2003 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 (Yoshiyama, 2000; 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 2003 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 2003 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. 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 beginning on 1 April 2003. 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.   Traps were checked two times per day from 12 April - 25 April 2003. 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 flow and debris, 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 2003, 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 10 April with the last test on 28 May (Table 2). 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 were approximately 2,000 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 green dye mark on the dorsal, anal or upper or lower lobe of the caudal fin.

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.

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 2003.

RESULTS AND DISCUSSION

Catch and Timing of Outmigration

Figure 2 shows fork length distribution for all captured Chinook salmon, and also indicates dates of vulnerability releases and dates which cone rotation was stopped by debris or other obstruction.

The total catch of unmarked juvenile chinook salmon in 2003 was 359 fish (Figure 3). The estimated total catch of naturally produced juvenile chinook in 2003 was 7,261 (Figure 4). There were no coded wire tagged (CWT) fish released in the Tuolumne River in 2003. Dye marked fish were of hatchery origin, but none were CWT marked fish.

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.

The 2003 survey season started on 1 April, well after the time during which fry migration would have occurred. Fry migration usually occurs January and February during freshets (in wetter years) which did not occur in 2002 or 2003. River flows in 2003 remained below 325 cfs from 1 January to 11 April 2003 when flows increased to about 1200 cfs. Flows were reduced to about 700 cfs on 12 April. Flows then ranged from 350 - 700 cfs through the end of the sample season. The 2002 and 2003 sample seasons had nearly the same flows during the fry migration period. Parr, silver parr and smolt size fish captures were low in 2002 and 2003 (438, 359 respectively). The escapement estimates from the previous fall surveys were also low for each year (2002 – 7,125 adults, 2003 – 2,163 adults). These factors most likely indicate that the fry migration was similarly low in both years. Essentially, fry migration most likely did not occur in 2003, therefore the juvenile production estimate would essentially be the same or similar if traps were fished throughout the entire outmigration season.

Smolt migration appears to occur mid-April through early May. Since sampling did not begin until 1 April, some smolt outmigrant may not have been sampled. For reason stated previously the number of fish which may have been missed was most likely small. The 2002 survey season caught only 27 fish from 15 January - 1 April (21 smolt, 6 fry). Smolt size class fish (FL>65mm) are better able to avoid capture in rotary screw traps. Fork length frequency of juvenile chinook captured in 2003 is displayed in Figure 5, and represents fork lengths only, not the number of chinook captured.

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 2003 there were eight vulnerability tests conducted (Table 2).

Juvenile Production Estimate

Expanded catch of naturally produced juvenile Chinook salmon was 7,261 for 2003 (Figure 4). 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, in 2001 was 111,644 and in 2002 was 14,450. The 1999 – 2001 sampling seasons saw much higher estimates due somewhat 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. The 2002 and 2003 seasons had low flows and no early freshets to aide in fry migration. During normal to dry years when Tuolumne River flows are strictly controlled, flows need to be allocated in sufficient quantities and correct timing 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 2003.

Common Name	Number Captured
Bluegill sunfish	169
Black bullhead	2
Common carp	1
Channel catfish	12
Green sunfish	10
Golden shiner	14
Hardhead	1
Mosquito fish	53
Inland silverside	99
Pacific lamprey	788
Prickly sculpin	1
Redear sunfish	1
Red shiner	140
Sacramento pikeminnow	3
Sacramento sucker	12
Smallmouth bass	17
Spotted bass	2
Splittail	2
Threadfin shad	13
Unknown catfish	12
Unknown centrarchid	306
Unknown cyprinid	4
Unknown	1
Unknown ammocoete	3
Warmouth	2
White catfish	1197
White crappie	1

Table 2. Vulnerability tests for 2003 Grayson rotary screw traps with release numbers and number recaptured for each test. Vulnerability values represent both traps combined.

Release Date	Mark[1]	Effective No. Release	Mean FL (range)	No. Recaptured	Vulnerability	Flow (cfs) @ Modesto[2]
04/10/03	GRUC	1956	77 (62-91)	138	0.071	294
04/17/03	GRLC	2047	77 (61-95)	65	0.032	1178
04/24/03	GRAN	1979	88 (66-102)	31	0.016	1022
05/01/03	GRDO	2044	96 (80-108)	113	0.055	662
05/08/03	GRUC	2078	83 (63-101)	206	0.099	755
05/15/03	GRLC	1996	83 (68-95)	125	0.063	598
05/20/03	GRAN	1989	89 (72-103)	60	0.030	491
05/28/03	GRUC	1950	94 (75-108)	125	0.064	740

[1] GR indicates green dye mark, UC - upper caudal, LC - lower caudal, DO - dorsal and AN - anal fin.

[2]Flow data are from California Data Exchange Center website, and is the 3 day average flow from 1 day before to 1 day after release date.

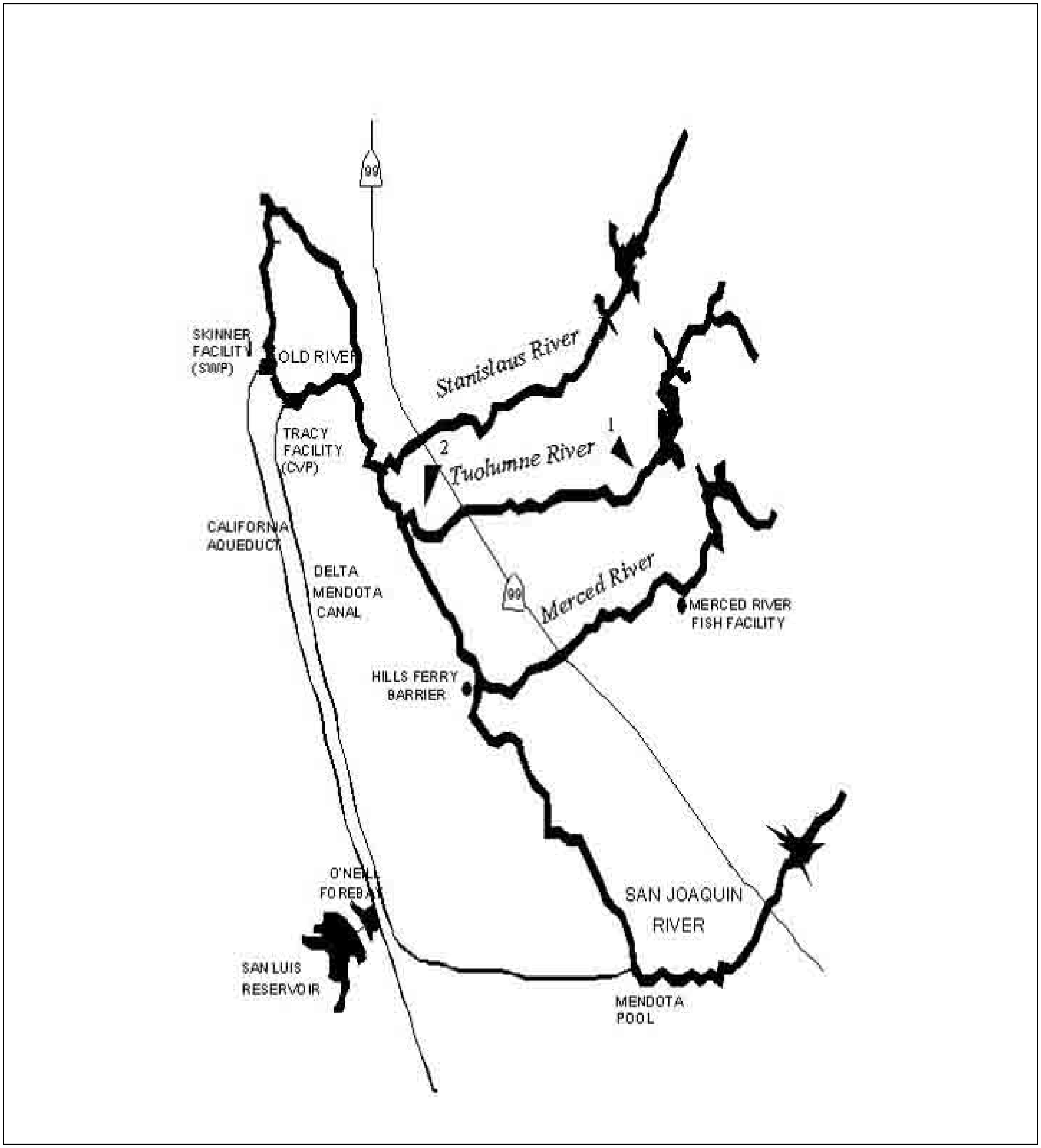

Figure 1. Map of San Joaquin River system with 1. La Grange and 2. Shiloh referenced for orientation.

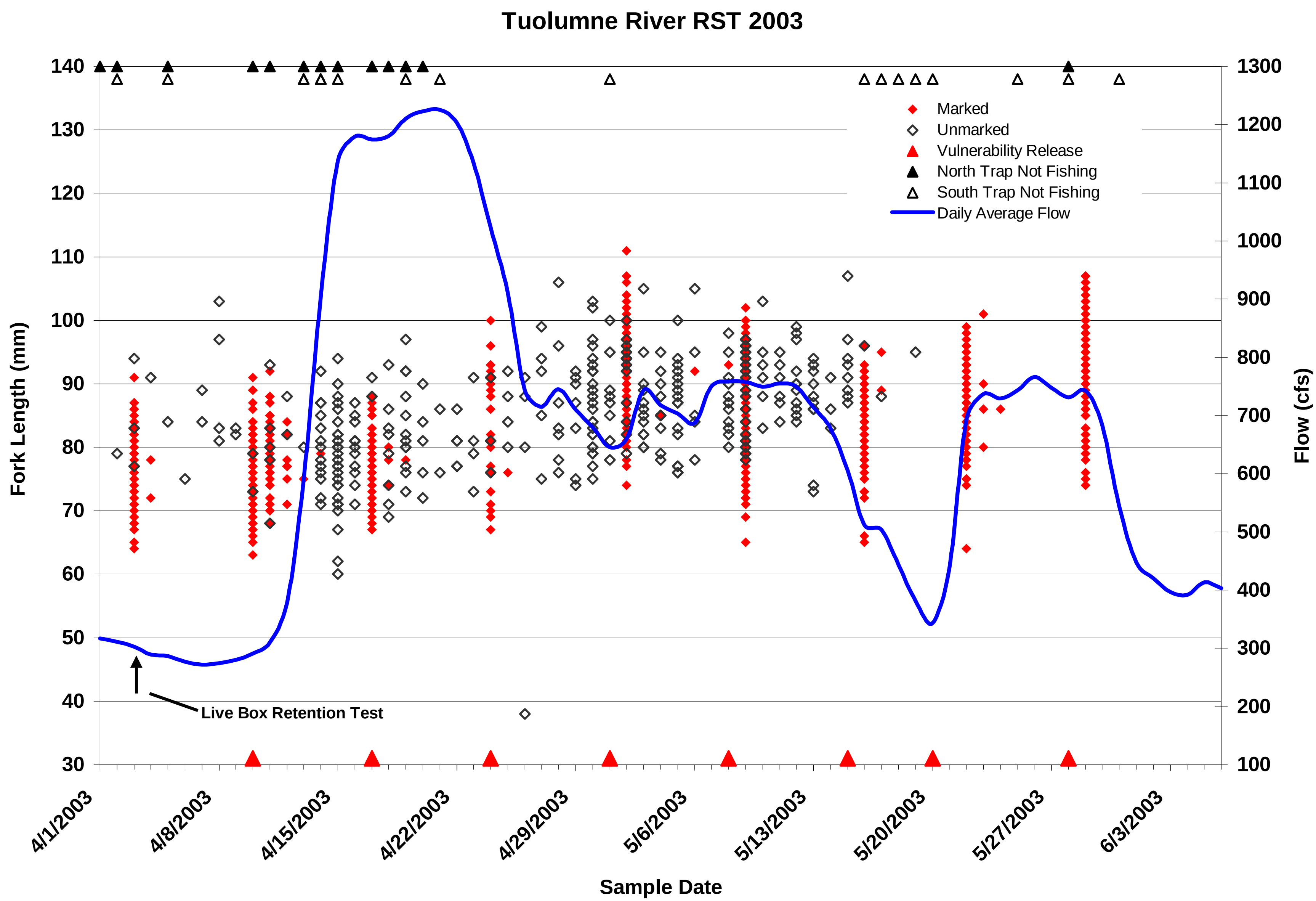

Figure 2. Fork length frequency of marked and unmarked Chinook salmon (CHN), flow (CFS, Modesto gage), vulnerability releases, and days which cones had stopped rotating at time of trap check.

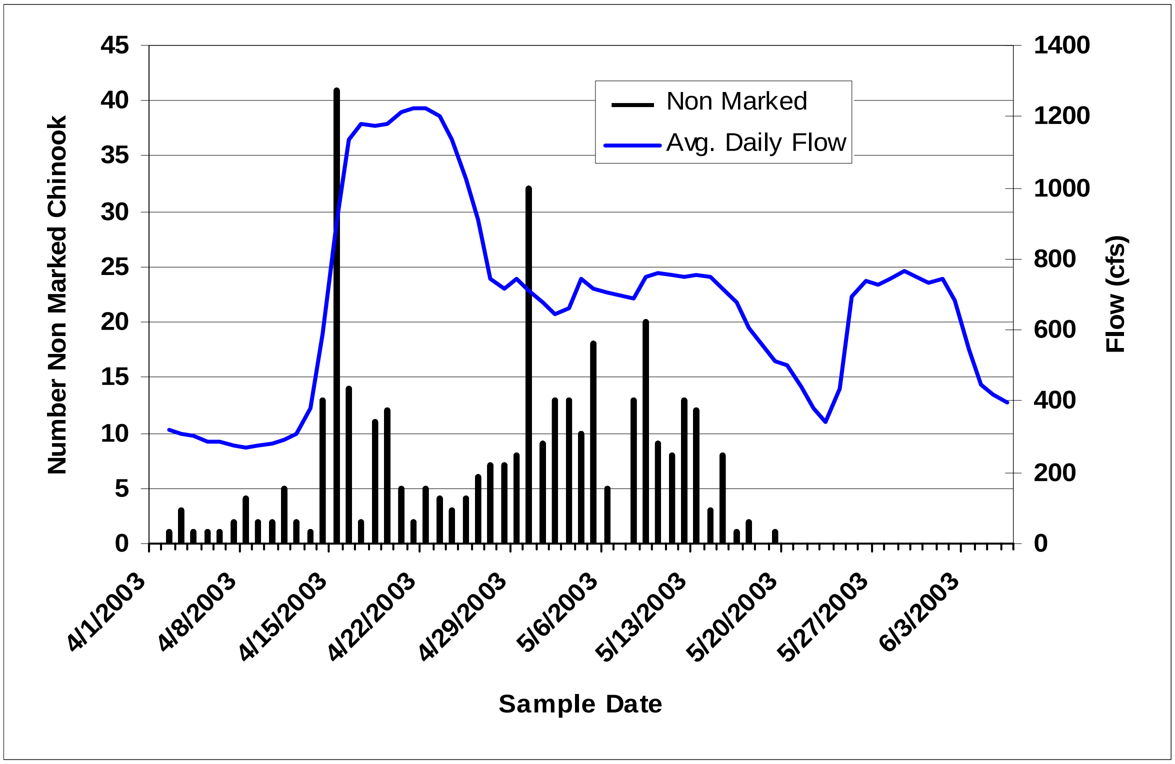

Figure 3. Daily catch of non adipose fin clipped juvenile chinook salmon with flow (cfs) at Modesto.

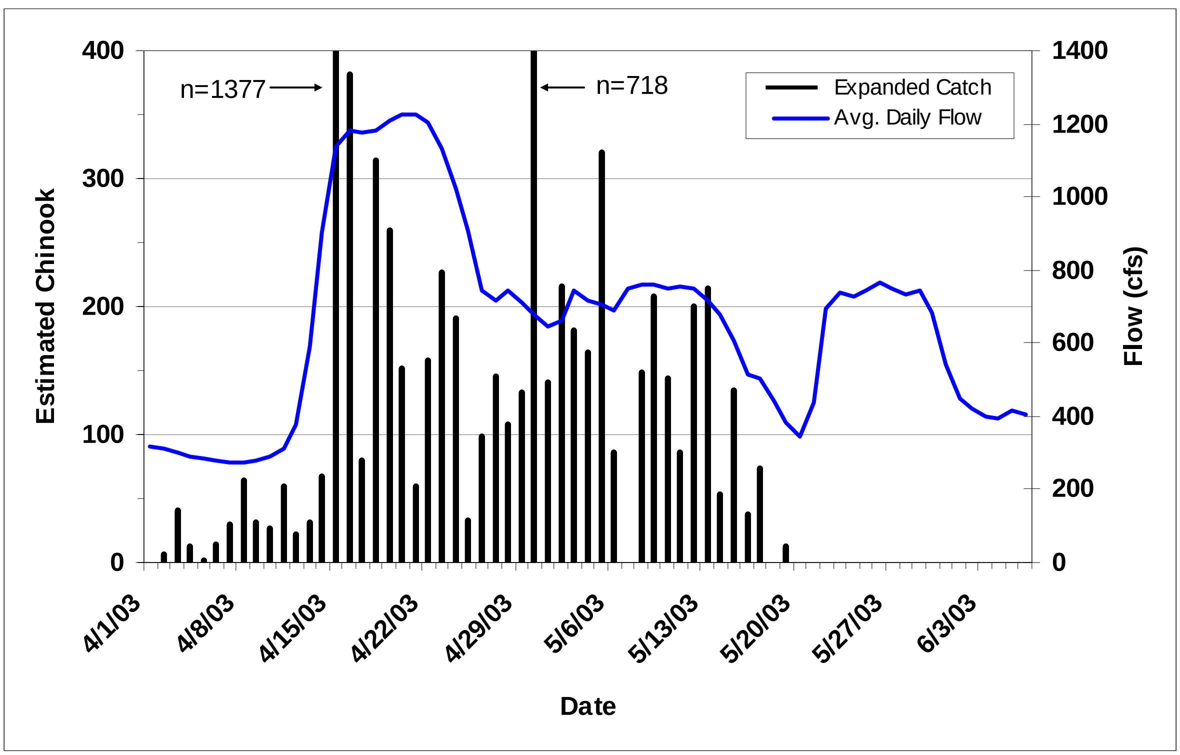

Figure 4. Expanded daily catch of naturally produced chinook salmon juveniles with flow (cfs) at Modesto guage.

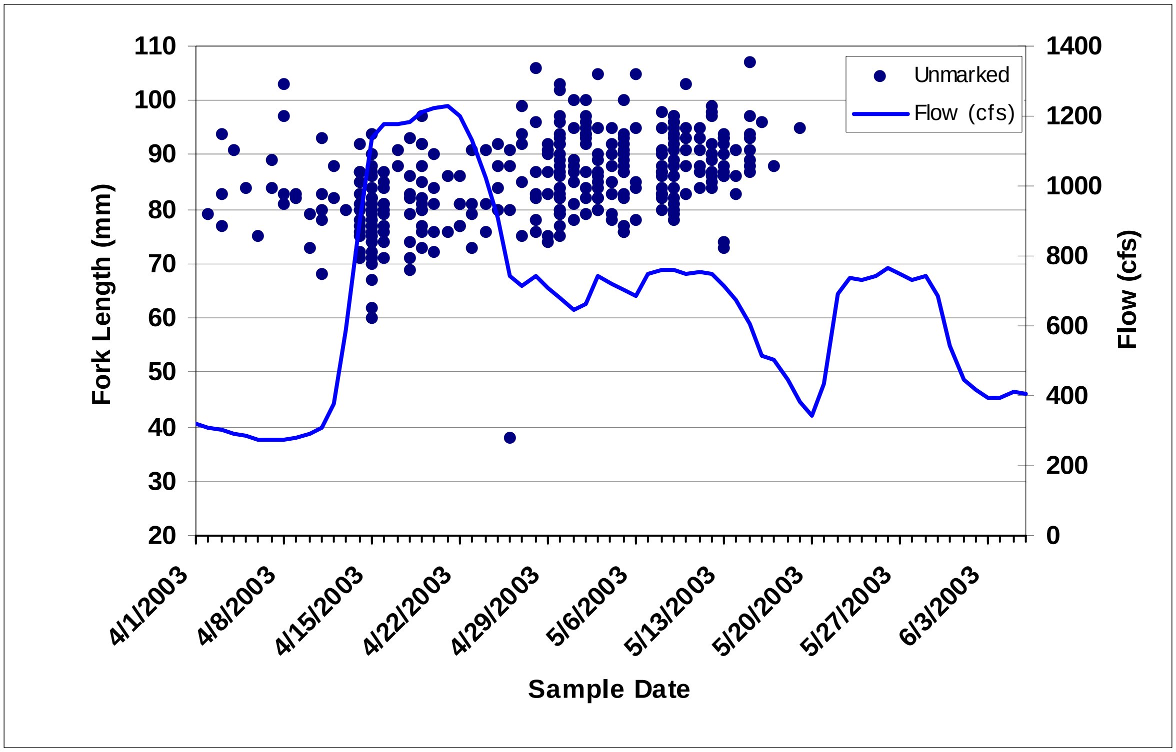

Figure 5. Fork lengths of non adipose fin clipped juvenile Chinook salmon captured in 2003. (Number of fish caught at each length is not represented.)

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