Emigration of Juvenile Chinook Salmon (*Oncorhynchus tschawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2013 – June 2014

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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 2013/14 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 17 December 2013 to 20 June 2014. The downstream rotary screw trap (GOLF) was located just below the Lower Sacramento Road Bridge at rkm 61.8 and was operated from 7 January to 29 May 2014. The smolt bypass trap (BYPASS), located at Woodbridge Irrigation District Dam (rkm 62.2), was operated from 14 April to 20 June 2014.

The first juvenile Chinook salmon was captured at the VINO RST on 20 December 2013. Including weekend estimates, 53,111 naturally produced young-of-the-year (YOY) Chinook salmon were caught during the monitoring period. Ten trap efficiency tests were conducted at VINO, six tests using naturally produced salmon and four tests using hatchery produced salmon. The annual estimated abundance of naturally produced YOY Chinook salmon at the VINO RST was 595,070 (95% CI: 437,148-955,327). Including weekend estimates, 306 wild YOY steelhead were caught at the VINO RST during the 2013/14 season. The estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 10,590 (95% CI: 7,054-20,182).

The first juvenile Chinook salmon was captured at the downstream RST (GOLF) on 8 January 2014. Including weekend estimates, 2,413 naturally produced YOY Chinook salmon were caught during the monitoring period. Six trap efficiency tests were conducted at GOLF, two tests using naturally produced salmon and four tests using hatchery produced salmon. The annual estimated abundance of naturally produced YOY Chinook salmon at the GOLF RST was 102,984 (95% CI: 67,793-221,085). Including weekend estimates, five wild YOY steelhead were captured at the GOLF RST during the 2013/14 season. The estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 440 (95% CI: 285-1,769).

The first juvenile Chinook salmon was captured at the bypass smolt trap (BYPASS) on 15 April 2014. Including weekend catch estimates, 66,880 naturally produced YOY Chinook salmon were caught at the BYPASS during the monitoring period. The total downstream salmon emigration estimate, calculated from adding the BYPASS trap catch to the GOLF RST abundance estimate, was 169,864 (95% CI: 134,673-287,964). Including weekend catch estimates, 44 wild YOY steelhead were caught at the BYPASS during the 2013/14 season. The total downstream passage estimate of wild YOY steelhead, calculated from adding the BYPASS trap catch to the GOLF RST estimate, was 484 (95% CI: 329-1,813).

Fifteen fish species were caught at the VINO RST during the survey period, eight native and seven non-native species. 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) twenty fish species were caught, six native and fourteen non-native species. Native fish species were more frequently caught than non-native species and Chinook salmon was the most abundant species caught.

Average daily water releases from Camanche Reservoir ranged from 204 cfs (5.8 m^3/s) to 530 cfs (15.0 m^3/s) during the monitoring period. From 1 October 2013 through 31 March 2014 EBMUD operated under a “Below Normal” JSA water year type. From 1 April through 30 September 2014 EBMUD operated under a “Dry” JSA water year type.

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 the 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 2013 through June 2014.

METHODS

Environmental Data

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 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) gauging stations (Figure 1).

Rotary screw traps

Two 8-ft and one 5-ft (cone diameter) rotary screw traps (E.G. Solutions, Inc.) were operated at upstream and downstream locations on the lower Mokelumne River (Figure 1). One 8-ft rotary screw trap (RST) was operated at the upstream location near the Elliott Road Bridge, adjacent to property owned by Vino Farms, at rkm 87.4. At the downstream location, one 8-ft RST was intermittently operated, just below Woodbridge Irrigation District Dam (WIDD) and adjacent to the Lodi Golf and Country Club at rkm 61.8. During low flow periods (~100-160 cfs), the 8-ft RST was taken out of service and the 5-ft RST was operated at the downstream site. In this report, the upstream and downstream RST sites are referred to as VINO and GOLF, respectively.

During the 2013/14 monitoring season, RSTs were generally operated Monday through Friday, between December and June. However, the GOLF trap was removed from the river on 30 May 2014 because of a dry water year for the April through October period. During dry water years, the minimum flow requirement below Woodbridge Dam during the month of June is 20 cfs, which is insufficient flow to operate 8-ft or 5-ft RSTs at the downstream site. 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 position RSTs in the thalweg of the river where water velocities were 0.6 m/s or greater (USFWS 2008). Water velocity was measured at the center of the trap cone, just below the water surface, at the beginning of each trap check. Rotations were measured using a stopwatch to record the time for three full rotations. RPMs were taken at each trap check. Efforts were made to maintain a rotational speed of two rotations per minute (RPM) or greater at both RSTs. 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. 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 2013/14 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 emigration period to provide an estimate of the proportion of juvenile Chinook salmon each RST was capturing. Naturally produced Chinook salmon were used for the trap efficiency trials when salmon catch was high enough to produce a group of test fish. Additional test salmon were provided by California Department of Fish and Wildlife at the Mokelumne River Fish Hatchery (MRFH). 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 and/or

Bismark® brown dye were used 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.

Rotary Screw Trap Abundance Estimates

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. Daily RST abundance estimates were generated for juvenile Chinook salmon and steelhead using the Petersen equation (Volkhardt et al. 2007):

$$\hat{A}_i = n_i \times \hat{e}_i^{\,-1}$$

where,

$$\hat{e}_i = \frac{m_i}{M_i}$$

$\hat{A}_i$ = Estimated daily abundance during period *i*
M_i = Number of fish marked and released during period *i*
n_i = Number of fish captured during period *i*
m_i = Number of marked fish captured during period *i*
$\hat{e}_i$ = Estimated trap efficiency during period *i*

Confidence intervals (95%) for daily abundance estimates were calculated as follows:

$$95\%\ LCI_i = n_i / \hat{e}_i + 1.96 \times \sqrt{\hat{e}_i} \times \frac{(1-\hat{e}_i)}{m_i}$$

and

$$95\%\ UCI_i = n_i / \hat{e}_i - 1.96 \times \sqrt{\hat{e}_i} \times \frac{(1-\hat{e}_i)}{m_i}$$

95% LCI_i = 95% Lower confidence interval during period *i*
95% UCI_i = 95% Upper confidence interval during period *i*

Annual abundance estimates were calculated by summing the daily abundance estimates. Confidence intervals for annual abundance estimates were calculated by summing the daily 95% confidence intervals.

BYPASS Trap Abundance Estimates

Daily catch estimates at the BYPASS trap were generated for non-trapping days by averaging daily catch to the nearest fish, for three days preceding and following these periods. Daily catch at the BYPASS was added to the daily abundance estimate at the GOLF trap to produce a daily downstream abundance estimate.

Fish Handling and Condition Factors

Captured fish were processed in the field, 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 beginning of the season and later transferred to Woodbridge Dam when smolt-sized salmon were caught at the GOLF and BYPASS traps. A 20-45 mg/L solution of eugenol (AQUI-S®20E is 10% eugenol) was used to anesthetize salmonids and lamprey, when needed. All sedation records were submitted to the USFWS Aquatic Animal Drug Approval Partnership (AADAP) Program as part of an ongoing study to establish the effectiveness and safety of AQUI-S® 20E as an anesthetic/sedative for various fish species under a variety of environmental conditions. The AADAP suggested guidelines for preparing and using AQUI-S®20E as a sedative were followed. 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 salmonids 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 emigrating 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 Wildlife (CDFW), 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. The CDFW, 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, trapping and trucking activities would be suspended if the 5-day average Chinook salmon count falls below 50 per day, and juvenile salmon would be trapped at Woodbridge Dam and transported to a release site with similar water temperatures.

A transport tank with two 284-liter 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 salmon were acclimated to within 2°C of the release water in the transport tanks before their release.

Juvenile Chinook Salmon Survival

Chinook salmon egg to young-of-the-year survival indices were calculated at the upstream and downstream trapping locations based on the brood year (BY) 2013 redd count and BY 2013 average fecundity per female at the MRFH. 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 2013 were compared with previous years. The minimum and maximum survival indices were expected to range between 0.0 and 1.0, respectively.

Migration response

Generalized linear models were constructed to examine the relationship between daily salmon abundance (expressed as percent of annual abundance) and daily average flow, change in daily average flow, water temperature, turbidity, photoperiod, and accumulated thermal units (ATU). A correlation matrix was built to determine if variables had a high level of collinearity with each other. Independent variables that correlated with one another at 0.70 or greater were not used together in the same models. The Minimum corrected Akaike Information Criterion (AICc) was used to select the best models. The top models at each trapping location were reported.

Spearman's rho correlation was used to examine the relationships between weekly salmon abundance and weekly salmon redd emergence at the upstream and downstream trapping locations. A weekly redd emergence timeline was constructed based on weekly salmonid redd surveys and a water temperature egg model developed by Vogel (1993) from Piper et al. (1992). 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).

Data Analysis

Graphics were created and data were analyzed using ArcMAP™ 10.0 (ESRI Inc.), JMP® 9.0.0 (SAS Institute Inc.), Microsoft® Office Access 2007 and Excel 2007. Statistical tests were considered significant if the P-value was ≤ 0.05. 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 158 cfs (4.5 m^3/s) to 494 cfs (14.0 m^3/s) during the time when the VINO trap was operated (17 December 2013 through 20 June 2014). The mean flow during that time was 247 cfs (7.0 m^3/s). Water temperatures recorded at VINO ranged from 9.6 to 18.7°C, with a mean of 13.4°C. Water turbidity at the VINO RST ranged from 1.2 to 24.8 Nephelometric Turbidity Units (NTU), with a mean of 2.1 NTU.

Average daily flow at the Golf gauging station ranged from 91 cfs (2.6 m^3/s) to 535 cfs (15.1 m^3/s) during the time when the GOLF RST was operated (7 January through 29 May 2014). The average daily flow during that time was 165 cfs (4.7 m^3/s). Water temperatures recorded at GOLF ranged from 9.0 to 20.4°C, with a mean of 14.5°C. Water turbidity at GOLF ranged from 1.3 to 5.8 NTU, with a mean of 2.4 NTU.

During the time that the BYPASS trap was operated (14 April through 20 June 2014) average daily flow at the Victor gauging station ranged from 138 cfs (3.9 m^3/s) to 439 cfs (12.4 m^3/s), with a mean of 260 cfs (7.4 m^3/s). Flow at the Woodbridge Irrigation District Canal ranged from 0 cfs to 106 cfs (3.0 m^3/s) and averaged 71 cfs (2.0 m^3/s). Water temperatures recorded at the BYPASS trap ranged from 15.9 to 22.4°C, with a mean of 19.2°C. Water turbidity at the BYPASS ranged from 2.0 to 3.8 NTU, with a mean of 2.7 NTU.

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

Trap Operations

The VINO RST was operated between 17 December 2013 and 20 June 2014. The cone was stopped by debris on 0 of 97 days when the trap was checked. Excluding days with trap stoppages, the minimum recorded cone rotation rate was 1.7 RPM and the maximum was 3.7 RPM. The mean rotation rate during the monitoring season was 3.0 RPM. The VINO trap met or exceeded a rotation speed of 2.0 RPMs on 99% 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 8-ft RST at GOLF was operated from 7 January to 24 February 2014. Debris stopped the cone from rotating on 1 of 24 days when the trap was checked. Excluding trap stoppages, the minimum cone rotation rate was 2.0 RPM and the maximum rate was 4.6 RPM. Average rotational speed was 2.8 RPM. The 8-ft RST met or exceeded a rotation speed of 2.0 RPMs on 100% of all operating days (excluding stoppage days). Water velocity entering the center of the trap cone ranged between 0.42 and 0.99 m/s, with a mean of 0.61 m/s.

The 5-ft RST at GOLF was operated from 25 February to 29 May 2014. Debris stopped the cone from rotating on 11 of 53 days when the trap was checked. Excluding trap stoppages, the minimum cone rotation rate was 2.3 RPM and the maximum rate was 7.8 RPM. Average rotational speed was 4.0 RPM. The 5-ft RST met or exceeded a rotation speed of 2.0 RPMs on 100% of all operating days (excluding stoppage days). Water velocity entering the center of the trap cone ranged between 0.2 and 0.9 m/s, with a mean of 0.6 m/s.

The BYPASS trap at WIDD was operated between 14 April and 20 June 2014. During this time frame the trap was checked on 38 days. Water velocity at the top of the trap ranged between 0.3 and 1.0 m/s and averaged 0.7 m/s.

RST Calibrations

Ten calibration tests were conducted for the VINO RST during the 2013/14 juvenile monitoring season (Table 1). Naturally produced Chinook salmon were used as test fish for six tests and Chinook salmon from the MRFH were used for four tests. Trap efficiency ranged from 1.0% to 22.7% and averaged 8.8% (n = 10).

Six calibration tests were conducted for the GOLF RST during the 2013/14 juvenile monitoring season (Table 1). Naturally produced Chinook salmon were used as test fish for two tests and Chinook salmon from the MRFH were used for four tests. Trap efficiency tests 4 and 5 were pooled because there was an insufficient number of salmon recaptured to generate 95% CIs for each individual test. Smolt-sized salmon were released under similar flow conditions during tests 4 and 5 (Table 1). GOLF trap efficiency ranged from 0.5% to 12.1%, with a mean of 4.7% (n = 6).

Chinook Salmon

<u>Catch and Abundance Estimates</u>

At the VINO RST, 28,248 naturally produced young-of-the-year (YOY) Chinook salmon were captured between 20 December 2013 and 19 June 2014. Estimates for weekend catch were added to actual catch to produce an estimated count of 53,111 YOY Chinook salmon. Using trap efficiency data, the total estimated abundance of YOY salmon passing the upstream RST (VINO) was 595,070 (95% CI: 437,148-955,327). The highest monthly abundance estimate was recorded in February at the VINO RST (Table 2).

At the GOLF RST, 1,289 naturally produced YOY Chinook salmon were captured between 9 January and 29 May 2014. Estimates for weekend catch were added to the actual catch to produce an estimated count of 2,413 YOY Chinook salmon. Using trap efficiency data, the estimated abundance of YOY Chinook salmon at the GOLF RST was 102,984 (95% CI: 67,793-221,085).

At the BYPASS trap, 37,323 naturally produced YOY Chinook salmon were captured between 15 April and 20 June 2014. Estimates for weekend catch were added to the actual catch to produce an estimated count of 66,880 YOY Chinook salmon.

The total downstream emigration estimate of 169,864 YOY Chinook salmon (95% CI: 134,673-287,964) was calculated by adding the BYPASS catch estimate to the GOLF RST abundance estimate. At the downstream traps (GOLF & BYPASS), the highest monthly abundance estimate was recorded during the month of May (Table 2).

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

At the VINO RST, 93.8% (n=26,490) of the naturally produced Chinook salmon catch was classified as fry. The remaining catch was classified as parr (0.8%, n=233), silvery parr (1.3%, n=360), smolts (4.1%, n=1,165), and yearlings (0.0%, n=1). In addition, twenty-three hatchery origin (adipose fin-clipped) Chinook salmon yearlings and five hatchery origin smolts were caught at the VINO RST. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the VINO RST during the 2013/14 season is provided by Figure 3.

At the downstream traps, naturally produced Chinook salmon catch was primarily composed of smolts (97.8%, n=37,783). The remaining catch was classified as fry (2.0%, n=779), parr (0.04%, n=17), silvery parr (0.1%, n=34), and yearlings (0.01%, n=3). In addition, 71 hatchery origin (adipose fin-clipped) Chinook salmon yearlings and three hatchery origin 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 2013/14 season is provided by Figure 3.

The monthly average condition factors by life stage for naturally produced Chinook salmon caught and measured at the upstream and downstream traps are presented in Figure 4. Monthly average condition factors were only reported if the number of observations by life stage was three or greater (n>=3).

<u>Migration Response</u>

The relationships between three environmental variables (average daily flow, water temperature and turbidity) and estimated daily salmon abundance at the upstream and downstream traps during the 2013/14 monitoring season are presented graphically in Figures 5 and 6.

At the upstream trap, daily water turbidity, photoperiod, and change in average daily flow (Elliot, rkm 86.1) were the variables included in the generalized linear model (GLM) with the lowest AICc (Table 3). None of the variables included in the GLM had a significant relationship with daily salmon abundance. In addition, weekly redd emergence and weekly salmon abundance did not have a significant correlation at the upstream trap (r = 0.25, r =0.2632).

At the downstream traps, daily water turbidity, ATU, average daily flow at Victor (rkm 80.7), average daily flow at Golf (rkm 61.3), change in average daily flow at Victor (rkm 80.7), and change in average daily flow at the WIDD canal (rkm 62.2) were the variables included in the GLM with the lowest AICc (Table 3). However, average daily flow at Victor and change in average daily flow at Victor were the only two of the variables included in the GLM that had a significant relationship with daily salmon abundance. Average daily flow at Victor had a significant positive relationship with daily salmon abundance (parameter estimate = 0.0137), while the change in average daily flow at Victor had a significant negative relationship with salmon abundance (parameter estimate = -0.0558). Weekly redd emergence and weekly salmon abundance had a significant negative correlation at the downstream traps (r = -0.52, r =0.0181).

Trapping and Trucking

Trapping and trucking was initiated on 13 May 2014. Juvenile Chinook salmon were transported for a total of thirteen trapping days, until 10 June 2014, when the 5-day Chinook salmon count average fell below 50 per day at the BYPASS trap. During this time 13,080 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). During the transport and release stages, 97 salmon mortalities occurred, resulting in a 0.7% mortality rate. The mortalities were attributed to handling and/or transport stress.

In addition, 1,187 salmon were trapped and transported to Jersey Point on the San Joaquin River, just downstream of its confluence with the LMR. Two experimental net pen releases took place at this location on 21 and 28 May 2014, during an outgoing and incoming tide, respectively. Six salmon mortalities occurred during the transport and release stages, resulting in a 0.5% mortality rate.

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

During the BY 2013 spawning season, 1,823 Chinook salmon redds were identified in the LMR. The BY 2013 average salmon fecundity estimate (per female spawned at the MRFH) was 5,540 eggs. The resulting estimated salmon production at 100% survival was 10,098,958 juveniles. The BY 2013 egg-to-YOY survival index for naturally produced YOY Chinook salmon at the upstream trap (VINO) was 0.06 (95% CI: 0.04-0.09). At the downstream traps (GOLF and BYPASS), the BY 2013 survival index was 0.02 (95% CI: 0.01-0.03). The BY 2013 upstream survival index was low, similar to BY 2011 (Table 4).

The BY 2013 downstream survival index was relatively low, similar to BY 2007, BY 2011, and BY 2012.

Steelhead

Catch and Abundance Estimates

At the VINO RST, 163 wild YOY steelhead were captured between 15 January and 20 June 2014. Estimates for weekend catch were added to actual catch to produce an estimated count of 306 naturally produced steelhead. The estimated abundance of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 10,590 (95% CI: 7,054-20,182). The largest monthly catch of wild steelhead (76) occurred at VINO in April.

At the GOLF RST, three wild YOY steelhead were captured between 14 and 29 May 2014. Estimates for weekend catch were added to actual catch to produce an estimated count of five wild steelhead. The estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 440 (95% CI: 285-1,769). The largest monthly catch of wild steelhead (3) occurred at GOLF in May.

At the BYPASS, twenty-two wild YOY steelhead were captured between 8 May and 13 June 2014. Estimates for weekend catch were added to actual catch to produce an estimated count of 44 naturally produced YOY steelhead. The estimated abundance of wild YOY steelhead at the downstream traps, calculated from adding the BYPASS trap catch to the GOLF RST estimate, was 484 (95% CI: 329-1,813). The largest monthly catch of wild steelhead (20) occurred at the downstream traps in May.

Life stage and size

At the VINO RST, 76.7% (n=125) of the naturally produced steelhead catch was classified as fry. The remaining wild steelhead catch was composed of parr (21.5%, n=35), age 1+ (1.2%, n=2), and silvery parr (0.6%, n=1). At the downstream traps (GOLF and BYPASS), 100% (n=25) of the wild steelhead catch was classified as parr. Steelhead catch at the downstream traps also consisted of one hatchery origin (adipose fin-clipped) smolt and three hatchery origin adults. The size distribution by life stage of all wild steelhead measured at the upstream and downstream traps is presented in Figure 8.

Species Composition

Fifteen fish species were caught at the VINO RST during the survey period, eight native and seven 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 (93.1%), followed by Pacific lamprey (*Lampetra tridentata)* (2.8%) and prickly sculpin (*Cottus asper*) (1.9%).

At the downstream traps (GOLF and BYPASS) twenty fish species were caught, six native and fourteen non-native species. Native fish species were more frequently caught than non-native species, comprising 63.7% of the total catch. Chinook salmon (no adipose fin-clip) was the most abundant species caught (61.1%) at the downstream traps, followed by unidentified black bass (*Micropterus* spp.) (36.1%) and prickly sculpin (2.0%).

DISCUSSION

During the 2013/2014 juvenile outmigration monitoring season, the VINO RST did not experience any stoppages. This was likely due to stable flow and light debris throughout the season. The GOLF RST, was stopped by debris twelve times throughout the monitoring season. Eleven of the stoppages took place when the 5-ft RST was in operation. Many of these stoppages occurred due to small debris, which is typically not capable of stopping the 8-ft RST from rotating. Salmon catch was estimated at GOLF on two of the twelve days with trap stoppages, during the peak of juvenile salmon outmigration (7 and 8 May 2014). During the other ten days when the trap was stopped, salmon catch was not estimated because the trap stops occurred outside of the peak of juvenile outmigration or after 3,000 trap revolutions. These days may have led to a small, but not significant, underestimate of salmon abundance at the GOLF trap.

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 (April through June), trap efficiency trials were conducted using parr and smolt-sized salmon from the MRFH. The results of the efficiency trials were consistent with previous seasons when the trap was operated at relatively stable low flows. Trap efficiencies steadily declined as salmon fork length increased. All of the tests were sufficient to generate reliable abundance estimates and 95% CIs.

At the GOLF RST, six trap efficiency trials were run using groups of naturally produced salmon and salmon from the MRFH. All of the tests were successful this season. However, tests 4 and 5, which used larger smolt-sized salmon from the MRFH, yielded just a few recaptures. This was likely due to the decreased capture efficiency of the 5-ft RST and the improved swimming ability of larger smolt-sized salmon. These tests were performed within one week of each other using smolt-sized salmon that were released under similar flows. Consequently, the tests were pooled to improve the abundance estimates and the 95% confidence intervals.

The GOLF trap was removed from the river on 30 May 2014 because of a dry water year for the April through October period. During dry water years, the minimum flow requirement below Woodbridge Dam during the month of June is 20 cfs, which is insufficient flow to operate 8-ft or 5-ft RSTs at the downstream site. Therefore, between 30 May and 20 June 2014, only BYPASS salmon catch was used for daily downstream salmon abundance estimates. This may have accounted for an underestimate of salmon abundance at the downstream traps during the month of June. However, the peak of juvenile outmigration occurred at the downstream traps in early May.

The upstream passage estimate of 595,070 YOY Chinook salmon ranked the 4th highest (of 8) on record since the 2007/08 juvenile outmigration season. The downstream

Chinook salmon passage estimate of 169,864 ranked the 10th highest (of 22) on record since the 1992/93 juvenile outmigration season. Although the annual upstream and downstream salmon passage estimates were relatively average, the BY 2013 survival indices at both traps were somewhat low due to the large number of salmon redds constructed during BY 2013 (1,823, 2nd highest on record). Dry conditions may have contributed to the low survival indices, as Calendar Years 2013 and 2014 were two of the driest on record in the Mokelumne River watershed. Other factors that may have contributed to the low survival rate of juvenile Chinook salmon in the upstream reaches of the LMR include predation by native and non-native fish species, egg loses that take place during egg deposition (Schroder et al. 2008), mortality associated with the physical and chemical habitat parameters associated at the spawning site (Merz et al. 2004), and small unscreened surface water diversions in the LMR. Moyle and Israel (2005) 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.

At the upstream trap, none of the variables included in the GLM with the lowest AICc had a significant relationship with daily salmon abundance. In addition, weekly redd emergence and weekly salmon abundance did not have a significant correlation at the upstream trap. However, in previous seasons, a significant positive relationship between weekly redd emergence and Chinook salmon abundance has been established (Bilski et al. 2013), indicating that the majority of juvenile salmon pass the upstream trapping location as fry. This season, a lack of large storm events and stable low flows provided very few migration cues and suitable rearing conditions in the uppermost reaches of the LMR, possibly causing a larger proportion of juvenile salmon to rear above the VINO RST.

At the downstream traps, average daily flow at Victor (rkm 80.7) and change in average daily flow at Victor were the only two of the variables included in the GLM that had a significant relationship with daily salmon abundance. The relationship between average daily flow at Victor and Chinook salmon abundance was positive, indicating that many juvenile salmon emigrated past the downstream traps when daily average flow was higher at the Victor gauge. Interestingly, the change in average daily flow at Victor had a significant negative relationship with salmon abundance, indicating the most of the juvenile salmon emigrated past the downstream traps when flows were stable at the Victor gauge. However, it is important to note that there was only one daily average flow change at Victor that exceeded 100 cfs throughout the season. In addition, there was a significant negative correlation between weekly redd emergence and weekly salmon abundance at the downstream traps. This result indicated were few juvenile Chinook salmon emigrated past the downstream traps as fry, as the vast majority of juvenile reared above the downstream traps and emigrated as smolts.

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Table 1. Summary of efficiency tests conducted at rotary screw trap locations on the lower Mokelumne River during the 2013/2014 season. Abbreviations are as follows: MRFH = 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	8-Jan-14	231	WILD	35	193	30	**15.5%**	Yes
2	14-Jan-14	237	WILD	35	159	29	**18.2%**	Yes
3	28-Jan-14	197	WILD	35	299	68	**22.7%**	Yes
4	11-Feb-14	235	WILD	36	296	38	**12.8%**	Yes
5	25-Feb-14	231	WILD	37	500	43	**8.6%**	Yes
6	11-Mar-14	189	WILD	36	632	32	**5.1%**	Yes
7	14-Apr-14	246	MRFH	69	992	13	**1.3%**	Yes
8	27-May-14	342	MRFH	82	1,001	11	**1.1%**	Yes
9	2-Jun-14	254	MRFH	89	995	11	**1.1%**	Yes
10	17-Jun-14	195	MRFH	96	1,014	10	**1.0%**	Yes

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-14	225	MRFH	39	501	25	**5.0%**	Yes
2	04-Mar-14	148	WILD	35	307	37	**12.1%**	Yes
3	18-Mar-14	124	WILD	35	130	11	**8.5%**	Yes
4	21-Apr-14	168	MRFH	71	799	4	**0.5%**	Yes
5	28-Apr-14	173	MRFH	73	948	8	**0.8%**	Yes
6	12-May-14	162	MRFH	76	995	13	**1.3%**	Yes

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 lower Mokelumne River during the 2013/14 season.

Upstream (VINO FARMS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
December	556	3,577	2,692	5,330	0.6%
January	9,346	51,460	39,162	75,357	8.6%
February	30,329	232,273	182,607	328,613	39.0%
March	10,385	136,587	107,956	202,278	23.0%
April	1,494	87,182	53,956	169,332	14.7%
May	905	75,214	45,247	153,088	12.6%
June	97	8,776	5,527	21,330	1.5%
Total	**53,111**	**595,070**	**437,148**	**955,327**	**100%**

Downstream (GOLF and BYPASS)

Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
January	12	244	176	395	0.1%
February	317	5,793	4,209	9,303	3.4%
March	1,129	9,668	7,293	14,742	5.7%
April	11,066	31,514	24,029	58,382	18.6%
May	55,220	121,095	97,417	203,593	71.3%
June	1,550	1,550	1,550	1,550	0.9%
Total	**69,292**	**169,864**	**134,673**	**287,964**	**100%**

Table 3. Generalized linear models for juvenile Chinook salmon abundance at the upstream and downstream trapping locations based on environmental variables on the lower Mokelumne River during the 2013/14 juvenile emigration monitoring season. ∆ DA Flow = Change in daily average flow. ATU = Accumulated Thermal Units.

Upstream (VINO FARMS)						
	Model					
AICc	df	*P*	Independent Variable	df	X^2	*P*
238.011	3, 120	0.1447				
			∆ DA Flow (Elliot)	1	1.579	0.2089
			Turbidity	1	2.068	0.1504
			Photoperiod	1	0.922	0.3368

Downstream (GOLF and BYPASS)						
	Model					
AICc	df	*P*	Independent Variable	df	X^2	*P*
176.675	6, 97	**<0.0001**				
			Turbidity	1	0.803	0.3703
			ATU	1	2.408	0.1207
			DA Flow (Golf)	1	1.086	0.2974
			DA Flow (Victor)	1	7.104	**0.0077**
			∆ DA Flow (Victor)	1	16.885	**<0.0001**
			∆ DA Flow (WIDD canal)	1	3.469	0.0625

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 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 (MRFH). JSA = 1998 Mokelumne River Joint Settle Agreement.

BY	Location(s) used	Chinook salmon redd count	Estimated production (at 100% survival)	Abundance estimate	95% LCI	95% UCI	Survival index (LCI - UCI)	JSA water year type (Apr.-Sept.)
Upstream (rkm 87.4)								
2007	Vino Farms	306	1,609,575	1,117,451	798,895	7,184,950	0.69 (0.50-4.46)	Below Normal
2008	Vino Farms	63	338,899	175,612	131,191	280,979	0.52 (0.39-0.83)	Below Normal
2009	Vino Farms	248	1,208,444	124,279	93,555	199,950	0.10 (0.08-0.17)	Below Normal
2010	Vino Farms	314	1,601,627	842,570	631,115	2,039,099	0.53 (0.39-1.27)	Normal & Above
2011	Vino Farms	564	2,983,439	202,772	152,937	312,856	0.07 (0.05-0.10)	Dry
2012	Vino Farms	1,287	6,509,206	1,203,754	958,664	1,724,580	0.18 (0.15-0.26)	Dry
2013	Vino Farms	1,823	10,098,958	595,070	437,148	955,327	0.06 (0.04-0.09)	Dry
Downstream (rkm 62)								
2007	Golf	306	1,609,575	18,347	14,513	25,152	0.01 (0.01-0.02)	Below Normal
2008	Golf & Bypass	63	338,899	30,614	29,171	32,802	0.09 (0.09-0.10)	Below Normal
2009	Golf & Bypass	248	1,208,444	67,349	39,512	283,914	0.06 (0.03-0.23)	Below Normal
2010	Golf & Bypass	314	1,601,627	281,500	186,249	606,084	0.18 (0.12-0.38)	Normal & Above
2011	Golf & Bypass	564	2,983,439	51,799	42,063	70,631	0.02 (0.01-0.02)	Dry
2012	Golf & Bypass	1,287	6,509,206	147,590	130,342	176,579	0.02 (0.02-0.03)	Dry
2013	Golf & Bypass	1,823	10,098,958	169,864	134,673	287,964	0.02 (0.01-0.03)	Dry

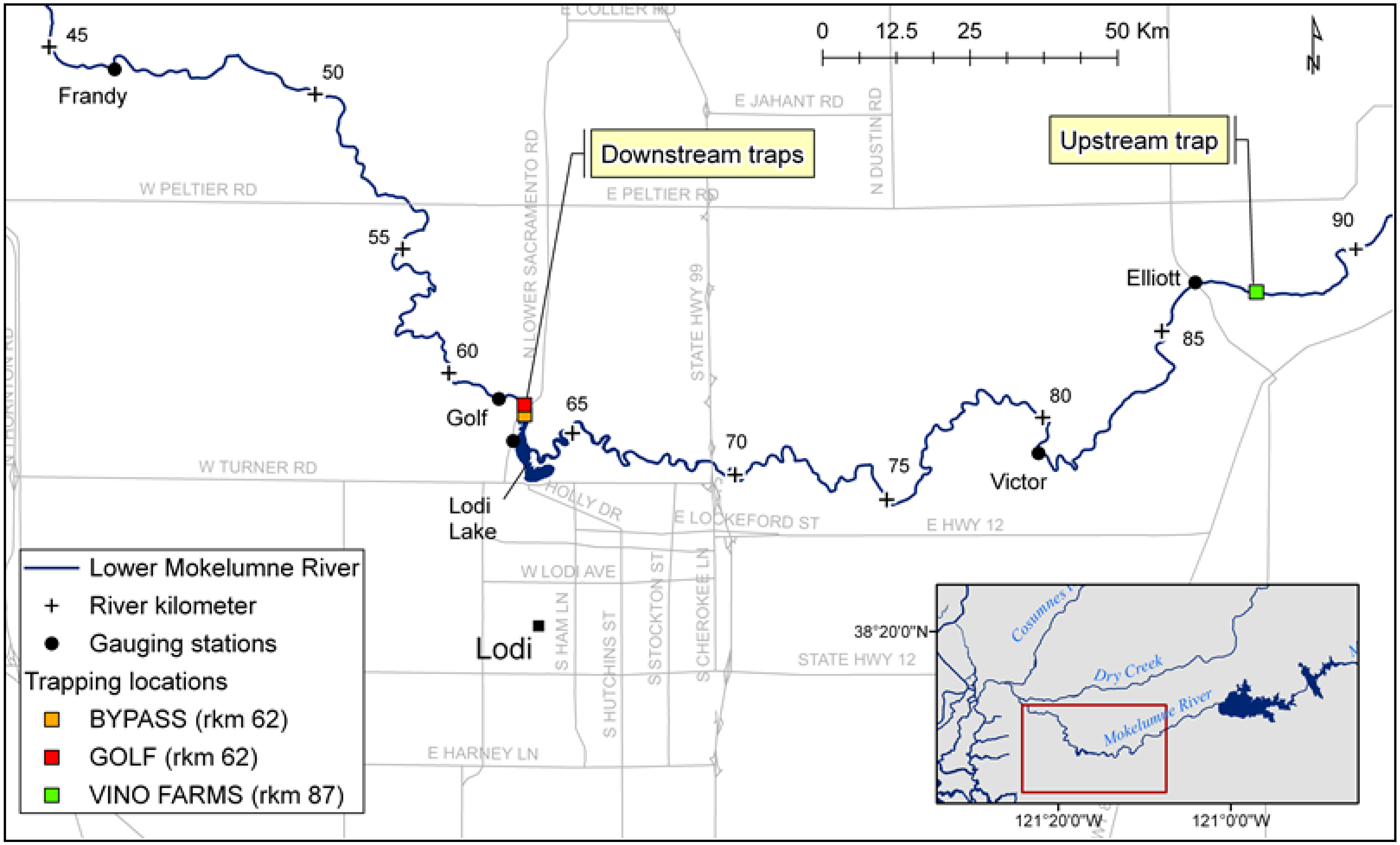


Figure 1. Trapping sites used for juvenile emigration monitoring on the lower Mokelumne River during the 2013/14 season.

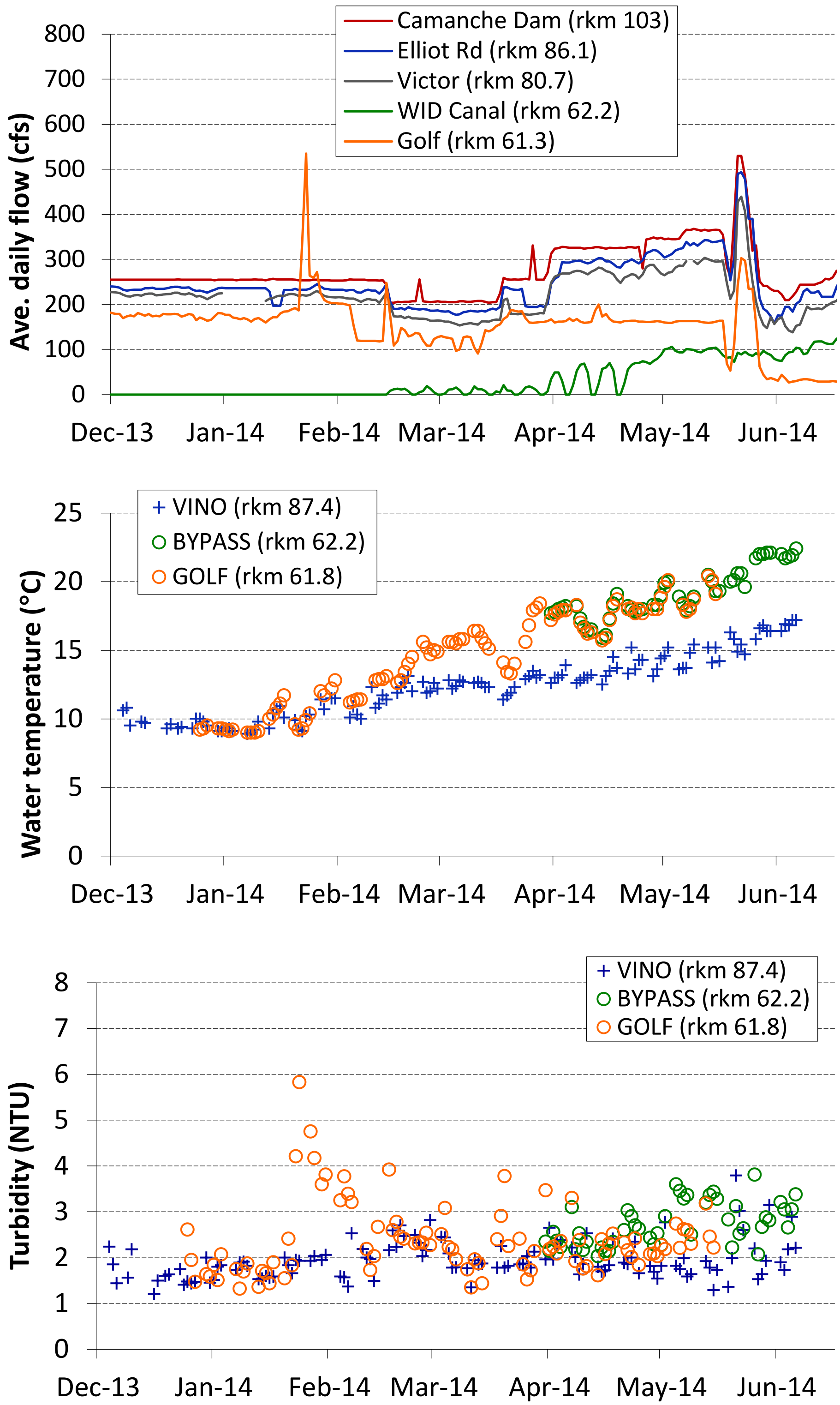


Figure 2. Average daily flow, turbidity and water temperature in the lower Mokelumne River between Camanche Dam (rkm 103) and Golf (rkm 61.3) during the 2013/14 juvenile emigration monitoring season.

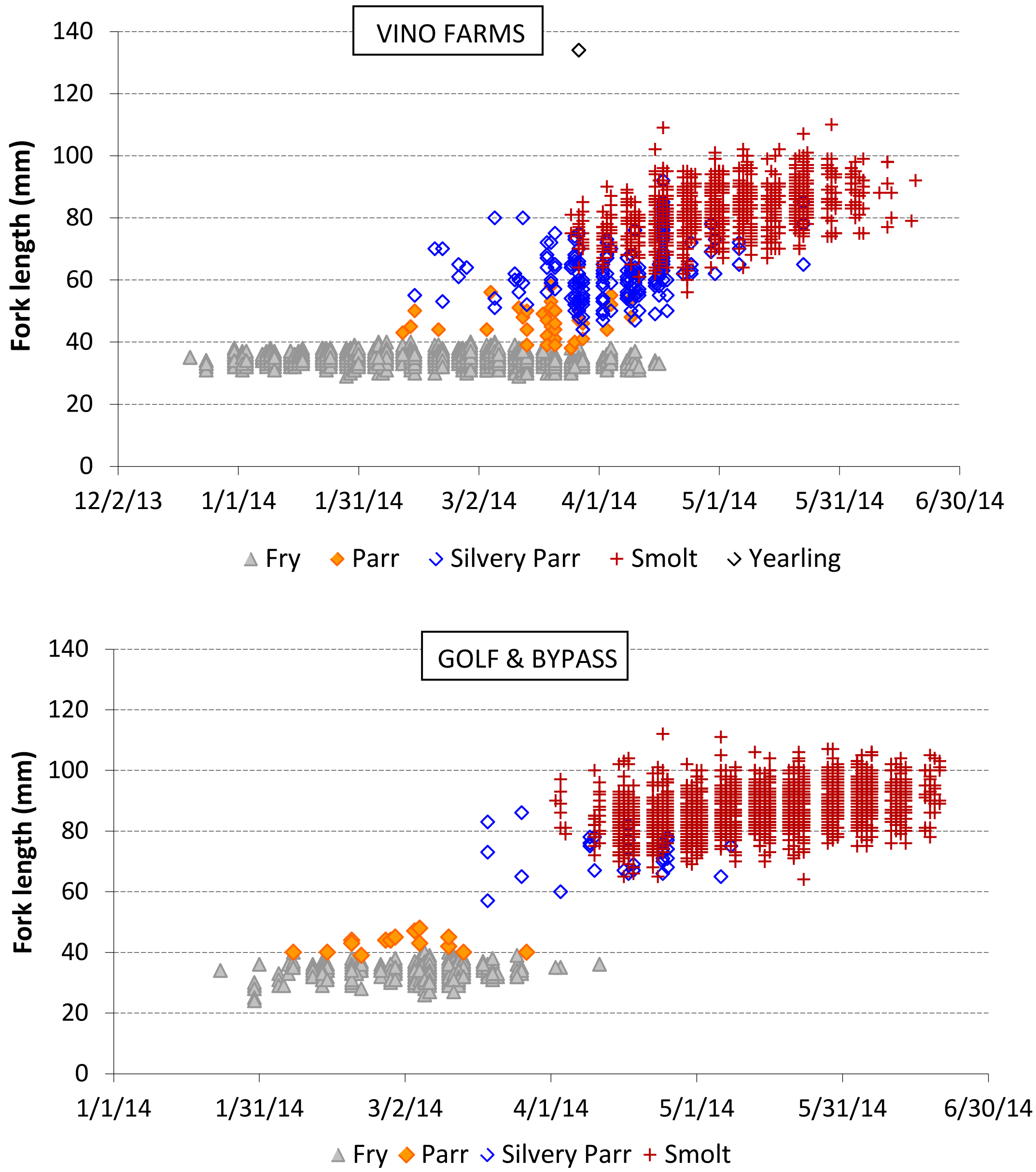


Figure 3. Size distribution by life stage of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF and BYPASS) trapping locations during the 2013/14 juvenile emigration season on the lower Mokelumne River.

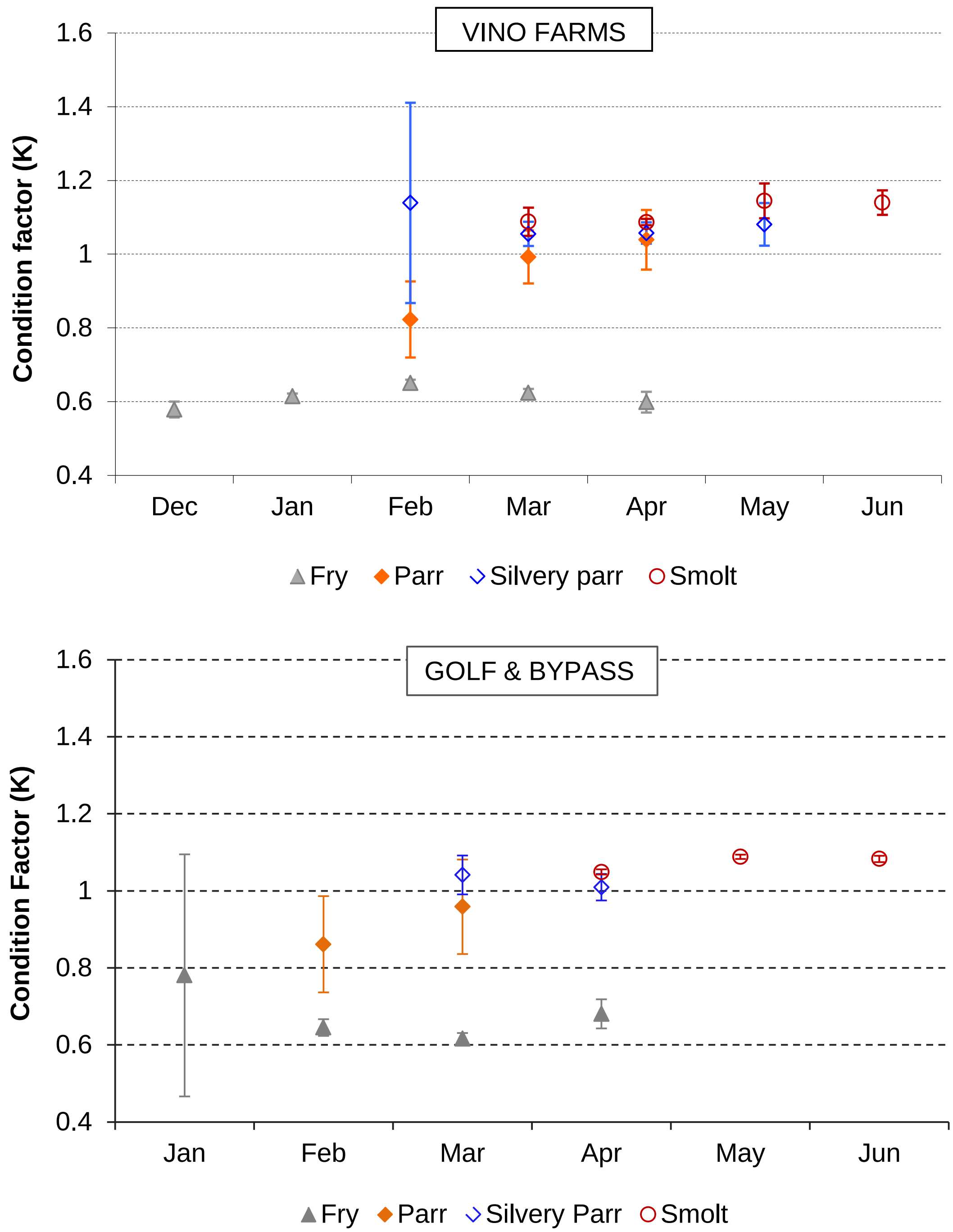


Figure 4. Monthly average condition factor ± 2 SE (vertical lines) of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF & BYPASS) trapping locations during the 2013/14 juvenile emigration monitoring season on the lower Mokelumne River.

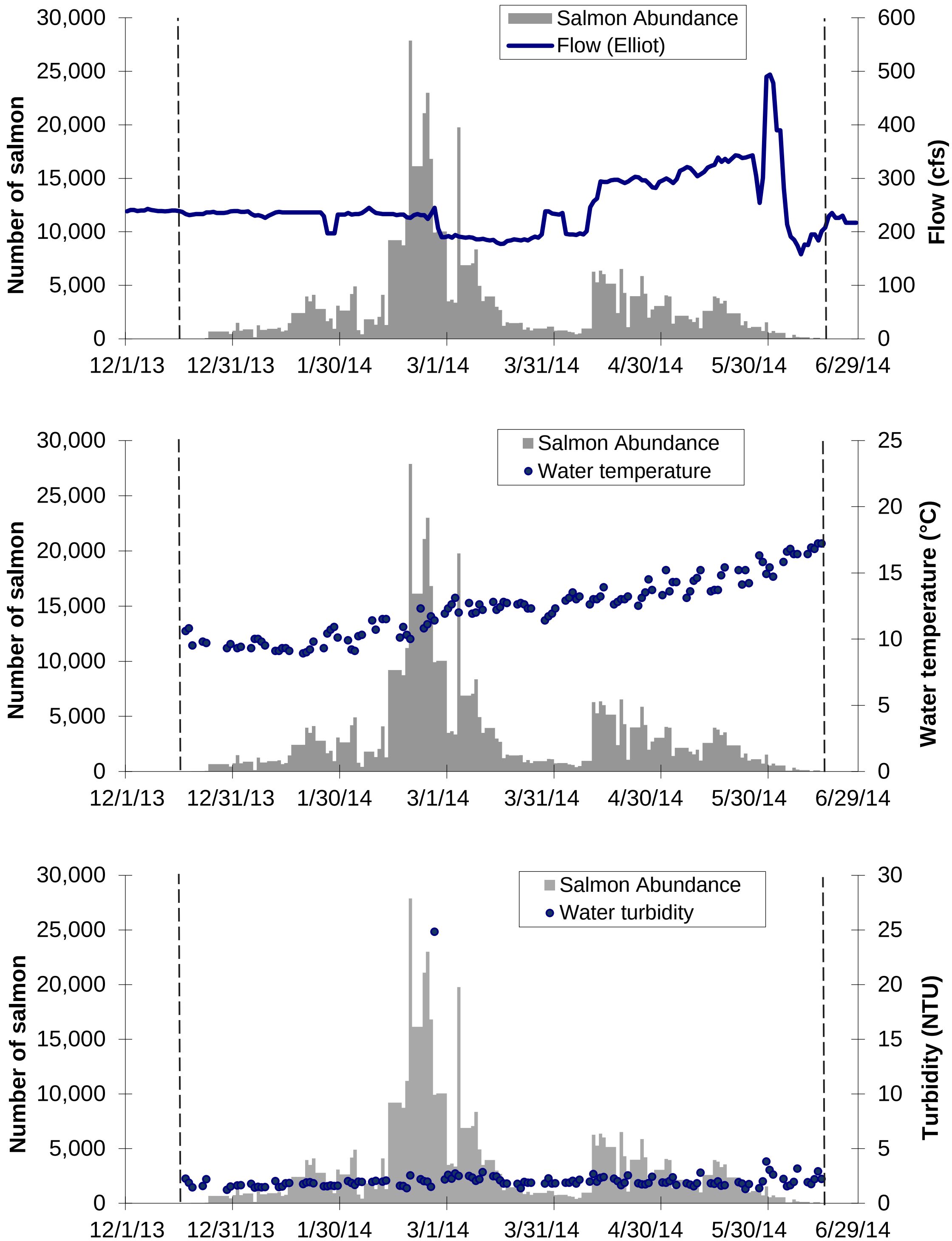


Figure 5. The relationship between estimated daily Chinook salmon abundance and flow (top), water temperature (middle), and turbidity (bottom) at the VINO RST (upstream trapping location) during the 2013/14 juvenile emigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.

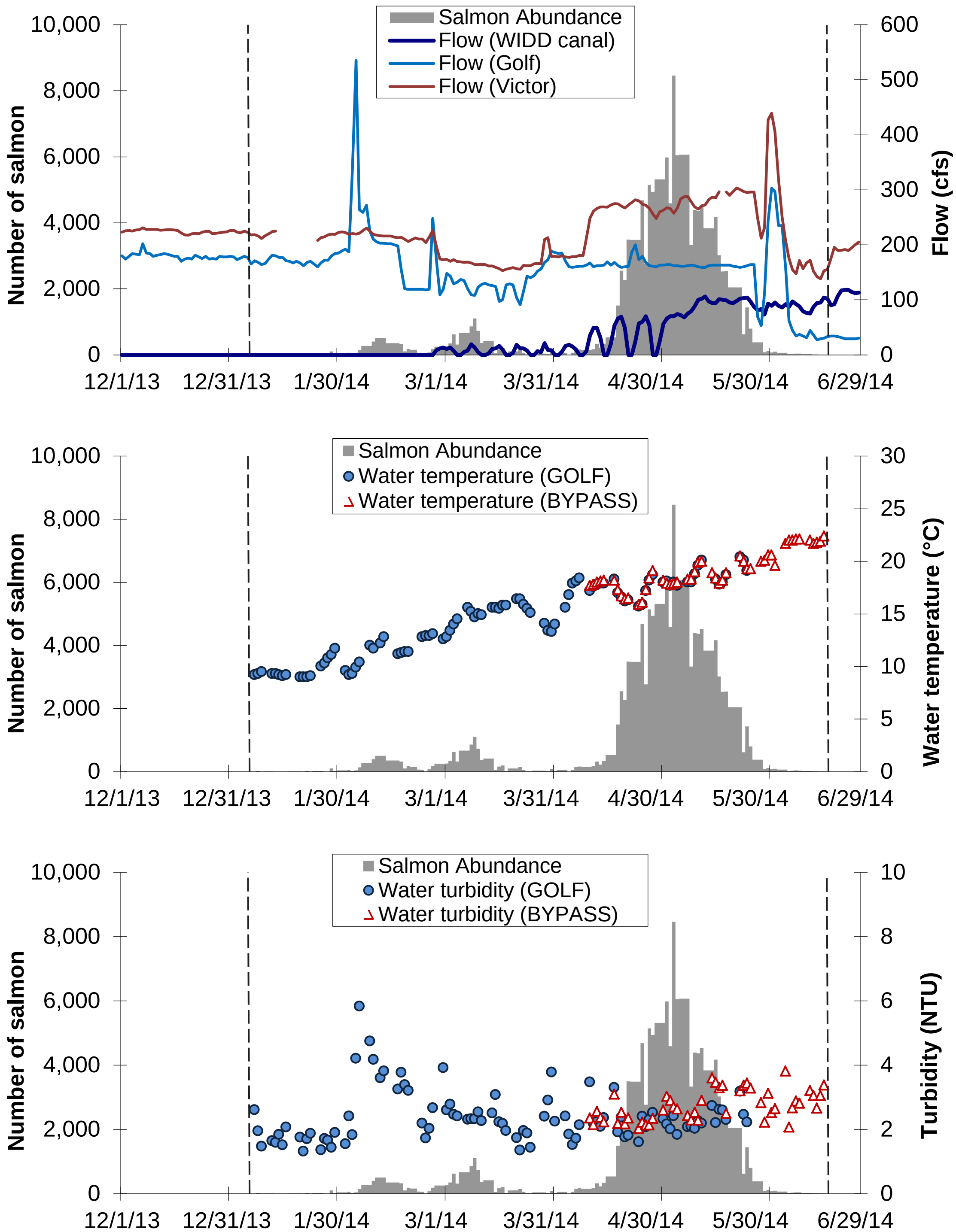
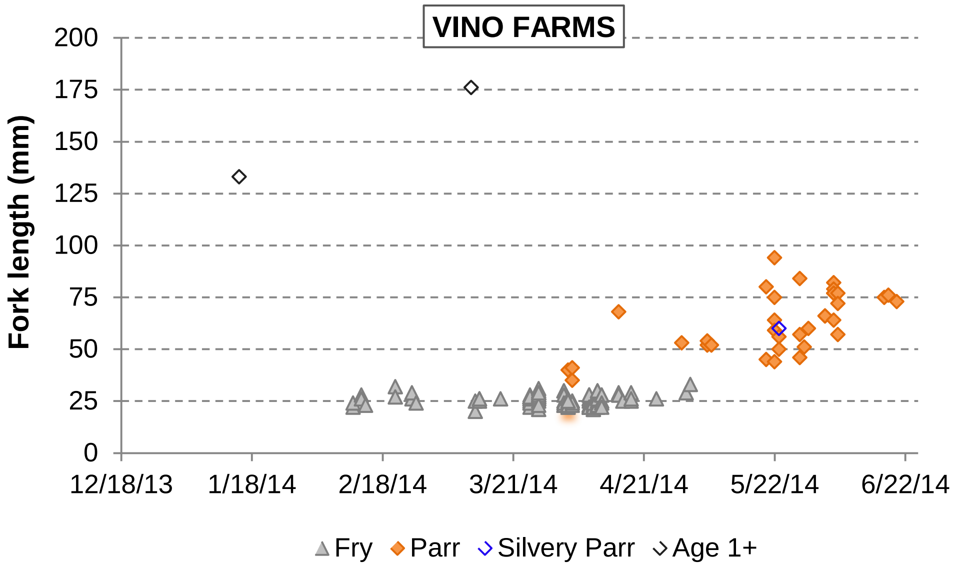


Figure 6. The relationship between estimated daily Chinook salmon abundance and flow (top), water temperature (middle), and turbidity (bottom) at the downstream trapping locations (GOLF & BYPASS) during the 2013/14 juvenile emigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.



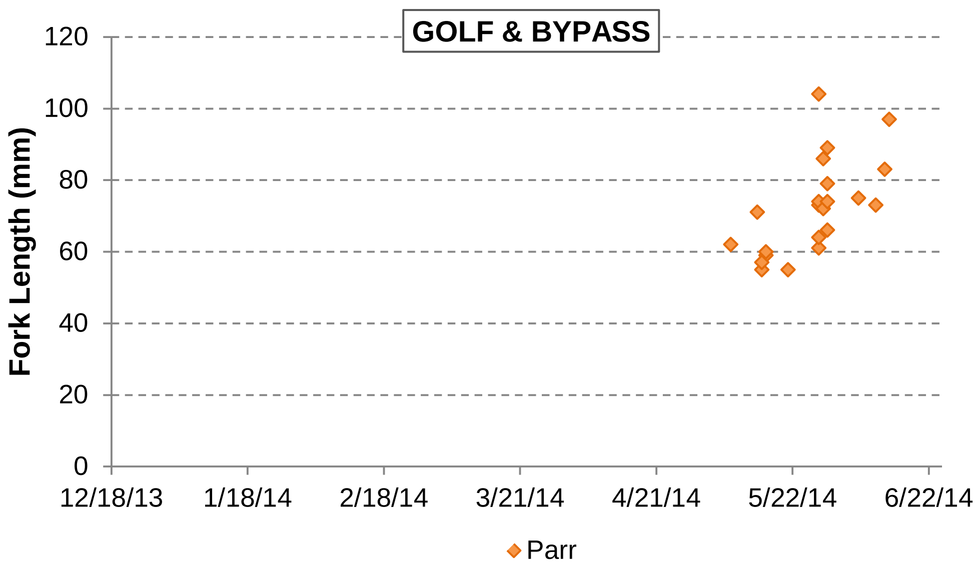


Figure 8. Size and life stage distribution of wild steelhead caught and measured at the upstream (VINO FARMS) and downstream (GOLF & BYPASS) trapping locations during the 2013/14 juvenile emigration monitoring season on the lower Mokelumne River.

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 2013/14 monitoring period. Shaded areas represent non-trapping periods.

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
12/18/2013	0	0.1554	**0**	0	0
12/19/2013	0	0.1554	**0**	0	0
12/20/2013	2	0.1554	**13**	10	19
12/21/2013	3	0.1554	**18**	13	26
12/22/2013	3	0.1554	**18**	13	26
12/23/2013	3	0.1554	**18**	13	26
12/24/2013	9	0.1554	**58**	44	86
12/25/2013	78	0.1554	**499**	376	744
12/26/2013	78	0.1554	**499**	376	744
12/27/2013	78	0.1554	**499**	376	744
12/28/2013	78	0.1554	**499**	376	744
12/29/2013	78	0.1554	**499**	376	744
12/30/2013	78	0.1554	**499**	376	744
12/31/2013	71	0.1554	**457**	344	681
1/1/2014	116	0.1554	**743**	559	1,107
1/2/2014	115	0.1554	**740**	557	1,102
1/3/2014	117	0.1554	**753**	566	1,122
1/4/2014	116	0.1554	**744**	560	1,108
1/5/2014	116	0.1554	**744**	560	1,108
1/6/2014	116	0.1554	**744**	560	1,108
1/7/2014	22	0.1554	**142**	107	211
1/8/2014	195	0.1554	**1,255**	944	1,869
1/9/2014	129	0.1554	**830**	625	1,237
1/10/2014	128	0.1554	**823**	620	1,227
1/11/2014	146	0.1554	**937**	705	1,396
1/12/2014	146	0.1554	**937**	705	1,396
1/13/2014	146	0.1554	**937**	705	1,396
1/14/2014	160	0.1554	**1,029**	775	1,534
1/15/2014	122	0.1824	**669**	503	997
1/16/2014	140	0.1824	**768**	578	1,144
1/17/2014	267	0.1824	**1,464**	1,101	2,182
1/18/2014	441	0.1824	**2,415**	1,817	3,600
1/19/2014	441	0.1824	**2,415**	1,817	3,600
1/20/2014	441	0.1824	**2,415**	1,817	3,600
1/21/2014	441	0.1824	**2,415**	1,817	3,600
1/22/2014	723	0.1824	**3,964**	2,982	5,909
1/23/2014	640	0.1824	**3,509**	2,640	5,230
1/24/2014	751	0.1824	**4,118**	3,098	6,137
1/25/2014	510	0.1824	**2,794**	2,102	4,165
1/26/2014	510	0.1824	**2,794**	2,102	4,165
1/27/2014	510	0.1824	**2,794**	2,102	4,165
1/28/2014	301	0.1824	**1,650**	1,242	2,460

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
1/29/2014	430	0.2274	**1,891**	1,564	2,390
1/30/2014	213	0.2274	**937**	775	1,184
1/31/2014	703	0.2274	**3,091**	2,557	3,907
2/1/2014	600	0.2274	**2,637**	2,181	3,333
2/2/2014	600	0.2274	**2,637**	2,181	3,333
2/3/2014	600	0.2274	**2,637**	2,181	3,333
2/4/2014	953	0.2274	**4,190**	3,466	5,297
2/5/2014	1,115	0.2274	**4,903**	4,055	6,197
2/6/2014	184	0.2274	**809**	669	1,023
2/7/2014	96	0.2274	**422**	349	534
2/8/2014	370	0.2274	**1,626**	1,345	2,056
2/9/2014	370	0.2274	**1,626**	1,345	2,056
2/10/2014	370	0.2274	**1,626**	1,345	2,056
2/11/2014	297	0.2274	**1,306**	1,080	1,651
2/12/2014	263	0.1284	**2,049**	1,580	2,913
2/13/2014	264	0.1284	**2,056**	1,586	2,925
2/14/2014	166	0.1284	**1,293**	997	1,839
2/15/2014	1,138	0.1284	**8,864**	6,835	12,607
2/16/2014	1,138	0.1284	**8,864**	6,835	12,607
2/17/2014	1,138	0.1284	**8,864**	6,835	12,607
2/18/2014	1,138	0.1284	**8,864**	6,835	12,607
2/19/2014	1,120	0.1284	**8,724**	6,727	12,407
2/20/2014	1,437	0.1284	**11,193**	8,631	15,919
2/21/2014	3,578	0.1284	**27,870**	21,491	39,637
2/22/2014	2,071	0.1284	**16,130**	12,438	22,940
2/23/2014	2,071	0.1284	**16,130**	12,438	22,940
2/24/2014	2,071	0.1284	**16,130**	12,438	22,940
2/25/2014	2,707	0.1284	**21,086**	16,260	29,988
2/26/2014	2,070	0.0900	**23,000**	18,720	33,700
2/27/2014	1,513	0.0900	**16,811**	13,683	24,632
2/28/2014	893	0.0900	**9,922**	8,076	14,538
3/1/2014	904	0.0900	**10,041**	8,172	14,712
3/2/2014	904	0.0900	**10,041**	8,172	14,712
3/3/2014	904	0.0900	**10,041**	8,172	14,712
3/4/2014	315	0.0900	**3,500**	2,849	5,128
3/5/2014	328	0.0900	**3,644**	2,966	5,340
3/6/2014	303	0.0900	**3,367**	2,740	4,933
3/7/2014	1,779	0.0900	**19,767**	16,089	28,962
3/8/2014	620	0.0900	**6,887**	5,606	10,091
3/9/2014	620	0.0900	**6,887**	5,606	10,091
3/10/2014	620	0.0900	**6,887**	5,606	10,091
3/11/2014	636	0.0900	**7,067**	5,752	10,354
3/12/2014	423	0.0506	**8,355**	6,246	12,612
3/13/2014	250	0.0506	**4,938**	3,691	7,454
3/14/2014	178	0.0506	**3,516**	2,628	5,307
3/15/2014	200	0.0506	**3,947**	2,951	5,958

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
3/16/2014	200	0.0506	**3,947**	2,951	5,958
3/17/2014	200	0.0506	**3,947**	2,951	5,958
3/18/2014	151	0.0506	**2,982**	2,230	4,502
3/19/2014	136	0.0506	**2,686**	2,008	4,055
3/20/2014	61	0.0506	**1,205**	901	1,819
3/21/2014	78	0.0506	**1,541**	1,152	2,326
3/22/2014	74	0.0506	**1,468**	1,098	2,216
3/23/2014	74	0.0506	**1,468**	1,098	2,216
3/24/2014	74	0.0506	**1,468**	1,098	2,216
3/25/2014	75	0.0506	**1,481**	1,107	2,236
3/26/2014	43	0.0506	**849**	635	1,282
3/27/2014	53	0.0506	**1,047**	783	1,580
3/28/2014	39	0.0506	**770**	576	1,163
3/29/2014	48	0.0506	**948**	709	1,431
3/30/2014	48	0.0506	**948**	709	1,431
3/31/2014	48	0.0506	**948**	709	1,431
4/1/2014	48	0.0506	**948**	709	1,431
4/2/2014	58	0.0506	**1,146**	856	1,729
4/3/2014	57	0.0506	**1,126**	842	1,699
4/4/2014	38	0.0506	**751**	561	1,133
4/5/2014	40	0.0506	**783**	586	1,183
4/6/2014	40	0.0506	**783**	586	1,183
4/7/2014	40	0.0506	**783**	586	1,183
4/8/2014	33	0.0506	**652**	487	984
4/9/2014	31	0.0506	**612**	458	924
4/10/2014	21	0.0506	**415**	310	626
4/11/2014	25	0.0506	**494**	369	745
4/12/2014	49	0.0506	**968**	723	1,461
4/13/2014	49	0.0506	**968**	723	1,461
4/14/2014	49	0.0506	**968**	723	1,461
4/15/2014	76	0.0121	**6,281**	3,766	12,608
4/16/2014	64	0.0121	**5,289**	3,171	10,617
4/17/2014	77	0.0121	**6,364**	3,815	12,774
4/18/2014	73	0.0121	**6,033**	3,617	12,111
4/19/2014	62	0.0121	**5,152**	3,089	10,341
4/20/2014	62	0.0121	**5,152**	3,089	10,341
4/21/2014	62	0.0121	**5,152**	3,089	10,341
4/22/2014	29	0.0121	**2,397**	1,437	4,811
4/23/2014	79	0.0121	**6,529**	3,914	13,106
4/24/2014	52	0.0121	**4,298**	2,577	8,627
4/25/2014	13	0.0121	**1,074**	644	2,157
4/26/2014	48	0.0121	**3,994**	2,395	8,018
4/27/2014	48	0.0121	**3,994**	2,395	8,018
4/28/2014	48	0.0121	**3,994**	2,395	8,018
4/29/2014	71	0.0121	**5,868**	3,518	11,779

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
4/30/2014	51	0.0121	**4,215**	2,527	8,461
5/1/2014	24	0.0121	**1,983**	1,189	3,982
5/2/2014	33	0.0121	**2,727**	1,635	5,475
5/3/2014	37	0.0121	**3,058**	1,833	6,138
5/4/2014	37	0.0121	**3,058**	1,833	6,138
5/5/2014	37	0.0121	**3,058**	1,833	6,138
5/6/2014	49	0.0121	**4,050**	2,428	8,129
5/7/2014	48	0.0121	**3,967**	2,378	7,963
5/8/2014	17	0.0121	**1,405**	842	2,820
5/9/2014	26	0.0121	**2,149**	1,288	4,313
5/10/2014	26	0.0121	**2,149**	1,288	4,313
5/11/2014	26	0.0121	**2,149**	1,288	4,313
5/12/2014	26	0.0121	**2,149**	1,288	4,313
5/13/2014	22	0.0121	**1,818**	1,090	3,650
5/14/2014	19	0.0121	**1,570**	941	3,152
5/15/2014	24	0.0121	**1,983**	1,189	3,982
5/16/2014	12	0.0121	**992**	595	1,991
5/17/2014	32	0.0121	**2,603**	1,561	5,226
5/18/2014	32	0.0121	**2,603**	1,561	5,226
5/19/2014	32	0.0121	**2,603**	1,561	5,226
5/20/2014	48	0.0121	**3,967**	2,378	7,963
5/21/2014	46	0.0121	**3,802**	2,279	7,631
5/22/2014	40	0.0121	**3,306**	1,982	6,636
5/23/2014	43	0.0121	**3,554**	2,131	7,134
5/24/2014	29	0.0121	**2,369**	1,420	4,756
5/25/2014	29	0.0121	**2,369**	1,420	4,756
5/26/2014	29	0.0121	**2,369**	1,420	4,756
5/27/2014	29	0.0121	**2,369**	1,420	4,756
5/28/2014	14	0.0110	**1,274**	802	3,090
5/29/2014	18	0.0110	**1,638**	1,032	3,973
5/30/2014	11	0.0110	**1,001**	630	2,428
5/31/2014	12	0.0110	**1,122**	707	2,722
6/1/2014	12	0.0110	**1,122**	707	2,722
6/2/2014	12	0.0110	**1,122**	707	2,722
6/3/2014	8	0.0111	**723**	456	1,755
6/4/2014	17	0.0111	**1,537**	969	3,730
6/5/2014	6	0.0111	**542**	342	1,316
6/6/2014	8	0.0111	**723**	456	1,755
6/7/2014	6	0.0111	**558**	351	1,353
6/8/2014	6	0.0111	**558**	351	1,353
6/9/2014	6	0.0111	**558**	351	1,353
6/10/2014	1	0.0111	**90**	57	219
6/11/2014	1	0.0111	**90**	57	219
6/12/2014	4	0.0111	**362**	228	878
6/13/2014	2	0.0111	**181**	114	439

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
6/14/2014	2	0.0111	**136**	85	329
6/15/2014	2	0.0111	**136**	85	329
6/16/2014	2	0.0111	**136**	85	329
6/17/2014	0	0.0111	**0**	0	0
6/18/2014	1	0.0099	**101**	63	265
6/19/2014	1	0.0099	**101**	63	265
6/20/2014	0	0.0099	**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 2013/14 monitoring period. Shaded areas represent non-trapping periods.

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
1/8/2014	0	0.0499	0	–	**0**	0	0
1/9/2014	1	0.0499	20	–	**20**	14	32
1/10/2014	0	0.0499	0	–	**0**	0	0
1/11/2014	0	0.0499	3	–	**3**	2	5
1/12/2014	0	0.0499	3	–	**3**	2	5
1/13/2014	0	0.0499	3	–	**3**	2	5
1/14/2014	0	0.0499	0	–	**0**	0	0
1/15/2014	0	0.0499	0	–	**0**	0	0
1/16/2014	0	0.0499	0	–	**0**	0	0
1/17/2014	0	0.0499	0	–	**0**	0	0
1/18/2014	0	0.0499	3	–	**3**	2	5
1/19/2014	0	0.0499	3	–	**3**	2	5
1/20/2014	0	0.0499	3	–	**3**	2	5
1/21/2014	0	0.0499	3	–	**3**	2	5
1/22/2014	0	0.0499	0	–	**0**	0	0
1/23/2014	1	0.0499	20	–	**20**	14	32
1/24/2014	0	0.0499	0	–	**0**	0	0
1/25/2014	1	0.0499	20	–	**20**	14	32
1/26/2014	1	0.0499	20	–	**20**	14	32
1/27/2014	1	0.0499	20	–	**20**	14	32
1/28/2014	0	0.0499	0	–	**0**	0	0
1/29/2014	0	0.0499	0	–	**0**	0	0
1/30/2014	5	0.0499	100	–	**100**	72	162
1/31/2014	1	0.0499	20	–	**20**	14	32
2/1/2014	2	0.0499	40	–	**40**	29	65
2/2/2014	2	0.0499	40	–	**40**	29	65
2/3/2014	2	0.0499	40	–	**40**	29	65
2/4/2014	3	0.0499	60	–	**60**	43	97
2/5/2014	1	0.0499	20	–	**20**	14	32
2/6/2014	2	0.0499	40	–	**40**	29	65
2/7/2014	7	0.0499	140	–	**140**	101	227
2/8/2014	13	0.0499	267	–	**267**	193	432
2/9/2014	13	0.0499	267	–	**267**	193	432
2/10/2014	13	0.0499	267	–	**267**	193	432
2/11/2014	20	0.0499	401	–	**401**	290	649
2/12/2014	25	0.0499	501	–	**501**	362	811
2/13/2014	25	0.0499	501	–	**501**	362	811
2/14/2014	25	0.0499	501	–	**501**	362	811
2/15/2014	18	0.0499	351	–	**351**	254	568
2/16/2014	18	0.0499	351	–	**351**	254	568
2/17/2014	18	0.0499	351	–	**351**	254	568
2/18/2014	18	0.0499	351	–	**351**	254	568
2/19/2014	16	0.0499	321	–	**321**	232	519

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
2/20/2014	5	0.0499	100	–	**100**	72	162
2/21/2014	9	0.0499	180	–	**180**	130	292
2/22/2014	8	0.0499	157	–	**157**	114	254
2/23/2014	8	0.0499	157	–	**157**	114	254
2/24/2014	8	0.1205	65	–	**65**	50	93
2/25/2014	7	0.1205	58	–	**58**	45	83
2/26/2014	1	0.1205	8	–	**8**	6	12
2/27/2014	9	0.1205	75	–	**75**	57	107
2/28/2014	22	0.1205	183	–	**183**	140	262
3/1/2014	30	0.1205	249	–	**249**	191	357
3/2/2014	30	0.1205	249	–	**249**	191	357
3/3/2014	30	0.1205	249	–	**249**	191	357
3/4/2014	31	0.1205	257	–	**257**	198	369
3/5/2014	42	0.1205	348	–	**348**	268	499
3/6/2014	75	0.1205	622	–	**622**	478	892
3/7/2014	38	0.1205	315	–	**315**	242	452
3/8/2014	80	0.1205	664	–	**664**	510	951
3/9/2014	80	0.1205	664	–	**664**	510	951
3/10/2014	80	0.1205	664	–	**664**	510	951
3/11/2014	104	0.1205	863	–	**863**	663	1,237
3/12/2014	133	0.1205	1,104	–	**1,104**	847	1,581
3/13/2014	88	0.1205	730	–	**730**	561	1,046
3/14/2014	44	0.1205	365	–	**365**	280	523
3/15/2014	50	0.1205	418	–	**418**	321	598
3/16/2014	50	0.1205	418	–	**418**	321	598
3/17/2014	50	0.1205	418	–	**418**	321	598
3/18/2014	6	0.1205	50	–	**50**	38	71
3/19/2014	14	0.0846	165	–	**165**	106	381
3/20/2014	17	0.0846	201	–	**201**	128	462
3/21/2014	2	0.0846	24	–	**24**	15	54
3/22/2014	9	0.0846	100	–	**100**	64	231
3/23/2014	9	0.0846	100	–	**100**	64	231
3/24/2014	9	0.0846	100	–	**100**	64	231
3/25/2014	12	0.0846	142	–	**142**	91	326
3/26/2014	5	0.0846	59	–	**59**	38	136
3/27/2014	1	0.0846	12	–	**12**	8	27
3/28/2014	1	0.0846	12	–	**12**	8	27
3/29/2014	3	0.0846	35	–	**35**	23	82
3/30/2014	3	0.0846	35	–	**35**	23	82
3/31/2014	3	0.0846	35	–	**35**	23	82
4/1/2014	3	0.0846	35	–	**35**	23	82
4/2/2014	2	0.0846	24	–	**24**	15	54
4/3/2014	7	0.0846	83	–	**83**	53	190
4/4/2014	2	0.0846	24	–	**24**	15	54
4/5/2014	5	0.0846	57	–	**57**	36	131
4/6/2014	5	0.0846	57	–	**57**	36	131

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
4/7/2014	5	0.0846	57	–	**57**	36	131
4/8/2014	0	0.0846	0	–	**0**	0	0
4/9/2014	5	0.0846	59	–	**59**	38	136
4/10/2014	13	0.0846	154	–	**154**	98	354
4/11/2014	14	0.0846	165	–	**165**	106	381
4/12/2014	13	0.0846	150	–	**150**	96	344
4/13/2014	13	0.0846	150	–	**150**	96	344
4/14/2014	13	0.0846	150	–	**150**	96	344
4/15/2014	10	0.0846	118	49	**167**	124	321
4/16/2014	22	0.0846	260	59	**319**	225	657
4/17/2014	12	0.0846	142	82	**224**	173	408
4/18/2014	8	0.0846	95	245	**340**	305	463
4/19/2014	12	0.0846	142	389	**531**	480	715
4/20/2014	12	0.0846	142	389	**531**	480	715
4/21/2014	12	0.0846	142	389	**531**	480	715
4/22/2014	8	0.0069	1,164	332	**1,496**	1,077	3,002
4/23/2014	13	0.0069	1,892	659	**2,551**	1,869	4,998
4/24/2014	9	0.0069	1,310	958	**2,268**	1,796	3,962
4/25/2014	14	0.0069	2,038	1,456	**3,494**	2,759	6,129
4/26/2014	16	0.0069	2,305	1,180	**3,484**	2,654	6,465
4/27/2014	16	0.0069	2,305	1,180	**3,484**	2,654	6,465
4/28/2014	16	0.0069	2,305	1,180	**3,484**	2,654	6,465
4/29/2014	27	0.0069	3,930	750	**4,680**	3,263	9,763
4/30/2014	9	0.0069	1,310	1,455	**2,765**	2,293	4,459
5/1/2014	23	0.0069	3,348	1,800	**5,148**	3,941	9,477
5/2/2014	23	0.0069	3,348	1,593	**4,941**	3,734	9,270
5/3/2014	20	0.0069	2,935	2,380	**5,315**	4,257	9,111
5/4/2014	20	0.0069	2,935	2,380	**5,315**	4,257	9,111
5/5/2014	20	0.0069	2,935	2,380	**5,315**	4,257	9,111
5/6/2014	23	0.0069	3,348	2,636	**5,984**	4,777	10,313
5/7/2014	22	0.0069	3,130	1,461	**4,591**	3,462	8,638
5/8/2014	22	0.0069	3,130	5,334	**8,464**	7,335	12,511
5/9/2014	14	0.0069	2,038	4,013	**6,051**	5,316	8,686
5/10/2014	22	0.0069	3,202	2,861	**6,063**	4,909	10,205
5/11/2014	22	0.0069	3,202	2,861	**6,063**	4,909	10,205
5/12/2014	22	0.0069	3,202	2,861	**6,063**	4,909	10,205
5/13/2014	23	0.0131	1,760	1,574	**3,334**	2,717	5,401
5/14/2014	23	0.0131	1,760	2,634	**4,394**	3,777	6,461
5/15/2014	29	0.0131	2,219	2,150	**4,369**	3,591	6,976
5/16/2014	27	0.0131	2,066	2,464	**4,530**	3,806	6,957
5/17/2014	29	0.0131	2,244	1,591	**3,835**	3,049	6,472
5/18/2014	29	0.0131	2,244	1,591	**3,835**	3,049	6,472
5/19/2014	29	0.0131	2,244	1,591	**3,835**	3,049	6,472
5/20/2014	46	0.0131	3,520	653	**4,173**	2,939	8,308
5/21/2014	30	0.0131	2,295	725	**3,020**	2,216	5,717
5/22/2014	21	0.0131	1,607	921	**2,528**	1,965	4,415

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
5/23/2014	23	0.0131	1,760	777	**2,537**	1,920	4,604
5/24/2014	17	0.0131	1,301	739	**2,040**	1,584	3,568
5/25/2014	17	0.0131	1,301	739	**2,040**	1,584	3,568
5/26/2014	17	0.0131	1,301	739	**2,040**	1,584	3,568
5/27/2014	17	0.0131	1,301	739	**2,040**	1,584	3,568
5/28/2014	2	0.0131	153	466	**619**	565	799
5/29/2014	9	0.0131	689	749	**1,438**	1,196	2,247
5/30/2014	–	–	–	796	**796**	796	796
5/31/2014	–	–	–	380	**380**	380	380
6/1/2014	–	–	–	380	**380**	380	380
6/2/2014	–	–	–	380	**380**	380	380
6/3/2014	–	–	–	82	**82**	82	82
6/4/2014	–	–	–	116	**116**	116	116
6/5/2014	–	–	–	72	**72**	72	72
6/6/2014	–	–	–	93	**93**	93	93
6/7/2014	–	–	–	63	**63**	63	63
6/8/2014	–	–	–	63	**63**	63	63
6/9/2014	–	–	–	63	**63**	63	63
6/10/2014	–	–	–	23	**23**	23	23
6/11/2014	–	–	–	32	**32**	32	32
6/12/2014	–	–	–	39	**39**	39	39
6/13/2014	–	–	–	36	**36**	36	36
6/14/2014	–	–	–	23	**23**	23	23
6/15/2014	–	–	–	23	**23**	23	23
6/16/2014	–	–	–	23	**23**	23	23
6/17/2014	–	–	–	13	**13**	13	13
6/18/2014	–	–	–	14	**14**	14	14
6/19/2014	–	–	–	6	**6**	6	6
6/20/2014	–	–	–	6	**6**	6	6

Appendix C. Monthly totals of species caught at the upstream RST (VINO) on the lower Mokelumne River during the 2013/14 juvenile emigration monitoring season.

Common Name	**Genus**	**Species**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Total**
Black Bass	*Micropterus*	*spp.*	0	0	0	0	0	1	65	**66**
Bluegill	*Lepomis*	*macrochirus*	0	0	0	0	1	3	7	**11**
Channel Catfish	*Ictalurus*	*punctatus*	0	0	0	0	1	0	0	**1**
Chinook Salmon (Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	2	10	5	6	5	0	0	**28**
Chinook Salmon (No Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	82	5,272	16,656	4,848	848	494	49	**28,249**
Common Carp	*Cyprinus*	*carpio*	0	0	0	0	0	0	4	**4**
Golden Shiner	*Notemigonus*	*crysoleucas*	0	0	0	6	2	0	0	**8**
Hitch	*Lavinia*	*exilicauda*	0	0	4	14	12	2	0	**32**
Pacific Lamprey	*Lampetra*	*tridentata*	22	51	66	115	132	153	295	**834**
Prickly Sculpin	*Cottus*	*asper*	0	4	4	15	11	127	407	**568**
Redear Sunfish	*Lepomis*	*microlophus*	0	0	0	0	0	2	12	**14**
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	0	0	0	0	4	1	0	**5**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	0	0	0	1	15	185	**201**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	0	1	10	43	76	20	15	**165**
Tule Perch	*Hysterocarpus*	*traski*	7	14	20	75	25	2	8	**151**
Western Mosquitofish	*Gambusia*	*affinis*	0	0	0	0	0	2	1	**3**

Appendix D. Monthly totals of fish species caught at the downstream traps (GOLF and BYPASS) on the lower Mokelumne River during the 2013/14 juvenile emigration monitoring season.

Common Name	**Genus**	**Species**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Total**
Black Bass	*Micropterus*	*spp.*	0	12	0	4,176	9,623	8,959	**22,770**
Black Crappie	*Pomoxis*	*nigromaculatus*	2	20	0	0	3	0	**25**
Bluegill	*Lepomis*	*macrochirus*	2	75	2	4	13	7	**103**
Brown Bullhead	*Ameiurus*	*nebulosus*	0	2	0	0	2	0	**4**
Chinook Salmon (Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	19	37	3	6	8	1	**74**
Chinook Salmon (No Ad-Clip)	*Oncorhyhchus*	*tshawytscha*	8	177	613	6,220	31,066	532	**38,616**
Common Carp	*Cyprinus*	*carpio*	0	2	0	0	7	3	**12**
Golden Shiner	*Notemigonus*	*crysoleucas*	0	3	4	0	1	0	**8**
Goldfish	*Carassius*	*auratus*	0	0	0	0	0	1	**1**
Green Sunfish	*Lepomis*	*cyanellus*	0	1	0	0	0	0	**1**
Largemouth Bass	*Micropterus*	*salmoides*	0	8	0	0	0	0	**8**
Lepomis hybrid	*Lepomis*	*spp.*	0	2	0	0	0	0	**2**
Pacific Lamprey	*Lampetra*	*tridentata*	1	2	1	11	6	5	**26**
Prickly Sculpin	*Cottus*	*asper*	7	32	25	754	342	76	**1,236**
Redear Sunfish	*Lepomis*	*microlophus*	0	1	0	0	2	1	**4**
Sacramento Sucker	*Catostomus*	*occidentalis*	0	0	0	53	2	0	**55**
Spotted Bass	*Micropterus*	*punctulatus*	0	3	0	0	0	0	**3**
Steelhead (Ad-Clip)	*Oncorhynchus*	*mykiss*	0	1	0	2	0	1	**4**
Steelhead (No Ad-Clip)	*Oncorhynchus*	*mykiss*	0	0	0	0	21	4	**25**
Striped Bass	*Morone*	*saxatilis*	0	0	0	0	1	0	**1**
Tule Perch	*Hysterocarpus*	*traski*	0	5	0	14	91	65	**175**
White Catfish	*Ameiurus*	*catus*	0	0	0	0	2	1	**3**