2005 Tuolumne River Fall Chinook Salmon Escapement Survey

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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 in the Tuolumne River have declined in the latter half of the 20^{th} century from a high of approximately 130,000 returning adults in 1944 (Fry 1961) to a low of 77 in 1991 (Neillands et al. 1993). Population levels increased to 17,873 in 2000 (Vasques 2001) indicating a slight recovery period. Current levels are once again declining from 7,125 in 2002 (Blakeman 2003), 2,163 in 2003 (Blakeman 2004) and 1,634 in 2004 (Blakeman 2005) with this years estimate continuing this trend. The decline of the species is believed to be caused by many factors. In general, reduction of spawning and rearing habitat and stream flow management practices are thought to be the 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 web of complex population dynamics which effect population numbers within the habitat currently available to Tuolumne River Chinook salmon.

The California Department of Fish and Game (CDFG) has conducted escapement surveys on the Tuolumne River since 1940 (Fry 1961). The Schaefer mark recapture escapement estimation model (Schaefer 1951) has been utilized since 1971. The 2005 escapement survey uses the Schaefer as well as reporting the Jolly-Seber (Seber 1973) estimate. Beginning in 1992, CDFG escapement surveys have been utilized as part of the New Don Pedro FERC Project No. 2299 license monitoring program and annual reporting.

The primary objectives of the Tuolumne River escapement survey are to:

- Estimate the escapement of fall run Chinook salmon on the Tuolumne River.
- Collect fork length and sex data.
- Collect scale and otolith samples with which to conduct age determination analysis and subsequent cohort analysis.
- Collect and analyze coded wire tag data from marked hatchery fish.
- Evaluate the distribution of salmon redds through the study area.

STUDY AREA

Approximately 26.5 river miles were surveyed during the Tuolumne River escapement survey in 2004 (Figure 1). The survey area was divided into 4 sections with Section 1 being the upstream most reach. Section 1, also referred to as the primary spawning reach, extends from riffle A1 at river mile 52.0 near La Grange Dam downstream to Basso Bridge at river mile 47.5. Section 2 extends from Basso Bridge down to the Turlock Lake State Recreation Area (TLSRA) at river mile 41.9. Section 3 covers the area between TLSRA and riffle S1 at river mile 34. Section 4 extends downstream to Fox Grove (river mile 26).

All riffles in the study area have been identified and mapped using a Trimble GPS unit and the GIS computer program ArcView. Each riffle has been systematically re-named upstream to downstream using sequential letter/number designations for river mile and riffle number, respectively. For example, the first riffle surveyed below La Grange Dam in the first river mile (51) is named A1. The riffle immediately below La Grange Dam (riffle A1) is surveyed by foot and only redd and fish counts are made. 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) and Jolly-Seber (Seber 1973) mark recapture models were used to estimate fall salmon escapement on the lower Tuolumne River. These methods utilize marked and subsequently recovered carcasses during weekly surveys of the spawning reach. A ratio of marked to unmarked fish is used to calculate weekly population estimates, which are then summed to estimate the total spawning population. The CDFG began the survey on 3 October 2005 (Week 1) and concluded on 22 December 2005 (Week 12). Carcasses were tagged for the entire 12 weeks.

All carcasses encountered were handled during weekly drift boat surveys of the study area. Carcasses were gaffed as the sampling crew drifted past and held in the boat until the end of the riffle and adjacent downstream pool. Subsequent to drifting the riffle and downstream pool the riverbanks were walked to collect carcasses that could not be seen or collected from the drift boat. 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 fresh carcass designation criteria used was at least one clear eye (Figure 2). Decayed fish had cloudy eyes. Skeletons were carcasses judged to be in an advanced state of decay and unlikely to have the same probability of recapture as fresh and decayed specimens. Criteria for skeleton designation survey included the presence of fungus covering the entire body at the freshest end of skeleton designation (dead approximately one week) to actual skeletons at the most decayed end (Figures 3 and 4).

All fresh and decayed carcasses were given a unique number by attaching a numbered aluminum tag to the lower jaw. These newly tagged carcasses were redistributed to river current near the lower end of the riffle for recovery in subsequent weeks. For tag recoveries, the unique tag number was noted and the carcass was chopped and returned to the river. All skeletons were enumerated, chopped, and returned to the river to avoid double counting. Estimates were made using the Schaefer (1951) equation as presented in Ricker (1975) and also using the Jolly-Seber equation (Seber 1973). Law (1994) found in simulations of various models, using a similar protocol as this survey, that the Peterson model (see Ricker, 1975) drastically over estimated, while the Schaefer model consistently overestimated the population and the Jolly-Seber model most accurately estimated the population. Therefore, Peterson's model was not used in this analysis and estimates using the Schaefer and Jolly-Seber models will be reported.

Weekly Fish Distribution and Redd Counts

Weekly live fish observation and redd counts were conducted during the survey (Table 2, Figure 5). These counts are conducted for each riffle and pool using the riffle identification system noted earlier. Counts are made using tally counters as field crews drifted through riffles and pools. For consistency the same observer was used each week to make live fish and redd counts.

Individual Fish Data Collection

Fork length (to the nearest 1 centimeter) and sex data are collected for all tagged carcasses. Scale and otolith samples are collected from a percentage of specimens to determine the size and age composition of annual spawning runs. Coded wire tags (CWTs) are collected from hatchery produced, marked (adipose fin clipped), carcasses as part of long term survival testing of releases of marked outmigrating smolts. This also allows for determining the incidence of straying from other river systems. CWT specimens are also used to validate scale and otolith age determination work. Scale and otolith samples were collected from both wild and CWT carcasses and are catalogued at the CDFG La Grange Field Office. CWTs and otolith samples are collected via removal of the head minus the lower jaw. Extraction and analysis of otoliths and CWTs is conducted after the spawning season. All fish samples are catalogued by the fish's unique jaw tag number, which allows the samples to be tracked to the specific data and riffle number of collection.

RESULTS

Population Estimate

Based on the Schaefer model using all tagged fish and recoveries the 2005 escapement estimate was **719 salmon**. The Jolly-Seber model using all tagged fish yielded an estimate of 503. Past estimates from carcass surveys conducted by CDFG have utilized the Schaefer model using only fresh tagged carcasses despite Law's (1994) findings that including all carcasses (fresh and decayed) only slightly effect the estimate for all models. The Schaefer and Jolly-Seber models utilize the number of recoveries of tagged carcasses, the total number of tagged fish, and the total number of carcasses handled each week to generate weekly escapement estimates (Table 3). Weekly estimates are summated to obtain the total escapement estimate over the course of the survey. Table 4, the mark-recapture matrix, shows the total number tagged each week in relation to the number of recoveries made in subsequent weeks. Weekly estimates are presented in Table 5. Weekly cumulative Schaefer and Jolly-Seber estimates are graphed in Figure 6. Overall tag recovery rate was very low at only 33%.

Weekly Counts

Live fish counts increased steadily through week 7, decreased in weeks 8 and 9, peaked again in week 10 and dropped off dramatically in week 12 (Table 2, Figure 5). Redd counts showed a slight delay in initial spawning indicated by the very slight increases through week 5 and a sharp increase in week 6. Redd counts increased from 87-124 in weeks 6 to 8 dropped in week 9 and again increased from weeks 9-11 (n=94-120) before a sharp decrease in week 12. Carcass counts remained low through week 5, increased slightly in week 6 and remained nearly the same through week 11 before a sharp drop in week 12.

Spawning Distribution

The results of total weekly redd counts indicate that the majority (greater than 38%) of spawning activity is concentrated in the riffles of Section 1 (Figures 7 and 8). Sections 1 and 3 combined saw nearly 74% of redds in 2005. The maximum redd count represents counts made when external factors like visibility and turbidity were at optimum conditions. The maximum redd counts for each riffle over the course of the season is listed in Table 6. During the 2005 survey 70, 21, 63, and 26 maximum redds were counted for sections 1 through 4 respectively (Figure 7).

Population Composition

Coded wire tagged (CWT) fish comprised 11% of the total tagged carcasses based on the ratio of adipose fin clipped fish to total tagged carcasses (Table 3). Skeletons were not checked for adipose fin clips due to their advanced state of decomposition. However, it is likely that ratios calculated for tagged fish are representative for skeletons as well. The total contributions (tagged fish only) to the spawning population were 30% for natural males, 3% for CWT males, 59% for natural females, and 8% for CWT females (Figure 9).

Length frequency histograms display a bimodal peak (Figures 10, 11). The first peak are likely grilse (age 1 and 2 fish) and the second peak is likely adult (age 3, 4, and 5 year fish). Total grilse composition was 15.9% of the Tuolumne River escapement estimate. Breakpoints between grilse and adult were determined from basin wide fork length data. Breakpoints used were 71cm for males and 64cm for females (Table 7). Grilse composition for CWT fish was not determined due to low CWT recaptures for the entire basin.

Sample Collection

Scales and otolith samples were collected from both natural and adipose fin clipped fish. Samples were collected throughout the survey period and survey area (Tables 8 and 9). Distribution of sampling is intended to best represent the spawning population over time, space, and origin. Scale and otolith samples will be utilized in the CDFG age determination program and for subsequent cohort analysis of San Joaquin River Basin Chinook salmon populations. Origin of CWT fish for 2005 were 16 from Merced River Fish Facility, 1 Feather River Hatchery, 1 American River Hatchery and 2 had no tag recovered.

Egg Production Estimate

An estimate of egg production by the 2005 fall run Chinook salmon is done using the relationship of fork length to fecundity. The relationship was developed using 48 San Joaquin fall run Chinook females ranging from fork length 62.5 to 94.0 cm (Loudermilk et al. 1990). The number of eggs was calculated for natural females (n=103, average FL=75.6) and CWT females (n=14, average FL=77.9) and then expanded to the entire estimate. Natural females made up 59% of the 2005 estimate and produced approximately 2,524,931 eggs. Adipose fin clipped females (8%) produced approximately 362,929 eggs.

Tuolumne River Flows

Tuolumne River flows at the La Grange gage ranged from approximately 356 to 7,637cfs during the 2005 spawning season (Figure 12). To attract fish into the Tuolumne from the San Joaquin River and improve spawning habitat a pulse flow was initiated on 11 October 2005. Mean daily flow at La Grange averaged approximately 625 cfs from 12 – 27 October 2005 and then reduced to approximately 395 cfs through 19 December 2005. Flows at La Grange were then increased to approximately 2,500 cfs by 26 December and continued increasing, peaking at about 7,837 on 01 January 2006. These flow increases were due mainly to increased storm run-off into Don Pedro Reservoir and Army Corp of Engineers reservoir elevation requirements.

Tuolumne River Temperature

Temperatures in the Tuolumne River ranged from 10^{o}C to 16 ^{o}C. Temperatures were taken with a hand held thermometer in the morning at the start of the sampling day and again at the end of the sample day.

DISCUSSION

Population Estimate

The 2005 tag recovery rate of 33.0% is the lowest since the 2000 recovery rate of 41.7% (Vasques 2001). From 2001 to 2004 recovery rates have been relatively high ranging from 55.3% to 65.4%. The difference in recovery rates is likely a function of the difference in stream flow between 2000/2005 seasons (daily average over 300cfs) and 2001 - 2004, (daily average under 200cfs). Tuolumne River daily average flows were relatively high in 2005 at over 395cfs. Stream flow dynamics affects the likelihood of collecting carcasses in that it effects both how carcasses are distributed in the system and the effectiveness in recovering carcasses by field crews. During the lower flows encountered during the 2001 - 04 surveys carcasses were easily visible and the lower flows allowed for collection in specific locations which were too deep or too swift to survey in 2000/2005 seasons. Furthermore, the banks of riffles were walked in an effort to collect carcasses that could not be seen or collected during the initial float through the riffle and subsequent pool. During 2000 bank efforts were not nearly so extensive. The Tuolumne River escapement estimate for 2005 of 719 salmon is the lowest since the 1994 estimate of 513 returning adults.

Weekly Counts

Live fish, redd and carcass counts as illustrated in Figure 5 should show a typical bell curve shape with counts gradually increasing, peaking near mid-spawning season and gradually decreasing when most fish are done spawning. The 2005 spawning season was not quite typical, in part due to higher base flows, fewer returning fish, poor visibilities, and a large flow increase occurring before the end of the spawning season. Redd counts only slightly increased through week 5 and did not keep pace with live counts as expected. Week 9 shows a decrease in live and redd counts likely due to poor visibility from rainy and windy conditions. The sharp decline in counts occurring in week 12 was due to daily average flows increasing from 375cfs to 1,974cfs from 19-21 December.

Spawning Distribution

Redd counts are strongly affected by time of day, visibility, sunlight , wind rippling the water surface, redd superimposition, and other physical factors as well as the natural variability between observers. The same observer was used each week during the Tuolumne escapement survey to minimize any bias which may occur when using different observers. Furthermore, redd counts are conducted with a single pass as opposed to an intensive systematic approach beyond the scope of this study. In the primary spawning riffles of Section 1 the problem of redd superimposition is more acute and leads to undercounting. On the other hand, redds in Section 2, 3, and 4 are more easily delineated as clean patches of freshly worked gravel among patches of darker undisturbed gravel. In these sections redd counts are accurate indicators of spawning density. For these reasons, the disparity between spawning density in Section 1 versus Sections 2, 3, and 4 is likely greater than displayed in Figures 7 and 8.

Population Composition

Coded wire tagged fish comprised 11 % of the total tagged carcasses based on the ratio of adipose fin clipped fish to total tagged carcasses (Table 3, Figure 9). Skeletons were not checked for adipose fin clips due to their advanced state of decomposition. However, it is likely that ratios calculated for tagged fish are representative for skeletons as well. The total contributions (tagged fish only) to the spawning population were 30% for natural males, 3% for adipose fin clipped males, 59% for natural females, and 8% for adipose fin clipped females (Figure 9).

Length frequency histograms of male fish display a bimodal peak (Figures 10). Female fish did not show a clear bimodal peak (Figure 11), but when females from the entire San Joaquin Basin were combined the bimodal peak was more clearly defined. The first peak are likely grilse (age 1 and 2 fish) and the second peak are likely adult (age 3, 4, and 5 year fish). Total grilse composition was 15.9% of the Tuolumne River escapement estimate. Breakpoints between grilse and adult were determined from basin wide fork length data and applied to Tuolumne River fork length data. Breakpoints used were 71cm for males and 64cm for females (Table 7). Grilse composition for CWT fish was not determined due to low CWT captures for the entire basin.

Sample Collection

Scales and otolith samples were collected from both natural and adipose fin clipped fish. Samples were collected throughout the survey period and survey area (Table 8 and 9). Distribution of sampling is intended to best represent the spawning population over time, space origin. Samples were collected from every other tagged fish at the start of the survey. Near the end of week 6 it was determined that in order to obtain a sufficient number of samples, scales would be collected from every tagged fish.

Tuolumne River Flows

Low dissolved oxygen (DO) levels in the San Joaquin River are believed to be a barrier for fall-run salmon migrating up the San Joaquin stem to spawn in the Merced, Tuolumne and Stanislaus Rivers. A fall pulse flow regime has been developed to lower river temperatures and elevate levels of dissolved oxygen in the San Joaquin River in order to attract salmon and prevent straying. Redd counts on the Tuolumne River started immediately at the start of the escapement survey. The 2005 escapement season saw relatively high flows throughout the basin which likely minimized any DO or temperature problems

Tuolumne River Temperatures

Thermographs deployed throughout the spawning reach were unable to be downloaded due to high river elevations. Normally this data would show a distinct relationship with increased live counts and increased DO levels in the San Joaquin River as well as increased spawning activity when river temperatures fell below the thermal limit of 13.3^{o}C. During the entire 2005 survey period river temperatures (instantaneous readings with a hand held thermometer) in section 1 and 2 remained below the thermal limit of 13.3^{o}C.

Table 1. Tuolumne River riffle identification cross-reference, 2005 to 2004.

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	1A	F1	F1	K1	K1	S1	S1
A2	A1	F2	F2	K2	K1	S2	S2
A3	A2	F3	F3	K3	K2	S3	S3
B1	B1	G1	G1	L1	L1	T1	T1
B2	B2	G2	G2	L2	L2	T2	T2
B3	B3	G3	G3	L2N	L2	T3	T3
B4	B3N	G4	G4	L3	L3	T4	T4
C1	C1	H1	H1	M1	M1	T5	T5
C2	C2	H2	H2	M2	M2	U1	U1
C3	C3	H3	H3	N1	N1	U2	U2
D1	D1	H4	H4	N2	N2	U3	U3
D2	D2	H5	H5	N3	N3	V1	V1
D3	D3	H6	H6	N4	N4	V2	V2
D4	D4	I1	I1	O1	O1	V3	V3
D5	D5	I2	I2	O2	O2	V4	V4
E1	E1	I3	New	O3	O3	W1	W1
		I4	New	O4	O4	W2	W2
		J1	I3	O5	O5	W3	W3
		J2	New	P1	O5	X1	X1
		J3	New	P2	P1	X2	X2
		J4	J1	P3	P2		
		J5	J2	P4	P2		
		J6	J3	P5	P3		
		J7	J4	P6	P4		
		J8	J5	Q1	Q1		
				Q2	Q2		
				Q3	Q3		
				R1	R1		
				R2	R2		
				R3	R3		

Table 2. Total weekly counts of live fish, redds, and carcasses.

Week	Live	Redds	Carcasses[1]
1	13	1	2
2	24	6	2
3	45	3	1
4	58	12	2
5	106	23	2
6	110	87	25
7	129	110	17
8	112	124	20
9	70	94	24
10	127	109	18
11	112	120	21
12	9	17	2
Totals	**915**	**706**	**136**

[1]Carcasses includes all tagged carcasses and skeletons but does not include recoveries.

Table 3. Weekly totals.

Week	Total Tagged	Skeletons	Fresh Recoveries	Total Counted[1]	Fresh Tagged[2]	CWT's
1	0	2	0	2	0	0
2	5	2	0	7	4	2
3	0	1	0	1	0	0
4	0	2	0	2	0	0
5	4	2	0	6	3	1
6	24	25	1	50	17	3
7	20	17	9	46	17	3
8	25	20	5	50	19	5
9	27	24	16	67	20	3
10	29	18	14	61	20	2
11	39	21	13	73	24	1
12	3	2	0	5	2	0
Totals	**176**	**136**	**58**	**370**	**126**	**20**

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

Table 4. Distribution of all tagged fish, tag week versus recovery week.

Recovery Week	Tag Week of Recovered Tags												Weekly Totals
	1	2	3	4	5	6	7	8	9	10	11	12	
2	0												**0**
3	0	0											**0**
4	0	0	0										**0**
5	0	0	0	0									**0**
6	0	0	0	0	1								**1**
7	0	0	0	0	0	9							**9**
8	0	0	0	0	0	1	4						**5**
9	0	0	0	0	0	2	0	14					**16**
10	0	0	0	0	0	1	1	0	12				**14**
11	0	0	0	0	0	0	0	0	1	12			**13**
12	0	0	0	0	0	0	0	0	0	0	0	0	**0**
All Recoveries	**0**	**0**	**0**	**0**	**1**	**13**	**5**	**14**	**13**	**12**	**0**	**0**	**58**
Total Tagged Carcasses	**0**	**5**	**0**	**0**	**4**	**24**	**20**	**25**	**27**	**29**	**39**	**3**	**Overall Recovery**
Percent Recovery	**0.0**	**0.0**	**0.0**	**0.0**	**25.0**	**54.2**	**25.0**	**56.0**	**48.1**	**41.4**	**0.0**	**0.0**	**33.0%**

Table 5. Weekly Schaefer and Jolly-Seber estimates.

Week	Number of Tags Recovered	Total Carcasses Handled	Schaefer Estimate	Jolly-Seber Estimate
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7[1]	32	59	274	152
8	20	106	152	31
9	25	50	78	125
10	27	67	91	41
11	29	61	124	64
12	39	73	0	90
Total Estimate			**719**	**503**

[1] Week 6 and 7 were combined due to low recaptures in week 6.

Table 6. Maximum redd count for each riffle over the course of the escapement survey by section.

Section 1		Section 2		Section 3		Section 4	
Riffle	Maximum Redd Count	Riffle	Maximum Redd Count	Riffle	Maximum Redd Count	Riffle	Maximum Redd Count
A1	5	F1	1	K1	3	S1	2
A2	4	F2	0	K2	0	S2	1
A3	1	F3	1	K3	8	S3	3
B1	10	G1	2	L1	8	T1	0
B2	17	G2	1	L2	2	T2	4
B3	2	G3	2	L3	1	T3	0
B4	2	G4	0	M1	1	T4	2
C1	8	H1	1	M2	2	T5	1
C2	1	H2	0	N1	3	U1	2
C3	6	H3	1	N2	6	U2	2
D1	1	H4	1	N3	2	U3	3
D2	6	H5	2	N4	1	V1	1
D3	1	H6	1	O1	1	V2	0
D4	4	I1	2	O2	2	V3	0
D5	1	I2	0	O3	0	V4	0
E1	1	I3	2	O4	0	W1	1
		I4	0	O5	2	W2	3
		J1	0	P1	0	W3	1
		J2	0	P2	0	X1	0
		J3	0	P3	2	X2	0
		J4	0	P4	0		
		J5	3	P5	2		
		J6	1	P6	1		
		J7	0	Q1	3		
		J8	0	Q2	3		
				Q3	1		
				R1	6		
				R2	1		
				R3	2		
Sub Total	70		21		63		26
Total	180						

Table 7. Grilse composition of Chinook salmon.

	Male	**Female**
Grilse	**12.5%** (n=22)	**3.4%** (n=6)
Adult	**21.0%** (n=37)	**63.1%** (n=111)

Table 8. Distribution of scale samples collected by section and week for natural and adipose fin clipped salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1	0	0	0	0	**0**
2	1(1)	1	0	0	**2(1)**
3	0	0	0	0	**0**
4	0	0	0	0	**0**
5	1	0	0	0	**1**
6	9	2	2	1	**14**
7	9(3)	3	4	1	**17(3)**
8	19(5)	0	1	0	**20(5)**
9	22(2)	1	1(1)	0	**24(3)**
10	21(2)	1	4	1	**27(2)**
11	30(1)	1	7	0	**38(1)**
12	2	0	0	1	**3**
Totals	**114(14)**	**9**	**18(1)**	**4**	**146(15)**

Parentheses indicate number of samples from adipose fin-clipped carcasses.

Table 9. Distribution of heads collected from Chinook salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1	0	0	0	0	0
2	2	0	0	0	2
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	1	0	1
6	3	0	0	0	3
7	3	0	0	0	3
8	5	0	0	0	5
9	2	0	1	0	3
10	2	0	0	0	2
11	1	0	0	0	1
12	0	0	0	0	0
Total	**18**	**0**	**2**	**0**	**20**

Heads were taken only from adipose fin-clipped carcasses.

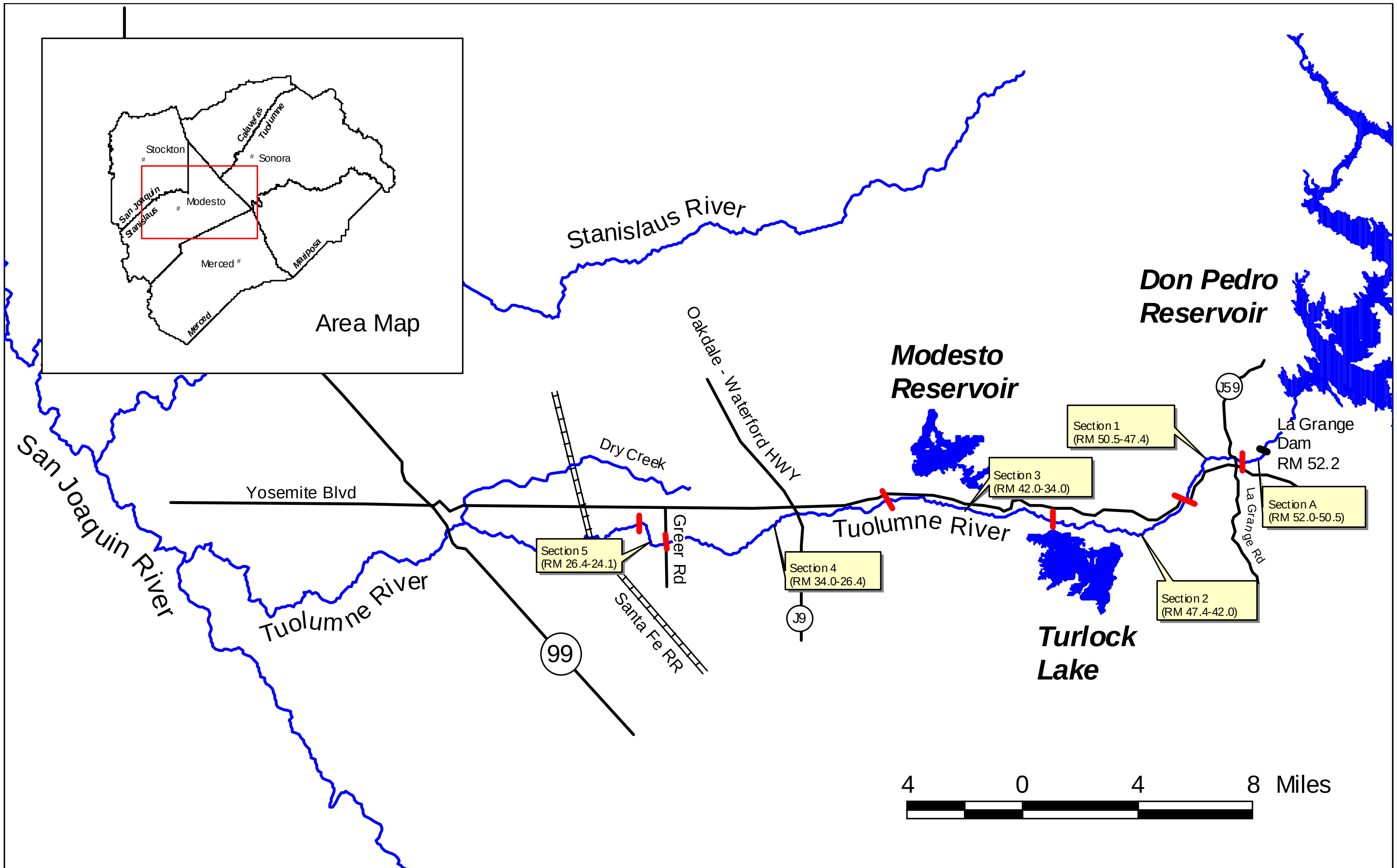

Figure 1. Salmon survey study areas, lower Tuolumne River.

California Department of Fish & Game

Prepared by: Gerald Hatler 01/18/2000

Figure 2. Fresh carcass indicated by clear eye.

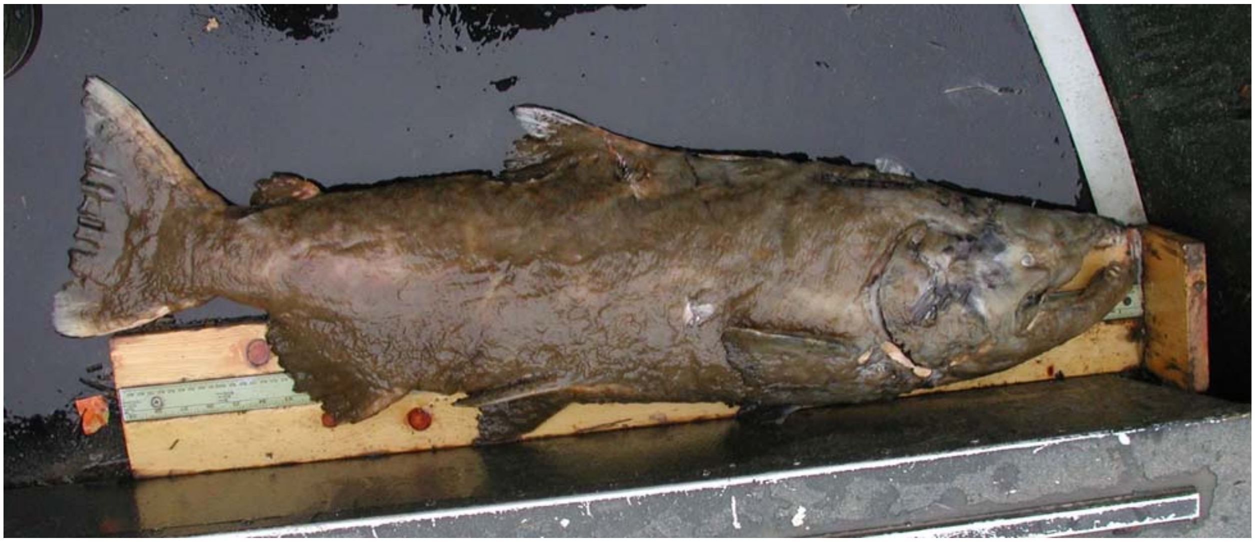

Figure 3. Fungus covered skeleton.

Figure 4. Two skeletons showing varied degrees of decomposition and a fresh carcass.

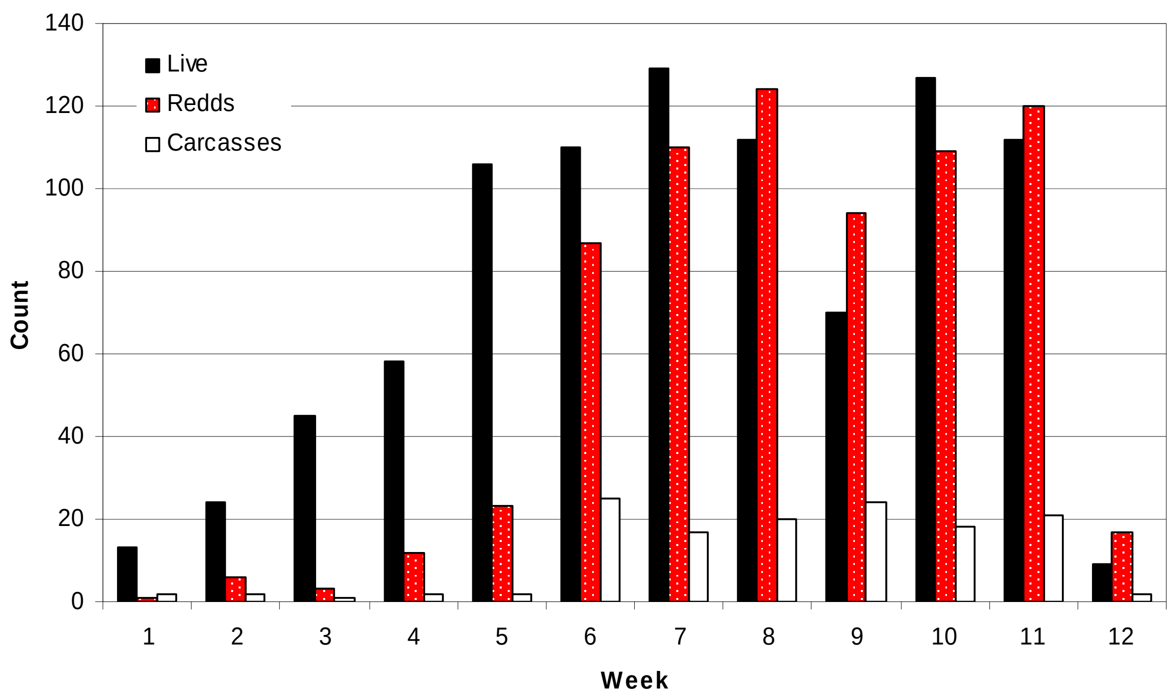

Figure 5. Live fish observation, redd, and total carcass weekly counts. Carcasses include all tagged carcasses and skeletons.

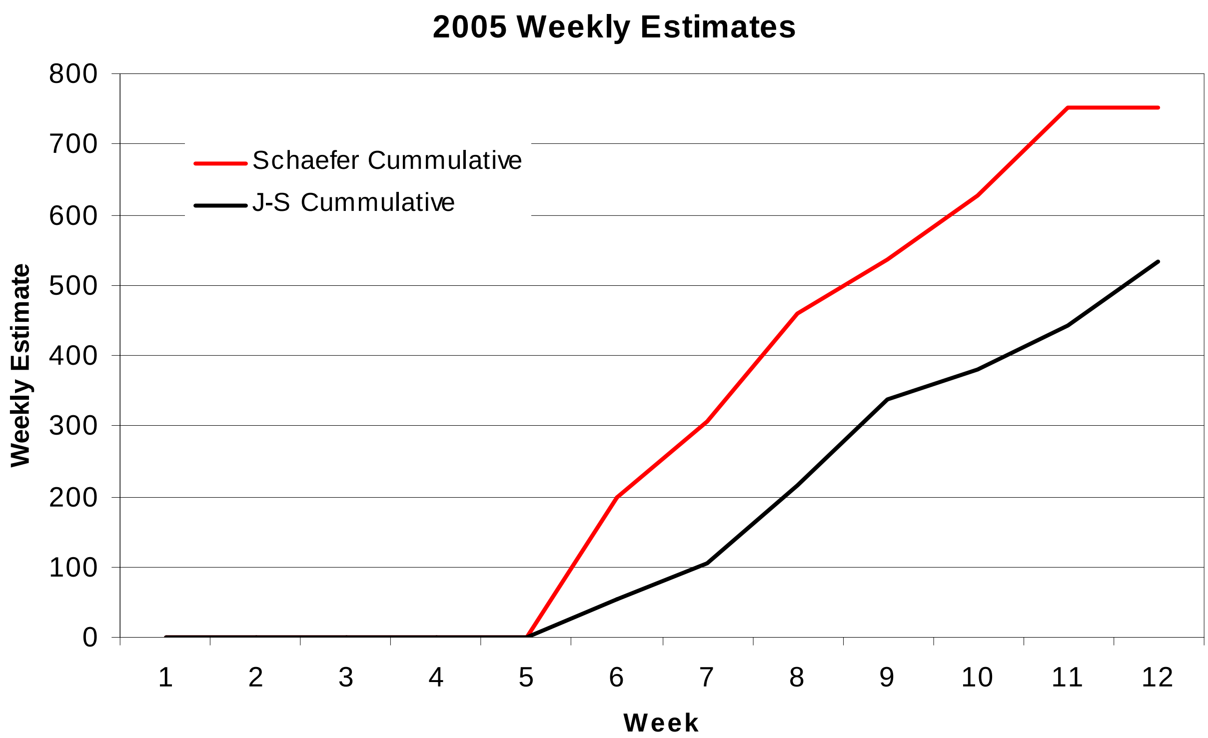

Figure 6. Weekly cumulative Schaeffer and Jolly-Seber escapement estimates.

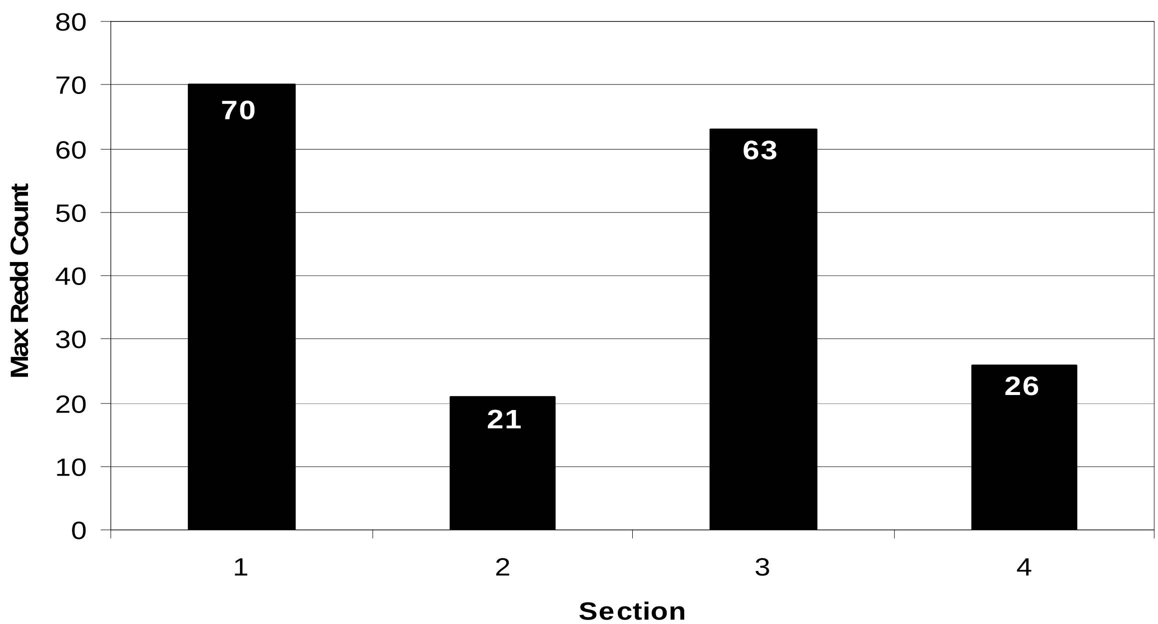

Figure 7. Maximum number of redds counted per section.

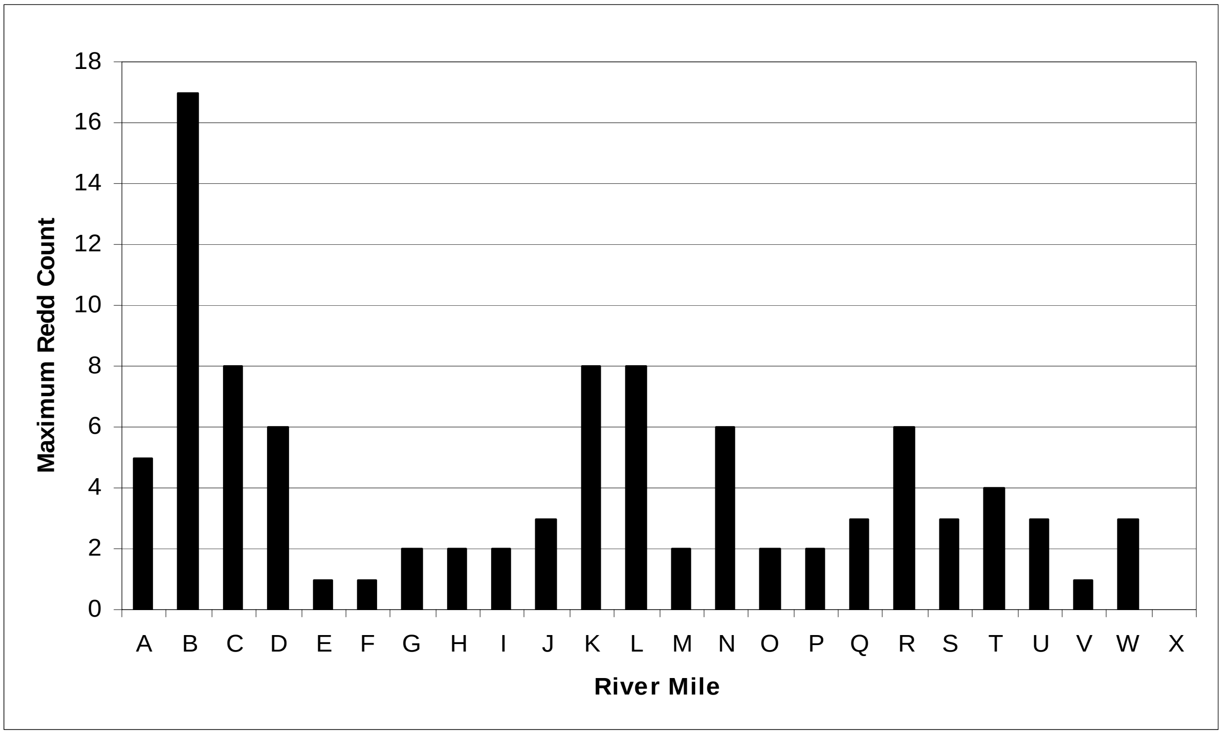

Figure 8. Maximum redds observed by riffle section. Each letter represents one river mile.

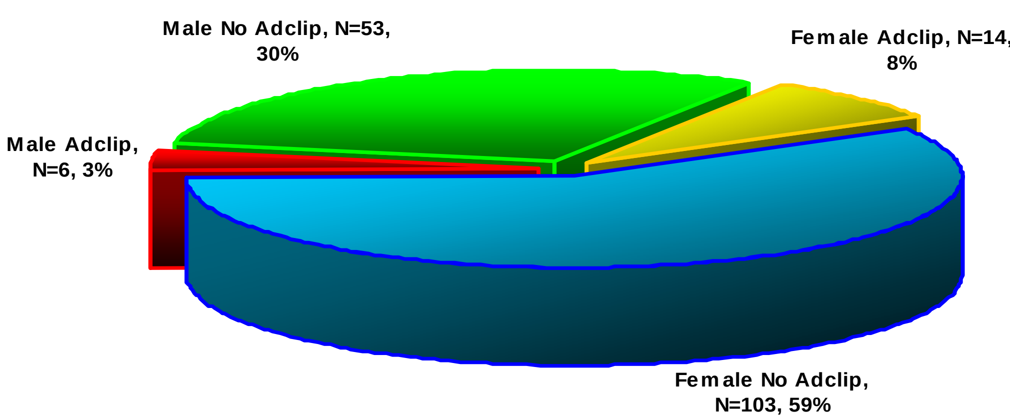

Figure 9. Contribution of natural female, adipose clipped female, natural male, and adipose fin clipped male to the 2005 Tuolumne River escapement.

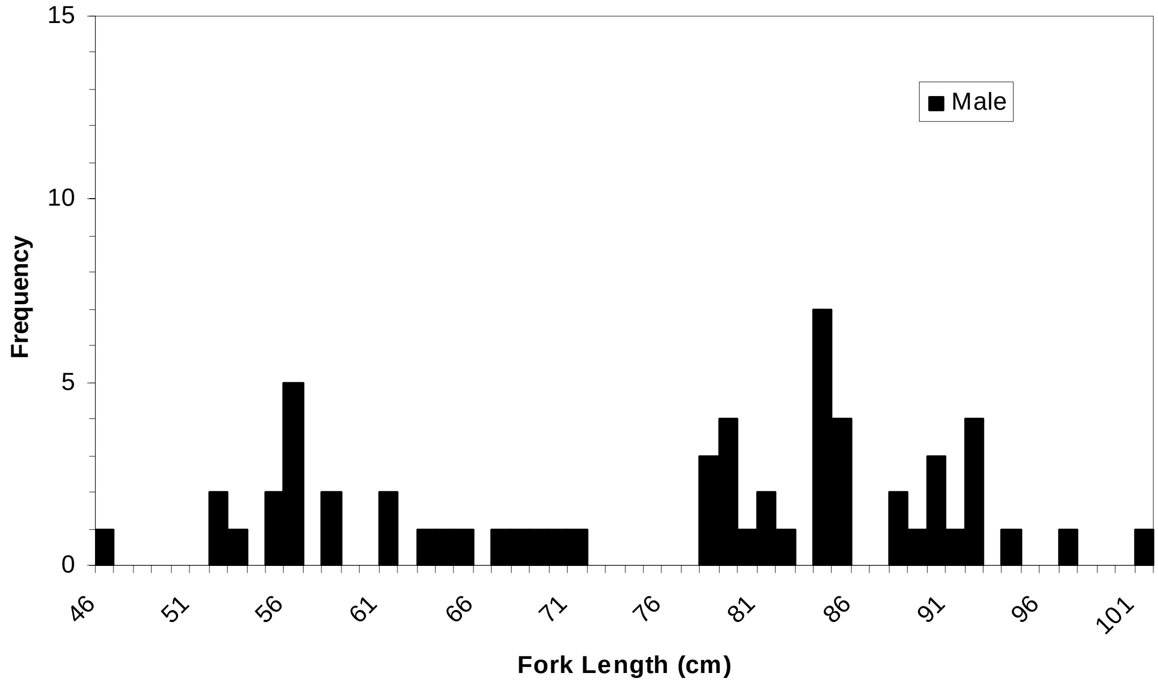

Figure 10. Length frequency histogram of natural male Chinook salmon.

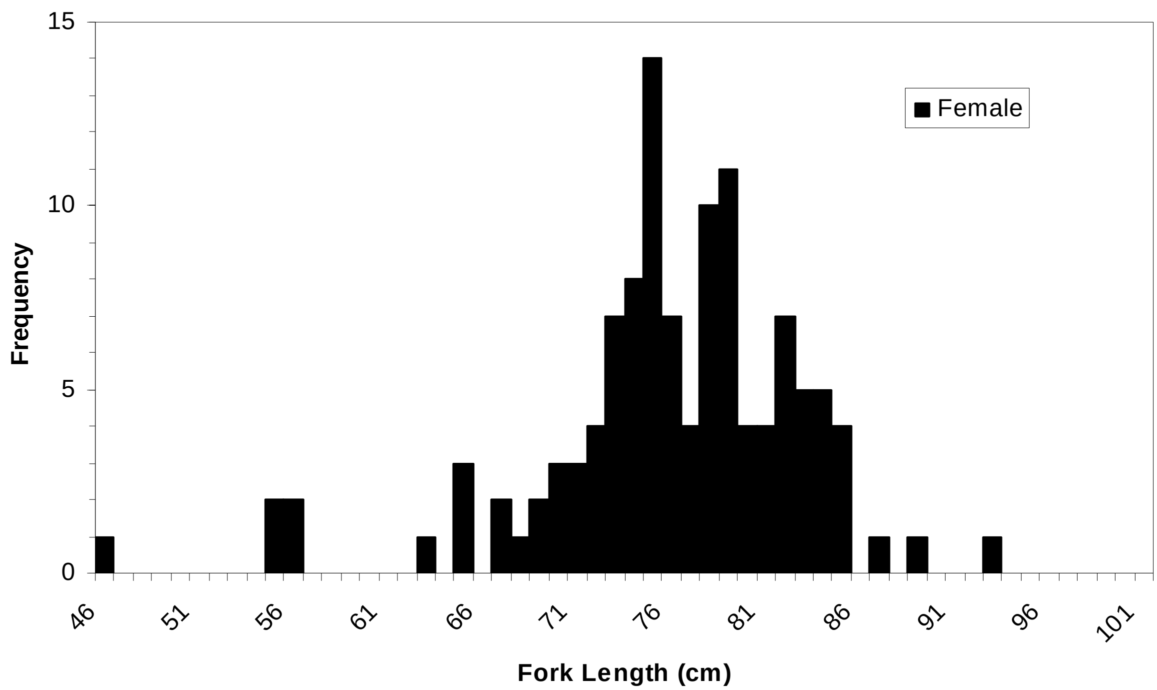

Figure 11. Length frequency histogram of female Chinook salmon.

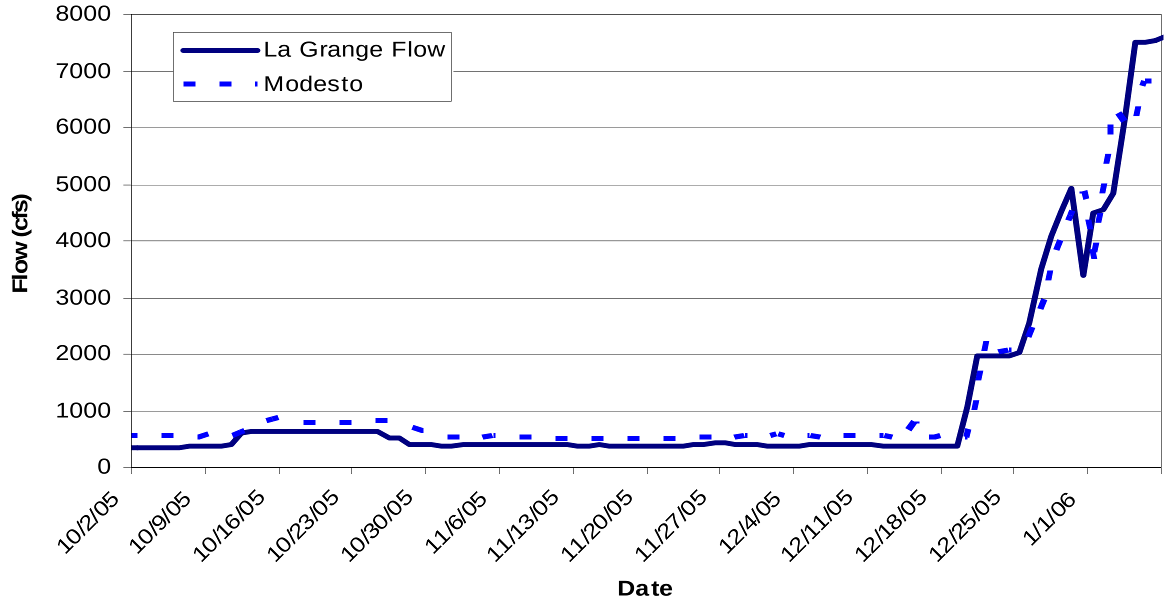

Figure 12. Average daily flow in the Tuolumne River (cubic feet per second) at the Modesto, and La Grange gauges. Preliminary data obtained from California Data Exchange Center (CDEC) website.

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