1998 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 one rotary-screw trap on the Tuolumne River for 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 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 1998 juvenile outmigrant data. The 1998 sample season used only one RST to conduct sampling. Previous and subsequent sampling seasons have used two traps operating side by side. 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 1998 sampling season.

METHODS

Site Description

One rotary screw trap was operated at the Shiloh Bridge, approximately 4 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 trap was attached by cable to the Shiloh Bridge. The north bank of this section of river is a steep bank armored by natural shrubs and trees. The south bank is a gentle sloping sandbar with natural riparian vegetation and a walnut tree orchard. 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 trap has 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, four times per day, beginning on 15 March 1998. Figure 2 displays catch of non-marked and marked salmon, flow, vulnerability releases, and days sampled. The trap sampled weekdays (cone raised on Friday and lowered again on Sunday) from 15 March – 12 April and again from 14 June – 1 July. The trap sampled everyday from 12 April – 14 June. Trap checks were scheduled to minimize time between each check. The last check was conducted on the morning of 1 July, and traps removed the following week. 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 box were removed and data recorded. All salmon captured were separated, checked for marks, and measured to the nearest millimeter. A smoltification index code was assigned to each measured salmon (marked and unmarked) and recorded. The smolt index criteria assign a number from 1 to 3 for different stages of development:

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. 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 18 March with the last test on 14 May (Table 2). Vulnerability tests consist of releasing a known number of dye marked fish approximately 0.5 miles upstream of the rotary-screw trap. 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 a subcutaneous 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.

$$R = \frac{\%recapture}{flow_{release}} \qquad \textbf{Equation 1}$$

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).

$$V_{daily} = \frac{Flow_{avg.daily} * R}{\%D} \qquad \textbf{Equation 2}$$

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).

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

Estimates developed for weekday sampling were expanded to weekends not sampled by multiplying the weekday estimates by 7/5. 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 days sampled.

The total catch of unmarked juvenile chinook salmon in 1998 was 2,521 fish (Figure 3). The estimated total catch of naturally produced juvenile chinook in 1998 was 1,615,673 (Figure 4). There were two releases of CWT marked fish conducted on 15 April (n=51,660 and n=48,634) at Old La Grange Bridge. 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 in previous sampling with rotary screw traps. 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) 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 1998 survey season started on 15 February, just after the time during which fry migration begins. Fry migration usually occurs January and February during freshets in wetter years. River flows in 1998 reached nearly 7,000 cfs in late February and early March. Fry migration occurred through March with over 99% of captured fry passing the trap before 30 March and declined in concurrence with dropping flows. Flows dropped to about 3,000 cfs in mid March and increased again to over 5,500 cfs in mid April.

Smolt migration appears to occur mid-April through early May. Fork length frequency of juvenile chinook captured in 1998 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. In 1998 there were eight vulnerability tests conducted (Table 2). One release (on 6 May, n=1,954) was not used in the analysis because there were no recaptures for the release. The first vulnerability release (18 March, n=1,954) was used to calculate estimates of all previous sample days because there were no vulnerability tests conducted earlier. This was done because the relationship of flow to vulnerability did not accurately represent vulnerabilities of the traps from 15 February – 15 March when mainly fry were migrating past the trap. The relationship of flow to vulnerability for smolt size fish is quite different from fry size fish.

Juvenile Production Estimate

Expanded catch of naturally produced juvenile Chinook salmon was 1,615,673 for 1998 (Figure 4). Production estimates for 1998 were made using only one trap. Previous sampling was conducted using two traps fishing side by side. In 1998 the single trap fished in nearly the same location within the channel as did the north trap in previous years. The north trap (north side of channel and usually in the thalweg) usually captures more fish in relation to the south trap. Using just one trap for sampling in 1998 while not as good as using two, is still sufficient to develop a reasonable estimate. Sampling did not start early enough to encompass the entire fry migration period. An earlier start date could yield more data on the timing of early fry migration as well as produce a more accurate estimate. Vulnerability tests conducted January and February using fry captured in RST and marked with Bismarck brown dye could give more accurate trap vulnerabilities for fry size fish.

Table 1. Non-salmonid fish captures in the Tuolumne River rotary screw trap in 1998.

Common Name	Count
American shad	1
Bluegill sunfish	8
Black bullhead	3
Brown bullhead	1
Carp	7
Channel catfish	8
Goldfish	73
Largemouth bass	2
Mosquitofish	34
Mississippi silverside	18
Pacific lamprey	3
Prickly sculpin	4
Redear sunfish	1
Red shiner	19
Sacramento pikeminnow	46
Sacramento sucker	2
Smallmouth bass	1
Threadfin shad	46
Unknown	2
Warmouth	15
Wakasagi	19
White catfish	64
Yellow bullhead	1

Table 2. Vulnerability tests for 1998 Shiloh rotary screw trap with release numbers and number recaptured for each test.

Release Date	Mark Code[1]	Effective Release	Mean FL (range)	Number Recaptured	Vulnerability	Flow (cfs) @ Modesto[2]
3/18/1998	BLUC	1956	57 (47-67)	2	0.0010	3014
4/3/1998	BLLC	2005	65 (54-75)	2	0.0010	4998
4/8/1998	BLAN	1962	68 (62-70)	5	0.0025	5177
4/15/1998	RDLC	2000	77 (69-86)	4	0.0020	5402
4/22/1998	RDUC	1998	79 (68-90)	6	0.0030	3568
4/29/1998	RDAN	1979	85 (74-98)	1	0.0005	3368
5/6/1998	RDUC	1954	89 (81-98)	0	0.0000	2711
5/14/1998	RDUC	1974	88 (78-102)	1	0.0005	2731

[1] BL indicates blue dye mark, RD indicates red dye mark, UC - upper caudal, LC - lower caudal 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.

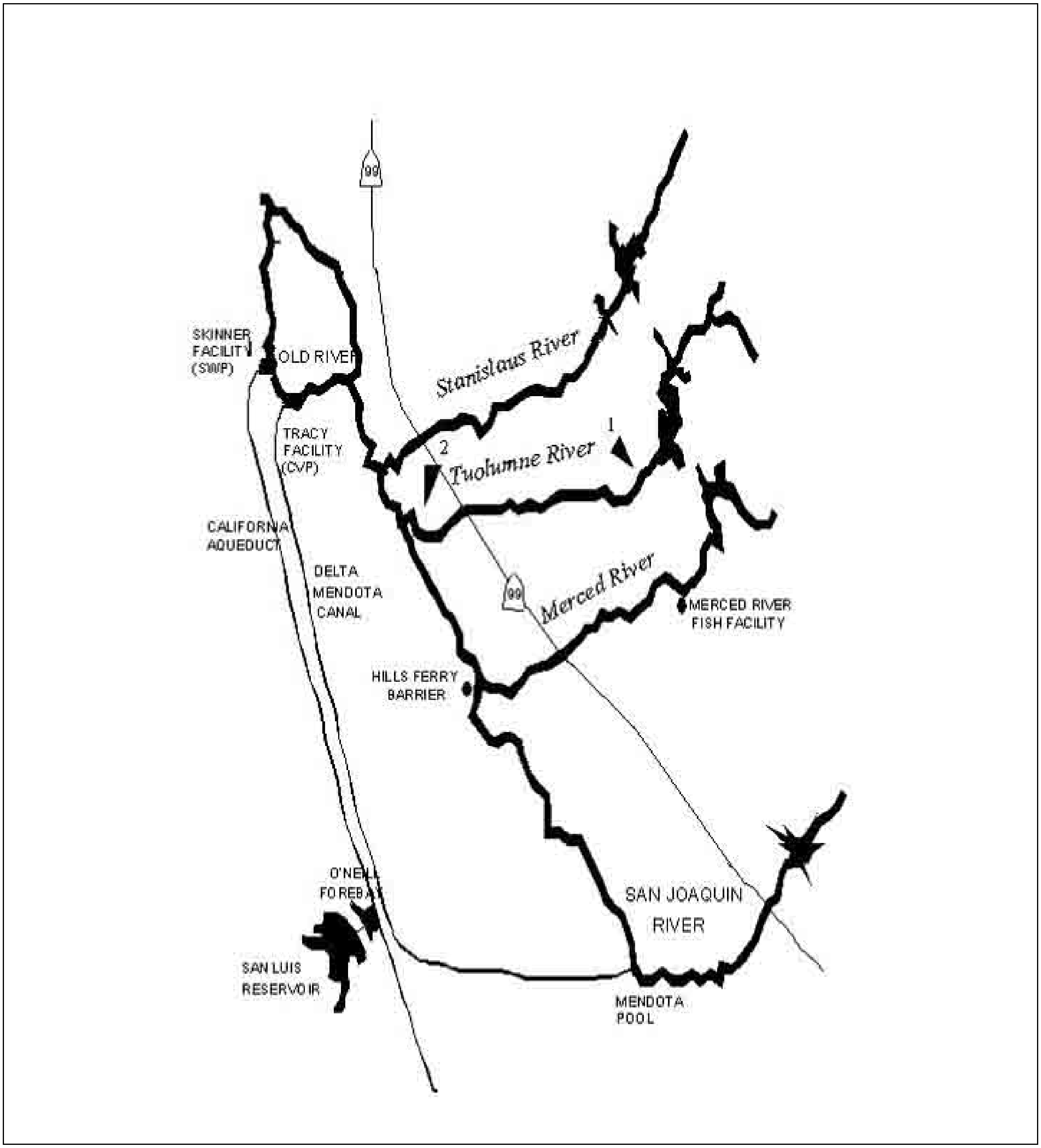

Figure 1. Map of San Joaquin River system with 1. La Grange and 2. Shiloh referenced for orientation.

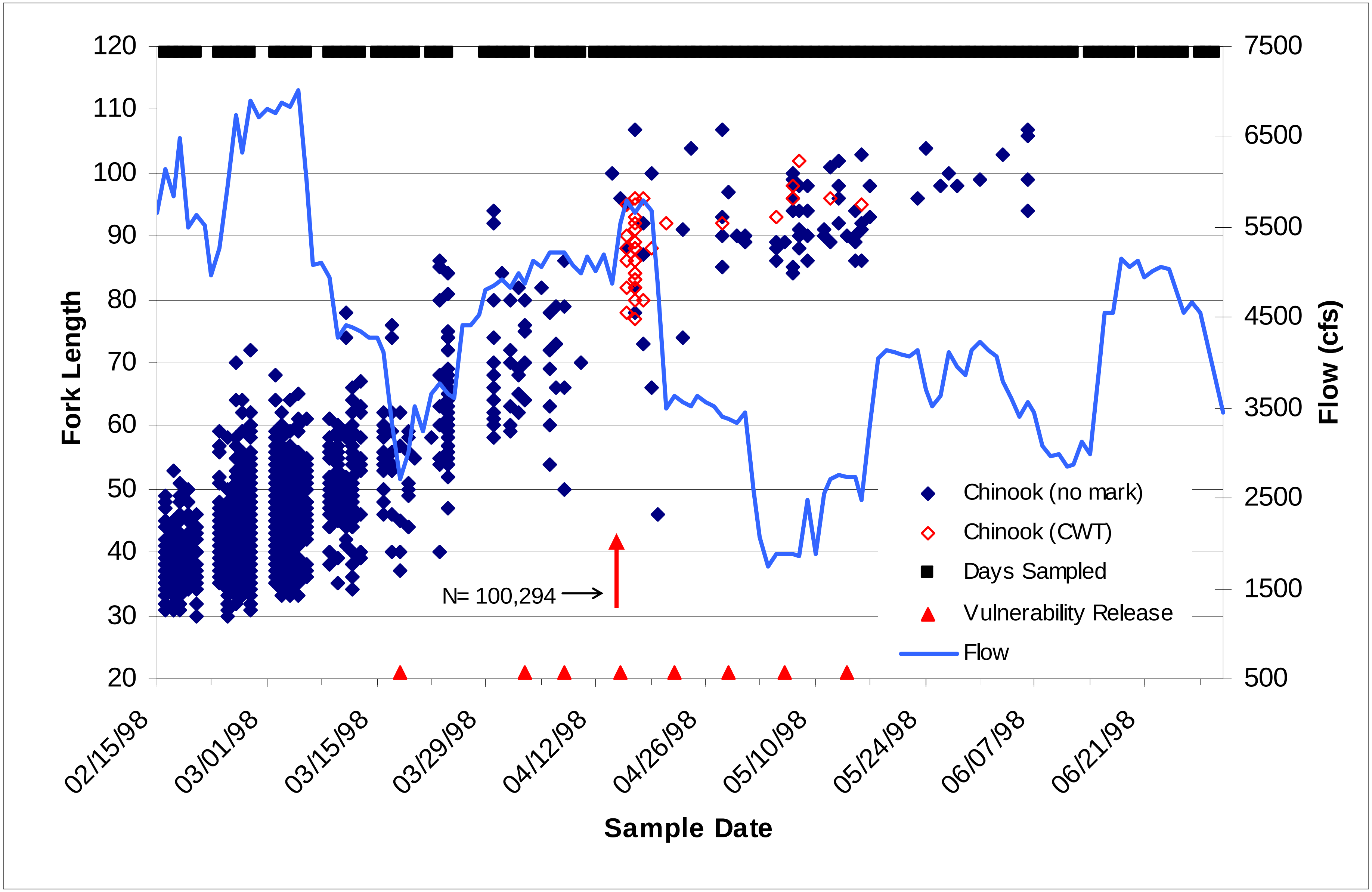

Figure 2. Fork length frequency of marked and unmarked Chinook salmon (CHN), flow (CFS, Modesto gage), vulnerability releases, CWT release on 15 April (N=100,294) and days which trap sampled.

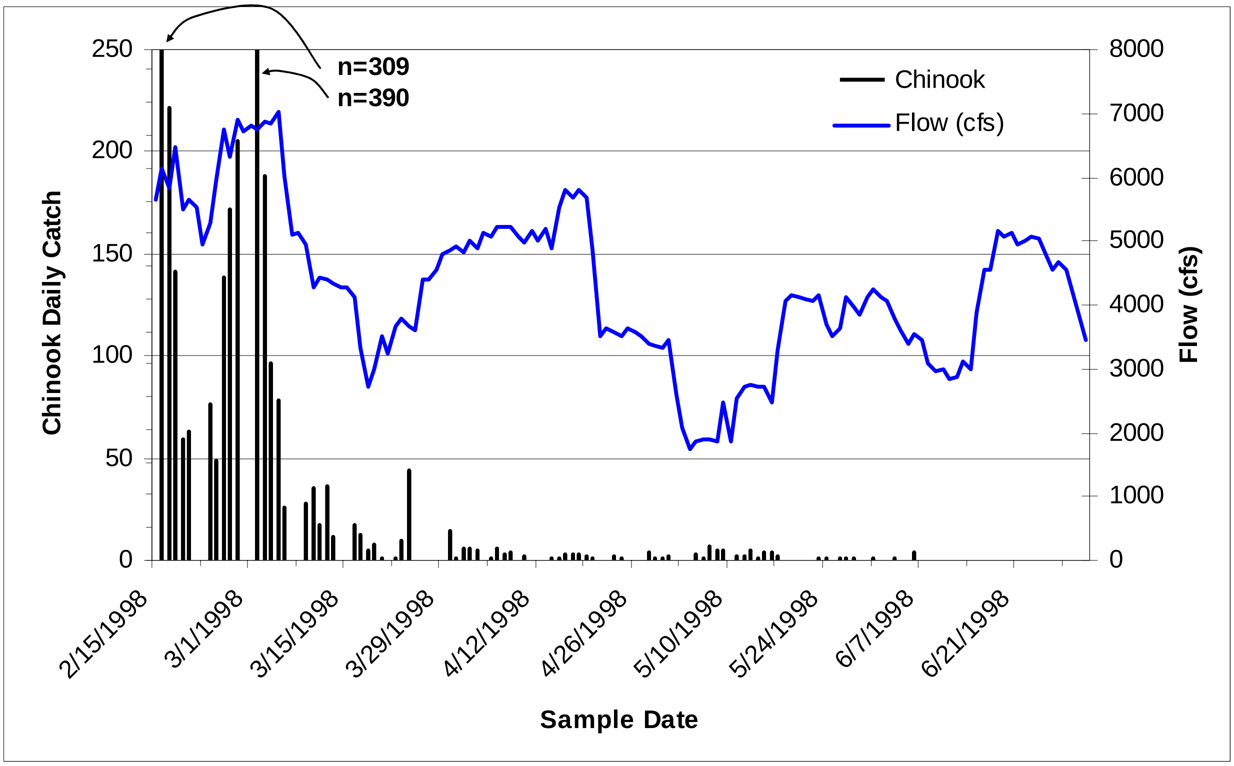

Figure 3. Daily catch of non adipose fin clipped juvenile chinook salmon with flow (cfs) at Modesto.

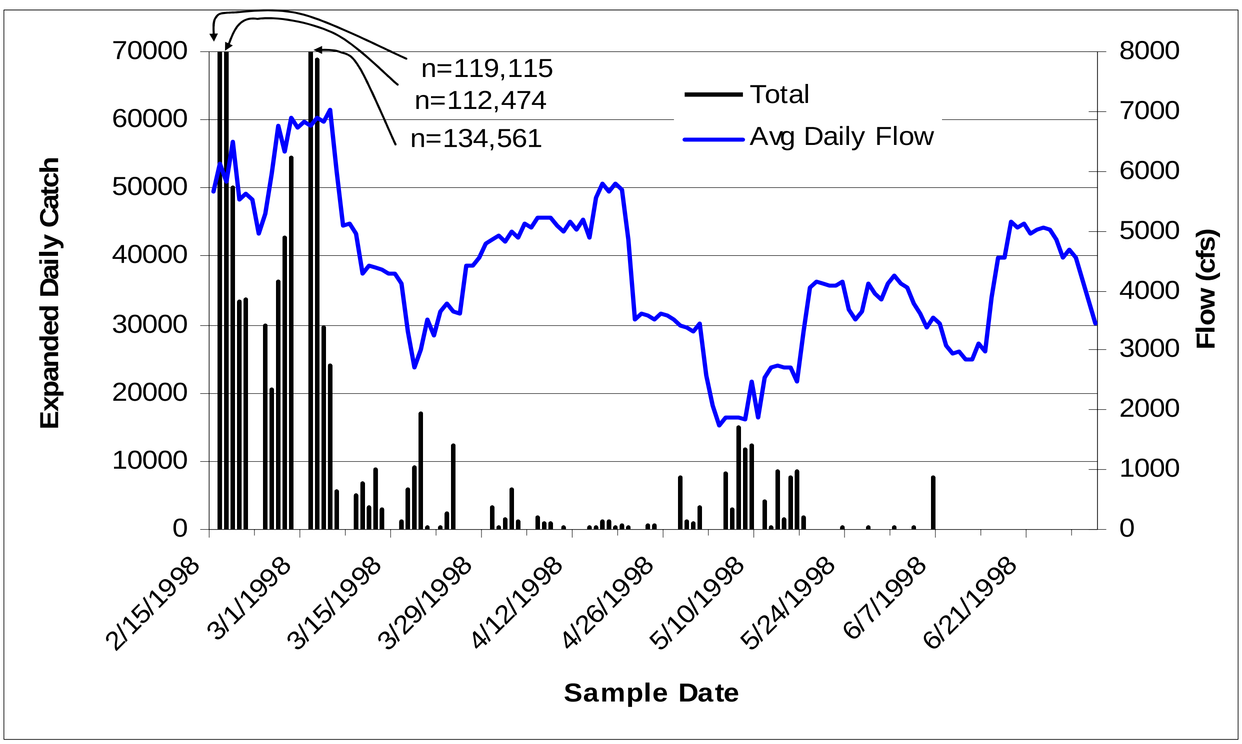

Figure 4. Expanded daily catch of naturally produced chinook salmon juveniles with flow (cfs) at Modesto gage.

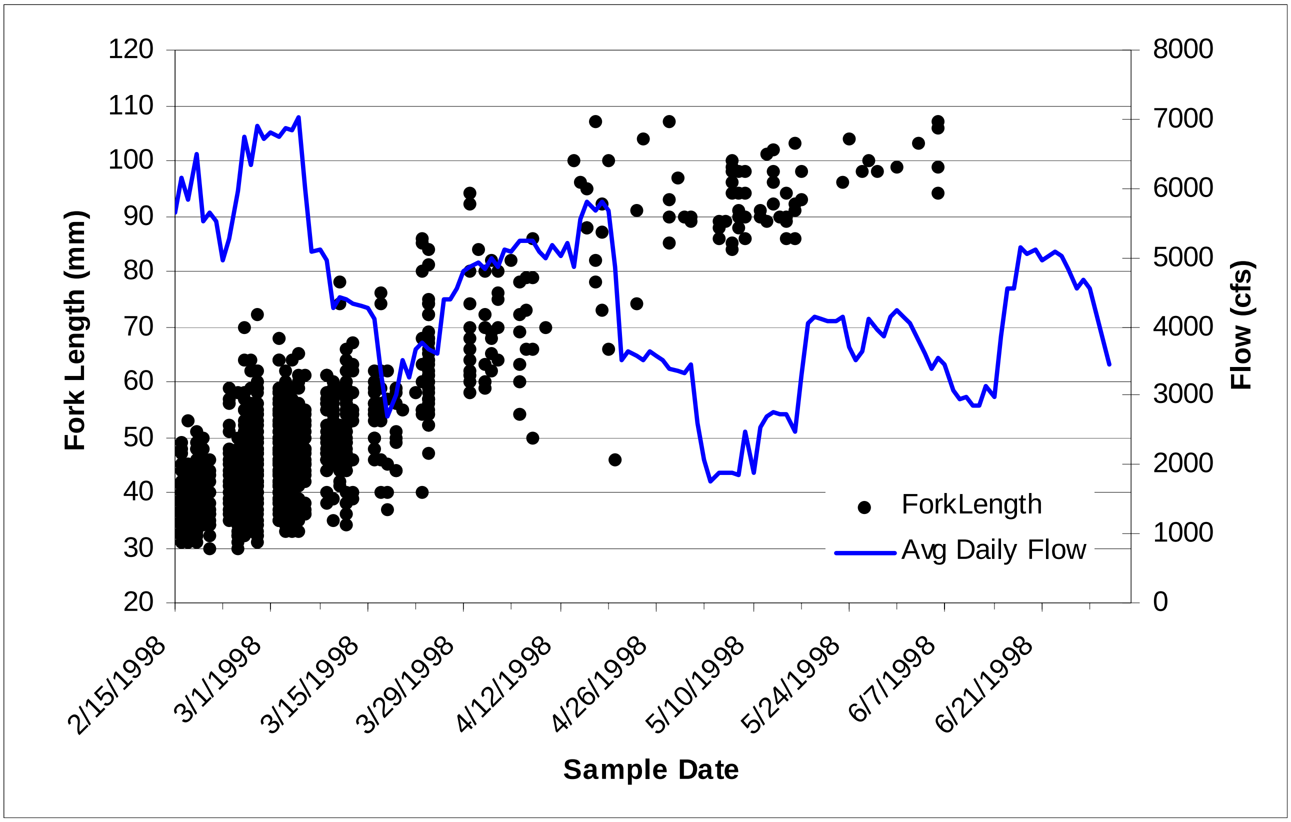

Figure 5. Fork lengths of non adipose fin clipped juvenile Chinook salmon captured in 1998. (Number of fish caught at each length is not represented.)

References

Demko, D. B., C. Gemperle, S. P. Cramer, and A. Phillips. 1999. Outmigrant trapping of juvenile salmonid in the Lower Stanislaus River Caswell State Park site 1998. USFWS Anadromous Fish Restoration Program. June 1999, 131 pp.

Fry, D.H. 1961. King Salmon Spawning Stocks of the California Central Valley, 1949-1059. *Calif. Fish and Game* **47**(1); 55-71.

Giorgi, A. E., T. W. Hillman, J. R. Stevenson, S. G. Hays, and C. M. Peven. 1997. Factors that influence downstream migration rates of juvenile salmon and steelhead through the hydroelectric system in the mid-Columbia River basin. *N. Am. J. Fish. Mgmt.* 17:286-282.

Heyne, T. and W. Loudermilk. 1997. Rotary-screw trap capture of chinook salmon smolts on the Tuolumne River in 1995 and 1996: Contribution to assessment of survival and production estimates. Federal Energy Regulatory Commission annual report FERC project # 2299-024, 21 pp.

Heyne, T. and W. Loudermilk. 1998. Rotary-screw trap capture of chinook salmon smolts with survival and production indices for the Tuolumne River in 1997. Federal Energy Regulatory Commission annual report FERC project # 2299-024, 24 pp.

NMFS. 2000. Salmonid travel time and survival related to flow in the Columbia River basin. NMFS Northwest Marine Fisheries Science Center, www.nwfsc.noaa.gov/pubs/nwfscpubs.html. March 2000, 68 pp.

Roper, B. B. and D. L. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 chinook salmon. *N. Am. J. Fish. Mgmt.* **16**:214-217.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska. *N. Am. J. Fish. Mgmt.* **14**:837-851.

Vasques, J. and K. Kundargi. 2001. 1999 and 2000 Juvenile chinook salmon capture and production indices using rotary-screw traps on the lower Tuolumne River. Federal Energy Regulatory Commission annual report FERC project #2299, report 2000-5, 75 pp.

Vick, J., P. Baker, and T. Ford. 1998. 1998 Lower Tuolumne River Annual Report. Federal Energy Regulatory Commission annual report FERC project # 2299, report 98-3, 47 pp.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in the California Central Valley.