Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2010 through July 2011

Robyn Bilski, Jason Shillam, Charles Hunter, Matt Saldate and Ed Rible
East Bay Municipal Utility District, 1 Winemasters Way, Unit K, Lodi, CA

Key Words: Chinook salmon, emigration, juvenile monitoring, lower Mokelumne River, steelhead

---

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 2010/2011 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 15 December 2010 to 24 June 2011. The downstream rotary screw trap (GOLF) was located just below the Lower Sacramento Road Bridge at RKM 61.8 and was operated from 18 January to 22 July 2011. The smolt bypass trap, located at Woodbridge Irrigation District Dam (RKM 62.2), was operated from 13 to 17 June 2011.

The first juvenile Chinook salmon was captured at the VINO RST on 23 December 2010. Twelve trap efficiency tests were conducted at VINO during the monitoring period. Ten of those tests were used to generate the Chinook salmon abundance estimate, five using naturally produced salmon and five using hatchery produced salmon. The total estimated abundance of naturally produced young-of-the-year Chinook salmon passing the VINO site during the monitoring period was 842,570 (95% CI: 631,115-2,039,099). Between 24 February and 23 June 2011, 105 wild age 0+ steelhead were caught at the VINO RST. Estimated passage of wild age 0+ steelhead (based on trap calibrations using salmon) was 57,253 (95% CI: 31,379-381,938).

At the downstream RST (GOLF), the first juvenile Chinook salmon was captured on 19 January 2011. Thirteen trap efficiency tests using hatchery produced and naturally produced Chinook salmon were conducted at GOLF during the monitoring period. Eight of those tests were used to calculate the total estimated abundance of naturally produced young-of-the-year Chinook salmon passing the GOLF site, which was 281,481 (95% CI: 186,230-606,065). Between 11 March and 22 July 2011, 203 wild age 0+ steelhead were captured at the GOLF RST. Estimated passage of wild age 0+ steelhead at the GOLF trap (based on salmon trap calibrations) was 35,212 (95% CI: 21,837-104,067).

A total of nineteen naturally produced Chinook salmon were caught at the smolt bypass trap (BYPASS) from 14 to 17 June 2011. The total downstream salmon emigration estimate, calculated from adding the BYPASS trap count to the GOLF RST estimate, was 281,500 (95% CI: 186,249-606,084). Twenty-seven wild age 0+ steelhead were caught at

the BYPASS from 14 to 17 June 2011. Adding the BYPASS catch to the GOLF abundance estimate, the total downstream passage estimate of wild age 0+ steelhead was 35,239 (95% CI: 21,864-104,094)

Twenty fish species were caught at the VINO RST during the survey period, 8 native and 12 non-native. Native fish species were more frequently caught than non-native species and Chinook salmon was the most abundant species caught. At the downstream traps (GOLF and BYPASS) 23 fish species were caught, 8 native and 15 non-native. Native fish species were more frequently caught than non-native species and Chinook salmon was the most abundant species caught.

Water releases from Camanche Reservoir ranged from 601 cfs (17.0 m^3/s) to 4,992 cfs (141.4 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 km 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 2010 through July 2011.

METHODS

Environmental Data

All water quality measurements were collected daily at each location when trap checks took place. 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. Flow measurements were provided by EBMUD's Golf and Elliot Road gauging stations.

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 rotary screw trap (RST) was located near the Elliott Road Bridge, adjacent to property owned by Vino Farms, at river kilometer (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). In this report, the upstream and downstream RST sites are referred to as VINO and GOLF, respectively.

During the 2010/11 monitoring season, RSTs were generally operated Monday through Friday, between December and July. Large flow fluctuations warranted a second debris check on many occasions 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 for a brief time in the bypass pipe at WIDD (RKM 62.2) during the 2010/11 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 between 13 and 17 June 2011. A fish crowder and a long-handled dip net were used to capture fish. Debris was cleared from the trap during each check.

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 and/or upper caudal fin clips were used to mark groups of test fish for the VINO trap. A lower caudal fin clip, Bismark® brown dye, and Visible Implant Elastomer (Northwest Marine Technology™) were used in different combinations to mark groups of test fish for the GOLF trap. The use of different marks provided 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

During the time that the BYPASS trap was in operation, daily catch was added to the daily estimate at the GOLF trap to produce a daily downstream abundance estimate.

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 when a large number of smolt-sized salmon were caught 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. All fish caught at the BYPASS trap were transported and released approximately 0.4 km downstream of the GOLF trap to avoid counting them twice.

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.

Juvenile Survival Index

Egg-to-young-of-the-year survival indices were calculated at the upstream and downstream trapping locations based on the brood year (BY) 2010 redd count and BY 2010 average fecundity per female at the MRFI. The annual redd count was multiplied by the average fecundity per female to estimate the total production of young-of-the-year (YOY) salmon at 100% survival. Chinook salmon passage estimates at each trapping location were divided by the total production estimate (at 100% survival) to calculate the survival index. The minimum and maximum survival indices were expected to range between 0.0 and 1.0, respectively.

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 at the VINO RST. Tagging was performed on trapped juvenile Chinook salmon with total lengths ≥ 40mm. One numeric tag code was used during the survey period. Standard coded-wire-tagging methods for marking juvenile salmon were followed (Vogel and Marine 1999).

Visible Implant Elastomer Tag Retention

A pilot study examining the retention of Visible Implant Elastomer (VIE) tags in juvenile Chinook salmon began on 23 March 2011 at the Mokelumne River Fish Installation (MRFI). The goal of this study was to determine if these tags would be acceptable for evaluating the in-river survival of juvenile Chinook salmon. This was determined by assessing the mark retention, growth, and survival of VIE tagged Chinook salmon fry, which were paired with control groups of untagged fry.

On 23 March 2011, 2,000 hatchery-origin Chinook salmon fry were obtained from the MRFI to use as test fish. One-thousand of these fish were taken from rearing trough 47 and split into groups of 500. One group was marked with red VIE tags, which were implanted on the top of the head and roughly 2-3 mm in length. All Chinook salmon fry from this group were anesthetized with a 70 to 100 mg/L solution of tricaine methanesulfonate (MS-222) prior to tagging. This group was designated as 47M, while the control group was referred to as 47C. Groups 47M and 47C were moved to and held within a divided indoor rearing trough (Figure 2). Another 1,000 Chinook salmon fry were obtained from rearing trough 34 and were split, marked, held, and named in the same manner as group 47 (Figure 2).

Mark retention rates and growth were measured monthly (~30 days) until day 104. A 104-day study period was chosen because it is close to the maximum length of time some juvenile Chinook salmon spend in the LMR before emigrating as smolts. A subset of 200 Chinook salmon from groups 47M and 34M were anesthetized with MS-222 and quickly handled to evaluate mark retention between each study interval until the end, when all remaining fish were examined. Two-hundred salmon from the control groups (47C and 34C) were also anesthetized and sorted between each study interval to ensure that the study groups were handled in the same manner (with the exception of initial tagging). The fork lengths of 50 Chinook salmon from each study group were also measured between study periods. Mortality was recorded daily by MRFI staff and hourly water temperatures were recorded in each rearing trough using StowAway Tidbit waterproof temperature loggers (Onset Computing).

Data Analysis

Multiple regression analysis was used to examine the relationship between weekly salmon passage (expressed as percent of total passage) and average weekly flow, water temperature, and turbidity at the upstream and downstream trapping locations. Weekly values were used in place of daily values to avoid transformations of non-normal data, which make interpretation of the results difficult. The relationship between Chinook salmon spawn timing and total weekly salmon passage was also examined at both locations using a linear regression analysis. A redd emergence timeline based on an egg model developed by Vogel (1993) from Piper et al. (1992) was used to offset Chinook salmon spawn timing by the appropriate length of time until fry emergence. Seven extra days were added to the date of predicted emergence at the downstream traps to account for travel time from the spawning grounds to the downstream traps. No timing offset was used at the upstream trap because it is located just downstream of the majority of Chinook salmon spawning habitat (Setka 2004).

A Chi-square test was used to determine if there was a significant difference in overall mortality between control and VIE tagged juvenile Chinook salmon within each study group. A t-test or Wilcoxon rank-sum test was used to determine if there was a significant difference in mean FL between control and VIE tagged salmon each month within each of the study groups.

All data distributions were evaluated for parametric testing. Extreme skewness and kurtosis values (> ±3) were set as the lower and upper limits for normality and Levene's test was used to determine if the variances were equal. For multiple regression analyses, a correlation matrix was built to determine if any environmental variables had a high level of collinearity with each other. Variables that correlated with one another at 0.70 or greater were not used together in the same models.

Graphics production and data analyses were performed using ArcMAP™ 9.3 (ESRI Inc.), JMP® 9.0.0 (SAS Institute Inc.), Microsoft® Office Access 2003 and Excel 2003. Statistical tests were considered significant if the P-value was ≤ 0.05. Mean fork lengths were 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, Water Temperature, Turbidity

Average daily flow at the Elliot Road gauging station (just downstream of the VINO trapping site) ranged from 550 cfs (15.6 m^3/s) to 3,460 cfs (98.0 m^3/s) during the time the VINO trap was operated (15 December 2010 through 24 June 2011). The mean flow during that time was 1,892 cfs (53.6 m^3/s). Water temperatures recorded at the VINO trapping site fell between 8.0 and 14.5°C with a mean of 10.7°C. Water turbidity at the VINO RST ranged from 1.7 to 7.2 nephelometric turbidity units (NTU) with a mean of 3.2 NTU.

Average daily flow at the Golf gauging station ranged from 380 cfs (10.8 m^3/s) to 4,106 cfs (116.3 m^3/s) during the time the GOLF RST was operated (18 January 2011 through 22 July 2011). The mean flow during that time was 1,840 cfs (52.1 m^3/s). Water temperatures recorded at the GOLF trapping site ranged between 8.5 and 18.0°C, with a mean of 12.2°C. Water turbidity at GOLF ranged from 2.4 to 23.2 NTU with a mean of 4.9 NTU.

During the time that the BYPASS trap was operated (13 through 17 June 2011) average daily flow at the Golf gauging station ranged from 1,192 cfs (33.8 m^3/s) to 1,607 cfs (45.5 m^3/s), with a mean of 1,366 cfs (38.7 m^3/s). Water temperatures recorded at the BYPASS trap ranged from 15.7 to 16.6°C, with a mean of 16.2°C. Water turbidity at the BYPASS ranged from 3.6 to 4.6 NTU with a mean of 4.1 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 3.

Trap Operations

The VINO RST was operated between 15 December 2010 and 24 June 2011. The cone was stopped by debris on 29 of 100 days when the trap was checked. Excluding days with trap stoppages, the minimum recorded cone rotation rate was 2.5 RPM and maximum was 5.3 RPM. Mean rotation rate during the monitoring season was 4.3 RPM. The VINO trap met or exceeded the CAMP recommended minimum 2.0 RPMs (USFWS 2008) on 100% of all operating days (excluding stoppage days). Water velocity entering the center of the trap cone ranged between 0.90 and 1.28 m/s, with a mean of 1.08 m/s.

The GOLF RST was operated between 18 January and 22 July 2011. Debris stopped the cone from rotating on 10 of 100 days when the trap was checked. Excluding trap stoppages, the minimum recorded cone rotation rate was 1.3 RPM and maximum was 4.4 RPM. Average rotational speed over the course of the monitoring period was 3.8 RPM. The GOLF trap met or exceeded the CAMP recommended minimum rotation of 2.0 RPMs (USFWS 2008) on 99% of all operating days (excluding stoppage days). Water velocities entering the center of the trap cone ranged between 0.61 and 1.15 m/s, with a mean of 0.99 m/s.

The BYPASS trap at WIDD was operated between 13 and 17 June 2011. During this time frame the trap was operated for 5 days. Water velocities at the top of the trap ranged between 0.82 and 0.94 m/s and averaged 0.87 m/s.

RST Calibrations

Twelve calibration tests were conducted at the VINO RST during the 2010/11 trapping season (Table 1). Naturally produced Chinook salmon were used as test fish for five tests and MRFI salmon were used for seven tests. One trap efficiency test (11) was excluded from use because the trap was stopped by debris shortly after the salmon were released. Trap efficiency tests 10 and 12 were pooled because there was an insufficient number of fish recaptured to generate 95% CIs for each individual test. Smolt-sized salmon were released under similar flow conditions during tests 10 and 12. Excluding the failed test, trap efficiencies ranged from 0.2% to 18.9% and averaged 6.4% (n = 11). One paired trap efficiency test took place, comparing trap efficiency rates using hatchery and naturally produced salmon as test fish. The number of fish recaptured and the efficiency rates for these groups was similar (Table 1). However, the efficiency test using naturally produced salmon was selected to generate daily Chinook salmon abundance estimates during that time frame (Table 1).

Thirteen trap calibration tests were conducted at the GOLF RST during the 2010/11 season (Table 1). Naturally produced Chinook salmon were used as test fish for three tests and MRFI salmon were used for ten tests. Trap efficiency tests 1, 3, 4, 6, and 13 were not used to generate daily abundance estimates for a variety of reasons; the trap was stopped by debris shortly after the test fish were released, test fish were released in poor condition, or there were an insufficient number of recaptures to generate 95% CIs. The ineffective calibrations were replaced using other trials conducted just before or after the unsuccessful test. Excluding the unused tests, GOLF trap efficiencies ranged from 0.6% to 5.1%, with a mean of 2.0% (n = 8).

Chinook Salmon

<u>Catch and Abundance Estimates</u>

During rotary screw trap monitoring, 29,795 naturally produced young-of-the-year (YOY) Chinook salmon were captured at the VINO RST. Estimates for weekend catch and for days with trap stoppages were added to actual catch to produce an estimated count of 57,910 YOY Chinook salmon. Using trap efficiency data, the total estimated abundance of YOY salmon passing the upstream RST (VINO) was 842,570 (95% CI: 631,115-2,039,099). The first and last salmon were caught on 23 December 2010 and 23 June 2011, respectively. The largest estimated number of salmon passed the VINO trap during the month of January (Table 2).

At the GOLF RST, 3,860 naturally produced YOY Chinook salmon were captured between 19 January and 15 July 2011. Estimates for weekend catch and for days with trap stoppages were added to the actual catch to produce an estimated count of 7,953 YOY Chinook salmon. Using trap efficiency data, the estimated abundance of YOY Chinook salmon at the downstream RST (GOLF) was 281,481 (95% CI: 186,230-606,065). Nineteen naturally produced juvenile Chinook salmon were captured at the BYPASS trap between 15 and 17 June 2011. The total downstream emigration estimate, calculated from adding the BYPASS trap catch to the GOLF RST estimate, was 281,500 YOY Chinook salmon (95% CI: 186,249-606,084). At the downstream traps, the highest monthly abundance estimate was recorded during the month of February (Table 2).

<u>Life stage, size and condition</u>

At the VINO RST, 99% (29,503) of the salmon catch was classified as fry. The remaining catch was composed of 0.8% (236) smolt, 0.1% (37) silvery parr, 0.1% (18) parr, and one yearling. Summary statistics for the size and weight of Chinook salmon caught and measured at the VINO trap are presented in Table 3. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the VINO trap during the 2010/11 season is provided by Figure 4.

Chinook salmon catch at the downstream traps (GOLF and BYPASS) was primarily composed of fry [81.4% (3,155)]. The remaining catch was composed of 16.9% (657) smolt, 0.9% (36) silvery parr and 0.8% (30) parr. Summary statistics for the size and weight of Chinook salmon caught and measured at the GOLF and BYPASS traps are presented in Table 4. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the downstream traps during the 2010/11 season is provided by Figure 4.

The monthly average condition factors by life stage for Chinook salmon caught and measured at the upstream and downstream traps are presented in Figure 5.

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 graphically in Figures 6 and 7.

Average weekly flow had a significant negative relationship with weekly salmon passage at the upstream trap; however average weekly water temperature and turbidity did not have a significant relationship with juvenile salmon passage (Table 5). Overall, the environmental variables explained 49% of the variation in weekly juvenile Chinook salmon passage at the upstream RST. In addition, Chinook salmon adult spawn timing had a significant positive linear relationship with juvenile Chinook salmon passage at the upstream RST and explained 63% of the variation in the data (Linear regression: F = 11.822; df = 1, 8; P = 0.011).

At the downstream traps, flow also had a significant negative relationship with Chinook salmon passage (Table 5). Although, average weekly water temperature and turbidity did not have significant relationships with weekly Chinook salmon passage, the regression model explained 40% of the variation in weekly juvenile Chinook salmon passage at the downstream trapping locations. Chinook salmon adult spawn timing did not have a significant relationship with salmon passage at the downstream traps (Linear regression: F = 2.334; df = 1, 6; P = 0.187).

Juvenile Survival Index

During the BY 2010 spawning season, 314 Chinook salmon redds were identified in the LMR. The average fecundity per female salmon spawned at the MRFI was 5,015 and the resulting estimated salmon production at 100% survival was 1,574,555 juveniles. The BY 2010 survival index for YOY Chinook salmon passing the upstream trap (VINO) was 0.54, however, the 95% CI was very large ranging from 0.40 (LCI) to 1.29 (UCI). At the downstream trapping locations (BYPASS and GOLF), the BY 2010 survival index was 0.18 (95% CI: 0.12-0.38). Both survival indices were relatively high in comparison to previous seasons (Table 6).

Coded Wire Tagging

Naturally produced Chinook salmon were coded-wire-tagged (CWT) at the VINO trap from 8 February to 11 March 2011. One tag code (06-09-02-00-03) was used to successfully tag 817 salmon captured at the VINO RST. Fork lengths of tagged salmon ranged from 37 to 56 mm with a mean of 39 mm (SD = 2). All of the tagged salmon were released just below the VINO RST.

Two (0.2%) of the 817 CWT Chinook salmon were recaptured at the GOLF RST. Due to the low number of recaptures, an estimate for CWT salmon caught at the downstream traps was not calculated.

Visible Implant Elastomer Tag Retention

Water temperatures in the indoor rearing troughs at the MRFI, which held the test salmon, ranged from 9 to 15°C with a mean of 12°C during the 104-day study period.

A summary of tag retention, mortality, and growth of juvenile Chinook salmon held during the study is provided by Table 7. There were no significant differences in FL between control and VIE tagged Chinook salmon within groups 34 and 47 throughout the study (Table 8). There were also no significant differences in overall mortality between control and VIE tagged Chinook salmon within group 34 (Chi-Square: $\chi^2 = 0.001$, df = 1, $P = 0.975$) and within group 47 (Chi-Square: $\chi^2 = 2.270$, df = 1, $P = 0.132$).

In general, retention of VIE tags remained high in both marked groups of juvenile Chinook salmon throughout the study (Table 7). The largest drop in mark retention in both tagged groups occurred towards the end of the study between day 64/65 and day 104. Figure 8 depicts a series of photographs of VIE tagged juvenile Chinook salmon between each study interval.

Steelhead

Catch and Abundance Estimates

The first wild (natural production) age 0+ steelhead was captured at the VINO RST on 24 February 2011. A total of 105 wild age 0+ steelhead was caught between 24 February and 23 June 2011. Estimated passage of wild age 0+ steelhead (based on trap calibrations using Chinook salmon) was 57,253 (95% CI: 31,379-381,938). Steelhead catch also consisted of 5 wild age 1+ individuals and one wild age 2+ individual. The largest monthly catch of wild steelhead (51) occurred at VINO in June.

At the GOLF RST, 203 wild age 0+ steelhead were captured between 11 March and 22 July 2011. Estimated passage of wild age 0+ steelhead at the GOLF trap (based on salmon trap calibrations) was 35,212 (95% CI: 21,837-104,067). Steelhead catch also consisted of 12 hatchery origin (adipose fin-clipped) yearlings. At the BYPASS trap, 27 age 0+ steelhead were captured between 14 and 17 June 2011.

Combining the GOLF and BYPASS estimates, the total downstream passage of wild age 0+ steelhead was 35,239 (95% CI: 21,864-104,094). The largest monthly catch of wild steelhead (129) occurred at the downstream traps in June.

<u>Life stage and size</u>

At the VINO RST, 90.1% of the naturally produced steelhead catch was classified as parr. The remaining catch was composed of fry (6.3%), silvery parr (2.7%), and smolt (0.9%). Steelhead parr were also frequently observed at the downstream traps (GOLF and BYPASS), comprising 90.9% of the wild catch. Other wild steelhead catch included fry (1.7%) and silvery parr (7.4%). The size distribution by life stage of all wild steelhead measured at the upstream and downstream traps is presented in Figure 9.

Species Composition

Twenty fish species were caught at the VINO RST during the survey period, 8 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 (no Ad-Clip) was the most abundant species caught (96.0%), followed by Pacific lamprey *Lampetra tridentata* (2.9%).

At the downstream traps (GOLF and BYPASS) 23 fish species were caught, 8 native and 15 non-native. Native fish species were more frequently caught than non-native species, comprising 68.4% of the total catch. Chinook salmon was the most abundant species caught (44.5%), followed by common carp *Cyprinus carpio* (21.7%), Pacific lamprey (9.8%), and prickly sculpin *Cottus asper* (9.3%).

DISCUSSION

Throughout the season, the VINO RST experienced stoppages due to high debris loads brought on by large changes in flow. Despite sustained efforts to check the RST twice daily, the trap was stopped by debris on 29 occasions, which was more than twice the number of stoppages in 2009/10. However, only two stoppages took place during the peak of passage in January and February. Chinook salmon catch was estimated on both of those days. Conversely, the GOLF RST had fewer stoppages this season than in 2009/10. Additional stoppages were likely prevented by several actions this season: the GOLF trap was checked twice daily when debris loads were high and large debris along the WIDD basin shoreline was cleared once a week, on Friday afternoons, after the GOLF RST was pulled.

At the VINO RST, naturally produced salmon were used as test fish for several trap efficiency trials that took place during the beginning of the monitoring season. One paired trap efficiency trail using hatchery and naturally produced salmon fry took place when flow was 574 cfs. Interestingly, the recapture rates were similar between the two groups. This result was much different than the previous season, when trap efficiencies using wild salmon as test fish were significantly higher than trap efficiencies using MRFI salmon as test fish (Bilski et al. 2010). However, all of those tests were conducted at lower flows (300-400 cfs). Our results over the last two seasons are consistent with the findings from Roper and Scarnecchiaa (1996), who reported significantly higher trap efficiencies using wild salmon as test fish, but only at low flows when the trap was spinning slowly. In the future, more tests should be conducted under a variety of flow conditions to test our preliminary findings. In addition, it remains unclear if hatchery produced smolt-sized salmon behave differently than naturally produced smolts, or if both groups are able to avoid the RST because of their size. This season, three trap efficiency trails were conducted using smolt-sized salmon from the MRFI. Recapture rates of these fish were very low, despite using a large number of test fish in each group.

At the GOLF RST, three trap efficiency trials were run using small release groups of naturally produced salmon. While test number one was successful, there was an insufficient number of recaptures to develop reliable confidence intervals, thereby preventing the use of the test to generate daily abundance estimates during that time period. Test number three was unsuccessful and not used because the test fish were released in poor condition and not distributed evenly across the river. Although, test number five was successful, the recapture rate was only slightly higher than the recapture rate using MRFI test salmon the day before. Despite running three trap efficiency tests using wild salmon as test fish at GOLF, it remains unclear if there are significant differences in recapture rates between MRFI and naturally produced salmon. More paired tests should be run during upcoming seasons when sufficient numbers of naturally produced salmon are available.

The downstream passage estimate of 842,570 YOY Chinook salmon at the VINO RST was much higher than the BY2008 and BY2009 estimates of 175,612 and 124,279, respectively (Boyd 2009; Bilski et al. 2010). However, there was a wide 95% confidence interval (631,115-2,039,099) due to low recapture rates of smolt-sized salmon during high flow periods in late spring/early summer. This was particularly evident in June when the 95% confidence interval for the downstream passage estimate of 117,050 was 62,412 - 939,735. As previously mentioned, it was difficult to determine if the low recapture rates of hatchery smolt-sized salmon were due to the size of the fish, high flows, fish origin, or a combination of the variables. In the future, it may be necessary to run multiple efficiency tests under the same conditions and pool the results to increase the accuracy and precision of the passage estimate for smolt-sized salmon under high flow conditions. The downstream Chinook salmon passage estimate of 281,500 was the 7th highest on record since the 1992/93 juvenile outmigration season. Similar to VINO, the 95% CI was somewhat wide due to low recapture rates of juvenile Chinook salmon during high flow conditions in the river throughout the season.

Flow was a significant factor in influencing the number of Chinook salmon passing the upstream and downstream trapping locations during the 2010/2011 outmigration season. Interestingly, the relationships were negative indicating that low flows were associated with larger numbers of outmigrating juvenile Chinook salmon. The results of other studies have indicated that flow may have the same or opposite effects. Conner et al. (2003) determined that increases in flow and decreases in water temperatures accelerate the movement of outmigrating Chinook salmon smolts. However, Sykes et al. (2009) found that increasing flow had a negative influence on the probability and magnitude of

Chinook salmon smolt outmigration. Long-term data from the lower Mokelumne River may help reveal how environmental cues influence Chinook salmon outmigration at upstream and downstream trapping locations over successive monitoring seasons. Additional environmental variables such as accumulated thermal units, photoperiod, lunar cycle, and change in discharge should also be examined and may improve the strength of the models (Roper and Scarnecchia 1999; Sykes et al. 2009).

This season Chinook salmon adult spawn timing was also assessed as an explanatory variable for juvenile Chinook salmon passage at both trapping locations. Although there was not a significant relationship at the downstream trapping location, Chinook salmon adult spawn timing had a significant positive linear relationship with juvenile Chinook salmon passage at the upstream RST and explained 63% of the variation in the data. This result reinforces the idea that the upstream RST provides a good measurement of salmon fry production and egg-to-fry survival rates during the first three to four months of the monitoring season. A similar relationship was found between Chinook salmon spawn timing and weekly Chinook salmon catch at the upstream RST in the lower Feather River, which was positioned just below the majority of Chinook salmon spawning habitat (Seesholtz et al. 2004).

Egg-to-YOY survival indices for juvenile Chinook salmon this season were 0.54 and 0.18 at the upstream and downstream trapping locations, respectively. These values appeared somewhat high when compared to the survival indices over the three previous seasons. Given the large degree of variation in survival indices between years and trapping locations it is important to take into account all factors that may influence the value on a year-by-year basis. For example, the BY 2007 downstream survival index may have been low because the trap was only operated through late May, instead of July. In many cases, June is an important time period when a large number of Chinook salmon smolts pass the downstream traps (Workman 2003; Workman 2005; Workman et al. 2007). In contrast, the BY 2007 and BY 2008 upstream survival indices may have been too high. During those two seasons, only trap efficiency trials using hatchery salmon were applied to produce daily abundance estimates. The following season it was determined that trap efficiency rates using hatchery fish were significantly lower than tests using wild salmon and may overestimate salmon abundance when applied to salmon catch at the upstream RST (Bilski et al. 2010). In 2010, a large in-river release of 163,093 age 1+ MRFI steelhead took place in mid-February, just below Camanche Dam. This time period coincided with the peak of Chinook salmon fry emergence. Consequently, predation by steelhead on emerging Chinook salmon fry may have resulted in a low BY 2009 survival index at the upstream trap. It is also important to note that survival indices include any mortality that takes place during egg deposition and incubation. A study by Schroder et al. (2008) found that an average of 93% of wild Chinook salmon embryos was successfully deposited in an artificial stream, indicating that some egg loss takes place prior to incubation. In addition, a high percentage of embryo mortality may take place within the incubation environment, depending on the physical and chemical habitat parameters associated with the spawning site (Merz et al. 2004).

Similar to the 2009/2010 trapping season, only a small number of Chinook salmon fry met the minimum size criteria for coded-wire-tagging at the upstream trap this season. In addition, only two of the coded-wire-tagged salmon were captured at the downstream trapping locations, preventing the calculation of a trap-to-trap survival estimate. However, the results of the VIE pilot study indicated that elastomer tags would be an acceptable surrogate for evaluating the in-river survival of juvenile Chinook salmon, as mark retention remained above 90% throughout the 104-day study period. In addition, there were no significant differences in mortality and growth between tagged and untagged juvenile Chinook salmon. However, one limitation of this study was that the tagged salmon were held indoors in a controlled environment, which did not account for the variable conditions that exist in the LMR (such as UVR exposure, variable water temperatures, and exposure to runoff containing contaminants). In addition, only red elastomer tags were applied and other colors may not have the same retention rate. Although more investigation is needed, there may be several added benefits to using VIE tags in the future. For example, VIE tags allow for easy recognition of marked fish with minimal handling and provide the means to distinguish multiple release groups with different colored batch marks. Due to fewer tagging size constraints, it will also be possible to mark smaller salmon fry with VIE tags, which will increase the sample size of marked fish.

ACKNOWLEDGEMENTS

We would like to thank Casey Del Real, Steve Boyd, and James Jones for field support and Terry Cummings for assistance with data entry and QA/QC. We also thank Jose Setka for his assistance, review, and support. Thanks to Woodbridge Irrigation District for help with access at downstream trapping sites. We also thank Bill Smith and hatchery staff from the California Department of Fish and Game who provided Mokelumne River hatchery-origin Chinook salmon to use as test fish for trap efficiency tests and VIE mark retention studies, as well as use of the MRFI facilities to hold study fish.

LITERATURE CITED

Bagenal, T. B. and F. W. Tesch. 1978. Age and growth. Pages 101-136 *in* T. B. Bagenal (editor). Methods for Assessment of Fish Production in Fresh Waters. IBP Handbook No. 3. Blackwell Scientific Publications. Oxford, England.

Bianchi, E.W., W. Walsh, and C. Marzuola. 1992. Task reports of fisheries studies on the Mokelumne River 1990-1992. (Appendix A of the Lower Mokelumne River Management Plan). Report to East Bay Municipal Utility District, Oakland, California. BioSystems Analysis, Inc., Tiburon, California.

Bilski, R., J. Shillam, C. Hunter, M. Saldate, and E. Rible. 2010. Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2009 through July 2010. East Bay Municipal Utility District, Lodi, California.

Boyd, S.R. 2009. Monitoring Emigration of Juvenile Chinook Salmon and Steelhead in the Mokelumne River, December 2008 through July 2009. East Bay Municipal Utility District, Lodi, California.

Conner, W.P., R.K. Steinhorst, and H.L. Burge. 2003. Migrational Behavior and Seaward Movement of Wild Subyearling Fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management 23: 414-430.

Marine, K. 2000. Lower Mokelumne River Fisheries Monitoring Program 1999-2000. Downstream Migration Monitoring at Woodbridge Dam During December 1999 through July 2000. Report to East Bay Municipal Utility District, Oakland, California. Natural Resource Scientists, Inc.

Merz, J.E., J.D. Setka, G.B. Pasternack, and J.M. Wheaton. 2004. Predicting benefits of spawning-habitat rehabilitation to salmonid (*Oncorhynchus* spp.) fry production in a regulated California river. Canadian Journal of Fisheries and Aquatic Sciences 61:1433-1446.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, J.R. Leonard. 1992. Fish Hatchery Management. USDI. Fish and Wildlife Service. Washington D.C.

Roper, B. and D.L. Scarnecchiaa. 1996. Comparison of Trap Efficiencies for Wild and Hatchery Age-0 Chinook Salmon. North American Journal of Fisheries Management 16: 214-217.

Roper, B. and D.L. Scarnecchiaa. 1999. Emigration of age-0 chinook salmon (*Oncorhynchus tshawytscha*) smolts from the upper South Umpqua River basin, Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 56: 939-946.

Setka, J. 2004. Summary of fall-run chinook salmon and steelhead trout spawning in the lower Mokelumne River, CA 1996-2003. East Bay Municipal Utility District, Orinda, California.

Seesholtz, A., B. J. Cavallo, J. Kindopp, and R. Kurth. 2004. Juvenile fishes of the lower Feather River: distribution, emigration patterns, and associations with environmental variables. American Fisheries Society Symposium 39:141-166.

Schroder, S.L., C. M. Knudsen, T. N. Pearsons, T. W. Kassler, S. F. Young, C. A. Busack, D. E. Fast. 2008. Breeding Success of Wild and First-Generation Hatchery Female Spring Chinook Salmon Spawning in an Artificial Stream, Transactions of the American Fisheries Society 137: 1475-1489.

Sykes, G.E., C.J. Johnson, and J.M. Shrimpton. 2009. Temperature and Flow Effects on Migration Timing of Chinook Salmon Smolts. Transactions of the American Fisheries Society 138:1252-1265.

USFWS. 2008. DRAFT CVPIA Comprehensive Assessment and Monitoring Program (CAMP). Rotary Screw Trap Protocol for Estimating Production of Juvenile Chinook Salmon. US Fish and Wildlife Service, Sacramento, California.

Volkhardt, G.C., S.L. Johnson, B.A. Miller, T.E. Nickelson, and D.E. Seiler. 2007. Rotary Screw Traps and Inclined Plane Screen Traps. Pages 235-266, *In* Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations. American Fisheries Society, Bethesda, Maryland.

Vogel, D. 1993. Model for predicting Chinook fry emergence from gravel. Natural Resource Scientists, Inc., Red Bluff, California.

Vogel, D.A. and K.R. Marine 1999. Evaluation of the downstream migration of juvenile Chinook salmon and steelhead in the lower Mokelumne River and the Sacramento-San Joaquin Delta (December 1997 through July 1998). A technical report prepared for EBMUD, Orinda, California. Natural Resources Scientists, Inc. Red Bluff, California.

Workman, M.L. 2003. Downstream Migration Monitoring at Woodbridge Dam on the Lower Mokelumne River, CA. December 2002 through July 2003. East Bay Municipal Utility District, Lodi, California.

Workman, M.L. 2005. Downstream Fish Migration Monitoring at Woodbridge Irrigation District Dam Lower Mokelumne River, January 2005 through July 2005. East Bay Municipal Utility District, Lodi, California.

Workman, M. L., C. E. Hunter, M. S. Saldate and J. L. Shillam. 2007. Downstream Fish Migration Monitoring at Woodbridge Irrigation District Dam Lower Mokelumne River, December 2006 through July 2007. East Bay Municipal Utility District, Lodi, California.

Table 1. Summary of trap efficiency tests conducted at rotary screw trap (RST) locations on the lower Mokelumne River during the 2010/2011 juvenile outmigration season. Abbreviations are as follows: MRFI = Mokelumne River Fish Installation, LMR = lower Mokelumne River.

VINO FARMS (UPSTREAM RST)

Test #	Release date	Flow at release (cfs)	Origin of test salmon	Ave. FL of test salmon (mm)	# Released	# Recaptured	% Recaptured	Used for abundance estimate?
1	04-Jan-11	2,615	MRFI	37	1,000	43	**4.3%**	Yes
2	19-Jan-11	950	LMR	35	979	50	**5.1%**	Yes
3	25-Jan-11	757	LMR	34	1,000	91	**9.1%**	Yes
4	01-Feb-11	574	LMR	34	500	52	**10.4%**	Yes
5	01-Feb-11	574	MRFI	34	499	57	**11.4%**	No
6	01-Mar-11	562	LMR	37	924	175	**18.9%**	Yes
7	09-Mar-11	880	LMR	36	599	51	**8.5%**	Yes
8	29-Mar-11	3,277	MRFI	40	1,000	12	**1.2%**	Yes
9	11-Apr-11	3,250	MRFI	49	1,000	7	**0.7%**	Yes
10	31-May-11	1,790	MRFI	81	1,000	3	**0.3%**	Yes
11	06-Jun-11	1,810	MRFI	98	999	1	**0.1%**	No
12	14-Jun-11	1,420	MRFI	102	1,002	2	**0.2%**	Yes

GOLF (DOWNSTREAM RST)

Test #	Release date	Flow at release (cfs)	Origin of test salmon	Ave. FL of test salmon (mm)	# Released	# Recaptured	% Recaptured	Used for abundance estimate?
1	25-Jan-11	801	LMR	34	47	2	**4.3%**	No
2	07-Feb-11	550	MRFI	40	500	18	**3.6%**	Yes
3	08-Feb-11	550	LMR	36	189	23	**12.2%**	No
4	22-Feb-11	535	MRFI	38	755	28	**3.7%**	No
5	23-Feb-11	534	LMR	36	277	14	**5.1%**	Yes
6	21-Mar-11	2,816	MRFI	37	999	2	**0.2%**	No
7	28-Mar-11	3,278	MRFI	41	1,000	19	**1.9%**	Yes
8	04-Apr-11	3,264	MRFI	43	999	13	**1.3%**	Yes
9	02-May-11	2,795	MRFI	71	1,028	9	**0.9%**	Yes
10	16-May-11	2,074	MRFI	84	1,005	14	**1.4%**	Yes
11	20-Jun-11	1,555	MRFI	94	1,008	12	**1.2%**	Yes
12	06-Jul-11	3,869	MRFI	109	958	6	**0.6%**	Yes
13	11-Jul-11	2,121	MRFI	101	1,000	2	**0.2%**	No

Indicates paired release (shaded rows: Vino Farms tests 4 and 5)

Table 2. Expanded monthly catch, juvenile passage estimates with 95% confidence intervals (LCI and UCI), and percent passage for Chinook salmon captured at the upstream and downstream trapping locations on the LMR during the 2010/2011 trapping season.

Upstream (VINO FARMS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
December	10	221	171	312	0.0%
January	21,824	341,398	274,119	454,025	40.5%
February	25,284	243,119	193,369	327,337	28.9%
March	9,900	72,937	60,400	96,768	8.7%
April	296	24,694	15,805	56,431	2.9%
May	303	43,151	24,839	164,491	5.1%
June	292	117,050	62,412	939,735	13.9%
Total	**57,910**	**842,570**	**631,115**	**2,039,099**	**100.0%**

Downstream (GOLF and BYPASS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
January	958	26,608	18,305	48,696	9.5%
February	4,262	109,155	74,503	204,617	38.8%
March	1,410	31,912	21,320	63,637	11.3%
April	53	4,641	2,929	11,491	1.6%
May	610	51,008	32,547	121,376	18.1%
June	603	46,992	30,301	104,905	16.7%
July	78	11,183	6,344	51,362	4.0%
Total	**7,973**	**281,500**	**186,249**	**606,084**	**100.0%**

Table 3. Summary statistics for the size and weight of naturally produced Chinook salmon caught and measured at the VINO trap during the 2010/11 juvenile outmigration season on the lower Mokelumne River.

	Fry	Parr	Silvery parr	Smolt	Yearling
Fork Length (mm)					
Mean	36	46	72	90	120
Standard deviation	2	5	8	8	—
Minimum	28	38	56	72	120
Maximum	43	53	86	117	120
Count (n)	1,684	10	16	224	1
Weight (g)					
Mean	0.3	0.9	3.9	8.4	18.3
Standard deviation	0.1	0.3	1.9	2.5	—
Minimum	0.1	0.4	1.0	3.0	18.3
Maximum	0.7	1.4	6.5	20.2	18.3
Count (n)	1,669	10	16	223	1

Table 4. Summary statistics for the size and weight of naturally produced Chinook salmon caught and measured at the downstream traps (GOLF and BYPASS) during the 2010/11 juvenile outmigration season on the lower Mokelumne River.

	Fry	Parr	Silvery parr	Smolt
Fork Length (mm)				
Mean	36	43	72	94
Standard deviation	2	9	16	7
Minimum	28	37	48	69
Maximum	43	79	96	120
Count (n)	1,257	26	23	647
Weight (g)				
Mean	0.3	0.9	4.2	9.1
Standard deviation	0.1	1.0	2.7	2.2
Minimum	0.1	0.4	0.8	3.4
Maximum	0.5	4.7	8.9	19.3
Count (n)	1,006	20	23	643

Table 5. Multiple linear regression models for juvenile Chinook salmon passage based on environmental variables at upstream and downstream trapping locations in the lower Mokelumne River. Abbreviations are as follows: CS JPE = Chinook salmon juvenile passage estimate; AWTURB = average weekly turbidity; AWTEMP = average weekly temperature; AWFLOW = average weekly flow.

Upstream (VINO FARMS)							
	Model						
Dependent Variable	R^2 (Adj.)	*P*	Independent Variable	Estimate	SE	*t*	*P*
Weekly CS JPE	0.489	<0.001					
			Intercept	0.1642	0.0568	2.89	0.008
			AWTURB	-0.0016	0.0103	-0.15	0.881
			AWTEMP	-0.0058	0.0043	-1.33	0.196
			AWFLOW	-3.2E-05	9.2E-06	-3.47	0.002

Downstream (GOLF and BYPASS)							
	Model						
Dependent Variable	R^2 (Adj.)	*P*	Independent Variable	Estimate	SE	*t*	*P*
Weekly CS JPE	0.437	0.001					
			Intercept	0.0726	0.0371	1.96	0.063
			AWTURB	0.0052	0.0032	1.61	0.121
			AWTEMP	-0.0012	0.0024	-0.49	0.630
			AWFLOW	-2.5E-05	6.0E-06	-4.22	<0.001

Table 6. A summary of annual upstream and downstream juvenile Chinook salmon survival indices (egg to young-of-the-year) on the lower Mokelumne River. Indices were calculated by dividing the annual upstream and downstream juvenile passage estimates by the estimated number of Chinook salmon naturally produced on the LMR for a given brood year (BY). The total estimated natural production for each BY was calculated by multiplying the annual Chinook salmon redd count by the average annual fecundity estimate for a female Chinook salmon spawned at the Mokelumne River Fish Installation (MRFI).

BY	Trap(s) used	Estimated production (at 100% survival)	Abundance estimate	95% LCI	95% UCI	Survival index (LCI - UCI)	Ave. daily flow Jan.-July (cfs) (min-max)
			Upstream (Rkm 87.4)				
2007	Vino Farms	1,615,887	1,117,451	798,895	7,184,950	0.69 (0.49-4.45)	264 (208-517)
2008	Vino Farms	377,044	175,612	131,191	280,979	0.47 (0.35-0.75)	293 (205-425)
2009	Vino Farms	1,329,217	124,279	93,555	199,950	0.09 (0.07-0.15)	647 (298-1,464)
2010	Vino Farms	1,574,651	842,570	631,115	2,039,099	0.54 (0.40-1.29)	1,903 (550-4,702)
			Downstream (Rkm 62)				
2007	Golf	1,615,887	18,347	14,513	25,152	0.01 (0.01-0.02)	138 (23-283)
2008	Golf & Bypass	377,044	30,614	29,171	32,802	0.08 (0.08-0.09)	150 (26-256)
2009	Golf & Bypass	1,329,217	67,349	39,512	283,914	0.05 (0.03-0.21)	512 (120-1,248)
2010	Golf & Bypass	1,574,651	281,500	186,249	606,084	0.18 (0.12-0.38)	1,822 (380-4,106)

Table 7. Summary of mark retention, growth, and mortality between paired groups of unmarked Chinook salmon fry and visible implant elastomer (VIE) tagged Chinook salmon fry over a 104-day study period. The number of each study group (34 and 47) indicates the rearing trough the fish were taken from at the Mokelumne River Fish Installation. Control and marked groups of Chinook salmon fry are distinguished by a C (control) or M (marked) following the rearing trough number.

Study group	Day 1	Day 33/34	Day 64/65	Day 104
Mark retention (%)				
34M	100.0%	100.0%	99.0%	95.5%
34C	–	–	–	–
47M	99.6%	99.0%	98.5%	93.0%
47C	–	–	–	–
Mortality: cumulative total (cumulative %)				
34M	0 (0.0%)	1 (0.2%)	2 (0.4%)	2 (0.4%)
34C	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)
47M	1 (0.2%)	1 (0.2%)	1 (0.2%)	6 (1.3%)
47C	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.4%)
Fork length (mm): mean (SD)				
34M	40 (3)	60 (4)	86 (9)	108 (15)
34C	40 (3)	61 (4)	85 (5)	105 (16)
47M	43 (2)	65 (5)	88 (7)	113 (6)
47C	44 (2)	66 (3)	89 (5)	114 (6)

Table 8. A summary of statistical tests used to determine if there were significant differences in mean fork length between unmarked and visible implant elastomer (VIE) tagged juvenile Chinook salmon each month, within study groups 34 and 47.

Day #	Statistical test used	*t*	*Z*	*n*	*P*
	Group 34				
1	Pooled t-Test	0.777	–	100	0.439
33	Wilcoxon rank-sum test	–	-0.800	100	0.424
65	Wilcoxon rank-sum test	–	1.484	100	0.138
104	Wilcoxon rank-sum test	–	1.320	100	0.187
	Group 47				
1	Pooled t-Test	-1.557	–	100	0.123
34	Wilcoxon rank-sum test	–	-1.096	100	0.272
64	Wilcoxon rank-sum test	–	-0.352	100	0.722
104	Pooled t-Test	-1.289	–	100	0.200

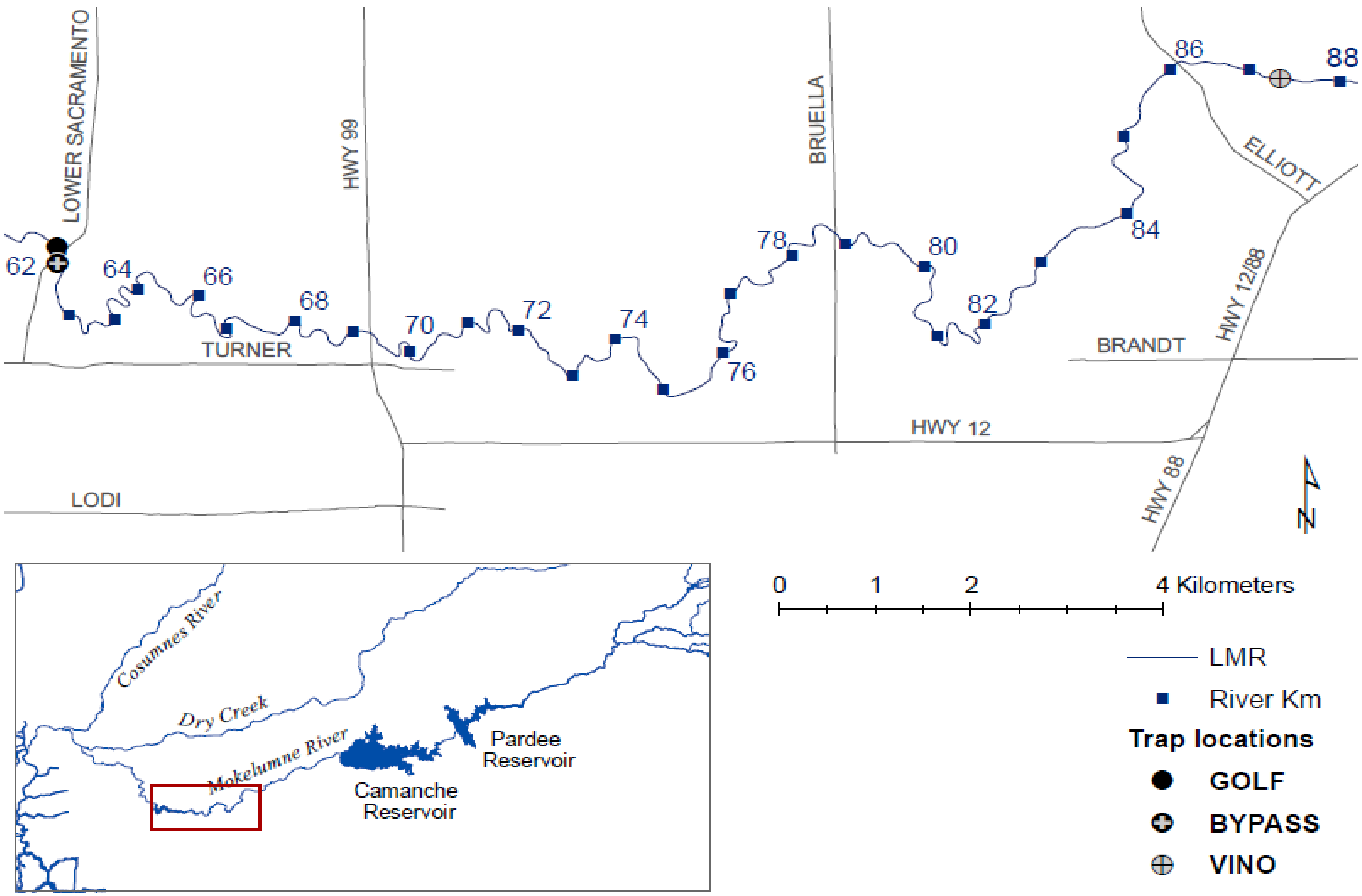


Figure 1. Trapping sites used for juvenile outmigration monitoring on the lower Mokelumne River (LMR) during the 2010/11 season.

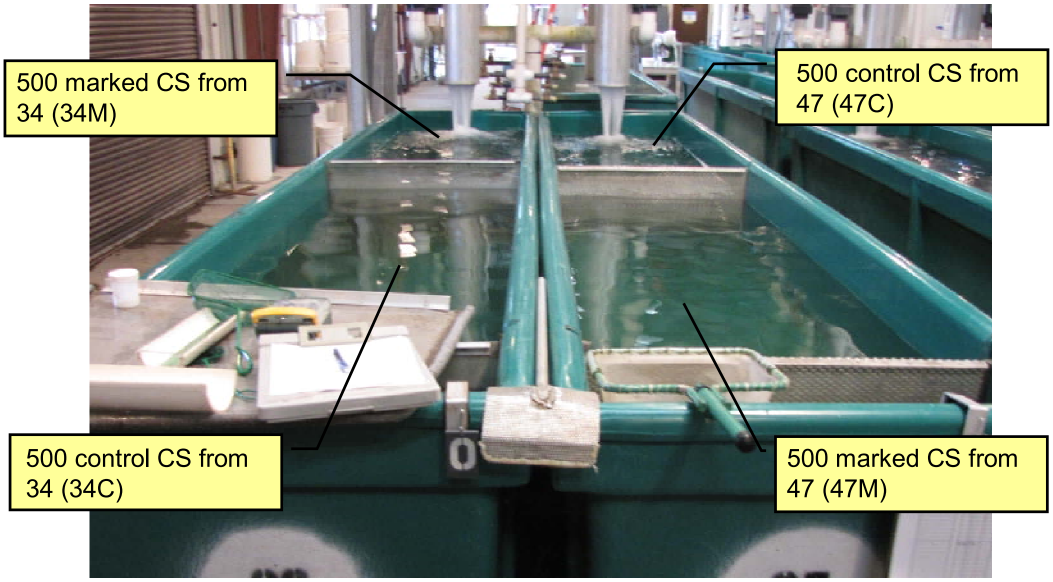


Figure 2. The location (MRFI indoor rearing troughs) and setup of a pilot study designed to evaluate the retention of visible implant elastomer in Chinook salmon (CS) fry. The yellow text boxes indicate the number of fish, status (marked or control), and original rearing trough number of each study group. Each group code (e.g. 34M) is noted in parenthesis.

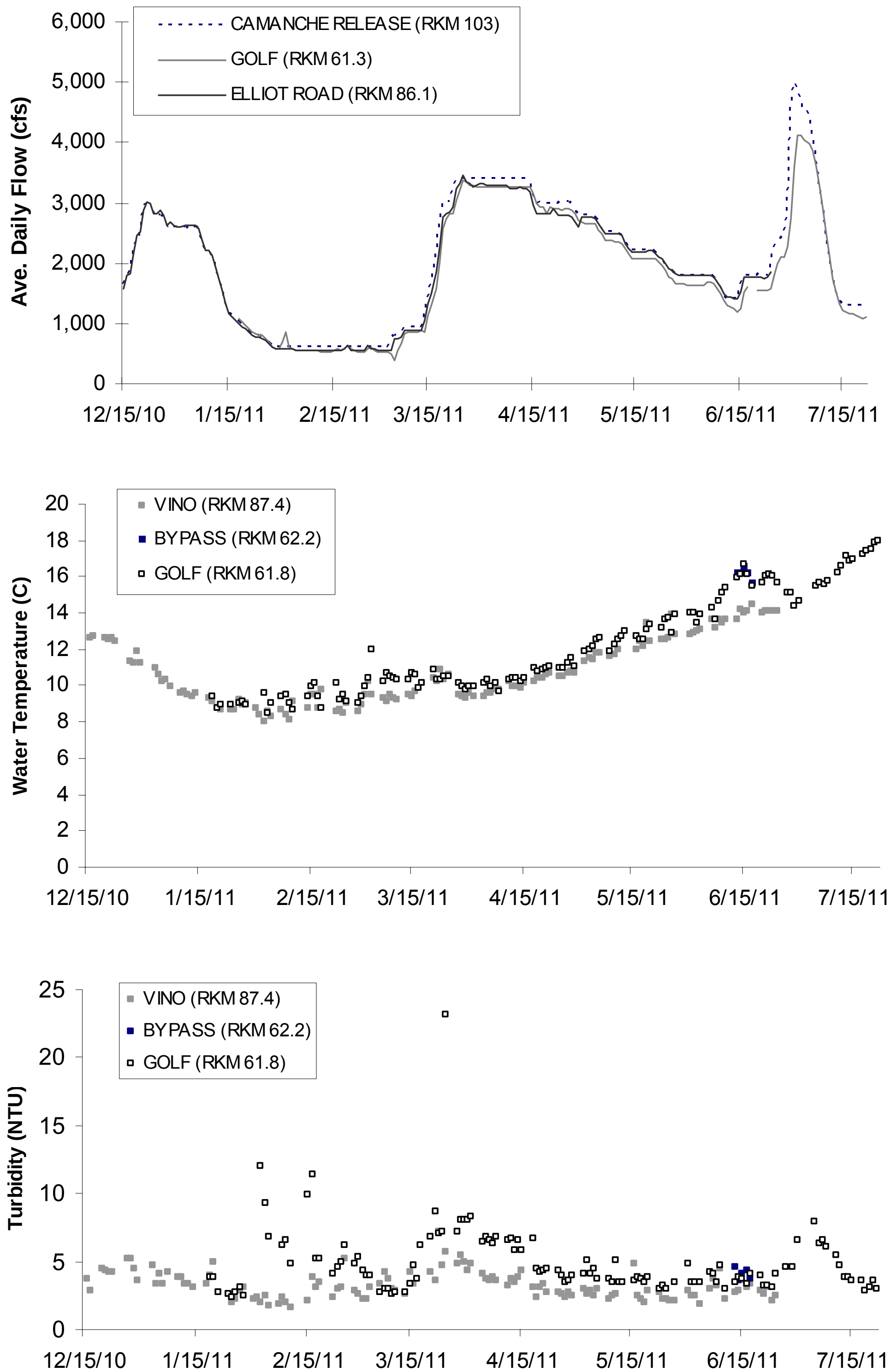
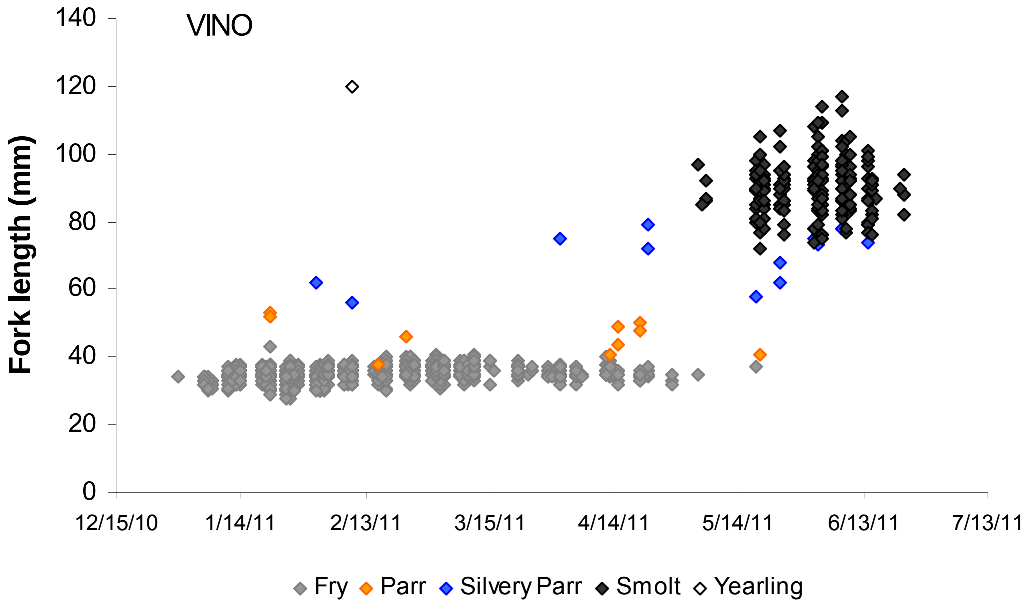


Figure 3. Average daily flow, turbidity and water temperature in the lower Mokelumne River between Camanche Dam (RKM 103) and GOLF (RKM 61.3) during the 2010/11 trapping season.



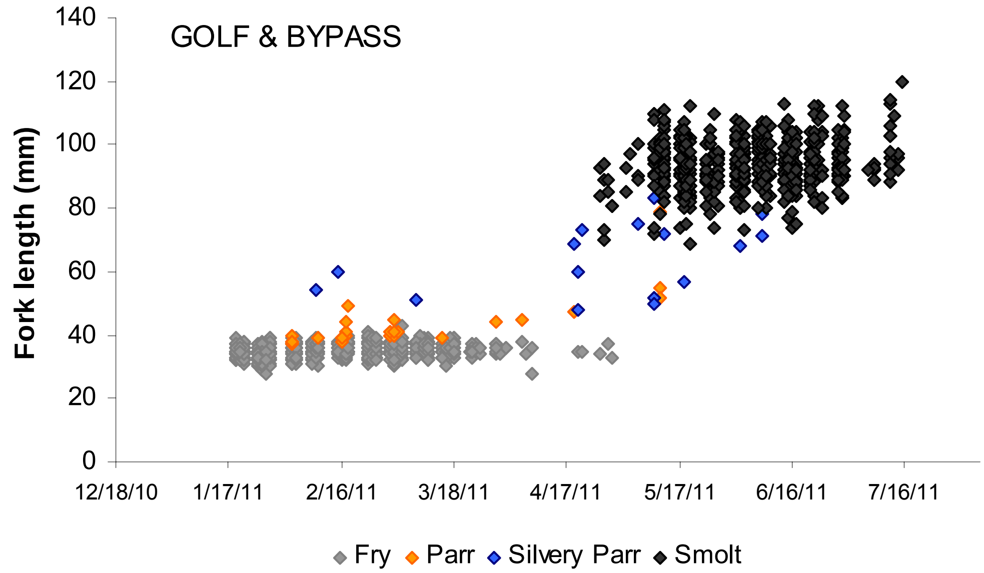
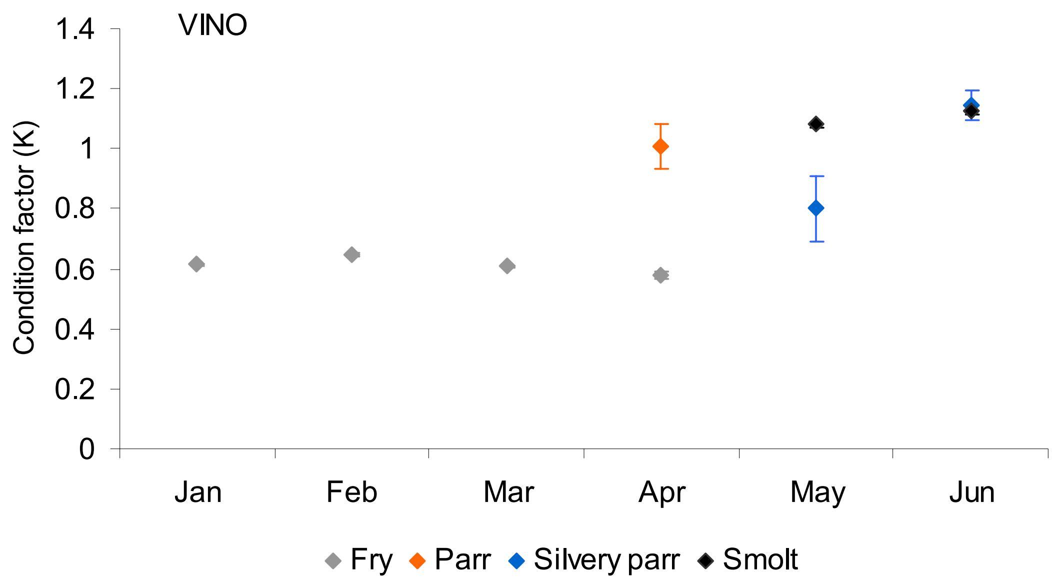


Figure 4. Size distribution by life stage of Chinook salmon caught and measured at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2010/11 juvenile outmigration season on the lower Mokelumne River.



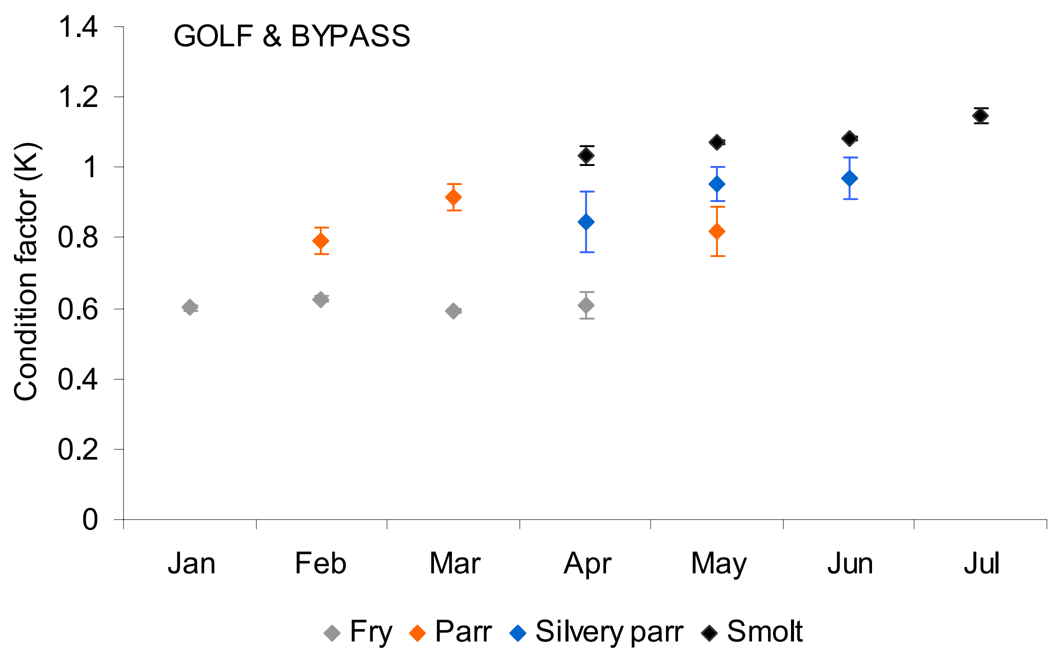


Figure 5. Monthly average condition factor (solid diamonds) ± 1 SE (vertical lines) of Chinook salmon caught and measured at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2010/11 juvenile outmigration monitoring season on the lower Mokelumne River.

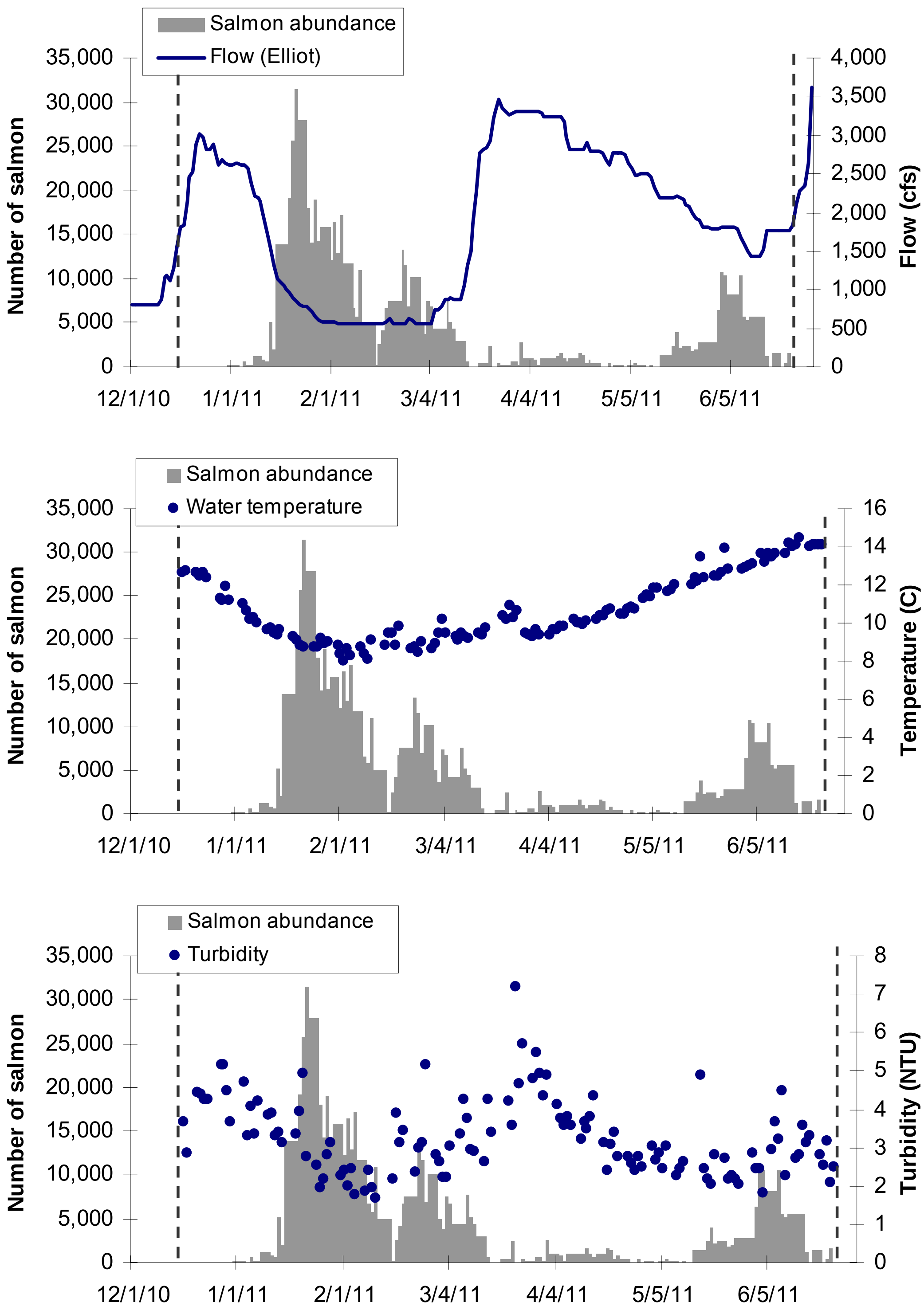


Figure 6. The relationship between estimated daily Chinook salmon passage and flow (top), water temperature (middle), and turbidity (bottom) at the VINO RST (upstream trapping location) during the 2010/11 juvenile outmigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring season.

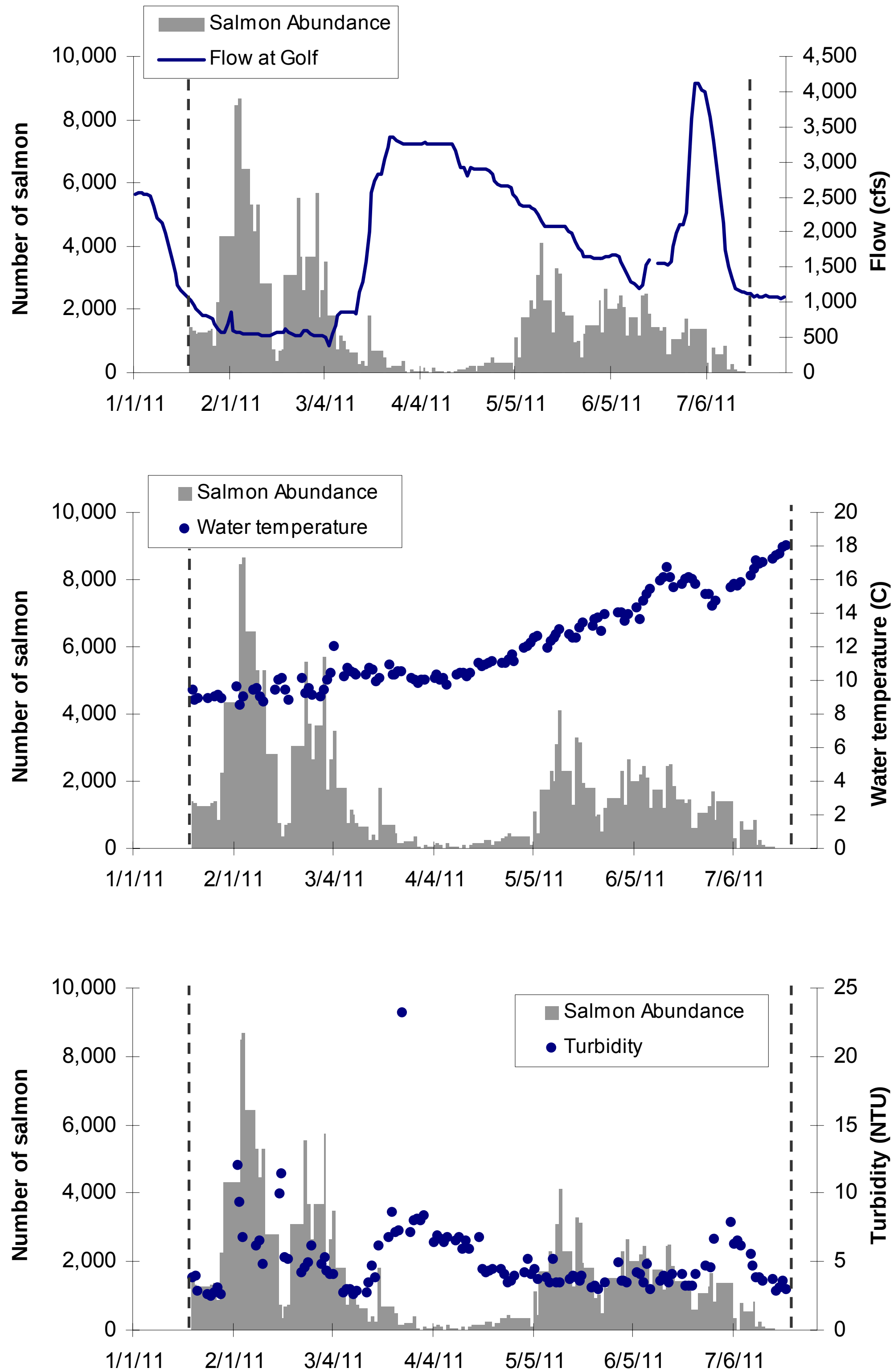


Figure 7. The relationship between estimated daily Chinook salmon passage and flow (top), water temperature (middle), and turbidity (bottom) at the downstream trapping locations (GOLF & BYPASS) during the 2010/11 juvenile outmigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring season.

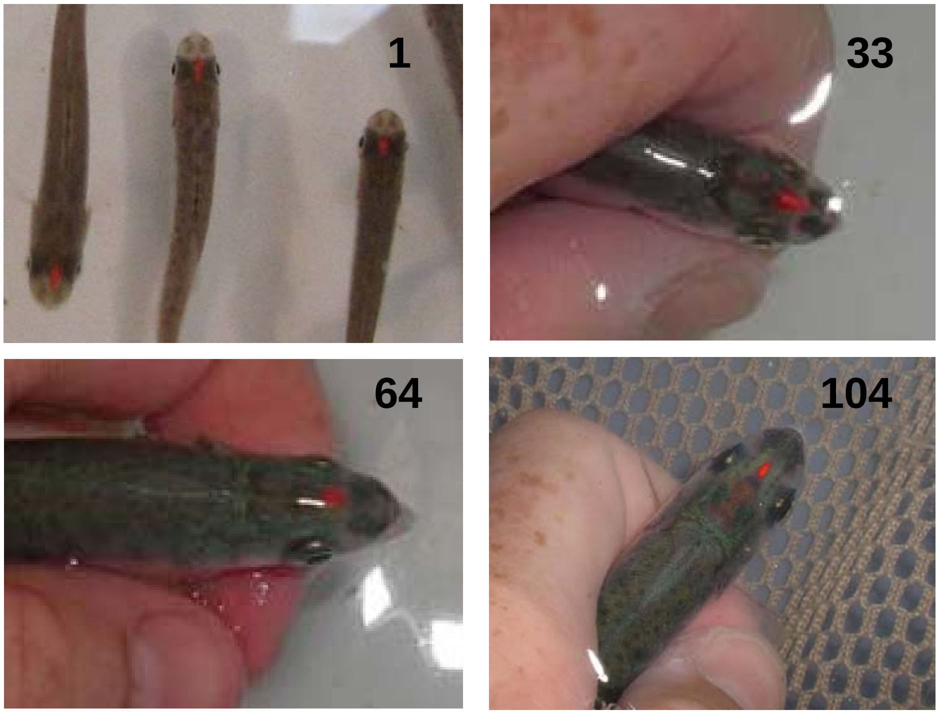


Figure 8. Visible implant elastomer (VIE) tagged juvenile Chinook salmon photographed on days 1 (top left), 33 (top right), 64 (bottom left), and 104 (bottom right) after initial tagging.

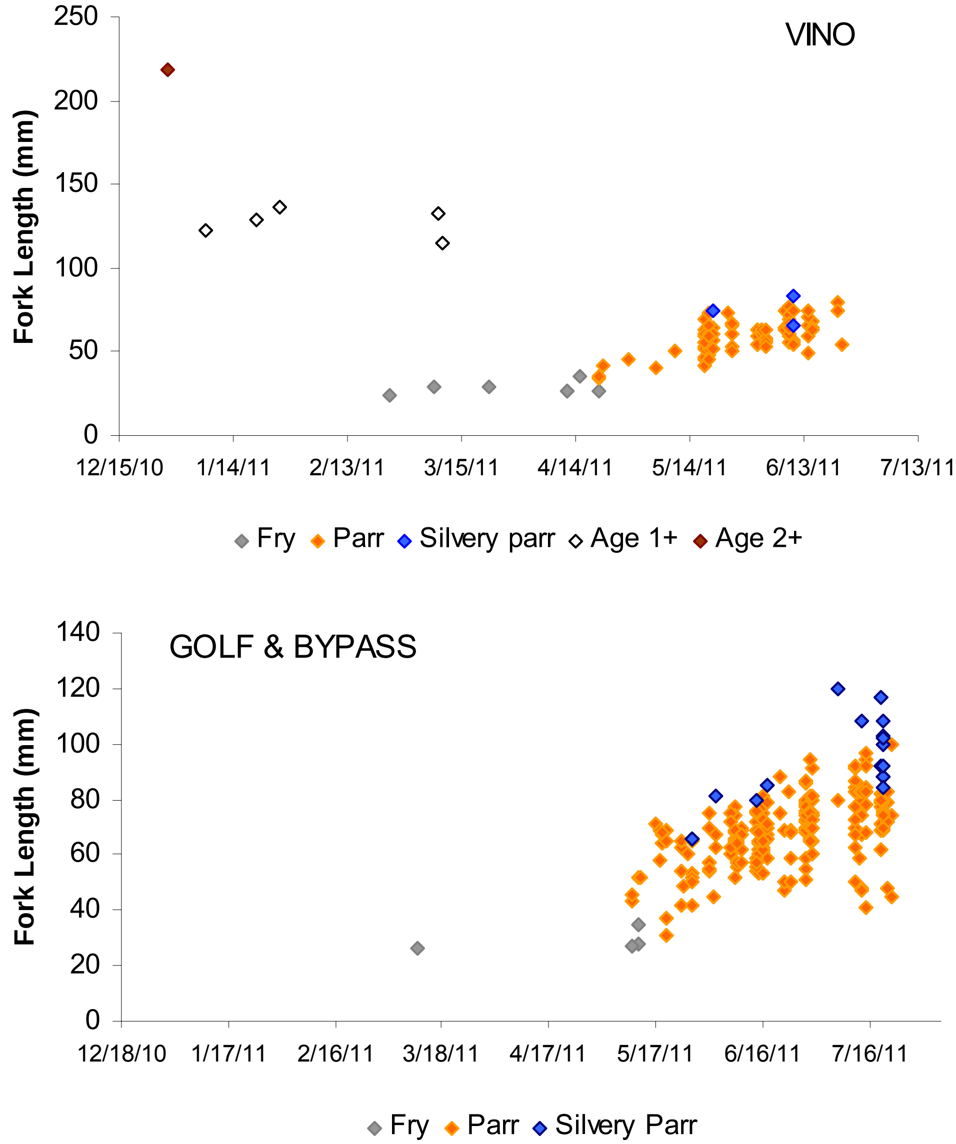


Figure 9. Size and life stage distribution of wild steelhead caught and measured at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2010/11 juvenile outmigration monitoring season on the lower Mokelumne River.

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 2010/11 monitoring period. Shaded areas represent non-trapping periods. Asterisks indicate that catch was estimated because of a trap stoppage.

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
12/16/2010	0	0.0430	0	0	0
12/17/2010	0	0.0430	0	0	0
12/18/2010	0	0.0430	0	0	0
12/19/2010	0	0.0430	0	0	0
12/20/2010	0	0.0430	0	0	0
12/21/2010	0	0.0430	0	0	0
12/22/2010	0	0.0430	0	0	0
12/23/2010	1	0.0430	23	18	33
12/24/2010	0	0.0430	8	6	11
12/25/2010	0	0.0430	8	6	11
12/26/2010	0	0.0430	8	6	11
12/27/2010	0	0.0430	8	6	11
12/28/2010	0	0.0430	0	0	0
12/29/2010	0	0.0430	0	0	0
12/30/2010	1	0.0430	23	18	33
12/31/2010	6	0.0430	143	111	203
1/1/2011	6	0.0430	143	111	203
1/2/2011	6	0.0430	143	111	203
1/3/2011	6	0.0430	143	111	203
1/4/2011	1	0.0430	23	18	33
1/5/2011	27	0.0430	628	486	887
1/6/2011	8	0.0430	186	144	263
1/7/2011	7	0.0430	163	126	230
1/8/2011	53	0.0430	1,233	954	1,742
1/9/2011	53	0.0430	1,233	954	1,742
1/10/2011	53	0.0430	1,233	954	1,742
1/11/2011	32	0.0430	744	576	1,052
1/12/2011	23	0.0430	535	414	756
1/13/2011	221	0.0430	5,140	3,977	7,263
1/14/2011	87	0.0430	2,023	1,566	2,859
1/15/2011	*705	0.0511	13,798	10,864	18,901
1/16/2011	705	0.0511	13,798	10,864	18,901
1/17/2011	705	0.0511	13,798	10,864	18,901
1/18/2011	705	0.0511	13,798	10,864	18,901
1/19/2011	981	0.0511	19,209	15,124	26,313
1/20/2011	1,309	0.0511	25,631	20,181	35,111
1/21/2011	1,607	0.0511	31,467	24,775	43,104
1/22/2011	1,424	0.0511	27,890	21,959	38,204
1/23/2011	1,424	0.0511	27,890	21,959	38,204
1/24/2011	1,424	0.0511	27,890	21,959	38,204
1/25/2011	1,633	0.0910	17,945	15,006	22,317

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
1/26/2011	1,289	0.0910	14,165	11,845	17,616
1/27/2011	1,727	0.0910	18,978	15,869	23,601
1/28/2011	1,295	0.0910	14,231	11,900	17,698
1/29/2011	1,436	0.0910	15,780	13,195	19,625
1/30/2011	1,436	0.0910	15,780	13,195	19,625
1/31/2011	1,436	0.0910	15,780	13,195	19,625
2/1/2011	1,266	0.1060	11,943	9,682	16,390
2/2/2011	1,698	0.1060	16,019	12,986	21,983
2/3/2011	1,341	0.1060	12,651	10,256	17,361
2/4/2011	1,788	0.1060	16,868	13,674	23,148
2/5/2011	1,223	0.1060	11,542	9,356	15,838
2/6/2011	1,223	0.1060	11,542	9,356	15,838
2/7/2011	1,223	0.1060	11,542	9,356	15,838
2/8/2011	691	0.1060	6,519	5,285	8,946
2/9/2011	599	0.1060	5,651	4,581	7,755
2/10/2011	1,135	0.1060	10,708	8,680	14,694
2/11/2011	522	0.1060	4,920	3,988	6,751
2/12/2011	522	0.1060	4,920	3,988	6,751
2/13/2011	522	0.1060	4,920	3,988	6,751
2/14/2011	522	0.1060	4,920	3,988	6,751
2/15/2011	16	0.1060	151	122	207
2/16/2011	258	0.1060	2,434	1,973	3,340
2/17/2011	430	0.1060	4,057	3,289	5,567
2/18/2011	697	0.1060	6,575	5,330	9,024
2/19/2011	782	0.1060	7,379	5,982	10,126
2/20/2011	782	0.1060	7,379	5,982	10,126
2/21/2011	782	0.1060	7,379	5,982	10,126
2/22/2011	782	0.1060	7,379	5,982	10,126
2/23/2011	1,388	0.1060	13,094	10,615	17,969
2/24/2011	1,206	0.1060	11,377	9,223	15,613
2/25/2011	714	0.1060	6,736	5,460	9,244
2/26/2011	1,058	0.1060	9,976	8,088	13,691
2/27/2011	1,058	0.1060	9,976	8,088	13,691
2/28/2011	1,058	0.1060	9,976	8,088	13,691
3/1/2011	931	0.1894	4,916	4,337	5,672
3/2/2011	694	0.1894	3,664	3,233	4,228
3/3/2011	1,412	0.1894	7,455	6,578	8,603
3/4/2011	1,283	0.1894	6,774	5,977	7,817
3/5/2011	808	0.1894	4,265	3,763	4,922
3/6/2011	808	0.1894	4,265	3,763	4,922
3/7/2011	808	0.1894	4,265	3,763	4,922
3/8/2011	*808	0.1894	4,265	3,763	4,922
3/9/2011	650	0.0851	7,634	6,047	10,352
3/10/2011	435	0.0851	5,109	4,047	6,928
3/11/2011	373	0.0851	4,381	3,470	5,940

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
3/12/2011	253	0.0851	2,966	2,349	4,021
3/13/2011	253	0.0851	2,966	2,349	4,021
3/14/2011	253	0.0851	2,966	2,349	4,021
3/15/2011	55	0.0851	646	512	876
3/16/2011	2	0.0851	23	19	32
3/17/2011	0	0.0851	0	0	0
3/18/2011	0	0.0851	0	0	0
3/19/2011	5	0.0120	444	284	1,016
3/20/2011	5	0.0120	444	284	1,016
3/21/2011	5	0.0120	444	284	1,016
3/22/2011	29	0.0120	2,417	1,547	5,523
3/23/2011	0	0.0120	0	0	0
3/24/2011	1	0.0120	83	53	190
3/25/2011	4	0.0120	333	213	762
3/26/2011	4	0.0120	292	187	667
3/27/2011	4	0.0120	292	187	667
3/28/2011	4	0.0120	292	187	667
3/29/2011	7	0.0120	583	373	1,333
3/30/2011	7	0.0120	583	373	1,333
3/31/2011	2	0.0120	167	107	381
4/1/2011	32	0.0120	2,667	1,707	6,094
4/2/2011	11	0.0120	900	576	2,057
4/3/2011	11	0.0120	900	576	2,057
4/4/2011	11	0.0120	900	576	2,057
4/5/2011	10	0.0120	833	533	1,904
4/6/2011	3	0.0120	250	160	571
4/7/2011	*11	0.0120	933	597	2,133
4/8/2011	*11	0.0120	933	597	2,133
4/9/2011	11	0.0120	950	608	2,171
4/10/2011	11	0.0120	950	608	2,171
4/11/2011	11	0.0120	950	608	2,171
4/12/2011	13	0.0120	1,083	693	2,476
4/13/2011	18	0.0120	1,500	960	3,428
4/14/2011	12	0.0120	1,000	640	2,285
4/15/2011	8	0.0120	667	427	1,523
4/16/2011	13	0.0120	1,069	684	2,444
4/17/2011	13	0.0120	1,069	684	2,444
4/18/2011	13	0.0120	1,069	684	2,444
4/19/2011	19	0.0120	1,583	1,013	3,618
4/20/2011	16	0.0120	1,333	853	3,047
4/21/2011	4	0.0120	333	213	762
4/22/2011	9	0.0120	750	480	1,714
4/23/2011	6	0.0120	486	311	1,111
4/24/2011	6	0.0120	486	311	1,111
4/25/2011	6	0.0120	486	311	1,111

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
4/26/2011	1	0.0120	83	53	190
4/27/2011	0	0.0120	0	0	0
4/28/2011	5	0.0120	417	267	952
4/29/2011	0	0.0120	0	0	0
4/30/2011	1	0.0120	111	71	254
5/1/2011	1	0.0120	111	71	254
5/2/2011	1	0.0120	111	71	254
5/3/2011	0	0.0120	0	0	0
5/4/2011	2	0.0070	286	164	1,091
5/5/2011	1	0.0070	143	82	546
5/6/2011	3	0.0070	429	247	1,637
5/7/2011	1	0.0070	167	96	637
5/8/2011	1	0.0070	167	96	637
5/9/2011	1	0.0070	167	96	637
5/10/2011	0	0.0070	0	0	0
5/11/2011	1	0.0070	143	82	546
5/12/2011	0	0.0070	0	0	0
5/13/2011	0	0.0070	0	0	0
5/14/2011	10	0.0070	1,429	822	5,457
5/15/2011	10	0.0070	1,429	822	5,457
5/16/2011	10	0.0070	1,429	822	5,457
5/17/2011	*10	0.0070	1,429	822	5,457
5/18/2011	17	0.0070	2,429	1,397	9,277
5/19/2011	27	0.0070	3,857	2,219	14,734
5/20/2011	15	0.0070	2,143	1,233	8,185
5/21/2011	17	0.0070	2,429	1,397	9,277
5/22/2011	17	0.0070	2,429	1,397	9,277
5/23/2011	17	0.0070	2,429	1,397	9,277
5/24/2011	12	0.0070	1,714	986	6,548
5/25/2011	14	0.0070	2,000	1,151	7,640
5/26/2011	*19	0.0070	2,714	1,562	10,368
5/27/2011	*19	0.0070	2,714	1,562	10,368
5/28/2011	19	0.0070	2,714	1,562	10,368
5/29/2011	19	0.0070	2,714	1,562	10,368
5/30/2011	19	0.0070	2,714	1,562	10,368
5/31/2011	19	0.0070	2,714	1,562	10,368
6/1/2011	16	0.0025	6,406	3,416	51,434
6/2/2011	27	0.0025	10,811	5,764	86,794
6/3/2011	26	0.0025	10,410	5,551	83,580
6/4/2011	20	0.0025	8,141	4,341	65,364
6/5/2011	20	0.0025	8,141	4,341	65,364
6/6/2011	20	0.0025	8,141	4,341	65,364
6/7/2011	*20	0.0025	8,141	4,341	65,364
6/8/2011	26	0.0025	10,410	5,551	83,580

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95 % Lower CI	95% Upper CI
6/9/2011	14	0.0025	5,606	2,989	45,004
6/10/2011	13	0.0025	5,205	2,775	41,790
6/11/2011	14	0.0025	5,606	2,989	45,004
6/12/2011	14	0.0025	5,606	2,989	45,004
6/13/2011	14	0.0025	5,606	2,989	45,004
6/14/2011	14	0.0025	5,606	2,989	45,004
6/15/2011	14	0.0025	5,606	2,989	45,004
6/16/2011	3	0.0025	1,201	640	9,644
6/17/2011	0	0.0025	0	0	0
6/18/2011	4	0.0025	1,468	783	11,787
6/19/2011	4	0.0025	1,468	783	11,787
6/20/2011	4	0.0025	1,468	783	11,787
6/21/2011	0	0.0025	0	0	0
6/22/2011	1	0.0025	400	213	3,215
6/23/2011	4	0.0025	1,602	854	12,858
6/24/2011	0	0.0025	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 2010/11 monitoring period. Shaded areas represent non-trapping periods. Asterisks indicate that catch was estimated because of a trap stoppage.

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
1/19/2011	51	–	0.0360	1,417	975	2,593
1/20/2011	48	–	0.0360	1,333	917	2,440
1/21/2011	45	–	0.0360	1,250	860	2,288
1/22/2011	46	–	0.0360	1,264	869	2,313
1/23/2011	46	–	0.0360	1,264	869	2,313
1/24/2011	46	–	0.0360	1,264	869	2,313
1/25/2011	48	–	0.0360	1,333	917	2,440
1/26/2011	50	–	0.0360	1,389	955	2,542
1/27/2011	31	–	0.0360	861	592	1,576
1/28/2011	81	–	0.0360	2,250	1,548	4,118
1/29/2011	156	–	0.0360	4,328	2,977	7,920
1/30/2011	156	–	0.0360	4,328	2,977	7,920
1/31/2011	156	–	0.0360	4,328	2,977	7,920
2/1/2011	*156	–	0.0360	4,328	2,977	7,920
2/2/2011	*156	–	0.0360	4,328	2,977	7,920
2/3/2011	305	–	0.0360	8,472	5,829	15,505
2/4/2011	312	–	0.0360	8,667	5,962	15,861
2/5/2011	232	–	0.0360	6,444	4,433	11,794
2/6/2011	232	–	0.0360	6,444	4,433	11,794
2/7/2011	232	–	0.0360	6,444	4,433	11,794
2/8/2011	191	–	0.0360	5,306	3,650	9,710
2/9/2011	161	–	0.0360	4,472	3,077	8,185
2/10/2011	191	–	0.0360	5,306	3,650	9,710
2/11/2011	101	–	0.0360	2,815	1,936	5,151
2/12/2011	101	–	0.0360	2,815	1,936	5,151
2/13/2011	101	–	0.0360	2,815	1,936	5,151
2/14/2011	101	–	0.0360	2,815	1,936	5,151
2/15/2011	27	–	0.0360	750	516	1,373
2/16/2011	13	–	0.0360	361	248	661
2/17/2011	25	–	0.0360	694	478	1,271
2/18/2011	27	–	0.0360	750	516	1,373
2/19/2011	111	–	0.0360	3,074	2,115	5,626
2/20/2011	111	–	0.0360	3,074	2,115	5,626
2/21/2011	111	–	0.0360	3,074	2,115	5,626
2/22/2011	111	–	0.0360	3,074	2,115	5,626
2/23/2011	280	–	0.0505	5,540	3,668	11,316
2/24/2011	186	–	0.0505	3,680	2,436	7,517
2/25/2011	133	–	0.0505	2,632	1,742	5,375
2/26/2011	185	–	0.0505	3,660	2,423	7,477

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
2/27/2011	185	–	0.0505	3,660	2,423	7,477
2/28/2011	185	–	0.0505	3,660	2,423	7,477
3/1/2011	289	–	0.0505	5,718	3,786	11,680
3/2/2011	89	–	0.0505	1,761	1,166	3,597
3/3/2011	133	–	0.0505	2,632	1,742	5,375
3/4/2011	177	–	0.0505	3,502	2,319	7,153
3/5/2011	91	–	0.0505	1,801	1,192	3,678
3/6/2011	91	–	0.0505	1,801	1,192	3,678
3/7/2011	91	–	0.0505	1,801	1,192	3,678
3/8/2011	38	–	0.0505	752	498	1,536
3/9/2011	59	–	0.0505	1,167	773	2,384
3/10/2011	50	–	0.0505	989	655	2,021
3/11/2011	38	–	0.0505	752	498	1,536
3/12/2011	32	–	0.0505	633	419	1,293
3/13/2011	32	–	0.0505	633	419	1,293
3/14/2011	32	–	0.0505	633	419	1,293
3/15/2011	13	–	0.0505	257	170	525
3/16/2011	20	–	0.0505	396	262	808
3/17/2011	12	–	0.0505	237	157	485
3/18/2011	34	–	0.0190	1,789	1,238	3,226
3/19/2011	14	–	0.0190	711	492	1,281
3/20/2011	14	–	0.0190	711	492	1,281
3/21/2011	14	–	0.0190	711	492	1,281
3/22/2011	*14	–	0.0190	711	492	1,281
3/23/2011	9	–	0.0190	474	328	854
3/24/2011	3	–	0.0190	158	109	285
3/25/2011	3	–	0.0190	158	109	285
3/26/2011	4	–	0.0190	202	140	364
3/27/2011	4	–	0.0190	202	140	364
3/28/2011	4	–	0.0190	202	140	364
3/29/2011	7	–	0.0190	368	255	664
3/30/2011	1	–	0.0190	53	36	95
3/31/2011	0	–	0.0190	0	0	0
4/1/2011	2	–	0.0190	105	73	190
4/2/2011	1	–	0.0190	53	36	95
4/3/2011	1	–	0.0190	53	36	95
4/4/2011	1	–	0.0130	77	50	167
4/5/2011	2	–	0.0130	154	100	334
4/6/2011	1	–	0.0130	77	50	167
4/7/2011	0	–	0.0130	0	0	0
4/8/2011	2	–	0.0130	154	100	334
4/9/2011	1	–	0.0130	51	33	111
4/10/2011	1	–	0.0130	51	33	111
4/11/2011	1	–	0.0130	51	33	111

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
4/12/2011	0	0	0.0130	0	0	0
4/13/2011	1	0	0.0130	77	50	167
4/14/2011	0	0	0.0130	0	0	0
4/15/2011	1	0	0.0130	77	50	167
4/16/2011	2	0	0.0130	128	83	278
4/17/2011	2	0	0.0130	128	83	278
4/18/2011	2	0	0.0130	128	83	278
4/19/2011	2	0	0.0130	154	100	334
4/20/2011	3	0	0.0130	231	150	501
4/21/2011	3	0	0.0130	231	150	501
4/22/2011	1	0	0.0130	77	50	167
4/23/2011	3	0	0.0130	218	141	473
4/24/2011	3	0	0.0130	218	141	473
4/25/2011	3	0	0.0088	324	196	926
4/26/2011	3	0	0.0088	343	208	980
4/27/2011	4	0	0.0088	457	277	1,307
4/28/2011	3	0	0.0088	343	208	980
4/29/2011	3	0	0.0088	343	208	980
4/30/2011	3	0	0.0088	343	208	980
5/1/2011	3	0	0.0088	343	208	980
5/2/2011	3	0	0.0088	343	208	980
5/3/2011	3	0	0.0088	343	208	980
5/4/2011	1	0	0.0088	114	69	327
5/5/2011	*10	0	0.0088	1,104	669	3,159
5/6/2011	4	0	0.0088	457	277	1,307
5/7/2011	15	0	0.0088	1,732	1,050	4,956
5/8/2011	15	0	0.0088	1,732	1,050	4,956
5/9/2011	15	0	0.0088	1,732	1,050	4,956
5/10/2011	20	0	0.0088	2,284	1,384	6,536
5/11/2011	*18	0	0.0088	2,018	1,223	5,773
5/12/2011	27	0	0.0088	3,084	1,869	8,823
5/13/2011	36	0	0.0088	4,112	2,491	11,764
5/14/2011	32	0	0.0139	2,285	1,503	4,762
5/15/2011	32	0	0.0139	2,285	1,503	4,762
5/16/2011	32	0	0.0139	2,285	1,503	4,762
5/17/2011	18	0	0.0139	1,292	850	2,693
5/18/2011	46	0	0.0139	3,302	2,172	6,882
5/19/2011	44	0	0.0139	3,159	2,078	6,583
5/20/2011	27	0	0.0139	1,938	1,275	4,039
5/21/2011	25	0	0.0139	1,807	1,188	3,765
5/22/2011	25	0	0.0139	1,807	1,188	3,765
5/23/2011	25	0	0.0139	1,807	1,188	3,765
5/24/2011	13	0	0.0139	933	614	1,945
5/25/2011	14	0	0.0139	1,005	661	2,094

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
5/26/2011	7	–	0.0139	503	331	1,047
5/27/2011	17	–	0.0139	1,220	803	2,543
5/28/2011	21	–	0.0139	1,496	984	3,117
5/29/2011	21	–	0.0139	1,496	984	3,117
5/30/2011	21	–	0.0139	1,496	984	3,117
5/31/2011	21	–	0.0139	1,496	984	3,117
6/1/2011	32	–	0.0139	2,297	1,511	4,787
6/2/2011	18	–	0.0139	1,292	850	2,693
6/3/2011	37	–	0.0139	2,656	1,747	5,535
6/4/2011	28	–	0.0139	1,998	1,314	4,164
6/5/2011	28	–	0.0139	1,998	1,314	4,164
6/6/2011	28	–	0.0139	1,998	1,314	4,164
6/7/2011	26	–	0.0119	2,184	1,398	4,991
6/8/2011	29	–	0.0119	2,436	1,559	5,567
6/9/2011	25	–	0.0119	2,100	1,344	4,799
6/10/2011	14	–	0.0119	1,176	753	2,688
6/11/2011	21	–	0.0119	1,750	1,120	3,999
6/12/2011	21	–	0.0119	1,750	1,120	3,999
6/13/2011	21	–	0.0119	1,750	1,120	3,999
6/14/2011	14	0	0.0119	1,176	753	2,688
6/15/2011	22	7	0.0119	1,855	1,190	4,230
6/16/2011	21	9	0.0119	1,773	1,138	4,040
6/17/2011	19	3	0.0119	1,599	1,024	3,650
6/18/2011	17	–	0.0119	1,428	914	3,263
6/19/2011	17	–	0.0119	1,428	914	3,263
6/20/2011	17	–	0.0119	1,428	914	3,263
6/21/2011	16	–	0.0119	1,344	860	3,071
6/22/2011	17	–	0.0119	1,428	914	3,263
6/23/2011	7	–	0.0119	588	376	1,344
6/24/2011	7	–	0.0119	588	376	1,344
6/25/2011	13	–	0.0119	1,064	681	2,432
6/26/2011	13	–	0.0119	1,064	681	2,432
6/27/2011	13	–	0.0119	1,064	681	2,432
6/28/2011	15	–	0.0119	1,260	806	2,880
6/29/2011	20	–	0.0119	1,680	1,075	3,839
6/30/2011	10	–	0.0119	840	538	1,920
7/1/2011	9	–	0.0063	1,384	770	6,839
7/2/2011	9	–	0.0063	1,384	770	6,839
7/3/2011	9	–	0.0063	1,384	770	6,839
7/4/2011	9	–	0.0063	1,384	770	6,839
7/5/2011	9	–	0.0063	1,384	770	6,839
7/6/2011	2	–	0.0063	319	178	1,578
7/7/2011	0	–	0.0063	0	0	0
7/8/2011	5	–	0.0063	798	444	3,945

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
7/9/2011	4	–	0.0063	559	311	2,762
7/10/2011	4	–	0.0063	559	311	2,762
7/11/2011	4	–	0.0063	559	311	2,762
7/12/2011	10	–	0.0119	840	538	1,920
7/13/2011	1	–	0.0119	84	54	192
7/14/2011	3	–	0.0119	252	161	576
7/15/2011	1	–	0.0119	84	54	192
7/16/2011	1	–	0.0119	70	45	160
7/17/2011	1	–	0.0119	70	45	160
7/18/2011	1	–	0.0119	70	45	160
7/19/2011	0	–	0.0119	0	0	0
7/20/2011	0	–	0.0119	0	0	0
7/21/2011	0	–	0.0119	0	0	0
7/22/2011	0	–	0.0119	0	0	0

Appendix C. Monthly totals of species caught at the upstream RST (VINO) on the lower Mokelumne river during the 2010/11 juvenile outmigration monitoring season.

Common Name	Genus	Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Black Bass	*Micropterus*	*sp.*	0	0	0	1	0	0	4	**5**
Black Crappie	*Pomoxis*	*nigromaculatus*	0	2	0	1	3	0	0	**6**
Bluegill	*Lepomis*	*macrochirus*	6	5	0	4	2	4	8	**29**
Channel Catfish	*Ictalurus*	*punctatus*	0	4	6	2	1	3	1	**17**
Chinook Salmon (Ad-Clip yearling)	*Oncorhynchus*	*tshawytscha*	0	8	3	0	0	0	0	**11**
Chinook Salmon (No Ad-Clip)	*Oncorhynchus*	*tshawytscha*	2	10,247	13,227	5,918	151	92	158	**29,795**
Golden Shiner	*Notemigonus*	*crysoleucas*	1	0	1	0	0	0	0	**2**
Goldfish	*Carassius*	*auratus*	0	3	1	0	0	0	0	**4**
Hardhead	*Mylopharodon*	*conocephalus*	0	1	1	0	0	0	0	**2**
Hitch	*Lavinia*	*exilicauda*	0	0	1	0	0	0	0	**1**
Kokanee	*Oncorhynchus*	*nerka kennerlyi*	2	1	1	1	0	4	0	**9**
Largemouth Bass	*Micropterus*	*salmoides*	0	1	0	0	0	0	0	**1**
Lepomis hybrid	*Lepomis*		0	0	0	1	0	0	0	**1**
Pacific Lamprey	*Lampetra*	*tridentata*	70	313	308	97	4	29	70	**891**
Prickly Sculpin	*Cottus*	*asper*	0	16	22	2	1	1	18	**60**
Redear Sunfish	*Lepomis*	*microlophus*	1	1	1	15	15	7	8	**48**
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	0	0	3	1	3	1	5	**13**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	1	3	1	4	8	43	51	**111**
Threadfin Shad	*Dorosoma*	*petenense*	5	15	0	0	0	0	0	**20**
Tule Perch	*Hysterocarpus*	*traski*	0	1	0	0	0	2	0	**3**
Unidentified Centrarchid			0	0	1	0	0	0	0	**1**
Warmouth	*Lepomis*	*gulosus*	0	0	0	1	0	0	0	**1**
Western Mosquitofish	*Gambusia*	*affinis*	2	2	0	1	9	2	1	**17**
White Catfish	*Ameiurus*	*catus*	1	0	0	0	0	0	0	**1**

Appendix D. Monthly totals of species caught at the downstream traps (GOLF and BYPASS) on the lower Mokelumne river during the 2010/11 juvenile outmigration monitoring season.

Common Name	**Genus**	**Species**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Total**
American Shad	*Alosa*	*sapidissima*	0	0	0	0	1	0	0	**1**
Black Bass	*Micropterus*	*sp*	0	29	0	0	0	77	40	**146**
Black Crappie	*Pomoxis*	*nigromaculatus*	0	17	3	1	29	10	7	**67**
Bluegill	*Lepomis*	*macrochirus*	2	131	8	4	3	9	13	**170**
Brown Bullhead	*Ameiurus*	*nebulosus*	0	0	0	0	0	1	0	**1**
Channel Catfish	*Ictalurus*	*punctatus*	0	9	0	0	1	3	2	**15**
Chinook Salmon (Ad-Clip yearling)	*Oncorhynchus*	*tshawytscha*	28	38	1	0	0	0	0	**67**
Chinook Salmon (No Ad-Clip)	*Oncorhynchus*	*tshawytscha*	354	1,851	976	31	277	368	22	**3,879**
Common Carp	*Cyprinus*	*carpio*	0	0	1	0	702	1,176	9	**1,888**
Golden Shiner	*Notemigonus*	*crysoleucas*	1	97	36	7	0	7	62	**210**
Goldfish	*Carassius*	*auratus*	0	4	2	0	8	0	0	**14**
Green Sunfish	*Lepomis*	*cyanellus*	0	1	0	0	0	0	0	**1**
Hitch	*Lavinia*	*exilicauda*	0	14	0	1	46	9	5	**75**
Kokanee	*Oncorhynchus*	*nerka kennerlyi*	0	0	0	0	14	10	4	**28**
Largemouth Bass	*Micropterus*	*salmoides*	0	35	0	0	0	0	1	**36**
Lepomis hybrid	*Lepomis*		0	1	0	0	0	0	0	**1**
Pacific Lamprey	*Lampetra*	*tridentata*	32	437	337	17	7	17	3	**850**
Prickly Sculpin	*Cottus*	*asper*	14	187	123	9	65	385	26	**809**
Redear Sunfish	*Lepomis*	*microlophus*	0	13	2	4	0	15	75	**109**
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	0	3	0	2	2	0	1	**8**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	6	1	0	2	0	1	**10**
Spotted Bass	*Micropterus*	*punctulatus*	0	1	0	0	0	0	0	**1**
Steelhead (Ad-Clip)	*Oncorhynchus*	*mykiss*	0	10	1	0	0	1	0	**12**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	0	0	1	0	30	129	70	**230**
Tule Perch	*Hysterocarpus*	*traski*	0	9	5	1	1	1	1	**18**
Western Mosquitofish	*Gambusia*	*affinis*	1	29	3	0	0	0	30	**63**
White Catfish	*Ameiurus*	*catus*	0	1	1	0	0	0	0	**2**