State of California
The Resources Agency
Department of Water Resources
Division of Environmental Services

Emigration of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Feather River. 2002-2004.

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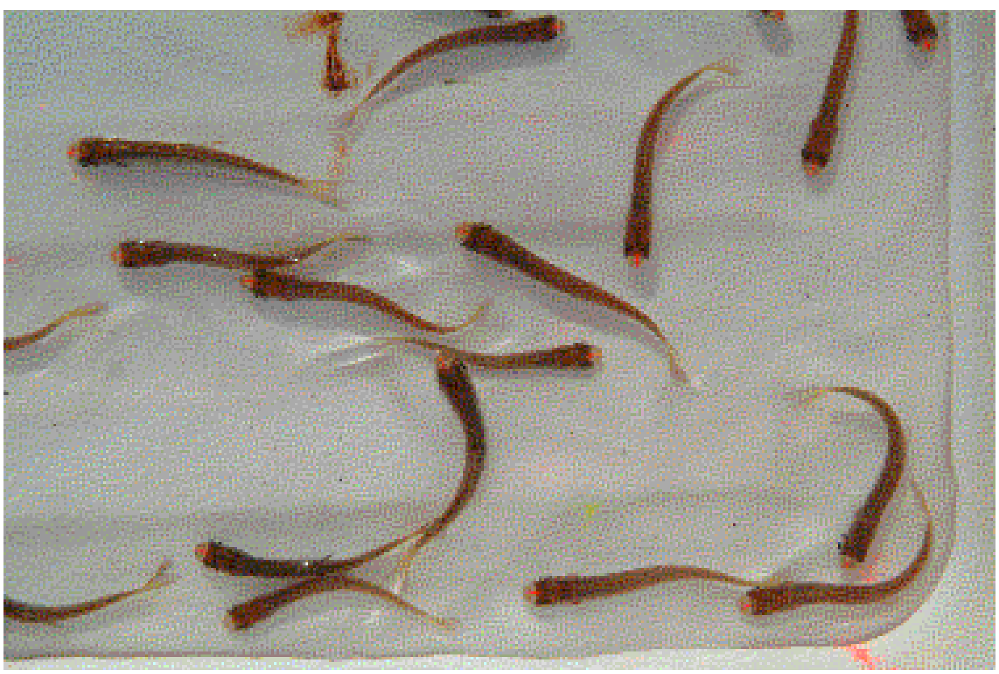

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Summary

This report presents the results from the past three seasons of the Feather River Study Chinook salmon emigration survey (2002-2004). The 2004 season was the seventh year Rotary Screw Traps were fished throughout the entire emigration period (December through June).

Two rotary screw trap locations were used to assess the timing and general abundance of juvenile Chinook salmon, steelhead and other fishes emigrating the Feather River. One RST (Thermalito) was stationed at river mile (RM) 60.1, approximately one mile above the Thermalito Afterbay Outlet. The second RST (Live Oak) was stationed at river mile 46, approximately 4.3 river miles upstream of the City of Live Oak Recreation Area boat ramp.

Although Chinook salmon and steelhead were the primary targets of trapping efforts, records were kept on all fish species caught. Twenty-nine species were caught over the three seasons of trapping. Chinook salmon was the dominant species, comprising over 99% of the catch. Of the total salmon catch, 1,791,730 (62%) were caught at the Live Oak RST and 1,117,946 (38%) were caught at the Thermalito RST.

Of the salmon trapped at Thermalito and Live Oak, 93.9 and 77.3%, respectively, were less than 50 mm, demonstrating that most Feather River salmon emigrate well before smolting. Salmon ranged from 26 to 210 mm fork length. Salmon emigration was observed as soon as the traps were installed in December, typically peaked in February, and continued through June at very low levels. Separate Fall-run Chinook emigration estimates were developed for the Low Flow Channel (LFC) and High Flow Channel (HFC). Over the three years, estimates ranged from 6.6 to 13.8 million Fall-run-size fish in the LFC and 8.9 to 29.2 million for the HFC.

In general, environmental variables such as river flow (cfs), turbidity and temperature did not influence Fall-run emigration timing or magnitude between December and April. However, during one short period of elevated turbidity in the LFC, turbidity was shown to be significant in influencing emigration (Thermalito RST 2004). However, the onset of spawning the previous fall probably plays a larger role in determining when juvenile salmon emigrate the Feather River. Although no stream-type life-history strategies are still evident in the Feather, alternative patterns to a strict ocean-type model still probably exist.

Based on adult escapement, average fecundity and the emigration estimate the egg-to-fry survival rate for Fall-run Chinook juveniles for the entire river ranged from 5.9% to 15.4%. The emigration index (per capita production) of juveniles ranged from a low of 137 in 2002 to a high of 566 in 2004.

A total of 1026 young-of-the-year steelhead were captured at the Thermalito RST during the three-year period. However, only 4 wild yearlings were collected over the same time period (>150 mm fork length). Only 46 young-of-the-year and one wild yearling steelhead were captured at Live Oak throughout the entire sampling period.

Introduction

In 1996 DWR began to monitor salmon and steelhead in support of the Federal Energy Regulatory Commission (FERC) relicensing of the State Water Project's Oroville Facilities and to address issues raised by the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (USFWS 1997a). To this end, DWR initiated a study to identify the timing and magnitude of emigration of naturally produced salmon relative to different physical conditions and spawning population size. Although the main focus of the study is salmon and steelhead, other fish species were also recorded.

This study is the first on the emigration of salmonids and other fish species in the Feather River since the 1970's (Painter et al. 1977). The salmon emigration study has the following objectives:

(1) Document general salmonid emigration attributes, such as timing, abundance and composition by species, race, and life stage.
(2) Investigate the influence of factors thought to initiate emigration, such as flow, turbidity, and water temperature.
(3) Develop annual indices of juvenile salmon production by relating information on spawning intensity and emigration. Use the indices to examine the effects of physical and biological factors on Feather River salmon production.

Salmon emigration is monitored primarily using rotary screw traps (RSTs). Two RST locations are used, one at the lower end of each of the two study reaches. The traps are operated for approximately seven months (December through June). Two trap locations are necessary because flow is strictly regulated above the Thermalito Outlet and therefore emigration cues and species composition may be different for the two reaches. Furthermore, two traps were used in the HFC in 2004 to increase capture of salmonids for trap efficiency trials.

The following report is a summary of salmon emigration between December 2001 and June 2004, representing three consecutive seasons of trapping efforts. Although the trapping season begins at the end of one calendar year and continues into the middle of the next (i.e. December through June), trapping years will be referenced by the spring season. For example, the 2001/2002 trapping period that progressed from December 2001 through June 2002 will be referenced as the 2002 season.

Methods

Study Area

The Fish Barrier Dam, just downstream of the Thermalito Diversion Dam, is the upper limit for upstream migrating fish. The base of the Fish Barrier Dam is where the fish ladder begins, guiding fish into the Feather River Hatchery. The hatchery was built by DWR to mitigate for the loss of Chinook salmon and steelhead spawning and rearing habitat resulting from the construction of Oroville Dam and ancillary facilities.

The lower Feather River (Figure 1) is located within the Central Valley of California, draining an extensive area of the western slope of the Sierra Nevada. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of approximately 3.5 million acre-feet (maf) of water and provides flood control, water supply, power generation, and recreation. Flow in the lower Feather River below the reservoir is regulated through releases from Oroville Dam, Thermalito Diversion Dam, and the Thermalito Afterbay Outlet. Under normal operations, the majority of water released from Lake Oroville is diverted at Thermalito Diversion Dam into the Power Canal and Thermalito Forebay. Water released from the Forebay is used to generate power as it is discharged into Thermalito Afterbay. Water is returned to the Feather River through the Thermalito Afterbay Outlet, and then flows southward to the confluence with the Sacramento River at Verona. The remainder of the flow, typically 600-650 cubic feet per second (cfs), flows through the Low Flow Channel. The reach between Oroville Dam and the confluence with the Sacramento River is of low gradient.

The salmonid emigration study area (Figure 2) is 21 river miles long and consists of the Low Flow and the upper 13 miles of the High Flow Channel. The LFC extends from the Fish Barrier Dam at river mile 67.25 to the Thermalito Outlet (RM 59). The HFC extends from the Thermalito Outlet to the confluence with the Sacramento River. The Yuba River (RM 27.5) is 16.5 river miles further downstream from Honcut Creek. The study is focused on the upper 21 river miles (RM 46 to 67) of the lower river because it is (1) the portion of the river where most Chinook salmon and steelhead spawn and initially rear, making them more affected by project operations and, (2) sampling in this reach provides the greatest opportunity to enumerate emigrating salmon and steelhead fry. River miles 0 to 42 are comprised mostly of flat-water habitat and fine substrates generally unsuitable for salmonid spawning.

Field Collection Methods

Eight-foot RSTs are the main sampling devices used for the emigration survey. RSTs are sturdy, relatively easy to move within the stream, easy to operate and maintain, are able to capture fish without harm in fast-moving water, and can be used to sample continuously. A RST operates in the following manner to capture fish: with the trapping cone lowered into flowing water, water strikes the baffles on the inside of the trapping cone, causing the cone to rotate. Fish enter the upstream end of the rotating trapping cone, become trapped inside the trapping cone, and are carried rearward into a live box.

One RST was placed at RM 60.1 to provide a sampling point near the end of the LFC. One RST was also placed in the HFC between the Cities of Live Oak and Gridley (RM 46, Figure 2). Two trap locations are needed because operation of the Oroville Complex results in two substantially different flow regimes: flow in the Low Flow Channel is strictly regulated (generally about 600-650 cfs), while the High Flow Channel is subject to flow fluctuations from 1050 to 40,000+ cfs during emigration. Therefore, emigration cues and species composition may differ between the two reaches. The RST sites were selected based on the following criteria for RST installation, operation, and maintenance: (1) depth greater than six feet at minimum flow; (2) velocity greater than two feet per second at minimum flow; (3) suitable anchoring point(s); (4) limited public access; and (5) general ability to capture juvenile salmonids. An additional trap was placed at the HFC location in 2004 to provide increased capture of Fall-run Chinook for trap efficiency evaluations.

The RSTs were fished continuously for approximately seven months (December through June), except for short periods when river conditions became unsafe or when heavy debris loads occurred due to high river flows. When serviced, trapped fish were removed from the live box, identified to species and counted. All fish were counted by hand if numbers permitted. When juvenile salmon were highly abundant, a simple volume displacement method was used to count them in increments of 1000. Fork length (to the nearest millimeter) was measured for up to 50 individuals of each salmonid species. Up to 25 non-salmonids were also measured and counted during processing. All fish were then released back to the river, except for salmon retained for coded-wire tagging and trap efficiency evaluations.

All Chinook salmon individuals were assigned to a race based on the length/date criterion set forth in the Sacramento River Daily Length Table (Greene 1992). All live salmon and steelhead that were measured were also inspected for characters such as presence of parr marks, silvery appearance, and deciduous scales to determine life stage. A simple designation was used for each salmon measured:

(1) yolk sac fry/parr: yolk sac is clearly visible.
(2) fry: may have parr marks but yolk sac is not fully absorbed
(3) parr: clearly parr, a darkly pigmented fish with characteristic dark, oval-to round-shaped parr marks on its sides and yolk sac is fully absorbed.
(4) intermediate: between parr and smolt. Usually has fading parr marks and some scale loss.
(5) smolt: highly faded or completely lacking parr marks, bright silver or nearly white color and heavy scale loss.

A salmon tagging station was set up at the Thermalito Afterbay Outlet to coded-wire tag (CWT) in-channel produced juvenile salmon. Juvenile salmon captured in the RSTs were transported to the tagging station and implanted with a CWT half-tag (Northwest Marine Technology, Inc., Washington) by a contractor, Big Eagle and Associates. The tagged salmon were held overnight while a sub-sample was checked for tag shedding and survival. Tagged salmon were released immediately downstream of the Live Oak RST.

Other measurements collected daily at each RST included: water clarity (turbidity, measured in NTUs), water temperature, sample period, average trapping cone revolutions per minute, and the total number of trapping cone revolutions during the sample period. Additionally, overall trap performance was evaluated by determining whether the trap was fishing was good, fair or poor during the trapping period. Simply put, a "good" code meant the trap was fishing normally; a "fair" code was assigned when the trap was spinning very slowly or was partially blocked with debris and "poor" code was assigned when the trap was not spinning or operating properly. Daily mean river flow (cfs) for the Thermalito trap was obtained by adding the Thermalito Diversion Dam flow (CA Department of Water Resources gauge AO 5191) to the Feather River Fish Hatchery Outflow (CA Department of Water Resources gauge AO 5990). River flow for the Live Oak trap was obtained by adding the Thermalito trap flow to the Feather River Outlet-Thermalito Afterbay flow (CA Department of Water Resources gauge AO 5975).

Trap Efficiency and Emigration Estimate

Trap efficiency was evaluated using fish collected in the RSTs. Eighty-eight evaluations (over the three year period) were conducted using salmon captured in their respective traps (i.e. salmon trapped at Live Oak were generally used for Live Oak trap efficiency evaluations). Evaluations were performed between mid-December and mid-March, the period when nearly all emigration occurred. For each evaluation, approximately 1000 marked fish were transported roughly two kilometers upstream of each RST. Fish were released in equal proportions along the river margin (i.e. if 1000 fish were tagged, approximately 500 were released on river right and 500 on river left). Because holding trials revealed insignificant losses of fish held for 24 hours after marking, fish were generally released within an hour of marking. However, when elastomer tags were applied in addition to Bismarck Brown, fish were generally held for 24 hours prior to release. Furthermore, previous diel sampling (DWR 2002) revealed that nearly all salmon were captured at night and therefore time of release was unlikely to influence recapture rates. Only healthy fish (based on visual observations) were released and time of release was recorded (i.e. time of day). Although most recaptures occurred within the first day of release, catch was monitored for recaptures for at least seven days based on previous observations that nearly all recaptures occurred in that time-period. However, because the traps were searched daily for marked fish, individuals could be recovered several weeks after release. Mortality between the release point and the trap was assumed to be negligible.

All salmon were marked with Bismarck Brown (Spectrum Chemical, Gardena, California) dye at a concentration of 2.8 grams to 115 L of water for 30 minutes. Most released fish were also tagged with colored latex elastomer in the nose (Northwest Marine Technology, Shaw Island, Washington). The secondary tag served two purposes; (1) it allowed multiple release groups to be identified separately, and (2) it provided long-term identification of marked individuals (tags often lasted several months).

Trap efficiency was defined as the proportion of the total number of emigrants that were captured as they moved past the trap. The approximate estimate of trap efficiency (*TE*) for each sampling period is similar to that given by Roper and Scarnecchia (2000):

$$TE = \frac{\sum_{i=1}^{n} R_{ji}}{M_j}$$

Where R_{ji} is the number of recaptured fish from the j^{th} release group on the i^{th} day, and M_j is the number of marked fish released. This estimate of efficiency assumes that (1) all released fish continue downstream after release, (2) handling does not affect fish behavior, (3) mortality rates are zero, and (4) marked fish mix randomly with unmarked fish.

Efficiency values were only applied to data for their respective year and location. Although efficiency tests were performed separately each week, two adjoining weeks of efficiency values were averaged to calculate daily trap efficiency and daily emigration past each trap for the respective time-period. This was done to avoid bias associated with few recaptures (less than 7; Roper and Scarnecchia, 1999). For weeks between 1 December and 15 April without efficiency tests, the average efficiency value for the year was used to calculate daily passage. Efficiency values were only applied to RST catch between 1 December and 15 April. For periods when the trap was set for less than seven consecutive days, daily catch for the un-sampled period (*DCU*) was estimated by the following formula, where CS1 = total catch in the sample days before the un-sampled period; CS2 = the total catch after the un-sampled period; D_1 = the number of days in sample period one and D_2 = the number of days in sample period two.

$$DCU = \frac{\sum(C_{S1}) + \sum(C_{S2})}{D_1 + D_2}$$

Daily passage estimates (DPE) were not made for periods when the trap was set for less than seven consecutive days, so as to avoid making unreasonable inferences about longer un-sampled periods (Roper and Scarnecchia, 2000). Daily passage estimates and 95% confidence intervals were calculated by Chapman's (1951) expression:

$$DPE = [(Mj + 1)(Cj + 1)/(Rj + 1)] - 1$$

Whereby *Mj* is the number of marked salmon released for the trap efficiency during time period j, Cj is the number of unmarked salmon captured in the trap during the time period j and Rj is the total number of recaptures during period j. Daily confidence intervals (95%) for the period are calculated as

$$C.I. = DPE + Z_{\alpha(2)}[(VarDPE)]^{1/2}$$

where

$$Var(DPE) = DPE^2(Cj - Rj)/[(Cj + 1)(Rj + 2)]$$

The annual emigration estimate (EE) is the sum of Daily Passage Estimates plus the sum of raw daily catch (DC) for periods without DPEs.

$$EE = \sum_{d=dec.1}^{Apr.15}(DPE) + \sum_{d=Apr.15}^{July1}(DC)$$

The resulting emigration estimate is inherently low for two reasons. First, it uses only raw catch before December 1 and after 15 April and in periods when the trap is fished for less than seven consecutive days. Second, and more importantly, the trap is not always fished during high flows (> 15,000 cfs) and heavy debris loads.

The emigration estimate for the river can then be used to calculate an emigration index (EI) using the spawning escapement estimate from the previous fall. The emigration index is a per-capita production estimate that may be used to compare production from year to year. The index is calculated by dividing the emigration estimate (*EE*) for the river by the estimated number of adult/grilse females (*F*) determined by the fall escapement survey.

$$EI = \frac{EE}{F}$$

Juvenile salmon survival rate (*SR*) for the Low Flow Channel is computed as follows

$$SR = \frac{EE}{SF \times 5522}$$

Where *SF* is the number of successfully spawned females in the Low Flow Channel, *5522* is the expected average fecundity of Feather River Chinook salmon females (personal communication with Armando Quinones, California Department of Fish and Game) and *EE* is the total juvenile Fall-run salmon emigration estimate for the Low Flow Channel.

Due to unequal sampling effort among years, trapping effort (in hours per month) and number of salmon captured per hour (CPH) is reported for each year. Effort calculations were only performed for days when trapping performance was good or fair. The effects of river flow, temperature and turbidity on emigration timing were examined with simple linear regression. In general, each variable (e.g. river flow) was reduced to a weekly average and plotted against the corresponding passage estimate for the respective week. However, unusual periods of elevated turbidity and flow were also analyzed to investigate the relationship that either may play in stimulating passage.

Results

RST Catch and Species Composition

Twenty-nine species were caught during the three survey years, 13 native and 16 non-native (Table 1). This is similar to the number of species caught in the three previous years of trapping (DWR 2002). Chinook salmon was the dominant species, comprising over 99% of the total catch for all three years combined. Of the total catch, 1,121,978 (39%) were caught at the Thermalito RST and 1,786,833 (61%) were caught at the Live Oak RST (Table 2 and 3).

The large numbers of salmon resulted in a high proportion of native fish (99.7%) in the total catch. Non-natives were also prevalent; 54.8% of all non-salmonids were non-native (Table 1). However, the proportion of native fish did not differ between the two traps: 99.9% of the fish captured at Thermalito were native species, while 99.7% of the fish captured at Live Oak were native.

Salmon Emigration

Salmon were caught in both RSTs as soon as they were deployed. Monthly salmon catch at each RST is reported in Tables 2 and 3. The highest daily catch at Thermalito was 59,415 on 19 February 2004. The highest daily catch at Live Oak was 65,667 on 18 February 2004. Catch was highest in January, February and March of each year. Salmon catch declined rapidly at both traps starting in April each year (Figures 3-8; Tables 2-3). The Thermalito trap averaged 0.02 % of the total catch for the months of April, May and June combined for all three years while the Live Oak trap averaged 0.28% of the total catch for the same time period. In contrast, January, February and March averaged 97.3% and 92.0% of the total Chinook catch at Live Oak and Thermalito, respectively.

Salmon size ranged from 26 to 104 mm FL at Thermalito and 28 to 210 mm at Live Oak. Weekly mean fork length ranged from 31 to 86 mm at Thermalito and 32 to 82 mm at Live Oak. Mean fork length at each RST changed little until late April, then steadily increased until the end of trapping (Figures 10 and 11).

Trap Efficiency and Emigration Estimates

Eighty-eight efficiency evaluations were conducted during the three-year study period (Tables 4 and 5). Recapture rates in the Thermalito RST ranged from 0.6% to 13.5% and averaged 3.63% ($\pm$ 2.43 SD) over the three-year period. The Live Oak RST efficiency ranged from 0% to 14.3% and averaged 4.02% ($\pm$ 2.92 SD) over the same three-year period. Emigration estimates for Fall-run size fish from 2002-2004 are presented in Tables 2 and 3.

Emigration index values increased over the three year period, however, survival rates fluctuated (Table 6). For example, the index means that for every adult female salmon that spawned in the river in fall 2001, 137 juvenile Chinook salmon passed the RST at Thermalito in the winter and spring of 2002. This corresponds to a survival of 6.3% from the time of egg deposition to capture at the Thermalito trap (2002 only).

Coded-wire Tagging of Naturally Spawned Salmon

A summary of DWR tagging efforts of naturally produced Fall-run Chinook salmon is presented in Table 8. To this point, low return rates of naturally produced Chinook have precluded formal analysis of the data. A recent increase in tagging effort should provide greater returns allowing us to evaluate the return success of naturally produced fish compared to hatchery stock.

Spring-run-Size Chinook

Figure 12 illustrates that the majority of Spring-run-sized fish caught at the traps are small. They are nearly identical in size to the Fall-run emigrating at the same time, clearly illustrating the uncertainties of using the Daily Length Table alone as an indicator of race.

Figure 12 also illustrates the emigration patterns and catch distribution for Spring-run-sized fish. In all three years, the highest catch was in December. Spring-run were caught at both traps throughout most of the sampling period, with a steady decline from December to March—a typical Fall-run or Ocean-type emigration pattern. After rearing in the river to a larger size, a very small group of Spring-run-sized fish passed Live Oak in April.

Late-fall-Size Chinook

Very few Late-fall-run Chinook were present in the Feather River. Immediately after emergence, Late-fall Chinook were captured at both RSTs (Figure 13). Catch at both traps peaked between March and May, then quickly dropped. The highest number of Late-fall-run Chinook were caught at Live Oak in April 2002 (Table 3.). Sixty-percent of all the Late-fall-run Chinook were caught at Thermalito and nearly all were captured as fry (Tables 2 and 3 and Figure 13).

Steelhead

Over the three years, a total of 1464 steelhead were caught at both locations. Of those, 1071 were naturally produced (wild) YOY steelhead (<150 mm) captured at Thermalito and Live Oak (Figure 14; Tables 2 and 3). Only five wild yearlings have been captured during the past three trapping seasons. One adult wild steelhead (>250 mm) was caught on 6 January 2004 at the Live Oak RST.

Steelhead catch predominantly occurs in March and April at both locations, with much smaller catch in May and June (Figure 15). Average fork length was 26.3 mm (± 7.9 SD) at Thermalito and 24.5 mm (± 7.2 SD) at Live Oak (Figure 16). Steelhead catch has decreased every year since 2002 at Thermalito (Table 1). Nearly 96% of all wild steelhead trapped were caught at the Thermalito RST (Figure 14 and Table 1).

Influence of Flow, Temperature and Turbidity on Emigration

Except for two brief events in 2004, LFC flows were approximately 600 cfs year round (Figure 3). High Flow Channel flows ranged from a low of 1047 cfs in March 2003 to a high of 19,000 cfs in February 2004 (Figure 4). There is no evidence of a connection between flow and Chinook catch at Thermalito or Live Oak (Table 7). Fry passage at Thermalito varies considerably through time, while flows remain nearly constant. Furthermore, although flows fluctuate at Live Oak, salmon catch rarely responds accordingly (Figure 4).

Water was normally clearer in the Low Flow Channel than in the High Flow Channel (Figures 7 and 8). No general relationship between turbidity and passage was observed for the HFC or LFC. However, a strong and significant relationship was observed for one elevated turbidity event in the LFC in 2004 (r^2=.554, $P<0.05$) (Table 7).

Although temperature was often statistically significant for predicting passage, it was not deemed to be biologically significant in influencing winter or early spring emigration because the average daily temperature at both traps never exceeded 14.0° C (57.2° F) until 90% of the population had already emigrated (Figures 5 and 6). Average daily water temperature ranged from 6.1 to 19.5 °C (43 to 67 °F) at the Thermalito RST and 7 to 24 °C (44.6 to 75 °F) at the Live Oak RST (Figures 5 and 6). Water temperature was low during winter, then steadily increased from March until the end of the sampling period at both locations.

Effort

Effort was generally consistent at Thermalito in all months except June 2003 (Table 9). Effort also doubled at Live Oak in 2004 with the addition of the second RST. Catch rates were generally greatest in January and February, although in March 2002 and 2004, Live Oak catch rates exceeded 168 salmon per hour (Table 9). Low effort in 2003 at Live Oak (419 hours in February) likely caused an underestimate of the number of salmon emigrating through the High Flow Channel (Table 9).

Discussion

Salmon Emigration: Trap Efficiency, Estimates and Timing

The accuracy of the emigration estimate is affected by several factors, the most important being trap efficiency. Searching for marked fish among thousands can be problematic. However, Bismarck Brown has consistently proven to be a safe, easy, and reliable method of mass marking individuals. Marked fish can be easily identified as many as five days after marking. Furthermore, salmon were often given an additional elastomer mark, making positive identification reliable for several weeks. Additionally, over 90% of the recaptures occurred within the first two days of release, the time when positive identification of marked fish is greatest.

Another factor affecting the emigration estimate at Live Oak is the lack of trapping during sustained high flow conditions. For example, six days of trapping were missed in February of 2004 at Live Oak near the probable peak of emigration. There is no reliable method to estimate passage during such long periods when the trap is not fishing. Roper and Scarnecchia (1999) used regression analysis of flow and catch to predict passage when traps could not be fished, but only for shorter periods of time (a few days). However, this requires a reliable relationship between flow and passage that has been problematic to develop on the Feather River. Furthermore, this method is only acceptable for short periods of trap inactivity. We investigated the relationship between river flow and trap efficiency in 2004 at both Thermalito and Live Oak and found no significant relationship ($P>0.9$ and $P>0.6$, respectively). In previous years, the relationship between the onset of adult spawning the previous fall and the onset of emigration has proved more valuable for predicting passage at the traps (DWR, 2002). Future work will continue to focus on all variables thought to predict passage when the traps are not fishing. Continuous efforts are in place to measure trap efficiency under varying flow conditions, release locations and turbidity levels in both the LFC and HFC. Although sustained high flows can be problematic for sampling with RSTs, the Feather River RSTs sample the majority of available days with trap efficiencies regularly performed throughout the emigration period.

The emigration pattern of Fall-run Chinook was similar in all three years at Thermalito. At Live Oak, however, a noteworthy change in the timing and magnitude of passage was observed in 2003. On average (dating back to 1999), 13 million more Fall-run Chinook pass the Live Oak location than Thermalito. In 2003, only 1.5 million more Fall-run passed Live Oak. The magnitude of the variation changes from year to year, but the unusually small passage difference observed in 2003 was alarming. A brief analysis of the 2002 adult escapement data for the LFC and HFC provided no clues as to the cause of the decline in passage. Because emigration estimates rely so heavily on trap efficiency trials, we investigated the likelihood of a problem with trap efficiencies performed at both locations. No obvious problems were found. We then investigated the likelihood of a large predation problem occurring between the Live Oak and Thermalito traps. In the fall of 2002, hatchery releases of steelhead smolts into the Feather River at Live Oak and Gridley totaled over 500,000. Observations of these fish by Feather River Program staff and anglers indicated that many were residualizing in both the LFC and HFC. Subsequent angling surveys conducted in the LFC in February revealed numerous salmon fry in the stomachs of steelhead smolts. One-hundred and one smolts were analyzed for stomach contents. The analysis revealed that each steelhead smolt had, on average, 1.38 ($\pm$ 3.98 SD) salmon fry in its stomach. This was likely the large predation problem that was most responsible for the unexpectedly low passage estimate at Live Oak. If only 10% of the smolts stayed and consumed only two Chinook fry per day they would consume 6,000,000 fry in just 60 days. Observations of these smolts continued into spring, indicating a rearing period potentially longer than 60 days. Rates of consumption would likely be even greater for the HFC (the release locations are both in the HFC) but increased flows in February prevented the collection of specimens for stomach analysis. It is possible that the increase in flow and turbidity in the HFC allowed many salmon fry to escape predation. However, it is likely that millions of fry were consumed during the winter and spring emigration period. The results of this limited predation study reveals the potential significance of releasing predator sized hatchery fish into the wild. Future studies should focus on the emigration strategies employed by hatchery reared steelhead so potential conflicts can be minimized.

Emigration Variables and Timing

This study confirmed all previous survey results (DWR 1999a, DWR 2002) that the bulk of the emigrating salmon are pre-smolt. The percentage of salmon that was clearly smolt or intermediate between parr and smolt was less than 2% at Thermalito and 15% at Live Oak. Most were smaller than 50 mm fork length (97% at Thermalito and 81% at Live Oak). The high percentages of pre-smolt fish and fish smaller than 50 mm indicate that most salmon smolt downstream of Live Oak.

In all years, 97% or more juvenile salmon had already passed the Live Oak screw trap by 1 April, probably ruling out temperature as a major driving force for the winter emigration pattern often observed. Environmental variables such as flow and turbidity (when muted or stabilized) appear to have a very small role in salmon emigration in the Feather River. However, the ability to monitor changes in turbidity and catch at both traps has been difficult. In the HFC, large increases in turbidity are usually accompanied by large increases in flow, preventing the traps from fishing continuously.

It is typical for LFC water clarity to remain high because flows are usually constant and low. However, in mid February 2004 the LFC experienced an unusually high turbidity event in the absence of a large flow increase (Figures 3 and 7). Initial analysis of the data (using weekly averages) revealed no significant relationship between turbidity and passage. However, isolating this single turbidity and corresponding passage event revealed a significant positive relationship between salmon passage and turbidity (Figure 9, Figure 15 and Table 7). This demonstrates that when turbidity is elevated and large numbers of parr are present, salmon probably emigrate at a greater rate, probably moving both during the day and night. For example, 31% percent of the LFC emigrant population passed during these two weeks. Approximately 12% of the entire LFC emigrant population passed the Thermalito trap in one 24-hour period during this two week event. Furthermore, more than 50% of the salmon passed the Thermalito trap in February, the month when turbidity is generally elevated (although not statistically significant). It is unknown, however, if the large number of passing fry in the month of February was caused by subtle changes in turbidity or simply because the fry had recently emerged from the gravel. It is likely that increased turbidity will stimulate emigration but, Chinook fry and parr still emigrate the Feather River in the absence of strong environmental cues. A combination of increased flows and highly elevated turbidity probably allows fry and parr the greatest opportunity for survival as they emigrate the Feather River. However, if flow pulses cannot be generated, increasing turbidity alone could still provide greatly increased survival for salmon smolts and fry.

Although it appears that flow, turbidity and temperature have little effect on emigration, it is possible that the altered flow regime on the Feather River mutes these historical emigration signals. Snider and Titus (1995) found that the timing of both fry and fingerling emigration was substantially different from that before construction of Folsom Dam on the American River. Additionally, measuring emigration during larger flow events (>15,000 cfs) is nearly impossible due to high debris loads. This creates bias toward more easily measured variables. It is also possible that warmer water on the valley floor (as compared to historical spawning grounds at higher elevations) causes fry to develop and emerge sooner than the river is capable of supporting them. The result is immediate and massive emigration due to a lack of food base in the winter/early spring. Historically, salmon may have emerged a month later and exploited the spring and summer food web. Perhaps salmon emigrate soon after emergence because competition for food in the LFC is so great that fry must disperse downstream to find adequate rearing habitat. Unwin (1986) found that the initial mass migration of Chinook fry in Glenariffe stream, New Zealand, was most likely a result of competition for rearing habitat. Healey (1991) reported that a large downstream movement of Chinook fry immediately after emergence is typical of most populations. He further reports that “the downstream migration of stream- and ocean-type Chinook fry, when spawning grounds are well upstream, is probably a dispersal mechanism that helps distribute fry among the suitable rearing habitats.” Salmon might also emigrate early to avoid high temperatures on the Sacramento Valley floor in the spring and summer. Unfortunately, the history of emigration in the Feather River is poorly known. Even the extensive sampling performed by Painter et al. (1977) between 1968 and 1973 provides little insight into the reasons for early emigration of fry.

The end of emigration in all three years was similar to previous years (DWR 1999a and DWR 2002). Painter and others (1977) found that, in 1968 through 1975, emigration could occur at least through the end of June in some years. Warner (1955) found that emigration ended around 1 June (in 1955). Snorkel surveys (DWR, unpublished data) and the rapid increase in fork-length at both traps between 23 March and the end of trapping implies that some Chinook use the upper river as a nursery area in the spring. Changing photoperiod and temperature together might create a migration cue for these fish. Roper and Scarnecchia (1999) found that photoperiod, or a correlated variable, was a migratory cue in the South Umpqua River, Oregon. However, the emigration peak in the South Umpqua is in summer, when long days might provide a strong cue. Furthermore, fish remaining in the river for several months grow larger and may have an advantage during emigration. They may be more adept at avoiding predators and finding food and be more physically prepared to smolt. However, fish emigrating in late spring may encounter much warmer conditions. Flain (in Unwin, 1986) reported that Chinook juveniles that reared in fresh water for several months to a year comprised 76% of the adult angler catch in the Rakaia River, although they comprised only 5% of the juvenile population. It is possible that a similar pattern of prolonged stream residence is successful on the Feather River and other Central Valley streams. Salmon rearing into the spring and summer could emigrate in the fall when temperatures are more suitable for passing the lower river and estuary. It is unknown if these late emigrants contribute substantially to the adult population. Current and future work focusing on otolith microstructure of Feather River Chinook will hopefully provide answers to questions circulating about various rearing strategies.

Spring-run Size Chinook

Although catch numbers were modest, the 2003 trapping season provided the highest catch of Spring-run size fish at both trapping locations (Table 2 and 3). During the last three trapping seasons emigration timing was similar to all previous years (DWR 2002). Spring-run size salmon were caught as soon as the RSTs were deployed (December), indicating that emigration began immediately after emergence.

The size difference between supposed Fall and Spring-run emigrants was typically only a few millimeters, demonstrating the difficulty of using the Daily Length Table alone as an indicator of race (Greene, 1992). As previously mentioned, most Spring-run sized salmon were small upon capture. Although probability of catch decreases as fish get larger, there is no reason to expect that great numbers of larger (>75 mm) Spring-run sized salmon were actively avoiding the traps at either location. Throughout spring, many Fall-run salmon are captured in the 60-100 mm range. This data, along with previous RST sampling, snorkel surveys and electrofishing implies that a true stream-type life-history no longer exists for Spring-run in the Feather River (assuming it ever existed). This would suggest an ocean-type life-history pattern typical of Fall-run Chinook in the Feather River and many other central valley rivers. While some larger fish of presumably all races (Fall, Spring and Late-fall) do persist throughout the summer (DWR unpublished data), there is no data to support the current existence of a true stream-type life-history for any race of salmon in the Feather River. Variations to the ocean-type life-history probably still exist in the Feather, however distinct populations that use these strategies exclusively are not apparent. Due to very low catch and the uncertainty of race designations, no estimate was generated for the population of “Spring-run” or Late-fall Chinook juveniles in the Feather River.

Late-fall-Size Chinook

Late-fall Chinook abundance and emigration timing was nearly identical to previous years. Catches at both Live Oak and Thermalito suggest little production of Late-fall-size Chinook in the Feather River. Most Late-fall-size Chinook appear to emigrate soon after emergence. Essentially all Late-fall-size salmon that were captured passed the traps within a month of emergence. This implies an emigration pattern similar to Fall-run-size fish. However, dive surveys (DWR, unpublished data) indicate that many Late-fall-size Chinook rear in the Feather River well into the summer. The recent capture of smolt size (>150 mm) Late-fall-run further supports the potential for an alternative life history strategy. Patterns of occurrence of Late-fall-size fish are subject to the same caution as for Spring-run-size fish. Their identification is based on the Daily Length Table, which provides little separation from Fall-run-size fish. However, the observations of adults spawning as late as March and the capture of smolt sized fish indicate that a true Late-fall-run may still exist. The small number of Late-fall juveniles captured and emigration pattern variability prohibit any firm conclusions about the status of this run.

Steelhead

Steelhead catch has declined every year since 2002 at both locations. The capture of wild juveniles at the Thermalito trap indicates a modest number of steelhead continue to spawn in the LFC.

Very few yearling steelhead were caught during this study. This is probably attributable to three factors: 1) the scarcity of adults; 2) the ability of the larger fish to avoid capture; and 3) their lack of movement. Unlike most emigrating salmon, few juvenile steelhead appear to emigrate the Feather River when they are susceptible to capture (immediately after emergence). Emigration typically peaks in March and continues through April in most years. Most steelhead probably set up a “home-range” and rear until they reach or surpass a size at which capture by screw trap is unlikely. Dive surveys confirm that even 60 mm salmon and steelhead can avoid the RSTs under some conditions of location and water velocity, making it difficult to gather information on steelhead emigration patterns (DWR, unpublished data). These observations further support the need for other methods (mark-recapture and diver surveys) to understand the basic life history of fry, juvenile and adult steelhead in the Feather River.

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Table 1. Summary of Non-Chinook fishes caught at both screw trap locations all three years.

Common Name	Scientific Name	Origin*	Thermalito 2002	Thermalito 2003	Thermalito 2004	Live Oak 2002	Live Oak 2003	Live Oak 2004	**Total**
American Shad	*Alosa sapidissima*	I	0	0	0	1	0	2	**3**
Bluegill	*Lepomis macrochirus*	I	0	0	1	15	11	20	**47**
Black Bullhead	*Ameiurus melas*	I	1	0	0	0	1	0	**2**
Black Crappie	*Pomoxis nigromaculatus*	I	0	0	1	0	0	2	**3**
Channel Catfish	*Ictalurus punctatus*	I	0	0	1	0	1	1	**3**
Brown Bullhead	*Ameiurus nebulosus*	I	0	0	0	1	0	0	**1**
Common Carp	*Cyprinus carpio*	I	1	0	0	1	0	0	**2**
Golden Shiner	*Notemigonus crysoleucas*	I	1	1	3	2	7	10	**24**
Green Sunfish	*Lepomis cyanellus*	I	0	0	0	0	3	10	**13**
Hard Head	*Mylopharadon conocephalus*	N	2	9	4	43	198	31	**287**
Hitch	*Lavinia exilicauda*	N	1	0	2	0	0	0	**3**
Largemouth Bass	*Micropterus salmoides*	I	8	3	9	36	28	3	**87**
Pacific Lamprey	*Lampetra tridentata*	N	493	112	2103	163	122	140	**3133**
Prickly Sculpin	*Cottus asper*	N	66	27	27	0	32	8	**160**
Steelhead (Clipped)	*Oncorhynchus mykiss mykiss*	N	2	11	0	334	35	6	**388**
Steelhead (Wild)	*Oncorhynchus mykiss mykiss*	N	470	378	182	18	10	18	**1076**
Redear Sunfish	*Lepomis microlophus*	I	0	0	0	6	3	7	**16**
Riffle Sculpin	*Cottus gulosus*	N	4	1	22	0	0	1	**28**
River Lamprey	*Lampetra ayresi*	N	10	25	39	111	301	485	**971**
Sacramento Pikeminnow	*Ptychocheilus grandis*	N	15	14	22	93	101	86	**331**
Sacramento Splittail	*Pogonichthys macrolepidotus*	N	0	0	0	0	0	1	**1**
Sacramento Sucker	*Catostomus occidentalis*	N	13	9	20	18	139	30	**229**
Smallmouth Bass	*Micropterus dolomieu*	I	0	0	0	6	0	3	**9**
Speckled Dace	*Rhinichthys osculus*	N	0	0	2	8	12	7	**29**
Tule perch	*Hysterocarpus traski*	N	0	7	5	222	21	25	**280**
Wakasagi	*Hypomesus nipponensis*	I	144	124	565	1587	1226	3367	**7013**
Warmouth	*Lepomis gulosus*	I	0	0	1	17	0	26	**44**
Western Mosquitofish	*Gambusia affinis*	I	28	7	8	28	8	8	**87**
White Crappie	*Pomoxis annularis*	I	0	0	1	0	0	9	**10**
Unidentified Bass	*Micropterus sp.*	I	22	0	1	11	0	2	**36**
Unidentified Lamprey	*Lampetra sp.*	N	103	71	208	134	349	501	**1366**
Unidentified Minnow	Cyprinidae	N	2	1	0	26	0	0	**29**
Unidentified Sculpin	*Cottus sp.*	I	260	55	0	123	49	74	**561**
Unidentified Sunfish	*Lepomis sp.*	I	0	0	0	0	1	3	**4**
Total			**1646**	**855**	**3227**	**3004**	**2658**	**4886**	

* N = Native, I = Introduced

Table 2. Monthly catch for three race of Chinook salmon caught from 2001-2004 at Thermalito. Monthly estimates were included for fall Chinook only.

	2001		2002						
	Nov.	Dec.	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	8753	140998	106281	17161	167	122	8	273490
Fall Chinook (estimate)	---	291524	3176581	2466434	725535	2252	122	8	6662456
% of Estimate	---	4%	48%	37%	11%	0.03%	0.002%	0.0001%	100%
Spring Chinook	83	68	3	8	6	1	---	---	169
Late Fall Chinook	---	---	---	---	---	80	61	---	141

	2002		2003						
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	51384	199495	71612	4087	336	66	21	327001
Fall Chinook (estimate)	---	1147813	4075062	2050333	170899	3679	66	21	7447872
% of Estimate	---	15%	55%	28%	2%	0.05%	0.001%	0.0003%	100%
Spring Chinook	---	5658	10	7	9	9	1	---	5694
Late Fall Chinook	---	---	---	---	---	34	60	---	94

	2003		2004						
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	27689	173919	296290	22874	461	231	23	521487
Fall Chinook (estimate)	---	571777	4627763	7079212	1554807	9698	231	23	13843511
% of Estimate	---	4%	33%	51%	11%	0.07%	0.002%	0.0002%	100%
Spring Chinook	---	1297	764	8	3	2	1	---	2075
Late Fall Chinook	---	---	---	---	---	76	6	---	82

Table 3. Monthly catch for three race of Chinook salmon caught from 2001-2004 at Live Oak. Monthly estimates were included for fall Chinook only. Two rotary screwtraps were used in the 2003-2004 trapping year.

	2001		2002						
	Nov.	Dec.	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	79	127792	300715	119317	1501	254	6	549664
Fall Chinook (estimate)	---	2844	2555454	9752959	3464567	25990	254	6	15802074
% of Estimate	---	0.02%	16%	62%	22%	0.2%	0.002%	0.00004%	100%
Spring Chinook	---	1	2	10	23	26	2	---	64
Late Fall Chinook	---	2	---	---	---	84	---	---	86

	2002		2003						
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	18033	177705	116908	19118	852	223	4	332843
Fall Chinook (estimate)	---	514205	5053937	2835676	543360	13263	223	4	8960669
% of Estimate	---	6%	56%	32%	6%	0.1%	0.002%	0.00004%	100%
Spring Chinook	---	3254	50	6	27	103	20	---	3460
Late Fall Chinook	---	---	---	---	55	17	2	---	74

	2003		2004						
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	**Total**
Fall Chinook (caught)	---	10020	137636	488983	250735	8252	8079	621	904326
Fall Chinook (estimate)	---	246133	2965321	8024689	17389138	641108	7159	621	29274170
% of Estimate	---	1%	10%	27%	59%	2%	0.02%	0.002%	100%
Spring Chinook	---	344	31	41	27	55	14	---	512
Late Fall Chinook	---	---	1	---	---	49	3	1	54

Table 4. Trap efficiency data for the Feather River Thermalito RSTR, 2002-2004.

	Mark Type	Release Date	Recovery Period	# Marked	# Recaptured	% Efficiency
2002						
	BB	1/4/02	1/04/02 - 1/07/02	996	31	3.11
	BB	1/8/02	1/08/02 - 1/11/02	1000	31	3.10
	BB	1/14/02	1/14/02 - 1/22/02	1495	40	2.68
	BB	1/22/02	1/22/02 - 1/27/02	1000	49	4.90
	BB	1/28/02	1/28/02 - 2/02/02	998	80	8.02
	BB	2/4/02	2/04/02 - 2/10/02	1000	34	3.40
	BB	2/11/02	2/11/02 - 2/17/02	996	25	2.51
	BB	2/19/02	2/19/02 - 2/23/02	998	44	4.41
	BB	2/26/02	2/26/02 - 3/01/02	996	62	6.22
	BB	3/4/02	3/04/02 - 3/06/02	998	23	2.30
	BB	3/7/02	3/07/02 - 3/10/02	1000	11	1.10
	BB	3/11/02	3/11/02 - 3/13/02	896	18	2.01
	BB	3/19/02	3/19/02 - 3/22/02	178	1	0.56
2003						
	BB	12/30/2002	12/30/02 - 1/07/03	1000	79	7.90
	BB/ Orange Nose	1/7/2003	1/07/03 - 1/10/03	692	32	4.62
	BB/ Green Nose	1/10/2003	1/10/03 - 1/15/03	980	9	0.92
	BB/ Orange Nose	1/15/2003	1/15/03 - 1/18/03	1178	91	7.72
	BB	1/18/2003	1/18/03 - 1/21/03	975	30	3.08
	BB/ Yellow Nose	1/21/2003	1/21/03 - 1/23/03	1020	48	4.71
	BB/ Orange Nose	1/23/2003	1/23/03 -1/29/03	1923	96	4.99
	BB/ Red Nose	1/29/2003	1/29/03 - 2/04/03	1482	56	3.78
	Orange Nose Only	2/4/2003	2/04/03 - 2/11/03	992	14	1.41
	BB	2/11/2003	2/11/03 - 2/21/03	1000	55	5.50
	BB/ Yellow Nose	2/21/2003	2/21/03 - 2/27/03	1084	21	1.94
	BB	2/27/2003	2/27/03 - 3/08/03	994	23	2.31
	BB	3/8/2003	3/08/03 - 3/12/03	572	10	1.75
2004						
	BB/ Orange Nose	12/23/2003	12/23/03 - 12/27/03	693	29	4.18
	BB/ Green Nose	12/27/2003	12/27/03 - 01/02/04	738	46	6.23
	BB/ Orange Nose	1/2/2004	1/03/04 - 1/08/04	1074	29	2.70
	BB/ Yellow Nose	1/8/2004	1/09/04 - 1/14/04	925	50	5.41
	BB/ Blue Nose	1/14/2004	1/15/04 - 1/23/04	1012	57	5.63
	BB/ Orange Nose	1/23/2004	1/24/04 - 1/29/04	1059	52	4.91
	BB	1/29/2004	1/30/04 - 2/01/04	982	22	2.24
	BB	2/1/2004	2/02/04 - 2/05/04	1000	15	1.50
	BB	2/5/2004	2/06/04 - 2/09/04	999	135	13.51
	BB	2/9/2004	2/10/04 - 2/12/04	995	39	3.92
	BB/ Red Nose	2/12/2004	2/13/04 - 2/16/04	1291	42	3.25
	BB	2/16/2004	2/17/04 - 2/19/04	1188	56	4.71
	BB	2/19/2004	2/20/04 - 2/23/04	1134	51	4.50
	BB	2/23/2004	2/23/04 - 2/24/04	997	28	2.81
	BB/ Orange Nose	2/28/2004	2/29/04 - 3/03/04	1085	8	0.74
	BB/ Yellow Nose	3/3/2004	3/04/04 - 3/06/04	1601	20	1.25
	BB/ Red Nose	3/6/2004	3/07/04 - 3/10/04	1030	21	2.04
	BB	3/10/2004	3/10/04 - 3/15/04	1191	18	1.51
	BB	3/15/2004	3/15/04 - 3/19/04	725	10	1.38
	BB/ Pink Nose	3/19/2004	3/19/04 - 3/25/04	850	15	1.76
	BB/ Red Nose	3/25/2004	3/25/04 - 3/31/04	492	7	1.42

Table 5. Trap efficiency data for the Feather River Live Oak RSTR, 2002-2004.

	Mark Type	Release Date	Recovery Period	# Marked	# Recaptured	% Efficiency
2002						
	BB	1/17/02	1/17/02 - 1/22/02	4000	136	3.40
	BB	1/22/02	1/22/02 - 1/27/02	998	143	14.33
	BB	1/28/02	1/28/02 - 2/02/02	1000	68	6.80
	BB	2/5/02	2/05/02 - 2/10/02	997	20	2.01
	BB	2/11/02	2/11/02 - 2/17/02	998	21	2.10
	BB	2/19/02	2/19/02 - 2/23/02	998	42	4.21
	BB	2/26/02	2/26/02 - 2/28/02	992	55	5.54
	BB	3/4/02	3/04/02 - 3/06/02	998	21	2.10
	BB	3/7/02	3/07/02 - 3/10/02	984	34	3.46
	BB	3/11/02	3/11/02 - 3/13/02	999	35	3.50
	BB	3/15/02	3/15/02 - 3/19/02	230	2	0.87
	BB	3/19/02	3/19/02 - 3/22/02	766	16	2.09
2003						
	BB	12/30/2002	12/30/02 - 1/09/03	995	65	6.53
	Pink/ Yellow Nose	1/9/2003	1/09/03 - 1/14/03	1052	0	0
	BB/ Blue Nose	1/14/2003	1/14/03 - 1/17/03	922	7	0.76
	BB/ Red Nose	1/17/2003	1/17/03 - 1/22/03	758	31	4.09
	BB	1/22/2003	1/22/03 - 1/25/03	1000	43	4.30
	BB/ Green Nose	1/25/2003	1/25/03 - 1/30/03	1015	39	3.84
	BB/ Green Nose	1/30/2003	1/30/03 - 2/05/03	1245	38	3.05
	BB/ Red Nose	2/5/2003	2/05/03 - 2/20/03	993	56	5.64
	BB	2/20/2003	2/20/03 - 3/04/03	486	6	1.23
	BB	3/4/2003	3/04/03 - 3/11/03	998	33	3.51
	BB	3/11/2003	3/11/03 - 3/15/03	819	39	4.76
2004						
	BB	12/30/2003	12/30/04 - 1/07/04	686	21	3.06
	BB	1/7/2004	1/07/04 - 1/12/04	540	28	5.19
	BB	1/12/2004	1/12/04 - 1/17/04	1995	80	4.01
	BB	1/17/2004	1/17/04 - 1/24/04	1309	64	4.89
	BB	1/24/2004	1/24/04 - 1/29/04	995	86	8.64
	BB	1/29/2004	1/29/04 - 2/02/04	1000	62	6.20
	BB	2/2/2004	2/02/04 - 2/05/04	988	54	5.47
	BB	2/5/2004	2/05/04 - 2/09/04	991	92	9.28
	BB	2/9/2004	2/09/04 - 2/12/04	1000	65	6.50
	BB	2/12/2004	2/12/04 - 2/16/04	992	63	6.35
	BB	2/16/2004	2/16/04 - 2/22/04	1000	89	8.90
	BB	2/22/2004	2/22/04 - 2/23/04	997	11	1.10
	BB	3/2/2004	3/02/04 - 3/08/04	992	21	2.12
	BB	3/8/2004	3/08/04 - 3/14/04	999	18	1.80
	BB	3/14/2004	3/14/04 - 3/24/04	1000	22	2.20
	BB	3/24/2004	3/24/04 - 3/30/04	995	4	0.40
	BB	3/30/2004	3/30/04 - 4/17/04	1089	5	0.46
	BB	4/17/2004	4/17/04 - 4/21/04	629	2	0.32

Table 6. Emigration index and egg-to-fry survival rates for the Feather River, calculated from emigration estimates and prior year's escapement data. Data from 2001 included as reference.

	2001 Trap Year		**Emigration Index**	**Survival Rate**
	Emigration Estimate ('01)	33839990	465	
	Total Escapement ('00)	116941		0.133053
Sampled (*n* =6246)	% Females	56%		
	% Females Spent	63%		
Estimated	Total Females	72700		
	Total Females Spent	46059		

	2002 Trap Year		**Emigration Index**	**Survival Rate**
	Emigration Estimate ('02)	15802074	137	
	Total Escapement ('01)	160672		0.063125
Sampled (*n* =4845)	% Females	72%		
	% Females Spent	39%		
Estimated	Total Females	114974		
	Total Females Spent	45333		

	2003 Trap Year		**Emigration Index**	**Survival Rate**
	Emigration Estimate ('03)	8960669	184	
	Total Escapement ('02)	83346		0.059066
Sampled (*n* =4942)	% Females	59%		
	% Females Spent	56%		
Estimated	Total Females	48773		
	Total Females Spent	27473		

	2004 Trap Year		**Emigration Index**	**Survival Rate**
	Emigration Estimate ('04)	29274115	566	
	Total Escapement ('03)	88830		0.153728
Sampled (*n* =6128)	% Females	66%		
	% Females Spent	59%		
Estimated	Total Females	58853		
	Total Females Spent	34485		

Table 7. Regression values for salmon passage on the Feather River, 2002-2004; for 2004 (a) corresponds to weekly averages for the entire trapping season and (b) corresponds to the week of 2/16/04-2/22/04.

		Thermalito		Live Oak	
		P-value	R^2 (adj.)	*P*-value	R^2 (adj.)
2002	Turbidity	0.268	3.8%	0.098	17.5%
	Flow	0.351	0.0%	0.078	20.6%
	Temperature	0.022	33.9%	0.492	0.0%
2003	Turbidity	0.445	0.0%	0.537	0.0%
	Flow	0.054	31.2%	0.395	0.0%
	Temperature	0.042	35.1%	0.455	0.0%
2004	Turbidity (a)	0.111	15.7%	0.340	0.0%
	Turbidity (b)	0.001	55.4%	---	---
	Flow (a)	0.925	0.0%	0.469	0.0%
	Flow (b)	0.445	0.0%		
	Temperature	0.781	0.0%	0.000	62.1%

Table 8. Naturally spawned coded-wire-tagged Feather River Fall-run Chinook salmon release totals, 1998-2004.

Year	**Total Release**
1998	63,989
1999	136,470
2000	147,156
2001	213,961
2002	202,796
2003	164,929
2004	168,612

Table 9. Monthly trap effort and catch per hour (cpue) at both trapping locations, 2002-2004.

	Thermalito		Live Oak	
2002	Effort (hours)	Catch/hour	Effort (hours)	Catch/hour
December	717	12.22	695	0.11
January	729	193.41	553	230.98
February	666	159.70	621	484.63
March	711	24.14	708	168.47
April	718	0.23	712	2.11
May	617	0.20	460	0.55
June	191	0.04	186	0.03
Totals	**4348**		**3935**	

2003	Effort (hours)	Catch/hour	Effort (hours)	Catch/hour
December	501	102.56	471	38.29
January	708	281.77	734	242.10
February	644	111.20	419	279.02
March	797	5.13	744	25.70
April	765	0.44	719	1.18
May	620	0.11	686	0.32
June	617	0.03	96	0.04
Totals	**4653**		**3869**	

2004	Effort (hours)	Catch/hour	Effort (hours)	Catch/hour
December	520	53.28	1039	9.65
January	730	238.25	1476	93.25
February	647	458.30	1036	471.88
March	729	31.39	1226	204.47
April	636	0.73	766	10.77
May	753	0.31	1512	5.35
June	286	0.08	239	2.60
Totals	**4300**		**7294**	

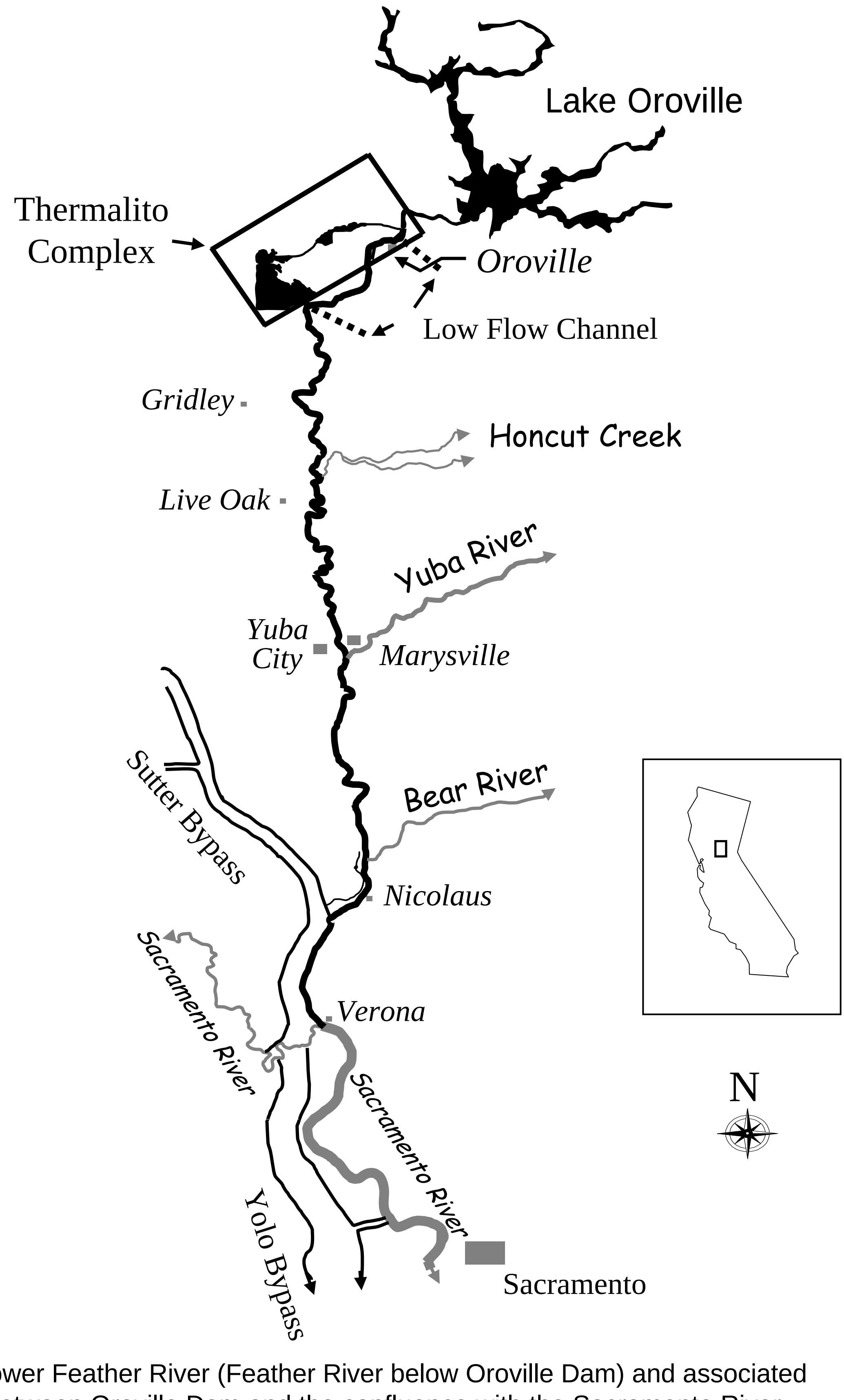

Figure 1: Lower Feather River (Feather River below Oroville Dam) and associated tributaries between Oroville Dam and the confluence with the Sacramento River.

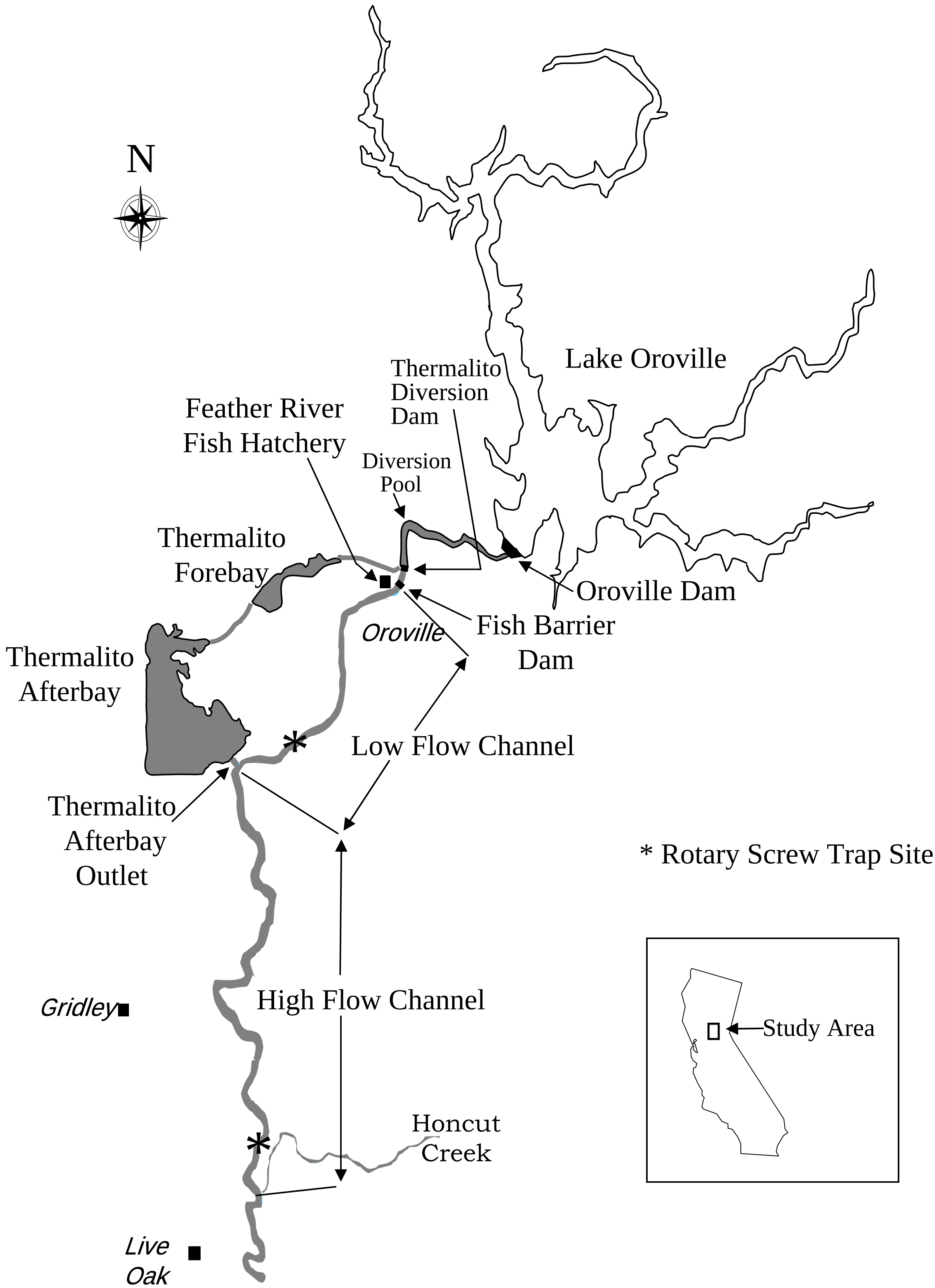

Figure 2: Lower Feather River Study Area.

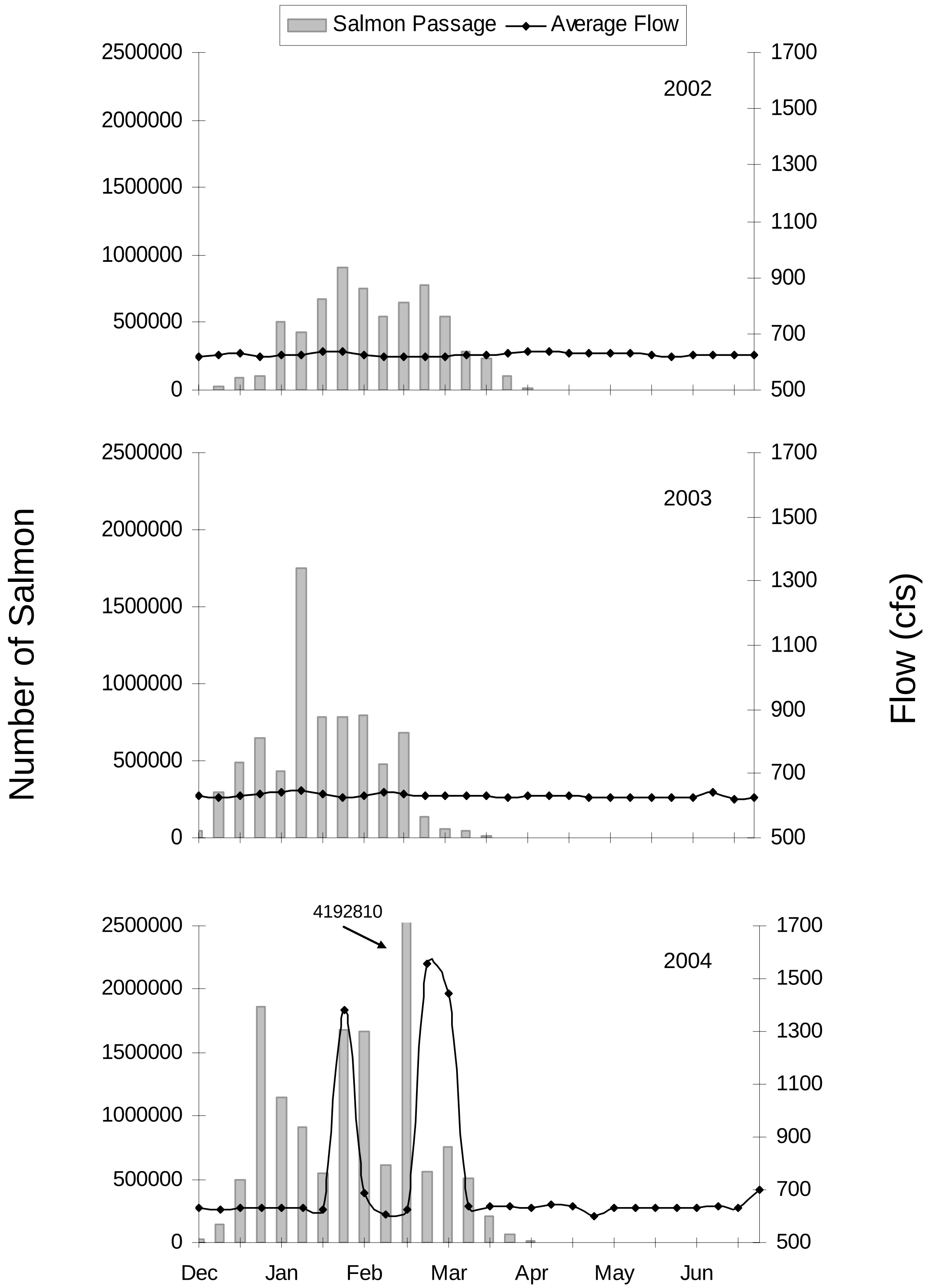

Figure 3. Estimated weekly passage and weekly average flow associated with catch of Fall-run-sized Chinook at the Thermalito RST during all three years of trapping.

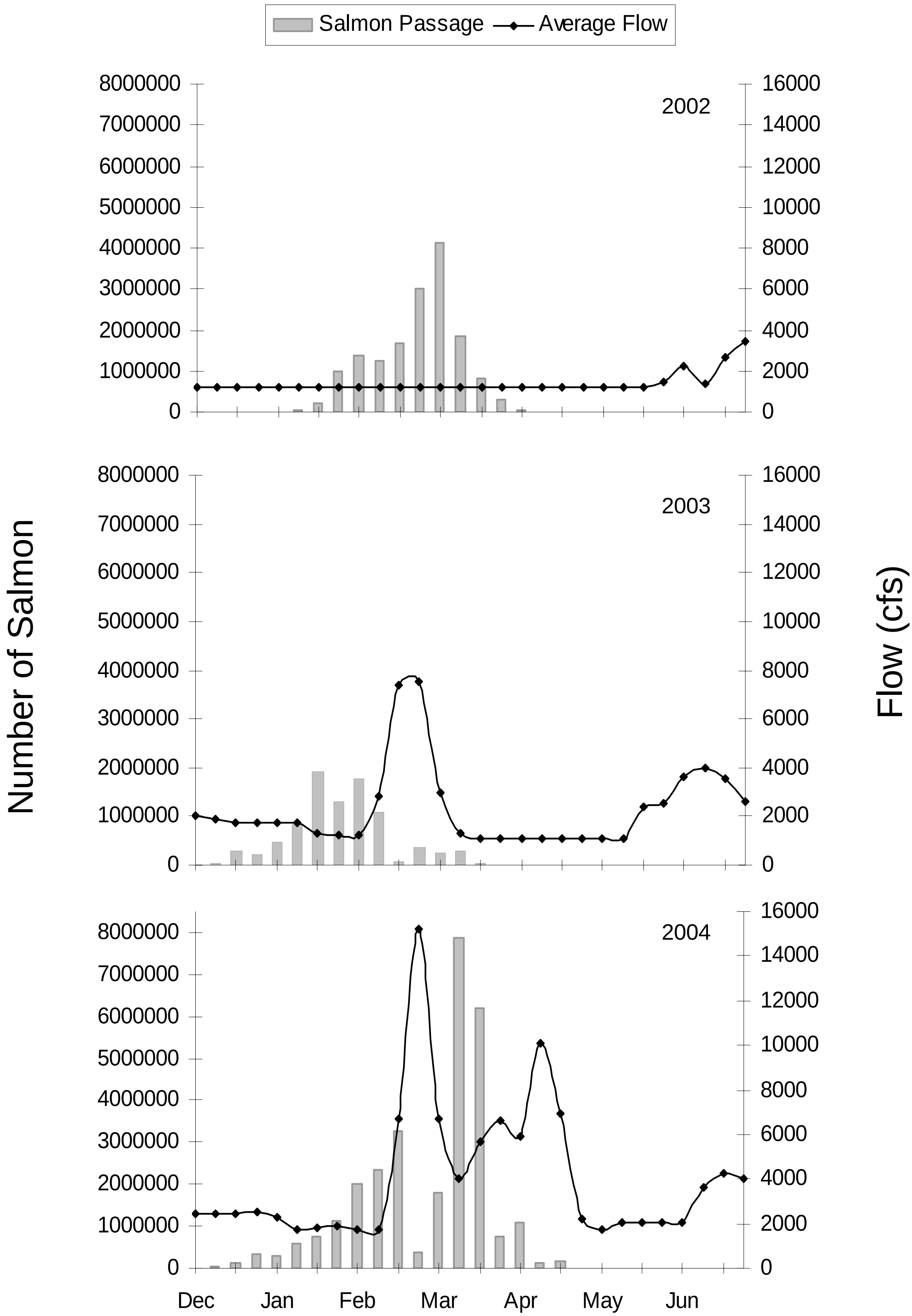

Figure 4. Estimated weekly passage and weekly average flow associated with catch of Fall-run-sized Chinook at the Live Oak RST during all three years of trapping.

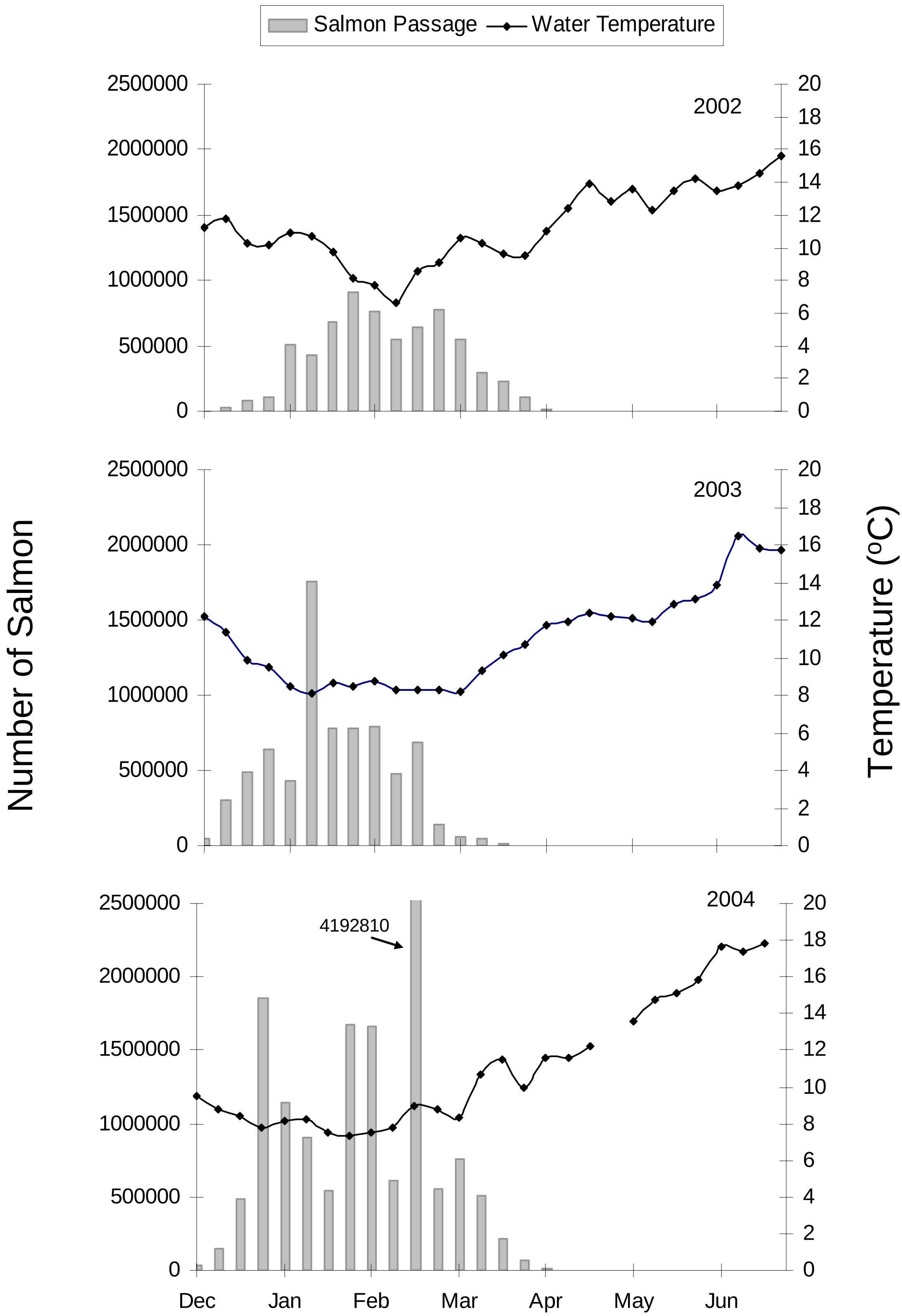

Figure 5. Estimated weekly passage and weekly average water temperature associated with catch of Fall-run-sized Chinook at the Thermalito RST during all three years of trapping.

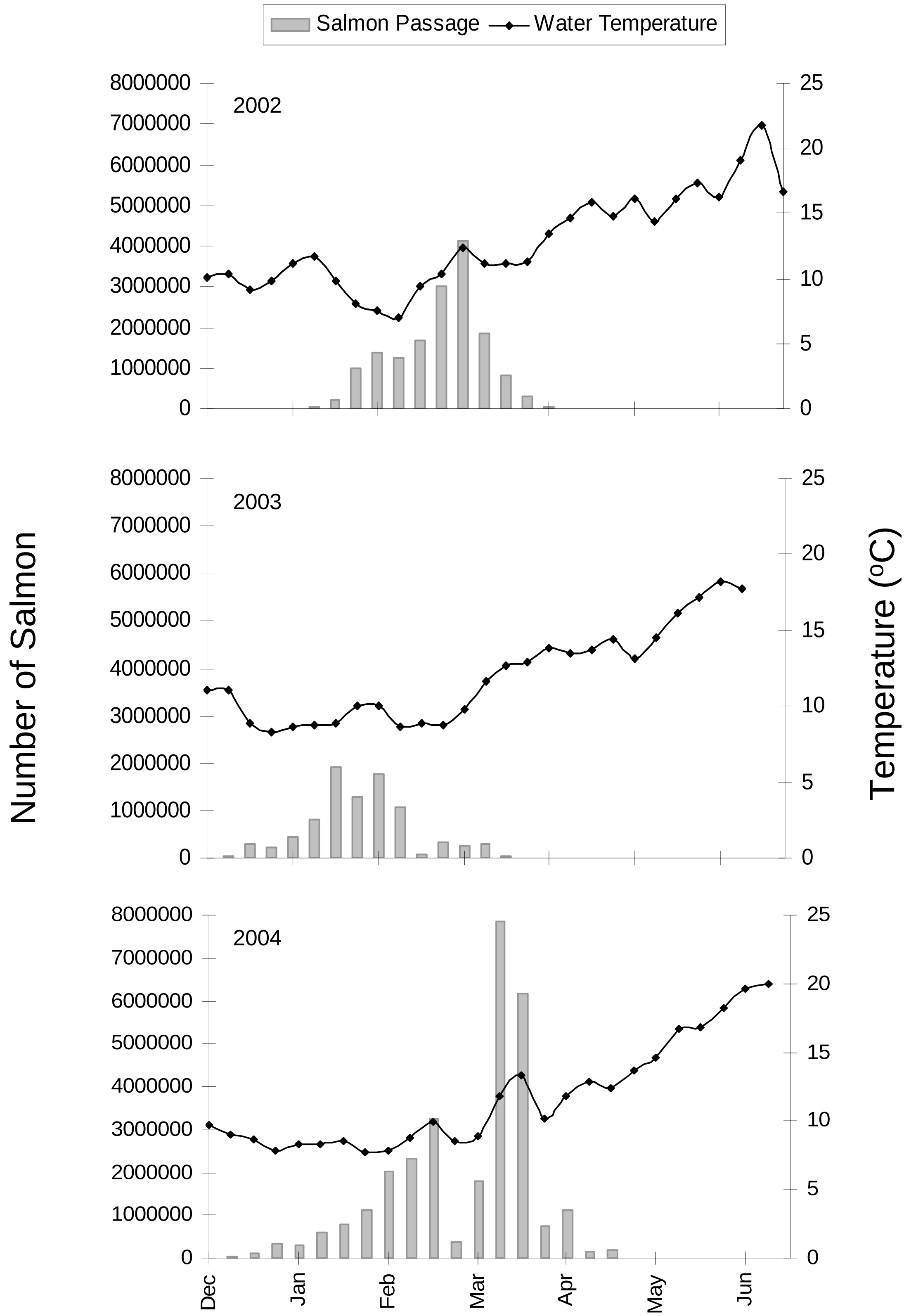

Figure 6. Estimated weekly passage and weekly average water temperature associated with catch of Fall-run-sized Chinook at the Live Oak RST during all three years of trapping.

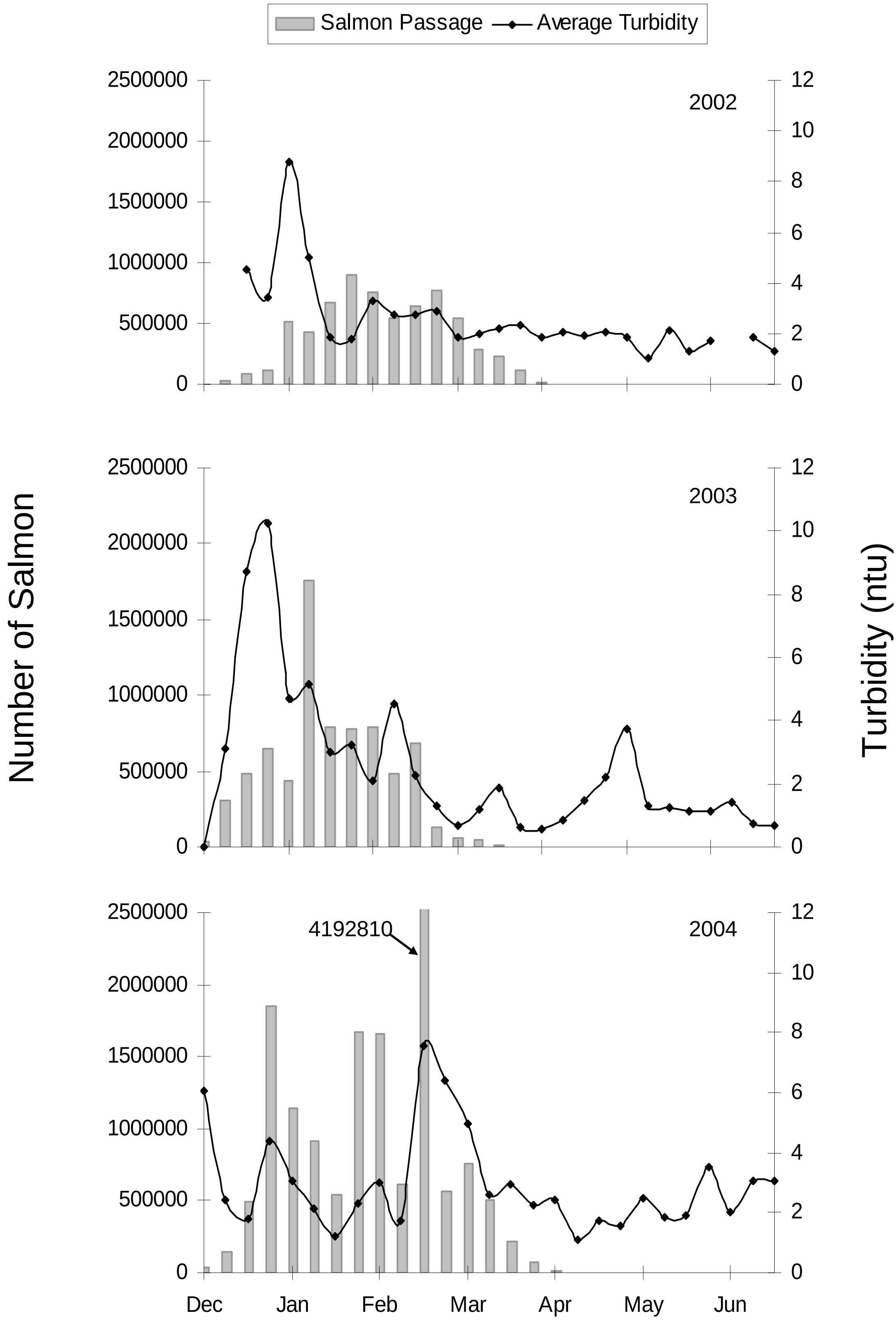

Figure 7. Estimated weekly passage and weekly average turbidity associated with catch of Fall-run-sized Chinook at the Thermalito RST during all three years of trapping.

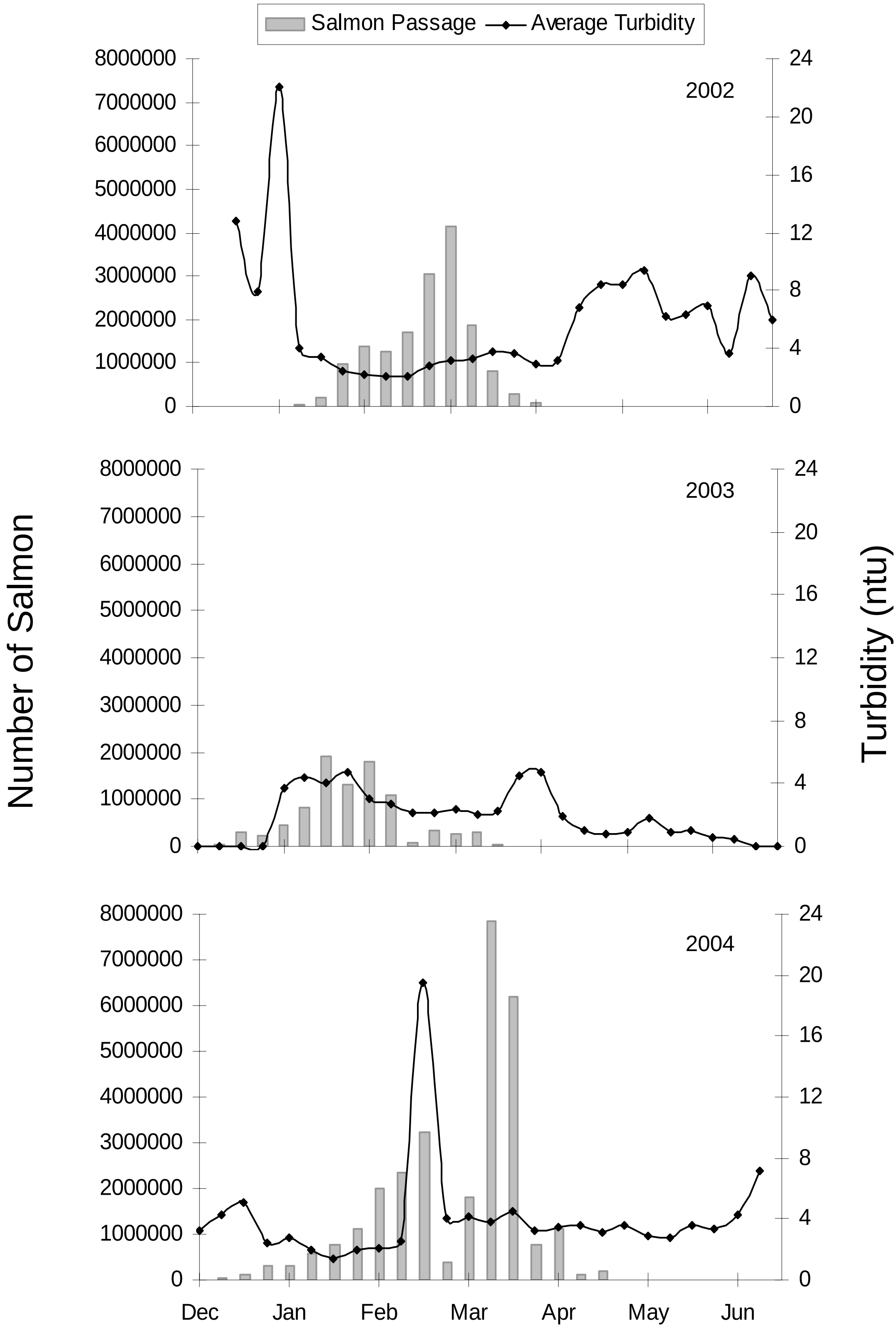

Figure 8. Estimated weekly passage and weekly average turbidity associated with catch of Fall-run-sized Chinook at the Live Oak RST during all three years of trapping.

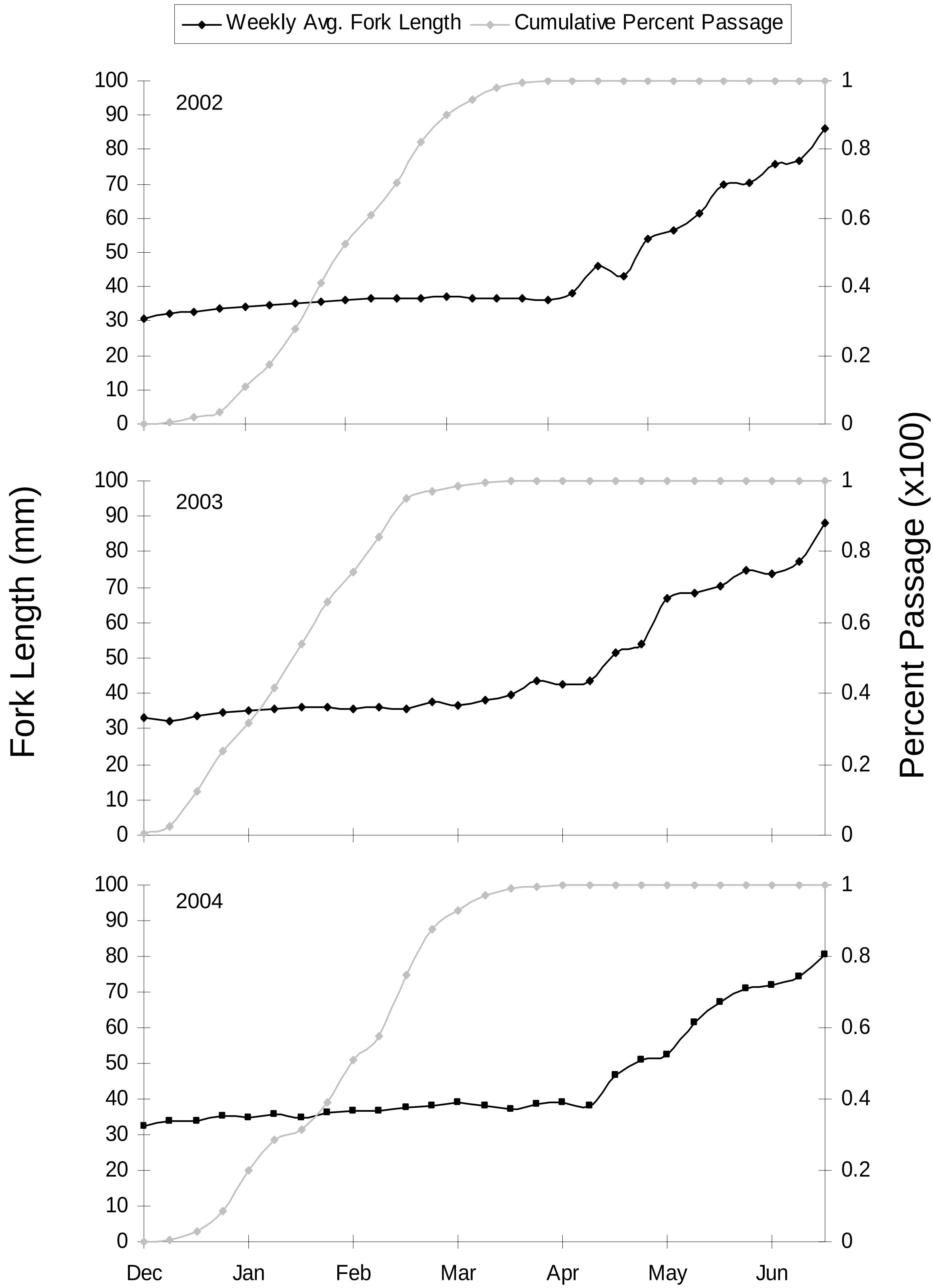

Figure 9. Average weekly fork length and cumulative percent observed Fall-run-sized Chinook salmon at Thermalito during all three years of trapping.

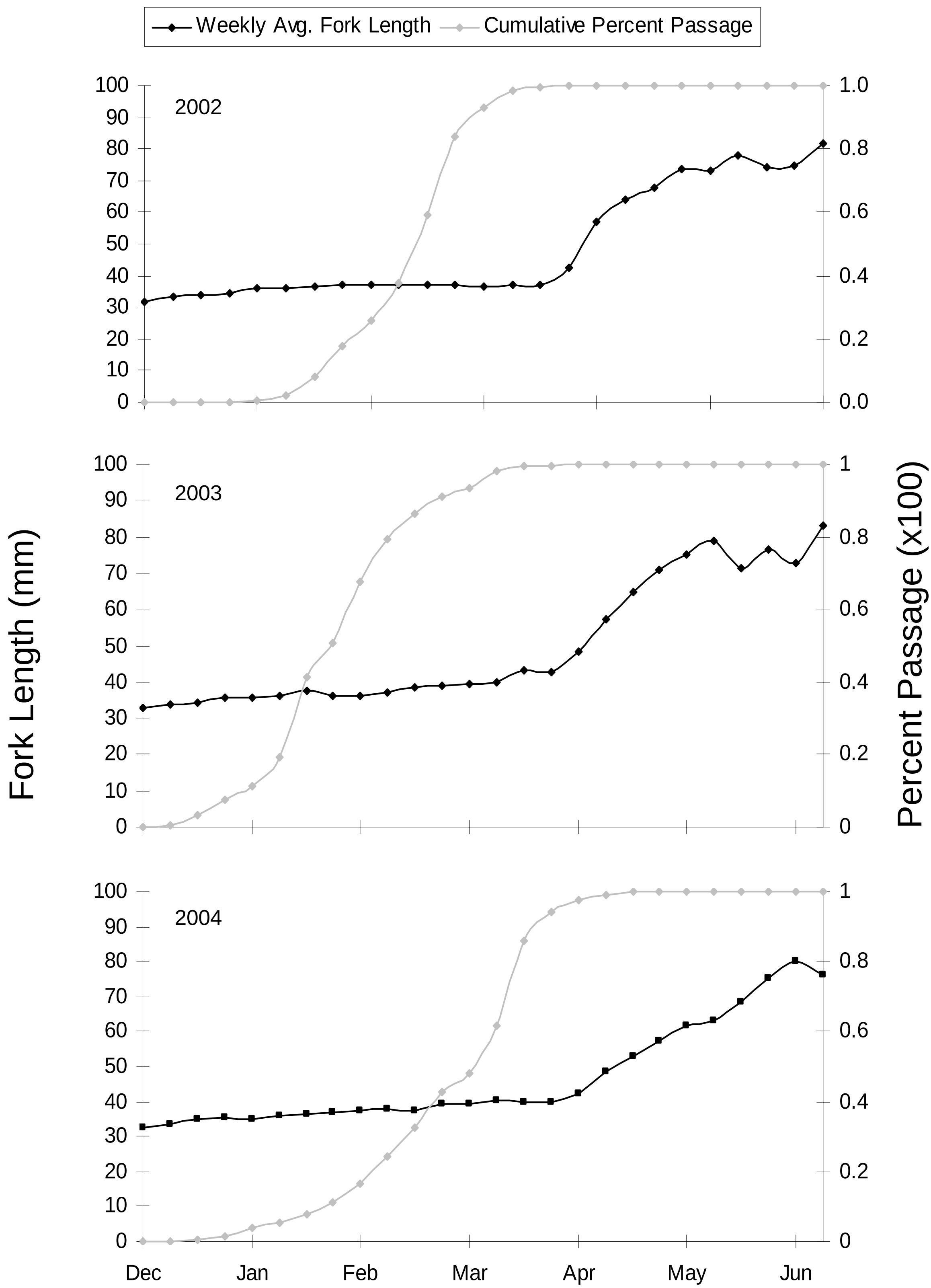

Figure 10. Average weekly fork length and cumulative percent observed Fall-run-sized Chinook salmon at Live Oak during all three years of trapping.

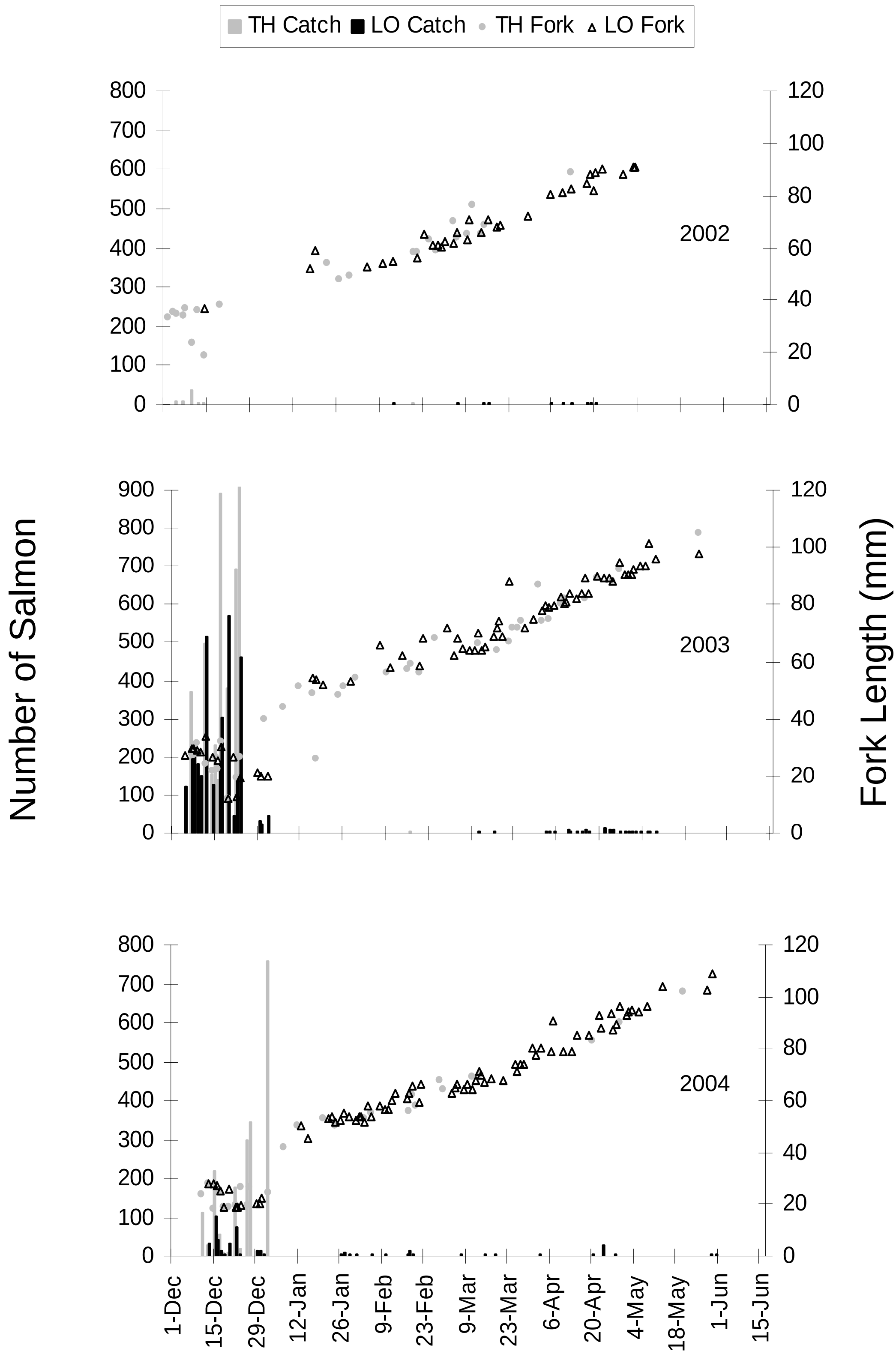

Figure 11. Daily catch distribution and daily average fork length for Spring-run-sized Chinook caught at Thermalito and Live Oak during all three years of trapping. Note y-axis scale change for 2003.

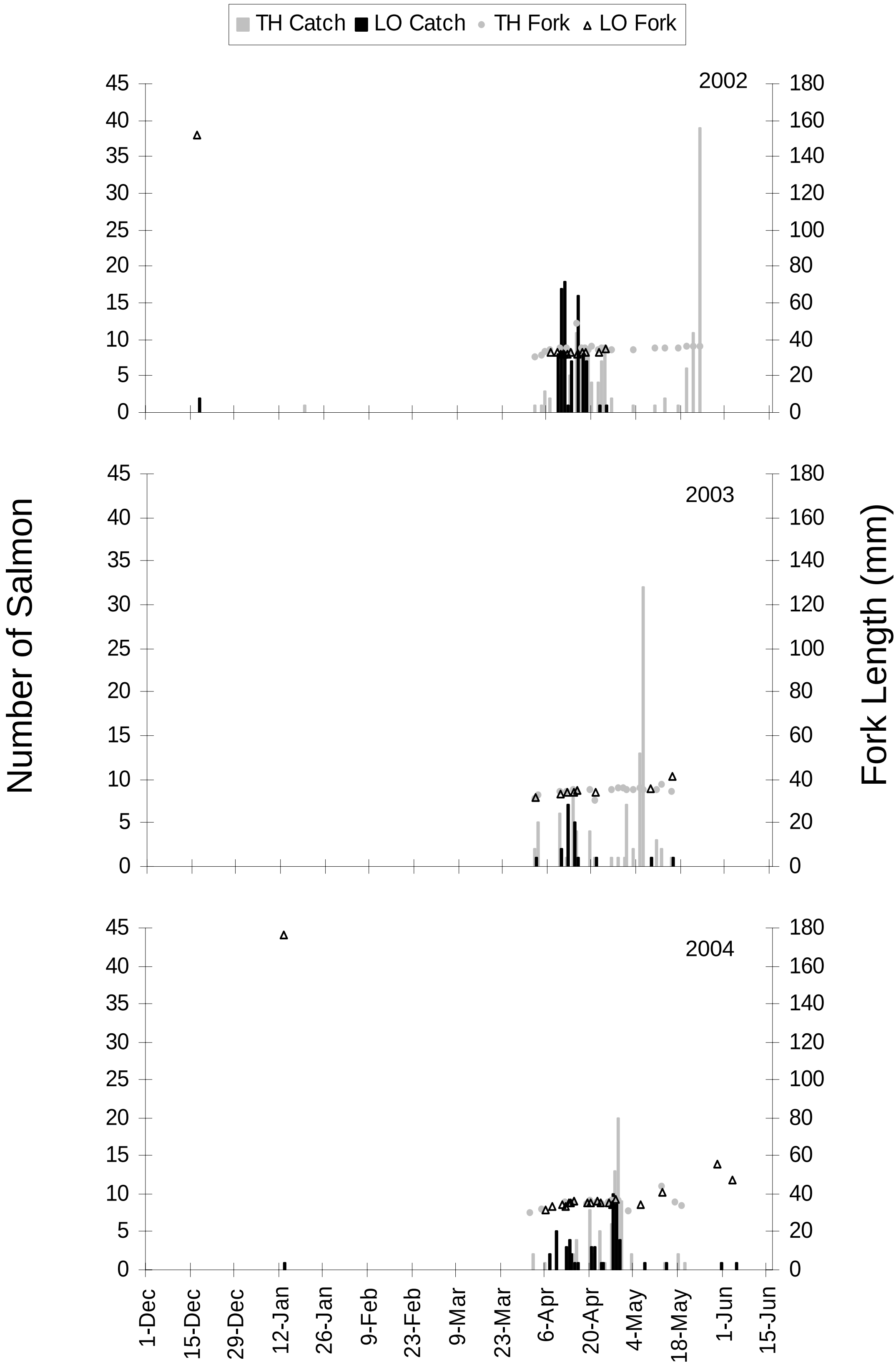

Figure 12. Daily catch distribution and daily average fork length for Late-fall-run-sized Chinook caught at Thermalito and Live Oak during all three years of trapping.

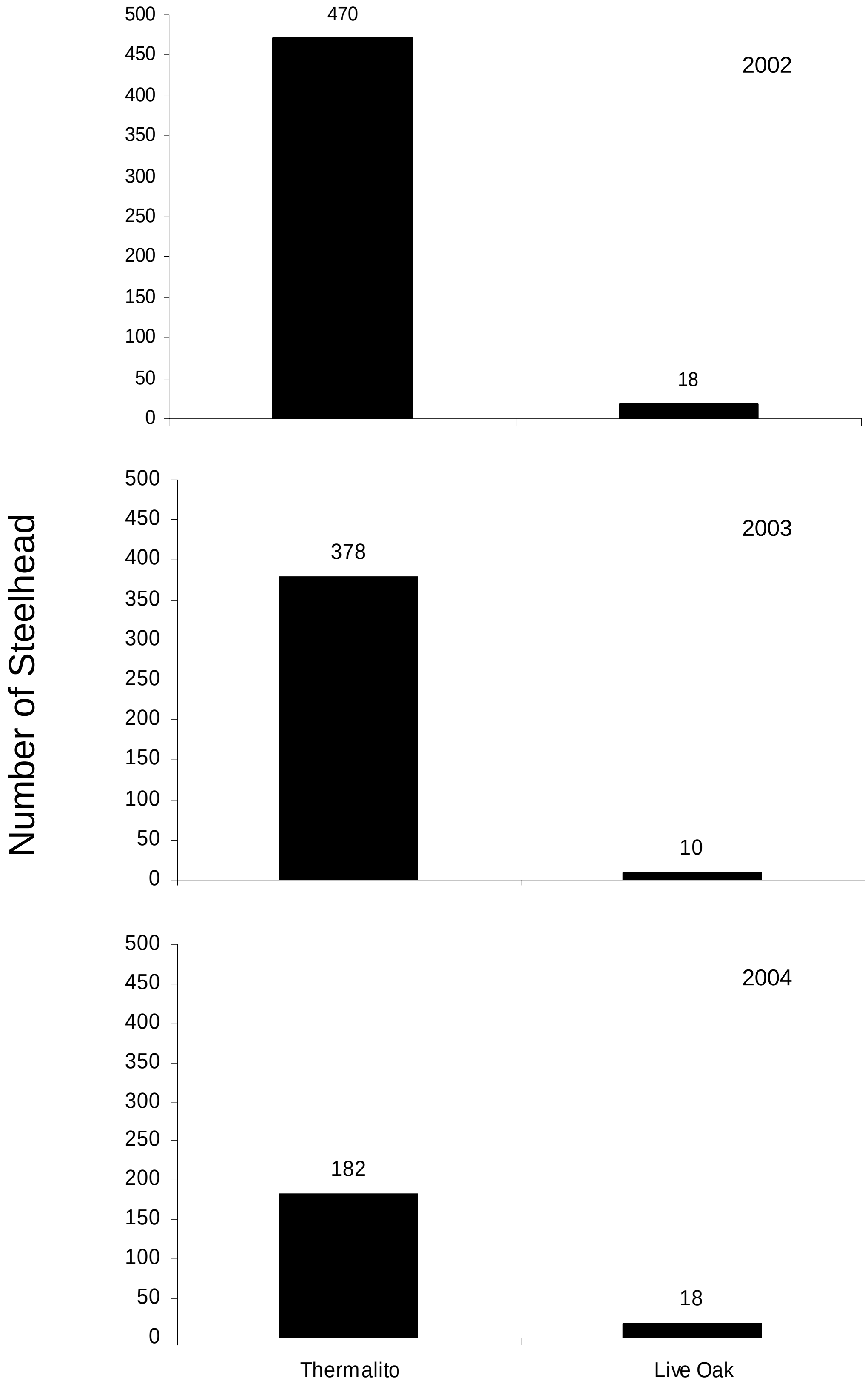

Figure 13. Total catch of wild steelhead at both trapping locations during all three years of trapping.

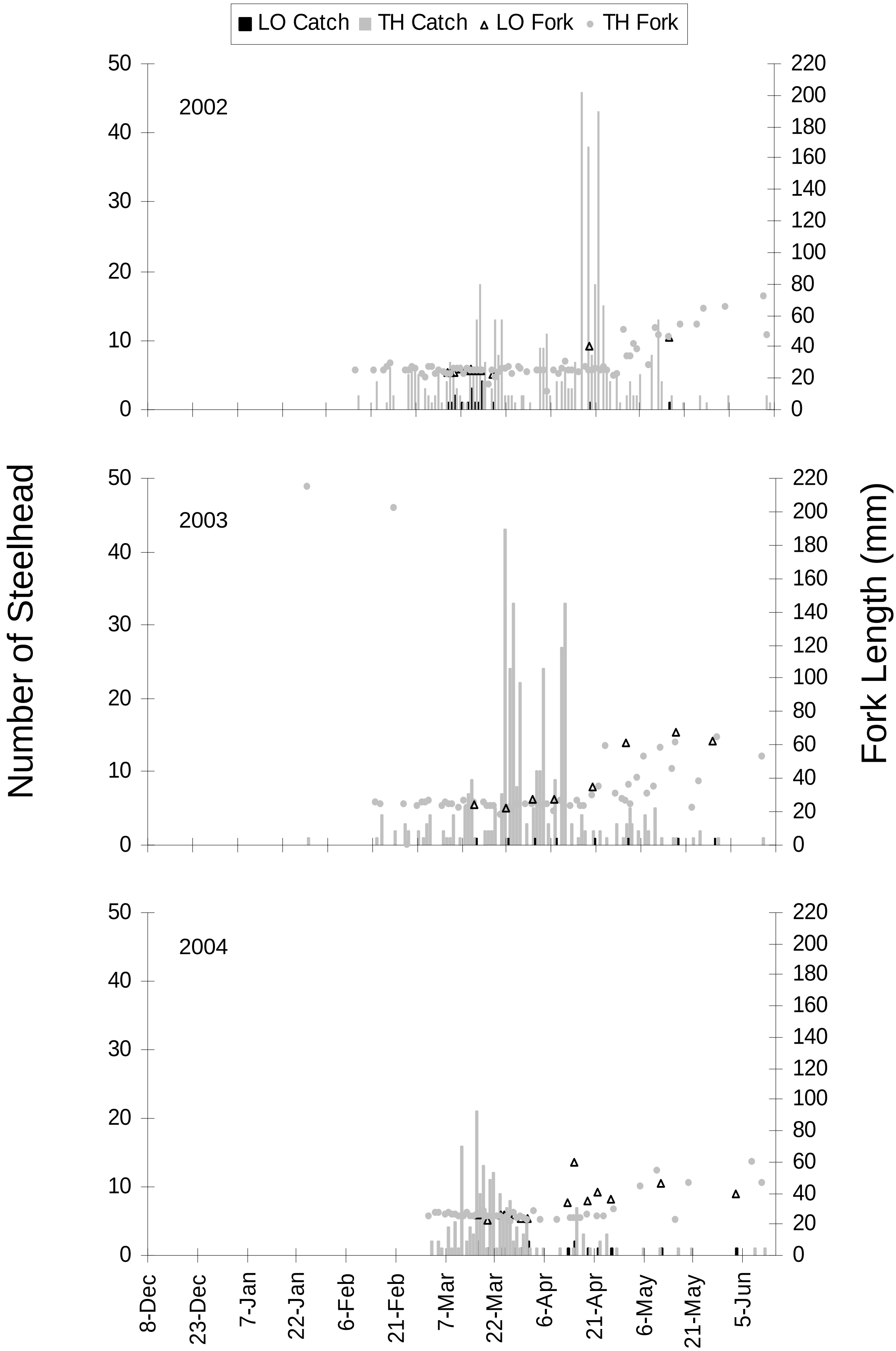

Figure 14. Daily catch distribution and daily average fork length for steelhead caught at Thermalito and Live Oak during all three years of trapping.

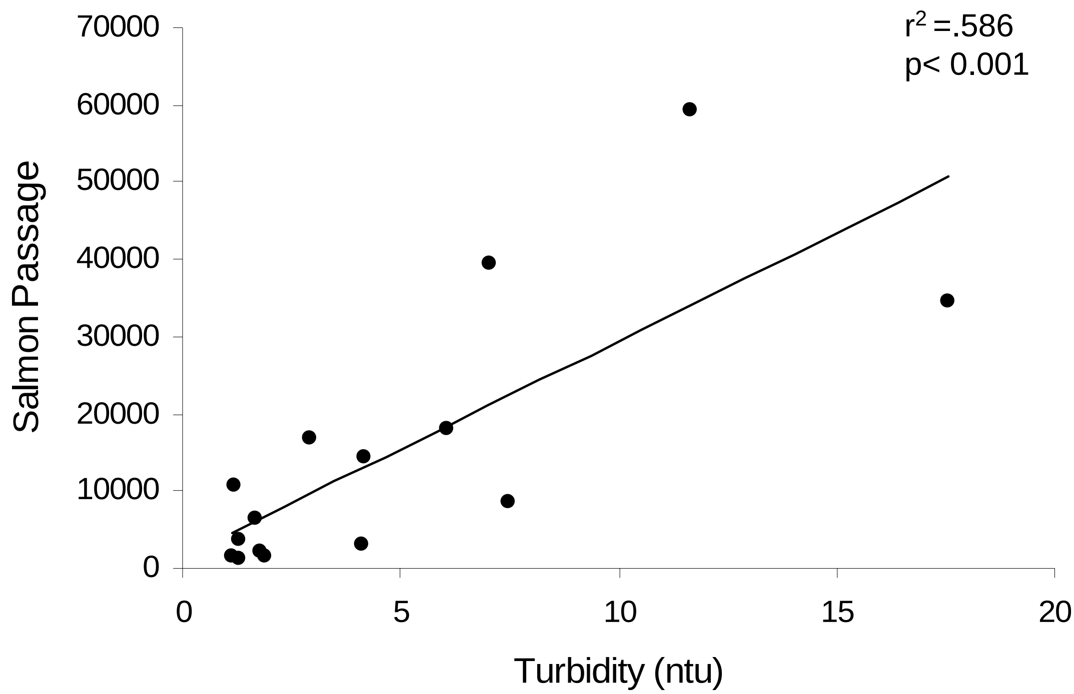

Figure 15. Regression plot of Fall-run-sized Chinook salmon passage and turbidity at Thermalito between 2/8/2004 and 2/22/2004.