Rotary-Screw trap Capture of Chinook Salmon Smolts

on the Tuolumne River in 1995 and 1996:

Contribution to Assessment of Survival

and Production Estimates

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Rotary-Screw Trap Monitoring Report: 1995 - 1996

Introduction

Chinook salmon populations in the San Joaquin River Basin have fluctuated widely and declined throughout the latter portion of the 20th century. Adult spawning escapements reached an all time low during the 1987 to 1992 drought (CDFG, 1990 and 1993). Low spawning escapements have persisted since that time. Recovery may be slowed due to poor production during several consecutive brood years and the lower total reproductive capacity of those small numbers of fish returning as adults.

Recent evaluation efforts have focused on the survival of smolts outmigrating from the San Joaquin River. Variations in spawning escapements are influenced by a number of factors including tributary and main stem San Joaquin River flows during the smolt outmigrant period (CDFG, 1987 and 1992; USFWS, 1987 and 1992). Smolt survival appears to be strongly affected by streamflow (e.g. CDFG, 1995 and 1996). The California Department of Fish and Game (CDFG), Modesto/Turlock Irrigation Districts (M/TID) and United States Fish and Wildlife Service (USFWS) desired a tool to help define more efficient use of water in the Tuolumne River to protect the smolt life stage of chinook salmon. Since 1986, studies have attempted to define the relationship between streamflow and smolt survival. Similar efforts were initiated on the Stanislaus and Merced Rivers nearby.

Test and control groups of coded-wire-tagged (CWT) smolts from the Merced River

Hatchery have been released in the Tuolumne River for survival studies in 1986, 1987, 1990, 1994, 1995 and 1996 (for locations see Figure 1). Test groups are released in the upper river and the control groups are released near the mouth. Recoveries in a Kodiak trawl at Mossdale on the San Joaquin River and at other locations are used to develop "survival rate indices" based on proportions of smolts recovered from the test and control groups. These indices are then related to streamflows (and other physical parameters) in the test reach to help define the relationship and provide useful information for fishery and water management decisions.

Rotary-screw traps (RSTs) have been used to sample outmigrant salmon smolts at various locations in the Pacific Northwest (Roper and Scarnecchia, 1996 and Thedinga et. al. 1994). The parties interested in Tuolumne River smolt survival evaluations decided to try this method in conjunction with the Kodiak trawl at Mossdale, for; a) indexing smolt survival and b) possibly indexing total numbers of smolts leaving the Tuolumne River (smolt production). Limited sampling with RSTs was performed in 1995 and 1996 in conjunction with the ongoing smolt survival index studies (CDFG, 1995 and 1996) to evaluate their utility for survival and production indices (or estimates) in the Tuolumne River. This report compiles information from the 1995 and 1996 smolt survival index studies and results from these RST evaluations.

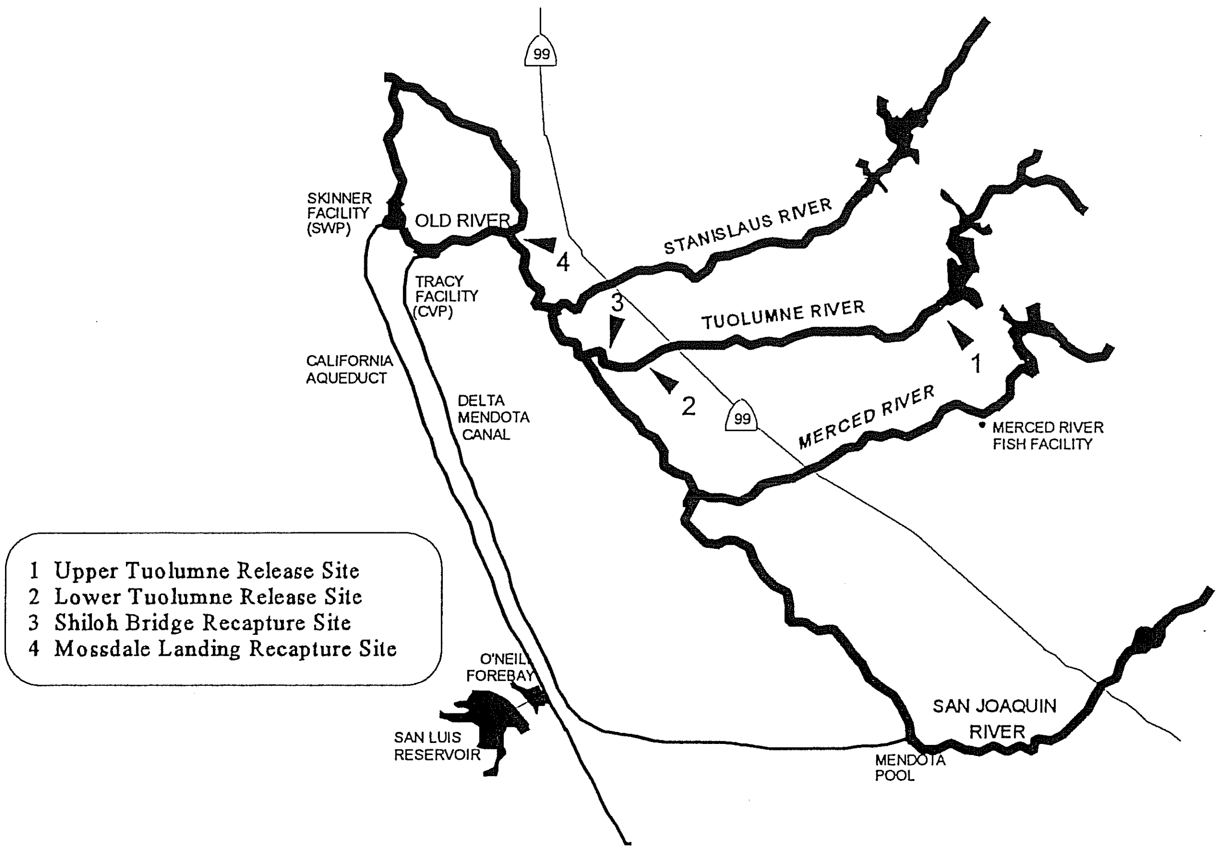

Figure 1. California Department of Fish and Game release and recapture sites for the chinook smolts released into the Tuolumne River.

Methods

Test Fish

Smolts at the Merced River Hatchery (MRH) were fin clipped (adipose fin) and tagged with binary coded-wire tags (CWT). Tagged smolts were released in two groups in both years with each group consisting of 2-3 tag codes. Test groups were released at Old LaGrange Bridge (RM 50.5) and control groups at the end of Service Road (RM 6) in both years. The release dates for the upper river groups were May 3, 1995 and April 27, 1996 and for the lower river groups were May 4, 1995 and April 28, 1996.

Nine groups of smolts from MRH (~1,000/group in 1995 and ~2,000/group in 1996) were released over the two years to test RST efficiency. RST efficiency is defined as the percentage of a specific group of smolts, released close to the RSTs, that are recaptured. Approximately one release per week was made during RST operation. Each group was dyed with green dye. The dye was applied to the caudal fin rays with Madajet and Panjet tattooing equipment. These fish were transported in small tanks and released approximately 900 m upstream of the RSTs just after sundown.

Trap Operation

Simultaneous with Kodiak trawl surveys being performed downstream at Mossdale Landing (CDFG, 1996), two 8' rotary-screw traps (RSTs) were deployed and operated at Shiloh Bridge (Fig. 1) in both years. The RSTs were operated during the release of tagged and dye-marked smolts for the smolt survival index study. They were operated from Apr. 25th to June

1st, 1995 and from Apr. 18th to May 29th, 1996. The two traps were fished side-by-side, 24 hours a day most of both years. They were fished adjacent (south of) to the thalweg in 1995 and directly in the thalweg in 1996 (Fig. 2). For information regarding the operation of the Kodiak trawl at Mossdale Landing see CDFG (1995 and 1996).

The RSTs were checked twice a day, except when more frequent checks were required to keep the traps operating. Large amounts of debris and releases of test fish were the primary reasons for more frequent checking. Occasionally, debris was such a problem with the RSTs that they required constant monitoring. Sampling was performed in both years by a combined effort of CDFG, M/TID and EA Engineering.

All fish and debris were removed from the RSTs each time they were checked. The fish were separated by species and counted. A subsample (usually all) of the chinook smolts were measured (FL to the nearest mm) and checked for external marks (dye or adipose-fin clips). Smolts with adipose fin clips were frozen and assumed to be coded-wire tagged (CWT). These CWT fish were later thawed and examined. Tags were removed for determination of release group. Lengths of other species of fish were estimated or occasionally measured.

The time that it took the RSTs to make 10 or 20 revolutions was recorded and water velocity was measured at the center of the RSTs. Velocity measurements were 0.5 meters below the surface. Air and water temperature were recorded along with general weather conditions. Date and time the fish were removed from the RST were also recorded.

Analysis

Graphical evaluations of most data collected were produced for this report.

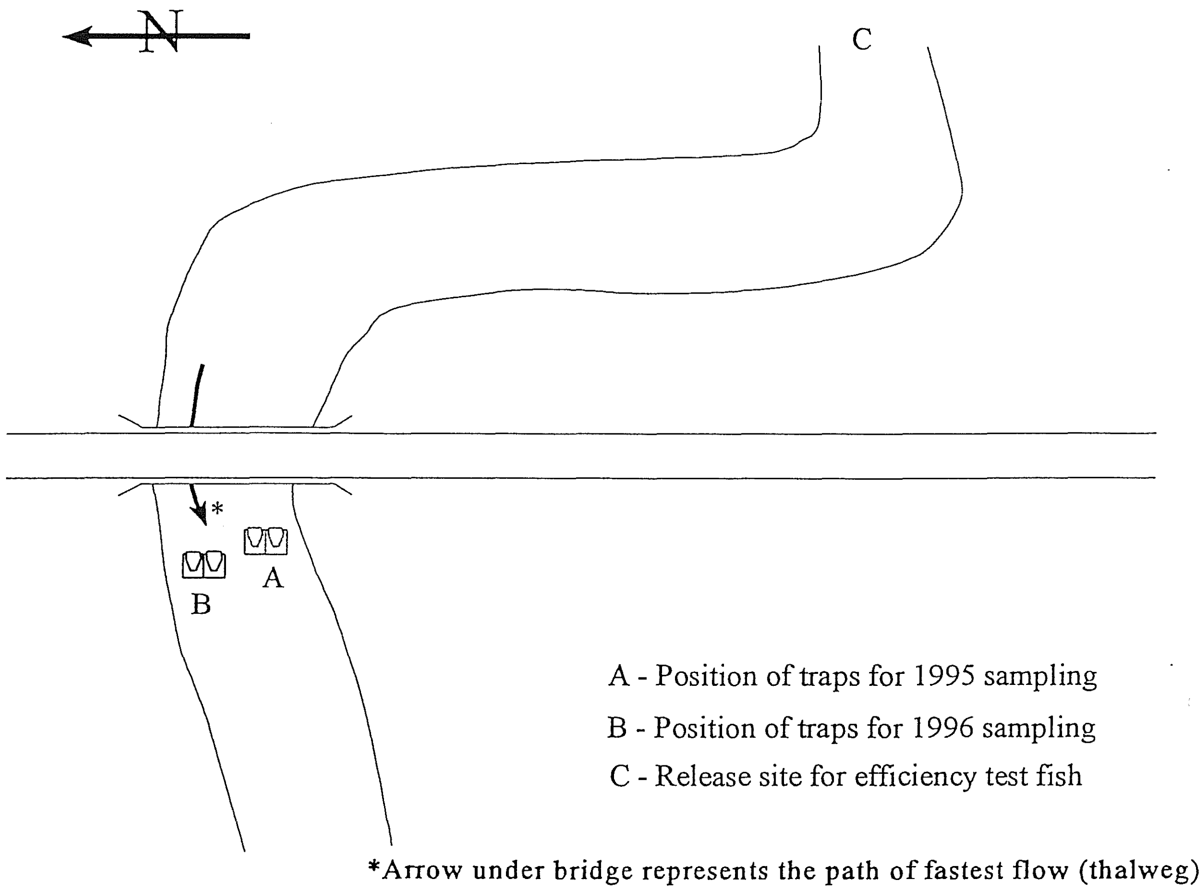

Figure 2. Map of the Shiloh Bridge sampling site. Position of the RSTs in 1995 and 1996 are shown as well as the release site for the trap efficiency testing fish.

The relationship of flow and time of capture to the numbers of smolts and their size were assessed graphically. Factors effecting trap efficiency were also assessed graphically.

Estimation of total numbers of chinook salmon smolts passing the RSTs (termed "smolt production") can be made by multiplying the number of smolts captured each day by the inverse of the RST efficiency at that flow. There are however some serious problems with this estimation. The RSTs are occasionally stopped by debris. Thus, the catch for that day is not really the "total" catch. Smolts released for daytime efficiency testing were not recaptured in the traps indicating that smolts are able to pass by without being detected by the RSTs during the daytime. The duration of RST sampling in 1995 and 1996 was shorter than the time period during which chinook salmon smolts were outmigrating from the Tuolumne River (based on sampling at other locations). Although at present, these problems and others not listed cast doubt on the accuracy of estimating total numbers of smolts, this preliminary estimate was made due to interest in the range of numbers that might be generated.

A low estimate of smolt production was made by multiplying the number of smolts captured by the inverse of the average RST efficiency in each year. Average RST efficiency was used because there is as yet no clearly defined relationship between RST efficiency and streamflow and the variation of RST efficiency within a year was small. A "daytime corrected" smolt production estimate is made by assuming that smolts move in equal numbers in the day and the night and are not captured simply because they avoid the RSTs during. There is evidence from other CDFG studies that smolts do migrate during both night and daylight hours. Since day and night are nearly equal length the "daytime corrected" production estimate is calculated by multiplying the low estimate by 2.

Lastly two "high" estimates (High-1 and High-2) for smolt production were produced by multiplying the low estimate and the "daytime corrected estimate" by a "seasonal correction factor". The "seasonal correction" factor is used because the RSTs were not used the entire time that the smolts were outmigrating. In order to estimate the "seasonal correction" factor data from sampling at Caswell on the Stanislaus River (RSTs) and at Mossdale on the San Joaquin River (Kodiak trawl) were used to estimate the percentage of smolts that outmigrated during the sampling periods. That percentage divided into 100 yields the "seasonal correction" factor.

Smolt survival index methodology is described in CDFG (1995 and 1996). This method was used to calculate survival indices for the RSTs and the Kodiak trawl in both years. The basic equation used is:

$$\hat{S}=\frac{R_1 * M_2}{R_2 * M_1}$$

Where:

$\hat{S}$ = Survival rate index
R_1 = Number of recaptures from upper release group
R_2 = Number of recaptures from lower release group
M_1 = Number effectively released for upper release group
M_2 = Number effectively released for lower release group

Results

One hundred and forty one natural smolts were captured at the Shiloh Bridge RSTs in

1995 and 630 were captured in 1996 . The catch trends were generally similar, although total numbers captured were greater in 1996 (Fig. 3 and 4). Appendix A shows the numbers of natural and CWT chinook smolts caught each day in 1995 and 1996. The catch of smolts is not uniform throughout the 24 hour cycle. Figures 5 and 6 show that few fish are captured in the daylight hours. The timing of smolt capture can be broken down even more by dividing the night into two parts. Comparison of the catch of smolts in 1996 during the day, before midnight and then after midnight (Figure 6), shows that there is variations in smolt capture rates during a 24 hour period.

Test groups of 83,500 (1995) or 67,200 (1996) were released in the Tuolumne River at Old LaGrange Bridge. Control groups of 53,300 (1995) and 50,500 (1996) were released in the Tuolumne River at the end of Service Road. Twenty-three CWT smolts (22 had tags) were recaptured in 1995 and 430 (355 had tags) were recaptured in 1996. Figures 7 and 8 show the catch of CWT smolts during the month and a half of sampling in each year.

Figures 9 and 10 show the fork lengths of the natural and CWT smolts in 1995 and 1996 respectively. Average fork length changed little during the sampling period for natural smolts but rose steadily for CWT smolts in 1995. The average fork length of the natural and CWT smolts is more difficult to separate in 1996. The CWT average fork length does however, go through a greater increase than the natural smolts just as in 1995.

The efficiency of the RSTs was tested 9 times. Comparison of percent recapture (RST efficiency) vs. flow are presented in Figure 11. There appears to be a linear relationship between these two parameters as there also appears to be the case between RST efficiency and percent of flow that was filtered by the traps (Figure 12). However, the small number of data and the clustered nature of the data, precludes further definition of the relationships among these variables

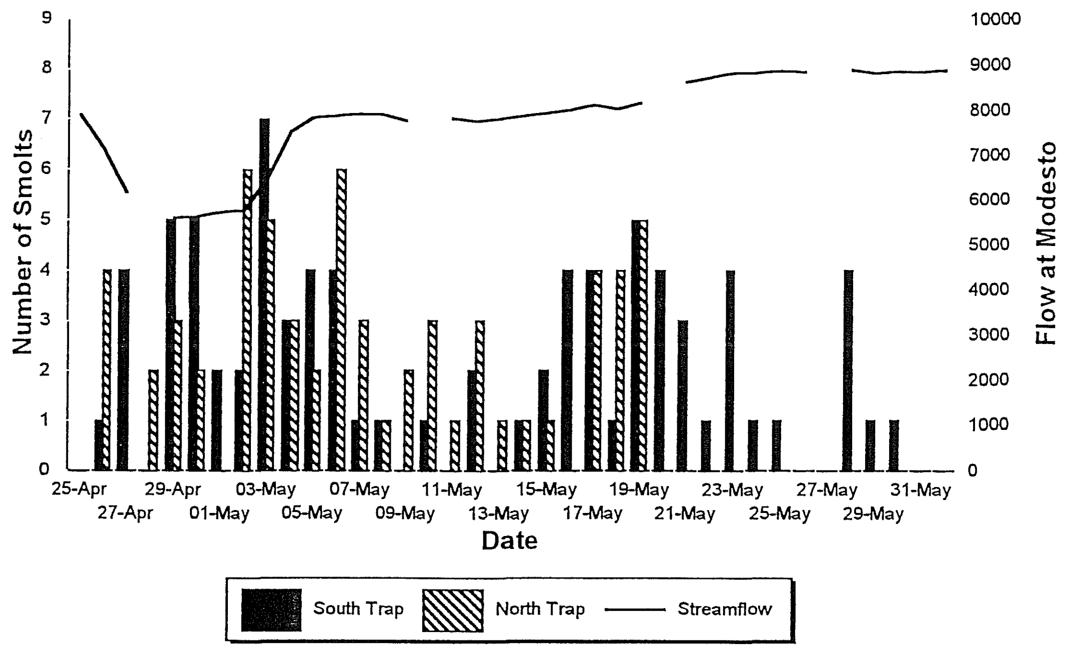

Figure 3. Natural chinook salmon smolts captured in both RSTs and the streamflows at Modesto on the previous day in 1995.

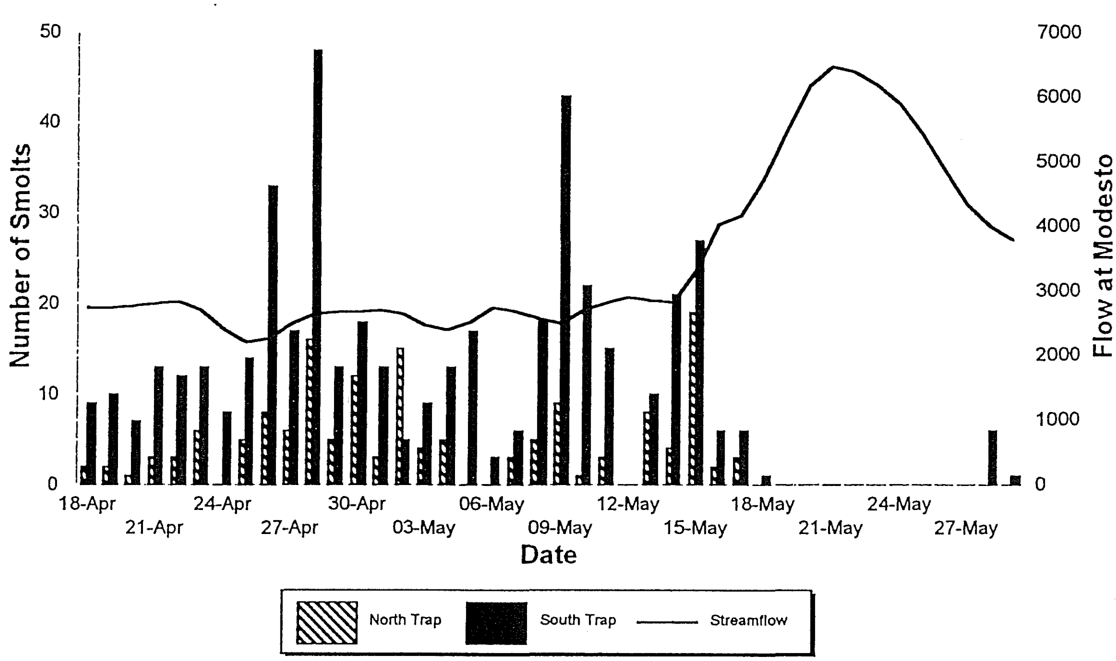

Figure 4. Natural chinook salmon smolts captured in both RSTs and the streamflows at Modesto on the previous day in 1996.

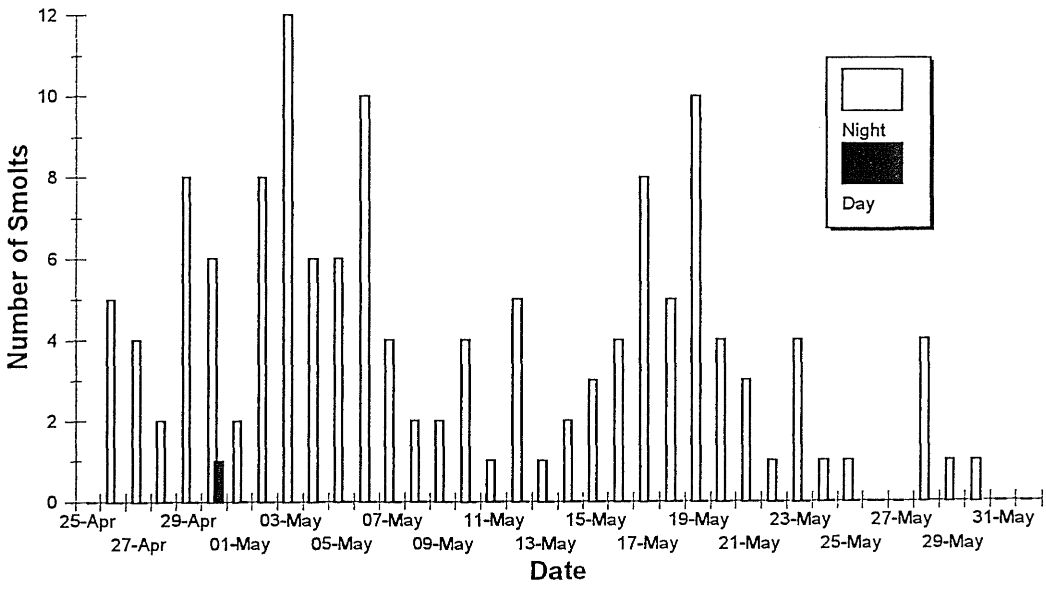

Figure 5. Diel variation in numbers of natural chinook smolts captured in Tuolumne River RSTs during 1995

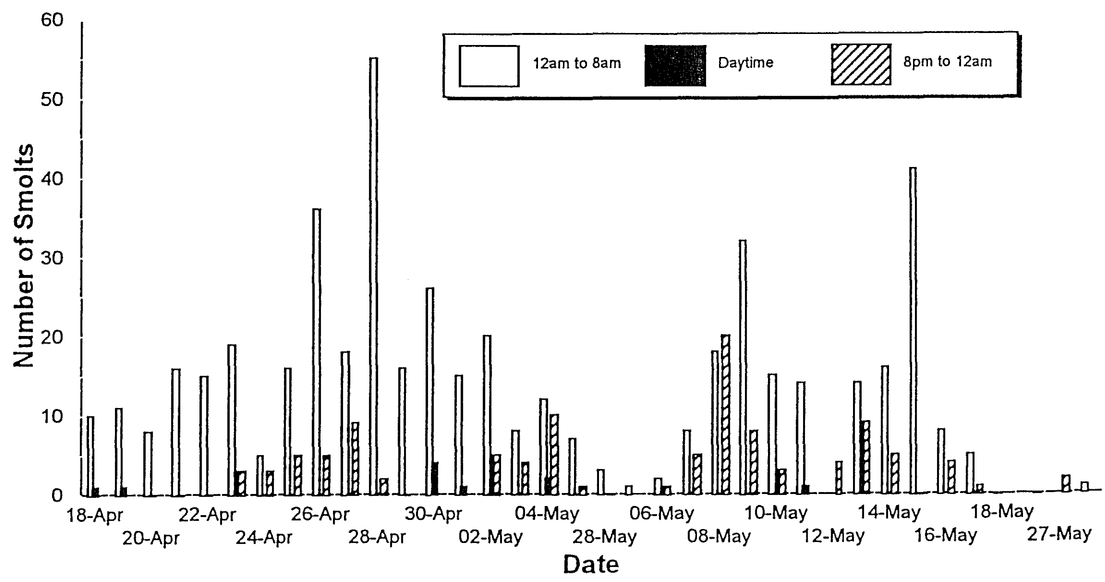

Figure 6. Diel variation in numbers of natural chinook smolts captured in Tuolumne River RSTs during 1996.

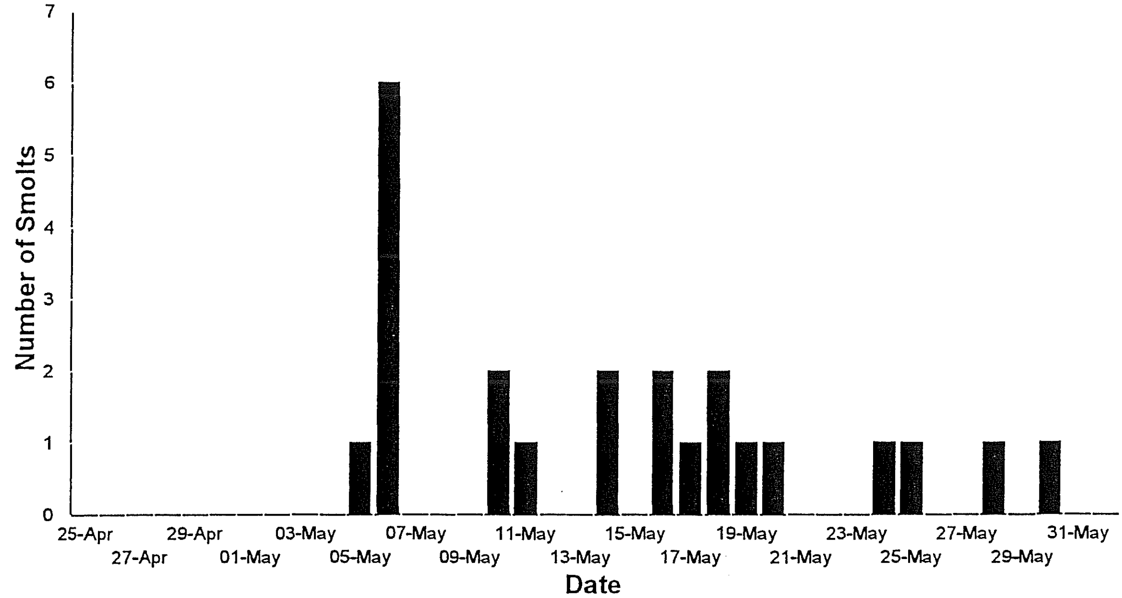

Figure 7. Coded-wire tagged smolts captured in Tuolumne River RSTs at Shiloh bridge in 1995.

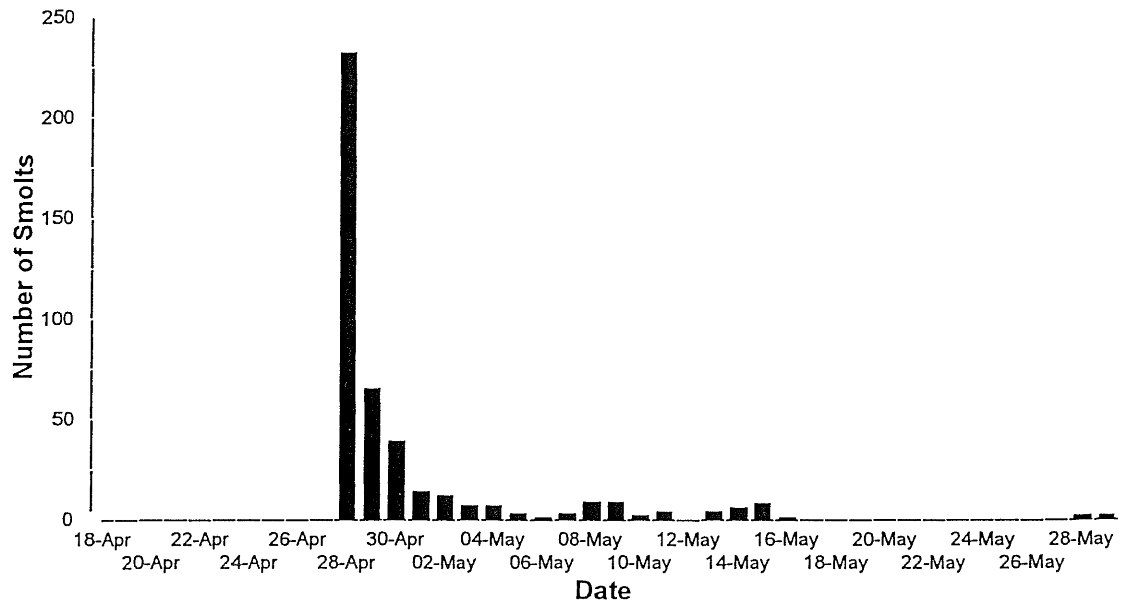

Figure 8. Coded-wire tagged smolts captured in Tuolumne River RSTs at Shiloh bridge in 1996.

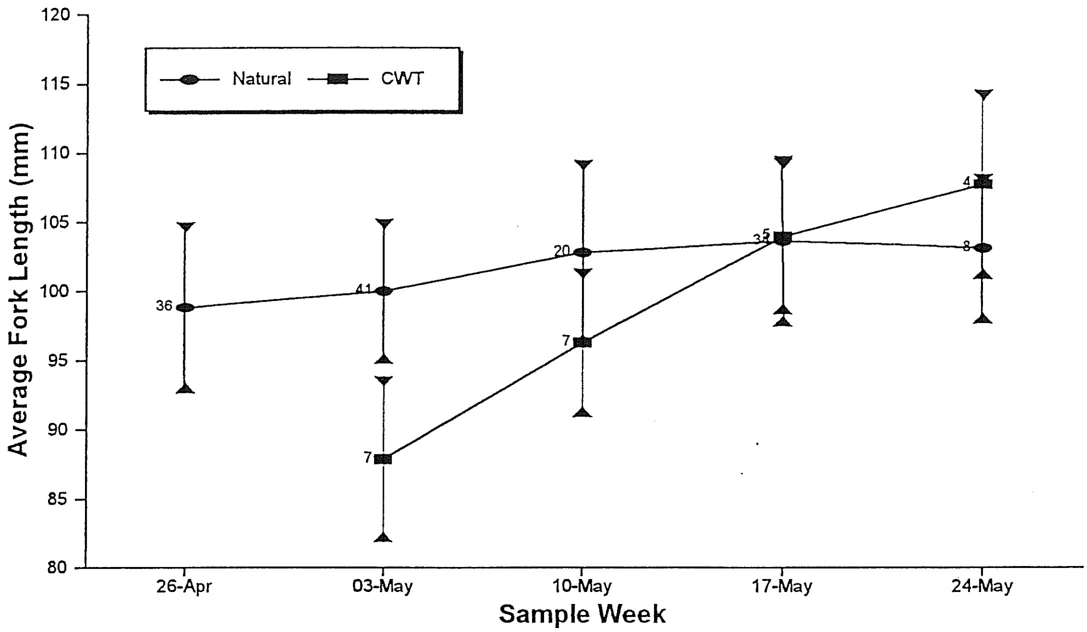

Figure 9. Average fork lengths of coded-wire tagged (CWT) and natural chinook salmon smolts in the Tuolumne River in 1995. Numbers beside each data point represent the number of fish included in the average. Bars represent the standard deviation for each week.

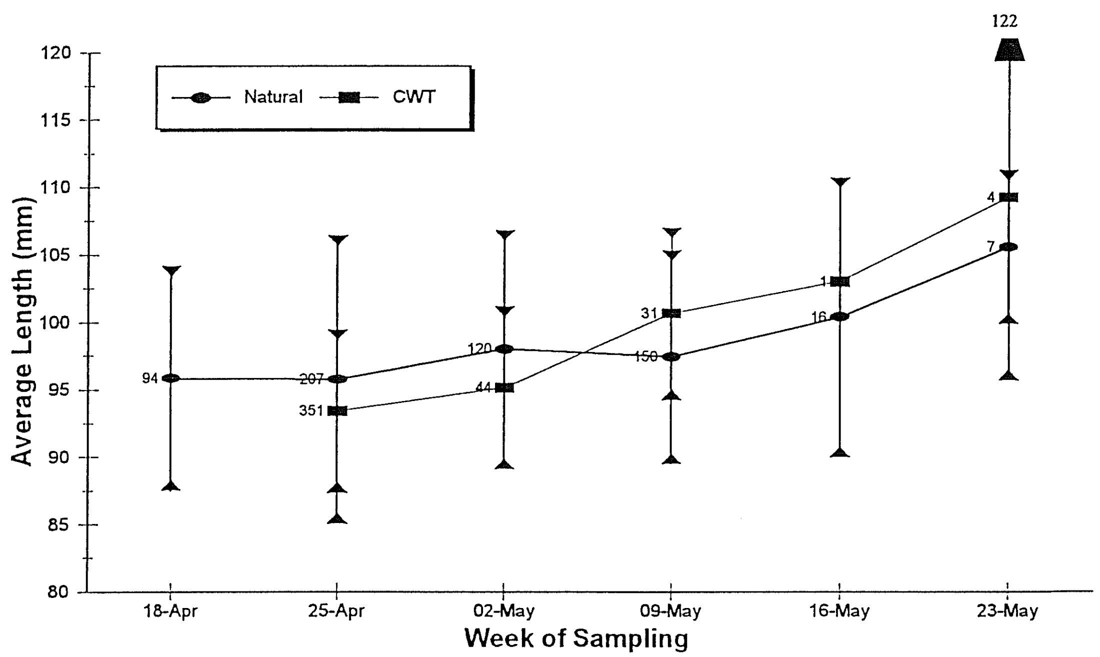

Figure 10. Average fork lengths of coded-wire tagged (CWT) and natural chinook salmon smolts in the Tuolumne River in 1996. Numbers beside each data point represent the number of fish included in the average. Bars represent the standard deviation for each week.

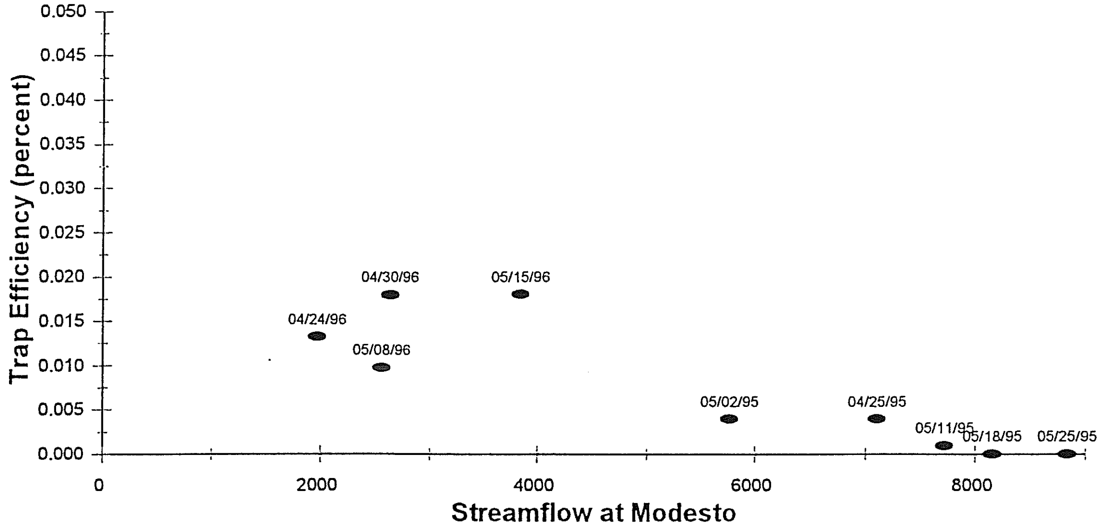

Figure 11. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to streamflow at Modesto.

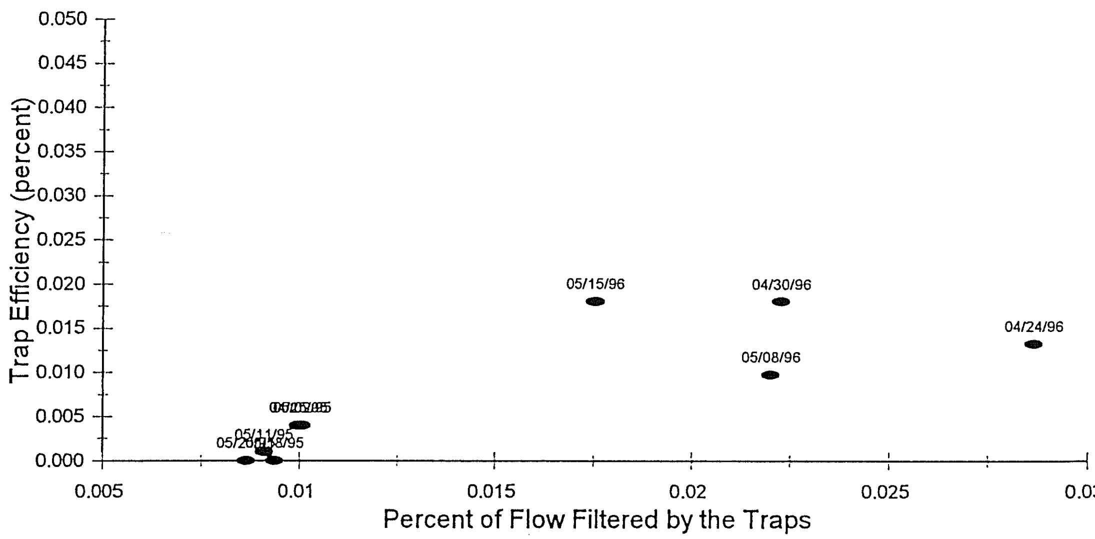

Figure 12. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to percent of the streamflow at Modesto filtered by the RST.

at this time.

Figures 13 and 14 indicate the relationship of velocity and smolt fork length to RST efficiency. These two variables appear to be randomly dispersed with respect to RST efficiency. Again the small number of points and their clustered values preclude a more complete analysis.

Calculation of preliminary smolt production estimates for 1995 and 1996 are presented in Table 1. Survival estimates were developed in both years from both the RSTs at Shiloh Bridge and Kodiak trawl at Mossdale. These data are presented in the Table 2.

Discussion

The information presented is based on two years of sampling information. This provides results with limited interpretation possible. All interpretations presented below should be treated as preliminary observations only.

There has been assumed to be a relationship between streamflow and the intensity of chinook salmon smolt outmigration. Although some of the subtle rises in streamflow (Fig. 3 and 4) are accompanied by higher catches of smolts, the effect does not last long. There are also times when the number of smolts caught rises while the flow remains constant. It would appear from the results that more variables than streamflow are responsible for initiating smolt outmigration.

Movement of the smolts seems to be effected by the time of day. This may be simply a result of smolts being more able to avoid the RSTs when there is more light or the smolts may not move during the daytime or both avoidance and lack of movement may be causing these results. This makes light (as effected by such things as moon phase, time of day and weather) a possible

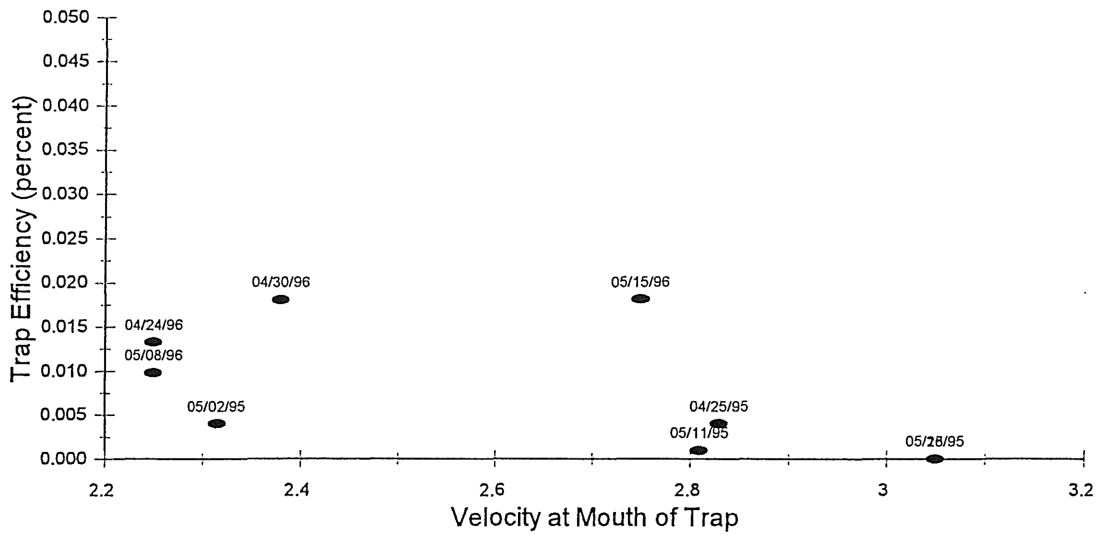

Figure 13. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to velocity at the mouth of the RSTs.

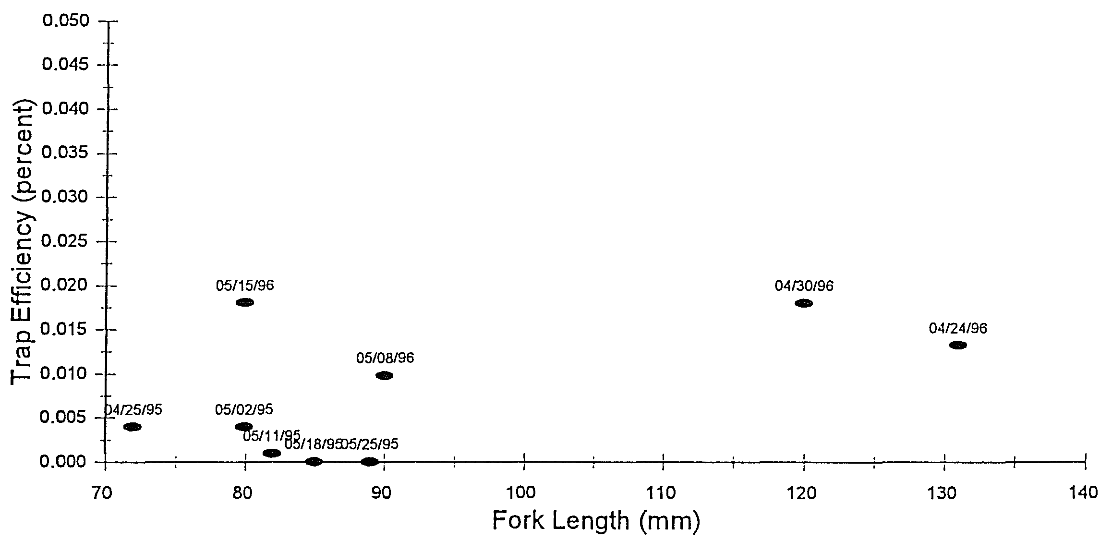

Figure 14. Percent of test fish recaptured (RST efficiency) that were released ~900m upstream of the RSTs compared to the average fork length of the smolts in the test groups.

Table 1. Preliminary chinook salmon smolt production estimates for the Tuolumne River during 1995 and 1996.

Year	Number of smolts captured	Efficiency estimate	Low estimate	Day-Cor. estimate	High-1 estimate	High-2 estimate
1995	141	0.0090	15,667	31,333	21,933	43,867
1996	630	0.0156	40,385	80,769	56,538	113,077

Table 2. Chinook salmon smolt survival indices and associated data for the Tuolumne River in 1995 and 1996.

Year	Release Site	Number of smolts released	Mean Flow	Number Captured at Mossdale	Number Captured at Shiloh	Survival Index at Mossdale	Survival Index at Shiloh
1995	Upper	83500	7600	58	11	0.80	0.64
	Lower	53300		46	11		
1996	Upper	67200	3000	64	222	0.31	1.25
	Lower	50500		156	133		

factor in addition to streamflow effecting the outmigration of smolts.

Average fork length of natural smolts changed little over the sampling season (~ 10 mm). The average fork length for CWT smolts during the same period generally exhibited an upward climb (as much as 20 mm in one year, 1995). It would appear that the natural smolts outmigrate when they reach a certain size (~ 95-100 mm). That would be one more factor effecting the catch of smolts at the RSTs; number of available smolts in the river above the traps that have reached the appropriate size to outmigrate. The effect on outmigration of increases in streamflow may be dependent to some degree on the number of the smolts that are at the appropriate size.

RST efficiency evaluations are an area that clearly need more work. These data are crucial to any index of smolt production for the river. The gaps in the present data will need to be filled in subsequent years. The apparent linear relationships, between RST efficiency and streamflow as well as RST efficiency and percent of the flow filtered by the traps, may change drastically as sampling is performed in low flow years. Some sort of independent evaluation of RST efficiency needs to be performed as well. Hydroacoustic sampling or radio-tagged smolts could provide independent information to evaluate present RST efficiency testing and help evaluate movement of smolts during the daytime.

The estimates of smolt production are very dependent on the RST efficiency evaluations. Until further work is completed on the RST efficiency the production estimates must be treated as preliminary at best. The results so far are lower than would be expected based on the adult escapement the preceding falls (CDFG, 1995; CDFG, 1996). Many factors including gravel quality, water quality and of course the efficiency estimates effect these numbers. All of them will need investigation in the future.

Smolt survival estimation are less dependent on the RST efficiency evaluations. The major assumption of survival estimation as presented here is that the upper and lower release groups are equally susceptible to the sampling gear (RSTs and Kodiak trawl). A second requirement is that sufficient numbers of the test and control groups are recaptured to make the assessment reasonable. Less than 30 recaptures is probably insufficient to assume average distribution of response (Ludwig and Reynolds, 1988).

The results in both years have some problems with these assumptions and requirements. The 1995 survival estimates (Mossdale and Shiloh) appear reasonable but the Shiloh recaptures are all less than 30. The 1996 survival estimates are completely different at the two locations. The assumption of equal susceptibility may have been violated. In Appendix A there is a clear spike in the recapture of the upper river release group and yet the lower release group (which should have an even tighter grouping of smolts) shows no spike. The lower river release group which was released three miles upstream at noon on the same day that recaptures began may have passed the RSTs predominantly during daylight when catch is minimal at best. This is likely to be the case as travel times of one mile an hour would not be unusual (CDFG, 1995; CDFG, 1996).

The recapture of smolts at Mossdale in 1996 appear to have had the same problem as Shiloh except that the upper river release group was under-represented instead of the lower river release group (George Neillands, pers. comm.). These problems can be alleviated to some degree in future studies by releasing the lower river release group at night instead of in the day and spreading the release groups out over a longer time period so that the spike of CWT recaptures at the recapture sites is not so extreme. Increasing sampling intensity may also improve the validity of smolt survival rate indices by increasing the number of recaptures.

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Appendix A. Numbers of natural chinook smolts captured in two RSTs deployed side by side at Shiloh Bridge on the Tuolumne River in Stanislaus County, CA. Only one trap was used after May 25th in 1995 and May 17th in 1996. Blanks indicate when no sampling occurred. (Total CWT includes adipose-clipped fish with no tag recovered)

Date	1995				1996			
	Natural	Upper CWT	Lower CWT	Total CWT	Natural	Upper CWT	Lower CWT	Total CWT
18-Apr					11			
19-Apr					12			
20-Apr					8			
21-Apr					16			
22-Apr					15			0
23-Apr					19			
24-Apr					8			
25-Apr	0				19			0
26-Apr	5				41			0
27-Apr	4				23	40	41	99
28-Apr	2				64	83	44	151
29-Apr	8				18	32	4	47
30-Apr	7				30	19	12	39
01-May	2				16	8	3	14
02-May	8				20	6	5	12
03-May	12				13	2	4	8
04-May	6				18	6	2	8
05-May	6	1	1	1	17		1	1
06-May	10	1	3	6	3		1	1
07-May	4			0	9	2	1	5
08-May	2			0	23	4	2	9
09-May	2			0	52	7	1	9
10-May	4		2	2	23			1
11-May	1	1		1	18	3		3
12-May	5			0		1		4
13-May	1			0	18	2	2	4
14-May	2	1	1	2	25	1	2	4
15-May	3			0	46	3		6
16-May	4	2		2	8	1		1
17-May	8	1		1	9			0
18-May	5		2	2	1			0
19-May	10	1		1				
20-May	4		1	1				
21-May	3			0	0			0
22-May	1			0				
23-May	4			0				
24-May	1		1	1				
25-May	1	1		1				
26-May	0			0				
27-May	0			0				
28-May	4		1	1	6	2		2
29-May	1			0	1			2
30-May	1	1		1				
31-May	0			0				
01-Jun	0			0				
TOTAL	141	10	12	23	610	222	125	430