2001 Merced River Fall Chinook Salmon Escapement Survey

Prepared by

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INTRODUCTION

The San Joaquin fall-run Chinook salmon is currently a candidate species under the Federal and State Endangered Species Acts. Population levels, as measured by escapement of returning adults, in the Merced River declined in the mid-1960's. The decline of the species is thought to be attributed to many factors. The reduction of spawning and rearing habitat in combination with stream flow management practices are believed to be major factors limiting overall population numbers. Numerous additional factors including but not limited to predation, streambed alteration, pump diversion, gravel mining, land use practices and ocean angler harvest contribute to a complex web population dynamics which effect the population of fall-run Chinook salmon within the Merced River.

The California Department of fish and Game (CDFG) has conducted escapement surveys on the Merced River since 1953. The Schaefer mark recapture escapement estimation model (Schaefer 1951) has been utilized since 1971. The 2001 escapement survey is a continuation of this method. Escapement estimates range from a high of 23,000 in 1984 to a low of 73 in 1990 (Heyne and Marston 1998-1999). The fall 2000 escapement survey, estimated at 13,076 fish, was the highest on record since 1985 (Beal 2001).

The current objectives of annual Merced River escapement surveys are:

- Estimate the escapement of fall-run Chinook salmon on the Merced River. Evaluate the distribution of salmon redds throughout the study area.
- Collect fork-length and sex data.
- Collect scale and otolith samples with which to conduct age determination analysis and subsequent cohort analysis.
- Collect DNA samples for storage at the CDFG Salmonid Tissue Archive for subsequent genetic analysis.
- Collect and analyze coded wire tag data from marked hatchery fish.

STUDY AREA

The Merced River escapement survey covered a 24.7 mile reach beginning at river mile (RM) 51.9 which is below the Crocker-Huffman dam, at the CDFG Merced River Fish Facility down to Santa Fe Road (RM 27.1), near Cressey, CA. The survey area was divided into 4 sections with section 1 being the upstream most reach. Section 1 begins at the Merced River Fish Facility (MRFF) (RM 51.9), and extends downstream to Snelling Road (RM 46.5), and includes riffles A1-F1. Section 2 starts below Snelling Road and continues downstream to Highway 59 (RM 42.1), and includes riffles F2-J6. Section 3 extends from Highway 59 downstream to Shaffer Bridge on Oakdale Road (RM 32.5), and includes riffles J7-T1. Section 4 extends below Shaffer Bridge downstream to Santa Fe Road (RM 27.1), and covers riffles T2-Y1.

All riffles in the study area have been geo-referenced using a Trimble GPS TDC1 and mapped with the GIS computer program ArcView. In 2002, each riffle within the entire

4 section spawning reach was systematically re-named using sequential letter/number designations for river mile and riffle respectively. For example, the first riffle immediately below Crocker-Huffman dam in River mile 1 is named A1. This numbering system is a departure from the historical riffle numbering system. However, the new riffle identification system is more logical and is more conducive to editing as river morphology changes. The riffle identification cross-reference is located in Table 1.

METHODS

Population Estimation

The Schaefer (1951) mark recapture method was used to estimate fall salmon escapement on the Merced River. Under this scheme, carcasses are marked and subsequently recovered during weekly surveys of the spawning reach. A ratio of recoveries to total fish counted (handled) is used to calculate weekly population estimates which are then summed to estimate the total spawning population. Total fish counted (handled) includes total fish tagged, skeletons and fresh recoveries by week. The CDFG survey began on October 16, 2001 (Week 1) and concluded on January 4, 2002 (Week 12). Carcasses were tagged for the first 10 weeks and weeks 11 and 12 were limited to the recovery of carcasses. During the two recovery weeks (weeks 11 and 12), carcasses were collected, examined for jaw tags and chopped in half.

Weekly drift boat surveys were conducted using 2 or 3 person crews, in which all or part of the 4 spawning reach sections was surveyed. All visible carcasses were collected from each riffle and pool immediately below, and then processed. Every carcass handled was designated as fresh, decayed, skeleton or recovery depending on the degree of decomposition or the presence of an aluminum jaw tag in the case of recoveries. The presence of at least one clear eye was used for designating carcasses as fresh (Figures 1). Decayed carcasses had cloudy eyes. Skeleton condition ranged from a fungus covered carcass (Figure 2) to an actual skeleton.

All fresh and decayed carcasses were given a unique number by attaching an aluminum head tag to the lower jaw. These newly tagged carcasses were redistributed to river current at the tail end of the riffle, above the pool from which they were collected for recovery in subsequent weeks. Previously tagged carcasses that were recovered were recorded by the unique tag number, chopped and returned to the river. All skeletons were enumerated, chopped and returned to the river.

Individual Fish Data Collection

Fork length (cm) and sex data were collected from all tagged carcasses. Scale, otolith and genetic samples were collected from a percentage of specimens to determine the size, age and genetic composition of annual spawning runs. Coded wire tags (CWT) were collected from hatchery produced marked (adipose fin clipped) carcasses returning to the Merced River to determine survivorship from releases of marked outmigrating smolts and to determine incidence of straying from other river systems. CWT specimens are being used to validate scale and otolith age determination work.

Genetic samples; caudal, dorsal or pectoral fin clips were preserved in vials of tris buffer solution and delivered to the CDFG Salmonid Tissue Archive at the end of the Survey. Scale and otolith samples collected from both wild and CWT carcasses are catalogued at the CDFG La Grange Field Office. Coded wire tags and otoliths are collected via removal of the head minus the lower tagged jaw. Extraction and analysis of otoliths and CWT's was conducted at La Grange after the spawning season. All fish samples were catalogued by the unique jaw tag number which allows the samples to be tracked to the specific date and riffle number of collection.

Weekly Fish Distribution and Redd Counts

Weekly live fish observations and redd counts were conducted during the survey. These counts were conducted for each riffle and pool using the riffle identification system noted earlier. Counts were made using tally counters as field crews drifted through riffles and pools. No live or redd counts were conducted during recovery weeks 11 and 12.

RESULTS

Escapement Estimate

A total of 1099 carcasses were tagged during the 2001 Merced River escapement survey. Three hundred and two tagged carcasses were recovered for a 40.6% recovery rate. Based on the Schaefer model, the 2001 escapement estimate is 9,181 salmon. The Schaefer model utilizes the number of recoveries of tagged carcasses that were fresh when tagged, the total number of fresh tagged fish and the total number of carcasses handled each week (Table 2) to generate weekly escapement estimates. These weekly Schaefer estimates are presented in Table 3 along with the total numbers of fresh carcasses tagged each week and the number of recoveries made in subsequent weeks in relation to tag week. Weekly cumulative Schaefer estimates are graphed in Figure 3. The Merced River Fish Facility (MRFF) reported an additional 1656 salmon that were processed at the Facility. Combining the Schaefer estimate with the numbers provided by the MRFF would yield a grand total of **10,837** fall-run Chinook salmon returning to the Merced River in 2001.

Live Salmon and Redd Counts

Weekly live fish observations increased steadily and peaked in week 5, with 560 live fish being observed, then sharply declined after week 7. Two weeks later, redd counts peaked in week 7 with a high of 402 redds counted and the steadily declined for the remainder of the study. One week after the redd counts peaked, total carcass counts peaked in week 8, at 997, and declined sharply thereafter (Table 4 and Figure 4). The number of live fish, redds and tagged carcasses observed by week are graphed in Figure 5. The maximum number of redds counted for individual riffles is presented in Table 5. Most of the spawning (66%) occurred within Section 1. The first 2 river miles (spawning riffle sections A and B) accounted for 65% of the total redds observed in Section 1 (Figure 6).

Fork-length, Scale, Otolith and DNA Collection

Length frequency histograms of male and female (both natural and CWT) display bimodal peaks (Figures 7, 8, 9 and 10). The first peaks are likely age 1 and 2 fish and the second peaks are likely age 3, 4 and 5 fish. Peak fork lengths for natural and CWT

females were similar. Peak fork length for natural males was 83 cm and CWT males was 63cm. 473 Scale, 335 otolith and 236 DNA samples were collected from both natural and adipose fin-clipped fish throughout the survey and survey area (Tables 6, 7, 8, 9, 10 and 11).

Coded Wire Tag Collection

The total contributions (Tagged fish only) to the spawning population were 42% natural females, 29% natural males, 15% CWT males and 14% CWT females. Coded wire tagged fish comprised approximately 29% of the total tagged carcasses (Table 2 and Figure 11). CWT males and females returning to the MRFF are presented in Figure 12. The percentage of CWT fish (45%) returning to the MRFF was higher than that found on the Merced River escapement survey.

Egg Production Estimation

An estimate for the number of eggs produced by the 2001 fall run was generated using a standard regression equation (158.45 * fork length cm- 6138.91= number of eggs). This fork length-fecundity relationship was determined for 48 San Joaquin fall-run Chinook salmon females ranging from 62.5 to 94.0 cm fork length (Loudermilk et al.1990). The number of eggs was calculated for natural (n=457) and CWT (n=153) females and expanded by the ratio method. Natural females were calculated to produce 24,846,252 eggs (average=6479) and CWT females produced 7,681,533 eggs (average=5983) giving a total 32,527,785 eggs produced in the river. The MRFF reported a total of 4,043,914 eggs spawned of which 623,982 eggs were discarded because either the egg source or sperm donor salmon originated outside of the basin (not originating from the Merced, Tuolumne or Stanislaus rivers). An additional 472,120 eggs were discarded as excess leaving a total of 2,947,812 eggs produced by the MRFF.

Merced River Flows

Merced River flows for the period of 20SEP01 through 04JAN02 are shown in Figure 13. A pulse flow (attraction flow) was initiated on 14OCT01 through 01NOV01. The increased flows are designed to improve spawning habitat conditions, and attract salmon into the Merced River from the San Joaquin River. Pulse flows ranged from 724 cfs to 795 cfs during this period. After 01NOV02, flows were decreased and stabilized around 400 cfs through the remainder of the spawning season.

Merced River Temperature

Water temperature on the Merced River was recorded at 3 locations starting below the Crocker-Huffman Dam. Data loggers were placed in the river at the MRFF (Section 1), Snelling Road (Section 2) and on the Gallo Ranch in the upper portion of Section 3. These data loggers recorded water temperatures hourly and the average daily water temperature for all 3 stations is presented in Figure 14.

DISCUSSION

The 2001 Merced River escapement survey recorded the second highest number of adult Chinook salmon (10,837) returning to spawn since 1985 and was slightly lower than the 2000 escapement survey estimate of 13,076 Chinook salmon. River conditions and water clarity were ideal for carcass recovery, live counts and redd counts throughout most of the spawning season due to the lack of significant rain events. These favorable conditions resulted in an overall carcass recovery rate of 40.6%.

Sections 1, 2, 3 and 4 accounted for 66%, 15%, 16% and 3% of the total observed redds respectively. This was similar to the percentage of redds per section reported for the 2000 escapement survey, with the exception of Section 2 which accounted for 22% of redds reported in 2000 (Beal 2001). The decline in the percentage of redds within this section can be attributed to the restoration activity occurring within the Robinson reach (riffles I4-J6) of Section 2. These riffles, created for the purpose of providing spawning habitat for salmon, were in the last stages of completion and considered unavailable as suitable spawning habitat for the 2001 spawning season. Few live fish, carcasses and no redds were observed throughout the Robinson reach during this time.

Peak fork lengths for females, both natural and CWT, were similar indicating that returning hatchery females were similar in age structure to returning natural females. However, peak fork lengths of returning natural males (84 cm) was larger than returning CWT males (63 cm). The bimodal peaks in fork length distribution suggest that a greater percent of CWT males were of the 1st and 2nd year age class and natural males were of the 3rd, 4th and 5th year age class. This suggests that hatchery males may return to spawn earlier than their natural counterparts.

Merced River temperatures remained above 13.3^{o} C for all of October and through the first 3 weeks of November. This temperature is considered to be the upper limit conducive to salmon spawning. Water temperatures in the Merced River reached and then fell below the 13.3^{o} C benchmark during survey week 7, which coincided with our highest weekly redd count. The temperature remained under 13.3^{o} C throughout the remainder of the spawning season. Live counts peaked in survey week 5 suggesting that the salmon may have delayed spawning until water temperatures were conducive to spawning.

Coded wire tag verification and tag reading will be conducted at a later date, therefore all CWT data presented here are preliminary. DNA samples were delivered to the CDFG Salmonid Tissue Archive at the end of the survey. These DNA samples along with scale and otolith samples, and CWT data will be utilized in the CDFG age determination program and for subsequent cohort analysis of San Joaquin River Chinook salmon populations.

The number of redds and live fish reported for this escapement survey are believed to be a conservative estimate. Redds constructed in Section 1 were most likely underestimated due to superimposition. Redds constructed within this area often overlapped due to the high concentration of salmon and limited amount of spawning area, making it difficult to delineate individual redds. Redds constructed in Sections 2-4 can be more accurately counted due to the lesser degree of superimposition. Accurate numbers of redds and live fish are difficult to assess in a single pass through a riffle and are affected by observer error, flow levels, and adverse weather conditions. Live fish numbers may be underrepresented in the lower sections because they were not surveyed as often as Sections 1 and 2. This primarily occurred during the height of the spawning season (Weeks 5, 6 and 7) when carcass numbers were high in Sections 1 and 2, prohibiting surveys in Sections 3 and 4 during these weeks due to time constraints. There are also a few long side channels in Sections 3 and 4 which were not surveyed where a lesser number of redds and live fish may have been missed.

Chinook salmon escapement estimates were made using the Schaefer (1951) equation as presented in Ricker (1975). The Peterson model was not used in this analysis because Law (1994) found that the Peterson model (see Ricker, 1975) consistently over estimated population estimates for various model simulations using protocols similar to this study. In the near future, we anticipate using the Jolly-Seber method, in addition to the current Schaeffer method, in the analysis of our Chinook salmon escapement estimates. Past escapement estimates will also be amended with the Jolly-Seber method at that time.

Table 1. Riffle identification cross-reference for 2001(New ID) and 2000 (Old ID).

Section 1		Section 2		Section 3		Section 4	
New ID	Old ID	New ID	Old ID	New ID	Old ID	New ID	Old ID
A1	1	F2	30, 33	J7	70	T2	117
A2	2	G1	34	K1	71	T3	118
A3	2A	G2	35	K2	72	U1	*
A4	3	G3	*	K3	73	U2	119B
A5	4	G4	36	K4	74, 75	U3	120
A6	5, 6	G5	37	K5	76	U4	121A
B1	7	G6	38	K6	78	U5	121B
B2	7A, 7B, 7C	G7	39	K7	79	U6	121
B3	8, 9	G8	41	L1	*	V1	122
B4	10	H1	44	L2	*	V2	123
B5	11	H2	46	L3	82	V3	124
B6	*	H3	47	L4	83	W1	126
C1	12	H4	48	M1	84	W2	127
C2	12B	H5	49	M2	85	W3	128
C3	13	H6	50A, 50B	M3	86	W4	129
C4	14A	H7		M4	*	W5	130
C5	14B	I1	51A, 51B	M5	87	X1	132
C6	14C	I2	51C	N1	89, 90	X2	133
D1	15	I3	51X	N2	91	X3	
D2	17	I4	52	N3	92	X4	134
D3	19	I5	**	O1	95	X5	135
D4	20	I6	**	O2	96	X6	136
E1	21, 21A, 21B	I7	**	O3	97	X7	137
E2	22	I8	**	O4	99	X8	138
E3	23	J1	**	P1	99A	X9	139
E4	24	J2	**	P2	100	Y1	140
E5	25, 27, 28	J3	**	P3	101		
F1	29	J4	**	P4	102		
		J5	**	P5	103		
		J6	**	P6	104		
				Q1	105		
				Q2	106		
				Q3	107		
				Q4	108		
				Q5	108A		
				R1	109		
				R2	110		
				S1	112		
				S2	113		
				S3	114		
				S4	115		
				T1	116		

* Unable to identify corresponding riffle.

** Riffles I5-J6 were created within the Robinson restoration reach (above Highway 59) and are no longer the same riffles surveyed in 2000.

Table 2. Weekly Schaeffer totals.

Week	Total Tagged	Skeletons	Fresh Recoveries[1]	Total Counted[2]	Tagged Fresh	CWT'S
1	0	0	0	0	0	0
2	2	0	0	2	2	1
3	4	0	0	4	4	1
4	123	19	0	142	48	41
5	352	220	10	582	241	131
6	325	425	108	858	238	95
7	127	226	30	383	88	31
8	114	883	82	1079	81	16
9	47	512	54	613	38	3
10	5	103	14	122	4	0
11	0	48	4	52	0	0
12	0	2	0	2	0	0
Total	1099	2438	302	3839	744	319

[1]Includes only fish that were deemed fresh when tagged
[2]Includes total tagged, skeletons and fresh recoveries

Table 3. Schaeffer distribution of mark versus recovery week, number of tags recovered per week and survey totals.

Recovery Week	Tag Week										Number of Tags Recovered	Total Carcasses Handled*	Weekly Escapement Estimate
	1	2	3	4	5	6	7	8	9	10			
2	0										0	2	2
3	0	0									0	4	4
4	0	0	0								0	142	142
5	0	0	1	9							10	582	2167
6	0	0	0	4	104						108	858	1834
7	0	0	0	0	7	23					30	383	962
8	0	0	0	0	5	53	24				82	1079	2694
9	0	0	0	0	0	14	11	29			54	613	1510
10	0	0	0	0	0	0	4	3	7		14	122	375
11	0	0	0	0	0	0	0	1	3	0	4	52	232
12	0	0	0	0	0	0	0	0	0	0	0	2	4
Recoveries per Tag Week	0	0	1	13	116	90	39	33	10	0	**Overall Recovery Rate**		**Total Escapement Estimate**
Fresh Tagged Carcasses	0	2	4	48	241	238	88	81	38	4	**40.6**		**9181**
Recovery Percentage per Tag week	00.0	00.0	25.0	27.1	48.1	37.8	44.3	40.7	26.3	0.0			

*Total carcasses handled is the same as total fish counted in Table 2.

Table 4. Total live fish, redds and carcass counts by survey week.

WEEK	LIVE	REDDS	CARCASSES[a]
1[b]	4	2	0
2[c]	68	19	2
3[c]	412	87	4
4[d]	518	164	142
5[c]	560	387	572
6[b]	266	243	750
7[e]	359	402	353
8[d]	163	295	997
9	38	223	559
10	18	197	108
11[d]	1	190	48
12		66	2
TOTAL	N/A	N/A	3537

[a]Carcasses include all tagged carcasses and skeletons but does not include recoveries.
[b]Only section 1 surveyed.
[c]Only sections 1 and 2 surveyed.
[d]Only sections 1, 2 and 3 surveyed.
[e]Sampling scheme of 1/3 (one carcass sampled for every three observed) was applied to sections 1 and 2. Sections 3 and 4 were sampled with the standard 1/1 sampling scheme.

Table 5. Maximum redd count for each riffle by section over the course of the 2001 salmon escapement survey.

Section 1		Section 2		Section 3		Section 4	
Riffle	**Maximum # of Redds**	Riffle	**Maximum # of Redds**	Riffle	**Maximum # of Redds**	Riffle	**Maximum # of Redds**
A1	28	F2	9	J7	0	T2	0
A2	63	G1	19	K1	3	T3	2
A3	17	G2	8	K2	6	U1	2
A4	18	G3	0	K3	2	U2	0
A5	0	G4	15	K4	1	U3	0
A6	25	G5	1	K5	6	U4	0
B1	24	G6	14	K6	3	U5	0
B2	66	G7	3	K7	1	U6	0
B3	16	G8	5	L1	0	V1	1
B4	12	H1	11	L2	2	V2	0
B5	15	H2	5	L3	2	V3	0
B6	26	H3	4	L4	7	W1	0
C1	4	H4	1	M1	2	W2	0
C2	3	H5	2	M2	5	W3	3
C3	23	H6	3	M3	2	W4	3
C4	3	H7	2	M4	0	W5	0
C5	4	I1	2	M5	9	X1	0
C6	8	I2	2	N1	8	X2	1
D1	8	I3	2	N2	4	X3	1
D2	10	I4	0	N3	9	X4	2
D3	27	I5	0	O1	2	X5	5
D4	23	I6	0	O2	2	X6	1
E1	9	I7	0	O3	2	X7	2
E2	15	I8	0	O4	4	X8	1
E3	4	J1	0	P1	3	X9	0
E4	2	J2	0	P2	2	Y1	0
E5	9	J3	0	P3	3		
F1	15	J4	0	P4	3		
		J5	0	P5	5		
		J6	0	P6	1		
				Q1	1		
				Q2	4		
				Q3	4		
				Q4	3		
				Q5	1		
				R1	0		
				R2	2		
				S1	0		
				S2	1		
				S3	0		
				S4	0		
				T1	1		
Subtotals	**477**		**108**		**116**		**24**
Total Redds	**725**						

Table 6. Distribution of scale samples collected by section and week for natural salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2	1				1
3	3				3
4	65	13			78
5	78				78
6	54				54
7	31	1	4	1	37
8	34	2	2		38
9	32	2	5		39
10	4		1		5
Total	302	18	12	1	333

Table 7. Distribution of scale samples collected by section and week for adipose fin clipped salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2	1				1
3	1				1
4	31	8	1		40
5	68				68
6	9				9
7	8		2		10
8	7	1			8
9	2		1		3
10					
Totals	127	9	4		140

Table 8. Distribution of heads collected for otolith analysis by section and week for natural salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2					
3					
4	2	1			3
5	10				10
6	2				2
7	2				2
8	3				3
9	6		2		8
10	1				1
Total	26	1	2		29

Table 9. Distribution of heads collected from adipose fin clipped salmon for CWT extraction and otolith analysis by section and week.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2	1				1
3					
4	31	8	1		40
5	125	2			127
6	91				91
7	26	1	2		29
8	14	1			15
9	2		1		3
10					
Total	290	12	4		306

Table 10. Distribution of DNA samples collected from natural salmon by section and week.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2					
3					
4	40	3			43
5	38				38
6	26				26
7	10		2		12
8	30	2	2		34
9	23	2	5		30
10	3		1		4
Total	170	7	10		187

Table 11. Distribution of DNA samples collected from adipose fin clipped salmon by section and week.

Week	**Section**				**Weekly Totals**
	1	**2**	**3**	**4**	
1					
2					
3					
4	18	2	1		21
5	16				16
6	2				2
7	1		2		3
8	5	1			6
9	1				1
10					
Total	43	3	3		49

Figure 1. Fresh carcass indicated by the presence of at least one clear eye.

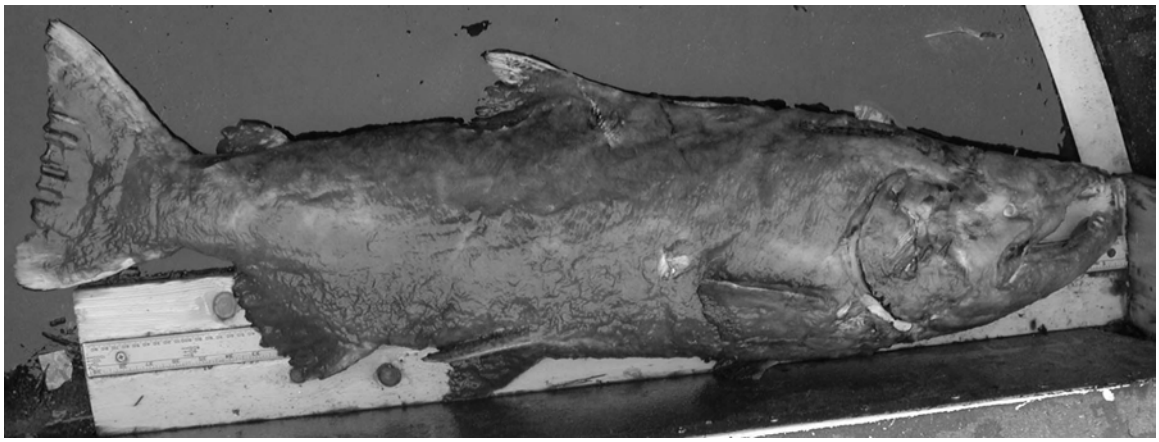

Figure 2. Skeleton covered with fungus.

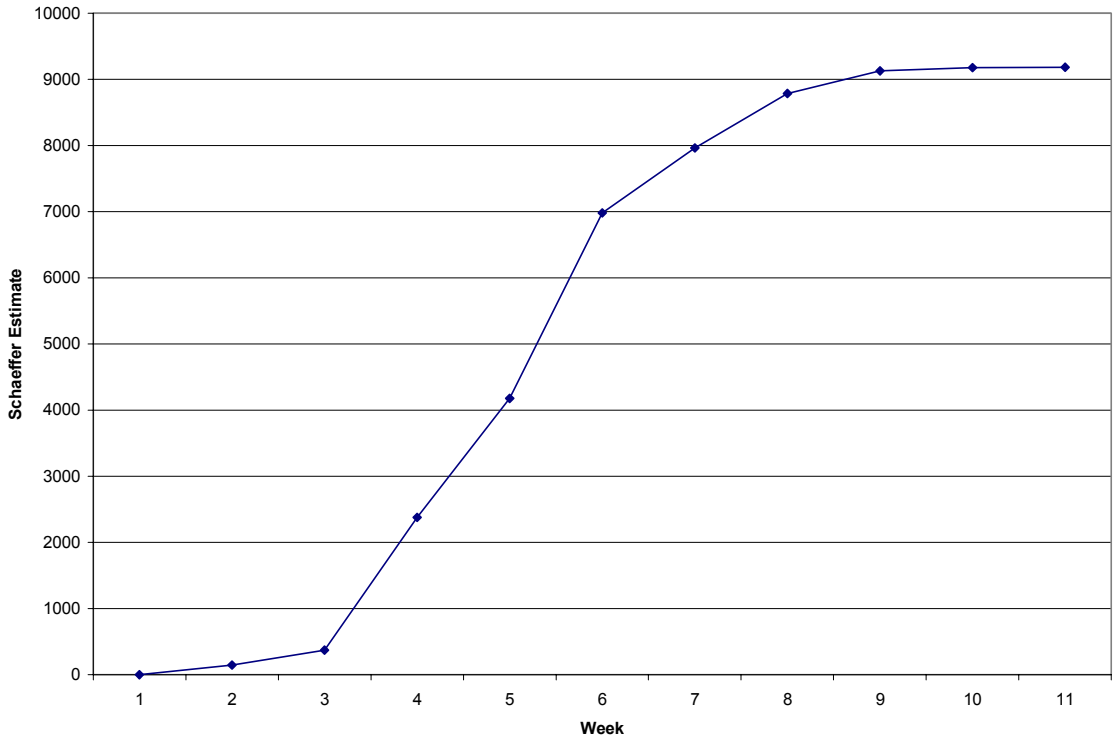

Figure 3. Weekly cumulative Schaeffer escapement estimate.

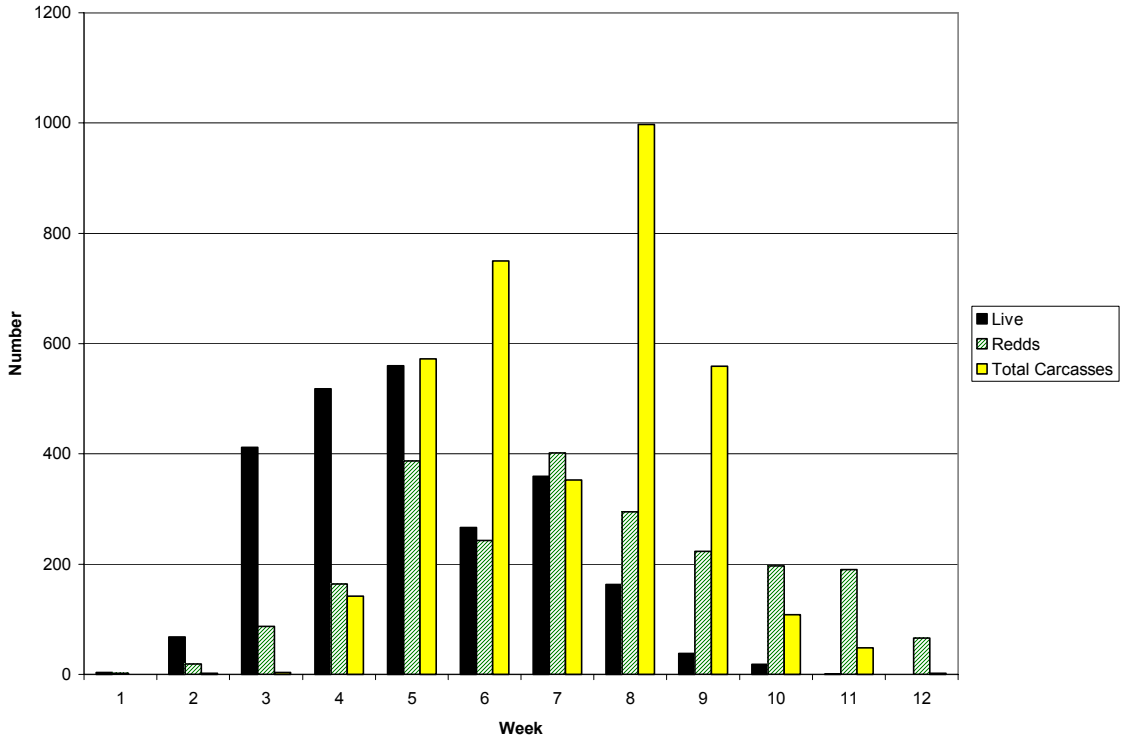

Figure 4. Live fish observation, redd and total carcass counts by week. Total carcasses includes tagged carcasses and skeletons.

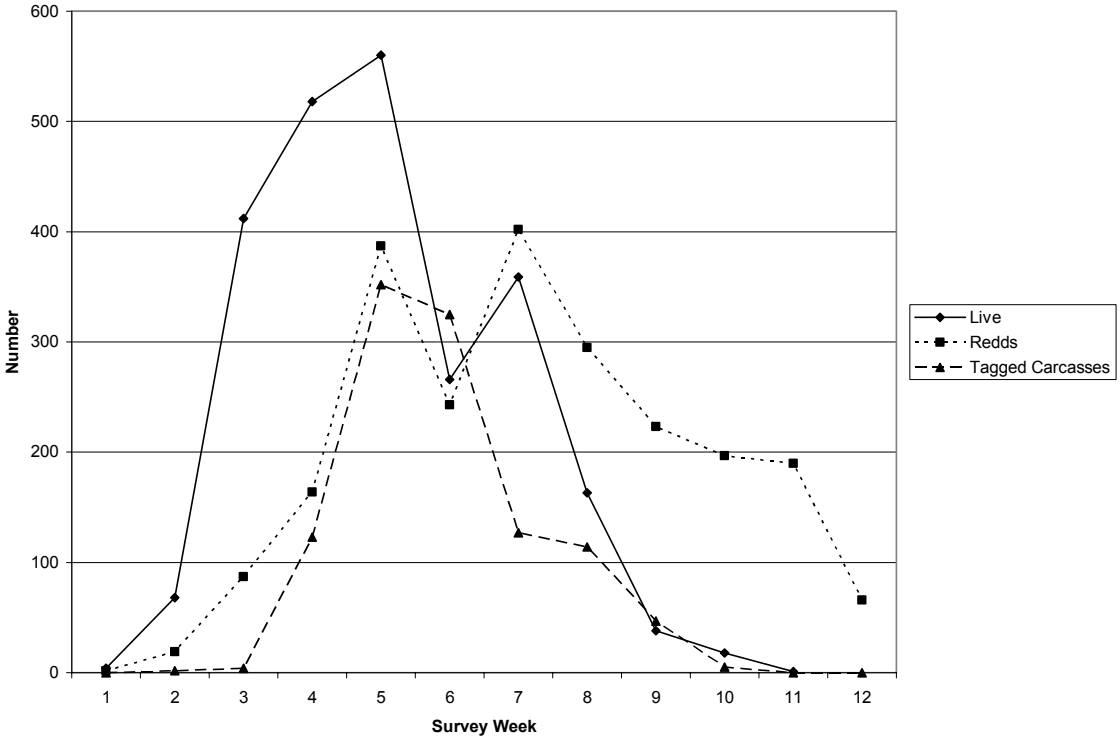

Figure 5. Total number of live fish, redds and tagged carcasses by survey week.

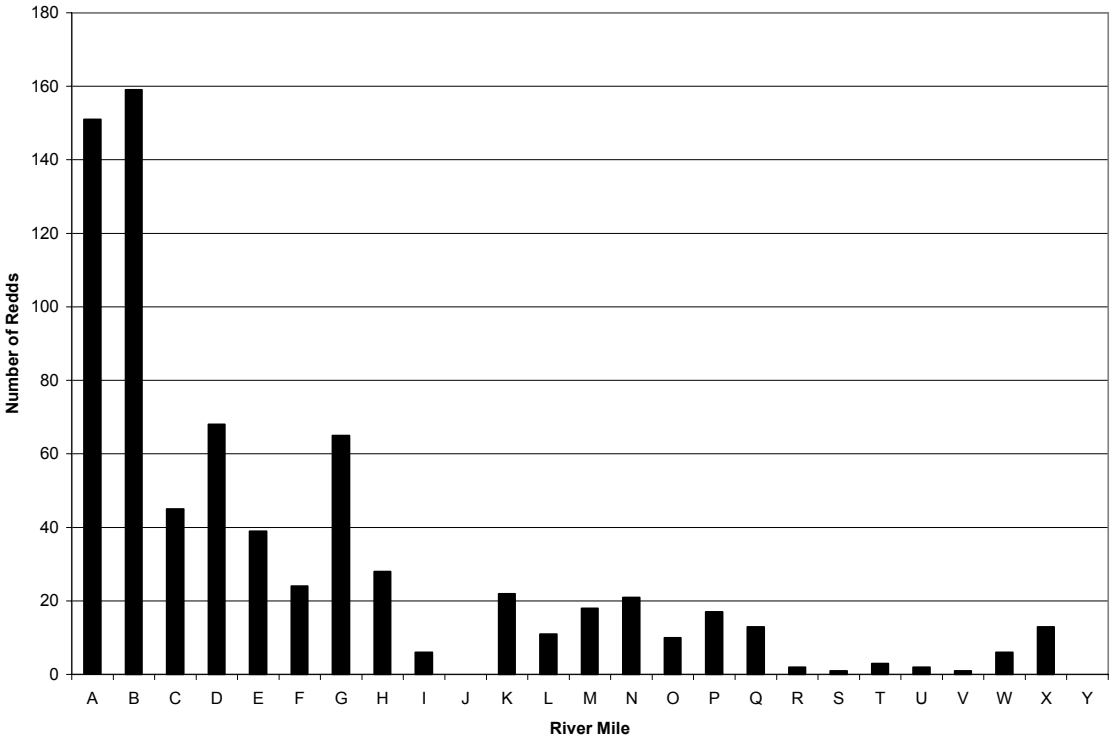

Figure 6. Total redds observed by riffle section.

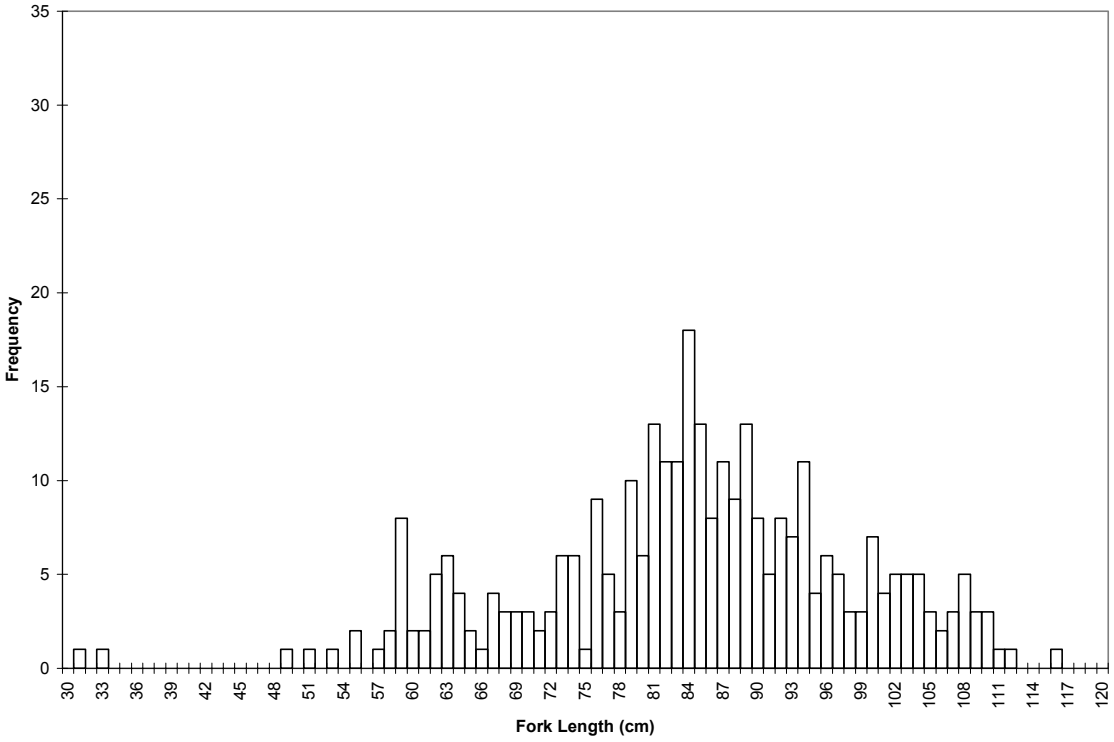

Figure 7. Length frequency histogram of natural male Chinook salmon.

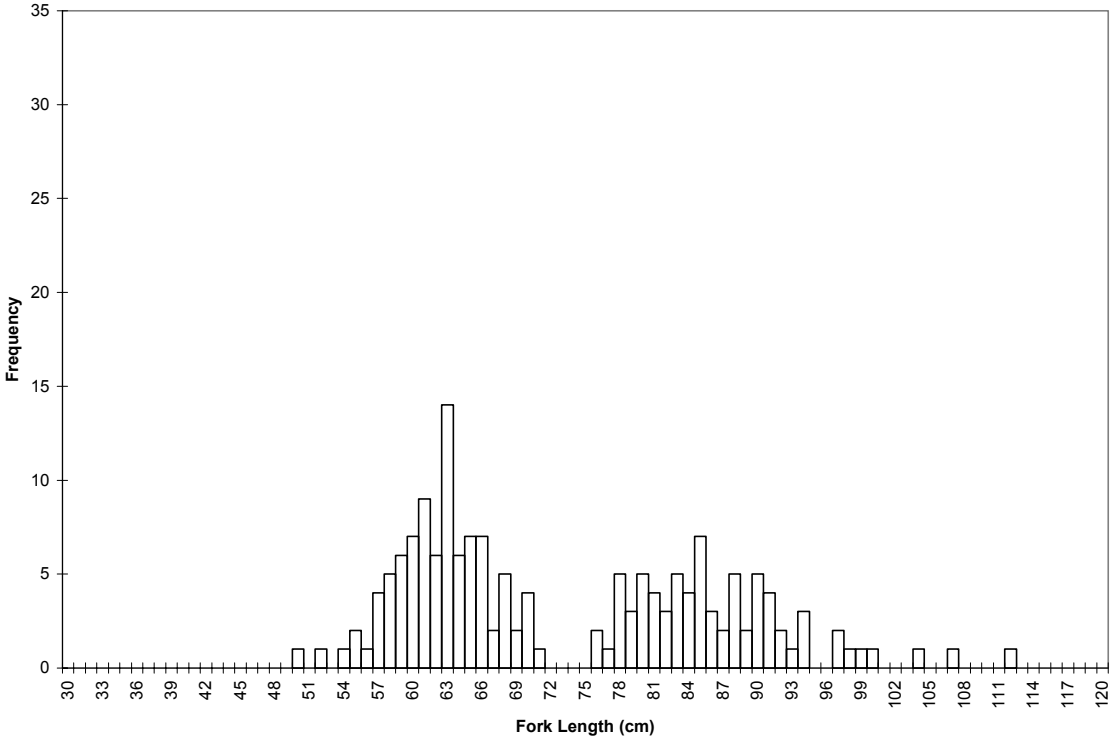

Figure 8. Length frequency histogram of CWT male Chinook salmon.

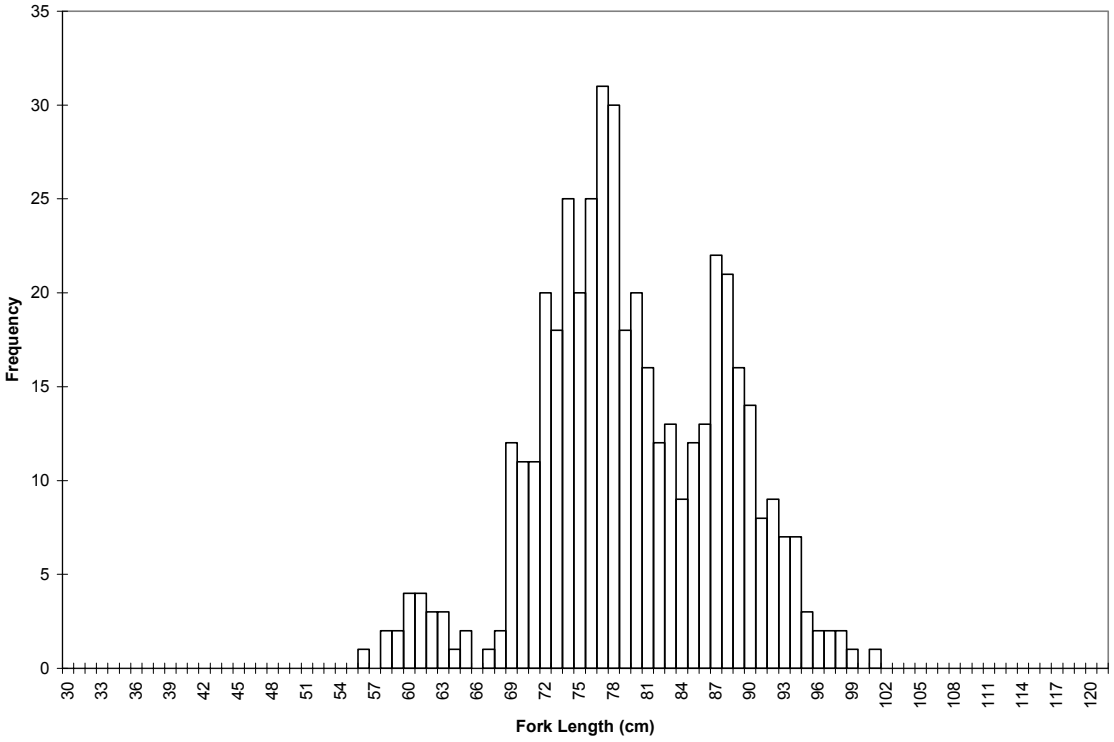

Figure 9. Length frequency histogram of natural female Chinook salmon.

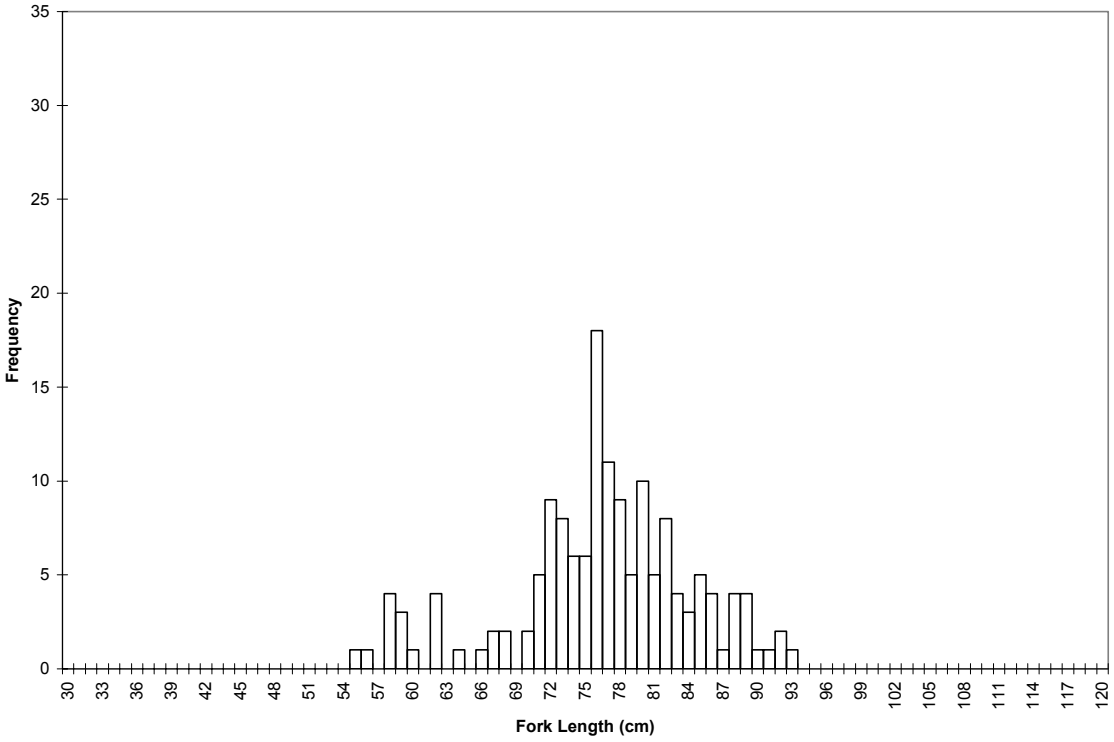

Figure 10. length frequency histogram of CWT female Chinook salmon.

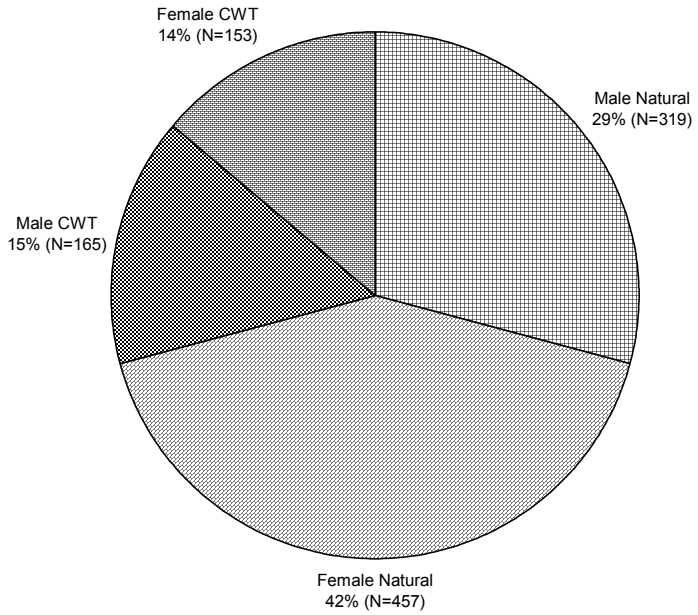

Figure 11. Contribution of male natural, male CWT, female natural and female CWT to the 2001 Merced River salmon escapement survey.

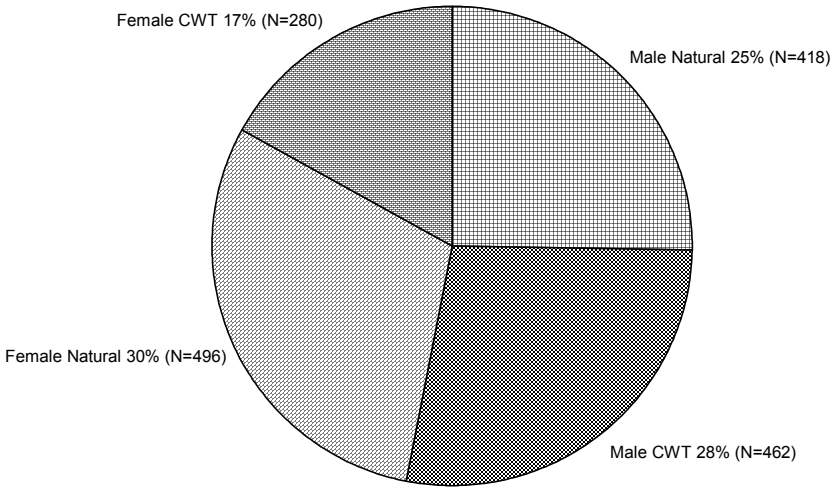

Figure 12. Composition of male natural, male CWT, female natural and Female CWT returning to the Merced River Fish Facility.

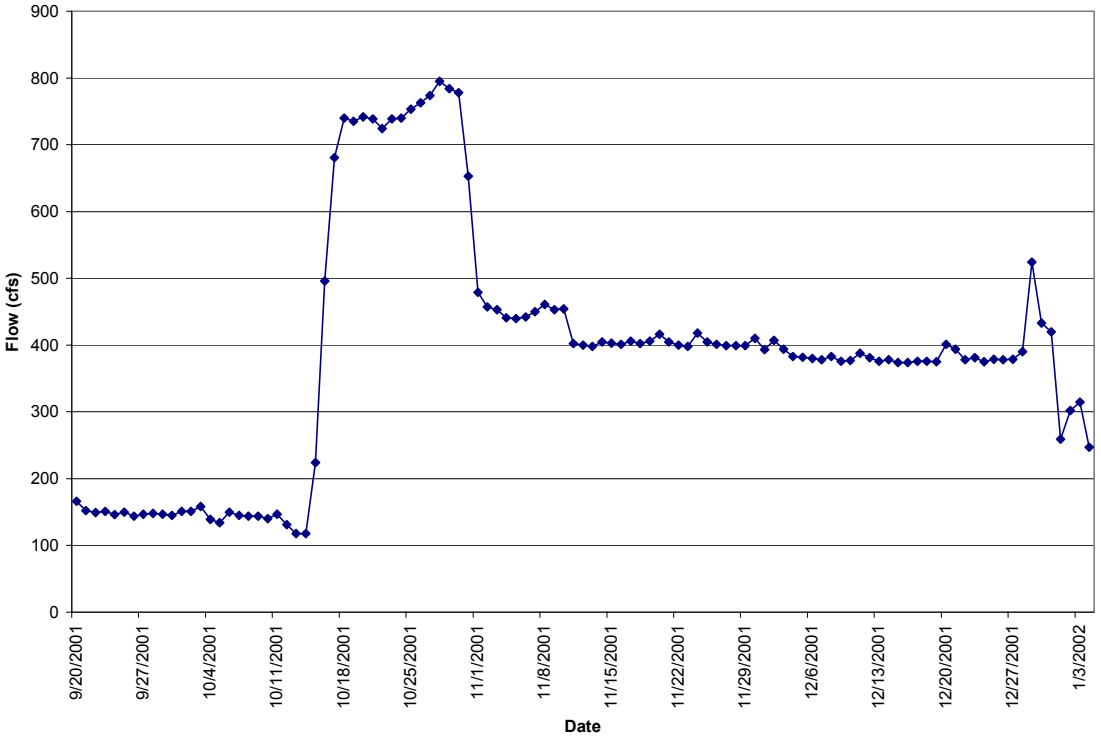

Figure 13. Merced River flows (cfs) graphed from 20SEP01 through 04JAN02.

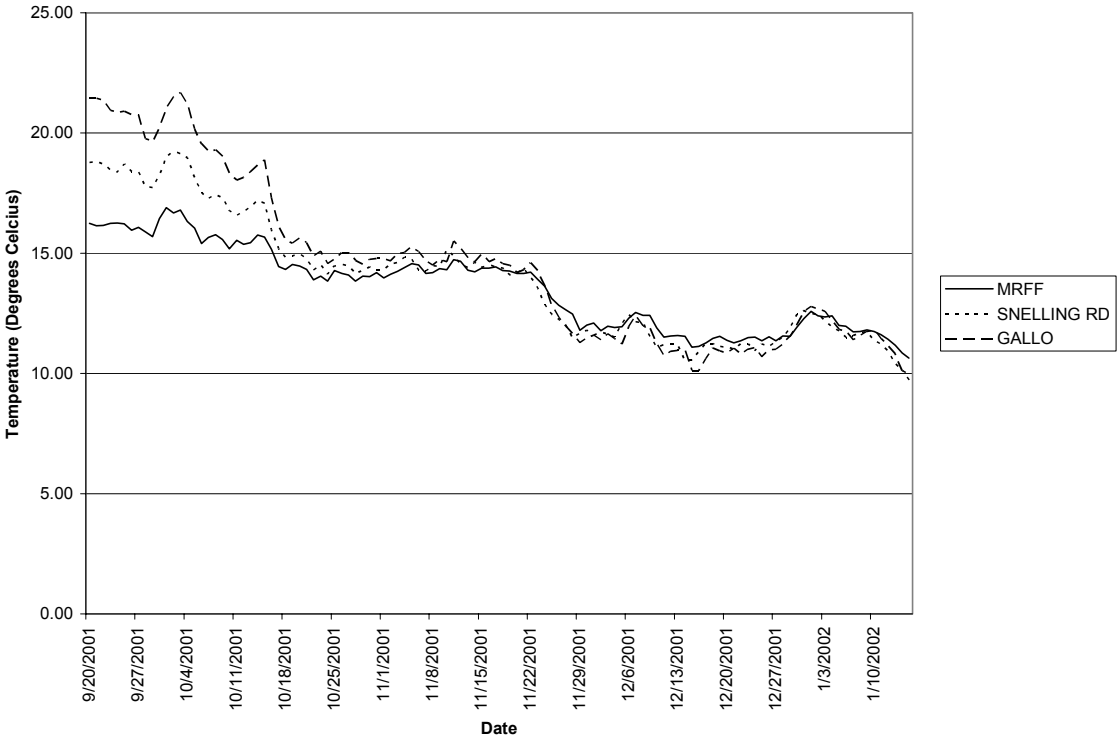

Figure 14. Merced River temperature, plotted for 3 locations below Crocker-Huffman Dam, from 20SEP01 though 15JAN02.

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