2008 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 Federal and State Endangered Species Acts. Population levels, as measured by escapement of returning adults, in the Tuolumne River 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 (Neilands et al. 1993). Population levels increased to 17,873 in 2000 (Vasques 2001) indicating a slight recovery period, and are once again declining with estimates of 625 in 2006 (Blakeman 2007), and just 211 in 2007 (Blakeman 2008). The decline of the species is believed to be caused by many factors. The reduction of spawning and rearing habitat in combination with 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, ocean angler harvest and ocean condition contribute to a complex web of factors which affect the population dynamics of fall-run Chinook salmon within the Tuolumne River.

The California Department of Fish and Game (CDFG) has reported salmon population estimates on the Tuolumne River since 1940 (Fry 1961). The Schaefer mark recapture escapement estimation model (Schaefer 1951) has been utilized since 1971. The 2008 escapement survey uses the adjusted Peterson method. 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.
- Evaluate the distribution of spawning 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 and analyze coded wire tag data from hatchery fish.

STUDY AREA

Approximately 26.5 river miles were surveyed during the Tuolumne River escapement in 2008 (Figure 1). The survey area was divided into four 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). Figure 1 also includes section 5, which was not surveyed, and extends downstream of Fox Grove to RM 24.1.

All riffles in the study area have bee 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 live fish counts are made. This numbering system is a departure from the historical riffle numbering system; however, the new riffle identification system is more conducive to editing and tracking riffles as river morphology changes. Changes in riffle locations which may occur during high flow periods, will affect riffle names only within that river mile. There were no changes in riffle names from 2007 to 2008 (Table 1).

METHODS

Population Estimation

CDFG has used the Schaefer (1951) model to estimate escapement since 1971. This year, the Adjusted Peterson equation was used in calculating the population estimate due to low numbers of Chinook salmon being marked. Carcasses are marked and subsequently recovered during weekly surveys of the spawning reach. A ratio of recoveries to total fish handled is used to calculate weekly population estimates which are then summed to estimate the total spawning population. Total fish handled includes total fish tagged, skeletons, and recoveries by week. The CDFG survey began on October 6, 2008 (Week 1) and concluded on January 8, 2009 (Week 14). Carcasses were tagged for the first 12 weeks. The final 2 weeks of the survey were considered recovery weeks. The eleven carcasses encountered during weeks 13 and 14 were treated as skeletons in the population estimation.

The Adjusted Peterson equation:

$$N = \frac{(M+1)(C+1)}{R+1}$$

Where:
N=Population estimate
M=Number of carcasses tagged
C=Catch (total number of tagged and skeletons)
R=Number of recoveries

All carcasses encountered were handled during weekly drift boat surveys of the study area. 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 (Figure 2). Carcasses exhibiting cloudy eyes were designated as decayed (Figure 3). Skeletons were carcasses judged to be in an advanced state of decay and unlikely to have the same probability of recapture as fresh or decayed specimens (Figure 4). Skeleton condition ranged from a fungus covered carcass to an actual skeleton.

All fresh and decayed carcasses were given a unique number by attaching an aluminum tag to the lower jaw. These newly tagged carcasses were redistributed to moving water in 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. Scales and otoliths were collected from a percentage of specimens to determine the size and age composition of annual spawning runs. Coded wire tags (CWT) were collected from hatchery (adipose fin clipped) carcasses returning to the Tuolumne River as part of survival testing 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.

Scale and otolith samples collected from both wild and CWT carcasses are catalogued and stored at the CDFG La Grange Field Office. Otoliths were collected in the field and stored in an individual vial marked with the field tag number. Coded wire tags are collected via removal of the head except for the lower tagged jaw. Extraction and analysis of CWT's was conducted at the La Grange office 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 observation 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 floated through riffles and pools in a drift boat.

RESULTS

Escapement Estimate
A total of 105 carcasses were tagged during the 2008 Tuolumne River escapement survey. An additional 56 skeletons were tallied and chopped, giving a total of 161 individual Chinook salmon handled during the escapement survey. The Adjusted Peterson model utilizes the number of recoveries of tagged carcasses, the total number of tagged fish, and the total number of carcasses handled to generate an escapement estimate**.** Week 14 live fish count was added to the Adjusted Peterson to account for them not being available for capture. The overall recovery rate for the 2008 escapement survey was 43.8%. Based on the Adjusted Peterson model, the 2008 escapement estimate was 372 salmon. Females and males accounted for 57% and 43% respectively of the total tagged fish on the Tuolumne River. Table 4 and figure 5 show historical Tuolumne River escapement estimates from 1978 to 2008.

Live Salmon and Redd Counts
Live fish observation peaked at week 5, and demonstrated an overall declining trend throughout the remainder of the survey. Redd counts peaked in week 8 with a maximum

of 165 redds counted and then steadily declined for the remainder of the study period. Total carcass counts peaked in week 7, at 52 (Table 3 and Figure 6). The maximum number of redds counted for individual riffles is presented in Table 5. Most of the spawning (48.9%) occurred within section 1 (Figure 7). Much of the spawning distribution within section 1 occurred within riffles B1 and B2 during the 2008 escapement survey (Figure 8).

Scale, Otolith, and DNA Collection
Scale, otolith, and DNA samples were collected from all tagged carcasses. Samples were not collected from skeletons due to the advanced state of decomposition. Scale and otolith samples will be utilized in the CDFG age determination program and for subsequent cohort analysis of the San Joaquin River Basin Chinook salmon populations. This data will also be essential for population models being developed as well as ongoing cohort analysis of factors affecting the populations.

Coded Wire Tag Collection
The total composition (tagged fish only) for fall-run Chinook salmon in the Tuolumne River was 52.4% natural females, 41.9% natural males, 4.8% CWT females, and 0.9% CWT males (Figure 11). Coded wire tagged fish comprised approximately 5.7% of the total tagged carcasses (Table 2). Table 7 shows the tag code, brood year, release year, and release location for all CWT fish collected in the Tuolumne River in 2008.

Egg Production Estimation
An estimate for the umber of eggs produced by the 2008 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 all females (CWT and natural) and expanded by the ratio method. The average fork length for all females in 2008 was 76.6cm. An estimated 1,271,892 eggs were produced by natural and CWT female Chinook in 2008.

Tuolumne River Flows
The Tuolumne River flows, recorded at the La Grange gauge, for the period of October 1, 2008 through January 15, 2009 are shown in figure 12 (preliminary data obtained from the California Data Exchange Center**). A pulse flow was released during the period between October 24th and October 27th with a maximum flow of 259 cfs**. The average daily flow between October 1, 2008 and January 15, 2009 was 168cfs.

Tuolumne River Temperature
Water temperature on the Tuolumne River is recorded using onset temperature monitors at twelve different locations starting below the La Grange powerhouse and ending downstream below the Hickman spillway. Figure 13 shows Tuolumne River water temperatures recorded at riffle C1 and at the above Hickman spillway sites. These water temperatures are plotted verses flow, maximum thermal limit for successful egg incubation, and live fish/redd counts.

Water temperature data for each river section is shown in figures 14, 15, and 16. The majority of spawning (Figure 7) occurred in section one where temperatures remained below the thermal limit for successful egg incubation (13.3°C) during most of the survey. Section two also dropped below 13.3°C but later in the season. Temperatures in section three remained above the thermal limit until the middle of November. Section four temperature data was unavailable.

Multiple Recaptures

In past years escapement surveys, tagged carcasses were chopped in half upon recovery to prevent multiple recaptures. During the 2008 survey, tagged carcasses were recovered as many times as they were found and returned to the water in tact each time. This new technique was utilized to collect data regarding the longevity of carcass retention within the river system. Of the forty six carcasses that were recovered during the 2008 survey, thirteen were recovered only one time, eighteen were recovered twice, ten were recovered three times, four were recovered four times, and one carcass was recovered five times (Figure 28). Multiple recapture data was not used in the data analysis for determining the population estimate.

Alteration of River Flow at the La Grange Powerhouse

During the 2008 annual Chinook salmon escapement survey, Department of Fish and Game biologists observed an alteration of river flow resulting from the rerouting of water at the La Grange powerhouse. Typically in dry years, water released from the La Grange reservoir travels via a Turlock Irrigation District (TID) canal until it reaches the La Grange powerhouse. A portion of that water is then run through the powerhouse and continues downstream in the Tuolumne River along the east channel. Water flowing into the east channel comes entirely from the TID canal (Figures 18 and 19).

During the November 4, 2008, escapement survey, Department biologists observed that the powerhouse was shut down and water was being rerouted through the Modesto Irrigation District (MID) canal. The water was then released down the hillside into the west channel. (Flow in the west channel was supplied predominately from water seepage through the dam prior to the alteration of river flow). The rerouting of water isolated the east channel from the flow, potentially de-watering redds that had been observed during the previous weeks' surveys (Figure 17).

Surveys conducted on riffle A1, (Figure 20) which is located in the east channel immediately downstream of the La Grange powerhouse, documented redds and spawning activity beginning on October 22 for the 2008 escapement survey season. Prior to the rerouting of water, ten live fish and three redds were observed in riffle A1 (October 22) while the number of redds increased to seven the following week when the section was surveyed on October 28. Following the rerouting of water during the November 4 survey, the number of redds decreased to five, and three live fish were observed in the channel with minimal flow. A female carcass that appeared to have spawned was recovered, tagged, and released back into the river. (Figures 21 and 22)

On November 6, 2008 Department biologists returned to the site to assess potential impacts on Chinook salmon and the previously identified redds. After TID rerouted the water, the flow was predominately in the west channel (Figures 25 and 26). The east channel had hardly any flow and was mostly stagnant consisting of intermittent pools separated by dry sections (Figures 23 and 24). One redd was easily distinguishable; however, it was difficult to clearly identify any additional redds due to overgrown algae and exposed gravel. It is unclear whether some of the previously identified redds had been left dry and exposed to air when the flow was rerouted. Measurements were taken to compare variations in temperature between the east channel and the west channel. East channel temperatures were taken in the general location where redds had been observed, approximately 75 feet upstream of where it converges with the west channel. The east channel temperature was recorded at 15°C, as compared to the west channel temperature of 11.5°C. (The thermal limit for successful egg incubation is 13.3°C.) (DFG thermograph temperature data collected near the powerhouse shows a rise in temperature corresponding to the period of time when water flow was altered in the east channel (Figure 27). A flowmeter was used to measure the flow rate of water passing through the east channel. Measurements were taken in one foot increments across the width of the east channel where redds had been documented. The flow rate averaged 0.35 cubic feet per second (cfs) in the east channel. Due to the fact that obtaining precise measurements from flows of such low velocity is difficult, it was estimated that the flow rate was less than 1 cfs. 1 cfs flowing in the east channel was compared to 163 cfs that was assumed to be flowing in the west channel based on data obtained from the USGS La Grange flow gage. No live fish were observed utilizing the east channel on November 6.

When Department biologists returned to the site on November 7, it appeared that work on the powerhouse had been completed. Water that had been rerouted through the MID canal was once again traveling downstream along its normal pathway into the east channel. Salmon were observed spawning again in riffle A1 after the flows were returned to the east channel. The November 12 carcass survey documented the presence of six live fish and seven redds in riffle A1. The number of live fish increased to nine the following week when the section was surveyed on November 12.

DISCUSSION

The Jolly-Seber model would be a better estimation if tagged and recovered fish are more than 10 for each survey week (Schwarz 1993, p. 1183) The Schaefer model overestimates when tagged and recovery are both low (Law 1994). In the 2008 Tuolumne River Escapement Survey, both tagged and recovered fish were both low. During the 14 weeks of the survey, only three weeks had more than 10 tagged carcasses, and only four weeks had more than 10 recovered tagged fish. Due to very low numbers, the Adjusted Peterson method was used to calculate the 2008 escapement estimate of 372 returning adults. Stream flow dynamics affect the likelihood of collecting carcasses in that it effects both how carcasses are distributed in the system and the effectiveness of recovering carcasses by field crews. During the low flow conditions in 2008 it is likely that most carcasses were found by field crews. The overall carcass recovery rate was 43.8%.

Redd counts are 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. Redd counts were conducted with a single pass as opposed to an intensive systematic approach which is beyond the scope of current funding. Redd distribution of section 1 to section 4 was 48.9%, 19.3%, 24.3%, and 7.4% of total observed redds. The majority of the spawning occurred in section 1 where conditions are more ideal for spawning**.** Riffles B1 and B2 demonstrated significantly higher spawning productivity as compared to other riffles within section 1 (Figure 8)**.** With so few fish returning to spawn there was likely very little redd superimposition occurring.

There were six CWT fish encountered during the escapement survey in 2008. Skeletons were not checked for adipose fin clips due to their advanced state of decomposition. Females made up 57.1% of the returning adult population. The male percentage of males returning to the Tuolumne in 2008 was 42.9%. The fork lengths of all salmon examined in the San Joaquin River Basin was utilized in determining grilse breakpoints. Two males were considered grilse based on fork lengths less than 70cm. Two females had fork lengths less than 66cm and were also considered grilse. The total percentage of grilse examined in the Tuolumne River was 3.8% of all examined fish.

As has been seen nearly every year, spawning activity and live counts very closely relate to the temperature dropping below 13°C. Water temperatures in section one remained below the thermal limit for successful egg incubation (13.3°C) during the most of the escapement survey (Figure 14). The majority of the carcasses recovered from the Tuolumne in 2008 were found in section one (Figure 29). In addition, section one had higher live counts and spawning activity than sections located further downstream. Temperatures downstream of section one dropped below 13.3°C, but this occurred later in the survey season (Figures 15 and 16).

The 2008 escapement estimate of 372 and 2007's estimate of 211 are the lowest numbers of Chinook returning to the Tuolumne River since the 1994 estimate of 506 adults (Table 4). Salmon population decline throughout the west coast resulted in the May 1, 2008 thru April 30, 2009 closure of both commercial and recreational salmon fishing between the U.S.-Mexico border and Cape Falcon, Oregon. At this point, there is not a definitive answer as to the cause of the Chinook population decline. A complex web of factors including but not limited to flow management practices, predation, reduction of spawning and rearing habitat, streambed alteration, pump diversion, gravel mining, land use practices, ocean angler harvest and ocean conditions affect the population dynamics of fall-run Chinook salmon in the Tuolumne River.

Table 1. Tuolumne River riffle identification cross-reference.

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	A1	F1	F1	K1	K1	S1	S1
A2	A2	F2	F2	K2	K2	S2	S2
A3	A3	F3	F3	K3	K3	S3	S3
A4	A4	G1	G1	L1	L1	S4	S4
B1	B1	G2	G2	L2	L2	T1	T1
B2	B2	G3	G3	L3	L3	T2	T2
B3	B3	G4	G4	L4	L4	T3	T3
B4	B4	G5	G5	M1	M1	T4	T4
C1	C1	G6	G6	M2	M2	T5	T5
C2	C2	H1	H1	N1	N1	U1	U1
C3	C3	H2	H2	N2	N2	U2	U2
D1	D1	H3	H3	N3	N3	U3	U3
D2	D2	H4	H4	N4	N4	V1	V1
D3	D3	H5	H5	O1	O1	V2	V2
D4	D4	H6	H6	O2	O2	V3	V3
D5	D5	H7	H7	O3	O3	V4	V4
D6	D6	I1	I1	O4	O4	W1	W1
E1	E1	I2	I2	O5	O5	W2	W2
		I3	I3	O6	O6	W3	W3
		I4	I4	O7	O7		
		J1	J1	O8	O8		
		J2	J2	P1	P1		
		J3	J3	P2	P2		
		J4	J4	P3	P3		
		J5	J5	P4	P4		
		J6	J6	P5	P5		
		J7	J7	Q1	Q1		
		J8	J8	Q2	Q2		
				Q3	Q3		
				R1	R1		
				R2	R2		
				R3	R3		

Table 2. Weekly Totals.

Week	Total Tagged	Skeletons	Recoveries	Total Counted*	CWT's
1	0	0	0	0	0
2	0	2	0	2	0
3	0	2	0	2	0
4	0	0	0	0	0
5	4	3	0	7	0
6	26	2	0	28	2
7	36	16	12	64	2
8	20	11	23	54	1
9	1	4	4	9	0
10	5	2	4	11	1
11	10	2	2	14	0
12	3	1	1	5	0
13	0	5	0	5	0
14	0	6	0	6	0
Total	105	56	46	207	6

***Includes total tagged, skeletons, and all recoveries.**

Table 3. Total live fish, redds, and carcass counts by survey week.

Week	Live	Redds	Carcasses*
1	4	0	0
2	9	0	2
3	22	6	2
4	64	41	0
5	200	100	7
6	159	141	28
7	117	139	52
8	85	165	31
9	54	126	5
10	62	108	7
11	31	68	12
12	16	57	4
13	16	22	5
14	7	13	6
TOTAL	846	986	161

*Carcasses include all tagged carcasses and skeletons, but does not include recoveries.

Table 4. Yearly escapement estimates

Year	Tuolumne River Estimate
1978	1,300
1979	1,183
1980	559
1981	14,253
1982	7,126
1983	14,836
1984	13,689
1985	40,322
1986	7,404
1987	14,751
1988	5,779
1989	1,275
1990	96
1991	77
1992	132
1993	471
1994	506
1995	827
1996	4,362
1997	7,146
1998	8,910
1999	8,232
2000	17,873
2001	8,782
2002	7,173
2003	2,163
2004	1,634
2005	724
2006	625
2007	211
2008	372

Table 5. Maximum weekly redd count for each riffle by section.

Section 1		Section 2		Section 3		Section 4	
Riffle	Max. # of Redds	Riffle	Max. # of Redds	Riffle	Max. # of Redds	Riffle	Max. # of Redds
A1	7	F1	7	K1	0	S1	0
A2	3	F2	1	K2	3	S2	1
A3	5	F3	3	K3	0	S3	2
A4	0	G1	0	L1	6	S4	3
B1	32	G2	0	L2	1	T1	2
B2	23	G3	2	L3	0	T2	3
B3	2	G4	3	L4	2	T3	0
B4	1	G5	1	M1	0	T4	1
C1	7	G6	0	M2	3	T5	0
C2	0	H1	1	N1	3	U1	1
C3	13	H2	4	N2	3	U2	0
D1	3	H3	1	N3	0	U3	0
D2	10	H4	2	N4	4	V1	0
D3	0	H5	2	O1	1	V2	0
D5	2	H6	2	O2	0	V3	0
D6	5	H7	3	O3	0	V4	1
E1	6	I1	0	O4	0	W1	1
		I2	2	O5	1	W2	2
		I3	2	O6	2	W3	1
		I4	0	O7	0		
		J1	0	O8	6		
		J2	1	P1	0		
		J3	1	P2	0		
		J4	1	P3	4		
		J5	2	P4	2		
		J6	2	P5	2		
		J7	2	Q1	6		
		J8	2	Q2	4		
				Q3	1		
				R1	2		
				R2	1		
				R3	2		
Sub Total	119		47		59		18
Total	243						

Table 6. Yearly percent composition of fall-run Chinook salmon on the Tuolumne River.

Year	%Female	% Male	% Unknown
1992	41.7%	56.3%	2.1%
1993	57.4%	42.6%	0.0%
1994	42.4%	42.9%	14.7%
1995	52.0%	47.5%	0.5%
1996	33.5%	66.3%	0.2%
1997	57.3%	42.7%	0.0%
1998	50.6%	49.3%	0.1%
1999	45.9%	54.1%	0.0%
2000	62.8%	37.1%	0.0%
2001	54.0%	45.9%	0.1%
2002	54.5%	45.5%	0.0%
2003	59.8%	40.2%	0.0%
2004	59.0%	40.6%	0.4%
2005	66.5%	33.5%	0.0%
2006	47.9%	52.1%	0.0%
2007	37.8%	62.2%	0.0%
2008	57.1%	42.9%	0.0%

Table 7. CWT Recovered from the Tuolumne River in 2008.

Tag Code	Brood Yr	Release Yr.	Hatchery Location	Release Location	# Recovered
06-47-05	2005	2006	Merced	Hatfield	2
06-47-09	2005	2006	Merced	MRFF	1
06-47-14	2005	2006	Merced	Mossdale	2
06-47-23	2005	2006	Merced	Mossdale	1

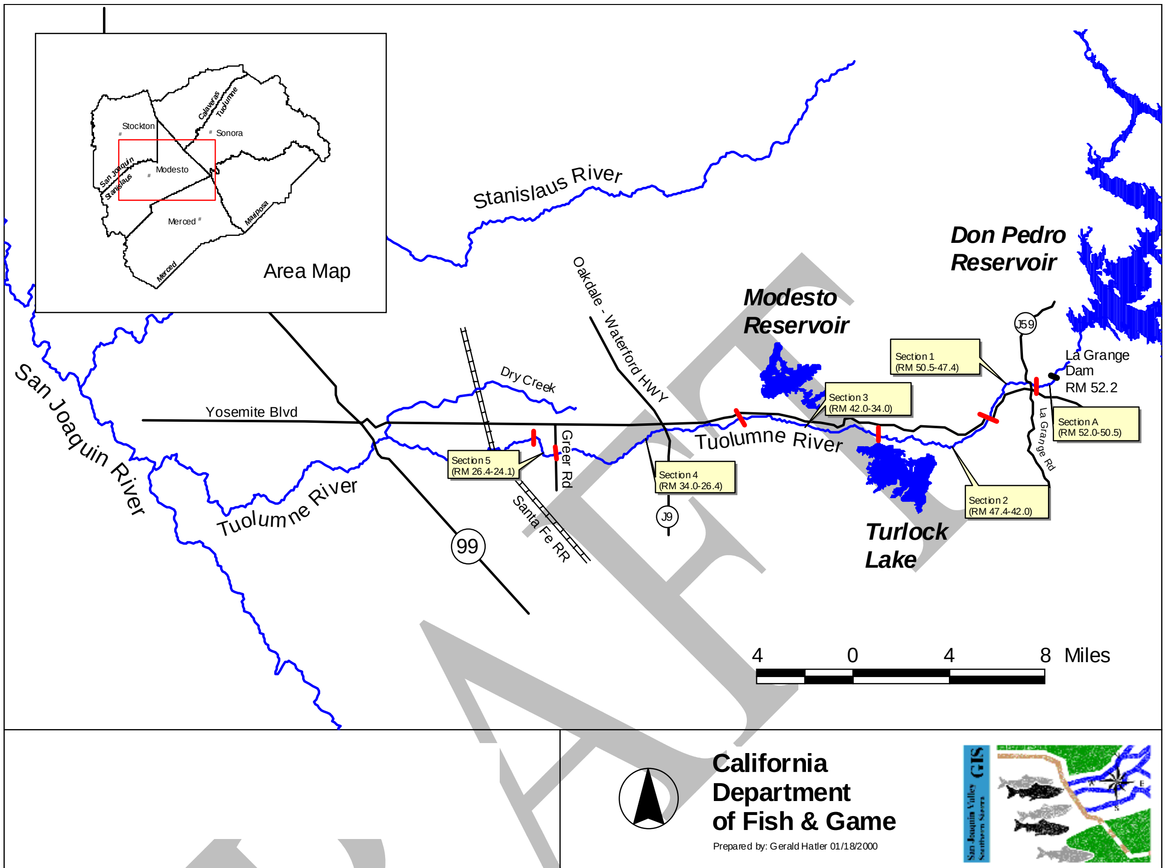

Figure 1. Salmon survey study areas. Lower Tuolumne River.

Figure 2. Fresh carcass indicated by clear eye.

Figure 3. Decayed carcass indicated by cloudy eyes.

Figure 4. “Skeletons” are in the advanced state of decomposition.

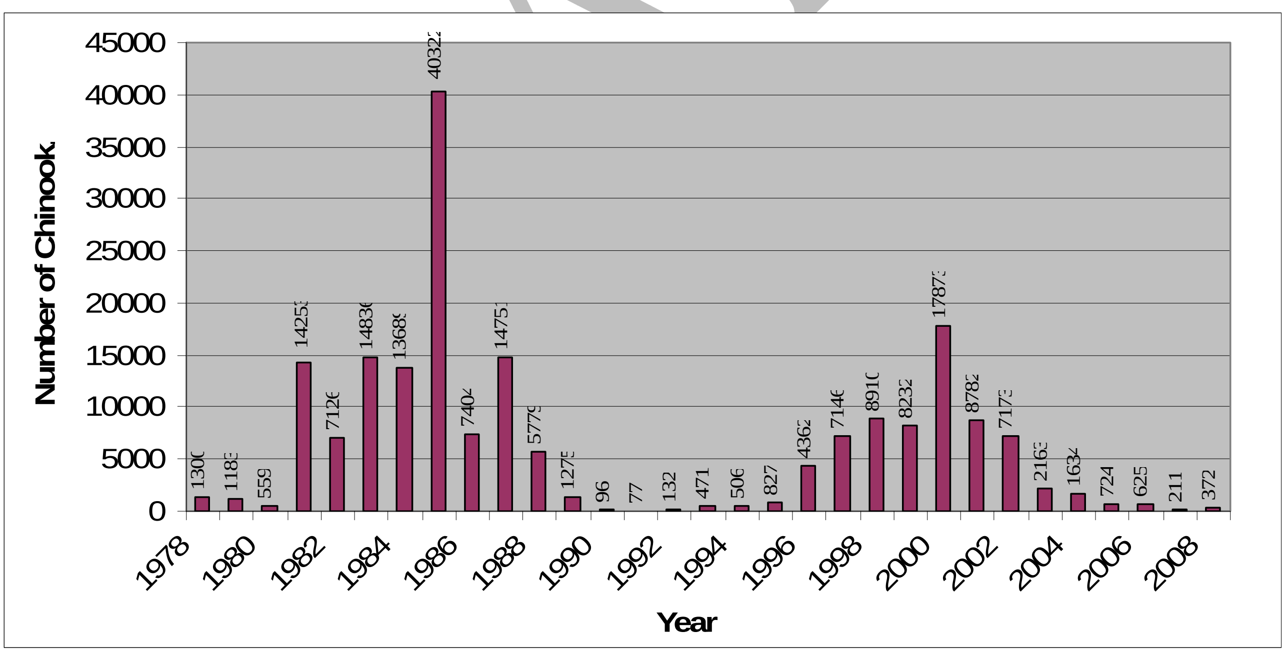

Figure 5. Yearly Tuolumne River Estimates.

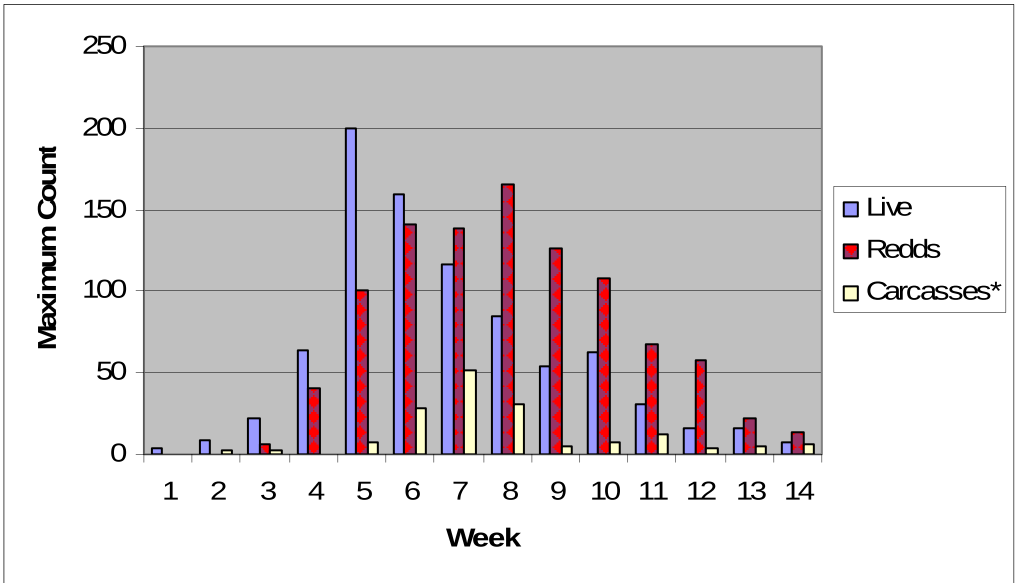

Figure 6. Live fish observation, redd, and carcass counts by week.
*Carcasses include all tagged carcasses and skeletons, but does not include recoveries.

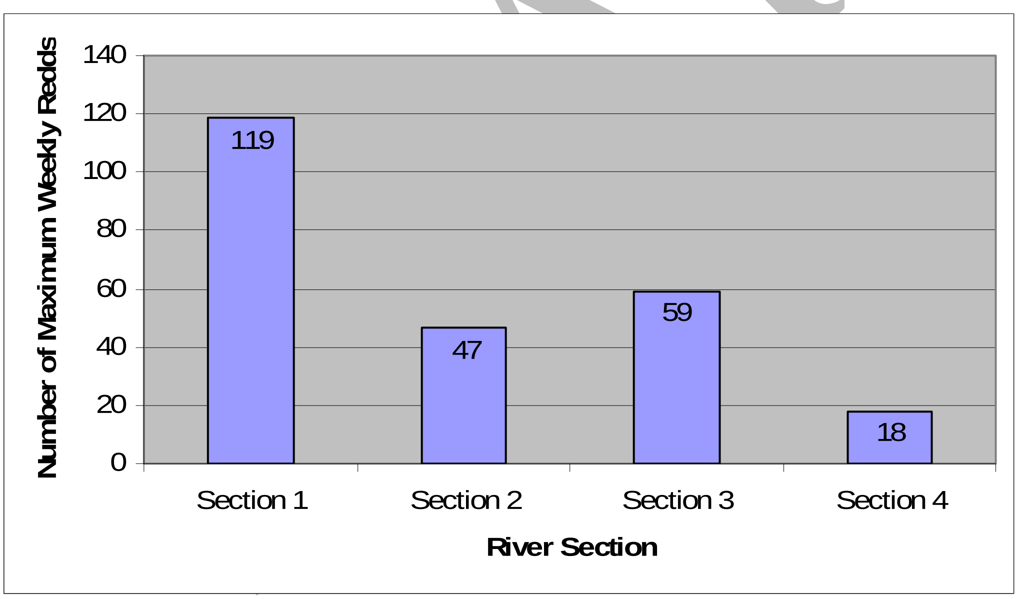

Figure 7. Weekly maximum redds observed by river section.

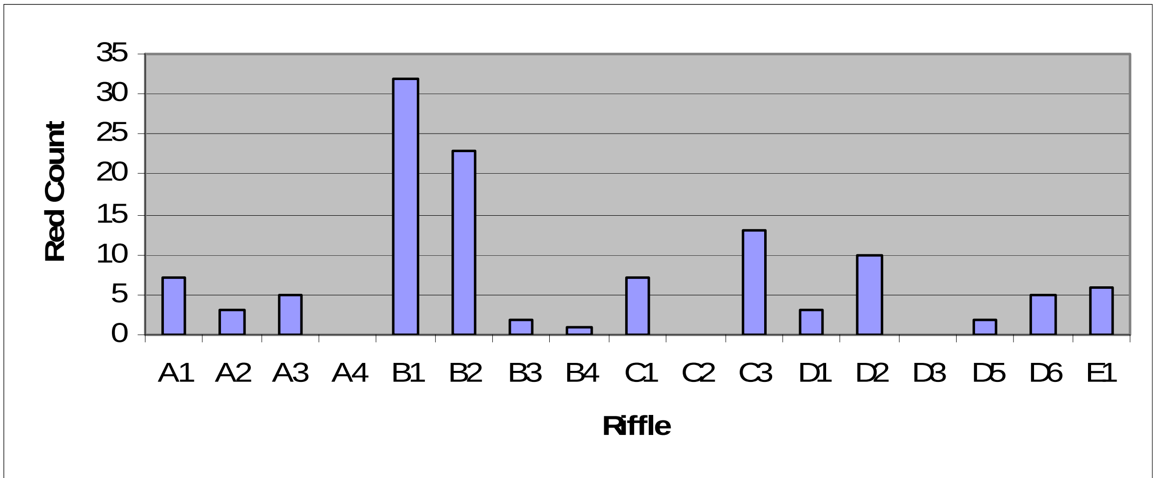

Figure 8. Maximum weekly redds in riffles within section one.

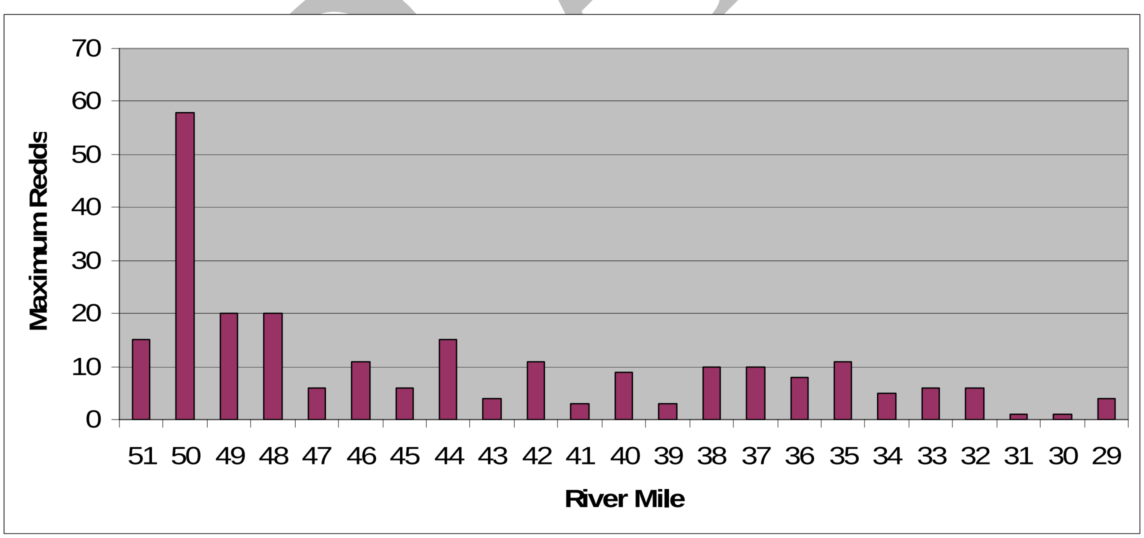

Figure 9. Weekly maximum redds observed by river mile.

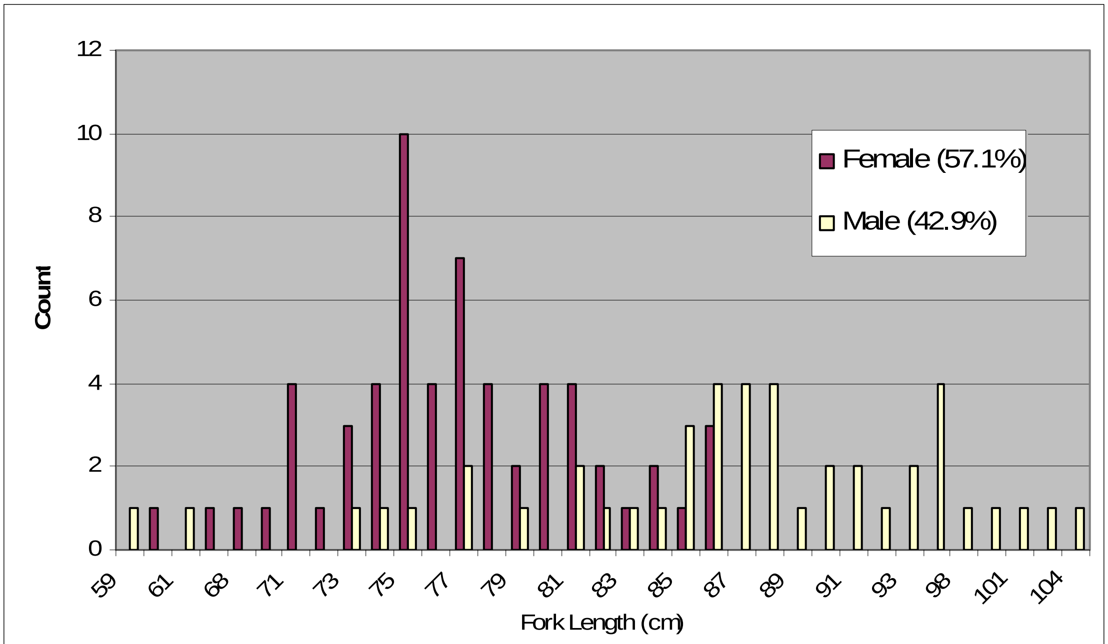

Figure 10. Length frequency histogram of female and male Chinook salmon.

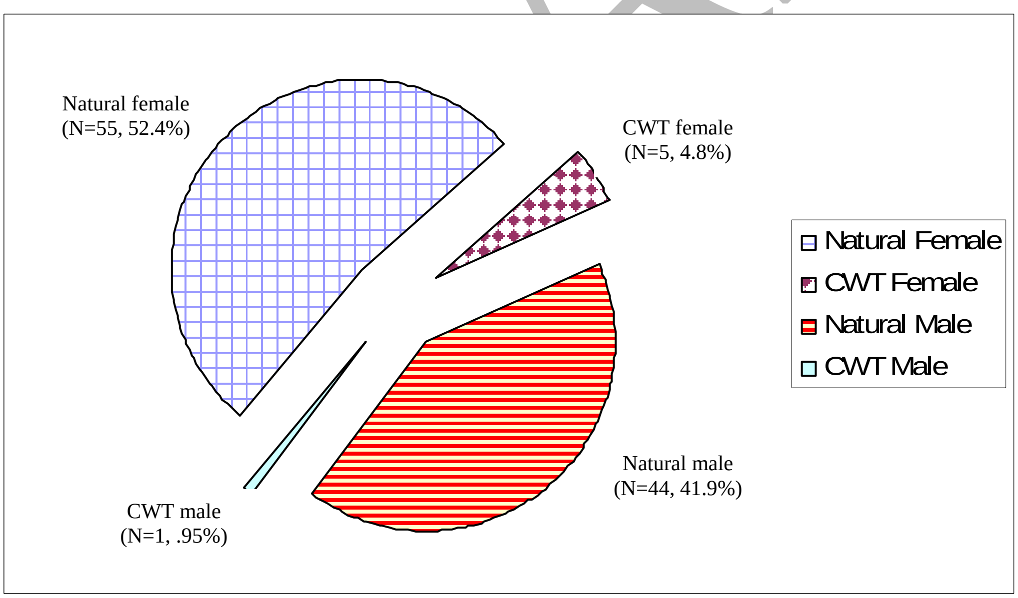

Figure 11. Composition of natural female, CWT female, natural male, and CWT male for the 2008 Tuolumne River escapement survey.

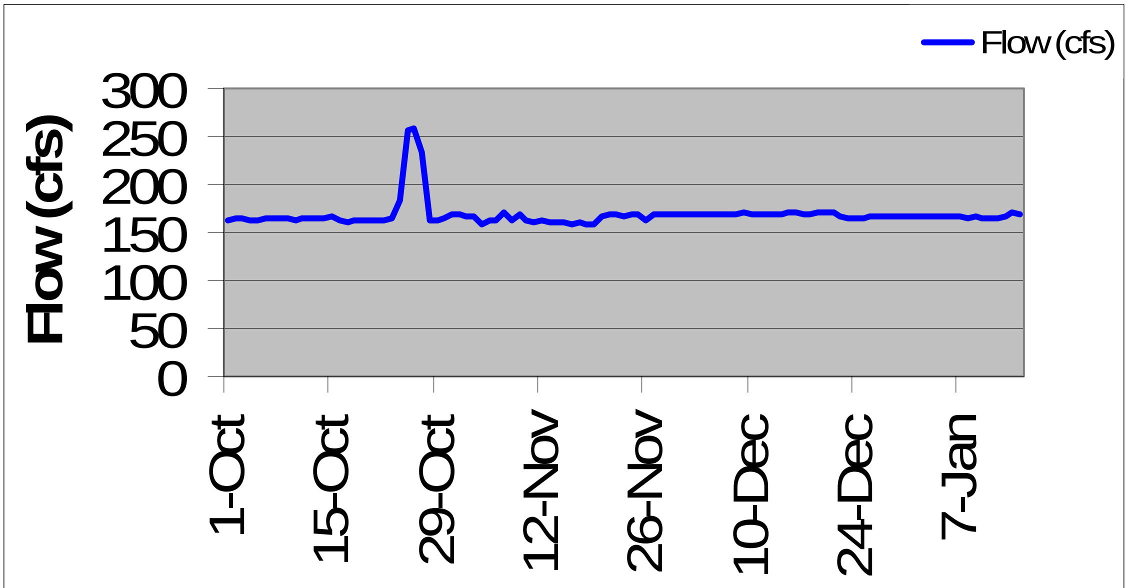

Figure 12. La Grange flow gage data from the period of October 1, 2008 through January 15, 2009. (California Data Exchange Center) The average flow during the 2008 escapement survey was 168 cfs.

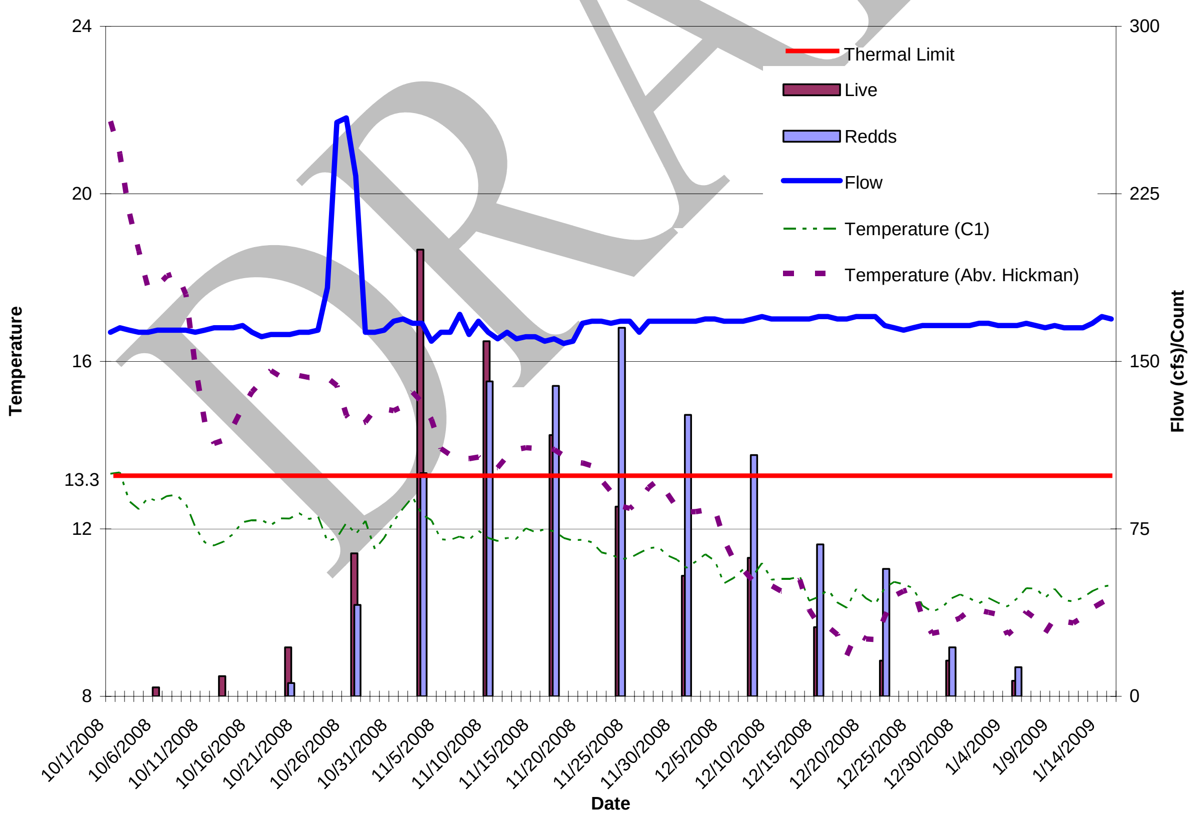

Figure 13. Tuolumne River flows (cfs) at the La grange gage, Temperature at riffle C1 and the Above Hickman site, upper thermal limit for successful egg incubation (13.3°C) and number of live fish and redds counted.

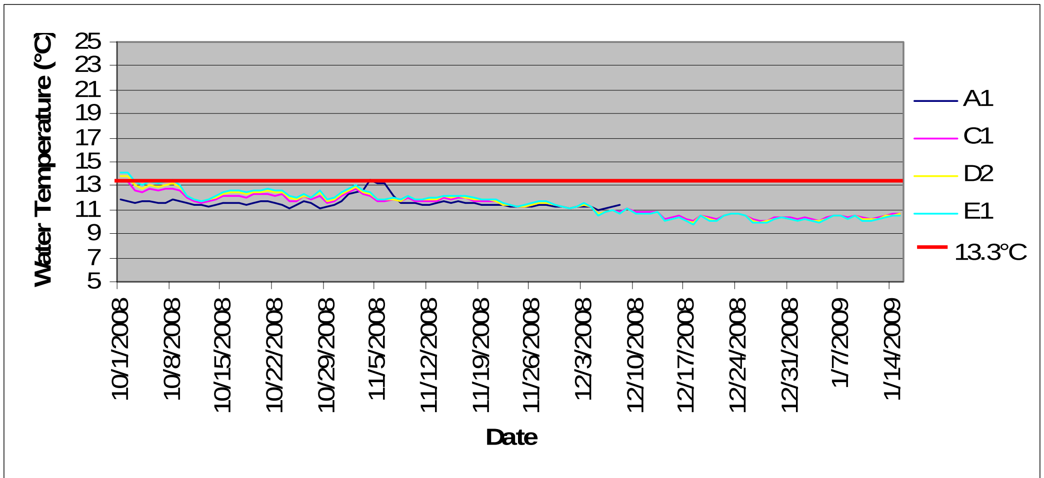

Figure 14. Section 1 remained below the thermal limit (13.3°C) during most of survey.

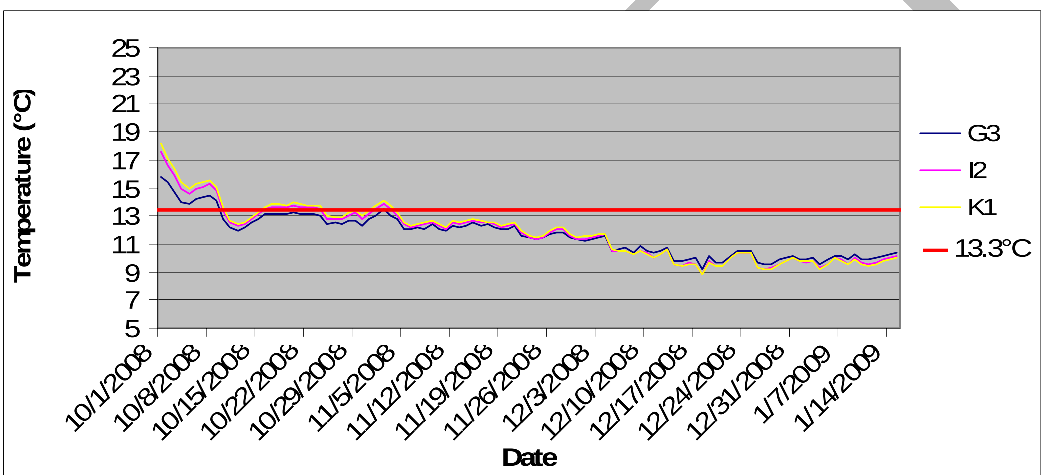

Figure 15. Section 2 temperature data between 10/1/08 and 1/15/09.

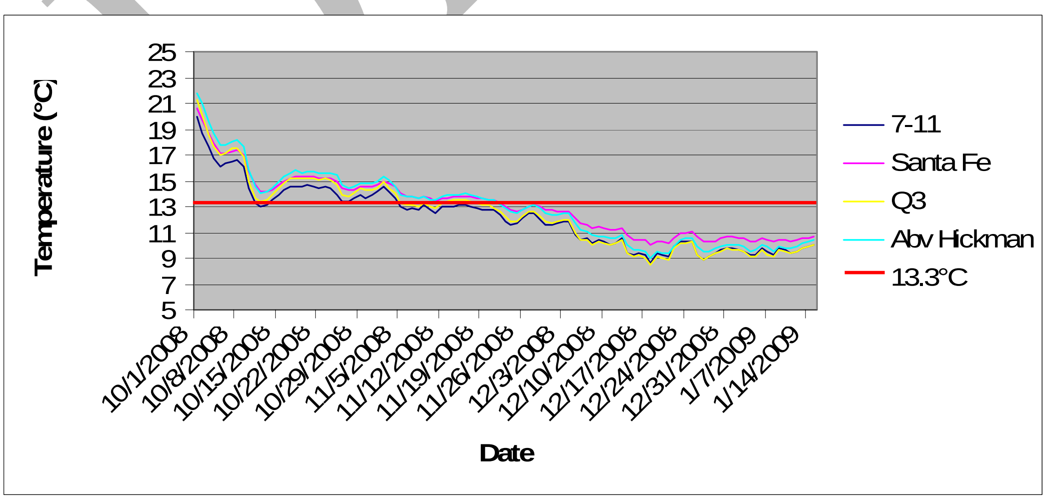

Figure 16. Most of section 3 did not drop below the thermal limit (13.3°C) until the middle of November.

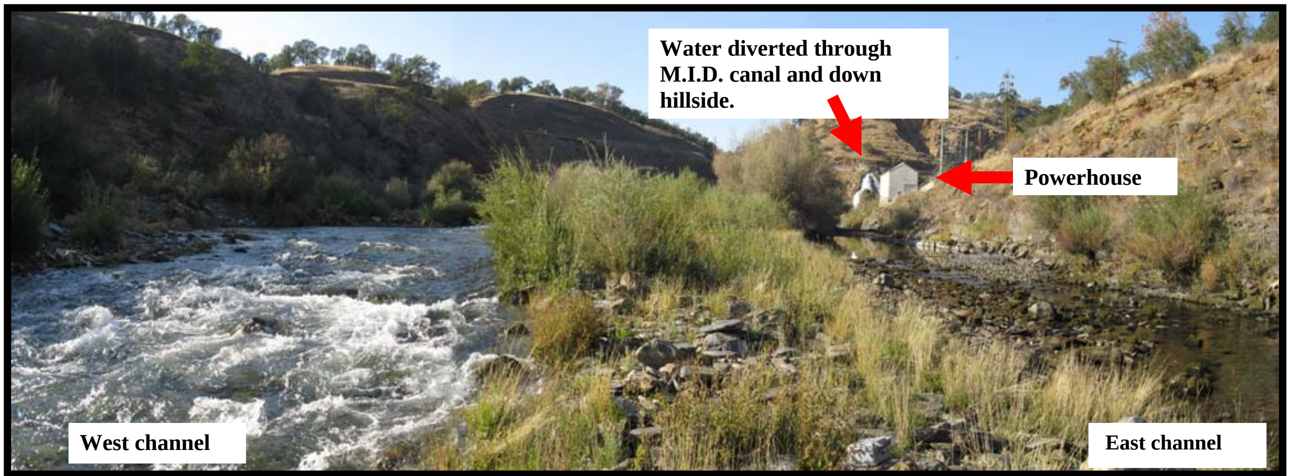

Figure 17. November 6, 2008. Water diverted through MID canal and down hillside into the west channel. The shutdown of the powerhouse resulted in the alteration of river flow to the east channel.

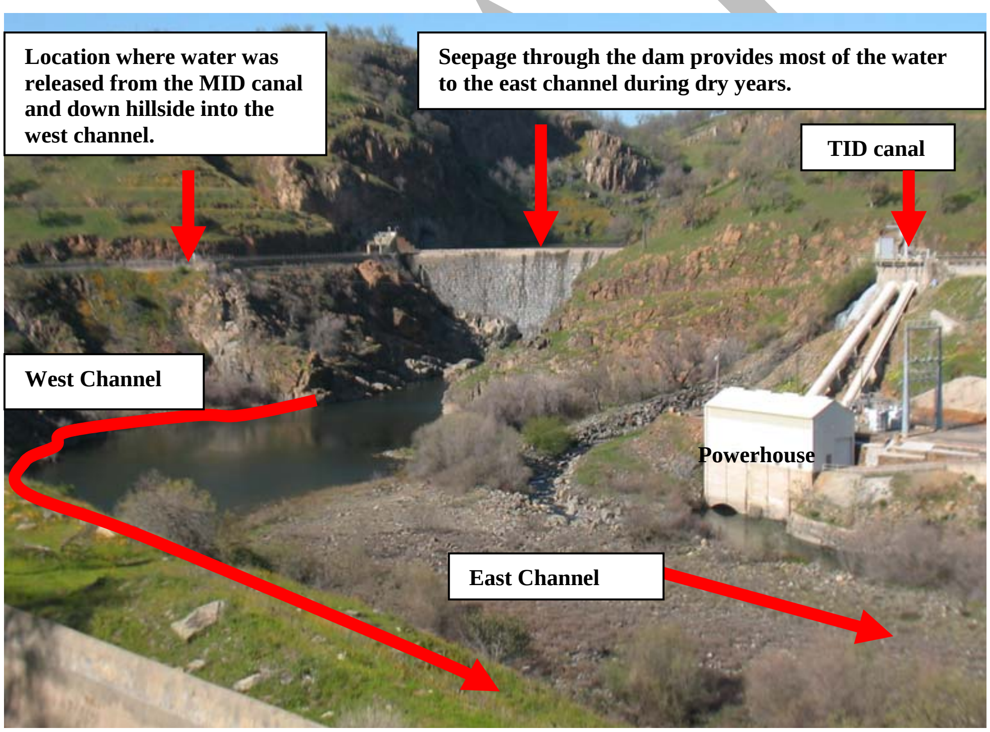

Figure 18. Upstream view of MID and TID canals showing the direction of water flow into the east and west channels during normal flows. March 12, 2009.

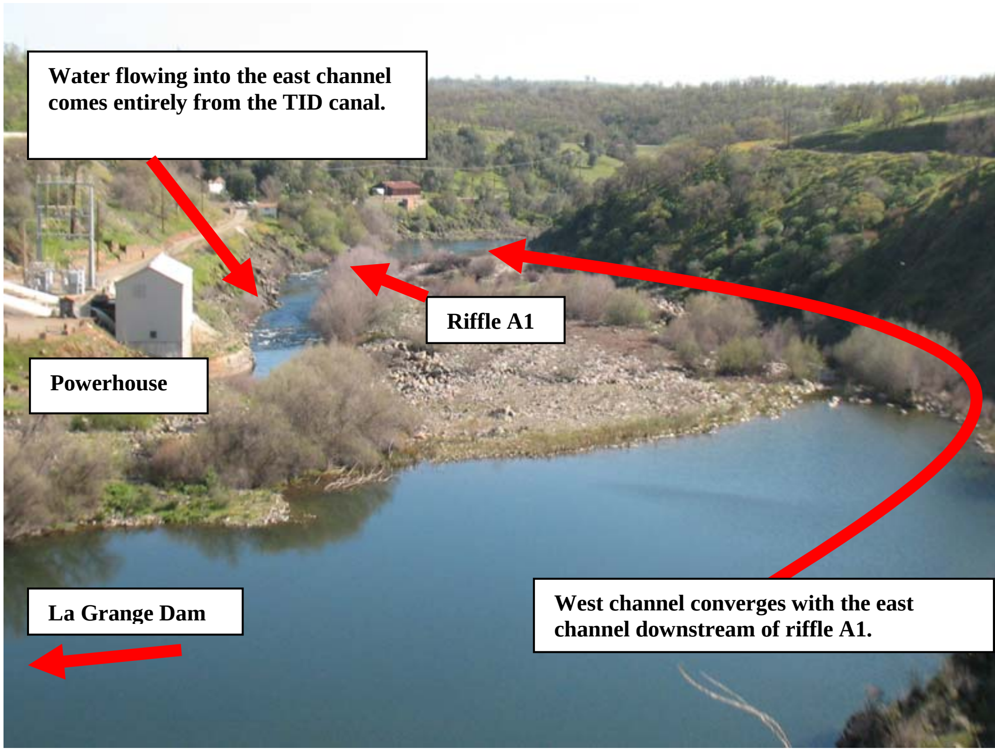

Figure 19. Downstream view taken during normal flows showing the junction of the east and west channels near riffle A1. March 12, 2009.

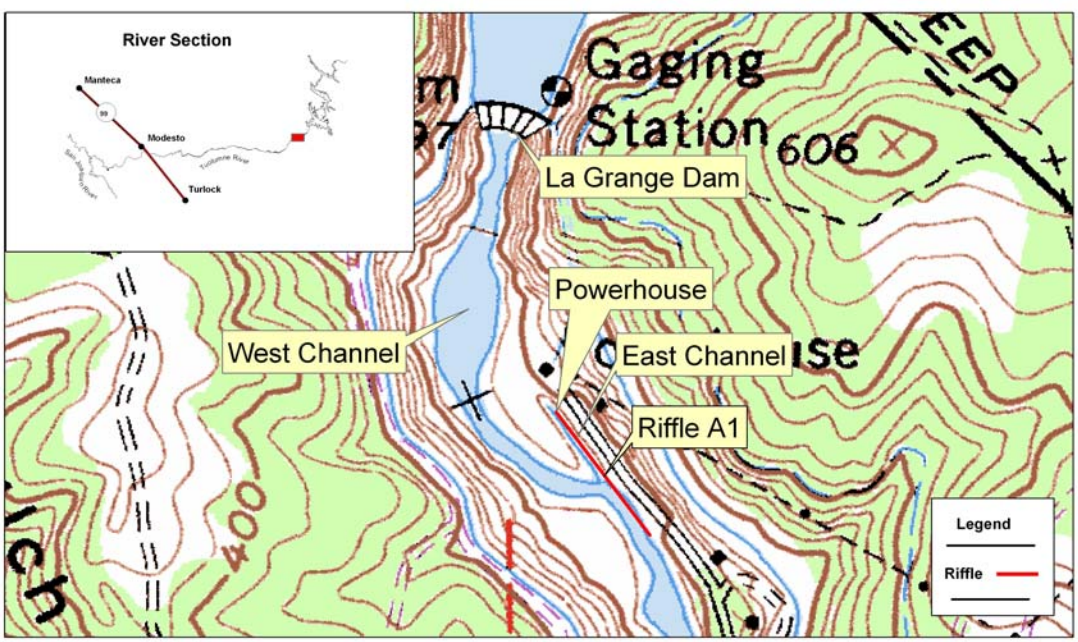

Figure 20. Location of riffle A1 within the east channel.

Figure 21. Redd location and a female carcass in the east channel with minimal flow following the re-routing of water during the November 4, 2008 survey.

Figure 22. Comparison of redd location during normal flows. (169 cfs based on USGS La Grange flow gage data). December 12, 2008.

Figure 23. East channel after the re-routing of water. Partially dry with intermittent pools. November 4, 2008.

Figure 24. Comparison of east channel during normal flow. (169 cfs based on USGS La Grange flow gage data). January 15, 2009.

Figure 25. Comparison between the west and east channels during the re-routing of river flow. November 6, 2008.

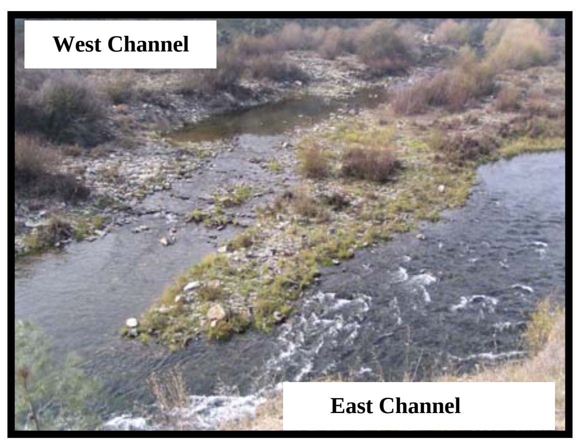

Figure 26. Comparison of flow between the west and east channels during normal flow. December 12, 2008.

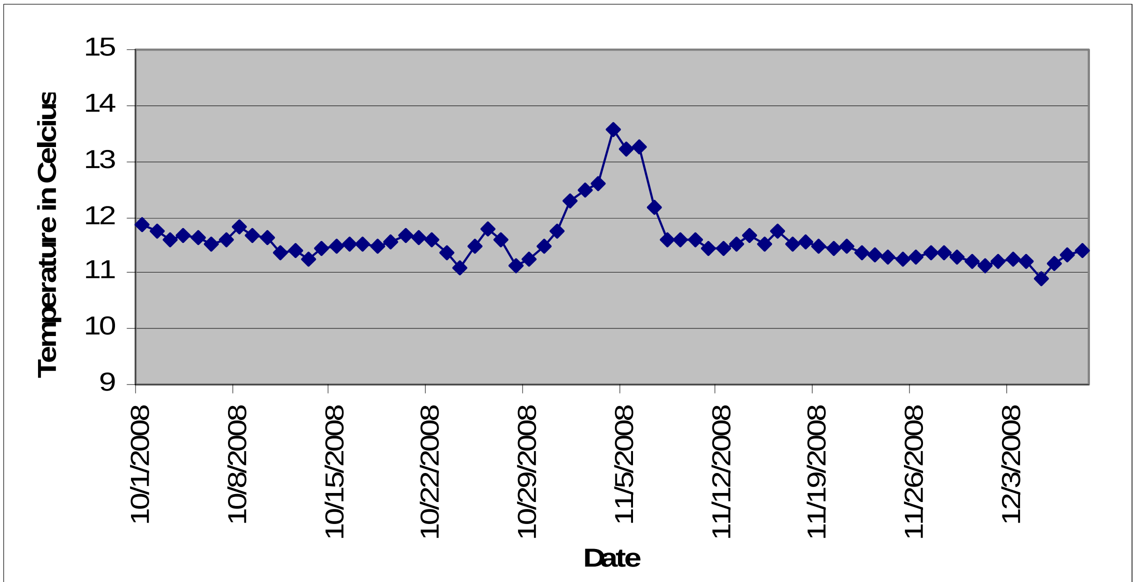

Figure 27. DFG thermograph data showing a rise in temperature near the La Grange powerhouse during the time period when the east channel river flow was altered as a result of the shutting down of the powerhouse.

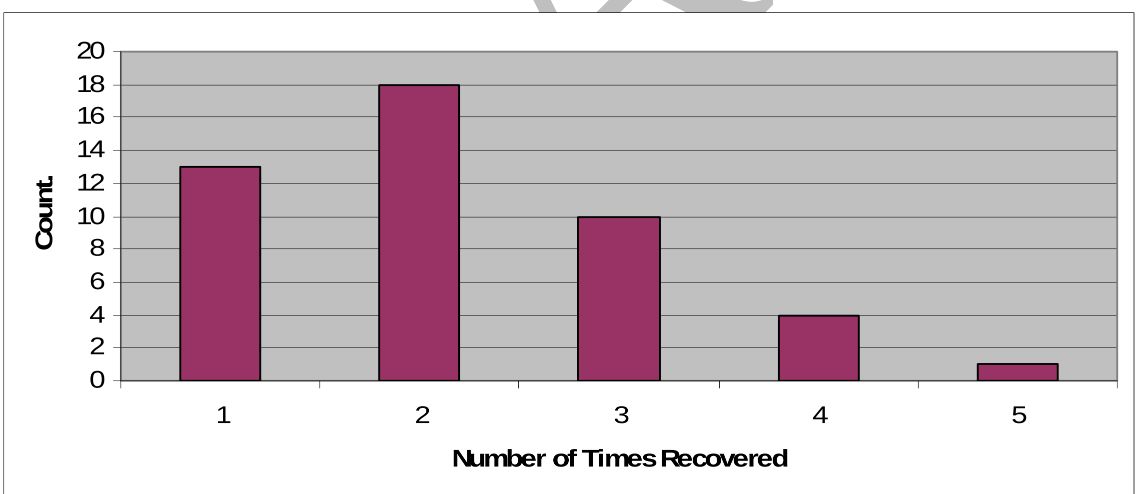

Figure 28. Multiple recapture data for the forty six carcasses that were recovered during the 2008 escapement survey.

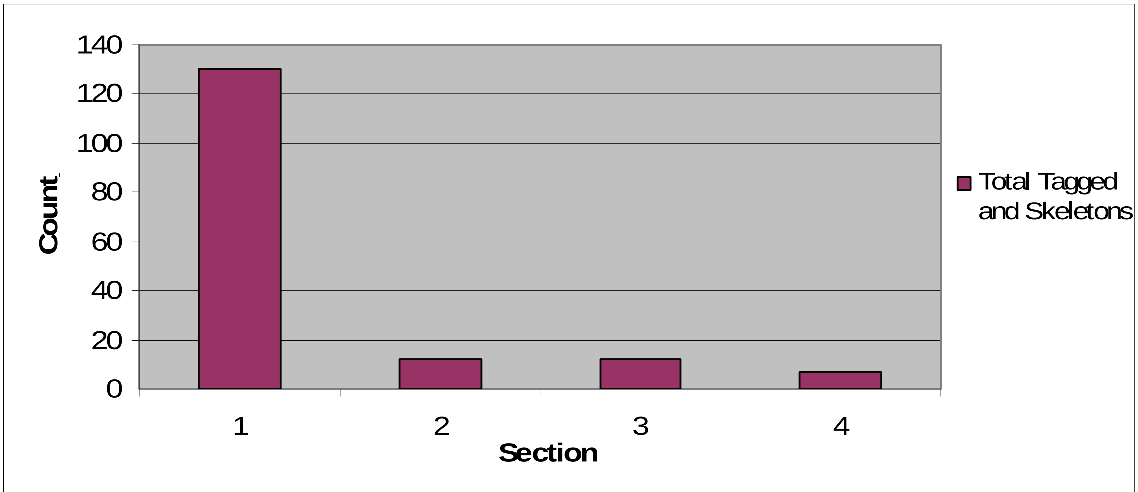

Figure 29. Distribution of carcasses found within the four river sections.