fish and Wildlife request to reduce adult fall-run Chinook salmon straying through the DCC. On November 24th the gates were closed for the remainder of the salmon run to implement winter-run Chinook salmon protection measures. Eighty percent of salmon passage occurred during DCC closures.

As in previous years, peaks in Chinook salmon passage corresponded with pulse flow events and DCC closures (Figure 6). Table 1 summarizes each pulse flow event and concurrent DCC closure conducted during the migration of fall-run Chinook salmon to the Mokelumne River.

Table 1 Summary of management actions, including pulse flow events and corresponding DCC closures, implemented during the 2017/2018 Mokelumne River Chinook salmon run.

Pulse	Date of Peak Flow	Peak Flow (cfs)[1]	Passage Peak	Daily Chinook Passage Total	DCC Operations
1	9/29/2017	1,606	9/29/2017	204	Closed
2	10/7/2017	1,003	10/8/2017	423	Open
3	10/13/2017	1,020	10/13/2017	575	Closed
4	10/19/2017	1,020	10/20/2017	945[2]	Closed
5	10/26/2017	946	10/27/2017	573	Closed
6	11/2/2017	1,087	11/3/2017	638	Closed
7	11/7/2017	1,288	11/8/2017	654	Closed
8	11/14/2017	818	11/15/20107	296	Closed
9	11/21/2017	874	11/21/2017	240	Open

[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]Highest daily passage of fall-run Chinook salmon recorded during the 2017/2018 monitoring period.

GAMs with smooth main effects plus interactions and a poisson distribution performed the best. Pulse flow events (lagged 7 days), DCC operations (lagged 7 days), change in average daily flow below WIDD, precipitation, Sacramento River flow (lagged 3 days), San Joaquin River flow (lagged 5 days), and the interactions between flow below WIDD (lagged 1 day) and temperature (lagged 3 days) significantly influenced Chinook salmon passage counts at WIDD (Table 2).

Table 2 Final GAM for Chinook salmon passage counts at WIDD based on environmental and management variables on the lower Mokelumne River during the 2017 salmon run.

Covariates	df	edf	Chi.sq	p-value
Pulse (7 days)	1	-	11.53	0.0007
DCC (7 days)	1	-	42.88	<0.0001
Flow Change Below WIDD	-	8.921	478.7	<0.0001
Precipitation	-	9.000	193.0	<0.0001
Sacramento River Flow at Rio Vista (3 days)	-	8.961	117.0	<0.0001
San Joaquin River Flow near Vernalis (5 days)	-	7.331	126.8	<0.0001
Flow Below WIDD (1 day) & Temp (3 days): No Pulse	-	23.816	1788.7	<0.0001
Flow Below WIDD (1 day) & Temp (3 days): Pulse Event	-	23.948	1179.9	<0.0001

Incidental Species

Steelhead (*O. mykiss*) have been observed since monitoring began in 1990. Spawning, typically occurs between January and March for winter steelhead in the Central Valley (IEP Steelhead PWT 1999). However, steelhead were observed in the ladder at WIDD from August through May. Yearling steelhead (FL <20 cm) and subadult steelhead (FL $\leq$35 cm) 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. Due to extended residency times of subadult steelhead within the ladder this year and the difficulty in documenting upstream passage, only steelhead presence is reported.

Presence and absence data of native and non-native species are presented in Table 3. Native fishes observed using the ladder include Pacific lamprey, Sacramento pikeminnow, Sacramento sucker, steelhead, and tule perch. Non-native fish using the fish ladders at WIDD include black bass, black crappie, bluegill, common carp, largemouth bass, and striped bass.

Table 3. Native and non-native fish observed in the Woodbridge Irrigation District Dam fish ladder, August 1, 2017 – May 12, 2018. Species names in bold represent native species.

	August	September	October	November	December	January	February	March	April	May
Pacific Lamprey	X	X						X	X	X
Sac. Pikeminnow	X	X	X	X				X	X	X
Sac. Sucker	X	X	X	X				X		X
Steelhead	X	X	X	X	X	X	X	X	X	X
Tule Perch									X	X
Black Bass									X	
Black Crappie		X						X		
Bluegill								X	X	
Common Carp		X								
Largemouth Bass		X						X		
Striped Bass	X									

Acknowledgements

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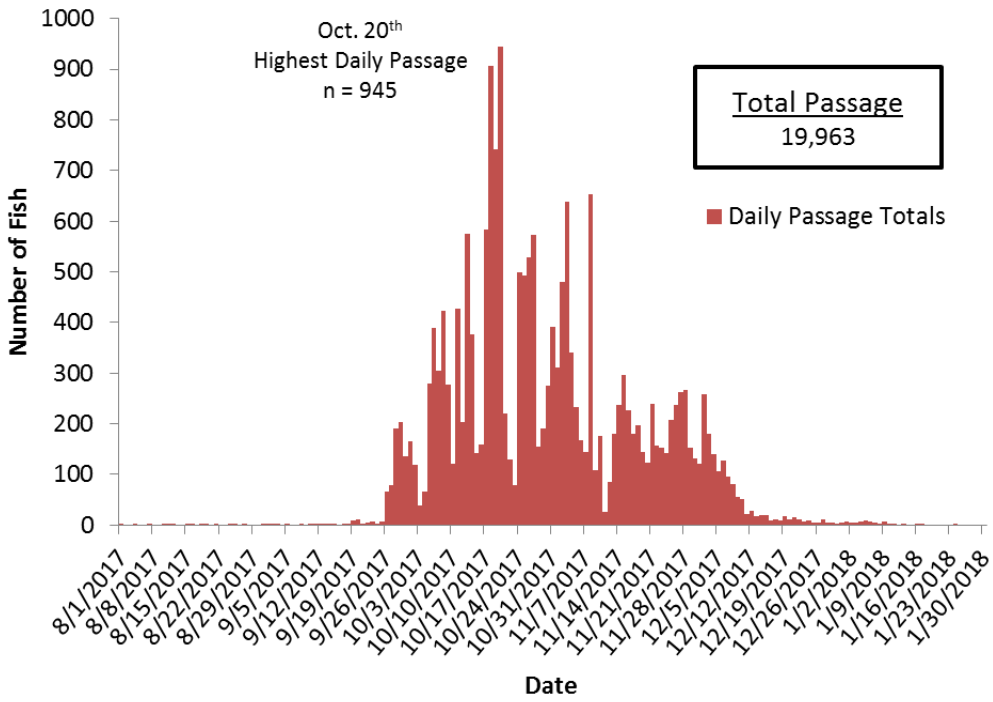

Figure 1. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD.

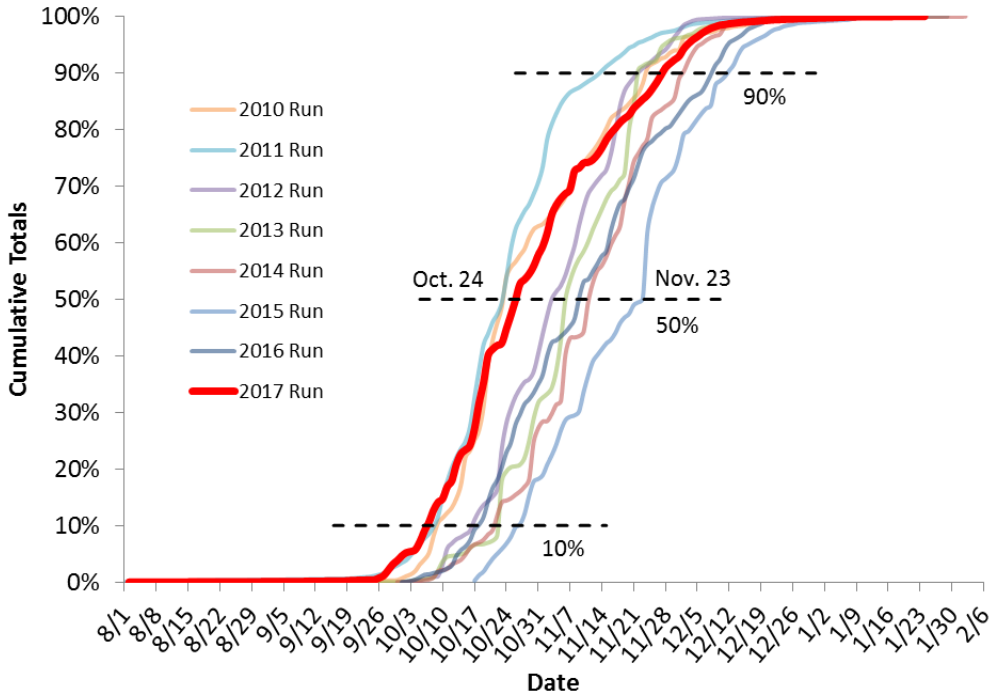

Figure 2. Run time of Chinook salmon migrating to the LMR. Dashed lines represent 10%, 50%, and 90% of fall-run Chinook salmon passed the Woodbridge Irrigation District Dam. Run years were limited to 2010 – present as this period encompasses the range of identified 50% passage dates on the LMR since monitoring began in 1990.

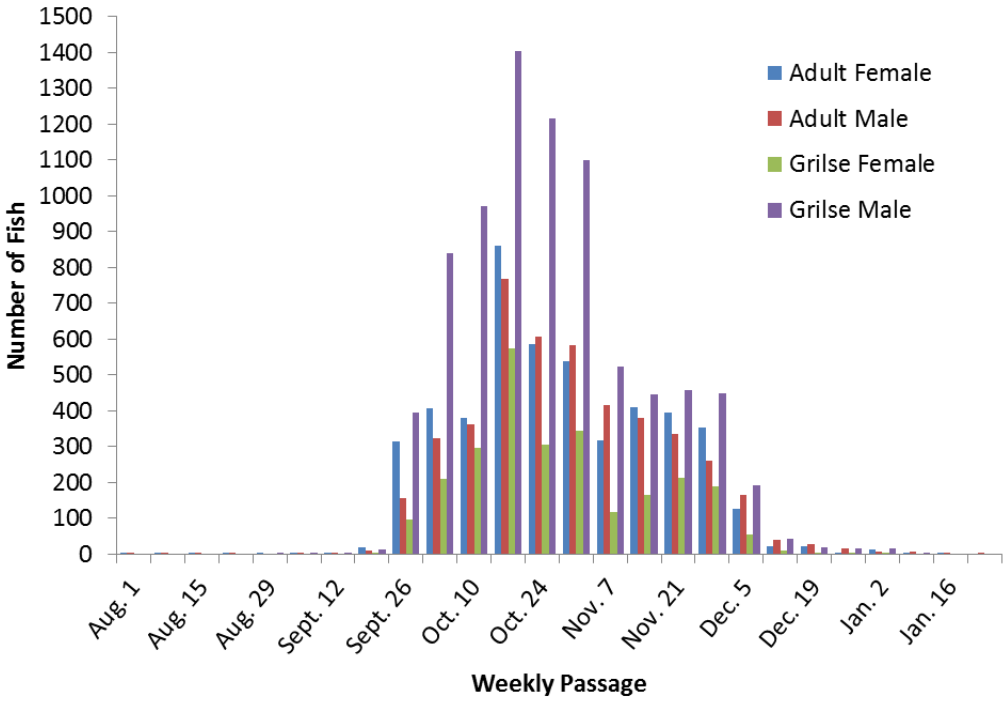

Figure 3. Weekly sex/age composition of fall-run Chinook salmon passing WIDD.

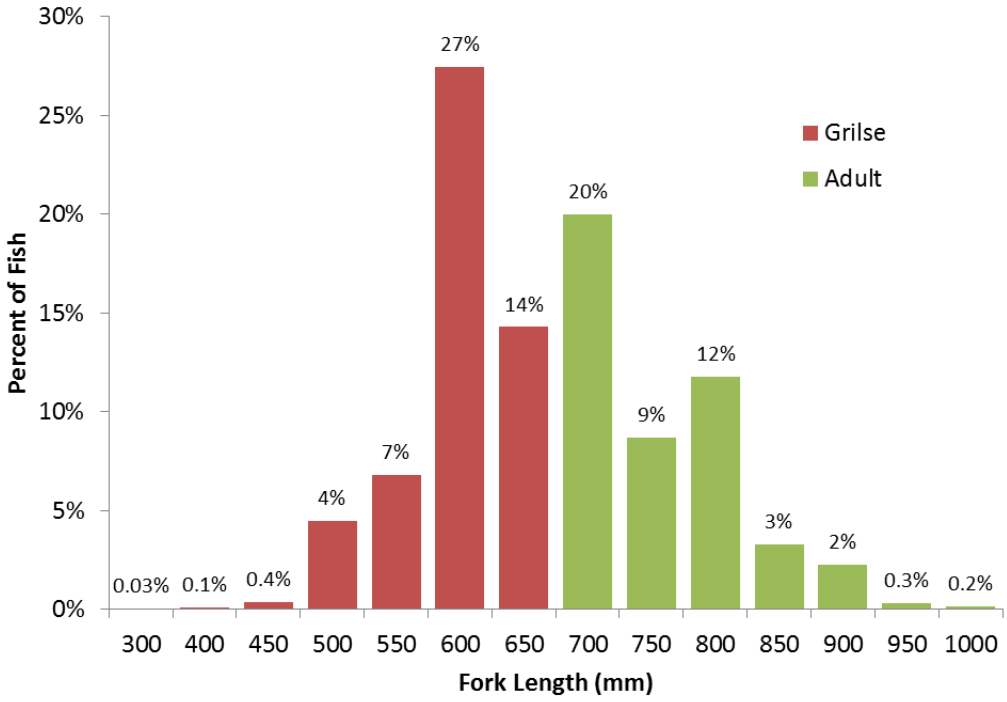

Figure 4. Length frequency of adult and grilse Chinook salmon (% by size class) passing WIDD.

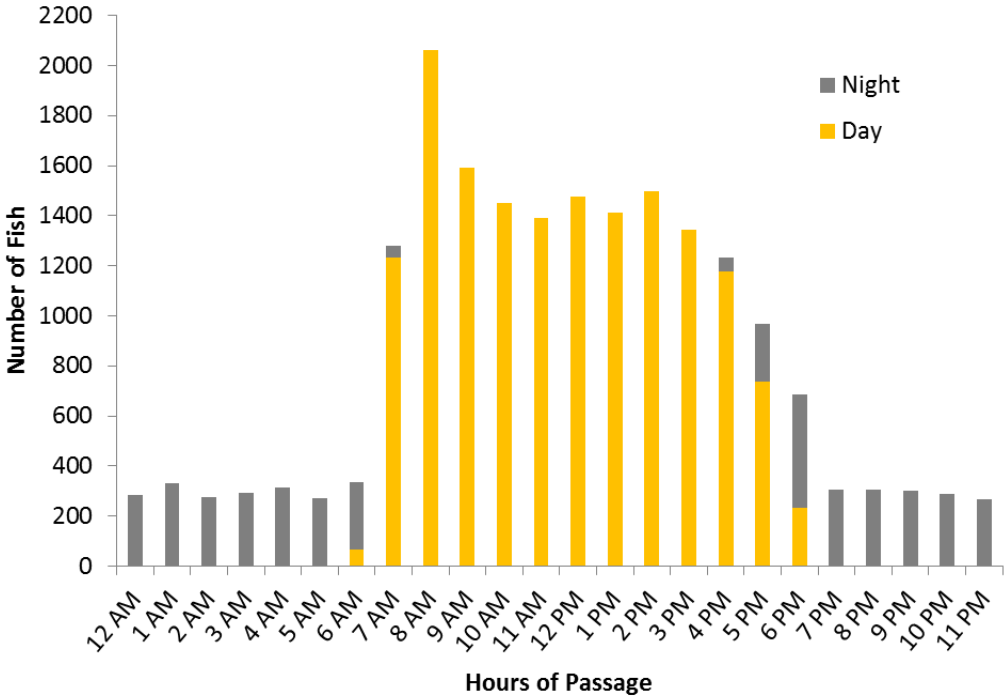

Figure 5. Hourly Chinook salmon passage recorded from video monitoring at WIDD.

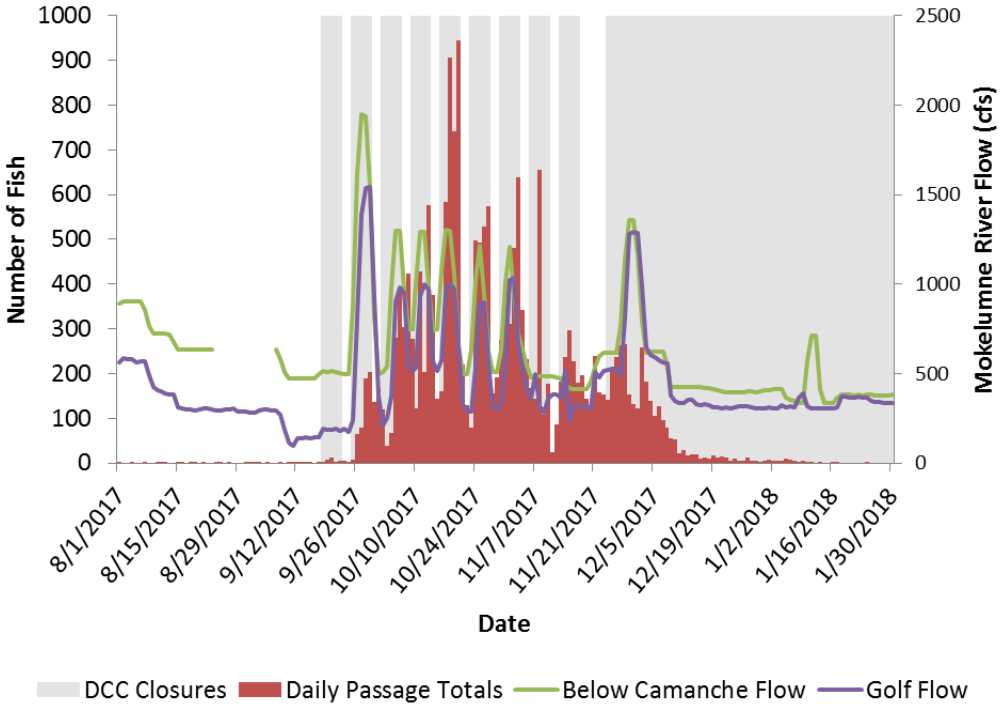

Figure 6. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to flow below WIDD, discharge from Camanche Reservoir, and DCC closures. Flow data are preliminary and subject to change.

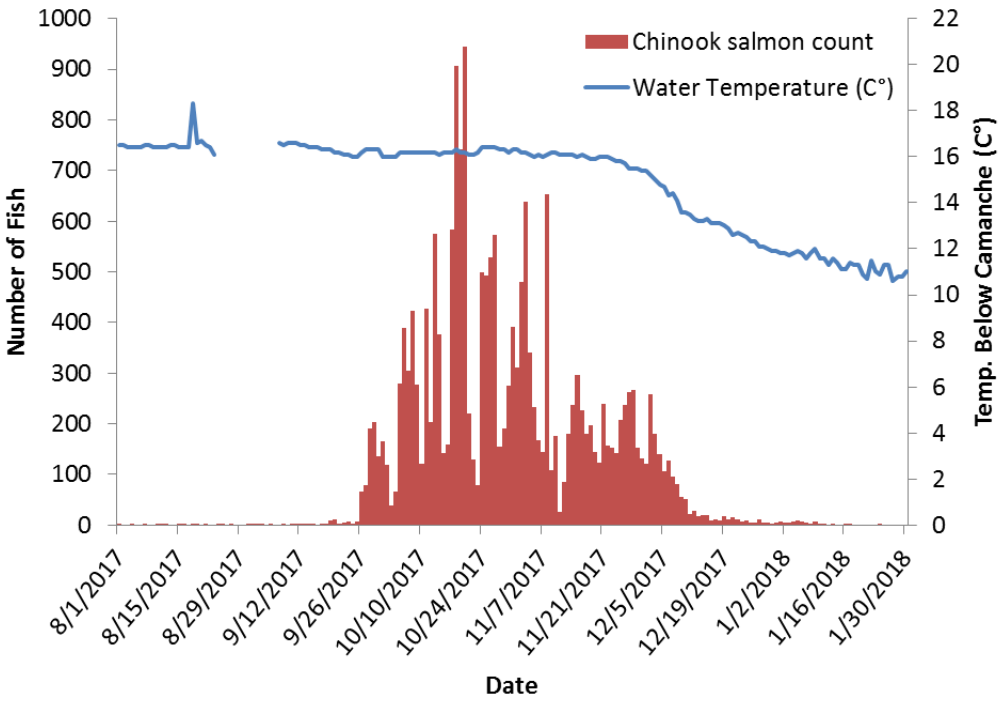

Figure 7. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below Camanche Reservoir. Temperature data are preliminary and subject to change.

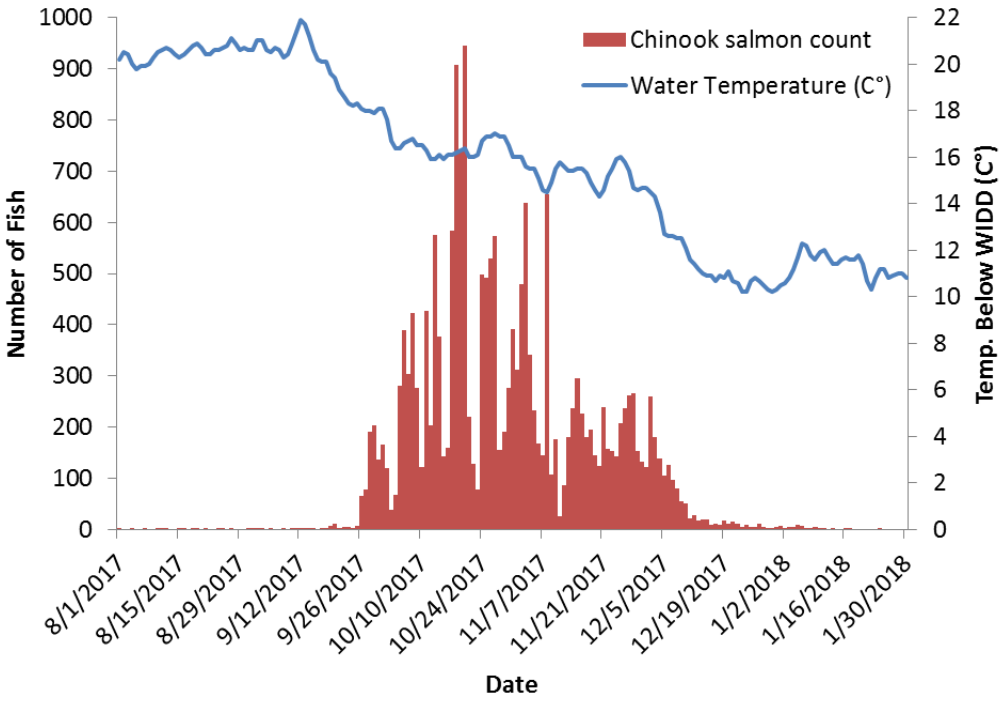

Figure 8. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to temperature below WIDD. Temperature data are preliminary and subject to change.

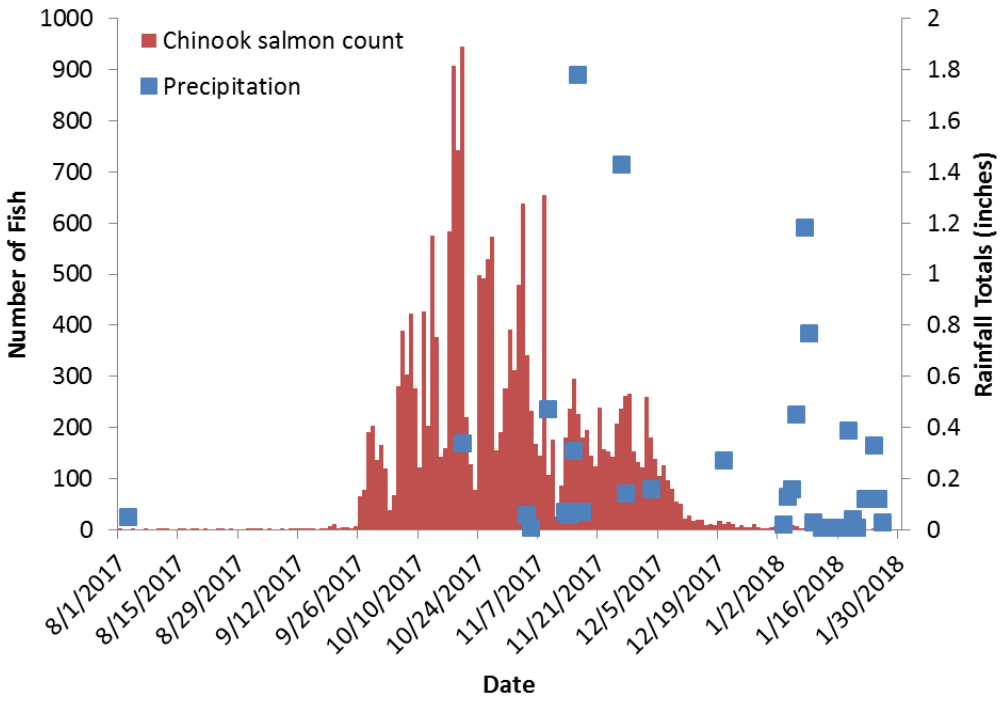

Figure 9. Daily abundance and timing of fall-run Chinook salmon migrating past WIDD compared to rainfall recorded at Pardee Reservoir. Precipitation data are preliminary and subject to change.

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