Lower Yuba River Accord Monitoring and Evaluation Plan

Annual Vaki Riverwatcher Report

March 1, 2008 – February 28, 2009

Prepared for: The Lower Yuba River Accord Planning Team

by

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Pacific States Marine Fisheries Commission

The information contained in this annual data report represents study results at the date of publication. Recent analysis using multi-year data have fostered a more up-to-date understanding of lower Yuba River fisheries interactions. The results presented in this annual data report may or may not represent the current understanding stemming from recent analysis using comprehensive multi-year data. Please refer to the M&E Interim Report for a more recent analysis and discussion.

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1. INTRODUCTION

The lower Yuba River Accord (Accord) consists of a Fisheries Agreement and several other elements. The Fisheries Agreement includes descriptions of the River Management Team (RMT), the River Management Fund (RMF), and the Monitoring and Evaluation Plan. The Fisheries Agreement in its entirety can be found on the RMT website[1].

The RMT Planning Group includes representatives of the California Department of Fish and Game (CDFG), National Marine Fisheries Service, Pacific Gas and Electric, U.S. Fish and Wildlife Service, Yuba County Water Agency, and one representative for the four non-government organizations (Friends of the River, South Yuba River Citizen's League, The Bay Institute and Trout Unlimited) that are parties to the Fisheries Agreement. The RMT planning group has developed a Monitoring and Evaluation Plan (M&E Plan) to guide study efforts through the efficient expenditure of RMF funds.

Multiple survey techniques will be utilized to address the specific analytics that are necessary to evaluate the performance indicators detailed in the M&E Plan. Infrared-imaging technology was used to monitor fish passage at Daguerre Point Dam (DPD) in the lower Yuba River using Vaki Riverwatcher systems to document specific observations addressing VSP parameters of adult abundance and diversity. Monitoring objectives included: 1) abundance estimation of spring-, fall-, and late fall-run Chinook salmon and steelhead trout[2] above DPD;, 2) identification of temporal distributions of immigrating spring-, fall-, and late fall-run Chinook salmon and steelhead trout above DPD;, 3) identify population-level diversity from length-frequency distributions for Chinook salmon and steelhead trout;, 4) identify the age structure of Chinook salmon and steelhead trout populations from observed length-frequency distributions;, 5) examine annual and multi-year trends in the temporal periodicity of immigrating Chinook salmon and steelhead trout above DPD;, and 6) evaluation of potential relationships between water temperature, flow, and the timing of adult salmonid immigration.

2. METHODS

2.1. Vaki Riverwatcher Systems Operation

The Vaki Riverwatcher systems were operated and maintained in strict accordance with the Specific Protocols and Procedures for Vaki Riverwatcher Monitoring (Appendix F of the Accord M&E Plan). The survey period for Chinook salmon and steelhead trout was defined as March 1, 2008 through February 28, 2009.

Vaki Riverwatcher system (Vaki systems) operation was described by daily (24-hour period) and monthly percent operation. Vaki Riverwatcher systems non-operation events were classified by three categories; low-voltage disconnections (LVD), system maintenance or unknown malfunctions. Daily passage events for upstream, downstream and net counts for Chinook salmon and steelhead trout were plotted. Net

[1] http://www.yubaaccordrmt.com/

[2] Steelhead trout refers to the species, *Oncorhynchus mykiss,* regardless of anadromous, potadromous or resident life history.

upstream passage for Chinook salmon was defined as the total number Chinook salmon that passed upstream minus the total number that passed downstream.

2.2. Fish Community

Total net passage at DPD for each fish species was enumerated. Total net passage for each species was defined as the total number fish that passed upstream minus the total number of fish that passed downstream. Upstream and downstream passages were listed separately for Chinook salmon and steelhead trout. Fractional passage at the North and South fish ladders for each species was calculated.

2.3. Abundance

Total net upstream passage for Chinook salmon (adipose fin clipped, adipose fin present, and adipose fin undetermined) and steelhead trout was calculated by summing daily net passage for the survey period (March 1, 2008 - February 28, 2009). The presence of an adipose fin clip was not examined for steelhead trout, as the Vaki systems could not provide sufficient image resolution for identification of morphological characters for this species.

2.4. Diversity

The temporal distribution of Chinook salmon and steelhead immigrating upstream of DPD was examined using frequency histograms for daily upstream, downstream and net passage for Chinook salmon and steelhead trout.

The size structure of Chinook salmon and steelhead trout was examined using length-frequency histograms and descriptive statistics from net passage observations.

The proportion of Chinook salmon adults and grilse was calculated. Chinook salmon grilse were defined as having a total length < 65 cm. This length has been used to separate grilse from adults in the lower Yuba River since 1997 (Jones & Stokes 1998).

Modal distributions of length frequency were examined to describe the age structure of the Chinook salmon population. Data were separated for each category of Chinook salmon (i.e., adipose fin present, adipose fin clipped, and adipose fin undetermined). Length-frequency distributions for Chinook salmon were compared with known length-at-age ranges observed from carcass sampled during a 2008-2009 mark-recapture carcass survey. Minimum, mean, and maximum length (cm) was calculated for each age class.

A scatter-plot of the cumulative distribution of the observed net upstream passage of Chinook salmon and steelhead trout above DPD was developed for the study period (March 1, 2008 through February 28, 2009). A generalized logistic function (Richards 1959) was used to describe the relationship:

$$\sum_{i=1}^{Di=n} Y_i = \left(\frac{1}{1 + \exp(\alpha + \beta \times D_i)} \right)^{\frac{1}{\delta}};$$

Where $\sum_{i=1}^{Di=n} Y_i$ is the net passage of Chinook salmon or steelhead trout upstream of DPD from the start of the survey period through the end of the survey period D_i; and α, β, and δ are parameters that describe the shape of the resulting logistic function.

3. RESULTS

3.1. Vaki Riverwatcher Systems Operation

The Vaki systems monitored fish passage at DPD from March 1, 2008 through February 28, 2009. The North and South Vaki systems operated without interruption for 306 and 297 days, respectively. The North system had 59 separate system failure events during the survey period. The maximum number of days with continuous monitoring for the North Vaki system was 105 days (August 21, 2008 to December 3, 2008). The South system experienced 68 separate system failure events during the survey period. The maximum period of continuous monitoring for the South Vaki system was 97 days (May 20, 2008 to August 24, 2008).

The Vaki systems were least reliable during January 2009; operating 21.6 of 31 available days (69.6%). The Vaki systems were online greater than 90% of the available monitoring hours during the survey period (Table 1). The combined percentage of operation for both Vaki systems during the survey period was 90.7%.

Table 1. Vaki Riverwatcher system operation.

North Ladder	Days of Operation	Days Possible	% Operation
Mar-08	30.9	31	99.6
Apr-08	29.9	30	99.6
May-08	30.9	31	99.6
Jun-08	28.3	30	94.2
Jul-08	28.0	31	90.3
Aug-08	29.3	31	94.4
Sep-08	30.0	30	100.0
Oct-08	31.0	31	100.0
Nov-08	30.0	30	100.0
Dec-08	22.5	31	72.6
Jan-09	18.4	31	59.3
Feb-09	21.8	28	77.7

South Ladder	Days of Operation	Days Possible	% Operation
Mar-08	28.0	31	90.3
Apr-08	30.0	30	100.0
May-08	27.8	31	89.5
Jun-08	30.0	30	100.0
Jul-08	31.0	31	100.0
Aug-08	30.9	31	99.6
Sep-08	25.3	30	84.2
Oct-08	29.3	31	94.4
Nov-08	26.5	30	88.3
Dec-08	23.9	31	77.0
Jan-09	24.8	31	79.8
Feb-09	24.3	28	86.6

Most non-operational events for the North Vaki system were caused by unknown malfunctions totaling 321 hours offline. The system was also offline due to maintenance and LVD for 12 hrs and 32 hrs, respectively. LVD was the cause of most (519 hrs) non-operational events with the South Vaki system. The South Vaki system was offline due to maintenance and unknown malfunctions for 15 hrs and 27 hrs, respectively.

3.2. Fish Community Composition

Chinook salmon comprised the majority of net upstream passage recorded by the Vaki Riverwatcher systems (59.0%). Steelhead trout represented 13.1%, whereas Sacramento sucker (11.6%), Sacramento pikeminnow (6.2%), hardhead (0.6%) and unidentified species (9.6%) accounted for the remainder of the sample (Table 2). The North ladder accounted for 79.8% of the total net passage at DPD observed for all species (Table 3), including 88.0% of the observed Chinook salmon and 58.2% of the observed steelhead trout passage.

Table 2. Monthly net fraction of total observed passage at Daguerre Point Dam by species.

N. and S. Ladders	Chinook salmon	Steelhead trout	Sacramento sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	2	60	153	31	0	103	349
April	2	23	137	101	10	46	319
May	104	17	64	88	13	17	303
June	192	105	16	18	1	20	352
July	179	32	8	5	0	28	252
August	272	5	2	4	0	0	283
September	694	8	-1	2	0	11	714
October	439	33	0	0	0	16	488
November	183	51	0	1	0	7	242
December	164	30	0	0	0	2	196
January	82	70	3	0	0	38	193
February	74	95	89	1	0	99	358
Net Total	2387	529	471	251	24	387	4049
% Total	59.0%	13.1%	11.6%	6.2%	0.6%	9.6%	100.0%

Table 3. Monthly net fraction of observed passage at the north and south ladders at Daguerre Point Dam by species.

North Ladder	Chinook salmon	Steelhead trout	Sacramento sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	1	51	105	28	0	70	255
April	1	18	108	98	10	44	279
May	99	6	51	77	13	17	263
June	187	5	16	13	1	15	237
July	170	1	6	3	0	19	199
August	263	3	2	2	0	5	275
September	570	6	0	2	0	-4	574
October	362	27	0	0	0	9	398
November	169	42	0	1	0	6	218
December	135	22	0	0	0	3	160
January	78	48	1	0	0	17	144
February	65	79	25	1	0	59	229
Net Total	2100	308	314	225	24	260	3231
% Ladder	88.0%	58.2%	66.7%	89.6%	100.0%	67.2%	79.8%

South Ladder	Chinook salmon	Steelhead trout	Sacramento sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	1	9	48	3	0	33	94
April	1	5	29	3	0	2	40
May	5	11	13	11	0	0	40
June	5	100	0	5	0	5	115
July	9	31	2	2	0	9	53
August	9	2	0	2	0	-5	8
September	124	2	-1	0	0	15	140
October	77	6	0	0	0	7	90
November	14	9	0	0	0	1	24
December	29	8	0	0	0	-1	36
January	4	22	2	0	0	21	49
February	9	16	64	0	0	40	129
Net Total	287	221	157	26	0	127	818
% Ladder	7.1%	5.5%	3.9%	0.6%	0.0%	3.1%	20.2%

3.3. Abundance

Observed net upstream passage of Chinook salmon and steelhead trout above DPD during the survey period was 2,387 and 529, respectively. Of the 2,387 total Chinook salmon, 2,080 (87.1%) had an adipose fin and 259 (10.8%) were adipose fin clipped (Table 4). The presence of an adipose fin could not be determined for 49 (2.1%) of the observed Chinook salmon.

Table 4. Monthly net fraction of Chinook salmon (adipose present, adipose clipped and adipose unknown) observed passage at the north and south ladders at Daguerre point Dam.

	Chinook Salmon			
	Adipose present	Adipose clipped	Adipose Unknown	Total
March	0	2	0	2
April	2	0	0	2
May	97	6	1	104
June	190	2	0	192
July	177	1	1	179
August	266	1	5	272
September	649	37	8	694
October	408	27	4	439
November	166	16	1	183
December	79	76	9	164
January	18	54	10	82
February	28	35	11	74
Total	2080	257	50	2387
% of Total	87.1%	10.8%	2.1%	100.0%

3.4. Diversity

Chinook salmon were observed migrating upstream of DPD during all months of the survey period. The majority of Chinook salmon passage was observed in September and October (Figure 1). Chinook salmon that exhibited spring-run phenotypic characteristics (i.e. early run timing, sexually undifferentiated, relatively small body size compared with fall- and late fall-runs) were first observed migrating upstream of DPD in March 2008. Phenotypic spring-run Chinook salmon (SRCS) were observed in the DPD fish ladders from March through April, with peak passage observed during mid-June 2008.

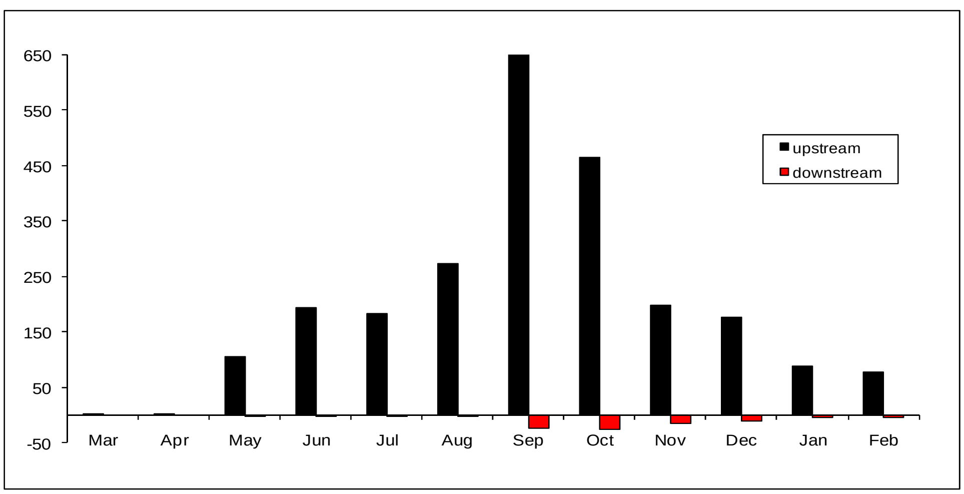

Figure 1. Monthly Chinook salmon net passage observed at Daguerre Point Dam.

Steelhead trout were also observed migrating upstream of DPD during all months of the survey period (Figure 2). The majority of steelhead trout were observed in June 2008, and from October 2008 through February 2009. The fewest steelhead trout were observed in August 2008.

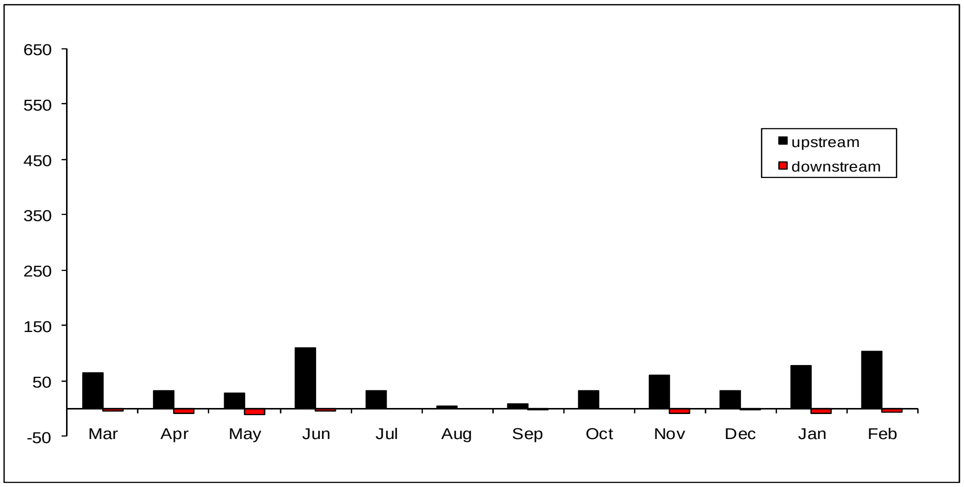

Figure 2. Monthly steelhead trout net passage observed at Daguerre Point Dam.

Chinook salmon from all categories (adipose fin present, adipose fin clipped and adipose fin undetermined) ranged in length from 18 cm to 111 cm (Figure 3). The average length was 77 cm (±0.56 cm; 95% CI) and median length was 78 cm. The most frequently observed length was 79 cm (Table 5).

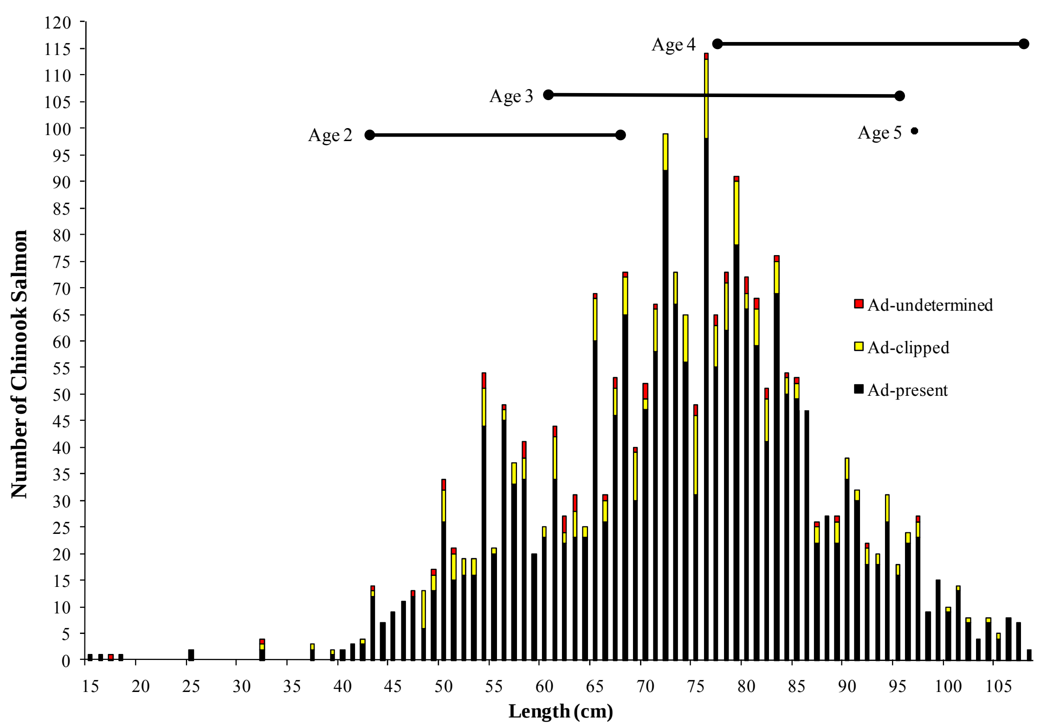

Figure 3. Length frequency of Chinook salmon (adipose fin present, adipose fin clipped, or adipose fin undetermined) observed upstream of Daguerre Point Dam in the lower Yuba River, CA from 3/1/2008-2/28/2009; and range of lengths at age for Chinook salmon carcasses sampled during the 2008-2009 carcass survey on the lower Yuba River (B. Kormos, CDFG, Pers. Comm., 2010).

Table 5. Chinook salmon and steelhead trout lengths and descriptive statistics from Vaki Riverwatcher systems at Daguerre Point Dam.

	Chinook Salmon				
Length (cm)	Adipose Present	Adipose Clipped	Adipose Unknown	All	Steelhead
Mean	77	75	71	77	36
Median	78	77	72	78	36
Mode	79	79	65	79	21
Minimum	18	40	32	18	18
Maximum	111	108	100	111	74
95% CI for Mean	0.59	1.68	3.84	0.56	1.06
SD	13.85	13.77	14.34	13.89	12.51
CV	0.18	0.18	0.20	0.18	0.35

Chinook salmon with an intact adipose fin ranged in length from 18 cm to 111 cm. The average length was 77 cm (±0.59 cm; 95% CI) and median length was 78 cm. The most frequently observed length was 79 cm.

Adipose fin clipped Chinook salmon ranged in length from 40 cm to 108 cm. The average length was 75 cm (±1.68 cm; 95% CI) and median length was 77 cm. The most frequently observed length was 79 cm.

The net fraction of all upstream migrating Chinook salmon above DPD identified as adults (≥ 65 cm) represented 80% of the total passage, whereas grilse accounted for 20%. Observations of adult and grilse Chinook salmon in each independent category followed similar distributions. Adults comprised 77% and 80% of adipose fin clipped and adipose fin unclipped Chinook salmon observed, respectively.

Steelhead trout length ranged from 18 cm to 74 cm (Figure 4). The average length was 36 cm (±1.06 cm 95% CI) and median length was 36 cm (Table 5). The most observed length was 21 cm.

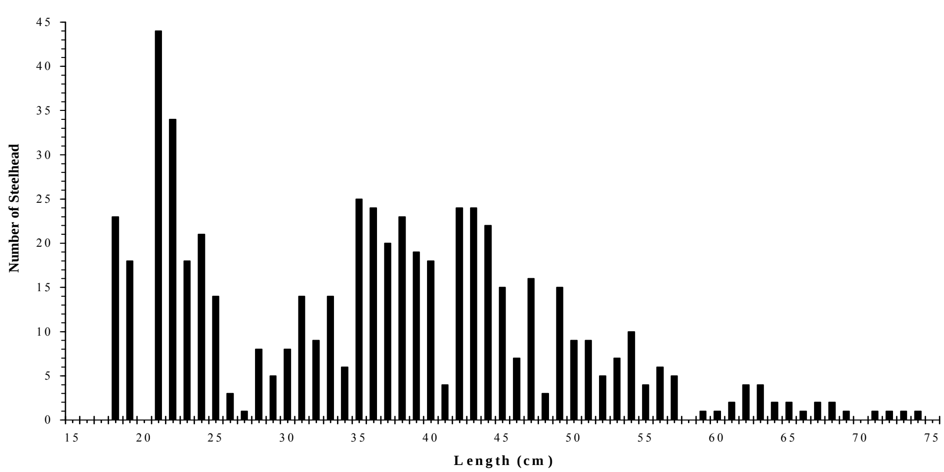

Figure 4. Length frequency of steelhead trout with net passage upstream at Daguerre Point Dam in the lower Yuba River, CA from 3/1/08-2/28/09.

4. DISCUSSION

The Vaki Riverwatcher systems were able to record and identify the timing and magnitude of passage for multiple species at DPD during most temporal periods, although system failures reduced the ability of the equipment to document ladder use during some months. Most system failures were caused by LVD. LVD events occurred when the electrical demands of the Vaki Riverwatcher systems exceeded photovoltaic power generation and/or storage (e.g. system voltage dropped below 11.7 volts). The units were also occasionally disconnected for maintenance by fishery technicians (e.g. battery recharging, camera lens cleaning, etc.). Other malfunctions were observed in which no direct explanations for system disconnect could be diagnosed.

LVD often affected system operation during the winter months as a result of low photovoltaic power generation and a lack of capacity to store sufficient power to bridge periods of low photoperiod caused by fog, rain, etc. In contrast, LVD occurred less frequently during the fall months (September – November), but other unidentified malfunctions resulted in system downtime during this period. Although the definitive causes of these unidentified system malfunctions were unknown, the periods of non-operation were suspected to be the result of data processing limitations. Multiple sustained passage events that coincided with peak fall-run Chinook salmon immigrations are thought to have exceeded the system's data processing capabilities. These unknown malfunctions ultimately resulted in multiple lapses of data continuity.

Since the Vaki systems at DPD were inoperable during much of January due to LVD, steelhead trout passages were likely missed. Data gaps caused by LVD were compounded by high water turbidity during winter storm flow events that made species identifications difficult. Surface runoff during winter storms often increased the level of suspended solids in the water column and decreased digital image resolution due to particle light reflection or backscatter. Although Chinook salmon can generally be identified from silhouettes alone, most positive steelhead trout identification required both a silhouette and a clear digital image. Digital image resolution was insufficient for positive steelhead trout identification during turbid winter flows and many passage events during this period were classified as unidentified. Additionally, downstream steelhead trout movement can only provide silhouettes without associated digital images, thus downstream movements are also often categorized as unidentified fish[3]. These steelhead trout identification limitations compounded existing system failures and hampered efforts to quantify Chinook salmon runs (i.e., spring-, fall-, and late fall-run), as well as to identify steelhead trout during known periods of passage. System failures during peak Chinook salmon and steelhead trout passage periods may have resulted in a truncation of observed versus actual asymptotic peaks. Davies *et al.* (2007) found that linear interpolation under this scenario exhibited substantial bias. Data presented in this report represent minimum passage for all species until data quality is improved.

Overall the migration timing and temporal passage distributions of Chinook salmon in the lower Yuba River were consistent with observations of spring- and fall-run Chinook salmon passage during previous monitoring efforts (Figure 5) and with observations from other Central Valley rivers. SRCS upstream migrations have been observed to peak in April and May in the upper Sacramento River and lower Yuba

[3] Does not include Chinook salmon. Chinook salmon are identifiable solely from silhouettes.

River (SWRI 2002; Vogel and Marine 1991), and have also been observed to occur in Mill Creek from March to June (Killam and Johnson 2008). Additionally, Yoshiyama *et al*. (2001) described spring-run migration to occur from April through June in the Sacramento River drainage. Of note, Chinook salmon were observed passing DPD through February 2009. This migratory timing is consistent with known periods of immigration for adult late fall-run Chinook salmon. Late fall-run Chinook salmon, although specific to the Sacramento River, have been known to spawn in other Sacramento River tributaries including the Feather and Yuba rivers (USFWS 1995). Their migration period has been documented to occur from October through April, and peaks in December (Moyle 2002). Coded-wire tag recoveries from carcasses collected from the Vaki weir structures in the ladders at DPD have been identified as late fall-run Chinook salmon from Coleman National Fish Hatchery.

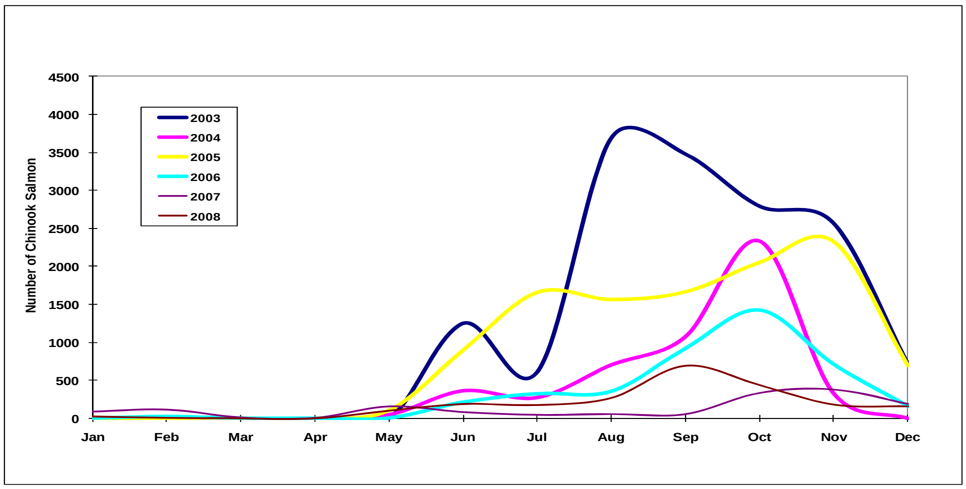

Figure 5. Minimum net Chinook salmon passage upstream of Daguerre Point Dam in the lower Yuba River, CA from January through December for years 2003-2008.

However, logistic function could not describe the cumulative distribution of observed daily net upstream passage of Chinook salmon at DPD (Figure 6).

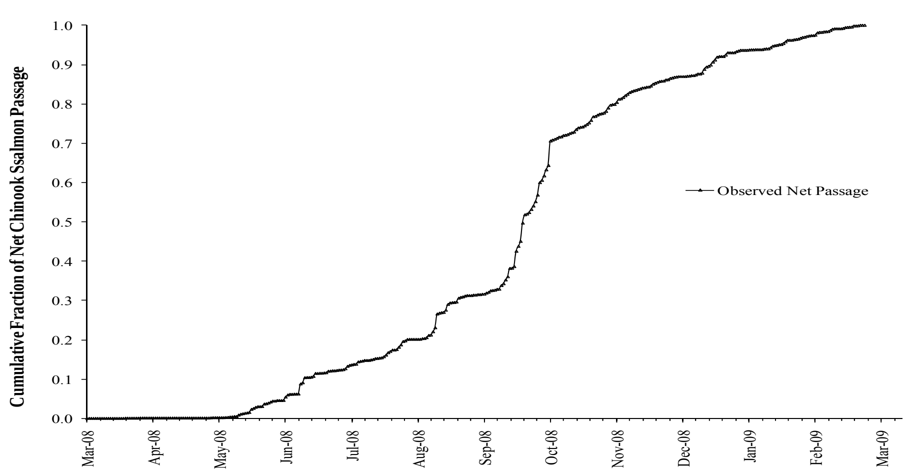

Figure 6. Cumulative fraction of net upstream passage of Chinook salmon at Daguerre Point Dam in the lower Yuba River, CA from 3/1/2008-2/28/2009.

Analytical attempts to converge on parameter estimates for the logistic function were unsuccessful. The logistic function likely does not describe Chinook salmon passage because multiple modes were observed during the survey period (Figure 7). Additionally, evidence from telemetry surveys of acoustically tagged SRCS suggest that the period in which this run enters the lower Yuba River may differ from the period in which passage at DPD was observed via the Vaki Riverwatchers. The telemetry surveys observed that acoustically tagged spring-run Chinook salmon spent an average of 41 days (95% CI of ± 12.8 days), and a maximum of 115 days in the plunge pool below DPD before moving upstream to spawn (Alber et al. 2011). Additionally, one-third of the tagged SRCS group ascended the ladders at DPD in August and September, and thus would have been incorrectly identified through phenotypic run timing as fall-run Chinook salmon (FRCS) because of the observed date of passage at the dam. Although analyses of modal distributions of Chinook salmon passage at the dam have identified run timing associated with SRCS and FRCS in the lower Yuba River that generally agree with known passage periods from other Central Valley streams, the temporal period in which some SRCS ascend DPD appears to be temporally disjunct from when this run actually enter the lower Yuba River, thus making identification run-specific temporal periods and abundance difficult to address.

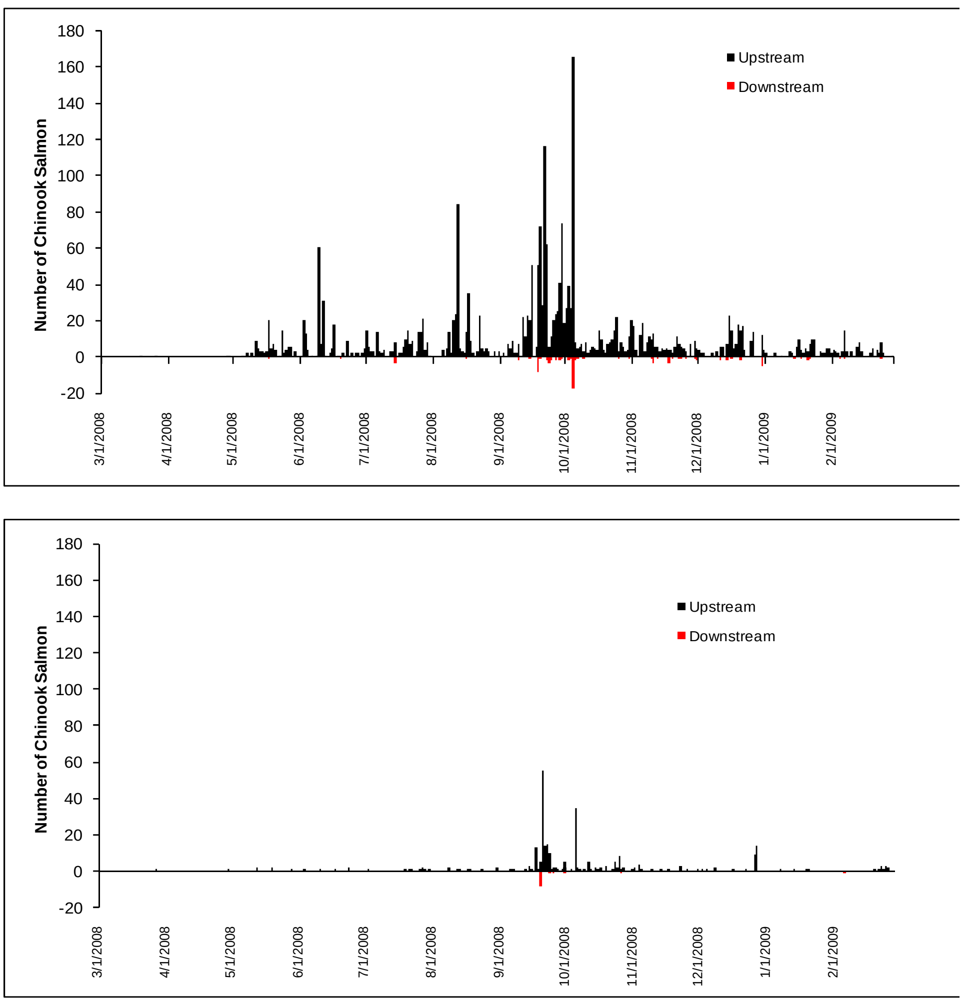

Figure 7. Daily upstream and downstream Chinook salmon passage observed at the North and South ladders of Daguerre Point Dam.

Length-frequency distributions for all Chinook salmon measured by the Vaki Riverwatcher systems were compared with known age distributions obtained from the CDFG Chinook Salmon Scale-Age Program results (CDFG, unpublished data). A total of 365 scale samples were collected during the 2008 escapement survey to obtain estimates of age structure for lower Yuba River Chinook salmon. The length distribution for age-3 Chinook overlapped with age-2 and age-4 fish (Table 6). Observations from the 2008 escapement survey identified that 12% of the Chinook salmon population were age-2 grilse (Massa et al. 2010b). This observation followed closely the results from scale-aging data from that year which identified 12.6% of the 2008 escapement to be comprised of grilse. In contrast, Vaki Riverwatcher observations using a 65 cm cutoff identified that 20% of Chinook salmon were age-2. Explanations for this observed discrepancy could likely be described by either of the following two scenarios; 1) mark-recapture carcass survey observations could under represent age-2 Chinook salmon due to a lower probability of detection due to small physical size;, or 2) length measurements from the Vaki systems are estimated from a body depth measurement and the defined length-to-depth ratio was not an actual measure of length. Since the length-to-depth ratio is an average of morphometric measurements and represents an amalgam of different age classes and sexually dimorphic characteristics, the system could have inaccurately estimated the size of small and large Chinook salmon proportionately with their distribution around a mean length. However, bioverification of estimated Chinook salmon lengths from a Vaki Riverwatcher system on the Stanislaus River found the estimated lengths to be greater than 95% accurate (J. Anderson, Cramer Fish Sciences, pers. comm.., 2010). Although a speculative conclusion, the authors suspect that the Vaki Riverwatcher systems are simply better equipped to observe grilse-sized Chinook salmon than a field surveyor using methods derived from an annual escapement survey.

Table 6. Chinook salmon scale-aging results from the 2008 Escapement Survey.

Age -2	470 - 675 mm	n = 46 (12.6%)
Age -3	610 – 950 mm	n = 222 (60.8%)
Age -4	785 – 1,100 mm	n = 96 (26.3%)
Age -5	970 mm	n = 1 (0.30%)

Passage observations of steelhead trout at DPD occurred during all months of the study period, with peak passage in June 2008. This observation contrasts results from other studies in the Central Valley which indicate that adult steelhead trout immigrate into Central Valley rivers from August through March (McEwan 2001; NMFS 2004), and peak during January and February (Moyle 2002). Baseline data for steelhead trout gathered from trapping studies conducted by Hallock (1989) in the mainstem Sacramento River above the Feather River confluence described migratory periods occurring from July through March, with peak occurrence during mid- to late-September (1989). Observations at the Red Bluff Diversion Dam from 1969-1982 also identified migration patterns that were dissimilar to lower Yuba River observations at DPD; adult immigration began in July and extended into May (Hallock 1989). Data from the Feather River observed adult steelhead trout immigration from November to April with peak occurrence from November through January (McEwan and Jackson 1996).

Passage observations during January and February were suspected to misrepresent actual steelhead trout passage at DPD because of multiple LVD events during this period resulting in unmonitored passage. The Vaki Riverwatcher systems were inoperable 30.4% of the available monitoring hours in January 2009. Additionally, turbidity caused by suspended sediments often obscure camera images during winter storm flows, thus making positive species identification for steelhead trout difficult during these periods. Analytical attempts to fit a logistic function to observed passage could not describe the cumulative distribution of daily net upstream passage for steelhead trout at DPD during the survey period (Figure 8).

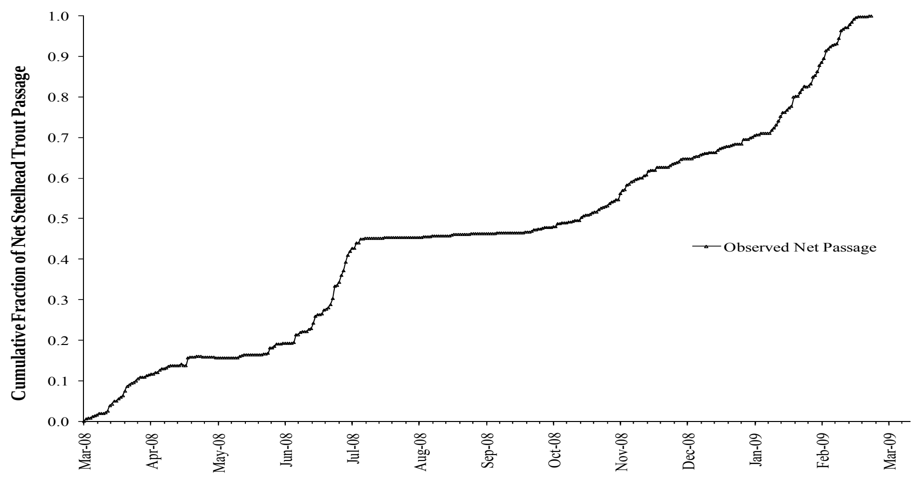

Figure 8. Cumulative fraction of net upstream passage of steelhead trout at Daguerre Point Dam in the lower Yuba River, CA from 3/1/2008-2/28/2009.

Two recent reports (Zimmerman et al. 2008, Mitchell 2010) concluded that the lower Yuba population of steelhead trout contains a relatively low proportion of anadromous individuals. Zimmerman et al. (2008) used otolith microchemistry to evaluate the maternal origin of juvenile steelhead trout from the Central Valley. Of 141 fish collected from the Yuba River between 2001 and 2007, 13% were of anadromous origin. Mitchell (2010) used scale analysis to investigate the life history characteristics of steelhead trout in the lower Yuba River; he determined from a limited sample of migrating adults from ladder trapping at Daguerre Point Dam that 14% of these fish were anadromous, whereas 1% of the fish captured by angling methods were identified as anadromous. The relative proportion of resident steelhead trout occurring in the Yuba River may explain the apparent misalignment (June) with known immigration periods, since the Vaki systems did observe larger steelhead trout (> 40.6 cm) passing DPD during the winter months (December through February). This observation is similar to known Feather River migrations from McEwan and Jackson (1996) and from adult counts at Clough Dam on Mill Creek for a 10-year period beginning in 1953 that indicated the adult steelhead trout peak migration occurred in late-October, with a smaller peak in mid-February (McEwan 2001). Additionally, the relatively high fraction of resident steelhead trout documented in the Yuba River by Zimmerman et al. (2008) and Mitchell (2010) do not reflect observations recorded prior or immediately following the construction of New Bullard's Bar Dam in 1969. For example, length-frequency data from steelhead collected in the lower Yuba River from 1968-1970 (Wooster and Wickwire 1970), observed a mean length for steelhead of 56 cm, whereas fish collected after completion of New Bullards in 1976-1977 (CDFG unpublished data) a mean length of 63 cm (excluding fish < 35.6 cm), possibly indicating an observed shift in expressed phenotypic life history traits. Since system failures caused by LVD were prevalent during these winter migration periods, a relative uncertainty exists that the temporally-fragmented picture of lower Yuba River steelhead trout passage provided by the Vaki Riverwatcher systems accurately explains actual migratory patterns.

Additional inquiry into these seemingly anomalous steelhead trout observations provided additional insight. In an attempt to address this issue, the observed steelhead passage at the north and south ladders at DPD were viewed outside of the context of net passage. The actual upstream and downstream passages were assembled and illustrated separately for each ladder (Figure 9). Only 8.7% of the observed passages for steelhead trout were categorized as downstream movements. The north and south ladders accounted for 43 (10.9%) and 13 (5.3%) of all downstream steelhead trout passages, respectively. This observation is likely an artifact of the Vaki system's difficulty in identifying downstream movements for species other than Chinook salmon. Downstream steelhead trout movements are currently identified using multiple indicators, since their silhouettes have been found to resemble other native lower Yuba River fishes of the same size. For a positive downstream identification to occur, a steelhead trout must first be observed moving upstream through one of the Vaki systems, thus capturing an associated silhouette and digital image. Downstream movements are identified by comparing the silhouette associated with the downstream passage with the preceding upstream silhouette. Additionally the temporal proximity of the downstream passage to the original upstream passage must agree with the event timestamp (i.e. the downstream passage must occur temporally proximal to the upstream passage for each individual steelhead trout). In short, for a downstream steelhead trout passage to be identified the fish must provide an identical silhouette and the time of passage must be temporally proximal to the original upstream record. In rare occasions, an exceptionally large steelhead trout can be identified by a silhouette alone. Individuals larger than 50 cm can provide a sufficient silhouette that contains the necessary characters for positive steelhead trout identification. Steelhead trout that move downstream through the Vaki systems cannot be positively indentified unless it recently moved upstream through the system and was identified, or if it was a rare individual in excess of 50 cm in length. The result of this data limitation is that steelhead trout downstream passages are the result of *same fish* passages only. Steelhead trout that move downstream through the ladders at DPD outside of these limited identification bounds were undoubtedly be recorded as an unidentified fish.

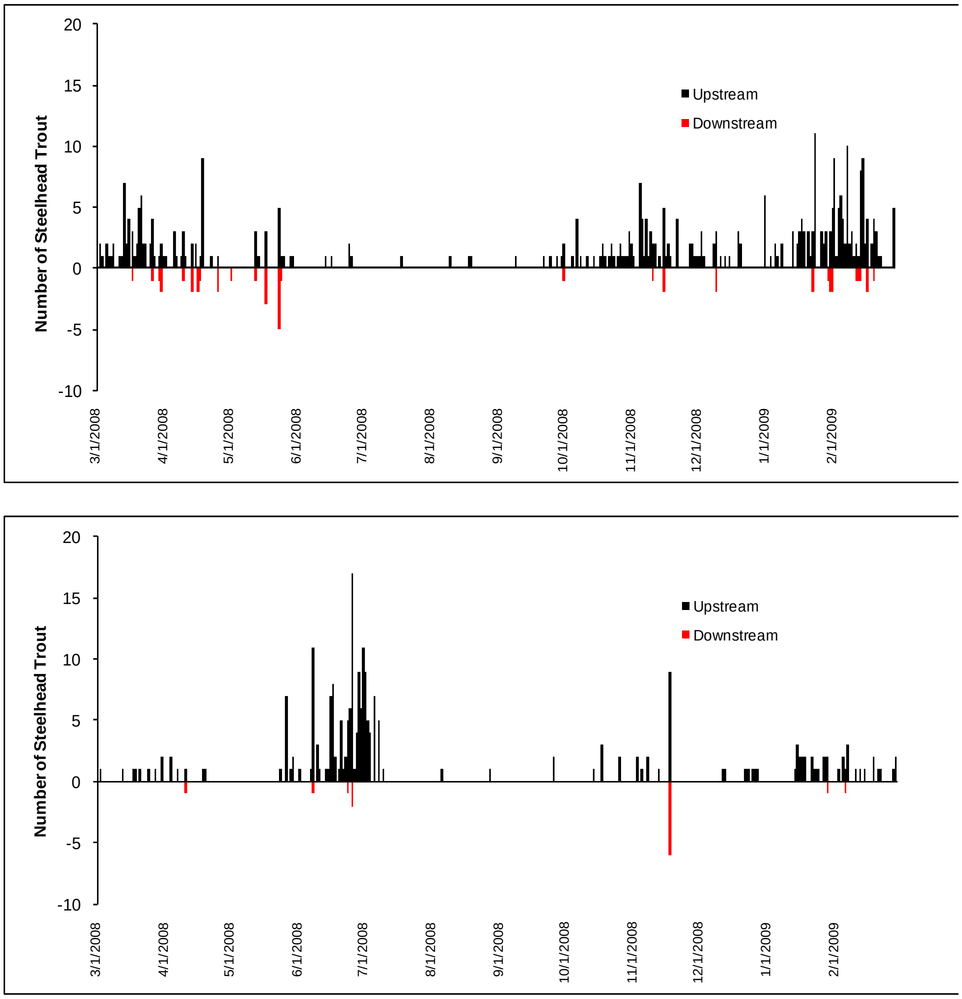

Figure 9. Daily upstream and downstream steelhead trout passage observed at the north and south ladders of Daguerre Point Dam.

5. REFERENCES

Davies, T.D., D.G. Kehler, and K.R. Meade. 2007. Retrospective sampling strategies using video recordings to estimate fish passage at fishways. North American Journal of Fisheries Management 27:992-1003.

Eilers, C. E., J. Bergman, and R., Nielson, 2010. A comprehensive monitoring plan for steelhead in the California Central Valley. California Department of Fish and Game Fisheries Branch, Administrative report number 2010-2.

Grover, A. and B. Kormos. 2008. The 2007 Central Valley Chinook Age Specific Run-Size Estimates. California Deparment of Fish and Game.

Hallock, R. J. 1989. Upper Sacramento River steelhead trout *Oncorhyachus mykiss*, 1952-1988. Report to USFWS.

Jones & Stokes Associates, Inc. 1998. 1997 fall-run Chinook salmon spawning escapements in the Yuba River. June 12, 1998. (JSA 97-238.) Sacramento, CA. Prepared for the Yuba County Water Agency, Marysville, CA.

Interagency Ecological Program Steelhead trout Project Work Team (IEPSPWT). 1998. Monitoring, assesement, and research on Central Valley steelhead trout: status of knowledge, review of existing programs, and assessment of needs.

Killam, D. 2008a. Results of the 2007 Cottonwood Creek video station fall-run Chinook salmon escapement. SRSSAP Technical Report No. 08-3.

Killam, D. 2008b.Results of the 2007 Cow Creek video station fall-run Chinook salmon escapement. SRSSAP Technical Report No. 08-2.

Killam, D. and M. Johnson. The 2007 Mill Creek video station steelhead trout and spring-run Chinook salmon counts. SRSSAP Technical Report No. 08-1.

Killam, D. and B. Kreb. Chinook salmon populations for the Upper Sacramento River Basin in 2007. SRSSAP Technical Report No. 08-4.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce. NOAA Technical Memo. NMFS-NWFSC-42, 156 pp.

McEwan, D. R. 2001. Central Valley steelhead trout in Contributions to the biology of Central Valley salmonids. R. L. Brown editor. Fish Bulletin 179. Contributions to the Biology of Central Valley Salmonids. Volumes 1 & 2. UC San Diego: Scripps Institution of Oceanography Library.

Massa, D. 2008. Lower Yuba River Chinook salmon escapement survey, October 2007-January 2008. California Department of Fish and Game.

Massa, D., J. Bergman, and R. Greathouse. 2010a. Lower Yuba River Accord Monitoring and Evaluation Plan annual Vaki Riverwatcher report March 1, 2007 – February 29, 2008. Prepared for the River Management Team.

Massa, D, J. Bergman, C. Campos, and C. Purdy. 2010b. Lower Yuba River Accord Monitoring and Evaluation Plan annual escapement report September 24, 2008 – December 23, 2008. Prepared for the River Management Team.

McEwan, D.R. and T. A. Jackson. 1996. Steelhead trout restoration and management plan for California. California Department of Fish and Game.

Mitchell, W.T. 2010. Age, Growth, and Life History of Steelhead Rainbow Trout (*Oncorhynchus mykiss*) in the Lower Yuba River, California. ICF Jones &Stokes, Inc.

Moyle, P.B. 2002. Inland fishes of California. Berkeley, CA: University of California Press.

NMFS. 2004. Biological opinion on the long-term Central Valley Project and State Water Project between April 1, 2002 and March 31, 2004, on Federally-listed threatened Central Valley spring-run

Chinook salmon and threatened Central Valley steelhead in accordance with Section 7 of the Endangered Species Act of 1973, as amended. Long Beach: National Marine Fisheries Service, Southwest Region

Satterthwaite, W. H., M. P. Beakes, E. M. Collins, D. R. Swank, J. E. Merz, R. G. Titus, S. M. Sogard, and M. Mangel. 2009. Steelhead life history on California's central coast: insights from a state-dependent model. Transactions of the American Fisheries Society 138: 532-548.

SWRI. 2002. Implementation plan for lower Yuba River: Anadromous fish habitat restoration (Draft – unpublished report).

USFWS. 1995. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Vol 2. Stockton, CA: U.S. Fish and Wildlife Service

Vogel, D. A. and K. R. Marine. 1991. Guide to upper Sacramento River Chinook salmon life history. U.S. Bureau of Reclamation Central Valley Project.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, P.B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. California Department of Fish and Game; Contributions to the biology of Central Valley salmonids. Vol. 1: 71-176.

Zimmerman, C. E., G. W. Edwards, and K. Perry. 2008. Maternal origin and migratory history of Oncorhynchus mykiss captured in the rivers of the Central Valley, California. Final report prepared for CDFG contract number P038530.