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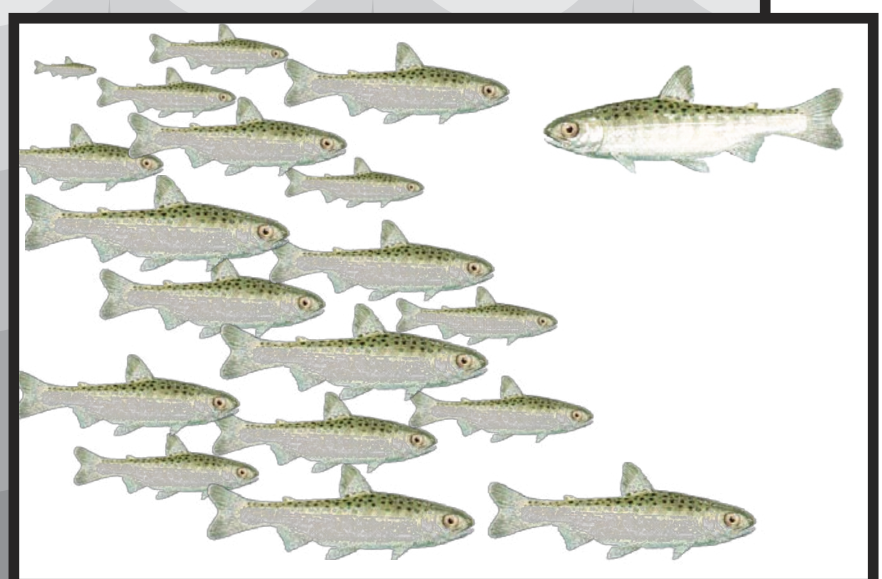
Evaluation of Downstream Migrant Salmon Production in 2004 from the Cedar River and Bear Creek



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CEDAR RIVER

The Boeing Company provided electrical power and a level of security for our fry trap.
The Renton Municipal Airport provided security for the fry trap.
The City of Renton Parks Department provided access and allowed us to attach anchor cables to their property.
The United States Geological Survey provided continuous flow monitoring.
Seattle Public Utilities communicated flow changes.

BEAR CREEK

Blockbuster Video provided electrical power.
The City of Redmond Police Department provided a measure of security for the crew and trap.
King County provided continuous flow monitoring.

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EXECUTIVE SUMMARY

This report provides the results of monitoring five salmonid species as downstream migrants in 2004 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 2004, 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 1980s and early 1990s prompted an 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 2004, the thirteenth 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 for natural spawners from egg deposition to lake entry, for hatchery produced fry from release to lake entry, and for both production components from lake entry to subsequent life stages of smolts and adults.

Beginning in January and continuing through May, a floating inclined-plane screen 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 54 nights, dye-marked fry were released upstream of the trap. Linear regression analysis found trap efficiency to be significantly correlated with flow while the level of Lake Washington was below capacity and river discharge was adequate. Daily trap efficiency was estimated using the regression from January to April 26. Following April 26, the rise in the lake level and the decreasing river flow reduced trap efficiency. For the interval from April 27 through May 30, we estimated migration with the average trap efficiency (8.6%) of the eight tests conducted during that interval.

Over the season, 9.9 million hatchery produced sockeye fry were released into the Cedar River from two locations. A portion of these fry (7.2 million) was released below the fry trap at the Cedar River Trail Park. The remaining 2.7 million fry were released from Landsburg Hatchery on 12 nights. All hatchery fry were internally marked on the otolith by slightly manipulating water temperatures in the hatchery.

Over the 82 nights trapped, 2.8 million sockeye fry were captured and this catch was expanded for intervals not fished. Application of the capture efficiency to the expanded catch estimated a total of 47.9 million wild and hatchery sockeye fry entered Lake Washington in 2004. This total included

38.7 million wild fry and 9.2 million hatchery produced fry. Average survival to the trap of the 2.7 million hatchery fry released upstream was estimated at 74.4%.

Migration timing for wild fry in 2004 was near average for the twelve broods measured thus far. February temperatures and flows explain most of the variation in median migration dates between years. Median migration dates for hatchery and wild fry were February 23 and March 21, respectively. Survival from egg deposition to lake entry of wild fry was estimated at 11.8%. This rate is the ratio of 38.7 million wild fry to an estimated deposition of 327 million eggs.

In response to the listing of the Puget Sound Chinook Evolutionary Significant Unit (ESU) under the Endangered Species Act as a threatened species, the existing sockeye fry monitoring program was expanded 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 chinook 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. 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 120,876 in 2004. Timing was bi-modal with fry emigrating in January through mid-April comprising approximately half of the total migration. Egg-to-migrant survival was estimated at 8.0%. Over the season, age 0+ chinook increased in size from less than 40 mm in January to over 100 mm by mid-June.

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 70,044, 120 and 3,480, respectively.

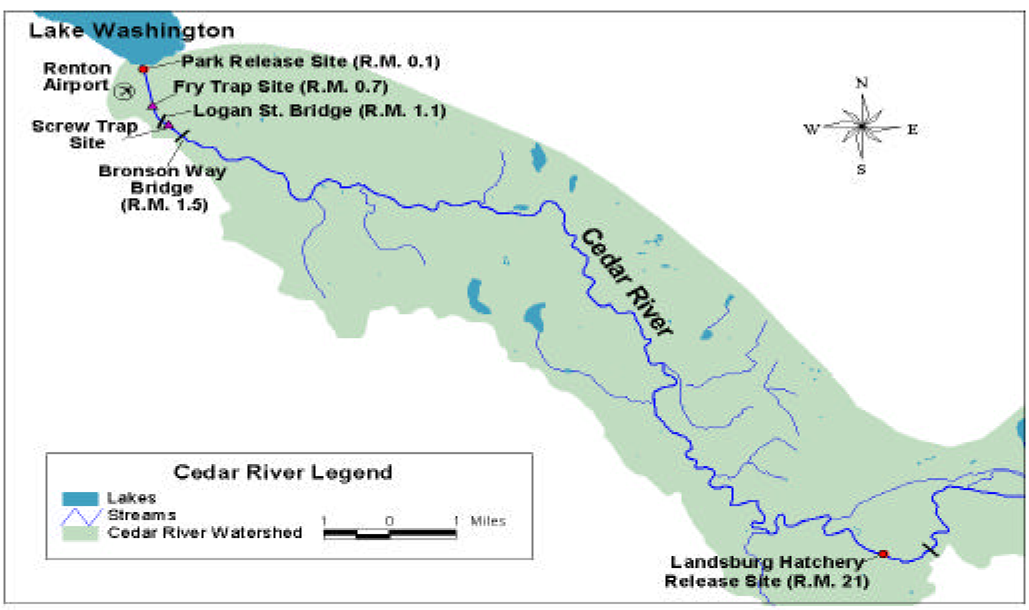

Figure 1. Site map of the lower Cedar River watershed depicting the fry and screw trap locations, hatchery sockeye release sites, and trap efficiency test release sites for the 2004 trapping season.

Bear Creek

We installed the fry trap on Big Bear Creek 100 yards downstream of the Redmond Way Bridge and operated it from February 5 through April 4. On April 5, we replaced it with a screw trap that fished until the morning of June 27. Using the approach described for the Cedar River, downstream migrant production was estimated for wild sockeye fry, age 0+ chinook, coho, steelhead, and cutthroat smolts.

Throughout the fry trapping season, 12 efficiency tests were conducted using sockeye fry. Capture rates ranged from 8.7% to 20.9% and averaged 16.5%. Linear regression analysis correlating efficiency and flow did not yield a significant relationship. Total sockeye production was estimated at 177,801 fry. Relating this production to the estimated deposition of 2.8 million eggs yielded a survival rate of 6.3%.

Migration of age 0+ chinook during fry trap operation was estimated using the average efficiency measured with sockeye fry. During screw trap operation capture rates averaged 49.2% for the 22 tests that were conducted using chinook smolts. Total production of age 0+ chinook was estimated at 23,647 in 2004. Migration timing was generally unimodal, with most chinook migrating as smolts in May. Weekly chinook fork lengths averaged less than 40 mm in February, and slightly exceeded 90 mm by late June. Egg to migrant survival was estimated at 5.0%.

Coho production was estimated at 21,085 smolts and cutthroat production at 4,540 smolts. During the 2004 trapping season, no steelhead were caught in the Bear Creek screw trap.

INTRODUCTION

The decline of sockeye salmon returns to Lake Washington from the mid 1980s to 1991 prompted managers to begin investigating the cause(s). Although over 500,000 fish returned in 1988, by 1991 less than 100,000 sockeye returned through the Ballard Locks. In 1991, a broad-based group was formed to address this decline. Resource managers developed a program involving population monitoring in combination with an artificial production program. Information generated by these efforts, which continued through 2004, 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%, 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, survival in freshwater, as measured by smolts per spawner rates, declined over this same 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 explain causes for population variation. In 1992, we developed the trapping gear and methodology to estimate wild and hatchery sockeye fry production from the Cedar River and began monitoring. To assess sockeye fry production on a basin scale, we began monitoring sockeye fry production in the Sammamish Slough in 1997 and since 1999 have continued in Bear Creek.

The Puget Sound Chinook 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 recovery 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 includes passage through the lake, Ship Canal, Locks, and 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 the chinook migration includes newly emerged fry and later, larger smolts, we employed two different gear types. The fry 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 fry trap in the lower Cedar River to evaluate the production of wild and hatchery sockeye fry. Production of sockeye fry at the Landsburg Hatchery on the Cedar River began with the 1991 brood. Released in 1992, this brood and all subsequent sockeye incubated at this hatchery, have been identified with thermally-induced otolith-marks (Volk *et al.* 1990). In 1995, we evaluated the effect of flow on survival by releasing ten hatchery groups 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 that over the twelve broods measured, 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. 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 rates during incubation and migration.

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 upstream 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 operated 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 successfully estimated sockeye fry production, velocities in the Sammamish 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 high enough to capture larger migrants. In addition to estimating chinook and sockeye production, higher velocities also enabled estimating the production of coho, steelhead and cutthroat smolts.

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. **Estimate in-river survival.** Relating total migrant production to the estimated egg deposition estimates in-river (egg-to-migrant) survival. Over time, we will correlate this rate among broods with such factors as spawner abundance, flows, and habitat condition.
2. **Estimate fry and smolt productions.** Relating the proportions of fry and smolts to brood specific factors will identify production determinants.
3. **Estimate lake/marine survival of natural production.** Relating subsequent adult returns to a brood's juvenile production will estimate survival through the lake, the Ballard Locks, and the marine environment.
4. **Tag wild chinook.** Tagging wild chinook emigrating from the Cedar River and Bear Creek with PIT tags will assess survival through the lake system.

Sockeye

1. **Estimate 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 and the relative importance of production determinants.
2. **Estimate 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. **Estimate survival of hatchery fry by release group (Cedar River).** 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. **Estimate incidence of hatchery fry in the population at lake entry (Cedar River).** 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. **Develop 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 the adaptive management process guiding Cedar River Hatchery sockeye fry production.

Coho, Steelhead, and Cutthroat

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

METHODS

Trapping Gear and Operation

Cedar River

In each year since 1999, two traps were operated in the lower Cedar River during the spring out-migration period. A small floating inclined plane (fry) trap was operated in late winter through spring to capture a proportion of the migrating sockeye and chinook fry emigrating during this period. The size and placement of this trap was chosen to avoid capturing yearling migrants and to avoid predation in the trap. A floating rotary screw trap was operated during the early spring to summer months to assess the migration of chinook, coho, steelhead, and cutthroat. Because this trap was employed to capture larger migrants that would prey on sockeye fry, the live box was designed so as not to retain sockeye fry. Together, these traps enabled estimating the production of each species while minimizing mortality.

Fry 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 40x13 ft steel pontoon barge. Fish are separated from the water via a perforated aluminum plate (33 - 1/8 in. holes per in.^{2}). 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.

This trap operated through most nights from mid-January to May. During each night of operation, trapping began before dusk and continued past dawn. Although most of the downstream migration occurs at night, we also conducted trapping during several daylight intervals to assess daytime movement. Captured fish were removed from the trap, identified by species, and counted each hour. Large sockeye fry catches were counted using an electronic counter. Calibration of this counter during the 2003 season determined that it counted 95.7% of the actual number of fish passing through it.

Over the season, 9,916,000 hatchery-produced sockeye fry were released into the Cedar River (Table 1). Seventy-three percent of this production (7,199,000) was released below the trap at the Cedar River Trail Park, and 27% (2,717,000) was released directly from the hatchery at Landsburg. Releases at Landsburg occurred on 12 nights, from January 20 to April 6. Releases below the trap occurred on nine nights, between February 4 and March 12. The group sizes released from Landsburg ranged from 11,000 to 389,000 fry.

Screw Trap

We used a 5 ft diameter screw trap supported by a 12 ft wide by 30 ft long steel pontoon barge (Seiler *et al.* 2003). As in previous seasons, we positioned this trap at RM 1.1, just upstream of the Logan Street Bridge near the right bank. This location is the lowest site with sufficient velocity to effectively operate the trap. The screw trap was operated continuously from mid-April through mid-May. The catches were enumerated at dusk and in the early morning in order to discern diel movements. From late May through July, when trapping ceased, we began to lift the trap during the daylight hours to avoid any potential hazard to recreational floaters using the river. Ad-marked chinook were detected for coded-wire tags (CWT), and positive samples were sacrificed to identify the hatchery of origin. 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 into the Cedar River in 2004.

Release Date	Number Released by Site	
	Landsburg (RM 21)	Below Trap (RM 0.1)
01/20/04	205,000	
02/04/04		586,000
02/09/04	389,000	
02/13/04		1,104,000
02/16/04	310,000	
02/17/04		595,000
02/20/04		1,183,000
02/21/04	240,000	
02/23/04		510,000
02/25/04	265,000	
02/26/04	305,000	
02/27/04		1,234,000
03/01/04		594,000
03/02/04	82,000	
03/03/04		1,014,000
03/04/04	351,000	
03/12/04		379,000
03/18/04	266,000	
03/22/04	198,000	
03/29/04	95,000	
04/06/04	11,000	
Total	2,717,000	7,199,000

Bear Creek

As with the Cedar River, we captured out-migrating salmonids using two traps in lower Bear Creek. A fry trap was used to capture sockeye and chinook fry early in the trapping season. This trap was replaced with a screw trap in early April to capture chinook, coho, steelhead, and cutthroat. A third trap (a fence weir) was installed upstream in Evans Creek, a major tributary to Bear Creek, to assess production from this tributary.

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 that employed in the Cedar River, was suspended from a 30x12 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 early February and ended in early April. On nearly every date the trap was operated, we began trapping before dusk and continued past dawn. Captured fish were removed from the trap and counted at various intervals, from hourly to several hours depending on migration rates.

Screw Trap

In early April we replaced the fry trap with a 5 ft diameter screw trap. Screw trap operation began on April 5, and continued through the morning of June 27. 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).

Weir Trap - Evans Creek

To assess coho production from a tributary to Bear Creek, we installed a fence weir on April 14 in Evans Creek just downstream of Union Hill Road in Redmond. The weir remained fish tight throughout the season, catching all downstream migrants. Every morning and in some evenings, fish were removed from the collection box, enumerated, and a random sample of fork lengths (mm) were collected. All coho and cutthroat migrants were marked with partial fin clips (upper-caudal-vertical) before release downstream. We applied this mark to identify Evans Creek smolts caught approximately two miles downstream in the Bear Creek screw trap. Season total catches of marked coho and cutthroat will assess average capture rates in the screw trap. The weir was removed from the creek on the morning of June 16.

Trap Efficiency

Cedar River

Fry Trap

We estimated the capture rate for sockeye fry in the Cedar River fry trap by marking, releasing, and recovering marked fry. Groups of approximately 2,000 marked sockeye fry were released at the Logan Street Bridge (R.M. 1.1) over a number of nights throughout 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). Marked fry were distributed across the middle of the channel from the bridge. Recovery rates were correlated with hourly discharge to assess the effect of flow on capture rate.

Screw Trap

Capture efficiency of the screw trap was estimated for chinook and coho smolts. Groups of 30 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. Marked smolts were 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. During trap checks, catches were examined for marks. Recapture rates were correlated with hourly 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 from the Redmond Way Bridge on a number of nights over the season. As in the Cedar River, 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, coho, and cutthroat smolts using the same approach described for the Cedar River screw trap. Mark groups were released from the Redmond Way Bridge. 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 - e_i.

Sockeye

Sockeye fry catch was estimated for nighttime periods when 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);

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

where;

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

If the interpolation was made using catch values that were not estimated (i.e., total catch over an uninterrupted night of fishing), then the variance of the mean was used.

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;

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

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) ($\hat{C}_u$) was (were) estimated by;

$$\hat{C}_u = T_u \overline{R} \qquad \textbf{Equation 3}$$

where;

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

The variance was estimated by;

$$Var(\hat{C}_u) = T_u^{\ 2} Var(\overline{R}) \qquad \textbf{Equation 4}$$

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*, and during night *i*.

The hatchery components of catches were estimated using one of three methods listed below. All hatchery fry were assumed to pass the trap within two nights, the release night and the following night.

1. During the first part of the season when hatchery releases occurred prior to and following nights of wild only catches, interpolation was used to estimate the components (January 20, February 8, 17, 26, and 27). Straight-line interpolation was used to estimate the wild catch during the hatchery release night. Hatchery catch was then estimated by subtracting the wild fry estimate from the total nightly catch.

2. When interpolation estimates were nonsensical (e.g., less than zero or greater than the number of hatchery fish released), we estimated the nightly wild and hatchery catch components through analysis of the nightly timing distribution of wild outmigrants (February 16, 21, and 25). Unless flows are high (over 1,000 cfs), fry released at Landsburg typically reach the trap after the 0100-hour on the night of release. Using this approach, we assumed that sockeye catches prior to the 0100-hour were comprised entirely of wild fry. Total nightly wild catch was estimated by dividing the catch prior to the 0100-hour by the proportion of the nightly wild catch occurring prior to the 0100-hour. This proportion was estimated by the mean proportion using data from adjacent nights when all outmigrants were assumed wild. The nightly hatchery catch was estimated by subtracting the estimated wild catch from the total catch.

3. During March and April, the high wild migration relative to hatchery releases precluded estimating survival with the previous two methods. Instead, we estimated survival of hatchery fry using the flow-based survival rates generated during previous years (1995, 2001-2003) when intensive otolith sampling was conducted. The hatchery migration estimates were then partitioned into first and second nights using a 1995 regression model.

We did not trap on two nights following hatchery releases (January 20 and February 22). Hatchery migrations during the nights following those releases were estimated using the previous years' survival regression to calculate total migration and then subtracting the first night's migration, which was estimated by method one (January 20) and method two (February 21). When releases occurred on subsequent nights, they were grouped due to Landsburg fry taking more than one night to migrate past the trap.

Due to the complexity of these estimates and the multiple assumptions involved, we did not calculate associated errors.

Daytime sockeye catches were estimated by multiplying the nighttime catch by the proportion of the 24 hr catch estimated to have been caught during the day. This proportion, (F_d), was found by;

$$F_d = \frac{T_d}{\frac{1}{\overline{Q}}T_n + T_d} \qquad \textbf{Equation 5}$$

and its variance by;

$$Var(F_d) = \frac{Var(\overline{Q})T_n^{\ 2}T_d^{\ 2}}{\overline{Q}^4\left(\frac{1}{\overline{Q}}T_n + T_d\right)^4} \qquad \textbf{Equation 6}$$

where,

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

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);

$$Var(\hat{C}_d) = \hat{C}_i^{\ 2}Var(F_d) + Var(\hat{C}_i)F_d^{\ 2} - Var(\hat{C}_i)Var(F_d) \qquad \textbf{Equation 7}$$

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, its variance was calculated by;

$$Var(\hat{e}) = M\hat{S}E\left(1 + \frac{1}{n} + \frac{(flow_i - \overline{flow})^2}{(n-1)s_f^{\ 2}}\right) \qquad \textbf{Equation 8}$$

Where the linear regression was used to predict daily efficiency, the variance of the daily migration estimates, $Var(\hat{N})$, was calculated by;

$$Var(\hat{N}) = \frac{Var(\hat{C}_i)}{\hat{e}_i^{\ 2}} + Var(\hat{e}_i)\left(\frac{C_i}{\hat{e}_i^{\ 2}}\right)^2 \qquad \textbf{Equation 9}$$

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

$$Cov\left(\frac{C_i}{\hat{e}_i}, \frac{C_j}{\hat{e}_j}\right) = \frac{C_i}{\hat{e}_i^{\,2}} \frac{C_j}{\hat{e}_j^{\,2}} \left[Var(\hat{a}) + flow_i\, flow_j Var(\hat{b})\right]$$ **Equation 10**

where;

$$\hat{a} = slope\ of\ the\ regression, and$$

$$\hat{b} = Intercept\ of\ the\ regression.$$

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;

$$\bar{e} = \frac{\sum_{i=1}^{n} e_i}{n}$$ **Equation 11**

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

$$Var(\hat{e}_i) = \frac{e_i(1-e_i)}{n}$$ **Equation 12**

$$Var(\bar{e}) = \frac{\sum (e_i - \bar{e}_i)^2}{n(n-1)}$$ **Equation 13**

Daily sockeye fry migrations were estimated by;

$$\hat{N} = \frac{(\hat{C}_i + \hat{C}_d)}{\bar{e}}$$ **Equation 14**

The variance of daily migrations estimated using the average efficiency was estimated using the delta method (Goodman 1960);

$$Var(\hat{N}) = \hat{N}^2 \left(\frac{Var(\bar{e})}{\bar{e}^2} + \frac{\sum \left(Var(\hat{C}_i) + Var(\hat{C}_d)\right)}{\left(\sum (\hat{C}_i + \hat{C}_d)\right)^2} \right)$$ **Equation 15**

Where trap efficiency was calculated using a simple mean efficiency over the season, the total migration was the sum of the daily migrations and its variance was calculated using Equation 15, substituting the season total catch for the daily catches.

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 12 broods of Cedar River sockeye. A number of regression equations were used to evaluate this relationship once the 2003 brood 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;

$$Var(\hat{C}_i) = T_u^{\;2}\,\frac{\sum(\hat{R}_i - \overline{R}_i)^2}{n(n-1)}$$ **Equation 16**

Wild chinook fry catch during daytime intervals not fished were estimated using the same methods as described for sockeye.

Daily chinook fry migration was estimated by using Equation 14 (substituting $\hat{e}$ for $\overline{e}$ when linear regression was used to predict daily efficiencies). The total season migration was estimated by summing the daily migration estimates. The chinook season migration variance was estimated using Equation 15 if the average efficiency was used to estimate migration, or using the daily sums of Equations 9 and 10 when trap efficiency was predicted using a linear regression.

Screw Trap

Chinook
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 interpolated catch rates from the preceding and following nighttime intervals trapped. Variances for these estimates were calculated using Equation 1.

Wild chinook 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 from trapping conducted in 2004. The catch during daytime, *d*, was estimated by;

$$\hat{C}_d = \overline{Q}\,\overline{R}_i\,T_d$$ **Equation 17**

and its variance was estimated by;

$$Var(\hat{C}_d) = T_d^{\;2}\left(Var(\overline{R}_i)\,\overline{Q}^{\,2} + Var(\overline{Q})\,\overline{R}_i^{\;2}\right)$$ **Equation 18**

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.*

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 12, and the mean trap efficiency using Equation 13. Equation 14 was used to estimate daily migration, and Equation 15 was used to estimate daily and total season variances of the migration estimates when using average efficiency.

Other Species

Estimating the production of steelhead smolts and cutthroat trout involved approximating a season average capture rate. Catches of these migrants were insufficient for directly assessing capture rate via mark and recapture. Therefore, capture rates were estimated from previous studies relating steelhead capture rates to rates 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. If flow did not appear to explain variation, the season average trap efficiency was used and its variance was calculated using Equation 13. Nightly migration was estimated using Equation 14, and the variance using Equation 15. 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 catch during un-fished nights and the catch 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 15, substituting the total season catch for the nightly catch.

Screw Trap

Estimation of chinook, coho, and cutthroat trout migrations occurred in several steps. The data collected every night consisted of the same as that collected at the Cedar River. Trap efficiency was estimated using the same methods as the Cedar trap. Daily migration was estimated using Equation 14, and the variance using Equation 15. Catch during days or nights not fished were estimated by interpolation, and the variances were estimated using Equations 1 or 2. The in-season production estimate was the sum of the daily migration estimates. The variance of the total migration was estimated using Equation 15, substituting the total season catch for the daily catch, when the season average trap efficiency was used to estimate migration.

CEDAR RIVER RESULTS

Sockeye

Trap Operation

Fry trap operation began on January 18, and occurred on 82 nights through the season until the last night of trapping on May 30. In January we fished every other night, and in February we fished four to six nights a week. During March and the first half of April the trap operated six nights a week, and during the second half of April through May we fished two to three nights a week. Four daytime trapping intervals were fished between February 18 and March 19.

On six of the scheduled trapping nights, we did not operate continuously through the night. During three nights, the hour-long trapping intervals were reduced to 5, 15, or 30 minutes due to heavy debris and high flows. Trapping started late and/or concluded early during two nights, and an hour interval was not fished on March 9 due to a power failure.

Catch

During the first night of trapping (January 18), 1,365 sockeye fry were caught. Catches increased and peaked at 145,936 fry on March 23. Catches decreased thereafter and on our last day of trapping, May 30, we caught 271 fry. Our combined nightly catches of wild and hatchery fry for the season totaled 2,844,598, and day catches totaled 771 fry (Appendix A). On the six nights that we did not fish continuously, catches were expanded to project entire nights' catch.

Trap Efficiency

Tests to determine the capture efficiency of the trap were conducted on 54 nights from February 4 to May 16. Towards the end of the season, as the level of Lake Washington increased and inundated the Cedar River, we observed a decrease in water velocity at the trap. Based on that observation and lake elevation data from USACE (Figure 2) (Ebel pers. comm.), we stratified efficiency data into two groups.

The level of Lake Washington was less than 22 ft above Seattle's mean lower low water level from January through April 26 (Stratum 1). During this stratum, 46 tests were conducted and efficiencies ranged from 4.3% to 12.1%. Linear regression analysis indicated a significant correlation between capture rate and flow ($r^2=0.54$, $p<0.01$) (Figure 3). We used this strong relationship to estimate daily trap efficiency for this stratum for flows up to 1,470 cfs. Flows ranged from 323 to 1,470 cfs on the nights that efficiency tests were conducted and ranged from 311 up to 2,039 cfs during the Stratum 1 interval. Because daily average flows exceeded the highest flow at which a test was conducted, we used the lowest efficiency observed (4.3%) for the seven nights that flows exceeded 1,470 cfs (January 29 through February 4).

Stratum 2 began on April 27, when the lake level reached 22 ft above Seattle's mean lower low water level. Recapture rates ranged from 6.0% to 12.7% for the eight tests conducted during this stratum (Table 2). Due to the low variability in flows during these tests (297 to 331 cfs), we used the average efficiency (8.6%) to estimate migration during this interval rather than a regression.

The lake elevation fluctuated from 21.8 to 21.99 ft following the peak height of 22 ft on April 27. Although these heights were also observed between April 18 and April 26 (Stratum 1), capture rates were higher during Stratum 1 than Stratum 2 at comparable heights. We believe that the combination of decreasing flows and rising lake elevation during Stratum 2 resulted in the lower capture rates. Mean daily flows from April 18 to April 26 ranged from 405 to 311 cfs, while flows on April 27 averaged 308 cfs and continued to decline through April and into May.

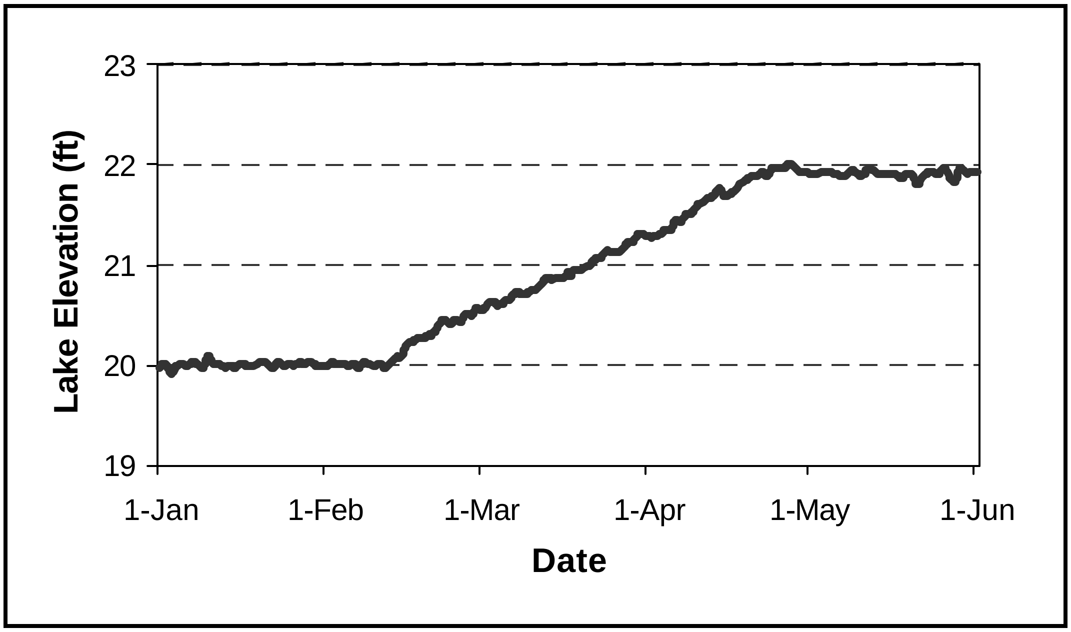

Figure 2. Provisional United States Army Corps of Engineers Lake Washington elevation data, 2004.

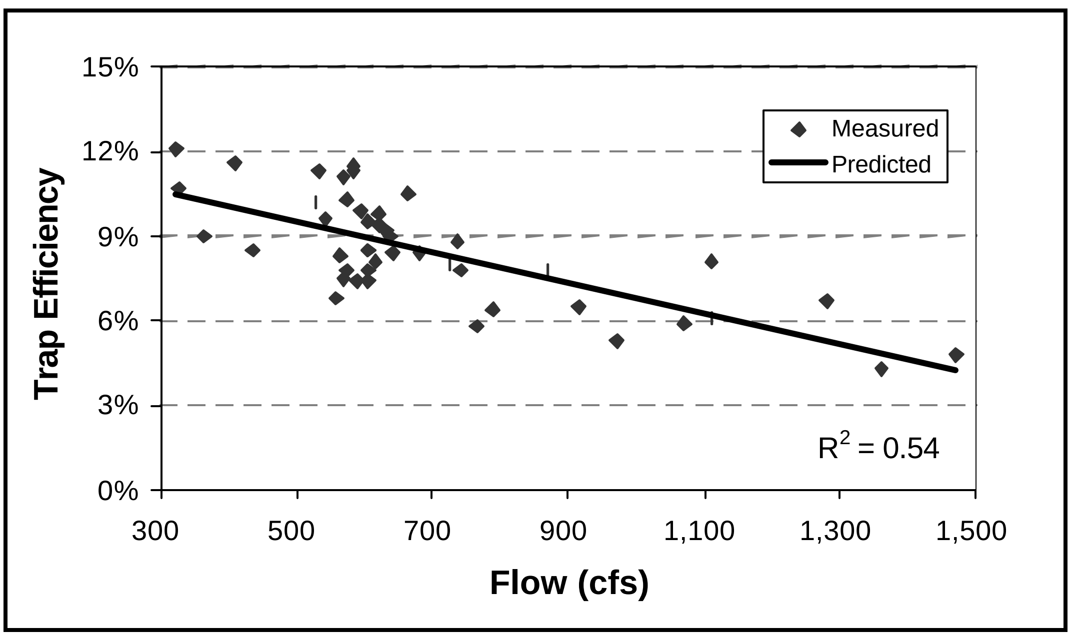

Figure 3. Linear relationship between trap efficiency tests using sockeye fry and hourly flow at release, Cedar River fry trap Stratum 1, 2004.

Table 2. Trap efficiency tests using sockeye fry during Stratum 2, Cedar River fry trap 2004.

Date	Flow (cfs) @ hour of release	Number Released	Number Recaptured	Efficiency	Var(e)
04/27	331	1,181	87	7.4%	0.000058
04/29	304	1,310	98	7.5%	0.000053
05/02	308	1,119	84	7.5%	0.000062
05/04	308	1,001	60	6.0%	0.000056
05/06	297	1,545	173	11.2%	0.000064
05/09	297	1,463	186	12.7%	0.000076
05/13	300	762	65	8.5%	0.000102
05/16	304	904	75	8.3%	0.000084
Total		9,285	828		
Average				8.6%	
Variance				0.000062	
n				8	

Diel Migration

While the vast majority of sockeye fry migrate at night, daytime trapping indicated small numbers of fry migrating during daylight. Over the four dates that we trapped during daylight intervals, the day to night catch rate ratios ranged from 0.36% to 0.88% (Table 3). Flows on these dates ranged from 578 to 953 cfs. The average day catch rate to night catch rate ratio (0.59%) was used to estimate daytime migrations.

Table 3. Day:night catch rate ratios of sockeye fry estimated using the night before and the night after the daytime interval, Cedar River fry trap, 2004.

NIGHTTIME Date	Time Down	Hours Fished	Catch	Catch/ Hour	DAYTIME Date	Time Down	Hours Fished	Catch	Catch/ Hour	DAY:NIGHT Ratio (D/N)	Flow (cfs)
02/17	18:00	13.00	14,340	1,103.1	02/18	7:00	11.00	100	9.09	0.88%	657
02/18	18:00	13.00	12,635	971.9							
	Sum	26.00	26,975	1,037.5							
02/24	18:00	13.00	32,929	2,533.0	02/24	7:00	11.00	104	9.45	0.36%	592
02/25	18:00	13.00	35,270	2,713.1							
	Sum	26.00	68,199	2,623.0							
03/02	18:30	12.50	43,206	3,456.5	03/03	7:00	11.50	189	16.43	0.61%	953
03/03	18:30	12.00	22,609	1,884.1							
	Sum	24.50	65,815	2,686.3							
03/18	18:30	11.50	73,849	6,421.7	03/19	6:00	12.50	378	30.24	0.50%	578
03/19	18:30	11.50	64,038	5,568.5							
	Sum	23.00	137,887	5,995.1							
				Average						0.59%	
				Variance						1.2E-06	

Production Estimate

We estimated 47.9 million sockeye fry entered Lake Washington from the Cedar River in 2004 (Table 4, Figure 4, Appendix A). The total included 38.7 million wild fry and 9.2 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. Logarithmic extrapolation from January 1 to January 17 and linear extrapolation from May 31 to July 1 resulted in an additional 108,588 and 66,495 wild fry, respectively. Addition of these estimates accounted for less than 0.5% of the total wild estimate.

Table 4. Estimated 2004 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 - 18	108,588	76,120	141,056	15.3%	0.2%
	During Trapping	January 18 - May 30	38,511,816	33,636,372	45,337,437	[a] 9.0%	80.4%
	After Trapping	May 31 - July 1	66,495	30,073	102,917	27.9%	0.1%
		Subtotal	38,686,899	31,863,087	45,510,711	9.0%	80.8%
Landsburg	During Trapping	January 20 - April 6	2,022,643				4.2%
Below Trap	During Trapping	February 2 - March 12	7,199,000				15.0%
		Subtotal	9,221,643			n/a	19.2%
		Total	47,908,542			n/a	100.0%

[a] Slightly underestimated due to lack of variance about hatchery estimates.

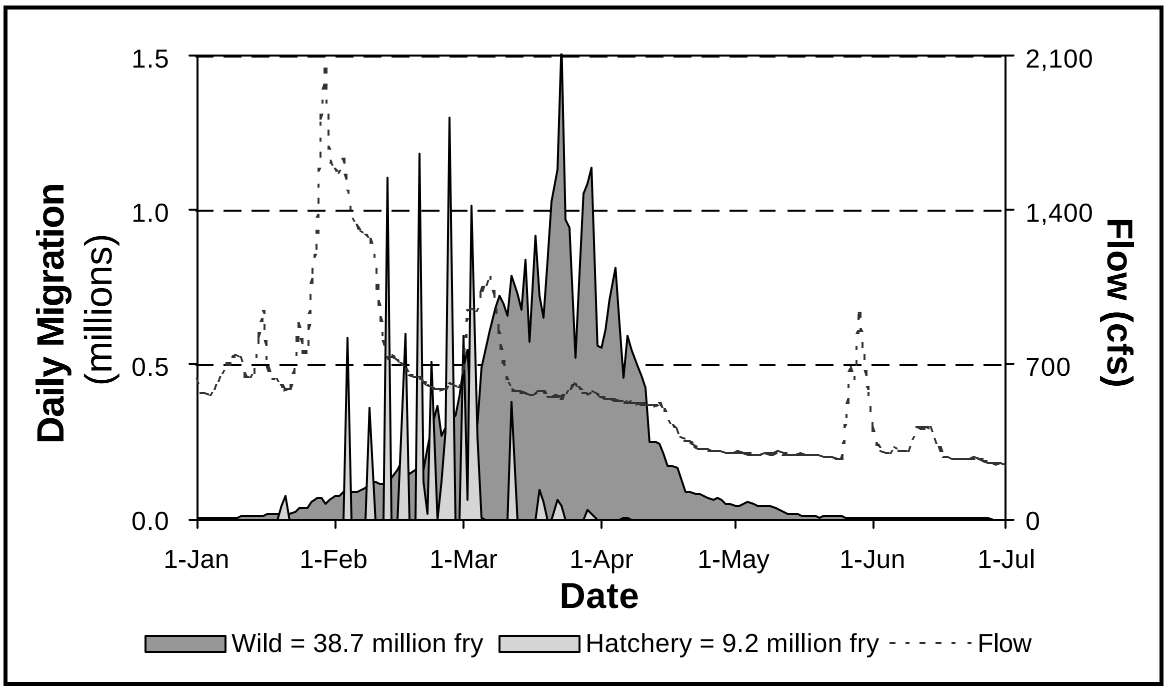

Figure 4. Estimated daily migration of wild and hatchery Cedar River sockeye fry into Lake Washington and daily average flow, 2004.

Wild and Hatchery Timing

Releases of hatchery-produced fry began on January 20 and continued through April 6 (Table 1, Figure 4). The wild fry migration was under way when we began trapping on January 18, peaked during late March, and declined through April to low levels by late May when we stopped trapping. Median migration dates for hatchery and wild fry occurred on February 23 and March 21, respectively (Table 5).

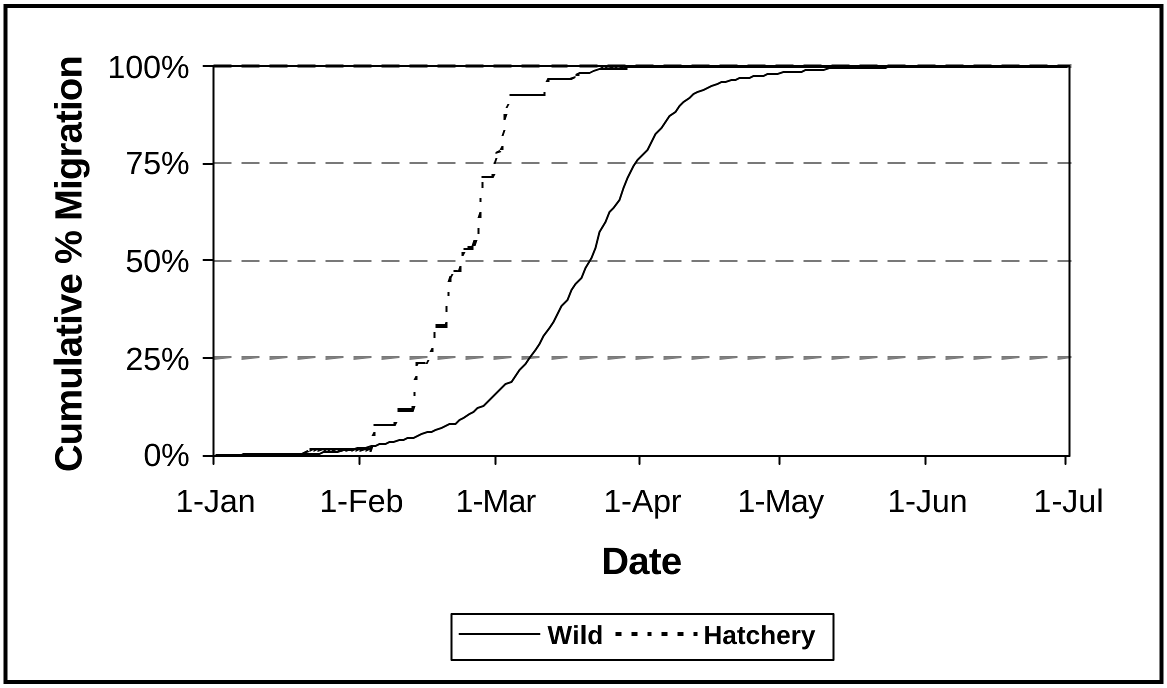

Figure 5. Cumulative wild and hatchery sockeye fry migration timing, Cedar River 2004.

Table 5. 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	02/23	03/08	15
2001	2002	03/25	03/04	03/19	21
2002	2003	03/08	02/24	03/03	12
2003	2004	03/21	02/23	03/15	26
	Average	03/24	03/01	03/14	23

The near average timing of the 2004 wild fry migration was consistent with the average stream temperatures experienced by this brood. Warmer temperatures result in earlier migration timing. After evaluating temperature data throughout the period of fry incubation and migration, we found February stream temperatures best explained observed variation in migration timing ($r^2 = 0.58$) (Figure 6). February stream temperatures averaged 6.7° C in 2004, slightly higher than the average (6.1° C) over 12 years. The 2001 fry migration was treated as an outlier due to extreme low flows that facilitated predation and an earthquake, which triggered a landslide that temporarily blocked flow and may have caused a significant mortality in the later-timed portion of the fry production.

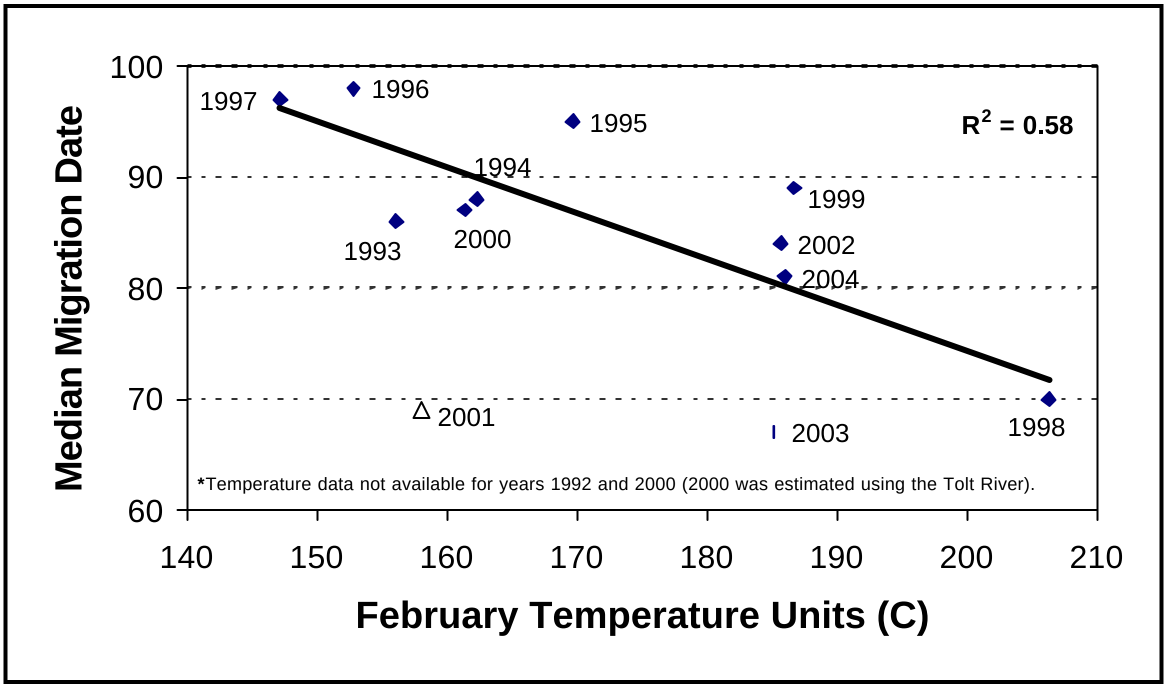

Figure 6. Linear regression of median migration Julian Calendar date for wild Cedar River sockeye fry as a function of the sum of daily average temperatures from February 1-28 as measured at the USGS Renton Gaging Station #12119000 for migration years 1993-2004, with 2001 as an outlier.

Survival of Hatchery Release Groups

Survival rates estimated for the groups of fry released at Landsburg Hatchery ranged from 51% to 96%. Over all release groups, we estimated 74.4% of hatchery fry survived to pass the trap (Table 6). Because no otoliths were collected during the 2004 season, we estimated survival using previous years' data for all but three releases. These exceptions occurred early in the season when wild migrations were still relatively low and, therefore, catches of these large hatchery releases were obvious. The logarithmic regression developed using otolith estimated survival rates and flow data from 1995 and 2001 through 2003 trapping years were combined to predict survival based on daily average flow (Figure 7). Following estimation of survival, the total migration was then partitioned into the night of and following the release. To estimate the proportion of fry migrating past the trap during the night of release, we used a logarithmic regression based on flow using the 1995 data (Figure 8).

Confidence intervals and percent standard errors of these survival estimates were not estimated.

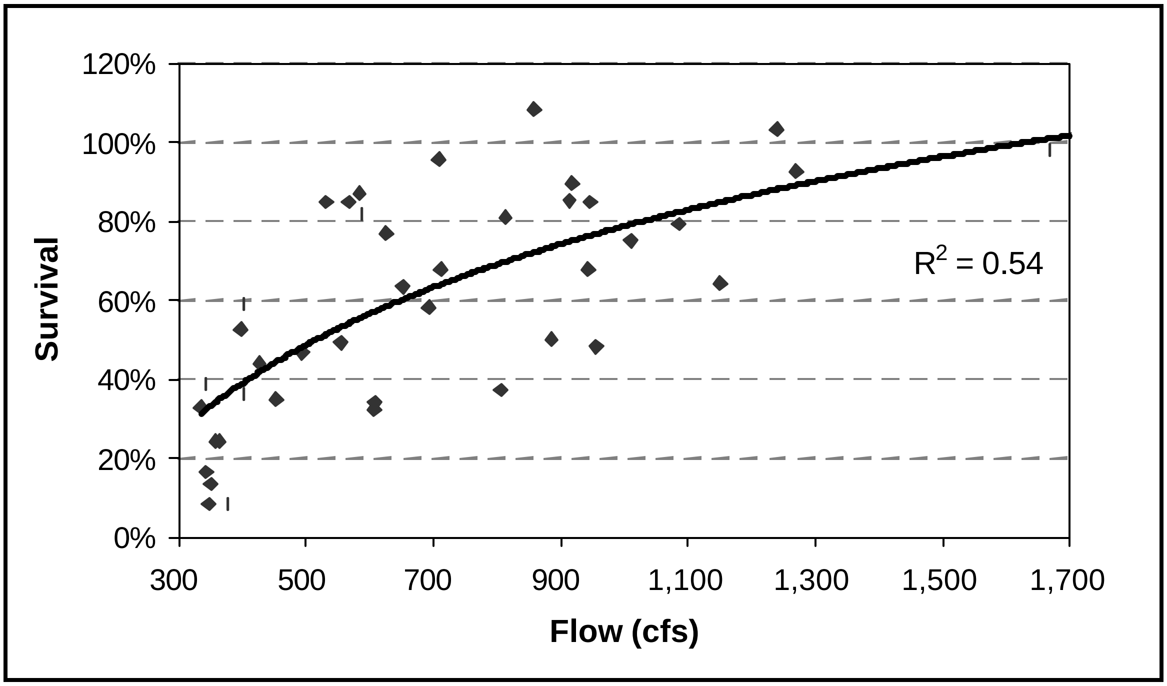

Figure 7. Logarithmic relationship between survival rates of hatchery fry released from Landsburg and daily mean flow, Cedar River 1995, and 2001 - 2003.

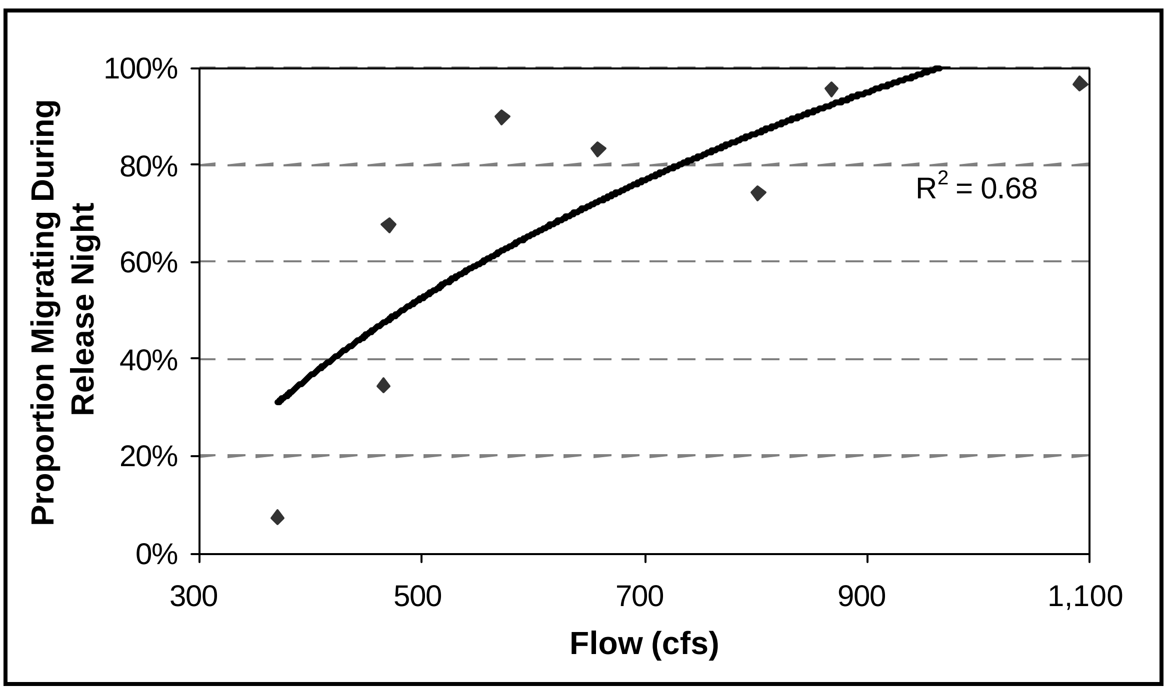

Figure 8. Logarithmic regression between the proportion of hatchery fry from Landsburg that migrate past the trap during the night of release and daily mean flow, Cedar River 1995.

Table 6. In-river survival estimates of hatchery sockeye fry released from Landsburg Hatchery, Cedar River 2004.

Release Date	Sockeye Released	Daily Avg. Flow	Recovery Date(s)	Estimated Migration	Estimated Survival	Estimation Method*
01/20	205,000	607	01/20	43,249		1
			01/21	73,896		Sub.
			Total	117,145	57.1%	3
02/09	389,000	1,270	02/09	360,780	92.7%	1
02/16	310,000	709	02/16	293,052		2
			02/17	3,561		1
			Total	296,613	95.7%	
02/21	240,000	626	02/21	120,374		2
			02/22	19,983		Sub.
			Total	140,357	58.5%	3
02/25	265,000	587	02/25	119,019		2
02/26	305,000	594	02/26	281,792		1
			02/27	65,705		1
			Total	466,516	81.8%	
03/02	82,000	946	03/02	62,652	76.4%	3
03/04	351,000	943	03/04	263,094		
			03/05	4,601		
			Total	267,695	76.3%	3
03/18	266,000	584	03/18	94,128		
			03/19	53,415		
			Total	147,543	55.5%	3
03/22	198,000	560	03/22	64,557		
			03/23	41,662		
			Total	106,219	53.6%	3
03/29	95,000	567	03/29	31,746		
			03/30	19,730		
			Total	51,476	54.2%	3
04/06	11,000	531	04/06	3,216		
				2,431		
			Total	5,647	51.3%	3
Season Total	2,717,000			2,022,643	74.4%	

* Methods
1 - Interpolation
2 - Nightly timing distribution
3 - Flow regression using previous years' data
Sub. - Second night estimated by subtracting the first night's migration estimate from the total migration estimated using #3

Egg to Migrant Survival of Naturally Produced Fry

Overall survival of the 2003 brood sockeye fry to lake entry was estimated at 11.8%. This rate is the ratio of 38.7 million wild fry to an estimated potential egg deposition of 327 million eggs. This PED is based on a spawning escapement estimate of 195,203, an assumed even sex ratio and an average fecundity of 3,412 (Table 7). Of these three values, the estimate of fecundity may be the most accurate since it is the average number of eggs per female estimated during broodstock collection (Antipa pers. comm.). For the purpose of this analysis, we computed Cedar River spawners for the 1991 through 2003 broods by subtracting the following estimates from the estimated sockeye run passing the Ballard Locks:

1. sockeye harvested in recreational and tribal fisheries;
2. sockeye estimated spawning on beaches and in all other tributaries (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 75% (Figure 9). 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.

The veracity of these survival rates depends on the accuracy of the fry estimates and the PED. If, for example, the PED is overestimated then survival of fry to lake entry is underestimated. In several recent years, it appears that actual numbers of spawning sockeye may be considerably lower than estimated using the Locks counts subtraction methodology. When this discrepancy is resolved we will base survival estimates on the best available spawning sockeye estimates.

Table 7. 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 1991-2003.

Brood Year	Spawners	Females (@50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1991	74,600	37,300	3,282	122,418,600	9,800,000	8.0%	2,060	01/28/1992
1992	183,190	91,595	3,470	317,834,650	27,100,000	8.5%	1,570	01/26/1993
1993	99,197	49,599	3,094	153,457,759	18,100,000	11.8%	927	01/14/1994
1994	124,000	62,000	3,176	196,912,000	8,700,000	4.4%	2,730	12/27/1994
1995	26,665	13,333	3,466	46,210,445	730,000	1.6%	7,310	11/30/1995
1996	332,182	166,091	3,298	547,768,118	24,390,000	4.5%	2,830	01/02/1997
1997	119,933	59,967	3,292	197,409,718	25,350,000	12.8%	1,790	01/23/1998
1998	80,799	40,400	3,176	128,308,812	9,500,000	7.4%	2,720	01/01/1999
1999	47,488	23,744	3,591	85,264,704	8,058,909	9.5%	2,680	12/18/1999
2000	215,364	107,682	3,451	371,610,582	38,447,878	10.3%	627	01/05/2001
2001	233,569	116,785	3,568	416,687,096	31,673,029	7.6%	1,930	11/23/2001
2002	264,046	132,023	3,395	448,218,085	27,859,466	6.2%	1,410	02/04/2003
2003	195,203	97,602	3,412	327,444,899	38,686,899	11.8%	2,039	01/30/2004

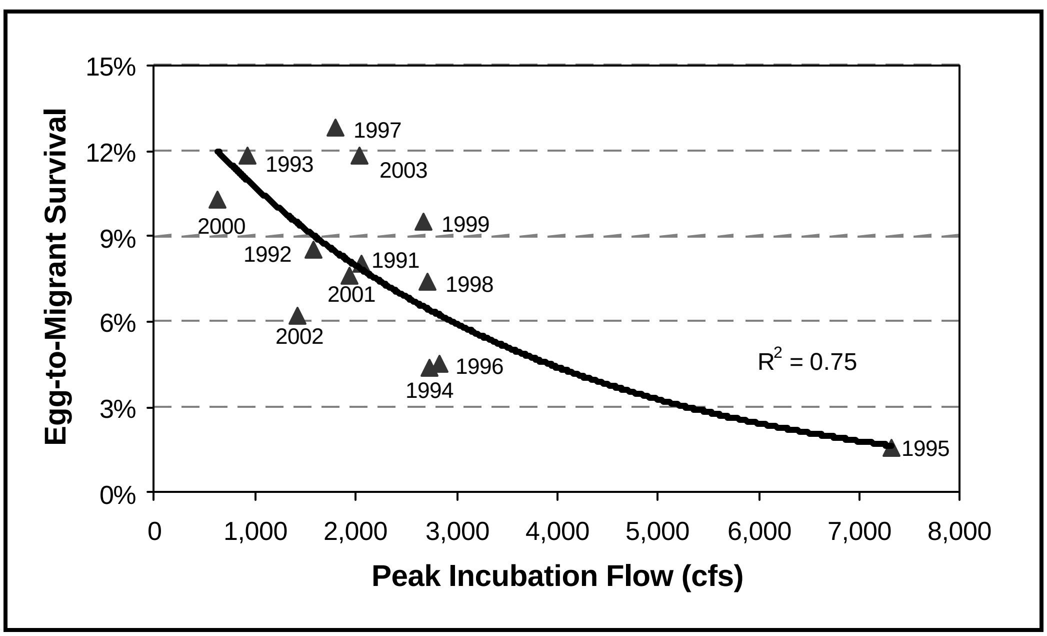

Figure 9. Exponential regression of wild sockeye egg-to-migrant survival from brood years 1991 to 2003 as a function of peak flow during the winter egg incubation period, Cedar River.

Chinook

Catch

Fry Trap

On the first night of fry trap operation (January 18), we caught one chinook fry. Nightly catches peaked at 295 fry on March 2. Through March, we caught a total of 2,736 chinook fry, 95% of the season total catch. During the 29 nights we fished, from April 1 through May 30, we caught only 150 juvenile chinook. Four daytime intervals were fished throughout the season. Day to night catch rate ratios ranged from 7% to 10% (Table 8). Over the season, a total of 2,918 chinook were captured in the fry trap.

Table 8. Day to night catch rate ratios estimated at the Cedar River fry trap, 2004.

Nighttime					Daytime					D:N	Flow
Start Date	Start Time	Hours	Catch	Catch/Hr	Start Date	Start Time	Hours	Catch	Catch/Hr	Ratio	(cfs)
02/17	17:00	13.00	30	2.3	02/18	7:00	11.00	2	0.18	10.28%	657
02/18	17:00	13.00	16	1.2							
	Total	26.00	46	1.8							
02/24	18:00	13.00	70	5.4	02/24	7:00	11.00	5	0.45	9.02%	592
02/25	18:00	13.00	61	4.7							
	Total	26.00	131	5.0							
03/02	18:30	12.50	295	23.6	03/03	7:00	11.50	11	0.96	6.95%	953
03/03	18:30	12.00	42	3.5							
	Total	24.50	337	13.8							
03/18	18:30	11.50	64	5.6	03/19	6:00	12.50	14	1.12	9.95%	578
03/19	18:30	11.50	195	17.0							
	Total	23.00	259	11.3							
Average										9.05%	
Variance										5.6E-05	

Screw Trap

Over the 98-day interval that we operated the screw trap (April 14 through July 20), we captured 6,156 wild and 241 hatchery chinook. From the first night of trapping to April 30, nightly catches ranged from six to 54 chinook. During May and June, we caught a total of 5,785 wild chinook smolts, 94% of the season total. Nightly catch peaked on May 26 with 408 chinook smolts caught.

Hatchery chinook, identified by the missing adipose fin, entered catches beginning on June 1. In order to identify the release location of these hatchery smolts, we sampled smolts for coded-wire tags (CWTs). All six of the hatchery smolts that tested positive for CWTs were sacrificed for tag recovery. All six tags recovered were code 63-23-88, released from Issaquah Creek Hatchery on May 11, 2004.

Catch Expansion

Fry Trap

We estimated the numbers of chinook we would have caught for the day and night periods not fished. Daytime migration was estimated by using the average (9.0%) ratio of day/night catch rates measured during operation of the fry trap. Due to high flows and large amounts of debris, on seven nights we expanded partial catches. We estimated that had we fished the trap continuously (day and night) we would have caught an additional 1,742 fry. Addition of these fish to the actual catches projects a season total catch of 4,660 chinook in the fry trap (Appendix B).

Screw Trap

Catch data was expanded to estimate the numbers of chinook smolts we would have caught in the screw trap had we fished the trap continuously from the evening of April 14 through the morning of July 21 (Appendix B). Expansion resulted in the addition of 562 chinook to the wild catch. This increase represented 8% of the total catch estimate. The catch expansion includes daytime and nighttime migration estimates when we did not fish, and five trapping intervals when we found the screw stopped by debris. Daytime migrations during June and July were estimated using the average of day catch rate to night catch rate ratios measured during May (0.4%). Ten other trapping intervals were slowed or stopped by debris but were not expanded due to an estimated catch of zero or because the actual catch was higher than what would have been projected.

Size

From January through March, the weekly mean fork length of chinook fry caught in the fry trap increased 3 mm, and averaged 40 mm (Table 9, Figure 10). The minimum size increased through April, and the weekly average increased to over 60 mm by mid-April. Fork lengths of the eight chinook fry measured in May ranged from 62 mm to 91 mm.

Chinook caught in the screw trap increased in size from a weekly average fork length of 67 mm in mid-April to 108 mm in early-July (Table 9, Figure 10). Over the season, sizes ranged from 42 mm to 129 mm and averaged 88 mm.

Trap Efficiency

Fry Trap

Capture rates for chinook fry in the fry trap was assumed to be equivalent to that of marked sockeye fry released upstream of the trap. A linear regression was used to evaluate the relationship between capture efficiency and flow prior to April 27, and a significant correlation was found (r^2=0.54, $p<0.01$) (Figure 3). Due to this strong relationship, the linear regression was used to predict daily trap efficiency using the daily average flow from January through April 26. The average of the efficiency tests (8.6%) after this date was used to estimate capture rate from April 27 to May 30 due to the increase in lake elevation and the reduction in trapping velocity.

Screw Trap

Capture rates of chinook in the screw trap were estimated by releasing twenty-six mark-recapture groups between April 25 and June 28. Capture rates ranged from 0% to 28%, and release group sizes ranged from seven to 199 chinook. In order to reduce the variation in these tests, we combined low number release groups to form a minimum of 40 individuals. Trap efficiencies for these 21 tests ranged from 4% to 28% (Table 10). Hourly flows during releases ranged from 258 to 836 cfs, and did not significantly explain the variation among trap efficiency tests. Therefore, we used the average rate (12.2%) of the grouped efficiency tests to estimate daily migration.

Table 9. Mean chinook fork length, standard deviation, range, sample size, and catches in the Cedar River fry and screw traps, 2004.

Statistical Week			FRY TRAP						SCREW TRAP					
					Range						Range			
Begin	End	No.	Avg.	s.d.	Min	Max	n	Catch	Avg.	s.d.	Min	Max	n	Catch
01/12	01/18	3	40.0				1	1						
01/19	01/25	4	38.0	1.69	35	40	15	29						
01/26	02/01	5	38.9	1.42	36	41	27	148						
02/02	02/08	6	38.9	1.14	37	42	43	207						
02/09	02/15	7	39.4	1.15	37	42	47	153						
02/16	02/22	8	40.2	1.83	37	47	54	136						
02/23	02/29	9	40.6	6.39	36	84	54	251						
03/01	03/07	10	39.7	1.77	34	48	118	826						
03/08	03/14	11	40.6	2.58	38	54	66	408						
03/15	03/21	12	41.5	3.77	38	61	62	388						
03/22	03/28	13	43.5	5.82	38	64	43	192						
03/29	04/04	14	43.8	5.71	39	66	47	103						
04/05	04/11	15	45.0	6.91	39	63	23	43						
04/12	04/18	16	59.1	8.27	42	69	17	19	67.0	9.52	42	86	56	59
04/19	04/25	17	63.5	9.95	52	76	4	4	70.9	8.53	52	93	85	167
04/26	05/02	18					0	0	77.1	6.97	61	91	67	114
05/03	05/09	19	62.0				1	1	79.7	8.44	57	95	50	655
05/10	05/16	20					0	0	85.2	7.50	64	102	151	1,094
05/17	05/23	21					0	0	82.4	4.73	74	90	20	957
05/24	05/30	22	82.4	9.62	63	91	7	9	87.7	6.16	75	99	21	1,181
05/31	06/06	23							90.3	8.37	75	111	35	549
06/07	06/13	24							96.2	7.18	75	114	142	847
06/14	06/20	25							97.5	5.50	90	110	13	256
06/21	06/27	26							101.3	6.27	80	126	118	171
06/28	07/04	27							105.4	8.05	86	122	42	55
07/05	07/11	28							104.0	6.56	92	115	12	41
07/12	07/18	29											0	10
07/19	07/25	30											0	0
Season Totals			41.9	7.09	34	91	629	2,918	87.4	13.82	42	126	812	6,156

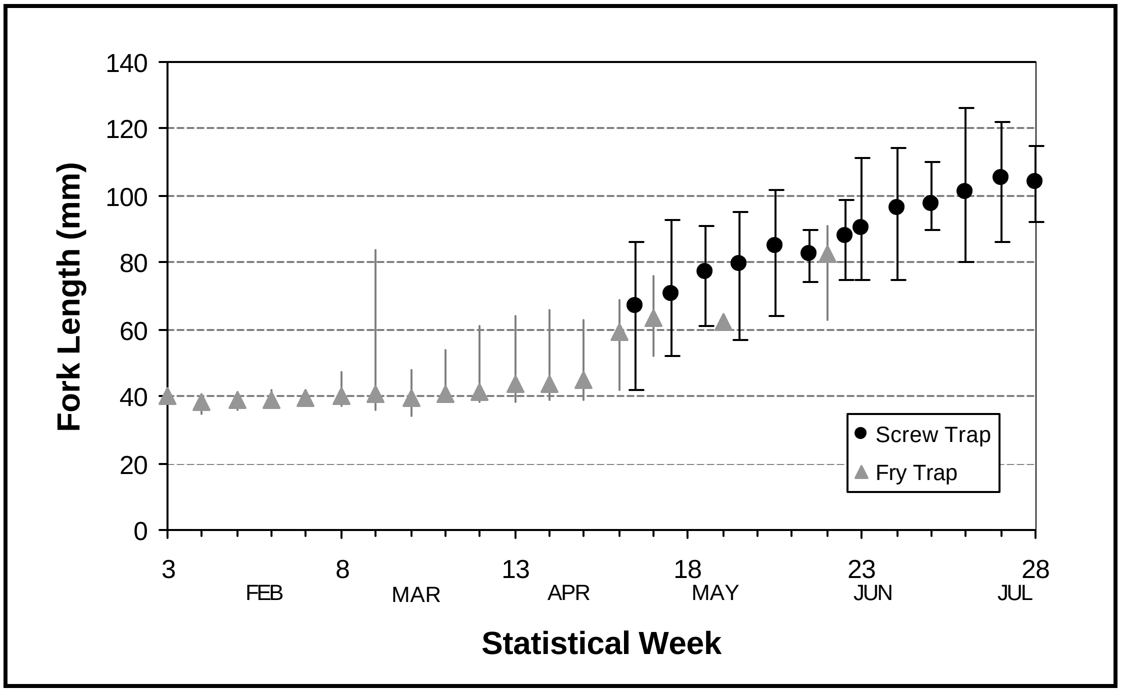

Figure 10. Average and range of fork lengths of chinook sampled from the Cedar River, 2004.

Table 10. Estimated chinook smolt recapture rates from grouped screw trap efficiency tests, Cedar River 2004.

Date(s)	Flow(s) (cfs)	NUMBER Released	Recaptured	Recapture Rate	Variance
4/25-4/26	320-323	57	8	14.0%	0.00212
5/01-5/03	304-316	57	9	15.8%	0.00233
5/05-5/07	297-308	90	11	12.2%	0.00119
05/08	312	80	10	12.5%	0.00137
05/12	308	50	4	8.0%	0.00147
05/13	304	50	6	12.0%	0.00211
05/14	300	50	4	8.0%	0.00147
05/15	312	60	5	8.3%	0.00127
05/17	304	50	2	4.0%	0.00077
05/18	300	50	4	8.0%	0.00147
05/21	282	100	28	28.0%	0.00202
05/24	282	50	3	6.0%	0.00113
05/25	297	50	11	22.0%	0.00343
05/26	836	50	5	10.0%	0.00180
05/27	616	89	13	14.6%	0.00140
06/01	605	50	5	10.0%	0.00180
06/02	391	50	8	16.0%	0.00269
06/07	327	45	8	17.8%	0.00325
06/08	320	50	2	4.0%	0.00077
06/10	316	50	3	6.0%	0.00113
6/12-6/28	400-258	236	44	18.6%	0.00064
Total		1,414	193		
Average				12.2%	
Variance				0.00017	
n				21	

Production Estimate

The fry trap and screw trap ran concurrently between April 14 and May 30, which provided independent daily estimates of chinook migration. Daily estimates from each trap were summed by week and tested for equality using a Z-test. Differences were significant in six of the seven weeks tested ($\alpha = 0.05$) (Table 11). After week 16, weekly population estimates based on fry trapping declined to low levels relative to screw trap-based estimates. Over the same period, weekly migrations estimated with the screw trap increased with the exception of just one week. As chinook grew in April, larger chinook were able to avoid the fry trap. Therefore, we used the screw trap estimates from April 14 through the end of the migration.

Combining the chinook production estimated from the fry trap for January 18 through April 13, with the estimate from the screw trap for April 14 through July 20, yielded a total migration over this interval of 120,876 age 0+ chinook (Table 12, Figure 11, Appendix B). Due to low catches early in the season, we did not estimate migration prior to fry trap operation.

As in the previous five seasons, emigration timing was clearly bi-modal (Figure 11). We estimate that the migration was 25%, 50%, and 75% complete by February 23, March 20, and May 22, respectively (Figure 12). Juvenile chinook emigrated in nearly equal proportions of fry and smolts during the 2004 migration. Relative to the patterns observed over the previous five broods, the smolt proportion of the 2004 migration was second only to that of brood year 2000 (Table 13). Brood year 2000 was notable because it experienced extremely low stable flows throughout the winter and also had the lowest number of parent spawners.

Table 11. Independent weekly estimates of chinook migration, N_w, from the fry and screw traps with results from a Z-test comparison of the weekly estimates, Cedar River 2004.

Statistical Week			Fry Trap		Screw Trap		Significant
Begin	End	Number	Estimated Migration (N_w)	$V(N_w)$	Estimated Migration (N_w)	$V(N_w)$	Difference? (Yes/No)
04/14	04/18	16	312	1,364	484	5,695	No
04/19	04/25	17	104	60	1,436	23,093	Yes
04/26	05/02	18	9	12	937	4,928	Yes
05/03	05/09	19	36	41	5,374	234,468	Yes
05/10	05/16	20	0	0	8,977	457,567	Yes
05/17	05/23	21	0	0	9,699	468,423	Yes
05/24	05/30	22	1,135	10,739	11,423	1,037,382	Yes

Table 12. 2004 Cedar River juvenile chinook production estimate and confidence intervals.

Gear	Period	Estimated		95% CI		CV
		Catch	Migration	Low	High	
Fry Trap	January 18 - April 13	4,517	65,752	43,176	88,328	17.5%
Screw Trap	April 14 - July 20	6,718	55,124	43,445	66,803	10.8%
	Season Total	11,235	120,876	95,458	146,294	10.7%

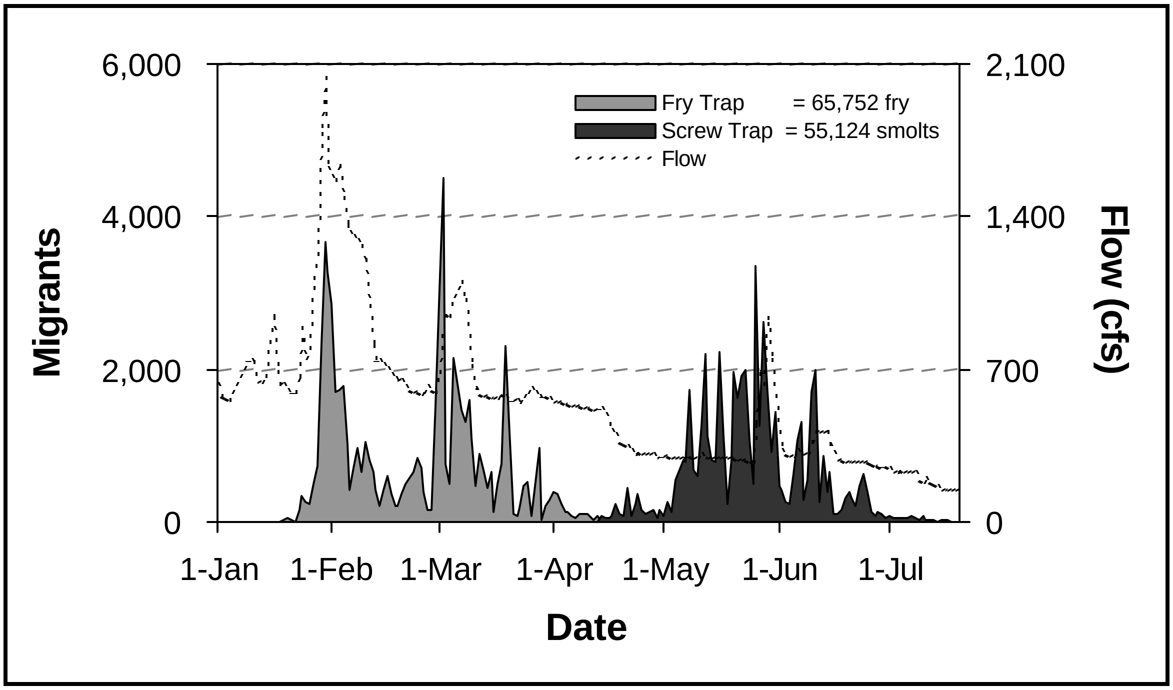

Figure 11. Estimated daily Cedar River chinook migration from fry and screw trap estimates and flow (USGS Renton Gage), 2004.

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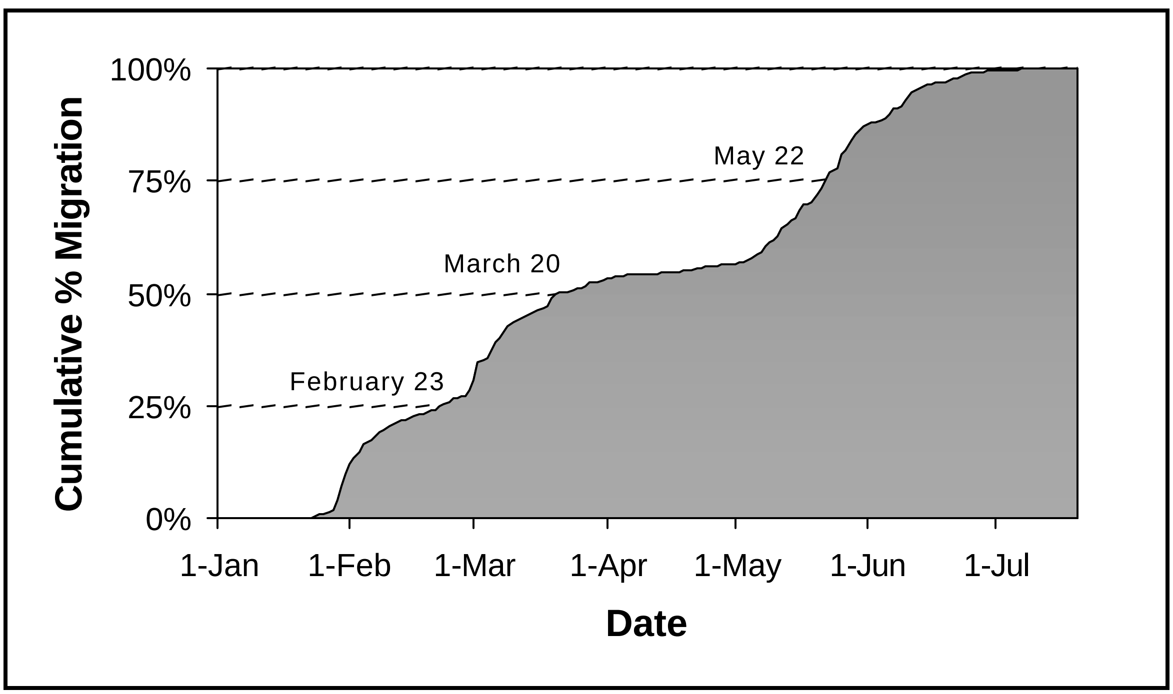

Figure 12. Cumulative percent migration of age 0+ chinook, Cedar River 2004.

Table 13. Comparison of fry and smolt components between brood years for wild chinook production, standardized by assuming a January 1 to July 13 migration period, Cedar River broods 1998 to 2003.

Brood Year	Migration			% Migration	
	Fry	Smolt	Total	Fry	Smolt
	Jan 1-Apr 15	Apr 16-Jul 13	Jan 1-Jul 13	Jan 1-Apr 15	Apr 16-Jul 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%
2002	194,135	41,262	235,397	82%	18%
2003	65,875	54,929	120,804	55%	45%

Egg-to-Migrant Survival

Relating estimates of juvenile chinook emigrating from the Cedar River to estimates of annual egg deposition estimates of egg-to-migrant survival. For the 2003 brood, we estimated a wild chinook egg-to-migrant survival rate of 8.0% based on an escapement of 337 females (Burton *et al.* 2004) and an assumed fecundity of 4,500 eggs per female (Table 14).

Table 14. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998-2003, Cedar River.

Brood Year	Estimated Migration	Est. Females	Potential Egg Deposition	Production/ Female	Survival Rates
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%
2002	235,397	281	1,264,500	838	18.6%
2003	120,876	337	1,516,500	359	8.0%

Coho

Catch

We captured a total of 2,668 wild coho smolts in the screw trap between April 14 and July 20. Approximately 70% of the catch occurred during May. Catch distribution was uni-modal with the peak catch of 237 smolts occurring on May 12.

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 only 140 coho. This addition represented 5% of the catch. These expansions account for additions made for nine screw stoppers that occurred during the season. Although six other screw stoppers occurred, catch was not expanded on those dates due to high actual catches or catches of zero for previous and following intervals. Expanded catch also includes estimates for four nights that the trap did not fish.

Size

Over the season, weekly coho smolt fork lengths averaged 110 mm and ranged from 86 mm to 145 mm (Table 15, Figure 13). There was little variation in weekly mean size over the season.

Table 15. Weekly mean fork length, standard deviation, range, sample size and catches for coho smolts from the Cedar River screw trap, 2004.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/14	04/18	16	115.1	10.31	95	143	58	94
04/19	04/25	17	111.9	9.09	92	137	114	262
04/26	05/02	18	110.4	9.46	90	136	77	370
05/03	05/09	19	108.6	7.45	91	126	57	581
05/10	05/16	20	107.5	6.56	95	127	60	722
05/17	05/23	21	105.9	7.67	98	121	21	203
05/24	05/30	22	103.5	9.42	86	127	31	169
05/31	06/06	23	117.4	13.22	101	145	15	65
06/07	06/13	24	107.8	13.67	92	139	12	91
06/14	06/20	25	107.5	11.11	91	126	11	37
06/21	06/27	26	107.7	7.30	101	121	7	20
06/28	07/04	27					0	27
07/05	07/11	28	112.0	8.54	104	121	3	19
07/12	07/18	29					0	7
07/19	07/25	30					0	1
Season Totals			109.8	10.04	86	145	466	2,668

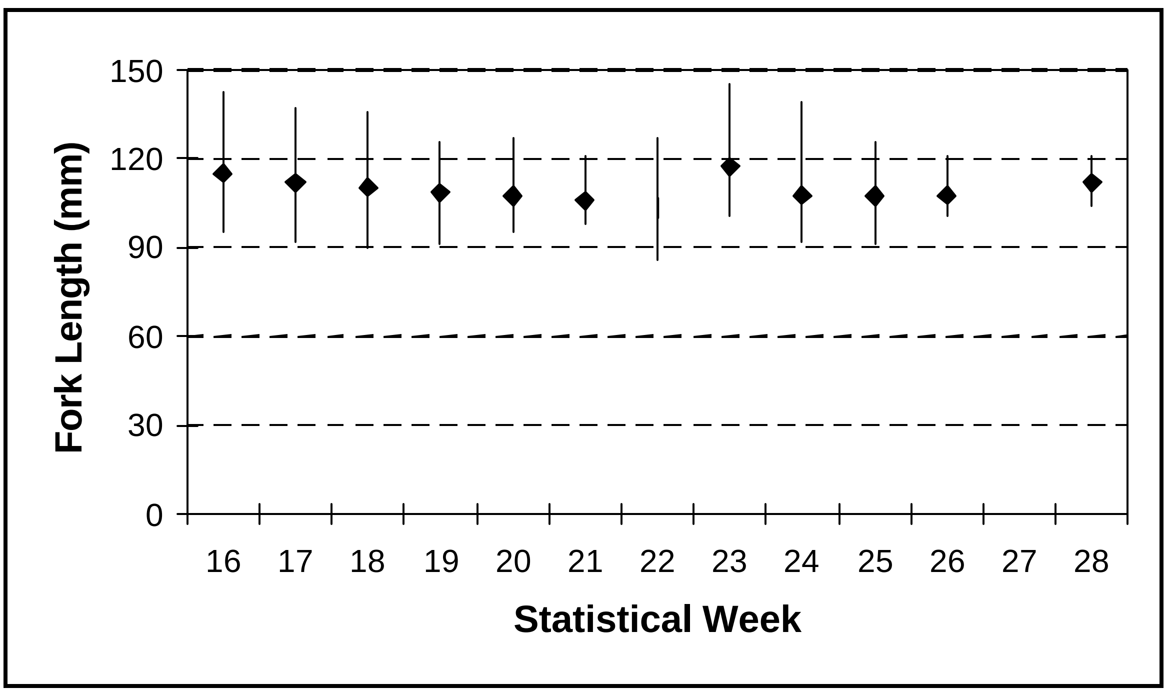

Figure 13. Weekly ranges and mean fork lengths for coho smolts captured in the Cedar River screw trap, 2004.

Trap Efficiency

Twenty-one mark-recapture tests were conducted to measure trap efficiency for coho. Recapture rates for individual release groups ranged from 0% to 11.7% (Table 16). In order to increase our confidence in the results, we combined small release groups to represent releases of more than 40 fish. Grouped efficiency tests ranged between 0.9% and 11.7%. As with chinook, regression analysis failed to find a significant flow effect on trap efficiency ($\alpha = 0.05$). Therefore, we used the average rate (4.2%) to estimate daily migration and season production.

Production Estimate

Coho production was estimated at 67,392 smolts during the trapping season. Using linear extrapolation to a starting migration date of April 1, we estimated that an additional 2,652 smolts migrated before trapping began on April 14. Total coho production was estimated at 70,044 smolts with a coefficient of variation of 17.0% and a 95% confidence interval of 46,735 to 93,353 smolts (Figure 14, Appendix B).

Table 16. Estimated coho smolt recapture rates from screw trap efficiency tests, Cedar River 2004.

Date(s)	Flow(s) (cfs)	NUMBER Released	NUMBER Recaptured	Recapture Rate	Variance
4/22-4/23	331	71	2	2.8%	0.000386
4/25-4/26	323-320	90	5	5.6%	0.000583
4/27	331	74	4	5.4%	0.000691
4/28	312	60	7	11.7%	0.001718
4/30-5/01	380-316	79	4	5.1%	0.000608
5/02	312	54	1	1.9%	0.000337
5/03	304	65	3	4.6%	0.000677
5/04-5/05	308-297	83	1	1.2%	0.000143
5/06	297	50	4	8.0%	0.001472
5/07	308	50	1	2.0%	0.000392
5/09	300	50	2	4.0%	0.000768
5/12	308	50	1	2.0%	0.000392
5/13	304	50	2	4.0%	0.000768
5/14-5/16	300-304	87	3	3.4%	0.000383
5/18-5/21	300-282	115	1	0.9%	0.000075
Total		1,028	41		
Average				4.17%	
Variance				0.000053	
n				15	

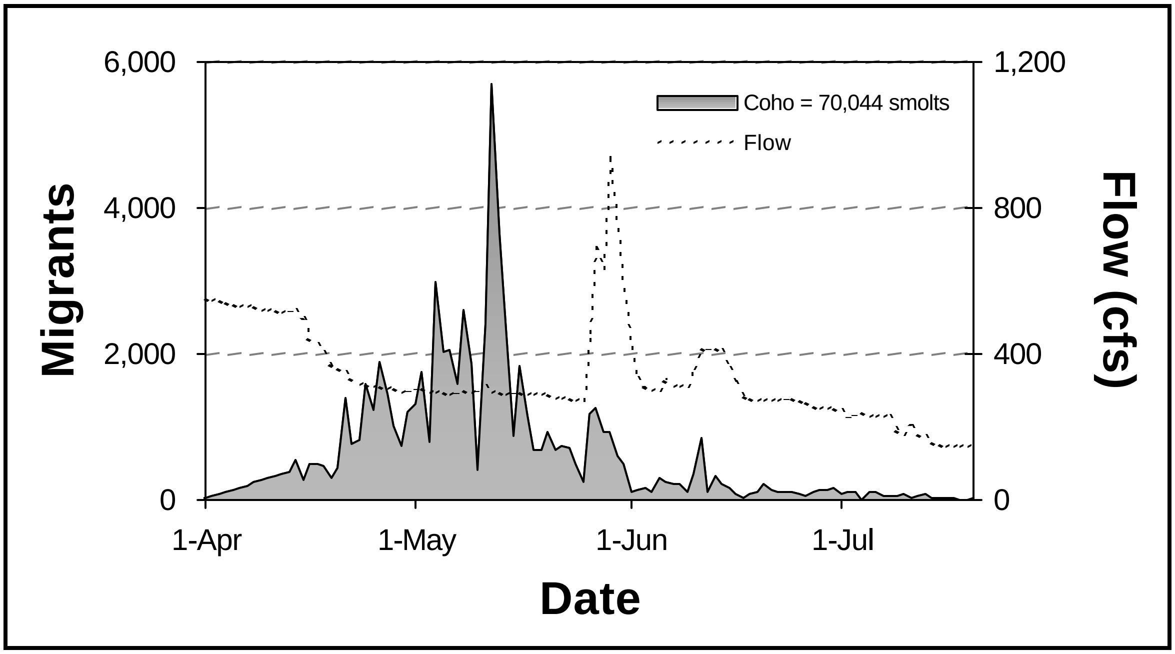

Figure 14. Estimate of daily coho smolt migration and daily average flow, Cedar River screw trap 2004.

Steelhead and Cutthroat

Catch

Only three steelhead smolts were captured throughout the season: two on May 8 and one on May 30.

A total of 84 cutthroat trout were captured in the screw trap between April 14 and July 14. Due to the low catches, there was no definable timing pattern. An additional three cutthroat smolts were estimated to have migrated past the trap during intervals where debris stopped the screw.

Size

Steelhead smolt fork lengths were 180 mm, 197 mm, and 220 mm. Cutthroat trout fork lengths averaged 164 mm, and ranged from 92 to 192 mm throughout the trapping season (Table 17).

Trap Efficiency

Because 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). The average of these rates (60%) indicates a steelhead-to-coho capture rate. Applying this rate to our average coho smolt catch rate (4.2%) estimates a steelhead capture rate in the Cedar River screw trap of 2.5%. Although the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape, Bear Creek screw trap data corroborates the 60% rate. In 2004, the capture rates in Bear Creek for coho and cutthroat averaged 43.2% and 25.6%, resulting in a cutthroat-to-coho capture rate of 59%. As cutthroat migrants in the Cedar River averaged 164 mm, similar in size to steelhead, we consider them an acceptable surrogate for steelhead smolts.

Table 17. Weekly mean cutthroat fork length, standard deviation, range, sample size and catches, Cedar River screw trap 2004.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/14	04/18	16	171.1	14.3	151	190	9	9
04/19	04/25	17	161.0	13.2	151	176	3	4
04/26	05/02	18	167.5	19.1	154	181	2	2
05/03	05/09	19	167.5	17.5	151	192	4	5
05/10	05/16	20	164.3	21.4	114	182	8	8
05/17	05/23	21	145.7	46.5	92	175	3	8
05/24	05/30	22	171.0	1.4	170	172	2	2
05/31	06/06	23					0	10
06/07	06/13	24	172.0	5.7	168	176	2	8
06/14	06/20	25					0	3
06/21	06/27	26					0	2
06/28	07/04	27					0	6
07/05	07/11	28	141.3	11.0	134	154	3	13
07/12	07/18	29					0	4
07/19	07/25	30						0
Season Total			163.6	20.3	92	192	36	84

Production Estimate

Application of a capture rate of 2.5% to the catch of three steelhead estimates a total migration of 120 smolts. Applying this rate to the expanded catch of 87 cutthroat estimates the total cutthroat migration during the trapping period at 3,480 smolts (Appendix B). No confidence intervals were developed for these estimates, which apply only to the period of screw trap operation (April 14 through July 20). While cutthroat migration 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.

PIT Tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington basin, we began tagging chinook with passive integrated transponder (PIT) tags on May 5 and tagged three days a week (Mondays, Wednesdays, and Fridays) through July 2. Chinook were held from the previous day in order to increase the number tagged per day. Over the season we tagged 2,185 wild and six hatchery chinook smolts (Table 18). This tag group comprised 4% of the chinook smolt production from the Cedar River in 2004. Weekly tag rates increased in June as a result of earlier than average migration timing.

DNA Collection

During fry trap operation, primarily in March, tissue samples were collected from 118 juvenile chinook (Table 19).

In April through June, a total of 137 juvenile chinook were sampled during screw trap operation (Table 19). A total of eight rainbow/steelhead trout tissue samples were also collected during screw trap operation for DNA analysis (Table 19).

Table 18. Chinook smolts PIT tagged and released from the Cedar River screw trap, 2004.

Statistical Week			Chinook		Proportion of Smolt
#	Start	End	Wild	Hatchery	Migration Tagged
19	05/03	05/09	129	0	2.4%
20	05/10	05/16	329	0	3.7%
21	05/17	05/23	274	0	2.8%
22	05/24	05/30	290	0	2.5%
23	05/31	06/06	208	0	4.6%
24	06/07	06/13	459	0	6.6%
25	06/14	06/20	244	0	11.6%
26	06/21	06/27	210	0	9.4%
27	06/28	07/04	42	6	8.4%
		Total	2,185	6	4.0%

Table 19. Chinook and rainbow/steelhead trout tissue samples collected from the Cedar River fry and screw traps, 2004.

Trap	Statistical Week	Samples Collected	
		Chinook	Rnbw/Sthd
Fry Trap	9	5	
	10	59	
	11	36	
	12	10	
	13	2	
	14	2	
	15	0	
	16	4	
Screw Trap	17	10	
	18	4	2
	19	10	4
	20	18	1
	21	32	
	22	8	
	23	16	1
	24	17	
	25	11	
	26	6	
	27	5	
Total		255	8

Mortality

Over the season, no chinook fry died in the fry trap.

Over the season, three coho, one cutthroat, and 97 chinook smolts were found dead in the screw trap. Debris stopped the screw trap during the night of May 28 resulting in 83 (85.6%) of the chinook smolt deaths.

Incidental Species

Additional catch in the fry trap, other than sockeye and chinook fry, included 439 pink salmon fry, one coho fry, 24 coho smolts, one sockeye smolt, and one cutthroat smolt. Other species caught included three-spine stickleback, sculpin, lamprey, large scale sucker fry, pumpkinseed, and long-fin smelt.

Catch in the screw trap, other than the salmonids estimated above, included seven chum fry, 36 coho fry, 132 sockeye smolts, one cutthroat adult, four resident rainbow trout, and 241 ad-marked chinook smolts. Other species caught included three-spine stickleback, sculpin, lamprey, pumpkinseed, large scale suckers (adult and fry), peamouth, and one Northern Pike Minnow.

BEAR CREEK RESULTS

Sockeye

Catch

We caught 77 sockeye fry during the first night of trapping, February 5. Thereafter, through the night of April 4 we fished two to four nights a week for a total of 25 nights. Catches peaked during the night of March 23 when 2,408 fry were caught. By the time trapping ended on the morning of April 5, our catches totaled 11,771 sockeye fry.

Expanding catches for the 35 nights not fished estimates that we would have caught an additional 17,156 sockeye fry during those nights. We would have caught a total of 28,927 fry had we fished continuously from February 5 through April 4. In previous years no sockeye fry were caught during daylight intervals fished. Therefore, migration during daylight hours was considered minimal and not estimated.

Trap Efficiency

Over the season, we released 12 groups of marked sockeye fry upstream of the fry trap. Capture rates ranged from 8.7% to 20.9% (Table 20). Efficiency test results were evaluated for a relationship with flow and there was a slight positive trend (r^2=0.42). Although the trend was marginally significant (α = 0.05), due to the low sample size we elected to use the average of the capture rate tests (16.5%) to estimate daily efficiency.

Table 20. Sockeye fry trap efficiency tests by date, Bear Creek 2004.

Date	Flow (cfs)	Released	Recaptured	Trap Efficiency	Variance
02/20	98	76	15	19.7%	0.00208
02/29	126	198	36	18.2%	0.00075
03/02	93	225	47	20.9%	0.00073
03/07	105	185	30	16.2%	0.00073
03/09	94	522	109	20.9%	0.00032
03/12	76	525	84	16.0%	0.00026
03/14	66	300	55	18.3%	0.00050
03/21	51	211	32	15.2%	0.00061
03/23	50	300	26	8.7%	0.00026
03/26	68	160	25	15.6%	0.00082
03/28	65	300	52	17.3%	0.00048
03/30	54	116	13	11.2%	0.00086
Total		3,118	524		
Average				16.5%	
Variance				1.1E-04	
n				12	

Production Estimate

During the period of fry trap operation (February 5 through April 4), we estimate that 175,107 sockeye fry passed the trap. The sockeye fry migration was still underway when we replaced the fry trap with the screw trap on April 5. Rather than attempting to calibrate the screw trap, we estimated the tail end of the migration using logarithmic extrapolation. Migration from April 4 to April 15 was estimated at 2,694 fry. We estimate a total of 177,801 sockeye fry migrated from Bear Creek in 2004 (Table 21, Figure 15, Appendix C).

Egg-to-migrant survival of the 2003 brood was estimated at 6.3%. This rate is the ratio of 177,801 fry to an estimate of 2.8 million eggs potentially deposited. Egg deposition is based on an estimated 1,765 sockeye adults in Bear Creek (Foley pers. comm.), an even sex ratio, and an assumed fecundity of 3,200 eggs per female.

Table 21. Estimated 2004 Bear Creek sockeye fry migration entering Lake Washington with 95% confidence intervals.

Period	Dates	Est. Migration	CV	95% CI	
				Low	High
Fry Trap	February 5 - April 4	175,107	9.7%	141,876	208,338
Post-Trapping	April 5 - April 15	2,694	17.6%	1,762	3,626
	Season Totals	177,801	9.5%	144,557	211,045

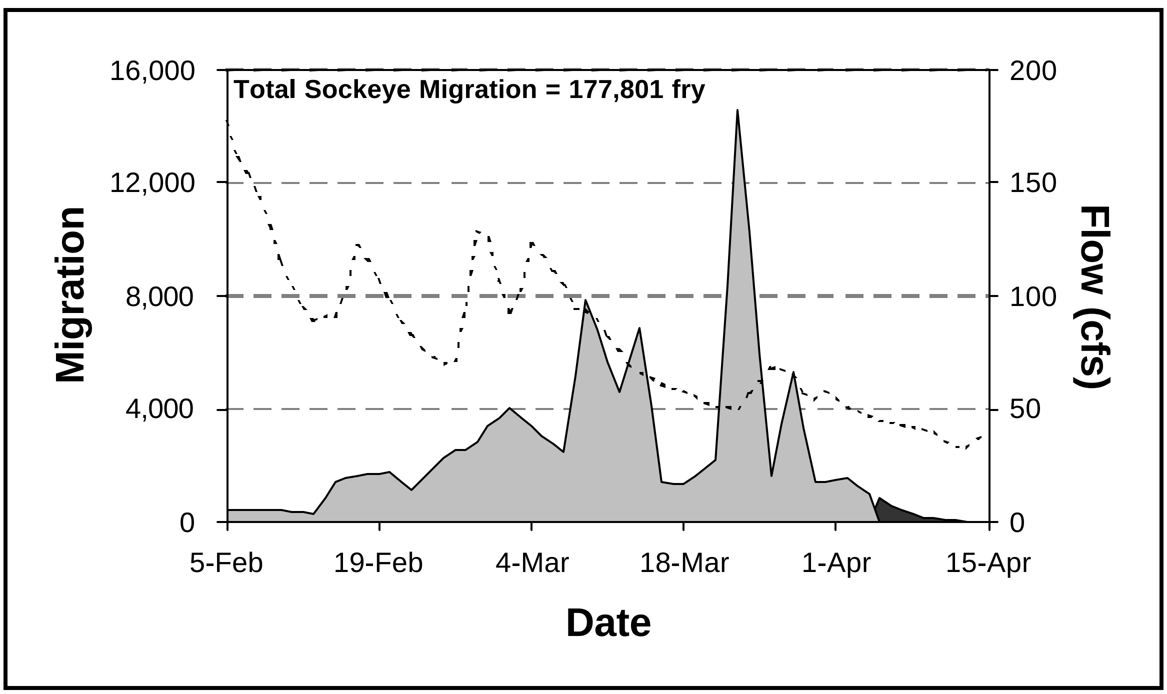

Figure 15. Estimated daily migration of sockeye fry from Bear Creek and daily average flow, 2004.

Chinook

Catch

Fry Trap

We caught three chinook fry on February 5, the first night of trapping. Catches peaked on the night of March 28 when 31 fry were caught. In total, 102 chinook fry were caught in the fry trap by the time trapping ended on the morning of April 5.

Catch expansion for the 35 nights not fished resulted in an estimated catch of 130 chinook fry.

Screw Trap

We replaced the screw trap with the fry trap on April 5, and fished it continuously through June 26. On the first night of trapping, we caught four chinook. Catches began to increase by late April, and peaked on May 7 when 955 chinook were caught. Catches then declined to less than ten per day by June 17. A total of 10,613 chinook were caught over the 83 days trapped.

Size

From early February through March, the weekly mean fork length of chinook fry increased by only five millimeters. Fork lengths ranged from 38 mm to 60 mm, and averaged 41.6 mm (Table 22, Figure 16).

Weekly average fork lengths during screw trap operation increased throughout the season. Chinook averaged 51 mm in early April, and grew to average 83 mm by late May (Table 22). Fork lengths over the season ranged from 40 mm to 107 mm (Figure 16).

Trap Efficiency

Sockeye fry were used to estimate fry trap efficiency because inadequate numbers of chinook fry were available to conduct efficiency tests. Capture efficiency was estimated at 16.5%, the average of all individual tests (Table 20).

Tests to estimate the capture rate of the screw trap were conducted on 22 days from April 27 to June 13. Efficiency rates ranged from 27% to 85% and averaged 49.2% (Table 23). Daily average flows ranged from 25 to 83 cfs during the tests, nearly identical to the flow range throughout the trapping season (21 to 83 cfs). Flow did not explain any of the variation in capture rates, therefore we used the average rate (49.2%) to estimate production.

Table 22. Chinook and coho smolt mean fork lengths, standard deviations, ranges, sample sizes, and catches in the Bear Creek fry and screw traps, 2004.

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	02/02	02/08	6	39.7	2.1	38	42	3	4						
	02/09	02/15	7	39.8	1.3	38	41	8	11						
	02/16	02/22	8	40.2	2.5	38	46	10	11						
	02/23	02/29	9					0	0						
	03/01	03/07	10	40.7	1.2	40	42	3	3						
	03/08	03/14	11	40.3	1.8	38	44	12	12						
	03/15	03/21	12	40.0				1	1						
	03/22	03/28	13	41.2	5.3	38	60	16	35						
	03/29	04/04	14	45.1	7.5	38	60	17	25						
	Trap Totals			41.6	5.0	38	60	70	102						
SCREW TRAP	04/05	04/11	15	51.0	8.1	42	60	6	6	127.4	17.8	98	198	36	45
	04/14	04/18	16	53.8	7.9	40	74	56	65	113.8	12.5	84	151	112	716
	04/19	04/25	17	58.6	7.5	45	91	91	183	113.5	11.2	94	142	64	1,211
	04/26	05/02	18	68.5	9.8	51	86	77	721	109.9	12.2	90	144	82	3,397
	05/03	05/09	19	72.7	7.7	54	92	98	3,157	110.9	13.0	90	194	116	2,324
	05/10	05/16	20	74.9	6.9	55	91	93	1,620	111.5	10.2	91	137	63	649
	05/17	05/23	21	79.8	7.7	64	107	234	2,445	110.4	8.3	93	127	49	227
	05/24	05/30	22	79.7	7.2	60	95	60	1,636	107.4	8.7	91	124	24	140
	05/31	06/06	23	82.5	5.8	70	98	75	455	111.2	14.4	89	145	24	182
	06/07	06/13	24	80.1	5.1	66	92	68	234	107.1	31.2	89	198	14	121
	06/14	06/20	25	75.8	5.8	65	85	11	84	100.0	24.8	80	167	24	95
	06/21	06/27	26	82.4	3.4	78	87	5	7	91.0	1.4	90	92	2	4
	Trap Totals			73.6	11.5	40	107	874	10,613	111.9	14.4	80	198	610	9,111

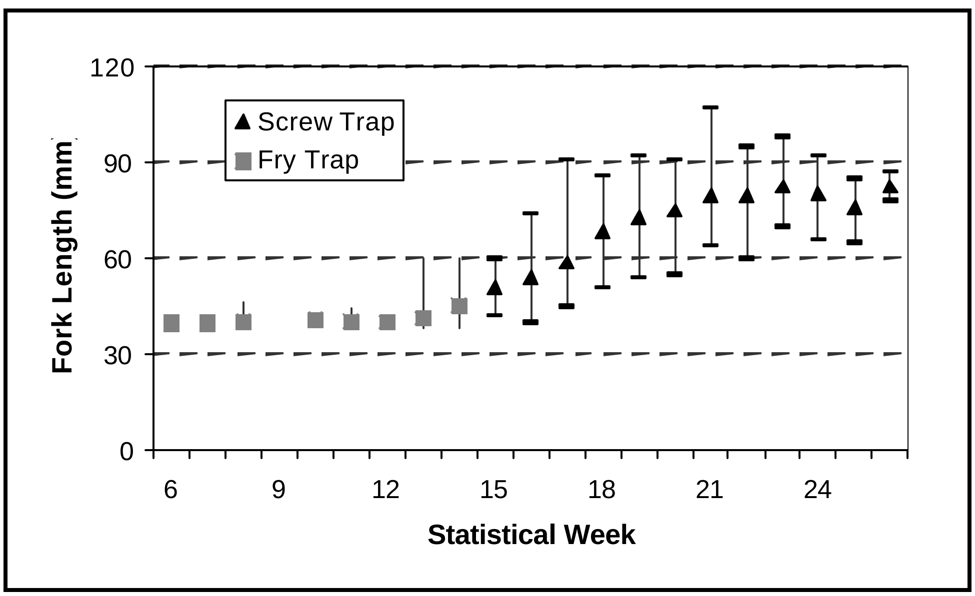

Figure 16. Average and range of chinook 0+ fork lengths sampled from Bear Creek, 2004.

Table 23. Chinook 0+ trap efficiency test results by date, Bear Creek 2004.

Date	NUMBER Released	NUMBER Recap	Efficiency Rate	Variance	Flow (cfs)
04/27	30	8	26.7%	6.5E-03	31
04/28	30	15	50.0%	8.3E-03	32
04/29	48	19	39.6%	5.0E-03	31
04/30	49	26	53.1%	5.1E-03	40
05/06	50	21	42.0%	4.9E-03	27
05/07	50	14	28.0%	4.0E-03	34
05/08	150	100	66.7%	1.5E-03	34
05/09	149	126	84.6%	8.8E-04	34
05/10	100	64	64.0%	2.3E-03	31
05/11	100	54	54.0%	2.5E-03	36
05/13	50	31	62.0%	4.7E-03	29
05/14	50	21	42.0%	4.9E-03	28
05/16	50	24	48.0%	5.0E-03	28
05/17	50	27	54.0%	5.0E-03	27
05/18	50	17	34.0%	4.5E-03	27
05/20	49	18	36.7%	4.7E-03	25
05/21	50	19	38.0%	4.7E-03	26
05/23	31	19	61.3%	7.7E-03	29
05/25	32	14	43.8%	7.7E-03	25
05/26	50	25	50.0%	5.0E-03	32
05/28	50	26	52.0%	5.0E-03	83
06/13	34	17	52.0%	7.3E-03	34
Total	1,302	705			
Average			49.2%		
Variance			8.4E-04		
n			22		

Production Estimate

From February 5 to April 4, we estimated a total of 2,079 chinook fry passed the fry trap. During screw trap operation (April 5 through June 26) we estimated that 21,568 chinook passed the trap. Daily migrations in early April averaged less than five chinook. Migration increased by late-April and averaged nearly 600 chinook per day for the month of May. Migration declined thereafter to average less than 100 chinook per day during the first half of June. Only two chinook migrated during the last four days of trapping.

Combining the chinook production estimates from the fry and screw traps estimates a total juvenile production of 23,647 chinook with a coefficient of variation of 5.5% and a 95% confidence interval of 21,115 to 26,179 juveniles (Figure 17, Appendix C).

Egg-to-migrant survival of the 2003 brood was estimated at 5.0%. This rate is the ratio of 23,674 chinook to an estimate of 472,500 eggs potentially deposited. Egg deposition is based on 105 spawning females in Bear Creek (Foley pers. comm.) and an assumed fecundity of 4,500 eggs per female.

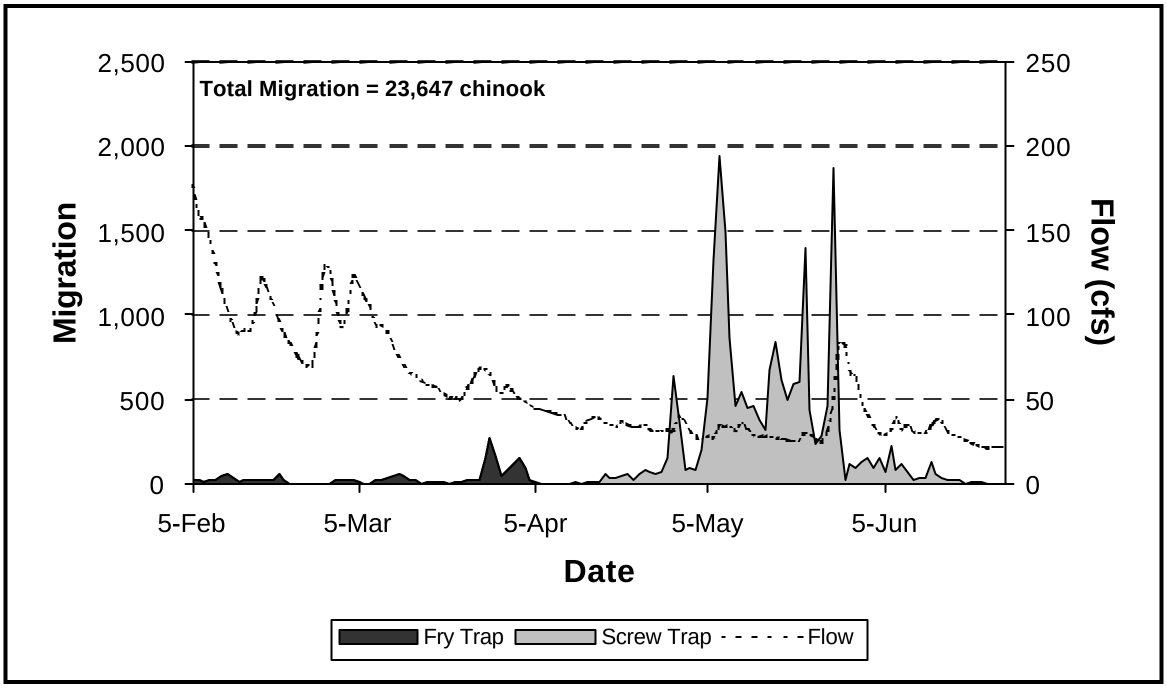

Figure 17. Estimated daily chinook 0+ migration and daily average flow from Bear Creek, 2004.

Coho

Catch

One coho smolt was caught on the first night of screw trapping, April 5. After this night, catches steadily increased and peaked at 1,053 smolts on April 29. Catches declined thereafter, and by late June daily catches averaged less than five smolts per day. Over the entire 83-day trapping season, which ended on the morning of June 27, we caught 9,111 coho smolts.

Size

Over the trapping period, fork lengths ranged from 80 mm to 198 mm and averaged 112 mm (Table 22). Weekly mean size varied little over the season (Figure 18).

Trap Efficiency

A total of 1,352 marked coho were released in 29 groups upstream of the trap between April 13 and May 21. Trap efficiencies ranged from 16% to 70% and averaged 43% (Table 24). The relationship between capture rate and mean daily flow was not significant enough to use for predictive purposes due to the small range of flows that occurred during the efficiency tests. We used the average of the efficiency tests (43%) to estimate daily migration.

Production Estimate

Coho production was estimated at 21,085 smolts with a coefficient of variation of 5.9% and a 95% confidence interval of 18,641 to 23,529 smolts (Figure 19).

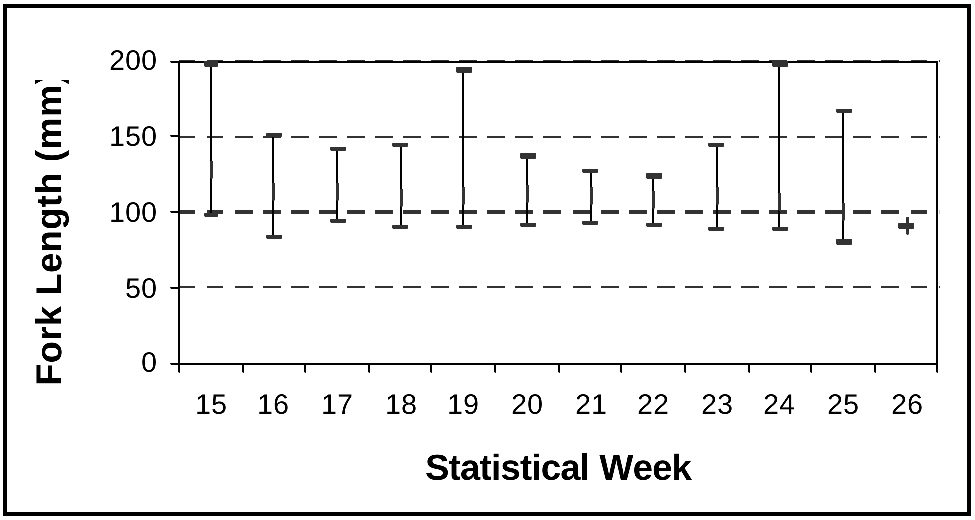

Figure 18. Average and range of fork lengths from coho smolts sampled from Bear Creek, 2004.

Table 24. Estimated coho smolt recapture rates from screw trap efficiency tests, Bear Creek 2004.

Date	Flow (cfs)	Efficiency Tests Released	Recaptured	Rate	Variance
04/13	33	50	25	50.0%	0.00500
04/14	37	56	22	39.3%	0.00426
04/15	39	50	32	64.0%	0.00461
04/16	39	29	15	51.7%	0.00861
04/18	35	50	23	42.0%	0.00487
04/20	37	38	21	55.3%	0.00651
04/21	35	50	27	54.0%	0.00497
04/22	34	50	21	42.0%	0.00487
04/23	34	50	23	46.0%	0.00497
04/24	35	50	25	50.0%	0.00500
04/25	32	50	24	48.0%	0.00499
04/26	31	50	19	38.0%	0.00471
04/27	31	50	35	70.0%	0.00420
04/28	32	50	24	48.0%	0.00499
04/29	31	50	26	52.0%	0.00499
04/30	40	50	21	42.0%	0.00487
05/01	37	50	18	36.0%	0.00461
05/02	31	50	10	20.0%	0.00320
05/03	28	50	16	30.0%	0.00420
05/04	26	50	17	34.0%	0.00449
05/05	28	50	25	50.0%	0.00500
05/06	27	50	17	34.0%	0.00449
05/07	34	50	32	64.0%	0.00461
05/10	31	50	19	38.0%	0.00471
05/11	36	38	24	63.2%	0.00612
05/12	32	50	8	16.0%	0.00269
05/13	29	30	8	26.7%	0.00652
05/18	27	30	8	23.3%	0.00596
05/21	26	31	8	25.8%	0.00618
Totals		1,352	593		
Average				43.2%	
Variance				0.00065	
n				29	

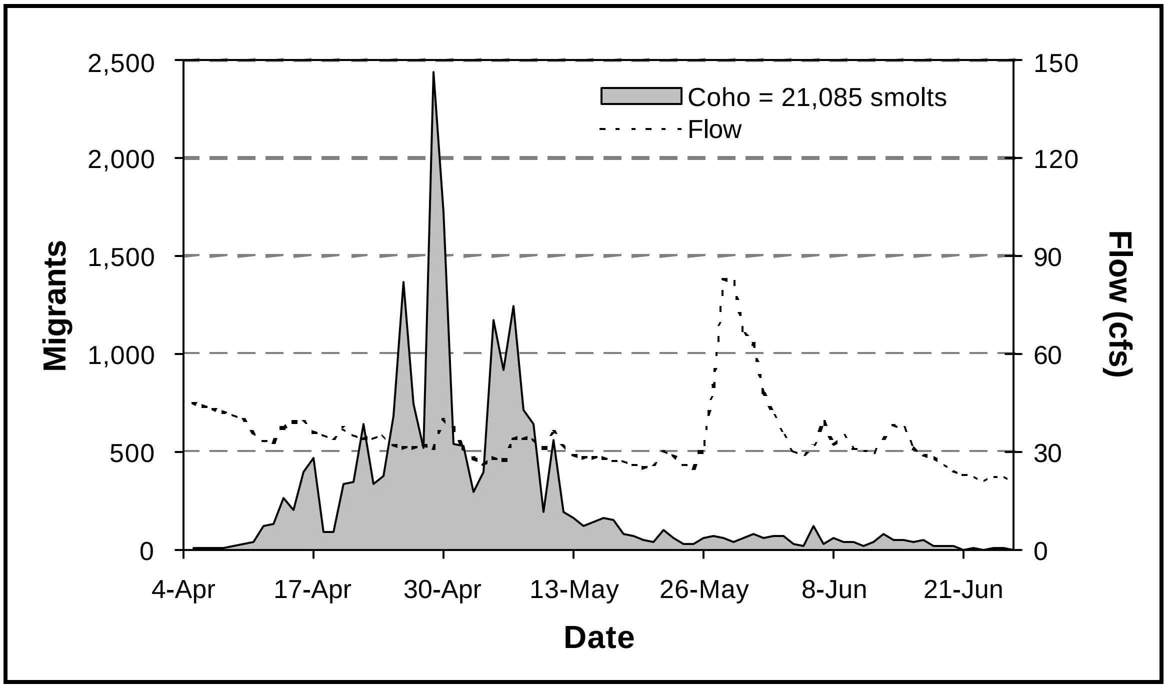

Figure 19. Estimated daily coho smolt migration, Bear Creek screw trap 2004.

Evans Creek Coho Evaluation

The weir trap we installed in Evans Creek was fish tight from April 14 at 1700 hours to June 16 at 0800 hours. Over this interval we caught 4,985 coho smolts and fin-clipped 4,943 of these before release. At the Bear Creek screw trap, we recaptured 1,631 Evans Creek fin-clipped coho smolts from April 15 to June 15. Using the Chapman modification to the Petersen estimate, we estimated that 27,604 coho smolts migrated from Bear Creek in 2004, based on marking and recapturing Evans Creek coho. This estimate is 6,500 smolts greater than the trap efficiency-based estimate. These two estimates are significantly different ($\alpha = 0.05$). We believe that this discrepancy indicates that a portion of the Evans Creek smolts did not pass the screw trap. Consequently the reduced recapture rate of Evans Creek fish resulted in an over-estimation of the coho smolt migration. The lower recapture rate of Evans Creek fish most likely resulted from predation between the weir site and the screw trap site (approximately two miles).

Fork length (mm) measurements of coho smolts fin-clipped and released at Evans Creek varied from 79 mm to 160 mm, and averaged 118.5 mm (Table 25). Of those recaptured at the Bear Creek screw trap, fork lengths ranged from 89 mm to 144 mm, and averaged 118.3 mm (Table 25). Weekly mean fork lengths were not significantly different between release from Evans Creek and recapture at Bear Creek. Evans Creek coho were significantly larger than un-marked coho caught in the Bear Creek screw trap, averaging as much as 10 mm larger during four statistical weeks (17 to 20, Z-test between means). Mean fork lengths during weeks 21 through 24 were not significantly different.

This evaluation estimated that Evans Creek accounted for nearly a quarter (23.6%) of Bear Creek's total coho smolt production in 2004.

Table 25. Comparison of weekly fork length statistics for fin-clipped (UCV) coho smolts released from Evans Creek versus those recaptured at the Bear Creek screw trap, 2004.

Statistical Week			UCV Coho Released from Evans Creek					UCV Coho Caught at Bear Creek				
					Range					Range		
Begin	End	No.	Avg.	s.d.	Min	Max	n	Avg.	s.d.	Min	Max	n
04/05	04/11	15					0					0
04/14	04/18	16	125.0	8.7	105	146	27					0
04/19	04/25	17	123.5	9.2	94	147	182	122.4	8.8	105	144	107
04/26	05/02	18	120.8	10.5	97	160	216	119.1	7.7	110	136	39
05/03	05/09	19	117.3	9.4	90	148	168	116.7	8.9	99	132	35
05/10	05/16	20	116.7	11.9	98	155	88	115.7	9.2	100	131	22
05/17	05/23	21	110.2	11.4	81	129	25	109.4	3.7	104	114	13
05/24	05/30	22	108.6	11.0	84	134	35	108.6	5.7	100	121	14
05/31	06/06	23	98.9	16.7	79	149	19	105.7	16.0	90	122	3
06/07	06/13	24	96.6	9.8	85	114	14	103.8	19.5	89	132	4
06/14	06/20	25					0					0
06/21	06/27	26					0					0
Season Totals			118.5	11.8	79	160	774	118.3	9.9	89	144	237

Steelhead and Cutthroat

No steelhead were captured throughout the 2004 trapping season in Bear Creek.

A total of 1,163 cutthroat trout were captured in the screw trap. Daily catch peaked on April 30 when 68 cutthroat were caught. Cutthroat trout fork lengths averaged 170 mm, and varied from 116 mm to 274 mm throughout the trapping season (Table 26). Four efficiency tests were conducted in late April when catches were high. Capture rates ranged from 17% to 33% and averaged 25.6% (Table 27). We estimated total cutthroat production at 4,540 smolts, with a coefficient of variation of 15.8% and a 95% confidence interval of 3,133 to 5,947 smolts (Figure 20, Appendix C). This estimate applies only to the interval trapped (April 5 through June 26). During the 2000 season, when we operated the screw trap from January through June, 35% of the cutthroat migration occurred prior to April 5. Applying this timing to the cutthroat estimated during the 2004 trapping season estimates that a total of 7,000 cutthroat migrated from Bear Creek.

Table 26. Mean cutthroat fork length, standard deviation, range, sample size, and catch by statistical week, Bear Creek screw trap 2004.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/05	04/11	15	176.9	29.7	119	242	53	117
04/14	04/18	16	179.5	21.5	137	252	90	188
04/19	04/25	17	169.8	21.5	116	217	62	144
04/26	05/02	18	171.9	27.8	118	274	60	228
05/03	05/09	19	162.5	24.2	120	224	55	221
05/10	05/16	20	161.0	21.9	130	231	26	41
05/17	05/23	21	154.1	15.4	132	191	33	68
05/24	05/30	22	159.1	18.2	134	204	23	87
05/31	06/06	23					0	37
06/07	06/13	24					0	22
06/14	06/20	25	162.8	23.5	141	186	4	9
06/21	06/27	26	138.0				1	1
Season Totals			169.6	24.8	116	274	407	1,163

Table 27. Cutthroat capture rates measured at Bear Creek screw trap, 2004.

Date	Flow (cfs)	Released	Recaptured	Efficiency	Variance
04/27	31	48	16	33.3%	4.6E-03
04/28	32	25	5	20.0%	6.4E-03
04/29	31	22	7	31.8%	9.9E-03
04/30	40	46	8	17.4%	3.1E-03
Total		141	36		
Average				25.6%	
Variance				1.6E-03	
n				4	

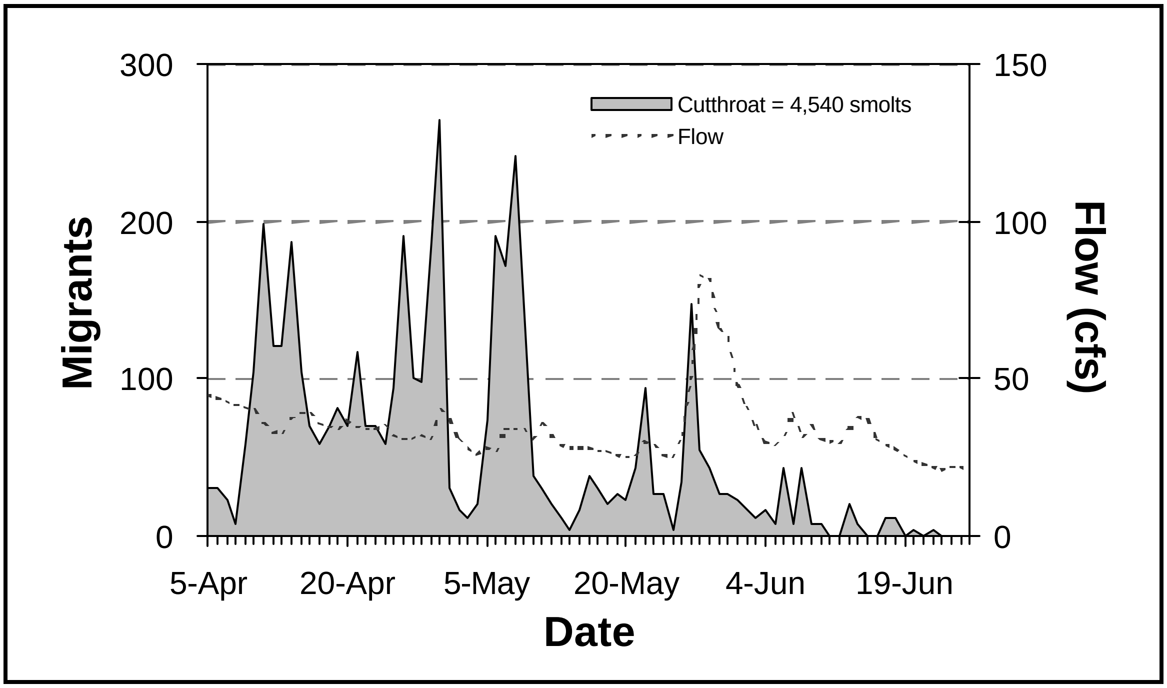

Figure 20. Daily estimated migration of cutthroat trout and flow, Bear Creek screw trap 2004.

Evans Creek Cutthroat Evaluation

The weir trap at Evans Creek was fish tight from April 14 at 1700 to June 16 at 0800. A total of 140 cutthroat smolts were caught, fin-clipped, and released downstream. Fork lengths of 130 of these cutthroat ranged from 96 mm to 323 mm and averaged 143 mm. We recaptured only 15 Evans Creek fin-clipped cutthroat smolts at the Bear Creek screw trap from April 27 to June 10. We measured 11 of these fin-clipped cutthroat. Fork lengths ranged from 139 mm to 192 mm and averaged 154 mm, 11 mm larger than the average size at Evans Creek. As with coho marked at Evans Creek, marked cutthroat from this stream were caught at a lower rate than the cutthroat released above the screw trap to measure efficiency. We believe that this discrepancy results from the fact that smaller cutthroat are more vulnerable to predation and tend to reside in the stream until age two.

PIT Tagging

We PIT tagged chinook beginning on May 5 and continued three days a week (Mondays, Wednesdays, and Fridays) through June 18. Chinook were held from the previous day in order to increase the number tagged per day. Throughout the trapping season, 1,512 chinook smolts were PIT tagged (Table 28). We tagged 6.5% of the total chinook production from Bear Creek in 2004.

Table 28. Chinook PIT tagged and released from the Bear Creek screw trap, 2004.

Statistical Week			Number	Proportion of
#	Start	End	Tagged	Migration Tagged
19	05/03	05/09	199	3.1%
20	05/10	05/16	200	6.1%
21	05/17	05/23	300	6.0%
22	05/24	05/30	288	8.7%
23	05/31	06/06	207	22.4%
24	06/07	06/13	219	46.0%
25	06/14	06/20	99	58.2%
		Total	1,512	6.4%

DNA Collection

A total of 13 juvenile chinook tissue samples were collected during fry trap operation and 161 during screw trap operation.

Mortality

During the fry trapping season, three chinook died in the trap. Those mortalities most likely occurred before they entered the trap, as each had visible parasite marks. In the screw trap, 44 chinook and two coho died over the trapping season.

Incidental Species

In addition to sockeye and chinook fry caught in the fry trap, we also caught two coho fry, two coho smolts, nine pink fry, 18 cutthroat smolts, and 15 cutthroat adults. In addition to the species estimated for the screw trap, we also caught sockeye fry, two trout parr, 13 two-year old coho smolts, one ad-marked resident rainbow trout, and 11 cutthroat adults. Other species caught included lamprey, large-scale suckers, three-spine stickleback, sculpin, pumpkinseed, large-mouth bass, peamouth, dace, whitefish, Northern Pike Minnow, and one oriental weatherfish.

CITATIONS

Literature Cited

Burton, C., L. Lowe, and H. Berge. 2004. Cedar River Chinook Salmon (*Oncorhynchus tshawytscha*) Redd and Carcass Surveys: Annual Report 2003 . Seattle Public Utilities. Seattle, 60 p.

Cramer, S.P., J. Norris, P.R. Mundy, G. Grette, K.P. O'Neal, J.S. Hogle, C. Steward, and P. Bahls. 1999. Status of chinook salmon and their habitat in Puget Sound. Volume 2, Final Report. Prepared for Coalition of Puget Sound Businesses. S.P. Cramer & Associates, Inc. Gresham, OR.

Goodman, L.A. 1960. On the exact variance of products. Journal of the American Statistical Association. 55: 708-713.

Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/Downstream Salmonid Project 1977-1980. WA Dept. of Fish. Prog. Rpt. No. 144. 195 p.

Seiler, D. and S. Neuhauser. 1985. Evaluation of downstream migrant passage at two dams: Condit Dam, Big White River, 1983 & 1984; Howard Hanson Dam, Green River, 1984. Wash. Dept. Fish. Prog. Rep. No. 235: 94p.

Seiler, D., S. Wolthausen, and L.E. Kishimoto. 1992. Evaluation of downstream migrant passage through the sediment retention structure, North Fork Toutle River, 1991. WA Dept. Fish, Prog. Rep. No. 297. 45 p.

Seiler, D. and L. Kishimoto. 1996. Annual report: 1995 Cedar River sockeye salmon fry production evaluation program. WA Dept. Fish & Wildlife. Olympia. 28 p.

Seiler, D., G. Volkhardt, and L. Kishimoto. 2003. Evaluation of downstream migrant salmon production in 1999 and 2000 from three Lake Washington tributaries: Cedar River, Bear Creek, and Issaquah Creek. WA Dept. Fish & Wildlife. Olympia, WA. 199 p.

U.S. Army Corps of Engineers, Seattle District. 1997. Cedar River Section 205 flood damage reduction study. Final Environmental Impact Statement.

Volk, E.C., S.L. Schroder, and K.L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific Salmon. Am. Fish. Soc. Symposium 7: 203-215.

Personal Communications

Antipa, Brodie. Hatchery Manager-Rainier Complex. Washington Department of Fish and Wildlife, Puyallup. Electronic mail on August 16, 2004.

Ebel, Charles. Biologist. United States Army Corps of Engineers, Seattle. Personal communication on August 17, 2004.

Foley, Steve. Fish and Wildlife Biologist. Washington Department of Fish and Wildlife, Mill Creek. Electronic mail on April 24, 2004.

Appendix A: Daily Estimated Cedar River Wild and Hatchery Sockeye Fry Migration into Lake Washington, 2004.

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2004.

Date	Flow (cfs)	Nightly Catch Actual	Nightly Catch Estimate	Estimated Daily Catch Wild	Estimated Daily Catch Hatchery	Trap Efficiency	Daily Migration Wild	Daily Migration Hatchery
01/01	632						1,544	
01/02	574						2,450	
01/03	571						2,750	
01/04	562						3,087	
01/05	597						3,465	
01/06	632						3,890	
01/07	667						4,366	
01/08	702						4,901	
01/09	736						5,501	
01/10	743						6,175	
01/11	733						6,931	
01/12	646						7,780	
01/13	645						8,732	
01/14	665						9,802	
01/15	828						11,002	
01/16	947						12,350	
01/17	686						13,862	
01/18	637	1,365		1,371	0	8.8%	15,597	0
01/19	632			1,380	0	8.8%	15,650	0
01/20	607	5,242		1,390	3,873	9.0%	15,522	43,249
01/21	587			1,400	6,699	9.1%	15,444	73,896
01/22	593	1,404		1,410	0	9.0%	15,611	0
01/23	673			2,048	0	8.6%	23,835	0
01/24	886	2,673		2,684	0	7.4%	36,161	0
01/25	752			2,689	0	8.2%	32,959	0
01/26	795	2,683		2,694	0	7.9%	34,005	0
01/27	1,120			3,274	0	6.1%	53,349	0
01/28	1,230	1,103	2,733	3,853	0	5.5%	69,641	0
01/29	1,820			2,936	0	4.3%	69,023	0
01/30	2,039	182	1,824	2,018	0	4.3%	47,441	0
01/31	1,620			2,658	0	4.3%	62,487	0
02/01	1,590	3,160	118	3,298	0	4.3%	77,533	0
02/02	1,570	3,096		3,110	0	4.3%	73,113	0
02/03	1,630			3,699	0	4.3%	86,960	0
02/04	1,490	4,267		4,286	0	4.3%	100,760	586,000
02/05	1,360			4,287	0	4.8%	88,969	0
02/06	1,330	4,266		4,287	0	5.0%	86,027	0
02/07	1,310			4,718	0	5.1%	92,633	0
02/08	1,290	5,124		5,149	0	5.2%	98,961	0
02/09	1,270	25,022		5,978	19,168	5.3%	112,518	360,780
02/10	1,200	6,772		6,806	0	5.7%	119,456	0
02/11	986			7,839	0	6.9%	114,054	0
02/12	807	8,827		8,871	0	7.9%	112,914	0
02/13	731			9,957	0	8.3%	120,342	1,104,000
02/14	741	10,989		11,043	0	8.2%	134,360	0
02/15	726			13,279	0	8.3%	159,961	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2004 (cont'd.).

Date	Flow (cfs)	Nightly Catch		Estimated Daily Catch		Trap Efficiency	Daily Migration	
		Actual	Estimate	Wild	Hatchery		Wild	Hatchery
02/16	709	39,919		15,515	24,601	8.4%	184,818	293,052
02/17	678	14,340		14,125	305	8.6%	164,914	598,561
02/18	657	12,635		12,735	0	8.7%	146,709	0
02/19	648			13,828	0	8.7%	158,399	0
02/20	647			13,679	0	8.7%	156,594	1,183,000
02/21	626	24,682		14,151	10,654	8.9%	159,885	120,374
02/22	609			20,533	1,787	8.9%	229,570	19,983
02/23	594	26,781		26,914	0	9.0%	298,166	510,000
02/24	592	32,929		33,033	0	9.0%	365,511	0
02/25	587	35,294		24,680	10,789	9.1%	272,257	119,019
02/26	594	51,683		26,503	25,436	9.0%	293,613	281,792
02/27	620	33,993		28,325	5,837	8.9%	318,843	1,299,705
02/28	608	29,998		30,147	0	8.9%	336,853	0
02/29	598			35,989	0	9.0%	399,676	0
03/01	687	41,588		41,831	0	8.5%	491,227	594,000
03/02	946	43,206		38,989	4,444	7.1%	549,700	62,652
03/03	953	22,609		22,798	0	7.1%	323,176	1,014,000
03/04	943	40,728		22,153	18,704	7.1%	311,604	263,094
03/05	1,040	32,538		32,424	303	6.6%	493,040	4,601
03/06	1,070			35,256	0	6.4%	549,876	0
03/07	1,100	32,473	5,394	38,088	0	6.2%	609,719	0
03/08	1,019	45,571		45,861	0	6.7%	685,332	0
03/09	856	46,997	7,689	55,033	0	7.6%	725,338	0
03/10	714	58,133		58,473	0	8.4%	698,828	0
03/11	617	58,047		58,386	0	8.9%	656,011	0
03/12	587	70,964		71,379	0	9.1%	787,416	379,000
03/13	581			66,700	0	9.1%	733,134	0
03/14	579	61,659		62,020	0	9.1%	680,872	0
03/15	569	76,550		76,998	0	9.2%	840,237	0
03/16	564	52,557		52,920	0	9.2%	575,761	0
03/17	566	83,635		84,124	0	9.2%	916,351	0
03/18	584	73,849		65,716	8,548	9.1%	723,628	94,128
03/19	578	64,038		59,548	4,868	9.1%	653,334	53,415
03/20	552			77,171	0	9.3%	833,629	0
03/21	555	94,197		94,795	0	9.2%	1,025,836	0
03/22	560	109,638		104,441	5,948	9.2%	1,133,593	64,557
03/23	551	145,936		142,980	3,859	9.3%	1,543,606	41,662
03/24	577	88,141		88,749	0	9.1%	973,136	0
03/25	598	84,293		84,829	0	9.0%	942,070	0
03/26	618	46,257		46,551	0	8.9%	523,359	0
03/27	600			71,246	0	9.0%	792,190	0
03/28	576	95,334		95,940	0	9.1%	1,051,352	0
03/29	567	101,959		99,675	2,913	9.2%	1,086,400	31,746
03/30	580	104,643		103,557	1,796	9.1%	1,137,561	19,730
03/31	569	50,853		51,176	0	9.2%	558,456	0
04/01	553	50,864		51,187	0	9.3%	553,269	0
04/02	549	56,340		56,698	0	9.3%	611,384	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2004 (cont'd.).

Date	Flow (cfs)	Nightly Catch Actual	Nightly Catch Estimate	Estimated Daily Catch Wild	Estimated Daily Catch Hatchery	Trap Efficiency	Daily Migration Wild	Daily Migration Hatchery
04/03	546			66,207	0	9.3%	712,655	0
04/04	540	75,152		75,716	0	9.3%	812,129	0
04/05	539	58,664		59,104	0	9.3%	633,575	0
04/06	531	43,165		43,186	301	9.4%	460,764	3,216
04/07	531	55,707		55,862	228	9.4%	596,016	2,431
04/08	530	51,270		51,655	0	9.4%	550,805	0
04/09	523	46,557		46,906	0	9.4%	498,123	0
04/10	523			43,495	0	9.4%	461,900	0
04/11	520	39,784		40,083	0	9.4%	424,922	0
04/12	517	23,471		23,663	0	9.4%	250,415	0
04/13	515	16,548	6,666	23,404	0	9.5%	247,387	0
04/14	521	22,956		23,144	0	9.4%	245,494	0
04/15	499			20,116	0	9.5%	210,674	0
04/16	446	16,950		17,088	0	9.8%	173,667	0
04/17	426			16,885	0	9.9%	169,709	0
04/18	405	16,546		16,681	0	10.1%	165,737	0
04/19	371			13,004	0	10.3%	126,849	0
04/20	361	9,249		9,325	0	10.3%	90,477	0
04/21	351			9,027	0	10.4%	87,121	0
04/22	334	8,644		8,728	0	10.5%	83,483	0
04/23	316			8,311	0	10.6%	78,750	0
04/24	318			7,895	0	10.5%	74,886	0
04/25	314	7,407		7,479	0	10.6%	70,793	0
04/26	311			6,851	0	10.6%	64,747	0
04/27	308	6,163		6,223	0	8.6%	72,061	0
04/28	309			5,124	0	8.6%	59,335	0
04/29	298	3,990		4,023	0	8.6%	46,585	0
04/30	298			3,992	0	8.6%	46,226	0
05/01	302			3,961	0	8.6%	45,868	0
05/02	305	3,898		3,930	0	8.6%	45,509	0
05/03	298			4,244	0	8.6%	49,145	0
05/04	296	4,519		4,556	0	8.6%	52,757	0
05/05	294			4,189	0	8.6%	48,508	0
05/06	291	3,791		3,822	0	8.6%	44,258	0
05/07	292			3,715	0	8.6%	43,019	0
05/08	299			3,608	0	8.6%	41,780	0
05/09	295	3,473		3,501	0	8.6%	40,541	0
05/10	296			3,008	0	8.6%	34,832	0
05/11	310			2,516	0	8.6%	29,135	0
05/12	297			2,024	0	8.6%	23,437	0
05/13	294	1,520		1,532	0	8.6%	17,740	0
05/14	291			1,391	0	8.6%	16,107	0
05/15	293			1,250	0	8.6%	14,475	0
05/16	295	1,100		1,109	0	8.6%	12,842	0
05/17	292			958	0	8.6%	11,093	0
05/18	290			806	0	8.6%	9,333	0
05/19	290			654	0	8.6%	7,573	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2004 (cont'd.).

Date	Flow	Nightly Catch		Estimated Daily Catch		Trap	Daily Migration	
	(cfs)	Actual	Estimate	Wild	Hatchery	Efficiency	Wild	Hatchery
05/20	289	498		502	0	8.6%	5,813	0
05/21	281			608	0	8.6%	7,041	0
05/22	281			715	0	8.6%	8,280	0
05/23	282	815		822	0	8.6%	9,519	0
05/24	275			704	0	8.6%	8,152	0
05/25	276			586	0	8.6%	6,786	0
05/26	460	464		468	0	8.6%	5,419	0
05/27	688			420	0	8.6%	4,864	0
05/28	634			371	0	8.6%	4,296	0
05/29	935			322	0	8.6%	3,729	0
05/30	741	271		273	0	8.6%	3,161	0
05/31	575						4,156	
06/01	415						4,022	
06/02	333						3,888	
06/03	310						3,754	
06/04	300						3,620	
06/05	301						3,486	
06/06	327						3,352	
06/07	313						3,218	
06/08	310						3,083	
06/09	312						2,949	
06/10	364						2,815	
06/11	415						2,681	
06/12	413						2,547	
06/13	416						2,413	
06/14	413						2,279	
06/15	360						2,145	
06/16	322						2,011	
06/17	285						1,877	
06/18	282						1,743	
06/19	274						1,609	
06/20	273						1,475	
06/21	272						1,341	
06/22	274						1,207	
06/23	274						1,073	
06/24	279						938	
06/25	273						804	
06/26	266						670	
06/27	257						536	
06/28	253						402	
06/29	251						268	
06/30	253						134	
07/01	247						0	
Season Total		2,844,598	24,420	3,366,003	161,061		38,686,899	9,221,643

Appendix B: Estimated Chinook, Coho, and Cutthroat Daily Migrations, Cedar River 2004.

Appendix B. Estimated chinook, coho, and cutthroat daily migrations, Cedar River 2004.

Date	Flow (cfs)	Est. Chinook Catch		Chinook Migration	Coho Migration	Cutthroat Migration
		Scoop	Screw			
01/18	637	1		11		
01/19	632	3		34		
01/20	607	4		45		
01/21	587	3		33		
01/22	593	1		11		
01/23	673	13		151		
01/24	886	25		337		
01/25	752	22		270		
01/26	795	18		227		
01/27	1,120	30		489		
01/28	1,230	41		741		
01/29	1,820	99		2,327		
01/30	2,039	156		3,667		
01/31	1,620	139		3,268		
02/01	1,590	122		2,868		
02/02	1,570	72		1,693		
02/03	1,630	74		1,740		
02/04	1,490	76		1,787		
02/05	1,360	49		1,017		
02/06	1,330	21		421		
02/07	1,310	36		707		
02/08	1,290	51		980		
02/09	1,270	35		659		
02/10	1,200	59		1,036		
02/11	986	55		800		
02/12	807	51		649		
02/13	731	35		423		
02/14	741	18		219		
02/15	726	34		410		
02/16	709	50		596		
02/17	678	32		374		
02/18	657	18		207		
02/19	648	18		206		
02/20	647	31		355		
02/21	626	44		497		
02/22	609	51		570		
02/23	594	58		643		
02/24	592	75		830		
02/25	587	65		717		
02/26	594	36		399		
02/27	620	15		169		
02/28	608	14		156		
02/29	598	136		1,510		
03/01	687	258		3,030		
03/02	946	319		4,498		
03/03	953	53		751		
03/04	943	36		506		
03/05	1,040	141		2,144		

Appendix B. Estimated chinook, coho, and cutthroat daily migrations, Cedar River 2004 (cont'd.).

Date	Flow (cfs)	Est. Chinook Catch Scoop	Est. Chinook Catch Screw	Chinook Migration	Coho Migration	Cutthroat Migration
03/06	1,070	116		1,809		
03/07	1,100	91		1,457		
03/08	1,019	87		1,300		
03/09	856	121		1,595		
03/10	714	93		1,111		
03/11	617	41		461		
03/12	587	81		894		
03/13	581	61		670		
03/14	579	40		439		
03/15	569	60		655		
03/16	564	11		120		
03/17	566	45		490		
03/18	584	70		771		
03/19	578	209		2,293		
03/20	552	109		1,177		
03/21	555	9		97		
03/22	560	8		87		
03/23	551	17		184		
03/24	577	43		471		
03/25	598	46		511		
03/26	618	7		79		
03/27	600	48		534		
03/28	576	89		975		
03/29	567	3		33		
03/30	580	18		198		
03/31	569	27		295		
04/01	553	36		389		
04/02	549	33		356		
04/03	546	23		248		
04/04	540	12		129		
04/05	539	12		129		
04/06	531	8		85		
04/07	531	4		43		
04/08	530	10		107		
04/09	523	10		106		
04/10	523	9		96		
04/11	520	8		85		
04/12	517	2		21		
04/13	515	7		74		
04/14	521	11	8	66	552	40
04/15	499	8	7	57	264	160
04/16	446	4	6	49	480	80
04/17	426	4	10	82	504	0
04/18	405	3	28	230	456	80
04/19	371	3	12	98	312	40
04/20	361	2	8	66	432	0

Appendix B. Estimated chinook, coho, and cutthroat daily migrations, Cedar River 2004 (cont'd.).

Date	Flow (cfs)	Est. Chinook Catch Scoop	Est. Chinook Catch Screw	Chinook Migration	Coho Migration	Cutthroat Migration
04/21	351	2	54	443	1,392	80
04/22	334	1	8	66	768	0
04/23	316	1	30	246	816	0
04/24	318	1	45	369	1,584	40
04/25	314	1	18	148	1,224	40
04/26	311	1	14	115	1,896	0
04/27	308	0	17	140	1,440	0
04/28	309	0	19	156	1,008	0
04/29	298	0	6	49	744	0
04/30	298	0	18	148	1,200	80
05/01	302	0	8	66	1,320	0
05/02	305	0	32	263	1,752	0
05/03	298	1	15	123	792	0
05/04	296	1	68	558	3,000	40
05/05	294	1	82	673	2,016	0
05/06	291	0	99	812	2,064	0
05/07	292	0	97	796	1,584	120
05/08	299	0	211	1,731	2,616	0
05/09	295	0	83	681	1,872	40
05/10	296	0	72	591	408	0
05/11	310	0	152	1,247	2,424	0
05/12	297	0	268	2,199	5,688	120
05/13	294	0	136	1,116	3,648	80
05/14	291	0	98	804	2,448	120
05/15	293	0	95	780	888	0
05/16	295	0	273	2,240	1,824	0
05/17	292	0	137	1,124	1,152	80
05/18	290	0	28	230	696	0
05/19	290	0	99	812	672	0
05/20	289	0	241	1,978	936	200
05/21	281	0	199	1,633	696	0
05/22	281	0	234	1,920	744	0
05/23	282	0	244	2,002	720	40
05/24	275	0	131	1,075	504	0
05/25	276	8	60	492	240	0
05/26	460	16	409	3,356	1,176	0
05/27	688	19	153	1,256	1,248	0
05/28	634	22	320	2,626	936	40
05/29	935	25	207	1,699	936	40
05/30	741	8	112	919	600	80
05/31	575		177	1,452	504	80
06/01	415		56	460	120	80
06/02	333		51	419	144	80
06/03	310		31	254	168	0
06/04	300		29	238	96	0
06/05	301		76	624	288	40
06/06	327		131	1075	240	120

Appendix B. Estimated chinook, coho, and cutthroat daily migrations, Cedar River 2004 (cont'd.).

Date	Flow (cfs)	Est. Chinook Catch Scoop	Est. Chinook Catch Screw	Chinook Migration	Coho Migration	Cutthroat Migration
06/07	313		161	1,321	216	40
06/08	310		36	295	216	80
06/09	312		68	558	120	40
06/10	364		206	1,690	360	0
06/11	415		243	1,994	840	0
06/12	413		31	254	96	0
06/13	416		106	870	336	160
06/14	413		48	394	216	0
06/15	360		79	648	168	40
06/16	322		14	115	72	40
06/17	285		12	98	24	0
06/18	282		18	148	72	0
06/19	274		37	304	120	0
06/20	273		48	394	216	40
06/21	272		38	312	144	0
06/22	274		26	213	96	0
06/23	274		56	460	96	0
06/24	279		78	640	96	0
06/25	273		47	386	72	0
06/26	266		16	131	48	40
06/27	257		11	90	96	40
06/28	253		16	131	144	0
06/29	251		12	98	144	0
06/30	253		7	57	168	40
07/01	247		8	66	72	80
07/02	227		6	49	96	40
07/03	231		5	41	120	0
07/04	239		7	57	0	80
07/05	231		7	57	120	120
07/06	229		5	41	96	40
07/07	231		8	66	48	120
07/08	228		6	49	48	40
07/09	192		3	25	48	40
07/10	182		8	66	72	80
07/11	202		4	33	24	80
07/12	179		2	16	48	80
07/13	175		4	33	72	40
07/14	161		1	8	24	40
07/15	151		2	16	24	0
07/16	148		2	16	24	0
07/17	147		2	16	24	0
07/18	147		1	8	0	0
07/19	147		1	8	0	0
07/20	147		0	0	24	0
Season Totals		4,660	6,718	120,876	70,044	3,480

Appendix C: Estimated Sockeye, Chinook, Coho, and Cutthroat Daily Migrations, Bear Creek 2004.

Appendix C. Estimated sockeye, chinook, coho, and cutthroat migrations, Bear Creek 2004.

Date	Flow (cfs)	Sockeye	Chinook	Coho	Cutthroat
FRY TRAP					
02/05	177	466	27		
02/06	161	454	18		
02/07	154	442	9		
02/08	144	430	27		
02/09	131	428	27		
02/10	115	416	45		
02/11	104	393	62		
02/12	95	351	36		
02/13	89	303	9		
02/14	91	872	18		
02/15	91	1,435	27		
02/16	103	1,538	27		
02/17	122	1,640	27		
02/18	116	1,677	27		
02/19	107	1,713	18		
02/20	98	1,749	54		
02/21	89	1,459	27		
02/22	83	1,168	0		
02/23	77	1,544	0		
02/24	73	1,919	0		
02/25	70	2,294	0		
02/26	71	2,577	0		
02/27	96	2,576	0		
02/28	129	2,859	0		
02/29	126	3,426	0		
03/01	107	3,717	18		
03/02	93	4,007	27		
03/03	102	3,697	27		
03/04	123	3,387	18		
03/05	118	3,078	9		
03/06	111	2,768	0		
03/07	105	2,458	0		
03/08	94	5,170	18		
03/09	94	7,875	27		
03/10	90	6,788	36		
03/11	82	5,700	45		
03/12	76	4,613	54		
03/13	70	5,733	45		
03/14	66	6,852	27		
03/15	64	4,134	18		
03/16	61	1,416	0		
03/17	59	1,368	9		
03/18	58	1,320	9		
03/19	56	1,606	9		
03/20	53	1,893	9		

Appendix C. Estimated sockeye, chinook, coho, and cutthroat migrations, Bear Creek 2004 (cont'd.).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Cutthroat
FRY TRAP					
03/21	51	2,179	0		
03/22	51	8,378	9		
03/23	50	14,577	9		
03/24	57	10,265	18		
03/25	62	5,952	27		
03/26	68	1,640	27		
03/27	68	3,475	152		
03/28	65	5,303	277		
03/29	57	3,354	161		
03/30	54	1,398	45		
03/31	58	1,465	80		
04/01	55	1,532	116		
04/02	51	1,598	152		
04/03	49	1,295	89		
04/04	47	987	27		
SCREW TRAP					
04/05	45	893	8	2	31
04/06	44	601	2	5	31
04/07	43	404	0	7	23
04/08	42	272	0	5	8
04/09	41	183	0	19	59
04/10	40	123	0	30	105
04/11	36	83	2	37	199
04/12	33	56	8	116	121
04/13	33	37	0	130	121
04/14	37	25	8	266	187
04/15	39	17	16	199	105
04/16	39		8	389	70
04/17	36		55	467	59
04/18	35		37	90	70
04/19	34		33	90	82
04/20	37		41	338	70
04/21	35		63	347	117
04/22	34		26	636	70
04/23	34		53	336	70
04/24	35		85	377	59
04/25	32		71	678	94
04/26	31		61	1,370	191
04/27	31		73	743	101
04/28	32		152	521	98
04/29	31		638	2,437	187
04/30	40		372	1,726	265
05/01	37		79	537	31
05/02	31		89	528	16

Appendix C. Estimated sockeye, chinook, coho, and cutthroat migrations, Bear Creek 2004 (cont'd.).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Cutthroat
SCREW TRAP					
05/03	28		87	296	12
05/04	26		195	396	20
05/05	28		506	1,171	74
05/06	27		1,323	916	191
05/07	34		1,941	1,247	172
05/08	34		1,498	713	242
05/09	34		866	639	152
05/10	31		465	187	39
05/11	36		547	555	31
05/12	32		451	185	20
05/13	29		461	155	12
05/14	28		382	118	4
05/15	28		317	137	16
05/16	28		669	164	39
05/17	27		842	150	31
05/18	27		618	74	20
05/19	26		496	67	27
05/20	25		587	46	23
05/21	26		600	35	43
05/22	30		1,392	95	94
05/23	29		435	58	27
05/24	26		234	23	27
05/25	25		289	23	4
05/26	32		461	60	35
05/27	50		1,870	72	148
05/28	83		323	53	55
05/29	82		26	35	43
05/30	66		122	58	27
05/31	63		91	74	27
06/01	48		134	53	23
06/02	41		150	65	16
06/03	35		94	69	12
06/04	30		157	30	16
06/05	29		75	14	8
06/06	32		224	116	43
06/07	39		79	25	8
06/08	32		114	56	43
06/09	35		65	37	8
06/10	31		22	32	8
06/11	30		37	16	0
06/12	30		33	35	0
06/13	34		126	79	20
06/14	38		63	44	8
06/15	37		35	49	0
06/16	31		22	37	0

Appendix C. Estimated sockeye, chinook, coho, and cutthroat migrations, Bear Creek 2004 (cont'd).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Cutthroat
SCREW TRAP					
06/17	29		20	44	12
06/18	28		18	19	12
06/19	26		4	12	0
06/20	24		8	16	4
06/21	23		6	0	0
06/22	22		6	5	4
06/23	21		0	0	0
06/24	22		0	2	0
06/25	22		0	2	0
06/26	21		2	0	0
Season Total		177,801	23,647	21,085	4,540