2004 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 20th 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 7,916 in 1998 (Heyne 1998), 7,685 in 1999 (Heyne 2000), 17,873 in 2000 (Vasques 2001) and 9,222 in 2001 (CDFG 2001), indicating a slight recovery period. Current levels are once again declining from 7,125 in 2002 (Blakeman 2003) and 2,163 in 2003 (Blakeman 2004) 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 2003 escapement survey used the Jolly-Seber (Seber 1973) escapement model as well as reporting Schaefer estimates. The 2004 escapement estimate once again used the Schaefer model but will continue to report Jolly-Seber 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.
- Collect DNA samples for storage at the CDFG Salmonid Tissue Archive for subsequent analysis.

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 1a 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 1a) 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 1972) 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 4 October 2004 (Week 1) and concluded on 6 January 2005 (Week 14). Carcasses were tagged for the first 12 weeks. Weeks 13 and 14 no carcasses were tagged, these were strictly carcass recovery weeks. During the two recovery weeks, carcasses were collected and examined for jaw tags and all carcasses collected were chopped in half.

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 during 2003 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 during the 2003 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. Genetic samples: caudal, dorsal, or pectoral fin clips were collected, and delivered to the CDFG Salmonid Tissue Archive at the end of the survey. Scale and otolith samples were collected from both wild and CWT carcasses and are catalogued at the CDFG La Grange Field Office. CWTs and otoliths 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 2004 escapement estimate was **1,634 salmon**. The Jolly-Seber model using all tagged fish yielded an estimate of 1,532. 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. Schaefer and Jolly-Seber estimates using only fresh fish in 2004 were 1,693 and 1,519, respectively. The Schaefer model utilizes the number of recoveries of tagged carcasses, the total number of tagged fish, and the total number carcasses handled each week to generate weekly escapement estimates (Table 3). Weekly estimates are summated to estimate total escapement over the course of the survey. Table 4 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. The fresh tagged recovery rate was 63.6% which is slightly lower than the overall recovery rate of 65.4%.

Weekly Counts

Live fish counts increased steadily, peaked in week 6 , and declined steadily through the remainder of the survey (Table 2, Figure 5). Carcass counts exhibited a similar incline, peak, and decline which were offset from live counts by about two weeks. The carcass count peaked in week 8. Redd counts increased through week 7 when the total number of observations was 455.

Spawning Distribution

The results of total weekly redd counts clearly indicate that the majority (greater than 53%) of spawning activity is concentrated in the riffles of Section 1 (Figures 7 and 8). The maximum number of redds counted in a particular riffle over the course of the season are listed in Table 6. The maximum redd count represents the redd count made when external factors like visibility were at optimum conditions. During the 2004 survey 262, 85, 106, and 38 maximum redds were counted for sections 1 through 4 respectively (Figure 7).

Population Composition

Coded wire tagged fish comprised 18% 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 36% for natural males, 5% for CWT males, 47% for natural females, and 12% for CWT females (Figure 9). CWT verification and tag reading will be conducted at a later date therefore all CWT data presented here are preliminary.

Length frequency histograms of male and female fish (both natural and CWT) display bimodal peaks (Figures 10 - 13). The first peaks are likely grilse (age 1 and 2 fish) and the second peaks are likely adult (age 3, 4, and 5 year fish). Total grilse composition was 37% of the Tuolumne River escapement estimate. Breakpoints between grilse and adult were determined from basin wide fork length data. Breakpoints used were 66 cm for natural females, 63 cm for adipose fin clipped females, 74 cm for natural males and 70 cm for ad-clipped males. Further breakdown of grilse is presented in Table 7.

Sample Collection

Scales and otolith samples were collected from both natural and adipose fin clipped fish. DNA samples were collected from non ad-clipped fish. Samples were collected throughout the survey period and survey area (Tables 8, 9 and 10). 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. Ninety-five DNA samples were collected and delivered to the CDFG Salmonid Tissue Archives.

Egg Production Estimate

An estimate of egg production by the 2004 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=245, average FL=72.2) and CWT females (n=65, average FL=75.8) and then expanded to the entire estimate. Natural females made up 47% of the 2004 estimate and produced approximately 4,074,180 eggs. Adipose fin clipped females (12%) produced approximately 1,149,869 eggs.

Tuolumne River Flows

Tuolumne River flows at the La Grange gage ranged from approximately 167cfs to 495cfs during the 2004 spawning season (Figure 14). To attract fish into the Tuolumne from the San Joaquin River and improve spawning habitat a pulse flow was initiated on 26 October 2003. Flow increased to approximately 490cfs on 27 October 2003 and was reduced to approximately 200cfs on 30 October 2003 and then further decreased to about 175cfs for the remainder of the spawning season.

Tuolumne River Temperature

Water temperatures are recorded in several locations throughout the spawning reach using data loggers placed and maintained by CDFG. Three sites are plotted in Figure 15.

DISCUSSION

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. 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 acute and leads to undercounting. On the other hand, redds in Section 2, 3, and 4 are 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 10 and 11.

Population Estimate

The 2004 tag recovery rate of 65.4% is the highest reported since the 2000 recovery rate of 41.7% (Vasques 2001). From 2001 to 2003 recovery rates have been relatively high ranging from 55.3% to 64.4%. The difference in recovery rates is likely a function of the difference in stream flow between 2000, (over 300cfs) and 2001 - 2004, (under 200cfs). 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 2002 - 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. 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 2004 of 1,634 salmon is the lowest since the 2003 estimate of 2,163 and the 1996 estimate of 4,550 salmon.

Population Composition

Coded wire tagged fish comprised 17 % 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 36% for natural males, 5% for adipose fin clipped males, 47% for natural females, and 12% for adipose fin clipped females (Figure 9). CWT verification and tag reading will be conducted at a later date therefore all CWT data presented here are preliminary.

Length frequency histograms of male and female fish (both natural and CWT) display bimodal peaks (Figures 10,11,12 and 13). The first peaks are likely grilse (age 1 and 2 fish) and the second peaks are likely adult (age 3, 4, and 5 year fish). Total grilse composition was 37 % 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 to determine grilse composition. Breakpoints used were 66 cm for natural females, 63 cm for adipose fin clipped females, 74 cm for natural males and 70 cm for adipose fin clipped. Further breakdown of grilse is presented in Table 7. Grilse made up 57% of all males with 53% being natural males.

Tuolumne River Flows

Low dissolved oxygen 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 in week 4 which coincided with temperatures dropping below the thermal limit of 13^{o}C. The flow, temperatures and observed redds are presented in Figure 15.

Tuolumne River Temperatures

Temperatures in the upper sections (Section 1 and 2) down to Tuolumne River State Recreation Area (TRSRA, RM 41.7) remained below the maximum thermal limit of 13.3^{o}C for most all of the spawning season except for a few days in early October. This temperature is considered to be the upper thermal limit for successful egg incubation (Myrick and Cech 1998). River temperatures at Turlock Lake State Recreation Area Campground fell below the 13.3^{o}C level in the beginning of November and coincided with the first few redd observations in week 5 of the survey.

Table 1. Tuolumne River riffle identification cross-reference, 2004 to 2003.

Section 1		Section 2		Section 3		Section 4	
New ID	Old ID	New ID	Old ID	New ID	Old ID	New ID	Old ID
1a	1a	F1	F1	K1	K1	S1	S1
A1	A1	F2	F2	K2	K2	S2	S2
A2	A2	F3	F3	L1	L1	S3	S3
B1	B1	G1	G1S	L2	L2	T1	T1
B2	B2	None	G1N	L2N	L2	T2	T2
B3	B3	G2	G2	L3	L3	T3	T3
C1	C1	G3	G3	M1	M1	T4	T4
C2	C2	G4	G4	M2	M2	T5	T5
C3	C3	H1	H1	N1	N1	U1	U1
D1	D1	H2	H2	N2	N2	U2	U2
D2	D2	H3N	H3N	N3	N3	U3	U3
D3	D3	H3S	H3S	N4	N4	V1	V1
D4	D4	H4	H4	O1	O1	V2	V2
D5	D5	H5	H5	O2	O2	V3	V3
E1	E1	H6	H6	O3	O3	V4	V4
		I1	I1	O4	O4	W1	W1
		I2	I2	O5	O5	W2	W2
		I3	I3	P1	P1	W3	W3
		J1	J1	P2	P2	X1	X1
		J2	J2	P3	P3	X2	X2
		J3	J3	P4	P4		
		J4	J4	Q1	Q1		
		J5	J5	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	6	0	0
2	39	0	0
3	26	0	0
4	157	13	1
5	591	176	1
6	618	353	34
7	528	455	290
8	379	422	391
9	189	325	238
10	130	232	119
11	63	131	99
12	35	51	32
13	14	16	13
14	2	2	6
Totals	**2777**	**2176**	**1224**

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

Table 3. Weekly totals.

Week	Total Tagged	Skeletons	Fresh Recoveries	Total Counted	Fresh Tagged	CWT's
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	1	0	1	0	0
5	1	0	0	1	1	1
6	24	10	0	34	21	7
7	146	144	11	301	116	36
8	175	216	69	460	152	31
9	112	126	97	335	99	9
10	38	81	71	190	32	3
11	16	83	26	125	13	4
12	11	21	6	38	11	1
13	0	13	3	16	0	0
14	0	6	0	6	0	0
Totals	**523**	**701**	**283**	**1507**	**445**	**92**

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

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

Recovery Week	Tag Week of Recovered Tags												Weekly Total
	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	0								0
7	0	0	0	0	0	13							13
8	0	0	0	0	0	1	88						89
9	0	0	0	0	0	0	9	107					116
10	0	0	0	0	0	0	2	13	61				76
11	0	0	0	0	0	0	1	5	8	19			33
12	0	0	0	0	0	0	0	1	2	3	4		10
13	0	0	0	0	0	0	0	0	0	3	0	2	5
14	0	0	0	0	0	0	0	0	0	0	0	0	0
All Recoveies	0	0	0	0	0	14	100	126	71	25	4	2	342
Total Tagged Carcasses	0	0	0	0	1	24	146	175	112	38	16	11	Overall Recovery
Percent Recovery	0.0	0.0	0.0	0.0	0.0	58.3	68.5	72.0	63.4	65.8	25.0	18.2	65.4%

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	1	11	3	55
6	24	144	94	46
7	146	216	386	220
8	175	126	472	370
9	112	81	442	354
10	38	83	141	357
11	16	21	96	59
12	11	19	0	71
13	0	0	0	0
14	0	0	0	0
Total Estimate			1634	1532

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
1A	10	F1	13	K1	9	S1	2
A1	10	F2	4	K2	9	S2	2
A2	1	F3	5	L1	5	S3	6
B1	17	G1	5	L2	6	T1	0
B2	40	G2	2	L3	8	T2	4
B3	19	G3	1	M1	0	T3	3
C1	46	G4	1	M2	2	T4	4
C2	0	H1	2	N1	5	T5	1
C3	38	H2	4	N2	5	U1	4
D1	8	H3	3	N3	3	U2	3
D2	30	H4	3	N4	5	U3	1
D3	1	H5	4	O1	2	V1	2
D4	35	H6	6	O2	1	V2	0
D5	4	I1	4	O3	2	V3	0
E1	3	I2	4	O4	0	V4	1
		I3	3	O5	6	W1	0
		J1	3	P1	0	W2	2
		J2	3	P2	4	W3	1
		J3	4	P3	6	X1	0
		J4	5	P4	1	X2	0
		J5	6	Q1	10		
				Q2	3		
				Q3	8		
				R1	4		
				R2	0		
				R3	2		
Subtotal	**262**		**85**		**106**		**36**
Total	**523**						

Table 7. Grilse composition of Chinook salmon.

	Male	Female	Male (n=235)		Female (n=349)	
			Adclip	Natural	Adclip	Natural
Grilse	**23%** (n=122)	**14%** (n=74)	**4%** (n=9)	**53%** (n=113)	**1%** (n=2)	**23%** (n=72)
Adult	**18%** (n=91)	**45%** (n=236)	**9%** (n=18)	**34%** (n=73)	**20%** (n=63)	**56%** (n=173)

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	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0(1)	0	1
6	8(3)	1	0	0	12
7	48(16)	4(1)	3	0	72
8	65(15)	3	4	2	89
9	39(3)	5	17	3(1)	68
10	17(1)	5	10(1)	2(1)	37
11	5(4)	0	6	1	16
12	3(1)	1	3	3	11
13	0	0	0	0	0
14	0	0	0	0	0
Totals	228	20	45	13	306

Parenthesis 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	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	1	0	1
6	6	1	0	0	7
7	33	2	1	0	36
8	31	0	0	0	31
9	6	2	0	1	9
10	1	0	1	1	3
11	4	0	0	0	4
12	1	0	0	0	1
13	0	0	0	0	0
14	0	0	0	0	0
	82	5	3	2	92

Heads were taken only from adipose fin-clipped carcasses.

Table 10. Distribution of DNA samples collected from non adipose clipped salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	2	0	0	0	2
7	6	1	1	0	8
8	20	2	5	0	27
9	14	5	0	0	19
10	7	2	9	2	20
11	3	0	5	1	9
12	3	1	3	3	10
13	0	0	0	0	0
14	0	0	0	0	0
	55	11	23	6	95

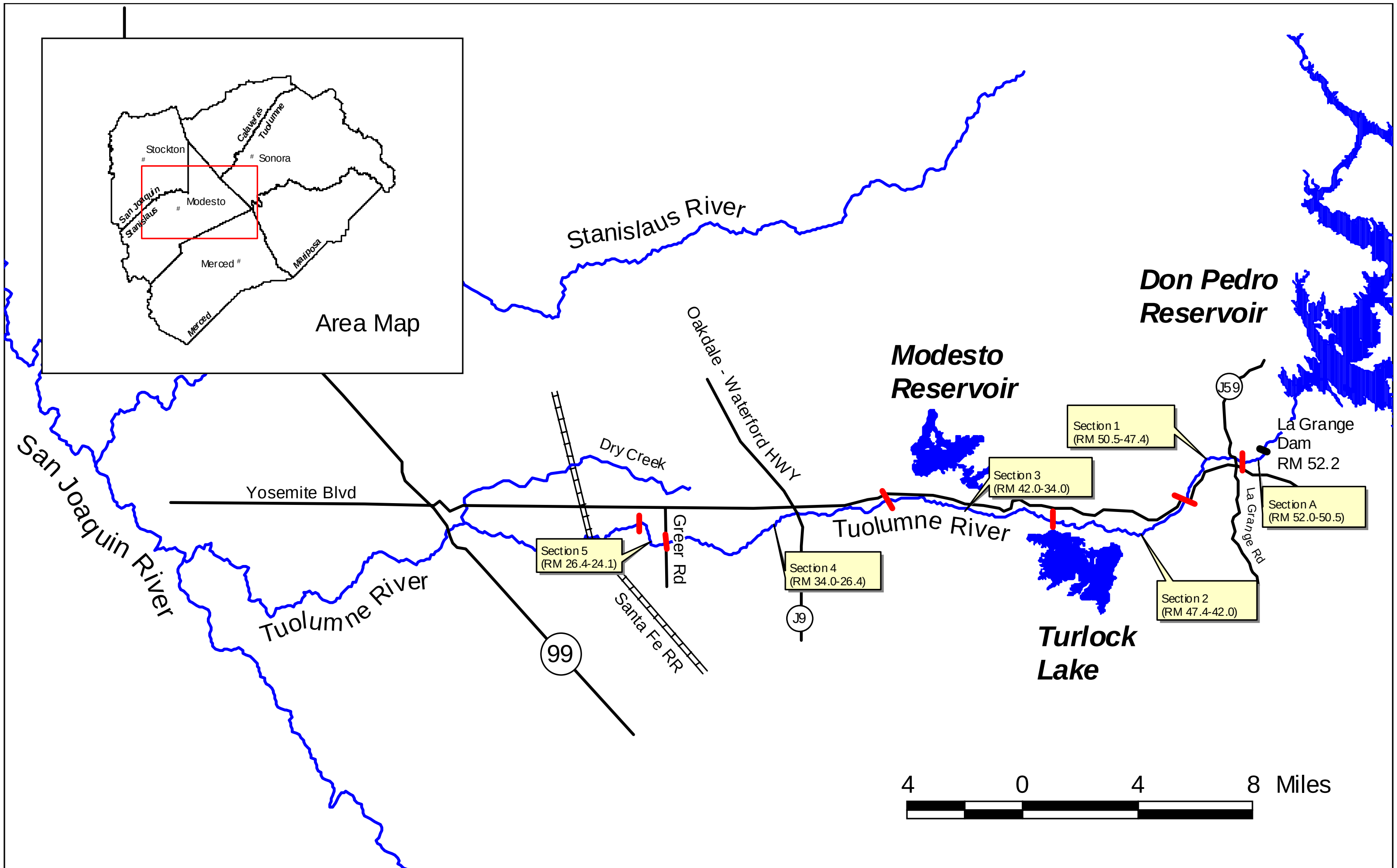

Figure 1. Salmon survey study areas, lower Tuolumne River.

California Department of Fish & Game

Prepared by: Gerald Hatler 01/18/2000

Figure 2. Fresh carcass indicated by clear eye.

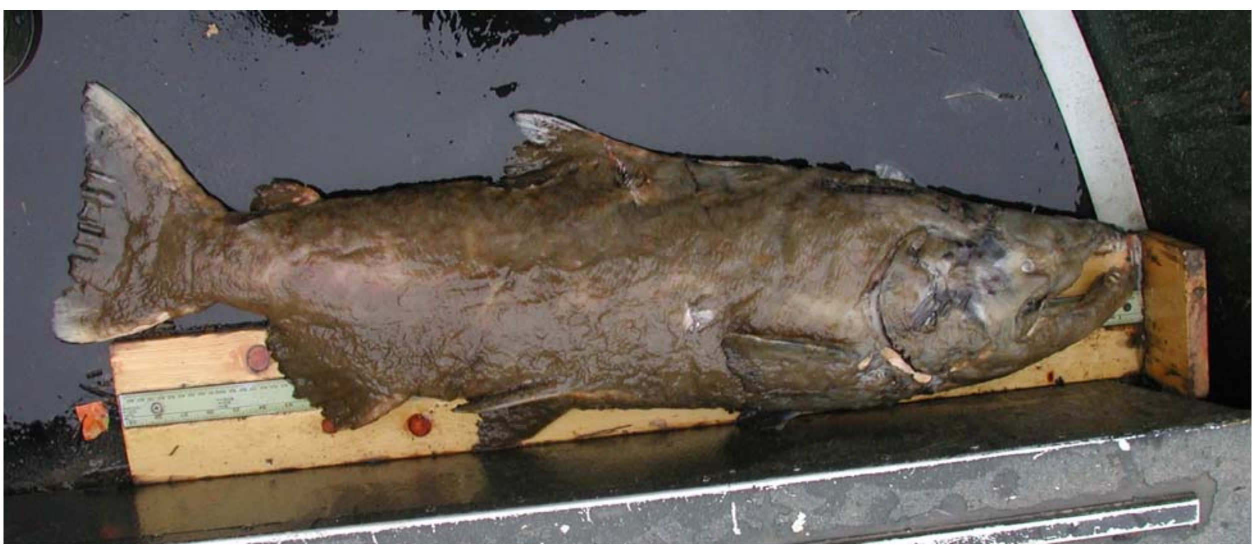

Figure 3. Fungus covered skeleton.

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

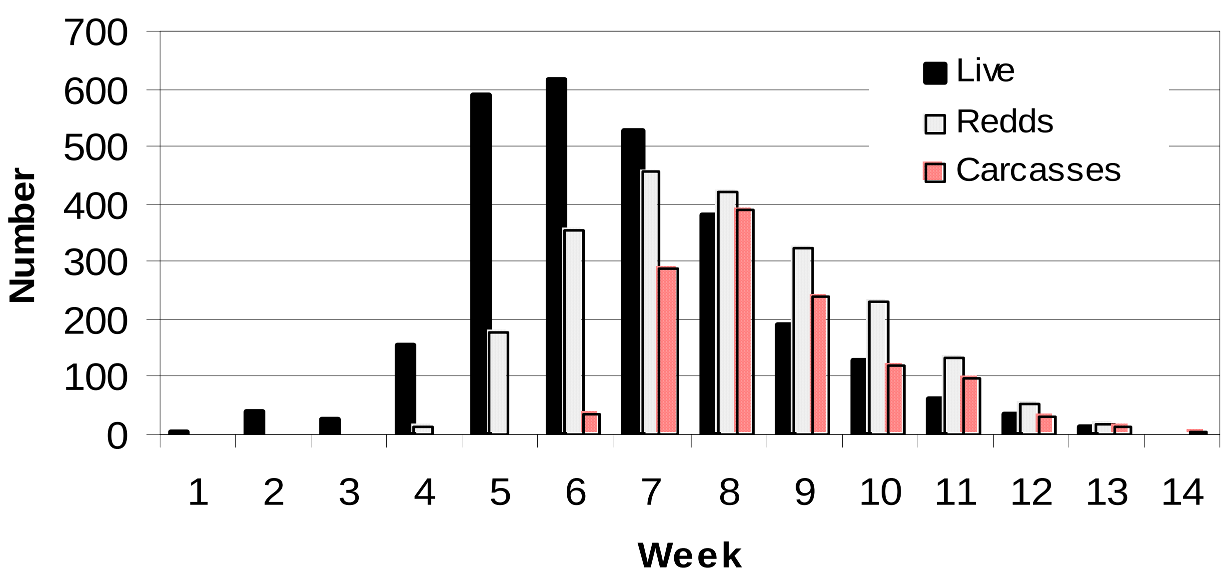

Figure 5. Live fish observation, redd, and total carcass weekly counts. Carcasses include all tagged carcasses and skeletons.

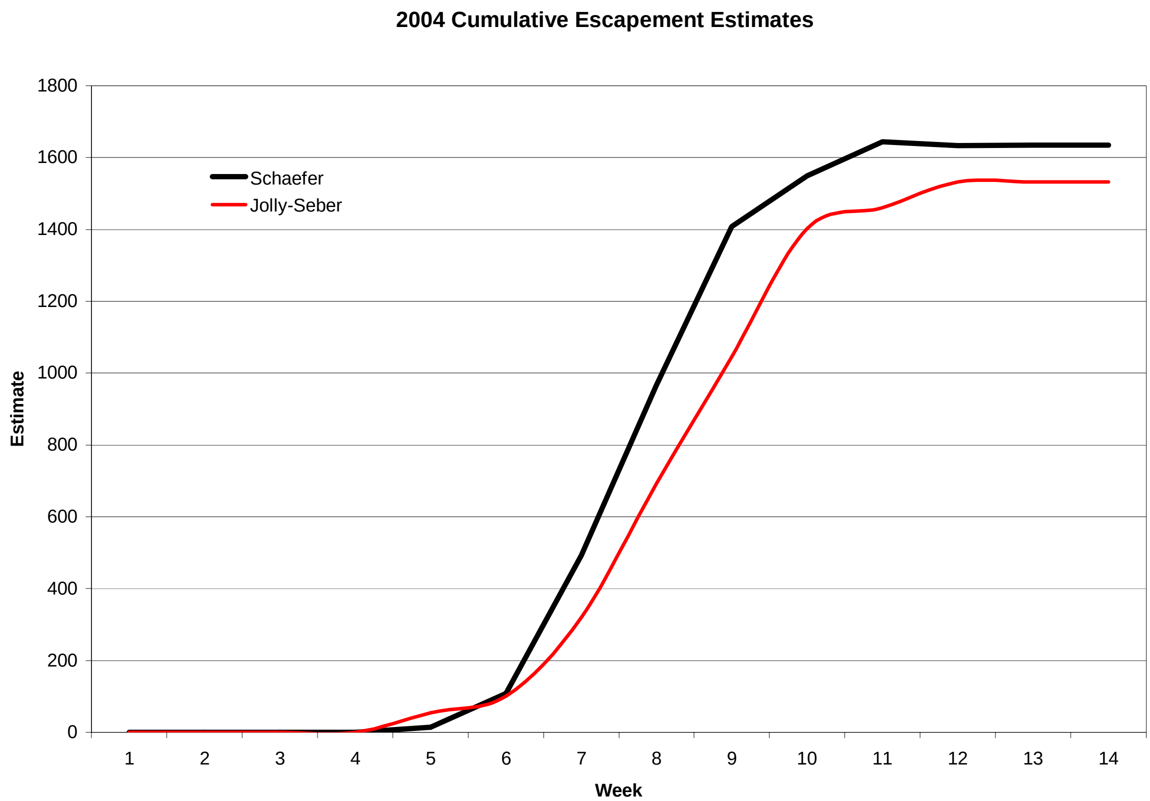

Figure 6. Weekly cumulative Schaeffer and Jolly-Seber escapement estimates.

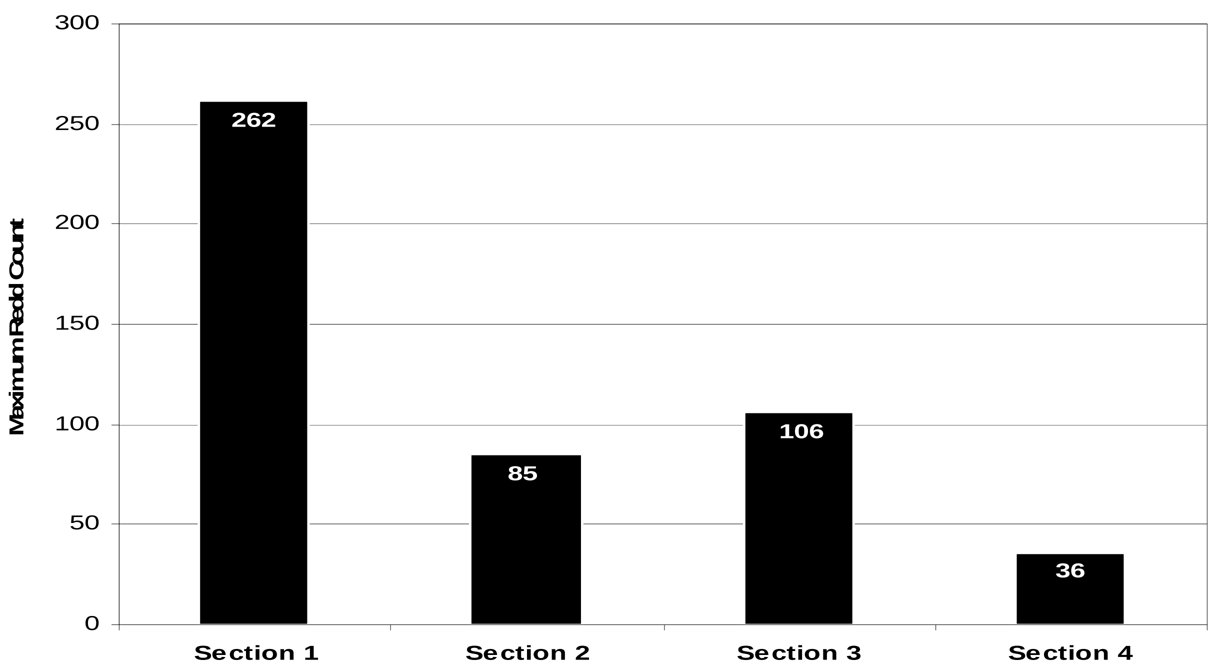

Figure 7. Total number of redds counted per section.

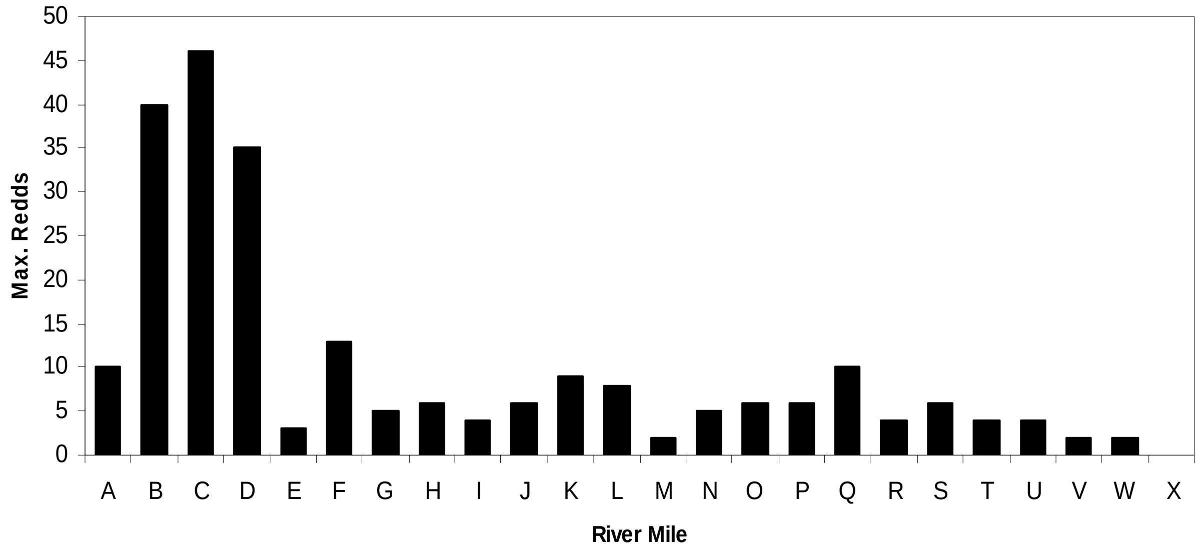

Figure 8. Maximum redds observed by riffle section. Each letter represents one river mile.

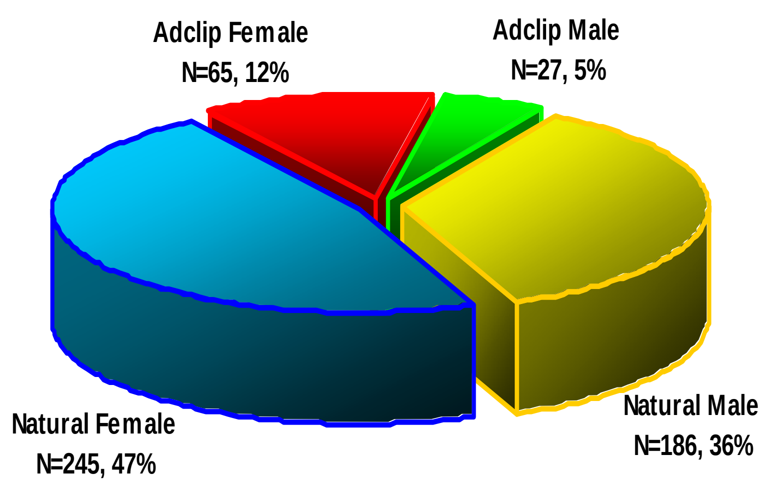

Figure 9. Contribution of natural female, adipose clipped female, natural male, and adipose fin clipped male to the 2003 Tuolumne River escapement.

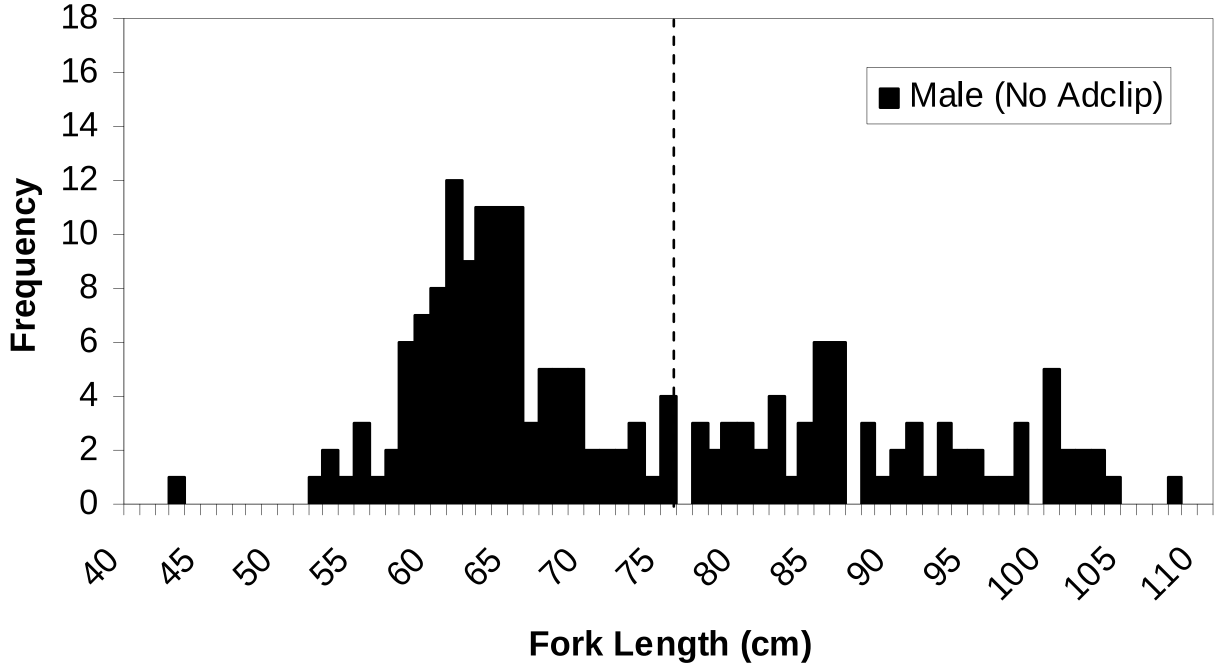

Figure 10. Length frequency histogram of natural male Chinook salmon.

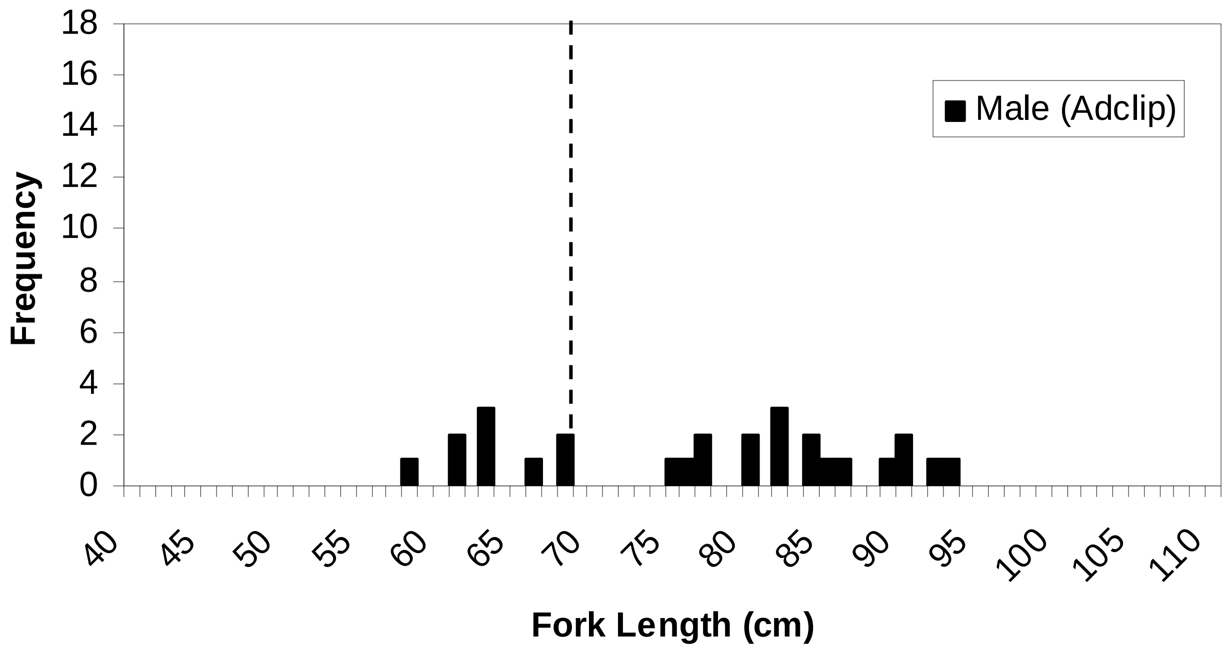

Figure 11. Length frequency histogram of adipose fin clipped male Chinook salmon.

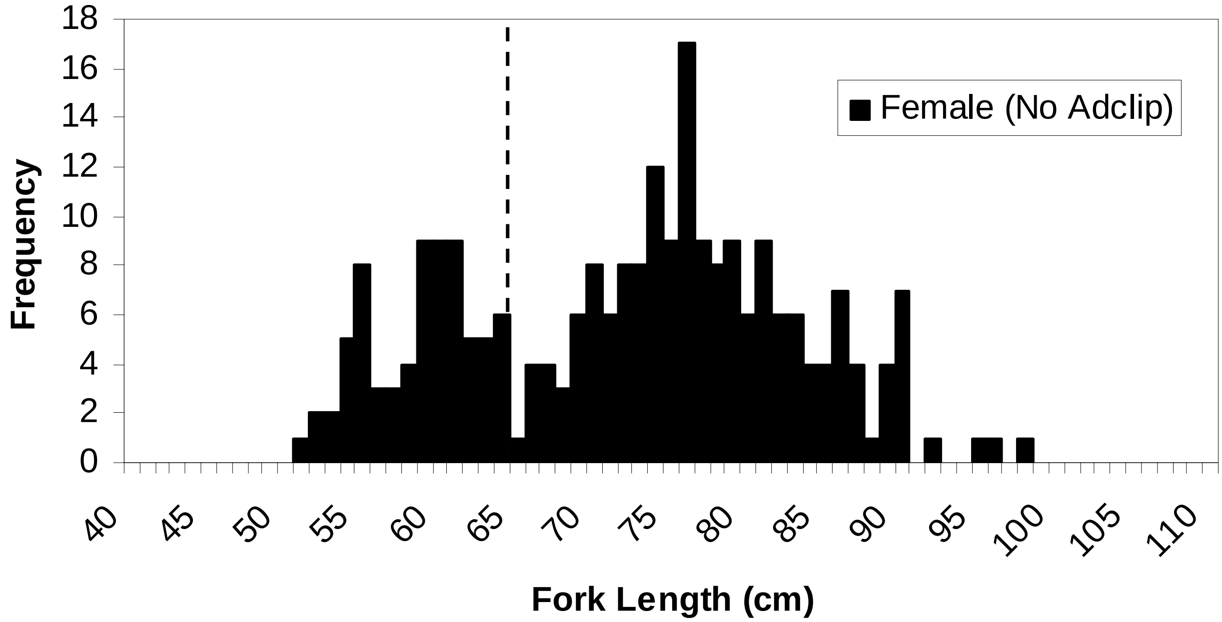

Figure 12. Length frequency histogram of natural female Chinook salmon.

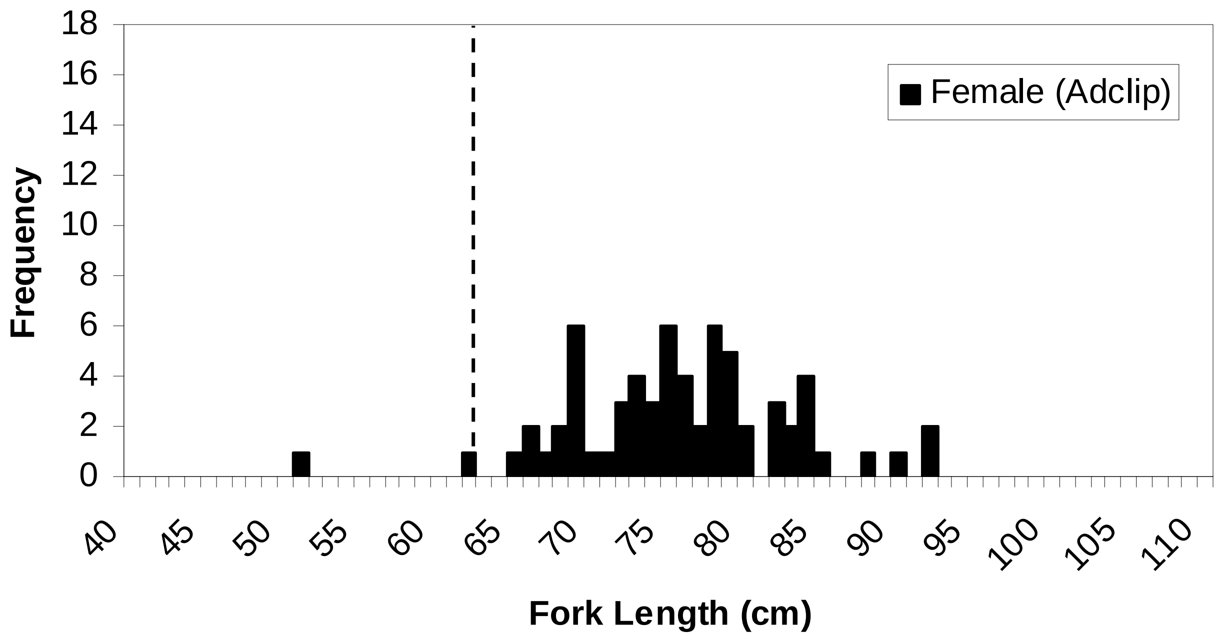

Figure 13. Length frequency histogram of adipose fin clipped female Chinook salmon.

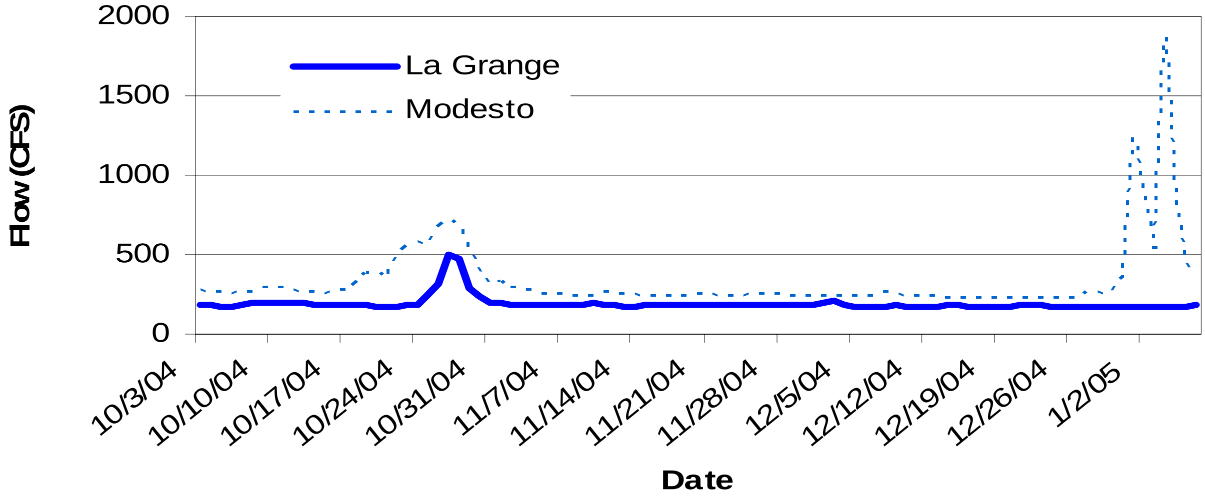

Figure 14. Average daily flow in the Tuolumne River (cubic feet per second) at the Modesto, and La Grange gauges. Preliminary data obtained from California Data Exchange Center (CDEC) website.

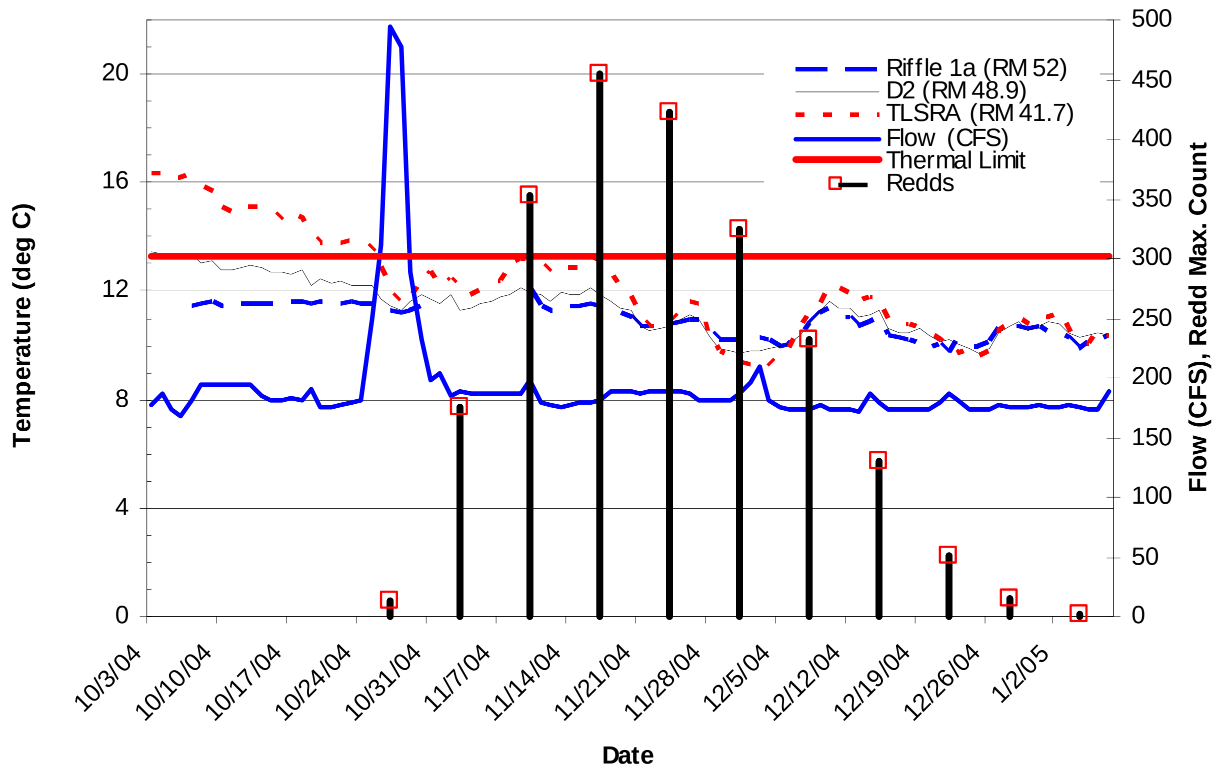

Figure 15. Weekly redd counts for the Tuolumne River escapement survey. Flow (cfs) at La Grange gage, temperatures from CDFG monitoring sites, maximum thermal limit.

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