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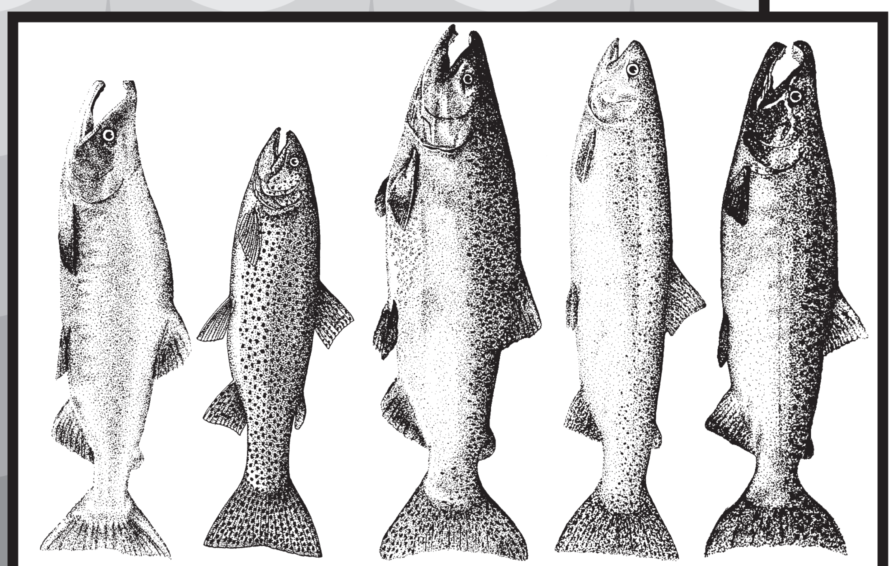
Evaluation of Downstream Migrant Salmon Production in 2002 from the Cedar River and Bear Creek



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Evaluation of Downstream Migrant Salmon Production in 2002 from the Cedar River and Bear Creek

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BEAR CREEK

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TABLE OF CONTENTS

LIST OF TABLES ..... **III**

LIST OF FIGURES ..... **V**

EXECUTIVE SUMMARY **1**

CEDAR RIVER 1
BEAR CREEK 2

INTRODUCTION **4**

CEDAR RIVER 4
BEAR CREEK 5

GOALS AND OBJECTIVES **6**

METHODS **8**

TRAPPING GEAR AND OPERATION 8
Cedar River *8*
Bear Creek *9*
TRAP EFFICIENCY 10
Cedar River *10*
Bear Creek *10*
PRODUCTION ESTIMATION 10
Cedar River *10*
Bear Creek *16*

CEDAR RIVER RESULTS **18**

SOCKEYE 18
Trap Operation *18*
Catch *18*
Efficiency and Flow *18*
Otolith Sampling *20*
Diel Migration *21*
Production Estimate *21*
Wild and Hatchery Timing *22*
Survival of Hatchery Release Groups *24*
Egg-to-Migrant Survival of Naturally-Produced Fry *25*
CHINOOK 27
Catch *27*
Catch Expansion *28*
Size *28*
Trap Efficiency *31*
Production Estimate *31*
Egg-to-Migrant Survival *34*
COHO 34
Catch *34*
Size *35*
Catch Expansion *36*

Trap Efficiency *36*
Production Estimate........ *37*
STEELHEAD AND CUTTHROAT........ 37
Catch........ *37*
Size........ *37*
Catch Expansion........ *38*
Trap Efficiency *38*
Production Estimates........ *38*
MORTALITY........ 39
INCIDENTAL SPECIES 39

BEAR CREEK RESULTS 40

SOCKEYE 40
Catch........ *40*
Trap Efficiency *40*
Production Estimate........ *41*
CHINOOK 42
Catch........ *42*
Catch Expansion........ *42*
Size........ *43*
Trap Efficiency *45*
Production Estimate........ *45*
Egg-to-Migrant Survival *47*
COHO........ 47
Catch........ *47*
Size........ *47*
Trap Efficiency *48*
Production Estimate........ *48*
STEELHEAD AND CUTTHROAT........ 51
Catch........ *51*
Size........ *51*
Trap Efficiency *51*
Production Estimate........ *52*
MORTALITY........ 52
INCIDENTAL SPECIES 52

CITATIONS........ 53

LITERATURE 53
PERSONAL COMMUNICATIONS........ 54

APPENDIX A: DAILY ESTIMATED CEDAR RIVER WILD AND HATCHERY SOCKEYE FRY MIGRATION INTO LAKE WASHINGTON, 2002. .... **55**

APPENDIX B: ESTIMATED DAILY MIGRATIONS OF CHINOOK, COHO, STEELHEAD AND CUTTHROAT, CEDAR RIVER 2002. .... **59**

APPENDIX C: ESTIMATED SOCKEYE, CHINOOK, COHO, STEELHEAD AND CUTTHROAT DAILY MIGRATIONS, BEAR CREEK 2002 .... **64**

LIST OF TABLES

Table 1. Hatchery-produced sockeye fry released at four locations, Cedar River 2002. 9

Table 2. Trap efficiency tests using sockeye fry released from three points on the Logan Street Bridge and were separated by at least one hour, Cedar River 2002. 19

Table 3. Sockeye fry otolith sampling results, Cedar River 2002. 20

Table 4. Day:night catch rate ratios of sockeye fry estimated using the night before and the night after the daytime interval, Cedar River scoop trap 2002. 21

Table 5. Estimated 2002 Cedar River wild and hatchery sockeye fry migrations entering Lake Washington with 95% confidence intervals. 21

Table 6. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River. 23

Table 7. In-river survival estimates of hatchery sockeye fry, Cedar River 2002. 26

Table 8. Estimated egg-to-migrant survival of naturally-produced sockeye fry in the Cedar River relative to peak mean daily flows during the incubation period as measured at the USGS Renton gage, brood years 1991-2001. 26

Table 9. Chinook day to night catch ratios for Cedar River fry trap, 2002. 29

Table 10. Mean chinook fork length (mm), standard deviation, range, sample size, and catches in the fry and screw traps, Cedar River 2002. 30

Table 11. Estimated chinook capture rates from grouped screw trap efficiency tests, Cedar River 2002. 31

Table 12. Independent weekly estimates of chinook migration, Nw, from the fry and screw traps with results from Z-test comparison of the weekly estimates (p = 0.05), Cedar River 2002. 32

Table 13. 2002 Cedar River juvenile chinook production estimate and confidence intervals. 32

Table 14. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a January 1 to July 13 migration period, for Cedar River broods 1998 to 2001. 32

Table 15. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998 to 2001, Cedar River. 34

Table 16. Weekly mean coho fork length, standard deviation, range, sample size and catch from the Cedar River screw trap, 2002. 35

Table 17. Coho smolt recapture rates from grouped screw trap efficiency tests, Cedar River 2002. 36

Table 18. Weekly mean fork lengths, standard deviations, ranges, sample sizes and catches for steelhead and cutthroat trout, Cedar River screw trap 2002. 38

Table 19. Sockeye fry trap efficiency test summary by fry trap position, Bear Creek 2002. 40

Table 20. 2002 Bear Creek sockeye fry migration estimate with 95% confidence intervals. 41

Table 21. Chinook and coho mean fork lengths, standard deviations, ranges, sample sizes, and catches in the Bear Creek fry and screw trap, 2002. 44

Table 22. Chinook 0+ trap efficiency test results by date, Bear Creek 2002. 45

Table 23. Estimated 2002 Bear Creek wild chinook 0+ migration entering Lake Washington with 95% confidence intervals. 46

Table 24. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a February 1 to July 13 migration period, Bear Creek broods 1998 to 2001. 47

Table 25. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998-2001, Bear Creek. 47

Table 26. Estimated coho smolt recapture rates from grouped screw trap efficiency tests, Bear Creek 2002. 49

Table 27. Mean fork lengths, standard deviations, ranges, sample sizes, and catches of steelhead and cutthroat by statistical week, Bear Creek screw trap 2002. 51

LIST OF FIGURES

Figure 1. Site map of the lower Cedar River watershed depicting the fry and screw trap locations, hatchery sockeye release sites, and trap efficiency test release sites for the 2002 trapping season. 3

Figure 2. Trap efficiency tests for Cedar River scoop trap using sockeye fry from mid-channel and left bank release positions related to daily average flow, 2002. 19

Figure 3. Estimated daily migration of wild and hatchery Cedar River sockeye fry into Lake Washington and mean daily flow, 2002. 22

Figure 4. Cumulative wild and hatchery sockeye fry migration timing, Cedar River 2002. 23

Figure 5. Linear regression of median migration Julian Calendar date for wild Cedar River sockeye fry as a function of the sum of February 1-28 daily average temperatures as measured at the USGS Renton Gaging Station #12119000 for brood years 1992-2001, with 2000 as an outlier. 24

Figure 6. Exponential regression of wild sockeye egg-to-migrant survival from brood years 1991 to 2001 as a function of peak flow during the winter egg incubation period, Cedar River. 27

Figure 7. Chinook day to night catch rate ratios, Cedar River screw trap 2002. 29

Figure 8. Weekly ranges and mean fork lengths for chinook migrants captured in the Cedar River fry and screw traps, 2002. 30

Figure 9. Daily estimated chinook migration and daily average flow, Cedar River 2002. 33

Figure 10. Cumulative percent migration of age 0+ chinook, Cedar River 2002. 33

Figure 11. Weekly average ratio of day to night coho catch rates, Cedar River screw trap 2002. 34

Figure 12. Weekly ranges and mean fork lengths for coho smolts captured in the Cedar River screw trap, 2002. 35

Figure 13. Estimated daily migration of coho smolts from Cedar River, 2002. 37

Figure 14. Estimated daily migration estimate of steelhead and cutthroat trout, Cedar River screw trap 2002. 39

Figure 15. Regression analysis of the relationship between average daily stream flow and trap efficiency measured with sockeye fry, Bear Creek fry trap Position 3, 2002. 41

Figure 16. Estimated daily migration of Bear Creek sockeye fry into Lake Washington and daily average flow, 2002. 42

Figure 17. Chinook day to night catch ratios related to flow, Bear Creek screw trap 2002. 43

Figure 18. Average and range of chinook 0+ fork lengths sampled from Bear Creek, 2002. 44

Figure 19. Estimated daily chinook 0+ migration from Bear Creek, 2002. 46

Figure 20. Average and range of fork lengths from coho smolts sampled from Bear Creek, 2002.... 48

Figure 21. Regression analysis of the relationship between average daily stream flow and coho trap efficiency, Bear Creek screw trap 2002. 50

Figure 22. Estimated daily coho smolt migration and daily average flow, Bear Creek screw trap 2002. 50

Figure 23. Daily estimated migration of steelhead and cutthroat trout and daily average flow, Bear Creek screw trap 2002. 52

EXECUTIVE SUMMARY

This report provides the results of monitoring five salmonid species as downstream migrants in 2002 from the two most heavily spawned tributaries in the Lake Washington Basin: the Cedar River and Bear Creek. Monitoring sockeye fry production in the Cedar River began in 1992 to investigate the causes of low adult sockeye returns. This annual trapping program, which continued through 2002, was expanded in 1999 with the addition of a second downstream migrant trap to estimate the production of juvenile chinook salmon. With this trap we also estimate the production of coho, steelhead and cutthroat smolts.

Assessment of sockeye fry production began in the Sammamish system in 1997. We placed the trap in the Sammamish River at Bothell where we also operated it during the 1998 season. In 1999, to assess chinook production as well as sockeye, we moved this monitoring program to Bear Creek. Since 1999, as in the Cedar River, this trapping operation has also estimated the populations of coho, steelhead and cutthroat smolts.

Cedar River

Declining adult sockeye salmon returns in the late 1980's and early 1990's prompted the creation of a multi-agency effort to investigate causes for this decline. To determine which life-stages were experiencing poor survival, an evaluation of fry production was undertaken in the Cedar River beginning in 1992. Assessing the sockeye population at this location and life-stage separates freshwater production into river and lake components. This report documents our evaluation during 2002, the eleventh year of this project. As in previous years, the primary study goal was to estimate the season total migration of Cedar River wild and hatchery sockeye fry into Lake Washington. These estimates enable calculation of survival rates from egg deposition to lake entry, for hatchery fry from release to the trap, and for both production components from lake entry to subsequent life stages of smolts and adults.

Beginning in January and continuing into June, a floating inclined-plane screen (fry) trap located at river mile (R.M.) 0.7 in the Cedar River was operated to capture a portion of the sockeye fry migrating into Lake Washington (Figure 1). To estimate the capture efficiency of this trap, on 43 nights, dye-marked sockeye fry were released upstream of the trap. Due to the wide range of flows exhibited during releases, we were able to examine the effects of flow on capture rate. Linear regression analysis found that trap efficiency was significantly correlated to flow. Daily trap efficiency was estimated by linear regression using a lower limit of 2.4% at flows greater than 2,000 cfs.

Over the season, 12.5 million hatchery sockeye fry were released into the Cedar River from four locations. A portion of those fry (4.3 million) was released below the fry trap at the Cedar River Trail Park. All hatchery fry were internally marked by slightly manipulating water temperatures in the hatchery. On most nights of and following hatchery releases, fry caught in the trap were randomly sampled for thermal marks to determine the proportion of hatchery fish present.

Over the 101 nights trapped, 2.3 million sockeye fry were captured. From this catch and the capture efficiency data, we estimated a total of 43.7 million wild and hatchery sockeye fry entered Lake Washington in 2002. Based on otolith analysis and the hatchery release figures, we estimated that this total included 31.7 million wild fry and 12.0 million hatchery produced fry. Average survival to the trap of the 8.3 million hatchery fry released upstream was estimated at 92.7%. Survival was a function of migration distance and flow during release. Survival of fry released at the Landsburg Hatchery, located 21 miles upstream, averaged 78.6%. Middle River releases, 13 miles upstream of the trap, averaged 89.2% survival. Fry released at the Riviera site, located one mile above the trap survived at an average rate of 100%. We attribute these relatively high survival rates to low predation rates as a result of higher flows during the 2002 migration.

Migration timing for wild fry was near the average for the ten broods measured thus far. February temperature explains most of the variation in median migration dates between years. Median migration dates for hatchery and wild fry were March 4 and March 25, respectively.

Survival from egg deposition to lake entry of wild fry was estimated at 7.5%. This rate is the ratio of 31.7 million wild fry to an estimated deposition of 420 million eggs. Survival of the 2001 brood was approximately the expected value in response to peak incubation flow. With the peak incubation flow of 1,930 cfs, the relationship between peak incubation flow and egg-to-migrant survival developed over the previous nine broods predicted a survival of 8.4%.

In response to the listing of the Puget Sound Chinook Evolutionary Significant Unit (ESU) under the Endangered Species Act as a threatened species, we expanded the existing sockeye fry monitoring program in 1999 to include an assessment of the natural chinook production in the Cedar River. The gear we operate each year starting in January to assess sockeye fry production also captures chinook fry. To capture the larger, later migrating chinook, which we classify as "smolts", we installed a screw trap at R.M. 1.1, and operated it until July.

Juvenile production was estimated through applying capture rate estimates to catch data. From the start of the season in January through mid-April, we used the capture rate data generated with releases of marked sockeye fry to estimate the migration of chinook fry. Screw trap efficiency was estimated by releasing groups of fin-marked chinook smolts above the trap.

Age 0+ chinook production from the Cedar River was estimated at 119,674 in 2002. Timing was bi-modal with fry emigrating in January through March comprising two-thirds (79,799) of the total migration. The smolt migration, which primarily occurred in May and June, was estimated at 39,875. Egg-to-migrant survival was estimated at 6.7%. Over the season, age 0+ chinook increased in size from less than 40 mm in January to over 100 mm by July.

Over the season, based on actual and projected catches and estimates of capture rates we estimated the migrations of coho, steelhead and cutthroat smolts at 60,513, 950, and 3,600, respectively.

Bear Creek

We installed the fry trap on Big Bear Creek 100 yards downstream of the Redmond Way Bridge and operated it from February 1 through April 11. On April 12, we replaced it with a screw trap that fished until the morning of July 16. Using the approach described for the Cedar River, we estimated the downstream migrant production of wild sockeye fry, age 0+ chinook, coho, steelhead, and cutthroat smolts.

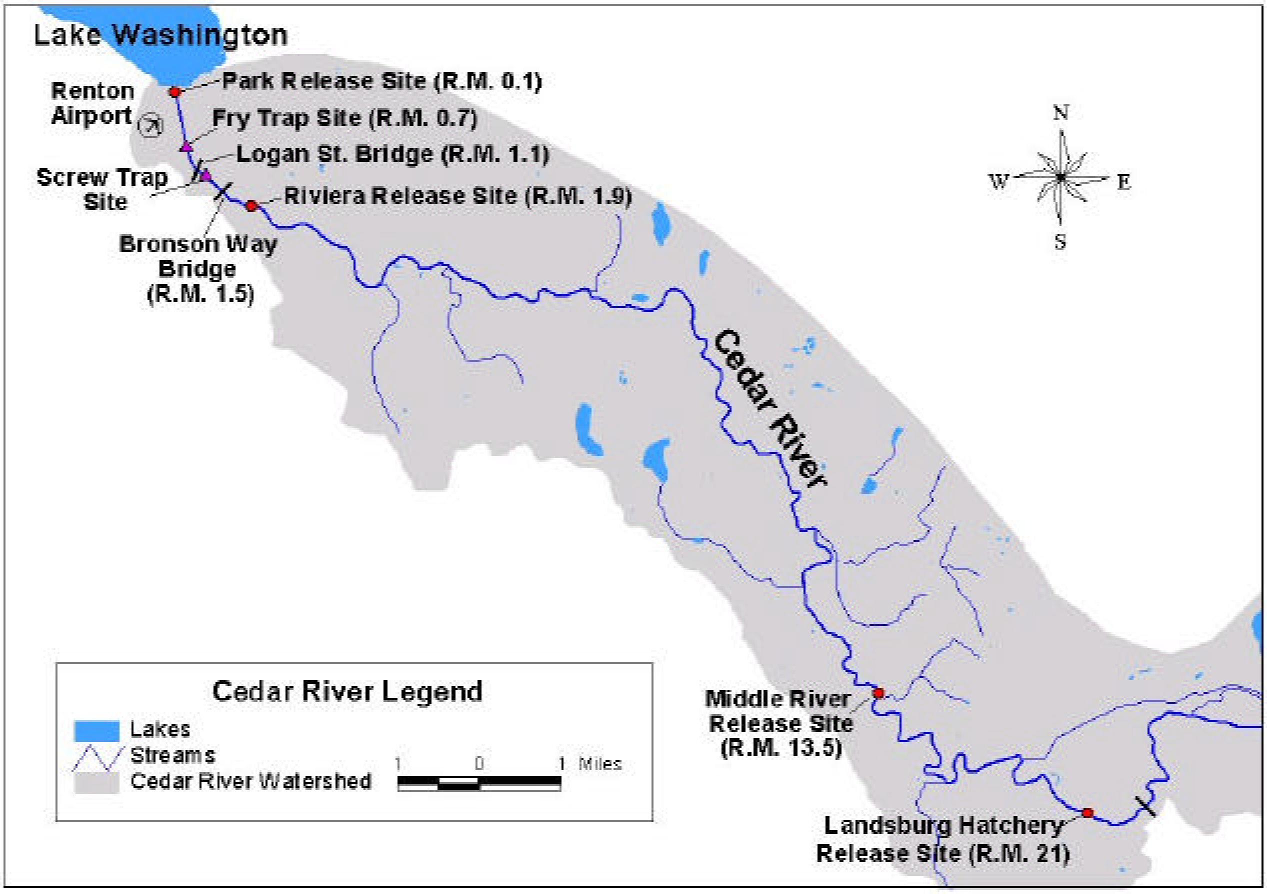

Figure 1. Site map of the lower Cedar River watershed depicting the fry and screw trap locations, hatchery sockeye release sites, and trap efficiency test release sites for the 2002 trapping season.

The scoop trap was moved twice during the fry trapping season in order for the trap to fish properly. Capture rates were estimated for each position of the trap. The average trap efficiencies for the first two positions were 12.4% and 16.5%. While the trap fished in the third position, using logarithmic regression analysis, flow described most of the variation between trap efficiency tests. This regression was used to predict daily efficiency while the trap fished in the third position. Capture rate of sockeye fry in the screw trap averaged 9.5%.

Capture rates for sockeye fry, chinook and coho smolts were evaluated throughout the season. Applying the respective capture rate estimates to actual catches estimates the production of sockeye fry, age 0+ chinook, and coho smolts at 2.7 million, 21,454, and 58,212.

As in previous years, chinook migration timing was bimodal, with most of the migration occurring in May and June. Chinook size increased from less than 40 mm in February to over 90 mm by July.

For the season, we also estimated the production of wild steelhead and cutthroat smolts at 60 and 2,775, respectively.

INTRODUCTION

Adult sockeye salmon returns to the Lake Washington system have declined from peak runs in excess of 600,000 fish as recently as 1988, to under 100,000 fish in subsequent years. In 1991, a broad-based group was formed to address this decline. Resource managers developed a program to investigate the cause(s) of the sockeye decline through research and population monitoring in combination with an artificial production program. Information generated by these efforts will be used to improve management of Lake Washington sockeye salmon.

At a gross-scale, sockeye life history can be partitioned into a freshwater incubation and rearing phase and a marine rearing phase. Existing management information indicated that marine survival had averaged 11.4%, varying eight-fold (2.6% to 21.4%), for the 1967 to 1993 broods with no apparent decline over the data set (WDFW unpublished data). In contrast, however, survival during the freshwater phase declined during this period.

During the freshwater phase, the majority of sockeye production involves two freshwater habitats: the stream, where spawning, egg incubation, fry emergence, and migration to the lake occurs; and the lake, where virtually all of the juveniles rear for one year before emigrating to the ocean as smolts. Measuring survival rates in both of these habitats will help in defining possible causes for population declines. In 1992, we developed the trapping gear and methodology to estimate wild and hatchery sockeye fry production from the Cedar River and began monitoring. Monitoring sockeye fry production in the Sammamish Slough began in 1997 and since 1999 has continued in Bear Creek.

The Puget Sound Chinook Evolutionary Significant Unit (ESU) was listed under the Endangered Species Act as a threatened species in March 1999 by the National Marine Fisheries Service. In the Lake Washington watershed, it was evident that planning efforts would be more effective if more were known about the habitat requirements, early life history, freshwater productivity, and survival of chinook salmon. Baseline information was available on the number of spawners, but adult counts provide little insight into survival during specific life stages. Estimating the number of juvenile migrants facilitates separating survival into two components: egg-to-migrant (freshwater) and migrant-to-returning adult. In the lake Washington system, this later stage also includes passage through the lake, Ship Canal, Locks as well as the marine environment. This provides a more direct accounting of the role that stream habitats play in regulating salmon production (Seiler *et al.* 1981, Cramer *et al.* 1999).

The downstream migrant evaluations conducted in the Cedar River and Bear Creek in 1999 were the first in the Lake Washington Basin directed at estimating the production of wild juvenile chinook. Since chinook migration occurs in two components, fry and smolt, we employed two different gear types. The scoop trap gently captures fry but larger migrants can avoid it. For the later-timed smolt migration we used a rotary screw trap.

Cedar River

Since 1992, we have operated a downstream migrant scoop trap in the lower Cedar River to evaluate the production of wild and hatchery sockeye fry (Seiler *et al*. 2002). Production of sockeye fry at the Landsburg Hatchery on the Cedar River began with the 1991 brood. This brood, released in 1992, and all subsequent sockeye incubated at this hatchery, has been identified with thermally-induced otolith-marks (Volk *et al.* 1990). In 1995, we evaluated the effect of flow on survival using ten hatchery groups released over a range of flows. Results demonstrated that in-river fry survival is largely a function of flow (Seiler and Kishimoto 1996).

We have also determined, over the ten brood years measured that the survival from egg deposition to fry emigration is largely a function of the severity of peak flows in the Cedar River during the egg incubation period (Seiler *et al.* 2001). Therefore, over the range of spawning population levels we have thus far evaluated, the numbers of naturally produced sockeye fry entering Lake Washington are the product of the number of eggs deposited and the flow affected survival rate.

In the summer of 1998, the lower Cedar River was dredged to reduce the flooding potential (USACOE 1997). This project lowered the streambed and created a wider and deeper channel, which reduced the velocity to near zero where the fry trap was located (R.M. 0.25). This dramatic change in the channel required moving the trap location in 1999 and 2000. In addition, we expanded the trapping program in 1999 to also evaluate the production of juvenile chinook (Seiler *et al.* 2003). To effectively capture larger chinook, in addition to the fry trap we elected to deploy and operate a different gear type (a screw trap) in faster water. Concurrent operation of the fry and screw traps assessed the capture and size biases of each trap.

Bear Creek

In 1997 and 1998, we operated a downstream migrant trap in the Sammamish Slough at Bothell to estimate the contribution of sockeye fry to Lake Washington from the Sammamish portion of the watershed. While this operation accomplished its goal of estimating sockeye fry production, velocities in the Sammamish Slough were too low to capture migrants larger than sockeye fry. Therefore, assessing the production of chinook and other migrants required selecting a trapping location with sufficient velocity.

With sockeye escapements in excess of 50,000 adults in some years, Bear Creek is the most heavily spawned tributary in the Sammamish watershed. Therefore, we elected to move the downstream migrant trapping operation in 1999 to the lower end of this stream where velocities were adequate. In addition to estimating chinook and sockeye production, operating the trap in high enough velocity to capture coho, steelhead and cutthroat smolts enabled estimating their production from Bear Creek as well.

GOALS AND OBJECTIVES

The overall goal of this project is to quantify the downstream migrant populations of sockeye, chinook and coho salmon and steelhead and cutthroat trout from the Cedar River and Bear Creek. In addition to estimating the daily migration for each species, describing their size at time and collecting additional biological data will enable accomplishing the following objectives.

Chinook

1. **In-river survival of natural production.** Estimating the in-river (egg-to-migrant) survival through relating total migrant production to the estimated egg deposition. Over time, explaining significant variation in this rate among broods, as a function of spawner abundance and flows, will determine the relative importance of these factors.
2. **Fry and smolt production.** Relating the proportions of fry and smolts to brood specific factors will identify production determinants.
3. **Lake/marine survival of natural production.** Estimating the combined survival through the lake, the Ballard Locks, and the marine environment via relating subsequent adult returns to the juvenile productions.
4. **Tag wild chinook.** As part of the multi-agency study to assess survival of juvenile salmon through the lake system, wild chinook emigrating from the Cedar River and Bear Creek will be injected with PIT tags.

Sockeye

1. **Survival of natural production.** Relating the estimate of wild fry produced to the estimated egg deposition measures the overall success of natural spawning. Significant variation in this rate among broods, as a function of spawner abundance, predator populations, and flows will be evaluated to assess stream carrying capacity.
2. **The season total of fry entering the lake.** Relating the combined estimate of wild and hatchery fry to the smolt production the following spring will measure rearing survival within the lake. Over time this information will help assess predation rates and the lake's carrying capacity. Relating brood year adult returns to the total fry production measures overall survival through the lake and marine environments.
3. **Survival of hatchery fry by release group (Cedar River only).** Correlating in-river survival of hatchery fry release groups with release location, timing, flow and total fry abundance will help explain the effects of habitat and environmental conditions on the in-river predation rates of hatchery and wild fry.
4. **Incidence of hatchery fry in the population at lake entry (Cedar River only).** Comparing this rate with the incidence of hatchery fish in the population at later life stages (smolts and adults) will assess relative hatchery and wild survival rates.
5. **Migration timing of wild and hatchery fry.** Comparison of the timing difference between wild and hatchery fry with subsequent survival to return rates will contribute to optimizing management decisions in the Cedar River.

Coho, Steelhead, and Cutthroat

Quantifying the annual production of these smolt populations will measure the ecosystem health of the Cedar River and Bear Creek. Population ratios between these species are indicative of habitat condition and fisheries management.

METHODS

Trapping Gear and Operation

Cedar River

Fry (Scoop) Trap

The fry trap consists of a low-angle inclined-plane screen trap (3 ft wide by 2 ft deep by 9 ft long) suspended from a 40x15 ft steel pontoon barge. The structure resembles the larger traps we use to capture smolts in larger river systems throughout the state (Seiler *et al.* 1981). Lowered to a depth of 16 inches, the fry trap screens a cross-sectional area of 4 ft^2. The trap was positioned at RM 0.7, just downstream of the South Boeing Bridge in the thalweg, approximately 25 ft off the west bank.

The fry trap was operated at night from mid-January through May. Trapping began before dusk and continued past dawn each night. Trapping also occurred during a few daylight intervals. Captured fish were removed from the trap and counted each hour. Large sockeye fry catches were counted using an electronic counter. Calibration of this electronic counter in previous seasons determined that it counted 96.6% of the actual number of fish passing through it.

On nights that hatchery fish were present, a sample of the catch was collected for otolith analysis. To insure that the samples were not biased by differences in migration timing between wild and hatchery fry, we retained a constant proportion of each hour's catch over the entire night. Each morning, we gently stirred the retention tank to thoroughly mix the fry, and then we collected 155 fry that we placed in a labeled jar of alcohol.

Over the season, 12,561,000 hatchery-produced fry were released into the Cedar River (Table 1). Thirty-four percent of this production (4,234,000) was released below the trap at the Cedar River Trail Park, 23% (2,861,000) was released directly from the hatchery at Landsburg, 20% (2,527,000) was transported downstream and released mid-river at R.M. 13.5, and 23% (2,900,000) was transported to the lower river and released at the Riviera Apartments site at R.M 1.9. Releases at Landsburg occurred on seven nights, from January 28 to March 7. Mid-river releases occurred on seven nights between February 7 and March 14. Fry were released at the Riviera site on eight nights, between January 22 and March 27. Releases below the trap occurred on four nights, between February 15 and May 21. The group sizes released above the trap ranged from 72,000 to 657,000 fry, and those released below the trap ranged from 883,000 to 1,177,000 fry. Hatchery fry were identified by eleven otolith codes: early, middle, and late releases from each release site, except there were no late releases from Landsburg.

Screw Trap

We used a 5 ft diameter screw trap supported by a 15 ft wide by 30 ft long steel pontoon barge (Seiler *et al.* 2003). As in the previous three seasons, we positioned this trap at RM 1.1, just upstream of the Logan Street Bridge near the right bank. Screw trap operation began mid-April and continued through mid-July. The catches were enumerated at dusk and in the early morning in order to discern diel movements. In May, we began to lift the trap during the daylight hours to avoid any potential hazard to recreational floaters using the river. By design, this trap allowed sockeye fry to escape from the live-box. All chinook, coho, steelhead, and cutthroat smolts were enumerated by species and randomly sampled for size (fork length).

Table 1. Hatchery-produced sockeye fry released at four locations, Cedar River 2002.

Release Timing	Release Date	Riviera	Middle	Landsburg	Below Trap
Early	01/22	201,000			
	01/24	319,000			
	01/28			310,000	
	02/07		322,000		
	02/11			642,000	
	02/12			559,000	
	02/15				883,000
	02/16			72,000	
	02/20			623,000	
	02/21		201,000		
Middle	02/27	277,000	260,000		
	02/28			325,000	
	03/01		315,000		
	03/04				1,177,000
	03/05		657,000		
	03/06	318,000	318,000		
	03/07	333,000		330,000	
	03/11				1,061,000
Late	03/12	556,000			
	03/13	564,000			
	03/14		454,000		
	03/21				1,122,000
	03/27	332,000			
Total		2,900,000	2,527,000	2,861,000	4,243,000

Bear Creek

Fry Trap

We started the trapping season in Bear Creek with a low-angle inclined-plane screen trap (3 ft wide by 9 ft long). This gear, identical to the trap employed in the Cedar River, was suspended from a 30x15 ft steel pontoon barge positioned approximately 100 yards downstream of Redmond Way, below the railroad trestle in the middle of the channel. Trapping began in late January and ended mid-April. On nearly every date the trap was operated, we began trapping before dusk and continued past dawn. On several dates we also operated the trap during daylight hours. Captured fish were removed from the trap and counted at various intervals from hourly to several hours depending on migration rates.

Screw Trap

In mid-April we replaced the fry trap with a 5 ft diameter screw trap. Screw trap operation began on April 12 and continued through July 16. Catches were usually enumerated at dusk and in the early morning. All chinook, coho, steelhead, and cutthroat smolts were enumerated by species and randomly sampled for size (fork length).

Trap Efficiency

Cedar River

Fry Trap

We estimated the capture rate for sockeye fry in the Cedar River fry trap by releasing marked sockeye fry at the Logan Street Bridge (R.M. 1.1) over a number of nights throughout the season. On most such nights we released 3,000 sockeye fry. Fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). Marked fry were usually equally distributed between left bank, mid-channel, and right bank release points from the bridge. When fewer fish were being released, the marked fry were released from the mid-channel point only or the left and right bank points. Pooled (left bank, mid-channel, and right bank) group recovery rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Screw Trap

Capture efficiency for the screw trap was determined for chinook and coho smolts. Groups of 50 or more smolts of each species were anesthetized in a solution of MS-222 and marked with variations of partial upper and lower caudal fin clips. Smolts were marked in the morning, and allowed to recover from the anesthetic during the day in flow through buckets suspended in calm river water. In the evening, the groups were released from the Bronson Way Bridge located one-half mile upstream. In the morning, the catch was examined for marks. Recapture rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Bear Creek

Fry Trap

In Bear Creek, we estimated the fry trap capture rate for sockeye by releasing groups of marked sockeye fry approximately 30 yards upstream of the trap on a number of nights over the season. Fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). Recapture rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Screw Trap

Capture efficiency for the screw trap was estimated for chinook and coho smolts on a number of days over the season. Groups of smolts of each species were anesthetized in a solution of MS-222 and marked with partial caudal fin clips. The smolts were marked in the morning, and allowed to recover from the anesthetic during the day. In the evening, the groups were released from the Redmond Way Bridge or 30 yards upstream of the trap. Recapture rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Production Estimation

Cedar River

Fry Trap

Estimation of total sockeye and chinook fry migrations occur in several steps. The data collected for each species every night, *i*, consisted of:

- count of total fry captured during a nighttime trapping interval - C_i, and
- flow - f_i.

Data taken less frequently included:

- count of total fry captured during a daytime trapping interval - C_d, and
- trap efficiency: proportion of marked fry released above the trap and subsequently retaken - $\hat{e}_i$.

Sockeye
Sockeye fry catch was estimated for nighttime periods when the trapping did not occur. Straight-line interpolation based on the catch from adjacent nights was used to estimate catch when one or more entire nights were not fished. Where the estimate was made for only a single night, the variance was estimated by the variance of the mean (i.e., the interpolated catch);

$$Var(\overline{C}_i) = \frac{\sum(\hat{C}_i - \overline{C}_i)^2}{n(n-1)} + \frac{\sum Var(\hat{C}_i)}{n}$$ **Equation 1**

where;

$$n = \textit{Number of sample nights used in the interpolation,}$$
$$\hat{C}_i = \textit{Nightly catch estimates used to estimate the un-fished interval, and}$$
$$\overline{C} = \textit{Interpolated nightly catch estimate.}$$

Where the nightly catch estimate was interpolated for two or more consecutive nights, the variance for each interpolated catch estimate was approximated by scaling the coefficient of variation (CV) of the mean catch from the adjacent night fishing periods by the interpolated catch estimates using;

$$Var(\hat{C}_i) = \left[\hat{C}_i\left(\frac{\sqrt{Var(\overline{C}_i)}}{\overline{C}_i}\right)\right]^2$$ **Equation 2**

Sockeye catch was also estimated when the trap was not operated continuously through the entire nighttime period. Where the trap was operated intermittently through the night, catch during the un-fished interval(s) was (were) estimated by;

Equation 3

$$\hat{C}_u = T_u \overline{R}$$

where;

$$T_u = \textit{Hours during non-fishing period u, and}$$
$$\overline{R} = \textit{Mean catch rate (fish/hour) from adjacent fished periods.}$$

The variance was estimated by;

Equation 4

$$Var(\hat{C}_u) = T_u^{\,2} Var(\overline{R})$$

where;

$$V(\overline{R}) = \textit{The variance of the mean catch rate from adjacent fished periods.}$$

The total catch on night *i* was estimated by the sum of the catches from the fished periods, *f*, and un-fished periods, *u*. The variance of the nightly catch was estimated by the sum of the variances for the un-fished periods, *u*, during night *i*.

Once total nightly catch was estimated, wild and hatchery catch components were estimated. Otolith sampling was used to estimate hatchery catch during most nights. The proportion of sockeye hatchery fry by release group in the nightly catch $(\hat{p}_{hi})$ was estimated using the number of otolith-marks (m_{hi}) observed in the nightly sample (o_i) by;

$$\hat{p}_{hi} = \frac{m_{hi}}{o_i} \qquad \textbf{Equation 5}$$

and its variance by;

$$Var(\hat{p}_{hi}) = \frac{\hat{p}_{hi}(1-\hat{p}_{hi})}{o_i} \qquad \textbf{Equation 6}$$

The number of hatchery group *h* caught on night *i* was estimated by;

$$H_{hi} = \hat{C}_i \hat{p}_{hi} \qquad \textbf{Equation 7}$$

and its variance using the delta method (Goodman 1960) by;

$$Var(H_{hi}) = Var(\hat{C}_i)\,\hat{p}_{hi}^{\,2} + \hat{C}_i^{\,2}\,Var(\hat{p}_{hi}) - Var(\hat{p}_{hi})Var(\hat{C}_i) \qquad \textbf{Equation 8}$$

The total number of hatchery fry caught on night *i* and the variance of the estimate were calculated by modifying Equations 7 and 8, respectively. The modifications involved substituting the proportion of hatchery fry from all groups in the nightly catch, $\hat{p}_i$, and the variance of this proportion, $Var(\hat{p}_i)$, for the proportion of hatchery fry from each release group, $\hat{p}_{hi}$, and its variance, $Var(\hat{p}_{hi})$, respectively.

Otolith sampling was used to estimate the composition of sockeye hatchery fry in catches during the nights of and following releases. Where otolith samples were not available for Landsburg releases, interpolation was used to estimate nightly wild catch based on the wild catch estimates from the preceding and following nights. The estimate of nightly wild fry catch was then subtracted from the estimated total nightly catch to estimate the nightly hatchery fry catch. The trap did not fish during four hatchery releases during the season. Migrations during two Riviera releases were estimated by assuming 100% survival due to the proximity of the releases to the trap. No variances were calculated for those estimates. Migrations from the two Landsburg releases were estimated by using the average survival rate measured by otolith sampling. The variances of those nights were estimated by modifying Equation 1; replacing C_i with s_i, where s_i is survival of the hatchery group released during night *i*.

When wild sockeye fry catch required interpolation for only a single night, straight-line interpolation was used, therefore the variance for the nightly wild fry catch estimate was found by using Equation 1, substituting $Var(W_i)$ for $Var(C_i)$. Hatchery catch was then estimated by subtracting the estimated nightly wild fry catch estimate from the total nightly catch. The variance for the hatchery catch estimate, $Var(\hat{H}_{hi})$, was found by summing the total nightly catch estimate and the wild catch estimate variances.

Where the nightly wild catch estimate was interpolated for two or more consecutive nights, the variance for each interpolated catch estimate was estimated by scaling the CV of the mean catch from adjacent nights by the interpolated catch estimates using Equation 2.

In order to estimate total sockeye migration, daytime catches were estimated. Daytime catch was estimated using the average day catch rate to night catch rate ratio ($\overline{Q}$) based on trap operations conducted in 2002. Daytime catch (C_d) was calculated by multiplying the nighttime catch estimate by the proportion (F_d) of the 24-hour catch caught during daylight. The proportion of the sockeye catch caught during daytime interval *d* was estimated by;

$$F_d = \frac{T_d}{\frac{1}{\overline{Q}}T_n + T_d} \qquad \textbf{Equation 9}$$

and its variance by;

$$Var(F_d) = \frac{V(\overline{Q})T_d^{\ 4}}{\overline{Q}^4\left(\frac{1}{\overline{Q}}T_n + T_d\right)^4} \qquad \textbf{Equation 10}$$

where,

$$\begin{aligned} T_n &= Hours\ of\ night\ during\ 24\ hour\ period, \\ T_d &= Hours\ of\ day\ during\ 24\ hour\ period, and \\ Q_d &= Average\ day/night\ catch\ ratio. \end{aligned}$$

Daytime catch was estimated by applying the estimated proportion caught during day to the nighttime catch. The variance for each daytime catch was estimated using the delta method (Goodman 1960);

$$Var(\hat{C}_d) = \hat{C}_i^{\ 2}Var(F_d) + Var(\hat{C}_i)F_d^{\ 2} - Var(\hat{C}_i)Var(F_d) \qquad \textbf{Equation 11}$$

To assess the relationship between trap efficiency and stream flow over the season we used linear regression analysis. Where the linear regression was used to predict daily efficiency, the variance of the daily migration estimates were calculated by;

$$Var\left(\frac{C_i}{\hat{e}_i}\right) = \frac{Var(C_i)}{\hat{e}_i^{\ 2}} + \left(\frac{C_i}{\hat{e}_i^{\ 2}}\right)^2 M\hat{S}E\left(1 + \frac{1}{n} + \frac{(flow_i - fl\overline{o}w)^2}{(n-1)s_f^{\ 2}}\right) \qquad \textbf{Equation 12}$$

Due to the dependence of each estimated daily efficiency on the same linear regression equation, covariance between daily migration estimates were calculated by;

$$Cov\left(\frac{C_i}{\hat{e}_i},\frac{C_j}{\hat{e}_j}\right)=\frac{C_i}{\hat{e}_i^{\,2}}\frac{C_j}{\hat{e}_j^{\,2}}\left[Var(\hat{a})+flow_i flow_j Var(\hat{b})\right] \qquad \textbf{Equation 13}$$

Where a non-linear regression produced a better fit, the variance of the daily estimates were calculated by:

$$Var\left(\frac{C_i}{\hat{e}_i}\right)=\frac{Var(C_i)}{\hat{e}_i^{\,2}}+\left(\frac{C_i}{\hat{e}_i}\right)^2 M\hat{S}E\left(1+\frac{1}{n}+\frac{(flow_i-\overline{flow})^2}{(n-1)s_f^{\,2}}\right) \qquad \textbf{Equation 14}$$

Due to the dependence of each estimated daily efficiency on the same non-linear regression equation, covariance between daily migration estimates were calculated by;

$$Cov\left(\frac{C_i}{\hat{e}_i},\frac{C_j}{\hat{e}_j}\right)=\frac{C_i}{\hat{e}_i}\frac{C_j}{\hat{e}_j}\left[Var(\hat{a})+flow_i flow_j Var(\hat{b})\right] \qquad \textbf{Equation 15}$$

Where flow was not found to be a significant predictor of trap efficiency, the mean of all the season's trap efficiency tests was used;

$$\bar{e}=\frac{\sum_{i=1}^{n}\hat{e}_i}{n} \qquad \textbf{Equation 16}$$

The variances of the individual trap efficiency estimates and the mean trap efficiency estimate were found using;

$$Var(\hat{e}_i)=\frac{\hat{e}_i(1-\hat{e}_i)}{n} \qquad \textbf{Equation 17}$$

$$Var(\bar{e})=\frac{\sum(\hat{e}_i-\bar{e}_i)^2}{n(n-1)} \qquad \textbf{Equation 18}$$

Daily sockeye fry migrations were estimated by;

$$\hat{N}=\frac{(\hat{C}_i+\hat{C}_d)}{\bar{e}} \qquad \textbf{Equation 19}$$

The daily migration variance was estimated using the delta method (Goodman 1960);

$$Var(\hat{N})=\hat{N}^2\left(\frac{Var(\bar{e})}{\bar{e}^2}+\frac{\left(Var(\hat{C}_i)+Var(\hat{C}_d)\right)}{(\hat{C}_i+\hat{C}_d)^2}\right) \qquad \textbf{Equation 20}$$

When multiple flow efficiency strata were used, the migration estimate and variance for the strata were estimated using Equations 19 and 20, substituting the total catch over the stratum for daily catches in both equations. Season total migration and variance were estimated by summing the migration and variance estimates for each flow strata. Where trap efficiency was calculated using a simple mean efficiency over the season, the total migration and its variance were calculated using Equations 19 and 20, substituting the season total catch for the daily catches in both equations.

Survival of Cedar River naturally produced sockeye fry to lake entry is the ratio of the wild fry migration estimate to an estimate of potential egg deposition (PED).

The severity of peak flow during sockeye egg incubation had been found to explain most of the inter-annual variation in egg-to-migrant survival between the previous nine broods of Cedar River sockeye. A number of regression equations were used to evaluate this relationship once the 2001 natural fry production estimate was added to the dataset.

Chinook

Estimation of juvenile chinook migration followed similar procedures to that of the sockeye fry migration estimate described above. Where chinook nightly catch was estimated, the interpolated value was the mean of the preceding and following night's catch rates (R_i) expanded by the hours of the night not fished (T_u), therefore the variance for this estimate was calculated by;

$$Var(\hat{C}_i) = T_u^{\ 2} \frac{\sum(\hat{R}_i - \overline{R}_i)^2}{n(n-1)} \qquad \textbf{Equation 21}$$

Wild chinook fry catch during daytime intervals not fished were estimated in order to estimate total daily (24-hour) migrations. The estimates were made by using the average day catch rate to night catch rate ratio based from trap operations conducted in 2002. The catch during daytime *d* was estimated by;

$$\hat{C}_d = \overline{Q}\,\overline{R}_i\,T_d \qquad \textbf{Equation 22}$$

and its variance was estimated by;

$$Var(\hat{C}_d) = T_d^{\ 2}\left(Var(\overline{R}_i)\,\overline{Q}^{\,2} + Var(\overline{Q})\,\overline{R}_i^{\ 2}\right) \qquad \textbf{Equation 23}$$

where,

$\overline{Q}$ = *Average chinook day/night catch ratio measured for scoop trap,*

$\overline{R}_i$ = *Average night catch rate preceding and following daytime interval d, and*

T_d = *Hours of estimated daytime interval d.*

Daily chinook fry migration was estimated by using Equation 19. The total season migration was estimated by summing the daily migration estimates. The chinook fry season migration variance was estimated using Equation 20 when the average trap efficiency was used to estimate total migration. Where multiple flow efficiency strata were used, the season migration variance was estimated by summing the migration variance estimates for each flow strata using Equation 20.

In addition to estimating migration during the interval of trap operation, since initial catches indicated that the chinook migration was underway when trapping began, we approximated the migration occurring before fry trap operation began. Logarithmic extrapolation was used to estimate migration from January 1 to January 24. The variance was calculated by interpolating between the coefficients of variation.

Screw Trap

For nighttime intervals not fished and during nights when heavy debris decreased the fishing ability of the trap we estimated catch for the hours missed by applying catch rates interpolated from the preceding and following nighttime intervals trapped. Variances for these estimates were calculated using Equation 21. Daytime intervals not fished were estimated with Equation 22, and its variance by Equation 23.

As with the fry trap, the effect of flow on measured capture rates was assessed using linear regression analysis. Where flow did not appear to explain variation in trap efficiency, the mean capture rate from all efficiency tests was used to estimate migration for each species. Variances were calculated for the individual efficiency tests using Equation 17, and the mean trap efficiency using Equation 18. Equation 19 was used to estimate daily migration, and Equation 20 was used to estimate daily and total season variances of the migration estimates when using average efficiency.

Estimating the production of steelhead smolts and cutthroat trout involved approximating a season average capture rate since catches of these migrants were insufficient for directly assessing capture rate via mark and recapture. Instead, we used a reduced capture rate, estimated from previous studies, relative to that measured with coho smolts.

Bear Creek

Fry Trap

Estimation of total sockeye and chinook fry migrations followed the same steps as described for the Cedar River. Where flow significantly explained variation in trap efficiency, a linear regression was developed to predict daily efficiencies. Where flow appeared to marginally affect efficiency, flow strata were developed and the mean of the trap efficiency tests conducted within those flows were used to estimate migration. If flow did not appear to explain variation, the average trap efficiency was used (Equation 16) and its variance was calculated using Equation 18. Nightly migration was estimated using Equation 19, and the variance using Equation 20. Day catch during fry trap operation was minimal, and therefore not estimated. When trapping did not occur every night, interpolation was used to estimate the migration during un-fished nights and the nightly variance was calculated using Equation 1. The in-season production estimate was the sum of the nightly migration estimates, and the variance was estimated using Equation 20, substituting the total season catch for the nightly catch.

Screw Trap

Estimation of sockeye fry, chinook, coho, and steelhead smolts and cutthroat trout migrations occurred in several steps. The data collected every night consisted of the same as that collected at Cedar River. Trap efficiency was estimated using the same methods as the fry trap. Nightly migration was estimated using Equation 19, and the variance using Equation 20. The trap operated continuously; therefore, catch did not need to be estimated. The in-season production estimate was the sum of the nightly migration estimates. The variance of the total migration was estimated using Equation 20, substituting the total season catch for the nightly catch, when the season trap efficiency average was used to estimate migration.

CEDAR RIVER RESULTS

Sockeye

Trap Operation

Trap operation began on January 21, and continued on January 25, 27, and 29. From January 31, through April 28, the trap fished every night except on April 14 in order to complete a trap repair. Trapping after April 28 was intermittent and occurred on ten nights until the last day of trapping on May 29. Eleven daytime trapping intervals were fished, occurring on a weekly basis starting on February 13 and ending on April 24. On the following six nights we did not fish continuously: January 21, February 22, April 12, April 13, April 15, and April 16.

Catch

During the first night of trapping (January 21), the sockeye catch totaled 582 fry during the 4.5 hours fished. Catches increased and peaked at 72,099 fry on March 5 when there was a large release of hatchery fry from the Middle River release site. Catches decreased thereafter, and on our last day of trapping, May 29, we caught 194 fry. Our combined catch of wild and hatchery fry for the season totaled 2,258,248, which includes day catches of 6,220 fry. Catch data on the six partial nights were expanded to represent entire nights fished, which added an additional 30,804 fry. Adding the catch estimates for nights not fished, projects a total catch of 2,411,046 fry had we fished every night during the trapping season (January 21 through May 29) (Appendix A).

Catch during the first night of fishing (January 21) was expanded to represent the entire night. The trap had been pulled at 2300, and an additional 970 fry were estimated by applying the night's average catch rate to the hours we would have fished for the entire night. During four of the partial nights fished, the hour trapping intervals were reduced to 10, 15 or 20 minutes. Expansions for February 22, April 13, April 15, and April 16 resulted in additional catches of 6,123, 13,263, 5,831, and 3,748 fry, respectively. The other night, April 12, was expanded due to large woody debris that entered the trap and blocked flow during the 2300-hour fishing interval; the expansion resulted in an additional 869 fry.

Efficiency and Flow

Tests to determine the capture efficiency of the trap were conducted on 43 nights from February 1 to May 7. All groups were released from the Logan Street Bridge at similar times during the night, except for ten nights, in which one hour separated the three releases. Analysis of those ten releases indicated that efficiencies from the right bank release point were significantly different from those released at the left and mid-channel points (Table 2). The difference between release locations may be due to flow vectors and/or predation. In order to represent the distribution of the actual population, we chose to exclude the releases from the right bank. Many releases only occurred from the mid-channel position, and the right bank releases and recaptures were removed from the ten releases that were separated by an hour or more. The remaining six releases were partitioned to represent only mid-channel and left bank release positions. The numbers released from each location were known, and recaptures were estimated by applying the average proportion (79%) of recaptures from the mid-channel and left bank release positions estimated from the ten release groups separated by at least an hour.

Table 2. Trap efficiency tests using sockeye fry released from three points on the Logan Street Bridge and were separated by at least one hour, Cedar River 2002.

DATE	RIGHT BANK			MIDDLE CHANNEL			LEFT BANK		
	Released	Recovered	Efficiency	Released	Recovered	Efficiency	Released	Recovered	Efficiency
2/19	933	66	7.07%	881	61	6.92%	869	74	8.52%
3/10	1,061	38	3.58%	1,000	57	5.70%	1,048	83	7.92%
3/12	940	25	2.66%	943	64	6.79%	952	76	7.98%
3/15	601	17	2.83%	954	52	5.45%	1,148	73	6.36%
3/18	1,079	61	5.65%	1,146	98	8.55%	1,114	116	10.41%
3/19	1,006	40	3.98%	1,020	65	6.37%	1,006	90	8.95%
3/22	1,429	7	0.49%	1,390	69	4.96%	532	13	2.44%
3/24	948	23	2.43%	948	56	5.91%	948	78	8.23%
3/26	948	47	4.96%	952	83	8.72%	939	68	7.24%
4/17	945	39	4.13%	924	24	2.60%	1,038	37	3.56%
Average			3.78%			6.20%			7.16%
Total	9,890	363		10,158	629		9,594	708	

Adjusted recapture rates for the 43 efficiency tests ranged from 0.94% to 11.44%, and averaged 6.5%. A linear regression was used to evaluate the relationship between capture efficiency and flow, and a significant correlation was found ($p<0.05$, $r^2=0.38$) (Figure 2). Although the efficiency tests were quite variable among lower to mid flows, we believe that the regression best represented the actual efficiency response to flow. We base this contention on our experience in this system and others. This regression was used to estimate daily trap efficiency and migration when flows occurred within the range of flows observed during actual efficiency tests. In order to estimate efficiency at flows higher than 2,000 cfs, we chose to use the lowest believed efficiency test result (2.4%). We believe the observed efficiency of 0.94% at 1,940 cfs on April 16 is biased low due to heavy debris loads. Flows ranged from 679 to 1,940 cfs on the nights that efficiency tests were conducted and ranged from 561 to 2,320 cfs during the entire trapping period.

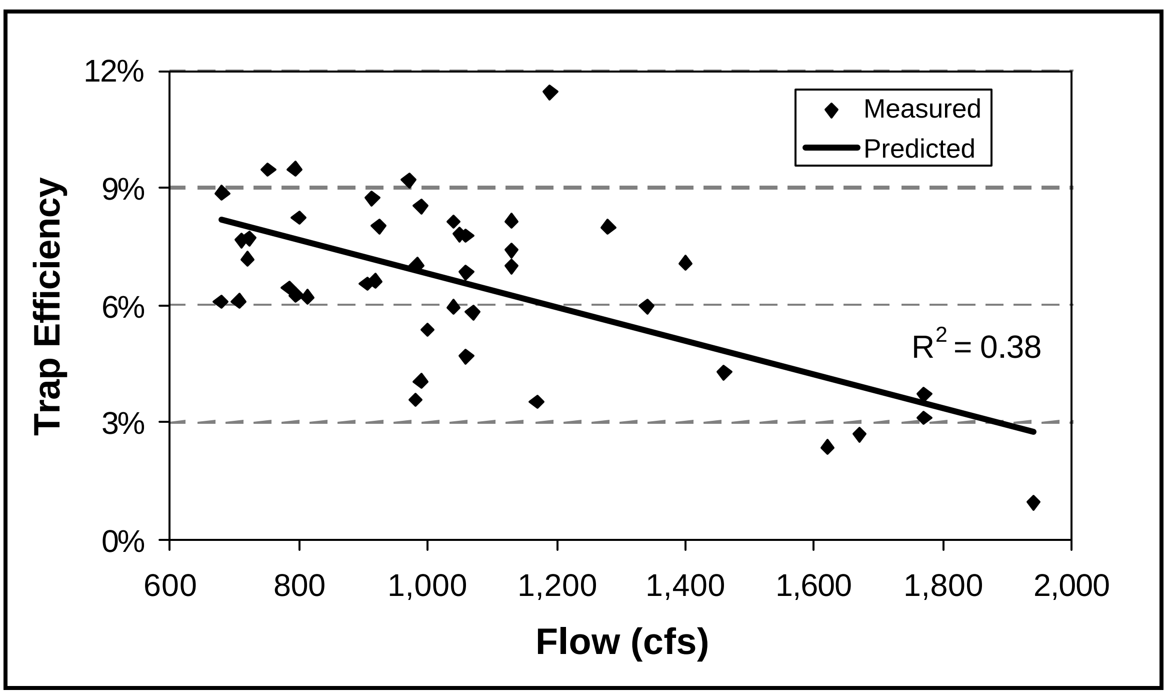

Figure 2. Trap efficiency tests for Cedar River scoop trap using sockeye fry from mid-channel and left bank release positions related to daily average flow, 2002.

Otolith Sampling

Otolith samples were collected on 21 nights of and following hatchery releases. Sampling did not occur on four hatchery release nights: two Landsburg releases on January 28 and February 11, and two Riviera releases on January 22 and 24. Over the 21 nights sampled, hatchery-produced fry comprised 45.5% of the 3,144 sockeye otoliths that were analyzed (Table 3). The incidence of hatchery fry in samples taken on the release nights ranged from 21.3% to 82.7% for Landsburg releases, 25.7% to 80.5% for Mid-River releases, and 43.2% to 62.7% for Riviera releases.

Otolith sampling revealed a few instances where otolith marked fish were recovered before they were scheduled for release. On March 14 and 15, 15.3% and 1.3% of the otoliths sampled, respectively, were identified as Riviera late releases (Table 3). This group of sockeye fry was to be released on March 27. When these anomalies in the data were found, the otoliths were re-examined and were found to have been read correctly. We surmise that these fish either escaped from the hatchery prior to release or were inadvertently released with another group.

Table 3. Sockeye fry otolith sampling results, Cedar River 2002.

Sample Date	Number Sampled	Number Marked	Percent Marked	Variance	Release Code	Release Location
02/07	149	120	80.5%	0.001059	E2	Middle
02/12	150	124	82.7%	0.000962	E1	Lansburg
		1	0.7%	0.000044	E2	Middle
02/13	150	9	6.0%	0.000379	E1	Landsburg
02/16	150	32	21.3%	0.001126	E4	Landsburg
02/17	150	2	1.3%	0.000088	E4	Landsburg
02/20	150	102	68.0%	0.001460	E1	Landsburg
02/21	150	39	26.0%	0.001291	E2	Middle
		2	1.3%	0.000088	E1	Landsburg
02/27	148	64	43.2%	0.001670	M3	Riviera
		38	25.7%	0.001298	M2	Middle
02/28	147	1	0.7%	0.000046	E1	Landsburg
		92	62.6%	0.001604	M1	Landsburg
		1	0.7%	0.000046	M2	Middle
03/01	150	95	63.3%	0.001559	M2	Middle
		2	1.3%	0.000088	M1	Landsburg
03/02	150	1	0.7%	0.000044	M1	Landsburg
		3	2.0%	0.000132	M2	Middle
03/05	150	109	72.7%	0.001333	M2	Middle
03/06	150	78	52.0%	0.001675	M3	Riviera
		53	35.3%	0.001533	M2	Middle
03/07	150	80	53.3%	0.001670	M3	Riviera
		34	22.7%	0.001176	M1	Landsburg
		2	1.3%	0.000088	M2	Middle
03/08	150	5	3.3%	0.000216	M1	Landsburg
		1	0.7%	0.000044	M2	Middle
		1	0.7%	0.000044	M3	Riviera
03/12	150	85	56.7%	0.001648	L3	Riviera
03/13	150	94	62.7%	0.001570	L3	Riviera
03/14	150	40	26.7%	0.001312	L2	Middle
		23	15.3%	0.000871	L3	Riviera
03/15	150	8	5.3%	0.000339	L2	Middle
		2	1.3%	0.000088	L3	Riviera
03/27	150	84	56.0%	0.001654	L3	Riviera
03/28	150	5	3.3%	0.000216	L3	Riviera
Total	3,144	1,432	45.5%			

Diel Migration

While the vast majority of sockeye fry migrate at night, daytime trapping indicated a small proportion of the migration occurred during the daylight. Over the 11 dates that we trapped during daylight intervals, the day to night catch rate (d:n) ratios ranged from 0.3% to 7.0% and averaged 2.0% (Table 4). Flows on these dates ranged from 712 to 1,770 cfs. The average d:n ratio was used to estimate daytime migrations for wild fry and for Mid-River and Landsburg hatchery releases. Riviera hatchery releases were not expanded due to their rapid movement downstream.

Table 4. Day:night catch rate ratios of sockeye fry estimated using the night before and the night after the daytime interval, Cedar River scoop trap 2002.

NIGHTTIME					DAYTIME						DAY:NIGHT	
Nights		Hours Fished	Catch	Catch/ Hour	Date	Time Down	Time Up	Hours Fished	Catch	Catch/ Hour	Ratio (D/N)	Flow (cfs)
02/12	02/13	28.50	48,923	1,717	02/13	7.00	17.00	10.00	101	10.10	0.59%	785
02/19	02/20	28.00	72,120	2,576	02/20	7.00	17.00	10.00	79	7.90	0.31%	712
02/27	02/28	26.50	91,203	3,442	02/28	7.00	18.00	11.00	300	27.27	0.79%	989
03/05	03/06	23.00	115,867	5,038	03/06	8.00	18.00	10.00	175	17.50	0.35%	1,080
03/11	03/12	24.00	102,319	4,263	03/12	6.50	16.00	9.50	438	46.11	1.08%	1,130
03/19	03/20	25.15	79,620	3,166	03/20	7.15	18.00	10.85	1,909	175.94	5.56%	1,040
03/26	03/27	23.50	71,068	3,024	03/27	6.00	18.00	12.00	574	47.83	1.58%	1,160
04/02	04/03	24.25	108,465	4,473	04/03	6.50	18.00	11.50	826	71.83	1.61%	1,180
04/10	04/11	23.50	70,752	3,011	04/11	6.50	19.00	12.50	895	71.60	2.38%	1,210
04/16	04/17	22.25	19,750	888	04/17	7.50	19.00	10.75	666	61.95	6.98%	1,770
04/23	04/24	20.50	24,458	1,193	04/24	6.00	20.00	14.00	257	18.36	1.54%	1,050
SEASON TOTAL		269.15	804,545	32,789				122.10	6,220	556.39		
Average											2.07%	
Variance											4E-05	

Production Estimate

We estimated 43.7 million sockeye fry entered Lake Washington from the Cedar River in 2002 (Table 5, Figure 3). The total included 31.7 million wild fry and 12.0 million hatchery-produced fry. To estimate fry migration before and after trapping, we selected migration starting and ending dates of January 1 and July 1. Linear extrapolation from January 1 to January 21 and from May 29 to July 1 resulted in an additional 329,000 and 75,000 wild fry, respectively. These migration components accounted for only 1% of the total wild estimate.

Table 5. Estimated 2002 Cedar River wild and hatchery sockeye fry migrations entering Lake Washington with 95% confidence intervals.

Component		Period	Dates	Estimated Migration	95% CI Low	95% CI High	Percent Standard Error	Prop. of Total
Wild		Before Trapping	January 1 - 21	328,790	38,043	619,537	45.1%	0.8%
		During Trapping	January 21 - May 29	31,269,106	16,154,467	46,383,745	24.7%	71.6%
		After Trapping	May 29 - July 1	75,133	0	154,020	53.6%	0.2%
			Wild Subtotal	31,673,029	16,555,388	46,790,669	24.4%	72.6%
Hatchery	Landsburg	During Trapping	January 28-March 8	2,249,090	2,064,598	2,433,581	4.2%	5.2%
	Middle	During Trapping	February 7-March 15	2,253,188	2,111,697	2,394,679	3.2%	5.2%
	Riviera	During Trapping	January 22-March 28	3,198,638	3,026,583	3,370,693	2.7%	7.3%
	Below Trap	During Trapping	February 15-March 21	4,272,000	4,272,000	4,272,000	0.0%	9.8%
			Hatchery Subtotal	11,972,916	11,683,676	12,262,155	1.9%	27.4%
			Total	43,645,945	28,525,537	58,766,352	17.7%	100.0%

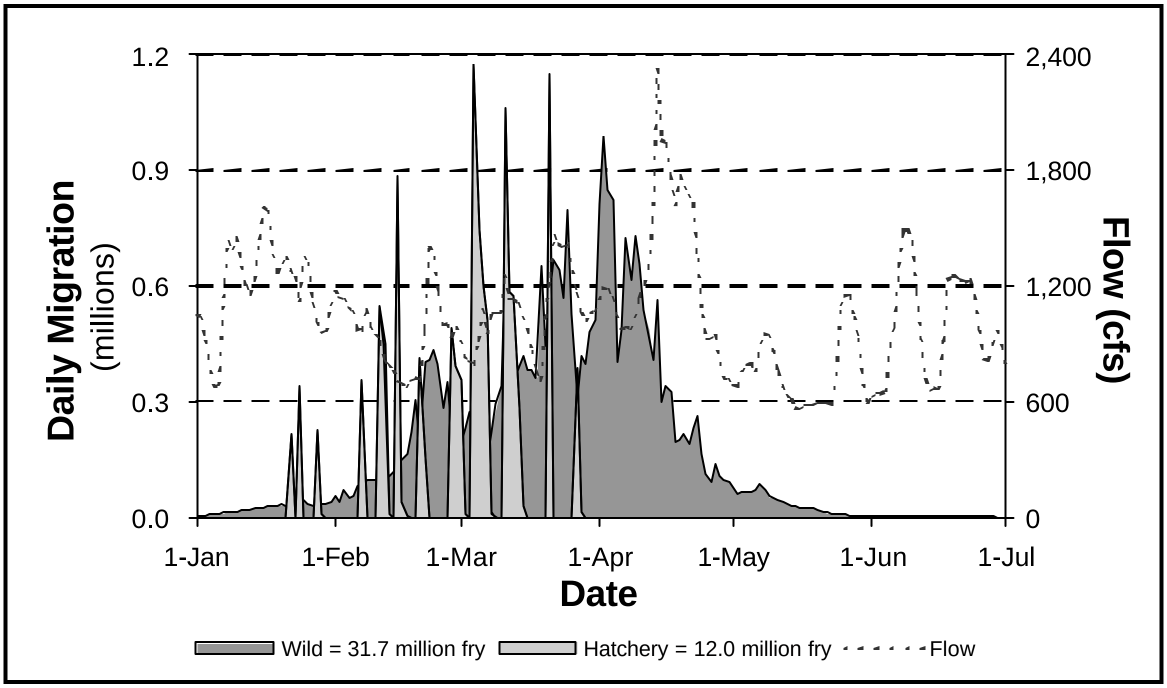

Figure 3. Estimated daily migration of wild and hatchery Cedar River sockeye fry into Lake Washington and mean daily flow, 2002.

Covariance resulting from incorporating a regression model to estimate capture rate of sockeye fry based on flow produced a relatively imprecise migration estimate (percent standard error = 24.4%). In comparison, rather than modeling the flow-efficiency relationship, simply averaging capture rates over the season yielded a production estimate of 30.0 million wild sockeye fry with a percent standard error of only 5.2% (95% CI ± 3 million fry). This estimate, however, is biased low because capture rate tests were not conducted during nights with high flows at the same frequency as on nights with lower flows. Therefore, the average capture rate of 6.5% is weighted toward lower flows and underestimates migration during higher flows. For this reason we elected to use the regression based approach to estimate total production.

Wild and Hatchery Timing

Releases of hatchery-produced fry began on January 22 and continued through March 27. The wild fry migration was under way when we began trapping on January 21, peaked during late March and early April, and declined to low levels by late May when we stopped trapping. The median migration date for hatchery fry occurred on March 4, while the median migration date for the wild migration occurred three weeks later on March 25 (Figure 4).

Wild timing in 2002 was average for the 11 broods evaluated thus far (Table 6). Over these broods, median migration dates for wild fry ranged from March 10 to April 7. Timing of hatchery fry in 2002 was also near average for the 11 broods so far evaluated. As in previous years, it appears that timing of the 2002 wild fry migration was related to stream temperature. Warmer temperatures result in earlier migration timing. After evaluating temperature data from throughout the period of fry incubation and migration, February stream temperatures best predicted migration timing (r^2 = 0.62) (Figure 5). Brood year 2000 was treated as an outlier due to extreme low flows and an earthquake, which triggered a landslide upstream that temporarily blocked flow. February stream temperatures averaged 6.1ºC in 2002, compared to 5.6ºC in 2001 and 6.7ºC in 1999.

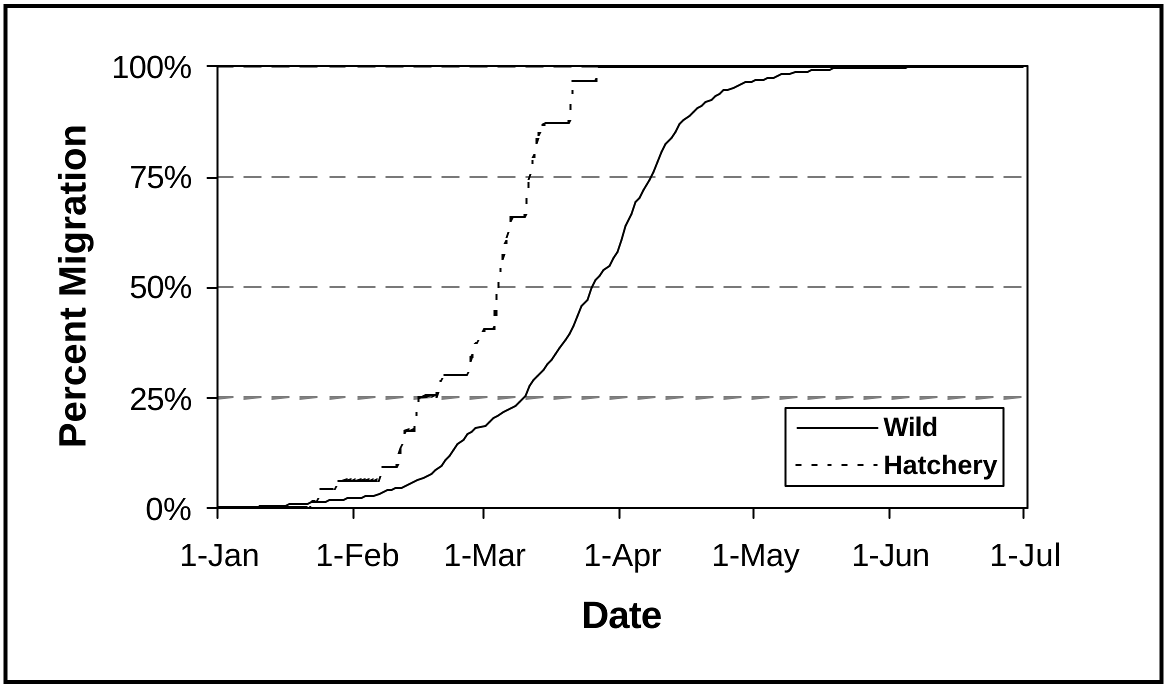

Figure 4. Cumulative wild and hatchery sockeye fry migration timing, Cedar River 2002.

Table 6. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River.

Brood Year i	Trap Year i+1	Median Migration Date Wild	Hatchery	Combined	Difference (days) W-H
1991	1992	03/18	02/28	03/12	19
1992	1993	03/27	03/07	03/25	20
1993	1994	03/29	03/21	03/26	8
1994	1995	04/05	03/17	03/29	19
1995	1996	04/07	02/26	02/28	41
1996	1997	04/07	02/20	03/16	46
1997	1998	03/11	02/23	03/06	16
1998	1999	03/30	03/03	03/15	27
1999	2000	03/27	02/23	03/20	32
2000	2001	03/10	02/26	03/06	12
2001	2002	03/25	03/04	03/18	19
	Average	03/26	03/02	03/15	24

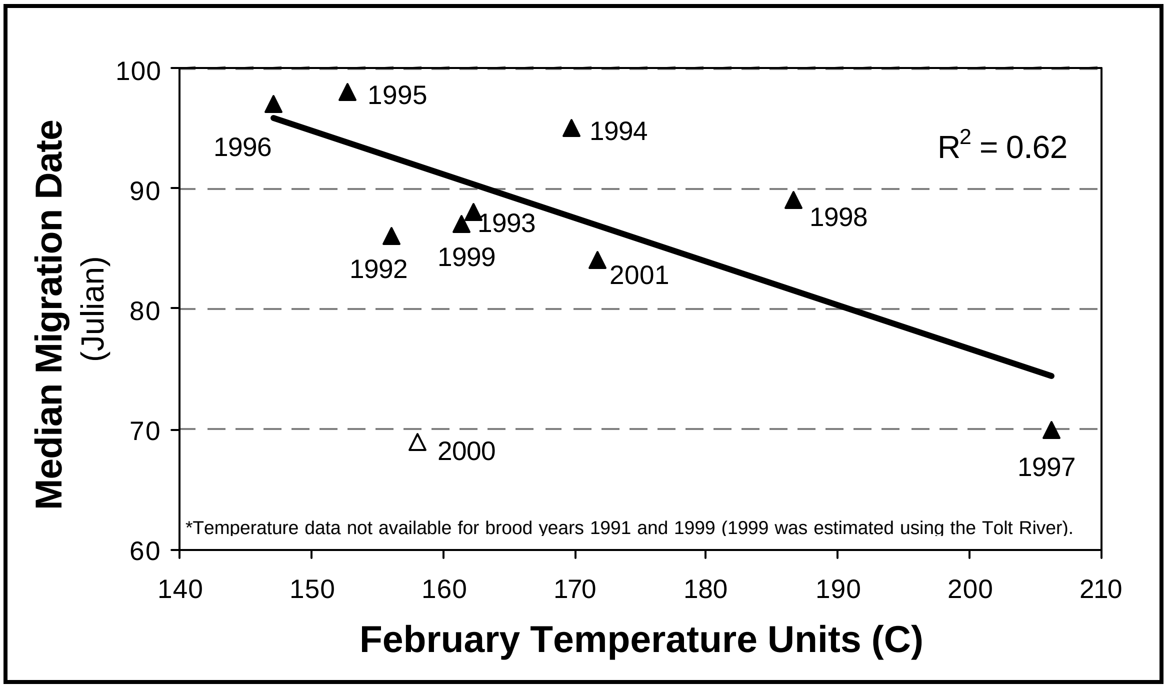

Figure 5. Linear regression of median migration Julian Calendar date for wild Cedar River sockeye fry as a function of the sum of February 1-28 daily average temperatures as measured at the USGS Renton Gaging Station #12119000 for brood years 1992-2001, with 2000 as an outlier.

Survival of Hatchery Release Groups

Survival of hatchery fry was assessed from the Landsburg, Riviera, and Middle-River release sites to the trap. Fry released at Landsburg were captured the night of and the night after release, while Riviera releases typically migrated past the trap during the night of the release. The majority of fry released from the Middle-River site passed the trap during the release night, but otolith sampling did reveal that a small proportion of fry from these groups remained above the trap for as long as one week.

Survival estimates of individual Riviera release groups ranged from 102% to 153% (Table 7). Survival of Riviera fry was estimated using otolith sampling on all but the first two releases. Because otolith samples were not collected on the first two release nights, January 22 and 24, we chose to use a survival rate of 100% to estimate the nightly hatchery migration on those nights. The average of the measured groups was not used because it exceeded 100%. The survival estimate of 153% on March 27 includes fry that were captured on March 14 and 15. We suspect that an error occurred at marking and that these fish were released on March 14 as part of the Middle-River group. If this is the correct explanation, then the survival rate estimated for the Middle-River release on March 14 is underestimated. If these fry were included with the Middle-River release, then the survival rate estimated for the March 27 Riviera release decreases from 153% to 120%. With this correction, survival over the eight release groups averages 107%.

Survival estimates of individual Middle-River release groups ranged from 45% to 112% (Table 7). While these estimates are based on otolith samples, as discussed above, we believe approximately half of the March 14 release was coded as a Riviera release. If this is correct, then the survival estimate for this release is biased low. Allocating the 108,000 fry estimated as Riviera released fry on March 14 and 15 to the Middle-River group increases survival to 69%. With this adjustment, over the seven groups, survival estimates averaged 91%.

Survival estimates of individual Landsburg release groups ranged from 48% to 120% (Table 7). Over all seven release groups, weighted survival averaged 79%. Survival was estimated using otolith samples, except for two releases: on January 28 when we did not trap, and February 11 when an otolith sample was not taken. Hatchery migration during the night of January 28 was estimated by using the sample average of the survival of the five releases estimated using otoliths. The hatchery migration during the night of February 11 was estimated by interpolating the wild migration estimate from the previous and following nights, then subtracting that estimate from the total night's estimate.

Survival estimates in excess of 100% indicate that either we overestimated the sockeye fry migration and/or hatchery release groups contained more fry than estimated. If the former explanation is correct, we believe that overestimation occurred through underestimating capture rate. In the 2000 season when the trap was operated in a new location below the Logan Street Bridge, which required releasing calibration groups further upstream, we determined that in-river predation on marked fry biased capture rate estimates low. This effect was not observed in any of the previous eight seasons or in 2001 or 2002 when the trap was operated downstream of the Boeing Company's South Bridge. Although these analyses didn't find any evidence of loss in the mark groups, it may still occur albeit at a low rate.

Confidence intervals and percent standard errors listed in Table 7 only account for the precision of trap-based estimates of fry. Error in the numbers of hatchery fry released per group is not estimated.

Egg-to-Migrant Survival of Naturally-Produced Fry

Overall survival of the 2001 brood sockeye fry to lake entry was estimated at 7.6%. This rate is the ratio of 31.7 million wild fry to an estimate of 420 million eggs potentially deposited. This PED is based on a spawning escapement estimate of 233,569, an assumed even sex ratio and an average fecundity of 3,568 (Table 8). Of these three values, the estimate of fecundity may be the most accurate since it is the average number of eggs per female estimated over the spawning season (Antipa 2002). For the purpose of this analysis, we computed Cedar River spawners for the 1991 through 2001 broods by subtracting from the estimated sockeye run passing the Ballard Locks the following estimates:

1. sockeye harvested in recreational and tribal fisheries,
2. sockeye estimated spawning on beaches and in all other tributaries (Steve Foley pers. comm.),
3. pre-spawning mortality rate of 5%, and
4. sockeye removed from the Cedar River for brood stock.

Regressing the survival estimates on peak brood year incubation flow resulted in a correlation coefficient of 84% (Figure 6). The best fit for this data series was derived from fitting the data to the first exponential equation ($y = ba^x$). This function generally describes an exponential decay in egg-to-migrant survival with increasing peak stream flow during the incubation period. As additional data are generated, we will continue to assess this model and others, to increase our understanding of the factors affecting natural sockeye fry production from the Cedar River.

Table 7. In-river survival estimates of hatchery sockeye fry, Cedar River 2002.

Release Site	Release Date	Sockeye Released	Recovery Date(s)	Estimated Migration	Estimated Survival	95% CI +/-	Percent Standard Error
Landsburg	01/28	310,000	01/28-01/29	233,022	75.2%	49.9%	33.8%
	02/11	642,000	02/11	547,665	85.3%	45.9%	27.4%
	02/12	559,000	02/12-02/13	453,438	81.1%	47.0%	29.5%
	02/16	72,000	02/16-02/17	41,983	58.3%	40.4%	35.3%
	02/20	623,000	02/20-02/28	422,749	67.9%	43.3%	32.5%
	02/28	325,000	02/28-03/02	390,758	120.2%	62.2%	26.4%
	03/07	330,000	03/07-03/08	159,475	48.3%	27.7%	29.3%
	Total	2,861,000		2,249,090	78.6%	6.4%	4.2%
Middle	02/07	322,000	02/07-02/12	358,114	111.2%	58.1%	26.7%
	02/21	201,000	02/21	143,909	71.6%	41.9%	29.9%
	02/27	260,000	02/27-03/08	225,671	86.8%	42.5%	25.0%
	03/01	315,000	03/01-03/02	353,671	112.3%	60.8%	27.6%
	03/05	657,000	03/05	713,347	108.6%	56.3%	26.4%
	03/06	318,000	03/06-03/07	254,173	79.9%	44.7%	28.5%
	03/14	454,000	03/14-03/15	204,303	45.0%	24.6%	27.9%
	Total	2,527,000		2,253,188	89.2%	5.6%	3.2%
Riviera	01/22	201,000	01/22	201,000	100.0%	n/a	n/a
	01/24	319,000	01/24	319,000	100.0%	n/a	n/a
	02/27	277,000	02/27	307,880	111.1%	20.5%	9.4%
	03/06	318,000	03/06	352,507	110.9%	17.0%	7.8%
	03/07	333,000	03/07-03/08	352,162	105.8%	16.7%	8.0%
	03/12	556,000	03/12	583,163	104.9%	14.7%	7.1%
	03/13	564,000	03/13	575,842	102.1%	12.6%	6.3%
	03/27	332,000	03/14-03/28	507,084	152.7%	20.6%	6.9%
	Total	2,900,000		3,198,638	110.3%	5.9%	2.7%

Table 8. Estimated egg-to-migrant survival of naturally-produced sockeye fry in the Cedar River relative to peak mean daily flows during the incubation period as measured at the USGS Renton gage, brood years 1991-2001.

Brood Year	Spawners	Females (@50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1991	75,196	37,598	3,282	123,396,636	9,800,000	7.9%	2,060	01/28/1992
1992	184,854	92,427	3,470	320,721,690	27,100,000	8.4%	1,570	01/26/1993
1993	100,684	50,342	3,094	155,758,148	18,100,000	11.6%	927	01/14/1994
1994	123,663	61,832	3,176	196,376,844	8,700,000	4.4%	2,730	12/27/1994
1995	26,627	13,314	3,466	46,144,591	730,000	1.6%	7,310	11/30/1995
1996	308,014	154,007	3,298	507,915,086	24,390,000	4.8%	2,830	01/02/1997
1997	118,883	59,442	3,292	195,681,418	25,350,000	13.0%	1,790	01/23/1998
1998	79,174	39,587	3,176	125,728,312	9,500,000	7.6%	2,720	01/01/1999
1999	47,395	23,698	3,591	85,097,723	8,058,909	9.5%	2,680	12/18/1999
2000	196,730	98,365	3,451	339,457,615	38,447,878	11.3%	627	01/06/2001
2001	233,569	116,785	3,568	416,687,096	31,673,029	7.6%	1,930	11/23/2001

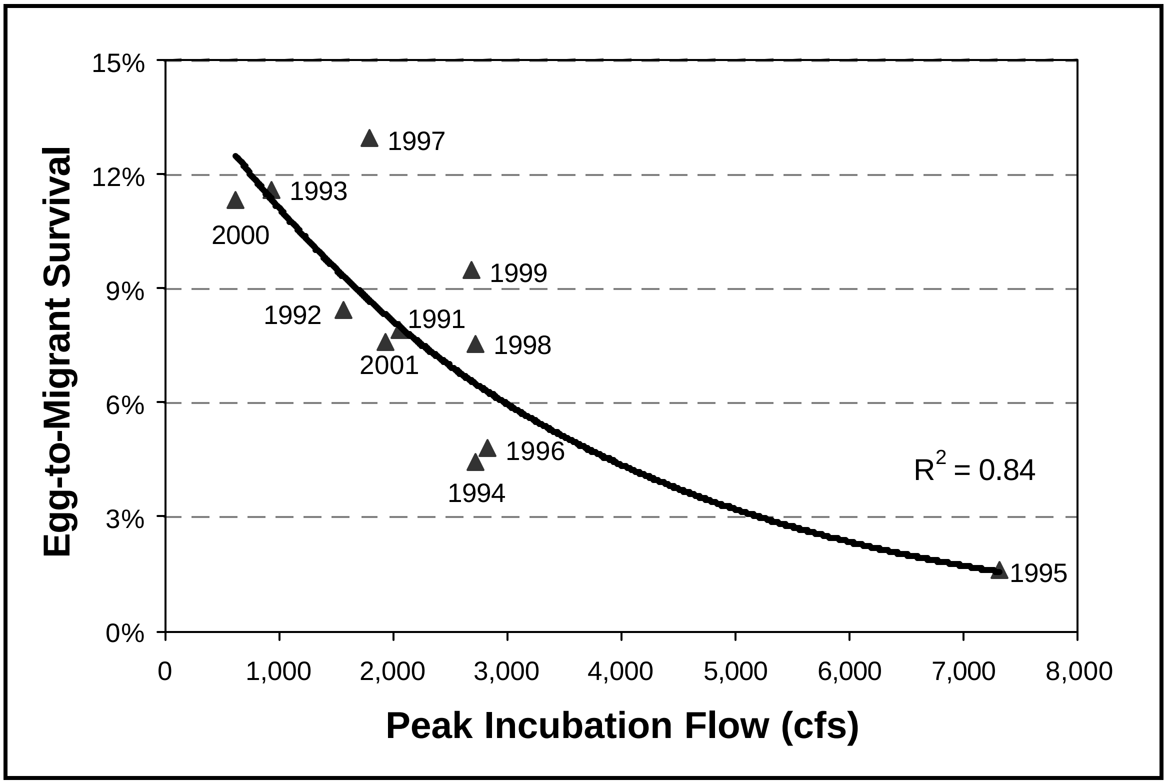

Figure 6. Exponential regression of wild sockeye egg-to-migrant survival from brood years 1991 to 2001 as a function of peak flow during the winter egg incubation period, Cedar River.

Chinook

Catch

Fry Trap

Trapping occurred on 100 nights, beginning January 25 and ending May 29. On the first night, we caught 50 chinook fry. Nightly catches increased thereafter to peak on the night of February 21 when we caught 291 chinook fry. Catches through the end of March totaled 3,590 fry, 90% of the fry trap total. Catches declined through April and May. A total of 3,989 fry were caught in the trap throughout the season.

Eleven daytime intervals were fished between February 13 and April 24 (Table 9). The daytime catch rate to nighttime catch rate (D:N) ratios ranged from 0% to 80%, and averaged 17.6%.

Screw Trap

Over the 107 night and 48 daytime intervals that we operated the screw trap (April 1 through July 22), we captured 2,592 wild age 0+. Although we also captured numbers of chum, pink, and sockeye fry, the trap was designed to allow small fry to escape. Small fry caught in April are underestimated, but by May fry had grown large enough to be retained in the trap and enable accurate counts.

Chinook catches were low in April, averaging only six fry per night. Catches began to increase in early May, and peaked the night of June 17 with a catch of 259 chinook.

During the 48 days that we operated the trap 24-hours, all species were captured at night at much higher rates than during daylight. Over the trapping season D:N ratios ranged from 0% to 146% and averaged 14.7% (Figure 7).

Catch Expansion

Fry Trap

During the 124 day trapping interval, the fry trap operated 1,304-hours out of 3,019-hours, or 43.2% of the time. Trapping did not occur nightly early and late in the season due to low numbers of fish migrating. Those intervals totaled 24 nights during the trapping season. High flows and heavy debris precluded trapping continuously through four nights, requiring hourly sub-sample intervals ranging from ten to 20 minutes. Catch missed between these sub-sample intervals was estimated by interpolation. The night of February 20 was estimated by interpolation due to an underestimate of the actual catch. High flows and large amounts of wild and hatchery sockeye fry during that night prevented field staff from identifying chinook fry within the large sockeye catch. Daytime intervals not fished were estimated by using the average D:N ratio measured during the trapping season. In total, we estimate 5,070 chinook fry would have been caught had we fished continuously (Appendix B.

Screw Trap

Expanding catch data from April 1 through the morning of July 23 estimated an additional 469 chinook would have been caught had trapping been continuous, an increase of 15.3% to the actual catch. The catch expansion included estimates for six days not fished due to heavy debris and trap repairs, and five nights when debris impaired the fishing ability of the trap. The expansion also includes catch estimated for daytime trapping intervals not fished. These daytime intervals were estimated by using the average measured D:N catch ratio of 14.7%.

Size

Fry Trap

From late January to early April, the mean fork length of chinook fry increased by only two millimeters, and averaged 39 mm (Table 10). While catches included individuals as large as 90 and 92 mm in April and May, size averaged 76 mm in early May when catches were low (Figure 8).

Screw Trap

Chinook increased in size from a weekly average fork length of 42 mm in early April to 127 mm in late July (Table 10, Figure 8). Chinook caught in the screw trap ranged form 32 mm to 151 mm.

Table 9. Chinook day to night catch ratios for Cedar River fry trap, 2002.

NIGHTTIME					DAYTIME						DAY/ NIGHT	Flow
Trap Date	Down Time	Hours Fished	Catch	Catch/ Hour	Date	Time Down	Time Up	Hours Fished	Catch	Catch/ Hour	Ratio	(cfs)
02/12	17.50	13.50	39	2.89	02/13	7.00	17.00	10.00	2	0.20	8.4%	785
02/13	17.00	15.00	29	1.93								
02/19	18.00	13.00	193	14.85	02/20	7.00	17.00	10.00	19	1.90	11.4%	712
02/20	17.00	15.00	274	18.27								
02/27	17.50	13.50	34	2.52	02/28	7.00	18.00	11.00	8	0.73	12.8%	989
02/28	18.00	13.00	116	8.92								
03/05	18.50	12.00	79	6.58	03/06	8.00	18.00	10.00	14	1.40	26.6%	1,080
03/06	18.00	11.00	42	3.82								
03/11	18.50	12.00	192	16.00	03/12	6.50	16.00	9.50	22	2.32	22.8%	1,130
03/12	18.50	12.00	52	4.33								
03/19	18.50	12.65	99	7.83	03/20	7.15	18.00	10.85	62	5.71	79.8%	1,040
03/20	18.00	12.50	81	6.48								
03/26	19.00	11.00	33	3.00	03/27	6.00	18.00	12.00	2	0.17	9.6%	1,160
03/27	18.00	12.50	8	0.64								
04/02	18.75	11.75	69	5.87	04/03	6.50	18.00	11.50	6	0.52	10.5%	1,180
04/03	18.00	12.50	51	4.08								
04/10	18.50	12.00	29	2.42	04/11	6.50	19.00	12.50	0	0.00	0.0%	1,210
04/11	19.00	11.50	8	0.70								
04/16	20.25	10.25	1	0.10	04/17	7.50	19.00	11.50	0	0.00	0.0%	1,770
04/17	19.00	11.50	6	0.52								
04/23	20.00	10.00	10	1.00	04/24	6.00	20.00	14.00	1	0.07	11.3%	1,050
04/24	20.00	10.50	3	0.29								
Totals		268.65	1,448	5.39				122.85	136	1.11		
Average											17.6%	
Variance											0.0446	

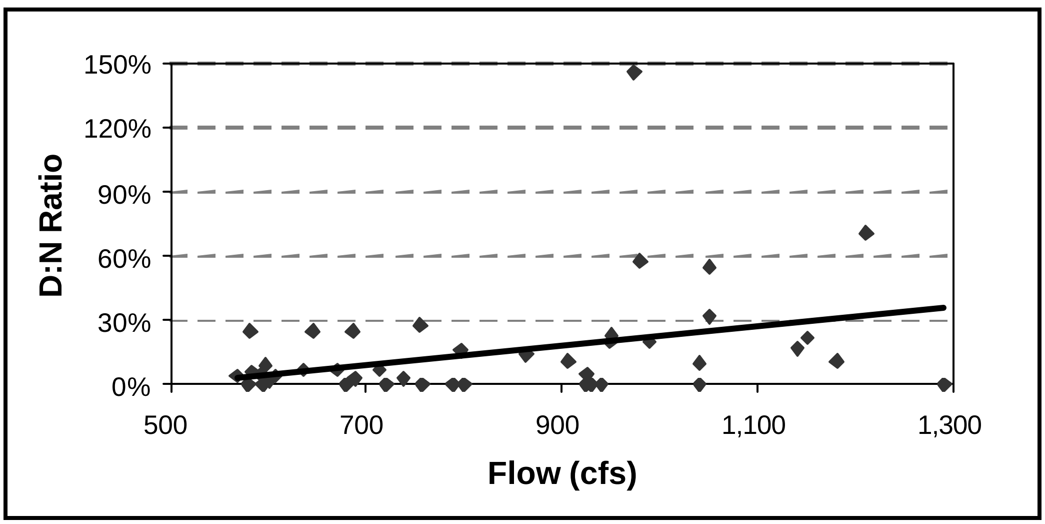

Figure 7. Chinook day to night catch rate ratios, Cedar River screw trap 2002.

Table 10. Mean chinook fork length (mm), standard deviation, range, sample size, and catches in the fry and screw traps, Cedar River 2002.

Statistical Week			FRY TRAP						SCREW TRAP					
Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
01/21	01/27	4	37.9	2.2	34	41	23	57						
01/28	02/03	5	37.6	2.8	34	44	40	93						
02/04	02/10	6	38.1	3.0	34	45	27	161						
02/11	02/17	7	38.9	2.3	34	45	74	354						
02/18	02/24	8	38.9	1.7	35	43	83	1,009						
02/25	03/03	9	39.2	2.2	34	43	46	463						
03/04	03/10	10	40.1	1.4	37	42	21	275						
03/11	03/17	11	40.2	1.7	37	44	49	395						
03/18	03/24	12	40.1	1.9	32	48	83	437						
03/25	03/31	13	39.4	1.8	36	43	37	151						
04/01	04/07	14	40.5	3.3	35	64	75	245	41.6	4.4	35	65	78	222
04/08	04/14	15	49.4	15.2	38	90	21	70	44.8	9.4	38	88	57	78
04/15	04/21	16	45.2	2.4	41	47	6	13					0	3
04/22	04/28	17	49.8	9.0	40	69	24	26	51.8	9.9	32	74	41	42
04/29	05/05	18	66.3	5.9	56	73	15	15	63.2	9.2	48	91	51	65
05/06	05/12	19	76.2	12.2	59	92	5	12	64.5	7.4	48	82	84	159
05/13	05/19	20	66.2	10.4	56	81	5	5	70.3	8.2	52	87	63	74
05/20	05/26	21							69.3	9.7	53	93	44	162
05/27	06/02	22							76.4	8.5	56	100	66	222
06/03	06/09	23							82.7	9.1	68	101	28	315
06/10	06/16	24							91.4	10.7	74	111	22	265
06/17	06/23	25							91.0	6.6	72	105	109	526
06/24	06/30	26							95.1	6.5	80	115	129	188
07/01	07/07	27							97.7	6.8	74	112	157	184
07/08	07/14	28							100.5	6.4	86	114	56	65
07/15	07/21	29							105.0	6.9	96	118	10	20
07/22	07/28	30							126.5	6.4	122	131	2	2
		Totals	41.3	7.5	32	92	634	3,781	78.1	21.2	32	131	997	2,592

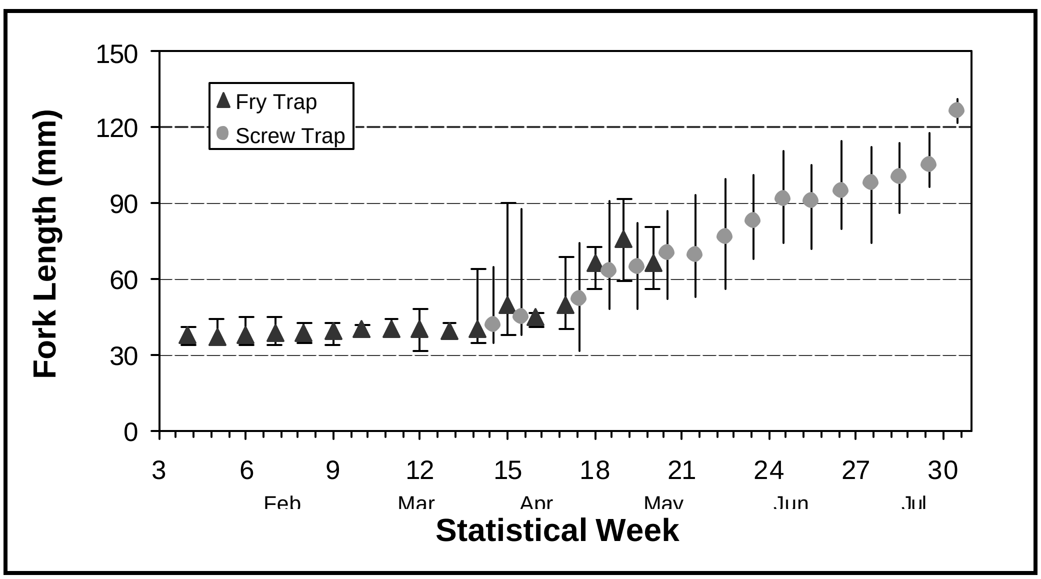

Figure 8. Weekly ranges and mean fork lengths for chinook migrants captured in the Cedar River fry and screw traps, 2002.

Trap Efficiency

Fry Trap

Capture rate for chinook during fry trap operation was estimated using sockeye fry (see Sockeye-Trap Efficiency section). Linear regression analysis found a significant relationship between capture efficiency and mean daily flow (as estimated from the USGS Renton Gage), ($p<0.05$, $r^2 = 0.38$) (Figure 2). This relationship was used to estimate daily trap efficiency and migration.

Screw Trap

Capture rates of 23 test groups released from May 22 to June 30 ranged from 0% to 44%. Because confidence in the results of tests using small numbers of marked fish was low, we combined groups from adjacent tests to develop test groups of at least 40 marked migrants. Pooling releases decreased the range to 3.4% to 11.6% (Table 11). Linear regression did not yield a significant relationship between mean daily flow and trap efficiency ($p>0.05$), therefore, we used the average trap efficiency of 6.9% to estimate production. Mean daily stream flow during the tests ranged from 597 to 1,490 cfs, while flows throughout the trapping season ranged from 234 to 2,320 cfs.

Production Estimate

The fry and screw trap operated concurrently between April 1 and May 29, which provided the opportunity to compare the independent daily estimates of chinook migration from each trap. Daily estimates from each trap were summed by week and tested for equality ($p<0.05$) using a Z-test. Differences were significant in six of the nine weeks tested (Table 12). We chose to use fry trap data through statistical week 15 (April 14), since the statistical difference between traps earlier in the spring may reflect smaller migrants being captured more efficiently by the fry trap. As chinook grew larger during the season, they were able to avoid the fry trap. The screw trap, which was operated in much faster water, was clearly more efficient in capturing the larger smolts.

Table 11. Estimated chinook capture rates from grouped screw trap efficiency tests, Cedar River 2002.

Date	NUMBER Released	NUMBER Recaptured	Recapture Rate	Variance
05/22-05/25	48	5	10.4%	0.00194
05/26-06/01	78	4	5.1%	0.00062
06/05-06/06	66	3	4.5%	0.00066
06/07-06/08	73	3	4.1%	0.00054
06/09-06/10	101	4	4.0%	0.00038
06/11	48	3	6.3%	0.00122
06/12-06/13	69	8	11.6%	0.00149
06/14-06/15	60	4	6.7%	0.00104
06/16	60	4	6.7%	0.00104
06/17	49	3	6.1%	0.00117
06/18	96	6	6.3%	0.00061
06/19	45	5	11.1%	0.00219
06/22-06/23	58	2	3.4%	0.00057
06/30	48	5	10.4%	0.00194
Total	899	59		
Average			6.9%	
Variance			5.7E-05	

Table 12. Independent weekly estimates of chinook migration, Nw, from the fry and screw traps with results from Z-test comparison of the weekly estimates (p = 0.05), Cedar River 2002.

Statistical Week			Fry Trap		Screw Trap		Significant Difference? (Yes/No)
Begin	End	Number	Estimated Migration (N_w)	$V(N_w)$	Estimated Migration (N_w)	$V(N_w)$	
04/01	04/07	14	4,478	222,945	3,939	131,271	No
04/08	04/14	15	2,151	24,546	505	4,855	Yes
04/15	04/21	16	344	4,824	143	345	No
04/22	04/28	17	574	3,848	824	5,225	No
04/29	05/05	18	622	3,160	1,173	6,222	Yes
05/06	05/12	19	545	2,054	2,070	54,167	Yes
05/13	05/19	20	211	173	1,057	24,967	Yes
05/20	05/26	21	307	256	2,796	45,225	Yes
05/27	05/29	22	238	286	1,607	17,030	Yes

Combining the chinook production estimate from the fry trap for January 25 through April 14, with the estimate from the screw trap for April 15 through July 22, yields a total migration over this interval of 115,704 age 0+ chinook (Table 13).

To estimate the number of chinook migrating before trapping began, from January 1 to January 24 we used logarithmic extrapolation. This estimated 3,970 chinook passed the fry trap before January 25 (Table 13). The total migration from the Cedar River in 2002 was estimated at 119,674 chinook (Figure 9).

The total estimated chinook migration was 25%, 50%, and 75% complete by February 21, March 14, and May 27, respectively (Figure 10). This includes both the fry and smolt portions of the migration. The majority of the population migrated as fry early in the season (67%), while the balance of 33% migrated as smolts after mid-April (Table 14). These proportions are similar to those of the first two broods quantified, 1998 and 1999. In contrast, the majority of the 2000 brood emigrated as smolts. We attribute this pattern to the anomalously low flows during emergence and early rearing in January through March of 2001.

Table 13. 2002 Cedar River juvenile chinook production estimate and confidence intervals.

Gear	Period	Estimated Migration	CV	95% CI Low	95% CI High	Variance
Before Trapping	January 1 - January 24	3,970	53.2%	0	8,110	4.5E+06
Fry Trap	January 25 - April 14	75,829	27.1%	35,615	116,043	4.2E+08
Screw Trap	April 15 - July 22	39,875	11.1%	31,186	48,564	2.0E+07
Total	January 1 - July 22	119,674	17.6%	78,325	161,023	4.5E+08

Table 14. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a January 1 to July 13 migration period, for Cedar River broods 1998 to 2001.

Brood Year	Estimated Migration			% Migration	
	Fry through Apr 15	Smolt Apr 16-July 13	Total	Fry through Apr 15	Smolt Apr 16-July 13
1998	67,293	12,811	80,104	84%	16%
1999	45,906	18,817	64,723	71%	29%
2000	10,994	21,157	32,151	34%	66%
2001	79,813	39,326	119,139	67%	33%

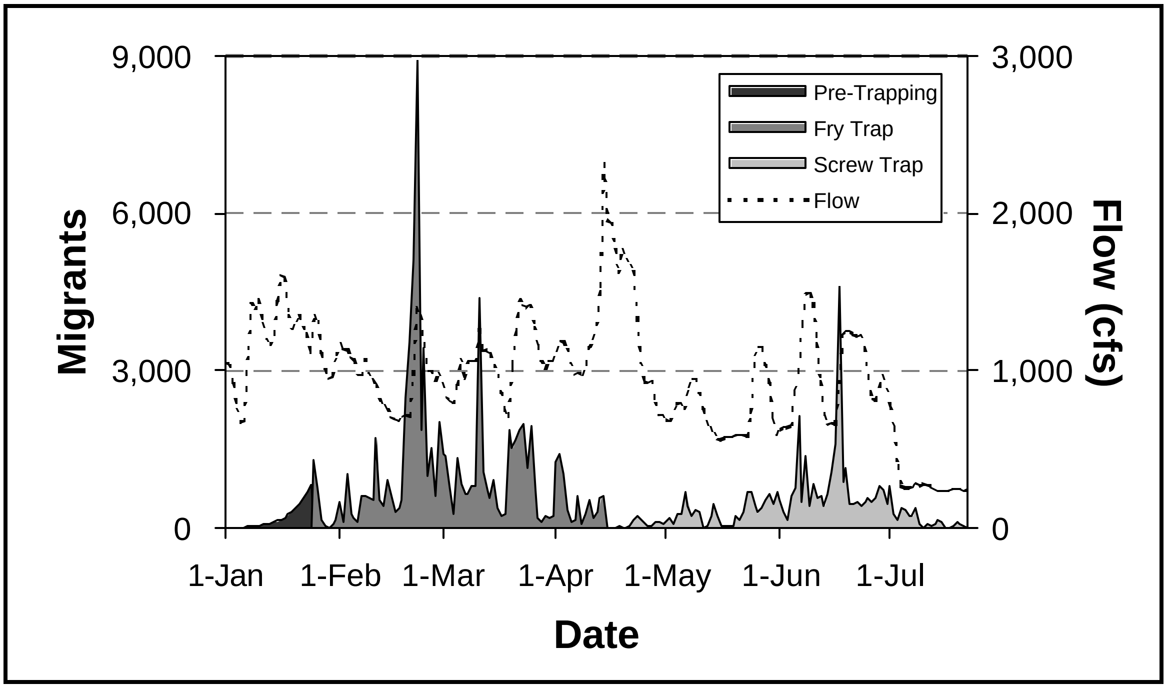

Figure 9. Daily estimated chinook migration and daily average flow, Cedar River 2002.

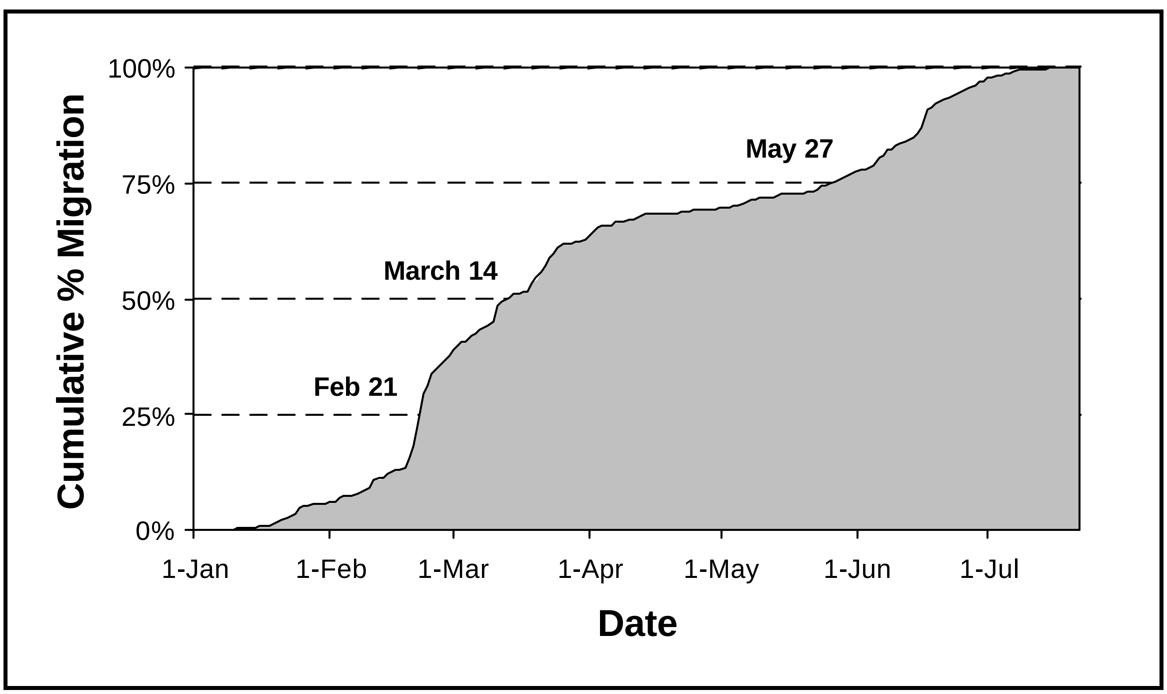

Figure 10. Cumulative percent migration of age 0+ chinook, Cedar River 2002.

Egg-to-Migrant Survival

Relating our overall estimates of juvenile chinook emigrating from the Cedar River to estimates of annual egg deposition yields an estimate of egg-to-migrant survival. For the 2001 brood, we estimated the egg-to-migrant survival of natural spawning chinook at 6.7%. This estimate is based on an escapement of 398 females and a fecundity of 4,500 eggs per female (Table 15).

Table 15. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998 to 2001, Cedar River.

Brood Year	Estimated Migration	Est. Females	Potential Egg Deposition	Production/ Female	Survival Rate
1998	80,932	173	778,500	468	10.4%
1999	64,723	180	810,000	360	8.0%
2000	32,249	53	238,500	608	13.5%
2001	119,674	398	1,791,000	301	6.7%

Coho

Catch

We captured a total of 3,406 coho smolts between April 1 and July 22. Catch distribution was unimodal with the peak daily catch of 183 smolts on May 10. Over the period of both daytime and nighttime screw trap operation, day/night catch rate ratios for coho smolts ranged from 0% to 23% and averaged 2.8 %. Weekly day/night ratios seemed to be higher towards the beginning and end of the coho migration interval (Figure 11). Although the higher ratios correspond to intervals when flows were higher, a significant correlation with flow was not found.

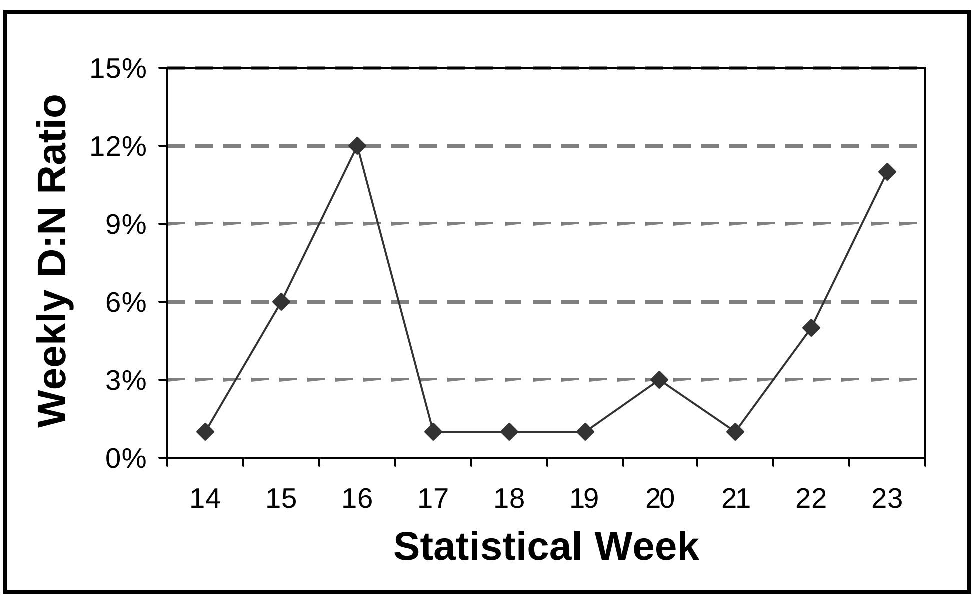

Figure 11. Weekly average ratio of day to night coho catch rates, Cedar River screw trap 2002.

Size

Over the season, coho smolt fork length averaged 108 mm (Table 16). As in previous years, there was little variation in mean fork length over the season (Figure 12).

Table 16. Weekly mean coho fork length, standard deviation, range, sample size and catch from the Cedar River screw trap, 2002.

Statistical Week			COHO SMOLTS					
					Range			
Begin	End	No.	Avg.	s.d.	Min	Max	n	Catch
04/01	04/07	14	103.3	11.59	84	133	44	65
04/08	04/14	15	106.3	9.61	85	128	73	66
04/15	04/21	16	108.7	10.58	89	134	55	92
04/22	04/28	17	107.1	8.83	88	140	99	253
04/29	05/05	18	109.7	8.90	88	136	110	532
05/06	05/12	19	109.4	13.49	91	142	33	814
05/13	05/19	20	105.4	10.83	91	124	22	576
05/20	05/26	21					0	578
05/27	06/02	22	111.0	8.89	96	124	22	256
06/03	06/09	23					0	118
06/10	06/16	24					0	24
06/17	06/23	25	95.0	n/a	95	95	1	17
06/24	06/30	26					0	4
07/01	07/07	27					0	8
07/08	07/14	28						0
07/15	07/21	29					0	4
07/22	07/28	30						0
		Totals	107.7	10.11	84	142	459	3,406

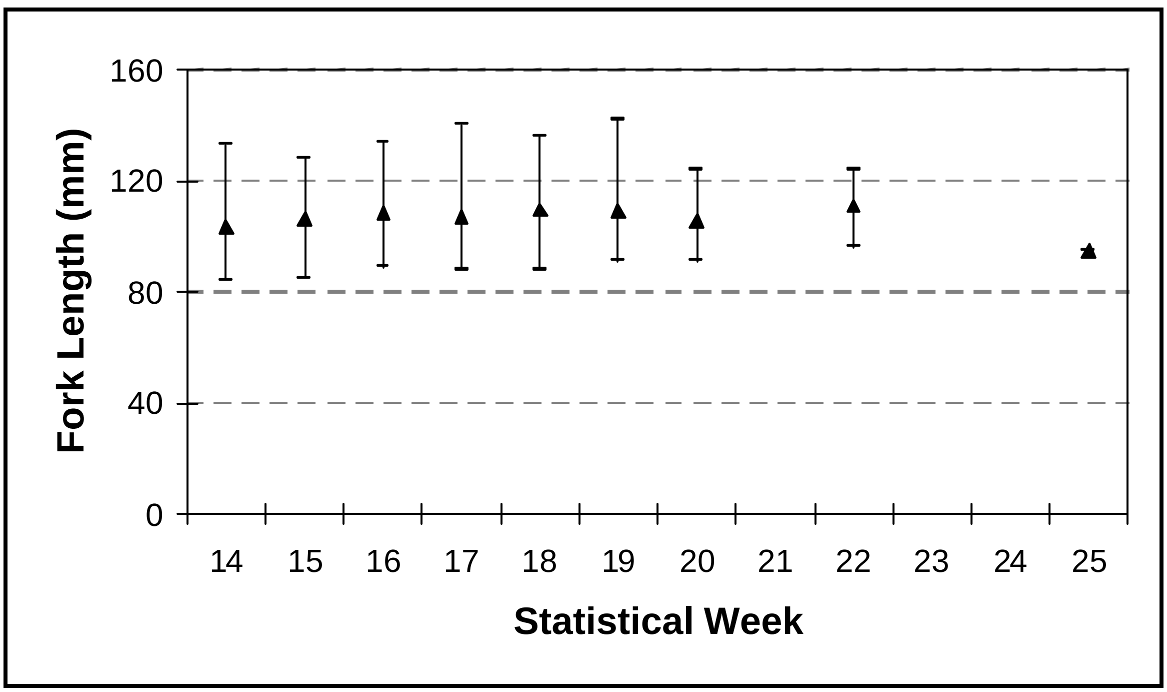

Figure 12. Weekly ranges and mean fork lengths for coho smolts captured in the Cedar River screw trap, 2002.

Catch Expansion

Expansion of the actual catch to represent the number of coho that would have been caught if the screw trap had fished continuously resulted in the addition of 310 coho. This addition represents 8.3% of the expanded catch.

Trap Efficiency

Recapture rates of the 36 trap efficiency tests ranged from 0% to 50%. Early and late in the season we combined small release groups with adjacent groups to form groups with a minimum of 40 smolts. Recapture rates for the 25 grouped efficiency tests ranged from 1.3% to 10.6% and averaged 6.1% (Table 17). As with chinook, regression analysis failed to find a significant flow effect on trap efficiency.

Table 17. Coho smolt recapture rates from grouped screw trap efficiency tests, Cedar River 2002.

Date(s)	NUMBER		Efficiency	Flow(s)	Var (e)
	Released	Recaptured	Rate	(cfs)	
04/21-04/24	64	4	6.3%	1,050-1,670	0.00092
04/25-04/27	48	3	6.3%	924-929	0.00122
04/28	58	4	6.9%	800	0.00111
04/29	61	5	8.2%	720	0.00123
05/03	64	4	6.3%	757	0.00092
05/04	54	3	5.6%	788	0.00097
05/05	47	5	10.6%	796	0.00202
05/06	50	1	2.0%	757	0.00039
05/07	40	4	10.0%	906	0.00225
05/08	48	3	6.3%	950	0.00122
05/09	50	3	6.0%	949	0.00113
05/11	70	6	8.6%	755	0.00112
05/12	95	5	5.3%	679	0.00052
05/15	50	4	8.0%	568	0.00147
05/16	100	2	2.0%	561	0.00020
05/17-05/18	93	7	7.5%	579	0.00075
05/19	48	4	8.3%	581	0.00159
05/22	56	1	1.8%	597	0.00031
05/24	78	1	1.3%	738	0.00016
05/25	56	4	7.1%	1,100	0.00118
05/26	100	9	9.0%	1,150	0.00082
05/27	63	5	7.9%	1,150	0.00116
05/30	74	3	4.1%	688	0.00053
06/01-06/06	66	4	6.1%	623-994	0.00086
06/08-06/19	44	1	2.3%	713-1,490	0.00050
Totals	1,577	95			
Average			6.1%		
Variance			2.8E-05		
n			25		

Production Estimate

Application of the average trap efficiency to the expanded catch estimates coho production at 60,513 smolts with a coefficient of variation of 8.6% and a 95% confidence interval of 50,286 to 70,740 smolts (Figure 13).

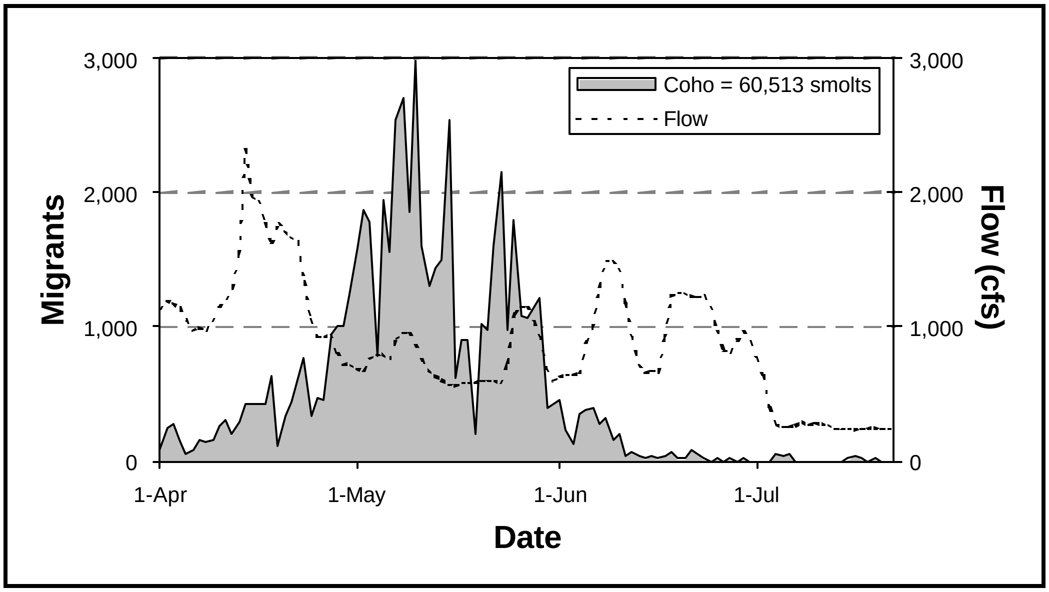

Figure 13. Estimated daily migration of coho smolts from Cedar River, 2002.

Steelhead and Cutthroat

Catch

A total of 34 steelhead smolts were captured between April 2 and July 7. Daily catch peaked on April 21 when four steelhead were caught. Due to the low catches, there was no definable timing pattern during the period of trap operation. Steelhead were not observed in any of the daytime catches. We PIT tagged seven steelhead smolts during the trapping season.

A total of 123 cutthroat trout were captured in the screw trap between April 1 and July 10. Due to the low catches, there was no definable timing pattern during the period of trap operation. Cutthroat were not observed in any of the daytime catches.

Size

Over the season, steelhead smolt fork length averaged 179 mm and varied little from week to week (Table 18). Cutthroat trout fork length averaged 161 mm, and varied from 94 to 228 mm throughout the trapping season (Table 18).

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Table 18. Weekly mean fork lengths, standard deviations, ranges, sample sizes and catches for steelhead and cutthroat trout, Cedar River screw trap 2002.

Statistical Week			STEELHEAD						CUTTHROAT					
Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
04/01	04/07	14	158.3	0.0	141	182	3	3	152.4	16.3	122	185	16	22
04/08	04/14	15	184.0	12.5	164	195	5	5	163.2	22.2	122	227	29	32
04/15	04/21	16	180.8	0.0	162	196	5	5	176.3	29.4	141	219	7	7
04/22	04/28	17	193.3	21.5	164	216	6	7	154.4	30.1	94	228	16	17
04/29	05/05	18	178.7	10.8	171	191	3	3	165.4	27.1	128	210	7	8
05/06	05/12	19	160.5	13.4	151	170	2	2	154.4	35.7	100	189	5	6
05/13	05/19	20					0	2	152.0	12.7	137	164	4	4
05/20	05/26	21	182.7	27.5	151	200	3	3					0	2
05/27	06/02	22	168.0	14.1	158	178	2	2					0	1
06/03	06/09	23						0					0	4
06/10	06/16	24						0	134.0	n/a	134	134	1	4
06/17	06/23	25						0	172.8	7.1	164	181	4	7
06/24	06/30	26						0	175.3	13.2	161	187	3	3
07/01	07/07	27					0	2	192.3	26.2	168	223	4	4
07/08	07/14	28						0	141.5	26.2	123	160	2	2
		Totals	179.3	19.1	141	216	29	34	161.4	25.0	94	228	98	123

Catch Expansion

The actual catch was expanded to represent the number of steelhead and cutthroat that would have been caught if the trap had fished continuously. Due to nighttime screw stoppers, we estimated an additional four steelhead would have been caught in the screw trap. We estimated an additional 21 cutthroat would have been caught throughout the season; three were estimated during screw stoppers and 18 were estimated during the April 13 through April 18 interval when the trap was pulled for mechanical repairs.

Trap Efficiency

Catches of steelhead and cutthroat migrants were too low on any one day to mark a group for calibrating the trap. Estimates of trap efficiency for these species were approximated from other studies.

During evaluation of downstream migrant passage in the Toutle, Green, and White Salmon Rivers, we captured steelhead smolts at rates that were 79%, 54%, and 47%, respectively, of the rates that marked coho were recaptured (Seiler and Neuhauser 1985, Seiler *et al.* 1992). Applying the average of these ratios (60%) to our average coho smolt catch rate (6.1%) estimates a steelhead capture rate in the Cedar River screw trap of 3.7%. This rate may underestimate the steelhead catch rate in the screw trap because the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape. Therefore, we selected a trap efficiency value of 4% for estimating steelhead and cutthroat migration in the Cedar River in 2002.

Production Estimates

Application of a catch rate of 4% to the expanded catch of 38 steelhead estimates a total migration of 950 smolts (Figure 14). Applying this rate to the expanded catch of 144 cutthroat estimates the total cutthroat migration during the trapping period at 3,600 smolts (Figure 14). No confidence intervals were developed for these estimates, which apply only to the period of screw trap operation (April 1 through July 22). While cutthroat migration very likely occurred before and after this interval, no migration timing trends were evident from the catch data, which would help to define the start or end of this migration. Therefore, we did not attempt to expand our cutthroat estimate beyond the trapping period. The estimate of cutthroat migration during the trapping season represents an unknown portion of the total production of downstream migrant cutthroat from the Cedar River.

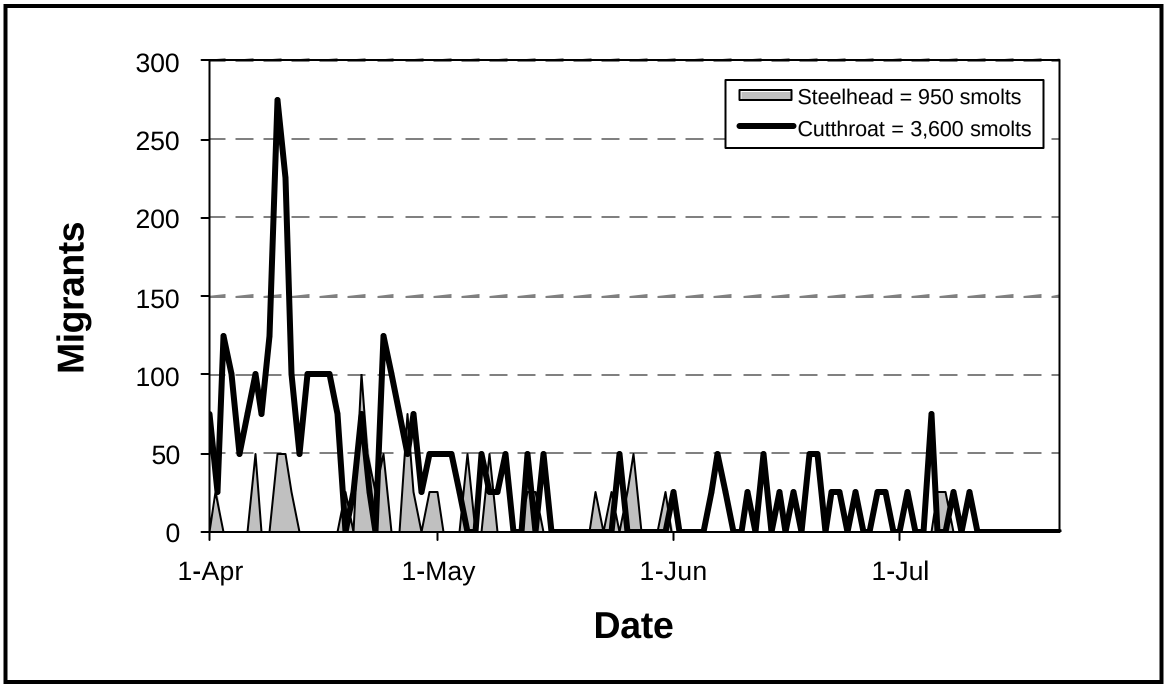

Figure 14. Estimated daily migration estimate of steelhead and cutthroat trout, Cedar River screw trap 2002.

Mortality

Mortalities of sockeye and chinook fry occurring in the fry trap and during enumeration totaled 2,708 and six, respectively, over the season. As a proportion of total catches, these losses amount to mortality rates of 0.1% for each species.

Over the season, one cutthroat, two steelhead, 14 chinook, and 15 coho smolts were found dead in the trap. Coho and chinook mortality rates were 0.44% and 0.46%. The steelhead and cutthroat mortalities occurred in July. Debris loads were not heavy when the trout were found dead in the trap. It was apparent they died prior to entering the trap. Virology analysis of the second steelhead mortality revealed that it contained high concentrations of the protozoan parasite *Ceratomyxa shasta.*

Incidental Species

In addition to the estimated species, we also caught in the fry trap 141 chum fry, 20 coho fry, and 57 pink fry. Catches also included 182 coho smolts, along with five trout parr, one steelhead smolt, and eight cutthroat. In the screw trap we also caught 39 hatchery chinook, 23 coho fry, two trout parr, and small numbers of pink and chum fry and large numbers of sockeye fry. In late June and July, we also caught ten age 1+ sockeye smolts in the screw trap. Other species caught included longfin smelt, lamprey, sculpin, three-spine sticklebacks, pea-mouth, and large-scale suckers.

BEAR CREEK RESULTS

Sockeye

Catch

Fry Trap

We caught 54 sockeye fry on February 1, the first night of trapping. Catches peaked the night of March 28 when 18,561 fry were caught during increasing flows. Over the season, we caught a total of 215,799 sockeye fry through the morning of April 12 (Appendix C). This catch represents nightly fishing except for four nights early in the season. We fished during one daytime interval for four hours on March 9 and caught no sockeye fry. As a result, migration during daylight hours was estimated to be minimal and, therefore, not calculated.

Screw Trap

Screw trap operation began the afternoon of April 12. Over the first five nights sockeye fry were counted frequently throughout the night, and catches totaled 10,736 sockeye fry. On the night of April 16 we caught only 69 fry. Thereafter, we only checked the trap each morning and evening, as sockeye fry catches were negligible.

Trap Efficiency

Over the 54 test groups released during fry trap operation, capture efficiencies ranged from 0.3% to 26.2%. Due to flow fluctuations throughout the season, we moved the fry trap two feet twice in order for the trap to fish properly. Trap efficiencies for the first two positions were estimated by using the average of the capture rate tests conducted while the trap fished those positions (Table 19). During high flows while the trap was in the second position, we observed that the fry released 30 yards upstream were being diverted into an overflow culvert. In response, we released marked fry further upstream at the Redmond Way Bridge. Efficiency tests conducted during the third position were evaluated for a relationship with flow. Logarithmic regression analysis using groups released during the third position yielded a significant relationship between mean daily flow and trap efficiency ($r^2 = 0.66$) ($p<0.01$) (Figure 15). This relationship was used to predict daily trap efficiency while the trap operated in the third position.

To estimate the capture rate of sockeye at the screw trap we released five mark-recapture groups between April 12 and April 16. Trap efficiencies ranged from 0% to 18%, and the mean (9.5%) was used to estimate capture rate during screw trap operation.

Table 19. Sockeye fry trap efficiency test summary by fry trap position, Bear Creek 2002.

Trap Position	Flow Range		# Release	Efficiency			Variance
	Min	Max	Groups	Min	Max	Average	
Original	114	180	5	8.5%	15.0%	12.4%	0.00014
Second	106	124	3	14.1%	18.0%	16.5%	0.00015
Third	75	328	46	0.3%	26.2%	11.1%	0.00005

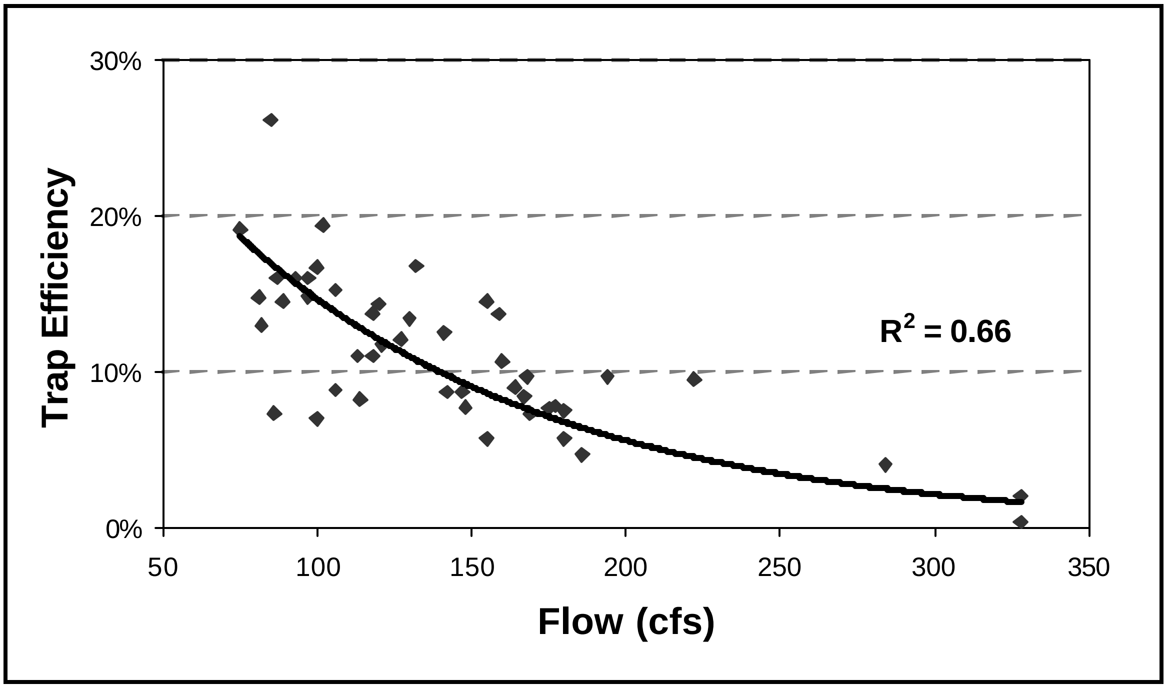

Figure 15. Regression analysis of the relationship between average daily stream flow and trap efficiency measured with sockeye fry, Bear Creek fry trap Position 3, 2002.

Production Estimate

During the period of fry trap operation (February 1 through April 11), we estimate that 2,546,174 sockeye fry passed the trap. This estimate is based on our catch, the estimated trap efficiency, and the estimated migration for four nights in early February when trapping occurred every other night. During the period of screw trap operation when sockeye were counted (April 12 through April 16), we estimate that 113,608 sockeye fry passed the trap. This estimate is based on our catch of 10,736 migrants, and the estimated average trap efficiency of 9.5%. Combining the migration estimates of the fry and screw traps, we estimate a total of 2,659,782 sockeye fry migrated from Bear Creek in 2002 (Table 20, Figure 16) (Appendix C).

Table 20. 2002 Bear Creek sockeye fry migration estimate with 95% confidence intervals.

Interval	Catch		Estimated	95% CI		CV
	Actual	Estimated	Migration	Low	High	
1st Position	3,887	1,032	39,808	32,071	47,545	9.9%
2nd Position	3,112	0	18,832	16,076	21,588	7.5%
3rd Position	208,800	0	2,487,534	1,744,097	3,230,971	15.2%
Screw Trap	10,736	0	113,608	38,483	188,733	33.7%
Totals	226,535	1,032	2,659,782	1,912,514	3,407,050	14.3%

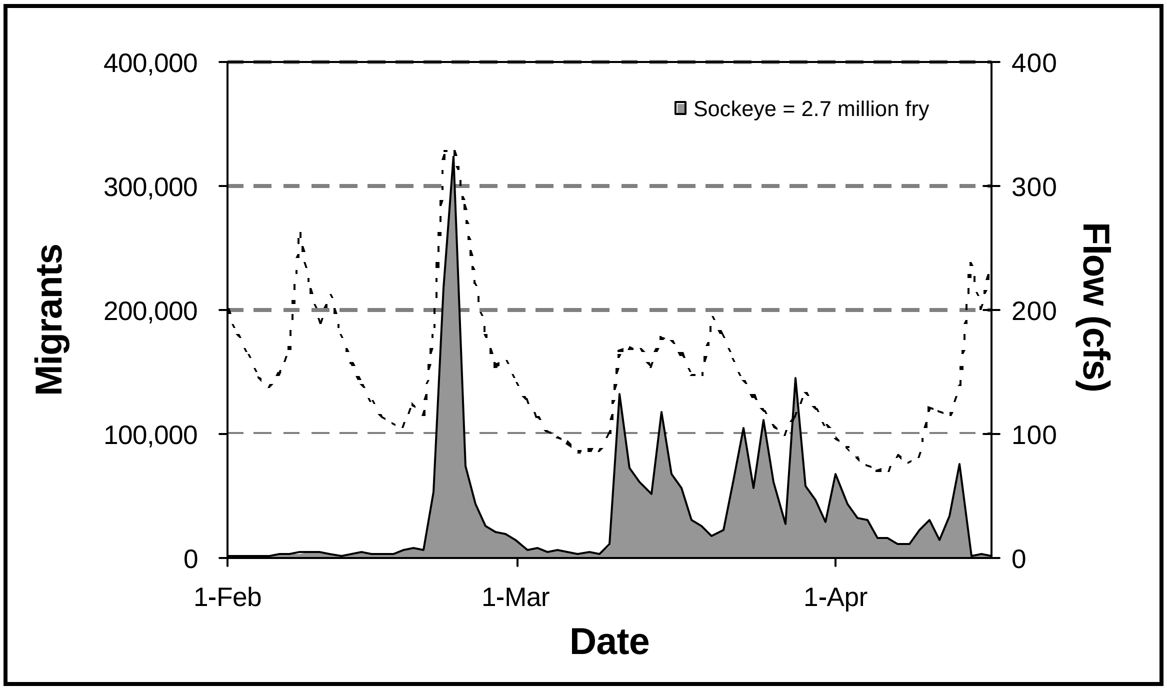

Figure 16. Estimated daily migration of Bear Creek sockeye fry into Lake Washington and daily average flow, 2002.

Chinook

Catch

Fry Trap

On the first night of fry trapping, February 1, we caught only one chinook fry. From that night through April 11 the trap fished 66 nights and a total of 278 age 0+ chinook were caught. Catches remained low until late February, and the peak occurred on the night of March 12 when 36 chinook fry were caught. Catches then declined to near zero up to the removal of the fry trap. The trap operated during one daylight interval on March 9, and no chinook were caught the day interval or the night following.

Screw Trap

On April 12 we installed the screw trap in place of the fry trap. It fished continuously through July 16. On the first night of trapping, we caught one chinook. Catches began to increase in late April, and peaked on July 6 when 597 chinook 0+ were caught. Catches declined thereafter and we stopped trapping on July 16. A total of 6,879 chinook were caught over the trapping period.

Catch Expansion

Fry Trap

Daytime migration during fry trap operation was estimated by using the average ratio of day/night (D:N) catch rates (38%) measured during the screw trap operation. A total of 78 daytime intervals were fished during the screw trap operation, from April 13 to July 7. Daily average flows ranged from 26 to 238 cfs during those daytime intervals, and D:N ratios were not significantly correlated with flow (Figure 17). We estimated that 96 chinook fry would have been caught had we fished 24 hours per day. An additional 16 chinook were estimated for the four nights not fished early in the season.

Screw Trap

The screw trap fished continuously from April 12 through July 16, and only two screw stoppages occurred. The first stoppage occurred during the night of April 24. The catch for this night was not expanded because it was greater than the preceding and following nights. The second stoppage occurred late in the season, July 14, and only one chinook was estimated to have migrated that day.

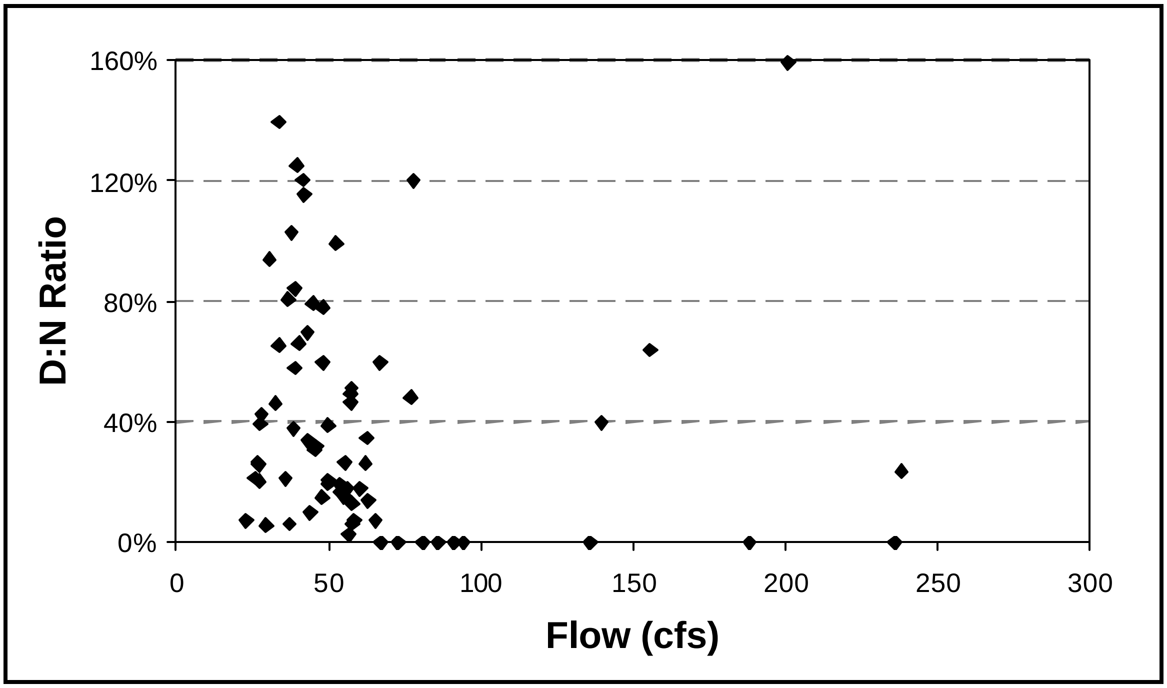

Figure 17. Chinook day to night catch ratios related to flow, Bear Creek screw trap 2002.

Size

From early February to late March, the mean fork length of chinook fry increased by less than two millimeters, and averaged 39 mm (Table 21). By early April mean size of chinook fry had increased to 52 mm, but few were migrating (Figure 18).

Weekly average fork lengths during screw trap operation increased throughout the season. Chinook averaged 51 mm in mid-April, and grew to average 70 mm by early May (Table 21). Fork lengths over the season ranged from 42 mm to 110 mm. Fork lengths of the four chinook 1+, which were all caught from late April to mid-May, ranged from 119 mm to 143 mm (Figure 18).

Table 21. Chinook and coho mean fork lengths, standard deviations, ranges, sample sizes, and catches in the Bear Creek fry and screw trap, 2002.

GEAR	Statistical Week			CHINOOK						COHO					
	Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
FRY TRAP	01/28	02/03	5					0	2						
	02/04	02/10	6	38.9	1.8	34	40	20	24						
	02/11	02/17	7	39.0	1.7	38	41	3	28						
	02/18	02/24	8	38.4	0.8	38	40	11	46						
	02/25	03/03	9	38.4	1.5	36	41	19	99						
	03/04	03/10	10					0	25						
	03/11	03/17	11	40.8	1.9	38	42	4	41						
	03/18	03/24	12	40.2	1.6	37	41	6	6						
	03/25	03/31	13	48.5	0.7	48	49	2	2						
	04/01	04/07	14	44.3	8.1	35	52	4	4						
	04/08	04/11	15	52.0	n/a	52	52	1	1						
SCREW TRAP	04/12	04/14	15	51.3	9.4	42	73	9	11	116.9	13.4	87	132	11	13
	04/15	04/21	16	61.2	8.0	48	68	6	8	125.6	13.4	75	153	46	73
	04/22	04/28	17	62.2	5.2	51	72	20	26	125.1	15.6	81	209	126	677
	04/29	05/05	18	67.3	8.3	51	98	50	76	119.0	9.8	97	145	141	2,137
	05/06	05/12	19	71.7	7.5	53	104	81	206	114.4	14.3	91	176	56	5,248
	05/13	05/19	20	76.0	7.9	45	92	95	280	114.6	15.2	91	148	26	3,535
	05/20	05/26	21	81.3	8.0	68	103	79	1,302	112.3	11.8	90	134	33	3,535
	05/27	06/02	22	81.3	6.7	67	101	53	1,568	116.3	11.7	99	141	22	1,275
	06/03	06/09	23	85.3	8.3	67	101	31	2,291					0	699
	06/10	06/16	24	83.7	7.3	71	99	33	542					0	82
	06/17	06/23	25	85.9	6.5	71	106	291	386					0	42
	06/24	06/30	26	91.5	7.3	77	106	64	126					0	22
	07/01	07/07	27	91.1	6.5	76	110	56	39					0	14
	07/08	07/14	28	93.2	4.6	88	104	17	18					0	14
			Totals	78.4	15.3	34	110	955	7,157	119.9	13.8	75	209	461	17,366

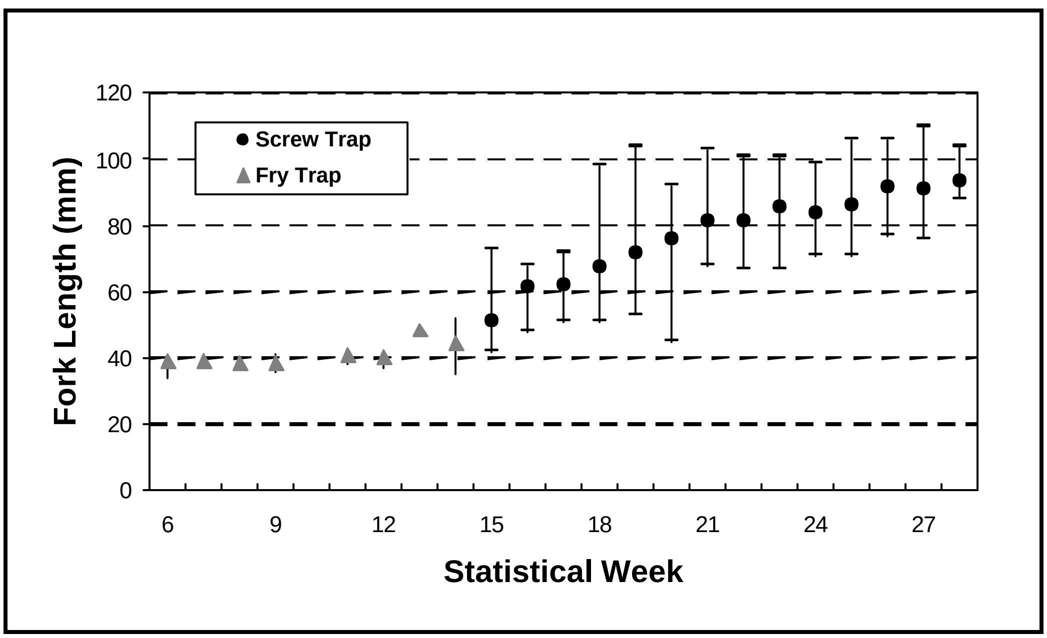

Figure 18. Average and range of chinook 0+ fork lengths sampled from Bear Creek, 2002.

Trap Efficiency

Fry Trap

Because chinook fry were not abundant enough to use for estimating capture rate, we used the trap efficiency data generated using sockeye fry (Table 19, Figure 15).

Screw Trap

Tests to measure trap efficiency were conducted on 22 days from May 24 to June 23. Efficiency rates ranged from 0% to 74%. We combined the last small release group of 22 chinook with the previous night's release to increase group size which decreased the range to 28% to 74% (Table 22). Daily average flows ranged from 27 to 57 cfs during the tests, while flows throughout the trapping season ranged from 26 to 238 cfs. Variation in the efficiency test results was not explained by flow, an outcome we attribute to the narrow flow range. Therefore, we used the average recapture rate (43%) to estimate daily migration.

Table 22. Chinook 0+ trap efficiency test results by date, Bear Creek 2002.

Date	NUMBER		Efficiency Rate	Variance	Flow (cfs)
	Released	Recap			
05/24	79	30	38.0%	0.00298	48
05/25	100	42	42.0%	0.00244	44
05/26	100	34	34.0%	0.00224	40
05/27	50	17	34.0%	0.00449	38
05/29	49	16	32.7%	0.00449	57
05/30	75	33	44.0%	0.00329	48
05/31	100	31	31.0%	0.00214	43
05/31	50	16	32.0%	0.00435	43
06/01	100	41	41.0%	0.00242	39
06/02	75	28	37.3%	0.00312	37
06/04	50	37	74.0%	0.00385	34
06/06	72	39	54.2%	0.00345	38
06/07	100	38	38.0%	0.00236	42
06/07	100	44	44.0%	0.00246	42
06/08	100	44	44.0%	0.00246	42
06/09	100	37	37.0%	0.00233	39
06/10	50	32	64.0%	0.00461	37
06/15	90	43	47.8%	0.00277	27
06/16	50	18	36.0%	0.00461	27
06/19	77	53	68.8%	0.00279	43
06/22-06/23	60	17	28.3%	0.00338	28
Totals	1,627	690			
Average			43.0%		
Variance			0.00075		
n			21		

Production Estimate

We estimated that 5,435 chinook fry passed the fry trap from February 1 through April 11. Application of the average screw trap efficiency to the daily estimated catches estimated 16,019 chinook passed the screw trap from April 12 to July 16. Combining the chinook production estimates from the fry and screw traps estimated a total juvenile migration of 21,454 chinook (Table 23, Figure 19, Appendix C). In 2002, we estimate that 26% of the chinook migration occurred as fry before April 16 (Table 24). The smolt portion of the migration between April 16 and July 13 represented 74% of the chinook migration. These proportions are similar to previous years showing more chinook migrating as smolts than fry.

Table 23. Estimated 2002 Bear Creek wild chinook 0+ migration entering Lake Washington with 95% confidence intervals.

Trap	Catch		Estimated	95% CI		CV
	Actual	Estimated	Migration	Low	High	
Fry Trap						
1st Position	52	36	713	559	867	11.0%
2nd Position	10	3	78	46	110	20.7%
3rd Position	216	73	4,644	2,877	6,411	19.4%
Screw Trap	6,879	1	16,019	13,978	18,060	6.5%
TOTAL	7,157	113	21,454	18,750	24,158	6.4%

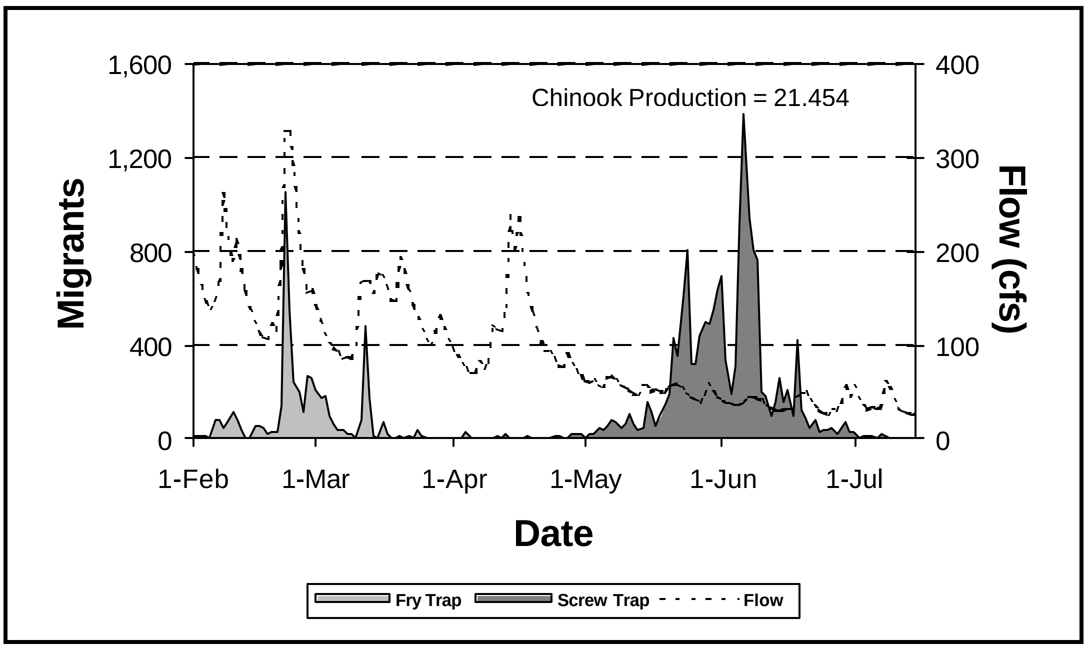

Figure 19. Estimated daily chinook 0+ migration from Bear Creek, 2002.

Table 24. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a February 1 to July 13 migration period, Bear Creek broods 1998 to 2001.

Brood Year	Estimated Migration			Percent Migration	
	Fry through Apr 15	Smolt Apr 16-Jul 13	Total	Fry through Apr 15	Smolt Apr 16-Jul 13
1998	1,720	13,282	15,002	11.5%	88.5%
1999	14,116	18,104	32,220	43.8%	56.2%
2000	457	10,131	10,588	4.3%	95.7%
2001	5,463	15,991	21,454	25.5%	74.5%

Egg-to-Migrant Survival

Relating our overall estimates of juvenile chinook emigrating from Bear Creek to estimates of annual egg deposition yields egg-to-migrant survival rates. For the 2001 brood, we estimated a wild chinook egg-to-migrant survival of 1.7%. This rate, which is based on an escapement of 276 females (Steve Foley pers. comm.) with an average fecundity of 4,500 eggs per female, is slightly lower than measured for the previous three broods (Table 25).

Table 25. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998-2001, Bear Creek.

Brood Year	Estimated Migration	Estimated Females	Potential Egg Deposition	Production/ Female	Survival Rates
1998	15,002	159	715,500	94	2.1%
1999	32,220	293	1,318,500	110	2.4%
2000	10,588	133	598,500	80	1.8%
2001	21,454	276	1,242,000	75	1.7%

Coho

Catch

Three coho smolts were caught on the first night of screw trapping, April 12. From this date on, catches steadily increased to peak on May 10 when 961 smolts were caught. Catches declined through May, and by mid-June averaged less than five smolts per day. Over the entire 95 day trapping season, we caught 17,366 coho smolts.

Debris stopped the screw trap on just one occasion during the coho migration, in the evening hours of April 24. Interpolating catch rates from the nights before and after estimated an additional catch of 15 coho smolts.

Size

Over the trapping period, fork lengths ranged from 75 mm to 209 mm while weekly average fork lengths averaged 120 mm (Table 21). Overall, fork lengths varied little over the trapping season (Figure 20).

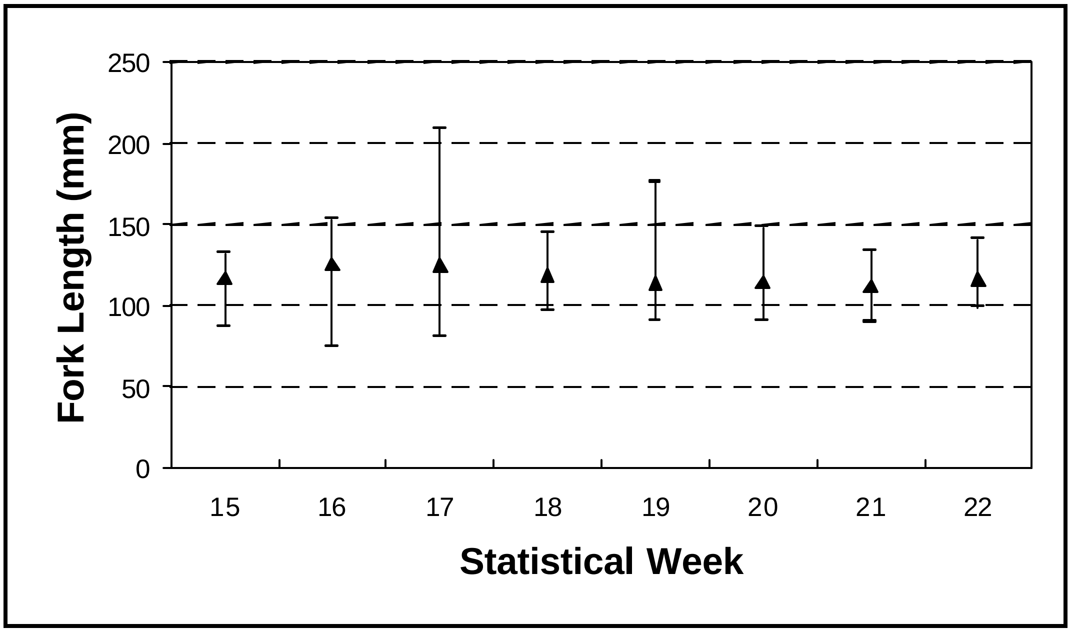

Figure 20. Average and range of fork lengths from coho smolts sampled from Bear Creek, 2002.

Trap Efficiency

A total of 3,362 marked coho were released in 49 groups upstream of the trap between April 13 and June 4. When catches were low early in the season, release groups were pooled in order to achieve group sizes greater than 30 coho smolts (Table 26). Grouped capture rates ranged from 5.9% to 46.3% and averaged 29.9%. Capture rates from grouped tests were significantly correlated with flow ($r^2 = 0.38$, $p<0.01$) (Figure 21). However, as flows varied little and remained below 100 cfs through most of the coho migration, we chose to use the average (29.9%) of the grouped efficiency tests to estimate daily migration.

Production Estimate

Applying the average coho smolt trap efficiency to the expanded catch of 17,381 smolts estimates coho production at 58,212 smolts with a coefficient of variation of 4.8%. The 95% confidence interval about the estimate ranges from 52,791 to 63,633 smolts (Figure 22).

Table 26. Estimated coho smolt recapture rates from grouped screw trap efficiency tests, Bear Creek 2002.

Date(s)	Flow (cfs)	Grouped Efficiency Tests Released	Recaptured	Rate	Variance
04/13-04/20	164	51	3	5.9%	0.00109
04/21-04/23	94	75	21	28.0%	0.00269
04/25	78	32	6	18.8%	0.00476
04/26	77	47	7	14.9%	0.00270
04/27	91	46	15	32.6%	0.00478
04/28	81	123	23	18.7%	0.00124
04/29	73	102	7	6.9%	0.00063
04/29	73	100	18	18.0%	0.00148
04/30	67	50	7	14.0%	0.00241
05/01	62	100	24	24.0%	0.00182
05/02	60	100	21	21.0%	0.00166
05/03	63	52	13	25.0%	0.00361
05/04	58	54	25	46.3%	0.00460
05/05	55	70	17	24.3%	0.00263
05/06	65	100	26	26.0%	0.00192
05/07	67	100	35	35.0%	0.00228
05/08	63	100	29	29.0%	0.00206
05/09	57	100	37	37.0%	0.00233
05/10	55	100	35	35.0%	0.00228
05/11	52	100	30	30.0%	0.00210
05/12	48	100	28	28.0%	0.00202
05/13	46	100	27	27.0%	0.00197
05/14	58	50	20	40.0%	0.00480
05/15	57	50	22	44.0%	0.00493
05/17	54	80	28	35.0%	0.00284
05/18	50	100	37	37.0%	0.00233
05/19	50	100	39	39.0%	0.00238
05/20	56	80	31	38.8%	0.00297
05/21	58	100	31	31.0%	0.00214
05/22	58	50	16	32.0%	0.00435
05/23	54	100	27	27.0%	0.00197
05/24	48	100	34	34.0%	0.00224
05/25	44	100	36	36.0%	0.00230
05/26	40	100	38	38.0%	0.00236
05/27	38	100	34	34.0%	0.00224
05/28	45	100	32	32.0%	0.00218
05/29	57	100	33	33.0%	0.00221
05/30	48	50	18	36.0%	0.00461
05/31	43	50	18	36.0%	0.00461
06/01	39	50	19	38.0%	0.00471
06/02	37	50	19	38.0%	0.00471
06/04	34	50	15	30.0%	0.00420
Totals		3,236	977		
Average				29.9%	
Variance				2.0E-04	
n				42	

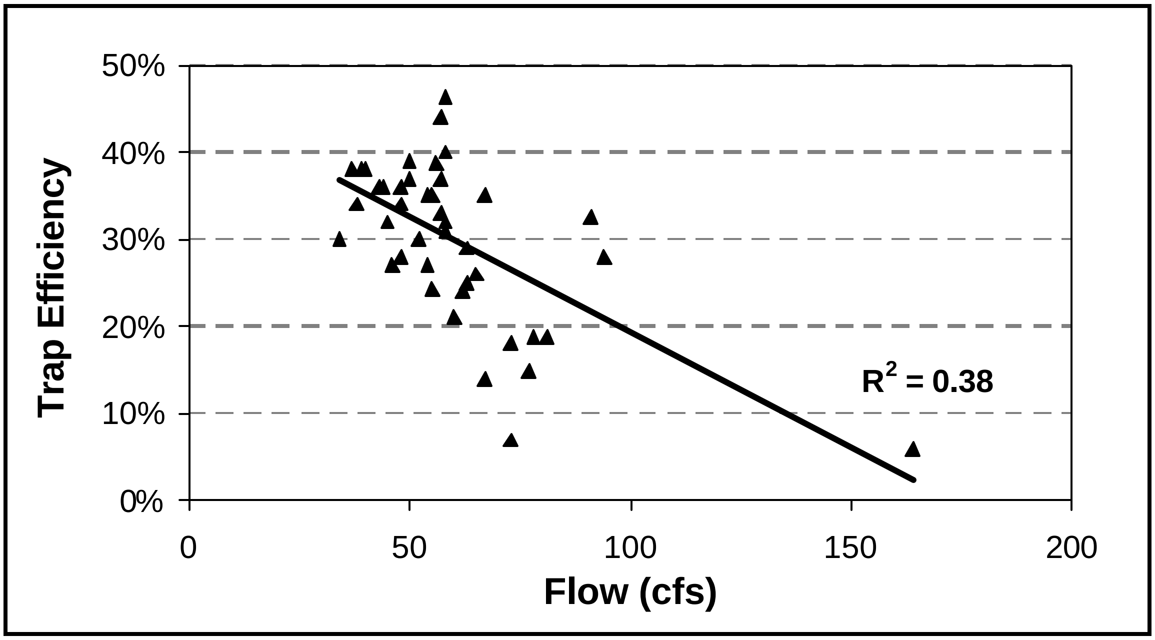

Figure 21. Regression analysis of the relationship between average daily stream flow and coho trap efficiency, Bear Creek screw trap 2002.

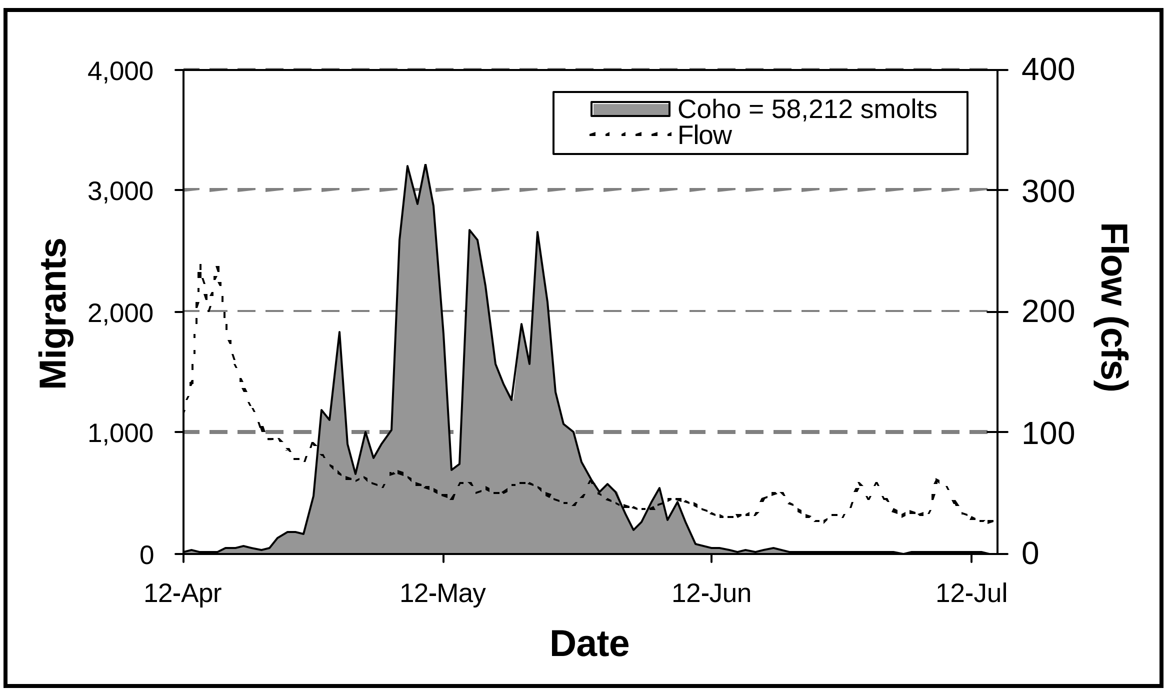

Figure 22. Estimated daily coho smolt migration and daily average flow, Bear Creek screw trap 2002.

Steelhead and Cutthroat

Catch

A total of 12 unmarked steelhead smolts were captured between April 29 and June 22. Daily catch peaked on April 30 when three steelhead were caught. Due to the low catches, there was no definable timing pattern during the period of trap operation. Four steelhead were PIT tagged during the trapping season.

A total of 555 cutthroat trout were captured in the screw trap between April 12 and July 15. Daily catch peaked on May 3 when 30 cutthroat were caught. Due to the low catches, there was no definable timing pattern during the period of trap operation.

Size

Over the season, steelhead smolt fork length averaged 193 mm and ranged from 164 to 237 mm (Table 27). Cutthroat trout fork length averaged 182 mm, and varied from 121 to 320 mm throughout the trapping season (Table 27).

Table 27. Mean fork lengths, standard deviations, ranges, sample sizes, and catches of steelhead and cutthroat by statistical week, Bear Creek screw trap 2002.

Statistical Week			STEELHEAD						CUTTHROAT					
					Range						Range			
Begin	End	No.	Avg.	s.d.	Min	Max	n	Catch	Avg.	s.d.	Min	Max	n	Catch
04/12	04/14	15						0	192.5	13.6	155	207	11	13
04/15	04/21	16						0	209.3	16.1	176	223	8	15
04/22	04/28	17						0	204.7	27.3	138	275	48	68
04/29	05/05	18	209.2	23.4	185	237	5	5	183.7	24.3	134	275	40	123
05/06	05/12	19	171.5	10.6	164	179	2	2	181.8	22.7	148	261	53	93
05/13	05/19	20	186.0	5.7	182	190	2	2	172.8	26.6	135	243	34	35
05/20	05/26	21						0	166.0	20.7	121	207	42	81
05/27	06/02	22	180.5	12.0	172	189	2	2	165.5	23.1	132	230	39	59
06/03	06/09	23						0	188.3	32.3	154	232	4	28
06/10	06/16	24						0					0	20
06/17	06/23	25					0	1	166.7	11.0	158	179	3	8
06/24	06/30	26						0	156.3	28.1	132	191	4	6
07/01	07/07	27						0	186.7	37.4	158	229	3	3
07/08	07/14	28						0	249.0	92.0	145	320	3	3
		Totals	192.9	22.6	164	237	11	12	181.8	29.2	121	320	292	555

Trap Efficiency

As in the Cedar River, daily catches of steelhead and cutthroat were too low to enable their use in mark-recapture trap efficiency experiments. Efficiency was estimated by applying the 60% average steelhead to coho capture rate, derived from the Toutle, Green, and White Salmon Rivers (p. 40), to the estimated average coho smolt catch rate of 30%. The resulting capture rate was estimated at 18%. This rate may underestimate the actual catch rate in the screw trap because the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape. Therefore, we selected to round the trap efficiency to 20% for estimating steelhead and cutthroat migration from Bear Creek in 2002.

Production Estimate

Application of these catch rates to the actual catch estimates a total migration of 60 steelhead smolts (Figure 23). Using the same rates, total cutthroat migration during the trapping period is estimated at 2,775 smolts (Figure 23). No confidence intervals were developed for these estimates, which apply only to the period of screw trap operation (April 12 through July 15). While cutthroat migration very likely occurred before and after this interval, the migration timing trends indicate that the majority of the catch migrated during the trapping season. Catches were low toward the beginning and end of the season, although this does not define the start or end of the migration. Therefore, we did not attempt to expand our cutthroat estimate beyond the trapping period. The estimate of cutthroat migration during the trapping season represents an unknown portion of the total production of downstream migrant cutthroat from Bear Creek.

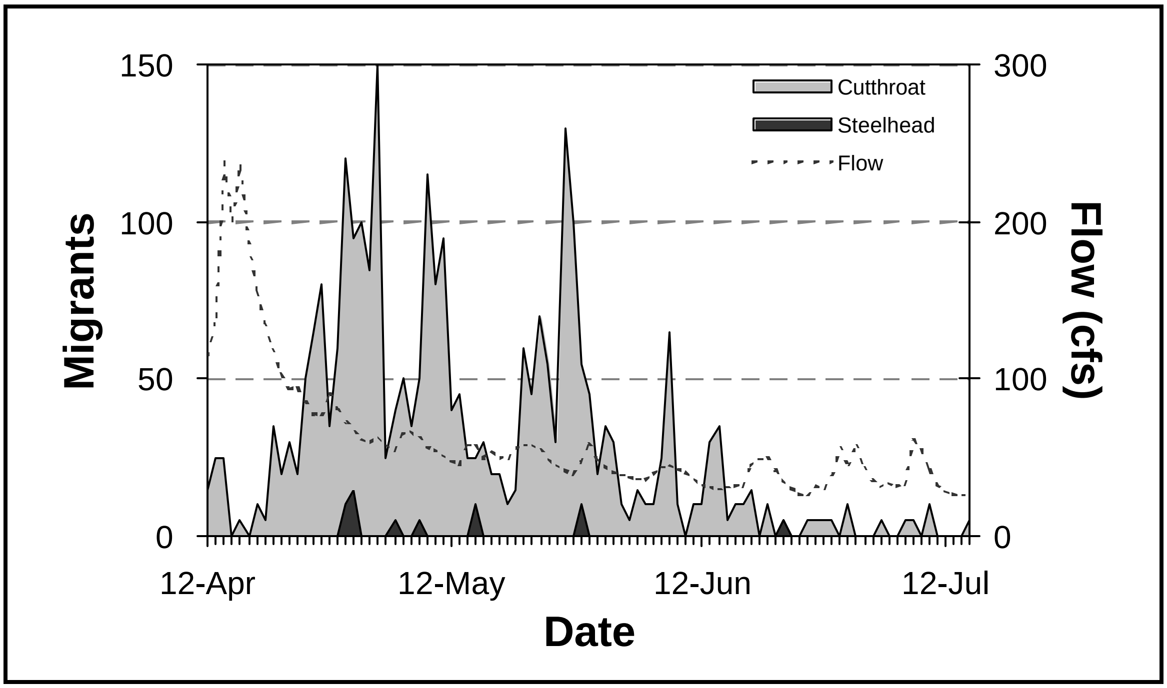

Figure 23. Daily estimated migration of steelhead and cutthroat trout and daily average flow, Bear Creek screw trap 2002.

Mortality

Throughout the fry trapping season, there were two chinook 0+ mortalities. The screw trap had ten chinook mortalities throughout the trapping season.

Incidental Species

In addition to sockeye and chinook fry caught at the fry trap, we also captured three trout parr, 23 coho fry, 16 coho smolts, 32 cutthroat smolts, 14 cutthroat adults, and one Northern Pike Minnow. In addition to the species estimated at the screw trap, we also caught five chinook 1+, six coho fry, one cutthroat adult, and two Northern Pike Minnows. Non-salmonids caught also included lamprey, sculpin, pumpkinseed, peamouth, dace, crawfish, perch, and bullfrog tadpoles.

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Personal Communications

Steve Foley, Fish and Wildlife Biologist. Washington Department of Fish and Wildlife, Mill Creek. Electronic mail on April 15, 2002.

Jack Tipping, Fish and Wildlife Biologist. Washington Department of Fish and Wildlife, Olympia. Memo on September 13, 2002.

Appendix A: Daily Estimated Cedar River Wild and Hatchery Sockeye Fry Migration into Lake Washington, 2002.

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2002.

Date	Flow (cfs)	Nightly Catch Actual	Nightly Catch Estimate	Trap Efficiency	Daily Migration Wild	Daily Migration Hatchery
01/21	1,350	582	970	5.3%	29,826	0
01/22	1,280		12,966	5.6%	31,119	201,000
01/23	1,240		1,866	5.8%	33,015	0
01/24	1,120		22,072	6.3%	32,907	319,000
01/25	1,350	2,179		5.3%	42,088	0
01/26	1,320		1,922	5.4%	36,120	0
01/27	1,110	1,665		6.3%	26,723	0
01/28	1,010		17,192	6.8%	29,145	225,327
01/29	953	2,756		7.0%	32,101	7,695
01/30	966		2,412	6.9%	35,180	0
01/31	1,100	2,606		6.4%	41,408	0
02/01	1,170	3,166		6.1%	52,741	0
02/02	1,140	2,465		6.2%	40,245	0
02/03	1,130	4,206		6.2%	68,276	0
02/04	1,090	3,237		6.4%	51,095	0
02/05	1,070	3,524		6.5%	54,946	0
02/06	971	5,461		6.9%	79,938	0
02/07	971	30,104		6.9%	85,673	354,508
02/08	1,080	6,239		6.5%	97,919	0
02/09	984	6,564		6.9%	97,230	0
02/10	943	6,569		7.0%	94,751	0
02/11	914	45,291		7.2%	94,296	547,665
02/12	813	40,427		7.6%	89,985	450,358
02/13	785	8,496		7.7%	104,730	6,685
02/14	758	9,037		7.8%	116,894	0
02/15	707	10,935		8.1%	137,457	883,000
02/16	693	14,937		8.1%	146,685	39,790
02/17	681	13,179		8.2%	162,016	2,193
02/18	709	17,694		8.0%	223,740	0
02/19	722	24,140		8.0%	303,172	0
02/20	712	47,980		8.0%	193,517	411,215
02/21	981	37,489		6.9%	402,222	151,293
02/22	1,400	14,220	6,123	5.1%	406,250	0
02/23	1,350	22,604		5.3%	434,391	0
02/24	1,170	23,645		6.1%	396,169	0
02/25	1,000	18,790		6.8%	281,126	0
02/26	1,000	23,342		6.8%	349,742	0
02/27	943	50,142		7.0%	225,554	493,577
02/28	989	41,061		6.8%	219,989	390,137
03/01	916	38,716		7.2%	194,685	356,289
03/02	835	17,413		7.5%	230,063	6,303
03/03	814	20,295		7.6%	272,213	0
03/04	794	18,056		7.7%	239,858	1,177,000
03/05	918	72,099		7.1%	278,572	747,643
03/06	1,080	43,768		6.5%	87,914	597,754
03/07	955	45,968		7.0%	151,831	511,406

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2002 (cont'd.).

Date	Flow (cfs)	Nightly Catch Actual	Nightly Catch Estimate	Trap Efficiency	Daily Migration Wild	Daily Migration Hatchery
03/08	1,060	14,752		6.5%	219,003	10,685
03/09	1,060	18,932		6.5%	295,265	0
03/10	1,060	21,742		6.5%	339,655	0
03/11	1,260	38,078		5.7%	683,263	1,061,000
03/12	1,130	64,241		6.2%	454,990	583,163
03/13	1,130	57,361		6.2%	349,469	575,842
03/14	1,110	42,009		6.3%	392,245	282,114
03/15	1,040	29,241		6.6%	419,478	29,860
03/16	974	25,913		6.9%	382,012	0
03/17	863	27,495		7.4%	380,498	0
03/18	753	27,654		7.9%	359,757	0
03/19	711	50,620		8.0%	653,703	0
03/20	1,040	29,000		6.6%	445,747	0
03/21	1,250	32,309		5.7%	575,414	1,151,000
03/22	1,460	31,692		4.8%	668,410	0
03/23	1,419	31,540		5.0%	643,978	0
03/24	1,400	28,306		5.1%	567,748	0
03/25	1,419	39,062		5.0%	797,551	0
03/26	1,280	28,996		5.6%	528,002	0
03/27	1,160	42,072		6.1%	308,443	385,349
03/28	1,060	27,600		6.5%	416,101	14,063
03/29	1,019	26,143		6.7%	398,472	0
03/30	1,060	30,733		6.5%	479,308	0
03/31	1,070	32,230		6.5%	508,761	0
04/01	1,130	49,827		6.2%	814,391	0
04/02	1,190	58,358		6.0%	988,783	0
04/03	1,180	50,107		6.0%	846,717	0
04/04	1,140	50,247		6.2%	825,642	0
04/05	1,050	26,162		6.6%	404,740	0
04/06	973	32,800		6.9%	486,674	0
04/07	989	48,607		6.8%	725,642	0
04/08	979	41,379		6.9%	615,031	0
04/09	1,040	47,380		6.6%	731,963	0
04/10	1,150	39,696		6.2%	659,294	0
04/11	1,210	31,056		5.9%	537,954	0
04/12	1,290	25,657	869	5.6%	486,977	0
04/13	1,540	4,696	13,263	4.5%	409,352	0
04/14	2,320		12,876	2.4%	561,047	0
04/15	1,960	1,961	5,831	2.7%	297,469	0
04/16	1,940	4,969	3,748	2.8%	338,050	0
04/17	1,770	11,033		3.5%	322,447	0
04/18	1,620	7,852		4.1%	194,322	0
04/19	1,770	6,881		3.5%	201,958	0
04/20	1,710	7,806		3.8%	213,457	0
04/21	1,670	7,342		3.9%	192,028	0
04/22	1,630	9,313		4.1%	233,400	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2002 (cont'd.).

Date	Flow (cfs)	Nightly Catch Actual	Nightly Catch Estimate	Trap Efficiency	Daily Migration Wild	Daily Migration Hatchery
04/23	1,340	13,905		5.3%	265,029	0
04/24	1,050	10,553		6.6%	164,411	0
04/25	929	7,901		7.1%	114,127	0
04/26	924	6,279		7.1%	90,427	0
04/27	940	9,492		7.1%	138,020	0
04/28	800	8,009		7.7%	107,568	0
04/29	720		7,424	8.0%	95,797	0
04/30	720	6,838		8.0%	88,620	0
05/01	686		5,804	8.1%	73,871	0
05/02	679	4,769		8.2%	60,471	0
05/03	757		4,834	7.8%	63,888	0
05/04	788		4,899	7.7%	65,870	0
05/05	796	4,964		7.7%	67,051	0
05/06	757		5,383	7.8%	71,172	0
05/07	906	5,802		7.2%	83,502	0
05/08	950		4,677	7.0%	69,203	0
05/09	949	3,551		7.0%	52,615	0
05/10	863		3,428	7.4%	48,336	0
05/11	755		3,304	7.8%	43,816	0
05/12	679	3,181		8.2%	40,465	0
05/13	636		2,857	8.4%	35,700	0
05/14	607		2,534	8.5%	31,055	0
05/15	568	2,210		8.6%	26,412	0
05/16	561		2,150	8.7%	25,704	0
05/17	579		2,089	8.6%	25,219	0
05/18	579		2,029	8.6%	24,504	0
05/19	581	1,968		8.6%	23,813	0
05/20	594		1,605	8.5%	19,549	0
05/21	592		1,242	8.5%	15,114	0
05/22	597		878	8.5%	10,726	0
05/23	583	515		8.6%	6,256	0
05/24	738		462	7.9%	6,080	0
05/25	1,100		408	6.4%	6,687	0
05/26	1,150		355	6.2%	6,018	0
05/27	1,150		301	6.2%	5,116	0
05/28	1,040		248	6.6%	3,915	0
05/29	925	194		7.1%	2,851	0
Total		2,252,028	159,018		31,269,106	11,972,914

Appendix B: Estimated Daily Migrations of Chinook, Coho, Steelhead and Cutthroat, Cedar River 2002.

Appendix B. Estimated daily migrations of chinook, coho, steelhead and cutthroat, Cedar River 2002.

Date	Flow (cfs)	Chinook Catch Scoop	Chinook Catch Screw	Chinook Migration	Coho Migration	Steelhead Migration	Cutthroat Migration
01/25	1,350	58		1,094			
01/26	1,320	36		663			
01/27	1,110	8		126			
01/28	1,010	4		59			
01/29	953	1		14			
01/30	966	5		72			
01/31	1,100	10		157			
02/01	1,170	27		445			
02/02	1,140	6		97			
02/03	1,130	59		945			
02/04	1,090	16		249			
02/05	1,070	11		169			
02/06	971	9		130			
02/07	971	41		592			
02/08	1,080	36		558			
02/09	984	37		539			
02/10	943	36		511			
02/11	914	120		1,674			
02/12	813	41		540			
02/13	785	35		453			
02/14	758	76		970			
02/15	707	54		671			
02/16	693	29		357			
02/17	681	36		441			
02/18	709	47		584			
02/19	722	212		2,654			
02/20	712	307		3,823			
02/21	981	336		4,884			
02/22	1,400	382		7,510			
02/23	1,350	84		1,585			
02/24	1,170	186		3,064			
02/25	1,000	65		956			
02/26	1,000	99		1,456			
02/27	943	42		596			
02/28	989	132		1,928			
03/01	916	100		1,397			
03/02	835	104		1,386			
03/03	814	63		830			
03/04	794	21		273			
03/05	918	94		1,315			
03/06	1,080	50		774			
03/07	955	43		615			
03/08	1,060	40		611			
03/09	1,060	48		734			
03/10	1,060	48		734			
03/11	1,260	217		3,816			

Appendix B. Estimated daily migrations of chinook, coho, steelhead and cutthroat, Cedar River 2002 (Cont'd.).

Date	Flow (cfs)	Chinook Catch Scoop	Chinook Catch Screw	Chinook Migration	Coho Migration	Steelhead Migration	Cutthroat Migration
03/12	1,130	60		961			
03/13	1,130	41		657			
03/14	1,110	33		521			
03/15	1,040	57		860			
03/16	974	26		376			
03/17	863	17		230			
03/18	753	23		293			
03/19	711	161		2,004			
03/20	1,040	94		1,418			
03/21	1,250	85		1,484			
03/22	1,460	75		1,553			
03/23	1,419	83		1,658			
03/24	1,400	49		963			
03/25	1,419	82		1,638			
03/26	1,280	35		625			
03/27	1,160	10		164			
03/28	1,060	8		122			
03/29	1,019	15		223			
03/30	1,060	11		168			
03/31	1,070	15		231			
04/01	1,130	71	48	1,137	81	0	75
04/02	1,190	76	54	1,270	244	25	25
04/03	1,180	55	77	912	277	0	125
04/04	1,140	20	32	323	163	0	100
04/05	1,050	8	8	121	49	0	50
04/06	973	10	8	145	81	0	75
04/07	989	39	45	570	163	50	100
04/08	979	6	4	87	147	0	75
04/09	1,040	17	14	257	163	0	125
04/10	1,150	29	9	471	261	50	275
04/11	1,210	10	3	169	309	50	225
04/12	1,290	14	3	252	195	25	100
04/13	1,540	22	1	490	293	0	50
04/14	2,320	10	1	425	423	0	100
04/15	1,960	0	1	14	423	0	100
04/16	1,940	1	1	14	423	0	100
04/17	1,770	7	1	14	423	0	100
04/18	1,620	1	2	29	635	0	75
04/19	1,770	2	1	14	114	25	0
04/20	1,710	1	0	0	342	0	25
04/21	1,670	0	4	58	440	100	75
04/22	1,630	4	10	145	603	50	25
04/23	1,340	11	17	246	765	25	0
04/24	1,050	4	10	145	342	50	125
04/25	929	7	5	72	472	0	100

Appendix B. Estimated daily migrations of chinook, coho, steelhead and cutthroat, Cedar River, 2002 (Cont'd.).

Date	Flow (cfs)	Chinook Catch		Chinook Migration	Coho Migration	Steelhead Migration	Cutthroat Migration
		Scoop	Screw				
04/26	924	4	3	43	456	0	75
04/27	940	2	3	43	945	75	50
04/28	800	2	9	130	1,010	25	75
04/29	720	1	9	130	1,010	0	25
04/30	720	1	6	87	1,238	25	50
05/01	686	6	9	130	1,580	25	50
05/02	679	11	14	203	1,873	0	50
05/03	757	11	6	87	1,775	0	50
05/04	788	10	18	261	782	0	25
05/05	796	9	19	275	1,938	50	0
05/06	757	9	48	695	1,563	0	0
05/07	906	9	29	420	2,540	0	50
05/08	950	8	17	246	2,703	50	25
05/09	949	6	25	362	1,856	0	25
05/10	863	4	20	290	2,980	0	50
05/11	755	4	1	14	1,596	0	0
05/12	679	0	3	43	1,303	0	0
05/13	636	1	16	232	1,433	25	50
05/14	607	1	31	449	1,498	25	0
05/15	568	3	15	217	2,540	0	50
05/16	561	3	3	43	619	0	0
05/17	579	3	2	29	896	0	0
05/18	579	3	4	58	896	0	0
05/19	581	4	2	29	195	0	0
05/20	594	3	16	232	1,026	0	0
05/21	592	3	11	159	977	0	0
05/22	597	3	22	319	1,596	25	0
05/23	583	2	48	695	2,150	0	0
05/24	738	4	47	681	977	25	0
05/25	1,100	4	29	420	1,791	0	50
05/26	1,150	4	20	290	1,075	25	0
05/27	1,150	4	28	405	1,059	50	0
05/28	1,040	5	37	536	1,140	0	0
05/29	925	7	46	666	1,221	0	0
05/30	688		33	478	391	0	0
05/31	600		47	681	423	25	0
06/01	623		37	536	456	0	25
06/02	645		20	290	228	0	0
06/03	639		11	159	130	0	0
06/04	654		44	637	358	0	0
06/05	886		52	753	375	0	0
06/06	994		147	2,129	391	0	25
06/07	1,300		35	507	277	0	50
06/08	1,490		96	1,390	326	0	25
06/09	1,490		29	420	163	0	0

Appendix B. Estimated daily migrations of chinook, coho, steelhead and cutthroat, Cedar River, 2002 (Cont'd.).

Date	Flow (cfs)	Chinook Catch Scoop	Chinook Catch Screw	Chinook Migration	Coho Migration	Steelhead Migration	Cutthroat Migration
06/10	1,429		58	840	195	0	0
06/11	1,170		39	565	33	0	25
06/12	928		43	623	65	0	0
06/13	713		30	434	33	0	50
06/14	655		45	652	16	0	0
06/15	670		75	1,086	33	0	25
06/16	664		112	1,622	16	0	0
06/17	920		320	4,634	33	0	25
06/18	1,230		62	898	65	0	0
06/19	1,250		80	1,158	16	0	50
06/20	1,250		33	478	16	0	50
06/21	1,230		32	463	81	0	0
06/22	1,220		35	507	49	0	25
06/23	1,230		29	420	16	0	25
06/24	1,150		34	492	0	0	0
06/25	968		41	594	16	0	25
06/26	822		34	492	0	0	0
06/27	815		41	594	16	0	0
06/28	900		55	796	0	0	25
06/29	967		51	738	16	0	25
06/30	889		33	478	0	0	0
07/01	770		56	811	0	0	0
07/02	640		19	275	0	0	25
07/03	400		12	174	0	0	0
07/04	270		26	376	49	0	0
07/05	257		23	333	33	0	75
07/06	257		15	217	49	25	0
07/07	265		17	246	0	25	0
07/08	290		28	405	0	0	25
07/09	270		6	87	0	0	0
07/10	280		0	0	0	0	25
07/11	279		5	72	0	0	0
07/12	266		3	43	0	0	0
07/13	245		6	87	0	0	0
07/14	241		12	174	0	0	0
07/15	239		7	101	16	0	0
07/16	234		1	14	33	0	0
07/17	242		0	0	16	0	0
07/18	246		2	29	0	0	0
07/19	247		8	116	16	0	0
07/20	245		5	72	0	0	0
07/21	241		2	29	0	0	0
07/22	241		0	0	0	0	0
Total		5,070	3,061	119,674	60,513	950	3,600

Appendix C: Estimated Sockeye, Chinook, Coho, Steelhead and Cutthroat Daily Migrations, Bear Creek 2002.

Appendix C. Estimated sockeye, chinook, coho, steelhead and cutthroat migrations, Bear Creek 2002.

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
FRY TRAP						
02/01	200	437	8			
02/02	180	607	8			
02/03	164	769	8			
02/04	146	672	8			
02/05	138	575	0			
02/06	148	2,258	81			
02/07	168	2,978	81			
02/08	262	3,698	49			
02/09	216	4,095	73			
02/10	190	4,491	113			
02/11	212	2,865	81			
02/12	180	1,295	40			
02/13	157	3,278	0			
02/14	139	3,852	0			
02/15	126	2,921	57			
02/16	114	2,630	57			
02/17	108	2,387	49			
02/18	106	6,275	18			
02/19	124	7,092	30			
02/20	116	5,465	30			
02/21	186	53,599	142			
02/22	328	217,592	1,051			
02/23	328	324,769	552			
02/24	284	74,513	242			
02/25	222	42,679	200			
02/26	180	25,593	118			
02/27	155	20,895	266			
02/28	159	19,527	264			
03/01	141	14,350	212			
03/02	127	6,522	177			
03/03	113	7,183	186			
03/04	102	4,560	97			
03/05	97	6,737	66			
03/06	93	4,547	38			
03/07	85	2,970	36			
03/08	87	4,403	18			
03/09	86	2,189	18			
03/10	100	10,082	0			
03/11	167	132,701	78			
03/12	169	72,060	478			
03/13	168	60,974	171			
03/14	155	52,057	12			
03/15	177	117,338	0			
03/16	175	67,779	70			

Appendix C. Estimated sockeye, chinook, coho, steelhead and cutthroat migrations, Bear Creek 2002 (Cont'd).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
FRY TRAP						
03/17	164	55,496	25			
03/18	148	30,630	0			
03/19	147	26,086	0			
03/20	194	17,254	17			
03/21	180	21,897	0			
03/22	160	62,831	12			
03/23	142	104,582	0			
03/24	130	56,778	36			
03/25	118	111,407	8			
03/26	106	61,257	7			
03/27	100	27,156	0			
03/28	114	144,707	0			
03/29	132	57,617	0			
03/30	120	45,704	0			
03/31	106	28,512	0			
04/01	97	67,441	7			
04/02	89	43,587	0			
04/03	81	31,822	0			
04/04	75	30,364	27			
04/05	70	15,109	5			
04/06	71	15,240	0			
04/07	83	10,409	0			
04/08	76	10,987	0			
04/09	82	21,915	0			
04/10	121	29,648	0			
04/11	118	13,479	8			
SCREW TRAP						
04/12	115	33,058	2	10	0	15
04/13	140	74,772	19	27	0	25
04/14	238	1,577	5	7	0	25
04/15	201	3,471	2	3	0	0
04/16	236	730	5	17	0	5
04/17	188		0	50	0	0
04/18	156		9	47	0	10
04/19	136		0	57	0	5
04/20	119		2	40	0	35
04/21	103		0	30	0	20
04/22	94		0	37	0	30
04/23	94		5	131	0	20
04/24	86		9	171	0	50
04/25	78		14	171	0	65
04/26	77		7	161	0	80
04/27	91		7	469	0	35
04/28	81		19	1,179	0	60

Appendix C. Estimated sockeye, chinook, coho, steelhead and cutthroat migrations, Bear Creek 2002 (Cont'd).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
SCREW TRAP						
04/29	73		19	1,099	10	120
04/30	67		23	1,819	15	95
05/01	62		5	898	0	100
05/02	60		23	660	0	85
05/03	63		21	995	0	150
05/04	58		51	790	0	25
05/05	55		35	898	5	40
05/06	65		54	1,011	0	50
05/07	67		81	2,579	0	35
05/08	63		72	3,195	5	50
05/09	57		44	2,890	0	115
05/10	55		61	3,219	0	80
05/11	52		105	2,874	0	95
05/12	48		63	1,809	0	40
05/13	46		37	680	0	45
05/14	58		44	740	0	25
05/15	57		154	2,663	10	25
05/16	50		112	2,582	0	30
05/17	54		58	2,210	0	20
05/18	50		95	1,561	0	20
05/19	50		151	1,403	0	10
05/20	56		189	1,269	0	15
05/21	58		433	1,899	0	60
05/22	58		354	1,557	0	45
05/23	55		612	2,646	0	70
05/24	49		805	2,073	0	55
05/25	45		319	1,326	0	30
05/26	42		319	1,068	0	130
05/27	40		442	1,008	0	100
05/28	47		494	757	10	55
05/29	59		491	600	0	45
05/30	50		554	512	0	20
05/31	45		636	566	0	35
06/01	41		698	502	0	30
06/02	39		335	325	0	10
06/03	38		196	191	0	5
06/04	36		314	251	0	15
06/05	36		929	419	0	10
06/06	40		1,390	533	0	10
06/07	44		941	268	0	25
06/08	45		803	415	0	65
06/09	43		761	265	0	10
06/10	41		198	70	0	0
06/11	36		186	60	0	10

Appendix C. Estimated sockeye, chinook, coho, steelhead and Cutthroat migrations, Bear Creek 2002 (Cont'd).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
SCREW TRAP						
06/12	33.1		98	44	0	10
06/13	31.4		156	40	0	30
06/14	30.1		258	27	0	35
06/15	31.0		161	13	0	5
06/16	31.5		205	20	0	10
06/17	31.8		100	10	0	10
06/18	44.5		424	27	0	15
06/19	48.6		119	47	0	0
06/20	50.2		91	23	0	10
06/21	41.6		49	10	0	0
06/22	35.7		84	13	5	5
06/23	30.5		33	10	0	0
06/24	27.5		40	13	0	0
06/25	25.6		37	10	0	5
06/26	31.6		42	17	0	5
06/27	30.8		23	13	0	5
06/28	38.8		51	10	0	5
06/29	56.6		70	7	0	0
06/30	44.6		30	3	0	10
07/01	57.6		28	7	0	0
07/02	44.0		5	3	0	0
07/03	36.4		12	10	0	0
07/04	30.5		9	0	0	5
07/05	33.8		9	7	0	0
07/06	32.1		7	10	0	0
07/07	32.6		21	10	0	5
07/08	61.1		16	17	0	5
07/09	55.3		5	13	0	0
07/10	42.1		5	7	0	10
07/11	33.3		7	3	0	0
07/12	29.0		5	3	0	0
07/13	26.6		5	3	0	0
07/14	25.7		2	0	0	0
07/15	25.8		0	0	0	5
Total		2,659,782	21,454	58,212	60	2,775