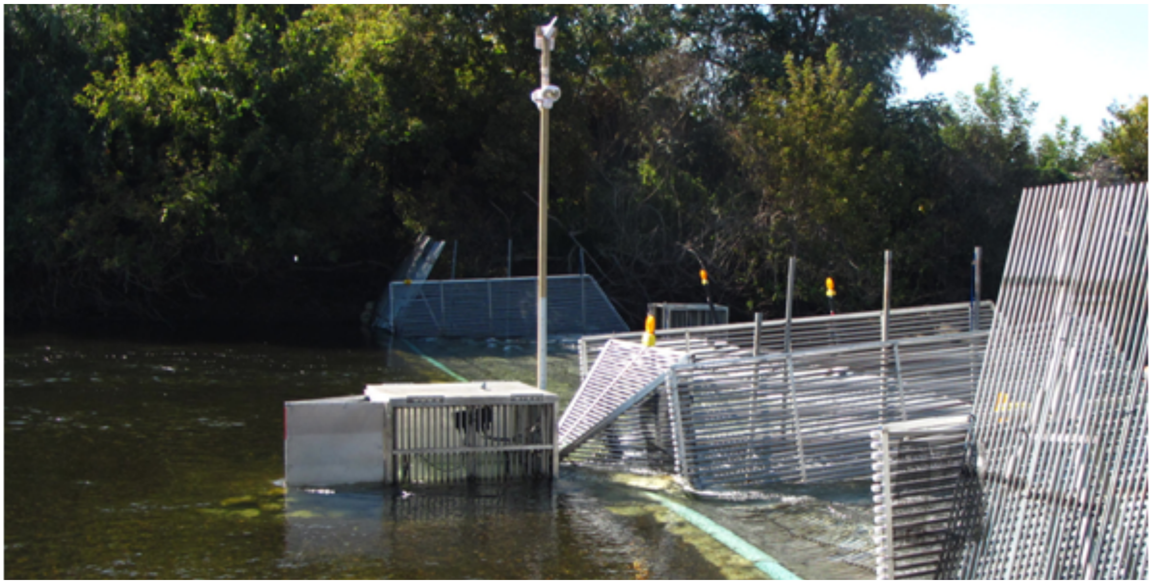
Fall/Winter Migration Monitoring at the Tuolumne River Weir

2011 Annual Report



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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 withenvironmental 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.

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 16, 2011, monitoring continued throughout the remainder of the fall-run Chinook salmon migration period.

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 six occasions due to debris, and half of the weir was briefly over-topped on December 1, 2011 (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 2).

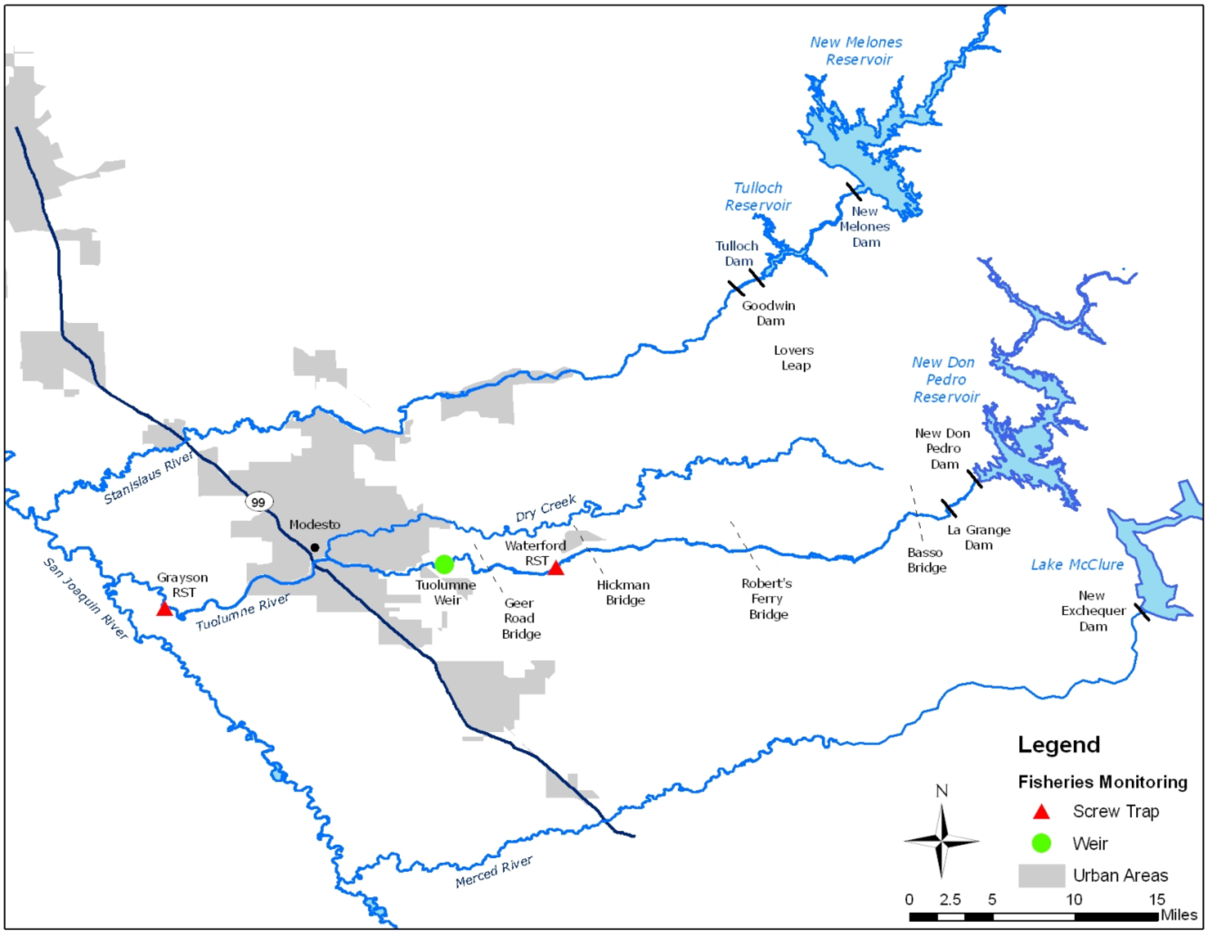

Figure 1. Map of the Tuolumne River displaying the location of the Tuolumne River Weir and other key points of interest.

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

Date	Time (hhmm)	Average Daily Flow (cfs)
Sept. 19	0900	331
Sept. 21	1300	319
Sept. 23	0845	305
Oct. 11	0800	1,290
Nov. 6	1230	365
Dec. 1	0800	363

Figure 2. 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 3).

Figure 3. 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, and data was relayed to a computer system that generated infrared silhouettes and video clips of passing objects (Figure 4). 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 5). 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 4. 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.

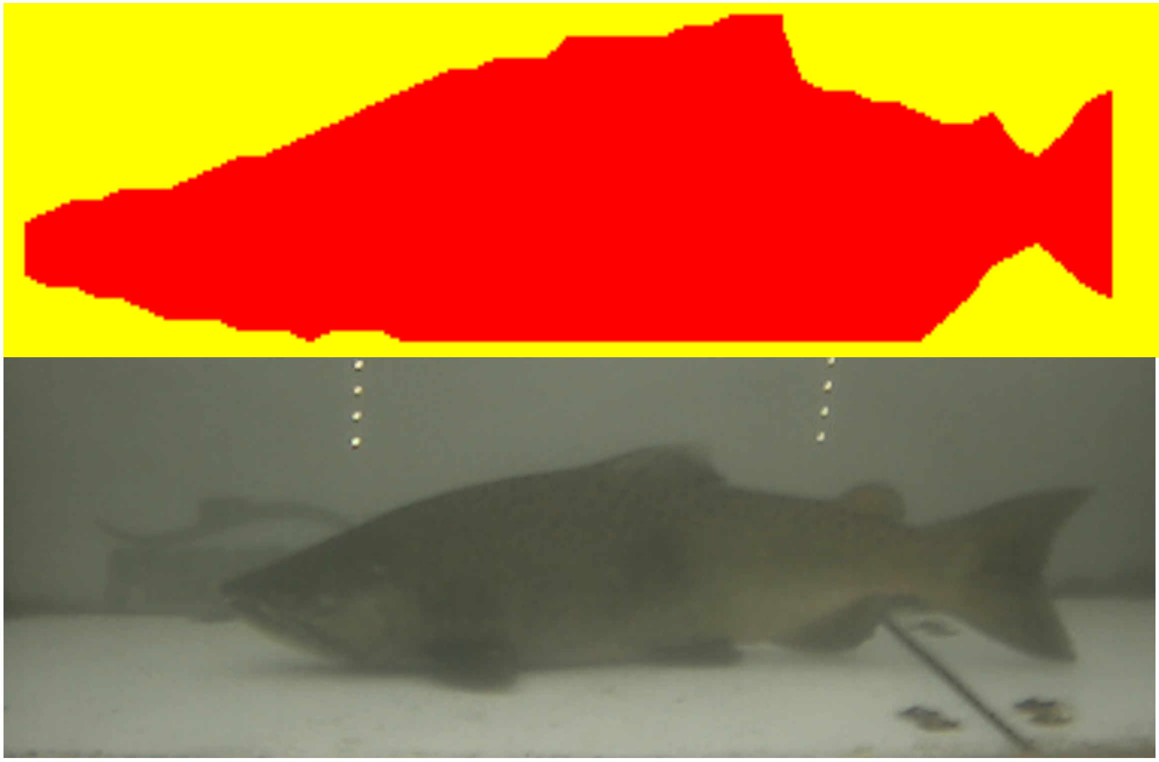

Figure 5. Top image is an example of a typical salmonid silhouette and the bottom image is a screen capture from a video clip of the same fish that is displayed in the top image. Note: Video clips are a higher quality image than the screen capture.

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 6), fish condition, and gender.

Video clips 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.

Physical data collected during each weir check included water temperature (°F), dissolved oxygen (mg/L), conductivity (μ), turbidity (NTU), stream gauge (ft), weather conditions (RAN = rain, CLD = cloudy, CLR = clear, FOG = fog), and water velocity (ft/s) measurements at the opening of the Riverwatcher scanner. Instantaneous water temperature and dissolved oxygen were recorded using an ExStik II model DO600

Dissolved Oxygen Meter and instantaneous conductivity was recorded using an ExStik II model EC500 Conductivity Meter (Extech Intruments Corporation). Hourly water temperature data was logged using a Hobo Water Temp Pro V2 submersible data logger (Onset Computer Corporation). 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 United States Geological Survey (USGS).

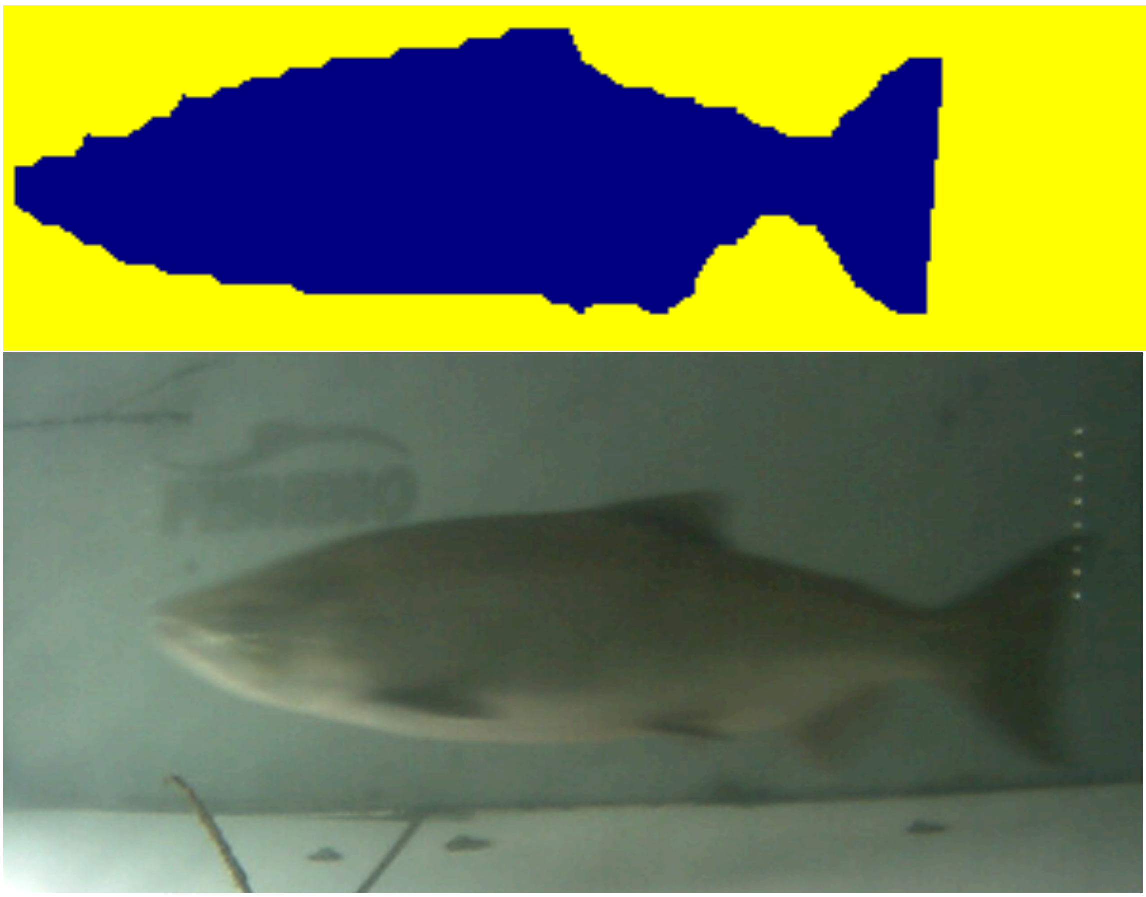

Figure 6. Example of a silhouette image and screen capture from a video clip of the same Chinook salmon that has a clipped adipose fin (ad-clip). Note: Video clips are a higher quality image than the screen capture.

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 15. After December 15 boat surveys were conducted Monday, Wednesday and Friday for the remainder of the season. 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 would be removed from the weir until CDFG allowed normal operations to resume. Five fish were observed downstream and fourteen fish were observed upstream of the weir during visual assessments from a boat, resulting in a maximum stacking ratio of 0.02 for the season, which is substantially less than the 1.15 threshold.

Results

Chinook salmon abundance and migration timing

Between September 16, 2011 and December 31, 2011, the Riverwatcher detected 2,817 adult fall-run Chinook salmon as they passed upstream of the weir. Daily passage ranged between 1 and 125 Chinook (Figure 7). Although Diel Chinook salmon passage was not signicantly different between dusk (1600-2159 hours), night (2200-0359 hours), dawn (0400-0959 hours), and day (1000-1559 hours) time-blocks (ANOVA: $F = 6.42$, $P = 0.3E\text{-}3$), it appears the majority of Chinook salmon passage occured between dusk and dawn with a substantial decrease in passage during the day (1000 hours – 1559 hours; Figure 8).

Chinook salmon gender and size

Total fall-run Chinook salmon passage was composed of 67% male (n = 1,892), 25% female (n = 712), and 8% unknown (n = 213). Mean total length for Chinook salmon upstream passages were: 583 mm (n = 2,801) for male, 614 mm (n = 892) for female, 562 mm (n = 270) for unknown; and 589 mm for all Chinook combined (Figutre 9). Mean lengths for male and female salmon differed slightly between size groups, but the length frequency distributions for males and females were predominately the 550 – 600 mm size class (Figure 9).

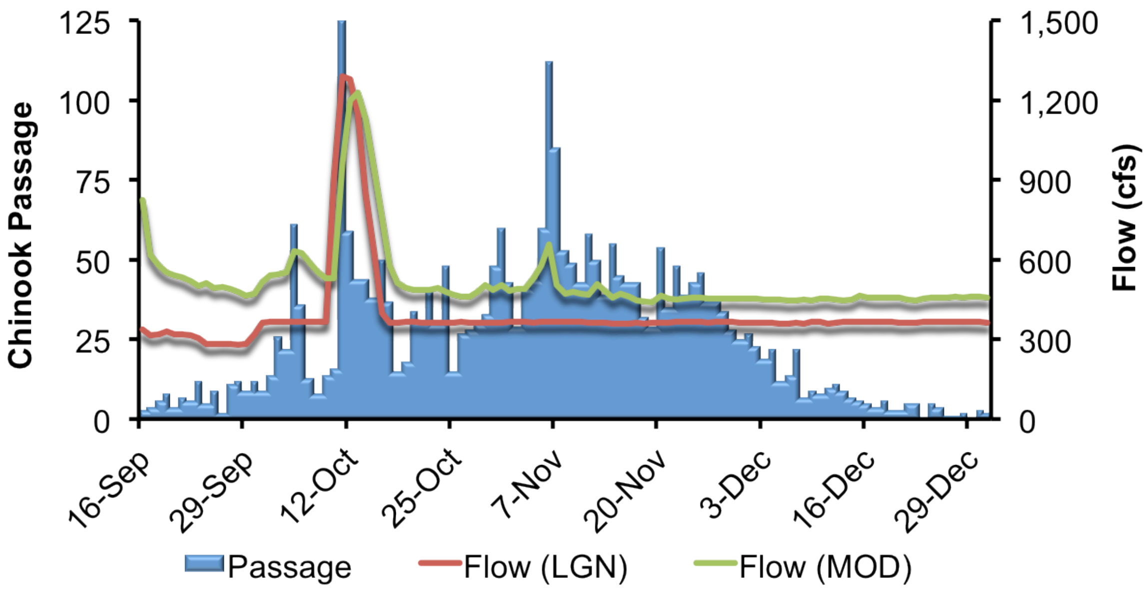

Figure 7. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to daily average flows (cfs) recorded in the Tuolumne River at La Grange (LGN) and Modesto (MOD) between September 16, 2011 and December 31, 2011 [Data source: CDEC].

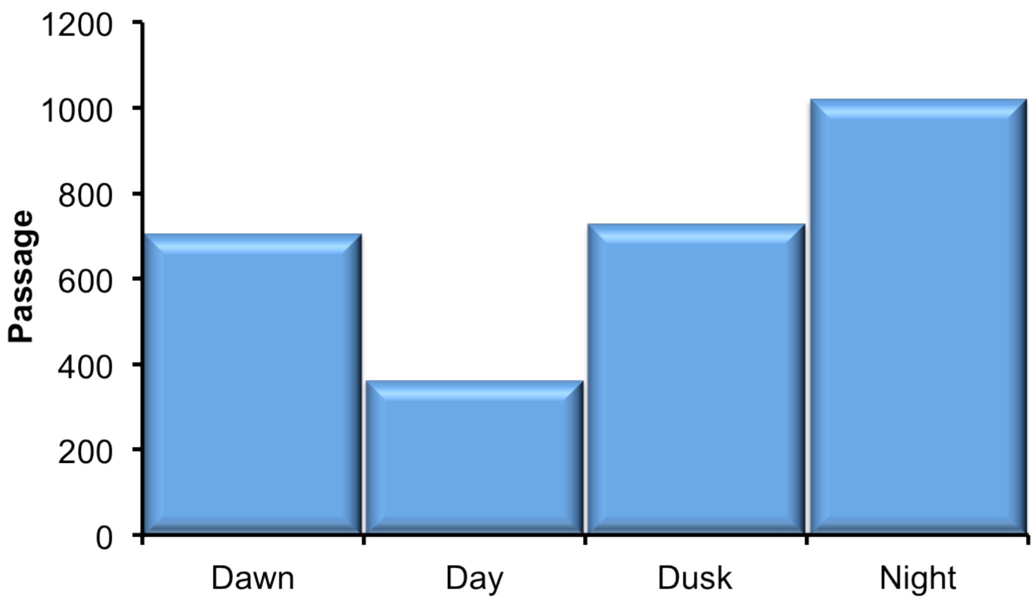

Figure 8. Chinook salmon passage in 6-hour time blocks. Diel Chinook salmon passage was not significant among the different time periods (ANOVA: *F = 6.42, P = 0.3E-3*).

Origin of Chinook salmon production

Chinook with adipose fin clips (ad-clips), suggesting hatchery origin, were observed in 55% (n=1,442) of Chinook that could be positively identified for presence/absence of adipose fin at the Tuolumne River weir during 2011. 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 2. Fall-run Chinook salmon upstream passage data from September 16, 2011 through December 31, 2011 (upstream passage counts only, data are not directly comparable to net passage). Parenthesis indicates range.

Sex – Adipose fin clip	Mean TL (mm)	95% CI (mm)	n
Male – No	589 (201 - 1,017)	589 ± 6	1,165
Male – Yes	580 (234 – 1,037)	580 ± 4	1,604
Male – Unknown	542 (205 - 873)	542 ± 42	32
Female – No	635 (386 - 952)	635 ± 11	404
Female – Yes	598 (347 - 944)	598 ± 8	486
Female – Unknown	511 (476 - 545)	511 ± 67	2
Unknown – No	571 (502 - 773)	571 ± 22	24
Unknown – Yes	484 (251 - 669)	484 ± 176	4
Unknown – Unknown	563 (272 - 823)	563 ± 10	242
Combined	589 (201 - 1,037)	589 ± 3	3,963

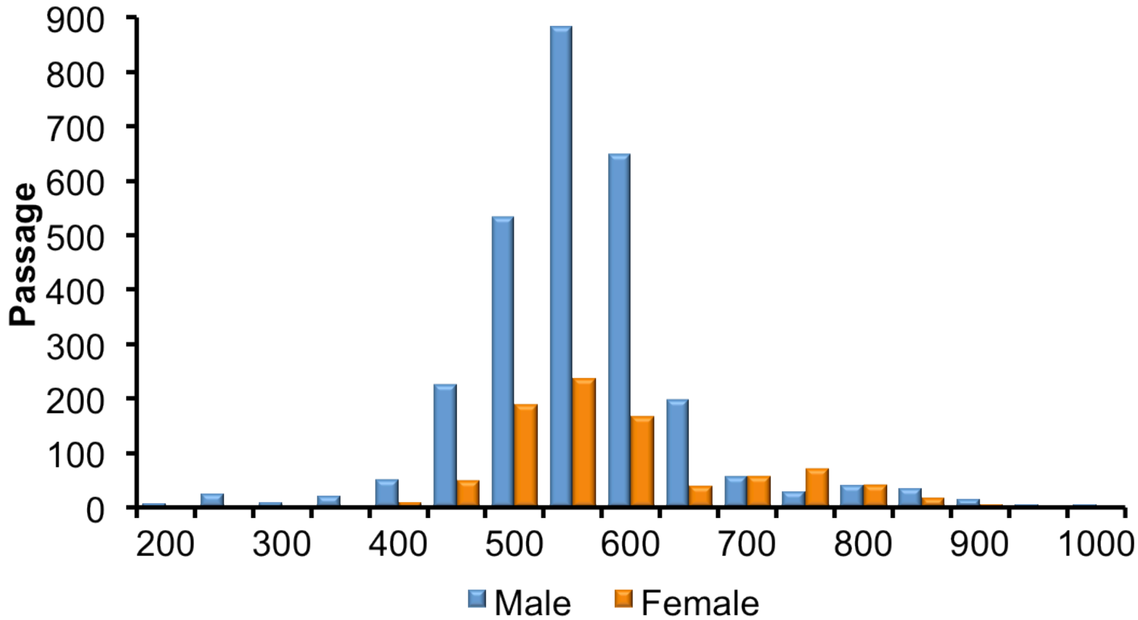

Figure 9. Length frequency of male and female fall-run Chinook salmon passage (upstream passage counts only, data are not directly comparable to net passage).

O. mykiss

Four *O. mykiss* were recorded passing through the weir between September 16, 2011 and December 31, 2011 (Table 3). One *O. mykiss* was recorded as an ad-clip and gender was not determinable for all *O. mykiss*, either due to fish size or quality of video.

Table 3. *O. mykiss* passages observed at the Tuolumne River weir between September 16, 2011 and December 31, 2011.

Species	Date	TL (mm)	Adipose Fin Clip
O. mykiss	9/20/11	384	No
O. mykiss	9/20/11	418	No
O. mykiss	9/23/11	360	No
O. mykiss	11/15/11	384	Yes

Non-salmonids

There were 12 other species identified passing the weir including bluegill sunfish (*Lepomis macrochirus*), common carp (*Cyprinuscarpio*), channel catfish (*Ictaluruspunctatus*), goldfish (*Carassiusauratus*), hardhead (*Mylopharodon conocephalus*), largemouth bass (*Micropterussalmoides*), Sacramento blackfish (*Orthodonmicrolepidotus*), Sacramento pikeminnow (*Ptychocheilusgrandis*), Sacramento sucker (*Catostomusoccidentalis*), smallmouth bass (*Micropterusdolomieu*), striped bass (*Moronesaxatilis*), white catfish (*Ictaluruscatus*); as well as unknown species of black bass (*Micropterus spp.*), catfish (*Ameiurus spp. and Ictalurus spp.*), and sunfish (Lepomis spp.) (Table 4). There were 11 net upstream passages that were identified as fish, but could not be identified to species.

Table 4. Incidental species passage data from September 16, 2011 through December 31, 2011. Only upstream passages were used for Total Length measurements (TL). Parenthesis indicates range.

Native Species	Mean TL (mm)	Date Range	Total Passage
Hardhead	291 (208 – 624)	9/18/11 – 12/31/11	489
Sacramento blackfish	419 (234 – 530)	9/20/11 – 12/21/11	44
Sacramento pikeminnow	325 (208 – 546)	9/18/11 – 12/31/11	94
Sacramento sucker	410 (224 – 784)	9/16/11 – 12/31/11	1,531
Non-native Species	Mean TL (mm)	Date Range	Total Passage
Bluegill sunfish	124	10/21/11	1
Common carp	518 (318 – 744)	9/16/11 – 12/7/11	354
Channel catfish	441 (284 – 611)	9/19/11 – 12/17/11	43
Goldfish	331 (246 – 375)	9/20/11 – 10/12/11	6
Largemouth bass	313 (174 – 426)	9/23/11 – 12/20/11	50
Smallmouth bass	285 (204 – 407)	9/17/11 – 12/30/11	53
Striped bass	434 (203 – 707)	9/21/11 – 11/20/11	14
White catfish	347 (180 – 572)	9/17/11 – 12/31/11	209
Unknown – black bass	274 (185 – 407)	9/21/11 – 12/2/11	25
Unknown – catfish	329 (180 – 509)	9/18/11 – 11/2/11	24
Unknown Species	Mean TL (mm)	Date Range	Total Passage
Unknown – sunfish	134	9/21/11 – 9/21/11	2
Unknown	511 (270 – 996)	9/18/11 – 12/20/11	11

Environmental Conditions

Between September 16, 2011 and December 31, 2011 daily average flow at La Grange (LGN; RM 51.8) ranged between 280 cfs and 1,290 cfs (393 cfs season average). Daily average flow at Modesto (MOD; RM 17) ranged between 440 cfs and 1,230 cfs (520 cfs season average) during weir monitoring (Figure 7).

Instantaneous water temperatures measured at the weir ranged between 47.5˚F and 69.6˚F (56.6˚F season average; Figure 10). Instantaneous turbidity ranged between 0.17 NTU and 2.42 NTU (0.87 NTU season average; Figure 11), and instantaneous dissolved oxygen ranged between 8.29 mg/L and 12.79 mg/L (10.60 mg/L season average; Figure 12).

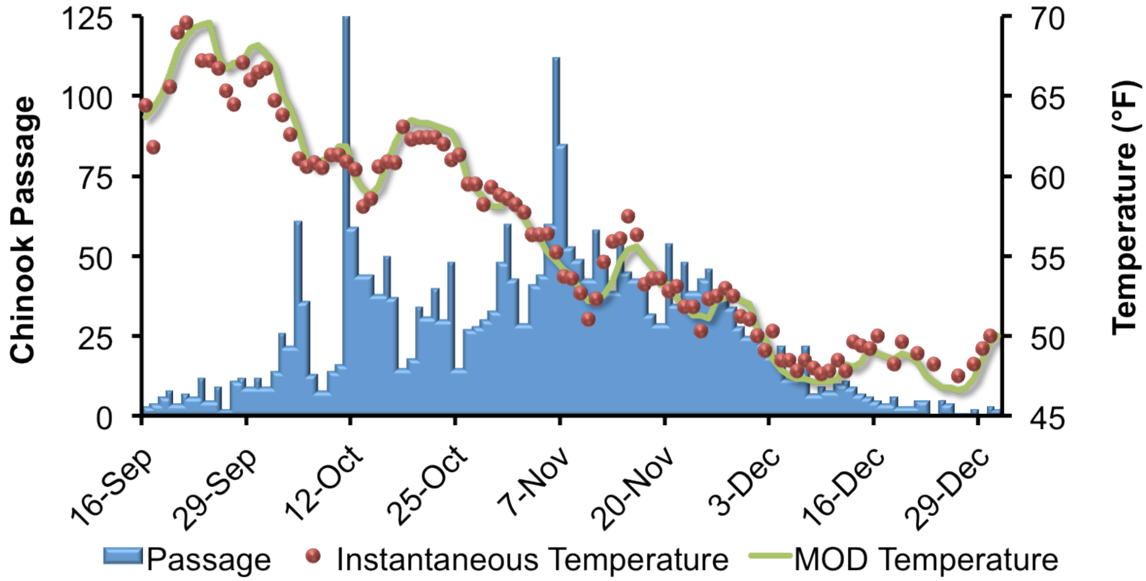

Figure 10. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous water temperature (°F) at the weir and daily average water temperature (°F) at Modesto (MOD) between September 16, 2011 and December 31, 2011 [Data source: CDEC – http://cdec.water.ca.gov].

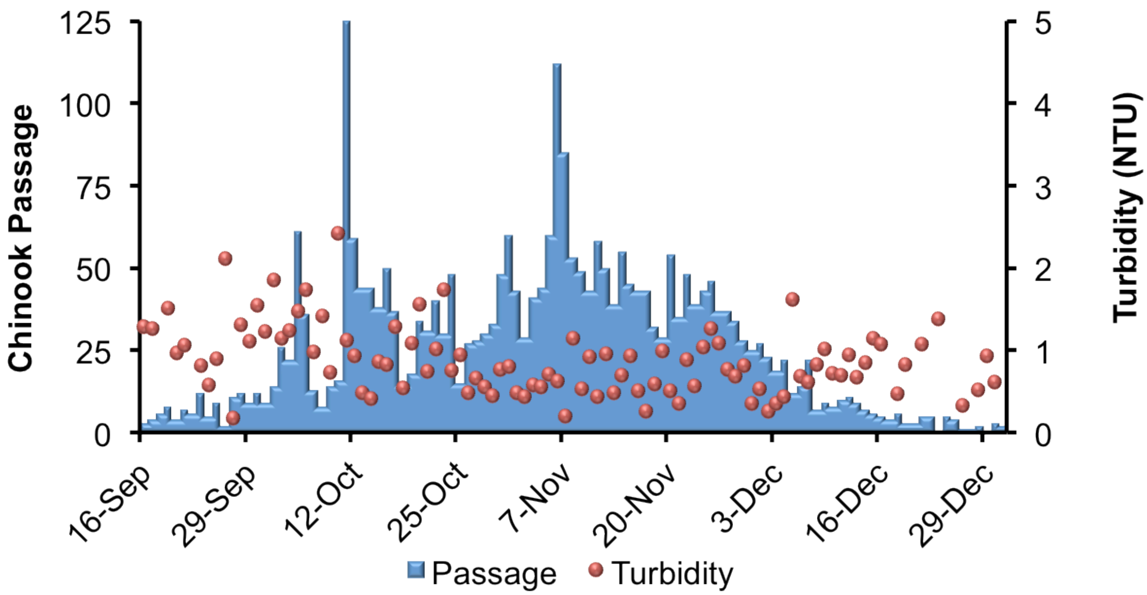

Figure 11. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous turbidity (NTU) between September 16, 2011 and December 31, 2011.

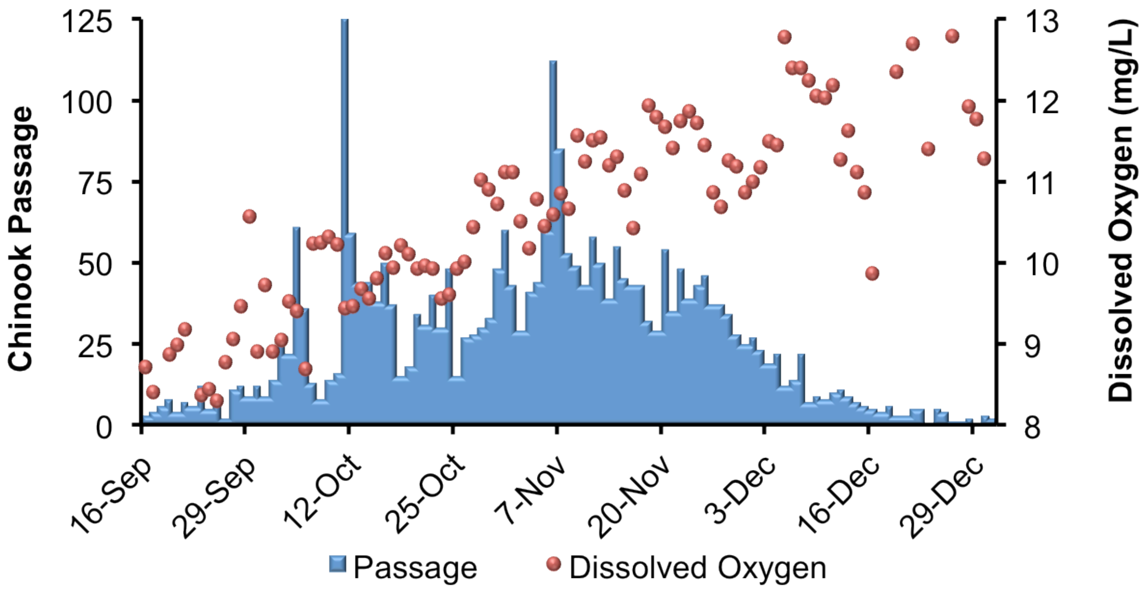

Figure 12. Daily upstream Chinook passage recorded at the Tuolumne River Weir in relation to instantaneous dissolved oxygen (mg/L) between September 16, 2011 and December 31, 2011.

Discussion

The Vaki Riverwatcher detected 2,817 fall-run Chinook salmon during 2011, which represents a substantial increase over the previous two years (Table 5). 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. There also appeared to be an increase in passage in relation to very small peaks (i.e. fluctuations) in flow. For example, small peaks in daily average flow (<100 cfs) appear to coincide with substantial inscreases in daily passage; thereby, suggesting that the magnitude of the peak flow does not influence daily passage rather it is simply the fluctuation, however small the magnitude might be, in flow that possibly triggers an increase in migratory response.

Table 5. 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
2011	Fall	September 16 – December 31	2,817
	Unknown	January 1 – Present	-
2010	Fall	September 9 – December 1	785
	Unknown	No sample	-
2009	Fall	September 22 – December 31	264
	Unknown	January 1 –February 10	31

Approximately 64% of the Chinook salmon observed at the Tuolumne River weir were two-year-old fish (≤ 600 mm TL), and the majority (74%) 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. However, the large increase in the number of jacks in the Sacramento and San Joaquin Basin have forced the Pacific Fishery Management Council to modify the prediction model and declare the Chinook salmon overfished (Tracy et. al. 2012).

The Tuolumne River Chinook salmon population is not supplemented with hatchery fish however, the 2011 fall-run was comprised of 55% 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 2011. 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 carcass survey counts were not available at the time that this report was prepared. However, escapement estimates from weir counts and carcass surveys differed greatly during the previous two years (2009 and 2010) of monitoring, whereby, the carcass survey estimate was substantially underestimated in comparison to the weir estimate.

In addition to providing information on migrating adult fall run Chinook salmon, the weir also provided information on the movement and sizes of 12 non-salmonid species observed passing the weir. Many (30%) of the non-salmonid species were non-native, and 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.

References

Beer, W. N., D. Salinger, S. Iltis, J. J. Anderson 2006. Evaluation of the 2004 Predictions of Run-size and Passage Distributions of Adult Chinook Salmon (*Oncorhynchustschawytscha*) Returning to the Columbia and Snake Rivers. Prepared by Columbia Basin Research School of Aquatic and Fishery Sciences, University of Washington. Seattle, WA, for the United States Department of Energy Bonneville Power Administration Division of Fish and Wildlife, Portland, OR. Annual Report January 2004 – December 2004 Project # 1989-108-00, 17 pp.

Blakeman, D. 2008. Tuolumne River Fall Chinook Salmon Escapement Survey. Federal Energy Regulatory Commission Annual Report FERC Project #2299, Report 2007-1.

CDFG and NMFS 2001. Final Report on Anadromous Salmonid Fish Hatcheries in California. California Department of Fish and Game National Marine Fisheries Service Joint Hatchery Review Committee Final Report, December 3, 2001.

Ford, T. and L. R. Brown, 2001. Distribution and Abundance of Chinook Salmon and Resident Fishes of the Lower Tuolumne River, California. In R.L. Brown (ed.) Fish Bulletin 179 Contributions to the Biology of Central Valley Salmonids Vol. 2:253-304. California Department of Fish and Game, Sacramento, California.

Fry, D. H., Jr. 1961. King Salmon Spawning Stocks of the California Central Valley, 1940-1959.24 *California Fish and Game* 47(1): 55-71.

McBain and Trush 2000.Habitat Restoration Plan for the Lower Tuolumne River Corridor.Arcata, CA, Prepared for the Tuolumne River Technical Advisory Committee. 240 pp.

Moyle, P. B. 2002. Inland fishes of California, revised and expanded. University of California Press, California. 502 pp.

O'Brien, J. 2009. 2008 Tuolumne River Fall Chinook Salmon Escapement Survey. California Department of Fish and Game, Tuolumne River Restoration Center, La Grange Field Office.

Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game.

Ricker, W. E. 1975.Computation and interpretation of biological statistics of fish populations.*Dept. of the Env. Fisheries and Marine Service, Bull.*,191, 382pp.

Seber, G. A. F., 1973, Estimation of animal abundance and related parameters, Griffin, London, 506 pp.

Schaefer, M. B. 1951.Estimation of the size of animal populations by marking experiments.*U.S. Fish and Wildlife Service Bull.*,52:189-203.

Stewart, R. 2002.Resistance board weir panel construction manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Artic-Yukon-Kuskokwim Region, Regional Information Report No. 3A02-21, Fairbanks, Alaska.

Stewart, R. 2003.Techniques for installing a resistance board fish weir. Alaska Department of Fish and Game, Division of Commercial Fisheries, Artic-Yukon-Kuskokwim Region, Regional Information Report No. 3A02-21, Fairbanks, Alaska.

Tabor, R. A., B. A. Footen, K. L. Fresh, M. T. Celedonia, F. Mejia, D. L. Low, and L. Park 2007. Smallmouth bass and largemouth bass predation on juvenile Chinook salmon and other salmonids in the Lake Washington Basin. North American Journal of Fisheries Management 27: 1174-1188.

Tobin, J. H. 1994.Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers.U. S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report Number 22, Kenai, Alaska.

Tracy, C., R. Dorval, K. Merydith, and K Kleinschmidt 2012. Preseason Report I Stock Abundance Analysis and Environmental Assessment Part 1 For 2012 Ocean Salmon Fishery Regulations. Pacific Fishery Management Council. February 2012.

Vasques, J. 2001. 2000 Tuolumne River Chinook Salmon Spawning Escapement Survey. Federal Energy Regulatory Commission Annual Report FERC Project #2299, Report 2002-2.

Yoshiyama, R. M., E. R. Gerstrung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Pages 71-176 in R. L. Brown, editor.Contributions to the Biology of Central Valley Salmonids, Fish Bulleting 179. California Department of Fish and Game, Sacramento.