Emigration of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*Oncorhynchus mykiss*) in the Lower Mokelumne River, December 2015 – July 2016

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SUMMARY

The emigration of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) on the lower Mokelumne River was monitored using two rotary screw traps (RST) and a bypass trap during the 2015/16 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 9 December 2015 to 1 July 2016. The downstream rotary screw trap (GOLF) was located just below the Lower Sacramento Road Bridge at rkm 61.8 and was operated from 6 January to 24 June 2016. The bypass trap (BYPASS), located at Woodbridge Irrigation District Dam (rkm 62.2), was operated from 5 April to 8 July 2016.

The first juvenile Chinook salmon was captured at the VINO RST on 12 January 2016. Including weekend estimates, catch of naturally produced young-of-the-year (YOY) Chinook salmon was 127,947 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 856,127 (95% CI: 689,152-1,201,359). Including weekend estimates, catch of wild YOY steelhead was 359 at the VINO RST during the 2015/16 season. The estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 7,007 (95% CI: 4,589-21,601).

The first juvenile Chinook salmon was captured at the downstream RST (GOLF) on 26 January 2016. Including weekend estimates, catch of naturally produced YOY Chinook salmon was 2,709 during the monitoring period. Nine trap efficiency tests were conducted at GOLF, all of which were conducted using hatchery produced salmon. The annual estimated abundance of naturally produced YOY Chinook salmon at the GOLF RST was 78,346 (95% CI: 56,589-127,458). Including weekend estimates, catch of wild YOY steelhead was 359 at the GOLF RST during the 2015/16 season. The estimated passage of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 428 (95% CI: 306-716).

The first juvenile Chinook salmon was captured at the bypass trap (BYPASS) on 6 April 2016. Including weekend estimates, catch of naturally produced YOY Chinook salmon was 31,373 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 134,593 (95% CI: 112,836-183,706). Including weekend estimates, catch of wild YOY was 35 at the BYPASS during the 2015/16 season. The total downstream passage estimate of wild YOY steelhead, calculated from adding the BYPASS trap catch to the GOLF RST estimate, was 463 (95% CI: 341-751).

Although age 1+ steelhead are captured during trapping, abundance estimates only calculate for YOY steelhead. Catch of other steelhead life stages are summarized below. At the VINO RST, four wild age 1+ steelhead were captured and classified as parr, smolts, and adults. Steelhead catch at the VINO RST also consisted of one hatchery origin (adipose fin-clipped) smolt. At the downstream traps (GOLF and BYPASS), four wild age 1+ steelhead were captured and classified as smolts. Steelhead catch at the downstream traps also consisted of 34 hatchery origin (adipose fin-clipped) age 1+ smolts and adults.

Twenty-one fish species were caught at the VINO RST during the survey period, eight native and thirteen 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) 23 fish species were caught, nine native and 14 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 161 cfs (4.6 m^3/s) to 667 cfs (18.9 m^3/s) during the monitoring period. From 1 October 2015 through 31 March 2016, EBMUD operated under a “Critically Dry” JSA water year type. From 1 April through 30 September 2016, EBMUD operated under a “Below Normal” 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 2015 through early July 2016.

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

One 8-ft and one 5-ft (cone diameter) rotary screw trap (E.G. Solutions, Inc.) were operated at upstream and downstream locations, respectively, on the lower Mokelumne River (Figure 1). The 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, a 5-ft RST was operated, just below Woodbridge Irrigation District Dam (WIDD) and adjacent to the Lodi Golf and Country Club at rkm 61.8. In this report, the upstream and downstream RST sites are referred to as VINO and GOLF, respectively.

During the 2015/16 monitoring season, RSTs were generally operated Monday through Friday, between December and June. During Monday through Friday operations, traps were taken out of service after each check on Friday afternoon and 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 2015/16 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 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 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 30 minutes. Approximately 0.5g of dye was added to a 5 gallon bucket of river water to prepare the solution. 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 taking an average of 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 taking an average of 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 lampreys, 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.

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) 2015 redd count and BY 2015 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 2015 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 0.50 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™ 10.2 (ESRI Inc.), JMP® 9.0.0 (SAS Institute Inc.), Microsoft® Office Access 2010 and Excel 2010. 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 154 cfs (4.4 m^3/s) to 653 cfs (18.5 m^3/s) during the time when the VINO trap was operated (8 December 2015 through 1 July 2016). The mean flow during that time was 312 cfs (8.8 m^3/s). Water temperatures recorded at VINO ranged from 7.9 to 14.8°C, with a mean of 11.5°C. Water turbidity at the VINO RST ranged from 2.2 to 20.9 Nephelometric Turbidity Units (NTU), with a mean of 5.3 NTU.

Average daily flow at the Golf gauging station ranged from 82 cfs (2.3 m^3/s) to 469 cfs (13.3 m^3/s) during the time when the GOLF RST was operated (6 January through 24 June 2016). The average daily flow during that time was 162 cfs (4.6 m^3/s). Water temperatures recorded at GOLF ranged from 8.3 to 19.0°C, with a mean of 14.2°C. Water turbidity at GOLF ranged from 3.3 to 13.8 NTU, with a mean of 6.0 NTU.

During the time that the BYPASS trap was operated (5 April through 8 July 2016) average daily flow at the Victor gauging station ranged from 291 cfs (8.3 m^3/s) to 605 cfs (17.1 m^3/s), with a mean of 400 cfs (11.3 m^3/s). Flow at the Woodbridge Irrigation District Canal ranged from 69 cfs (2.0 m^3/s) to 200 cfs (5.7 m^3/s) and averaged 138 cfs (3.9 m^3/s). Water temperatures recorded at the BYPASS ranged from 13.2 to 20.6°C, with a mean of 17.1°C. Water turbidity at the BYPASS ranged from 3.4 to 8.7 NTU, with a mean of 4.6 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 9 December 2015 and 1 July 2016. The cone was stopped by debris on 4 of 111 days when the trap was checked. Excluding days with trap stoppages, the minimum recorded cone rotation rate was 1.9 RPM and the maximum was 3.8 RPM. The mean rotation rate during the monitoring season was 2.8 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 0.5 and 1.0 m/s, with a mean of 0.8 m/s.

The 5-ft RST at GOLF was operated from 6 January to 24 June 2016. Debris stopped the cone from rotating on 12 of 76 days when the trap was checked. Excluding trap stoppages, the minimum cone rotation rate was 2.0 RPM and the maximum rate was 6.9 RPM. Average rotational speed was 4.1 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 1.0 m/s, with a mean of 0.7 m/s.

The BYPASS trap at WIDD was operated between 5 April and 8 July 2016. During this time frame the trap was checked on 53 days. Water velocity at the top of the trap ranged between 0.5 and 1.0 m/s and averaged 0.8 m/s.

RST Calibrations

Ten calibration tests were conducted for the VINO RST during the 2015/16 juvenile monitoring season (Table 1). Naturally produced Chinook salmon were used as test fish for six tests and Chinook salmon from the MRFI were used for four tests. Trap efficiency tests 9 and 10 were not used to generate daily abundance estimates because there were insufficient recaptures to produce reliable 95% confidence intervals. Excluding tests 9 and 10, trap efficiency ranged from 1.8% to 25.7% and averaged 11.5% (n = 8).

Nine calibration tests were conducted for the GOLF RST during the 2015/16 juvenile monitoring season (Table 1). Chinook salmon from the MRFI were used for all nine tests. Trap efficiency test 9 was not used to generate daily abundance estimates because there were insufficient recaptures to produce reliable 95% confidence intervals. Excluding test 9, trap efficiency ranged from 3.1% to 7.6%, with a mean of 4.8% (n = 8).

Chinook Salmon

<u>Catch and Abundance Estimates</u>

At the VINO RST, 66,524 naturally produced young-of-the-year (YOY) Chinook salmon were captured between 12 January and 1 July 2016. Estimates for weekend catch and selected trap stoppages were added to actual catch to produce an estimated count of 127,947 YOY Chinook salmon. Using trap efficiency data, the total estimated abundance of YOY salmon passing the upstream RST (VINO) was 856,127 (95% CI: 689,152-1,201,359). The highest monthly salmon abundance estimate was recorded in March at the VINO RST (Table 2).

At the GOLF RST, 1,261 naturally produced YOY Chinook salmon were captured between 26 January and 24 June 2016. Estimates for weekend catch and trap stoppages were added to the actual catch to produce an estimated count of 2,709 YOY Chinook salmon. Using trap efficiency data, the estimated abundance of YOY Chinook salmon at the GOLF RST was 78,346 (95% CI: 56,589-127,458).

At the BYPASS trap, 31,373 naturally produced YOY Chinook salmon were captured between 6 April and 8 July 2016. Estimates for weekend catch were added to the actual catch to produce an estimated count of 56,247 YOY Chinook salmon.

The total downstream emigration estimate of 134,593 YOY Chinook salmon (95% CI: 112,836-183,706) was calculated by adding the BYPASS catch estimate to the GOLF RST abundance estimate. At the downstream traps (GOLF & BYPASS), the highest monthly salmon abundance estimate was recorded during the month of May (Table 2).

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

At the VINO RST, 96.1% (n=65,823) of the naturally produced Chinook salmon catch was classified as fry. The remaining catch was classified as parr (0.4%, n=272), silvery parr (0.3%, n=178), smolts (1.5%, n=1,068), and YOY (1.7%, n=1,145). In addition, 2,335 hatchery origin (adipose fin-clipped) Chinook salmon smolts and 41 hatchery origin silvery parr 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 2015/16 season is provided by Figure 3.

At the downstream traps, naturally produced Chinook salmon catch was primarily composed of smolts (99.2%, n=32,385). The remaining catch was classified as fry (0.6%, n=192), parr (0.02%, n=8), and silvery parr (0.2%, n=50). In addition, 17,108 hatchery origin (adipose fin-clipped) Chinook salmon smolts were caught at the GOLF and BYPASS traps. The size distribution by life stage of naturally produced Chinook salmon caught and measured at the downstream traps during the 2015/16 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).

Migration Response

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 2015/16 monitoring season are presented graphically in Figures 5 and 6.

At the upstream trap, daily water turbidity and average daily water temperature (Elliot, rkm 86.1) were the variables included in the generalized linear model (GLM) with the lowest AICc (Table 3). Turbidity had a significant positive relationship with daily salmon abundance (parameter estimate = 0.1291). Weekly salmon redd emergence and weekly salmon abundance had a significant positive correlation at the upstream trap (r = 0.59, r =0.0011).

At the downstream traps, daily water turbidity was the only variable included in the GLM with the lowest AICc (Table 3). Turbidity had a significant negative relationship with daily salmon abundance (parameter estimate = -0.3695). Weekly redd emergence and weekly salmon abundance had a significant negative correlation at the downstream traps (r = -0.58, r = 0.0027).

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

During the BY 2015 spawning season, 1,359 Chinook salmon redds were identified in the LMR. The BY 2015 average salmon fecundity estimate (per female spawned at the MRFI) was 4,239 eggs. The resulting estimated salmon production at 100% survival was 5,760,801 juveniles. The BY 2015 egg-to-YOY survival index for naturally produced YOY Chinook salmon at the upstream trap (VINO) was 0.15 (95% CI: 0.11-0.21). At the downstream traps (GOLF and BYPASS), the BY 2015 survival index was 0.02 (95% CI: 0.02-0.03). The BY 2015 upstream survival index was average, relative to other brood years that experienced below normal or dry water year types (Table 4). The BY 2015 downstream survival index was low, similar to BY 2011-2014.

Steelhead

Catch and Abundance Estimates

At the VINO RST, 207 wild YOY steelhead were captured between 2 March and 1 July 2016. Estimates for weekend catch were added to actual catch to produce an estimated count of 359 naturally produced steelhead. The estimated abundance of wild YOY steelhead (based on trap calibrations using Chinook salmon) was 7,007 (95% CI: 4,589-21,601). The largest monthly catch of wild steelhead (111) occurred at VINO in April.

At the GOLF RST, nine wild YOY steelhead were captured between 24 March and 23 June 2016. Estimates for weekend catch and trap stoppages were added to actual catch to produce an estimated count of 16 naturally produced YOY steelhead. The estimated passage of wild YOY steelhead at GOLF (based on trap calibrations using Chinook salmon) was 428 (95% CI: 306-716). At the BYPASS, 21 YOY steelhead were captured between 12 April and 8 July 2016. Estimates for weekend catch were added to actual catch to produce an estimated count of 35 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 463 (95% CI: 341-751). The largest monthly catch of wild YOY steelhead (11) occurred at the downstream traps in June.

Life stage and size

At the VINO RST, 90.0% (n=190) of the naturally produced steelhead catch was classified as fry. The remaining wild steelhead catch was composed of parr (8.1%, n=17) and age 1+ parr, smolts, and adults (1.9%, n=4). Steelhead catch at the VINO RST also consisted of one hatchery origin (adipose fin-clipped) smolt.

At the downstream traps (GOLF and BYPASS), 61.1% (n=22) of the wild steelhead catch was classified as parr. The remaining wild steelhead catch was composed of fry (27.8%, n=10) and age 1+ smolts (11.1%, n=4). Steelhead catch at the downstream traps also consisted of 34 hatchery origin (adipose fin-clipped) age 1+ smolts and adults.

The size distribution by life stage of all wild steelhead measured at the upstream and downstream traps is presented in Figure 7.

Species Composition

Twenty-one fish species were caught at the VINO RST during the survey period, eight native and thirteen non-native species. Native fish species were more frequently caught than non-native species, comprising 99.5% of the total catch. Chinook salmon (no adipose fin-clip) was the most abundant species caught (75.1%), followed by Pacific lamprey (*Entosphenus tridentatus)* (20.8%), and tule perch (*Hysterocarpus traski*) (0.5%).

At the downstream traps (GOLF and BYPASS), twenty-three fish species were caught, nine native and fourteen non-native species. Native fish species were more frequently caught than non-native species, comprising 66.5% of the total catch. Chinook salmon (no adipose fin-clip) was the most abundant species caught (33.4%), followed by unidentified juvenile black bass (*Micropterus spp.)* (29.5%), and prickly sculpin (*Cottus asper*) (10.5%).

DISCUSSION

During the 2015/2016 juvenile outmigration monitoring season, the VINO RST was stopped by debris on four of 111 days when the trap was checked. Salmon catch was estimated at VINO on one of the four days with trap stoppages (1 March 2016), which occurred near the peak of juvenile salmon outmigration at the upstream trap. The GOLF RST was stopped by debris twelve times throughout the monitoring season. Salmon catch was estimated at GOLF on seven of the twelve days with trap stoppages, when trap revolutions were low and moderate numbers of salmon were moving past the trap. During the other days when the GOLF or VINO traps were stopped, salmon catch was not estimated because the trap stops occurred outside of the peak of salmon outmigration at the traps. These days may have led to a small, but not significant, underestimate of salmon abundance at the VINO and GOLF traps.

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 (late April through June), trap efficiency trials were conducted using parr and smolt-sized salmon from the MRFI. 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. Two tests (10 and 11) were not used due to an inadequate number of recaptures, which are needed to generate reliable 95% confidence intervals. These tests were conducted with larger smolt-sized salmon from the MRFI. The decreased capture efficiency was likely due to the improved swimming ability of larger smolt-sized salmon. In future monitoring seasons, it is recommended to increase the size of trap efficiency release groups towards the end of the season, when smolt-sized salmon are used as the test fish.

At the GOLF RST, all nine trap efficiency trials were run using groups of salmon from the MRFI. Eight of the nine tests were successful this season. Test 9 was not successful due to a trap stoppage the day after the release. Similar to the VINO RST, trap efficiencies steadily declined as salmon fork length increased.

The upstream juvenile abundance estimate at VINO, of 856,127 YOY Chinook salmon, ranked the 3rd highest (of 9) on record since the trap site was initiated in the 2007/08 juvenile outmigration season. The downstream juvenile salmon abundance estimate of 134,593 ranked the 15th highest (of 24) on record since the 1992/93 season. The annual juvenile salmon abundance estimates from upstream and downstream traps were somewhat average, relative to previous estimates. The BY 2015 upstream survival index was average, relative to other brood years that experienced below normal or dry water year types. The BY 2015 downstream survival index was low, similar to BY 2011-2014. Factors that may have contributed to the mortality of juvenile Chinook salmon in the

LMR include predation by native and non-native fish species, egg losses 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), warm water temperatures, limited rearing habitat, 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, daily water turbidity and average daily water temperature were the variables included in the GLM with the lowest AICc. Turbidity had a significant positive relationship with daily salmon abundance, establishing that most of the salmon passed the upstream trap when turbidity was high. In addition, weekly redd emergence and weekly salmon abundance had a significant positive correlation at the upstream trap. In previous seasons, a significant positive relationship between weekly redd emergence and Chinook salmon abundance has also been established (Bilski et al. 2013), indicating that the majority of juvenile salmon pass the upstream trap as fry and rear below Elliot Road.

At the downstream traps, turbidity was the only variable included in the GLM with the lowest AICc. Turbidity had a significant negative relationship with daily salmon abundance indicating that many juvenile salmon emigrated past the downstream traps when turbidity was low. In addition, weekly redd emergence and weekly salmon abundance had a significant negative correlation at the downstream traps. This result confirmed that few juvenile Chinook salmon moved past the downstream traps as fry and that the majority of juvenile salmon reared above the downstream traps and emigrated as smolts.

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Table 1. Summary of trap efficiency tests conducted at trapping locations on the lower Mokelumne River during the 2015/2016 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	28-Jan-16	189	LMR	35	221	39	**17.6%**	Yes
2	02-Feb-16	163	LMR	34	202	52	**25.7%**	Yes
3	23-Feb-16	156	LMR	35	513	99	**19.3%**	Yes
4	09-Mar-16	206	LMR	34	500	56	**11.2%**	Yes
5	29-Mar-16	279	LMR	35	585	36	**6.2%**	Yes
6	05-Apr-16	332	LMR	35	158	6	**3.8%**	Yes
7	19-Apr-16	345	MRFI	56	764	47	**6.2%**	Yes
8	16-May-16	430	MRFI	66	704	13	**1.8%**	Yes
9	06-Jun-16	474	MRFI	74	1,003	4	**0.4%**	No
10	20-Jun-16	512	MRFI	84	999	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	08-Feb-16	107	MRFI	37	502	38	**7.6%**	Yes
2	22-Feb-16	107	MRFI	42	501	26	**5.2%**	Yes
3	07-Mar-16	166	MRFI	36	502	23	**4.6%**	Yes
4	28-Mar-16	86	MRFI	50	500	21	**4.2%**	Yes
5	11-Apr-16	229	MRFI	55	516	33	**6.4%**	Yes
6	26-Apr-16	160	MRFI	65	774	29	**3.7%**	Yes
7	02-May-16	204	MRFI	63	811	25	**3.1%**	Yes
8	31-May-16	205	MRFI	80	703	23	**3.3%**	Yes
9	13-Jun-16	206	MRFI	78	988	0	**0.0%**	No

Table 2. Expanded monthly catch, juvenile abundance 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 2015/2016 trapping season.

Upstream (VINO FARMS)					
Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
December	0	0	0	0	0.0%
January	1,299	7,358	5,727	10,288	0.9%
February	46,169	210,277	175,038	263,885	24.6%
March	76,728	526,101	432,677	673,016	61.5%
April	1,937	36,820	25,283	98,010	4.3%
May	1,265	45,766	31,050	91,553	5.3%
June	546	29,534	19,200	64,020	3.4%
July	5	271	176	587	0.0%
Total	**127,947**	**856,127**	**689,152**	**1,201,359**	**100%**
Downstream (GOLF and BYPASS)					
Month	Catch	Estimate	95% LCI	95% UCI	Percent passage (%)
January	7	90	69	130	0.1%
February	120	1,995	1,478	3,080	1.5%
March	235	4,918	3,536	8,083	3.7%
April	1,852	7,317	5,826	10,432	5.4%
May	39,703	89,872	75,486	122,295	66.8%
June	16,716	30,077	26,117	39,362	22.3%
July	324	324	324	324	0.2%
Total	**58,956**	**134,593**	**112,836**	**183,706**	**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 2015/16 juvenile outmigration monitoring season.

			Upstream (VINO FARMS)			
	Model					
AICc	df	*P*	Independent Variable	df	X^2	*P*
183.81	2, 133	**0.0023**				
			Turbidity	1	11.906	**0.0006**
			Water temperature (Elliot)	1	0.067	0.7954
			Downstream (GOLF and BYPASS)			
	Model					
AICc	df	*P*	Independent Variable	df	X^2	*P*
216.09	1, 126	**<0.0001**				
			Turbidity	1	24.306	**<0.0001**

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 abundance estimates by the estimated number of Chinook salmon naturally produced on the LMR for a given brood year (BY). The total estimated natural production for each BY was calculated by multiplying the annual Chinook salmon redd count by the average annual fecundity estimate for a female Chinook salmon spawned at the Mokelumne River Fish Installation (MRFI). JSA = 1998 Mokelumne River Joint Settle Agreement.

BY	Trap(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)				
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
2014	Vino Farms	911	4,520,382	431,677	338,021	769,057	0.10 (0.07-0.17)	Critically Dry
2015	Vino Farms	1,359	5,760,801	856,127	689,152	1,201,359	0.15 (0.11-0.21)	Below Normal
				Downstream (rkm 62)				
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
2014	Golf & Bypass	911	4,520,382	61,305	57,120	74,069	0.01 (0.01-0.02)	Critically Dry
2015	Golf & Bypass	1,359	5,760,801	134,593	112,836	183,706	0.02 (0.02-0.03)	Below Normal

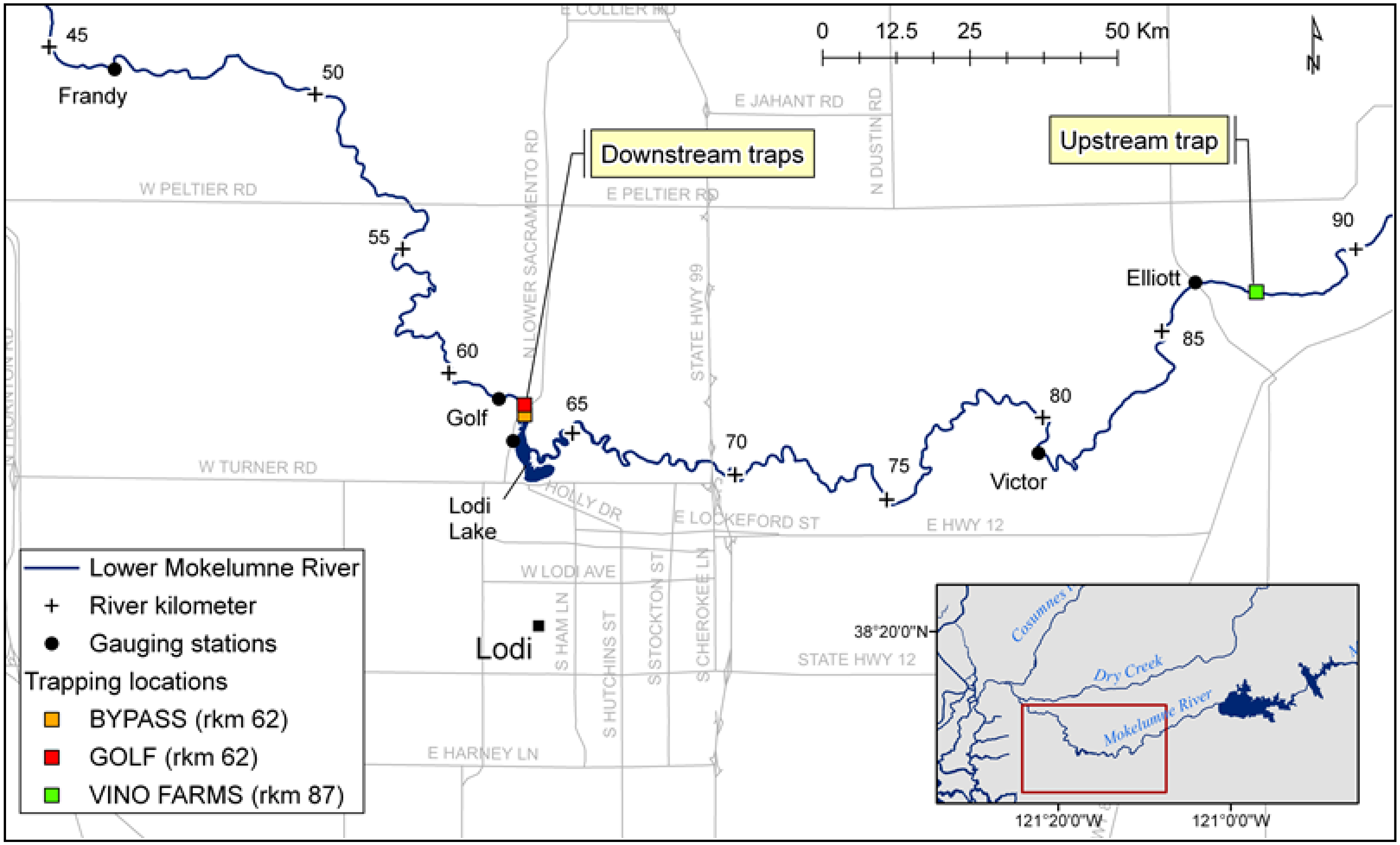


Figure 1. Trapping sites used for juvenile emigration monitoring on the lower Mokelumne River during the 2015/16 season.

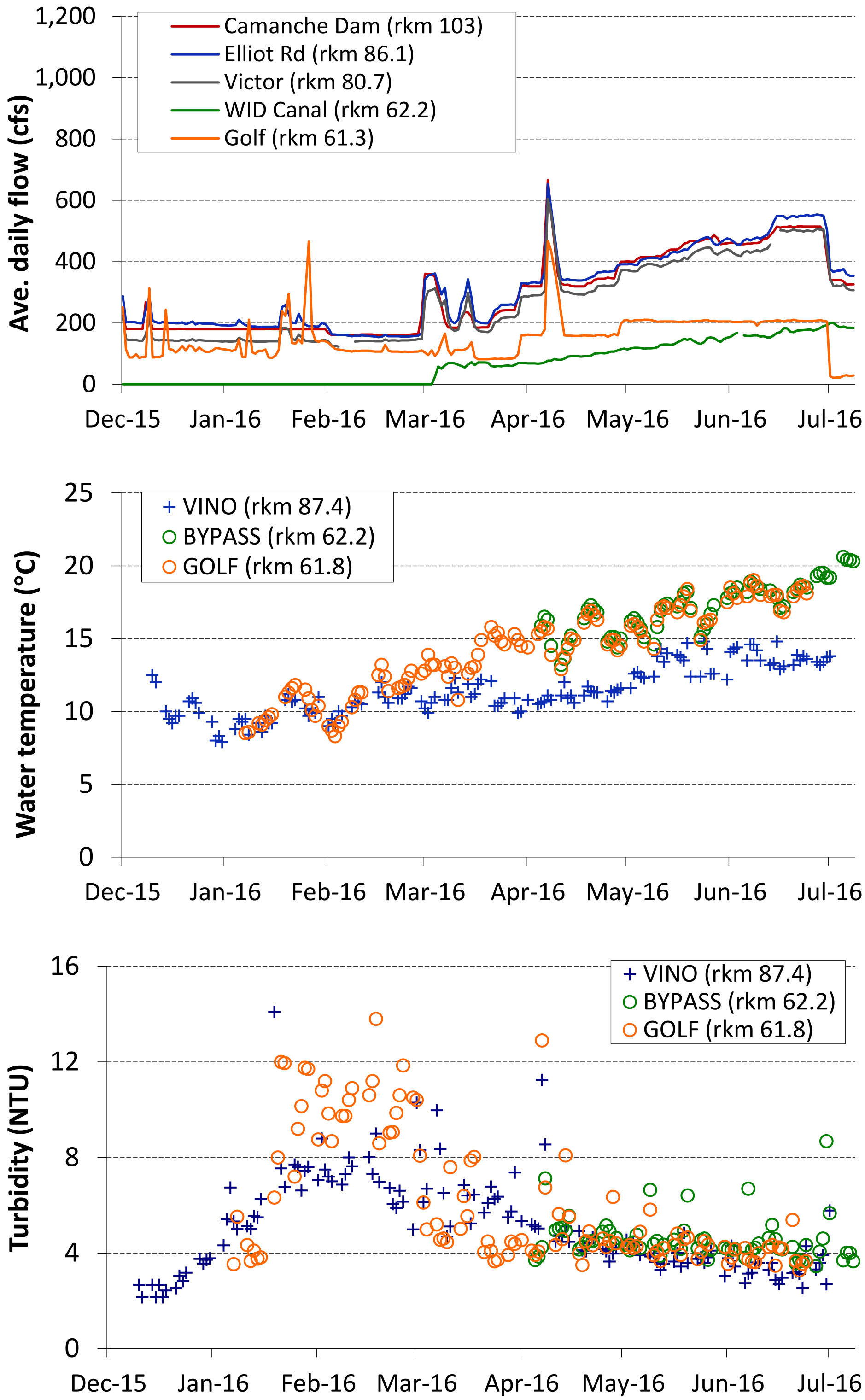
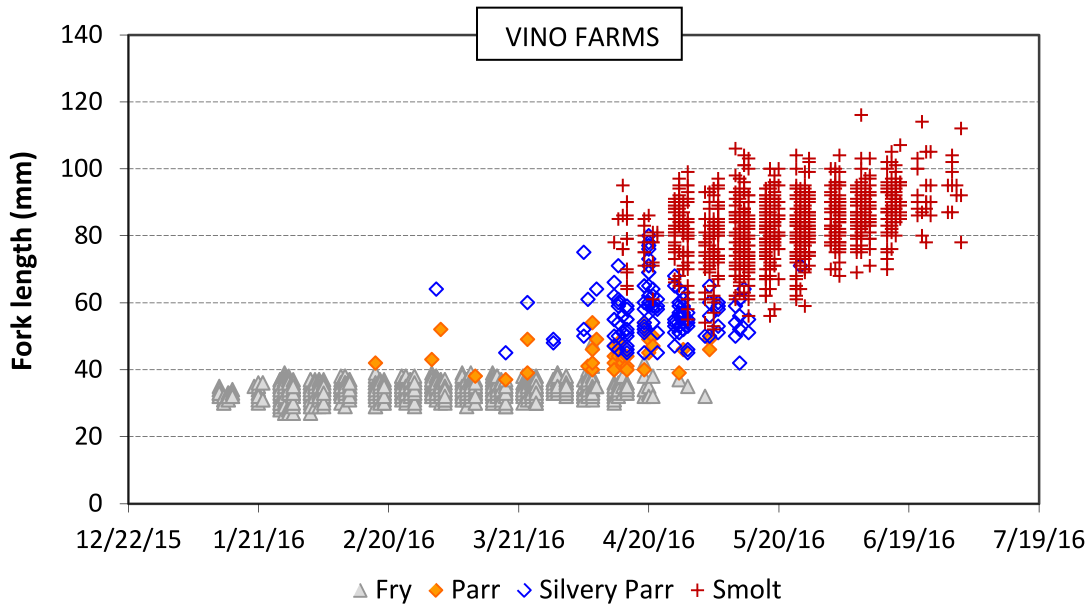


Figure 2. Average daily flow, water temperature, and turbidity on the lower Mokelumne River between Camanche Dam (rkm 103) and Golf (rkm 61.3) during the 2015/16 juvenile emigration monitoring season.



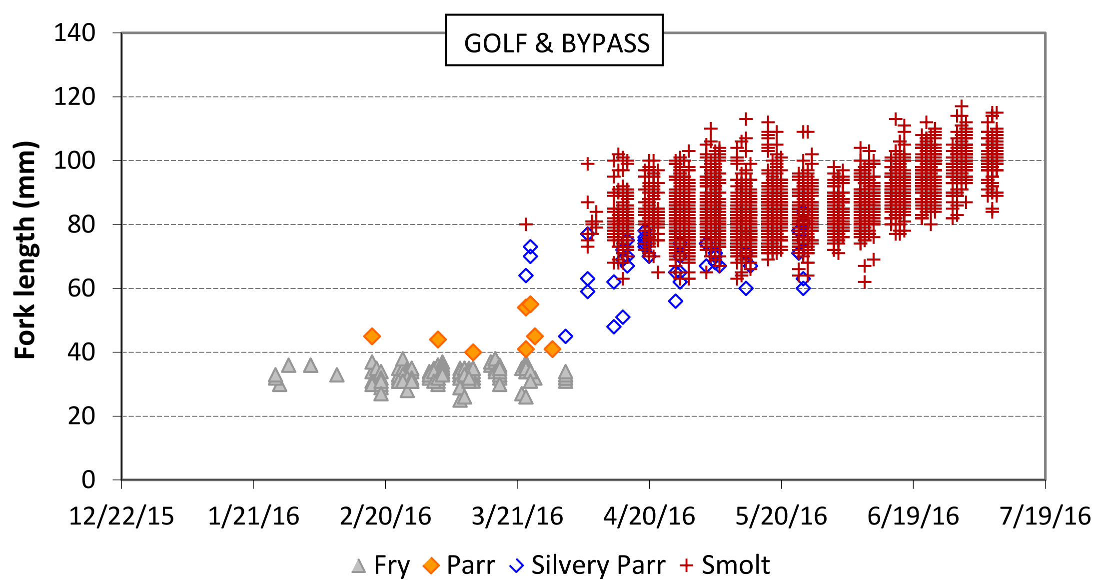
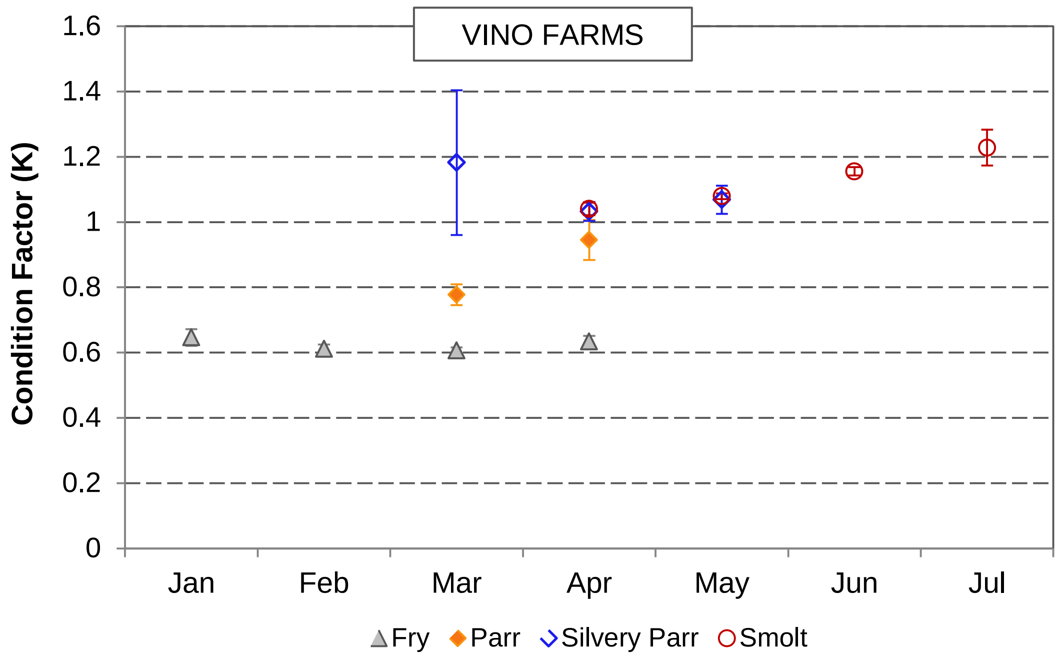


Figure 3. Size distribution by life stage of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF and BYPASS) trapping locations during the 2015/16 juvenile emigration season on the lower Mokelumne River.



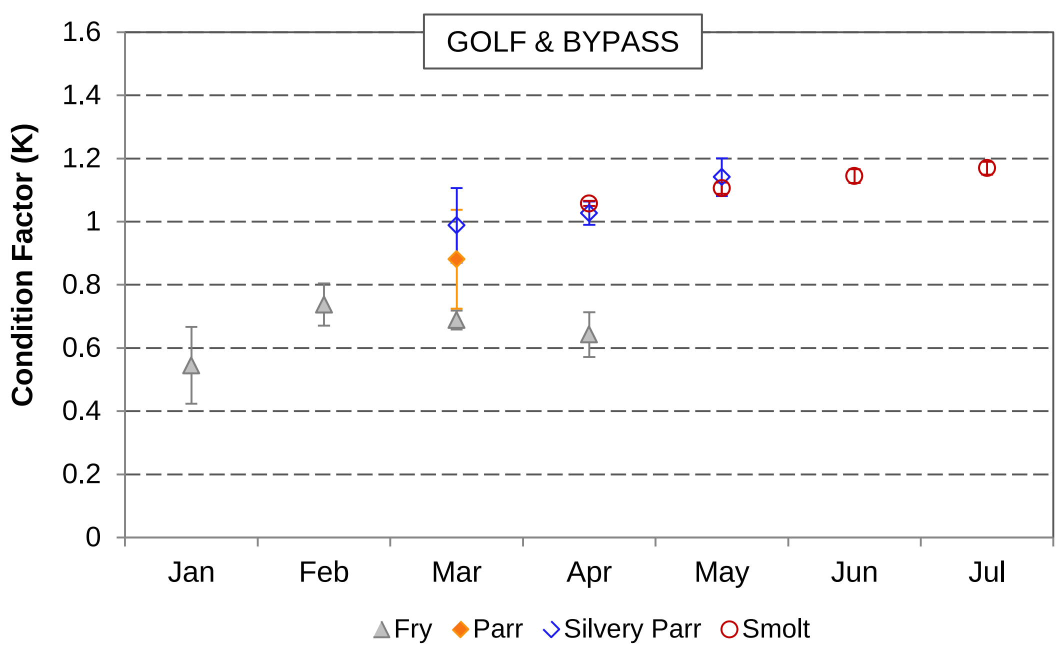


Figure 4. Monthly average condition factor ± 2 SE (vertical lines) of wild juvenile Chinook salmon caught and measured at the upstream (VINO FARMS) and downstream (GOLF & BYPASS) trapping locations during the 2015/16 juvenile emigration monitoring season on the lower Mokelumne River.

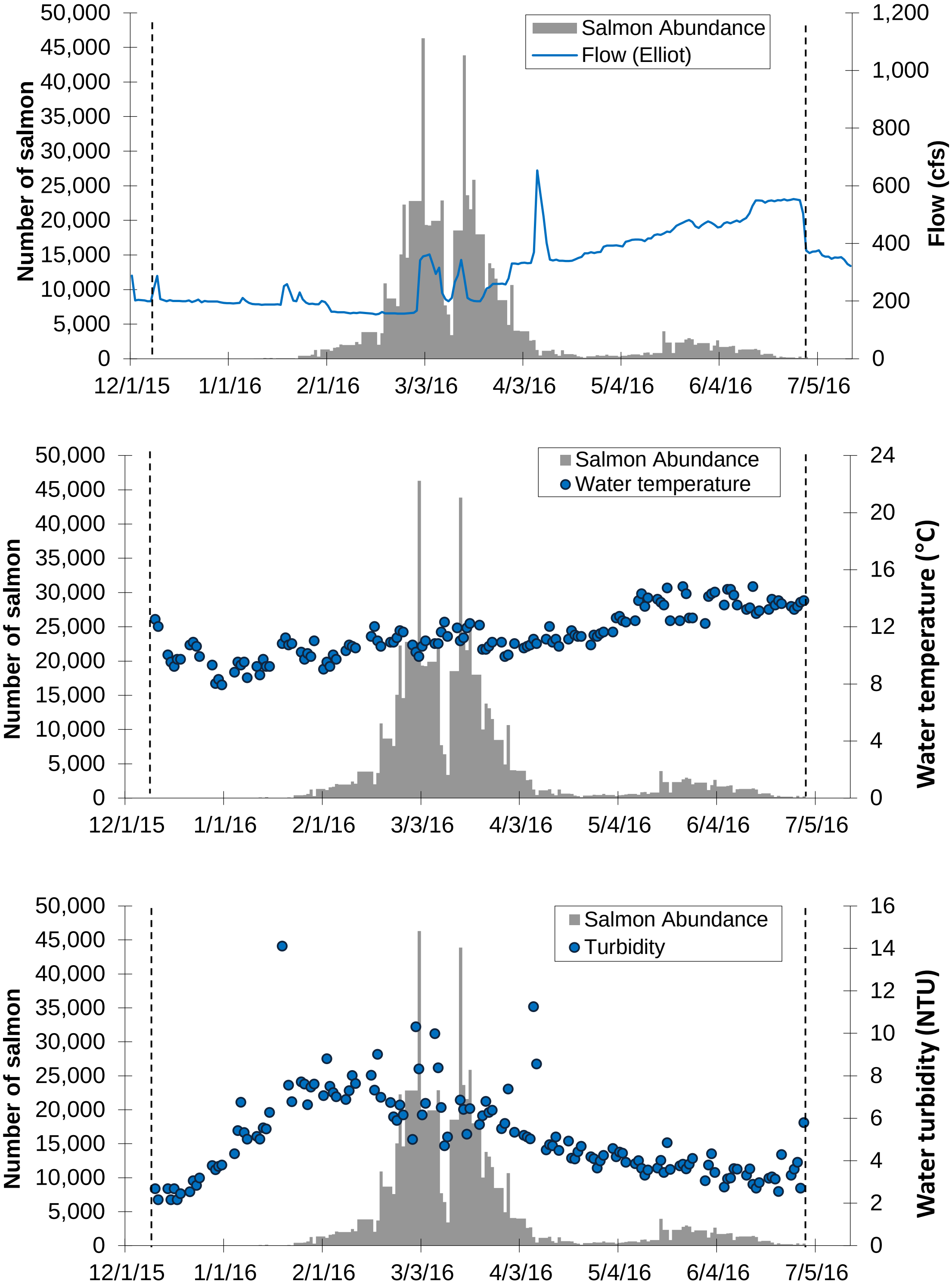


Figure 5. The relationships between estimated daily Chinook salmon abundance and flow (top), water temperature (middle), and turbidity (bottom) at the VINO RST (upstream trapping location) during the 2015/16 juvenile emigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.

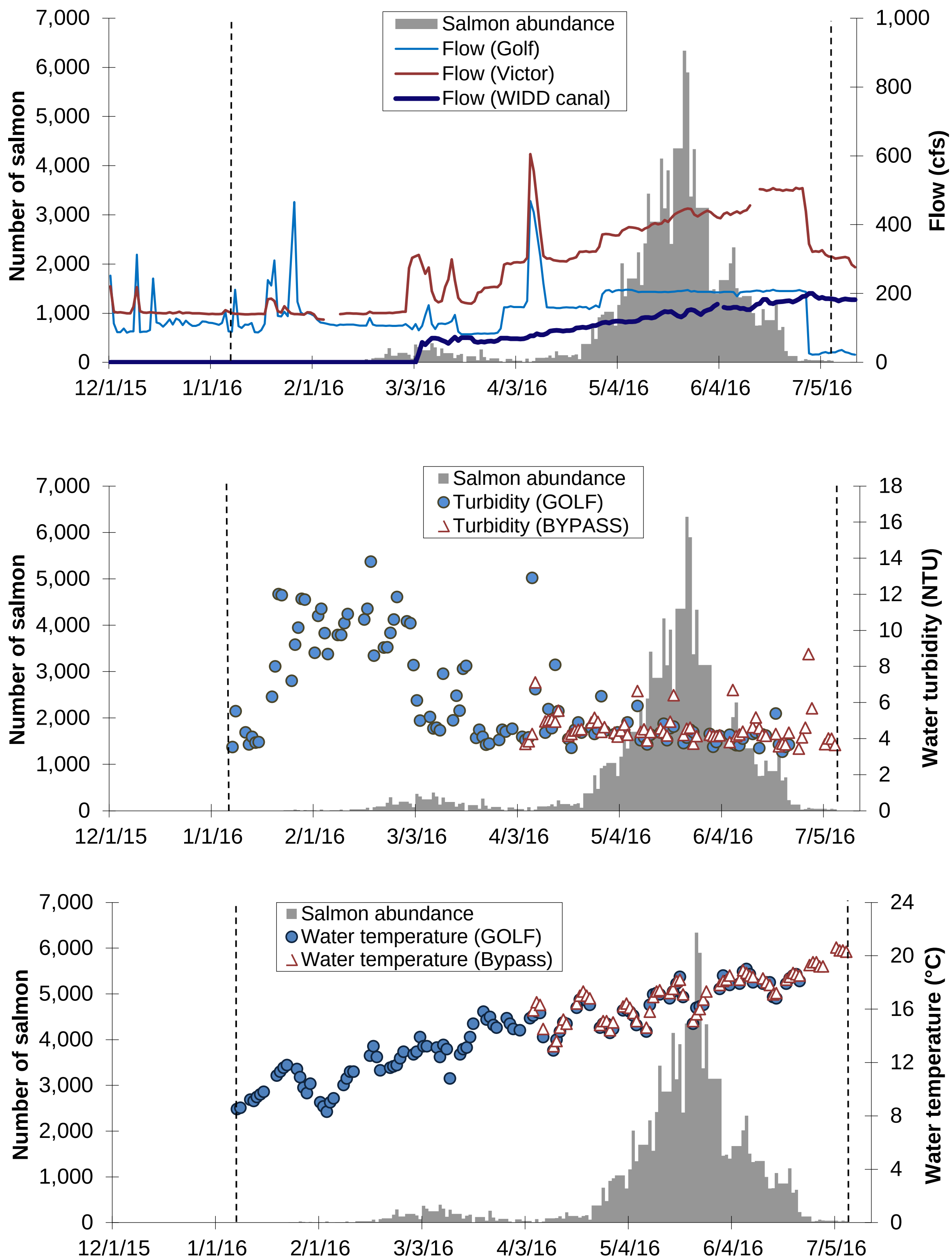
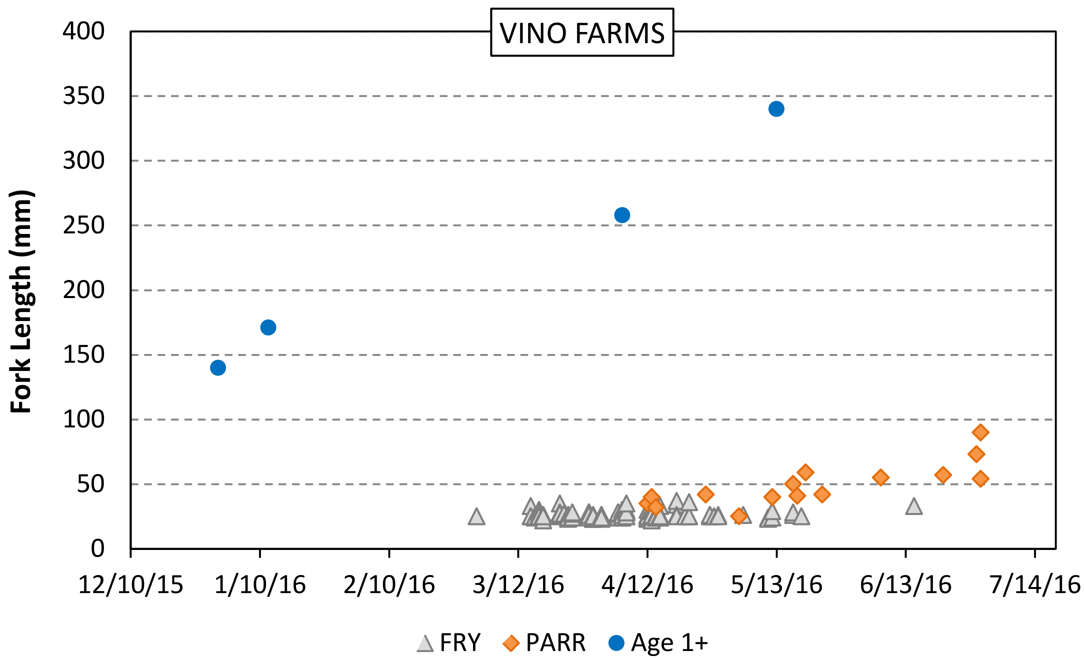


Figure 6. The relationships between estimated daily Chinook salmon abundance and flow (top), water temperature (middle), and turbidity (bottom) at the downstream trapping locations (GOLF & BYPASS) during the 2015/16 juvenile emigration monitoring season. The dashed vertical lines indicate the beginning and the end of the monitoring period.



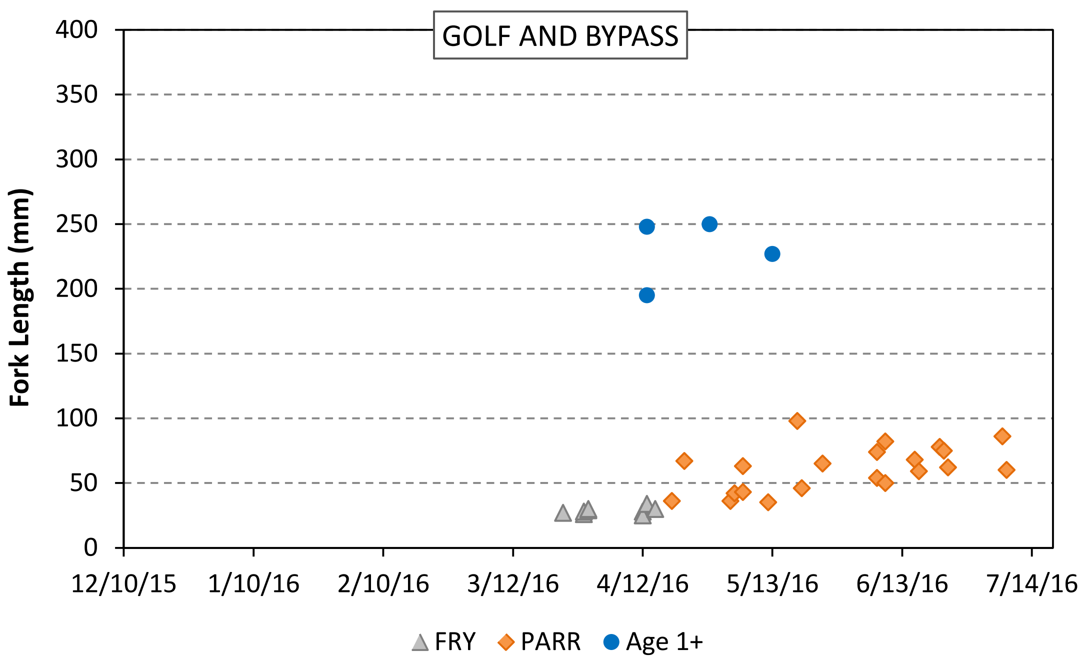


Figure 7. Size and life stage distribution of wild steelhead caught and measured at the upstream (VINO FARMS) and downstream (GOLF & BYPASS) trapping locations during the 2015/16 juvenile emigration monitoring season on the lower Mokelumne River.

Appendix A. Daily trap catch, trap efficiency, abundance estimates, and 95% confidence intervals (CI) of juvenile Chinook salmon at the upstream rotary screw trap (VINO) on the lower Mokelumne River during the 2015/16 monitoring period. Shaded areas represent non-trapping periods or days with trap stoppages where catch was estimated.

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
12/9/2015	0	0.1765	**0**	0	0
12/10/2015	0	0.1765	**0**	0	0
12/11/2015	0	0.1765	**0**	0	0
12/12/2015	0	0.1765	**0**	0	0
12/13/2015	0	0.1765	**0**	0	0
12/14/2015	0	0.1765	**0**	0	0
12/15/2015	0	0.1765	**0**	0	0
12/16/2015	0	0.1765	**0**	0	0
12/17/2015	0	0.1765	**0**	0	0
12/18/2015	0	0.1765	**0**	0	0
12/19/2015	0	0.1765	**0**	0	0
12/20/2015	0	0.1765	**0**	0	0
12/21/2015	0	0.1765	**0**	0	0
12/22/2015	0	0.1765	**0**	0	0
12/23/2015	0	0.1765	**0**	0	0
12/24/2015	0	0.1765	**0**	0	0
12/25/2015	0	0.1765	**0**	0	0
12/26/2015	0	0.1765	**0**	0	0
12/27/2015	0	0.1765	**0**	0	0
12/28/2015	0	0.1765	**0**	0	0
12/29/2015	0	0.1765	**0**	0	0
12/30/2015	0	0.1765	**0**	0	0
12/31/2015	0	0.1765	**0**	0	0
1/1/2016	0	0.1765	**0**	0	0
1/2/2016	0	0.1765	**0**	0	0
1/3/2016	0	0.1765	**0**	0	0
1/4/2016	0	0.1765	**0**	0	0
1/5/2016	0	0.1765	**0**	0	0
1/6/2016	0	0.1765	**0**	0	0
1/7/2016	0	0.1765	**0**	0	0
1/8/2016	0	0.1765	**0**	0	0
1/9/2016	8	0.1765	**46**	36	65
1/10/2016	8	0.1765	**46**	36	65
1/11/2016	8	0.1765	**46**	36	65
1/12/2016	18	0.1765	**102**	79	143
1/13/2016	9	0.1765	**51**	40	71
1/14/2016	22	0.1765	**125**	97	174
1/15/2016	6	0.1765	**34**	26	48
1/16/2016	11	0.1765	**60**	47	85
1/17/2016	11	0.1765	**60**	47	85
1/18/2016	11	0.1765	**60**	47	85
1/19/2016	11	0.1765	**60**	47	85
1/20/2016	9	0.1765	**51**	40	71

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
1/21/2016	13	0.1765	**74**	57	103
1/22/2016	5	0.1765	**28**	22	40
1/23/2016	72	0.1765	**408**	318	570
1/24/2016	72	0.1765	**408**	318	570
1/25/2016	72	0.1765	**408**	318	570
1/26/2016	77	0.1765	**436**	340	610
1/27/2016	105	0.1765	**595**	463	832
1/28/2016	223	0.1765	**1,264**	984	1,767
1/29/2016	53	0.1765	**300**	234	420
1/30/2016	238	0.1765	**1,347**	1,048	1,883
1/31/2016	238	0.1765	**1,347**	1,048	1,883
2/1/2016	238	0.1765	**1,347**	1,048	1,883
2/2/2016	205	0.1765	**1,162**	904	1,624
2/3/2016	410	0.2574	**1,593**	1,290	2,080
2/4/2016	430	0.2574	**1,670**	1,353	2,181
2/5/2016	535	0.2574	**2,078**	1,684	2,714
2/6/2016	509	0.2574	**1,976**	1,601	2,580
2/7/2016	509	0.2574	**1,976**	1,601	2,580
2/8/2016	509	0.2574	**1,976**	1,601	2,580
2/9/2016	509	0.2574	**1,977**	1,602	2,582
2/10/2016	624	0.2574	**2,424**	1,964	3,165
2/11/2016	544	0.2574	**2,113**	1,712	2,760
2/12/2016	992	0.2574	**3,854**	3,123	5,033
2/13/2016	992	0.2574	**3,854**	3,123	5,033
2/14/2016	992	0.2574	**3,854**	3,123	5,033
2/15/2016	992	0.2574	**3,854**	3,123	5,033
2/16/2016	992	0.2574	**3,854**	3,123	5,033
2/17/2016	524	0.2574	**2,036**	1,649	2,658
2/18/2016	947	0.2574	**3,679**	2,981	4,804
2/19/2016	2,805	0.2574	**10,896**	8,829	14,229
2/20/2016	2,240	0.2574	**8,701**	7,050	11,362
2/21/2016	2,240	0.2574	**8,701**	7,050	11,362
2/22/2016	2,240	0.2574	**8,701**	7,050	11,362
2/23/2016	1,956	0.2574	**7,598**	6,156	9,922
2/24/2016	2,907	0.1930	**15,064**	12,799	18,302
2/25/2016	4,300	0.1930	**22,282**	18,932	27,073
2/26/2016	2,820	0.1930	**14,613**	12,416	17,755
2/27/2016	4,403	0.1930	**22,815**	19,384	27,720
2/28/2016	4,403	0.1930	**22,815**	19,384	27,720
2/29/2016	4,403	0.1930	**22,815**	19,384	27,720
3/1/2016	4,403	0.1930	**22,815**	19,384	27,720
3/2/2016	8,940	0.1930	**46,326**	39,360	56,286
3/3/2016	3,732	0.1930	**19,339**	16,431	23,497
3/4/2016	3,718	0.1930	**19,266**	16,369	23,408
3/5/2016	3,844	0.1930	**19,919**	16,924	24,202

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
3/6/2016	3,844	0.1930	**19,919**	16,924	24,202
3/7/2016	3,844	0.1930	**19,919**	16,924	24,202
3/8/2016	4,414	0.1930	**22,873**	19,434	27,790
3/9/2016	1,490	0.1930	**7,721**	6,560	9,381
3/10/2016	770	0.1200	**6,417**	5,186	8,414
3/11/2016	408	0.1200	**3,400**	2,748	4,458
3/12/2016	2,226	0.1200	**18,553**	14,994	24,327
3/13/2016	2,226	0.1200	**18,553**	14,994	24,327
3/14/2016	2,226	0.1200	**18,553**	14,994	24,327
3/15/2016	5,264	0.1200	**43,867**	35,452	57,520
3/16/2016	2,835	0.1200	**23,625**	19,093	30,978
3/17/2016	2,591	0.1200	**21,592**	17,450	28,312
3/18/2016	3,104	0.1200	**25,867**	20,905	33,918
3/19/2016	2,160	0.1200	**18,001**	14,548	23,604
3/20/2016	2,160	0.1200	**18,001**	14,548	23,604
3/21/2016	2,160	0.1200	**18,001**	14,548	23,604
3/22/2016	1,202	0.1200	**10,017**	8,095	13,134
3/23/2016	1,657	0.1200	**13,808**	11,159	18,106
3/24/2016	1,572	0.1200	**13,100**	10,587	17,177
3/25/2016	1,387	0.1200	**11,558**	9,341	15,156
3/26/2016	1,018	0.1200	**8,487**	6,859	11,128
3/27/2016	1,018	0.1200	**8,487**	6,859	11,128
3/28/2016	1,018	0.1200	**8,487**	6,859	11,128
3/29/2016	588	0.1200	**4,900**	3,960	6,425
3/30/2016	657	0.0615	**10,676**	8,110	15,619
3/31/2016	250	0.0615	**4,054**	3,080	5,931
4/1/2016	250	0.0615	**4,054**	3,080	5,931
4/2/2016	245	0.0615	**3,973**	3,018	5,813
4/3/2016	245	0.0615	**3,973**	3,018	5,813
4/4/2016	245	0.0615	**3,973**	3,018	5,813
4/5/2016	161	0.0615	**2,616**	1,987	3,827
4/6/2016	102	0.0380	**2,686**	1,505	12,483
4/7/2016	48	0.0380	**1,264**	708	5,874
4/8/2016	17	0.0380	**448**	251	2,080
4/9/2016	43	0.0380	**1,128**	632	5,242
4/10/2016	43	0.0380	**1,128**	632	5,242
4/11/2016	43	0.0380	**1,128**	632	5,242
4/12/2016	49	0.0380	**1,290**	723	5,997
4/13/2016	25	0.0380	**658**	369	3,060
4/14/2016	16	0.0380	**421**	236	1,958
4/15/2016	47	0.0380	**1,238**	693	5,752
4/16/2016	25	0.0380	**658**	369	3,060
4/17/2016	25	0.0380	**658**	369	3,060
4/18/2016	25	0.0380	**658**	369	3,060
4/19/2016	23	0.0380	**606**	339	2,815
4/20/2016	22	0.0615	**358**	280	495
4/21/2016	17	0.0615	**276**	216	382

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
4/22/2016	8	0.0615	**130**	102	180
4/23/2016	22	0.0615	**358**	280	495
4/24/2016	22	0.0615	**358**	280	495
4/25/2016	22	0.0615	**358**	280	495
4/26/2016	31	0.0615	**504**	395	697
4/27/2016	27	0.0615	**439**	344	607
4/28/2016	27	0.0615	**439**	344	607
4/29/2016	37	0.0615	**601**	471	832
4/30/2016	27	0.0615	**439**	344	607
5/1/2016	27	0.0615	**439**	344	607
5/2/2016	27	0.0615	**439**	344	607
5/3/2016	18	0.0615	**293**	229	405
5/4/2016	26	0.0615	**423**	331	585
5/5/2016	27	0.0615	**439**	344	607
5/6/2016	34	0.0615	**553**	433	764
5/7/2016	38	0.0615	**612**	479	847
5/8/2016	38	0.0615	**612**	479	847
5/9/2016	38	0.0615	**612**	479	847
5/10/2016	31	0.0615	**504**	395	697
5/11/2016	53	0.0615	**862**	675	1,192
5/12/2016	55	0.0615	**894**	700	1,237
5/13/2016	37	0.0615	**601**	471	832
5/14/2016	51	0.0615	**824**	645	1,139
5/15/2016	51	0.0615	**824**	645	1,139
5/16/2016	51	0.0615	**824**	645	1,139
5/17/2016	73	0.0185	**3,952**	2,569	8,567
5/18/2016	43	0.0185	**2,328**	1,513	5,046
5/19/2016	43	0.0185	**2,328**	1,513	5,046
5/20/2016	15	0.0185	**812**	528	1,760
5/21/2016	43	0.0185	**2,337**	1,519	5,066
5/22/2016	43	0.0185	**2,337**	1,519	5,066
5/23/2016	43	0.0185	**2,337**	1,519	5,066
5/24/2016	51	0.0185	**2,761**	1,795	5,985
5/25/2016	55	0.0185	**2,978**	1,936	6,455
5/26/2016	52	0.0185	**2,815**	1,830	6,103
5/27/2016	37	0.0185	**2,003**	1,302	4,342
5/28/2016	42	0.0185	**2,256**	1,467	4,890
5/29/2016	42	0.0185	**2,256**	1,467	4,890
5/30/2016	42	0.0185	**2,256**	1,467	4,890
5/31/2016	42	0.0185	**2,256**	1,467	4,890
6/1/2016	22	0.0185	**1,191**	774	2,582
6/2/2016	35	0.0185	**1,895**	1,232	4,108
6/3/2016	49	0.0185	**2,653**	1,725	5,751
6/4/2016	31	0.0185	**1,696**	1,103	3,677
6/5/2016	31	0.0185	**1,696**	1,103	3,677
6/6/2016	31	0.0185	**1,696**	1,103	3,677
6/7/2016	33	0.0185	**1,787**	1,162	3,873

Appendix A continued

Date	Catch	Efficiency	Abundance estimate	95% Lower CI	95% Upper CI
6/8/2016	34	0.0185	**1,841**	1,197	3,990
6/9/2016	15	0.0185	**812**	528	1,760
6/10/2016	24	0.0185	**1,299**	845	2,817
6/11/2016	25	0.0185	**1,326**	862	2,875
6/12/2016	25	0.0185	**1,326**	862	2,875
6/13/2016	25	0.0185	**1,326**	862	2,875
6/14/2016	25	0.0185	**1,354**	880	2,934
6/15/2016	26	0.0185	**1,408**	915	3,051
6/16/2016	23	0.0185	**1,245**	810	2,699
6/17/2016	11	0.0185	**596**	387	1,291
6/18/2016	13	0.0185	**695**	452	1,506
6/19/2016	13	0.0185	**695**	452	1,506
6/20/2016	13	0.0185	**695**	452	1,506
6/21/2016	8	0.0185	**433**	282	939
6/22/2016	3	0.0185	**162**	106	352
6/23/2016	6	0.0185	**325**	211	704
6/24/2016	4	0.0185	**217**	141	469
6/25/2016	4	0.0185	**208**	135	450
6/26/2016	4	0.0185	**208**	135	450
6/27/2016	4	0.0185	**208**	135	450
6/28/2016	2	0.0185	**108**	70	235
6/29/2016	6	0.0185	**325**	211	704
6/30/2016	2	0.0185	**108**	70	235
7/1/2016	5	0.0185	**271**	176	587

Appendix B. Daily trap catch, trap efficiency, abundance estimates, and 95% confidence intervals (CI) of juvenile Chinook salmon at the downstream traps (GOLF and BYPASS) on the lower Mokelumne River during the 2015/16 monitoring period. Shaded areas represent non-trapping periods or days with trap stoppages where catch was estimated.

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
1/7/2016	0	0.07570	0	–	**0**	0	0
1/8/2016	0	0.07570	0	–	**0**	0	0
1/9/2016	0	0.07570	0	–	**0**	0	0
1/10/2016	0	0.07570	0	–	**0**	0	0
1/11/2016	0	0.07570	0	–	**0**	0	0
1/12/2016	0	0.07570	0	–	**0**	0	0
1/13/2016	0	0.07570	0	–	**0**	0	0
1/14/2016	0	0.07570	0	–	**0**	0	0
1/15/2016	0	0.07570	0	–	**0**	0	0
1/16/2016	0	0.07570	0	–	**0**	0	0
1/17/2016	0	0.07570	0	–	**0**	0	0
1/18/2016	0	0.07570	0	–	**0**	0	0
1/19/2016	0	0.07570	0	–	**0**	0	0
1/20/2016	0	0.07570	0	–	**0**	0	0
1/21/2016	0	0.07570	0	–	**0**	0	0
1/22/2016	0	0.07570	0	–	**0**	0	0
1/23/2016	1	0.07570	7	–	**7**	5	10
1/24/2016	1	0.07570	7	–	**7**	5	10
1/25/2016	1	0.07570	7	–	**7**	5	10
1/26/2016	2	0.07570	26	–	**26**	20	38
1/27/2016	1	0.07570	13	–	**13**	10	19
1/28/2016	0	0.07570	0	–	**0**	0	0
1/29/2016	1	0.07570	13	–	**13**	10	19
1/30/2016	1	0.07570	9	–	**9**	7	13
1/31/2016	1	0.07570	9	–	**9**	7	13
2/1/2016	1	0.07570	9	–	**9**	7	13
2/2/2016	0	0.07570	0	–	**0**	0	0
2/3/2016	2	0.07570	26	–	**26**	20	38
2/4/2016	0	0.07570	0	–	**0**	0	0
2/5/2016	0	0.07570	0	–	**0**	0	0
2/6/2016	1	0.07570	9	–	**9**	7	13
2/7/2016	1	0.07570	9	–	**9**	7	13
2/8/2016	1	0.07570	9	–	**9**	7	13
2/9/2016	2	0.07570	26	–	**26**	20	38
2/10/2016	0	0.07570	0	–	**0**	0	0
2/11/2016	0	0.07570	0	–	**0**	0	0
2/12/2016	2	0.07570	31	–	**31**	24	44
2/13/2016	2	0.07570	31	–	**31**	24	44
2/14/2016	2	0.07570	31	–	**31**	24	44
2/15/2016	2	0.07570	31	–	**31**	24	44
2/16/2016	2	0.07570	31	–	**31**	24	44
2/17/2016	5	0.07570	66	–	**66**	51	95
2/18/2016	1	0.07570	13	–	**13**	10	19

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
2/19/2016	6	0.07570	79	–	**79**	61	114
2/20/2016	7	0.07570	95	–	**95**	73	136
2/21/2016	7	0.07570	95	–	**95**	73	136
2/22/2016	7	0.07570	95	–	**95**	73	136
2/23/2016	9	0.05190	173	–	**173**	126	277
2/24/2016	15	0.05190	289	–	**289**	210	462
2/25/2016	7	0.05190	135	–	**135**	98	216
2/26/2016	7	0.05190	135	–	**135**	98	216
2/27/2016	10	0.05190	193	–	**193**	140	308
2/28/2016	10	0.05190	193	–	**193**	140	308
2/29/2016	10	0.05190	193	–	**193**	140	308
3/1/2016	8	0.05190	154	–	**154**	112	246
3/2/2016	4	0.05190	77	–	**77**	56	123
3/3/2016	19	0.05190	366	–	**366**	266	585
3/4/2016	16	0.05190	308	–	**308**	224	493
3/5/2016	13	0.05190	247	–	**247**	180	395
3/6/2016	13	0.05190	247	–	**247**	180	395
3/7/2016	13	0.05190	247	–	**247**	180	395
3/8/2016	18	0.04582	393	–	**393**	281	654
3/9/2016	14	0.04582	306	–	**306**	218	509
3/10/2016	6	0.04582	131	–	**131**	94	218
3/11/2016	13	0.04582	284	–	**284**	203	472
3/12/2016	9	0.04582	189	–	**189**	135	315
3/13/2016	9	0.04582	189	–	**189**	135	315
3/14/2016	9	0.04582	189	–	**189**	135	315
3/15/2016	4	0.04582	87	–	**87**	62	145
3/16/2016	7	0.04582	153	–	**153**	109	254
3/17/2016	8	0.04582	175	–	**175**	125	291
3/18/2016	0	0.04582	0	–	**0**	0	0
3/19/2016	6	0.04582	124	–	**124**	88	206
3/20/2016	6	0.04582	124	–	**124**	88	206
3/21/2016	6	0.04582	124	–	**124**	88	206
3/22/2016	2	0.04582	44	–	**44**	31	73
3/23/2016	12	0.04582	262	–	**262**	187	436
3/24/2016	5	0.04582	109	–	**109**	78	182
3/25/2016	2	0.04582	44	–	**44**	31	73
3/26/2016	4	0.04582	84	–	**84**	60	139
3/27/2016	4	0.04582	84	–	**84**	60	139
3/28/2016	4	0.04582	84	–	**84**	60	139
3/29/2016	1	0.04200	24	–	**24**	17	41
3/30/2016	0	0.04200	0	–	**0**	0	0
3/31/2016	3	0.04200	71	–	**71**	50	123
4/1/2016	3	0.04200	71	–	**71**	50	123
4/2/2016	2	0.04200	36	–	**36**	25	61
4/3/2016	2	0.04200	36	–	**36**	25	61
4/4/2016	2	0.04200	36	–	**36**	25	61
4/5/2016	0	0.04200	0	–	**0**	0	0

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
4/6/2016	3	0.04200	71	5	**76**	55	128
4/7/2016	0	0.04200	0	4	**4**	4	4
4/8/2016	1	0.04200	24	3	**27**	20	44
4/9/2016	3	0.04200	79	15	**94**	71	151
4/10/2016	3	0.04200	79	15	**94**	71	151
4/11/2016	3	0.04200	79	15	**94**	71	151
4/12/2016	5	0.06395	78	19	**97**	78	136
4/13/2016	8	0.06395	125	14	**139**	108	201
4/14/2016	3	0.06395	47	44	**91**	79	114
4/15/2016	12	0.06395	188	38	**226**	179	318
4/16/2016	7	0.06395	115	31	**145**	117	202
4/17/2016	7	0.06395	115	31	**145**	117	202
4/18/2016	7	0.06395	115	31	**145**	117	202
4/19/2016	6	0.06395	94	16	**110**	87	156
4/20/2016	6	0.06395	94	49	**143**	120	189
4/21/2016	9	0.06395	141	22	**163**	128	232
4/22/2016	3	0.06395	47	18	**65**	53	88
4/23/2016	17	0.06395	268	108	**376**	310	509
4/24/2016	17	0.06395	268	108	**376**	310	509
4/25/2016	17	0.06395	268	108	**376**	310	509
4/26/2016	43	0.06395	672	91	**763**	596	1,095
4/27/2016	11	0.03747	294	180	**474**	396	637
4/28/2016	24	0.03747	627	288	**915**	750	1,264
4/29/2016	31	0.03747	827	141	**968**	751	1,428
4/30/2016	32	0.03747	858	172	**1,030**	805	1,507
5/1/2016	32	0.03747	858	172	**1,030**	805	1,507
5/2/2016	32	0.03747	858	172	**1,030**	805	1,507
5/3/2016	21	0.03083	681	65	**746**	557	1,174
5/4/2016	32	0.03083	1,038	128	**1,166**	877	1,818
5/5/2016	55	0.03083	1,784	230	**2,014**	1,517	3,135
5/6/2016	37	0.03083	1,211	133	**1,344**	1,007	2,105
5/7/2016	37	0.03083	1,211	493	**1,704**	1,367	2,465
5/8/2016	37	0.03083	1,211	493	**1,704**	1,367	2,465
5/9/2016	37	0.03083	1,211	493	**1,704**	1,367	2,465
5/10/2016	33	0.03083	1,070	1,167	**2,237**	1,939	2,910
5/11/2016	24	0.03083	778	795	**1,573**	1,357	2,063
5/12/2016	59	0.03083	1,914	505	**2,419**	1,886	3,622
5/13/2016	63	0.03083	2,043	1,388	**3,431**	2,863	4,716
5/14/2016	59	0.03083	1,914	950	**2,863**	2,331	4,066
5/15/2016	59	0.03083	1,914	950	**2,863**	2,331	4,066
5/16/2016	59	0.03083	1,914	950	**2,863**	2,331	4,066
5/17/2016	100	0.03083	3,244	902	**4,146**	3,243	6,185
5/18/2016	67	0.03083	2,173	961	**3,134**	2,529	4,500
5/19/2016	85	0.03083	2,757	1,146	**3,903**	3,136	5,636
5/20/2016	23	0.03083	746	1,663	**2,409**	2,201	2,878
5/21/2016	69	0.03083	2,227	2,127	**4,354**	3,734	5,754

Appendix B continued

Date	GOLF catch	GOLF efficiency	GOLF abundance	BYPASS catch	Downstream abundance estimate	95% Lower CI	95% Upper CI
5/22/2016	69	0.03083	2,227	2,127	**4,354**	3,734	5,754
5/23/2016	69	0.03083	2,227	2,127	**4,354**	3,734	5,754
5/24/2016	72	0.03083	2,335	4,002	**6,337**	5,687	7,805
5/25/2016	96	0.03083	3,114	2,783	**5,897**	5,030	7,854
5/26/2016	36	0.03083	1,168	2,207	**3,375**	3,050	4,109
5/27/2016	49	0.03083	1,589	2,746	**4,335**	3,893	5,334
5/28/2016	49	0.03083	1,589	1,556	**3,145**	2,702	4,144
5/29/2016	49	0.03083	1,589	1,556	**3,145**	2,702	4,144
5/30/2016	49	0.03083	1,589	1,556	**3,145**	2,702	4,144
5/31/2016	49	0.03083	1,589	1,556	**3,145**	2,702	4,144
6/1/2016	21	0.03272	642	821	**1,463**	1,279	1,894
6/2/2016	33	0.03272	1,009	478	**1,487**	1,197	2,165
6/3/2016	36	0.03272	1,100	298	**1,398**	1,083	2,138
6/4/2016	28	0.03272	846	830	**1,676**	1,434	2,244
6/5/2016	28	0.03272	846	830	**1,676**	1,434	2,244
6/6/2016	28	0.03272	846	830	**1,676**	1,434	2,244
6/7/2016	34	0.03272	1,039	978	**2,017**	1,719	2,716
6/8/2016	27	0.03272	825	1,512	**2,337**	2,101	2,892
6/9/2016	20	0.03272	611	895	**1,506**	1,331	1,917
6/10/2016	15	0.03272	458	865	**1,323**	1,192	1,632
6/11/2016	17	0.03272	513	836	**1,349**	1,202	1,695
6/12/2016	17	0.03272	513	836	**1,349**	1,202	1,695
6/13/2016	17	0.03272	513	836	**1,349**	1,202	1,695
6/14/2016	17	0.03272	513	487	**1,000**	853	1,346
6/15/2016	1	0.03272	31	716	**747**	738	767
6/16/2016	7	0.03272	214	541	**755**	694	899
6/17/2016	13	0.03272	390	692	**1,082**	970	1,344
6/18/2016	13	0.03272	390	468	**858**	746	1,119
6/19/2016	13	0.03272	390	468	**858**	746	1,119
6/20/2016	13	0.03272	390	468	**858**	746	1,119
6/21/2016	26	0.03272	795	392	**1,187**	959	1,721
6/22/2016	13	0.03272	390	265	**655**	543	917
6/23/2016	17	0.03272	520	201	**721**	572	1,070
6/24/2016	1	0.03272	31	198	**229**	220	249
6/25/2016	–	–	–	132	**132**	132	132
6/26/2016	–	–	–	132	**132**	132	132
6/27/2016	–	–	–	132	**132**	132	132
6/28/2016	–	–	–	26	**26**	26	26
6/29/2016	–	–	–	36	**36**	36	36
6/30/2016	–	–	–	65	**65**	65	65
7/1/2016	–	–	–	50	**50**	50	50
7/2/2016	–	–	–	43	**43**	43	43
7/3/2016	–	–	–	43	**43**	43	43
7/4/2016	–	–	–	43	**43**	43	43
7/5/2016	–	–	–	43	**43**	43	43
7/6/2016	–	–	–	27	**27**	27	27
7/7/2016	–	–	–	45	**45**	45	45
7/8/2016	–	–	–	32	**32**	32	32

Appendix C. Monthly totals of species caught at the upstream RST (VINO) on the lower Mokelumne River during the 2015/16 juvenile outmigration monitoring season.

Common Name	Genus	Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
black bass	*Micropterus*	*spp.*	0	0	1	1	0	2	5	0	**9**
black crappie	*Pomoxis*	*nigromaculatus*	2	1	1	1	1		14	0	**20**
bluegill	*Lepomis*	*macrochirus*	0	0	0	3	0	1	9	0	**13**
channel catfish	*Ictalurus*	*punctatus*	0	0	0	2	0	1	0	0	**3**
Chinook salmon (ad-clip)	*Oncorhyhchus*	*tshawytscha*	0	0	0	0	240	2,084	49	3	**2,376**
Chinook salmon (no ad-clip)	*Oncorhyhchus*	*tshawytscha*	1	540	19,516	46,291	1,156	650	328	5	**68,487**
common carp	*Cyprinus*	*carpio*	0	0	0	0	0	1	2	0	**3**
golden shiner	*Notemigonus*	*crysoleucas*	1	26	7	99	6	0	2	0	**141**
green sunfish	*Lepomis*	*cyanellus*	0	0	0	0	0	0	2	0	**2**
hitch	*Lavinia*	*exilicauda*	3	3	1	4	0	0	1	0	**12**
Kokanee salmon	*Oncorhynchus*	*nerka*	0	0	0	0	0	1	0	0	**1**
largemouth bass	*Micropterus*	*salmoides*	0	2	0	0	0	0	0	0	**2**
lepomis hybrid	*Lepomis*	*spp.*	0	0	0	0	1	0	0	0	**1**
Pacific lamprey	*Entosphenus*	*tridentatus*	9	2,872	74	15,299	243	256	208	19	**18,980**
prickly sculpin	*Cottus*	*asper*	5	17	12	27	11	2	29	6	**109**
redear sunfish	*Lepomis*	*microlophus*	0	0	0	0	2	1	4	1	**8**
Sacramento pikeminnow	*Ptychocheilus*	*grandis*	0	1	0	2	0	6	7	0	**16**
Sacramento sucker	*Catostomus*	*occidentalis*	2	0	2	0	1	0	0	0	**5**
spotted bass	*Micropterus*	*punctulatus*	0	1	0	0	0	1	0	0	**2**
steelhead (ad-clip)	*Oncorhynchus*	*mykiss*	0	0	0	0	1	0	0	0	**1**
steelhead (no ad-clip)	*Oncorhynchus*	*mykiss*	1	1	0	74	112	17	4	2	**211**
threadfin shad	*Dorosoma*	*petenense*	99	2	0	0	0	0	0	0	**101**
tule perch	*Hysterocarpus*	*traski*	66	184	79	49	39	5	56	7	**485**
western mosquitofish	*Gambusia*	*affinis*	1	8	6	47	91	13	5	1	**172**

Appendix D. Monthly totals of fish species caught at the downstream traps (GOLF and BYPASS) on the lower Mokelumne River during the 2015/16 juvenile outmigration monitoring season.

Common Name	Genus	Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
black bass	*Micropterus*	*spp.*	4	4	0	101	13,942	13,118	1,732	**28,901**
black crappie	*Pomoxis*	*nigromaculatus*	4	0	0	0	0	5	4	**13**
bluegill	*Lepomis*	*macrochirus*	2,961	435	152	58	27	20	5	**3,658**
Chinook salmon (ad-clip)	*Oncorhyhchus*	*tshawytscha*	0	0	0	91	269	16,706	42	**17,108**
Chinook salmon (no ad-clip)	*Oncorhyhchus*	*tshawytscha*	4	54	139	1,079	21,520	9,685	154	**32,635**
common carp	*Cyprinus*	*carpio*	0	0	0	0	1	0	0	**1**
fathead minnow	*Pimephales*	*promelas*	0	0	0	0	0	1	0	**1**
golden shiner	*Notemigonus*	*crysoleucas*	13	9	4	3	5	2	1	**37**
goldfish	*Carassius*	*auratus*	0	0	10	3	1	0	0	**14**
green sunfish	*Lepomis*	*cyanellus*	8	2	2	1	3	1	0	**17**
hitch	*Lavinia*	*exilicauda*	0	0	0	0	1	0	0	**1**
largemouth bass	*Micropterus*	*salmoides*	5	3	0	0	0	0	0	**8**
lepomis hybrid	*Lepomis*	*spp.*	1	0	0	0	0	1	0	**2**
Pacific lamprey	*Entosphenus*	*tridentatus*	20	7	4,123	163	169	71	0	**4,553**
prickly sculpin	*Cottus*	*asper*	9	7	16	2,726	6,143	1,365	34	**10,300**
redear sunfish	*Lepomis*	*microlophus*	1	7	4	0	2	2	0	**16**
redeye bass	*Micropterus*	*coosae*	0	1	3	1	0	1	0	**6**
Sacramento pikeminnow	*Ptychocheilus*	*grandis*	0	0	1		2	2		**5**
Sacramento sucker	*Catostomus*	*occidentalis*	0	0	1	20	4	5	2	**32**
spotted bass	*Micropterus*	*punctulatus*	7	0	1	0	0	0	0	**8**
steelhead (ad-clip)	*Oncorhynchus*	*mykiss*	0	0	0	0	1	33	0	**34**
steelhead (no ad-clip)	*Oncorhynchus*	*mykiss*	0	0	6	7	9	10	2	**34**
threadfin shad	*Dorosoma*	*petenense*	0	0	1	0	0	0	0	**1**
tule perch	*Hysterocarpus*	*traski*	1	0	0	56	40	257	55	**409**
white catfish	*Ameiurus*	*catus*	0	0	0	0	1	0	1	**2**
western mosquitofish	*Gambusia*	*affinis*	15	2	20	3	0	1	0	**41**