Lower Tuolumne River
Fall Chinook Salmon Escapement Survey 2001

California Department of Fish and Game
Anadromous Fisheries Program
San Joaquin Valley Southern Sierra Region

INTRODUCITON

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 approximately 122,000 returning adults in 1940 to an estimated 7,916 in 1998 (Heyne, 1998 draft data), 7,685 in 1999 (Heyne, 2000 draft data) and 17,873 in 2000 (Vasques 2001). The decline of the species can be attributed to many factors. In general, reduction of spawning and rearing habitat and stream flow management practices, are thought 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 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 1953. The Schaefer mark recapture escapement estimation model (1951) has been utilized since 1971 and the 2001 escapement survey is a continuation of this method. Beginning in 1992 CDFG escapement surveys have been utilized as part of the New Don Pedro Project FERC license monitoring program and annual reporting.

The primary objectives of this study 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.
- Collect DNA samples for storage at the CDFG Salmonid Tissue Archive for subsequent genetic analysis.

- Evaluate the distribution of salmon redds through the study area.

STUDY AREA

Approximately 26.5 river miles were studied during the Tuolumne River escapement survey in 2001 (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 riffles A3 and A4 at river mile 51.6 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 river mile 41.9). Section 3 covers the area between TLSRA and riffle 46 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 GPS 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 immediately below La Grange 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. During the survey designation of pools was sometimes necessary. In these cases the pool was given the riffle name of the upstream riffle followed by the letter P. For example, the pool below riffle A1 is designated A1P.

METHODS

Population Estimation

The Schaefer mark recapture method was used to estimate fall salmon escapement on the Lower Tuolumne River. Under this scheme carcasses are marked and subsequently recovered 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 October 4, 2001(Week 1) and concluded on January 5, 2002 (Week 14). Carcasses were tagged for the first 12 weeks and weeks 13 and 14 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 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 driftboat. 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 2001 were clear eyes and the presence of blood remaining in the gills (Figures 2 and 3). Decayed fish had a cloudy eye and no blood in the gills. Skeletons were fish 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 2001 survey included the presence of fungus covering the entire body at the freshest end of the skeleton designation (approximately one week) to actual skeletons at the most decayed end (Figures 4 and 5).

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 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 despite findings by Law (1994) suggesting that untagged carcasses not removed after initial count only slightly affected Schaefer's (1951) population estimate. Estimates were made using the Schaefer (1951) equation as presented in Ricker (1975). Law (1994) found in simulations of various models, using a similar protocol as this survey, that the Peterson model (see Ricker, 1975) consistently overestimated the population. Therefore, Peterson's model was not used in this analysis.

Individual Fish Data Collection

Fork length (to the nearest 0.5 centimeter) and sex data are collected for all tagged carcasses. Scale, otolith, and genetic samples are collected from a percentage of specimens to determine the size, age, and genetic composition of annual spawning runs. Additionally, CWT's are collected from wild and hatchery produced marked (adipose fin clipped) carcasses returning the Tuolumne River as part of long term survival testing releases of marked outmigrating smolts and to determine 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 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 were collected from both wild and CWT carcasses and 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 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 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 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. No redd or live counts were conducted during recovery weeks 13 and 14.

RESULTS

Weekly Counts

Live fish counts increased steadily, peaked in Week 6, and declined steadily through the remainder of the survey (Table 2, Figure 6). Carcass counts exhibited a similar incline, peak, and decline which was offset from live counts by three weeks. The peak carcass count occurred in Week 9. Redd counts increased steadily through Week 6 when the total number of observations was 1145. During weeks 7 through 12 redd counts remained consistently high but varied from 984 (Week 10) to 1252 (Week 12).

Population Estimation

Based on the Schaefer model, the 2001 escapement estimate is 9,222 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 carcasses handled each week to generate weekly escapement estimates (Table 3). These weekly estimates are summated to estimate total escapement over the course of the survey. These weekly Schaefer estimates are presented in Table 4 along with the total number fresh carcasses tagged each week and the number of recoveries made in subsequent weeks in relation to the tag week. Weekly cumulative Schaefer estimates are graphed in Figure 7. The overall recovery rate was 61.3% (Table 4) which is higher than the overall recovery rate of 41.7% encountered during the 2000 escapement survey.

Spawning Distribution

The results of maximum weekly redd counts clearly indicate that the majority of spawning activity is concentrate in the riffles of Section 1 (Figures 10 and 11). The maximum number of redds counted in a particular riffle over the course of the season are listed in Table 5. The maximum redd count represents the redd count made when external factors like visibility were at optimum conditions. During the 2001 survey 1344, 333, 361, and 101 redds were counted for Sections 1 through 4 respectively. Redds per river mile declined from 328 in Section 1 to 59, 46, and 13 in Sections 2, 3, and 4 respectively.

Population Composition

Coded wire tagged fish comprised approximately 15% of the total tagged carcasses based on the ratio of adipose 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 37 % for natural males, 9% for CWT males, 47% for natural females, and 7% for CWT females (Figure 12). 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 13, 14, 15 and 16). The first peaks are likely age 1 and 2 fish and the second peaks are likely age 3,4, and 5 fish. Because the histograms display overlap between age groups, separation of cohorts will be determined upon completion of age determination studies (CWT, scale and otolith analysis).

Sample Collection

Scales, otolith, and DNA samples were collected from both natural and adipose fin clipped fish throughout the survey period and survey area (Tables 6, 7, 8, 9, 10, and 11). 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.

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 Sections 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 Estimation

The 2001 tag recovery rate of 61.3% is very high compared to the recovery rate of 41.7% encountered in 2000 (Vasques 2001) which is itself a high tag recovery rate. The difference in recovery rates is likely a function of the difference in stream flow between 2000, over 300 cfs, and 2001, under 200 cfs (Figures 8 and 9). Stream flow dynamic effects 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 survey 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.

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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
A1A	A1A	E2	6	K1	24A, 24B	S1	48A
A1	A1	F1	7	K2	25	S2	48B
A2	A2	F2	8A	L1	26	S3	NONE
A3	A3	F4	8B	L2	27A, 28B	T1	50, 51
A4	A4	F5	9	L3	28A, 28B	T2	52A
A5	A5	G1N	12	N1A	28C	T3	52B
A6	A6	G1S	12	N1	29	T4	53
B1	A7	G2	13A	N2	30A	T5	54
B2	1A	G3	13B	N3	31A	U1	55A, 55B
B3	1B	G4	13C	N4	31B	U2	56
B4	1C	H1	14	O1	32	U3	58, 59
C1	2	H2	15	O2	33	V1	60N, 60S
C2	3A	H3	16N	03	33B	V2	61
C3	3B	H4	16S	O5	34	V3	63A
D1	3C	H5	17A	P1	35A, 35B	V4	63B
D2	4A	H6	17B	P2	36A, 36AA	W1	64
D3	4B	H7	17C	P3	36B	W2	65
D4	4C	I1	18A	P4	37	W3	66N, 66S
D5	5A	I2	18B	Q1	38	W4	66B
E1	5B	I2A	19	Q2	41	X1	67
		I2B	20	Q3	42A,42B,43A,43B	X2	68
		I3	21	R1	44		
		J1	22A	R2	45		
		J2	22B	R3	46		
		J3	23B				
		J4	23C				
		J5	23D				

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

Week	Live	Redds	Carcasses[a]
1[b]	24	6	8
2	260	6	12
3	557	56	14
4	1395	258	38
5[c]	1359	792	150
6	1865	1145	654
7[c]	863	1104	1118
8c	921	1154	1137
9	396	1251	1191
10[c]	228	984	529
11	137	1153	293
12	48	1252	184
13			60
14[c]			12
Total	N/A	N/A	5400

[a] Carcasses includes all tagged carcasses and skeletons but does not include recoveries
[b] Only Section 1 surveyed
[c] Only Sections 1 and 2 surveyed

Table 3. Weekly Schaeffer totals.

Week	Total Tagged	Skeletons	Fresh Recoverie[1]	Total Counted[2]	Tagged Fresh	CWT's
1	8	0	N/A	8	5	
2	8	4	3	15	4	
3	12	2	4	18	2	1
4	32	6	1	39	20	1
5	128	22	8	158	85	25
6	411	243	55	709	277	90
7	339	779	149	1267	194	71
8	340	797	111	1248	249	56
9	312	879	149	1340	199	29
10	118	411	127	656	76	11
11	74	219	75	368	47	2
12	26	158	28	212	12	1
13	N/A	60	6	66	N/A	
14	N/A	12	1	13	N/A	
Total	1808	3592	717	6117	1170	287

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

Table 4. Schaeffer distribution of mark week versus recovery week, number of tags recovered per week with 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	11	12			
2	3												3	8	8
3	2	2											4	15	23
4	0	0	2										2	18	18
5	0	0	0	8									8	39	65
6	0	0	0	3	52								55	158	223
7	0	0	0	1	9	139							149	709	1115
8	0	0	0	0	0	25	85						110	1267	2052
9	0	0	0	0	0	10	29	110					149	1248	2038
10	0	0	0	0	0	1	3	36	87				127	1340	2176
11	0	0	0	0	0	0	2	5	33	35			75	656	1096
12	0	0	0	0	0	0	0	1	2	9	16		28	368	817
13	0	0	0	0	0	0	0	0	1	0	2	3	6	212	560
14	0	0	0	0	0	0	0	0	0	0	0	1	1	66	198
15	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0
Recoveries per Tag Week	5	2	2	12	61	175	119	152	123	44	18	4	**Overall Recovery Rate**		**Total Escapement Estimate**
Fresh Tagged Carcasses	5	4	2	20	85	277	194	249	199	76	47	12	**61.3%**		**9222**
Recovery Percentage per Tag Week	100.0	50.0	100.0	60.0	71.8	63.2	61.3	61.0	61.8	57.9	38.3	33.3			

Table 5. 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 # of Redds	Riffle	Maximum # of Redds	Riffle	Maximum # of Redds	Riffle	Maximum # of Redds
A1	7	E2	0	K1	29	S1	7
A2	0	F1	30	K2	21	S2	7
A3	29	F2	21	L1	19	S3	11
A4	39	F3	25	L1P	0	S3A	1
A5	4	F4	9	L2	20	T1	7
A6	0	F5	0	L2A	0	T1P	0
A7	0	G1N	10	L3	7	T2	3
B1	189	G1S	14	N1	10	T2A	0
B2	132	G2	17	N1A	4	T3	1
B3	65	G3	12	N2	8	T3A	1
B4	6	G4	4	N2A	0	T4	1
C1	187	H1	3	N2B	0	T5	1
C2	10	H2	20	N3	28	U1	16
C2A	96	H3	15	N4	19	U2	7
C3	158	H4A	7	O1	10	U3	1
D1	36	H4N	9	O2	6	V1	11
D2	132	H4S	11	O3	6	V2	9
D3	143	H5	6	O4	12	V3	4
D4	31	H6	9	O5	7	V4	3
D5	53	H7	15	P1	16	W1	3
E1	27	I1	20	P1A	1	W2	5
		I2	13	P2	14	W3	1
		I2A	0	P2A	1	W4	1
		I2B	1	P3	19	Y1	0
		I3	11	P4	8		
		J1	11	Q1	19		
		J2	11	Q2	12		
		J3	7	Q3	35		
		J4	11	R1	7		
		J5	11	R2	13		
				R3	10		
				R4	0		
Subtotals	**1344**		**333**		**361**		**101**
Total Redds	**2139**						

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

Week	Section				Weekly Totals
	1	2	3	4	
1	4				4
2	2				2
3	2				2
4	6				6
5	30				30
6	71	27	5		103
7	79	14			93
8	68	1			69
9	68		9		77
10	67	6			73
11	20	3	3		26
12	8	1			9
Section Totals	425	52	17		494

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					
3	1				1
4	1				1
5	25				25
6	42	3	1		46
7	25	2			27
8	30				30
9	12				12
10	11				11
11	1				1
12	1				1
Section Totals	149	5	1		155

Table 8. Distribution of heads collected from natural salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2	2				2
3	1				1
4	6				6
5	11				11
6	16	26	5		47
7	34	10			44
8	42	1			43
9	57	1	7		65
10	48	6			54
11	14				14
12	5	1			6
Section Totals	236	45	12		293

Table 9. Distribution of heads collected from adipose fin clipped salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2					
3	1				1
4	1				1
5	25				25
6	86	3	1		90
7	64	7			71
8	54	1			55
9	28				28
10	11				11
11	2				2
12	1				1
Section Totals	273	11	1		285

Table 10. Distribution of DNA samples collected from natural salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2					
3	4				4
4	7				7
5	13				13
6	30	26	5		61
7	33	12			45
8	47	8			55
9	19		11	1	31
10	3				3
11		6	6	1	13
12	6	1	2	1	10
Section Totals	162	53	24	3	242

Table 11. Distribution of DNA samples collected from adipose fin clipped salmon.

Week	Section				Weekly Totals
	1	2	3	4	
1					
2					
3	1				1
4					
5	13				13
6	14	2	1		17
7	5				5
8	8				8
9	1				1
10					
11					
12					
Section Totals	42	2	1		45

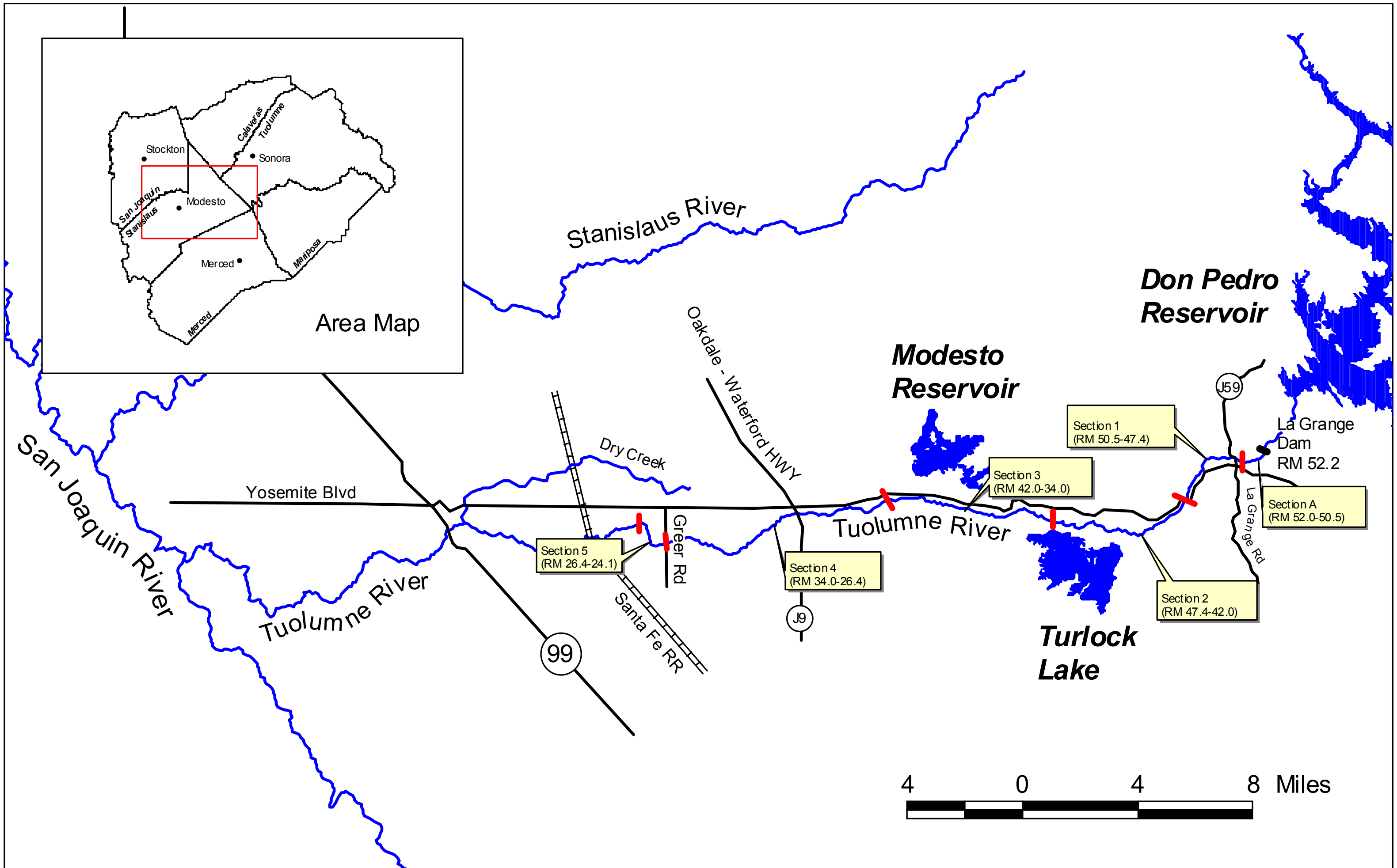

Figure 1. Salmon survey study areas, lower Tuolumne River.

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Prepared by: Gerald Hatler 01/18/2000

Figure 2. Fresh carcass indicated by clear eye.

Figure 3. Fresh carcass indicated by presence of blood remaining in gill.

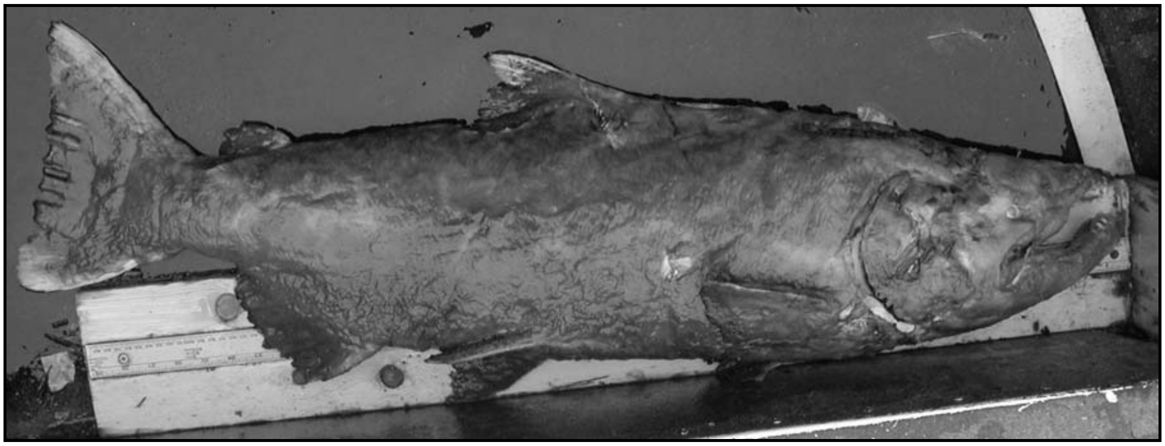

Figure 4. Fungus covered skeleton.

Figure 5. Two skeletons showing varied degrees of decomposition and a fresh carcass.

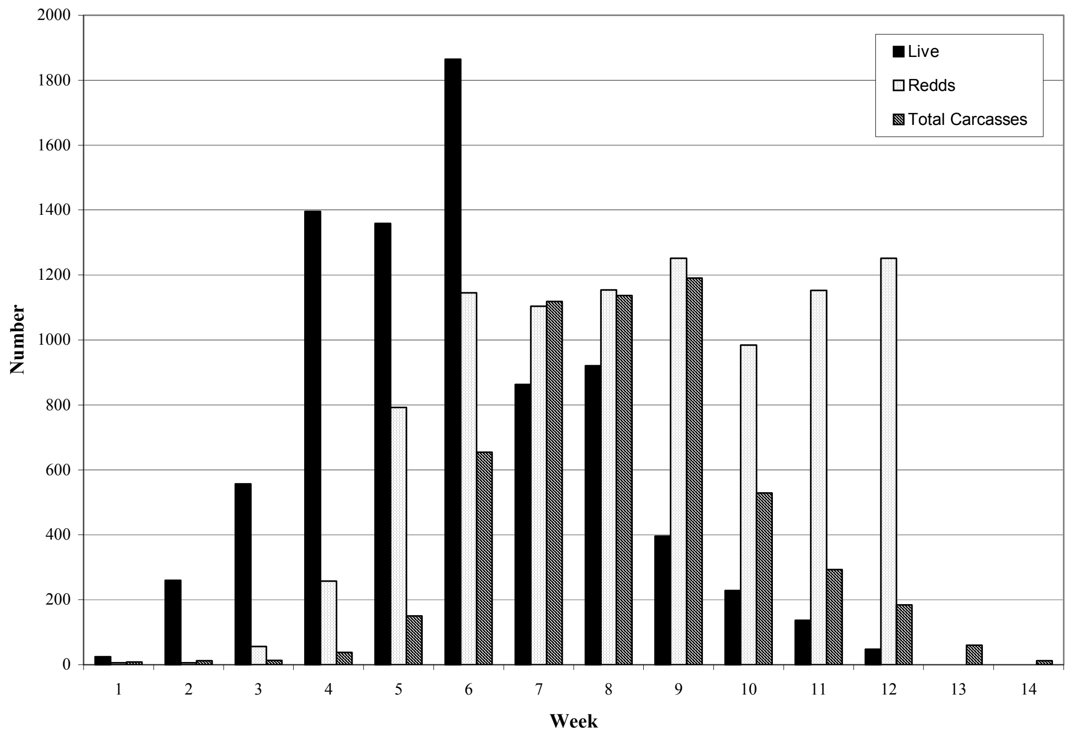

Figure 6. **Live fish observation, redd, and total carcass weekly counts. Total carcasses includes all tagged carcasses and skeletons. Live fish and redd counts were not conducted during weeks 13 and 14.**

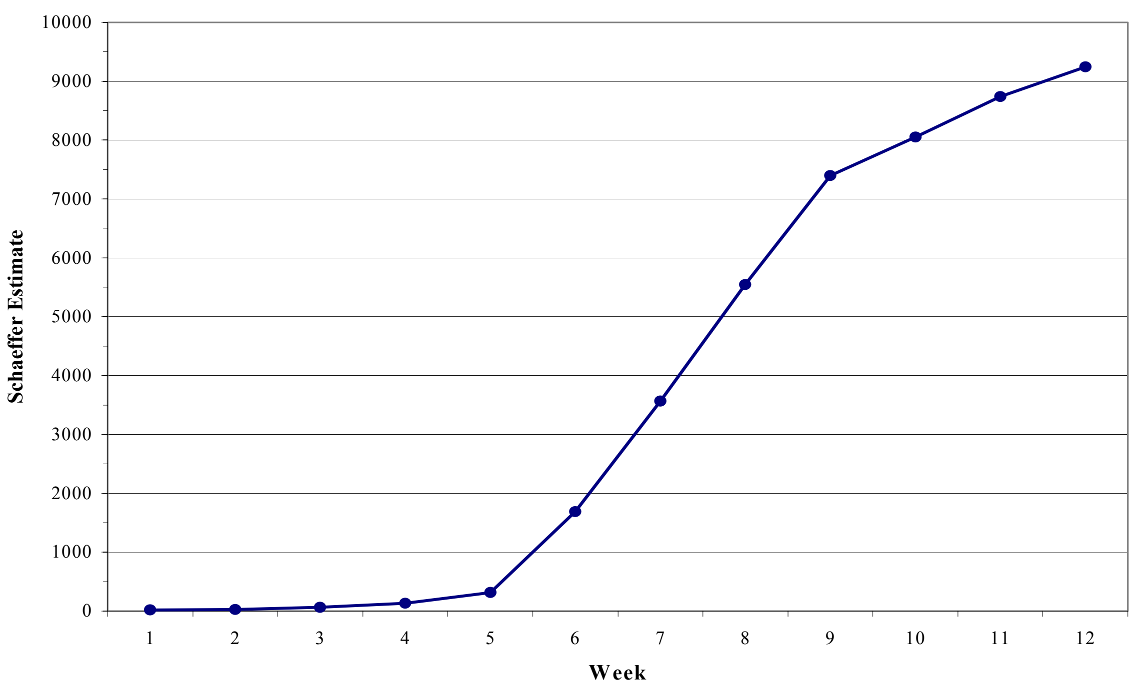

Figure 7. Weekly cumulative Schaeffer escapement estimate.

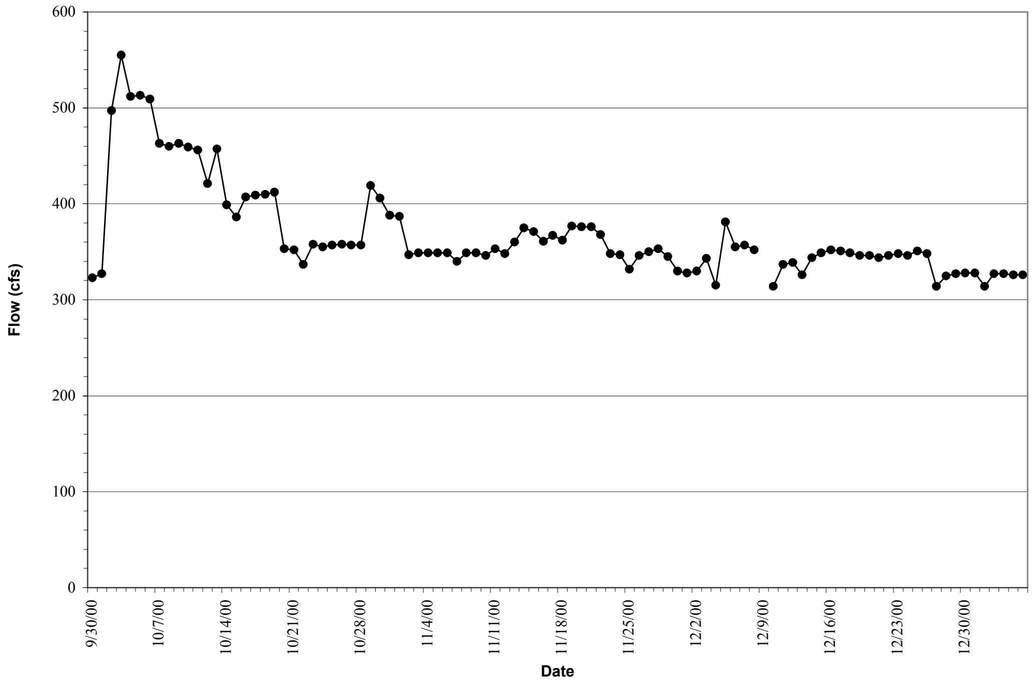

Figure 8. Average daily Tuolumne River steam flow (cubic feet per second) during the 2000 escapement survey. Preliminary data obtained from the California Data Exchange Center.

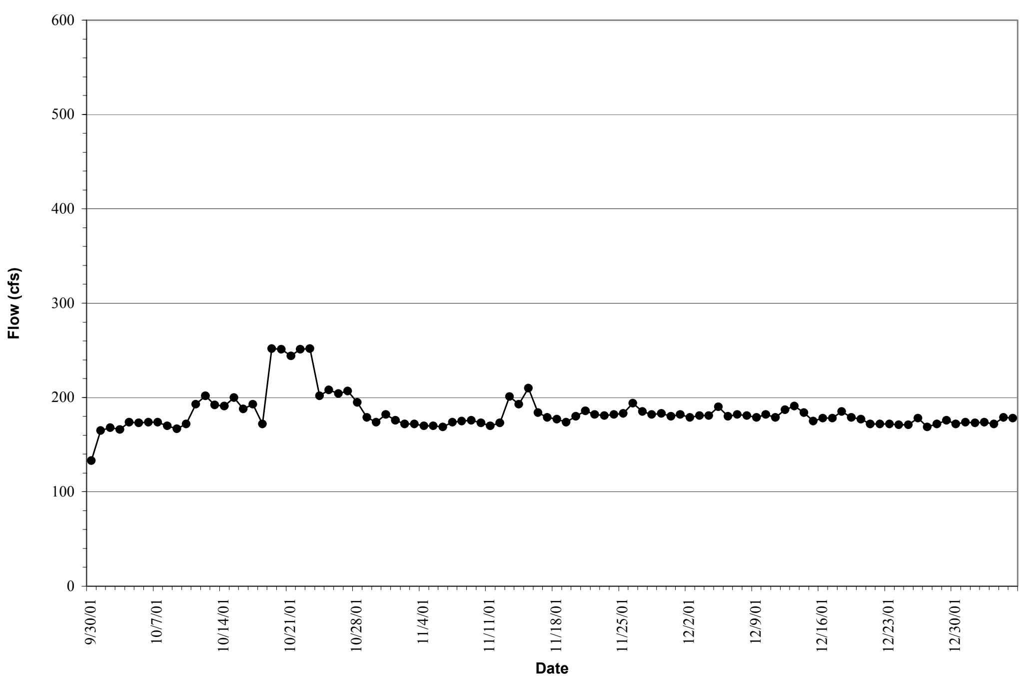

Figure 9. Average daily Tuolumne River steam flow (cubic feet per second) during the 2001 escapement survey. Preliminary data obtained from the California Data Exchange Center.

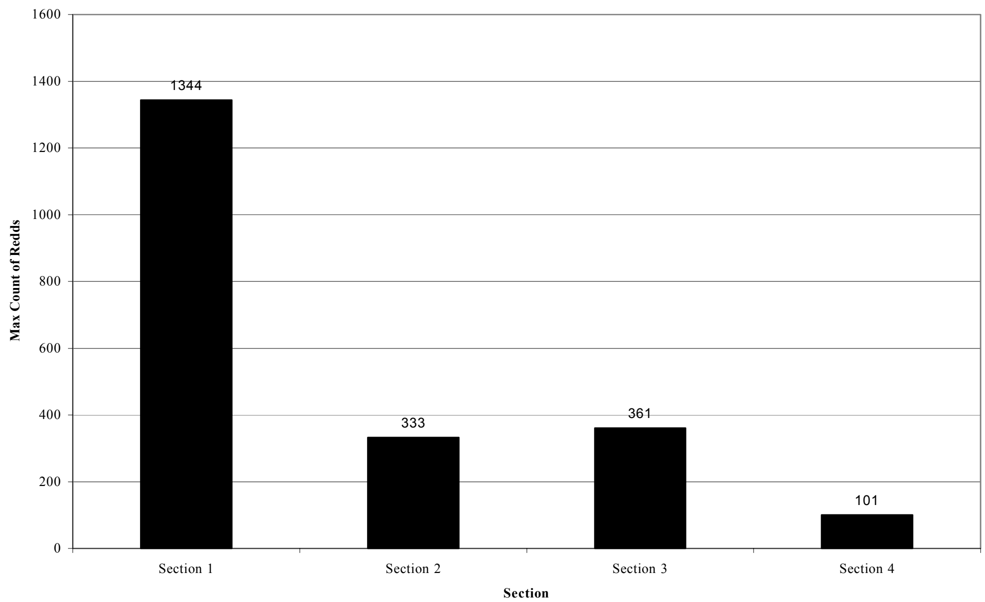

Figure 10. Maximum number of redds counted per section. Values reflect the highest redd count per riffle over the total period of the escapement survey.

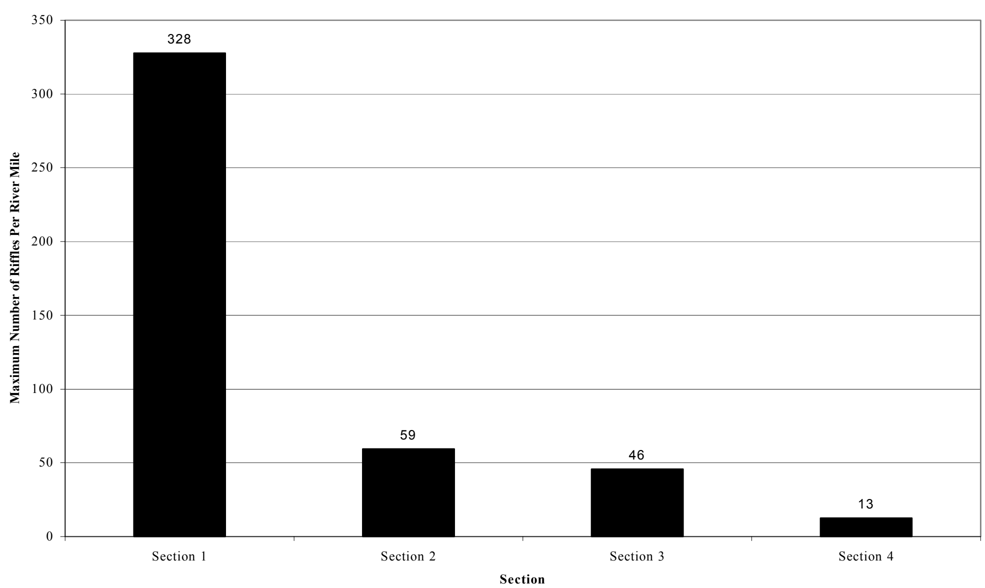

Figure 11. Maximum number of redds counted per river mile per section. Values reflect the highest redd count per riffle over the total period of the escapement survey.

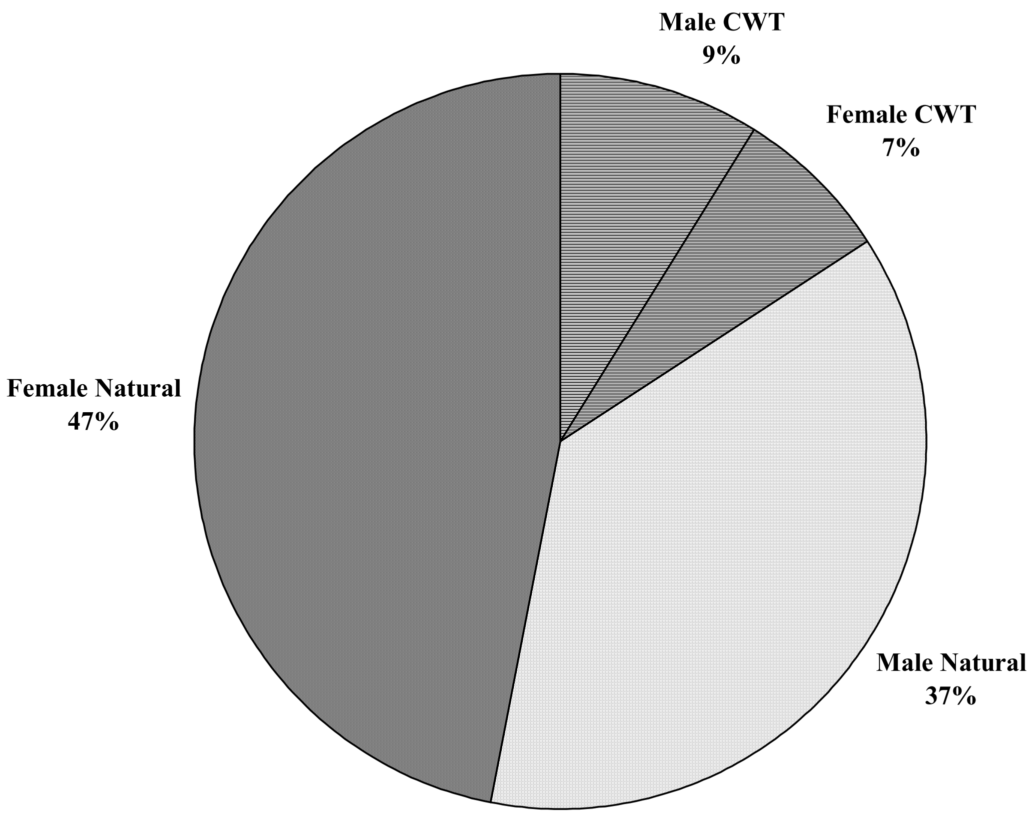

Figure 12. Contribution of male natural, male CWT, female natural, and female CWT to the 2001 Tuolumne River escapement.

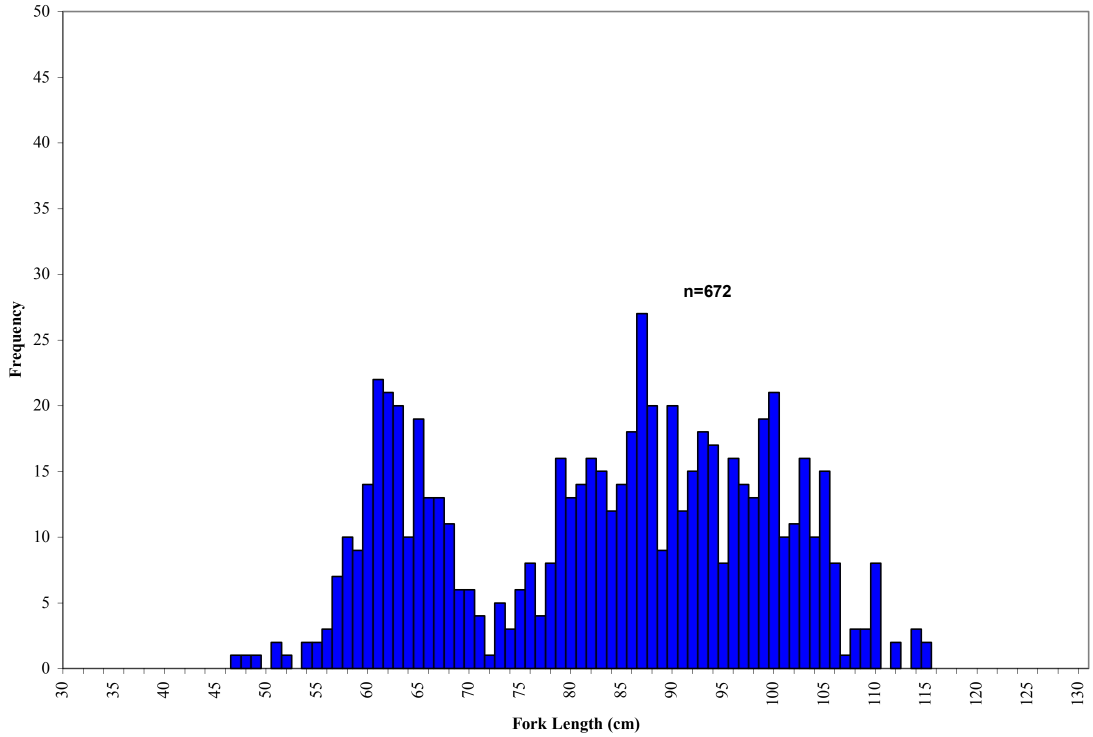

Figure 12. Length frequency histogram of natural male chinook salmon.

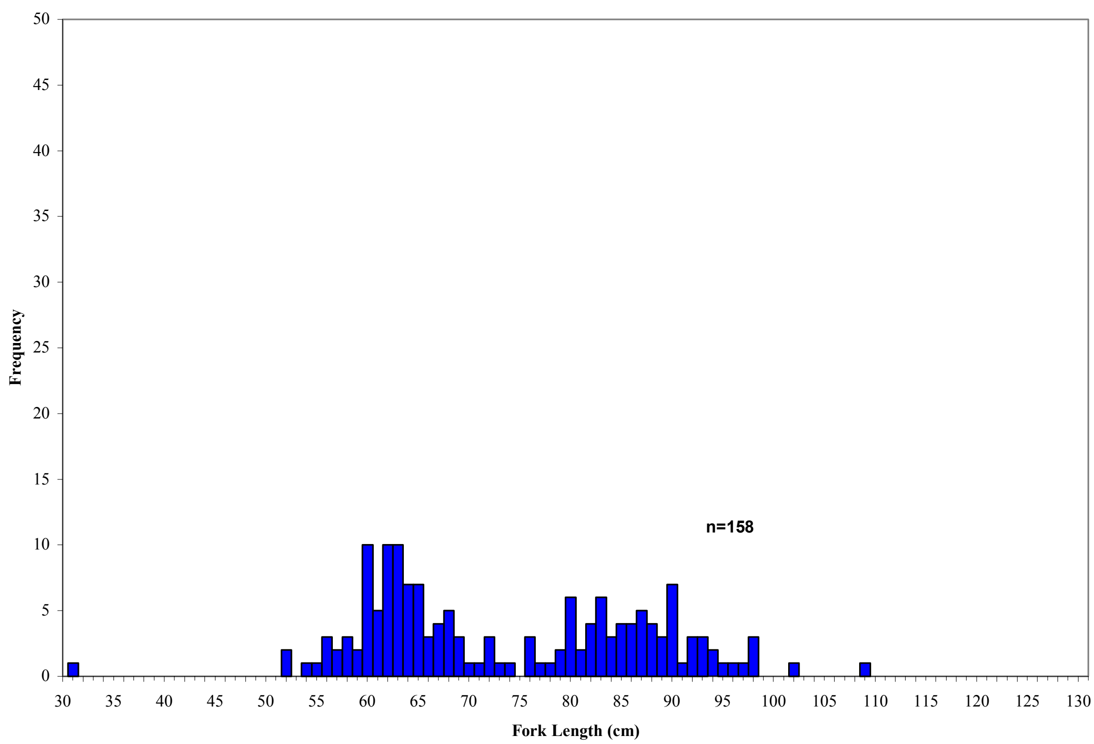

Figure 13. Length frequency histogram of CWT male chinook salmon.

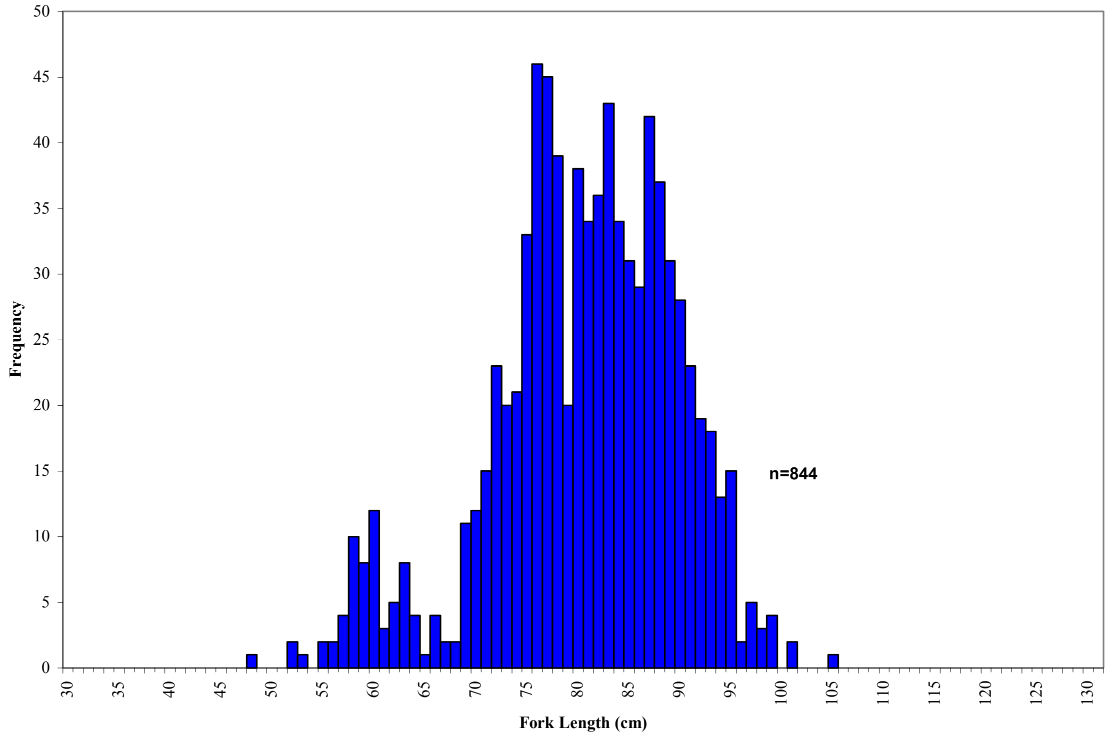

Figure 14. Length frequency histogram of natural female chinook salmon.

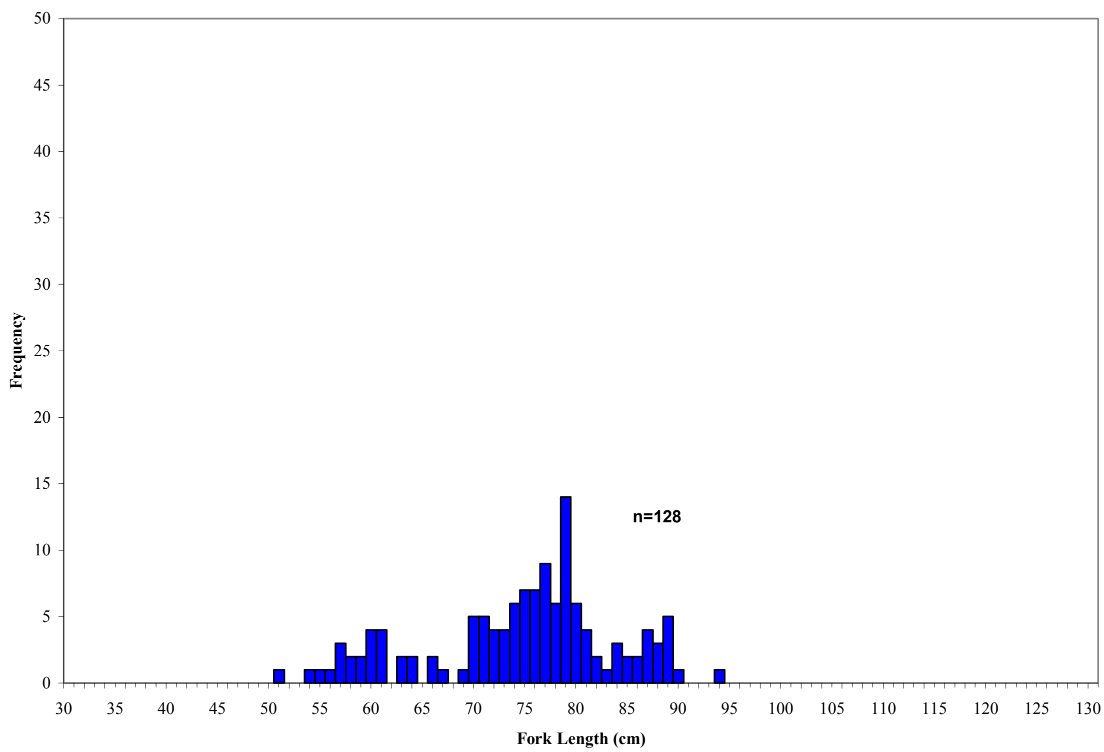

Figure 15. Length frequency histogram of CWT female chinook salmon.

References

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