LOWER YUBA RIVER ACCORD MONITORING AND EVALUATION PLAN

ANNUAL VAKI RIVERWATCHER REPORT

MARCH 1, 2009 – FEBRUARY 28, 2010

Prepared for: The Lower Yuba River Accord Planning Team

by

Duane Massa, Jennifer Bergman and Ryan Greathouse

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, 2009 through February 28, 2010.

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

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

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

passage was defined as the total number of fish 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 of 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 (adipose fin clipped, adipose fin present and adipose fin undetermined) was calculated by summing daily net passage for the survey period (March 1, 2009 – February 28, 2010).

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 upstream 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 for Chinook salmon and steelhead trout. Age data from carcasses collected during the 2009-2010 carcass survey were not available to examine with the length frequency distributions. Length frequency data were separated for each category of Chinook salmon and steelhead trout (*e.g.*, adipose fin present, adipose fin clipped, and adipose fin undetermined).

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, 2009 - February 28, 2010). 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, 2009 through February 28, 2010. The North and South Vaki systems operated without interruption for 263 and 294 days, respectively. The North system had 102 separate system failure events during the survey period. The maximum number of days with continuous monitoring for the North Vaki system was 91 days (June 30, 2009 - August 30, 2009). The South system experienced 71 separate system failure events during the survey period. The maximum period of continuous monitoring for the South Vaki system was 144 days (July 26, 2009 - December 16, 2009).

The Vaki systems were least reliable during January 2010; operating on average 7.3 of 31 available days (23.4%). The Vaki systems were online greater than 82% 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 82.6%.

Table 1. Vaki Riverwatcher systems operation at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

North Ladder	Days of Operation	Days Possible	% Operation	South Ladder	Days of Operation	Days Possible	% Operation
Mar-09	22.6	31	73.0	Mar-09	29.3	31	94.4
Apr-09	28.4	30	94.6	Apr-09	30.0	30	100.0
May-09	20.6	31	66.5	May-09	24.0	31	77.4
Jun-09	29.9	30	99.6	Jun-09	29.9	30	99.6
Jul-09	31.0	31	100.0	Jul-09	30.9	31	99.6
Aug-09	30.9	31	99.6	Aug-09	31.0	31	100.0
Sep-09	24.6	30	82.1	Sep-09	30.0	30	100.0
Oct-09	24.8	31	79.8	Oct-09	31.0	31	100.0
Nov-09	26.4	30	87.9	Nov-09	30.0	30	100.0
Dec-09	20.0	31	64.5	Dec-09	23.1	31	74.6
Jan-10	3.4	31	10.9	Jan-10	11.1	31	35.9
Feb-10	25.3	28	90.2	Feb-10	14.4	28	51.3

Most non-operational events for the North Vaki system were caused by LVD totaling 978 hours offline. The system was also offline due to maintenance or unknown system errors for 204 hrs and 651 hrs, respectively. LVD was also the cause of most (765 hrs) non-operational events with the South Vaki system. The South Vaki system was offline due to maintenance or unknown system errors for 249 hrs and 207 hrs, respectively.

3.2. Fish Community Composition

Chinook salmon comprised the majority of net upstream passage recorded by the Vaki Riverwatcher systems (62.9%). Steelhead trout represented 4.2%, whereas Sacramento sucker (18.3%), Sacramento pikeminnow (7.2%), hardhead (0.3%) and unidentified species (7.1%) accounted for the remainder of the sample (Table 2). The North ladder accounted for 83.4% of the total net passage at DPD observed for all species (Table 3), including 95.7% of the observed Chinook salmon and 50% of the observed steelhead trout passage.

Table 2. Monthly net passage and total fraction for each species observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

N. and S. Ladders	Chinook salmon	Steelhead trout	Sacramento Sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	1	24	255	47	0	65	392
April	10	0	84	54	4	9	161
May	101	8	703	324	8	269	1413
June	462	18	17	37	2	32	568
July	190	58	35	8	2	10	303
August	582	41	24	7	2	13	669
September	1368	14	5	1	0	26	1414
October	1086	36	2	0	0	7	1131
November	286	4	0	4	0	1	295
December	126	7	0	1	0	3	137
January	59	4	3	0	0	14	80
February	45	76	128	9	0	39	297
Net Total	4316	290	1256	492	18	488	6860
% Total	62.9%	4.2%	18.3%	7.2%	0.3%	7.1%	100.0%

Table 3. Monthly net passage and total fraction for each species observed in the North and South fish ladders at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

North Ladder	Chinook salmon	Steelhead trout	Sacramento Sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	1	20	64	46	0	8	139
April	10	-3	16	41	4	-1	67
May	94	7	491	302	8	151	1053
June	453	7	15	25	2	26	528
July	189	5	32	6	1	13	246
August	552	8	19	1	2	14	596
September	1349	4	4	1	0	16	1374
October	988	13	0	1	0	6	1008
November	280	3	0	4	0	-3	284
December	124	6	0	1	0	1	132
January	46	2	2	0	0	6	56
February	44	73	96	9	0	14	236
Net Total	4130	145	739	437	17	251	5719
% Total	72.2%	2.5%	12.9%	7.6%	0.3%	4.4%	100.0%

South Ladder	Chinook salmon	Steelhead trout	Sacramento Sucker	Sacramento pikeminnow	Hardhead	Unidentified	Total
March	0	4	191	1	0	57	253
April	0	3	68	13	0	10	94
May	7	1	212	22	0	118	360
June	9	11	2	12	0	6	40
July	1	53	3	2	1	-3	57
August	30	33	5	6	0	-1	73
September	19	10	1	-3	0	10	37
October	98	23	2	2	0	1	126
November	6	1	0	0	0	4	11
December	2	1	0	0	0	2	5
January	13	2	1	0	0	8	24
February	1	3	32	0	0	25	61
Net Total	186	145	517	55	1	237	1141
% Total	16.3%	12.7%	45.3%	4.8%	0.1%	20.8%	100.0%

3.3. Abundance

Observed net passage of Chinook salmon and steelhead trout upstream of DPD during the survey period was 4,316 and 290, respectively. Of the 4,316 Chinook salmon, 3,462 (80.2%) had an adipose fin and 755 (17.5%) were adipose fin clipped (Table 4). The presence of an adipose fin could not be determined for 99 (2.3%) of the observed Chinook salmon. Of the 290 steelhead trout, 97 (33.4%) had an adipose fin and 36 (12.4%) were adipose fin clipped (Table 5). The presence of an adipose fin could not be determined for 157 (54.2%) of the observed steelhead trout.

Table 4. Monthly net passage and total fraction of Chinook salmon (adipose fin present, adipose fin clipped and adipose fin unknown) observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

Month	Adipose Present	Adipose Clipped	Adipose Unknown	Total
March	0	1	0	1
April	10	0	0	10
May	58	36	7	101
June	281	148	33	462
July	147	38	5	190
August	469	94	19	582
September	1108	235	25	1368
October	959	129	-2	1086
November	249	35	2	286
December	109	14	4	127
January	44	10	4	58
February	28	15	2	45
Total	3462	755	99	4316
% Total	80.2%	17.5%	2.3%	100.0%

Table 5. Monthly net passage and total fraction of steelhead trout (adipose fin present, adipose fin clipped and adipose fin unknown) observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

Month	Adipose Present	Adipose Clipped	Adipose Unknown	Total
March	18	0	6	24
April	-1	0	1	0
May	5	1	2	8
June	5	0	13	18
July	3	0	55	58
August	4	1	36	41
September	4	0	10	14
October	13	0	23	36
November	3	0	1	4
December	6	0	1	7
January	2	0	2	4
February	34	34	8	76
Total	96	36	158	290
% Total	33.1%	12.4%	54.5%	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 (*e.g.*, 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 2009 (n=1). Phenotypic spring-run Chinook salmon (SRCS) were observed in the DPD fish ladders from March through July, with peak passage observed during mid-June 2009.

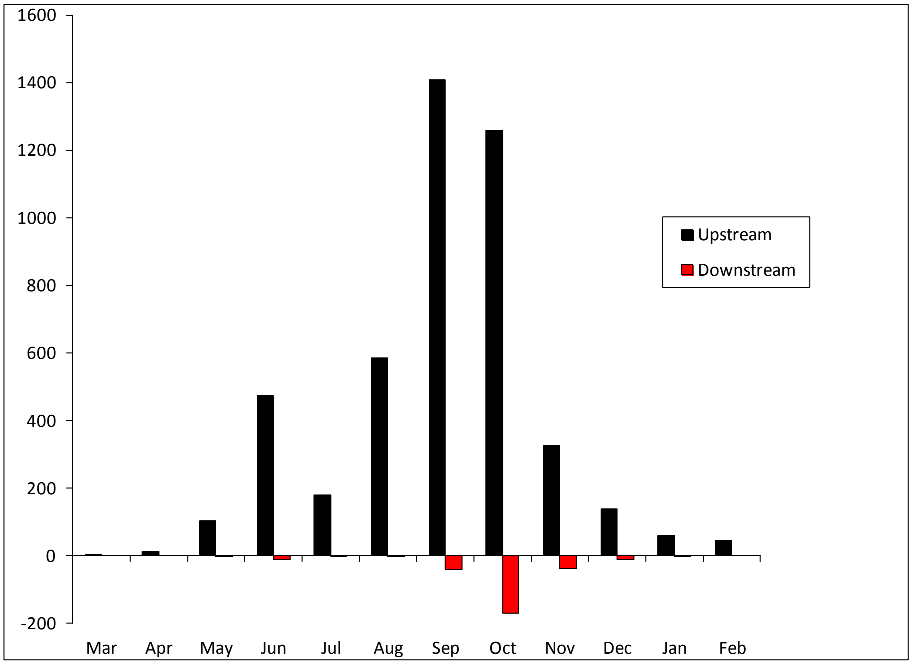


Figure 1. Monthly Chinook salmon upstream and downstream passage observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

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 February 2010. The fewest steelhead trout were observed in April through May 2009, and November through January 2010.

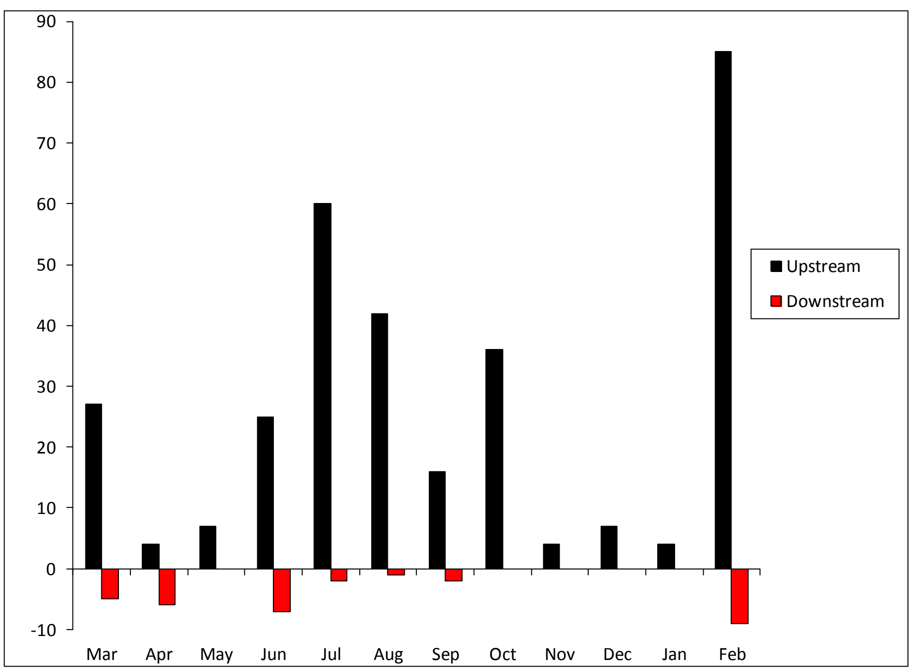


Figure 2. Monthly steelhead trout upstream and downstream passage observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

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 71 cm (0.43 cm; 95% CI) and median length was 71 cm. The most frequently observed length was 79 cm (Table 6).

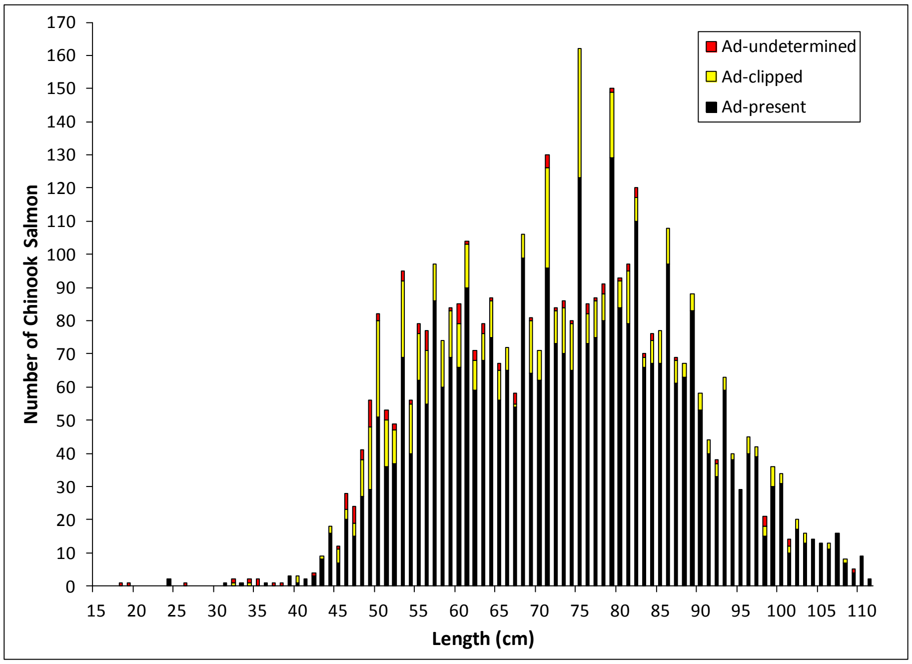


Figure 3. Length frequency of Chinook salmon (adipose fin present, adipose fin clipped, or adipose fin undetermined) observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

Table 6. Descriptive statistics for Chinook salmon and steelhead trout approximated lengths from the Vaki Riverwatcher systems at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

	Chinook Salmon				Steelhead trout			
Length (cm)	Adipose Present	Adipose Clipped	Adipose Unknown	All	Adipose Present	Adipose Clipped	Adipose Unknown	All
Mean	73	67	59	71	36	23	24	28
Median	73	66	57	71	36	22	22	23
Mode	79	75	49	79	39	23	21	21
Minimum	18	32	18	18	18	18	18	18
Maximum	111	108	109	111	60	48	57	60
95% CI for Mean	0.47	0.99	2.45	0.43	1.95	2.11	1.03	1.05
SD	15.09	14.54	16.33	15.39	10.53	6.60	7.34	10
CV	0.21	0.22	0.28	0.22	0.29	0.29	0.31	0.36

Chinook salmon with an intact adipose fin ranged in length from 18 cm to 111 cm. The average length was 73 cm (0.47 cm; 95% CI) and median length was 73 cm. The most frequently observed length was 79 cm.

Adipose fin clipped Chinook salmon ranged in length from 32 cm to 108 cm. The average length was 67 cm (0.99 cm; 95% CI) and median length was 66 cm. The most frequently observed length was 75 cm.

The net fraction of all upstream migrating Chinook salmon above DPD identified as adults (≥ 65 cm) represented 66.8% of the total passage, whereas grilse accounted for 33.2%. Observations of adults and grilse in each independent category exhibited dissimilar distributions. Adults comprised 53.0% and 70.6% of adipose fin clipped and adipose fin unclipped Chinook salmon observed, respectively.

Steelhead trout length ranged from 18 cm to 60 cm (Figure 4). The average length of all observed steelhead trout was 28 cm (±1.05 cm 95% CI) and median length was 23 cm (Table 6). The most observed length was 21 cm.

Steelhead trout with an adipose fin ranged in length from 18 cm to 60 cm. The average length was 36 cm (1.95 cm; 95% CI) and median length was 36 cm. The most frequently observed length was 39 cm.

Adipose fin clipped steelhead trout ranged in length from18 cm to 48 cm. The average length was 23 cm (2.11 cm; 95% CI) and median length was 22 cm. The most frequently observed length was 23 cm.

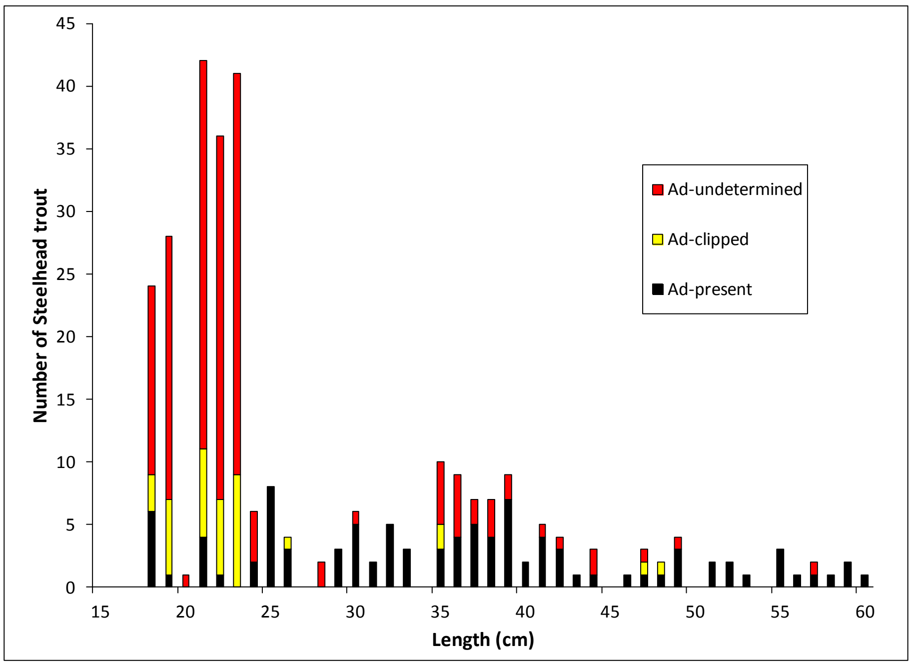


Figure 4. Length frequency of steelhead trout (adipose fin present, adipose fin clipped, or adipose fin undetermined) observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

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 (*i.e.* 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 including unknown system errors 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, or other light-reducing weather phenomon. In contrast, LVD occurred less frequently during the summer and fall, but other malfunctions resulted in system downtime during this period. Although the definitive causes of these latter 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 observations 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 were compounded by existing system failures and also 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. Generalized additive models or a Bayesian approach are recommended methods to fill data gaps for fish device counters (Bergman *et al.* 2011), whereas 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 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 2010. This migratory timing is consistent with known periods of immigration for 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

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

Feather and Yuba rivers (USFWS 1995). Their migration period has been documented to occur from October through April, and peaks in December (Moyle 2002). In the past, 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 (unpublished data).

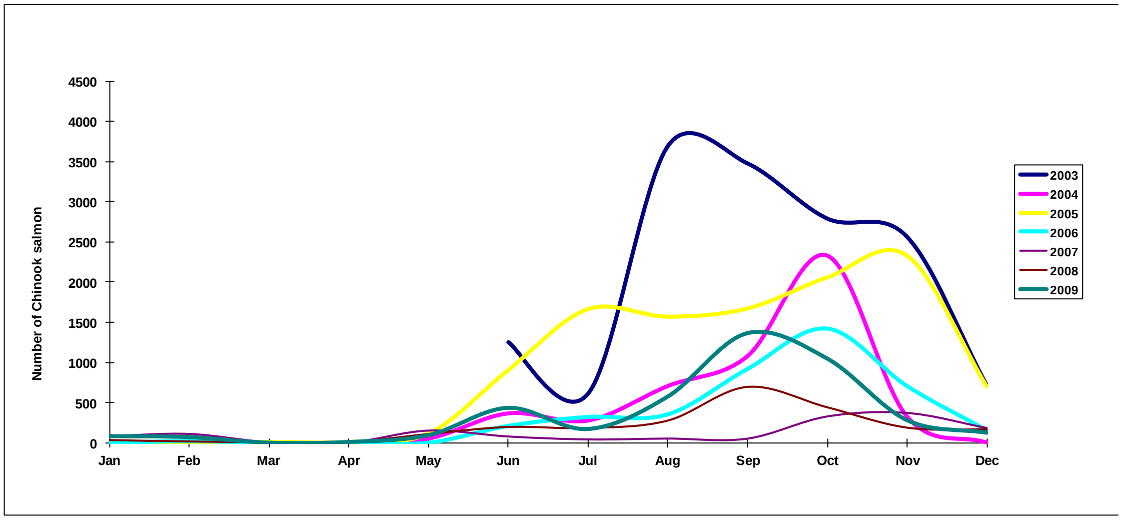


Figure 5. Net upstream Chinook salmon passage observed at Daguerre Point Dam in the lower Yuba River, CA from January through December for years 2003-2009.

A logistic function could not describe the cumulative distribution of observed daily net upstream passage of Chinook salmon at DPD (Figure 6). Analytical attempts to converge on parameter estimates for the logistic function were unsuccessful, likely because multiple modes in fish passage 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 when passage at DPD was observed via the Vaki Riverwatchers. In 2009, acoustically tagged SRCS spent an average of 41 days (95% CI of ± 12.8 days), and a maximum of 115 days in the DPD plunge pool before passing upstream of the dam (unpublished data). In 2010, acoustically tagged SRCS spent an average of 36 days (95% CI of ± 18 days), and a maximum of 111 days in the DPD plunge before passing upstream of the dam (unpublished data). Additionally, one-third (2009) and one-half (2010) of the tagged SRCS group that ascended the ladders at DPD occurred in August and September, and thus would have been incorrectly identified through phenotypic run timing as FRCS. Although analyses of modal distributions of Chinook salmon passage at DPD 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 they actually enter the lower Yuba River, thus making identification of run-specific temporal periods and abundance difficult to address from single year observations alone.

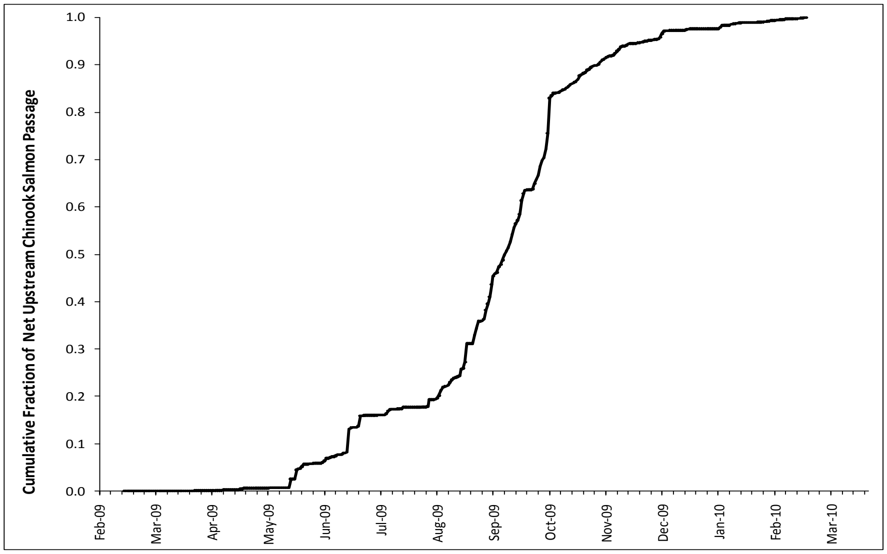
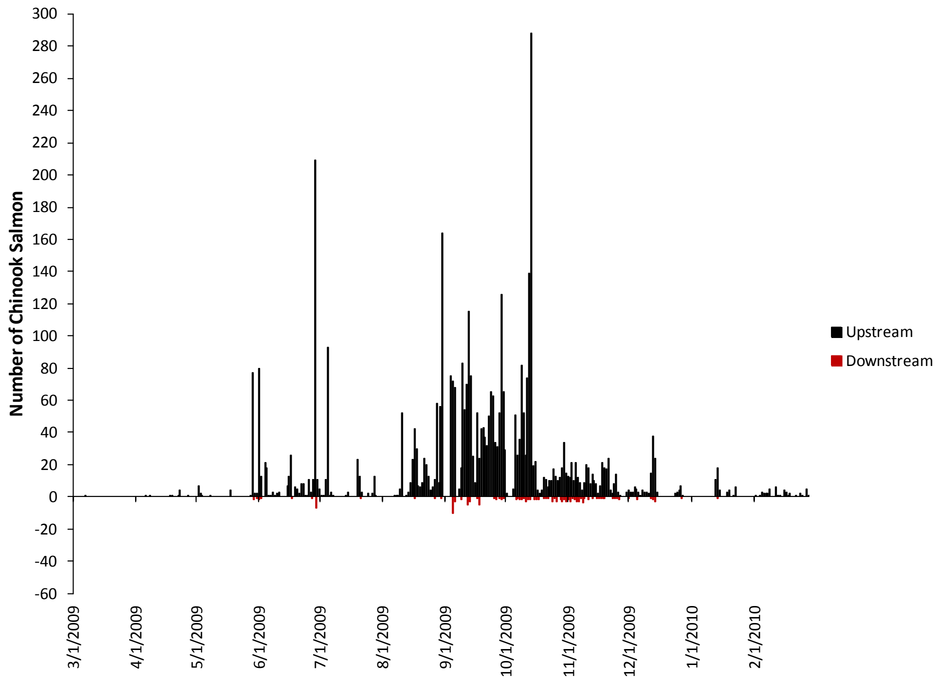


Figure 6. Cumulative fraction of net upstream passage of Chinook salmon at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

Modalities of length-frequency distributions for Chinook salmon measured by the Vaki Riverwatcher systems could not be compared with known length-at-age distributions because age estimates from scales collected during the 2009 escapement survey were unavailable. Observations from the 2009 escapement survey identified that 16.6% of the Chinook salmon population were age-2 grilse (<65 cm; unpublished data). This observation differs from Vaki Riverwatcher observations, where 33.2% of Chinook salmon were identified as grilse. Explanations for this observed discrepancy could likely be described by: 1) escapement 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 employing a visual encounter survey *via* annual escapement survey methodology. A higher percentage of grilse were also observed with the Vaki Riverwatcher systems compared to observations from the carcass survey in 2007-2008 and 2008-2009 (Massa *et al.* 2010 and 2011). In 2007-2008, the percentage of grilse was calculated to be 7.1% and 3.1% with data from the Vaki Riverwatcher and carcass survey, respectively. In 2008-2009, the percentage of grilse was calculated to be 20% and 12% with the data from the Vaki Riverwatcher and carcass survey, respectively.



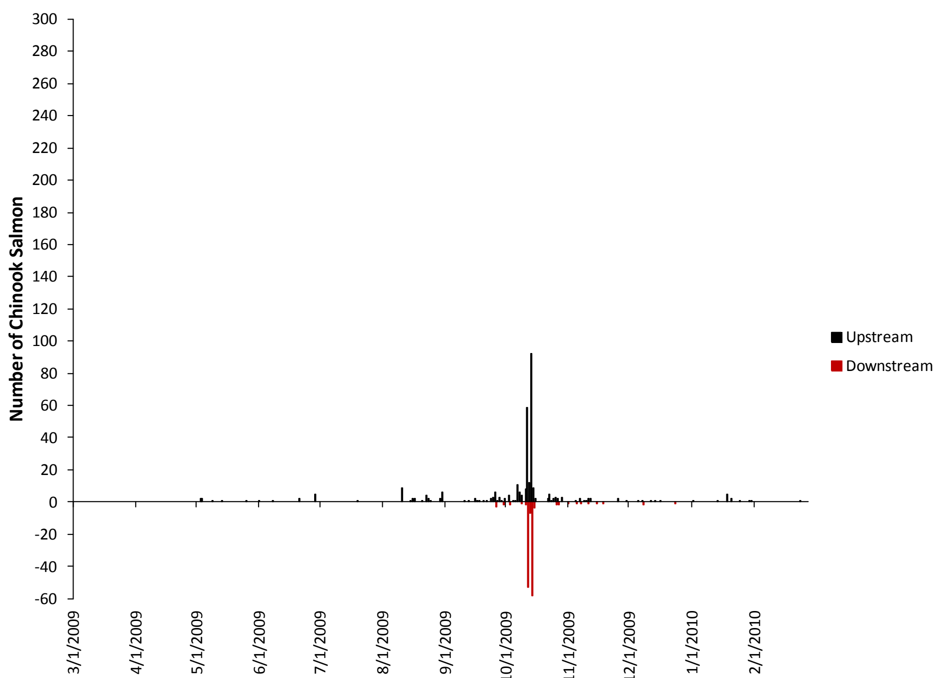


Figure 7. Daily upstream and downstream Chinook salmon passage observed in the North (top) and South (bottom) fish ladders at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

Passage observations of steelhead trout at DPD occurred during all months of the study period, with peak passage in February 2010. February 2010 results support other studies 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). An analysis of the size of steelhead trout observed for each month during the study period indicated that larger steelhead trout (>40 cm) were observed during all survey periods, excluding September and December 2009 (see Appendix, Figure A1-A2). The majority (92.5%) of the steelhead trout observed in February 2010 were <40 cm (see Appendix, Figure A2). Observations of the second highest modal peak of steelhead trout, occurring in July, was not supported by other studies. Over 98% of steelhead trout observed in July 2009 were <40cm, where 93% of steelhead trout observed were <26cm. The largest number of large steelhead trout (>40 cm) were observed in March 2009 (n=14) (see Appendix, Figure A1). 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).

Additionally, passage observations during December through February are suspected to misrepresent actual steelhead trout passage at DPD because of multiple LVD events during this period resulting in unmonitored periods of passage. The Vaki Riverwatcher systems were inoperable 76.6% of the available monitoring hours in January 2010. 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).

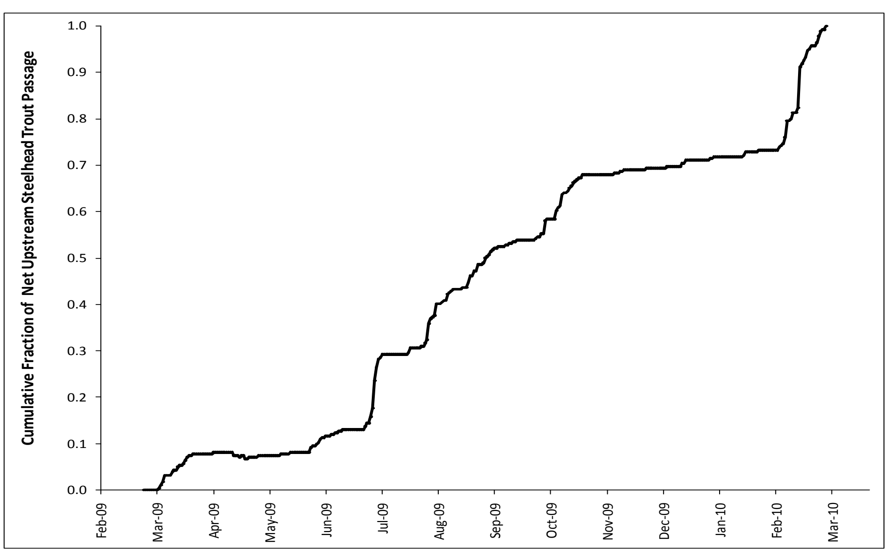
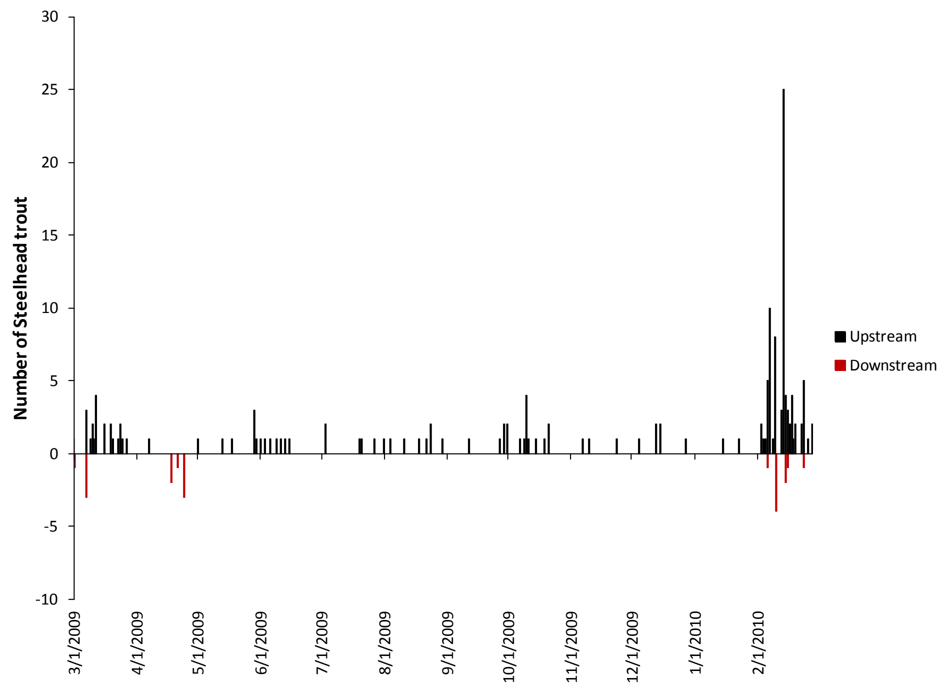


Figure 8. Cumulative fraction of net upstream passage of steelhead trout at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

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; a limited sample of migrating adults from ladder trapping at DPD indicated that 14% 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 with known immigration periods and low numbers of larger steelhead trout (> 40 cm; n=49) passing DPD throughout the study period. 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. For the study period (March 1, 2009 to February 28, 2010) the mean length of steelhead (excluding fish <35 cm) was 43 cm. Since system failures caused by LVD were prevalent during winter migration periods, a relative uncertainty exists that the lower Yuba River steelhead trout passage estimates, as provided by the Vaki Riverwatcher systems, accurately explains their migratory patterns and length distributions.

Additional inquiry into the steelhead trout observations was completed by examining observed upstream and downstream steelhead passage at the DPD fish ladders rather than net passage. The actual upstream and downstream passages were assembled and illustrated separately for each ladder (Figure 9). Only 8.0% of the observed passages for steelhead trout were categorized as downstream movements. Downstream passage observations for the north and south ladders were 19 (12%) and 13 (8%) 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, unless 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 recorded as an unidentified fish.



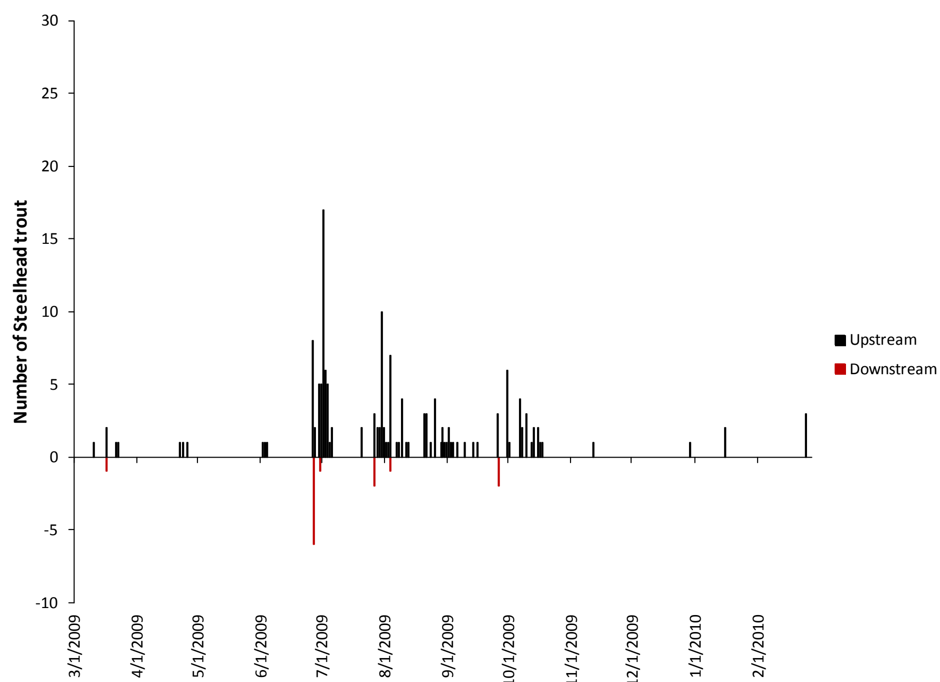


Figure 9. Daily upstream and downstream steelhead trout passage observed in the North (top) and South (bottom) fish ladders at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to February 28, 2010.

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6. APPENDIX

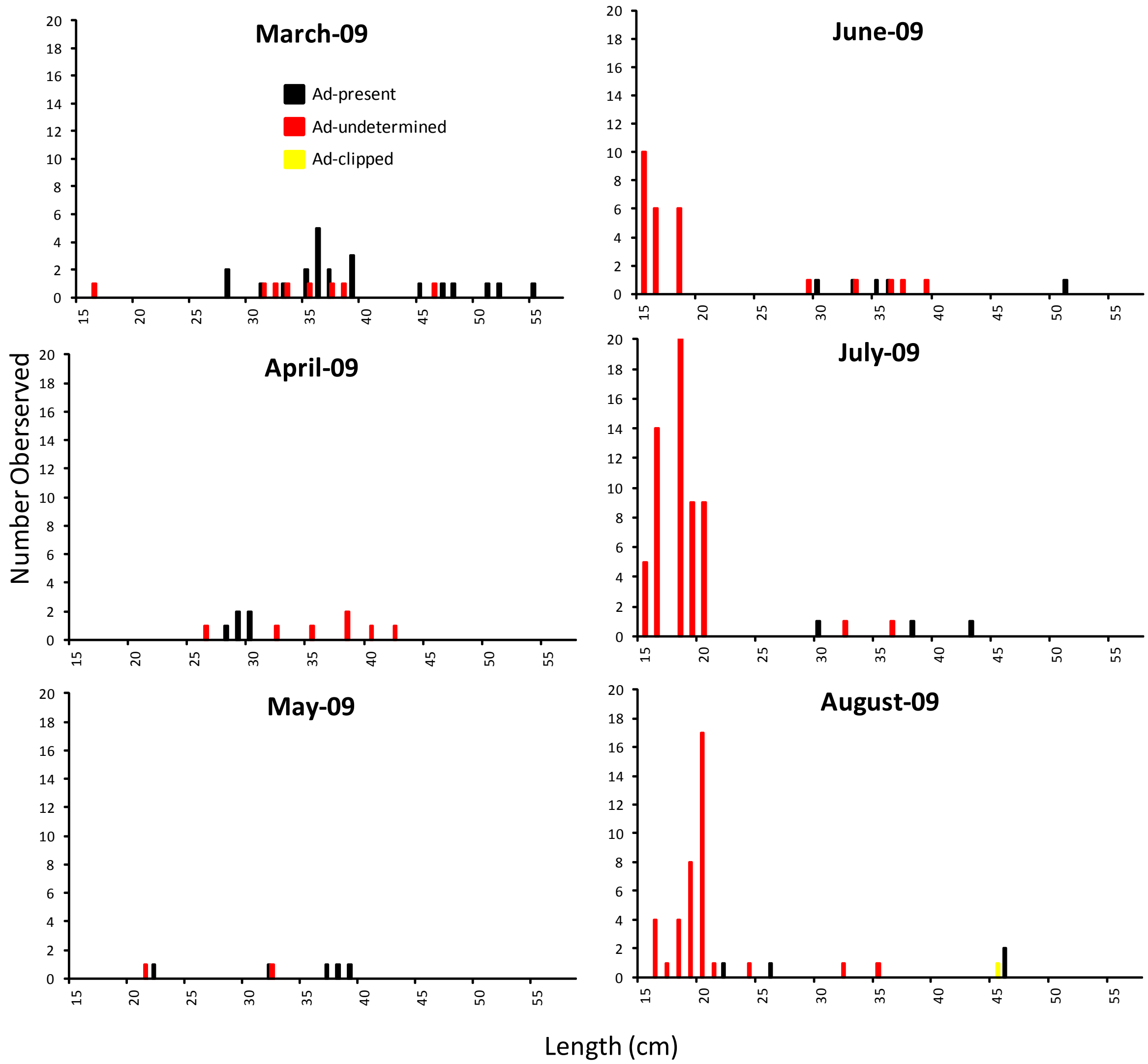

Figure A1. Length frequency distributions of steelhead trout observed at Daguerre Point Dam in the lower Yuba River, CA from March 1, 2009 to August 31, 2010.

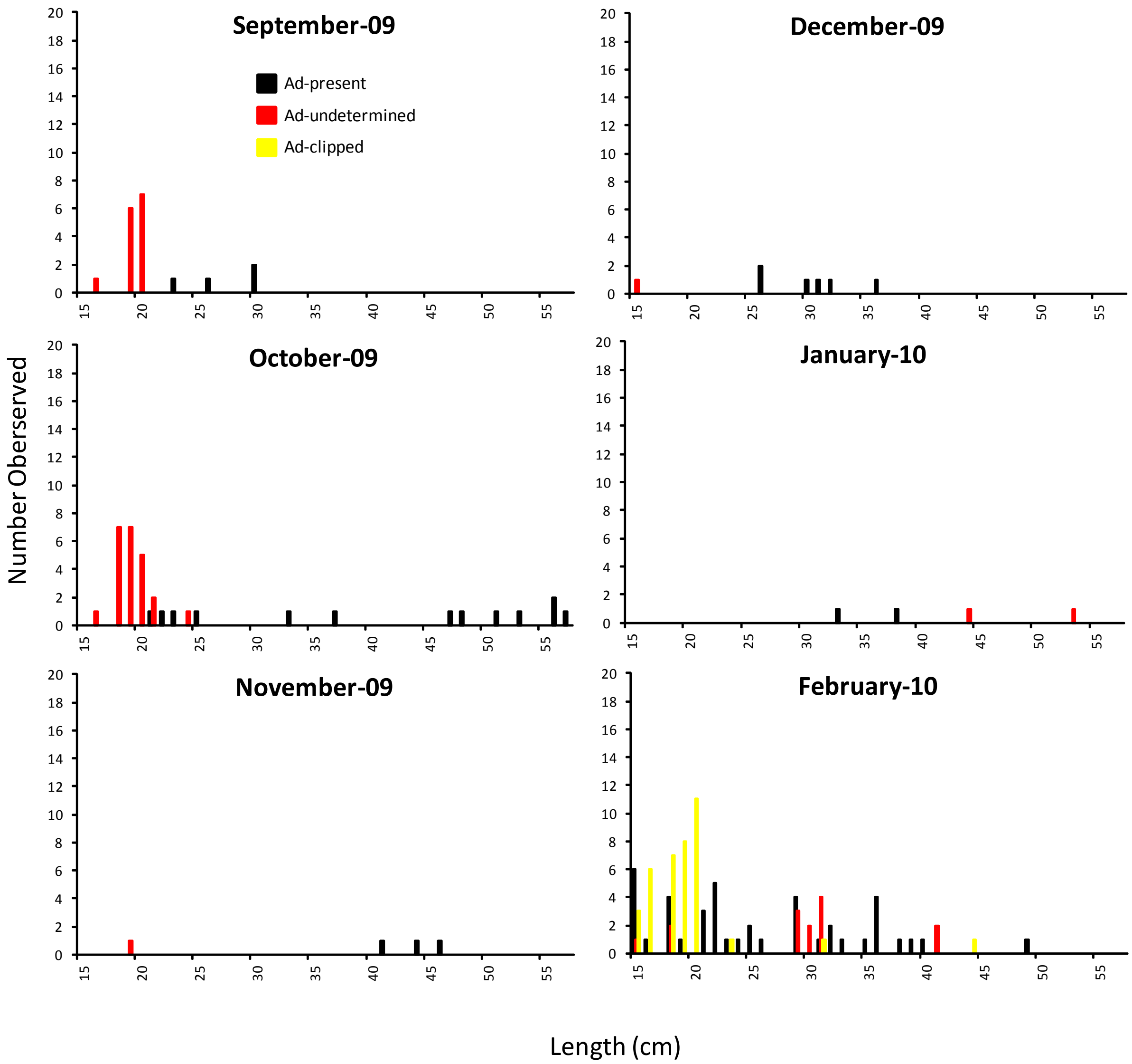

Figure A2. Length frequency distributions of steelhead trout observed at Daguerre Point Dam in the lower Yuba River, CA from September 1, 2009 to February 28, 2010.