Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2009 through July 2010

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SUMMARY

The emigration of juvenile chinook salmon (*Oncorhynchus tschawytscha*) and steelhead (*Oncorhynchus mykiss*) on the lower Mokelumne River was monitored using two rotary screw traps (RST) and a bypass trap during the 2009/2010 season. The upstream rotary screw trap (VINO) was positioned just upstream of the Elliot Road bridge at river kilometer (Rkm) 87.4 and was operated from 30 November 2009 to 9 July 2010. The downstream rotary screw trap (GOLF) was located just below the Lower Sacramento Road Bridge at Rkm 61.8 and was operated from 14 December 2009 to 14 July 2010. The smolt bypass trap was located at Woodbridge Irrigation District Dam (Rkm 62.2) and was operated from 7 April 2010 to 16 July 2010.

The first juvenile chinook salmon was captured at the VINO RST on 18 December 2009. Fourteen trap efficiency tests were conducted at VINO during the monitoring period. Trap efficiencies using wild salmon as test fish were significantly higher than trap efficiencies using hatchery salmon as test fish. Consequently, eight trap efficiency trials were used to generate the chinook salmon abundance estimate, seven using naturally produced salmon and one using hatchery produced salmon. The total estimated abundance of naturally produced juvenile chinook salmon passing the VINO site during the monitoring period was 124,279 (95% CI: 93,555-199,950). Twenty-four wild age 0+ steelhead were caught at VINO between 25 February and 2 July 2010. Estimated passage of wild age 0+ steelhead (based on trap calibrations using salmon) was 745 (95% CI: 507-1,406).

At the downstream RST (GOLF), the first juvenile chinook salmon was captured on 5 January 2010. Eight trap efficiency tests using hatchery produced salmon were conducted at GOLF during the monitoring period. Trap efficiencies ranged from 0.3% to 4.4% and averaged 1.9%. The total estimated abundance of naturally produced juvenile chinook salmon passing the GOLF site was 66,751 (95% CI: 38,914-283,316). Thirty-five wild age 0+ steelhead were captured at GOLF between 22 April and 14 July 2010. Based on trap efficiencies using salmon, the estimated abundance of wild age 0+ steelhead passing the GOLF RST was 6,955 (95% CI: 4,344-20,897).

A total of 397 naturally produced chinook salmon were caught at the smolt bypass trap (BYPASS). Estimates for weekend catch were added to actual catch to produce an

estimated count of 598. The total downstream salmon emigration estimate, calculated from adding the BYPASS trap and the GOLF RST estimates, was 67,349 (95% CI: 39,512-283,914). Ninety wild age 0+ steelhead were caught at the BYPASS trap during the season. Estimates for weekend catch were added to actual catch to produce an estimated count of 149 age 0+ wild steelhead.

Nineteen fish species were caught at the VINO RST during the survey period, 7 native and 12 non-native. Native fish species were more frequently caught than non-native species and chinook salmon were the most abundant species caught. At the downstream traps (GOLF and BYPASS) 28 fish species were caught, 8 native and 20 non-native. Native fish species were more frequently caught than non-native species and prickly sculpin (*Cottus asper*) were the most abundant species caught.

Water releases from Camanche Reservoir ranged from 329 cubic feet per second (cfs) (9.3 cubic meters per second (m^3/s)) to 1,453 cfs (41.1 m^3/s) during the monitoring period.

INTRODUCTION

East Bay Municipal Utility District (EBMUD) has been monitoring juvenile salmonid emigration on the lower Mokelumne River (LMR) since 1990 (Bianchi et al. 1992, Marine 2000). Nearly all salmonid spawning occurs in a 16 kilometer reach of the LMR below Camanche Dam (Setka 2004). Fish traps are operated with the objectives of estimating abundance and monitoring the emigration patterns of anadromous fish species in the LMR. This report presents the monitoring results for rotary screw trap and bypass trap operations from December 2009 through July 2010.

METHODS

Rotary screw traps

Two eight-foot diameter rotary screw traps (E.G. Solutions, Inc.) were operated at upstream and downstream locations on the lower Mokelumne River (Figure 1). The upstream RST was located near the Elliott Road Bridge, adjacent to property owned by Vino Farms, at Rkm 87.4. The downstream RST was located adjacent to the Lodi Golf and Country Club at Rkm 61.8, just downstream of Woodbridge Irrigation District Dam (WIDD). Both traps were operated at the same locations used during the previous two seasons (Pagliughi et al. 2008; Boyd 2009). In this report, the upstream and downstream RST sites are referred to as VINO and GOLF, respectively.

The traps were operated Monday through Friday, except between 13 April 2010 and 21 May 2010, when they were operated every day of the week. Rotary screw trap checks were performed once daily unless large flow fluctuations warranted a second debris check in effort to keep the traps rotating. During Monday through Friday operations, traps were taken out of service after each check on Friday afternoon. Traps were reset each Monday morning.

Efforts were made to maintain a rotational speed of two rotations per minute (RPM) or greater at both RSTs (USFWS 2008). Rotations were measured using a stopwatch to record the time for three full rotations. RPMs were taken at each trap check. Trap cables were adjusted to optimize rotations. Cone rotations since the previous trap check were read off of a Redington® mechanical counter mounted on side rails near the mouth of the cone. Water velocity was measured at the center of the trap cone, just below the water surface, at the beginning of each trap check. Pontoons, cones, live boxes and decks were cleaned daily to maintain traps in good working order. Cables, pulleys, counters and cones were inspected daily to ensure proper function.

Bypass Trap

A smolt bypass trap was operated in the bypass pipe at WIDD (Rkm 62.2) during the 2009/10 trapping season. The bypass trap (referred to as BYPASS) conveys fish that are screened off of the Woodbridge Irrigation Canal when Woodbridge Irrigation District is diverting water from the LMR. The trap was checked once daily and was operated Monday through Friday, except between 13 April 2010 and 21 May 2010, when it was operated seven days per week. A fish crowder and a long-handled dip net were used to capture fish. Debris was cleared from the trap during each check. The bypass trap was also operated during the 2006/07 and 2008/09 monitoring seasons (Workman et. al. 2007; Boyd 2009).

Calibrations

Multiple trap efficiency tests were conducted at each RST throughout the outmigration period to provide an estimate of the proportion of juvenile chinook salmon each RST was capturing. Standard mark-recapture ratios were used as measurements of trap efficiency and calculated as follows:

$$TE = \frac{m}{M}, \text{ where}$$

TE = trap efficiency,
m = number of marked fish recaptured,
M = number of marked fish released.

Naturally produced chinook salmon were used for the trap efficiency trials when catch was high enough to produce a group of test fish. Additional test fish were provided by California Department of Fish and Game at the Mokelumne River Fish Installation (MRFI). Bismark® brown dye, upper caudal fin clips, and Visible Implant Elastomer (Northwest Marine Technology ™) were used in different combinations to mark groups of test fish for the VINO trap. A lower caudal fin clip (sometimes in combination with Bismark® brown dye) was always used to mark test fish for the GOLF trap, providing the means to distinguish test fish between the two traps. The Bismark® brown dye was applied by holding test fish in an aerated tank of dye solution for approximately 60 minutes.

Mark retention and mortality rates were determined before releasing test fish. Calibration fish for GOLF were released below the face of Woodbridge Dam, approximately 0.1 km upstream of the trap location. Test fish for VINO were released approximately 0.25 km upstream of the trap location. The test fish were distributed proportionally to the flow across the river at each location.

Rotary Screw Trap Abundance Estimates

RST abundance estimates were generated for juvenile chinook salmon and steelhead using the Petersen equation (Volkhardt et al. 2007). Daily catch estimates were generated for non-trapping days by averaging daily catch for three days preceding and following these periods (Appendix A). Trap efficiencies were applied to daily catch estimates and daily catch numbers to produce daily abundance estimates:

$$DA = \frac{C}{TE}\text{, where}$$

DA = daily abundance estimate,
C = daily catch or daily catch estimate,
TE = trap efficiency.

Annual abundance estimates were calculated by summing the daily abundance estimates. Ninety-five percent confidence intervals were calculated for each trap efficiency test using:

$$LCL = TE - 1.96\sqrt{TE\frac{(1-TE)}{M}}\text{, and}$$

$$UCL = TE + 1.96\sqrt{TE\frac{(1-TE)}{M}}\text{, where}$$

LCL = trap efficiency lower 95% confidence limit,
UCL = trap efficiency upper 95% confidence limit,
TE = trap efficiency,
M = number of marked fish released,
$TE\frac{(1-TE)}{M}$ = estimated variance of TE.

Daily confidence intervals for daily abundance estimates were calculated as follows:

$$DCI_{\text{low}} = \frac{C}{UCL}\text{, and}$$

$$DCI_{\text{high}} = \frac{C}{LCL}\text{, where}$$

DCI_{low} = daily abundance lower 95% confidence limit,
DCI_{high} = daily abundance upper 95% confidence limit,

C = daily catch or daily catch estimate,
UCL = trap efficiency upper 95% confidence limit,
LCL = trap efficiency lower 95% confidence limit.

Confidence intervals for annual abundance estimates were calculated by summing the daily abundance confidence intervals.

BYPASS Trap Abundance Estimates

Daily catch estimates at the BYPASS trap were generated for non-trapping days by averaging daily catch to the nearest fish, for three days preceding and following these periods. Seasonal abundance was estimated by summing daily trap counts and daily estimates for non-trapping days over the monitoring period.

Fish Handling and Condition Factors

Captured fish were processed in the field, just adjacent to the trapping site, or in a tagging trailer near the trap. The trailer was equipped with a flow-through water supply and re-circulating anesthetic bath to allow safe processing of larger numbers of fish. The trailer was used at VINO during the early season and later transferred to Woodbridge Dam to accommodate the processing of larger volumes fish at the GOLF and BYPASS traps. A 70 to 100 mg/L solution of tricaine methanesulfonate (MS-222) was used to anesthetize fish. Pumps and mechanical aerators were used to maintain suitable dissolved oxygen concentrations in all fish holding receptacles during processing.

During each trap check, up to 50 chinook salmon and up to 20 fish of other species from each trap were weighed and measured. Fish were weighed to the nearest 0.1 gram using an Ohaus® Scout portable scale. Fork lengths (FL) and total lengths (TL) of each fish were measured to the nearest millimeter (mm). Life stage and any observations of marks, injuries or anomalies were also recorded. Processed fish were allowed to recover before being transported to the release site by truck or boat. The fish were transported in 19 liter (5 gallon) buckets equipped with battery operated aerators and released approximately 0.4 kilometers (0.25 miles) downstream of the capture sites.

Fulton's Condition Factors (Bagenal and Tesh 1978) were calculated for up to 50 chinook salmon caught each trapping day:

$$K = \left(\frac{W}{FL^3}\right) * 100{,}000 \text{, where}$$

K = Fulton's Condition Factor,
W = weight in grams,
FL = fork length in mm.

Coded Wire Tagging

Mark IV tagging machines (Northwest Marine Technologies, Inc.) were used to implant half-length Coded Wire Tags (CWT) in juvenile chinook salmon caught in all traps.

Tagging was performed on trapped juvenile chinook salmon with total lengths ≥ 40mm. Two numeric tag codes were used during the survey period. Standard coded wire tagging methods for juvenile salmon were followed (Vogel and Marine 1999).

Environmental Data

Turbidity samples were collected by submerging a sample jar to a depth of 0.3 m (1 ft) and allowing it to fill with water. Turbidity samples were processed in the lab using a Hach ®P1000 turbidimeter. Water temperature and dissolved oxygen data were collected using a YSI 550A handheld dissolved oxygen meter. All water quality measurements were collected daily at each location when trap checks took place. Flow measurements were provided by EBMUD's Golf and Elliot Road gauging stations.

Data Analysis

Graphics production and data analyses were performed using ArcMAP, Arc/Info (ESRI) systems, JMPIN 4.0.4 (Academic), Microsoft (MS) Access 2003 and MS Excel 2003. A P-value ≤ 0.05 was considered statistically significant. Mean fork length was reported with ±1 standard deviation (SD) for $n \geq 3$. Rotary screw trap abundance estimates were reported with 95% confidence intervals (CI).

RESULTS

Mokelumne River Flow, Temperature, Turbidity

Average daily flow at the Elliot Road gauging station (just below the VINO trapping site) ranged from 298 cfs (8.43 m^3/s) to 1,464 cfs (41.43 m^3/s), x = 590 cfs (16.7 m^3/s) during the time the VINO trap was operated (30 November 2009 through 9 July 2010). Water temperatures recorded at the VINO trapping site were between 9.2 and 14.6°C, with an average of 11.6°C. Water turbidity in Nephelometric Turbidity Units (NTU) at the VINO RST ranged from 1.4 to 10.1 NTU with a mean of 2.4 NTU.

Average daily flow at the Golf gauging station ranged from 120 cfs (3.40 m^3/s) to 1,248 cfs (35.32 m^3/s), x = 480 cfs (13.59 m^3/s) during the time the BYPASS trap was operated (7 April 2010 through 16 July 2010). Water temperatures recorded at the BYPASS trap were between 12.1 and 18.1°C, with an average of 15.1°C. Water turbidity at the BYPASS ranged from 1.8 to 4.2 NTU with a mean of 2.6 NTU.

Average daily flow at the Golf gauging station ranged from 120 cfs (3.40 m^3/s) to 1,248 cfs (35.32 m^3/s), x = 480 cfs (13.58 m^3/s) during the time the GOLF RST was operated (14 December 2009 through 14 July 2010). Water temperatures recorded at the GOLF trapping site were between 8.6 and 17.5°C, with an average of 13.0°C. Water turbidity at GOLF ranged from 1.6 to 13.0 NTU with a mean of 3.2 NTU.

Average daily flow, water temperature and turbidity in the lower Mokelumne River are summarized at locations between Camanche Dam and the GOLF gauging station in Figure 2.

Trap Operations

The VINO RST was operated between 30 November 2009 and 9 July 2010. The cone was stopped by debris on 14 of 162 operating days. The minimum recorded cone rotation rate was 2.9 RPM and maximum was 5.1 RPM. Mean rotation rate during the monitoring season was 3.7 RPM. Excluding days with trap stoppages, the VINO trap met or exceeded the CAMP recommended minimum 2 RPMs (USFWS 2008) on 100% of all operating days. Water velocity entering the center of the trap cone ranged between 0.75 and 1.22 meters per second (m/s) and averaged 0.97 m/s.

The GOLF RST was operated between 14 December 2009 and 14 July 2010. Debris stopped the cone from rotating on 13 of 156 operating days. The minimum recorded cone rotation rate was 1.7 RPM and maximum was 4.7 RPM. Average rotational speed over the course of the monitoring period was 3.7 RPM. Excluding trap stoppages, the GOLF trap met or exceeded the CAMP recommended minimum rotation of 2 RPMs (USFWS 2008) on 99 % of all operating days. Water velocities entering the center of the trap cone ranged between 0.40 and 1.05 m/s and averaged 0.84 m/s.

The BYPASS trap at WIDD was operated between 7 April and 16 July 2010. During this time frame the trap was operated for 81 days. Water velocities at the top of the trap ranged between 0.74 and 1.01 m/s and averaged 0.89 m/s.

Calibrations

Fourteen calibration tests were conducted at the VINO RST during the 2009/10 trapping season (Table 1). Naturally produced chinook salmon were used as test fish for seven tests and MRFI salmon were used for seven tests. The final trap efficiency test (#14) was excluded because the trap was stopped by debris shortly after the test fish were released. VINO trap efficiencies using naturally produced salmon ranged from 7.5% to 24.2%, averaging 15.1% (n = 7). Trap efficiencies using MRFI salmon ranged from 0.9% to 11.7% and averaged 3.0% (n = 6). At flows ranging between 300-400 cfs, trap efficiencies using wild salmon as test fish were significantly higher than trap efficiencies using MRFI salmon as test fish (t-test: $t = -3.845$; df = 11; $P = 0.0027$). In addition, two paired tests took place, comparing trap efficiency rates using hatchery and naturally produced salmon. In both cases, efficiency rates were higher using naturally produced salmon (Table 1). Because of these significant findings, many efficiency tests using MRFI salmon were not used to generate salmon abundance estimates when tests using naturally produced fish were available (Table 1).

Eight calibration tests were conducted at the GOLF RST during the 2009/10 season (Table 1). All efficiency tests were conducted using MRFI salmon because only a small number of naturally produced salmon were available. Trap efficiency tests #2 and #6 were not used because the trap was stopped by debris shortly after the test fish were released. The failed calibrations were replaced using the following prediction formula:

$\text{Log}(TE^R) = -0.87533 + -0.00828 * (\text{Mean FL}) + -0.00020 * (\text{Mean flow})$

Where,

TE^R = Trap efficiency test replacement value
Mean FL = Mean fork length of chinook salmon caught at GOLF during the replacement time period.
Mean Flow = Mean flow at GOLF during the replacement time period.

This equation was derived using long-term efficiency data collected at the GOLF trap from 2005-2010. Average daily flow at release and mean FL of MRFI test salmon were used as the model effects (Logistic regression: $F = 20.8874$; df = 2, 56; $P < 0.0001$). The model explained 44% of the variation in the long-term efficiency data at GOLF. Using the prediction formula, efficiency rates for tests #2 and #6 were estimated to be 5.8% and 1.3%, respectively. Excluding the estimated values used for tests #2 and #6, GOLF trap efficiencies ranged from 0.3% to 4.4%, averaging 1.9% (n = 6).

Chinook Salmon

Catch and Abundance Estimates

During rotary screw trap monitoring, 8,401 naturally produced juvenile chinook salmon were captured at the VINO RST. Estimates for weekend catch were added to actual catch to produce a count of 16,610. Using trap efficiency data, the total estimated abundance of salmon passing the upstream RST (VINO) was 124,279 (CI: 93,555-199,950). The first and last salmon were caught on 18 December 2009 and 2 July 2010, respectively. The largest estimated number of salmon passed the VINO trap in January (Table 2).

At the GOLF RST, 441 naturally produced juvenile chinook salmon were captured between 5 January and 8 July 2010. Estimated weekend catch was added to the actual catch to produce a total count of 665. Using trap efficiency data, estimated salmon abundance at the downstream RST (GOLF) was 66,751 (CI: 38,914-283,316). The BYPASS trap captured 397 naturally produced juvenile chinook salmon between 16 April and 13 July 2010. Estimates for weekend catch were added to actual catch to produce an estimated count of 598. The total downstream emigration estimate, calculated from adding the BYPASS trap and the GOLF RST estimates, was 67,349 (95% CI: 39,512-283,914). At the downstream traps, the highest monthly abundance estimate was recorded in May (Table 2).

Life stage, size and condition

At the VINO RST, 84.6% of the salmon catch was classified as fry. Salmon fry fork lengths ranged from 27 to 40 mm and averaged 35±2 mm (n = 1,847). The remaining catch was composed of 2.6% parr (FL ave. = 55±9 mm, FL range = 38-77 mm, n = 54), 6.0% silvery parr (FL ave. = 66±12 mm, FL range = 45-134 mm, n = 132), and 6.8% smolt (FL ave. = 90±9 mm, FL range = 64-119 mm, n = 140). With the exception of two yearlings, all of the salmon caught at VINO were young of the year (age 0+) (Figure 3).

Chinook salmon catch at the downstream traps (GOLF and BYPASS) was dominated by smolt (90.7%). Smolt fork lengths ranged from 72 to 136 mm and averaged 97±8 mm (n = 735). Other salmon catch included; 6.3% fry (FL ave. = 34±2, FL range = 29-37 mm, n = 47), 0.2% parr (no FLs taken), and 2.8% silvery parr (FL ave. = 79±11 mm, FL range = 54-93 mm, n = 22). With the exception of one yearling, all of the salmon caught at the downstream traps were age 0+ (Figure 3).

The monthly average condition factor of all salmon life stages caught in the upstream and downstream traps is presented in Figure 4.

Migration Response

The relationships between three environmental variables (average daily flow, water temperature and turbidity) and estimated daily salmon passage at the upstream and downstream traps are presented in Figures 5 and 6. Linear regression analyses showed that each environmental variable had a significant linear relationship with salmon passage at the upstream trap; however they explained little of the variation in outmigration (Table 3). At the downstream traps, each environmental variable also had a significant relationship with salmon passage, but only explained some of the variation in outmigration (Table 3). Average daily releases from Camanche Dam explained the largest amount of variation (20%) in daily salmon passage estimates at the downstream traps (Linear regression: $F = 53.5197$; df = 1, 211; $P < 0.0001$).

Coded Wire Tagging

Naturally produced chinook salmon were coded wire tagged (CWT) at the VINO trap from 6 January to 12 May 2010. One tag code (06-09-02-01-02) was used to successfully tag 685 salmon captured at the VINO RST. Another 14 salmon did not survive the tagging process. Fork lengths of tagged salmon ranged from 37 to 134 mm and averaged 58±20 mm (n = 400). All successfully tagged salmon (685) were released just below the VINO RST.

A different tag code (06-09-02-01-03) was used to tag 414 chinook salmon at the downstream traps (GOLF and BYPASS). The salmon were tagged from 16 April to 15 July 2010. Mean FL was 96±7 mm (n = 414). Fish ranged in size from 76 to 116 mm. All salmon survived the tagging process and were released below the GOLF RST.

Six (1%) of the 685 chinook salmon coded wire tagged at the VINO FARMS were recaptured at the downstream traps (BYPASS and GOLF). One of the CWT salmon was recaptured at the GOLF trap, and the other five were recaptured at the BYPASS trap. Due to the low number of recaptures, a downstream abundance estimate for CWT salmon was not calculated.

A summary of coded-wire tagging efforts of naturally produced salmon since 1990 and corresponding recovery data is provided by Table 4.

Steelhead

Catch and Abundance Estimates

The first wild (natural production) age 0+ (<120 mm) steelhead was captured at the VINO RST on 25 February 2010. A total of 24 wild age 0+ steelhead was caught between 25 February and 2 July 2010. Estimated passage of wild age 0+ steelhead (based on salmon trap calibrations) was 745 (95% CI: 507-1,406). Steelhead catch also consisted of 4 wild age 1+ (≥120 mm) individuals and 26 hatchery origin (adipose fin clipped) yearlings (age 1+). The largest number of hatchery steelhead (16) was caught at VINO in March. The largest number of wild steelhead (10) was caught at VINO in April.

At the GOLF RST, 35 age 0+ (<120 mm) steelhead were captured between 22 April and 14 July 2010. Estimated passage of wild age 0+ steelhead at the GOLF trap (based on salmon trap calibrations) was 6,955 (95% CI: 4,344 - 20,897). Steelhead catch also consisted of 697 hatchery origin yearlings and 11 wild age 1+ (≥120 mm) individuals. At the BYPASS trap, 90 age 0+ (<120 mm) steelhead were captured between 20 April and 16 July 2010. Estimates of catch for non-trapping days were added to the count producing an estimate of 149 age 0+ steelhead. In addition, 6 wild age 1+ steelhead and 81 hatchery origin yearlings were caught at the BYPASS trap.

Combining the GOLF and BYPASS estimates, the total downstream passage of wild age 0+ steelhead was 7,144 (95% CI: 4,344 - 20,897). The largest number of hatchery steelhead (430) was caught at the downstream traps in March. The largest number of wild steelhead (66) was caught at the downstream traps in May.

Life stage and size

At the VINO RST, 75.0% of the naturally produced steelhead catch was classified as parr. The remaining catch was composed of 17.9% fry and 7.1% silvery parr. Naturally produced steelhead catch at the downstream traps (GOLF and BYPASS) was dominated by parr (83.5%). Other wild steelhead catch included 0.7% fry, 7.9% silvery parr, and 7.9% smolt.

Size and life stage data of wild steelhead caught at the upstream and downstream traps are presented in Figure 7.

Species Composition

At least 19 fish species were caught at the VINO RST during the survey period, 7 native and 12 non-native. Native fish species were more frequently caught than non-native species, comprising 99.5% of the total catch. Chinook salmon were the most abundant species caught (79.8%), followed by pacific lamprey (*Lampetra tridentata*) (18.4%) and prickly sculpin (*Cottus asper*) (0.6%).

At the downstream traps (GOLF and BYPASS) 28 fish species were caught, 8 native and 20 non-native. Native fish species were more frequently caught than non-native species, comprising 96.7% of the total catch. Prickly sculpin were the most abundant species caught (69.6%), followed by pacific lamprey (12.4%), steelhead (wild and hatchery origin) (7.0%) and chinook salmon (6.4%).

DISCUSSION

At the upstream RST (VINO), frequent trap stoppages occurred towards the end of the season due to large changes in flow brought on by several cold storms. However, by this time over 90% of chinook salmon had passed the upstream trap, suggesting that the upstream passage estimate was minimally affected by the stoppages. Also, during this time, efforts were made to check the RST twice daily, thereby preventing additional stoppages. Conversely, many of the trap stoppages at the downstream RST (GOLF) occurred prior to the peak of chinook salmon emigration when less than 5% of the salmon had passed the downstream traps. The trap stoppages coincided with the filling of Lodi Lake, when large amounts of debris were washed past WIDD. Again, efforts were made to check the trap twice daily to prevent any additional stoppages.

The abundant catch of chinook salmon at the VINO RST allowed a large number of efficiency tests to take place during the beginning of the monitoring season. The significant difference in efficiency rates between hatchery and wild age 0+ salmon suggests that hatchery salmon may not be an acceptable surrogate for naturally produced salmon at the upstream RST. Roper and Scarnecchia (1996) also reported significantly higher trap efficiencies when using wild salmon (age 0+) as test fish. However, their result was obtained only when the trap was spinning slowly (2.4 RPM). Additional tests should be conducted in the future to determine if the same results are found under a variety of conditions. For example, almost all of the 2009/10 efficiency tests were conducted under similar flow conditions using age 0+ salmon fry (~ 40 mm). Nonetheless, when a sufficient number of naturally produced salmon are available for calibration tests at the VINO RST, they will likely provide an improved estimate of trap efficiency.

Only a small number of chinook salmon were caught at the GOLF RST and the BYPASS trap this season, preventing the use of naturally produced salmon as test fish for the efficiency trials at GOLF. Since the RST began fishing at GOLF in 2005, only five efficiency tests have been conducted using naturally produced salmon as test fish (EBMUD unpublished data). Three of the trials have yielded zero recaptures. In the future, the BYPASS trap may provide a large number of wild salmon to use as test fish.

Currently, our efficiency modeling efforts at GOLF rely on calibration tests using hatchery salmon as test fish. The logistic regression analysis established that GOLF trap efficiencies (2005-2010) were significantly related to the variables flow and average fork length and explained 44% of the variation in the data. Other Central Valley streams have established similar relationships between trap efficiency and the variables flow and fork length (Watry et al. 2008). Additional trap efficiency data under a larger range of flows may provide an improved model fit in the future. Although, if efficiency tests using wild salmon yield a significantly different result than efficiency tests using hatchery salmon, the modeling process will need to alternately rely on efficiency trials using wild salmon as test fish.

The chinook salmon passage estimate of 124,279 at the VINO RST was lower than the 2007/08 and 2008/09 estimates of 1,117,451 and 175,612, respectively (Pagliughi et al. 2008; Boyd 2009). The number of salmon redds found during the 2007, 2008, and 2009 spawning seasons was 306, 63, and 248, respectively, providing no clues as to the cause of the decline (Pagliughi 2007; Del Real and Rible 2008; Bilski and Rible 2009). However, several other factors may explain the unexpectedly low upstream passage estimate this season; trap efficiency data and/or predation by hatchery steelhead. This season the trap efficiency trials used to produce the abundance estimate at VINO were mostly trials using wild salmon as test fish. During the previous two seasons, only trials using hatchery salmon were applied (Pagliughi et al. 2008; Boyd 2009). Trap efficiency rates using hatchery fish were significantly lower than tests using wild salmon and may overestimate salmon abundance when applied to salmon catch.

In addition, a large in-river release of 163,093 age 1+ MRFI steelhead took place from 10 February to 19 February 2010 at Rkm 103, just below Camanche Dam (EBMUD unpublished data). This time period coincided with the peak of chinook salmon fry emergence according to the lower Mokelumne River egg model developed by Vogel (1993) (Figure 8). There also appeared to be a corresponding drop in chinook salmon passage at the VINO trap shortly after the release. A similar event occurred on the Feather River in 2002, when a large in-river release of hatchery steelhead (500,000) may have resulted in an unexpectedly low passage estimate at a nearby rotary screw trap (Kindopp and Gonzales 2007). During this monitoring effort, angling surveys were conducted concurrent with the peak of chinook salmon emigration and an average of 1.38 (± 3.98 SD) salmon fry were found in the stomachs of residualized hatchery steelhead (n = 101). While in-river releases of MRFI steelhead are important to help prevent straying, future release sites and release timing should be evaluated to consider the potential impacts of MRFI steelhead predation and competition on emerging and rearing wild chinook salmon.

The downstream chinook salmon passage estimate of 67,349 indicated that chinook salmon survival was high between the upstream and downstream rotary screw traps, given the upstream abundance estimate of 124,279. Last season, CWT recapture data also suggested that survival may be high between the upstream and downstream RSTs (Boyd 2009). However, it is important to note that the downstream abundance estimate relied on hatchery salmon as calibration fish, which may overestimate salmon abundance. In the future, mark/recapture studies using CWTs and/or VIE may be used to further investigate survival trends between the upstream and downstream trapping sites on the LMR.

During the 2009/10 trapping season, as well as previous two trapping seasons, environmental variables such as flow, water temperature, and turbidity have explained little of the variation in the estimated daily abundance of chinook salmon caught at the VINO RST (Pagliughi et al. 2008; Boyd 2009). On the lower Feather River, adult spawn timing had a significant relationship with rotary screw trap catch at the upstream RST, positioned just below where the majority of chinook salmon spawn (Seesholtz et al. 2004). The same relationship may exist on the LMR at the VINO RST. In the future, adult spawn timing should be examined as an additional explanatory variable for the estimated daily abundance of chinook salmon caught at the upstream RST.

Water releases from Camanche Dam (flow) explained 20% of the variation in estimated daily abundance of chinook salmon at the downstream traps, and there was a significant linear relationship between the two variables. The ascending and descending limbs of the first spring pulse (mid-April) appeared to have the largest effect on salmon emigration. The following two pulses did not appear to influence salmon emigration. However, this may have been due to the fact that most of the salmon had already moved past WIDD during the first pulse.

Sixteen years of CWT recovery data from naturally produced salmon on the LMR indicate that the likelihood of an adult recovery is low. From 1990-2006, CWT recovery data (ignoring expansion factors) demonstrate that it takes an average of 1,286 naturally produced CWTd juvenile salmon from the LMR to obtain one adult recovery record. Unless more than 15,000 naturally produced LMR salmon can be CWTd each year, formal analysis of the data will be limited (as demonstrated by recovery data from 1999-2006). Future coded-wire-tagging efforts may be better suited towards gaining a better understanding of in-river survival of outmigrating juvenile salmon on the LMR.

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Table 1. Summary of trap efficiency tests conducted at rotary screw trap (RST) locations on the lower Mokelumne River during the 2009/10 trapping season.

VINO FARMS (UPSTREAM RST)

Test #	Release date	Flow at release (cfs)	Origin of test salmon	Ave. FL of test salmon (mm)	# Marked	# Recaptured	% Recaptured	Used for estimate?
1	13-Jan-10	314	LMR	36.2	287	68	**23.7%**	Yes
2	20-Jan-10	320	LMR	34.5	309	34	**11.0%**	Yes
3	25-Jan-10	311	MRFI	39.1	848	8	**0.9%**	No
4	26-Jan-10	314	MRFI	41.4	314	8	**2.5%**	No
5	26-Jan-10	314	LMR	36.0	321	24	**7.5%**	Yes
6	03-Feb-10	308	LMR	36.2	491	119	**24.2%**	Yes
7	22-Feb-10	307	MRFI	45.2	850	14	**1.6%**	No
8	24-Feb-10	311	MRFI	44.8	94	11	**11.7%**	No
9	24-Feb-10	311	LMR	36.0	94	13	**13.8%**	Yes
10	17-Mar-10	308	LMR	46.3	43	5	**11.6%**	Yes
11	22-Mar-10	301	MRFI	47.3	1002	13	**1.3%**	No
12	24-Mar-10	304	LMR	38.8	107	15	**14.0%**	Yes
13	19-Apr-10	379	MRFI	63.8	799	17	**2.1%**	Yes
14	13-May-10	1429	MRFI	78.5	750	3	**0.4%**	No

GOLF (DOWNSTREAM RST)

Test #	Release date	Flow at release (cfs)	Origin of test salmon	Ave. FL of test salmon (mm)	# Marked	# Recaptured	% Recaptured	Used for estimate?
1	26-Jan-10	263	MRFI	39.6	849	37	**4.4%**	Yes
2	22-Feb-10	261	MRFI	45.0	853	5	**0.6%**	No
3	22-Mar-10	215	MRFI	46.7	997	11	**1.1%**	Yes
4	20-Apr-10	348	MRFI	70.4	801	22	**2.7%**	Yes
5	13-May-10	1242	MRFI	80.4	750	6	**0.8%**	Yes
6	07-Jun-10	1181	MRFI	92.5	1013	4	**0.4%**	No
7	14-Jun-10	582	MRFI	99.1	1005	3	**0.3%**	Yes
8	21-Jun-10	564	MRFI	98.7	515	11	**2.1%**	Yes

Indicates paired releases

Table 2. Expanded monthly catch, juvenile passage estimates with 95% lower and upper confidence intervals (LCI and UCI), and cumulative passage for chinook salmon captured at the upstream and downstream trapping locations on the LMR during the 2009/10 trapping season.

Upstream (VINO FARMS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage
December	115	480	398	604	0.4%
January	9,088	67,459	51,668	98,759	54.3%
February	5,238	31,153	24,783	43,952	25.1%
March	1,740	12,897	8,347	33,441	10.4%
April	243	3,540	2,408	6,677	2.8%
May	150	7,027	4,779	13,265	5.7%
June	30	1,410	959	2,662	1.1%
July	7	313	213	592	0.3%
Total	**16,610**	**124,279**	**93,555**	**199,950**	**100.0%**

Downstream (GOLF and BYPASS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage
December	0	0	0	0	0.0%
January	26	593	451	866	0.9%
February	12	241	185	345	0.4%
March	65	1,997	1,402	3,880	3.0%
April	146	6,791	4,019	26,305	10.1%
May	537	42,077	23,303	206,240	62.5%
June	449	14,740	8,969	43,821	21.9%
July	29	911	585	1,860	1.4%
Total	**1,262**	**67,349**	**38,914**	**283,316**	**100.0%**

Table 3. Results of linear regression analyses between salmon passage and flow, water temperature, and turbidity at upstream and downstream trapping locations on the lower Mokelumne River during the 2009/10 trapping season.

	Upstream passage (VINO FARMS)		
	P-value	*n*	R^2
Camanche Release	0.0004	221	0.06
Flow at Elliot station	0.0006	221	0.05
Water Temp. at VINO RST	<0.0001	161	0.16
Turbidity at VINO RST	0.0065	160	0.05

	Downstream passage (GOLF and BYPASS)		
	P-value	*n*	R^2
Camanche Release	<0.0001	212	0.20
Flow at GOLF station	<0.0001	212	0.18
Water Temp. at GOLF RST	0.0024	155	0.06
Turbidity at GOLF RST	0.0374	152	0.03

Table 4. Release and recovery totals of naturally produced CWT chinook salmon on the lower Mokelumne River from 1990-2009.

			Recovery Type **				
Brood Year	Estimated number released*	Release Location	Ocean/Bay Catch	In-river (LMR)	Hatchery (MRFI)	Stray	Total number recovered**
1990	6,860	Rio Vista	19	0	0	0	**19**
	21,246	San Pablo Bay	26	0	0	0	**26**
1991	67,309	San Pablo Bay	34	0	0	0	**34**
1992	17,532	Lower Mokelumne River	26	0	0	0	**26**
1993	8,166	Lower Mokelumne River	3	0	0	0	**3**
1994	4,569	Lower Mokelumne River	14	0	0	0	**14**
1995	6,545	Lower Mokelumne River	6	0	0	0	**6**
1996	80,804	Lower Mokelumne River	8	0	0	0	**8**
1997	48,893	Lower Mokelumne River	55	0	35	4	**94**
1998	54,273	Lower Mokelumne River	21	5	8	2	**36**
1999	11,531	Lower Mokelumne River	2	2	0	0	**4**
2000	3,338	Lower Mokelumne River	2	0	0	0	**2**
2001	8,444	Lower Mokelumne River	1	2	2	0	**5**
2002	5,031	Lower Mokelumne River	1	3	0	0	**4**
2003	4,200	Lower Mokelumne River	0	0	0	0	**0**
2004	3,082	Lower Mokelumne River	0	1	0	0	**1**
2006	10,968	Lower Mokelumne River	0	0	0	0	**0**
2007	315	Lower Mokelumne River	–	–	–	–	**–**
2008	20,681	Lower Mokelumne River	–	–	–	–	**–**
2009	1,099	Lower Mokelumne River	–	–	–	–	**–**
Totals	**383,787**		**218**	**13**	**45**	**6**	**282**

* Data were obtained from EBMUD CWT release reports and the Mokelumne River Science Database.

** Data were retrieved from the Regional Mark Information System (RMIS) database. URL:<http://www.rmpc.org>. [2 September 2010].

** Recoveries were not expanded to account for sampling effort.

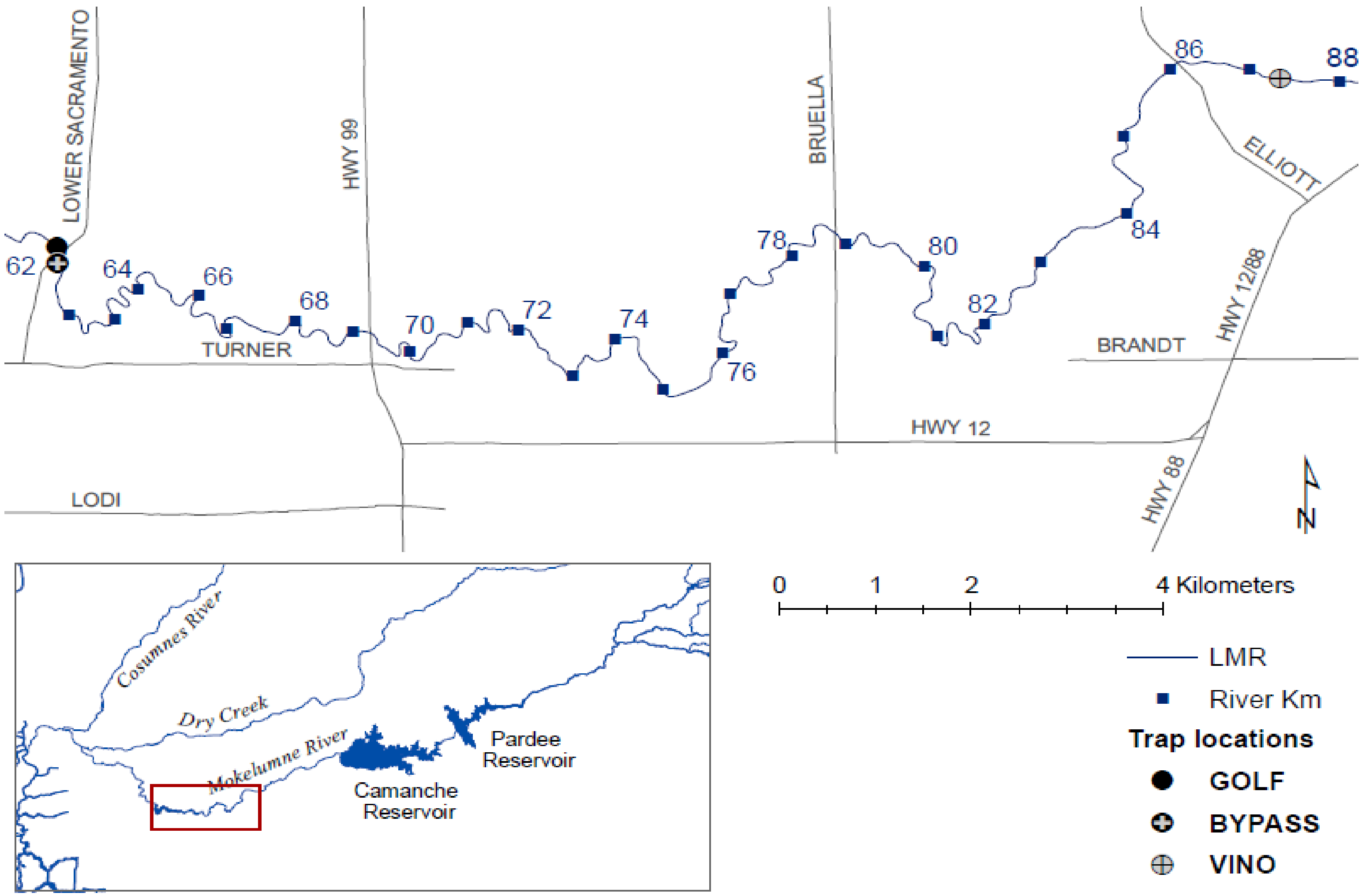


Figure 1. Trapping sites used for juvenile outmigration monitoring on the lower Mokelumne River during the 2009/10 season.

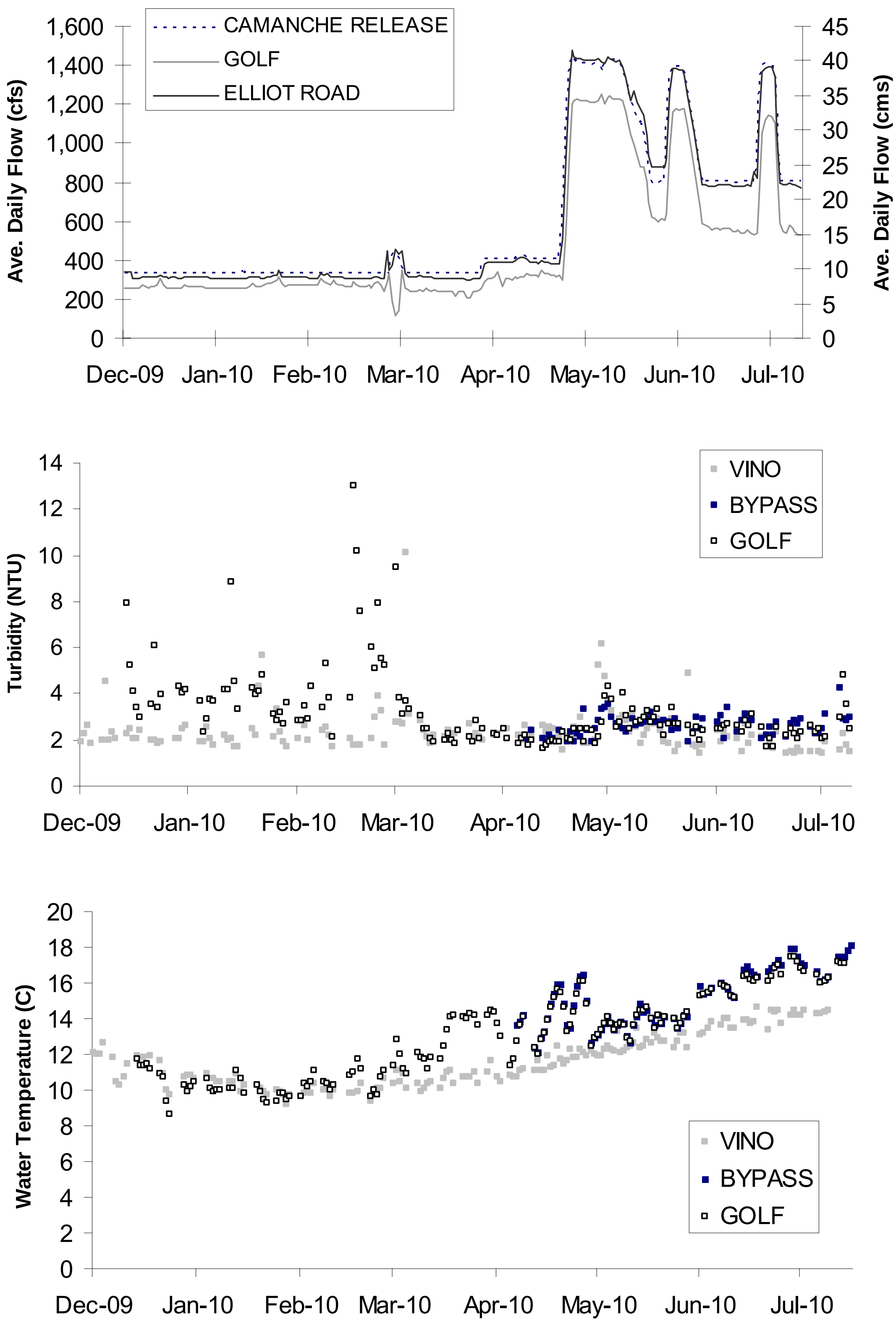
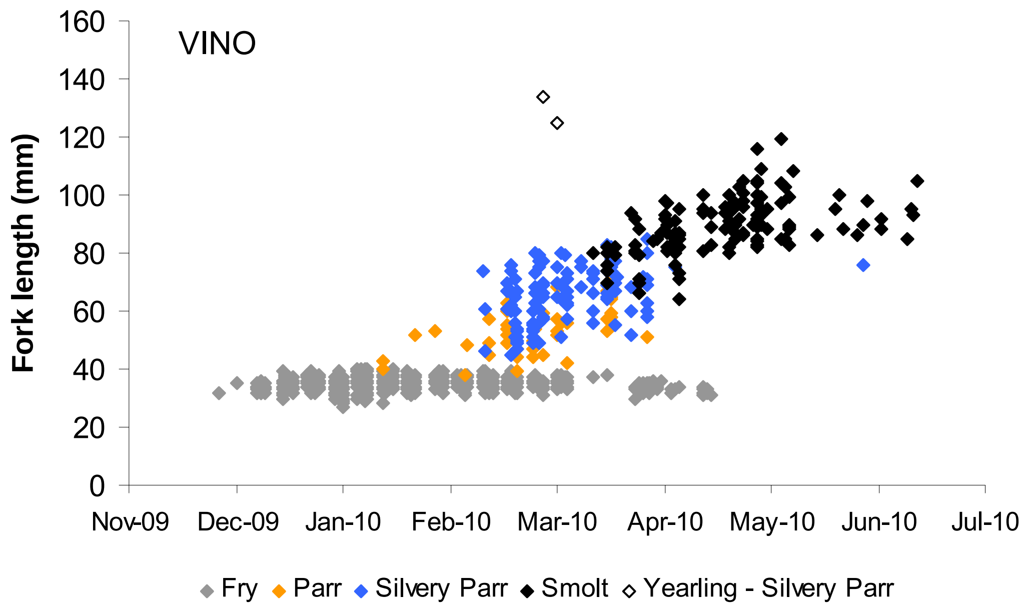


Figure 2. Average daily flow, turbidity and water temperature in the lower Mokelumne River between Camanche Dam (Rkm 103) and GOLF (Rkm 61.8) during the 2009/10 trapping season.



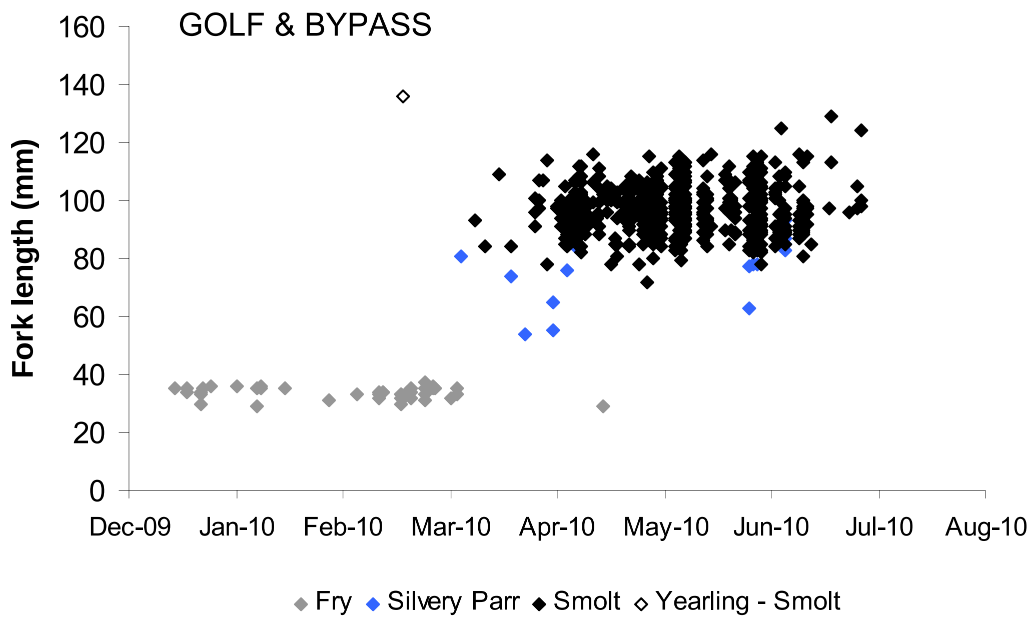


Figure 3. Size and life stage distribution of chinook salmon caught at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2009/10 juvenile outmigration monitoring season on the lower Mokelumne River.

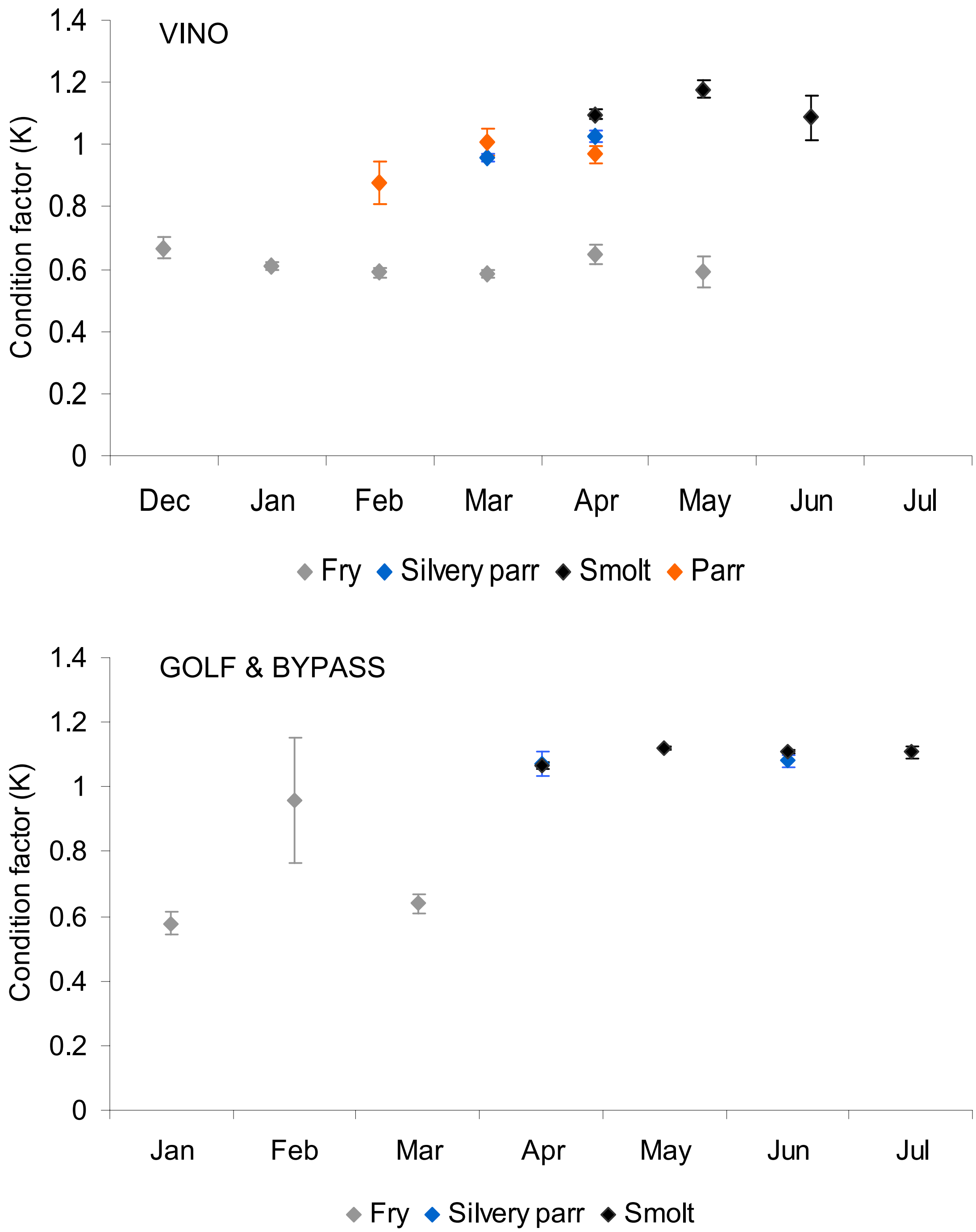


Figure 4. Monthly average condition factor (K) ± 1 SE (for $n \geq 3$) of chinook salmon caught at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2009/10 juvenile outmigration monitoring season on the lower Mokelumne River.

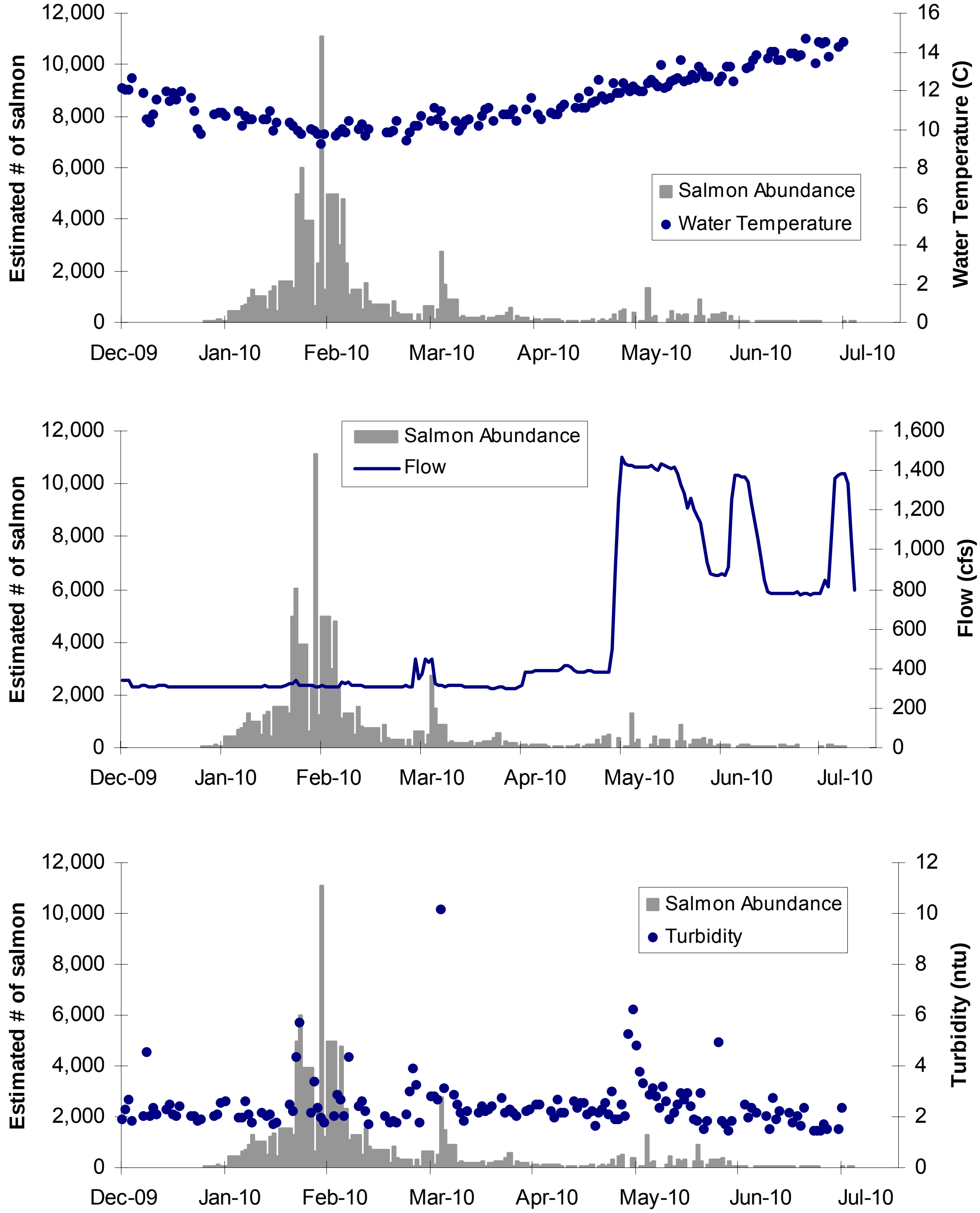


Figure 5. The relationship between estimated chinook salmon passage and water temperature (top), flow (middle), and turbidity (bottom) at the VINO RST (upstream trapping location) during the 2009/10 juvenile outmigration monitoring season.

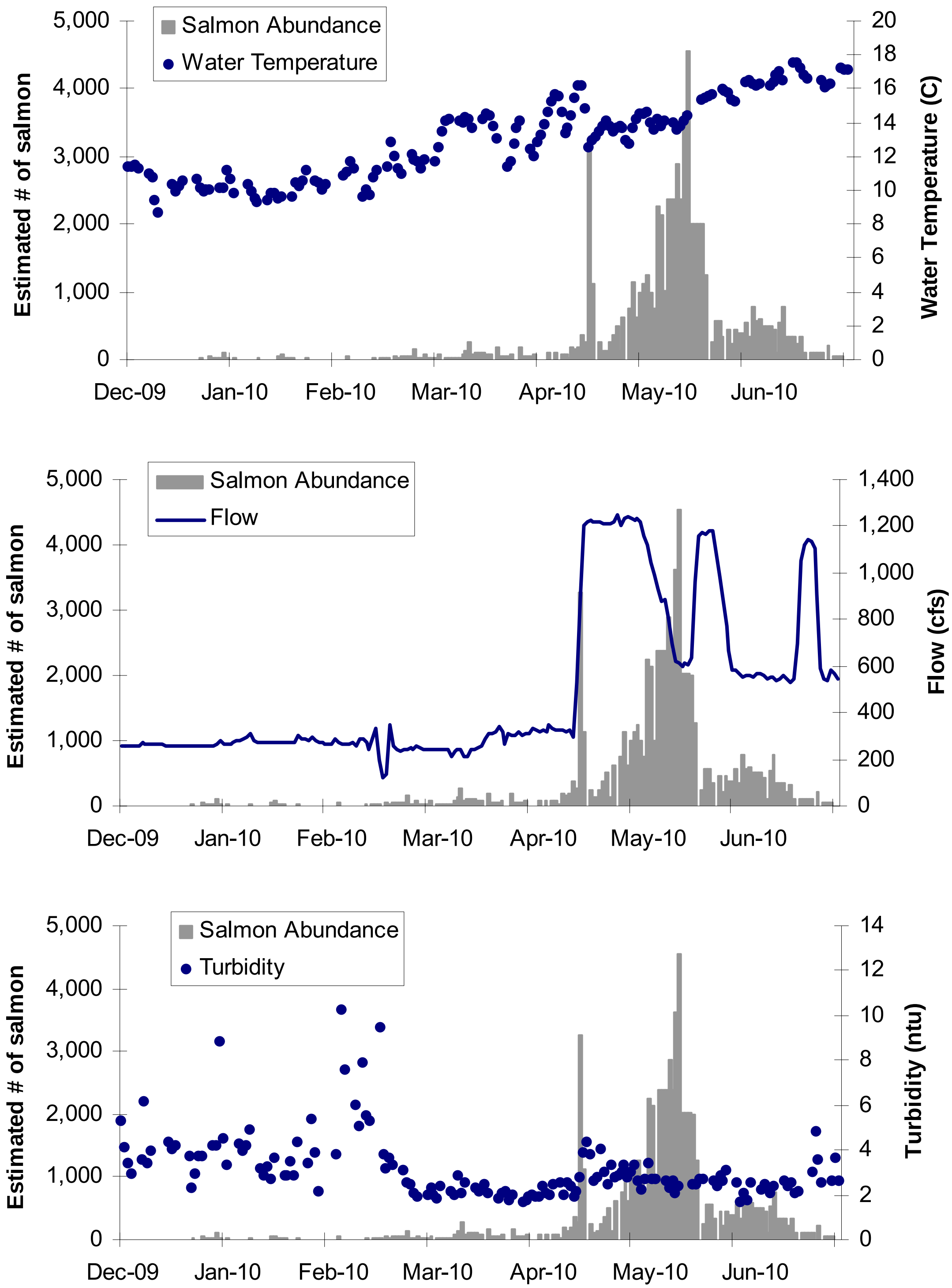
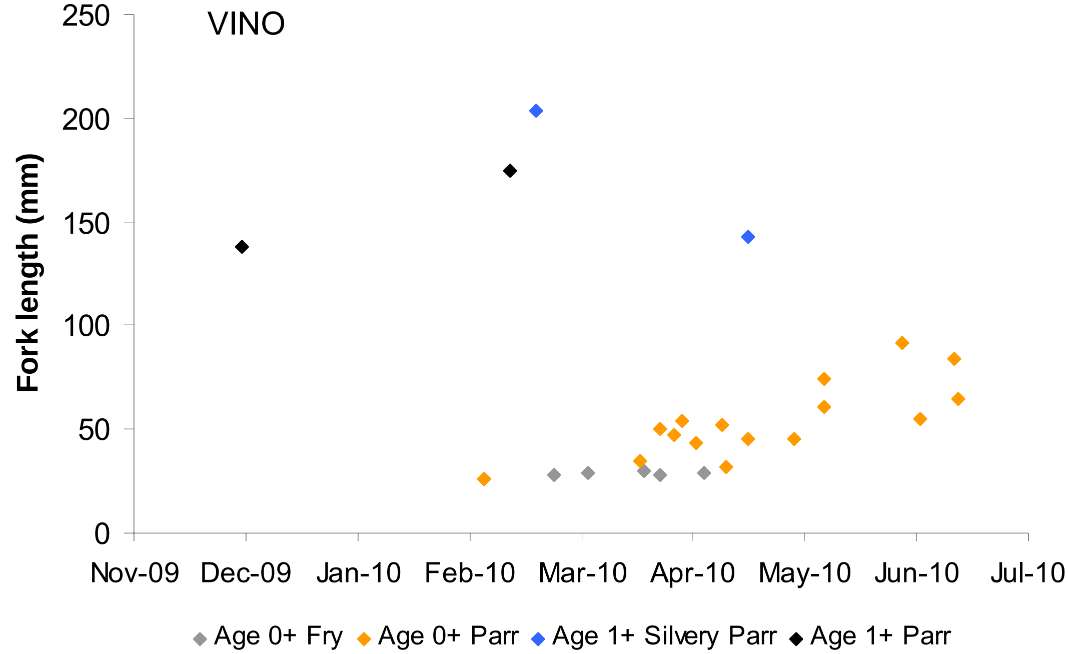


Figure 6. The relationship between estimated chinook salmon passage and water temperature (top), flow (middle), and turbidity (bottom) at the downstream trapping locations (GOLF & BYPASS) during the 2009/10 juvenile outmigration monitoring season.



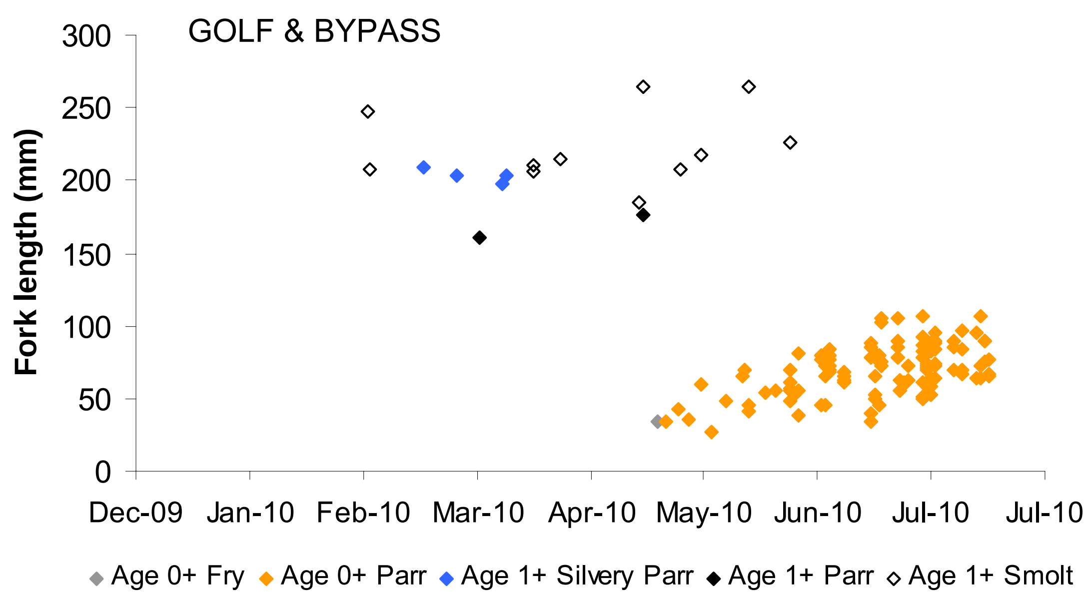


Figure 7. Size and life stage distribution of wild steelhead caught at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2009/10 juvenile outmigration monitoring season on the lower Mokelumne River.

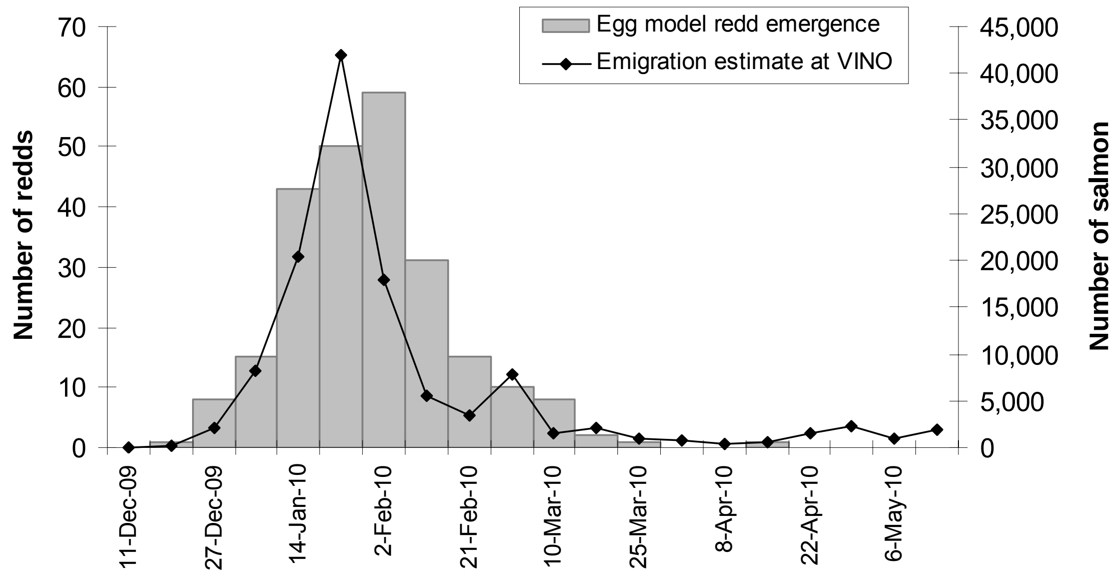


Figure 8. The relationship between estimated weekly chinook salmon passage at the upstream trapping site (VINO) and estimated weekly salmon redd emergence (using the egg model developed by Vogel (1993)) on the lower Mokelumne River during the 2009/10 season.

Appendix A. Daily trap catch, trap efficiency, abundance estimates, and 95% confidence intervals (CI) of emigrating juvenile chinook salmon at the upstream rotary screw trap (VINO) on the lower Mokelumne River during the 2009/10 monitoring period. Shaded areas represent non-trapping periods.

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
12/1/2009	0	0.2404	0	0	0
12/2/2009	0	0.2404	0	0	0
12/3/2009	0	0.2404	0	0	0
12/4/2009	0	0.2404	0	0	0
12/5/2009	0	0.2404	0	0	0
12/6/2009	0	0.2404	0	0	0
12/7/2009	0	0.2404	0	0	0
12/8/2009	0	0.2404	0	0	0
12/9/2009	0	0.2404	0	0	0
12/10/2009	0	0.2404	0	0	0
12/11/2009	0	0.2404	0	0	0
12/12/2009	0	0.2404	0	0	0
12/13/2009	0	0.2404	0	0	0
12/14/2009	0	0.2404	0	0	0
12/15/2009	0	0.2404	0	0	0
12/16/2009	0	0.2404	0	0	0
12/17/2009	0	0.2404	0	0	0
12/18/2009	1	0.2404	4	3	5
12/19/2009	0	0.2404	1	1	2
12/20/2009	0	0.2404	1	1	2
12/21/2009	0	0.2404	1	1	2
12/22/2009	0	0.2404	0	0	0
12/23/2009	1	0.2404	4	3	5
12/24/2009	0	0.2404	0	0	0
12/25/2009	11	0.2404	47	39	59
12/26/2009	11	0.2404	47	39	59
12/27/2009	11	0.2404	47	39	59
12/28/2009	11	0.2404	47	39	59
12/29/2009	32	0.2404	133	110	168
12/30/2009	22	0.2404	92	76	115
12/31/2009	13	0.2404	54	45	68
1/1/2010	103	0.2404	429	356	540
1/2/2010	103	0.2404	429	356	540
1/3/2010	103	0.2404	429	356	540
1/4/2010	103	0.2404	429	356	540
1/5/2010	157	0.2404	653	542	822
1/6/2010	172	0.2404	715	593	901
1/7/2010	223	0.2404	928	769	1,168
1/8/2010	307	0.2404	1,277	1,059	1,608
1/9/2010	241	0.2404	1,002	831	1,261
1/10/2010	241	0.2404	1,002	831	1,261

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
1/11/2010	241	0.2404	1,002	831	1,261
1/12/2010	118	0.2404	491	407	618
1/13/2010	292	0.2404	1,215	1,007	1,529
1/14/2010	333	0.2404	1,385	1,149	1,744
1/15/2010	109	0.2404	453	376	571
1/16/2010	377	0.2404	1,567	1,299	1,972
1/17/2010	377	0.2404	1,567	1,299	1,972
1/18/2010	377	0.2404	1,567	1,299	1,972
1/19/2010	377	0.2404	1,567	1,299	1,972
1/20/2010	317	0.2404	1,319	1,094	1,660
1/21/2010	548	0.1100	4,980	3,781	7,293
1/22/2010	661	0.1100	6,007	4,561	8,797
1/23/2010	433	0.1100	3,935	2,988	5,763
1/24/2010	433	0.1100	3,935	2,988	5,763
1/25/2010	433	0.1100	3,935	2,988	5,763
1/26/2010	71	0.1100	645	490	945
1/27/2010	170	0.0748	2,274	1,642	3,696
1/28/2010	831	0.0748	11,115	8,026	18,068
1/29/2010	94	0.0748	1,257	908	2,044
1/30/2010	372	0.0748	4,976	3,593	8,088
1/31/2010	372	0.0748	4,976	3,593	8,088
2/1/2010	372	0.0748	4,976	3,593	8,088
2/2/2010	222	0.0748	2,969	2,144	4,827
2/3/2010	359	0.0748	4,802	3,467	7,805
2/4/2010	556	0.2424	2,294	1,984	2,719
2/5/2010	268	0.2424	1,106	956	1,311
2/6/2010	315	0.2424	1,299	1,123	1,540
2/7/2010	315	0.2424	1,299	1,123	1,540
2/8/2010	315	0.2424	1,299	1,123	1,540
2/9/2010	126	0.2424	520	450	616
2/10/2010	377	0.2424	1,556	1,345	1,844
2/11/2010	203	0.2424	838	724	993
2/12/2010	177	0.2424	728	630	863
2/13/2010	177	0.2424	728	630	863
2/14/2010	177	0.2424	728	630	863
2/15/2010	177	0.2424	728	630	863
2/16/2010	177	0.2424	728	630	863
2/17/2010	51	0.2424	210	182	249
2/18/2010	207	0.2424	854	739	1,012
2/19/2010	95	0.2424	392	339	465
2/20/2010	82	0.2424	339	293	402
2/21/2010	82	0.2424	339	293	402
2/22/2010	82	0.2424	339	293	402
2/23/2010	80	0.2424	330	285	391
2/24/2010	14	0.2424	58	50	68

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
2/25/2010	46	0.1383	333	221	671
2/26/2010	9	0.1383	65	43	131
2/27/2010	90	0.1383	648	431	1,309
2/28/2010	90	0.1383	648	431	1,309
3/1/2010	90	0.1383	648	431	1,309
3/2/2010	15	0.1383	108	72	219
3/3/2010	73	0.1383	528	351	1,066
3/4/2010	381	0.1383	2,755	1,831	5,561
3/5/2010	204	0.1383	1,475	980	2,978
3/6/2010	124	0.1383	898	597	1,812
3/7/2010	124	0.1383	898	597	1,812
3/8/2010	124	0.1383	898	597	1,812
3/9/2010	27	0.1383	195	130	394
3/10/2010	34	0.1383	246	163	496
3/11/2010	26	0.1383	188	125	380
3/12/2010	27	0.1383	195	130	394
3/13/2010	26	0.1383	186	123	375
3/14/2010	26	0.1383	186	123	375
3/15/2010	26	0.1383	186	123	375
3/16/2010	34	0.1383	246	163	496
3/17/2010	12	0.1383	87	58	175
3/18/2010	21	0.1163	181	99	1,026
3/19/2010	20	0.1163	172	94	977
3/20/2010	29	0.1163	247	135	1,401
3/21/2010	29	0.1163	247	135	1,401
3/22/2010	29	0.1163	247	135	1,401
3/23/2010	45	0.1163	387	212	2,199
3/24/2010	67	0.1163	576	316	3,274
3/25/2010	7	0.1402	50	34	94
3/26/2010	32	0.1402	228	155	430
3/27/2010	23	0.1402	165	112	311
3/28/2010	23	0.1402	165	112	311
3/29/2010	23	0.1402	165	112	311
3/30/2010	5	0.1402	36	24	67
3/31/2010	16	0.1402	111	75	208
4/1/2010	16	0.1402	111	75	208
4/2/2010	12	0.1402	86	58	161
4/3/2010	15	0.1402	109	74	206
4/4/2010	15	0.1402	109	74	206
4/5/2010	15	0.1402	109	74	206
4/6/2010	16	0.1402	114	78	215
4/7/2010	21	0.1402	150	102	282
4/8/2010	6	0.1402	43	29	81
4/9/2010	1	0.1402	7	5	13
4/10/2010	9	0.1402	62	42	116
4/11/2010	9	0.1402	62	42	116

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
4/12/2010	9	0.1402	62	42	116
4/13/2010	4	0.1402	29	19	54
4/14/2010	9	0.1402	64	44	121
4/15/2010	11	0.1402	78	53	148
4/16/2010	6	0.1402	43	29	81
4/17/2010	14	0.1402	100	68	188
4/18/2010	3	0.1402	21	15	40
4/19/2010	7	0.1402	50	34	94
4/20/2010	3	0.0213	141	96	266
4/21/2010	2	0.0213	94	64	177
4/22/2010	3	0.0213	141	96	266
4/23/2010	7	0.0213	329	224	621
4/24/2010	2	0.0213	94	64	177
4/25/2010	9	0.0213	423	288	799
4/26/2010	11	0.0213	517	352	976
4/27/2010	0	0.0213	0	0	0
4/28/2010	0	0.0213	0	0	0
4/29/2010	8	0.0213	392	266	739
4/30/2010	0	0.0213	0	0	0
5/1/2010	1	0.0213	47	32	89
5/2/2010	1	0.0213	47	32	89
5/3/2010	28	0.0213	1,316	895	2,484
5/4/2010	4	0.0213	188	128	355
5/5/2010	6	0.0213	282	192	532
5/6/2010	0	0.0213	0	0	0
5/7/2010	0	0.0213	0	0	0
5/8/2010	0	0.0213	0	0	0
5/9/2010	3	0.0213	141	96	266
5/10/2010	9	0.0213	423	288	799
5/11/2010	1	0.0213	47	32	89
5/12/2010	7	0.0213	329	224	621
5/13/2010	6	0.0213	282	192	532
5/14/2010	7	0.0213	329	224	621
5/15/2010	0	0.0213	0	0	0
5/16/2010	0	0.0213	0	0	0
5/17/2010	5	0.0213	235	160	444
5/18/2010	19	0.0213	893	607	1,686
5/19/2010	5	0.0213	235	160	444
5/20/2010	0	0.0213	0	0	0
5/21/2010	3	0.0213	141	96	266
5/22/2010	7	0.0213	337	229	636
5/23/2010	7	0.0213	337	229	636
5/24/2010	7	0.0213	337	229	636
5/25/2010	8	0.0213	376	256	710
5/26/2010	2	0.0213	94	64	177
5/27/2010	6	0.0213	282	192	532

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
5/28/2010	1	0.0213	47	32	89
5/29/2010	2	0.0213	94	64	177
5/30/2010	2	0.0213	94	64	177
5/31/2010	2	0.0213	94	64	177
6/1/2010	2	0.0213	94	64	177
6/2/2010	0	0.0213	0	0	0
6/3/2010	0	0.0213	0	0	0
6/4/2010	1	0.0213	47	32	89
6/5/2010	2	0.0213	94	64	177
6/6/2010	2	0.0213	94	64	177
6/7/2010	2	0.0213	94	64	177
6/8/2010	1	0.0213	47	32	89
6/9/2010	1	0.0213	47	32	89
6/10/2010	1	0.0213	47	32	89
6/11/2010	1	0.0213	47	32	89
6/12/2010	1	0.0213	63	43	118
6/13/2010	1	0.0213	63	43	118
6/14/2010	1	0.0213	63	43	118
6/15/2010	1	0.0213	47	32	89
6/16/2010	0	0.0213	0	0	0
6/17/2010	2	0.0213	94	64	177
6/18/2010	2	0.0213	94	64	177
6/19/2010	1	0.0213	55	37	104
6/20/2010	1	0.0213	55	37	104
6/21/2010	1	0.0213	55	37	104
6/22/2010	2	0.0213	94	64	177
6/23/2010	0	0.0213	0	0	0
6/24/2010	0	0.0213	0	0	0
6/25/2010	0	0.0213	0	0	0
6/26/2010	1	0.0213	24	16	44
6/27/2010	1	0.0213	24	16	44
6/28/2010	1	0.0213	24	16	44
6/29/2010	1	0.0213	47	32	89
6/30/2010	0	0.0213	0	0	0
7/1/2010	2	0.0213	94	64	177
7/2/2010	2	0.0213	94	64	177
7/3/2010	1	0.0213	31	21	59
7/4/2010	1	0.0213	31	21	59
7/5/2010	1	0.0213	31	21	59
7/6/2010	1	0.0213	31	21	59
7/7/2010	0	0.0213	0	0	0
7/8/2010	0	0.0213	0	0	0
7/9/2010	0	0.0213	0	0	0

Appendix B. Daily trap catch, trap efficiency, abundance estimates, and 95% confidence intervals (CI) of emigrating juvenile chinook salmon at the downstream traps (GOLF and BYPASS) on the lower Mokelumne River during the 2009/10 monitoring period. Shaded areas represent non-trapping periods.

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
12/15/2009	0	–	0.0436	0	0	0
12/16/2009	0	–	0.0436	0	0	0
12/17/2009	0	–	0.0436	0	0	0
12/18/2009	0	–	0.0436	0	0	0
12/19/2009	0	–	0.0436	0	0	0
12/20/2009	0	–	0.0436	0	0	0
12/21/2009	0	–	0.0436	0	0	0
12/22/2009	0	–	0.0436	0	0	0
12/23/2009	0	–	0.0436	0	0	0
12/24/2009	0	–	0.0436	0	0	0
12/25/2009	0	–	0.0436	0	0	0
12/26/2009	0	–	0.0436	0	0	0
12/27/2009	0	–	0.0436	0	0	0
12/28/2009	0	–	0.0436	0	0	0
12/29/2009	0	–	0.0436	0	0	0
12/30/2009	0	–	0.0436	0	0	0
12/31/2009	0	–	0.0436	0	0	0
1/1/2010	0	–	0.0436	4	3	6
1/2/2010	0	–	0.0436	4	3	6
1/3/2010	0	–	0.0436	4	3	6
1/4/2010	0	–	0.0436	4	3	6
1/5/2010	1	–	0.0436	23	17	34
1/6/2010	0	–	0.0436	0	0	0
1/7/2010	0	–	0.0436	0	0	0
1/8/2010	2	–	0.0436	46	35	67
1/9/2010	1	–	0.0436	31	23	45
1/10/2010	1	–	0.0436	31	23	45
1/11/2010	1	–	0.0436	31	23	45
1/12/2010	5	–	0.0436	115	87	168
1/13/2010	1	–	0.0436	23	17	34
1/14/2010	0	–	0.0436	0	0	0
1/15/2010	1	–	0.0436	23	17	34
1/16/2010	1	–	0.0436	11	9	17
1/17/2010	1	–	0.0436	11	9	17
1/18/2010	1	–	0.0436	11	9	17
1/19/2010	1	–	0.0436	11	9	17
1/20/2010	0	–	0.0436	0	0	0
1/21/2010	0	–	0.0436	0	0	0
1/22/2010	1	–	0.0436	23	17	34

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
1/23/2010	1	–	0.0436	11	9	17
1/24/2010	1	–	0.0436	11	9	17
1/25/2010	1	–	0.0436	11	9	17
1/26/2010	0	–	0.0436	0	0	0
1/27/2010	0	–	0.0436	0	0	0
1/28/2010	2	–	0.0436	46	35	67
1/29/2010	3	–	0.0436	69	52	101
1/30/2010	1	–	0.0436	19	15	28
1/31/2010	1	–	0.0436	19	15	28
2/1/2010	1	–	0.0436	19	15	28
2/2/2010	0	–	0.0436	0	0	0
2/3/2010	0	–	0.0436	0	0	0
2/4/2010	0	–	0.0436	0	0	0
2/5/2010	1	–	0.0436	23	17	34
2/6/2010	0	–	0.0436	4	3	6
2/7/2010	0	–	0.0436	4	3	6
2/8/2010	0	–	0.0436	4	3	6
2/9/2010	0	–	0.0436	0	0	0
2/10/2010	0	–	0.0436	0	0	0
2/11/2010	0	–	0.0436	0	0	0
2/12/2010	0	–	0.0436	8	6	11
2/13/2010	0	–	0.0436	8	6	11
2/14/2010	0	–	0.0436	8	6	11
2/15/2010	0	–	0.0436	8	6	11
2/16/2010	0	–	0.0436	8	6	11
2/17/2010	2	–	0.0436	46	35	67
2/18/2010	0	–	0.0436	0	0	0
2/19/2010	0	–	0.0436	0	0	0
2/20/2010	1	–	0.0436	11	9	17
2/21/2010	1	–	0.0436	11	9	17
2/22/2010	1	–	0.0436	11	9	17
2/23/2010	0	–	0.0583	0	0	0
2/24/2010	0	–	0.0583	0	0	0
2/25/2010	1	–	0.0583	17	14	23
2/26/2010	0	–	0.0583	0	0	0
2/27/2010	2	–	0.0583	26	20	35
2/28/2010	2	–	0.0583	26	20	35
3/1/2010	2	–	0.0583	26	20	35
3/2/2010	0	–	0.0583	0	0	0
3/3/2010	3	–	0.0583	51	41	70
3/4/2010	2	–	0.0583	34	27	47
3/5/2010	3	–	0.0583	51	41	70
3/6/2010	3	–	0.0583	57	45	78
3/7/2010	3	–	0.0583	57	45	78
3/8/2010	3	–	0.0583	57	45	78

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
3/9/2010	9	–	0.0583	154	122	211
3/10/2010	2	–	0.0583	34	27	47
3/11/2010	1	–	0.0583	17	14	23
3/12/2010	4	–	0.0583	69	54	94
3/13/2010	2	–	0.0583	37	29	51
3/14/2010	2	–	0.0583	37	29	51
3/15/2010	2	–	0.0583	37	29	51
3/16/2010	4	–	0.0583	69	54	94
3/17/2010	0	–	0.0583	0	0	0
3/18/2010	2	–	0.0583	34	27	47
3/19/2010	1	–	0.0583	17	14	23
3/20/2010	1	–	0.0583	23	18	31
3/21/2010	1	–	0.0583	23	18	31
3/22/2010	1	–	0.0583	23	18	31
3/23/2010	1	–	0.011	91	57	220
3/24/2010	2	–	0.011	136	86	330
3/25/2010	3	–	0.011	272	171	659
3/26/2010	1	–	0.011	91	57	220
3/27/2010	1	–	0.011	106	67	256
3/28/2010	1	–	0.011	106	67	256
3/29/2010	1	–	0.011	106	67	256
3/30/2010	1	–	0.011	91	57	220
3/31/2010	1	–	0.011	91	57	220
4/1/2010	0	–	0.011	0	0	0
4/2/2010	2	–	0.011	181	114	440
4/3/2010	1	–	0.011	60	38	147
4/4/2010	1	–	0.011	60	38	147
4/5/2010	1	–	0.011	60	38	147
4/6/2010	1	–	0.011	91	57	220
4/7/2010	0	0	0.011	0	0	0
4/8/2010	0	0	0.011	0	0	0
4/9/2010	2	0	0.011	181	114	440
4/10/2010	1	0	0.011	45	29	110
4/11/2010	1	0	0.011	45	29	110
4/12/2010	1	0	0.011	45	29	110
4/13/2010	1	0	0.011	91	57	220
4/14/2010	0	0	0.011	0	0	0
4/15/2010	0	0	0.011	0	0	0
4/16/2010	0	4	0.011	4	0	0
4/17/2010	1	2	0.011	93	57	220
4/18/2010	0	1	0.011	1	0	0
4/19/2010	1	1	0.011	92	57	220
4/20/2010	0	0	0.011	0	0	0
4/21/2010	2	0	0.027	73	52	124
4/22/2010	2	0	0.027	73	52	124

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
4/23/2010	1	2	0.027	38	26	62
4/24/2010	5	1	0.027	183	129	310
4/25/2010	4	6	0.027	152	103	248
4/26/2010	5	5	0.027	187	129	310
4/27/2010	10	13	0.027	377	258	619
4/28/2010	7	15	0.027	270	180	434
4/29/2010	26	11	0.008	3,261	1,809	16,007
4/30/2010	9	2	0.008	1,127	626	5,541
5/1/2010	0	1	0.008	1	0	0
5/2/2010	2	2	0.008	252	139	1,231
5/3/2010	1	1	0.008	126	70	616
5/4/2010	1	6	0.008	131	70	616
5/5/2010	2	0	0.008	250	139	1,231
5/6/2010	3	0	0.008	375	209	1,847
5/7/2010	4	1	0.008	501	278	2,463
5/8/2010	1	3	0.008	128	70	616
5/9/2010	5	3	0.008	628	348	3,078
5/10/2010	0	1	0.008	1	0	0
5/11/2010	6	4	0.008	754	417	3,694
5/12/2010	9	9	0.008	1,134	626	5,541
5/13/2010	5	5	0.008	630	348	3,078
5/14/2010	8	2	0.008	1,002	556	4,925
5/15/2010	9	5	0.008	1,130	626	5,541
5/16/2010	10	5	0.008	1,255	696	6,156
5/17/2010	8	0	0.008	1,000	556	4,925
5/18/2010	6	4	0.008	754	417	3,694
5/19/2010	18	3	0.008	2,253	1,252	11,082
5/20/2010	17	5	0.008	2,130	1,183	10,466
5/21/2010	8	12	0.008	1,012	556	4,925
5/22/2010	19	6	0.008	2,381	1,322	11,697
5/23/2010	19	6	0.008	2,381	1,322	11,697
5/24/2010	19	6	0.008	2,381	1,322	11,697
5/25/2010	23	4	0.008	2,879	1,600	14,160
5/26/2010	19	4	0.008	2,379	1,322	11,697
5/27/2010	29	10	0.008	3,635	2,017	17,854
5/28/2010	36	50	0.008	4,550	2,504	22,163
5/29/2010	16	14	0.008	2,014	1,113	9,850
5/30/2010	16	14	0.008	2,014	1,113	9,850
5/31/2010	16	14	0.008	2,014	1,113	9,850
6/1/2010	16	0	0.008	2,000	1,113	9,850
6/2/2010	10	10	0.008	1,260	696	6,156
6/3/2010	0	11	0.008	11	0	0
6/4/2010	2	0	0.008	250	139	1,231
6/5/2010	5	5	0.008	568	313	2,770
6/6/2010	5	5	0.008	568	313	2,770

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
6/7/2010	5	5	0.013	341	214	787
6/8/2010	0	4	0.013	4	0	0
6/9/2010	6	2	0.013	450	285	1,050
6/10/2010	3	5	0.013	229	142	525
6/11/2010	6	1	0.013	449	285	1,050
6/12/2010	5	12	0.013	385	237	875
6/13/2010	5	12	0.013	385	237	875
6/14/2010	5	12	0.009	554	357	1,134
6/15/2010	3	13	0.009	339	214	681
6/16/2010	7	21	0.009	781	500	1,588
6/17/2010	5	27	0.009	570	357	1,134
6/18/2010	5	49	0.009	592	357	1,134
6/19/2010	5	18	0.009	507	321	1,021
6/20/2010	5	18	0.009	507	321	1,021
6/21/2010	5	18	0.009	507	321	1,021
6/22/2010	4	5	0.009	439	285	907
6/23/2010	1	7	0.009	116	71	227
6/24/2010	5	0	0.009	543	357	1,134
6/25/2010	7	11	0.009	771	500	1,588
6/26/2010	3	7	0.009	351	226	718
6/27/2010	3	7	0.009	351	226	718
6/28/2010	3	7	0.009	351	226	718
6/29/2010	2	8	0.009	225	143	454
6/30/2010	3	12	0.009	338	214	681
7/1/2010	1	5	0.009	114	71	227
7/2/2010	0	1	0.009	1	0	0
7/3/2010	1	3	0.009	112	71	227
7/4/2010	1	3	0.009	112	71	227
7/5/2010	1	3	0.009	112	71	227
7/6/2010	1	3	0.009	112	71	227
7/7/2010	0	1	0.009	1	0	0
7/8/2010	2	0	0.009	217	143	454
7/9/2010	0	0	0.009	0	0	0
7/10/2010	0	0	0.009	43	29	91
7/11/2010	0	0	0.009	43	29	91
7/12/2010	0	0	0.009	43	29	91
7/13/2010	0	1	0.009	1	0	0
7/14/2010	0	0	0.009	0	0	0

Appendix C. Monthly catch of all species at the upstream RST (VINO) on the lower Mokelumne river during the 2009/10 juvenile outmigration monitoring season.

Common Name	**Genus**	**Species**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Total**
Black Bass	*Micropterus*	*sp.*	0	0	0	0	0	0	0	2	**2**
Bluegill	*Lepomis*	*macrochirus*	0	1	0	0	0	5	0	1	**7**
Channel Catfish	*Ictalurus*	*punctatus*	3	2	1	4	0	2	4	0	**16**
Chinook Salmon	*Oncorhyhchus*	*tshawytscha*	69	4,403	2,613	1,030	147	122	13	4	**8,401**
Common Carp	*Cyprinus*	*carpio*	0	0	0	0	1	0	0	0	**1**
Gambusia	*Gambusia*	*affinis*	0	0	0	0	0	3	0	0	**3**
Golden Shiner	*Notemigonus*	*crysoleucas*	0	0	1	1	3	2	0	0	**7**
Goldfish	*Carassius*	*auratus*	0	2	0	1	0	0	0	0	**3**
Hitch	*Lavinia*	*exilicauda*	0	0	0	5	10	1	0	0	**16**
Kokanee	*Oncorhynchus*	*nerka kennerlyi*	1	4	0	0	0	0	0	0	**5**
Pacific Lamprey	*Lampetra*	*tridentata*	32	265	87	1,240	158	99	42	12	**1,935**
Prickly Sculpin	*Cottus*	*asper*	6	7	6	8	7	5	22	4	**65**
Redear Sunfish	*Lepomis*	*microlophus*	0	0	0	0	0	1	0	0	**1**
Sac. Pikeminnow	*Ptychocheilus*	*grandis*	0	1	0	0	0	2	1	0	**4**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	0	0	1	0	0	0	0	**1**
Steelhead	*Oncorhynchus*	*mykiss*	1	0	3	4	10	6	2	2	**28**
Steelhead (Ad-Clip)	*Oncorhynchus*	*mykiss*	0	0	8	18	0	0	0	0	**26**
Threadfin Shad	*Dorosoma*	*petenense*	5	0	0	0	0	0	0	0	**5**
White Catfish	*Ameiurus*	*catus*	0	0	0	0	0	0	1	0	**1**
White Crappie	*Pomoxis*	*annularis*	2	0	0	0	0	0	0	0	**2**

Appendix D. Monthly catch of all species at the downstream traps (GOLF and BYPASS) on the lower Mokelumne river during the 2009/10 juvenile outmigration monitoring season.

Common Name	Genus	Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
Black Bass	*Micropterus*	*sp.*	1	1	0	0	1	5	107	103	**218**
Black Crappie	*Pomoxis*	*nigromaculatus*	1	0	0	0	0	4	0	0	**5**
Bluegill	*Lepomis*	*macrochirus*	4	6	12	6	15	43	23	4	**113**
Brown Bullhead	*Ameiurus*	*nebulosus*	0	0	0	1	0	0	0	1	**2**
Channel Catfish	*Ictalurus*	*punctatus*	0	0	0	0	0	1	0	0	**1**
Chinook Salmon	*Oncorhyhchus*	*tshawytscha*	0	16	4	39	142	370	255	11	**837**
Common Carp	*Cyprinus*	*carpio*	0	1	0	0	0	3	4	4	**12**
Gambusia	*Gambusia*	*affinis*	1	1	0	0	0	0	0	0	**2**
Golden Shiner	*Notemigonus*	*crysoleucas*	0	1	3	1	1	5	0	0	**11**
Goldfish	*Carassius*	*auratus*	3	1	2	0	0	0	0	0	**6**
Green Sunfish	*Lepomis*	*cyanellus*	0	0	0	0	2	0	0	0	**2**
Hitch	*Lavinia*	*exilicauda*	0	0	0	0	1	0	1	2	**4**
Kokanee	*Oncorhynchus*	*nerka kennerlyi*	1	1	1	1	0	2	1	0	**7**
Largemouth Bass	*Micropterus*	*salmoides*	0	2	2	0	2	0	0	0	**6**
Lepomis hybrid	*Lepomis*		0	0	0	0	0	1	0	0	**1**
Pacific Lamprey	*Lampetra*	*tridentata*	14	72	453	283	333	428	51	7	**1,641**
Prickly Sculpin	*Cottus*	*asper*	10	37	43	53	581	4,898	3,311	376	**9,309**
Redear Sunfish	*Lepomis*	*microlophus*	1	4	0	0	7	26	5	3	**46**
Redeye bass	*Micropterus*	*coosae*	0	0	0	1	0	0	0	0	**1**
Sac. Pikeminnow	*Ptychocheilus*	*grandis*	0	0	2	0	8	2	2	0	**14**
Sacramento Sucker	*Catostomus*	*occidentalis*	1	0	1	3	1	8	0	2	**16**
Spotted Bass	*Micropterus*	*punctulatus*	1	1	0	0	0	1	0	0	**3**
Steelhead	*Oncorhynchus*	*mykiss*	0	0	4	6	8	26	66	32	**142**
Steelhead (Ad-Clip)	*Oncorhynchus*	*mykiss*	0	1	154	430	177	12	2	2	**778**
Striped Bass	*Morone*	*saxatilis*	0	0	0	0	0	0	1	0	**1**
Tule Perch	*Hysterocarpus*	*traski*	2	2	4	5	11	76	26	13	**139**
Unknown cyprinid			0	0	0	0	0	0	0	1	**1**
Wakasagi	*Hypomesus*	*nipponensis*	0	0	1	0	0	0	0	0	**1**
Warmouth	*Lepomis*	*gulosus*	0	0	3	0	0	1	0	1	**5**
White Catfish	*Ameiurus*	*catus*	0	0	0	0	0	0	0	1	**1**
White Crappie	*Pomoxis*	*annularis*	0	0	0	0	0	1	0	0	**1**