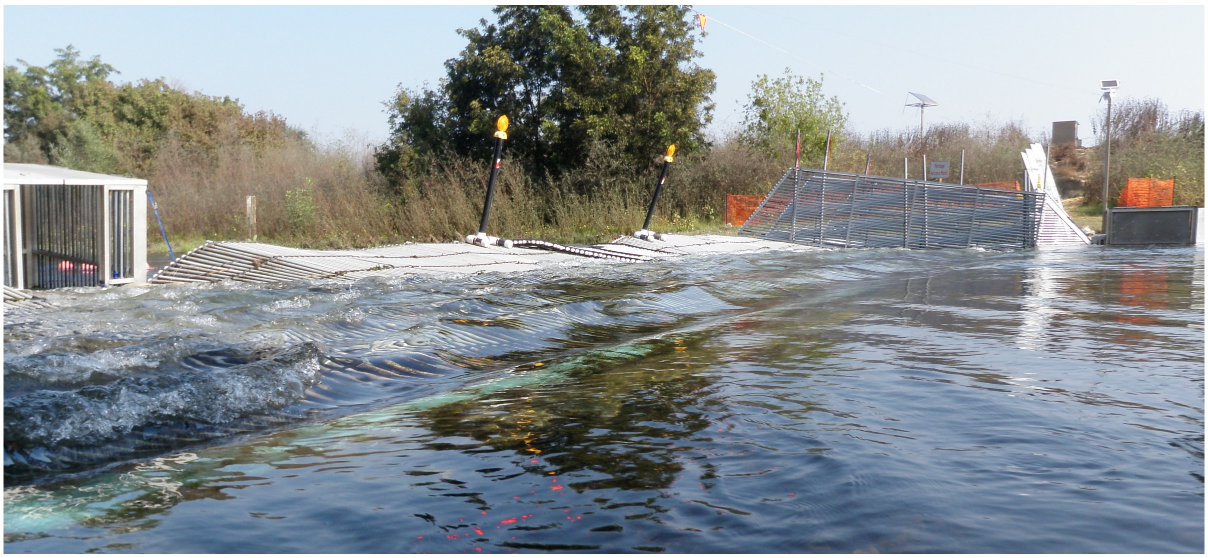
Fall/Winter Migration Monitoring at the Tuolumne River Weir

2010 Annual Report



Submitted To:
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Introduction

The California Department of Fish and Game (CDFG) has reported salmon escapement estimates on the Tuolumne River since 1940 (Fry 1961). Estimates of adult fall-run Chinook salmon escapement have varied from about 100 to 130,000 from 1940 to 1997 (mean: 18,300; median: 7,100) (Ford and Brown 2001). Over the last decade, estimates of adult fall-run Chinook salmon have ranged from a high of 17,873 in 2000 (Vasques 2001) to a low of 211 in 2007 (Blakeman 2008). Most, estimates of fall-run population size were obtained using carcass surveys (some weir counts were made at Modesto in the 1940's). While carcass surveys provide essential data to document the timing and distribution of spawning, population estimates from mark-recapture models are prone to bias if rigid assumptions are not met. Alternatively, resistance board weirs provide direct counts that are not subject to the same biases. Weirs also provide precise migration timing information, while carcass surveys provide essential data to document the timing and distribution of spawning. Resistance board weirs have been widely used in Alaska to estimate salmonid escapement since the early 1990's (Tobin 1994), and a weir has been operated successfully on the nearby Stanislaus River since 2003.

The Tuolumne River weir project was initiated during fall 2009, and the Turlock Irrigation District (TID), Modesto Irrigation District (MID), and the City and County of San Francisco jointly supported this effort. The objectives of the Tuolumne River Weir Project include:

- Determine escapement of fall-run Chinook salmon and steelhead to the Tuolumne River through direct counts.
- Document migration timing of adult fall-run Chinook salmon and steelhead in the Tuolumne River and evaluate potential relationships with environmental factors.
- Determine size and gender composition of returning adult salmon population.
- Estimate hatchery contribution to spawning population
- Document passage of non-salmonids

Study Area

The Tuolumne River is the largest tributary to the San Joaquin River, draining a 1,900 square-mile watershed that includes the northern half of Yosemite National Park (McBain and Trush 2000). The Tuolumne River originates in the central Sierra Nevada Mountains and flows west between the Merced River to the south and the Stanislaus River to the north (Figure 1). The San Joaquin River flows north and joins the Sacramento River in the Sacramento-San Joaquin Delta within California's Central Valley.

The Tuolumne River is dammed at several locations for power generation, water supply, and flood control – the largest impoundment is Don Pedro Reservoir. The lower Tuolumne River corridor extends from its confluence with the San Joaquin River to La Grange Dam at river mile (RM) 52.2. The La Grange Dam site has been the upstream limit for anadromous migration since 1871. The spawning reach of the Tuolumne River has been defined as extending 28.1 miles downstream of La Grange Dam to RM 24.1 (O'Brien 2009).

The weir is located at RM 24.5 (Figure 1), and this site was selected for weir operation because it is located below the typical downstream boundary of the CDFG spawning surveys.

Site selection was also based on operational criteria that include water velocity, channel width, bank slope, channel gradient, channel uniformity, and substrate type.

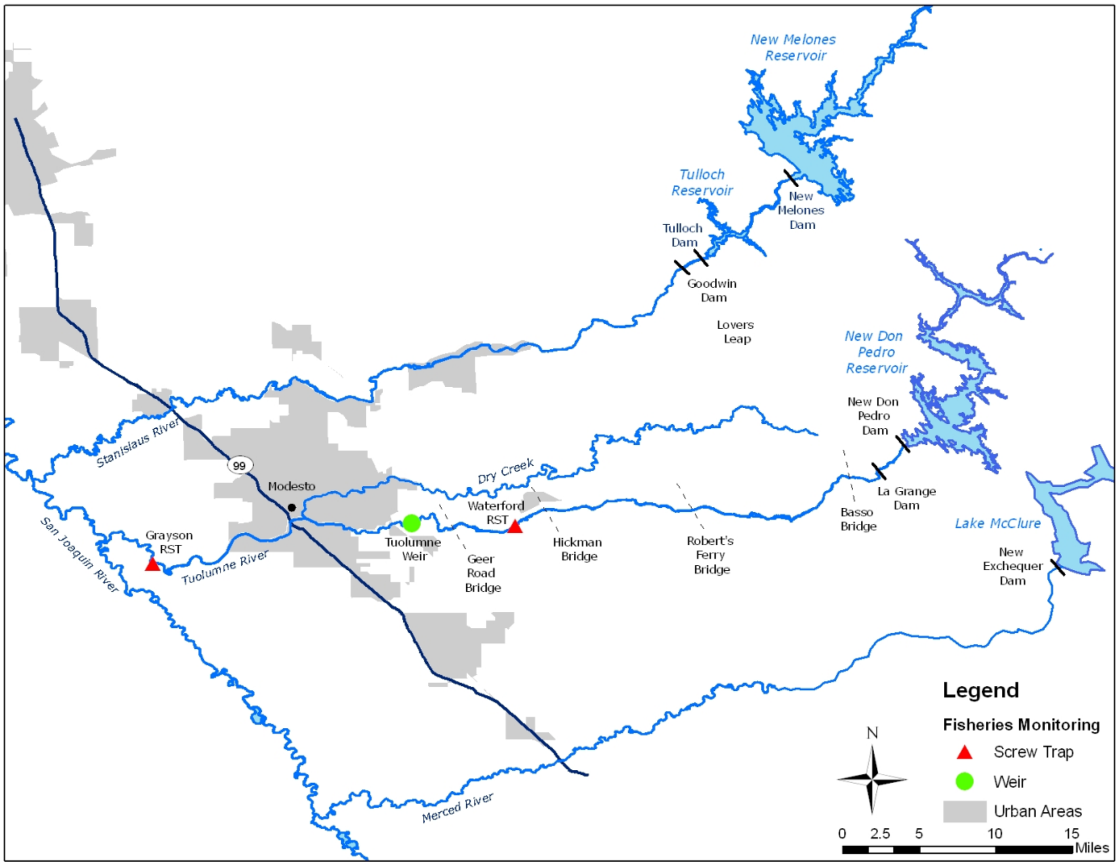

Figure 1. Map of the Tuolumne River displaying the location of the Tuolumne River Weir and other key points of interest.

Methods

A resistance board weir (Tobin 1994; Stewart 2002, 2003) and Vaki Riverwatcher fish counting system (Vaki system) were installed in the Tuolumne River at RM 24.5 on September 9, 2010, monitoring continued until December 1, 2010 when the weir and the Vaki were removed in anticipation of high flow, due to flood control releases, that were expected to exceed the operational threshold (i.e. >1,300 cfs; Figure 8). The weir was not re-installed, as flows remained high throughout the remainder of the fall-run Chinook salmon migration period.

Some modifications were made to the weir design prior to the 2010 season to facilitate passage of fish through the weir. Modifications included: removal of the upstream trap (Figure 2), removal of the fyke at the entrance to the camera viewing lane (Figure 3); removal of a nine foot section of substrate rail; removal of three resistance board panels (i.e. nine feet); installation of two floating bulkheads; and installation of a large nine foot wide by five foot high aluminum fyke (Figure 4). Since the upstream trap was removed no trapping was conducted this season.

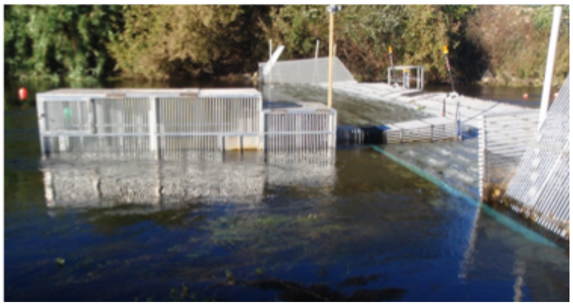

Figure 2. Tuolumne River Weir upstream trap and camera box before modifications (left photo) and camera box (upstream trap removed) after modifications (right photo).

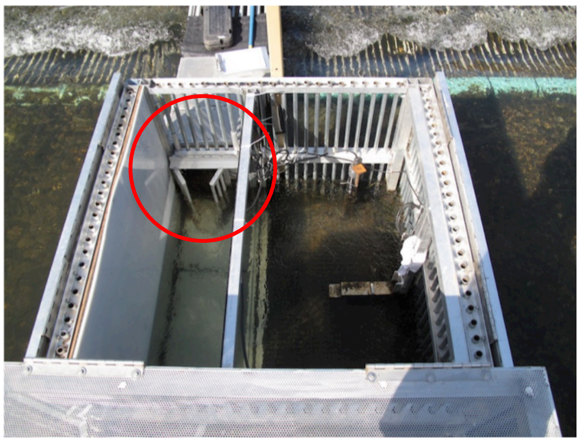

Figure 3. Tuolumne River camera viewing lane before modifications. Circle indicates fyke that was removed.

Figure 4. Tuolumne River Weir passage chute before modifications (left photo) and after modifications (right photo).

Weir and Vaki components were inspected and cleaned daily or more frequently when debris loads were heavy. The boat passage portion of the weir was briefly over-topped (submerged) on nine occasions due to debris, and the entire length of the weir was briefly over-topped on October 11, 2010 (Table 1). Maintenance procedures generally followed guidelines found in Tobin (1994) and Stewart (2002, 2003), although slight adjustments were made to accommodate site-specific attributes of the Tuolumne River Weir. For example, sealed plastic barrels were used for additional floatation during periods of high flows (Figure 5).

Table 1. Date, time, and flow of weir over-topping occasions.

Date	Time (hhmm)	Average Daily Flow (cfs)
Sept. 14	0845	309
Sept. 15	1200	312
Sept. 17	0830	309
Sept. 20	1245	307
Oct. 3	1145	358
Oct. 7	0840	857
Oct. 9	0900	860
Oct. 11	1200	855
Nov. 5	1130	361
Nov. 28	1115	619

Figure 5. Photograph of the flotation barrels lining the underneath of the resistance weir.

In conjunction with the weir, a Vaki Riverwatcher fish counting system (Vaki system) was used during the majority of the study period to monitor fish passage without the need to capture or handle fish. The Vaki system is comprised of three main components: an infrared scanner, a digital video camera with lights, and a computer system (Figure 6).

Figure 6. Left: Photograph of the Vaki Riverwatcher infrared scanner looking from upstream to downstream at the upstream side of the scanner plates. Center: Example of the riverwatcher camera and lights. Right: Tuolumne Weir Vaki Riverwatcher computer system and job box.

The Vaki infrared scanner was attached to a fyke at an opening in the weir (Figure 6), and data was relayed to a computer system that generated infrared silhouettes and video clips of passing objects (Figure 7). The system also recorded the time, speed, and direction of passage, as well as the depth of the passing object.

The Riverwatcher estimates length based on the depth (body depth) of the fish. A user-defined coefficient was derived from a body depth to total length ratio from measurements of trapped fish and carcasses. The user-defined coefficient is applied to the Riverwatcher measured depth to estimate total length. The coefficient is derived by the following equation:

$$l = \frac{tl}{d}$$

where, *l* is the length coefficient, *tl* is the total length, and *d* is the body depth of the measured fish. Total length is estimated by the following equation:

$$L = D \times l$$

where, *L* is the estimated total length, *D* is the body depth measured by the Riverwatcher, and *l* is the length coefficient. Only trapped fish were used for Chinook salmon ratio measurements.

Data from the Vaki computer was downloaded and reviewed daily during the peak migration periods. Infrared silhouettes were used in conjunction with digital video to identify passing objects (Figure 8). Video aids in the determination of gender, total length, presence/absence of adipose fin, distinguishing salmonids to species, and provides the only evidence of the condition of the fish.

Figure 7. Example of silhouette images produced from both sets of scanner diodes (one image from one set of diodes is displayed in blue and the other is displayed in red). The left set of images is an example of a typical salmonid silhouette and the right set of images is an example of a poor salmonid silhouette.

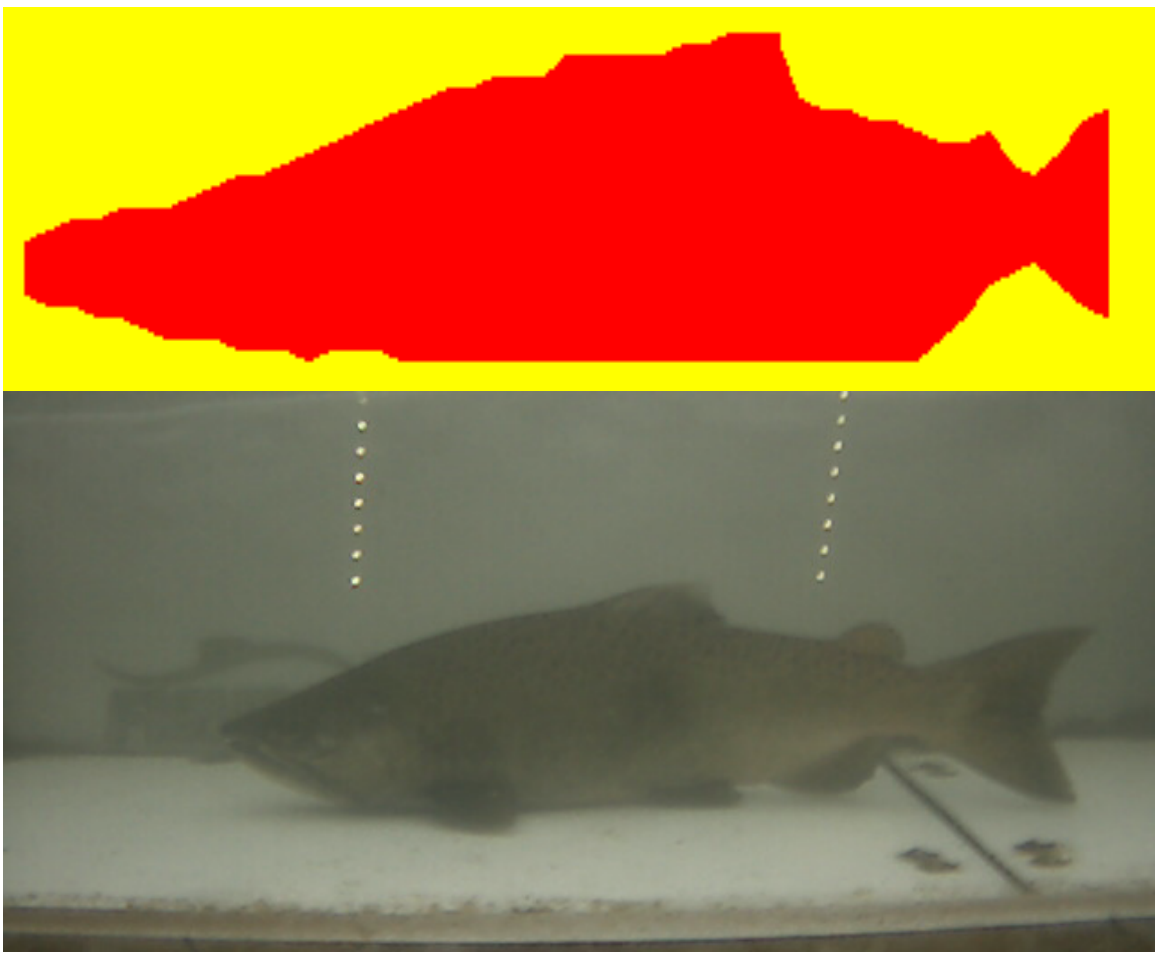

Figure 8. Top image is an example of a typical salmonid silhouette and the bottom image is a screen capture from a video clip of the same fish that is displayed in the top image. Note: Video clips are a higher quality image than the screen capture.

After each passage was identified to species, data were exported into an excel spreadsheet. The daily passage counts consisted of net upstream passages (upstream passages –

downstream passages). Other information obtained from video clips was recorded including whether the presence/absence of an adipose fin (ad-clipped; Figure 9), fish condition, and gender.

Video provide the only means by which Chinook salmon and *O. mykiss* may be distinguished, and the identity of many species is uncertain based on infrared silhouettes alone. The quality of video is reduced when turbidity increases and can preclude identification of fish to species.

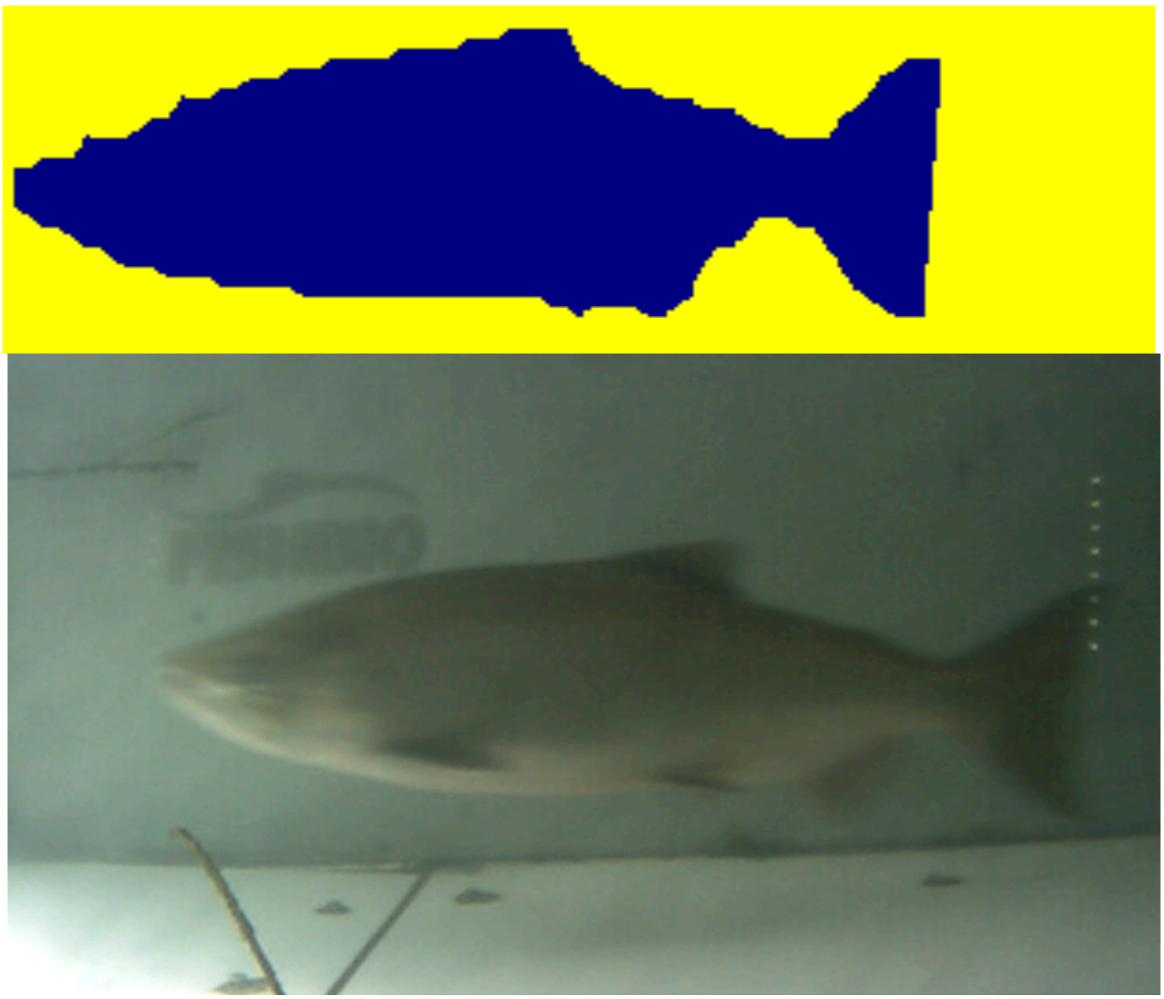

Figure 9. Example of a silhouette image and screen capture from a video clip of the same Chinook salmon that has a clipped adipose fin (ad-clip). Note: Video clips are a higher quality image than the screen capture.

Physical data collected during each weir check included water temperature (°F), dissolved oxygen (mg/L), turbidity (NTU), weather conditions (RAN = rain, CLD = cloudy, CLR = clear, FOG = fog), and water velocity (ft/s) measurements at the opening of the livebox. Instantaneous water temperature and dissolved oxygen were recorded using an Exstick II model DO600 Dissolved Oxygen Meter (Extech Intruments Corporation). Hourly water temperature data was logged using an iBCod type G submersible data logger (Alpha Mach, Inc.). Turbidity was recorded using a model 2020e Turbidimeter (LaMotte Co.), and water velocity was measured using a digital Flow Probe model FP-101 (Global Water Instrumentation, Inc.). Tuolumne River flow was also downloaded from the California Data Exchange Center (CDEC).

Visual assessments in a half-mile reach upstream and downstream of the weir were conducted to monitor potential migration delay or digging activity. Boat surveys were conducted on Monday, Wednesday and Friday of each week during September and daily from October 1 through December 1. A "stacking ratio" was calculated using the number of salmon observed downstream of the weir and the number of salmon recorded by the Riverwatcher passing the weir during a three-day period to identify potential migration delays and if the ratio exceeded 1.15, three panels will be removed from the weir until CDFG allowed normal operations to resume.

At the request of California Department of Fish and Game an overhead video system was installed to observe fish behavior associated with the weir (Figure 10); however, the overhead video equipment did not give us high enough quality imagery to successfully make any observations. However, only one fish was observed downstream of the weir during visual assessments from a boat, resulting in a maximum stacking ratio of 0.07 for the season, which is substantially less than the 1.15 threshold.


Figure 10. Overhead camera system circled in yellow.

Results

Chinook salmon abundance and migration timing

Between September 9, 2010 and December 1, 2010, the Riverwatcher detected 785 adult fall-run Chinook salmon as they passed upstream of the weir (Figure 11). Due to flood control releases on the Tuolumne River monitoring ended on December 1.

Daily passage ranged between zero and 50 Chinook (Figure 11). Most Chinook salmon passage significantly decreased during the day (1000 hours – 1559 hours), increased at dusk and night (1600 – 2159 hours and 2200 – 0359 hours; respectively), and remained high during the dawn (0400 – 0959 hours) (ANOVA: $F = 8.71, P = 0.01E03$) (Figure 12).

During 2009, 17.6% of fall-run Chinook salmon passed between December 1 and December 31, 2009. If it is assumed that the same proportion of Chinook salmon passed during the same time period in 2009, it is estimated that an additional 138 adult fall-run Chinook salmon may have passed the weir site undetected.

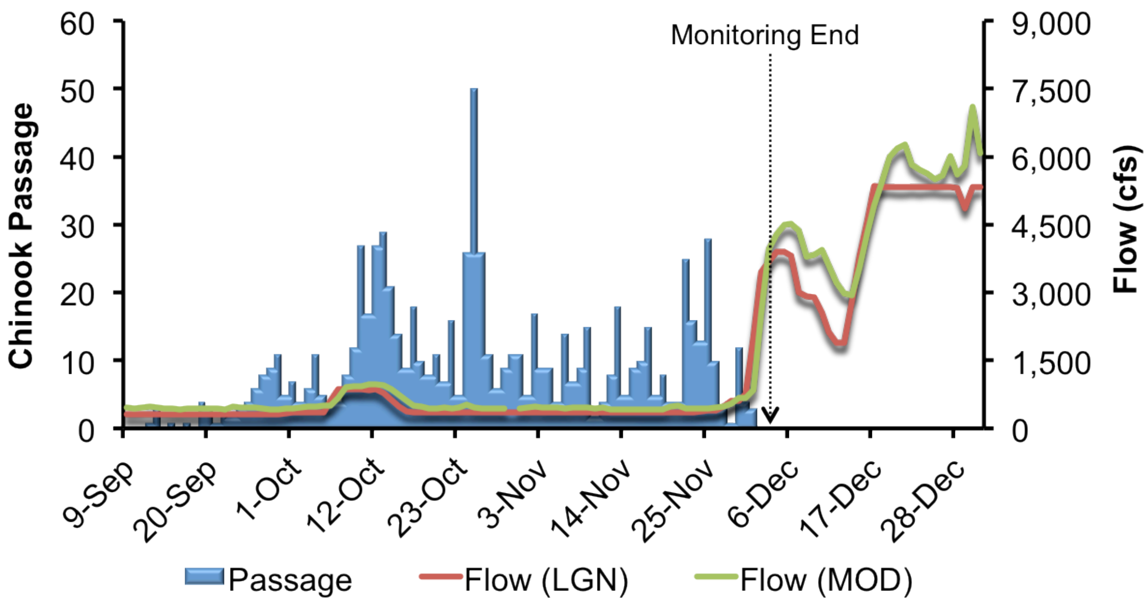

Figure 11. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to daily average flows (cfs) recorded in the Tuolumne River at La Grange (LGN) and Modesto (MOD) between September 9, 2010 and December 31, 2010 [Data source: CDEC – http://cdec.water.ca.gov].

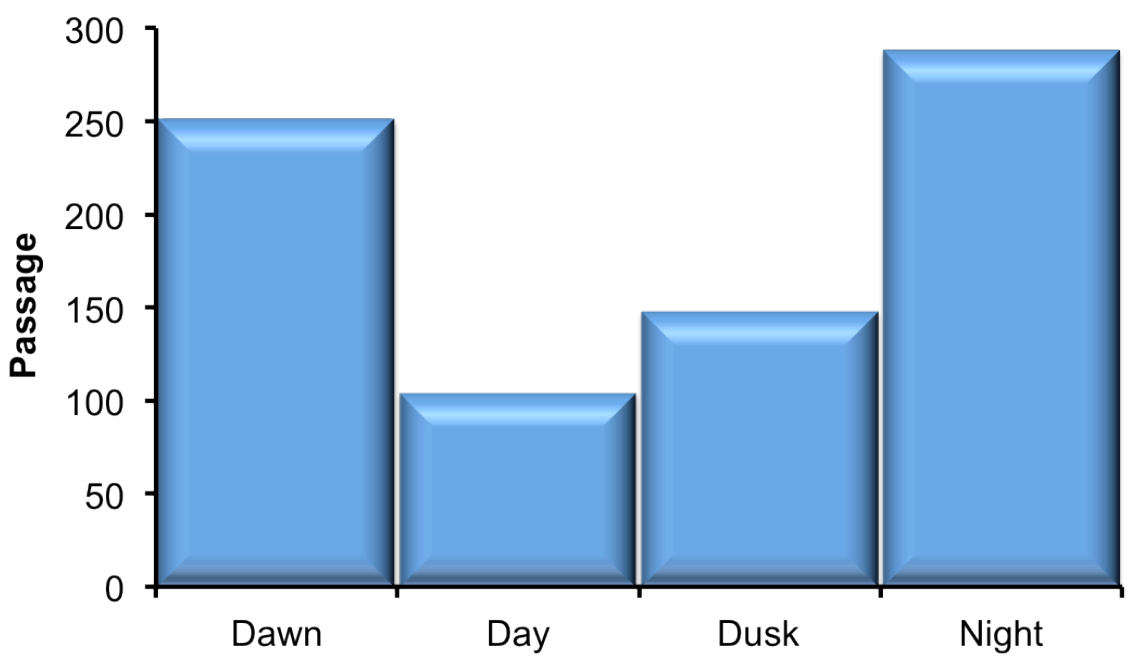

Figure 12. Chinook salmon passage in 6-hour time blocks. Diel Chinook salmon passage was not significant among the different time periods (ANOVA: *F = 8.71, P = 0.01E03*).

One post-spawn male fall-run Chinook salmon carcass was recovered from the top of the weir and one ripe (pre-spawn) male Chinook carcass was impinged between the resistance weir and the substrate on September 22, 2010 (Table 2).

Table 2. Post-spawn and pre-spawn (ripe) fall-run Chinook salmon carcasses recovered from the Tuolumne River Weir between September 9, 2010 and December 1, 2010.

Species	Date	TL (mm)	Adipose Fin Clip	Sex	Post-spawn
Chinook salmon	9/22/10	1,010	No	Male	No
Chinook salmon	11/11/10	760	No	Male	Yes

Chinook salmon gender and size

Total fall-run Chinook salmon passage was composed of 40% male (n = 317), 42% female (n = 326), and 18% unknown (n = 142). Mean total length for Chinook salmon upstream passages were: 708 mm (n = 398) for male, 693 mm (n = 387) for female, 550 mm (n = 194) for unknown; and 670 mm for all Chinook combined (Table 3). While mean lengths were similar for male and female salmon, the length frequency distributions differed with males predominately the 550 – 600 mm size class and females were predominately the 750 – 800 mm size class (Figure 13).

Origin of Chinook salmon production

Adipose fin clips, suggesting hatchery origin, were observed in 32% of Chinook counted at the Tuolumne River weir during 2010. Although releases of hatchery origin Chinook have not been made in the Tuolumne River in recent years, straying from other basins is common as evidenced by the recovery of coded wire tags during annual carcass surveys.

Table 3. Fall-run Chinook salmon upstream passage data from September 9, 2010 through December 1, 2010 (upstream passage counts only, data are not directly comparable to net passage). Parenthesis indicate range.

Sex – Adipose fin clip	Mean TL (mm)	95% CI (mm)	n
Male – No	748 (472 - 1,033)	748 ± 17	243
Male – Yes	650 (480 - 943)	650 ± 18	128
Male – Unknown	625 (500 - 972)	625 ± 41	27
Female – No	733 (463 - 940)	733 ± 12	234
Female – Yes	629 (450 - 845)	629 ± 15	136
Female – Unknown	656 (446 - 841)	656 ± 43	19
Unknown – No	670 (217 - 915)	670 ± 41	64
Unknown – Yes	423 (167 - 865)	423 ± 47	55
Unknown – Unknown	543 (209 - 1,003)	541 ± 41	82

Combined	670 (167 - 1,033)	671 ± 10	984

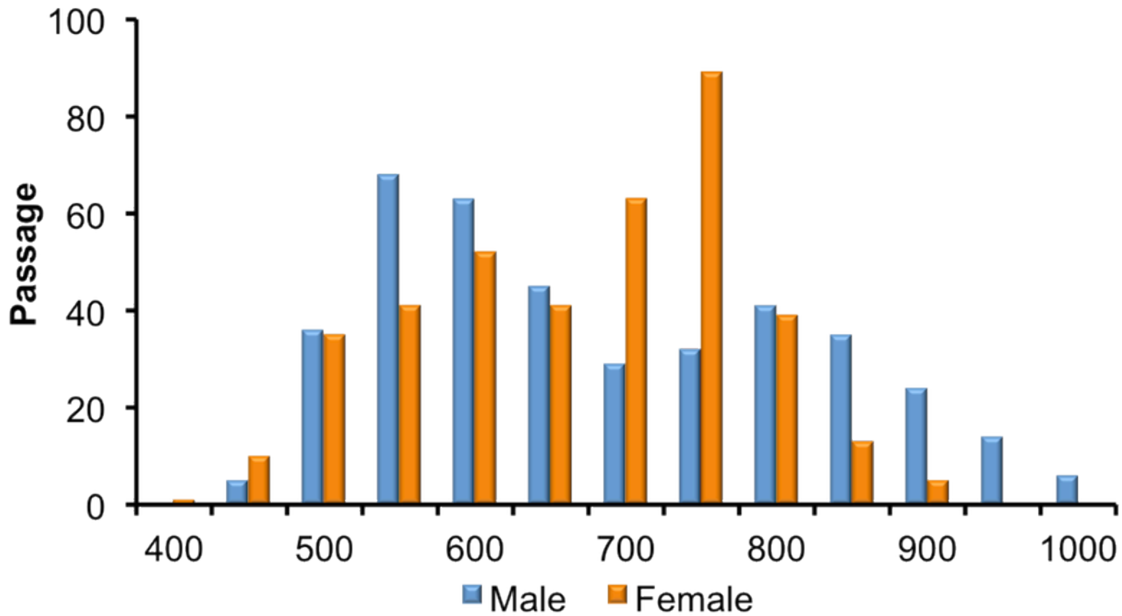

Figure 13. Length frequency of male and female fall-run Chinook salmon passage (upstream passage counts only, data are not directly comparable to net passage).

<u>*O. mykiss*</u>

No *O. mykiss* were recorded passing through the weir between September 9, 2010 and December 1, 2010.

<u>*Non-salmonids*</u>

There were 11 other species identified passing the weir including American shad (*Alosa sapidissima*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), Sacramento blackfish (*Orthodon microlepidotus*), Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento sucker (*Catostomus occidentalis*), smallmouth bass (*Micropterus dolomieu*), striped bass (*Morone saxatilis*), white catfish (*Ictalurus catus*); as well as unknown species of black bass (*Micropterus spp.*), catfish (*Ameiurus spp. and Ictalurus spp.*), and sunfish (Lepomis spp.) (Table 4). There were 67 passages that were identified as fish, but could not be identified to species.

Table 4. Incidental species passage data from September 9, 2010 through December 1, 2010 (upstream passage counts only, data are not directly comparable to net passage). Parenthesis indicates range.

Native Species	Mean TL (mm)	Date Range	Total Passage
Sacramento blackfish	359 (218 – 582)	9/14/10 – 11/30/10	14
Sacramento pikeminnow	272 (208 – 374)	9/13/10 – 11/30/10	63
Sacramento sucker	390 (224 – 767)	9/10/10 – 12/1/10	141
Non-native Species	**Mean TL (mm)**	**Date Range**	**Total Passage**
American shad	250 (247 – 253)	9/17/10 – 9/19/10	2
Common carp	466 (167 – 914)	9/12/10 – 12/1/10	572

Channel catfish	425 (252 – 945)	9/15/10 – 10/31/10	9
Goldfish	339 (303 – 405)	9/18/10 – 11/8/10	4
Largemouth bass	270 (174 – 596)	9/17/10 – 11/30/10	53
Smallmouth bass	276 (148 – 377)	9/25/10 – 11/29/10	8
Striped bass	346 (180 – 878)	9/11/10 – 11/30/10	38
White catfish	336 (180 – 518)	9/11/10 – 11/28/10	102
Unknown – black bass	270 (174 – 500)	9/10/10 – 11/30/10	79
Unknown – catfish	300 (180 – 473)	9/13/10 – 11/29/10	44
Unknown Species	**Mean TL (mm)**	**Date Range**	**Total Passage**
Unknown – sunfish	117 (84 – 134)	9/25/10 – 9/29/10	3
Unknown	462 (240 – 1,008)	9/12/10 – 11/25/10	67

Environmental Conditions

Between September 9, 2010 and December 1, 2010 daily average flow at La Grange (LGN; RM 51.8) ranged between 304 cfs and 860 cfs (399 cfs season average). After the weir was removed, flows ranged between 1,890 cfs and 5,350 cfs through December 31, 2010. Daily average flow at Modesto (MOD; RM 17) ranged between 417 cfs and 968 cfs (502 cfs season average) during weir monitoring and from 2,530 cfs to 7,100 cfs during December after the weir was removed (Figure 11).

Instantaneous water temperatures measured at the weir ranged between 48.3˚F and 70.1˚F (59.7˚F season average; Figure 14). Instantaneous turbidity ranged between 0.22 NTU and 3.48 NTU (1.35 NTU season average; Figure 15), and instantaneous dissolved oxygen ranged between 7.47 mg/L and 10.87 mg/L (8.78 mg/L season average; Figure 16).

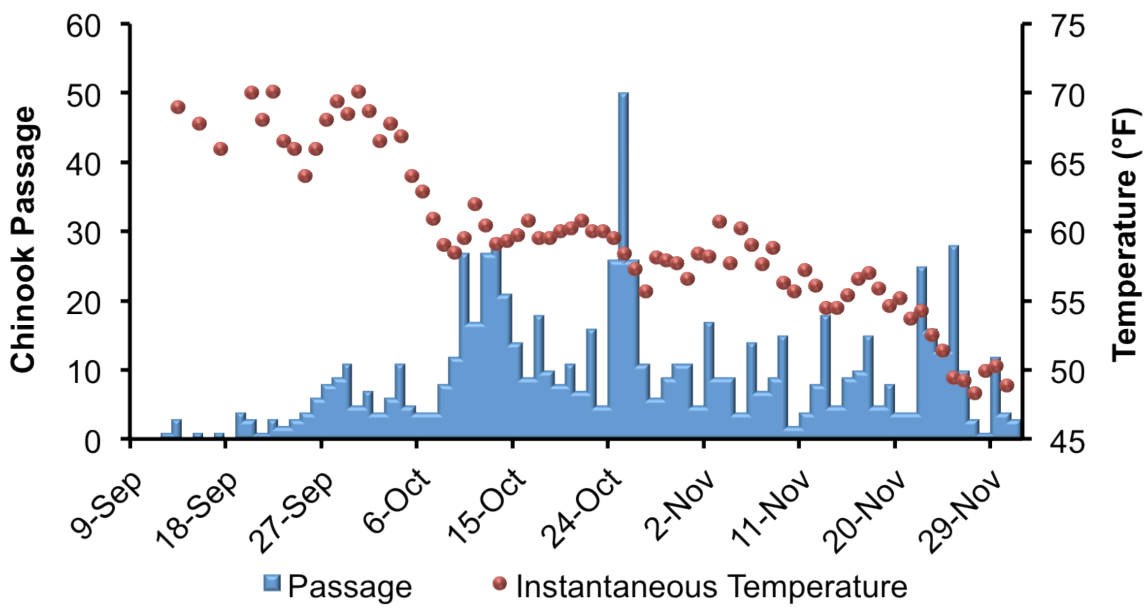

Figure 14. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous water temperature (°F) at the weir and daily average water temperature (°F) at Modesto (MOD) between September 9, 2010 and December 1, 2010 [Data source: CDEC – http://cdec.water.ca.gov].

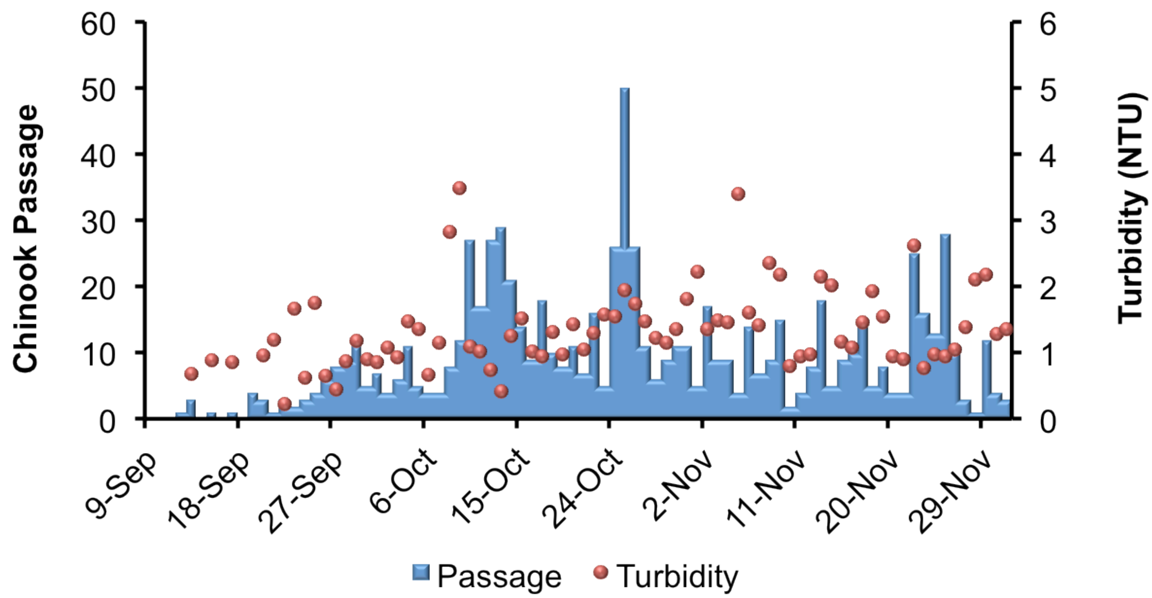

Figure 15. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous turbidity (NTU) between September 9, 2010 and December 1, 2010.

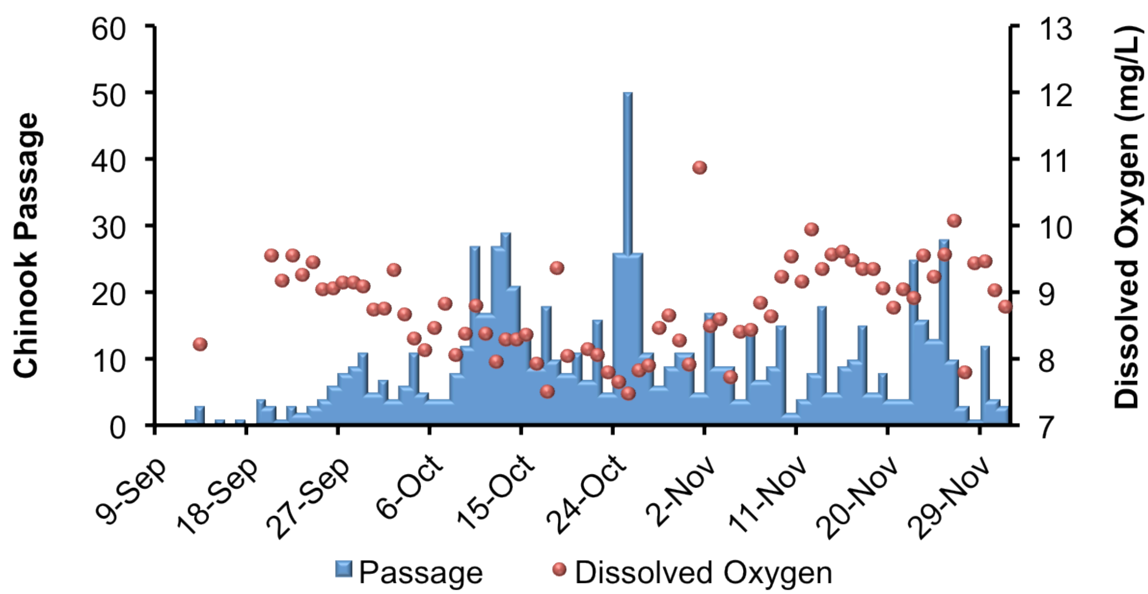

Figure 16. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous dissolved oxygen (mg/L) between September 9, 2010 and December 1, 2010.

Discussion

The Vaki Riverwatcher detected 785 fall-run Chinook salmon during 2010, which represents a substantial increase over the previous year (Table 4). It is estimated that an additional 138 adult fall-run Chinook salmon may have passed between December 1 and December 31 when the weir was removed due to elevated flows (due to flood control releases) that exceed the operational range of the weir. Although there were no apparent relationships between migration timing and turbidity or dissolved oxygen during 2010; there appeared to be an increase in passage once temperature decreased below 60°F which coincided with a small increase in flow due to managed pulse flow releases for fall-run Chinook salmon migration attraction.

Table 4. Annual adult Chinook salmon passage counts by run-type and range of dates that adult Chinook salmon passed the Tuolumne River Weir.

Year	Run Type	Passage Date Range	Total Passage Count
2010	Fall	September 9 – December 1	785
	Unknown	No sample	-
2009	Fall	September 22 – December 31	264
	Unknown	January 1 – February 10	31

Approximately 31% of the Chinook salmon observed at the Tuolumne River weir were two-year-old fish (≤ 600 mm TL), and the majority (56%) of these were males. Two-year-old males are commonly known as jacks and these fish may contribute up to 67% of the run in some years (Moyle 2002). Jacks are widely used in escapement prediction models (Beer et. al. 2006) where a large return of jacks suggests an increase in escapement for the following year.

The Tuolumne River Chinook salmon population is not supplemented with hatchery fish however, the 2010 fall-run was comprised of 33% ad-clipped Chinook (suggesting hatchery origin). Given that roughly 75% of hatchery fish are not clipped and assuming that un-clipped and clipped hatchery fish are equally likely to stray, it is likely that quite a few un-clipped hatchery fish also entered this river in 2010. In previous years, straying of fish released off-site into San Pablo Bay has been estimated to be as high as 70% (CDFG & NMFS 2001) and may be found to be even greater once analysis of CWT data for the most recent years are completed.

Escapement estimates from weir counts and carcass survey differed greatly during 2010, demonstrating the importance of weir monitoring in this system. At the Tuolumne weir, 791 fall-run Chinook salmon were counted while the preliminary adjusted Petersen estimate based on carcass survey data was only 540 fall-run Chinook salmon (CDFG GrandTab). Similarly, carcass surveys also underestimated Chinook salmon escapement to the Stanislaus River during the September to December 2010 period and the Tuolumne River during the previous year. Although the weir was removed prematurely due to elevated flows, the ability for researchers to recover tagged-carcasses during carcass surveys violates assumptions that the adjusted Petersen model must adhere to establish any confidence in the escapement estimate.

In addition to providing information on migrating adult fall run Chinook salmon, the weir also provided information on the movement and sizes of 11 non-salmonid species observed passing the weir. Most (81%) of the non-salmonid species were non-native, any many of the non-native species are known to prey on juvenile Chinook salmon (e.g. largemouth bass, smallmouth, striped bass, and catfish) (Tabor et. al. 2007). Year-round monitoring could provide more insight into Chinook salmon run dynamics on the Tuolumne River as well as abundance indicators for predatory fishes.

Although we were unable to observe fish passage behavior with the overhead video monitoring the calculated stacking ratio and visual assessments downstream of the weir suggest that the fish passage modifications provided improved fish passage conditions at the weir.

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