Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2011 through July 2012

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

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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 2011/2012 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 12 December 2011 to 29 June 2012. The downstream rotary screw trap (GOLF) was located just below the Lower Sacramento Road Bridge at rkm 61.8 and was operated from 27 December 2011 to 18 March 2012 and from 12 April 2012 to 23 May 2012. The smolt bypass trap (BYPASS), located at Woodbridge Irrigation District Dam (rkm 62.2), was operated from 21 March to 13 July 2012.

The first juvenile Chinook salmon was captured at the VINO RST on 20 December 2011. Eight trap efficiency tests were conducted at VINO during the monitoring period, four using naturally produced salmon and four using hatchery produced salmon. The total estimated abundance of naturally produced young-of-the-year (YOY) Chinook salmon passing the VINO site during the monitoring period was 202,772 (95% CI: 152,937-312,856). A total of 105 wild YOY steelhead was caught at the VINO RST during the 2011/2012 season. Estimated passage of wild YOY steelhead (based on trap calibrations using salmon) was 1,309 (95% CI: 985-1,965).

At the downstream RST (GOLF), the first juvenile Chinook salmon was captured on 18 January 2012. Six trap efficiency tests were conducted at GOLF, four using hatchery produced salmon and two using naturally produced salmon. The total estimated abundance of naturally produced YOY Chinook salmon passing the GOLF site during the monitoring period was 25,605 (95% CI: 20,195-36,433). Zero wild YOY steelhead were captured at the GOLF RST during the 2011/2012 season.

A total of 7,622 naturally produced YOY Chinook salmon was caught at the smolt bypass trap (BYPASS) during the monitoring period. After the GOLF RST was pulled for the season, three trap efficiency tests were conducted at the BYPASS, all using hatchery produced salmon. The total estimated abundance of naturally produced YOY Chinook

salmon at the BYPASS was 26,194 (95% CI: 21,868-34,198). The total downstream salmon emigration estimate, calculated from adding the BYPASS trap estimate to the GOLF RST estimate, was 51,799 (95% CI: 42,063-70,631). A total of 100 wild YOY steelhead was caught at the BYPASS between 6 April and 12 July 2012. The total downstream passage estimate of wild YOY steelhead (based on trap calibrations using salmon) was 483 (95% CI: 376-686)

Sixteen fish species were caught at the VINO RST during the survey period, 8 native and 8 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, however unidentified black bass (*Micropterus* spp.) were the most abundant fishes caught.

Average daily water releases from Camanche Reservoir ranged from 202 cfs (5.7 m^3/s) to 370 cfs (10.5 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, Workman et al. 2007). Nearly all salmonid spawning occurs in a 16-rkm 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 2011 through mid-July 2012.

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 and additional water temperature measurements were provided by EBMUD's Camanche Dam (rkm 103), Elliot Road (rkm 86.1), Victor (rkm 80.7), Golf (rkm 61.3), and Frandy (rkm 46.4) monitoring stations (Figure 1).

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 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 2011/12 monitoring season, RSTs were generally operated Monday through Friday, between December and July. However, the GOLF trap was removed from the river from 19 March to 11 April 2012 due to the possibility of a critically dry water year for the April through October period. During critically dry water years, the minimum flow below Woodbridge Dam during the month of April is 75 cfs, which is insufficient flow to operate the GOLF RST. Once the April through October water year type was officially determined to be dry, the GOLF trap was reinstalled and put into service on 12 April 2012. 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 2011/12 trapping season (Figure 1). 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. 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 rkm upstream of the trap location. Test fish for VINO were released approximately 0.25 rkm upstream of the trap location. The test fish were distributed proportionally to the flow across the river at each location. Salmon caught within seven days of the release date for each trap efficiency test were recorded as valid recaptures for a given test.

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

When the BYPASS trap was in operation from 22 March to 23 May 2012, daily catch was added to the daily estimate at the GOLF trap to produce a daily downstream abundance estimate.

However, from 24 May to 13 July 2012, when the GOLF trap was removed for the season, abundance estimates were generated at the BYPASS trap using the same methods described previously for the RSTs. Test fish used to calibrate the BYPASS trap were released in the lower Mokelumne River channel at rkm 63.3, within the Lodi Lake area. This release site was located approximately 0.5 rkm upstream of the WID canal/bypass pipe intake and approximately 0.9 rkm upstream of the WID dam and the end of the bypass pipe (where the BYPASS trap is located). A lower caudal clip and Visible Implant Elastomer were used to mark the test salmon. The test salmon were distributed proportionally to the flow across the river at the release location.

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 for 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 rkm (0.25 miles) downstream of the capture sites. When the GOLF and BYPASS traps were both in service, all fish caught at the BYPASS trap were transported and released approximately 0.4 rkm downstream of the GOLF trap to avoid counting them twice.

Fulton's Condition Factor (Bagenal and Tesh 1978) was 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.

Trapping and Trucking

The Lower Mokelumne River Joint Settlement Agreement (1998) recommends that outmigrating Chinook salmon smolts be trapped at Woodbridge Dam and transported to the Delta during dry and critically dry water years, when agreed upon by the California Department of Fish and Game (CDFG), the United States Fish and Wildlife Service (USFWS), and EBMUD. The purpose of the trapping and trucking operation is to reduce mortalities of emigrating juvenile salmon due to elevated water temperatures in the lower Mokelumne River downstream of Woodbridge Dam. Based on the Partnership Coordinating Committee (PCC) meeting (3 April 2012), the CDFG, USFWS, and EBMUD agreed to the criteria listed below to initiate trapping and trucking this season. Water temperature at the Frandy gage (rkm 46) must exceed 24°C or a 7-day moving average of 20°C in April, May, June or July. PCC members also established that trapping and trucking activities would be suspended if the 5-day average Chinook salmon count falls below 50 per day. The juvenile salmon would be trapped at Woodbridge Dam and transported to a release site with similar water temperatures.

A transport tank with two 75-gallon compartments equipped with mechanical aerators was used to haul the salmon. Compartments were filled with water from the bypass trap using a submersible pump. Water was treated with Novaqua®, ice made from Mokelumne River water, and salt to minimize stress to fish. A recommended concentration of salt (0.1 to 0.3% salt solution) was used for fish transport (Piper et al 1992). Water temperatures and dissolved oxygen levels were recorded before transport, immediately after arrival at the release site, and just before the salmon were released. Mechanical aerators were used to maintain dissolved oxygen levels greater than 7.00 mg/L during transport. All fish were acclimated to within 1°C of the release water in the transport tanks before their release.

Juvenile Chinook Salmon Survival

<u>Egg to young-of-the-year survival indices</u>

Egg to young-of-the-year survival indices were calculated at the upstream and downstream trapping locations based on the brood year (BY) 2012 redd count and BY 2012 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. Survival indices for BY 2012 were compared with previous years. The minimum and maximum survival indices were expected to range between 0.0 and 1.0, respectively.

<u>In-river survival</u>

A mark-recapture study was conducted between upstream and downstream trapping locations (25-rkm reach) on the LMR during the 2011/2012 outmigration season. Naturally produced juvenile Chinook salmon were captured and marked with Visible Implant Elastomer (VIE) at the VINO RST over a span of 19 trapping days (between 12 January to 8 March 2012). A 70 to 100 mg/L solution of MS-222 was used to anesthetize the fish prior to tagging. Red, green, and yellow VIE was used to tag three groups of salmon. VIE marks were implanted in the snout of the salmon and approximately 2-3mm in length. All VIE-tagged salmon were held in 19 liter (5 gallon) buckets equipped with battery operated aerators for 30 minutes prior to their release roughly 0.15 rkm downstream of the VINO RST. Tag retention rates were estimated based on an independent mark retention study conducted over a 104-day study period during the previous season (Bilski et al. 2011)

The minimum and maximum migration times (*Tmn* and *Tmx*), to the nearest day, were calculated for each recaptured salmon by subtracting the number of days between the recapture date (*Rc*) and the minimum and maximum release dates ($Rlmn_n$ and $Rlmx_n$) from the *nth* release group:

$$Tmn_n = Rc - Rlmn_n\ ,\ \ Tmx_n = Rc - Rlmx_n$$

The Peterson equation was used to estimate the abundance of VIE-tagged salmon at the GOLF RST, where $\hat{N}g_i$ equals the estimated number of VIE-tagged salmon passing the GOLF RST during period *i*, M_i equals the number of salmon marked and released for a trap efficiency test during period *i*, ng_i equals the number of VIE-tagged salmon captured at GOLF during period *i*, and m_i equals the number of marked salmon recaptured during a trap efficiency test for period *i*:

$$\hat{N}g_i = \frac{ng_i M_i}{m_i}$$

The Peterson equation was also used to estimate the abundance of VIE-tagged salmon at the BYPASS when the GOLF RST was not in service: where $\hat{N}b_i$ equals the estimated number of VIE-tagged salmon passing the GOLF RST during period *i*, M_i equals the number of salmon marked and released for a trap efficiency test during period *i*, nb_i

equals the number of VIE-tagged salmon captured at BYPASS during period *i*, and m_i equals the number of marked salmon recaptured during a trap efficiency test for period *i*:

$$\hat{N}b_i = \frac{nb_i M_i}{m_i}$$

The in-river survival index (*SI*) was calculated by dividing the sum of the total estimated number of VIE recaptures at the downstream traps ($\hat{N}g$ and $\hat{N}b$) by the estimated number of VIE-tagged salmon released at the upstream trap ($\hat{N}v$), where *Nv* equals the number of VIE-tagged salmon released at the upstream trap and *Re* is the mark retention of VIE-tagged salmon fry over a 104-day study period, as determined by the study previously mentioned.

$$SI = \frac{\hat{N}g + +\hat{N}b}{\hat{N}v}, \text{ where } \hat{N}g = \sum_{i=1}^{ng} \hat{N}g_i, \quad \hat{N}b = \sum_{i=1}^{nb} \hat{N}b_i \text{ and } \hat{N}v = Nv \times Re$$

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, photoperiod, and turbidity at the upstream and downstream trapping locations. All data distributions were evaluated for parametric testing. Skewness and kurtosis values > ±2 were set as the lower and upper limits for normality. In cases where data were not normally distributed, the following transformation was used: $\log_e(y + 0.5)$. A correlation matrix was built to determine if 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. The Minimum AICc (corrected Akaike Information Criterion) was used to select the best model.

The relationship between Chinook salmon redd emergence timing and 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).

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 > 3. Trap abundance estimates were reported with 95% confidence intervals (CI).

RESULTS

Mokelumne River Flow, Water Temperature,and Turbidity

Average daily flow at the Elliot Road gauging station (just downstream of the VINO trapping site) ranged from 177 cfs (5.0 m^3/s) to 344 cfs (9.7 m^3/s) during the time when the VINO trap was operated (12 December 2011 through 29 June 2012). The mean flow during that time was 274 cfs (7.8 m^3/s). Water temperatures recorded at the VINO trapping site fell between 8.0 and 15.9°C, with a mean of 11.7°C. Water turbidity at the VINO RST ranged from 1.4 to 7.0 Nephelometric Turbidity Units (NTU), with a mean of 2.5 NTU.

Average daily flow at the GOLF gauging station ranged from 134 cfs (3.8 m^3/s) to 499 cfs (14.1 m^3/s) during the time when the GOLF RST was operated (27 December 2011 through 18 March 2012 and 12 April 2012 through 23 May 2012). The mean flow during that time was 221 cfs (6.3 m^3/s). Water temperatures recorded at the GOLF trapping site ranged between 7.5 and 20.0°C, with a mean of 12.8°C. Water turbidity at GOLF ranged from 1.5 to 11.6 NTU, with a mean of 3.0 NTU.

During the time that the BYPASS trap was operated (22 March through 13 July 2012) average daily flow at the Victor gauging station ranged from 136 cfs (3.9 m^3/s) to 301 cfs (8.5 m^3/s), with a mean of 220 cfs (6.2 m^3/s). Flow at the Woodbridge Irrigation District Canal ranged from 0 cfs to 155 cfs (4.4 m^3/s) and averaged 78 cfs (2.2 m^3/s) when the BYPASS was in service. Water temperatures recorded at the BYPASS trap ranged from 12.7 to 23.3°C, with a mean of 18.6°C. Water turbidity at the BYPASS ranged from 1.9 to 5.2 NTU, with a mean of 2.8 NTU.

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

Trap Operations

The VINO RST was operated between 12 December 2011 and 29 June 2012. The cone was stopped by debris on 2 of 109 days when the trap was checked. Excluding days with trap stoppages, the minimum recorded cone rotation rate was 1.6 RPM and the maximum was 3.5 RPM. The mean rotation rate during the monitoring season was 2.5 RPM. The VINO trap met or exceeded the CAMP recommended minimum rotation speed of 2.0 RPMs (USFWS 2008) on 93% of all operating days (excluding stoppage days). Water velocity entering the center of the trap cone ranged between 0.6 and 1.1 m/s, with a mean of 0.9 m/s.

The GOLF RST was operated from 27 December 2011 to 18 March 2012 and from 12 April 2012 to 23 May 2012. Debris stopped the cone from rotating on 7 of 66 days when the trap was checked. Excluding trap stoppages, the minimum recorded cone rotation rate was 1.9 RPM and the maximum was 4.4 RPM. Average rotational speed over the course of the monitoring period was 3.2 RPM. The GOLF trap met or exceeded the CAMP recommended minimum rotation speed of 2.0 RPMs (USFWS 2008) on 98% of all operating days (excluding stoppage days). Water velocities entering the center of the trap cone ranged between 0.4 and 1.1 m/s, with a mean of 0.6 m/s.

The BYPASS trap at WIDD was operated between 21 March and 13 July 2012. During this time frame the trap was checked on 62 days. Water velocities at the top of the trap ranged between 0.4 and 1.0 m/s and averaged 0.7 m/s.

RST Calibrations

Eight calibration tests were conducted for the VINO RST during the 2011/12 juvenile monitoring season (Table 1). Naturally produced Chinook salmon were used as test fish for four tests and Chinook salmon from the MRFI were used for four tests. Two trap efficiency tests (7 and 8) were not used to generate abundance estimates because there were an insufficient number of fish recaptured to generate 95% CIs. Excluding tests 7 and 8, trap efficiencies ranged from 2.8% to 23.0% and averaged 11.5% (n = 6).

Six calibration tests were conducted for the GOLF RST during the 2011/12 juvenile monitoring season (Table 1). Naturally produced Chinook salmon were used as test fish for two tests and MRFI salmon were used for four tests. Trap efficiency tests 2 and 3 were not used to generate daily abundance estimates because the trap was stopped by debris shortly after the test fish were released. Trap efficiency tests 5 and 6 were pooled because there was an insufficient number of fish recaptured to generate 95% CIs for test 5. Smolt-sized salmon were released under similar flow conditions during tests 5 and 6 (Table 1). Excluding the unused tests, GOLF trap efficiencies ranged from 2.5% to 9.0%, with a mean of 5.4% (n = 4).

Three calibration tests were conducted for the BYPASS during the 2011/12 juvenile monitoring season (Table 1). Chinook salmon from the MRFI were used for all three tests. Trap efficiencies for the BYPASS ranged from 31.9% to 34.0%, with a mean of 32.6%.

Chinook Salmon

<u>Catch and Abundance Estimates</u>

During rotary screw trap monitoring 13,931 naturally produced young-of-the-year (YOY) Chinook salmon were captured at the VINO RST. Estimates for weekend catch were added to actual catch to produce an estimated count of 26,761 YOY Chinook salmon. Using trap efficiency data, the total estimated abundance of YOY salmon passing the upstream RST (VINO) was 202,772 (95% CI: 152,937-312,856). The first and last salmon were caught on 20 December 2011 and 28 June 2012, respectively. The highest monthly abundance estimate was recorded at the VINO trap during the month of February (Table 2).

At the GOLF RST, 959 naturally produced YOY Chinook salmon were captured from 18 January 2012 through 18 March 2012 and 12 April 2012 through 23 May 2012. Estimates for weekend catch were added to the actual catch to produce an estimated count of 1,773 YOY Chinook salmon. Using trap efficiency data, the estimated abundance of YOY Chinook salmon at the downstream RST (GOLF) was 25,605 (95% CI: 20,195-36,433).

A total of 7,622 naturally produced juvenile Chinook salmon were captured at the BYPASS trap between 22 March and 13 June 2012. Estimates for weekend catch were added to the actual catch to produce an estimated count of 13,849 YOY Chinook salmon. Using trap efficiency data, the estimated abundance of YOY Chinook salmon at the BYPASS trap was 26,194 (95% CI: 21,868-34,198).

The total downstream emigration estimate of 51,799 YOY Chinook salmon (95% CI: 42,063-70,631) was calculated by adding the BYPASS trap estimate to the GOLF RST estimate. At the downstream traps, the highest monthly abundance estimate was recorded during the month of May (Table 2).

Life stage, size and condition

At the VINO RST, 97% (n=13,513) of the Chinook salmon catch (natural production) was classified as fry. The remaining naturally produced Chinook salmon catch was classified as parr (2%, n=288), silvery parr (0.3%, n=38), and smolts (0.7%, n=92). In addition, 24 adipose fin-clipped (hatchery origin) Chinook salmon yearlings and one adipose fin-clipped (hatchery origin) Chinook salmon smolt were caught at the VINO trap. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the VINO trap during the 2011/12 season is provided by Figure 3.

Chinook salmon catch (natural production) at the downstream traps (GOLF and BYPASS) was primarily composed of smolts (91.8%, n=7,878). The remaining naturally produced Chinook salmon catch was classified as fry (7.8%, n=668), parr (0.1%, n=9), silvery parr (0.2%, n=21), and yearlings (0.1%, n=4). In addition, 434 adipose fin-clipped (hatchery origin) Chinook salmon yearlings and 32 adipose fin-clipped (hatchery origin) Chinook salmon smolts were caught at the downstream traps. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the downstream traps during the 2011/12 season is provided by Figure 3.

The monthly average condition factors by life stage for Chinook salmon caught and measured at the upstream and downstream traps are 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 graphically in Figures 5 and 6.

Average weekly water temperature (rkm 86) was the only environmental variable included in the regression model for the upstream trapping location (Table 3). The model explained 33% of the variation in weekly juvenile Chinook salmon passage at the upstream RST. Other variables examined, but not included in the model, were average weekly turbidity (rkm 87), average weekly photoperiod (daylight hours), and average weekly flow (rkm 86). In addition, Chinook salmon redd emergence timing (log transformed) had a significant positive linear relationship with juvenile Chinook salmon passage at the upstream RST and explained 69% of the variation in the data (Linear regression: $F = 50.014$; df = 1, 22; $P < 0.001$).

At the downstream traps, photoperiod was the only variable included in the regression model (Table 3). The model explained just 18% of the variation in weekly juvenile Chinook salmon passage at the downstream trapping locations. Average weekly water temperature (rkm 61, 80), average weekly flow (rkm 61, 80), average weekly water diversion at the WID canal (rkm 62), and average weekly turbidity (rkm 62) were other variables examined, but not included in the model. Chinook salmon redd emergence timing did not have a significant relationship with salmon passage at the downstream traps (Linear regression: $F = 1.909$; df = 1, 22; $P = 0.181$).

Trapping and Trucking

Trapping and trucking was initiated on 5 June 2012, the first trapping day after the daily mean water temperature at the Frandy gauging station (rkm 46) exceeded a 7-day moving average of 20°C. Juvenile Chinook salmon were transported for a total of 7 trapping days, until 19 June 2012, when the 5-day Chinook salmon count average fell below 50 per day at the BYPASS trap. During this time, 904 smolt-sized Chinook salmon were trapped at Woodbridge Dam (BYPASS, rkm 62) and transported to the South Fork of the lower Mokelumne River at Wimpy's Marina (rkm 30). The number of fish released alive was 903, and one salmon died during transport, resulting in a 0.1% mortality rate. The mortality was attributed to handling and/or transport stress. All fish were acclimated in the transport tanks to within 1.0ºC of the release water temperature by introducing water into the tanks before release.

Egg-to-young-of-the-year survival indices

During the BY 2011 spawning season, 564 Chinook salmon redds were identified in the LMR. The average fecundity per female salmon spawned at the MRFI was 5,468 and the resulting estimated salmon production at 100% survival was 3,083,952 juveniles. The BY 2011 survival index for YOY Chinook salmon passing the upstream trap (VINO) was 0.07 (95% CI: 0.05-0.10). At the downstream trapping locations (BYPASS and GOLF), the BY 2011 survival index was 0.02 (95% CI: 0.01-0.02). Both survival indices were relatively low, similar to BY 2009 (Table 4).

In-River Survival

A total of 4,300 naturally produced juvenile Chinook salmon were captured and marked with VIE at the Vino Farms RST over the course of 19 trapping days, which fell between 12 January and 8 March 2012. Subsampled VIE-tagged Chinook salmon had a mean FL of 34.2 mm (SD = 2.5). A total of 4,255 (99%) VIE-tagged salmon were classified as fry, while 45 (1%) were classified as parr.

The release timing of VIE-tagged salmon was similar to the outmigration pattern of juvenile Chinook salmon caught at the upstream trap (Figure 7A). However, at the downstream traps, the outmigration timing of VIE-tagged salmon appeared to be earlier than the overall passage of juvenile Chinook salmon (Figure 7B). A total of 30 (86%) recaptured VIE-tagged salmon remained in the 25-rkm reach for more than 60 days, while 5 (14%) recaptured VIE-tagged salmon spent less than 10 days in the reach. Recaptured VIE-tagged salmon consisted of 5 seamed fry having a mean FL of 33.4 mm (SD = 1.8) and 30 smolts with a mean FL of 86.8 mm (SD = 4.5).

A total of 35 VIE-tagged Chinook salmon were recaptured at the downstream traps (GOLF and BYPASS) between 10 February and 31 May 2012. Estimates for weekend catch were added to the actual catch to produce an estimated count of 46 recaptured VIE-tagged Chinook salmon. Using trap efficiency data, the estimated abundance of VIE-tagged Chinook salmon at the downstream traps was 310 (95% CI: 245-427). The in-river survival index of VIE-tagged salmon was 0.08 (95% CI: 0.06-0.11), while the in-river survival index of all naturally produced salmon was 0.26 (Table 5).

Steelhead

Catch and Abundance Estimates

The first wild (natural production) YOY steelhead was captured at the VINO RST on 24 February 2012. A total of 55 wild YOY steelhead was caught between 13 December 2011 and 29 June 2012. Estimates for weekend catch were added to actual catch to produce an estimated count of 100 naturally produced steelhead. Estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 1,309 (95% CI: 985-1,965). Steelhead catch also consisted of three wild age 1+ individuals and three wild age 2+ individuals. The largest monthly catch of wild steelhead (18) at VINO occurred in March.

Zero wild YOY steelhead were captured at the GOLF RST during the 2011/2012 season. Steelhead catch at GOLF also consisted of six wild age 1+ smolts and 21 hatchery origin (adipose fin-clipped) yearlings. One hatchery origin adult male was also caught at GOLF.

At the BYPASS trap, 100 wild YOY steelhead were captured between 6 April and 12 July 2012. Estimates for weekend catch were added to actual catch to produce an estimated count of 183 naturally produced YOY steelhead. The estimated passage of wild YOY steelhead (based on BYPASS trap calibrations using Chinook salmon) was 483 (95% CI: 376-686). Steelhead catch at the BYPASS also consisted of 14 wild age 1+ individuals, one wild age 2+ individual, seven hatchery origin (adipose fin-clipped) yearlings, and one hatchery origin adult. The largest monthly catch of wild steelhead (71) at the downstream traps occurred in June.

Life stage and size

At the VINO RST, 51% of the naturally produced YOY steelhead catch was classified as parr. The remaining catch was composed of fry (47%) and silvery parr (2%). Steelhead parr were also frequently observed at the downstream traps (GOLF and BYPASS), comprising 96% of the wild YOY catch. Other wild YOY steelhead catch at the downstream traps included fry (1%) and silvery parr (3%). The size distribution by life stage of all wild steelhead measured at the upstream and downstream traps is presented in Figure 8.

Species Composition

Sixteen fish species were caught at the VINO RST during the survey period, 8 native and 8 non-native species. Native fish species were more frequently caught than non-native species, comprising 99.6% of the total catch. Chinook salmon (no adipose fin-clip) was the most abundant species caught (83.4%), followed by Pacific lamprey (*Lampetra tridentata)* (12.6%).

At the downstream traps (GOLF and BYPASS) 23 fish species were caught, 8 native and 15 non-native species. Native fish species were more frequently caught than non-native species, comprising 54% of the total catch. Unidentified black bass (*Micropterus* spp.) was the most abundant fish caught (45.1%) at the downstream traps, followed Pacific lamprey (25.8%), Chinook salmon (no adipose fin-clip) (14.0%), and prickly sculpin (*Cottus asper*) (12.3%).

DISCUSSION

During the 2011/2012 monitoring season, the VINO RST experienced only two stoppages. The stoppages took place in December and late May when small numbers of salmon were being caught at the trap. Consequently, salmon catch was not estimated at VINO on the two trapping days with stoppages. At the GOLF RST, seven trap stoppages took place throughout the 2011/2012 monitoring season. Many of these stoppages also took place when small numbers of salmon were being caught at GOLF, therefore salmon catch was not estimated at GOLF on days with trap stoppages.

At the VINO RST, naturally produced salmon fry were used as test fish for trap efficiency trials that took place during the beginning of the monitoring season. Conversely, near the middle and the end of the season, trap efficiency trials were conducted using parr and smolt-sized salmon from the MRFI. Initially, recapture rates of the MRFI salmon were sufficient to generate reliable abundance estimates and 95% CIs. However, tests 7 and 8, which used larger smolt-sized salmon from the MRFI, yielded just a few recaptures and could not be used to estimate salmon smolt abundance in June. In the future, tests conducted with large smolt-sized salmon should contain large numbers of salmon in each group (in excess of 1,000). In addition, if environmental conditions and salmon sizes are similar between tests, these tests may be pooled to help generate more reliable salmon abundance estimates and 95% CIs.

At the GOLF RST, six trap efficiency trials were run using release groups of both naturally produced salmon and salmon from the MRFI. While most of the tests were successful, tests 2 and 3 could not be used because the GOLF trap was stopped by debris shortly after the test fish were released. Tests 5 and 6, which used naturally produced smolt-sized salmon caught at the BYPASS, were pooled to improve the abundance estimates and the 95% confidence intervals. These tests were performed within one week of each other using naturally produced smolt-sized salmon that were released under similar flow conditions.

The 2011/2012 monitoring season was the first season that calibration tests for the BYPASS trap took place. Interestingly, the recapture rates of test salmon from all three releases were very similar despite differences in the proportion of flow diverted into the WID canal during each release. A lower caudal fin-clip was applied to mark the salmon used for the first two tests, which made distinguishing salmon from each test group difficult. Subsequently, a 7-day period from the date of release was used as a cutoff to determine the number of recaptures from each efficiency test. In the future, a unique mark should be used for each release group. This will help determine how quickly the test salmon move from their release location (just adjacent to Lodi Lake) to the BYPASS trap.

The upstream passage estimate of 202,772 YOY Chinook salmon was higher than the BY2008 and BY2009 estimates, but lower than the BY2007 and BY 2010 estimates (Bilski et al. 2011), despite the construction of 564 Chinook salmon redds in the LMR this season. In addition, the BY2011 egg-to-YOY survival index of 0.07 was the lowest on record at the upstream trap. The downstream Chinook salmon passage estimate of 51,799 was the 4th lowest on record since the 1992/93 juvenile outmigration season. The downstream egg-to-YOY survival index of 0.02 was also low relative to previous seasons.

Although it remains unclear why the BY2011 egg-to-YOY survival indices were low, there are a series of potential factors that may have contributed to the high mortality rate of juvenile Chinook salmon in the upstream reaches of the LMR. In BY2011, there were an unusually high proportion of two-year-old spawners that returned to the LMR to spawn. Video monitoring data indicated that 76% of the adult Chinook salmon passing WIDD was identified as grilse (< 70cm) (Del Real and Saldate 2012). This appeared to result in the production of smaller salmon (Figure 9), which may have experienced lower in-river survival rates. In addition, riparian water pumps were operated in the upstream reaches of the river this season in December, January, and February due to very dry winter conditions. A comparison between riparian water diversions and the proportion of salmon passing the VINO RST since BY2007 revealed that BY2011 was the only year when riparian pumping took place during the peak of salmon fry passage (EBMUD, unpublished data). Currently, it is unclear if small unscreened surface water diversions have a substantial impact on the survival of outmigrating or rearing juvenile Chinook salmon. Moyle and Israel (2012) indicated that small diversions may have a cumulative impact on fish populations, but the impacts of individual diversions may be highly variable depending on their size and location.

It is also possible that predation by native and non-native species had an impact on the survival of juvenile Chinook salmon. Fish community surveys conducted at sites between Camanche Dam and the GOLF RST in January, February, and May 2012 indicated that largemouth bass (*Micropterus salmoides*), Sacramento pikeminnow (*Ptychocheilus grandis*), spotted bass (*Micropterus punctulatus*), steelhead, and striped bass (*Morone saxatilis*) were present (EBMUD, unpublished data). In addition, predatory birds, including the great blue heron (*Ardea herodias*), double-crested cormorant (*Phalucrocorax auritis*), common merganser (*Mergus merganser*), and the belted kingfisher (*Ceryle alcyon*), are frequently observed on the LMR. 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. Finally, 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).

The 2011/2012 in-river survival indices were also somewhat low; however there was a noticeable difference between the survival index calculated by using VIE- tagged salmon and the survival index calculated by using the upstream and downstream abundance estimates. The in-river survival index generated by using VIE-tagged salmon was 0.08. In contrast, the in-river survival index calculated by using the upstream and downstream abundance estimates was 0.26. This season, a mark-recapture study using VIE-tagged salmon was carried out in an effort to reduce the uncertainty associated with calculating an in-river survival index using two abundance estimates. Using a fixed number (4,300) of VIE-tagged salmon at the upstream trap helped to narrow the 95% CIs associated with the in-river survival index. However, it is possible that 4,300 was an insufficient release number due to the low probability of recapture at the GOLF RST, which had trap efficiencies that ranged between 2.5% and 9.0% this season. It is also possible that VIE-tagged salmon had a higher mortality rate due to increased stress associated with handling and/or reduced fitness associated with possessing a mark. Additional long-term tag retention and mortality studies may be warranted in the future. In addition, a larger number of VIE-tagged salmon may be needed for release at the upstream trapping location to help increase the number of recaptures at the downstream trapping locations.

Water temperature was a significant factor in influencing the number of Chinook salmon passing the upstream trapping location during the 2011/2012 outmigration season. Interestingly, the relationship was negative indicating that low water temperatures were associated with larger numbers of outmigrating juvenile Chinook salmon. However, water temperature only explained 33% of the variation in Chinook salmon passage at VINO. Similar to the 2010/2011 outmigration season, adult spawn timing had a significant positive linear relationship with juvenile Chinook salmon passage at the upstream RST and explained 69% of the variation in the data. 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 also positioned just below the majority of Chinook salmon spawning habitat (Seesholtz et al. 2004). These results reinforce 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.

Photoperiod was the only significant factor influencing Chinook salmon passage at the downstream trapping locations during the 2011/2012 outmigration season. The relationship was positive, indicating that longer daylight hours were associated with larger numbers of outmigrating juvenile Chinook salmon. However, photoperiod explained just 18% of the variation in Chinook salmon passage. Long-term trapping data from the lower Mokelumne River may help reveal how environmental cues influence Chinook salmon outmigration at the downstream trapping locations over successive monitoring seasons, particularly during specific water year types. Additional environmental variables such as accumulated thermal units, 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).

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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. 2011. Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2010 through July 2011. East Bay Municipal Utility District, Lodi, California.

Del Real, C. and M. Saldate. 2012. Lower Mokelumne River Upstream Fish Migration Monitoring: Conducted at Woodbridge Irrigation District Dam August 2011 through July 2012. East Bay Municipal Utility District, Lodi, California.

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.

Moyle, P.B. and J.A. Israel. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30(5):20-28.

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.

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 trapping locations on the lower Mokelumne River during the 2011/2012 trapping 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) - Elliot Rd.	Origin of test salmon	Ave. FL of test salmon (mm)	# Released	# Recaptured	% Recaptured	Used for abundance estimate?
1	18-Jan-12	317	LMR	34	157	17	**10.8%**	Yes
2	24-Jan-12	306	LMR	35	690	79	**11.4%**	Yes
3	07-Feb-12	298	LMR	33	159	22	**13.8%**	Yes
4	06-Mar-12	228	LMR	35	196	45	**23.0%**	Yes
5	17-Apr-12	224	MRFI	56	833	23	**2.8%**	Yes
6	14-May-12	315	MRFI	72	1,001	71	**7.1%**	Yes
7	12-Jun-12	183	MRFI	83	517	2	**0.4%**	No
8	26-Jun-12	250	MRFI	88	1,097	1	**0.1%**	No

GOLF (DOWNSTREAM RST)

Test #	Release date	Flow at release (cfs) - Golf	Origin of test salmon	Ave. FL of test salmon (mm)	# Released	# Recaptured	% Recaptured	Used for abundance estimate?
1	06-Feb-12	280	MRFI	36	766	69	**9.0%**	Yes
2	05-Mar-12	155	MRFI	34	750	13	**1.7%**	No
3	12-Mar-12	172	MRFI	34	522	13	**2.5%**	No
4	16-Apr-12	175	MRFI	57	800	28	**3.5%**	Yes
5	08-May-12	160	LMR	88	161	4	**2.5%**	Yes
6	15-May-12	172	LMR	92	416	28	**6.7%**	Yes

BYPASS (DOWNSTREAM)

Test #	Release date	Flow at release (cfs) - Victor (WID canal)	Origin of test salmon	Ave. FL of test salmon (mm)	# Released	# Recaptured	% Recaptured	Used for abundance estimate?
1	29-May-12	298 (110)	MRFI	78	250	85	**34.0%**	Yes
2	05-Jun-12	161 (103)	MRFI	81	251	80	**31.9%**	Yes
3	19-Jun-12	218 (134)	MRFI	85	251	80	**31.9%**	Yes

Table 2. Expanded monthly catch, juvenile passage estimates with 95% confidence intervals (LCI and UCI), and percent passage for wild juvenile Chinook salmon captured at the upstream and downstream trapping locations on the LMR during the 2011/2012 trapping season.

Upstream (VINO FARMS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
December	78	722	498	1,310	0.4%
January	7,570	68,015	51,496	105,172	33.5%
February	13,359	100,653	75,079	155,590	49.6%
March	5,452	28,477	22,114	42,920	14.0%
April	152	1,220	919	1,851	0.6%
May	127	3,367	2,573	5,604	1.7%
June	23	317	259	409	0.2%
Total	**26,761**	**202,772**	**152,937**	**312,856**	**100%**

Downstream (GOLF and BYPASS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
January	10	113	92	146	0.2%
February	365	4,054	3,309	5,231	7.8%
March	876	9,721	7,935	12,545	18.8%
April	490	4,585	3,453	7,012	8.9%
May	11,531	26,082	21,777	35,200	50.4%
June	2,269	6,990	5,305	10,124	13.5%
July	81	253	192	373	0.5%
Total	**15,622**	**51,799**	**42,063**	**70,631**	**100%**

Table 3. Regression models for juvenile Chinook salmon passage based on environmental variables at the upstream and downstream trapping locations on the lower Mokelumne River during the 2011/12 outmigration monitoring season. Abbreviations are as follows: CS JPE = Chinook salmon juvenile passage estimate; AWTURB = average weekly turbidity; AWTEMP = average weekly water temperature; AWFLOW = average weekly flow.

Upstream (VINO FARMS)							
	Model						
Dependent Variable	R^2 (Adj.)	AICc	Independent Variable	Entered	Estimate	*F*	*P*
Weekly CS JPE	0.328	171.256					
			Intercept	Yes	17.905	0.000	1.000
			AWTEMP (rkm 86)	Yes	-1.152	14.664	0.001
			AWFLOW (rkm 86)	No	0.000	0.012	0.915
			AWTURB (rkm 87)	No	0.000	0.024	0.877

Downstream (GOLF and BYPASS)							
	Model						
Dependent Variable	R^2 (Adj.)	AICc	Independent Variable	Entered	Estimate	*F*	*P*
Weekly CS JPE	0.182	91.402					
			Intercept	Yes	-2.841	0.000	1.000
			PHOTOPERIOD	Yes	0.285	7.217	0.012
			AWTURB (rkm 62)	No	0.000	0.588	0.450
			AWFLOW (rkm 80)	No	0.000	1.872	0.183

Table 4. 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 natural production of Chinook salmon 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. Ave. flow = Average of daily flow (cfs) at Camanche Dam (upstream) and Golf (downstream) from January-July (2012).

BY	Trap(s) used	Chinook salmon redd count	Estimated production (at 100% survival)	Abundance estimate	95% LCI	95% UCI	Survival index (LCI - UCI)	Ave. flow (min-max)
				Upstream (rkm 87.4)				
2007	Vino Farms	306	1,615,887	1,117,451	798,895	7,184,950	0.69 (0.49-4.45)	264 (208-517)
2008	Vino Farms	63	377,044	175,612	131,191	280,979	0.47 (0.35-0.75)	293 (205-425)
2009	Vino Farms	248	1,329,217	124,279	93,555	199,950	0.09 (0.07-0.15)	647 (298-1,464)
2010	Vino Farms	314	1,574,651	842,570	631,115	2,039,099	0.54 (0.40-1.29)	1,903 (550-4,702)
2011	Vino Farms	564	3,083,952	202,772	152,937	312,856	0.07(0.05-0.10)	293 (202-370)
				Downstream (rkm 62)				
2007	Golf	306	1,615,887	18,347	14,513	25,152	0.01 (0.01-0.02)	138 (23-283)
2008	Golf & Bypass	63	377,044	30,614	29,171	32,802	0.08 (0.08-0.09)	150 (26-256)
2009	Golf & Bypass	248	1,329,217	67,349	39,512	283,914	0.05 (0.03-0.21)	512 (120-1,248)
2010	Golf & Bypass	314	1,574,651	281,500	186,249	606,084	0.18 (0.12-0.38)	1,822 (380-4,106)
2011	Golf & Bypass	564	3,083,952	51,799	42,063	70,631	0.02 (0.01-0.02)	162 (32-506)

Table 5. A comparison of the in-river survival indices (SI) between VIE-tagged Chinook salmon and all naturally produced Chinook salmon within a 25-rkm reach of the lower Mokelumne River during the 2011/2012 juvenile monitoring season.

	Upstream release estimate (Nv)	Downstream abundance estimate (Ng+Nb)	95% LCI (downstream abundance)	95% UCI (downstream abundance)	SI ((Ng+Nb)/Nv)
VIE-tagged salmon	4,053	310	245	427	0.08
	Upstream abundance estimate (UAb)	Downstream abundance estimate (DAb)	95% LCI (downstream abundance)	95% UCI (downstream abundance)	SI (DAb/UAb)
All naturally produced salmon	202,772	51,799	42,063	70,631	0.26

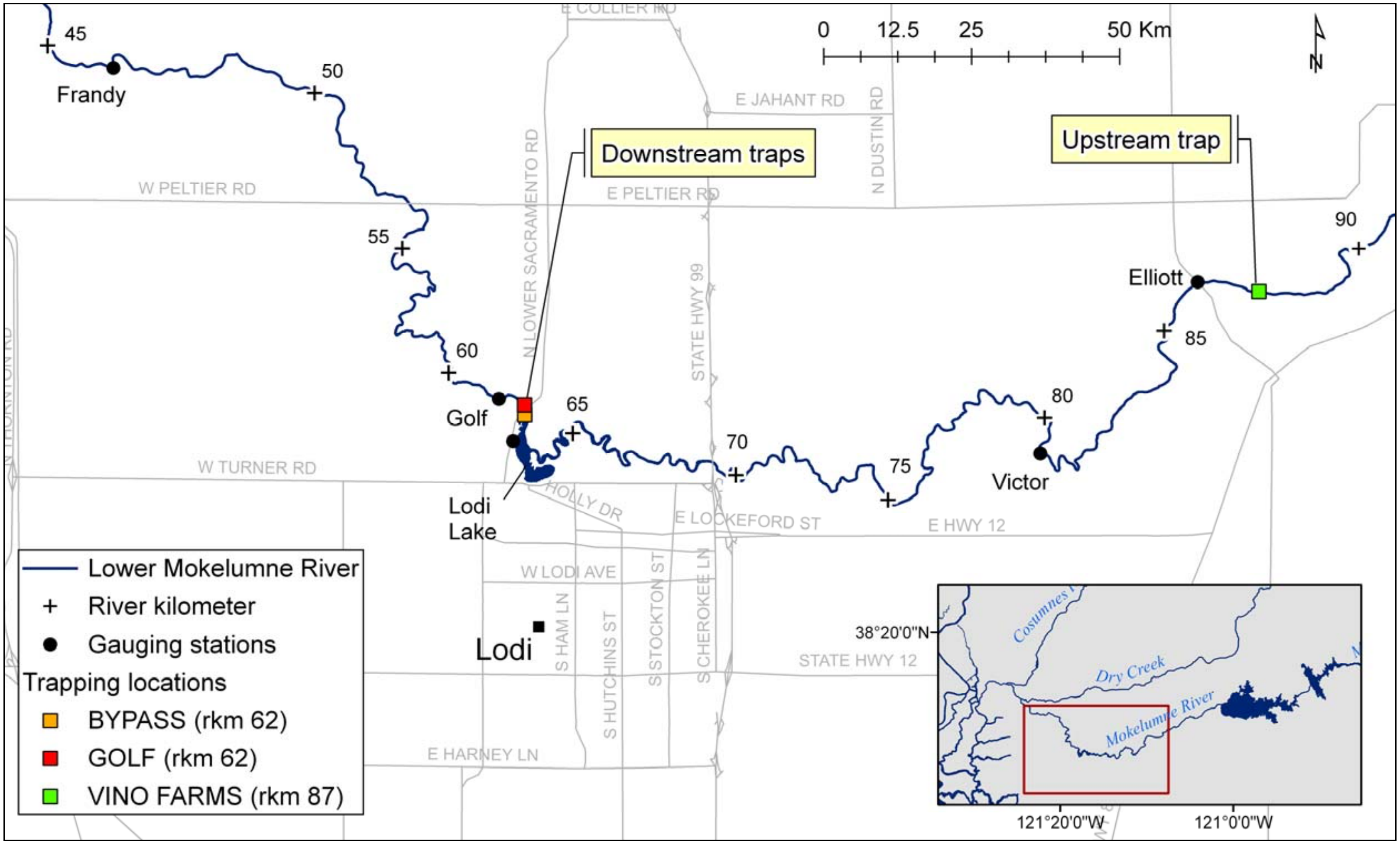


Figure 1. Trapping sites used for juvenile outmigration monitoring on the lower Mokelumne River during the 2011/12 season.

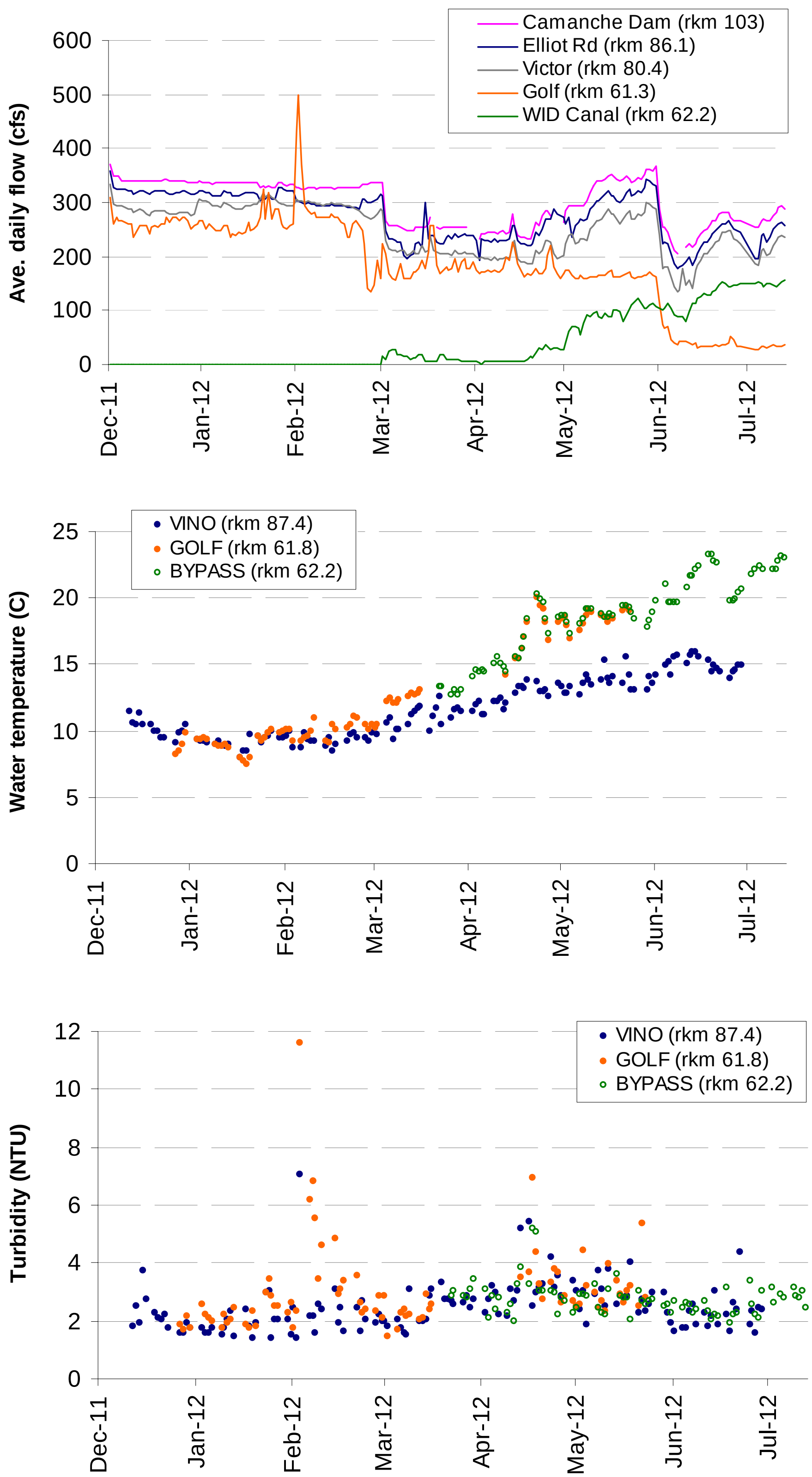


Figure 2. Average daily flow, turbidity and water temperature in the lower Mokelumne River between Camanche Dam (rkm 103) and Golf (rkm 61.3) during the 2011/12 trapping season.

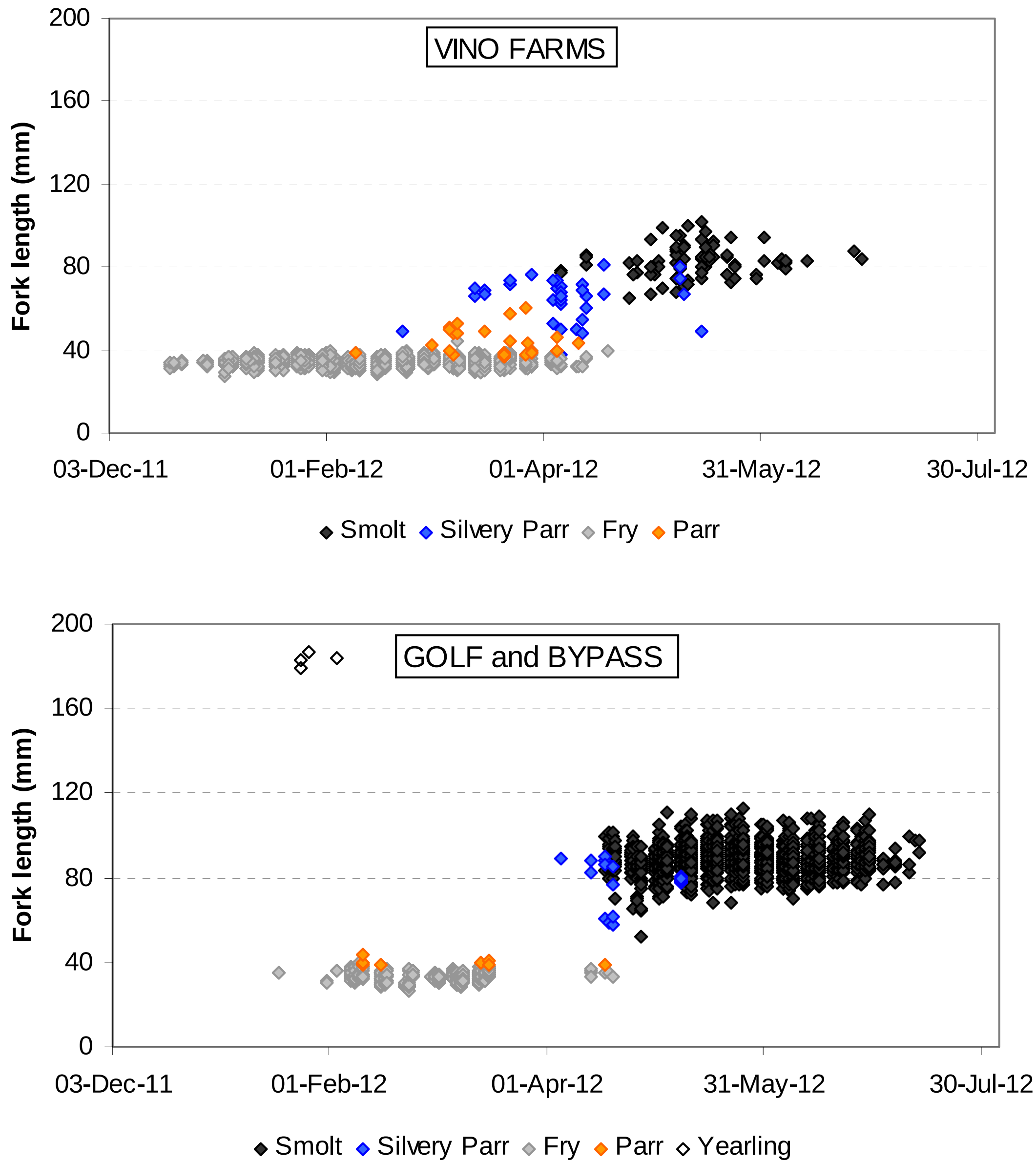


Figure 3. Size distribution by life stage of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF and BYPASS) trapping locations during the 2011/12 juvenile outmigration season on the lower Mokelumne River.

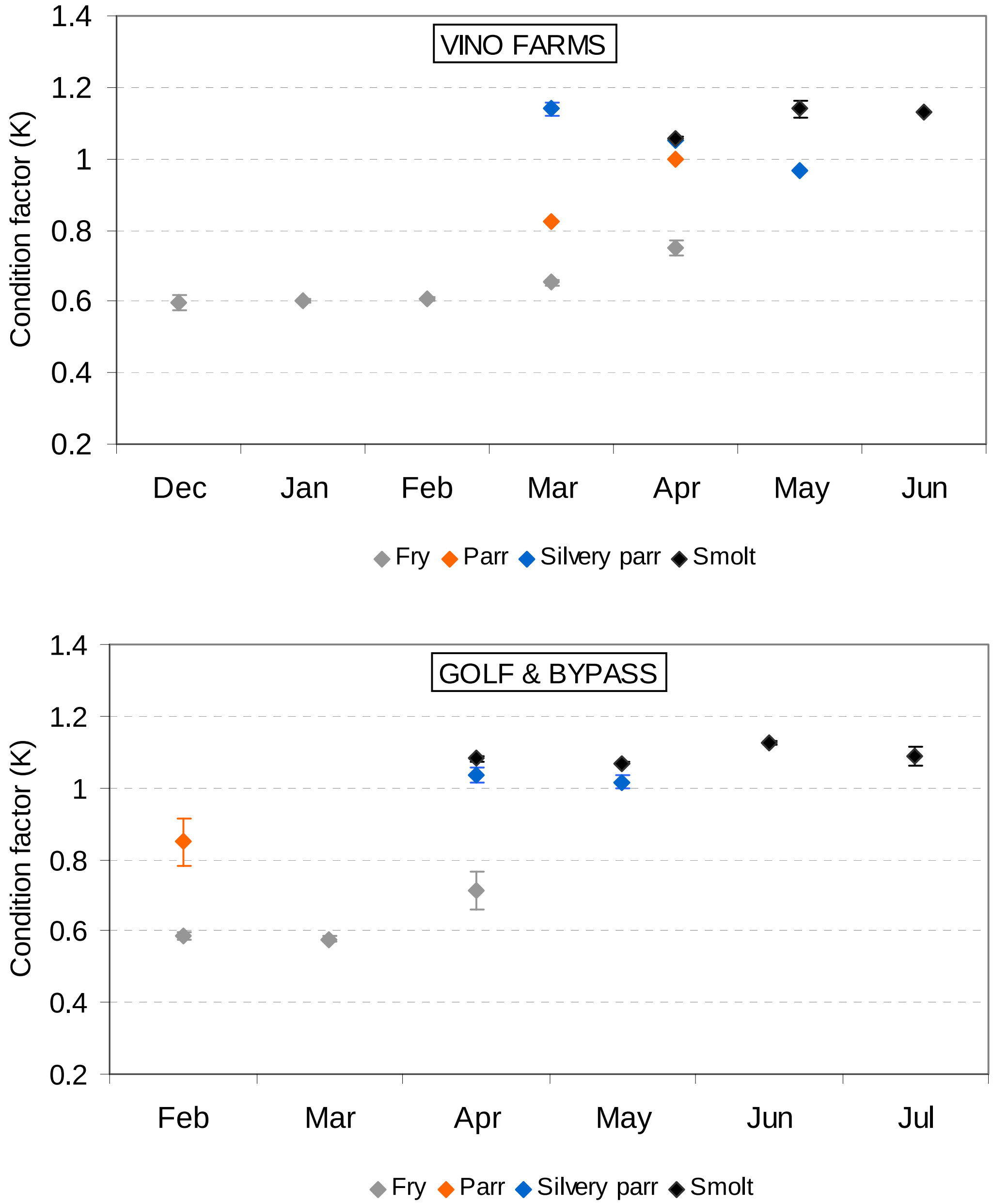


Figure 4. Monthly average condition factor (solid diamonds) ± 1 SE (vertical lines) of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF & BYPASS) trapping locations during the 2011/12 juvenile outmigration monitoring season on the lower Mokelumne River.

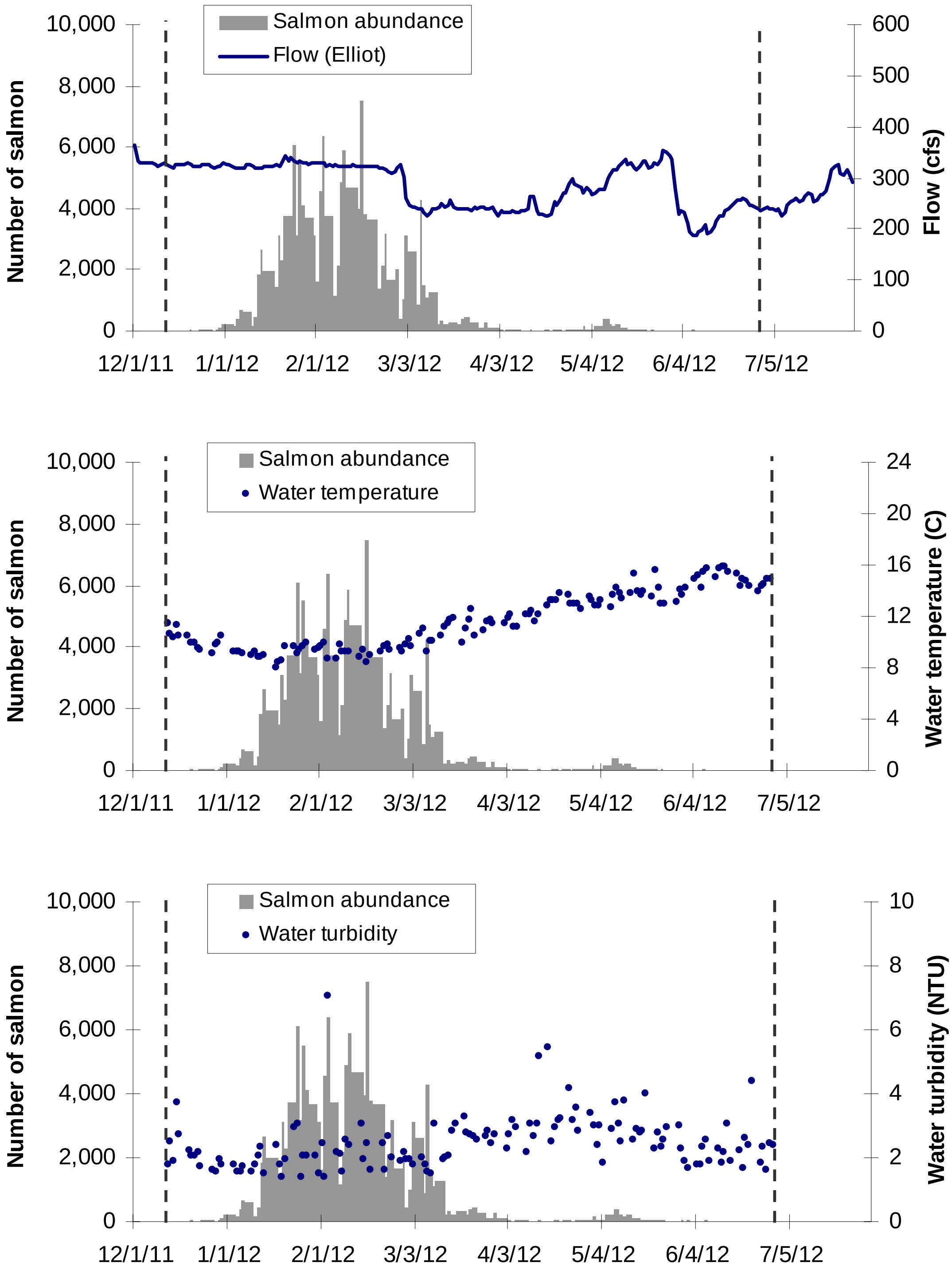


Figure 5. The relationship between estimated daily Chinook salmon passage and flow (top), water temperature (middle), and turbidity (bottom) at the VINO RST (upstream trapping location) during the 2011/12 juvenile outmigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.

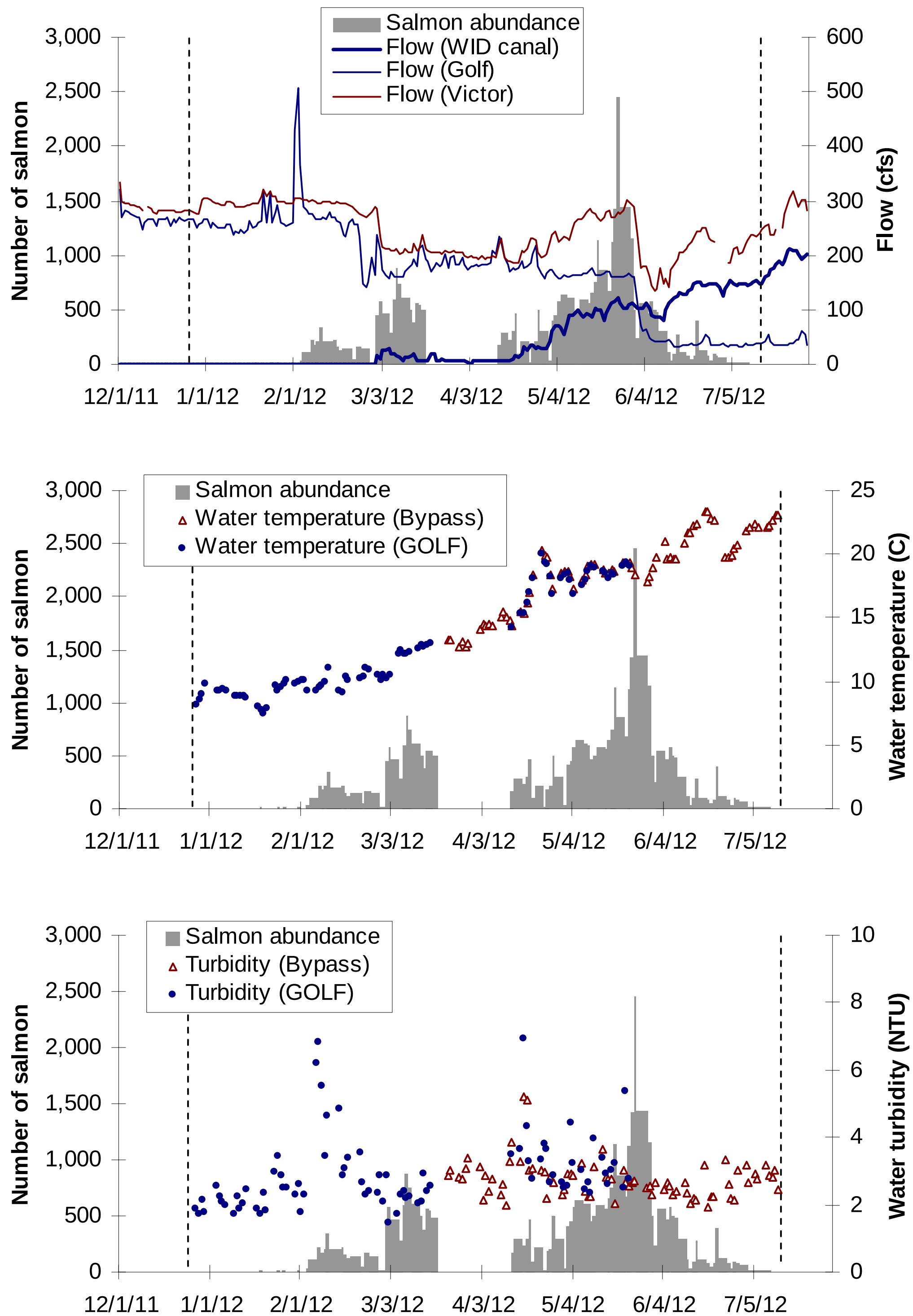
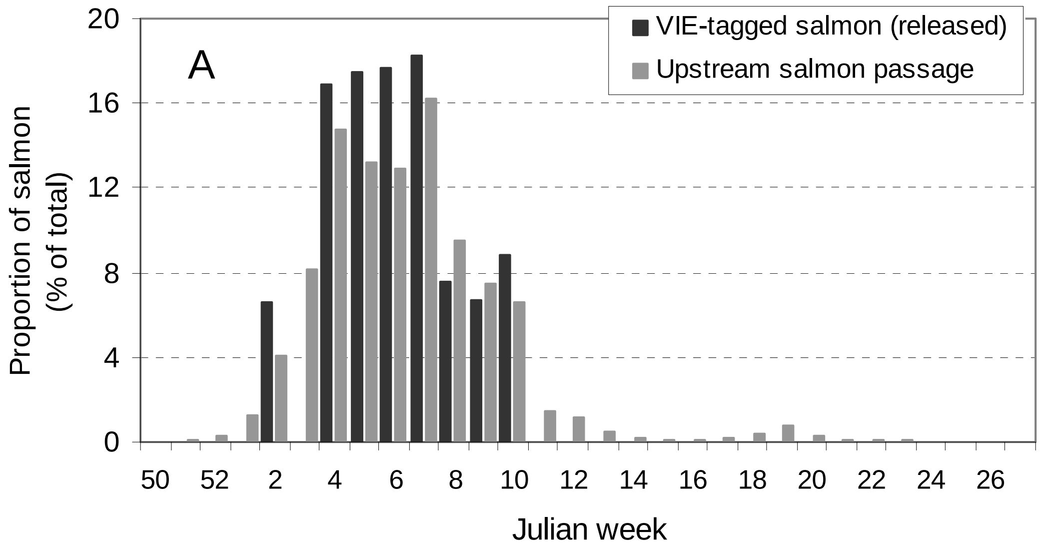


Figure 6. The relationship between estimated daily Chinook salmon passage and flow (top), water temperature (middle), and turbidity (bottom) at the downstream trapping locations (GOLF & BYPASS) during the 2011/12 juvenile outmigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.



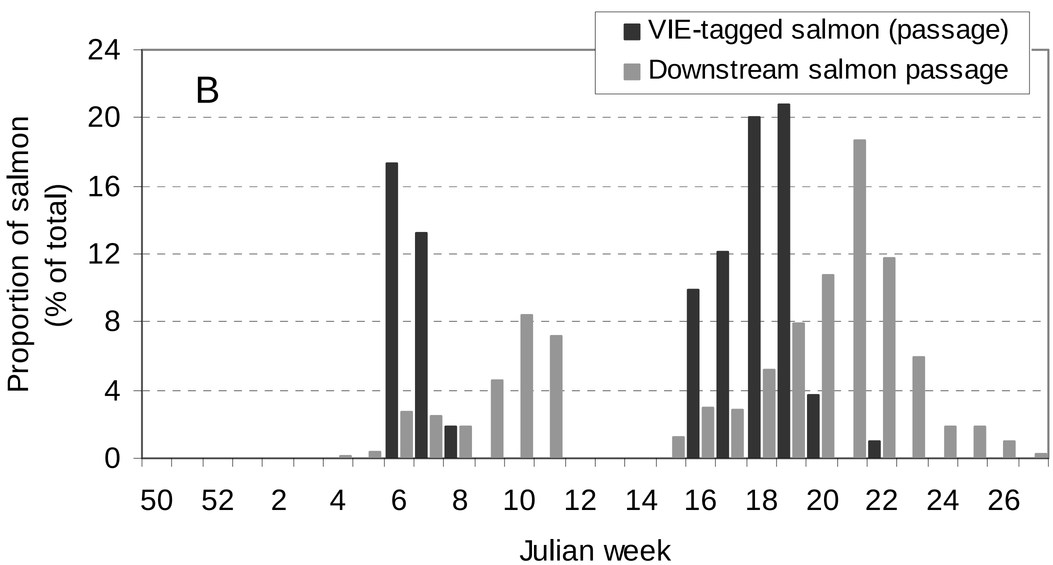
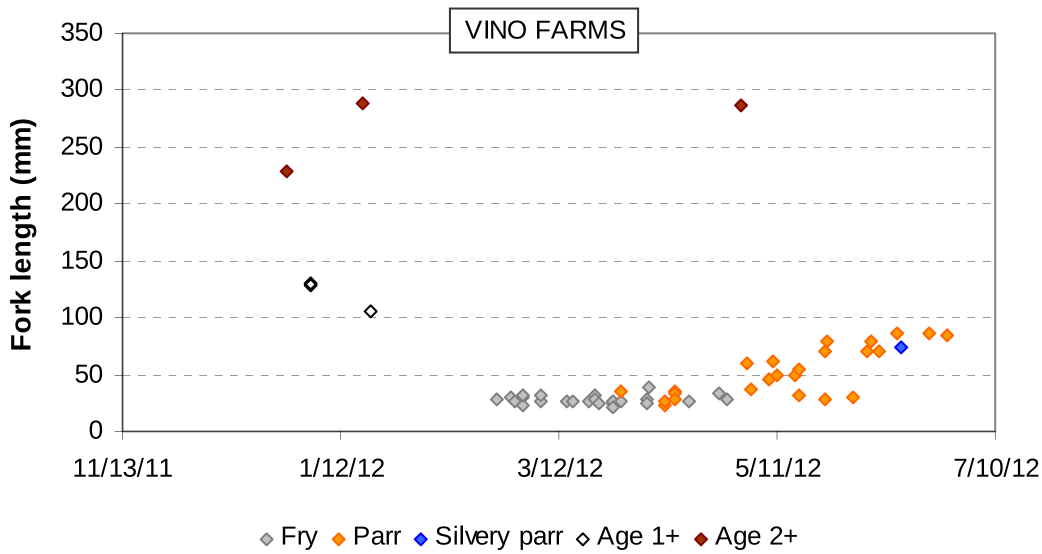


Figure 7. A comparison between the release timing of VIE-tagged Chinook salmon and the passage of all juvenile Chinook salmon at the upstream trapping location (**A**). A comparison between the passage of recaptured VIE-tagged Chinook salmon and the passage of all juvenile Chinook salmon at the downstream trapping locations (**B**).



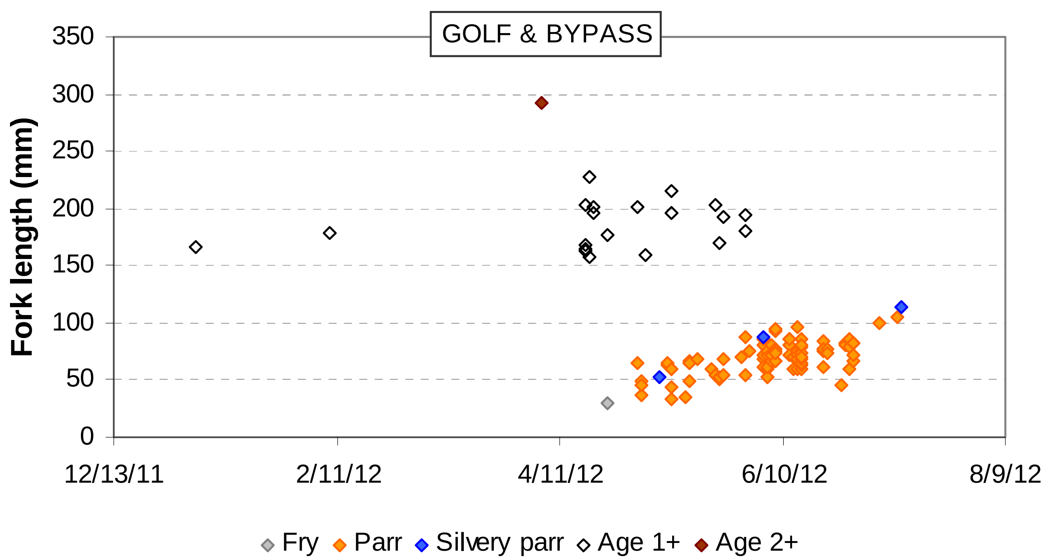


Figure 8. Size and life stage distribution of wild steelhead caught and measured at the upstream (VINO) and downstream (GOLF & BYPASS) trapping locations during the 2011/12 juvenile outmigration monitoring season on the lower Mokelumne River.

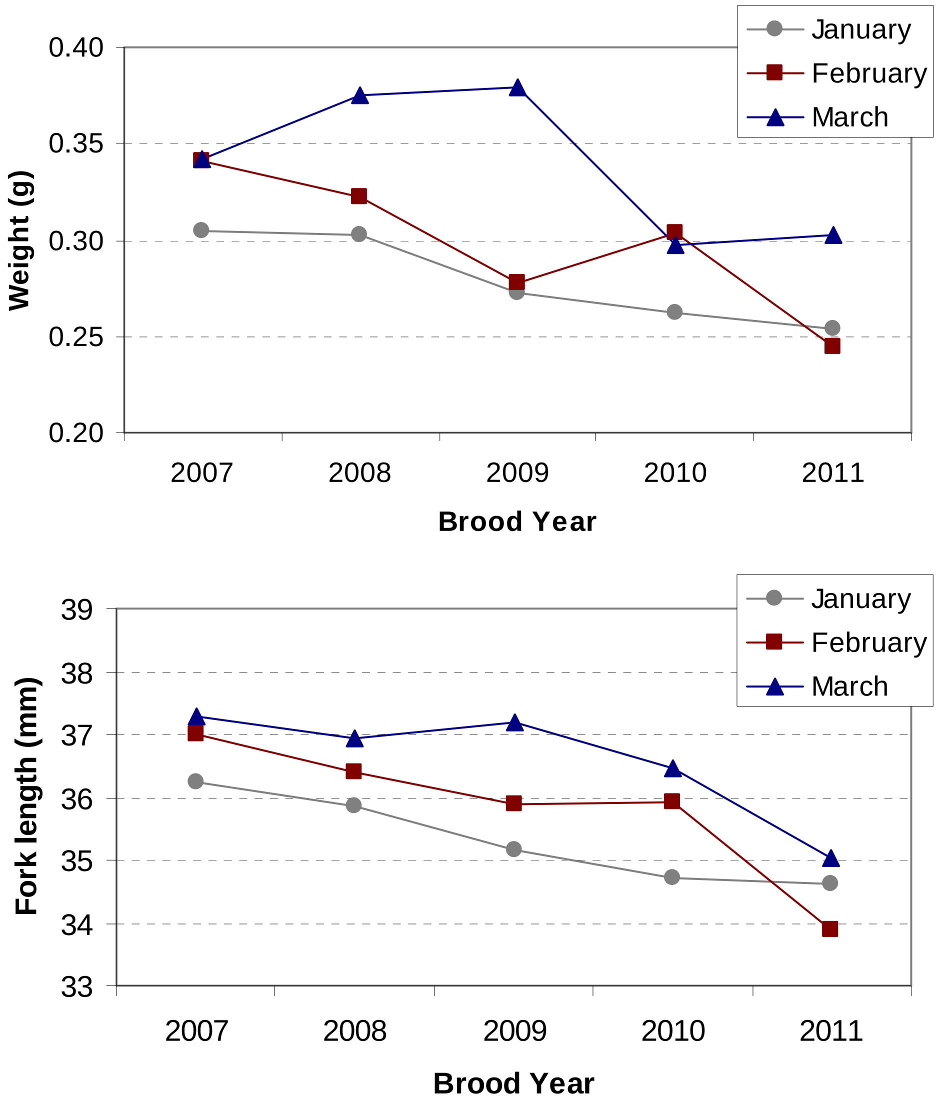


Figure 9. Monthly average weight (top) and fork length (bottom) of wild Chinook salmon fry and parr caught and measured at the upstream rotary screw trap (VINO FARMS) on the lower Mokelumne River between brood year 2007 and 2011.

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 2011/12 monitoring period. Shaded areas represent non-trapping periods.

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
12/13/2011	0	0.1083	**0**	0	0
12/14/2011	0	0.1083	**0**	0	0
12/15/2011	0	0.1083	**0**	0	0
12/16/2011	0	0.1083	**0**	0	0
12/17/2011	1	0.1083	**12**	8	22
12/18/2011	1	0.1083	**12**	8	22
12/19/2011	1	0.1083	**12**	8	22
12/20/2011	5	0.1083	**46**	32	84
12/21/2011	3	0.1083	**28**	19	50
12/22/2011	0	0.1083	**0**	0	0
12/23/2011	5	0.1083	**46**	32	84
12/24/2011	4	0.1083	**40**	28	73
12/25/2011	4	0.1083	**40**	28	73
12/26/2011	4	0.1083	**40**	28	73
12/27/2011	4	0.1083	**40**	28	73
12/28/2011	0	0.1083	**0**	0	0
12/29/2011	6	0.1083	**55**	38	101
12/30/2011	12	0.1083	**111**	76	201
12/31/2011	26	0.1083	**239**	165	433
1/1/2012	26	0.1083	**239**	165	433
1/2/2012	26	0.1083	**239**	165	433
1/3/2012	26	0.1083	**239**	165	433
1/4/2012	21	0.1083	**194**	134	352
1/5/2012	44	0.1083	**406**	280	737
1/6/2012	72	0.1083	**665**	459	1,207
1/7/2012	68	0.1083	**623**	430	1,131
1/8/2012	68	0.1083	**623**	430	1,131
1/9/2012	68	0.1083	**623**	430	1,131
1/10/2012	20	0.1083	**185**	127	335
1/11/2012	48	0.1083	**443**	306	804
1/12/2012	200	0.1083	**1,847**	1,275	3,352
1/13/2012	288	0.1083	**2,660**	1,836	4,826
1/14/2012	214	0.1083	**1,973**	1,362	3,581
1/15/2012	214	0.1083	**1,973**	1,362	3,581
1/16/2012	214	0.1083	**1,973**	1,362	3,581
1/17/2012	214	0.1083	**1,973**	1,362	3,581
1/18/2012	159	0.1083	**1,468**	1,013	2,664
1/19/2012	338	0.1083	**3,122**	2,154	5,664
1/20/2012	249	0.1083	**2,300**	1,587	4,173
1/21/2012	406	0.1083	**3,746**	2,586	6,798
1/22/2012	406	0.1083	**3,746**	2,586	6,798
1/23/2012	406	0.1083	**3,746**	2,586	6,798

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
1/24/2012	698	0.1145	**6,097**	5,049	7,693
1/25/2012	360	0.1145	**3,144**	2,604	3,968
1/26/2012	630	0.1145	**5,503**	4,557	6,943
1/27/2012	473	0.1145	**4,131**	3,421	5,213
1/28/2012	421	0.1145	**3,677**	3,045	4,640
1/29/2012	421	0.1145	**3,677**	3,045	4,640
1/30/2012	421	0.1145	**3,677**	3,045	4,640
1/31/2012	355	0.1145	**3,101**	2,568	3,913
2/1/2012	184	0.1145	**1,607**	1,331	2,028
2/2/2012	524	0.1145	**4,577**	3,790	5,775
2/3/2012	729	0.1145	**6,367**	5,273	8,034
2/4/2012	428	0.1145	**3,741**	3,098	4,721
2/5/2012	428	0.1145	**3,741**	3,098	4,721
2/6/2012	428	0.1145	**3,741**	3,098	4,721
2/7/2012	162	0.1384	**1,171**	844	1,913
2/8/2012	298	0.1384	**2,154**	1,552	3,519
2/9/2012	673	0.1384	**4,864**	3,505	7,946
2/10/2012	812	0.1384	**5,869**	4,228	9,587
2/11/2012	649	0.1384	**4,691**	3,380	7,663
2/12/2012	649	0.1384	**4,691**	3,380	7,663
2/13/2012	649	0.1384	**4,691**	3,380	7,663
2/14/2012	649	0.1384	**4,691**	3,380	7,663
2/15/2012	549	0.1384	**3,968**	2,859	6,482
2/16/2012	1036	0.1384	**7,488**	5,395	12,232
2/17/2012	526	0.1384	**3,802**	2,739	6,211
2/18/2012	506	0.1384	**3,656**	2,634	5,972
2/19/2012	506	0.1384	**3,656**	2,634	5,972
2/20/2012	506	0.1384	**3,656**	2,634	5,972
2/21/2012	506	0.1384	**3,656**	2,634	5,972
2/22/2012	190	0.1384	**1,373**	989	2,243
2/23/2012	294	0.1384	**2,125**	1,531	3,471
2/24/2012	440	0.1384	**3,180**	2,291	5,195
2/25/2012	234	0.1384	**1,688**	1,216	2,757
2/26/2012	234	0.1384	**1,688**	1,216	2,757
2/27/2012	234	0.1384	**1,688**	1,216	2,757
2/28/2012	278	0.1384	**2,009**	1,448	3,282
2/29/2012	59	0.1384	**426**	307	697
3/1/2012	140	0.1384	**1,012**	729	1,653
3/2/2012	432	0.1384	**3,122**	2,250	5,101
3/3/2012	358	0.1384	**2,590**	1,866	4,231
3/4/2012	358	0.1384	**2,590**	1,866	4,231
3/5/2012	358	0.1384	**2,590**	1,866	4,231
3/6/2012	199	0.2296	**867**	1,036	2,350
3/7/2012	977	0.2296	**4,255**	3,387	5,723
3/8/2012	343	0.2296	**1,494**	1,189	2,009
3/9/2012	255	0.2296	**1,111**	884	1,494

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
3/10/2012	293	0.2296	**1,275**	1,015	1,715
3/11/2012	293	0.2296	**1,275**	1,015	1,715
3/12/2012	293	0.2296	**1,275**	1,015	1,715
3/13/2012	56	0.2296	**244**	194	328
3/14/2012	73	0.2296	**318**	253	428
3/15/2012	53	0.2296	**231**	184	310
3/16/2012	49	0.2296	**213**	170	287
3/17/2012	71	0.2296	**309**	246	415
3/18/2012	71	0.2296	**309**	246	415
3/19/2012	71	0.2296	**309**	246	415
3/20/2012	51	0.2296	**222**	177	299
3/21/2012	91	0.2296	**396**	315	533
3/22/2012	108	0.2296	**470**	374	633
3/23/2012	105	0.2296	**457**	364	615
3/24/2012	68	0.2296	**297**	236	399
3/25/2012	68	0.2296	**297**	236	399
3/26/2012	68	0.2296	**297**	236	399
3/27/2012	22	0.2296	**96**	76	129
3/28/2012	22	0.2296	**96**	76	129
3/29/2012	61	0.2296	**266**	211	357
3/30/2012	22	0.2296	**97**	77	131
3/31/2012	22	0.2296	**97**	77	131
4/1/2012	22	0.2296	**97**	77	131
4/2/2012	22	0.2296	**97**	77	131
4/3/2012	10	0.2296	**44**	35	59
4/4/2012	4	0.2296	**17**	14	23
4/5/2012	15	0.2296	**65**	52	88
4/6/2012	15	0.2296	**65**	52	88
4/7/2012	7	0.2296	**31**	25	42
4/8/2012	7	0.2296	**31**	25	42
4/9/2012	7	0.2296	**31**	25	42
4/10/2012	2	0.2296	**9**	7	12
4/11/2012	2	0.2296	**9**	7	12
4/12/2012	5	0.2296	**22**	17	29
4/13/2012	7	0.2296	**30**	24	41
4/14/2012	3	0.2296	**12**	10	17
4/15/2012	3	0.2296	**12**	10	17
4/16/2012	3	0.2296	**12**	10	17
4/17/2012	0	0.0276	**0**	0	0
4/18/2012	2	0.0276	**72**	52	121
4/19/2012	1	0.0276	**36**	26	61
4/20/2012	0	0.0276	**0**	0	0
4/21/2012	1	0.0276	**36**	26	61
4/22/2012	1	0.0276	**36**	26	61
4/23/2012	1	0.0276	**36**	26	61

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
4/24/2012	0	0.0276	**0**	0	0
4/25/2012	2	0.0276	**72**	52	121
4/26/2012	1	0.0276	**36**	26	61
4/27/2012	2	0.0276	**72**	52	121
4/28/2012	2	0.0276	**78**	56	131
4/29/2012	2	0.0276	**78**	56	131
4/30/2012	2	0.0276	**78**	56	131
5/1/2012	5	0.0276	**181**	129	303
5/2/2012	1	0.0276	**36**	26	61
5/3/2012	2	0.0276	**72**	52	121
5/4/2012	2	0.0276	**72**	52	121
5/5/2012	6	0.0276	**199**	142	334
5/6/2012	6	0.0276	**199**	142	334
5/7/2012	6	0.0276	**199**	142	334
5/8/2012	11	0.0276	**398**	284	667
5/9/2012	11	0.0276	**398**	284	667
5/10/2012	6	0.0276	**217**	155	364
5/11/2012	4	0.0276	**145**	103	243
5/12/2012	6	0.0276	**229**	163	384
5/13/2012	6	0.0276	**229**	163	384
5/14/2012	6	0.0709	**89**	163	384
5/15/2012	8	0.0709	**113**	92	145
5/16/2012	6	0.0709	**85**	69	109
5/17/2012	3	0.0709	**42**	35	55
5/18/2012	3	0.0709	**42**	35	55
5/19/2012	4	0.0709	**52**	42	67
5/20/2012	4	0.0709	**52**	42	67
5/21/2012	4	0.0709	**52**	42	67
5/22/2012	4	0.0709	**56**	46	73
5/23/2012	2	0.0709	**28**	23	36
5/24/2012	4	0.0709	**56**	46	73
5/25/2012	0	0.0709	**0**	0	0
5/26/2012	2	0.0709	**23**	19	30
5/27/2012	2	0.0709	**23**	19	30
5/28/2012	2	0.0709	**23**	19	30
5/29/2012	2	0.0709	**23**	19	30
5/30/2012	2	0.0709	**28**	23	36
5/31/2012	0	0.0709	**0**	0	0
6/1/2012	2	0.0709	**28**	23	36
6/2/2012	2	0.0709	**26**	21	33
6/3/2012	2	0.0709	**26**	21	33
6/4/2012	2	0.0709	**26**	21	33
6/5/2012	1	0.0709	**14**	12	18
6/6/2012	1	0.0709	**14**	12	18
6/7/2012	5	0.0709	**70**	58	91
6/8/2012	0	0.0709	**0**	0	0

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
6/9/2012	1	0.0709	**16**	13	21
6/10/2012	1	0.0709	**16**	13	21
6/11/2012	1	0.0709	**16**	13	21
6/12/2012	0	0.0709	**0**	0	0
6/13/2012	1	0.0709	**14**	12	18
6/14/2012	0	0.0709	**0**	0	0
6/15/2012	0	0.0709	**0**	0	0
6/16/2012	0	0.0709	**2**	2	3
6/17/2012	0	0.0709	**2**	2	3
6/18/2012	0	0.0709	**2**	2	3
6/19/2012	0	0.0709	**0**	0	0
6/20/2012	0	0.0709	**0**	0	0
6/21/2012	0	0.0709	**0**	0	0
6/22/2012	0	0.0709	**0**	0	0
6/23/2012	0	0.0709	**5**	4	6
6/24/2012	0	0.0709	**5**	4	6
6/25/2012	0	0.0709	**5**	4	6
6/26/2012	1	0.0709	**14**	12	18
6/27/2012	0	0.0709	**0**	0	0
6/28/2012	1	0.0709	**14**	12	18
6/29/2012	0	0.0709	**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 2011/12 monitoring period. Shaded areas represent non-trapping periods.

Date	GOLF catch	Bypass catch	GOLF efficiency	BYPASS efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
12/28/2011	0	–	0.0901	–	**0**	0	0
12/29/2011	0	–	0.0901	–	**0**	0	0
12/30/2011	0	–	0.0901	–	**0**	0	0
12/31/2011	0	–	0.0901	–	**0**	0	0
1/1/2012	0	–	0.0901	–	**0**	0	0
1/2/2012	0	–	0.0901	–	**0**	0	0
1/3/2012	0	–	0.0901	–	**0**	0	0
1/4/2012	0	–	0.0901	–	**0**	0	0
1/5/2012	0	–	0.0901	–	**0**	0	0
1/6/2012	0	–	0.0901	–	**0**	0	0
1/7/2012	0	–	0.0901	–	**0**	0	0
1/8/2012	0	–	0.0901	–	**0**	0	0
1/9/2012	0	–	0.0901	–	**0**	0	0
1/10/2012	0	–	0.0901	–	**0**	0	0
1/11/2012	0	–	0.0901	–	**0**	0	0
1/12/2012	0	–	0.0901	–	**0**	0	0
1/13/2012	0	–	0.0901	–	**0**	0	0
1/14/2012	0	–	0.0901	–	**2**	2	2
1/15/2012	0	–	0.0901	–	**2**	2	2
1/16/2012	0	–	0.0901	–	**2**	2	2
1/17/2012	0	–	0.0901	–	**2**	2	2
1/18/2012	1	–	0.0901	–	**11**	9	14
1/19/2012	0	–	0.0901	–	**0**	0	0
1/20/2012	0	–	0.0901	–	**0**	0	0
1/21/2012	1	–	0.0901	–	**7**	6	10
1/22/2012	1	–	0.0901	–	**7**	6	10
1/23/2012	1	–	0.0901	–	**7**	6	10
1/24/2012	2	–	0.0901	–	**22**	18	29
1/25/2012	0	–	0.0901	–	**0**	0	0
1/26/2012	1	–	0.0901	–	**11**	9	14
1/27/2012	0	–	0.0901	–	**0**	0	0
1/28/2012	1	–	0.0901	–	**6**	5	7
1/29/2012	1	–	0.0901	–	**6**	5	7
1/30/2012	1	–	0.0901	–	**6**	5	7
1/31/2012	2	–	0.0901	–	**22**	18	29
2/1/2012	0	–	0.0901	–	**0**	0	0
2/2/2012	0	–	0.0901	–	**0**	0	0
2/3/2012	3	–	0.0901	–	**33**	27	43
2/4/2012	10	–	0.0901	–	**107**	88	138
2/5/2012	10	–	0.0901	–	**107**	88	138
2/6/2012	10	–	0.0901	–	**107**	88	138
2/7/2012	20	–	0.0901	–	**222**	181	287
2/8/2012	16	–	0.0901	–	**178**	145	229

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	BYPASS efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
2/9/2012	19	–	0.0901	–	**211**	172	272
2/10/2012	31	–	0.0901	–	**344**	281	444
2/11/2012	19	–	0.0901	–	**205**	168	265
2/12/2012	19	–	0.0901	–	**205**	168	265
2/13/2012	19	–	0.0901	–	**205**	168	265
2/14/2012	19	–	0.0901	–	**205**	168	265
2/15/2012	20	–	0.0901	–	**222**	181	287
2/16/2012	14	–	0.0901	–	**155**	127	201
2/17/2012	11	–	0.0901	–	**122**	100	158
2/18/2012	13	–	0.0901	–	**146**	119	189
2/19/2012	13	–	0.0901	–	**146**	119	189
2/20/2012	13	–	0.0901	–	**146**	119	189
2/21/2012	13	–	0.0901	–	**146**	119	189
2/22/2012	4	–	0.0901	–	**44**	36	57
2/23/2012	15	–	0.0901	–	**167**	136	215
2/24/2012	15	–	0.0901	–	**167**	136	215
2/25/2012	13	–	0.0901	–	**142**	116	184
2/26/2012	13	–	0.0901	–	**142**	116	184
2/27/2012	13	–	0.0901	–	**142**	116	184
2/28/2012	1	–	0.0901	–	**11**	9	14
2/29/2012	2	–	0.0901	–	**22**	18	29
3/1/2012	40	–	0.0901	–	**444**	362	573
3/2/2012	52	–	0.0901	–	**577**	471	745
3/3/2012	42	–	0.0901	–	**468**	382	604
3/4/2012	42	–	0.0901	–	**468**	382	604
3/5/2012	42	–	0.0901	–	**468**	382	604
3/6/2012	26	–	0.0901	–	**289**	236	372
3/7/2012	54	–	0.0901	–	**599**	489	774
3/8/2012	79	–	0.0901	–	**877**	716	1,132
3/9/2012	67	–	0.0901	–	**744**	607	960
3/10/2012	55	–	0.0901	–	**609**	497	786
3/11/2012	55	–	0.0901	–	**609**	497	786
3/12/2012	55	–	0.0901	–	**609**	497	786
3/13/2012	45	–	0.0901	–	**500**	408	645
3/14/2012	34	–	0.0901	–	**377**	308	487
3/15/2012	50	–	0.0901	–	**555**	453	716
3/16/2012	49	–	0.0901	–	**544**	444	702
3/17/2012	44	–	0.0901	–	**492**	402	635
3/18/2012	44	–	0.0901	–	**492**	402	635
3/19/2012	–	–	–	–	**–**	–	–
3/20/2012	–	–	–	–	**–**	–	–
3/21/2012	–	–	–	–	**–**	–	–
3/22/2012	–	0	–	–	**0**	0	0
3/23/2012	–	0	–	–	**0**	0	0
3/24/2012	–	0	–	–	**0**	0	0
3/25/2012	–	0	–	–	**0**	0	0

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	BYPASS efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
3/26/2012	–	0	–	–	**0**	0	0
3/27/2012	–	0	–	–	**0**	0	0
3/28/2012	–	0	–	–	**0**	0	0
3/29/2012	–	0	–	–	**0**	0	0
3/30/2012	–	0	–	–	**0**	0	0
3/31/2012	–	0	–	–	**0**	0	0
4/1/2012	–	0	–	–	**0**	0	0
4/2/2012	–	0	–	–	**0**	0	0
4/3/2012	–	0	–	–	**0**	0	0
4/4/2012	–	0	–	–	**0**	0	0
4/5/2012	–	1	–	–	**1**	1	1
4/6/2012	–	0	–	–	**0**	0	0
4/7/2012	–	0	–	–	**0**	0	0
4/8/2012	–	0	–	–	**0**	0	0
4/9/2012	–	0	–	–	**0**	0	0
4/10/2012	–	0	–	–	**0**	0	0
4/11/2012	–	0	–	–	**0**	0	0
4/12/2012	–	0	–	–	**0**	0	0
4/13/2012	6	0	0.0350	–	**171**	126	269
4/14/2012	10	4	0.0350	–	**290**	214	453
4/15/2012	10	4	0.0350	–	**290**	214	453
4/16/2012	10	4	0.0350	–	**290**	214	453
4/17/2012	8	0	0.0350	–	**229**	168	359
4/18/2012	10	16	0.0350	–	**302**	225	465
4/19/2012	16	9	0.0350	–	**466**	344	728
4/20/2012	3	13	0.0350	–	**99**	76	148
4/21/2012	7	13	0.0350	–	**213**	159	327
4/22/2012	7	13	0.0350	–	**213**	159	327
4/23/2012	7	13	0.0350	–	**213**	159	327
4/24/2012	0	16	0.0350	–	**16**	16	16
4/25/2012	6	13	0.0350	–	**184**	139	282
4/26/2012	7	10	0.0350	–	**210**	157	324
4/27/2012	17	19	0.0350	–	**505**	375	783
4/28/2012	8	64	0.0350	–	**298**	235	431
4/29/2012	8	64	0.0350	–	**298**	235	431
4/30/2012	8	64	0.0350	–	**298**	235	431
5/1/2012	0	31	0.0350	–	**31**	31	31
5/2/2012	11	93	0.0350	–	**407**	323	587
5/3/2012	8	220	0.0350	–	**449**	388	579
5/4/2012	5	430	0.0350	–	**573**	535	655
5/5/2012	16	196	0.0350	–	**639**	521	893
5/6/2012	16	196	0.0350	–	**639**	521	893
5/7/2012	16	196	0.0350	–	**639**	521	893
5/8/2012	25	166	0.0555	–	**617**	690	1,289
5/9/2012	24	172	0.0555	–	**605**	496	824
5/10/2012	20	97	0.0555	–	**458**	367	641

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	BYPASS efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
5/11/2012	19	161	0.0555	–	**504**	417	678
5/12/2012	19	239	0.0555	–	**588**	500	765
5/13/2012	19	239	0.0555	–	**588**	500	765
5/14/2012	19	239	0.0555	–	**588**	500	765
5/15/2012	8	418	0.0555	–	**562**	526	635
5/16/2012	19	309	0.0555	–	**652**	565	826
5/17/2012	26	278	0.0555	–	**747**	629	985
5/18/2012	27	653	0.0555	–	**1,140**	1,017	1,387
5/19/2012	19	523	0.0555	–	**859**	774	1,029
5/20/2012	19	523	0.0555	–	**859**	774	1,029
5/21/2012	19	523	0.0555	–	**859**	774	1,029
5/22/2012	13	441	0.0555	–	**675**	616	794
5/23/2012	8	975	0.0555	–	**1,119**	1,083	1,192
5/24/2012	–	483	–	0.3400	**1,421**	1,096	2,018
5/25/2012	–	836	–	0.3400	**2,459**	1,897	3,494
5/26/2012	–	490	–	0.3400	**1,440**	1,111	2,046
5/27/2012	–	490	–	0.3400	**1,440**	1,111	2,046
5/28/2012	–	490	–	0.3400	**1,440**	1,111	2,046
5/29/2012	–	490	–	0.3400	**1,440**	1,111	2,046
5/30/2012	–	392	–	0.3400	**1,153**	889	1,638
5/31/2012	–	169	–	0.3400	**497**	383	706
6/1/2012	–	82	–	0.3400	**241**	186	343
6/2/2012	–	189	–	0.3400	**555**	428	788
6/3/2012	–	189	–	0.3400	**555**	428	788
6/4/2012	–	189	–	0.3400	**555**	428	788
6/5/2012	–	148	–	0.3187	**464**	336	618
6/6/2012	–	183	–	0.3187	**574**	435	845
6/7/2012	–	158	–	0.3187	**496**	375	729
6/8/2012	–	153	–	0.3187	**480**	364	706
6/9/2012	–	95	–	0.3187	**299**	226	439
6/10/2012	–	95	–	0.3187	**299**	226	439
6/11/2012	–	95	–	0.3187	**299**	226	439
6/12/2012	–	35	–	0.3187	**110**	83	162
6/13/2012	–	12	–	0.3187	**38**	29	55
6/14/2012	–	30	–	0.3187	**94**	71	138
6/15/2012	–	89	–	0.3187	**279**	211	411
6/16/2012	–	33	–	0.3187	**105**	79	154
6/17/2012	–	33	–	0.3187	**105**	79	154
6/18/2012	–	33	–	0.3187	**105**	79	154
6/19/2012	–	27	–	0.3187	**85**	64	125
6/20/2012	–	15	–	0.3187	**47**	36	69
6/21/2012	–	27	–	0.3187	**85**	64	125
6/22/2012	–	126	–	0.3187	**395**	299	582
6/23/2012	–	39	–	0.3187	**123**	93	182
6/24/2012	–	39	–	0.3187	**123**	93	182
6/25/2012	–	39	–	0.3187	**123**	93	182

Appendix B continued

Date	GOLF catch	Bypass catch	GOLF efficiency	BYPASS efficiency	Downstream abundance estimate	95% Lower CI	95% Upper CI
6/26/2012	–	25	–	0.3187	**78**	59	115
6/27/2012	–	12	–	0.3187	**38**	29	55
6/28/2012	–	31	–	0.3187	**97**	74	143
6/29/2012	–	27	–	0.3187	**85**	64	125
6/30/2012	–	19	–	0.3187	**60**	45	88
7/1/2012	–	19	–	0.3187	**60**	45	88
7/2/2012	–	19	–	0.3187	**60**	45	88
7/3/2012	–	6	–	0.3187	**19**	14	28
7/4/2012	–	6	–	0.3187	**19**	14	28
7/5/2012	–	6	–	0.3187	**19**	14	28
7/6/2012	–	6	–	0.3187	**19**	14	28
7/7/2012	–	3	–	0.3187	**10**	8	15
7/8/2012	–	3	–	0.3187	**10**	8	15
7/9/2012	–	3	–	0.3187	**10**	8	15
7/10/2012	–	3	–	0.3187	**9**	7	14
7/11/2012	–	2	–	0.3187	**6**	5	9
7/12/2012	–	2	–	0.3187	**6**	5	9
7/13/2012	–	2	–	0.3187	**6**	5	9

Appendix C. Monthly totals of fish caught at the upstream RST (VINO FARMS) on the lower Mokelumne river during the 2011/12 juvenile outmigration monitoring season.

Common Name	Genus	Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Black Bass	*Micropterus*	spp.	0	0	0	0	0	0	7	**7**
Black Crappie	*Pomoxis*	*nigromaculatus*	1	0	0	0	1	2	2	**6**
Bluegill	*Lepomis*	*macrochirus*	1	0	0	1	1	8	4	**15**
Channel Catfish	*Ictalurus*	*punctatus*	0	1	1	0	0	1	0	**3**
Chinook Salmon (Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	9	14	0	1	1	1	0	**26**
Chinook Salmon (No Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	31	3,955	6,754	3,037	68	74	12	**13,931**
Golden Shiner	*Notemigonus*	*crysoleucas*	3	2	4	7	3	2	0	**21**
Hitch	*Lavinia*	*exilicauda*	2	0	3	7	14	16	7	**49**
Largemouth Bass	*Micropterus*	*salmoides*	0	0	0	0	0	0	1	**1**
Pacific Lamprey	*Lampetra*	*tridentata*	41	74	100	313	907	474	202	**2,111**
Prickly Sculpin	*Cottus*	*asper*	0	4	7	14	25	18	29	**97**
Redear Sunfish	*Lepomis*	*microlophus*	2	0	1	0	0	0	1	**4**
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	0	0	0	0	1	0	0	**1**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	0	0	0	0	11	326	**337**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	1	4	3	18	11	14	10	**61**
Tule Perch	*Hysterocarpus*	*traski*	5	0	0	11	8	4	7	**35**
Western Mosquitofish	*Gambusia*	*affinis*	0	0	0	0	0	0	2	**2**

Appendix D. Monthly totals of fish caught at the downstream traps (GOLF and BYPASS) on the lower Mokelumne river during the 2011/12 juvenile outmigration monitoring season.

Common Name	**Genus**	**Species**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Total**
American Shad	*Alosa*	*sapidissima*	0	0	0	0	0	2	0	0	**2**
Black Bass	*Micropterus*	spp.	0	0	1	0	0	21,906	4,973	661	**27,541**
Black Crappie	*Pomoxis*	*nigromaculatus*	0	0	5	0	0	0	361	25	**391**
Bluegill	*Lepomis*	*macrochirus*	0	0	11	0	1	1	4	11	**28**
Channel Catfish	*Ictalurus*	*punctatus*	0	0	2	1	0	0	0	0	**3**
Chinook Salmon (Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	3	122	303	1	4	25	8	0	**463**
Chinook Salmon (No Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	0	6	171	496	170	6,537	1,180	21	**8,581**
Common Carp	*Cyprinus*	*carpio*	0	0	0	0	0	6	3	0	**9**
Golden Shiner	*Notemigonus*	*crysoleucas*	1	1	70	0	2	0	0	0	**73**
Goldfish	*Carassius*	*auratus*	0	0	2	0	1	0	1	0	**4**
Green Sunfish	*Lepomis*	*cyanellus*	0	0	5	0	0	0	0	0	**5**
Hitch	*Lavinia*	*exilicauda*	0	0	2	0	0	4	0	0	**6**
Kokanee	*Oncorhynchus*	*nerka kennerlyi*	0	0	2	1	1	1	0	0	**5**
Largemouth Bass	*Micropterus*	*salmoides*	0	0	14	0	0	0	0	0	**14**
Pacific Lamprey	*Lampetra*	*tridentata*	1	27	31	72	15,545	56	1	0	**15,733**
Prickly Sculpin	*Cottus*	*asper*	3	37	131	73	2,139	4,996	93	17	**7,489**
Redear Sunfish	*Lepomis*	*microlophus*	0	0	16	0	1	3	1	0	**21**
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	0	1	0	0	0	0	0	0	**1**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	0	0	0	0	30	1	0	**31**
Steelhead (Ad-Clip)	*Oncorhynchus*	*mykiss*	0	6	15	1	1	0	4	3	**30**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	0	1	1	0	11	34	71	3	**121**
Tule Perch	*Hysterocarpus*	*traski*	0	0	1	11	63	52	390	20	**537**
Wakasagi	*Hypomesus*	*nipponensis*	0	0	1	0	0	0	0	0	**1**
Western Mosquitofish	*Gambusia*	*affinis*	0	0	3	0	0	1	0	0	**4**
White Crappie	*Pomoxis*	*annularis*	0	0	1	0	0	0	0	0	**1**