2002 Juvenile Chinook Salmon Capture and Production Indices Using Rotary-Screw Traps on the Lower Tuolumne River

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INTRODUCTION

The Tuolumne River, California, originates in Yosemite National Park, flows through the San Joaquin Valley and into the San Joaquin River draining a 1,900 square mile basin of the western Sierra Nevada Mountains (Figure 1). The Lower Tuolumne River has been severely impacted by the construction of dams, which impede fish passage, large scale historical gold dredging, in-channel gravel mining, and water withdrawals. Declines in salmon stocks along the Pacific Coast, and particularly in the San Joaquin Valley, California, starting in the late 1800 led to increasing efforts at conservation and protective measures. Historically, California boasted strong pacific salmon stocks with runs of winter, spring, fall, and late-fall chinook salmon, and the Tuolumne River at times had the largest runs of fall run salmon in the Central Valley except for the Sacramento River (Fry, 1961). The San Joaquin Basin runs have declined appreciably and the Tuolumne River has experienced similar declines in the various stocks. Over fishing, habitat loss, and water quality degradation have jointly led to the decline of chinook salmon stocks in the Tuolumne River. The National Marine Fisheries Service (NMFS) currently lists the fall run chinook salmon as a candidate species for federal ESU listing in the central valley.

The Central Valley Project Improvement Act (CVPIA) requires the USFWS to take measures to restore native anadromous fisheries stocks to sustainable levels. The Comprehensive Assessment and Monitoring Program (CAMP) was implemented to evaluate success towards achieving this requirement. The California Department of Fish and Game (CDFG) operate two rotary-screw traps on the Tuolumne River for CAMP. One of the traps is provided by Turlock and Modesto Irrigation Districts (TID and MID, respectively) as part of the juvenile salmon monitoring component to CAMP. The monitoring is also a component of the New Don Pedro FERC Settlement Agreement (Sections 13d, e, f, and g).

Rotary-screw traps (RST) are used in many studies of salmon along the Pacific Coast (Demko et al., 1999; Roper and Scarnecchia, 1996; Thedinga et al., 1994). RST's have been operated on the Tuolumne River near the confluence with the San Joaquin River since 1995 (Heyne and Loudermilk, 1997; 1998; Vasques and Kundargi, 2001).

Several factors affect juvenile salmon migration rate and timing. Studies on the Columbia River indicate that the rate of migration (Giorgi et al., 1997; NMFS, 2000) and survival (NMFS, 2000) both increase with increasing flow. Previous studies on the Tuolumne River (Heyne and Loudermilk, 1997; 1998; Vasques and Kundargi, 2001) present preliminary assessments of smolt migration and production using rotary-screw traps. This paper attempts to expand the existing data by examining the 2002 juvenile outmigrant data. The objectives of this study are to: 1) estimate the production of juvenile chinook salmon and 2) determine the timing of juvenile Chinook salmon migration during the 2002 sampling season.

METHODS

Site Description

Two rotary screw traps were operated side by side at the Grayson River Ranch, approximately 5.2 river miles from the confluence of the San Joaquin and the Tuolumne Rivers (Figure 1). No attempt was made to enhance trap efficiency by altering the river channel. In the summer of 2000 some riparian restoration efforts began on the Grayson River Ranch, but there were no alterations to the channel. The traps were located approximately one mile upstream of the Shiloh Bridge anchored by a cable crossing the river. The north bank of this section of river is a steep riprap bank. The south bank has a gentle slope with heavy riparian vegetation. The substrate through this area is dominated by sand. The thalweg generally runs near the north bank but varies at low flows.

Rotary Screw Traps and Operations

The rotary screw traps have an 8 ft. diameter cone, screened with 3 mm diameter perforated plate and mounted between two pontoons. The perforated plate effectively sieves fish from the water. An internal helical aluminum plate transfers water flow into rotational energy causing the cone to turn. As the cone rotates, migrating fish which swim into the mouth of the cone are directed toward the back and into the attached live box where they are held until processed. The helical design of the cone prevents fish from escaping the live box and exiting through the entrance of the cone.

Trap checks were performed on a daily basis, although, at the start of the 2002 season the cones were raised so that traps did not sample on the weekends. Figure 2 displays catch of non marked and marked salmon, flow, vulnerability releases, and days which cones were not rotating when RST crew members arrived for trap checks. When the traps were not sampled on the weekend the cones were raised after the Friday evening check and lowered on Sunday afternoon. From 15 January 2002 – 24 March 2002 traps were not sampled on weekends, and were checked once per day when operating. Trap checks were increased to 7 days per week and two checks per day from 1 April through 6 June 2002, the end of the sample period. Trap checks were scheduled for morning and evening checks to minimize time between each check. The last check was conducted on the morning of 6 June, and traps removed the following week. Personnel shortages due to the states hiring freeze, prohibited any further increase in trap checks at critical times, such as increases in flows and increases in salmonid captures. Data collection for each trap check included: (1) fish capture data, (2) environmental variable data, and (3) trap operation data. Fish were identified, enumerated and fork length measured to the nearest millimeter. All fish held in the live boxes were removed and recorded for each respective trap. All salmon captured were separated, checked for marks, and measured to the nearest millimeter. A smoltification index code as specified in the Interagency Ecological Program Steelhead Project Work Team, Steelhead Life-stage Assessment Protocol was assessed for every measured salmon (marked and unmarked) and recorded. The smolt index criteria assign a number from 1 to 5 for different stages of development: yolk sac fry; fry; parr; silvery parr; and smolt respectively. When non-marked salmon captures were large (greater than 100) approximately 100 salmon fork lengths were measured and recorded. The remaining salmon were counted and recorded as plus counts. In 2002, captures of non marked salmon were low and there was no need to implement the plus count protocol as has been needed in past years. Non salmonid captures were identified to species and a maximum of 20 individuals measured with extras recorded as plus counts. Air and water temperatures (^{o}C), water turbidity, water velocity and conductivity data were collected for each trap check. Turbidity (NTU) was measured with a Hach portable turbidity meter. Conductivity (μs cm^{-1}) was measured with a Cole-Palmer CON 5 conductivity meter. Water velocities were taken at the mouth of each trap at a depth of 1.5 ft using a Global Water Flow Probe flow meter. Unidentifiable fish were labeled as unknown and preserved for later identification in the laboratory. Table 1 summarizes capture of all non-salmon catches.

Vulnerability Tests

Vulnerability tests were conducted weekly beginning on 20 February with the last test on 30 May (Table 2). The last vulnerability release was discarded due to a high number of mortalities from high river temperatures. Vulnerability tests consist of releasing a known number of dye marked fish approximately 0.5 miles upstream of the rotary-screw traps. Marked fish were held for 24 hours prior to release in live cars placed in the river at the release site. This allowed the fish ample time to acclimate to the river conditions and account for handling mortality. Releases were conducted close to or after sunset prior to the routine trap check. Fish were released into the river over a 5-10 minute period, approximately one half mile upstream from the trap site. Recaptures generally occurred the night of the test through the morning check the following day. The test release groups ranged in number from approximately 2,000 to 4,000 fish per test. All of the fish used in the vulnerability tests were of Merced River Fish Facility (MRFF) origin. The test fish were marked at the hatchery with subcutaneous dye. Marks consisted of red dye mark on the dorsal, anal or upper or lower lobe of the caudal fin. The first five vulnerability release groups were dye marked only, the remaining vulnerability releases used coded wire tag (CWT) marked fish in combination with the dye mark.

Vulnerability, also referred to as trap efficiency, is the ratio of total number of marked fish released to the total number of recaptured marked fish during a vulnerability test. The data and prior information (Demko et al., 1999; Vasques and Kundargi, 2001) suggest that juvenile salmon exhibit varying degrees of vulnerability to capture by size. There was no obvious peak in fry captures, therefore vulnerability calculations were not separated for fry and smolt size classes. Peak fry captures occur during freshets in wetter water years, which did not occur during the drier 2002 season.

Hatchery produced marked fish were used to determine trap vulnerabilities as a function of flow. Estimated numbers of naturally produced salmon passing the trap was determined by dividing the number of juveniles caught during one sample period (trap check to trap check) by the estimated vulnerability for that sample period. Vulnerability (V) was determined by first creating a relationship (R) between trap efficiency and flow (Equation 1). This was done using the trap efficiency (*% recapture*) and average flow over three days at release ($flow_{release}$), from the day before to the day after each release test.

$$R = \frac{\%recapture}{flow_{release}}$$

Equation 1

Daily vulnerabilities (V_{daily}) were determined by applying the relationship (R) to the daily average river flow ($Flow_{avg.daily}$) passing the trap on each day and dividing by the percent of day ($\%D$) the trap fished for that day (Equation 2).

$$V_{daily} = \frac{Flow_{avg.daily} * R}{\%D}$$

Equation 2

The percent day fished was determined by dividing trap revolutions by theoretical revolutions. Theoretical revolutions was calculated by multiplying the average revolutions per minute for the sample period (readings taken daily) by the minutes fished. Using the percent of day the trap sampled accounts for days which the cone may have stopped rotating during the sample period. The number of naturally produced salmon (N_{daily}) passing the trap during each sample period was then divided by the daily vulnerability (V_{daily}) to obtain a total daily estimate (E_{daily}) of naturally produced juvenile fish passing the trap each day (Equation 3).

$$E_{daily} = \frac{N_{daily}}{V_{daily}}$$ **Equation 3**

Daily estimates were then summed to obtain a total juvenile production estimate for 2002. When sampling only occurred five days per week, weekly catch was expanded to the entire week by simply multiplying the weekly catch by $^{7}/_{5}$.

RESULTS AND DISCUSSION

Catch and Timing of Outmigration

Figure 2 shows fork length distribution for all captured Chinook salmon. Marked salmon captured are grouped together (i.e. dye marks and CWT). Other releases shown in Figure 2 include a small, (N=36) live box evaluation release and a large CWT survivability release at Old La Grange Bridge conducted over a two day period. Figure 2 also indicates dates of vulnerability releases and dates which cone rotation was stopped by debris or other obstruction.

The total catch of non adipose fin clipped chinook salmon in 2002 was a meager 438 fish (Figure 3). The total catch of naturally produced juveniles in 1999 was 19,327, in 2000 was 2,250 and in 2001 was 6,478. A total of 1008 CWT marked salmon were recaptured from the smolt survival test releases of 75,109 (effective release number) at the Old La Grange Bridge. Daily CWT captures are presented in Figure 4.

The length frequency of non-marked and CWT marked salmon is displayed in Figure 5. This figure represents fork lengths only, not the number of fish caught at each length. In other words, each point is a length that was recorded for that day but may contain any number of fish at that given length. This graph represents the fish sizes passing the traps throughout the season. This figure also shows the lack of an obvious fry peak migration from January to March which has been seen in the past (e.g. 1999 to 2001), as well as an increase of out migration with an increase of flow. In the 1999 and 2000 sample year's flows reached 2,000 cfs in late February and March. An increase to 7,000 cfs occurred mid February of 1999 and early March of 2000. The 2001 sample year saw flows over 3,500 cfs in late February and over 2,500 cfs in early March (Figure 6). Flows during the 2002 sampling season remained below 350 cfs from mid January through the first week of April and never got above 1,220 cfs, only increasing in mid April with the scheduled FERC spring pulse flow. Large concentrations of salmon fry (FL<65mm) were captured during freshets which occurred in previous years, but not in 2002, probably as a result of the lack of freshets and substantially lower flow levels.

Catches of juvenile salmon appear to correlate to changes in river flow. Heyne and Loudermilk (1998) made a similar observation when the screw traps were located under the Shiloh Bridge approximately 1.5 miles downstream. Peaks in fry captures occur temporally with early peaks of fry occurring in January and February. Similar studies (Vick et al., 1998; Heyne and Loudermilk, 1999) in previous years indicate similar temporal peaks in outmigration. This data indicates that on the Tuolumne River, fry migrate down river in January and early to mid February. Additionally, it appears that changes in flow, particularly flow increases, may initiate this movement downstream.

Smolt migration appears to occur mid-April through early May. Smolt size class fish (FL>65mm) are better able to avoid capture in rotary screw traps. Without the January and February high flows and freshets, fry migration essentially did not occur in 2002. Salmon fry that might have migrated downstream as a result of elevated flow conditions may have remained in the river and outmigrated as smolts. Since a lower juvenile salmon smolt catch occurred in 2002 concurrent with lower flow conditions, it is presumed that holdover fry did not migrate as smolts. Possibly they held over in the river as yearlings. Scale and otolith analysis from escapement surveys conducted 3 to 4 years later will determine whether or not an elevated fraction of juvenile salmon left the river as yearlings.

Vulnerability Tests

There are inherent problems conducting vulnerability tests to estimate trap efficiencies. Accuracy of estimating trap efficiencies is dependent on conducting numerous test releases to completely and adequately quantify how vulnerability changes over time as flows change and juvenile salmon size increases. Personnel, financial, and other logistical constraints (e.g. hatchery fish availability, etc.) limit the number of efficiency tests which can be effectively conducted during the sampling period. Accurate efficiency estimates and expanded daily estimates assume the trap operated throughout 100% of the sample period. This is rarely, if ever, the case. It is often impossible to estimate the actual amount of time sampled, so here again estimates must be calculated. The more estimates that are used, the less accurate the result. To minimize trap stoppages during critical times (i.e. increases in catch and or flow) more personnel could be used to monitor traps 24 hours per day. In 2002 there were fourteen vulnerability tests conducted (Table 2). One release was discarded due to high mortalities during the release and was not included in Table 2.

Juvenile Production Estimate

Expanded catch of non marked (naturally produced) juvenile Chinook salmon was 14,540 for 2002 (Figure 7). This is a marked decrease from previous years. The total estimate of juvenile Chinook production in 1999 was 1,133,887, in 2000 was 139,024 and in 2001 was 111,644. The 1999 – 2001 sampling seasons saw much higher estimates due mostly to the large numbers of fry passing the traps in January and February. Higher flows and freshets seen during this time flush Chinook salmon juveniles from the spawning reach out into the delta. During normal to dry years when Tuolumne River flows are strictly controlled, flows need to be allocated in sufficient quantities to actually aide in juvenile outmigration and survival. Pulse flows must also be timed properly to gain the most benefit for juvenile salmon.

Table 1. Non-salmonid fish captures in the Tuolumne River rotary screw trap in 2002.

Common Name	Number Captured
American Shad	2
Bluegill sunfish	169
Black crappie	66
Channel catfish	12
Fathead minnow	1
Goldfish	3
Green sunfish	8
Golden shiner	5
Largemouth bass	474
Bigscale logperch	3
Mosquito fish	60
Inland silverside	48
Pacific lamprey	215
Prickly sculpin	3
Redear sunfish	3
Red shiner	225
Sacramento pikeminnow	23
Sacramento sucker	58
Sacramento blackfish	2
Smallmouth bass	510
Spotted bass	125
Splittail	3
Striped bass	1
Threadfin shad	43
Unknown centrarchid	30
Unknown cyprinid	10
Unknown	1
Unknown ammocoete	76
Warmouth	9
White catfish	2141
White crappie	1

Table 2. Vulnerability tests for 2002 Grayson rotary screw traps with release numbers and number recaptured for each test. Vulnerability values represent both traps combined. *Note-last release of 4062 on 30 May was not included due to high mortality of fish.

Date	Mark[1]	Effective No. Released	Mean FL (range)	No. Recaptured	Vulnerability	Flow (cfs) @ Modesto[2]
2/20/2002	RDLC	2094	57 (45-72)	444	0.21	280
3/6/2002	RDAN	2331	68 (58-87)	316	0.14	283
3/13/2002	RDUC	2042	65 (51-81)	324	0.16	311
3/20/2002	RDDO	2105	68 (56-77)	242	0.11	307
3/27/2002	RDLC	2121	68 (57-77)	147	0.07	307
4/3/2002	ac-RDAN	1962	76 (63-89)	130	0.07	298
4/9/2002	ac-RDUC	1995	79 (65-91)	56	0.03	322
4/17/2002	ac-RDDO	2048	84 (74-97)	40	0.02	788
4/25/2002	ac-RDLC	2001	86 (78-89)	22	0.01	1027
5/1/2002	ac-RDAN	2033	89 (68-99)	14	0.01	1182
5/8/2002	ac-RDDO	2021	95 (82-105)	31	0.02	746
5/15/2002	ac-RDUC	2047	97 (74-107)	26	0.01	645
5/22/2002	ac-RDLC	2043	94 (68-114)	10	0.004	403

[1] ac indicates adipose fin clip and CWT, RD indicates red dye mark. UC indicates upper caudal, LC indicates lower caudal, DO indicates dorsal, and AN indicates anal fin.

[2] Flow data are from California Data Exchange Center website, and is the average of the flow 1 day before and 1 day after release date.

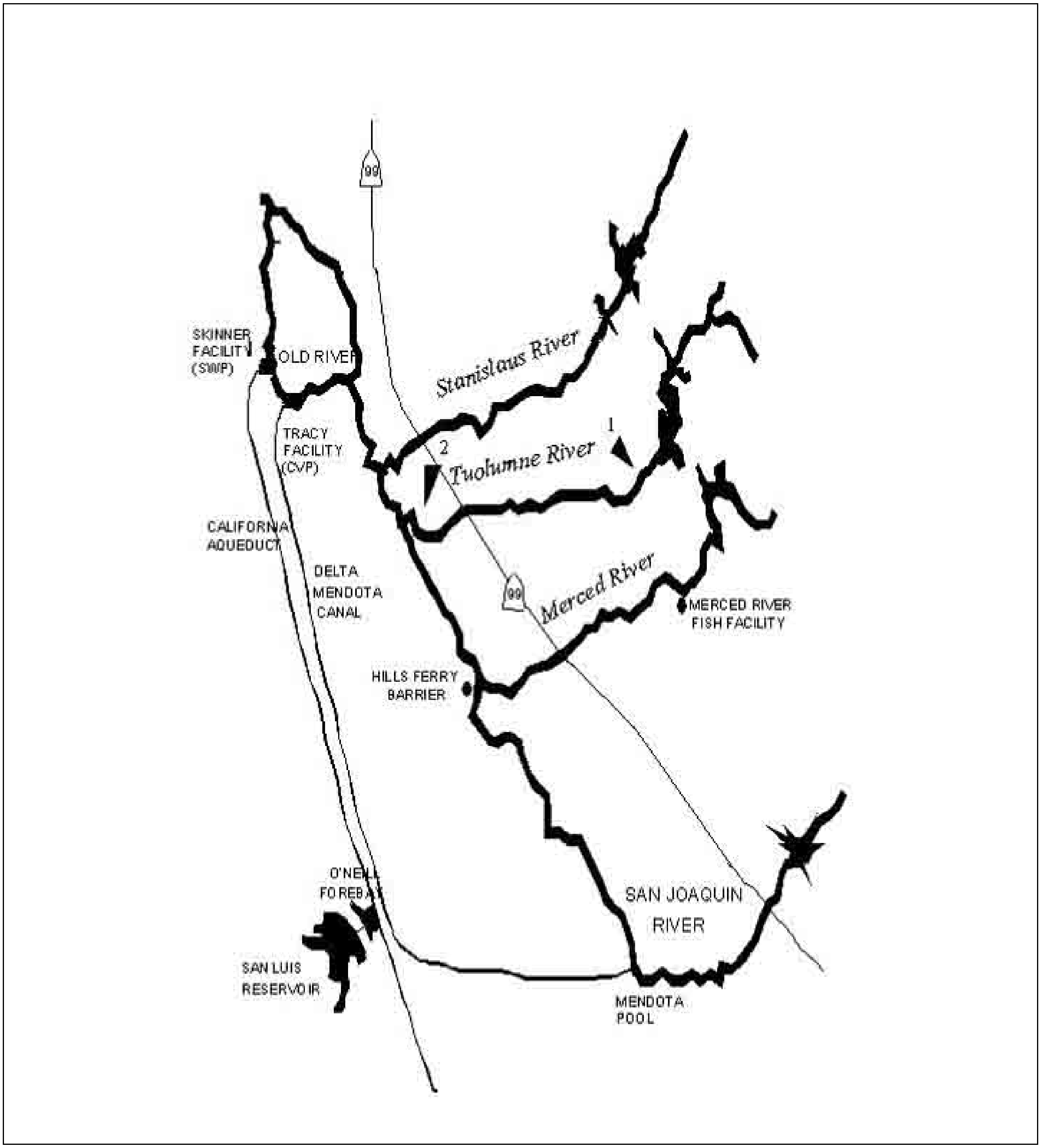

Figure 1. Map of San Joaquin River with 1. La Grange and 2. Shiloh referenced for orientation.

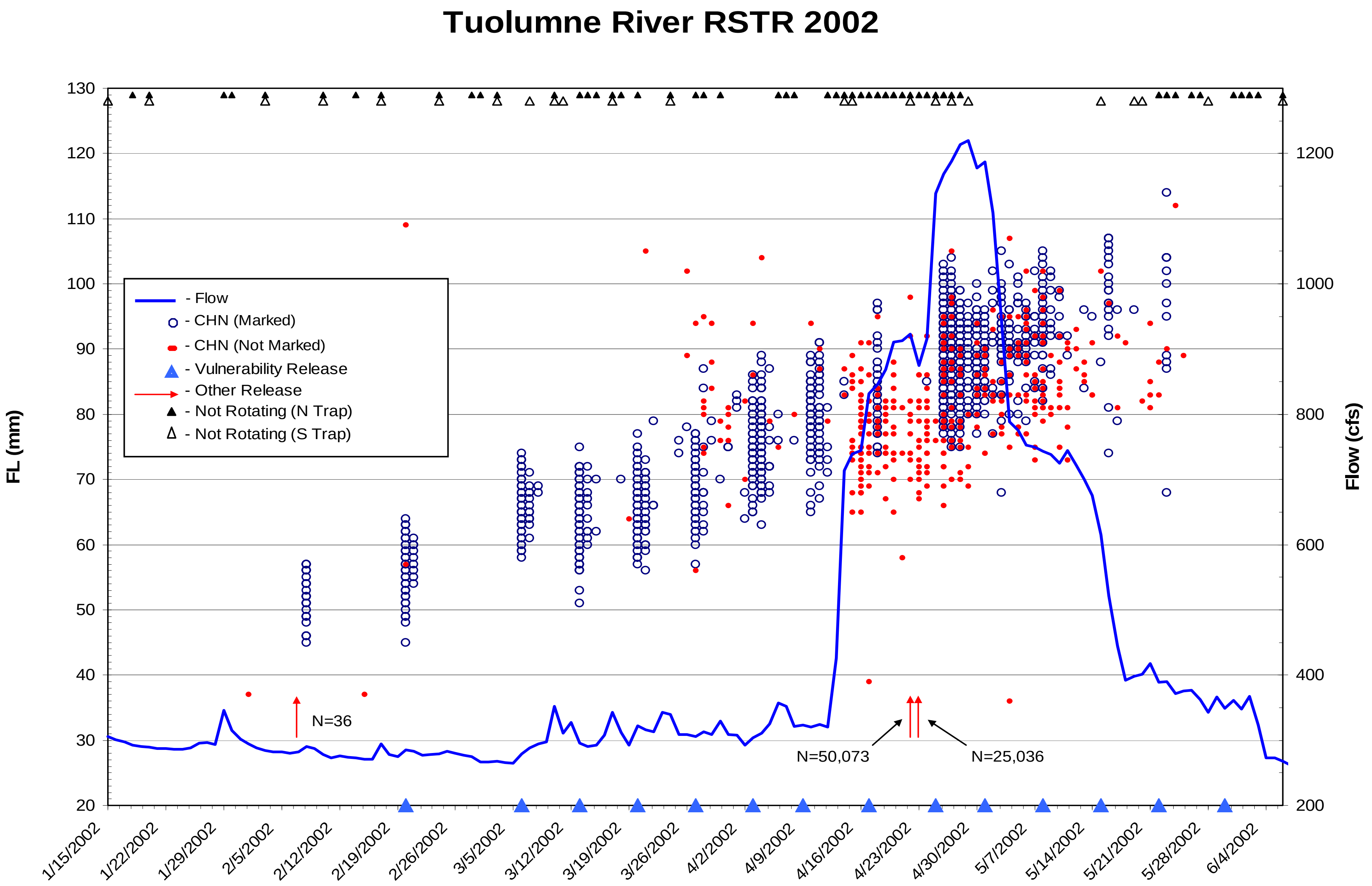

Figure 2. Fork length frequency of marked and unmarked Chinook salmon (CHN), flow (CFS, Modesto gage), vulnerability releases, and cones stopped rotating (N- north trap, S-south trap) at time of trap check. Other releases conducted were for live box integrity (N=36) on 7 February, and two releases for upper Tuolumne survival tests, (N=50,073 and N=25,036).

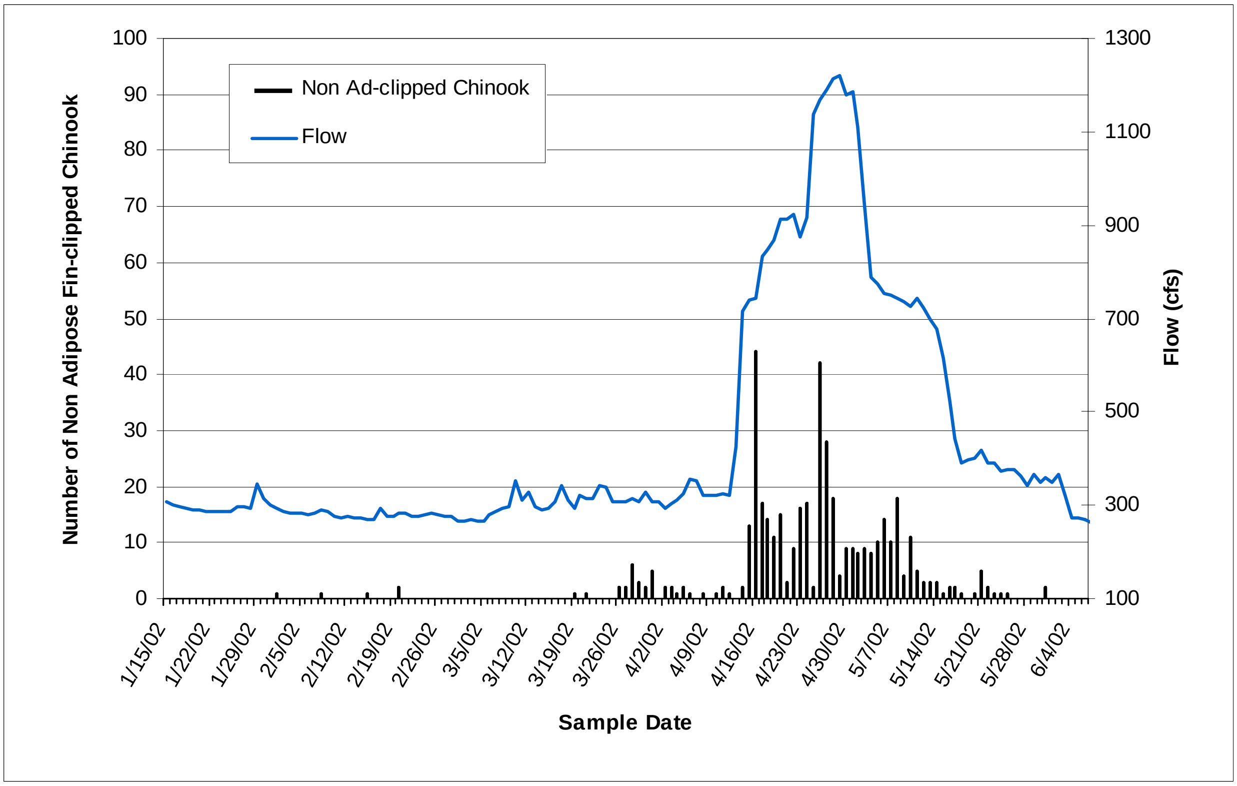

Figure 3. Daily catch of non adipose fin clipped juvenile chinook salmon with flow (cfs) at Modesto.

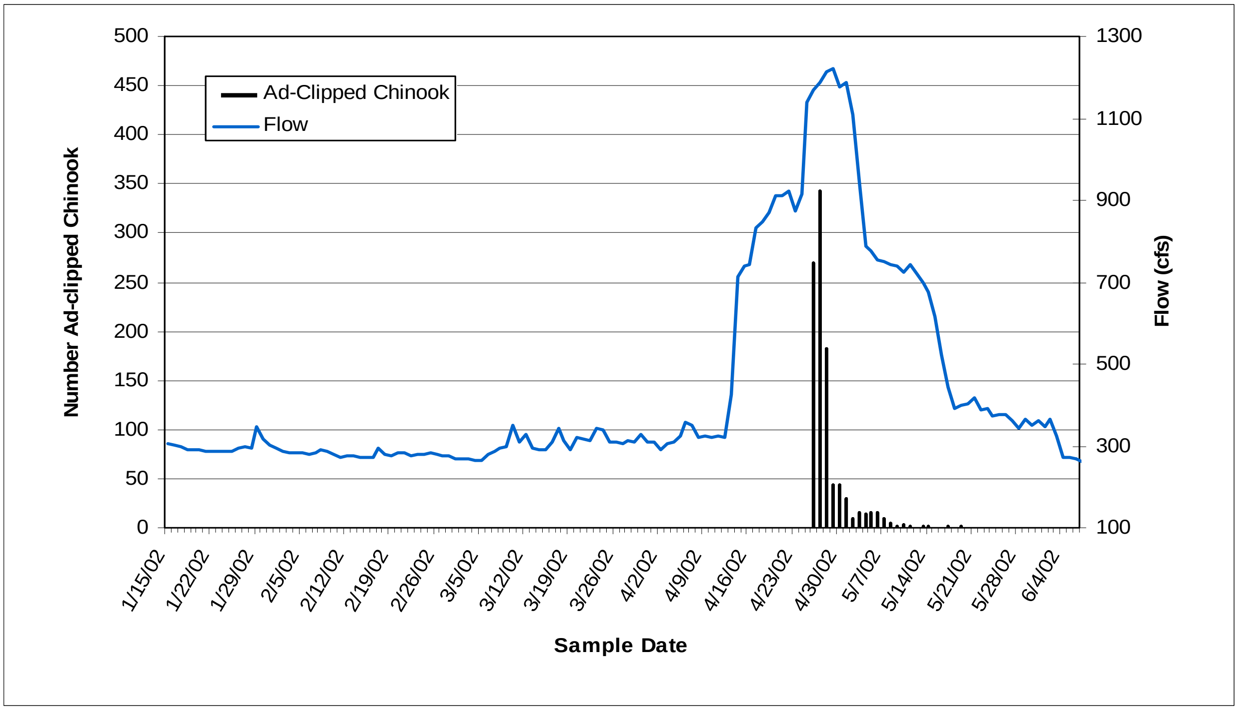

Figure 4. Daily catch of coded wire-tagged juvenile chinook salmon used in survival studies with flow at Modesto.

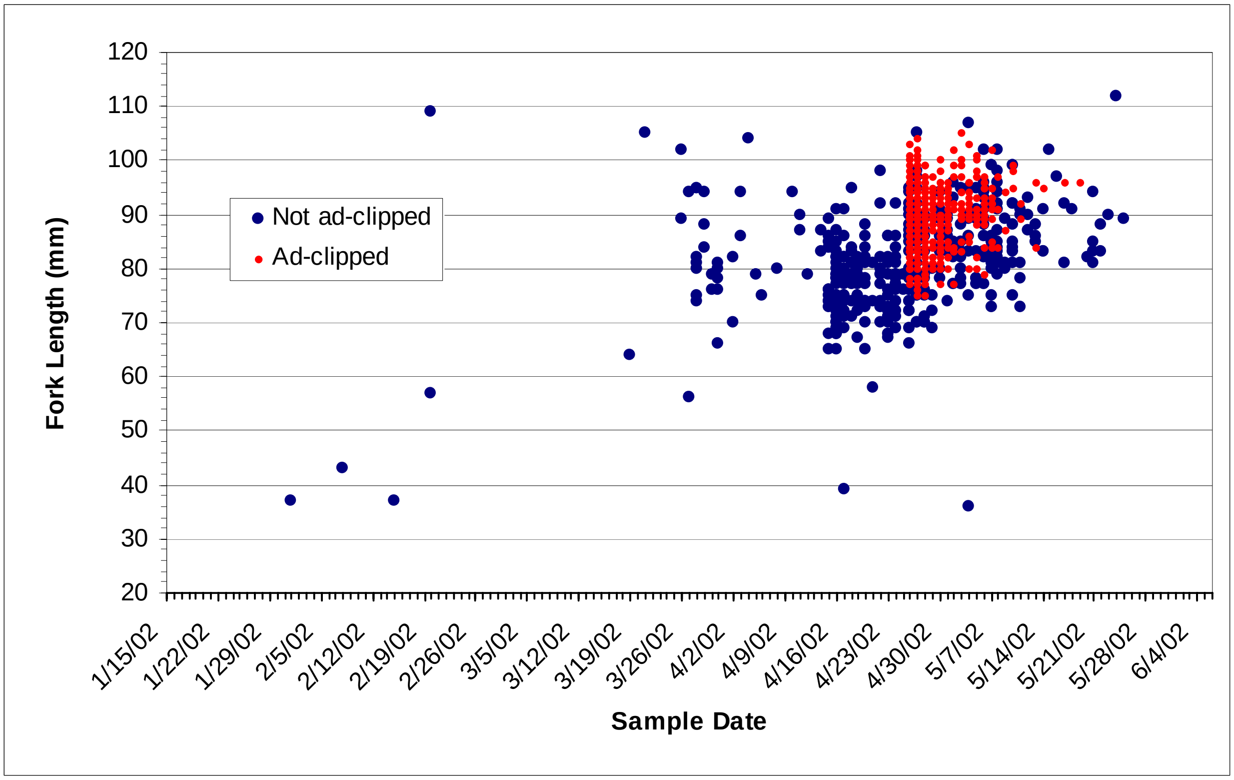

Figure 5. Fork lengths of non adipose fin clipped and adipose fin clipped Chinook salmon captured in 2002. Note the number of fish caught at each length is not represented in this figure.

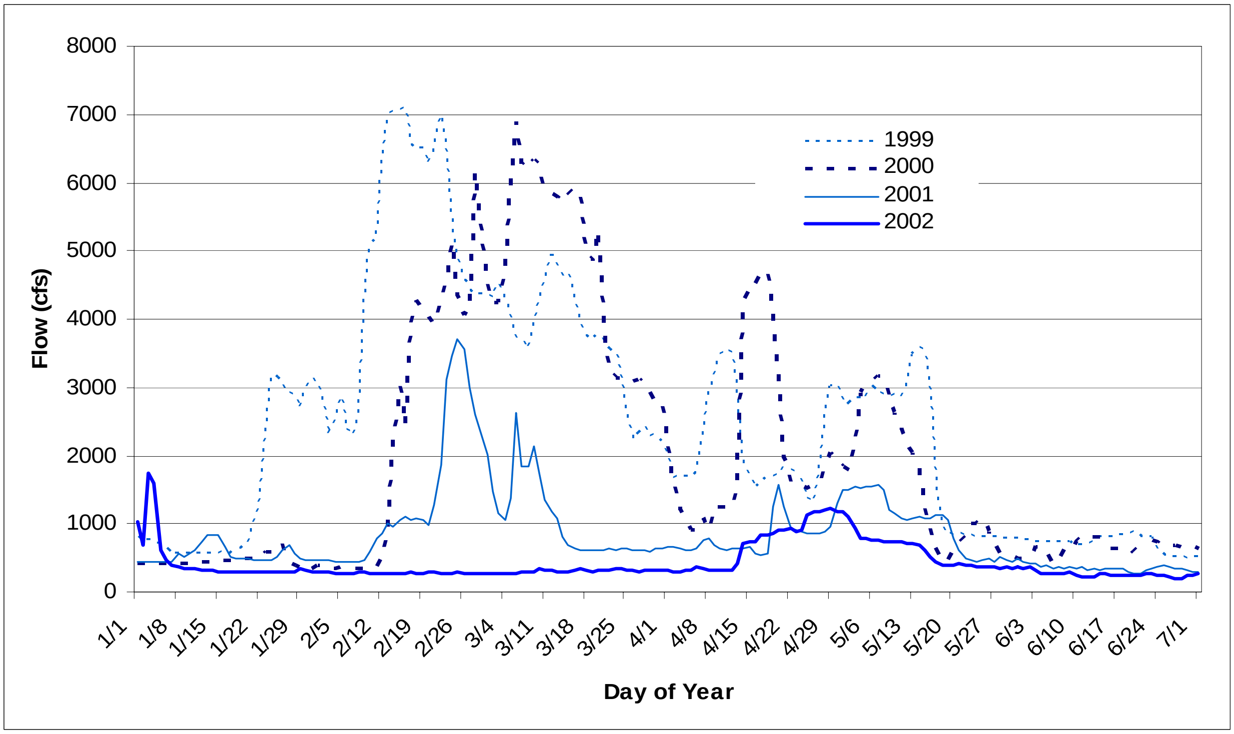

Figure 6. Tuolumne River flow at Modesto gage during RST sampling period, 1999-2002.

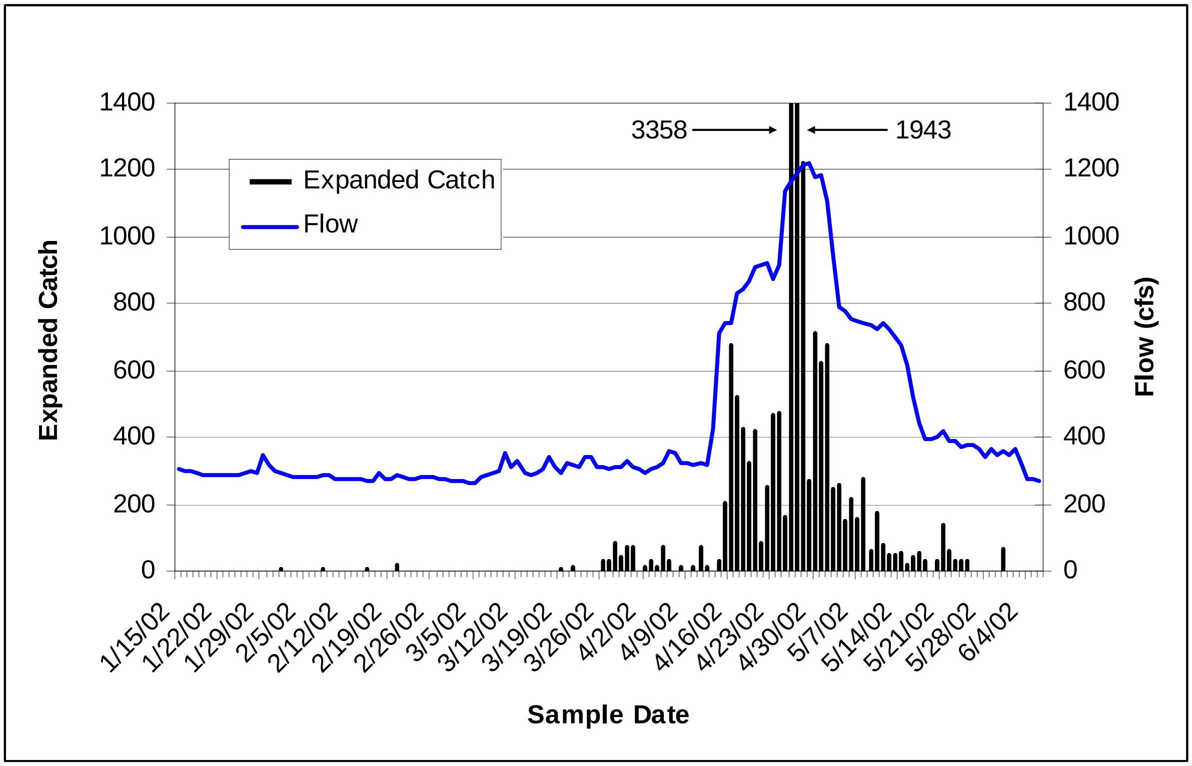

Figure 7. Expanded daily catch of naturally produced chinook salmon juveniles with flow at Modesto.

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