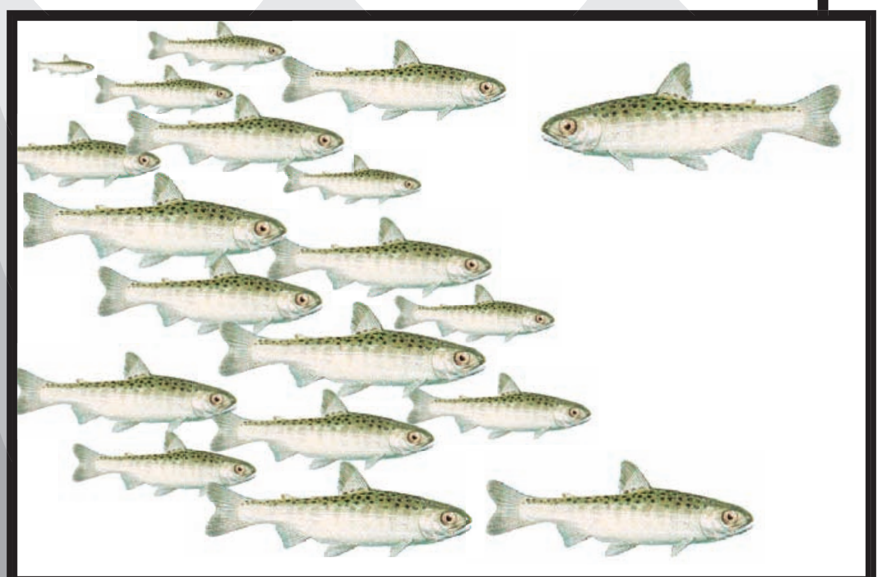
STATE OF WASHINGTON October 2005

2004 Juvenile Salmonid Production Evaluation Report

Green River, Wenatchee RIver, and Cedar Creek



by Greg Volkhardt, Pete Topping,
Lindsey Fleischer, Todd Miller and
Steve Schonning, WDFW Science Division

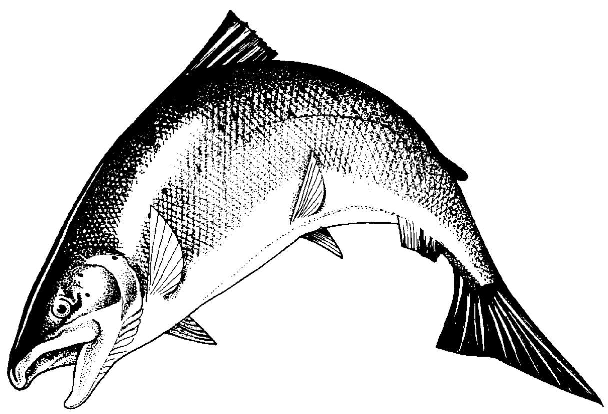
and Dan Rawding and Michelle Groesbeck,
WDFW Fish Management Division

Washington Department of
FISH AND WILDLIFE
Fish Program

FPA 05-13

2004 Juvenile Salmonid Production Evaluation Report

Green River, Wenatchee River, and Cedar Creek



Greg Volkhardt, Pete Topping, Lindsey Fleischer, Todd Miller, and Steve Schonning

Washington Department of Fish and Wildlife Fish Science Division

and

Dan Rawding and Michelle Groesbeck

Washington Department of Fish and Wildlife Fish Management Division

October 2005

Prepared for

The Washington Salmon Recovery Funding Board

Acknowledgments

Green River

Measuring juvenile salmon production from large river systems like the Green River involves a tremendous amount of work. Key to developing these estimates are the long hours of trap operation provided by our dedicated scientific technicians: Brett Brown, Matt Kinne, and Paul Lorenz. Logistical support and map development was provided by Wild Salmon Production Evaluation Unit biologists, Mike Ackley and Laurie Peterson, respectively.

A number of other individuals and agencies contributed to this project. For providing access to the trap site, we thank the adjacent landowner, Bill Mosby. We also thank Mike Wilson, manager of the Soos Creek Hatchery, for providing logistical support, office space, and a secure staging site near the trap.

Wenatchee River

We would like to thank our scientific technicians: Jay Deason, Joel Dirks, and Schuyler Zwar for all the long hours of operating and maintaining the smolt trap on the Wenatchee River. We also would like to thank the various scientific technicians from the Supplementation Research Team (SRT) in Wenatchee for assisting during times of need. We thank the Yakama Nation (YN) for the use of equipment and support. In addition, we would like to thank Chelan County Public Utility District No. 1 Central Maintenance for logistic and technical support.

Cedar Creek

Skip Walsch and Bao Le from the USFWS provided the CWT tagging machine and screw trap for this study. Julie Grobelny, Josua Howolatz, and Scott Nelson worked the trap during the 2004 field season. Their field work was exceptional, and allowed for project goals to be achieved. Additionally field staff were responsible for data entry, which was accurate and timely. Jeff Grim analyzed the otoliths to determine the number of RSI origin coho salmon smolts collected. Michelle Groesbeck developed the database and supplied the queries used in this analysis. Steve VanderPloeg created the site map. Pat Frazier and Jim Scott reviewed an earlier draft of this report and their comments improved this manuscript.

Table of Contents

List of Tables

List of Figures

Executive Summary

Declining salmon populations in the 1980s and 1990s has resulted in the listing of a number of Washington State salmon populations under the Endangered Species Act (ESA). Most of these listings occurred between 1997 and 1999, impacting fisheries and land management over the entire state. To better monitor the status of these listed species and their production trends, the Washington Department of Fish and Wildlife (WDFW) expanded its salmon freshwater production monitoring (smolt monitoring) program. The new sites established during this period included monitoring of lower Columbia steelhead in Cedar Creek in 1998, Puget Sound chinook in the Green River, and upper Columbia spring chinook in the Wenatchee River in 2000. Continuation of this work has relied on funding provided by the Salmon Recovery Funding Board (SRFB). The SRFB has funded smolt monitoring on the Green River, Wenatchee River, and Cedar Creek since 2002. This annual report describes the smolt monitoring activities that occurred on these three streams during the 2004 field season.

Fish were captured using a rotary screw trap on all three streams. The Green River trap, located 55 km upstream of the mouth, was operated from February 3 to July 14, 2004. The focus of this project was to estimate the number of naturally produced Puget Sound chinook originating from this river system. Over this period, 11,185 naturally produced subyearling chinook were captured. As in previous years, the timing distribution of chinook outmigrants was bimodal, with the majority migrating as fry between February and early-to-mid-April. The fork length of these fish averaged less than 45mm. A smaller production component reared upstream of the trap and migrated as smolts from mid-May through June. The fork lengths of these larger migrants averaged between 65 and 90-mm.

Forty four releases of marked chinook were made upstream of the Green River trap to estimate the proportion of downstream migrants captured (trap efficiency). During the February to April fry migration period, trap efficiency averaged 7.7% when flows were between 29 and 43 cms, and 4.0% when flows were above 43 cms. During the later smolt migration period when the migrants were larger, stream discharge had little influence on trap efficiency, averaging 3.0%. Using these efficiency estimates at these flows resulted in an estimated 238,000 naturally produced age 0+ chinook migrated during the trapping period. The 95% confidence interval for this estimate was 187,261 to 289,482 age 0+ migrants. By extrapolating for chinook migrating outside the trapping period, we estimate the total production above the trap site at 271,000.

Accounting for chinook spawning that occurred downstream of the trap and production from Big Soos Creek estimates the total Green River chinook production at 423,000 migrants. Based on the number of parent brood spawners, we estimate the Green River chinook egg-to-migrant survival at 1.9% for the 2003 brood.

A secondary objective for the Green River trapping project is to monitor naturally produced coho and steelhead smolt production. Over the season we captured 3,064

unmarked coho smolts, however, an unknown proportion of these were of hatchery origin. We also captured 239 naturally produced steelhead smolts. Large numbers of hatchery fish were released during the period when most of the naturally produced coho and steelhead were migrating past the smolt trap. Moreover, a large proportion of the hatchery coho were unmarked and indistinguishable from naturally produced migrants. These releases required the suspension of trapping for extended periods to avoid causing mortality to hatchery fish. As a result, we were unable to estimate the natural production of coho and steelhead from the basin.

On the Wenatchee River, screw traps are operated in three locations. A trap on the lower Chiwawa River is used to estimate production of spring chinook from this basin. Another trap below the outlet of Lake Wenatchee estimates sockeye smolt production from the lake. Finally, a third trap is operated low in the system, near the town of Monitor, to measure production from the entire Wenatchee basin. This report presents results from trapping the Monitor site, which is funded by this project.

The Monitor trap, located 9.6 kilometers upstream of the confluence with the Columbia River, was operated from February 13 to July 29. As in previous years, chinook from two broods were captured. Based on differences in life history, yearling chinook (2002 brood) were considered to be spring chinook and subyearling (2003 brood) were considered to be summer chinook. Spring run chinook from the Wenatchee River make up a portion of the endangered Upper Columbia Spring Chinook ESU. The summer run is not listed.

A total of 1,064 naturally produced yearling chinook were captured in 2004. The majority (90%) of the fish were captured by May 17. The majority of subyearlings migrated between May and June. There was some overlap in migration timing, but scale analysis confirmed that the two age classes could be differentiated by fork length, which averaged over 90 mm for yearlings and less than 60 mm for subyearlings.

A total of 24 efficiency tests (10 with yearling hatchery chinook and coho, and 14 with subyearling chinook) were conducted for two trap positions at the Monitor trap site over the season. Recapture rates ranged from 0.00% to 2.33% (0.94% average) for yearling fish and 0.38% to 3.82% (1.46% average) for subyearling chinook. Regression-based models using streamflow were developed to estimate trap efficiency for yearling and sub-yearling chinook.

An estimated 200,000 yearling Upper Columbia spring chinook migrated from the Wenatchee River in 2004. Due to low trap efficiency and since river discharge was outside the data range used to develop the regression model, confidence intervals were deemed too wide to be useful and not reported.

In addition to yearling spring chinook, we estimated 19 million subyearling chinook, 45,000 wild steelhead smolts, and 8,700 wild coho smolts which were recently re-introduced into the Wenatchee system. A total of 5.8 million sockeye smolts were estimated to have migrated past the Lake Wenatchee trap.

Trapping in a major tributary of the Wenatchee, Chiwawa River, provided some additional insight into spring chinook production and survival from the Wenatchee basin. Of the spring chinook redds created the Wenatchee system in 2001, 30.3% were found in the Chiwawa River subbasin. Yearling smolt production from the Chiwawa subbasin was 64,300, or 32% of the total Wenatchee basin production.

The Cedar Creek trap was operated from March 16 to June 26, 2004. Located 4.0 kilometers upstream from its confluence with the North Fork Lewis River, this trap monitors the steelhead production from Cedar Creek. This stream's production makes up part of the listed Lower Columbia steelhead ESU. In addition to steelhead, coho and cutthroat productions are measured in the system. ESA listed Lower Columbia chinook are also present in Cedar Creek, but current funding is insufficient to monitor their production.

During the trapping period, a total of 1,080 steelhead pre-smolts and smolts were captured. Steelhead fork length averaged 176 mm, with a declining trend in weekly mean steelhead sizes observed (187 mm to 158 mm fork length) over the season. Of the steelhead captured, 1,067 were marked by fin coloration using a Panjet inoculator and released upstream of the trap to assess trap efficiency. Mark placement was changed weekly and 11 groups were marked. A total of 3,260 +/- 228 (95% CI) steelhead smolts were estimated to have migrated past the Cedar Creek trap using a pooled Peterson estimate.

In addition to steelhead, 34,999 +/- 1,728 (95% CI) naturally produced coho, 1,970 +/- 917 (95% CI) RSI produced coho, and 2,157 +/- 249 (95% CI) cutthroat smolts were estimated to have migrated past the trap. In addition to these estimates, 49,554 chinook, 2,977 coho, and 104 trout fry were captured, as well as 73 cutthroat, 99 rainbow/steelhead, and 100 coho parr.

1 Introduction

Declining salmon populations in the 1980s and 1990s resulted in the listing of a number of Washington State salmon populations under the Endangered Species Act (ESA), impacting fisheries and land management over the entire state. With the advent of these listings, the Washington Department of Fish and Wildlife (WDFW) expanded its salmon freshwater production monitoring (smolt monitoring) program to better measure the status and trends in listed populations, determine population structure, assess habitat and environmental impacts on production, and monitor the effects of recovery measures on these listed populations. New sites established during this period included Cedar Creek (1998) to monitor Lower Columbia steelhead, Green River (2000) to monitor Puget Sound chinook, and Wenatchee River (2000) to monitor upper Columbia spring chinook. Funding from the legislature established (Green and Wenatchee Rivers) or maintained (Cedar Creek) the monitoring of these listed species.

The legislature requested that the Washington Salmon Recovery Funding Board (SRFB) consider funding smolt monitoring in spring 2002. The SRFB has subsequently funded smolt monitoring on the Green River, Wenatchee River, and Cedar Creek in 2002 through 2004. This report describes the smolt monitoring activities that occurred during the 2004 field season. It also presents production estimates for the listed species as well as for a number of other populations rearing in these watersheds.

2 Green River

2004 Green River Juvenile Salmonid Production Evaluation

Greg Volkhardt
Pete Topping
Lindsey Fleischer

Washington Department of Fish and Wildlife
Fish Program, Science Division
Olympia, Washington 98501-1091

2.1 Methods

2.1.1 Trap Operations

A floating screw trap (Busack *et al.* 1991) was used on the Green River to capture downstream migrant chinook, coho, chum, pink, and steelhead. The 1.5-m diameter trap was located at river kilometer (rkm) 55.5; approximately 1-km upstream of the Highway 18 bridge, on the left bank (Figure 2-1). This trap is fully described in Seiler *et al*. 2002.

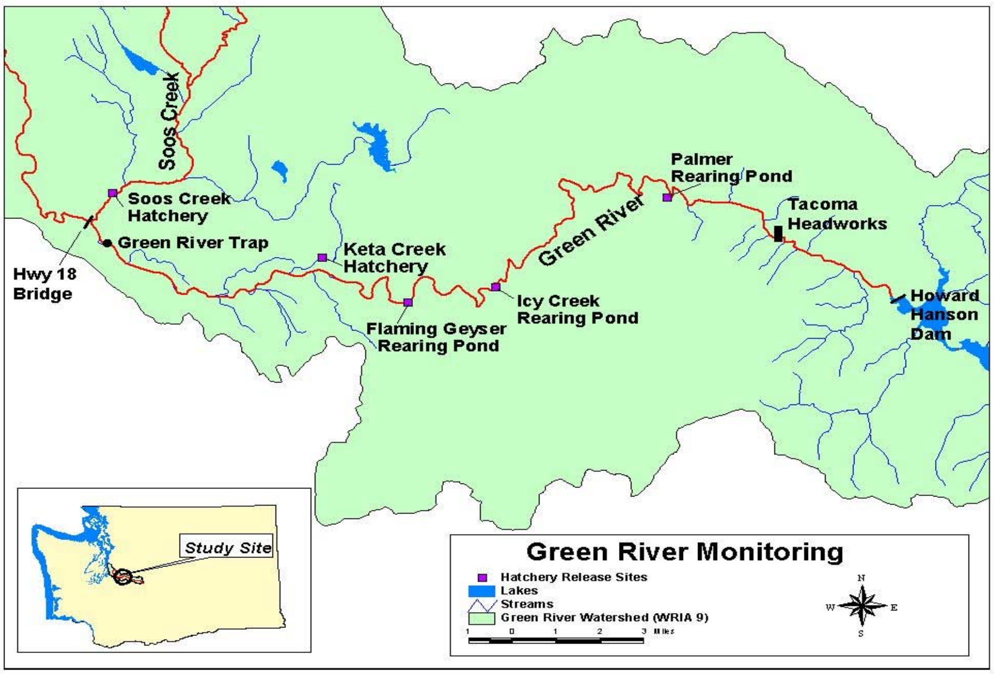


Figure 2-1. Location map of the Green River screw trap relative to hatcheries and hydro projects, Middle Green River 2003.

The trap on the Green River was operated between February 3 and July 14, except for periods when debris, mechanical failure, or large numbers of hatchery fish released above our trap caused the cessation of trapping. Trapping was also suspended during daytime periods late in the trapping season, when catches were low and recreational use of the river was high. Fish were usually removed from the trap and counted at dawn and at dusk. In addition to these periods the trap was checked, as needed, based on debris loads and capture rates. At the end of each trapping period, all fish captured in the trap were identified to species and enumerated. Fork length measurements were taken from a sample of the various wild salmonids captured.

In order to estimate migration, groups of chinook and chum were used to test the capture efficiency of the trap. Fish used for trap efficiency testing were anesthetized with tricaine methanesulfonate (MS 222), identified to species, and marked with a unique partial fin clip or with Bismark brown dye. Marked fish were allowed to recover in fresh water before being placed in buckets, transported 150 meters upstream of the trap and released. Capture rates were estimated by the proportion of marked fish that were recaptured in the trap after release.

2.1.2 Production Estimate

Estimating chinook, coho, and steelhead production from the Green River was done in two steps. Since the trap did not operate continuously over the entire trapping period, the first step involved estimating or interpolating catch for periods when the trap did not fish. The second step involved estimating the capture rate or trap efficiency.

To interpolate catch for periods when the trap was not fishing, diel differences in migration rates were evaluated. Salmonids often migrate at different rates between day and night periods (Seiler *et al.* 1981), therefore, fishing periods were stratified into daytime, nighttime, and combined periods. The stratification was simplified by performing the trap checks near daybreak and twilight periods. Catch during trapping intervals not fished were estimated by interpolating between catch rates from the previous and following dates of the same diel stratum, and then expanding by the hours not fished. Trapping was interrupted by debris only twice during the season, both occurrences happened during day light hours and no missed catch was estimated for these periods. The outage interval was estimated based on the expected number of trap rotations (RPM x fishing time) compared to the count of the revolution counter. Catch for the hours not fished was then estimated using the average catch rate from the previous and following diel stratum and the interval fished. Catch rates were estimated by;

$$\hat{R}_{fj} = \frac{C_{fj}}{T_{fj}}$$ **Equation 2-1**

where:

R_{fj} = *the catch rate during fishing period f in diel stratum j,*

C_{fj} = *catch during fishing period f in diel stratum j, and*

T_{fj} = *the duration of fishing period f in diel stratum j.*

The variance of the interpolated catch rate was estimated by;

$$V(\overline{R}_{fj}) = \frac{\sum(\hat{R}_{fj} - \overline{R}_{fj})^2}{n(n-1)}$$ **Equation 2-2**

Catch during the un-fished interval was then estimated by expanding the mean catch rate by the hours not fished (*T*). The catch variance was then estimated by;

$$V(\hat{C}) = V(\overline{R}_{fj})\hat{T}^2$$ **Equation 2-3**

In order to estimate the capture rate of the trap, groups of marked migrants were released upstream of the trap and subsequently recaptured. The capture rate was calculated for individual tests using;

$$\hat{e}_i = \frac{r_i}{m_i}$$ **Equation 2-4**

where;

$\hat{e}_i =$ *the capture rate estimated for trap efficiency test i,*

$r_i =$ *the number of marked or dyed migrants captured in trap efficiency test i, and*

$m_i =$ *the number of marked or dyed migrants released in trap efficiency test i.*

The variance of each trap efficiency test was calculated using the variance of a binomial expression by;

$$V(\hat{e}_i) = \frac{\hat{e}_i(1-\hat{e}_i)}{m_i}$$ **Equation 2-5**

Daily migration was estimated by dividing the estimated catch by the estimated trap efficiency. Where mean daily flow failed to show a relationship with individual trap efficiencies, the average trap efficiency was used. The variance of the average trap efficiency was calculated using Equation 2-2, substituting $\bar{e}$ for $\bar{R}_{fj}$ and $\hat{e}_i$ for $\hat{R}_{fj}$. Daily migration was estimated by summing daytime and nighttime catch intervals to estimate 24 hour catch and dividing by the estimated efficiency. Total season migration was estimated by the sum of the daily estimated migrations, and the season migration variance for was estimated by;

$$V(N) = N^2\left(\frac{V(\bar{e})}{\bar{e}^2} + \frac{\sum V(\hat{C})}{C_t^{\,2}}\right)$$ **Equation 2-6**

where;

$N =$ *the season migration estimate, and*

$C_t =$ *the total actual and estmimated catch during the trapping season.*

2.2 Results

Estimating the production of naturally-produced chinook, coho, and steelhead migrants was complicated by the large numbers of hatchery salmonids released into the river (Table 2-1). The Keta Creek, Icy Creek, Palmer, Flaming Geyser, and Howard Hanson Dam release sites are located upstream of the trap. Soos Creek enters the Green River approximately 0.8 km downstream of the trap. Fish released into this tributary may swim upstream to enter the trap.

Table 2-1. Hatchery releases that could have contributed to catches in the Green River screw trap in 2004.

Species	Release		Brood	CWT	CWT	Ad-mark	Ad-mark	Unmarked
	Date(s)	Location	Year	Only	Ad-mark	Only	RV	
2003 Releases Above Howard Hanson Dam								
Coho	4/14-4/15	Howard Hanson Dam	2002					548,240
Chinook	3/20-3/25	Howard Hanson Dam	2002			417,600		
2004 Releases								
Chinook	3/17-3/24	Howard Hanson Dam	2003			496,637		
	5/1	Icy Creek	2002		81,200	198,800		
	5/13-5/31	Soos Creek	2003	199,900	199,800	2,893,000		
Coho	3/31-4/2	Howard Hanson Dam	2003					497,726
	5/3-5/10	Keta Creek	2002		50,000			230,000
	4/08-4/15	Soos Creek	2002	45,000	104,601	385,607		
Steelhead	5/03-5/10	Keta Creek	2002				25,400	
	4/26	Soos Creek	2002			74,700		
	5/1	Palmer	2002			26,865		
	5/1	Icy Creek	2002			43,005		
	5/8	Flaming Geyser	2002			14,985		
Chum	3/9-4/23	Keta Creek	2003					1,341,048

2.2.1 Chinook

2.2.1.1 Catch

Over the 162-day season, we captured 11,185 unmarked and 102 adipose (ad)-marked age 0+ chinook migrants (Appendix A). All hatchery age 0+ chinook released were ad-clipped, so the unmarked captures represent naturally produced fish. Daily catch of unmarked age 0+ chinook averaged 124 migrants over the first two complete days of trapping (February 4-5). Daily catches of unmarked migrants increased to 537 on March 1, and 529 on March 4. After March 4, daily catches then declined to a single-night low of four migrants on April 23. After this date daily catches increased slowly and peaked again in late May and early June, when 203 and 174 migrants were captured, on May 28 and June 6 respectively, before declining to less than ten migrants a day by June 29.

Hatchery ad-marked age 0+ chinook began entering the trap on March 18 when one chinook was caught. The last hatchery chinook capture occurred on June 24. Daily catches ranged from zero to 13 ad-marked age 0+ chinook.

Over the season, we also caught 4 unmarked, 30 hatchery ad-marked/CWT, and 187 hatchery ad-marked age 1+ chinook migrants. We caught our first ad-marked age 1+ chinook beginning on May 3, the reported release date from the Icy Creek facility. Eighty-two percent of the hatchery ad-marked catches occurred within the first 10 days following the release. The last hatchery yearling captured for the season occurred on the night of July 3.

2.2.1.2 Size

Wild chinook 0+ averaged less than 42-mm through the first week in April. From this point through the end of the trapping season the wild chinook fry grew rapidly, averaging 3.5-mm of growth per week, and by the second week of July averaged just under 90mm (Table 2-2, Figure 2-2). Migrants measuring less than 40-mm were found through the middle of April, after which, the minimum size increased to over 60-mm at the end of the trapping period. We speculated that 40-mm and smaller chinook were largely comprised of newly emerged fry; therefore, we believe that the increase in the minimum size was an indication that incubation was completed.

2.2.1.3 Catch Expansion

The trap was operated 3,536 hours out of 3,882 possible hours in the 161-day trapping period, or 91.1% of the time. From the start of the season through May 4 (our first prolonged outage), the trap operated continually except for two short periods when trapping was suspended for debris removal, and for one longer period when the trap was halted by debris (screw stopper) for a total estimated out time of 1 hour and 25 minutes. The loss of trapping time from these events resulted in no estimated missed catch. The only other unexpected interruption to trap operation occurred in late June when three inner tubes and a raft were caught in the screw. This resulted in an estimated 1 hour and 45 minutes of missed fishing time and no estimated missed catch.

In addition to the debris removal and screw stoppages, the trap was also pulled during the nights of May 4-12, a total of 97.6 hours, in order to avoid the capture of thousands of hatchery fish. During each of these nine nights, the trap was operated for approximately 30 minutes total, in five to ten minute interval per hour, starting just after dark until approximately 2300 hrs each night. This limited fishing was done to capture hatchery steelhead for a predation study. We captured a total of 53 naturally produced chinook during the short fishing intervals. When we expand this catch to include the hours not fished results in an unrealistically high expanded catch and migration rate. The trap lights, which are normally off when the unmanned trap is in operation, were on during this period. The increased light in the vicinity of the trap seemed to influence (increase) the trapping efficiency. Therefore, we decided to use the capture rate observed before and after the nine-night period to estimate the missed catch for the entire nights, and exclude the fish we captured while the lights were on. For this period we estimate we would have captured 164 unmarked wild chinook.

Trapping operations were halted during most daylight periods beginning on June 18 when recreational use of the river was high and few fish were caught. Trapping was suspended for a total of 247.3 hours during these periods. By interpolating between the daylight periods fished weekly, we estimated the missed catch totaled five naturally produced chinook.

Table 2-2. Mean fork length (mm), standard deviation, range, and sample size of naturally produced age 0+ chinook measured by statistical week, Green River 2004.

Statistical Week			Average	s.d.	Range		Total		Percent
No.	Begin	End			Min	Max	Sampled	Catch	Sample
6	2/2	2/8	40.0	1.41	37	42	47	390	12.05%
7	2/9	2/15	39.6	1.38	37	42	54	418	12.92%
8	2/16	2/22	40.4	1.36	37	44	108	801	13.48%
9	2/23	2/29	40.4	1.35	37	44	198	1363	14.53%
10	3/1	3/7	40.6	1.48	37	44	115	2140	5.37%
11	3/8	3/14	40.3	1.23	38	43	67	1141	5.87%
12	3/15	3/21	40.7	1.88	38	54	100	794	12.59%
13	3/22	3/28	40.9	2.00	38	50	122	503	24.25%
14	3/29	4/4	41.7	2.21	38	52	136	502	27.09%
15	4/5	4/11	44.5	4.65	39	59	26	220	11.82%
16	4/12	4/18	47.0	8.97	40	73	26	123	21.14%
17	4/19	4/25	53.1	7.75	41	66	10	70	14.29%
18	4/26	5/2	58.8	10.15	43	81	25	93	26.88%
19	5/3	5/9	67.4	10.50	50	83	17	80	21.25%
20	5/10	5/16	74.4	11.00	55	96	27	207	13.04%
21	5/17	5/23	76.4	7.96	62	90	18	228	7.89%
22	5/24	5/30	65.3	8.85	52	76	6	324	1.85%
23	5/31	6/6	83.2	7.22	67	97	54	491	11.00%
24	6/7	6/13	83.0	8.63	55	102	55	710	7.75%
25	6/14	6/20	88.1	7.58	79	101	10	288	3.47%
26	6/21	6/27	86.0	5.33	76	101	39	207	18.84%
27	6/28	7/4	82.0	9.09	74	94	4	51	7.84%
28	7/5	7/11	89.9	7.47	80	100	7	38	18.42%
29	7/12	7/18	---	---	---	---	0	3	0.00%
Season Total			48.8	16.42	37	102	1,271	11,185	11.37%

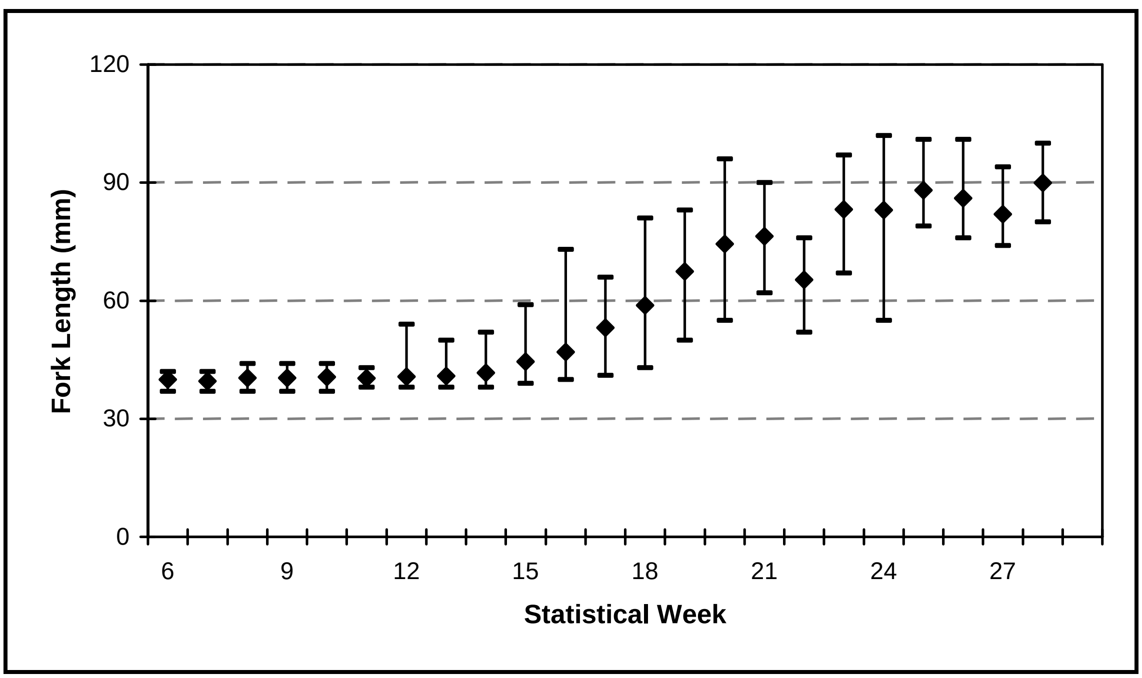


Figure 2-2. Weekly average, minimum, and maximum 0+ chinook fork lengths (mm) measured at the Green River screw trap, 2004.

For the entire season we estimated a total of 11,354 naturally produced naturally produced chinook would have been captured if continuous trapping had occurred between February 3 and July 14 (Appendix

A). This represents a 1.5% increase over the actual catch of naturally produced migrants. We estimated no additional hatchery age 0+ chinook would have been caught during periods when trap was not operated.

2.2.1.4 Trap Efficiency

A total of 4,901 age 0+ wild chinook migrants in 44 groups were marked and released 150-meters upstream of the trap. The number of fish released in each group ranged from 21 to 403 chinook. On five occasions in late May and June, two release groups were combined in order to increase our confidence due to the low numbers of chinook in those releases. Recapture rates averaged 5.13%, for the combined groups, and ranged from 0.95% to 13.19% (Table 2-3).

Trap efficiency was influenced by river discharge and fish size. Flows ranged from 17.9 to 83.5 cubic meters per second (cms) during the chinook trap efficiency tests. Although a regression-based relationship between flow and efficiency was not statistically significant (α=0.05), trap efficiencies have often been found to decrease with increased flow (Seiler et al. 2003).

We also noted that trap efficiency was negatively correlated with fish size. Migration timing and size information indicated a “fry” migration period occurred from the beginning of trapping through approximately April 15, followed by a “smolt” migration period occurring after April 15.

The distribution of trap efficiency results relative to river discharge suggested partitioning the efficiencies into two strata during the fry migration period February 3 through April 15). The efficiency distributions between strata were found to be significantly different using a Wilcoxin two-sample test (α=0.05). The first stratum (discharge below 42.5 cms at the USGS Auburn gage), had an average capture efficiency of 7.69%. The second stratum (discharge above 42.5 cms), averaged 3.96%. Trap efficiency averaged 2.96% over the entire smolt migration period (Table 2-3). Trap efficiency was not sufficiently influenced by flow to warrant stratification during this period.

2.2.1.5 Production Estimate

From February 3 through July 14, we estimated 238,371 naturally produced age 0+ chinook migrants passed the screw trap with a coefficient of variation of 10.9% and 95% confidence interval of 187,261 to 289,482 chinook.

The migration was well underway when trapping began. Over the years, we have observed that downstream migration timing is influenced by stream discharge. In the Green River, the highest flows recorded during the winter/spring migration period occurred a few days before trapping began; therefore, simple extrapolation from the first few days of trap operation would have underestimated the migration that occurred during this flow event. Chinook migration timing in the Green River has correlated well with Cedar River timing over the last three years. Therefore, we used chinook migration timing from the Cedar River trap to estimate the percentage of the migration we missed prior to trapping. Data from the Cedar River indicated that 12% of the total 2004 migration occurred between January 1 and February 3, the first day of trapping on the Green River (Seiler et al. 2005). Expanding the Green River migration by the proportion of the migration observed on the Cedar resulted in an additional 32,505 wild 0+ migrants for a total wild migration of 270,877 (Figure 2-3). In addition to the wild fish, we estimate 2,934 ad-marked hatchery age 0+ chinook migrated during the February 3 through July 13 trapping period.

Table 2-3. Chinook 0+ trap efficiency tests conducted on the Green River screw trap separated by flow and size/timing strata, 2004.

Strata	Date	Flow (cms)	Number Marked		Percent Recovered
			Released	Recovered	
Stratum 1, Feb 3- Apr 15, Flow 0 -42.5 cms	2/12	39.4	125	8	6.40%
	2/18	36.8	150	11	7.33%
	2/21	37.4	200	26	13.00%
	2/23	35.7	150	7	4.67%
	2/25	30.3	179	19	10.61%
	2/27	30.3	209	15	7.18%
	2/29	29.4	210	22	10.48%
	3/2	31.1	403	41	10.17%
	3/4	37.7	103	4	3.88%
	3/8	42.5	143	11	7.69%
	3/13	41.6	250	11	4.40%
	3/16	36.8	137	14	10.22%
	3/22	37.9	91	12	13.19%
	3/27	42.2	65	1	1.54%
	4/2	38.5	101	7	6.93%
	4/5	38.2	74	4	5.41%
	Total		2590	213	
	Average				7.69%
	Variance				7.0E-05
	n				16
Stratum 2, Feb 3-Apr 15, Flow > 42.5 cms	2/6	54.4	135	4	2.96%
	2/9	46.2	80	1	1.25%
	3/6	45.3	153	16	10.46%
	3/10	64.8	100	1	1.00%
	3/19	47.3	103	5	4.85%
	3/25	45.0	85	2	2.35%
	3/30	45.0	104	5	4.81%
	Total		760	34	
	Average				3.96%
	Variance				1.5E-04
	n				7
Stratum 3, 4Apr 16-Jul 14, All Flows	5/19-5/20	22.2	59	3	5.08%
	5/21-5/24	23.4	76	3	3.95%
	5/28	49.6	100	3	3.00%
	6/1	83.5	238	3	1.26%
	6/3	51.5	70	2	2.86%
	6/4	42.5	105	1	0.95%
	6/6	41.1	104	1	0.96%
	6/7	42.5	100	1	1.00%
	6/9	36.5	110	8	7.27%
	6/10	38.5	105	3	2.86%
	6/11	32.6	100	4	4.00%
	6/12	31.4	100	1	1.00%
	6/14-6/15	28.5	130	8	6.15%
	6/16-6/19	24.1	72	1	1.39%
	6/23-6/25	18.3	82	2	2.44%
	Total		1,551	44	
	Average				2.95%
	Variance				2.7E-05
	n				15

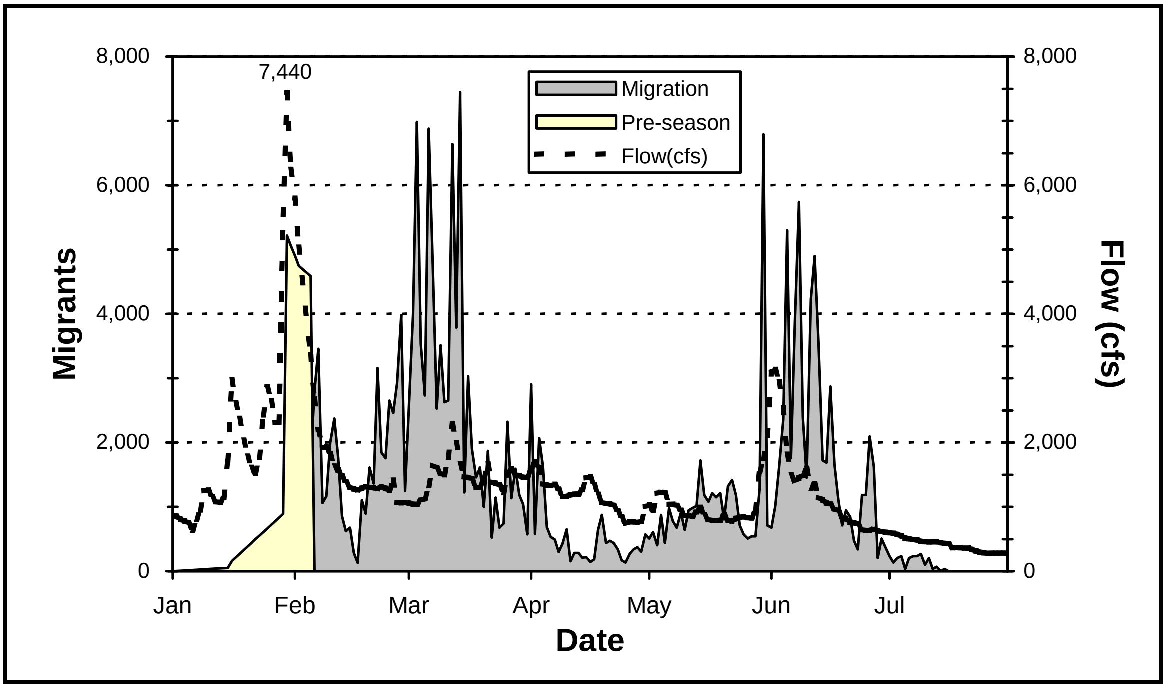


Figure 2-3. Daily migration of wild age 0+ chinook in the Green River screw trap relative to stream discharge measured at USGS Gage #12113000, January 1 through July 31, 2004.

2.2.2 Coho

2.2.2.1 Catch

We began capturing yearling coho salmon on the first night of trapping. Catch rates were low, generally less than 3 smolts per day through mid April, with the exception of the first five days when catches averaged 9 smolts per day. We attribute this relatively high capture rate early in the season to the high water conditions occurring at this time. By May 1, the daily catch had only increased slightly to 21 smolts. On May 2, Keta Creek Hatchery started a volitional release of 280,000 smolts (230,000 unmarked, and 50,000 ad/CWT). From this date through May 13 the majority of these fish passed the trap. Daily catches quickly declined to nearly zero by the June 1. Over the season we captured 3,243 smolts (115 ad-marked, 62 ad/CWT, 2 CWT-only, and 3,064 unmarked).

We caught one hatchery ad-marked (no CWT) coho smolt in the trap starting on the second night of fishing. Catches of ad-marked hatchery fish remained sporadic from the early part of the season through May 3 (when the Keta Creek hatchery fish were released), with 28 ad-only hatchery smolts captured. All of the ad-marked fish released from Keta Creek contained CWTs; therefore these 28 smolts had likely escaped from Soos Creek Hatchery and swam upstream of our trap before being captured.

The total coho production from the Green River was not estimated in 2004. Factors contributing to this decision include:

1) Suspension of nightly trapping between May 4 and May 13 when most naturally produced coho were emigrating past the trap,
2) The presence of large numbers of unmarked hatchery fish in the catch, and

3) No directed trap efficiency tests were conducted for coho.

2.2.2.2 Size

Unmarked wild coho fork lengths averaged between 98-mm and 115-mm throughout the trapping season (Table 2-4, Figure 2-4). Over the trapping season, the individual smolts ranged in size from 60-mm to 145-mm, and averaged 105.8 mm.

Table 2-4. Mean fork length (mm), standard deviation, range, and sample size of unmarked coho smolts by statistical week, Green River 2004.

Statistical Week			Average	s.d.	Range		Number		Percent
#	Begin	End			Min	Max	Sampled	Caught	Sampled
6	2/2	2/8						45	0.0%
7	2/9	2/15						14	0.0%
8	2/16	2/22						6	0.0%
9	2/23	2/29	100.2	20.53	86	141	6	14	42.9%
10	3/1	3/7						22	0.0%
11	3/8	3/14	102.2	14.53	60	130	26	41	63.4%
12	3/15	3/21						0	0.0%
13	3/22	3/28						6	0.0%
14	3/29	4/4	99.3	6.13	93	105	4	16	25.0%
15	4/5	4/11	102.0	5.18	96	111	6	32	18.8%
16	4/12	4/18	105.1	7.23	97	123	12	46	26.1%
17	4/19	4/25	115.3	17.41	96	145	6	73	8.2%
18	4/26	5/2	100.7	7.74	87	109	6	96	6.3%
19	5/3	5/9	114.1	7.21	102	128	20	1,638	1.2%
20	5/10	5/16	109.7	8.47	94	122	12	747	1.6%
21	5/17	5/23	98.0	5.93	87	104	6	150	4.0%
22	5/24	5/30						30	0.0%
23	5/31	6/6						45	0.0%
24-26	6/7	6/13	103.2	14.89	92	132	6	23	26.1%
25	6/14	6/20						8	0.0%
26	6/21	6/27						12	0.0%
27	6/28	7/4						0	0.0%
28	7/5	7/11						0	0.0%
29	7/12	7/18						0	0.0%
SEASON TOTAL			105.8	12.30	60	145	110	3,064	3.6%

Note: The majority of the length samples for weeks 19-20 are likely to be unmarked hatchery fish

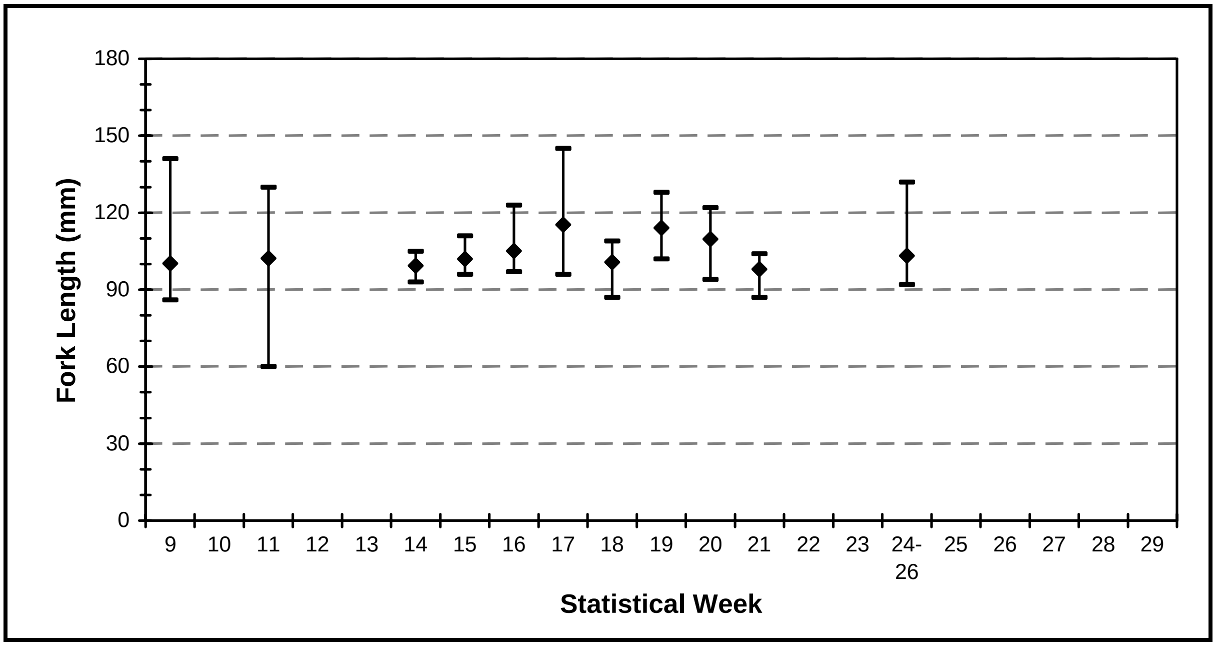


Figure 2-4. Weekly average, minimum, and maximum fork lengths for unmarked yearling coho measured at the Green River screw trap, 2004.

2.2.3 Steelhead

2.2.3.1 Catch

Over the trapping period, we caught a total of 504 steelhead (199 ad-marked, 66 ad-mark/RV, and 239 naturally produced unmarked smolts). A total of 134 unmarked and 1 ad-marked steelhead were caught in the first week of trapping. This large catch so early in the season was due to the high river flows just before trapping began on February 3. These fish were likely displaced by the high flows and not actively migrating. After the first week, catches dropped to low levels through the end of April, with only 29 additional naturally produced unmarked smolts being captured. The ad-marked steelhead caught on February 3, was most likely a hold over from the previous years release. The 25,400 hatchery steelhead released from Keta Creek Hatchery with the ad/RV-mark were offspring from wild steelhead collected for broodstock.

As with coho, the total steelhead production from the Green River was not estimated in 2004. Factors contributing to this decision include:

1) Suspension of nightly trapping between May 4 and May 13 when most naturally produced steelhead were emigrating past the trap,
2) Catch rates for unmarked naturally produced steelhead smolts were too low to estimate migration from the brief periods of nighttime trapping we were able to accomplish between May 4 and May 13, and
3) No directed trap efficiency tests were conducted for steelhead.

2.2.3.2 Size

A total of 42 unmarked steelhead fork lengths were recorded throughout the trapping season, 18% of the total unmarked catch. Individuals ranged from 106-mm to 197-mm, and averaged 148-mm for the season (Table 2-5,Figure 2-5).

Table 2-5. Mean fork length (mm), standard deviation, range, and sample size of wild steelhead Smolts measured by statistical week, Green River, 2004.

Statistical Week					Range			Catch Data	
Number	Begin	End	Average	s.d.	Min	Max	Number	Captured	Percent
6	2/2	2/8	135.9	22.23	106	197	24	132	18.2%
7	2/9	2/15						4	0.0%
8	2/16	2/22			No sample			2	0.0%
9	2/23	2/29						0	
10	3/1	3/7	131.0	N/A	131		1	4	25.0%
11	3/8	3/14						1	0.0%
12	3/15	3/21						1	0.0%
13	3/22	3/28						2	0.0%
14	3/29	4/4			No sample			2	0.0%
15	4/5	4/11						3	0.0%
16	4/12	4/18						2	0.0%
17	4/19	4/25	162.0	18.38	149	175	2	4	50.0%
18	4/26	5/2	160.3	22.94	134	176	3	9	33.3%
19	5/3	5/9	159.3	4.04	155	163	3	23	13.0%
20	5/10	5/16	179.0	11.69	167	195	4	19	21.1%
21	5/17	5/23			No sample			4	0.0%
22	5/24	5/30	173.0	Na	173		1	7	14.3%
23	5/31	6/6			No sample			14	0.0%
24	6/7	6/13	164.0	14.42	152	180	3	4	75.0%
25	6/14	6/20	168.0	Na	168		1	1	100.0%
26	6/21	6/27						0	
27	6/28	7/4			No sample			0	
28	7/5	7/11						0	
29	7/12	7/18						1	0.0%
Season Total			148.2	24.33	106	197	42	239	17.6%

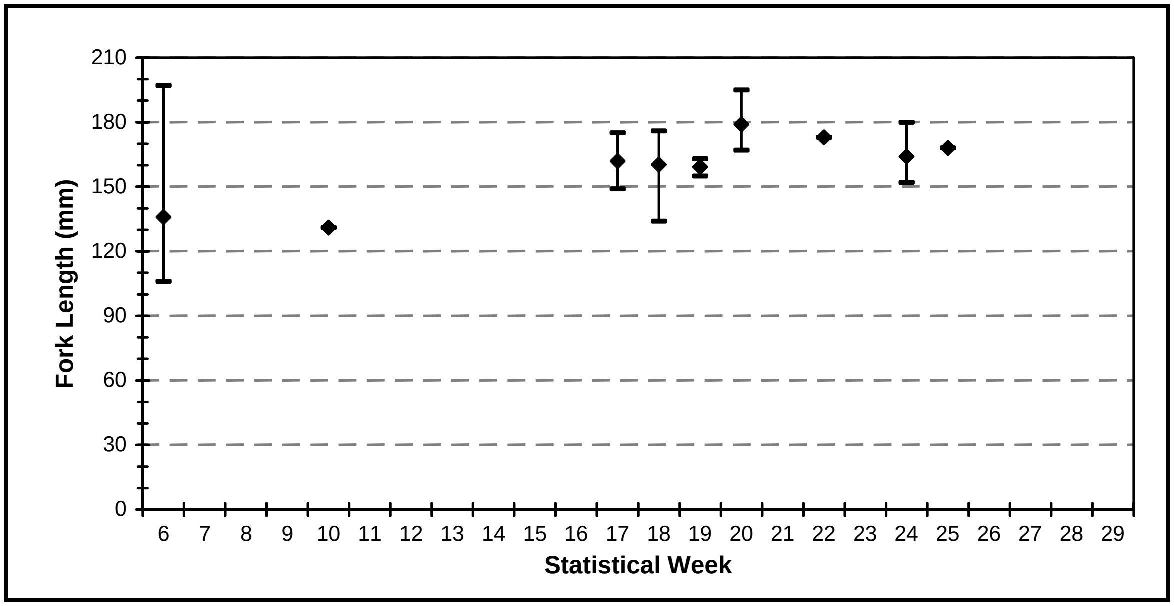


Figure 2-5. Weekly average, minimum, and maximum unmarked yearling steelhead fork lengths measured at the Green River screw trap, 2004.

2.2.4 Other Species

A number of other fish species and other salmonid age classes were captured and enumerated in the catch. Over the trapping period, a total of 77,615 chum, 135,852 pink, and 1,422 age 0+ coho fry were caught. We also captured 81steelhead parr, 5 cutthroat smolts, 1 cutthroat adult, and one steelhead adult. In addition to salmonids, a number of other species were captured, including sculpin, three-spine sticklebacks, longnose dace, and lamprey ammocoetes.

2.2.5 Predation

During the trapping season 1,032 yearling salmonids were netted as they entered the trap and sampled for stomach content. This was done to determine predation rates on wild chinook fry by yearling salmonids. Stomach contents were sampled using gastric lavage. A small diameter brass pipe was orally inserted into the esophagus of each fish and the stomach contents were displaced with injected water. The stomach content was collected on a fine mesh screen to allow the water to drain off. The material was then identified and enumerated by type. Only one chum fry was found out of all the fish sampled. In addition to the yearling salmonids, 8 sculpin ranging in size from 111 to 154-mm were sacrificed for the same purpose. All the sculpin contained juvenile salmon fry and ranged from 3 to 36 fry per fish (Table 2-6). The sculpin were sampled at the morning trap checks and not as they entered the trap so there was a high probability that most if not all of the predation occurred in the trap livebox.

Table 2-6. Predation sampling conducted at the Green River Screw Trap, 2004.

Species	Origin	Number Sampled	Stomach Content					
			Chum	Pink	Chinook	Lamprey	Crayfish	Insects
Steelhead	Wild	8						8
	Ad/RV	370	1					264
	Ad-mark	533						442
Coho	Ad-mark	12						7
Chinook1+	Ad-mark	109						31
Sculpin	Wild	8	5	125	1	3	1	3

2.3 Discussion

Estimates of migration past the trap were developed for Green River wild and hatchery age 0+ chinook. Coho salmon and steelhead smolt catches during periods of trap operation provide indices of abundance for these species. While our inability to estimate production for coho and steelhead was disappointing, the monitoring of these species is only a secondary goal of the project. We were successful in accomplishing our primary goal: to monitor the production of listed Puget Sound chinook from the Green River.

Assumptions used to develop the chinook estimates are discussed below. In addition, the estimates for wild chinook migrants are expanded to represent total basin production.

2.3.1 Chinook

The accuracy of the wild age 0+ chinook production estimate for the Green River is partially dependent on the veracity of the estimated catch that was missed during the periods when the trap was not fishing and on the accuracy of our estimated capture efficiency. Trap efficiencies were variable over the season. Therefore, while we believe the mean trap efficiencies calculated for flow strata best estimates total migration over each stratum period; they may not accurately estimate daily migration. Significant differences ($\alpha = 0.05$) between mean stratified trap efficiencies suggest capture rates change at a flow threshold of 42.5 cms. It was observed that at the river stage height related to this discharge level, water covered a gravel bar on the right bank above the trap. This greatly widened the flow and migration pathways. The effect of widening the flow pathway was not as prominent for the larger smolt-size chinook that migrated after April 15, possibly due to changes in habitat preference. Therefore, an un-stratified average efficiency was used for the later-migrating smolts. As in 2003, the chinook migration was well underway when trapping began February 3. Flows were decreasing from the peak of the season, and an unknown portion of the migration moved downstream before trapping began. In order to estimate migration prior to the trapping season, we chose to use chinook migration timing from the Cedar River. Migration timing curves were similar between the Green River and Cedar River during periods of concurrent trapping in 2002 through 2004. From this, we expect migration timing was also similar in January, when only the Cedar River trap was operating. However, this assumption remains unproven.

Egg-to-migrant survival is a measure of freshwater productivity for naturally-reared salmon. The estimated migration of 270,877 wild age 0+ chinook migrants, divided by the estimated egg deposition above the trap site results in an egg-to-migrant survival of 1.9%. This low survival may be the result of redd scour during the 211 cms flow event that occurred in late January. The estimated egg deposition was derived using an above the trap escapement estimate of 3,124 chinook females (Cropp pers. comm.) and an average fecundity of 4,500 eggs per female.

The wild age 0+ chinook production estimate made at the Green River trap site only represents the production that occurred upstream of the trap. An additional 1,038 females were estimated to have spawned downstream of the trap. Assuming the same egg-to-migrant survival, we estimated the total Green River production downstream of the trap at 90,003 wild chinook migrants. A total of 720 female chinook were passed above the weir on Big Soos Creek, assuming they all spawned and had similar egg-to-migrant survival we would estimate 62,430 from Soos Creek, and results in a total basin production estimate of 423,311 naturally-produced age 0+ chinook migrants.

The wild age 0+ chinook migration for the Green River assumed a bimodal timing distribution. The earliest component, composed of newly emerged chinook fry, migrated past the trap from January through mid April, and peaked in the first week of March. This was followed by a smolt component that migrated from mid April through June, and peaked in late May/early June. The fry component in 2004 made up 63% of the production above the Green River trap.

2.3.2 Recommendations

Precision of the age 0+ chinook production estimates would increase if we began trapping two to three weeks earlier, in early to mid-January, to intercept a larger portion of the early migrants.

We estimated approximately 12% of the chinook migration occurred prior to the beginning of trap operation in 2004. While the peak flow event in late January and early February certainly triggered a large part of this early migration, the movement of these fish indicates a substantial presence of fry in the river prior to installation of the trap. By moving the start date back to early-mid January, we will be in position to trap these early migrants should they head downstream.

This recommendation is currently unfunded. We will attempt to locate funding in order to implement these recommendations for the 2005 trapping season.

The release of large numbers of hatchery fish from Keta Creek Hatchery and other release sites will continue to influence trap operation. We believe that 2004 chinook catch rates were affected by lighting around the trap during the short nighttime fishing intervals occurring between May 4 and May 13, when hatchery fish were migrating past the trap. In the future, we will attempt to limit the use of trap lights during nighttime trapping periods. Impacts to trap operations as a result of hatchery practices will likely have a greater effect on coho and steelhead production estimates due to the timing of the hatchery releases and our inability to discern unmarked hatchery from naturally produced coho smolts. While we will continue to attempt to estimate production for these species in the future, this remains a secondary objective for the project.

2.4 References

2.4.1 Literature Cited

Busack, C., Knudsen, A., Marshall, A., Phelps, S., and D. Seiler. 1991. Yakima Hatchery experimental design. Wash. Dept. Fish. Annual Progress Report prepared for BPA Division of Fish and Wildlife. Olympia, WA.

Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/downstream salmonid trapping project 1977-1980. Wash. Dep. Fish. Prog. Rpt. No. 144: 113pp.

Seiler, D., G. Volkhardt, and L. Kishimoto. 2003. Evaluation of downstream migrant salmon production in 1999 and 2000 from three Lake Washington tributaries: Cedar River, Bear Creek, and Issaquah Creek. Washington Department of Fish and Wildlife. Olympia, WA.

Seiler, D., Volkhardt, G., Kishimoto, L., and P. Topping. 2002. 2000 Green River juvenile salmonid production evaluation. Washington Department of Fish and Wildlife. Olympia, WA.

Seiler, D., Volkhardt, G., and L. Fleischer. 2005. Evaluation of downstream migrant salmon production in 2004 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife. Olympia, WA.

2.4.2 Personal Communications

Cropp, Tom. District Fish and Wildlife Biologist. Washington Department of Fish and Wildlife.

2.5 Appendix A

Daily Actual and Estimated Catches and Migration Estimates
for Age 0+ Chinook Migrants, Green River 2004.

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2004.

Date	Daily Average Flow	Wild Chinook Catch Actual	Wild Chinook Catch Estimated	Wild Chinook Migration	Hatchery Chinook Catch Actual	Hatchery Chinook Catch Estimated	Hatchery Chinook Migration
2/3	3,370	38		960			
2/4	2,680	111		2803			
2/5	2,200	137		3460			
2/6	1,920	42		1061			
2/7	1,930	46		1162			
2/8	1,830	79		1995			
2/9	1,630	94		2374			
2/10	1,570	70		1768			
2/11	1,480	66		858			
2/12	1,390	48		624			
2/13	1,310	52		676			
2/14	1,280	22		286			
2/15	1,260	10		130			
2/16	1,290	85		1105			
2/17	1,320	69		897			
2/18	1,300	124		1612			
2/19	1,300	105		1365			
2/20	1,280	243		3160			
2/21	1,320	142		1847			
2/22	1,290	135		1756			
2/23	1,260	204		2653			
2/24	1,419	189		2458			
2/25	1,070	225		2926			
2/26	1,060	306		3979			
2/27	1,070	96		1248			
2/28	1,060	197		2562			
2/29	1,040	308		4005			
3/1	1,040	537		6983			
3/2	1,100	272		3537			
3/3	1,130	210		2731			
3/4	1,330	529		6879			
3/5	1,650	192		4848			
3/6	1,600	100		2525			
3/7	1,520	139		3510			
3/8	1,500	104		2626			
3/9	1,770	105		2652			
3/10	2,290	263		6641			
3/11	2,000	150		3788			
3/12	1,670	295		7449			
3/13	1,470	94		1222			
3/14	1,460	233		3030			
3/15	1,440	146		1899			
3/16	1,300	112		1456			
3/17	1,310	124		1612			
3/18	1,450	77		1001	1		13

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2004 (cont'd.).

Date	Daily Average Flow	Wild Chinook			Hatchery Chinook		
		Catch		Migration	Catch		Migration
		Actual	Estimated		Actual	Estimated	
3/20	1,390	40		520			
3/21	1,370	88		1144			
3/22	1,340	52		676			
3/23	1,220	57		741			
3/24	1,500	92		2323			
3/25	1,590	45		1136	1		25
3/26	1,500	63		1591	6		152
3/27	1,490	91		1183	4		52
3/28	1,460	80		1040	2		26
3/29	1,460	44		572	2		26
3/30	1,590	115		2904	8		202
3/31	1,700	23		581	2		51
4/1	1,610	82		2071	1		25
4/2	1,360	125		1625	4		52
4/3	1,340	53		689	1		13
4/4	1,330	41		533			
4/5	1,350	38		494			
4/6	1,280	23		299			
4/7	1,160	33		429			
4/8	1,160	50		650			
4/9	1,190	12		156			
4/10	1,200	22		286			
4/11	1,200	22		286			
4/12	1,270	16		208			
4/13	1,450	17		221			
4/14	1,470	11		143			
4/15	1,350	14		182			
4/16	1,200	19		642			
4/17	1,070	26		878			
4/18	1,050	13		439			
4/19	1,050	14		473			
4/20	1,019	13		439			
4/21	933	10		338			
4/22	844	5		169			
4/23	734	4		135			
4/24	773	8		270			
4/25	768	10		338			
4/26	757	11		372			
4/27	776	9		304	1		34
4/28	1,000	17		574	2		68
4/29	1,030	15		507			
4/30	942	18		608			
5/1	1,210	12		405			
5/2	1,230	26		878			
5/3	1,220	13		439			

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2004 (cont'd.).

Date	Daily Average Flow	Wild Chinook Catch Actual	Wild Chinook Catch Estimated	Wild Chinook Migration	Hatchery Chinook Catch Actual	Hatchery Chinook Catch Estimated	Hatchery Chinook Migration
5/4	1,040	9	20	980			
5/5	1,040	9	14	777			
5/6	1,019	1	19	676			
5/7	944	7	20	912			
5/8	867	1	18	642			
5/9	861	9	19	946			
5/10	854	11	18	980			
5/11	925	12	18	1014			
5/12	993	33	18	1723			
5/13	874	35		1182	1		34
5/14	804	32		1081			
5/15	785	36		1216	3		101
5/16	787	34		1149			
5/17	796	36		1216			
5/18	883	24		811			
5/19	797	39		1318			
5/20	771	42		1419			
5/21	821	35		1182			
5/22	840	21		709			
5/23	845	17		574			
5/24	830	15		507			
5/25	828	16		541	2		68
5/26	957	16		541			
5/27	1,550	38		1284			
5/28	1,750	201		6791	2		68
5/29	2,110	21		709			
5/30	3,090	20		676			
5/31	3,140	30		1014	2		68
6/1	2,950	48		1622	5		169
6/2	2,540	70		2365	11		372
6/3	1,820	157		5304	4		135
6/4	1,500	52		1757	2		68
6/5	1,400	114		3851	2		68
6/6	1,450	170		5743	4		135
6/7	1,500	71		2399			
6/8	1,600	43		1453			
6/9	1,290	125		4223			
6/10	1,360	145		4899	13		439
6/11	1,150	105		3547	6		203
6/12	1,110	51		1723	2		68
6/13	1,060	50		1689			
6/14	1,040	85		2872			
6/15	970	49		1655			
6/16	942	33		1115	2		68
6/17	847	21		709	2		68

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2004 (cont'd.).

Date	**Daily Average Flow**	**Wild Chinook** Catch Actual	**Wild Chinook** Catch Estimated	**Wild Chinook** Migration	**Hatchery Chinook** Catch Actual	**Hatchery Chinook** Catch Estimated	**Hatchery Chinook** Migration
6/18	819	27	1	946	1		34
6/19	761	24	1	845			
6/20	753	13	1	473			
6/21	737	9	1	338			
6/22	649	35		1182			
6/23	632	34	1	1182			
6/24	631	62		2095	1		34
6/25	659	48		1622			
6/26	628	6		203			
6/27	615	15		507			
6/28	607	11		372			
6/29	599	7		236			
6/30	591	4		135			
7/1	574	6		203			
7/2	552	7		236			
7/3	512	1		34			
7/4	502	6		203			
7/5	494	7		236			
7/6	489	7		236			
7/7	465	8		270			
7/8	456	3		101			
7/9	451	6		203			
7/10	455	1		34			
7/11	456	2		68			
7/12	442	0		0			
7/13	433	1		34			
Season Total		11185	169	238371	102	0	2934

Note The shaded rows represent catches occurring during daylight hours only. An additional 57 chinook (55 unmarked and 2 ad-marked) were captured during nighttime sampling over the 5/4 - 5/12 hatchery migration period. These fish were not used in the migration estimate or included in this table (see Chinook Catch Expansion section).

3 Wenatchee River

2004 Wenatchee River Basin Juvenile Salmonid Production

Todd Miller
Steve Schonning

Washington Department of Fish and Wildlife
Fish Program, Science Division
Olympia, Washington 98501-1091

3.1 Methods

3.1.1 Trap Operations

An 2.4-meter diameter floating screw trap was operated on the Wenatchee River to capture downstream migrant chinook, coho, and steelhead. The trap was located immediately downstream of the West Monitor Bridge (rkm 9.6) on the right bank (Figure 3-1).

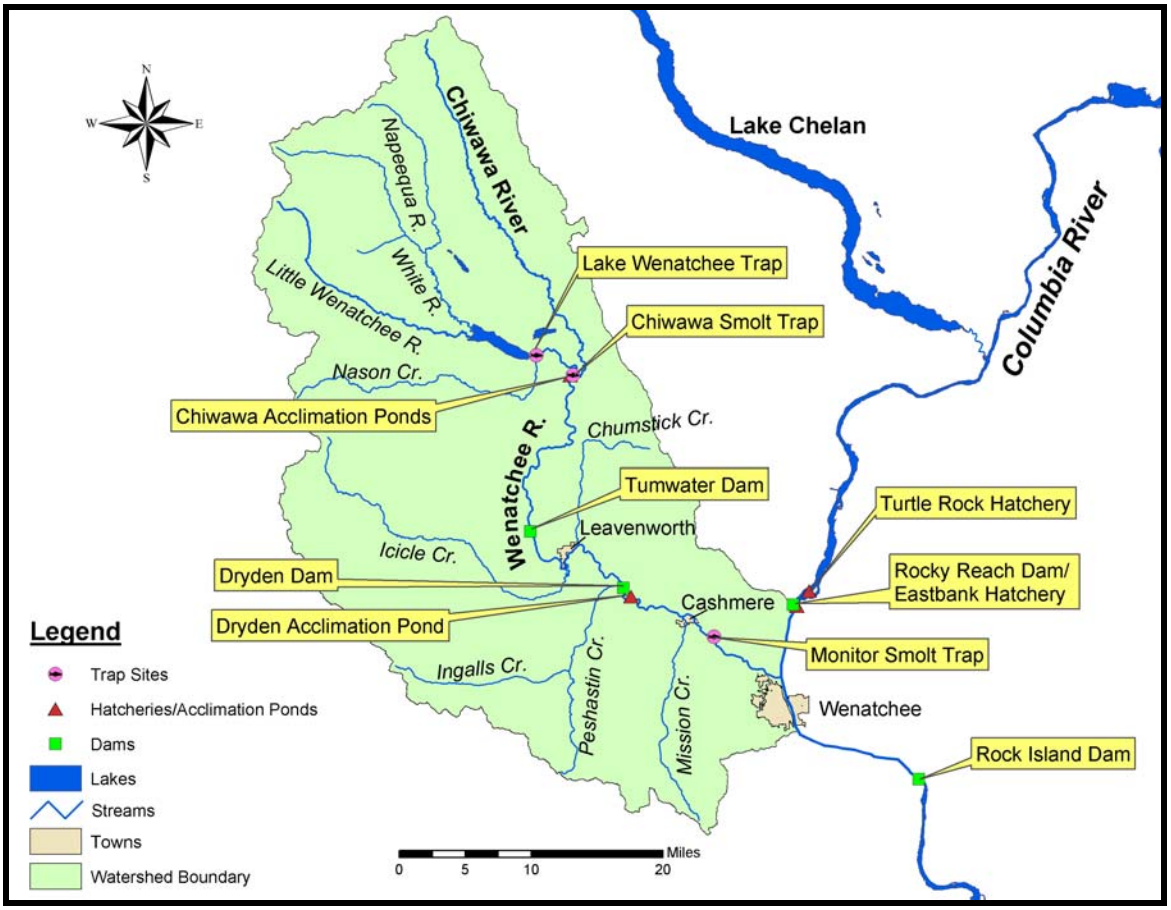


Figure 3-1. Location of the Monitor smolt trap, Wenatchee River Basin.

The trap on the Wenatchee River was operated between February 13 and July 29 during nighttime hours only. Trap operation started one half hour prior to sun down and ended at one half hour after sun up. However, during periods of high discharge, debris, hatchery releases, or mechanical failures trapping did not occur. During breaks in trapping we estimated the number of fish captured from the mean of the two days prior and two days after the break. All fish captured were removed from the livebox in 1 to 3 hour intervals throughout the night. All fish were identified to species and enumerated.

All yearling chinook and steelhead captured were placed in an anesthetic solution of MS-222 and fork lengths and weights were recorded. A sub-sample of subyearling chinook, coho, and all other species were treated in the same manner. Fish were allowed to recover in freshwater, and subsequently released below the trap. This area allowed fish to hold in current or disperse quickly.

Any fish that were captured and retained for trap efficiency trials (used when estimating emigration) were held in a 984 liter recirculating tank on shore. Yearling type salmon were marked with a unique caudal fin clip and subyearlings were marked with Bismark Brown dye. All marked fish were transported upstream approximately 19.6 rkm and released with equal numbers on the right and left bank to ensure adequate dispersal within the water column with nonmarked fish.

The trap was operated in two positions over the season depending on river discharge. The “in” position was used when discharge was generally less than 141.6 cms. Flows exceeding this level in this trap position resulted in injuries to captured fish. Therefore, the trap was moved to the “flood” position when flows exceeded 141.6 cms.

3.1.2 Production Estimate

Emigration estimates were calculated using an estimated daily trap efficiency derived from a regression equation that predicted trap efficiency (dependent variable) from river discharge (independent variable). The regression equation was developed from trap efficiency trials where efficiency, (E_i), was calculated using the following:

Equation 3-1

$$E_i = R_i / M_i$$

Where M_i is the number of marked fish released during time period i; and R_i is the number of marked fish recaptured during time period i. The number of fish captured was expanded by the regression-derived estimated daily trap efficiency, (e), to estimate the number of fish migrating past the trap during time period i, (N_i), using the following:

Equation 3-2

$$\hat{N}_i = C_i / \hat{e}_i$$

Where C_i is the number of unmarked fish captured during time period i. The variance for the total daily number of fish migrating past the trap was calculated using the following:

Equation 3-3

$$\operatorname{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{\text{MSE}\left(1 + \frac{1}{n} + \frac{\left(X_i - \overline{X}\right)^2}{(n-1)s_X^2}\right)}{\hat{e}_i^2}$$

where X_i is the discharge for time period i, and n is the sample size. If a relationship between discharge and trap efficiency was not present (i.e. $P < 0.05$; $r^2 \approx 0.5$), a pooled trap efficiency was used to estimate daily emigration:

Equation 3-4

$$E_p = \sum R / \sum M$$

The daily emigration estimate was calculated using the formula:

Equation 3-5

$$\hat{N}_i = C_i / E_p$$

The variance for daily emigration estimates using the pooled trap efficiency was calculated using the formula:

Equation 3-6

$$\operatorname{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{E_p(1 - E_p)/\sum M}{E_p^2}$$

The total emigration estimate and confidence interval were calculated using the following formulas:

Equation 3-7

$$\hat{N} = \sum \hat{N}_i$$

Equation 3-8

$$\hat{N} \pm 1.96 \times \sqrt{\sum \operatorname{var}\left[\hat{N}_i\right]}$$

A valid estimate would require the following assumptions to be true concerning the trap efficiency trials:

1) All marked fish migrated downstream past the trap site in the time period in which they were released.

2) The probability of capturing a marked or unmarked fish is equal.

3) All marked fish recaptured were identified.

4) Marks were not lost between the time of release and recapture.

Estimates for salmon and steelhead were calculated using efficiency trials conducted with subyearling chinook, hatchery yearling chinook, and hatchery coho. Mark/recapture trials were conducted when river discharge changed between 14 and 28 m^3/s (cms) or the trap position had changed. The preferable minimum mark group size is greater than 300. Most groups were closer to 500 fish. No other species were used in mark/recapture trials because too few fish were captured.

3.2 Results

The trap was operated a total of 160 days out of a possible 168 days (95.2% of the time) between February 13 and July 29. Over the season, the trap was operated in the "in" position 120 days and in the "flood" position 40 days, or 71.4% and 23.8% of the time, respectively.

All production estimates were calculated using separate regression models (independent variable = river discharge) for each trap position. In some cases, efficiency trials from multiple years (i.e., 2001-2004) were used in the regression model. Because the abundance of wild yearling chinook, wild coho, and steelhead was too low to perform effective species-specific efficiency trials, surrogate species (e.g., subyearling chinook, yearling hatchery chinook, yearling hatchery coho, and wild sockeye) were utilized.

3.2.1 Chinook

3.2.1.1 Catch

Chinook salmon were captured from two brood years, subyearlings (2003 brood) and yearlings (2002 brood). The separation of brood years was based on size and emigration timing. Many of the 2003 brood were alevins and easily identifiable as subyearlings. Due to differences in life history characteristics of summer and spring chinook, subyearling and yearling salmon captured were considered summer and spring chinook, respectively.

During the season, a total of 1,064 wild yearling chinook and 11,846 hatchery yearling chinook were trapped (Figure 3-2). A total of 225,549 subyearling chinook were also captured comprising 87% of the total salmon captured in 2004. Cumulative passage dates for yearling chinook in 2004 were 50% passage by April 12 and 90% passage by May 17 (Appendix A). The peak daily total capture for yearling chinook was 57 on April 10. The dates for 50% and 90% passage for subyearling Chinook were May 25 and June 13, respectively (Appendix B). The peak daily total capture for subyearlings was 11,768 on May 22.

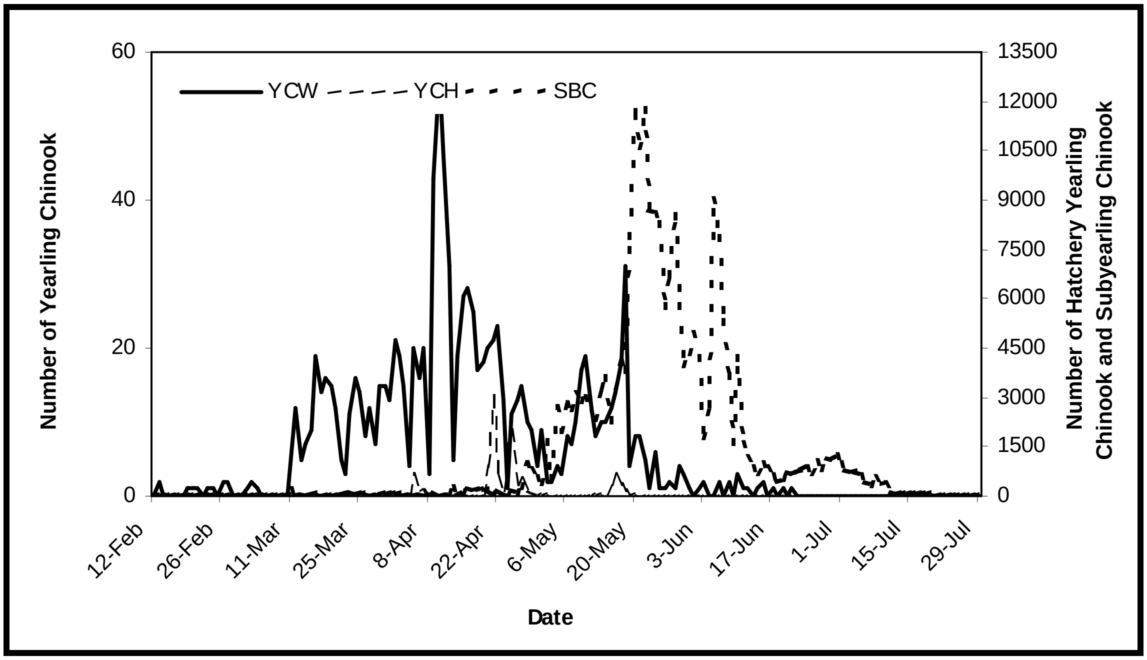


Figure 3-2. The daily number of wild yearling (YCW), subyearling (SBC), and hatchery yearling chinook (YCH) captured in the Wenatchee River trap in 2004.

3.2.1.2 Size

Fork lengths for yearling chinook averaged 97.3 mm the first three months of trapping. May fork lengths averaged 99.5 mm (Table 3-1, Figure 3-3). To ensure that subyearlings were not incorporated into the sample, scale samples were taken from fish that could not be discernable to age from size. Results of the scale samples suggest that using size to differentiate between age classes was accurate for the month of June when you would expect the most difficulties differentiating between yearlings and subyearlings.

Table 3-1. Average fork length (mm), standard deviation, range, sample size, and sample percentage of yearling chinook, Wenatchee River 2003.

Month	Average	SD	Range		Number		Percent Sampled
			Min	Max	Sampled	Caught	
Feb	100.11	13.33	77	120	9	11	81.82
Mar	96.70	11.34	67	146	229	237	96.62
Apr	95.09	9.60	70	130	555	557	99.64
May	99.52	10.05	78	141	236	241	97.93
Jun	106.39	4.98	99	115	18	18	94.44
Jul	--	--	--	--	0	0	--
Total	96.67	10.30	67	146	1,047	1,064	98.40

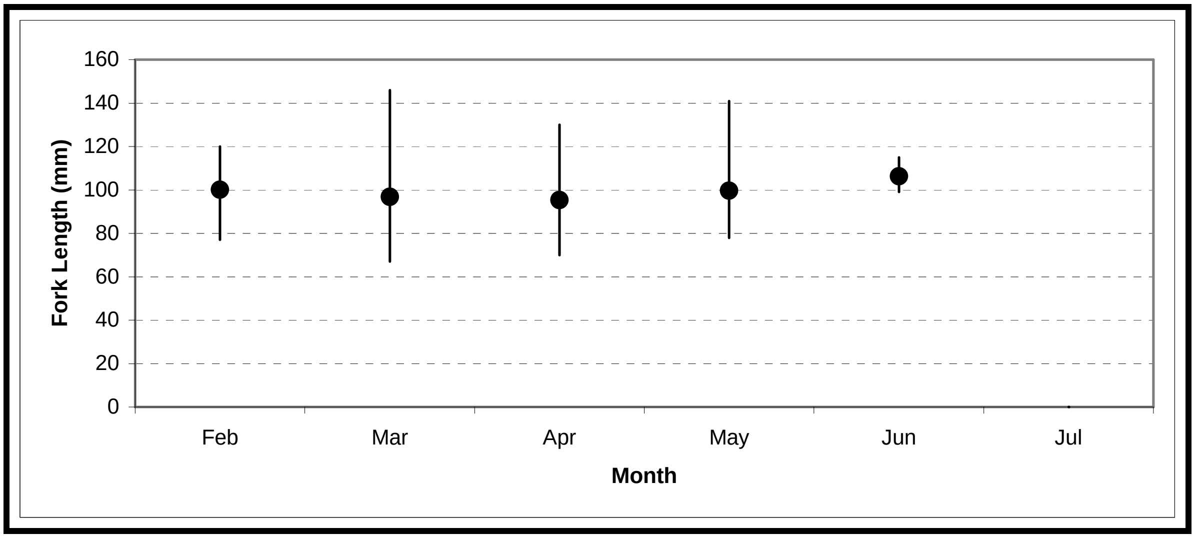


Figure 3-3. Monthly average, minimum, and maximum yearling chinook fork lengths (mm) measured at the Wenatchee River screw trap, 2004.

Subyearling chinook fork lengths averaged 40.1 mm through May. June and July fork lengths averaged 53.1 mm. The average fork length for the season was 46.7 mm (Table 3-2, Figure 3-4).

Table 3-2. Average fork length (mm), standard deviation, range, sample size, and sample percentage of subyearling chinook, Wenatchee River 2004.

Month	Average	SD	Range		Number		Percent Sampled
			Min	Max	Sampled	Caught	
Feb	39.08	1.59	35	42	127	129	98.45
Mar	39.65	1.87	34	47	295	1,001	29.47
Apr	40.43	2.83	33	56	245	4,895	5.01
May	41.17	5.09	34	76	322	149,570	0.22
Jun	47.64	11.74	36	112	411	63,410	0.65
Jul	58.58	13.75	37	94	329	6,544	5.01
Total	46.65	11.18	33	112	1,729	225,549	0.77

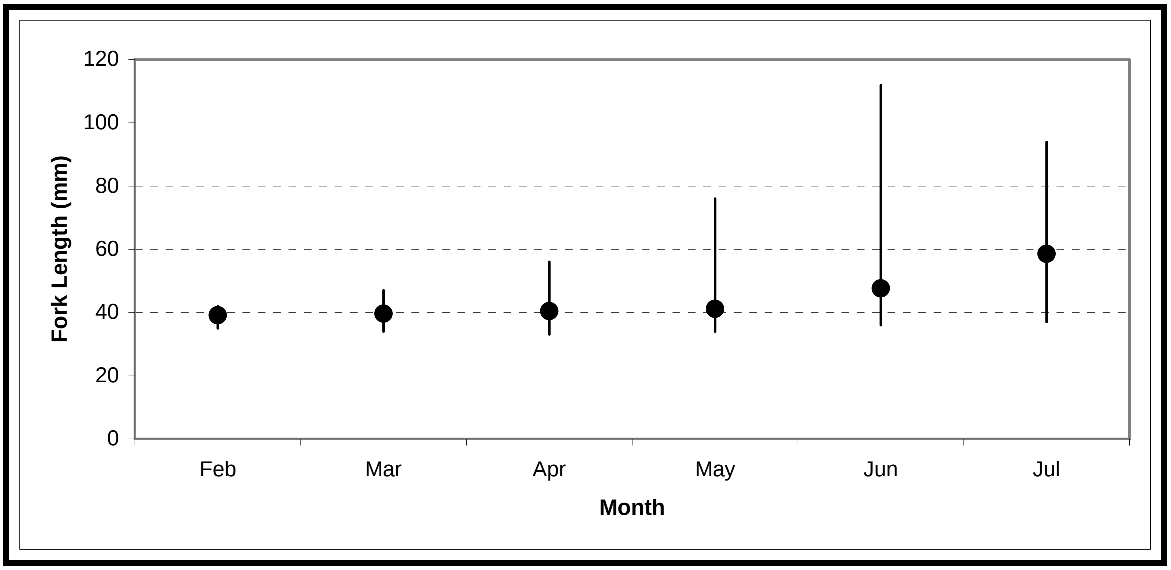


Figure 3-4. Monthly average, minimum, and maximum subyearling chinook fork lengths (mm) measured at the Wenatchee River screw trap, 2004.

3.2.1.3 Catch Expansion

The catch of the trap must be expanded for the time it was not in operation to estimate production. Table 3-3 provides a summary of trapping during 2004. During the 167-day trapping season, the trap operated 95.2% (160 days) of the time. Catch was expanded for a total of eight days when the trap was non-operational due to river discharge, heavy debris, hatchery releases, and trap repairs. During the breaks in trapping, the estimated capture for subyearling chinook was 2,053. Based on the positive relationship between discharge and capture of subyearling chinook, this is likely a conservative estimate of the total capture. The estimate of 40 yearling chinook is likely representative of the true capture because most breaks in trapping occurred during little to no movement of yearling chinook.

Table 3-3. Summary of trapping days (sunset to sunrise) for the lower Wenatchee River smolt trap at Monitor, 2004.

Date		Number of days	
Set	Pulled	Trapped	Missed
13 Feb	20 April	67	1
21 April	24 April	3	1
25 April	03 May	8	1
04 May	20 July	77	1
21 July	23 July	2	1
24 July	29 July	3	3
Total (percent)		160 (95.2)	8 (4.8)

3.2.1.4 Trap Efficiency

A total of 24 efficiency trial groups were released at Dryden Dam. The number of fish released in each group ranged from 334 to 1,175. Efficiency trials were conducted in two trap positions based on river discharge. Subyearling recapture rates averaged 1.46% and efficiency trials ranged from 0.38% to 3.82%. Yearling recapture rates averaged 0.94% and trials ranged from 0.00% to 2.33% (Table 3-4). River discharge during efficiency trials ranged from 74 to 266 cms. Discharge varied substantially between yearling hatchery chinook efficiency trials conducted in April and hatchery coho efficiency trials conducted in May. Since hatchery yearling chinook and coho were similar in size to each other and to wild smolts, we assumed they were caught at equal rates under similar flow conditions. Therefore, these trials were combined for our regression analysis in order to broaden the range of flows applicable to the models.

Regression models were used to estimate trap efficiency for sub-yearlings at both trap positions and for yearlings in the "IN" position (Table 3-5). Even though a significant relationship between efficiency and river discharge (r^2=0.88, P=0.018 (Flood); r^2=0.97, P=0.013 (In)) was evident, not all observed discharges were included in the models. For the days when river discharge was outside of the efficiency trials used in calculating our regression, we used the minimum and maximum discharge from our trials. This could cause some considerable over/under estimation of our production estimate.

3.2.1.5 Production Estimate

An estimated 200,159 yearling chinook emigrated from the Wenatchee River from February 13 to June 21 (Appendix A). From February 13 to July 29 we estimated 19,253,224 subyearling chinook emigrated the Wenatchee River (Appendix B). Because trap efficiencies were low and river discharge was outside our regression model creating extreme variance, confidence intervals were not reported.

Table 3-4. Subyearling chinook, yearling chinook, and coho trap efficiency trials conducted for moderate-flow (In) and high-flow (flood) trap positions on the lower Wenatchee River, 2004.

Position	Species	Date	Flow (cms)	# Marked Released	# Marked Recaptured	Trap Efficiency
In	Sub-Yearling Chinook	15-May	161	1070	11	0.0103
		09-Jun	161	1033	11	0.0106
		13-Jun	144	634	12	0.0189
		15-Jun	123	498	19	0.0382
		19-Jun	132	589	14	0.0238
		29-Jun	103	606	7	0.0116
		04-Jul	74	521	10	0.0192
	Yearling Chinook	05-Apr	121	662	9	0.0136
		08-Apr	160	344	8	0.0233
		21-Apr	125	500	9	0.0180
Flood	Sub-Yearling Chinook	04-May	266	1007	8	0.0079
		07-May	204	937	12	0.0128
		12-May	166	1085	14	0.0129
		20-May	235	1055	4	0.0038
		24-May	183	994	12	0.0121
		27-May	221	1127	11	0.0098
		01-Jun	157	1175	14	0.0119
	Yearling Chinook	28-Apr	179	506	7	0.0138
		02-May	214	371	4	0.0108
	Coho	08-May	204	539	0	0.0000
		12-May	174	334	1	0.0030
		20-May	220	528	2	0.0038
		22-May	247	626	5	0.0080
		02-Jun	157	366	0	0.0000

Table 3-5. Trap efficiency estimators used to estimate salmonid production at the lower Wenatchee trap site, 2004.

Species/Life Stage Trapped	**Position**	**Estimator**	**Equation**
Sub-yearlings Chinook 0+	"IN"	Regression	$\hat{e}_i = -7.1336E\text{-}04\ X_i + 0.1245$
	"FLOOD"	Regression	$\hat{e}_i = -5.085E\text{-}05\ X_i + 2.21E\text{-}02$
Yearlings Chinook 1+ Steelhead Smolts Coho Smolts	"IN"	Regression	$\hat{e}_i = 2.20E\text{-}04\ X_i - 1.8826E\text{-}02$
	"FLOOD"	Pooled Trap Efficiency	$E_p = 19/3270$

3.2.2 Steelhead

3.2.2.1 Catch

Juvenile steelhead were also captured during the spring emigration. All steelhead were enumerated and scale samples were taken from smolts for freshwater age analysis. Fish sampled were visually examined to determine their degree of smoltification. Steelhead were classified as either smolt, transitional, parr, or fry. Fish less than 50 mm in length were considered fry. During trapping in 2004, we captured 299 wild steelhead smolts (Figure 3-5, Appendix C). Of these, two were captured during a very brief trapping period and were not used in the subsequent analysis of production (Appendix D). In addition to wild smolts, a total of 3,465 hatchery steelhead smolts were also captured. The first wild steelhead smolt was captured March 15 with the peak catch of 16 on April 27. The first hatchery steelhead was captured shortly after hatchery releases began on April 20. The peak capture of 181 fish was May 18. Cumulative passage dates for wild steelhead were 50% passage on May 7 and 90% passage on May 27 (Appendix D).

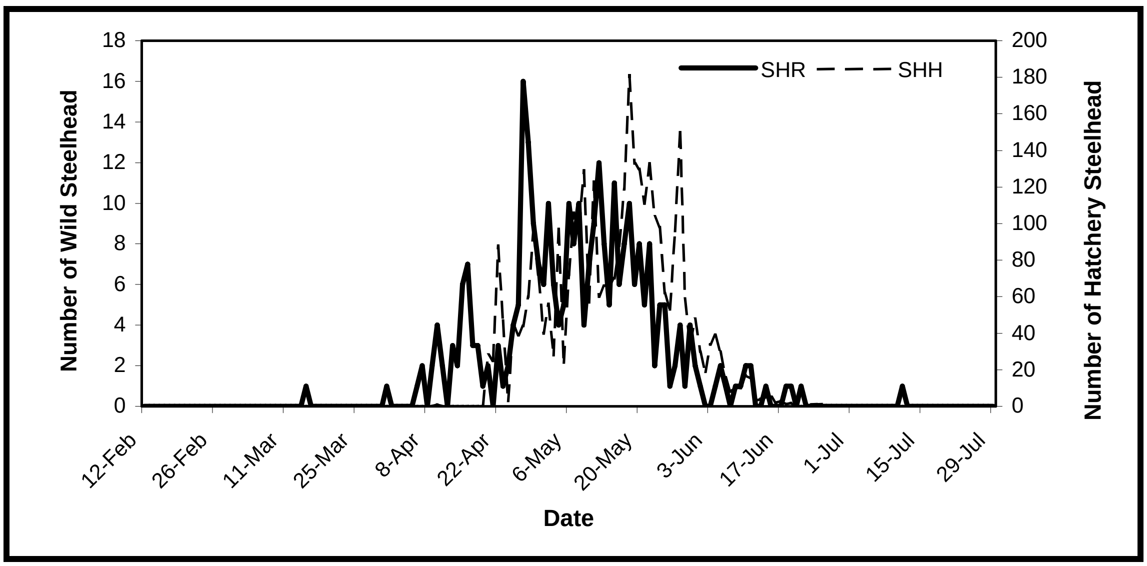


Figure 3-5. The daily number of wild and hatchery steelhead captured in the Wenatchee River trap in 2004.

3.2.2.2 Size

A total of 299 wild steelhead smolts had fork length and weight recorded. Fork lengths ranged from 102 mm to 249 mm, and averaged 169.8 mm throughout the season (Table 3-6, Figure 3-6). Age-2 fish fork lengths averaged 169.5 mm and made up 66.3% of the total estimated steelhead to emigrate the Wenatchee.

Table 3-6. Average fork length (mm), standard deviation, range, sample size, and sample percentage of wild steelhead at Monitor, 2004.

Month	Average	SD	Range		Number		Percent Sampled
			Min	Max	Sampled	Caught	
Feb	--	--	--	--	--	--	--
Mar	163.50	14.85	153	174	2	2	100.00
Apr	168.89	24.21	112	232	94	94	100.00
May	170.39	19.41	102	249	187	187	100.00
Jun	167.47	21.35	110	201	15	15	100.00
Jul	157.00	--	157	157	1	1	100.00
Total	169.80	21.03	102	249	299	299	100.00

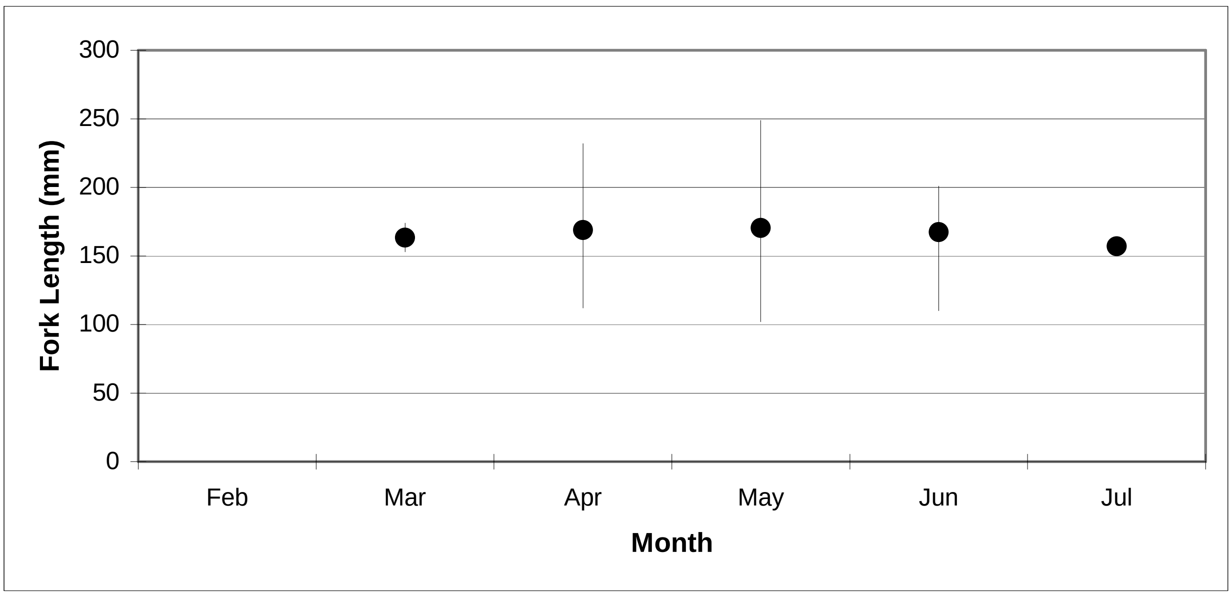


Figure 3-6. Monthly average, minimum, and maximum steelhead smolt fork lengths (mm) measured at the Wenatchee River screw trap, 2004.

3.2.2.3 Catch Expansion

Periods when the trap was not operated largely occurred after nearly all steelhead had emigrated past the trap. Therefore, we estimated only 10 additional steelhead smolts would have been captured if the trap operated without interruption.

3.2.2.4 Trap Efficiency

Because the relative capture rates of wild steelhead smolts were small, no efficiency trials were attempted with steelhead. Without adequate numbers of steelhead captured for efficiency trials, we utilized hatchery coho and hatchery chinook as surrogates for steelhead.

3.2.2.5 Production Estimate

After applying the calculated regression to the daily and expanded catch of steelhead smolts, an estimate of 43,942 wild steelhead smolts emigrated from March 15 March through July 11 (Appendix D). A confidence interval is not reported because trap efficiency for steelhead was not estimated.

3.2.3 Coho

3.2.3.1 Catch

During trapping in 2004, we captured 58 wild and 15,455 hatchery coho smolts (Figure 3-7, Appendix C). The first wild coho smolt was captured on March 29 with the peak catch of 5 fish on April 15. Cumulative passage dates for wild coho were 50% passage on June 4 and 90% passage on July 2 (Appendix E). We captured the first hatchery coho March 24. The peak capture of hatchery coho totaled 1,498 fish on May 15. Coho fry/parr were also captured during the trapping season. A total of 927 fry were trapped from March 22 through July 19. It was assumed that coho fry/parr were captured during redistribution after emerging in the spring for rearing purposes.

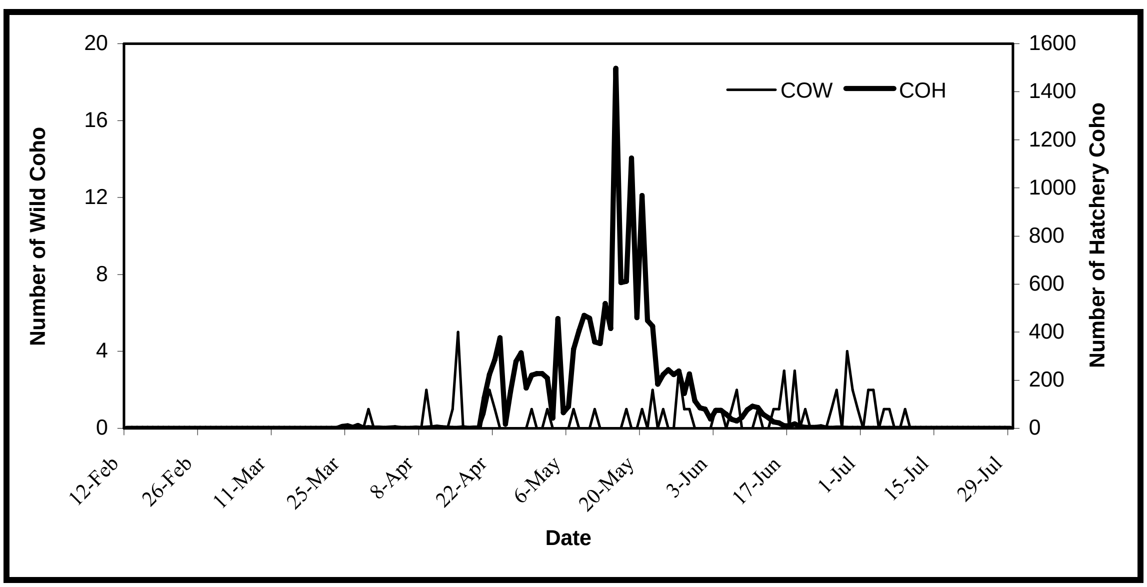


Figure 3-7. The daily number of wild and hatchery coho captured in the Wenatchee River trap in 2004.

3.2.3.2 Size

Wild yearling coho fork lengths averaged 103.79 mm throughout the trapping season (Table 3-7, Figure 3-8). The minimum and maximum sizes ranged from 79 to 141 mm.

Table 3-7. Average fork length (mm), standard deviation, range, sample size, and sample percentage of wild yearling Coho Wenatchee River screw trap, 2004.

Month	Average	SD	Range		Number		Percent Sampled
			Min	Max	Sampled	Caught	
Feb	--	--	--	--	--	--	--
Mar	90.00	--	90	90	1	1	100.00
Apr	122.5	16.32	90	141	12	12	100.00
May	103.85	9.61	86	115	13	13	100.00
Jun	97.76	10.06	79	115	25	25	100.00
Jul	95.14	8.59	86	113	7	7	100.00
Total	103.79	14.94	79	141	58	58	100.00

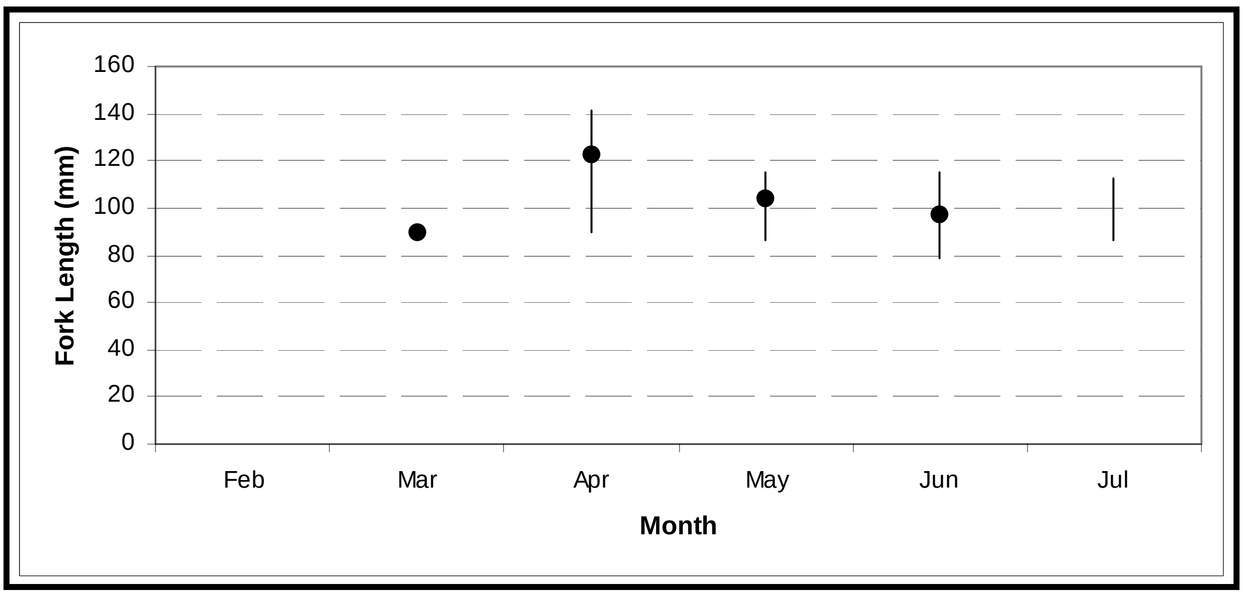


Figure 3-8. Monthly average, minimum, and maximum coho smolt fork lengths (mm) measured at the Wenatchee River screw trap, 2004.

3.2.3.3 Catch Expansion

We estimated only one wild coho yearling would have been caught over the eight evenings the trap was non-operational. The total expanded catch was estimated at 59 wild yearling coho for the season.

3.2.3.4 Trap Efficiency

Returning coho adults began spawning in the Wenatchee Basin in 2001, a result of YN's (Yakama Nation) re-introduction of coho in 1999. Smolts produced from the returning adults provided capture rates too small to try efficiency trials. Again, not having adequate numbers of wild coho for trials resulted in the utilization of hatchery coho and hatchery chinook in trials as surrogates for wild coho smolts. The relationship between efficiency and river discharge found for surrogates is thought to be similar for wild coho smolts. It was felt that using a yearling salmon surrogate for efficiency trials was a conservative approach to attaining an estimate.

3.2.3.5 Production Estimate

The estimated production of 8,706 wild coho smolts was calculated during the emigration period from March 29 through June 30 after applying the calculated regression to the daily and expanded catch. A confidence interval is not reported because trap efficiency for wild coho was not estimated.

3.2.4 Other Species

Several other species of fish were captured and enumerated during the trapping season. Throughout the season, 2 bull trout were captured. In addition, 3,224 wild sockeye and 335 hatchery sockeye were captured. Sockeye production estimates were calculated at the Lake Wenatchee trap site. The estimated production for Lake Wenatchee sockeye was 5,771,492 (Miller 2005). We also captured 622 pacific lamprey ammocoetes and 28 eyed juveniles. Pacific lamprey counts, both ammocoetes and eyed juveniles, peaked in May with 211 and 10, respectively. The monthly totals of all fish captured are listed in Appendix C.

3.3 Discussion

While conducting efficiency trials during the season, less than desirable efficiencies were calculated. In the 2005 trapping season we will have two smolt traps operating at this location in attempt to satisfy our efficiency shortcomings. We expect the increase in trap efficiency to be sufficient for calculating confidence intervals as well as reasonable production estimates. We also need to perform efficiency trials at the minimum and maximum river discharge to further increase the utility of our regression models. In the future, we recommend that our methods and analytic approach be reviewed by WDFW Biometrics Unit to improve our production estimates and our ability to calculate useable confidence intervals.

3.3.1 Chinook

3.3.1.1 Subyearling

The subyearling chinook estimate of 19,253,224 may be high when compared to egg deposition. Our production estimate appears to show 89% over-winter survival. Egg depositon may be under estimated when using peak redd counts that Chelan County Fish and Wildlife crews perform. The totals for the Wenatchee Basin in 2003 were 4,328 redds (Grassell 2004). When using peak counts to estimate maximum egg deposition (i.e. 5,000 eggs/redd), an estimate of 21,640,000 eggs were deposited. It should also be recognized that peak redd counts versus a total redd count could grossly under estimate total redd production.

3.3.1.2 Yearling

The yearling chinook production estimate in the Wenatchee basin was 200,159. Spring chinook redd counts for the Wenatchee Basin in 2002 was 1,139 redds (Grassell 2004). Redd counts in the Chiwawa River accounted for 30.3% (N=345) of the total Wenatchee River Basin redd counts. The Chiwawa River production estimate of 64,305 smolts (Miller 2005) is 32.1% of the estimated population in the basin.

3.3.2 Steelhead

The use of surrogate species to estimate trap efficiency (i.e., coho and chinook) for steelhead likely introduces error in the steelhead production estimate. Catch efficiencies of hatchery coho and hatchery chinook are probably higher than the larger steelhead smolt. Knowing that the actual steelhead catch efficiency may be lower, the production estimate calculated may be conservative. The additional trap in 2005 may sufficiently increase our steelhead catch to perform efficiency trials without the use of surrogates.

3.3.3 Coho

The coho estimate of 8,706 wild smolts was dependent on the ability to differentiate between hatchery coho among the wild coho. The hatchery coho in the Wenatchee were CWT marked but not adipose fin clipped. Each coho was scanned for tags and separated. All non-tagged coho were visually scanned for "hatchery fins" and for morphological traits to identify the coho as wild or hatchery. Questionable fish had scales sampled to ensure greater accuracy. A total of 54 coho were scaled and 22 were considered wild yearlings. Two fish were considered age-2 migrants.

Redd production was a poor in 2002. Only 28 redds were counted by YN personnel in the Icicle River, Nason Creek, Peshastin Creek, and Wenatchee River (C. Kamphaus, YN Biologist, personal communication). When comparing egg deposition to emigrants a 7.7% egg to smolt survival rate was calculated.

3.4 References

3.4.1 Literature Cited

Grassel, A. 2003. 2002 Wenatchee River Basin Spring and Summer Chinook Spawning Ground Surveys. Chelan County PUD, Wenatchee, WA.

Grassel, A. 2004. 2003 Wenatchee River Basin Spring and Summer Chinook Spawning Ground Surveys. Chelan County PUD, Wenatchee, WA.

Miller, T. 2005. 2004 Chiwawa and Wenatchee River Smolt Estimates. Washington Department of Fish and Wildlife, Science Division, Mid-Columbia Field Office, Wenatchee, WA.

Murdoch A., K. Petersen, T. Miller, M. Tonseth, and T. Randolph. 2001. Freshwater Production and Emigration of Juvenile Spring Chinook from the Chiwawa River in 2000. Washington Department of Fish and Wildlife, Science Division, Mid-Columbia Field Office, Wenatchee, WA.

3.4.2 Personal Communication

Kamphaus, Cory . Fisheries Biologist. Yakama Nation. 2 June, 2005. Phone conversation.

3.5 Appendix A

Actual Daily and Estimated Captures and Emigration Estimates for Wild Yearling Chinook, Wenatchee River 2004

Appendix A. Actual daily and estimated captures and emigration estimates for wild yearling Chinook, Wenatchee River 2004.

Date	Discharge (cms)	Position	Catch		Estimated Daily	Estimated Daily Emmigration	
			Actual	Estimated	Efficiency	"IN" Position	"FLOOD" Position
2/13/04	*39.62	IN	2		0.00155233	1288	
2/14/04	*39.90	IN	0		0.00155233	0	
2/15/04	*38.91	IN	0		0.00155233	0	
2/16/04	*39.08	IN	0		0.00155233	0	
2/17/04	*38.88	IN	0		0.00155233	0	
2/18/04	*38.48	IN	0		0.00155233	0	
2/19/04	*37.89	IN	1		0.00155233	644	
2/20/04	*37.29	IN	1		0.00155233	644	
2/21/04	*36.47	IN	1		0.00155233	644	
2/22/04	*35.91	IN	0		0.00155233	0	
2/23/04	*35.85	IN	1		0.00155233	644	
2/24/04	*36.76	IN	1		0.00155233	644	
2/25/04	*37.97	IN	0		0.00155233	0	
2/26/04	*37.58	IN	2		0.00155233	1288	
2/27/04	*37.38	IN	2		0.00155233	1288	
2/28/04	*37.15	IN	0		0.00155233	0	
2/29/04	*37.24	IN	0		0.00155233	0	
3/1/04	*37.24	IN	0		0.00155233	0	
3/2/04	*37.29	IN	1		0.00155233	644	
3/3/04	*37.26	IN	2		0.00155233	1288	
3/4/04	*37.18	IN	1		0.00155233	644	
3/5/04	*37.83	IN	0		0.00155233	0	
3/6/04	*39.16	IN	0		0.00155233	0	
3/7/04	*38.40	IN	0		0.00155233	0	
3/8/04	*41.63	IN	0		0.00155233	0	
3/9/04	*62.01	IN	0		0.00155233	0	
3/10/04	*86.25	IN	0		0.00155233	0	

3/11/04	93.45	IN	6	0.001733	3462
3/12/04	*92.03	IN	12	0.00155233	7730
3/13/04	94.07	IN	5	0.00187006	2674
3/14/04	*92.6	IN	7	0.00155233	4509
3/15/04	92.71	IN	9	0.00157102	5729
3/16/04	93.64	IN	19	0.00177661	10695
3/17/04	95.65	IN	14	0.00221894	6309
3/18/04	100.86	IN	16	0.00336526	4754
3/19/04	104.72	IN	15	0.00421254	3561
3/20/04	102.28	IN	12	0.00367676	3264
3/21/04	95.88	IN	5	0.00226878	2204
3/22/04	*91.46	IN	3	0.00155233	1933
3/23/04	94.61	IN	11	0.00198843	5532
3/24/04	106.84	IN	16	0.00467979	3419
3/25/04	115.11	IN	14	0.00649895	2154
3/26/04	117.49	IN	8	0.00702227	1139
3/27/04	114.94	IN	12	0.00646157	1857
3/28/04	110.69	IN	7	0.00552707	1266
3/29/04	106.78	IN	15	0.00466733	3214
3/30/04	105.23	IN	15	0.00432468	3468
3/31/04	108.28	IN	13	0.00499752	2601
4/1/04	106.87	IN	21	0.00468602	4481
4/2/04	102.37	IN	19	0.00369545	5141
4/3/04	99.31	IN	15	0.00302261	4963
4/4/04	101.06	IN	4	0.00340887	1173
4/5/04	109.30	IN	20	0.0052218	3830
4/6/04	120.91	IN	16	0.0077761	2058
4/7/04	130.40	IN	20	0.00986315	2028
4/8/04	151.35	IN	3	0.01447335	207
4/9/04	160.33	IN	43	0.01644826	2614
4/10/04	163.64	IN	57	0.01717717	3318

4/11/04	*169.25	IN	46		0.01816151	2533	
4/12/04	180.77	FLOOD	31		0.005810398		5335
4/13/04	204.36	FLOOD	5		0.005810398		861
4/14/04	225.91	FLOOD	19		0.005810398		3270
4/15/04	214.73	FLOOD	27		0.005810398		4647
4/16/04	192.41	FLOOD	28		0.005810398		4819
4/17/04	*172.22	IN	25		0.01816151	1377	
4/18/04	156.88	IN	17		0.0156882	1084	
4/19/04	145.61	IN	18		0.01320866	1363	
4/20/04	135.64	IN		20	0.0110157	1816	
4/21/04	130.26	IN	21		0.009832	2136	
4/22/04	125.02	IN	23		0.00867945	2650	
4/23/04	119.87	IN	13		0.00754559	1723	
4/24/04	124.59	IN		15	0.008586	1747	
4/25/04	123.55	IN	11		0.00835549	1316	
4/26/04	123.72	IN	13		0.00839287	1549	
4/27/04	139.63	IN	15		0.01189413	1261	
4/28/04	178.79	FLOOD	10		0.005810398		1721
4/29/04	180.97	FLOOD	9		0.005810398		1549
4/30/04	174.77	FLOOD	4		0.005810398		688
5/1/04	183.18	FLOOD	9		0.005810398		1549
5/2/04	213.91	FLOOD	2		0.005810398		344
5/3/04	261.36	FLOOD		5	0.005810398		861
5/4/04	271.93	FLOOD	4		0.005810398		688
5/5/04	265.75	FLOOD	3		0.005810398		516
5/6/04	245.00	FLOOD	8		0.005810398		1377
5/7/04	214.56	FLOOD	7		0.005810398		1205
5/8/04	204.42	FLOOD	10		0.005810398		1721
5/9/04	210.56	FLOOD	17		0.005810398		2926
5/10/04	201.33	FLOOD	19		0.005810398		3270
5/11/04	188.73	FLOOD	12		0.005810398		2065

5/12/04	174.21	FLOOD	8	0.005810398		1377
5/13/04	166.02	FLOOD	10	0.005810398		1721
5/14/04	160.44	FLOOD	10	0.005810398		1721
5/15/04	158.57	IN	12	0.016062	747	
5/16/04	159.96	IN	14	0.01636727	855	
5/17/04	161.46	IN	18	0.01669746	1078	
5/18/04	*168.91	IN	31	0.01816151	1708	
5/19/04	183.89	FLOOD	4	0.005810398		688
5/20/04	220.31	FLOOD	8	0.005810398		1377
5/21/04	235.23	FLOOD	8	0.005810398		1377
5/22/04	246.98	FLOOD	5	0.005810398		861
5/23/04	236.50	FLOOD	1	0.005810398		172
5/24/04	219.29	FLOOD	6	0.005810398		1033
5/25/04	196.12	FLOOD	1	0.005810398		172
5/26/04	182.93	FLOOD	1	0.005810398		172
5/27/04	220.22	FLOOD	2	0.005810398		344
5/28/04	244.63	FLOOD	1	0.005810398		172
5/29/04	221.13	FLOOD	4	0.005810398		688
5/30/04	187.03	FLOOD	3	0.005810398		516
5/31/04	180.77	FLOOD	1	0.005810398		172
6/1/04	172.73	FLOOD	0	0.005810398		0
6/2/04	157.19	FLOOD	1	0.005810398		172
6/3/04	150.31	IN	3	0.01424284	211	
6/4/04	159.51	IN	0	0.01626759	0	
6/5/04	196.66	FLOOD	0	0.005810398		0
6/6/04	222.29	FLOOD	2	0.005810398		344
6/7/04	201.19	FLOOD	0	0.005810398		0
6/8/04	174.09	FLOOD	3	0.005810398		516
6/9/04	155.74	IN	0	0.015439	0	
6/10/04	161.04	IN	4	0.01660401	241	
6/11/04	*180.92	IN	1	0.01816151	55	

6/12/04	162.34	IN	1		0.01689059	59	
6/13/04	142.15	IN	1		0.0124486	80	
6/14/04	143.85	IN	1		0.0128224	78	
6/15/04	139.01	IN	2		0.01175707	170	
6/16/04	123.18	IN	0		0.0082745	0	
6/17/04	114.40	IN	1		0.0063432	158	
6/18/04	120.20	IN	0		0.00762035	0	
6/19/04	132.47	IN	1		0.01031794	97	
6/20/04	131.70	IN	0		0.01014973	0	
6/21/04	127.60	IN	1		0.00924638	108	
Total			**1063**	**40**		**147151**	**53008**

*River discharge measured was outside the range of flow used in the calculated regression. The highest/lowest flow represented in the calculated regression was substituted for the actual river discharge.

3.6 Appendix B

Actual Daily and Estimated Captures and Emigration Estimates for Wild Subyearling Chinook, Wenatchee River 2004

Appendix B. Actual daily and estimated captures and emigration estimates for wild subyearling Chinook, Wenatchee River 2004.

Date	Discharge (cms)	Position	Catch		Estimated Daily	Estimated Daily Emmigration	
			Actual	Estimated	Efficiency	"IN" Position	"FLOOD" Position
2/13/04	*39.62	IN	4		0.03663	109	
2/14/04	*39.90	IN	4		0.03663	109	
2/15/04	*38.91	IN	1		0.03663	27	
2/16/04	*39.08	IN	4		0.03663	109	
2/17/04	*38.88	IN	4		0.03663	109	
2/18/04	*38.48	IN	4		0.03663	109	
2/19/04	*37.89	IN	17		0.03663	464	
2/20/04	*37.29	IN	3		0.03663	82	
2/21/04	*36.47	IN	16		0.03663	437	
2/22/04	*35.91	IN	12		0.03663	328	
2/23/04	*35.85	IN	5		0.03663	137	
2/24/04	*36.76	IN	3		0.03663	82	
2/25/04	*37.97	IN	4		0.03663	109	
2/26/04	*37.58	IN	3		0.03663	82	
2/27/04	*37.38	IN	3		0.03663	82	
2/28/04	*37.15	IN	25		0.03663	683	
2/29/04	*37.24	IN	17		0.03663	464	
3/1/04	*37.24	IN	4		0.03663	109	
3/2/04	*37.29	IN	4		0.03663	109	
3/3/04	*37.26	IN	14		0.03663	382	
3/4/04	*37.18	IN	15		0.03663	410	
3/5/04	*37.83	IN	12		0.03663	328	
3/6/04	*39.16	IN	6		0.03663	164	
3/7/04	*38.40	IN	1		0.03663	27	
3/8/04	*41.63	IN	10		0.03663	273	
3/9/04	*62.01	IN	0		0.03663	0	
3/10/04	*86.25	IN	0		0.03663	0	

3/11/04	*93.45	IN	188	0.03663	5132
3/12/04	*92.03	IN	3	0.03663	82
3/13/04	*94.07	IN	34	0.03663	928
3/14/04	*92.60	IN	12	0.03663	328
3/15/04	*92.71	IN	34	0.03663	928
3/16/04	*93.64	IN	36	0.03663	983
3/17/04	*95.65	IN	20	0.03663	546
3/18/04	*100.86	IN	21	0.03663	573
3/19/04	*104.72	IN	17	0.03663	464
3/20/04	*102.28	IN	13	0.03663	355
3/21/04	*95.88	IN	34	0.03663	928
3/22/04	*91.46	IN	77	0.03663	2102
3/23/04	*94.61	IN	115	0.03663	3140
3/24/04	*106.84	IN	71	0.03663	1938
3/25/04	*115.11	IN	33	0.03663	901
3/26/04	*117.49	IN	79	0.03663	2157
3/27/04	*114.94	IN	9	0.03663	246
3/28/04	*110.69	IN	24	0.03663	655
3/29/04	*106.78	IN	35	0.03663	956
3/30/04	*105.23	IN	31	0.03663	846
3/31/04	*108.28	IN	49	0.03663	1338
4/1/04	*106.87	IN	56	0.03663	1529
4/2/04	*102.37	IN	67	0.03663	1829
4/3/04	*99.31	IN	22	0.03663	601
4/4/04	*101.06	IN	38	0.03663	1037
4/5/04	*109.30	IN	3	0.03663	82
4/6/04	*120.91	IN	40	0.03663	1092
4/7/04	130.40	IN	3	0.031479	95
4/8/04	151.35	IN	28	0.016531	1694
4/9/04	160.33	IN	141	0.0101276	13922
4/10/04	*163.64	IN	23	0.0093196	2468

4/11/04	*169.25	IN	1		0.0093196	107	
4/12/04	180.77	FLOOD	34		0.01290704		2634
4/13/04	204.36	FLOOD	303		0.01170752		25881
4/14/04	225.91	FLOOD	15		0.01061168		1414
4/15/04	214.73	FLOOD	116		0.01118048		10375
4/16/04	192.41	FLOOD	224		0.0123152		18189
4/17/04	*172.22	IN	169		0.0093196	18134	
4/18/04	156.88	IN	165		0.012592	13104	
4/19/04	145.61	IN	204		0.0206316	9888	
4/20/04	135.64	IN		160	0.027742	5767	
4/21/04	130.26	IN	81		0.03158	2565	
4/22/04	125.02	IN	188		0.035317	5323	
4/23/04	*119.87	IN	81		0.03663	2211	
4/24/04	124.59	IN		138	0.03562	3874	
4/25/04	123.55	IN	173		0.0363674	4757	
4/26/04	123.72	IN	109		0.0362462	3007	
4/27/04	139.63	IN	214		0.0248938	8597	
4/28/04	178.79	FLOOD	1034		0.01300784		79491
4/29/04	180.97	FLOOD	808		0.01289696		62650
4/30/04	174.77	FLOOD	547		0.01321232		41401
5/1/04	183.18	FLOOD	382		0.01278464		29880
5/2/04	213.91	FLOOD	1733		0.01122224		154425
5/3/04	261.36	FLOOD		1703	0.0088088		193329
5/4/04	*271.93	FLOOD	2743		0.0085856		319488
5/5/04	265.75	FLOOD	1919		0.0085856		223514
5/6/04	245.00	FLOOD	2777		0.00964112		288037
5/7/04	214.56	FLOOD	2585		0.01118912		231028
5/8/04	204.42	FLOOD	3118		0.01170464		266390
5/9/04	210.56	FLOOD	2904		0.01139216		254912
5/10/04	201.33	FLOOD	3036		0.0118616		255952
5/11/04	188.73	FLOOD	2499		0.0125024		199882

5/12/04	174.21	FLOOD	2327	0.01324112		175740
5/13/04	166.02	FLOOD	3312	0.01365728		242508
5/14/04	160.44	FLOOD	3671	0.01394096		263325
5/15/04	158.57	IN	2264	0.01138	198946	
5/16/04	159.96	IN	3259	0.0103902	313661	
5/17/04	161.46	IN	4111	0.0093196	441113	
5/18/04	*168.91	IN	3786	0.0093196	406241	
5/19/04	183.89	FLOOD	7861	0.01274864		616615
5/20/04	220.31	FLOOD	11726	0.0108968		1076096
5/21/04	235.23	FLOOD	10558	0.01013792		1041437
5/22/04	246.98	FLOOD	11768	0.00954032		1233502
5/23/04	236.50	FLOOD	8669	0.01007312		860607
5/24/04	219.29	FLOOD	8648	0.01094864		789870
5/25/04	196.12	FLOOD	8318	0.01212656		685932
5/26/04	182.93	FLOOD	5694	0.0127976		444927
5/27/04	220.22	FLOOD	6696	0.01090112		614249
5/28/04	244.63	FLOOD	8586	0.00965984		888835
5/29/04	221.13	FLOOD	5829	0.01085504		536986
5/30/04	187.03	FLOOD	4011	0.0125888		318617
5/31/04	180.77	FLOOD	4313	0.01290704		334159
6/1/04	172.73	FLOOD	4993	0.013316		374962
6/2/04	*157.19	FLOOD	4249	0.01365728		311116
6/3/04	150.62	IN	1770	0.0170562	103775	
6/4/04	159.51	IN	2715	0.0107134	253421	
6/5/04	196.66	FLOOD	9075	0.0120992		750050
6/6/04	222.29	FLOOD	7886	0.010796		730456
6/7/04	201.19	FLOOD	5366	0.0118688		452110
6/8/04	174.09	FLOOD	3732	0.01324688		281727
6/9/04	155.74	IN	1578	0.0134	117761	
6/10/04	161.04	IN	4282	0.0096226	444994	
6/11/04	*180.92	IN	1615	0.0093196	173291	

6/12/04	*162.34	IN	1200	0.0093196	128761
6/13/04	142.15	IN	860	0.023096	37236
6/14/04	143.85	IN	705	0.021884	32215
6/15/04	139.01	IN	1002	0.0253382	39545
6/16/04	123.18	IN	858	0.03663	23423
6/17/04	*114.40	IN	698	0.03663	19055
6/18/04	*120.20	IN	440	0.03663	12012
6/19/04	132.47	IN	499	0.0300044	16631
6/20/04	131.70	IN	739	0.0305498	24190
6/21/04	127.60	IN	671	0.0334788	20043
6/22/04	134.11	IN	708	0.0288328	24555
6/23/04	160.41	IN	808	0.010067	80262
6/24/04	150.56	IN	891	0.0170966	52116
6/25/04	154.50	IN	692	0.0142888	48430
6/26/04	160.08	IN	1019	0.0103094	98842
6/27/04	149.17	IN	841	0.0180864	46499
6/28/04	130.09	IN	1166	0.0317012	36781
6/29/04	*112.98	IN	1106	0.03663	30194
6/30/04	*103.72	IN	1245	0.03663	33989
7/1/04	*101.20	IN	1006	0.03663	27464
7/2/04	*95.17	IN	781	0.03663	21321
7/3/04	*87.61	IN	712	0.03663	19438
7/4/04	*82.88	IN	701	0.03663	19137
7/5/04	*77.22	IN	668	0.03663	18236
7/6/04	*71.70	IN	412	0.03663	11248
7/7/04	*69.66	IN	368	0.03663	10046
7/8/04	*67.85	IN	547	0.03663	14933
7/9/04	*59.92	IN	380	0.03663	10374
7/10/04	*53.77	IN	385	0.03663	10511
7/11/04	*49.44	IN	143	0.03663	3904
7/12/04	*45.39	IN	48	0.03663	1310

7/13/04	*43.44	IN	52		0.03663	1420	
7/14/04	*42.76	IN	60		0.03663	1638	
7/15/04	*42.48	IN	56		0.03663	1529	
7/16/04	*43.10	IN	45		0.03663	1229	
7/17/04	*43.75	IN	48		0.03663	1310	
7/18/04	*42.19	IN	42		0.03663	1147	
7/19/04	*42.11	IN	34		0.03663	928	
7/20/04	*43.18	IN		29	0.03663	792	
7/21/04	*40.89	IN	24		0.03663	655	
7/22/04	*37.72	IN	15		0.03663	410	
7/23/04	*34.91	IN		12	0.03663	328	
7/24/04	*35.40	IN	4		0.03663	109	
7/25/04	*32.85	IN	3		0.03663	82	
7/26/04	*32.00	IN	8		0.03663	218	
7/27/04	*31.15	IN		3	0.03663	82	
7/28/04	*29.17	IN		4	0.03663	109	
7/29/04	*28.60	IN		4	0.03663	109	
Total			**225071**	**2053**		**3570529**	**15682695**

*River discharge measured was outside the range of flow used in the calculated regression. The highest/lowest flow represented in the calculated regression was substituted for the actual river discharge.

3.7 Appendix C

Total Juvenile Capture Information for the Wenatchee River Trap, 2004

Appendix C. Yearly and monthly total juvenile capture information for the Wenatchee River trap.

Species/Origin	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
					2004						
Chinook											
Wild yearling	11	237	557	241	18	0	-	-	-	-	1064
Wild subyearling	129	1001	4895	149570	63410	6544	-	-	-	-	225549
Hatchery yearling	0	36	9693	2108	8	1	-	-	-	-	11846
Steelhead											
Wild	1	12	117	205	23	2	-	-	-	-	360
Smolt	0	2	94	187	15	1	-	-	-	-	299
Parr	1	10	23	18	8	1	-	-	-	-	61
Hatchery	0	0	519	2690	256	0	-	-	-	-	3465
Sockeye											
Wild	0	48	3047	106	23	0	-	-	-	-	3224
Hatchery	0	3	139	128	52	13	-	-	-	-	335
Coho											
Wild yearling	0	1	12	13	25	7	-	-	-	-	58
Wild subyearling	0	5	27	572	233	90	-	-	-	-	927
Hatchery yearling	0	40	2285	12216	914	0	-	-	-	-	15455
Bull trout											
Juvenile	0	0	1	1	0	0	-	-	-	-	2
Adult	0	0	0	0	0	0	-	-	-	-	0
Cutthroat	0	0	0	0	0	0	-	-	-	-	0
White fish	0	2	1	12	15	4	-	-	-	-	34
Northern pikeminnow	0	0	3	25	14	33	-	-	-	-	75
Longnose dace	5	66	498	1444	241	120	-	-	-	-	2374
Speckled dace	0	4	0	0	0	1	-	-	-	-	5
Umatilla dace	1	0	0	1	0	0	-	-	-	-	2
Sucker spp.	0	7	13	67	95	26	-	-	-	-	208
Peamouth	0	0	0	0	0	0	-	-	-	-	0
Chiselmouth	0	0	0	0	4	3	-	-	-	-	7
Redside shiner	0	0	2	46	34	18	-	-	-	-	100
Yellow bullhead	0	0	0	0	0	0	-	-	-	-	0
Pacific lamprey	2	69	147	221	201	10	-	-	-	-	650
River lamprey	0	0	0	0	0	0	-	-	-	-	0
Sculpin spp.	1	5	17	30	19	14	-	-	-	-	86
Stickleback (3 spined)	0	0	0	6	9	70	-	-	-	-	85

3.8 Appendix D

Actual Daily and Estimated Captures and Emigration Estimates for Wild Steelhead, Wenatchee River 2004

Appendix D. Actual daily and estimated captures and emigration estimates for wild steelhead, Wenatchee River 2004.

Date	Discharge (cms)	Position	Catch		Estimated Daily	Estimated Daily Emmigration	
			Actual	Estimated	Efficiency	"IN" Position	"FLOOD" Position
3/30/04	105.23	IN	2		0.00432468	462	
3/31/04	108.28	IN	0		0.00499752	0	
4/1/04	106.87	IN	0		0.00468602	0	
4/2/04	102.37	IN	0		0.00369545	0	
4/3/04	99.31	IN	0		0.00302261	0	
4/4/04	101.06	IN	0		0.00340887	0	
4/5/04	109.30	IN	0		0.0052218	0	
4/6/04	120.91	IN	1		0.0077761	129	
4/7/04	130.40	IN	2		0.00986315	203	
4/8/04	151.35	IN	0		0.01447335	0	
4/9/04	160.33	IN	2		0.01644826	122	
4/10/04	163.64	IN	4		0.01717717	233	
4/11/04	*169.25	IN	2		0.01816151	110	
4/12/04	180.77	FLOOD	0		0.005810398		0
4/13/04	204.36	FLOOD	3		0.005810398		516
4/14/04	225.91	FLOOD	2		0.005810398		344
4/15/04	214.73	FLOOD	6		0.005810398		1033
4/16/04	192.41	FLOOD	7		0.005810398		1205
4/17/04	*172.22	IN	3		0.01816151	165	
4/18/04	156.88	IN	3		0.0156882	191	
4/19/04	145.61	IN	1		0.01320866	76	
4/20/04	135.64	IN		2	0.0110157	182	
4/21/04	130.26	IN	0		0.009832	0	
4/22/04	125.02	IN	3		0.00867945	346	
4/23/04	119.87	IN	1		0.00754559	133	
4/24/04	124.59	IN		3	0.008586	349	
4/25/04	123.55	IN	4		0.00835549	479	

4/26/04	123.72	IN	5		0.00839287	596	
4/27/04	139.63	IN	16		0.01189413	1345	
4/28/04	178.79	FLOOD	13		0.005810398		2237
4/29/04	180.97	FLOOD	9		0.005810398		1549
4/30/04	174.77	FLOOD	7		0.005810398		1205
5/1/04	183.18	FLOOD	6		0.005810398		1033
5/2/04	213.91	FLOOD	10		0.005810398		1721
5/3/04	261.36	FLOOD		6	0.005810398		1033
5/4/04	271.93	FLOOD	4		0.005810398		688
5/5/04	265.75	FLOOD	5		0.005810398		861
5/6/04	245.00	FLOOD	10		0.005810398		1721
5/7/04	214.56	FLOOD	8		0.005810398		1377
5/8/04	204.42	FLOOD	10		0.005810398		1721
5/9/04	210.56	FLOOD	4		0.005810398		688
5/10/04	201.33	FLOOD	7		0.005810398		1205
5/11/04	188.73	FLOOD	9		0.005810398		1549
5/12/04	174.21	FLOOD	12		0.005810398		2065
5/13/04	166.02	FLOOD	8		0.005810398		1377
5/14/04	160.44	FLOOD	5		0.005810398		861
5/15/04	158.57	IN	11		0.016062	685	
5/16/04	159.96	IN	6		0.01636727	367	
5/17/04	161.46	IN	8		0.01669746	479	
5/18/04	*168.91	IN	10		0.01816151	551	
5/19/04	183.89	FLOOD	6		0.005810398		1033
5/20/04	220.31	FLOOD	8		0.005810398		1377
5/21/04	235.23	FLOOD	5		0.005810398		861
5/22/04	246.98	FLOOD	8		0.005810398		1377
5/23/04	236.50	FLOOD	2		0.005810398		344
5/24/04	219.29	FLOOD	5		0.005810398		861
5/25/04	196.12	FLOOD	5		0.005810398		861
5/26/04	182.93	FLOOD	1		0.005810398		172

5/27/04	220.22	FLOOD	2	0.005810398		344
5/28/04	244.63	FLOOD	4	0.005810398		688
5/29/04	221.13	FLOOD	1	0.005810398		172
5/30/04	187.03	FLOOD	4	0.005810398		688
5/31/04	180.77	FLOOD	2	0.005810398		344
6/1/04	172.73	FLOOD	1	0.005810398		172
6/2/04	157.19	FLOOD	0	0.005810398		0
6/3/04	150.31	IN	0	0.01424284	0	
6/4/04	159.51	IN	1	0.01626759	61	
6/5/04	196.66	FLOOD	2	0.005810398		344
6/6/04	222.29	FLOOD	1	0.005810398		172
6/7/04	201.19	FLOOD	0	0.005810398		0
6/8/04	174.09	FLOOD	1	0.005810398		172
6/9/04	155.74	IN	1	0.015439	65	
6/10/04	161.04	IN	2	0.01660401	120	
6/11/04	*180.92	IN	2	0.01816151	110	
6/12/04	162.34	IN	0	0.01689059	0	
6/13/04	142.15	IN	0	0.0124486	0	
6/14/04	143.85	IN	1	0.0128224	78	
6/15/04	139.01	IN	0	0.01175707	0	
6/16/04	123.18	IN	0	0.0082745	0	
6/17/04	114.40	IN	0	0.0063432	0	
6/18/04	120.20	IN	1	0.00762035	131	
6/19/04	132.47	IN	1	0.01031794	97	
6/20/04	131.70	IN	0	0.01014973	0	
6/21/04	127.60	IN	1	0.00924638	108	
Total			****297**	**11**	**7972**	**35970**

*River discharge measured was outside the range of flow used in the calculated regression. The highest/lowest flow represented in the calculated regression was substituted for the actual river discharge.

**Two fish were sampled but excluded from the daily catch because trapping was incomplete. Therefore, that days catch was estimated.

3.9 Appendix E

Actual Daily and Estimated Captures and Emigration Estimates for Wild Coho, Wenatchee River 2004

Appendix E. Actual daily and estimated captures and emigration estimates for wild coho, Wenatchee River 2004.

Date	Discharge (cms)	Position	Catch		Estimated Daily	Estimated daily emmigration	
			Actual	Estimated	Efficiency	"IN" Position	"FLOOD" Position
3/29/04	106.78	IN	1		0.00466733	214	
3/30/04	105.23	IN	0		0.00432468	0	
3/31/04	108.28	IN	0		0.00499752	0	
4/1/04	106.87	IN	0		0.00468602	0	
4/2/04	102.37	IN	0		0.00369545	0	
4/3/04	99.31	IN	0		0.00302261	0	
4/4/04	101.06	IN	0		0.00340887	0	
4/5/04	109.30	IN	0		0.0052218	0	
4/6/04	120.91	IN	0		0.0077761	0	
4/7/04	130.40	IN	0		0.00986315	0	
4/8/04	151.35	IN	0		0.01447335	0	
4/9/04	160.33	IN	2		0.01644826	122	
4/10/04	163.64	IN	0		0.01717717	0	
4/11/04	*169.25	IN	0		0.01816151	0	
4/12/04	180.77	FLOOD	0		0.005810398		0
4/13/04	204.36	FLOOD	0		0.005810398		0
4/14/04	225.91	FLOOD	1		0.005810398		172
4/15/04	214.73	FLOOD	0		0.005810398		0
4/16/04	192.41	FLOOD	0		0.005810398		0
4/17/04	*172.22	IN	0		0.01816151	0	
4/18/04	156.88	IN	0		0.0156882	0	
4/19/04	145.61	IN	0		0.01320866	0	
4/20/04	135.64	IN		1	0.0110157	91	
4/21/04	130.26	IN	2		0.009832	203	
4/22/04	125.02	IN	0		0.00867945	0	
4/23/04	119.87	IN	0		0.00754559	0	
4/24/04	124.59	IN		0	0.008586	0	

4/25/04	123.55	IN	0		0.00835549	0	
4/26/04	123.72	IN	0		0.00839287	0	
4/27/04	139.63	IN	0		0.01189413	0	
4/28/04	178.79	FLOOD	0		0.005810398		0
4/29/04	180.97	FLOOD	1		0.005810398		172
4/30/04	174.77	FLOOD	0		0.005810398		0
5/1/04	183.18	FLOOD	0		0.005810398		0
5/2/04	213.91	FLOOD	1		0.005810398		172
5/3/04	261.36	FLOOD		0	0.005810398		0
5/4/04	271.93	FLOOD	0		0.005810398		0
5/5/04	265.75	FLOOD	0		0.005810398		0
5/6/04	245.00	FLOOD	0		0.005810398		0
5/7/04	214.56	FLOOD	1		0.005810398		172
5/8/04	204.42	FLOOD	0		0.005810398		0
5/9/04	210.56	FLOOD	0		0.005810398		0
5/10/04	201.33	FLOOD	0		0.005810398		0
5/11/04	188.73	FLOOD	1		0.005810398		172
5/12/04	174.21	FLOOD	0		0.005810398		0
5/13/04	166.02	FLOOD	0		0.005810398		0
5/14/04	160.44	FLOOD	0		0.005810398		0
5/15/04	158.57	IN	0		0.016062	0	
5/16/04	159.96	IN	0		0.01636727	0	
5/17/04	161.46	IN	1		0.01669746	60	
5/18/04	*168.91	IN	0		0.01816151	0	
5/19/04	183.89	FLOOD	0		0.005810398		0
5/20/04	220.31	FLOOD	1		0.005810398		172
5/21/04	235.23	FLOOD	0		0.005810398		0
5/22/04	246.98	FLOOD	2		0.005810398		344
5/23/04	236.50	FLOOD	0		0.005810398		0
5/24/04	219.29	FLOOD	1		0.005810398		172
5/25/04	196.12	FLOOD	0		0.005810398		0

5/26/04	182.93	FLOOD	0	0.005810398		0
5/27/04	220.22	FLOOD	3	0.005810398		516
5/28/04	244.63	FLOOD	1	0.005810398		172
5/29/04	221.13	FLOOD	0	0.005810398		0
5/30/04	187.03	FLOOD	0	0.005810398		0
5/31/04	180.77	FLOOD	0	0.005810398		0
6/1/04	172.73	FLOOD	0	0.005810398		0
6/2/04	157.19	FLOOD	0	0.005810398		0
6/3/04	150.31	IN	1	0.01424284	70	
6/4/04	159.51	IN	1	0.01626759	61	
6/5/04	196.66	FLOOD	0	0.005810398		0
6/6/04	222.29	FLOOD	1	0.005810398		172
6/7/04	201.19	FLOOD	2	0.005810398		344
6/8/04	174.09	FLOOD	0	0.005810398		0
6/9/04	155.74	IN	0	0.015439	0	
6/10/04	161.04	IN	0	0.01660401	0	
6/11/04	*180.92	IN	1	0.01816151	55	
6/12/04	162.34	IN	0	0.01689059	0	
6/13/04	142.15	IN	0	0.0124486	0	
6/14/04	143.85	IN	1	0.0128224	78	
6/15/04	139.01	IN	1	0.01175707	85	
6/16/04	123.18	IN	3	0.0082745	363	
6/17/04	114.40	IN	0	0.0063432	0	
6/18/04	120.20	IN	3	0.00762035	394	
6/19/04	132.47	IN	0	0.01031794	0	
6/20/04	131.70	IN	1	0.01014973	99	
6/21/04	127.60	IN	0	0.00924638	0	
6/22/04	134.11	IN	0	0.01067928	0	
6/23/04	160.41	IN	0	0.01646695	0	
6/24/04	150.56	IN	0	0.01429891	0	
6/25/04	154.50	IN	1	0.01516488	66	

6/26/04	160.08	IN	2		0.01639219	122	
6/27/04	149.17	IN	0		0.01399364	0	
6/28/04	130.09	IN	4		0.00979462	408	
6/29/04	112.98	IN	2		0.0060317	332	
6/30/04	103.72	IN	1		0.00399449	250	
7/1/04	101.20	IN	0		0.00344002	0	
7/2/04	95.17	IN	2		0.00211303	947	
7/3/04	*87.61	IN	0		0.00155233	0	
7/4/04	*82.88	IN	0		0.00155233	0	
7/5/04	*77.22	IN	1		0.00155233	644	
7/6/04	*71.70	IN	1		0.00155233	644	
7/7/04	*69.66	IN	0		0.00155233	0	
7/8/04	*67.85	IN	0		0.00155233	0	
7/9/04	*59.92	IN	1		0.00155233	644	
Total			**49**	**1**		**5952**	**2754**

*River discharge measured was outside the range of flow used in the calculated regression. The highest/lowest flow represented in the calculated regression was substituted for the actual river discharge.

4 Cedar Creek

2004 Cedar Creek Juvenile Salmonid Production Evaluation

Dan Rawding
Michelle Groesbeck

Washington Department of Fish and Wildlife
Fish Program, Region 5
2108 Grand Blvd.
Vancouver, WA 98661

4.1 METHODS

4.1.1 Monitoring History

The Washington Department of Fish and Wildlife (WDFW) began adult steelhead monitoring in the Cedar Creek watershed during February 1998 after the installation of an adult trap in the Cedar Creek fishway (Rkm 4.0). This occurred after the National Marine Fisheries Service (NMFS) status review indicated populations of wild steelhead in the Lower Columbia River were at risk (Busby et al. 1996). The original intention was to monitor adult steelhead escapement and maintain the genetic diversity of wild steelhead in this basin by limiting the number of out of ESU hatchery steelhead spawning in the upper watershed. Later that year the adult monitoring program was expanded to include Chinook salmon, coho salmon, and sea-run cutthroat trout. In March 1998, a rotary screw was installed to estimate steelhead, coho salmon, and sea-run cutthroat smolt production in this watershed. Smolt monitoring has continued through 2004 and has been funded by the Salmon Recovery Funding (SRF) Board. Sufficient funding was not available to begin juvenile trapping prior to the start of the fall chinook outmigration in late January; therefore, population estimates were not made for this species.

4.1.2 Study Site

Cedar Creek is a third order tributary to the Columbia River and located in Clark County, WA (Figure 4-1). The mouth of Cedar Creek is located across from the Lewis River Salmon Hatchery at RM 15.5 on the Lewis River. The Cedar Creek basin, which drains approximately 88.6 square kilometers, is a low gradient system with elevations ranging from 10 to 565 meters. The anadromous salmonid species identified in Cedar Creek include chinook salmon, chum salmon, coho salmon, cutthroat trout, and steelhead. Hatchery smolt releases of steelhead, coho and spring chinook into the Lewis River strongly influence the escapement of these species in Cedar Creek. The hatchery influence on fall Chinook escapement in Cedar Creek is strongly influenced by hatchery strays from outside the Lewis River basin. A natural fall exists at Rkm 4.0, which restricts salmon and steelhead passage at some flows. In the 1950's, a fish ladder was constructed by the Washington Department of Fisheries (WDF) to ensure salmon and steelhead passage at this location. This site is located below most of the coho salmon, steelhead, and sea-run cutthroat trout spawning, the property is owned by WDFW, and the constricted river allows for acceptable trap efficiencies. These characteristics and properties make this site ideal for juvenile trapping.

4.1.3 Trap Operation

On March 16, 2004, prior to the start of the smolt outmigration, a 1.5 meter rotary screw trap was installed just above the fish ladder at Rkm 4.0 (Rawding et al. 2004). The trap was fished until the end of the smolt migration on June 26, 2004. The trap was located near the head of a pool, just below a narrow section of fast turbulent flowing water. The trap was positioned so that stream flow entered in a straight line. Water velocities at this site were generally greater than 1.5

meter/second producing cone revolutions of between 3 and 12 revolutions per minute (rpm). It is difficult to trap at this location over the range of flows without moving the trap. The trap was installed in the downstream section of the riffle and later during this same week it was moved upstream and remained at this site for the remainder of the season. Minor repositioning occurred during the first and last week in May to better position the trap in the thalwag as flows were dropping. The upstream sites are narrower and have higher water velocities. Trap efficiency is usually higher in these conditions, since the trap fishes a higher cross sectional area when the stream width is narrower and trap avoidance is lower in faster more turbulent water.

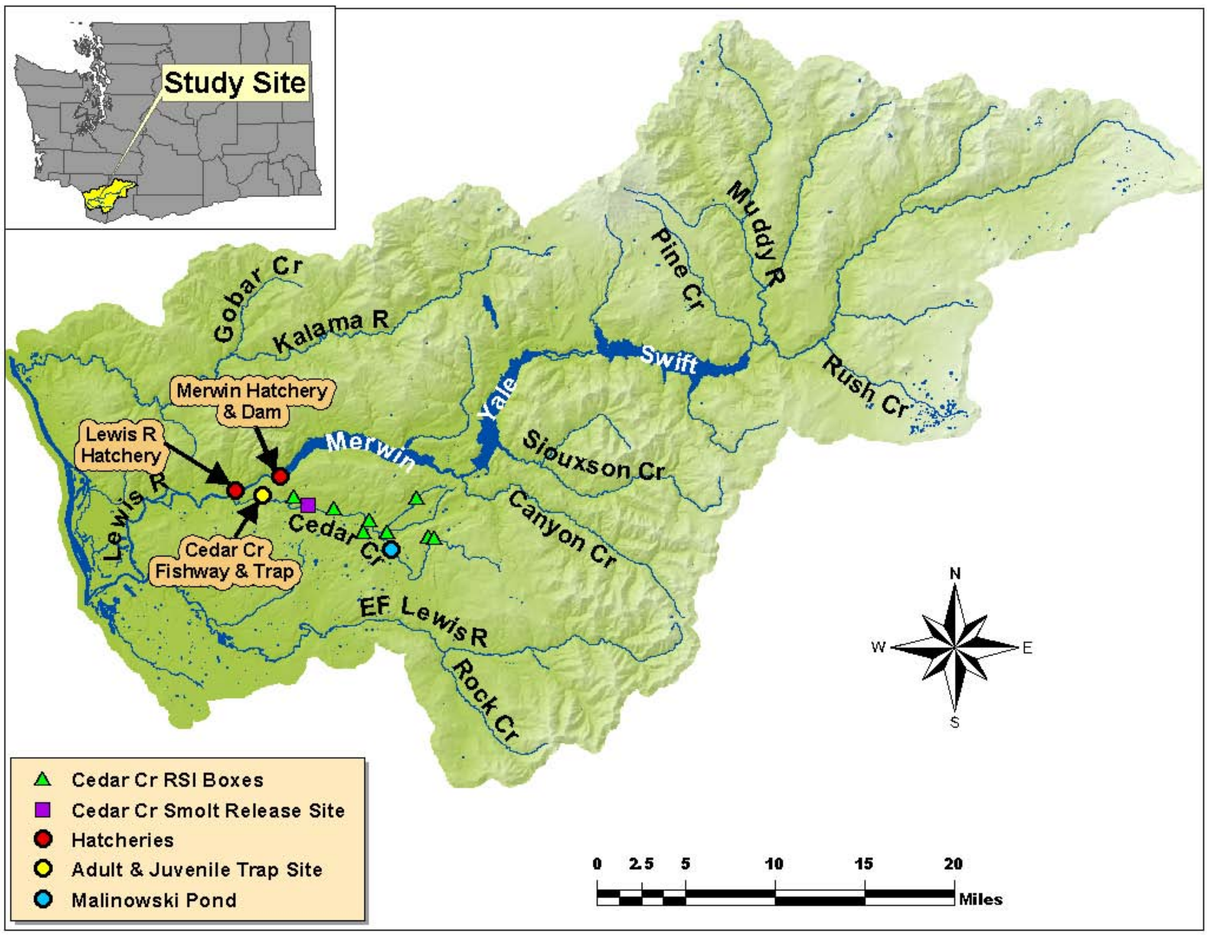


Figure 4-1. Lewis River subbasin map with the Lewis River hatcheries and dam, Cedar Creek trap, acclimation, remote site incubator sites.

The trap was fished 24 hours/day throughout the smolt outmigration period. A total of 2 days, between June 8 and June 9, were lost due to high flow and debris. Since this followed a trap efficiency release of hatchery and wild coho salmon smolts on June 7, these released were not used for the trap efficiency. There was no estimate to correct for these days and therefore the reported population estimates are biased low. The trap was checked daily in the morning; fish were removed from the live well and placed into aerated coolers. Salmonid juveniles were sorted by species composition and life history stage. Wild salmonids were classified as fry, parr, pre-smolt, or smolt (Rawding et al. 1999). The criteria for parr included well-developed parr marks and heavy spotting across the dorsal surface. Pre-smolts were those fish that had faint parr marks, less prominent dorsal spotting, silvery appearance, and no dark caudal fin margin. Smolts consisted of those salmonids with deciduous scales, silver appearance, and a dark band on the outer margin of the caudal fin. Since smoltification is a process that salmon, steelhead, and cutthroat undergo along their downstream migration, and these salmonids are more than 140 Rkm from the ocean, we felt it was more accurate to classify fish as pre-smolts and smolts. However, both groups were combined for the outmigration analysis.

In all cases, captured juveniles were anesthetized with MS-222 (~ 40 mg/l) before handling, sampled as quickly as possible and were allowed to recover fully before being released into the river. The release occurred at the next available public access approximately 5.9 Rkm above the trap site. Since steelhead and sea-run cutthroat abundance is low, all steelhead and sea-run cutthroat smolts were marked and released upstream to increase the precision of the trap efficiency estimate. Wild coho salmon were more numerous, and up to 40 per day were released for trap efficiency tests with the remainder being released below the trap to continue their outmigration. Since we were less concerned with estimating hatchery coho salmon because the release number is known, approximately 40 hatchery coho salmon smolts were marked each week to validate our hatchery estimate by comparing it to the release of hatchery coho salmon. All marked fish were enumerated by species, life stage and fork lengths (mm). Water temperatures were recorded by the United States Fish and Wildlife Service (USFWS) and stream discharge was measured and recorded by the Washington State Department of Ecology (DOE).

4.1.4 Juvenile Production Estimates

The number of juvenile outmigrants was estimated by using a trap efficiency method of releasing marked fish upstream of the trap (Dempson and Stansbury 1991, Thedinga et al. 1994, Carlson et al. 1996). Captured juvenile salmonids were marked with a Panjet inoculator (Hart and Pitcher 1969). Our marking schedule rotated every week and used different fin combinations to distinguish between weeks. Since the marking schedule was Sunday through Saturday, marks were recovered Monday through Sunday. Data was analyzed by recovery week and statistical weeks in this report were from Monday through Sunday. To achieve the desired level of precision all maiden steelhead and cutthroat were marked and released 5.9 miles upstream while up to 40 maiden coho smolts per day were marked and released upstream to develop trap efficiency estimates.

Smolt abundance estimates in 1998 and 1999 were based on a temporal stratification design. Hale (1999), used BOOTN software as presented in Thedinga et al. 1994 and further described in Murphy et al. (1996) to estimate smolt yield. This software uses Bailey (1951) estimate for trap efficiency (e) = (R+1)/(M+1), where M is the number of marked fish released upstream of the trap, and R is the number of marked fish recaptured. The number of migrants (N) = U/e, where U is the total unmarked catch, and e is the trap efficiency. Variance for each N was determined by a bootstrapping method (Efron and Tibshirani 1986) with 1,000 iterations from a Fortran program (Murphy et al. 1996). The 95% Confidence interval (95% CI) = $1.96 * \sqrt{V}$ where V is the variance determined from bootstrapping. From 2000 to 2003, population and trap efficiency estimates were calculated using Stratified Population Analysis Software (SPAS) developed by Arnason et al. (1996), which is based on the maximum likelihood estimator developed by Plante

(1990). Trap efficiencies, population estimates, and standard error (SE) are estimated using standard likelihood methods using equations. SPAS computes a pooled Petersen (Chapman 1951), a Darroch Moment estimate, and a ML Darroch estimate for non-square arrays. The partially pooled ML Darroch estimate was used to estimate smolt yield during this period (Rawding et al. 2004).

The Chapman's modification to the Lincoln-Petersen estimate is often used to estimate smolt abundance. When stratified estimates are pooled this is referred to as the pooled Petersen and is:

$$N = \frac{(C+1)(M+1)}{(R+1)} - 1 \qquad (1)$$

where N is the population estimate, M is the total fish that are marked and released, C is the total of fish captured, and R is the number of marked fish that are recaptured. Seber (1982) provides and approximate unbiased estimate of the variance:

$$Var = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)(R+1)(R+2)} \qquad (2)$$

and normal confidence intervals were calculated from the equation:

$$95\%\ CI = 1.96 * \sqrt{V}. \qquad (3)$$

Since trap efficiencies may change with flow or temperature (Seiler et al.1997, Schwartz and Dempson 1994, and Mantyniemi and Romakkaniemi 2002, Cheng and Gallinat 2004), the pooled Petersen estimate may not always be valid and in this case a stratified estimate is more appropriate (Darroch 1961, Seber 1982, Warren and Dempson 1995, Bannehaka et al. 1997, Miyakoshi and Kudo 1999). Outmigration data was analyzed using the maximum likelihood estimator for a stratified populations developed by Darroch (1961) as illustrated by Seber (1982). This is a standard analysis for salmonid smolt populations (Dempson and Stansbury 1991). The software used in this analysis is a program called DARR (Darroch Analysis with Rank Reduction) developed by Bjorkstedt (2000). DARR 2.0 was in this analysis and is an improved version of the original program Bjorkstedt (2005). In a temporally stratified study design fish are marked and released in *s* tagging strata, and tagged and untagged fish are recovered in *t* recovery strata. The number of smolts captured in recovery stratum j is u_j , m_i is the number of marked individuals released in tagging stratum *i*, and r_{ij} is the number of marked fish released in tagging stratum *i* that are recaptured in recovery stratum *j*. The probability that a fish tagged in the i^{th} period, will be captured in the j^{th} period, is the joint probability (π_{ij}) that an individual released in period *i* will resume migration and is susceptible to capture during period *j* (migration probability θ_{ij}) and is captured during period *j* (capture probability p_j). The joint probability is $\pi_{ij} = \theta_{ij}\, p_j$. Darroch (1961) provided a maximum likelihood estimator for obtaining n_j where $s = t$ and the rows of $\mathbf{R}, \{r_i\}$, are mutually independent and

$$r_i \sim \text{multinomial}\ (m_i, \pi_{ij})$$
$$u_j \sim \text{binomial}\ (n_j, p_j)$$

where $i = 1, 2, 3, \ldots s$, and $j = 1,2,3,\ldots t$.

Data are arranged in matrices as

$$\mathbf{u} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix}, \quad \mathbf{m} = \begin{pmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{pmatrix}, \quad \mathbf{R} = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1t} \\ 0 & r_{22} & \dots & r_{2t} \\ \dots & \dots & \dots & \dots \\ 0 & \dots & 0 & r_{st} \end{pmatrix}$$

The capture probability or the trap efficiency for each period is estimated as the proportion of marked fish that are recaptured from the matrices :

$$\mathbf{P} = \mathbf{p}^{-1} \qquad (4)$$

Counts of smolts are expanded to estimates of abundance

$$\mathbf{n} = \mathbf{D_u} \mathbf{P} \qquad (5)$$

where $\mathbf{p} = \mathbf{R}^{-1} \mathbf{m}$, $\mathbf{R}^{-1}$ is the inverse of the recapture matrix, n_j are the estimated number of smolts migrating past the trap in the j^{th} recovery period, $\mathbf{D_u}$ is a matrix with elements **u** arranged along the diagonal with zeros elsewhere, and **u** is the number of unmarked fish passing the trap during recovery stratum. The total abundance is estimated by summing the estimated number of unmarked individuals.

$$N = \Sigma\, n_j \qquad (6)$$

The variance-covariance matrix for **n** is approximated by:

$$\text{cov}\,(\mathbf{n}) \sim \mathbf{D_n}\, \theta^{-1}\, \mathbf{D_u}\, \mathbf{D_m}^{-1}\, (\theta')^{-1}\, \mathbf{D_n} + \mathbf{D_n}\,(\mathbf{D_n} - \mathbf{I}) \qquad (7)$$

where D is the diagonal matrix, **I** is an identity matrix, elements of the vector **u** are calculated $u_i = \Sigma_j\, (\theta_{ij} / p_j) - 1$, and $\boldsymbol{\theta} = \mathbf{D_m}^{-1}\, \mathbf{R}\, \mathbf{D_p}$. The estimated variance is for the total population estimate is obtained by summing the elements of the variance-covariance matrix for the stratum estimates. Normal confidence limits were calculated from equation (3).

Initial data inputs to DARR consisted of a matrix of marks released, recaptures, and captures by week. DARR 2.0 applies a series of algorithms to aggregate data to yield an admissible estimate of abundance while preserving as much of the data structure as possible (Bjorkstedt 2005). To increase the precision of the smolt estimate, the partial pooling option in DARR was implemented. Guidance on appropriate methods of pooling mark and recovery strata are not always clear (Schwarz and Taylor 1998). Two diagnostic chi-square tests were used to determine if pooling adjacent strata was valid (Darroch 1961, Arnason et al. 1996, Schwatrz and Taylor 1998). The equal proportions test determines if the ratio of marked to unmarked fish is constant across all strata and the complete mixing test determines if recovery probabilities are constant across all strata. If either test yields P values greater than 0.05, strata can be pooled. Therefore, after the initial stratified estimate, a chi-square test was used to compare marked and unmarked smolts per release group to formally test pooling (Murphy et al. 1996). The first two weeks were tested for a significant difference (P value <0.05). If not significant, then additional weeks were added until a significant difference was detected. This process was repeated beginning with the week that caused the P value to drop below 0.05. Schwarz and Taylor (1998) indicated that recovery strata may be arbitrarily pooled without affecting the consistency of the Petersen estimate. Since the Darroch estimate is only valid when the number of tagging and recovery strata are equal, a DARR algorithm pools the recovery strata to match the tagging strata. The purpose of this pooling was to develop homogeneous periods for the population estimate and to increase the precision of the seasonal migration estimate. This the same pooling procedure used for the 1998-2003 smolt estimates.

Murphy et al. (1996) listed the standard assumptions of the Petersen method that apply in trap efficiency experiments: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (4) marking does not affect catchability; (5) fish do not lose their marks; and (6) all recaptured marks are recognized. During the smolt trapping season, we took steps to reduce the possibility that these assumptions were violated. Assumption 1 is that of closure, which assumes that no fish leave or enter between sampling occasions. However, the Petersen estimate is still consistent if the loss rate of tagged and untagged smolts is the same (Arnason et al. 1996). Therefore, the closure assumption is considered be met in this study except on the 2+ days in early June when the trap was not fished due to high water and debris load.

To the extent possible, we conducted experiments to determine the bias caused by violations of other assumptions and develop correction factors. Assumptions 2 and 3 were addressed by estimating populations by species, origin and life stage. A Kolmogrov-Smirnov (KS) test was used to test for differences in recovery rates by length. Although Seber (1982) recommends a comparison of recaptured fish with those captured not seen again with a KS test, this is not possible with the batch mark we used for smolt trapping. For batch marked fish, we followed the recommendation of Thedinga et al. (1994) and compared recaptured fish with all marked fish. Assumptions 4 and 5 were estimated by holding marked fish to assess tag loss and handling mortality (Thedinga et al. 1994, Carlson et al. 1996, Rawding et al 1999). When properly applied the panjet mark is easily observed, and retention consistently exceeded the three week period required for this study (Thedinga and Johnson 1995, Rawding and Cochran 2001).

Contribution of Remote Site Incubator (RSI) to Coho Salmon Smolt Production

Habitat restoration projects have been implemented in the Cedar Creek watershed to increase juvenile salmon and steelhead productivity and capacity by Fish First, a local fishing and conservation group. Eggs were collected from adult coho salmon returning in the fall and winter of 2002. Eggs were incubated at Lewis River hatchery and transferred to Washougal Hatchery for otolith marking. Thermal marks were created by manipulating water temperature between the eyed egg and yolk absorption stages. Each time the water temperature is dropped by two to four degrees centigrade, a distinctive black band is deposited in the microstructure of the developing otolith. Exposure to chilled water for periods of 8 to 48 hours will create "bar" codes on the otolith that can be read (Figure 4-2). Voucher samples were taken to determine mark quality and form. Otoliths collected from sampling coho salmon smolts were analyzed by WDFW, Science Division, Otolith Laboratory. A total of 72,250 thermally marked eggs for RSI were given to Fish First (Robin Nicholay, WDFW personal communication).

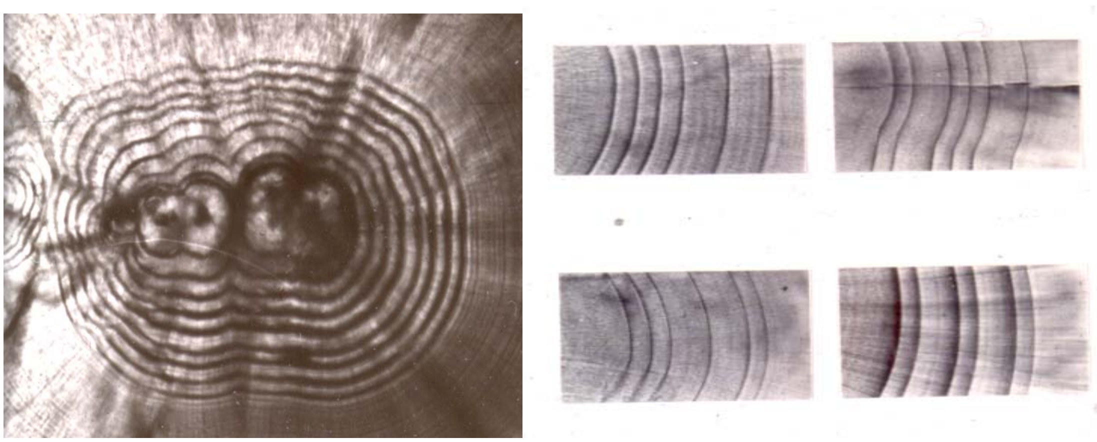


Figure 4-2. Thermally marked otolith (Photo courtesy of Eric Volk, WDFW)

Naturally produced coho salmon smolts were classified as RSI or wild. The proportion of coho salmon smolts in each category was estimated as:

$$p_k = n_k / n_t; \qquad (8)$$

Where n_k = the number of wild or RSI otoliths from examined coho salmon smolts, and n_t = the number of analyzed otoliths. The variance of the proportion was estimates as:

$$V(p_k) = (p_k(1 - p_k)) / (n_t - 1) \qquad (9)$$

Abundance by origin was estimated as:

$$N = V(N)p_k^2 + V(p_k)N^2 + V(N)V(p_k); \qquad (10)$$

where N = coho smolt estimate from natural production and V(N) = the variance of the coho salmon smolt estimate from natural production.

4.2 RESULTS

4.2.1 Assumptions

Assumptions 2 and 3 address equal catchability. In mark-recapture studies, most biologists try to estimate population size for homogeneous groups because they are likely to have the same capture and recapture probabilities. In this study design, separate estimates were made for different species and hatchery coho salmon were estimated separately from wild fish. Furthermore, estimates were only made for the pre-smolt/smolt life stage. Parr or fry are smaller than smolts and may not be actively migrating; therefore, parr and fry were identified and enumerated separately. In addition, trap efficiency and ultimately population estimates may be affected by fish size or length. KS tests were not significant for sea-run cutthroat, and hatchery coho salmon smolts with P values of 0.479 and 0.981 respectively (Figure 4-3).

In comparison to all smolts, wild coho salmon that were recaptured fish were smaller and recaptured steelhead smolts were larger. The KS test for wild coho salmon and steelhead were significant (P value = 0.00) indicating a size selectivity in trap catch. One explanation is that a greater number of wild steelhead and coho salmon smolts were captured and available for the KS-test. This increase in sample size allowed additional power to detect differences. The fork length of smolts are measured to the nearest mm and measurement error may have contributed to the observed statistical differences. Examination of the Figure 4-3 indicates little difference between wild steelhead and hatchery coho salmon. This "statistically significant" difference may not be biologically meaningful (Geiger and Zhang 2002, Schwarz and Link 2000).

Assumptions 4, 5, and 6 address tag induced mortality, tag loss, and tag recognition. A secondary experiment was conducted to assess tag loss and handling mortality. A total of 98 coho salmon were tagged and held in a live box for a period of 24 to 96 hours after being trapped and marked. Panjet mark retention and survival were 100% indicating the tag loss and mortality assumptions were met. Coded-wire-tag (CWT) retention was 100% except for the April 7 test when it was 0%. Shortly after this date a new CWT machine was used for tagging. Given the double marking it is likely that even when the CWT machine was not functioning properly fish still retained their Panjet mark.

We did not specifically assess if field staff properly identified marked or tagged fish. However, these experienced staff knew the importance of carefully sampling fish and the need to identify all tagged fish. The likelihood that staff did not identify tags in this study is believed to be low. Based on this information, no serious violation of the assumptions required for unbiased population estimates occurred and it is believed that the smolt population estimates for sea-run cutthroat trout, steelhead, and coho salmon are not significantly biased.

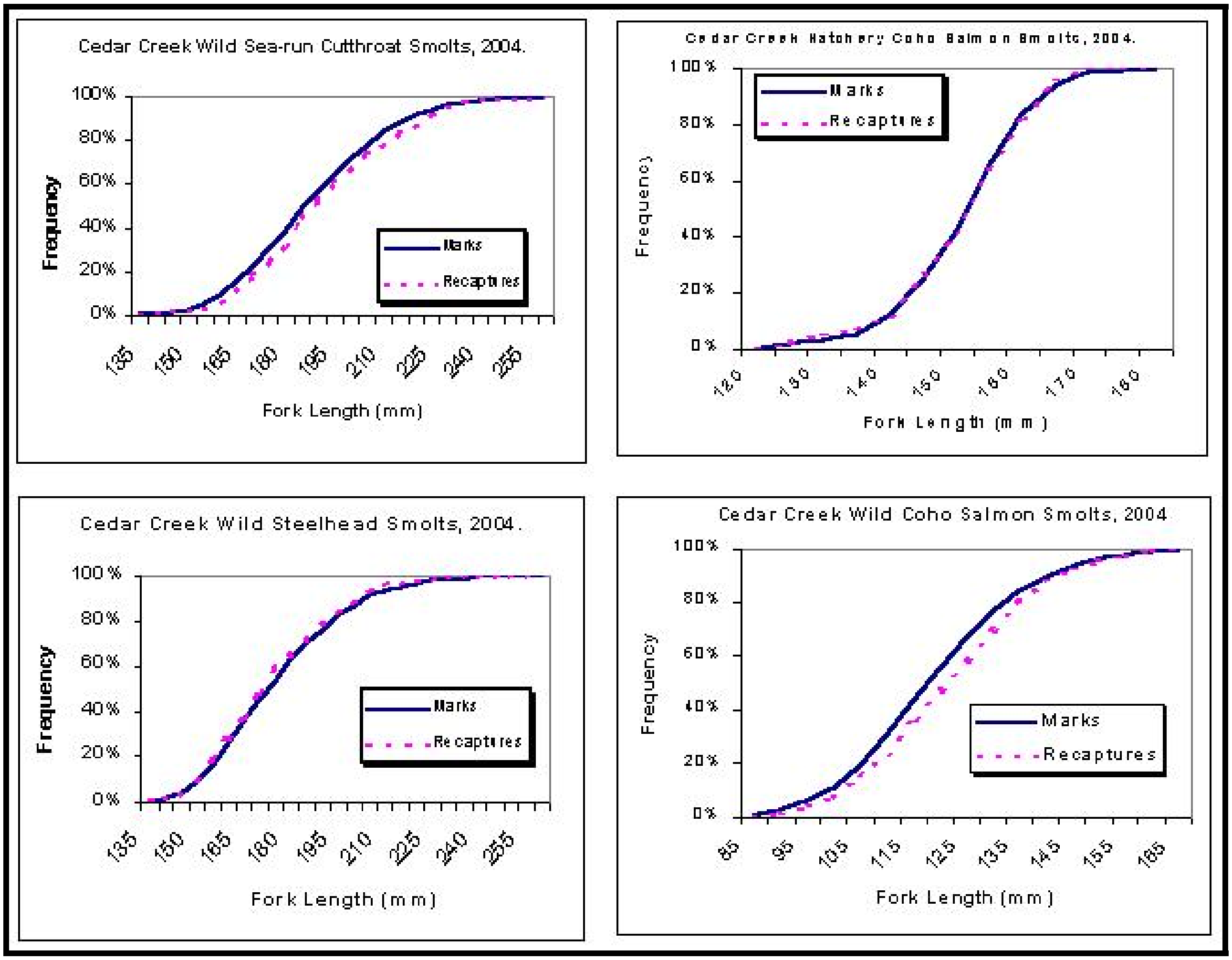


Figure 4-3. KS tests for hatchery coho salmon, wild coho salmon, wild steelhead, and wild sea-run cutthroat trout smolts captured at the Cedar Creek trap in 2004. The dashed blue line indicates maiden captures and the solid magenta line indicates recaptures. The KS test was not significant for wild cutthroat and hatchery coho salmon smolts but was significant for wild steelhead and coho salmon smolts.

4.2.2 Cutthroat

A total of 582 cutthroat trout classified as pre-smolts and smolts were captured during the trapping period. The mean size for wild sea-run cutthroat smolts was 188.5 mm with a SE of 22.60 (Table 4-1). Over the season the weekly mean size declined from 202 mm to 167 mm (Table 4-1 and Figure 4-4).

Table 4-1. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of wild sea-run cutthroat trout smolts measured by statistical week, Cedar Creek, 2004.

Statistical Week No.	Begin	End	Mean	Stnd Dev	Range Min	Range Max	Number Sampled	Total Catch	Percent Sampled
12	03/16	03/21	202.4	25.29	154	239	9	13	69.2%
13	03/22	03/28	194.0	28.61	131	260	30	34	88.2%
14	03/29	04/04	201.5	23.03	152	253	51	51	100.0%
15	04/05	04/11	210.9	23.03	165	257	27	27	100.0%
16	04/12	04/18	191.4	22.44	143	254	43	43	100.0%
17	04/19	04/26	195.7	18.87	157	243	104	106	98.1%
18	04/27	05/02	187.7	21.10	147	270	103	104	99.0%
19	05/03	05/09	177.2	17.52	132	223	73	73	100.0%
20	05/10	05/16	176.9	17.18	140	220	58	59	98.3%
21	05/17	05/23	178.9	16.16	144	227	44	45	97.8%
22	05/24	05/30	173.1	18.30	140	207	25	25	100.0%
23	05/31	06/06	167.0	8.49	161	173	2	2	100.0%
Season Total			188.5	22.60	131	270	569	582	97.8%

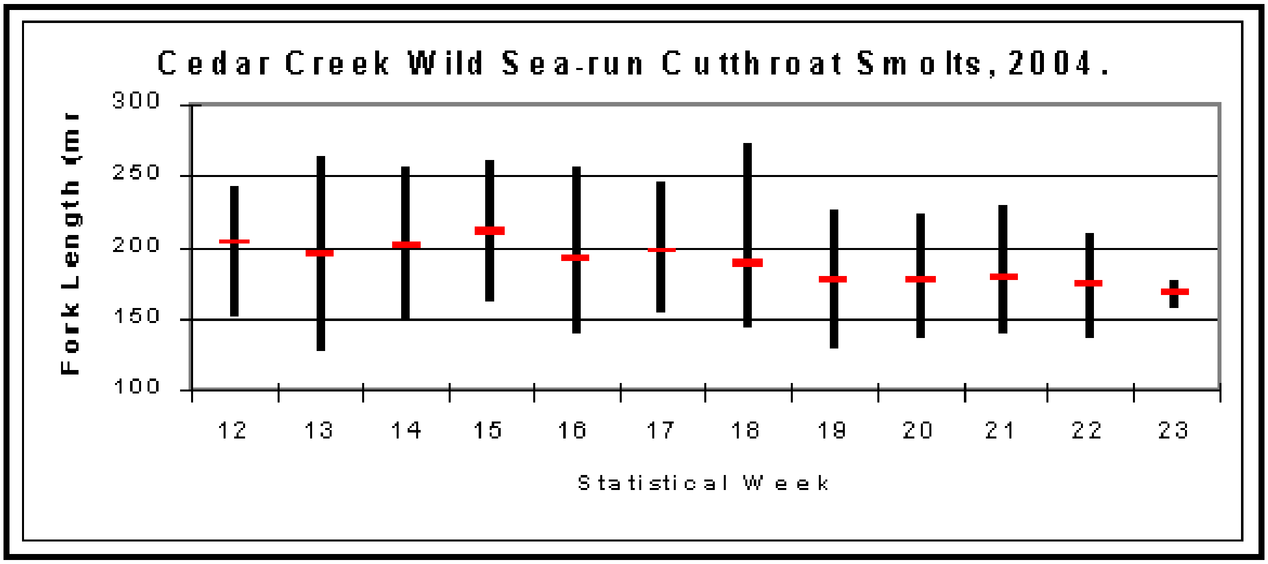


Figure 4-4. Weekly average, minimum, and maximum sea-run cutthroat trout smolt fork lengths measured at the Cedar Creek screw trap, 2004.

A total of 569 cutthroat trout were marked for 12 different release groups. The chi-square diagnostic complete mixing and equal proportions tests yielded P values of 0.054 and 0.00, respectively. Since one of these P values exceeded 0.05, the pooled Petersen estimate is valid. From March 17 to June 25, the wild cutthroat smolt outmigration estimate (SE) was 2,157 (127). Since the diagnostic tests indicated the pooled Petersen estimate met the assumption it was used as the final estimate. The 95% CI ranged from 1,908 to 2,406 for sea-run cutthroat trout smolts (Table 4-2). Trap efficiency (SE) for wild sea-run cutthroat smolts was 26.89% (1.8%). Since trapping was initiated before the smolt outmigration period started, no expansion of the estimate was required.

Table 4-2. Catch and population estimates for sea-run cutthroat trout smolts emigrating past the Cedar Creek Trap during 2004.

Petersen Estimate	Periods	Catch	Smolt Yield	SE	Lower 95% CI	Upper 95% CI	CV
Pooled	1	582	2156.86	127.02	1908	2406	5.89%
Init. Strat.	8	582	2386.15	231.19	1933	2839	9.69%
Final Strat.	1	582	2156.86	127.02	1908	2406	5.89%

Weekly trap catches increased from statistical week 12 (March 16-21) to week 17, and steadily declined to few fish after week 22 (Figure 4-5). Weekly population estimates were approximated by dividing the stratum estimate by the proportion of the total captures that occurred during that week.

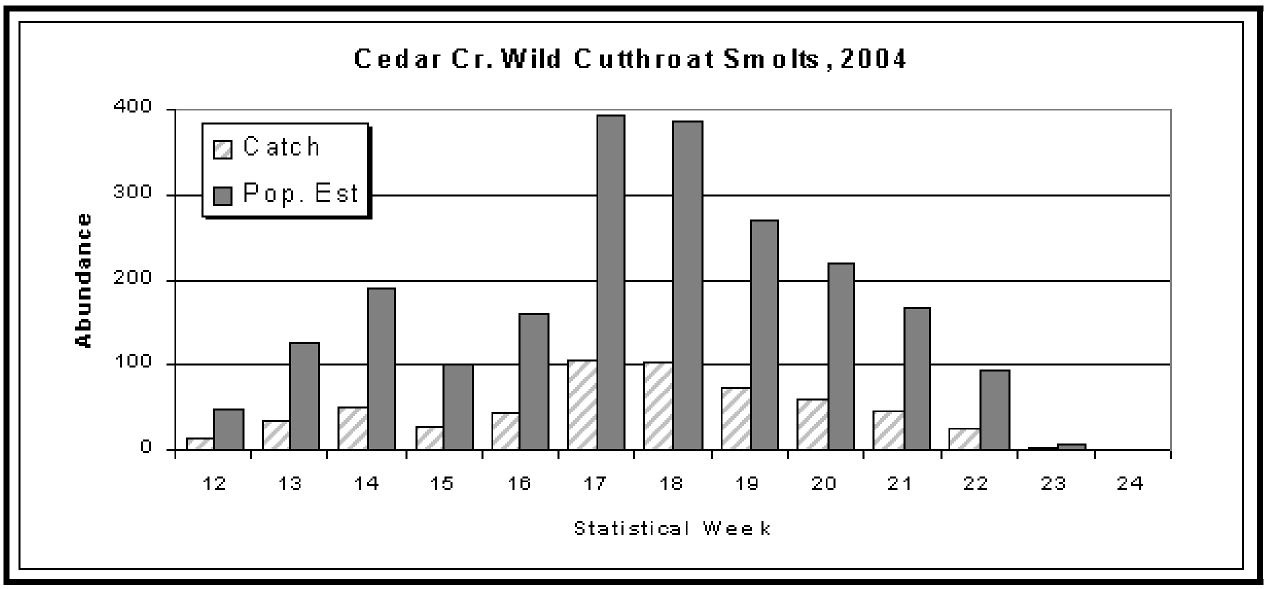


Figure 4-5. Weekly catch and population estimates for sea-run cutthroat trout smolts migrating past the Cedar Creek trap in 2004.

4.2.3 Steelhead

A total of 1,080 steelhead trout classified as pre-smolts and smolts were captured during the trapping period. The mean size for wild steelhead smolts was 176.4 mm. As with sea-run cutthroat trout, the mean weekly size declined from 187.0 mm to 157.5 mm during the trapping period (Table 4-3 and Figure 4-6).

Table 4-3. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of wild steelhead smolts measured by statistical week, Cedar Creek, 2004.

Statistical Week No.	Begin	End	Mean	Stnd Dev	Range Min	Max	Number Sampled	Total Catch	Percent Sampled
12	03/16	03/21	187.0	22.39	162	220	8	11	72.7%
13	03/22	03/28	186.2	34.04	113	246	16	17	94.1%
14	03/29	04/04	187.8	23.11	143	260	40	40	100.0%
15	04/05	04/11	190.5	21.83	137	240	72	72	100.0%
16	04/12	04/18	180.4	23.90	134	277	149	150	99.3%
17	04/19	04/26	180.8	21.69	137	288	321	325	98.8%
18	04/27	05/02	171.3	20.70	134	233	230	233	98.7%
19	05/03	05/09	167.2	16.71	136	219	138	138	100.0%
20	05/10	05/16	164.8	13.06	138	199	58	58	100.0%
21	05/17	05/23	157.5	15.63	138	201	22	23	95.7%
22	05/24	05/30	161.8	13.64	147	197	13	13	100.0%
Season Total			**176.4**	**22.31**	**113**	**288**	**1,067**	**1,080**	**98.8%**

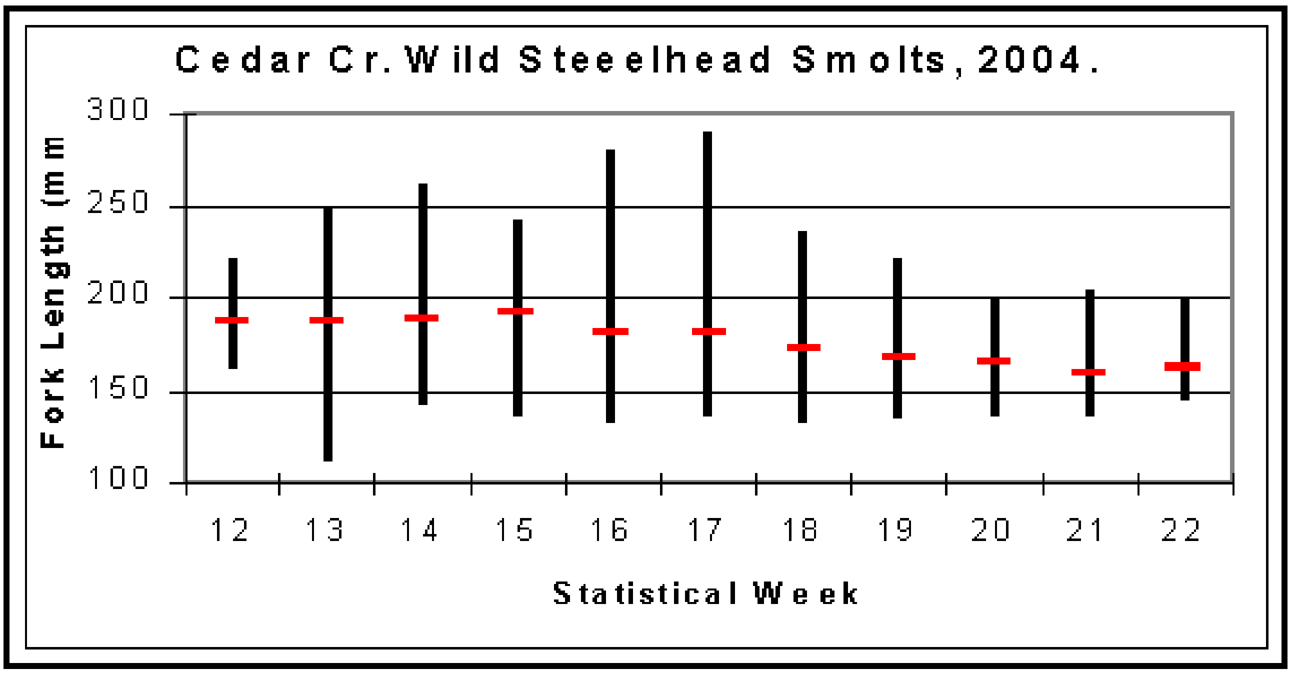


Figure 4-6. Weekly average, minimum, and maximum yearling steelhead fork lengths measured at the Cedar Creek screw trap, 2004.

A total of 1,067 steelhead trout were marked for 11 different release groups. The chi-square diagnostic complete mixing and equal proportions tests yielded P values of 0.12 and 0.00, respectively. The complete mixing test indicated the pooled Petersen estimate is valid. From March 17 to June 25, the wild steelhead smolt outmigration using the pooled Petersen estimate (SE) was estimated at 3,260 (116). The 95% CI for the final estimated ranged from 3,033 to 3,488 smolts (Table 4-4). Since trapping was initiated prior to the smolt outmigration period, no expansion of the estimate was required to obtain a total smolt outmigration estimate.

Table 4-4. Catch and population estimates for steelhead smolts emigrating past the Cedar Creek Trap during 2004.

Petersen Estimate	Periods	Catch	Smolt Yield	SE	Lower 95% CI	Upper 95% CI	CV
Pooled	1	1080	3260.32	116.06	3033	3488	3.56%
Init. Strat.	8	1080	3421.16	176.38	3075	3767	5.16%
Final Strat.	1	1080	3260.32	116.06	3033	3488	3.56%

Weekly trap catches increased from statistical week 12 to week 17, and steadily declined to few fish after week 20 (Figure 4-7). Weekly population estimates were approximated by dividing the stratum estimate by the proportion of the total captures that occurred during that week.

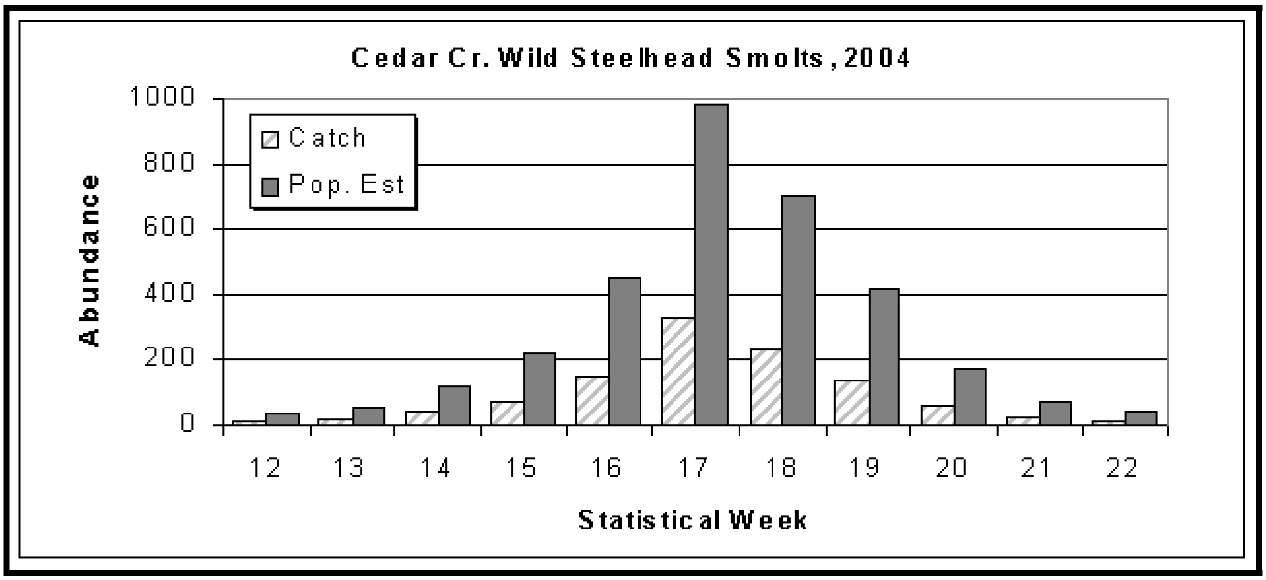


Figure 4-7. Weekly catch and population estimates for steelhead smolts migrating past the Cedar Creek trap in 2004.

4.2.4 Coho Salmon

Both hatchery and naturally produced coho salmon smolts were found in Cedar Creek. A supplementation program for coho salmon was initiated for Cedar Creek coho salmon to ensure fish could utilize habitat where restoration projects improved access and habitat. Hatchery coho salmon smolts were acclimated from November 25, 2003 to April 14, 2004 at an acclimation pond located approximately 14 km above the trap site (Figure 4-1). On April 14, screens were removed and hatchery smolts could begin their emigration. By May most hatchery coho salmon smolts had emigrated.

A total of 17,503 wild and 7,831 hatchery coho salmon classified as pre-smolts and smolts were captured during the trapping period. The mean size for wild and hatchery coho salmon smolts were 119.4 mm and 151.7 mm, respectively (Table 4-5 and Table 4-6). Over the season the mean weekly size of wild coho salmon increased from 118 mm to 136 mm in week 15 and declined to 94 mm be the end of the trapping period (Figure 4-8). Hatchery coho salmon, although larger, exhibited the decline in size from 155 mm to 146 mm (Figure 4-9).

Table 4-5. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of wild coho salmon smolts measured by statistical week, Cedar Creek, 2004.

Statistical Week			Mean	Stnd	Range		Number	Total	Percent
No.	Begin	End		Dev	Min	Max	Sampled	Catch	Sampled
12	03/16	03/21	118.2	12.21	90	140	16	27	59.3%
13	03/22	03/28	123.4	15.37	94	162	122	143	85.3%
14	03/29	04/04	124.9	13.66	100	168	215	283	76.0%
15	04/05	04/11	136.7	13.90	103	173	128	138	92.8%
16	04/12	04/18	135.6	13.32	101	195	210	1,011	20.8%
17	04/19	04/26	129.9	11.57	100	163	320	1,996	16.0%
18	04/27	05/02	124.9	10.62	98	166	248	3,358	7.4%
19	05/03	05/09	119.3	10.23	88	153	280	4,706	5.9%
20	05/10	05/16	117.2	11.34	94	150	280	2,413	11.6%
21	05/17	05/23	111.0	8.76	91	157	280	1,564	17.9%
22	05/24	05/30	105.3	12.51	81	194	277	1,419	19.5%
23	05/31	06/06	101.5	11.92	83	147	160	445	36.0%
24	06/07	06/26	94.6	10.86	59	144	40	774	5.2%
		Season Total	**119.4**	**16.23**	**59**	**195**	**2,576**	**18,277**	14.1%

Table 4-6. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of hatchery coho salmon smolts measured by statistical week, Cedar Creek, 2004.

Statistical Week			Mean	Stnd	Range		Number	Total	Percent
No.	Begin	End		Dev	Min	Max	Sampled	Catch	Sampled
16	04/12	04/18	155.1	9.27	130	190	40	2,573	1.6%
17	04/19	04/26	150.0	7.56	137	167	40	1,213	3.3%
18	04/27	05/02	152.4	7.98	137	168	40	742	5.4%
19	05/03	05/09	149.2	8.92	126	168	40	653	6.1%
20	05/10	05/16	152.0	8.01	123	166	40	860	4.7%
21	05/10	05/16	152.0	8.01	123	166	40	860	4.7%
22	05/17	05/22	150.4	10.96	124	173	52	129	40.3%
23	05/31	06/06	151.8	12.52	120	168	27	33	81.8%
24	06/07	06/07	146.4	10.59	122	166	41	51	80.4%
		Season Total	**151.7**	**10.42**	**0**	**190**	**360**	**7,114**	5.1%

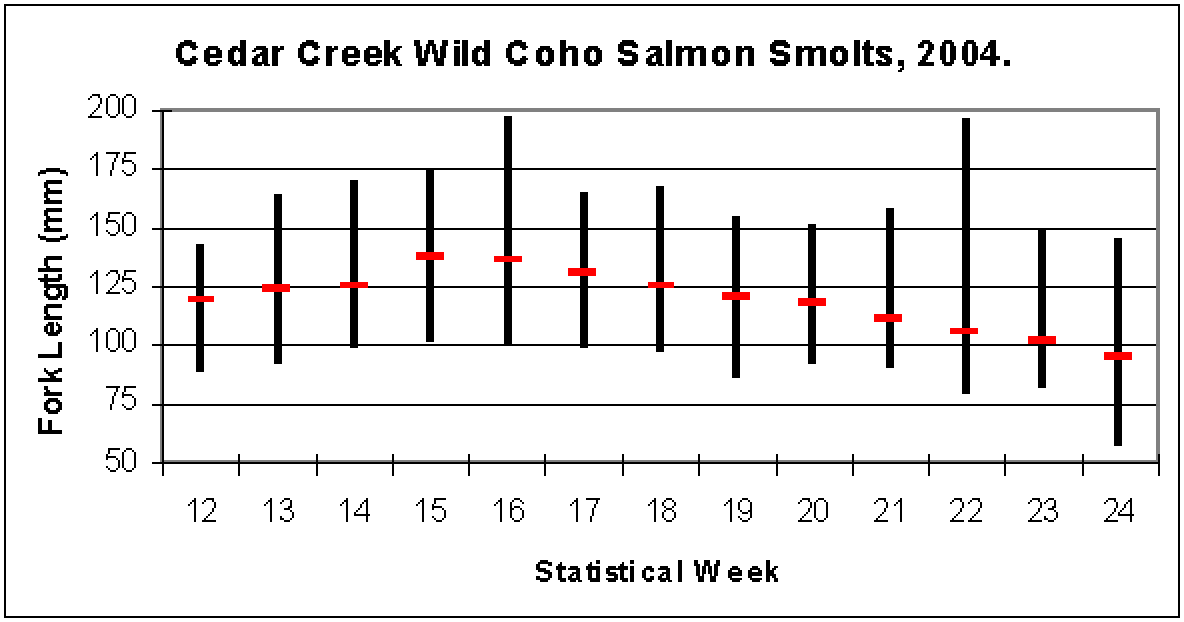


Figure 4-8. Weekly average, minimum, and maximum yearling wild coho salmon fork lengths measured at the Cedar Creek screw trap, 2004.

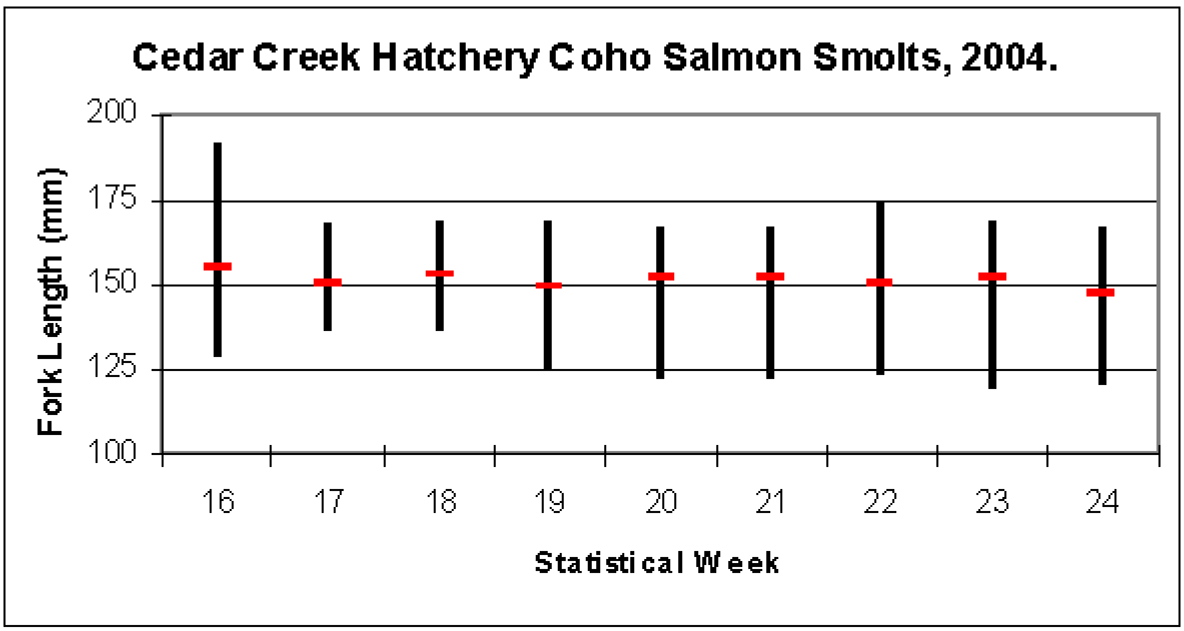


Figure 4-9. Weekly average, minimum, and maximum yearling hatchery coho salmon fork lengths measured at the Cedar Creek screw trap, 2004.

A total of 2,536 natural coho salmon were marked for 12 different release groups. The release group for week 24 was not used in the analysis because the trap was not fished during the two days following release due to debris. The chi-square diagnostic complete mixing and equal proportions tests yielded P values of 0.00 for both tests, which indicated the pooled Petersen estimate is not valid. An admissible estimate of 36,269 wild coho salmon smolts was obtained from DARR without pooling.   A chi-square test was used to compare marked and unmarked coho salmon smolts by release groups to formally test pooling. The results indicated trap efficiencies were significantly different for four periods and population estimates were calculated for these periods separately. For weeks 12-14, the trap efficiency was estimated to be 31% while it was estimated to be 38% for week 15, and 59% for weeks 16-17, and 49% for weeks 18-26.

From March 17 to June 25, the natural coho salmon smolt outmigration using the pooled Petersen estimate (SE) was estimated to be 37,947 (755), using the stratified Petersen estimate it was estimated to be 36,269 (856), and using the final three period stratification the outmigration was estimated to be 36,969 (791).   The 95% CI for the final estimated ranged from 34,591 to 37,947 smolts (Table 4-7). Since trapping was initiated prior to the smolt outmigration no expansion of the estimate was required to obtain a total smolt outmigration estimate.

Coho salmon smolts were collected from May 2 through June 22 using a systematic sampling rate of 1:40. A total of 388 fish were sacrificed for otolith collection but 71 of the heads had no otoliths because technicians removed only the front portion of the head, which contained no otoliths. A total of 319 otoliths were analyzed. The results indicate that 302 were collected from adults that spawned in the river and 17 were collected from smolts originating from an RSI's. Releases from RSI's contributed 5.23% of the natural Cedar Creek production in 2004.

The estimated natural production was 34,999 smolts with a 95% CI of 33,271 to 36,727 smolts. Production from RSI's totaled 1,970 smolts with a 95% CI from 1,054 to 2,887 smolts. Based on a total of 72,250 thermally marked eggs, the estimated egg to smolt survival was 2.73% with a 95% CI from 1.46% to 4.00%.

Table 4-7. Catch and population estimates for wild coho salmon smolts emigrating past the Cedar Creek Trap during 2004.

Petersen Estimate	Periods	Catch	Smolt Yield	SE	Lower 95% CI	Upper 95% CI	CV
Pooled	1	18277	37947	754.64	36468	39426	1.99%
Init. Strat.	8	18277	36269	856.14	34591	37947	2.36%
Final Strat.	4	18277	36969	790.91	35419	38519	2.14%

A total of 319 hatchery coho salmon smolts were marked in eight different release groups to develop trap efficiency estimates. The chi-square diagnostic complete mixing and equal proportions tests yielded P values of 0.28 and 0.00, which indicated the pooled Petersen estimate is valid. From March 17 to June 25, the hatchery coho salmon smolt outmigration using the pooled Petersen estimate (SE) was estimated to be 17,650 (1091), using the stratified Petersen estimate it was estimated to be 20,831 (3531)(Table 4-8).   The 95% CI for the final estimated ranged from 15,512 to 19,787 smolts. Since trapping was initiated prior to the hatchery smolt release and fishing continued to the end of June, no expansion of the estimate was required to obtain a total smolt outmigration estimate.

Table 4-8. Catch and population estimates for hatchery coho salmon smolts emigrating past the Cedar Creek Trap during 2004.

Petersen Estimate	Periods	Catch	Smolt Yield	SE	Lower 95% CI	Upper 95% CI	CV
Pooled	1	7831	17650	1090.76	15512	19787	6.18%
Init. Strat.	8	7831	20831	3530.97	13910	27752	16.95%
Final Strat.	1	7831	17650	1090.76	15512	19787	6.18%

The weekly trap catches and population estimates for wild coho salmon smolts increased from week 12 to a peak in week 19, and rapidly declined to a few fish by the last week of the season (Figure 4-10). Unlike wild salmonids, which followed a normal distribution, weekly hatchery coho salmon catches and population estimates were highly variable, with significant movement in weeks 16 and 22 (Figure 4-11). Hatchery coho salmon catch and population estimate peaked the week after release.

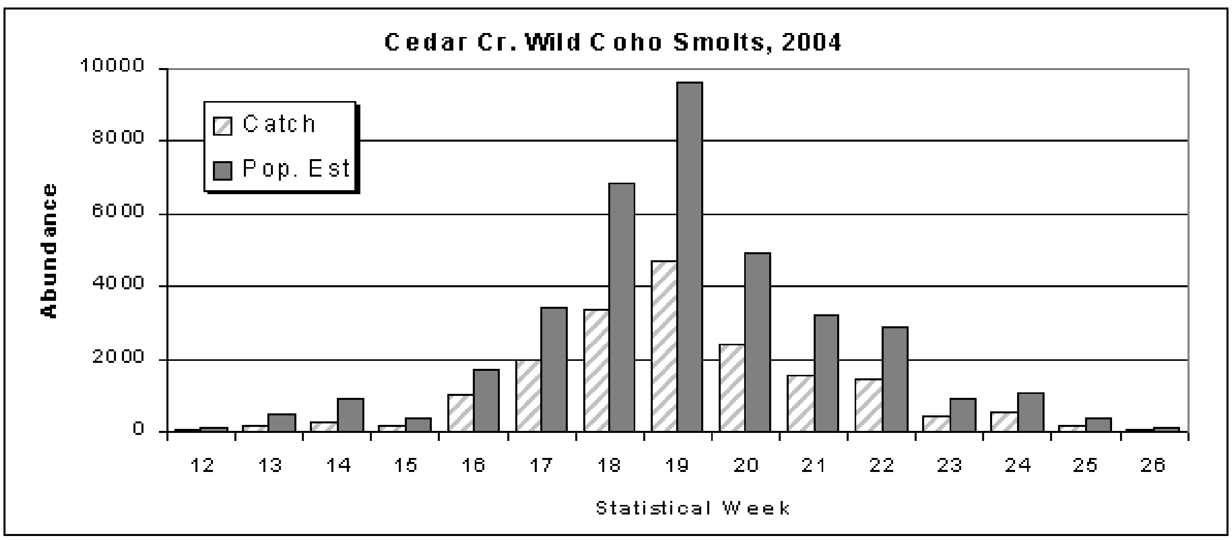


Figure 4-10. Weekly catch and population estimates for wild coho salmon smolts migrating past the Cedar Creek trap in 2004.

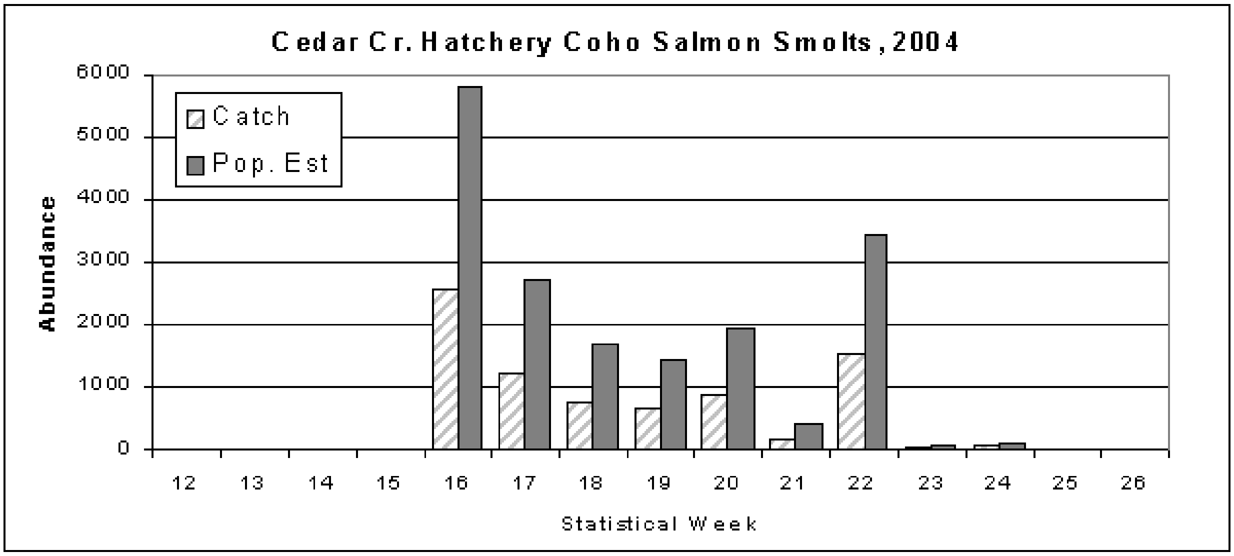


Figure 4-11. Weekly catch and population estimates for hatchery coho salmon smolts migrating past the Cedar Creek trap in 2004.

4.2.5 Other species and life stages

A total of 2,977 coho fry, 49,554 chinook fry, and 104 trout fry were captured at the Cedar Creek trap during its operation period. An additional 73 cutthroat, 99 rainbow/steelhead, and 100 coho salmon parr were trapped. Largemouth bass, bluegill, pumpkinseed, brown bullhead, crappie, sculpins, mountain whitefish, largescale sucker, three-spine stickleback ,western brook lamprey, Pacific lamprey, adult steelhead, adult cutthroat, and adult spring chinook were also identified by the sampling crew.

4.3 DISCUSSION

Since the assumptions of the Petersen estimate were met, it's likely the population estimates are relatively unbiased. During the three trapping days that were missed from June 8 to 10 and an unknown number of fish passed during this period. Since the steelhead and cutthroat migration was nearly complete, the number of fish passing during this time is likely insignificant. A total of 45 hatchery coho smolts were counted on June 7 with another two on June 11. The average daily catch was 24, and when expanded for the three missed days, a total of 71 fish would have been trapped during the three missing days. When divided by the 44.37% trap efficiency, a total of 159 hatchery coho salmon smolts were estimated to have passed the trap during these three days. A total of 463 wild coho smolts were counted on June 7 with another 63 on June 11. The average daily catch was 237, and when expanded for the three missed days, a total of 791 would be expected to have passed the trap. When divided by the 48.9% trap efficiency for wild smolts, a total of 1,617 wild coho salmon smolts were estimated to have passed the trap during these three days. These total are not included in the above estimates. If these estimates are credible, the estimates presented above are biased by 1% and 4% for hatchery and wild coho salmon, respectively.

In previous years, the estimated number of hatchery coho salmon smolts migrating past the trap was not significantly different from the number of hatchery coho salmon smolts released into Cedar Creek as long as the trap was operated throughout the entire migration period (Rawding et al. 2004). In November 2003, a total of 16,885 coho smolts were released into an acclimation facility on Cedar Creek. Based on juvenile trapping the estimated hatchery smolt outmigration was 17,650, with a 95% CI from 15,512 to 19,787 smolts. This estimated coho smolt outmigration number is slightly higher than the actual release number, which indicates a bias of approximately 5%. However, the release number falls within the 95% CI for the hatchery coho salmon smolt migration estimate.

Robson and Reiger (1964) suggested that the precision of population estimates be scaled to the use of the estimate. For management, they recommended the 95% CI of the population estimate be less than 25% and for research they recommended 10% or less. This equates to a coefficient of variation (CV) of 12.7% and 5.1%, respectively. Since this monitoring project goes beyond management, project goals were for CV of 5% or less for wild populations. For wild cutthroat, steelhead, and coho salmon smolts the CV were 5.9%, 3.6%, and 2.1%, respectively. The precision of population estimates is directly tied to the number of recoveries, and for small populations like sea-run cutthroat trout there are no easy solutions to increasing the level of precision other than marking all fish and choosing efficient sites to fish. In 2004, all steelhead cutthroat smolts were marked and transported upstream, and the trap efficiency was 27% . As long as abundance levels for steelhead and cutthroat smolts remain less than 3,000 smolts, it will be difficult to achieve the precision goals for these species. However, it should be noted despite this difficulty, the CV was 5.9% compared to the goal of 5.1%.

Based on simulations (Dan Rawding - WDFW, unpublished), it was estimated that up to 40 coho salmon smolts per day should be used for trap efficiency tests. Catch above this level were CWT and released below the trap. The CV for wild coho salmon was 2.1% and exceeded our precision target of a CV less than 5%. Since the number of hatchery coho salmon smolts is known, there is no precision goal for this group. Approximately, 40 smolts are marked weekly and the CV for hatchery coho salmon smolts was 6.2% in 2004. Improving the precision of this estimate is possible but would require marking additional hatchery smolts. Given the other wild salmonid priorities in the study this is not likely to occur without additional funding.

A total of 17,039 wild coho salmon smolts were tagged with a CWT. This tagging serves two purposes, the first is to provide marks for a coho salmon smolt estimate obtained from adults (Seiler et al. 1997) and the second is to provide information about the ocean and Columbia River fisheries interception of wild Lower Columbia River coho salmon, which are listed as a candidate species under the Endangered Species Act (ESA). Since, adult coho salmon typically return after two summers in the ocean, an independent smolt estimate from adult returns and harvest information will be available after the 2005 adult return.

4.3.1 Recommendations

1) Funding for this trapping operation covers a field season from late March to late June, which coincides with the migration of yearling coho salmon, steelhead, and sea-run cutthroat smolts. Fall chinook salmon are listed for protection under the ESA, and these fish spawn also in the area above the trap. Funding should be provided to estimate the fall chinook outmigration. This would necessitate initiating trapping by mid to late January.
2) An adult trap currently is operated by WDFW in a fish ladder adjacent to the juvenile trapping site. Currently, WDFW maintains a count of adult salmon, cutthroat, and steelhead. With additional funding, fish caught in the trap could be tagged and carcass surveys, snorkeling, or an upstream trap could be used to obtain recoveries. Using mark-recapture, accurate and precise populations estimates could be obtained in Cedar Creek, thereby increasing the value of the juvenile dataset.
3) Hatchery fish were marked with a green elastomer in the fatty tissue adjacent to the eye. Tag retention for this mark was poor. Therefore, a portion of the hatchery fish had no mark and field staff used other characteristics to identify these fish. Circumstantial evidence, such as, outmigration estimate not being significantly different than the released estimate and the wild population estimate being within the observed range, indicate these estimates are reasonable but mark retention should be improved for hatchery releases.
4) Population estimates were obtained from standard mark-recapture methods. Since temperature and flow are known to influence smolt migration (Seiler et al. 1997 and Rawding et al. 1999), flow and temperature data could be incorporated as co-variates to potentially develop estimates that are less biased and more precise (Schwarz and Dempson 1994, Mantyniemi and Romakkaniemi 2002, Cheng and Gillinant 2004).
5) Otolith collection should start at the beginning of trapping rather than waiting until May 2. Entire heads should be removed for otolith analysis to ensure that they contain otoliths.

4.4 REFERENCES

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapement and other populations. Canadian Tech. Report of Fisheries and Aquatic Science 2106. 37p.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Bannehaka, S.G., R.D. Routledge, and C.J. Schwarz. 1997. Stratified two sample tag-recovery census of a closed populations. Biometrics 53: 1212-1224.

Bjorkstedt, E. 2000. DARR (Darroch analysis with rank reduction): A method for analysis of stratified mark-recapture data from small populations with application to estimating abundance of smolts from outmigrant trap data. NOAA-NMFS Southwest Fisheries Science Center. Administrative Report SC-00-02. 28 pp. http://santacruz.nmfs.noaa.gov/files/pubs/00116.pdf

Bjorkstedt, E. 2005. DARR 2.0: Updated software for estimating abundance from stratified mark-recapture data. NOAA-TM-NMFS-SWFSC 68. 21pp. http://santacruz.nmfs.noaa.gov/files/pubs/00439.pdf

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Oregon, and California. U.S. Dept of Commerce, NOAA Tech. Memo. NMFS-NWDSC-27, 261p.

Carlson, S.R., L. Coggins, and C.O. Swanton. 1998. A simple stratified design for mark recapture of salmon smolt abundance. Alaska Fisheries Research Bulletin. Vol 5(2): 88-102. http://www.adfg.state.ak.us/pubs/afrb/vol5_n2/carlv5n2.pdf

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1:131-160.

Cheng, Y.W., and M.P. Gillinant. 2004. Statistical analysis of the relationship amoung environmental variables, inter-annual variability and smolt trap efficiency of salmonids in the Tucannon River. Fisheries Research 70 (2004) 229-238.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Dempson, J. B., and D. E. Stansbury. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. North American Journal of Fisheries Management 11:27-31.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1:54-77.

Geiger, H.J., and X. Zhang. 2002. A Simple Procedure to Evaluate Salmon Escapement Trends that Emphasizes Biological Meaning Over Statistical Significance Alaska Fisheries Research Bulletin Vol. 9(2):128–134.

Hart, P. J., and T. J. Pitcher. 1969. Field trials of fish marking using a jet inoculator. Journal of Fish Biology 1: 383-386.

Mäntyniemi, S. and Romakkaniemi, A. 2002. Bayesian mark-recapture estimation with an application to a salmonid smolt population. Canadian Journal of Fisheries and Aquatic Sciences 59: 1748-1758. http://www.rni.helsinki.fi/~shm/fish11.pdf

Miakoshi, Y., and S. Kudo. 1999. Mark-recapture estimation of escapement of Masu Salmon *Oncorhynchu masou* with a comparison to a fence count. North American Journal of Fish Management 19: 1108-1111.

Murphy, M. L., J. F. Thedinga, and J. J. Pella. 1996. Bootstrap confidence intervals for trap efficiency estimates of migrating fish. National Marine Fisheries Service, Juneau, AK.

Plante, N. 1990. Estimation de la taille d'une population animale à l'aide d'un modèle de capture-recapture avec stratification. M.Sc. thesis, Université Laval, Quebec.

Plante,N., L.P. Rivest, G. Tramblay. 1998. Stratified capture-recapture estimation of a closed population. Biometrics 54:47-60.

Rawding, D, P.C. Cochran, and T. King. 1999. Wind River steelhead smolt and parr production monitoring during the 1998 spring outmigration. Washington Department of Fish and Wildlife. Vancouver, WA. 30pp.

Rawding. D. and P.C. Cochran. 2001. Wind River steelhead smolt and parr production monitoring during the 1999 spring outmigration. Washington Department of Fish and Wildlife. Vancouver, WA. 25pp.

Rawding, D., and S. VanderPloeg. 2001. The relationship between the 2000 juvenile salmon and steelhead smolt yield and salmon habitat in the East Fork Lewis River. Washington Department of Fish and Wildlife. Olympia, WA. 25pp.

Robson, D.S., and H.A. Reiger. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93: 215-226.

Schwarz, C.J. and B. Dempson. 1994. Mark-recapture estimation of a salmon smolt population. Biometrics 50: 98-108.

Schwarz, C. J., and C. G. Taylor. 1998. Use of the stratified- Petersen estimator in fisheries management: estimating the number of pink salmon (Oncorhynchus gorbuscha) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55:281-296.

Schwarz, C.J., Andrews, M.A, and Links, M. 1999. The stratified Petersen with a known number of unread tags. Biometrics 55, 1014-1021.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin and Company, London.

Seiler, D., and five co-authors. 1997. Wild salmon production and survival evaluation. Annual Report No. RAD97-03. Washington Department of Fish and Wildlife, Olympia.

Thedinga, J. F., S. W. Johnson, K V. Koski, J. M. Lorenz, and M. L. Murphy. 1994. Determination of salmonid smolt yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Thedinga, J. F., and S. W. Johnson. 1995. Retention of jet-injected marks on juvenile coho and sockeye salmon. Transactions of the American Fisheries Society 124:782-785.

Warren, W. G., and J. B. Dempson. 1995. Does temporal stratification improve the accuracy of mark-recapture estimates of smolt production: a case study based on the Conne River, Newfoundland. N. Am. J. Fish. Manage. 15:126-136.

This program receives Federal financial assistance from the U.S. Fish and Wildlife Service Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972. The U.S. Department of the Interior and its bureaus prohibit discrimination on the bases of race, color, national origin, age, disability and sex (in educational programs). If you believe that you have been discriminated against in any program, activity or facility, please write to:

U.S. Fish and Wildlife Service
Office of External Programs
4040 N. Fairfax Drive, Suite 130
Arlington, VA 22203