Evaluation of Downstream Migrant Salmon Production in 2001 from the Cedar River and Bear Creek

Dave Seiler
Greg Volkhardt
Lindsey Fleischer

Washington Department of Fish and Wildlife
Olympia, Washington 98501-10191

June 2004

Supported by:
King County Wastewater Treatment Division
City of Seattle Public Utilities

Acknowledgements

The evaluations of downstream migrant salmon production in the Cedar River and Bear Creek in 2001 were made possible with funding from the King County Wastewater Treatment Division. In addition, the City of Seattle Public Utilities funded the evaluation of Cedar River sockeye fry production. The success of these projects relied on the hard work of a number of dedicated permanent and temporary WDFW personnel. The Hatcheries Program successfully collected adult sockeye broodstock and incubated eggs, releasing over 17.1 million sockeye fry in the Cedar River. Eric Volk and Gene Sanborn designed and implemented the otolith-marking program at Landsburg Hatchery. Volk and his staff at the Otolith Lab extracted and analyzed sockeye otoliths from the fry sampled at the Cedar River fry trap. Escapement data were collected and estimates were developed by Region 4 biologist Steve Foley and staff. Scientific Technicians Paul Lorenz, Dan Estelle, Tim Eichler, and Lindsey Fleischer worked long hours, usually at night, operating the traps, marking, identifying and counting fish. Biologists Mike Ackley and Pete Topping provided valuable experience and logistical support.

We also appreciate and acknowledge the contributions of the following companies and agencies to these studies:

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.

Table of Contents

List of Tables

List of Figures

Executive Summary

This report provides the results of monitoring five salmonid species as downstream migrants in 2001 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 2001, 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 other smolt populations: coho, steelhead and cutthroat.

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.

The 2001 trapping season was notable for two unusual events. The interval from Fall 2000 through March of 2001 has become known as the "winter without rain". Flows throughout this period were anomalously low as a result. The second anomaly, an earthquake measuring 6.8 on the Richter scale occurred on the morning of February 28. This quake, which was centered in the lower Nisqually Basin, was strong enough to trigger a landslide that temporarily blocked the Cedar River at River Mile 8.

Cedar River

Declining adult sockeye salmon returns in the late 1980's and early 1990's prompted the creation of a multi-agency effort to investigate causes for this decline. To determine which life-stages of sockeye 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 2001, the tenth year of this project. As in previous years, the primary study goal was to estimate the season total migration of Cedar River wild and hatchery sockeye fry into Lake Washington. These estimates enable calculation of survival rates from egg deposition to lake entry, for hatchery fry from release to the trap, and for both production components from lake entry to subsequent life stages of smolts and adults.

Beginning in January and continuing into June, a floating inclined-plane screen 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 69 nights, dye-marked fry were released upstream of the trap. At base flows, 350 to 400 cfs, capture rates averaged 10%. At the highest flows (800 cfs) the capture rate averaged 4.6%. Stream flows were anomalously low and steady through most of the season, and capture rate varied little compared to previous seasons.

Over the season, 17.2 million hatchery sockeye fry were released into the Cedar River from three locations. All hatchery fry were internally marked by slightly manipulating water temperatures in the hatchery. On most nights of and following hatchery releases, fry caught in the trap were randomly sampled for thermal marks to determine the proportion of hatchery fish present.

Over the 115 nights trapped, 4.0 million sockeye fry were captured. From this catch and the capture efficiency data, we estimated a total of 52.0 million wild and hatchery sockeye fry entered Lake Washington in 2001. Based on otolith analysis and the hatchery release figures, we estimated that this total included 38.5 million wild fry and 13.5 million hatchery produced fry. Average survival to the trap of the 8.4 million hatchery fry released upstream was estimated at 56.5%. Survival was a function of migration distance. Survival of fry released at the Landsburg Hatchery, located 21 miles upstream, averaged 26.3%. Fry released at the Riviera site, located 1.5 miles above the trap survived at an average rate of 75.3%, nearly three times higher. We attribute this difference to the low flows throughout the season, which enabled high predation rates.

Migration timing for wild fry was earlier than in any of the previous nine years. This timing was also 23 days earlier than that predicted by the relationship between timing and February temperature units developed over the previous nine brood years. We attribute this discrepancy to two factors; higher predation rates later in the season as a result of the low flows, and mortality resulting from the 6.8 magnitude earthquake on February 28. This quake triggered a river-blocking landslide at R.M. 8. When flow was restored a short time later, a large quantity of mud was transported down the river, which likely smothered eggs and alevins in the lower river.

Survival from egg deposition to lake entry of wild fry was estimated at 11.3%. This rate is the ratio of 38.5 million wild fry to an estimated deposition of 339 million eggs. Survival of the 2000 brood was the third highest measured thus far, but less than we expected given the low and steady incubation flows. With the peak incubation flow of just 627 cfs, the relationship between peak incubation flow and egg to migrant survival developed over the previous nine broods predicted a survival of 13%. As with migration timing, we attribute the lower survival of eggs and fry to a combination of high predation rates resulting from the anomalously low flows throughout the migration and mortality caused by the earthquake-triggered landslide.

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

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

Age 0+ chinook production from the Cedar River was estimated at 32,249 in 2001. Timing was bi-modal with smolts emigrating in May and June comprising two thirds (21,400) of the total migration. The fry migration, from January through March, was estimated at 10,800. Egg-to-migrant survival was estimated at 13.5%. We believe that the low flows during the 2001 season allowed a higher than normal proportion of fry to remain in the river longer and grow to smolts before migrating downstream. In comparison, fry have accounted for the majority of the migration in the two previous seasons. Over the season, age 0+ chinook increased in size from less than 40 mm in January to over 100 mm by July.

Over the season, based on actual and projected catches and estimates of capture rates we estimated the migrations of coho, steelhead and cutthroat smolts at 82,462, 1,860 and 2,680, respectively.

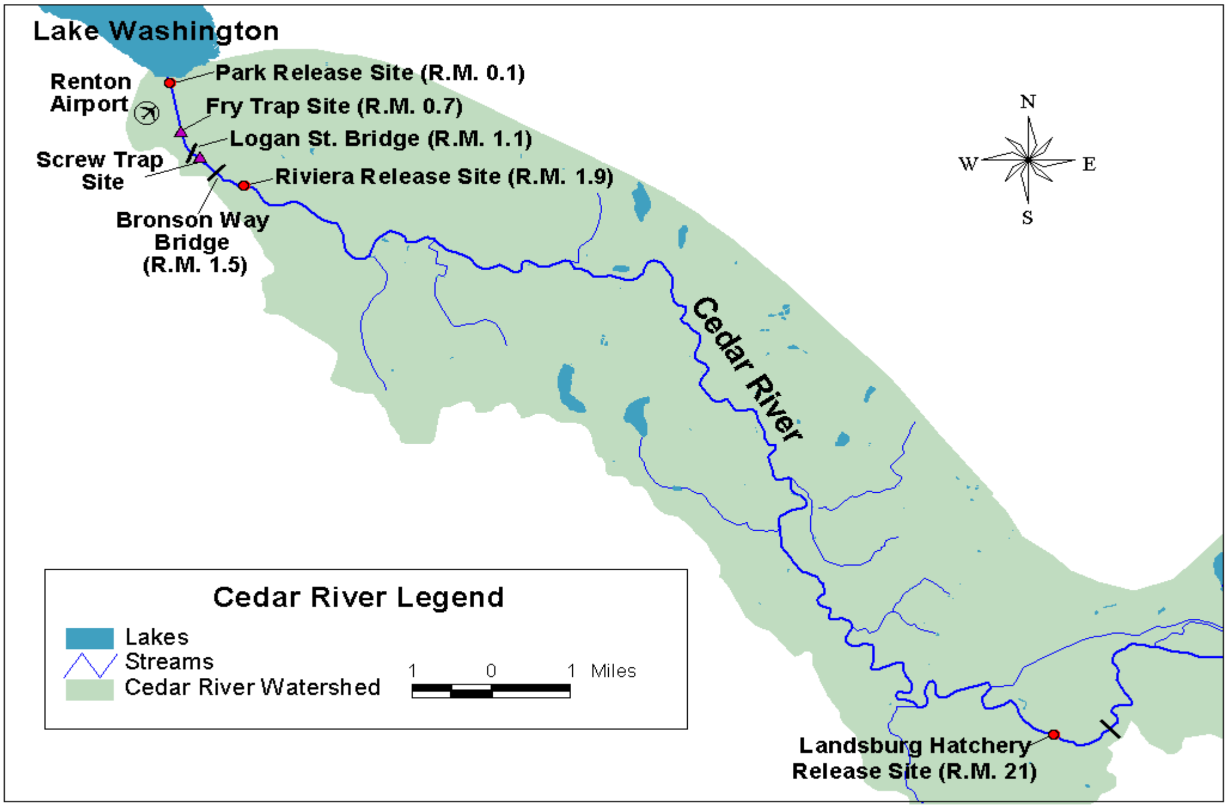

Figure 1. Site map of the lower Cedar River watershed depicting the fry and screw trap locations, hatchery sockeye release sites, and trap efficiency test release sites for the 2001 trapping season.

Bear Creek

We installed a scoop trap on Big Bear Creek 100 yards downstream of the Redmond Way Bridge and operated it from January 27 through April 9. On April 10, we replaced it with a screw trap that fished until July 12. 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.

Applying the average scoop and screw trap capture rates of 15% and 21% to respective catches estimated sockeye production at 2.2 million fry.

Production of age 0+ chinook was estimated at 10,588. Migration timing was bi-modal, however most chinook migrated as smolts in May and June.

For the season, we estimated the production of coho, wild steelhead and cutthroat smolts at 21,665, 139 and 2,869, respectively.

Introduction

Adult sockeye salmon returns to the Lake Washington system have declined from peak runs in excess of 600,000 fish as recently as 1988, to under 100,000 fish in subsequent years. In 1991, a broad-based group comprised of representatives of local governments, the Muckleshoot Indian Tribe, state and federal fisheries agencies, academic institutions, and concerned citizens was formed to address this decline. Resource managers developed a program to investigate the cause(s) of the sockeye decline through research and population monitoring in combination with an artificial production program. Information generated by these efforts will be used to devise a restoration plan for 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. Habitat and environmental conditions during each of these phases affects survival of the brood. Existing management information indicated that marine survival had averaged 11.4%, varying eight-fold (2.6% to 21.4%), for the 1967 to 1993 broods with no apparent decline over the data set (WDFW unpublished data). In contrast, however, survival during the freshwater phase declined during this period. For the 1985 through 1993 broods, freshwater survival (as indicated by the estimated numbers of pre-smolts produced per spawner) has averaged only 6.9. This rate is less than half of the average production rate of 14.1 pre-smolts per spawner for the previous 18 broods (1967 to 1984) (WDFW unpublished data).

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

The Puget Sound Chinook Evolutionary Significant Unit (ESU) was listed under the Endangered Species Act as a threatened species in March 1999 by the National Marine Fisheries Service. The ESU includes 22 populations of chinook salmon, two of which are located in the Lake Washington basin. The North Lake Washington population includes tributaries to the Sammamish River, including Bear and Issaquah Creeks. In addition to wild chinook production, the Issaquah Hatchery releases approximately 2 million fingerling fall chinook each year. A second population of chinook salmon has been identified in the Cedar River, a tributary to the southern end of Lake Washington. Analysis of genetic data have shown that the Cedar River chinook population is genetically divergent from the North Lake Washington population, and that chinook salmon sampled from Bear and Issaquah Creeks are genetically similar (Marshall 2000).

Anticipating the listing, land, water, and fish managers in city, county, state, tribal, and federal government agencies began discussing and planning appropriate responses. In the Lake Washington watershed, it was evident that these planning efforts would be more effective if more were known about the habitat requirements, early life history, freshwater productivity, and survival of chinook salmon. Baseline information was available on the number of spawners, but adult counts provide little insight into survival during specific life stages. Estimating the number of juvenile migrants facilitates separating survival into two components: egg-to-migrant (freshwater) and migrant-to-returning adult. In the lake Washington system, this later stage also includes passage through the lake, Ship Canal, Locks as well as the marine environment. This provides a more direct accounting of the role that stream habitats play in regulating salmon production (Seiler *et al.* 1981, Cramer *et al.* 1999).

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

Cedar River

Since 1992, we have operated a downstream migrant scoop trap in the lower Cedar River to evaluate the production of wild and hatchery sockeye fry (Seiler *et al.* 2002). Production of sockeye fry at the Landsburg Hatchery on the Cedar River began with the 1991 brood. This brood, released in 1992, and all subsequent sockeye incubated at this hatchery, has been identified with thermally-induced otolith-marks (Volk *et al.* 1990). During the first three years of this evaluation, we determined that survival of hatchery fry from Landsburg to the trap was very low, often less than 10% (Seiler 1994, 1995). In these three seasons, however, flows during most upriver releases were at or near minimum levels. To avoid this high in-river mortality, beginning in the second year (1993), the majority of the hatchery production was transported and released in the lower river just upstream of Highway I-405. In 1995, we evaluated the effect of flow on survival using ten groups released over a range of flows. Results corroborated the earlier estimates, demonstrating that in-river fry survival is largely a function of flow (Seiler and Kishimoto 1996).

Over the first nine brood years of this evaluation (1991 to 1999), we have also determined that the survival from egg deposition to fry emigration is largely a function of the severity of peak flows in the Cedar River during the egg incubation period (Seiler *et al.* 2001). Therefore, over the range of spawning population levels we have thus far evaluated, the numbers of naturally produced sockeye fry entering Lake Washington are the product of the number of eggs deposited and the flow-effected survival rate. In fall 2000, WDFW biologists estimated that 148,000 adult sockeye spawned in the Cedar River.

Our ability to capture fry and make a precise estimate of migration is predicated on selection of trapping sites with optimal flow characteristics for trapping. Sites are required to direct a relatively high percentage of downstream migrants into the trap and to have sufficient velocity so that targeted species are captured without bias to size or swimming ability. The importance of velocity to unbiased capture is illustrated by the 1998 fry trap results. As a result of extensive sediment deposition in the lower Cedar River, the streambed in the 1998 season was substantially aggrading. This resulted in sizable bed elevation increases compared to observations from the previous six seasons. The resulting difference in bed elevations between the lower river channel and the lake created sufficient stream energy to cut a distinct channel, which at low discharge, confined flow. The resulting velocities were high enough in the trap even at minimum flows to capture large chinook smolts. This was also evident by the high numbers of coho smolts (which are larger than chinook smolts) that we captured relative to catches in all other years. In 1998, we caught 646 coho smolts, compared to an average catch for the previous seasons of just 92 coho smolts (WDFW unpublished data).

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 (RM 0.25). Given this dramatic change in the channel, it was clear that capturing an unbiased sample of migrants over the entire flow range would require a different trap location in 1999 and 2000. In addition, the scope of our trapping program was expanded in 1999 to also evaluate the production of juvenile chinook (Seiler *et al.* 2003). To effectively capture larger chinook, in addition to the fry trap we elected to deploy and operate a different gear type (a screw trap) in faster water. Concurrent operation of the fry and screw traps in 1999 and 2001 assessed the capture and size bias of the traps. Determining the effectiveness of the fry trap also assessed the potential to estimate chinook migrants over the previous years from fry trap catch data.

In 2001, both the fry and screw traps were used to capture chinook migrants. The fry trap operated from late-January through early-June and the screw trap operated from mid-April through late-July. This trapping project estimated the numbers of 2000 brood Cedar River wild and hatchery-produced sockeye fry, wild chinook, coho smolts, steelhead smolts and downstream migrant cutthroat trout that entered Lake Washington during 2001.

Bear Creek

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

With estimated sockeye escapements of over 50,000 adults in some years, Bear Creek is the most heavily spawned tributary in the Sammamish watershed. Approximately 90% of the Sammamish Basin sockeye spawners utilizing tributaries below Lake Sammamish are thought to spawn in Bear Creek (Steve Foley WDFW, pers. comm.). Therefore, we elected to move the downstream migrant trapping operation in 1999 to the lower end of this stream where velocities were adequate. Trapping in the Sammamish Slough had demonstrated that sockeye fry produced from its tributaries migrate downstream to Lake Washington. Prior to conducting this work, it had been theorized that sockeye fry emigrating from Bear Creek may migrate up the Slough to rear in Lake Sammamish. With this question answered, estimating the numbers of sockeye fry emigrating from Bear Creek would account for the majority of sockeye fry produced in the Sammamish Basin that recruit to Lake Washington. The numbers of fry entering Lake Sammamish from its tributaries, primarily Issaquah Creek, presumably rear to smolts in Lake Sammamish.

To estimate production from the entire Sammamish system below the lake, the numbers of sockeye fry and age 0+ chinook emigrating from Bear Creek can be expanded on the basis if the proportion of system spawners using Bear Creek. In addition to estimating chinook and sockeye production, operating the trap in high enough velocity to capture coho, steelhead and cutthroat smolts enabled estimating their production from Bear Creek as well.

Bear Creek, along with most other tributaries in the Sammamish and Lake Washington basins, has been planted with hatchery produced coho fry for many years. In May of 1998, 166,000 coho fry from Issaquah Hatchery were stocked throughout the Bear Creek system. In addition to the coho release, a remote-site incubation project on a tributary to Evans Creek incubated 20,000 coho eggs in both 1998 and 1999. Steelhead parr from two broods were also stocked into Bear Creek. These fish were the offspring of a small number of wild steelhead captured at the Ballard Locks during the spring of 1997 and 1998 and incubated and reared at Issaquah hatchery. On October 15, 1997 a total of 13,464 steelhead fry were scatter planted throughout the Bear Creek system. A similar number of steelhead fry (13,000) were stocked into Bear Creek on September 24, 1998. In September 1999, 6,650 steelhead fry were released into Bear Creek. Prior to release, all of these groups were identified with the removal of the adipose fin.

Goals and Objectives

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

Chinook

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

Sockeye

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

Coho, Steelhead, and Cutthroat

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

Methods

Trapping Gear and Operation

Cedar River

Fry (Scoop) Trap

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

Trap operation began on January 18 and fishing occurred on five nights until January 26. From this date through April 30 the trap was fished every night. After April 30, fishing occurred on 15 nights until fry trapping ceased for the season the morning of June 4. On nearly every date the trap was operated, we began trapping before dusk and continued past dawn. Trapping also occurred during daylight hours over 12 dates.

Captured fish were removed from the trap and counted each hour. Large sockeye fry catches were counted using an electronic counter. Calibration of the electronic counter in previous seasons determined that it counted 96.6% of the actual number of fish passing through it.

Over the season, 17,149,000 hatchery-produced fry were released into the Cedar River (Table 1). Fifty-one percent of this production (8,788,000) was released below the trap at the Cedar River Trail, 19% (3,210,000) was released directly from the hatchery at Landsburg, and 30% (5,151,000) was transported to the lower river and released at the Riviera Apartments site. Releases at Landsburg occurred on 11 nights, from January 22 to March 21. Fry were released at the Riviera site on ten nights, between February 14 and March 23. Releases below the trap occurred on 20 nights, between January 30 and April 5. The group sizes released above the trap ranged from 61,000 to 665,000 fry, and those released below the trap ranged from 39,000 to 672,000 fry. Hatchery fry were identified by five otolith codes: early, middle, and late releases from Landsburg; and early and late releases from Riviera.

To estimate wild and hatchery sockeye fry, samples were collected for otolith analysis. As otolith-marks are internal, their detection requires lethal sampling of the fry. A systematic random sample of sockeye fry was collected from the catch on 19 nights over the season. Samples of fry were collected on ten of the eleven nights that fry were released from Landsburg. The one exception occurred on February 28, the night following the earthquake. Fry were also sampled on nine of the nights following the releases from Riviera. To insure that the samples were not biased by differences in migration timing between wild and hatchery fry, we retained a constant proportion of each hour's catch over the entire night. Each morning, we gently stirred the retention tank to thoroughly mix the fry, and then we collected 155 fry that we placed in a labeled jar of alcohol.

Table 1. Hatchery-produced sockeye fry released at three locations, Cedar River 2001.

Release		Number Released By Site			
Timing	Date	Landsburg	Riviera	Below Trap	Total
	01/22	79,000			79,000
	01/29	193,000			193,000
	01/30			367,000	367,000
	02/01			535,000	535,000
	02/05	380,000		288,000	668,000
	02/06			654,000	654,000
Early	02/07	307,000			307,000
	02/08			550,000	550,000
	02/12			559,000	559,000
	02/14		560,000		560,000
	02/15	61,000	293,000		354,000
	02/16		615,000		615,000
	02/21		638,000		638,000
	02/22	213,000		388,000	601,000
	02/23		309,000	322,000	631,000
	02/24	64,000		396,000	460,000
Middle	02/26	361,000		282,000	643,000
	02/27			640,000	640,000
	02/28	273,000		294,000	567,000
	03/01			532,000	532,000
	03/05			414,000	414,000
	03/06		553,000		553,000
	03/07		598,000		598,000
	03/08		653,000		653,000
	03/09		648,000		648,000
	03/10	614,000			614,000
Late	03/13			637,000	637,000
	03/15			672,000	672,000
	03/21	665,000			665,000
	03/22			582,000	582,000
	03/23		284,000	280,000	564,000
	03/28			357,000	357,000
	04/05			39,000	39,000
	Total	3,210,000	5,151,000	8,788,000	17,149,000

Screw Trap

We used a 5 ft in diameter screw trap supported from a 15ft wide by 30 ft long steel pontoon barge (Seiler *et al.* 2003). As in the previous two seasons, we positioned this trap at RM 1.0, just upstream of the Logan Street Bridge near the right bank.

Screw trap operation began on the evening of April 8, and continued (except for brief periods for debris removal or repairs) through mid-May. The catches were enumerated at dusk and in the early morning in order to discern diel movements. In May, we began to lift the trap during the daylight hours to avoid any potential hazard to recreational floaters using the river. By design, this trap allowed sockeye fry to escape from the live-box. All chinook, coho, steelhead, and cutthroat smolts were enumerated by species and randomly sampled for size (fork length).

Bear Creek

Fry Trap

As in the Cedar River, we started the season trapping in Bear Creek with an identical low-angle inclined-plane screen trap (3 ft wide by 9 ft long). This gear was suspended from a 30x15 ft steel pontoon barge positioned approximately 100 yards downstream of Redmond Way, below the railroad trestle in the middle of the channel. Trapping began on January 27 and we fished every other night until February 26. From February 27 until April 9 we fished each night. On nearly every date the trap was operated, we began trapping before dusk and continued past dawn. On several dates we also operated the trap during daylight hours. Captured fish were removed from the trap and counted at various intervals from hourly to several hours depending on migration rates.

Screw Trap

On the morning of April 9, we removed the fry trap and replaced it with a 5 ft diameter screw trap. Screw trap operation began on the evening of April 9, and continued through mid-July. Catches were usually enumerated at dusk and in the early morning. All chinook, coho, steelhead, and cutthroat smolts were enumerated by species and randomly sampled for size (fork length).

Trap Efficiency

Cedar River

Fry Trap

We estimated the capture rate for sockeye fry in the Cedar River fry trap by releasing marked sockeye fry at the Logan Street Bridge over a number of nights throughout the season. On most such nights we released 3,000 sockeye fry. Fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). The bridge is approximately one-half mile upstream from the trap, and was selected as a compromise between the opposing needs of releasing fish close enough to minimize predation loss and distant enough to ensure natural distribution. Marked fry were usually equally distributed between left bank, mid-channel, and right bank release points from the bridge. When fewer fish were being released, the marked fry were released from the mid-channel point only or the left and right bank points. Pooled (left bank, mid-channel, and right bank) group recovery rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Screw Trap

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

Bear Creek

Fry Trap

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

Screw Trap

Capture efficiency for the screw trap was estimated for chinook and coho smolts on a number of days over the season. Groups of smolts of each species were anesthetized in a solution of MS-222 and marked with partial caudal fin clips. The smolts were marked in the morning, and allowed to recover from the anesthetic during the day. In the evening, the groups were released from the Redmond Way Bridge or 100 yards upstream of the trap. Recapture rates were correlated with mean daily discharge to assess the effect of flow on capture rate.

Production Estimation

Cedar River

Fry Trap

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

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

Data taken less frequently included:

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

Sockeye

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

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

where;

$$n = \textit{the number of sample nights used in the interpolation,}$$
$$\hat{C}_i = \textit{the preceeding and following nightly catch estimates, and}$$
$$\overline{C} = \textit{the interpolated nightly catch estimate.}$$

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

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

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) was (were) estimated by;

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

where;

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

The variance was estimated by;

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

where;

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

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

When trapping started past dusk or concluded before dawn, the actual nightly catch was expanded to estimate the catch for a complete night of fishing. The expanded nightly catch ($\hat{C}_i$) was estimated by dividing the actual catch (C_f) by the average proportion ($\overline{p}$) of catch from that same time interval two nights before and after the incomplete night. The variance for those nights was calculated using the delta method (Goodman 1960);

$$Var(\hat{C}_i) = \hat{C}_i^{\,2} \left(\frac{Var(C_f)}{C_f^{\,2}} + \frac{Var(\overline{p})}{\overline{p}^{\,2}} \right) - Var(C_f) \frac{Var(\overline{p})}{\overline{p}^{\,4}} \qquad \textbf{Equation 5}$$

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

$$\hat{p}_{hi} = \frac{m_{hi}}{o_i}$$ **Equation 6**

and its variance by;

Equation 7

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

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

$$H_{hi} = C_i \hat{p}_{hi}$$ **Equation 8**

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

$$Var(H_{hi}) = Var(C_i)\hat{p}_{hi}^{\;2} + C_i^{\;2} Var(\hat{p}_{hi}) - Var(\hat{p}_{hi}) Var(C_i)$$ **Equation 9**

The total number of hatchery fry caught on night *i* and the variance of the estimate were calculated by modifying Equations 8 and 9, respectively. The modifications involved substituting the proportion of hatchery fry from all groups in the nightly catch, $\hat{p}_i$, and the variance of this proportion, $Var(\hat{p}_i)$, for the proportion of hatchery fry from each release group, $\hat{p}_{hi}$, and its variance, $Var(\hat{p}_{hi})$, respectively.

Otolith sampling was used to estimate the composition of sockeye hatchery fry in catches during the nights of and following releases from the Landsburg site, and it was used for five nights when fish were released from the Riviera site. On the other nights, interpolation was used in lieu of otolith sampling to estimate nightly wild catch based on the wild catch estimates from the preceding and following nights. The estimate of nightly wild fry catch was then subtracted from the estimated total nightly catch to estimate the nightly hatchery fry catch.

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

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

In order to estimate total sockeye migration, daytime catches were estimated. Daytime catch was estimated using the average day catch rate to night catch rate ratio (Q_d) based on trap operations conducted in 2001. Daytime catch (C_d) was calculated by multiplying the nighttime catch estimate by the proportion (F_d) of the 24-hour catch caught during daylight. The proportion of the sockeye catch caught during daytime interval *d* was estimated by;

$$F_d = \frac{T_d}{\frac{1}{Q_d} T_n + T_d}$$ **Equation 10**

and its variance by;

$$Var(F_d) = \frac{V(Q_d)\, T_n^{\,2}\, T_d^{\,2}}{Q_d^{\,4} \left(\frac{1}{Q_d} T_n + T_d \right)^4}$$ **Equation 11**

where,

$$T_n = \text{hours of night during 24 hour period,}$$
$$T_d = \text{hours of day during 24 hour period, and}$$
$$Q_d = \text{average day/night catch ratio for day } d.$$

The variance for each daytime catch was estimated using the delta method (Goodman 1960) by;

$$Var(C_d) = C_i^{\,2}\, Var(F_d) + Var(C_i)\, F_d^{\,2} - Var(C_i) Var(F_d)$$ **Equation 12**

To assess the relationship between trap efficiency and stream flow over the season we arrayed these data in scatter plots. Where flow appeared to explain variation in trap efficiency, flow strata were developed and trap efficiency for each flow stratum was estimated by the mean of the trap efficiency tests conducted within these flow ranges. This approach was used in lieu of predicting trap efficiency using a regression model since the variances of the migration estimates made using regression models were found to be exceedingly high due to co-variation. Where flow was not found to be a significant predictor of trap efficiency, the mean over all the season's trap efficiency tests was used;

$$\bar{e} = \frac{\sum_{i=1}^{n} \hat{e}_i}{n}$$ **Equation 13**

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

$$Var(\hat{e}_i) = \frac{\hat{e}_i (1 - \hat{e}_i)}{n}$$ **Equation 14**

$$Var(\bar{e}) = \frac{\sum (\hat{e}_i - \bar{e}_i)^2}{n(n-1)}$$ **Equation 15**

Daily sockeye fry migrations were estimated by;

$$N = \frac{(C_i + C_d)}{\bar{e}} \qquad \textbf{Equation 16}$$

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

$$Var(N) = N^2\left(\frac{Var(\bar{e})}{\bar{e}^2} + \frac{\left(Var(C_i) + Var(C_d)\right)}{(C_i + C_d)^2}\right) \qquad \textbf{Equation 17}$$

When multiple flow efficiency strata were used, the migration estimate and variance for the strata were estimated using Equations 16 and 17, substituting the total catch over the stratum for daily catches in both equations. Season total migration and variance were estimated by summing the migration and variance estimates for each flow strata. Where trap efficiency was calculated using a simple mean efficiency over the season, the total migration and its variance were calculated using Equations 16 and 17, substituting the season total catch for the daily catches in both equations.

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

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

These include:

Linear:		$y = ax + b$
Logarithmic:	1.	$y = a(\ln x) + b$
	2.	$\ln y = a(\ln x) + b$
Inverse:		$y = a/x + b$
Quadratic:		$y = a_1x + a_2x + b$
Exponential	1.	$y = ba^x$
	2.	$y = be^{ax}$
	3.	$y = ba^{\ln x}$
Power:		$y = bx^a$

Where *y* is egg-to-migrant survival, *x* is flow, and *a* and *b* are the slope and intercept parameters for the regression equations. The equation that resulted in the best fit with the data was found by comparing the coefficients of determination (r^2) for each.

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;

$$Var(\hat{C}_i) = T_u^{\,2} \frac{\sum(\hat{R}_i - \overline{R}_i)^2}{n(n-1)}$$ **Equation 18**

Wild chinook fry catch during daytime intervals not fished were estimated in order to estimate total daily (24-hour) migrations. The estimates were made by using the average day catch rate to night catch rate ratio based from trap operations conducted in 2001. The catch during daytime *d* was estimated by;

$$C_d = \overline{Q}\, \overline{R}_i\, T_d$$ **Equation 19**

and its variance was estimated by;

$$Var(C_d) = T_d^{\,2}\left(Var(\overline{R}_i)\ \overline{Q}^{\,2} + Var(\overline{Q})\ R_i^{\,2}\right)$$ **Equation 20**

where,

$\overline{Q}$ = *average chinook day/night catch ratio measured for scoop trap,*
$\overline{R}_i$ = *average night catch rate preceding and following daytime interval d, and*
T_d = *hours of estimated daytime interval d.*

Daily chinook fry migration was estimated by using Equation 16. The total season migration was estimated by summing the daily migration estimates. The chinook fry season migration variance was estimated using Equation 17 when the average trap efficiency was used to estimate total migration. Where multiple flow efficiency strata were used, the season migration variance was estimated by summing the migration variance estimates for each flow strata using Equation 17.

Screw Trap
For nighttime intervals not fished and during nights when heavy debris decreased the fishing ability of the trap we estimated catch for the hours missed by applying catch rates interpolated from the preceding and following nighttime intervals trapped. Variances for these estimates were calculated using Equation 18. Daytime intervals not fished were estimated with Equation 19, and its variance by Equation 20.

As with the fry trap, the effect of flow on measured capture rates was assessed using scatter plots. 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 14, and the mean trap efficiency using Equation 15. Equation 16 was used to estimate daily migration, and Equation 17 was used to estimate daily and total season variances of the migration estimates.

In addition to estimating migration during the interval of trap operation, since initial catches indicated that the coho smolt migration was underway, we approximated the migration occurring before screw trap operation began. Logarithmic extrapolation was used to estimate migration from March 15 to April 8. The variance was calculated by interpolating between the coefficients of variation.

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

Bear Creek

Fry Trap

Estimation of total sockeye and chinook fry migrations occurred in the same steps as described for the Cedar River. Where flow appeared to explain variation in trap efficiency, flow strata were developed and trap efficiency for each flow stratum was estimated by the mean of the trap efficiency tests conducted while stream flow was within that range. If flow did not appear to explain variation, the average trap efficiency was used (Equation 13) and its variance was calculated using Equation 15. Nightly migration was estimated using Equation 16, and the variance using Equation 17. 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 nightly migration and the nightly variance was calculated using Equation 1. The in-season production estimate was the sum of the nightly migration estimates, and the variance was estimated using Equation 17, substituting the total season catch for the nightly catch.

Screw Trap

Estimation of sockeye fry, chinook, coho, and steelhead smolts and cutthroat trout migrations occurred in several steps. The data collected every night consisted of the same as that collected at Cedar River. Trap efficiency was estimated using the same methods as the fry trap. Nightly migration was estimated using Equation 16, and the variance using Equation 17. The trap operated continuously; therefore catch did not need to be estimated. The in-season production estimate was the sum of the nightly migration estimates. The variance of the total migration was estimated using Equation 17, substituting the total season catch for the nightly catch, when the season trap efficiency average was used to estimate migration.

Cedar River Results

Sockeye

Trap Operation

Trap operation began on January 18 and continued through June 3. Over this 137 day interval, we trapped 115 nights. From January 26 through April 30 we trapped each night. Trapping did not occur every night in January and again in May when the catches were low. Due to heavy debris loads, on four nights we operated the trap for a portion of the night. On three of these nights, trapping was reduced to 30 minutes of each hour.

To assess diel migration, on 12 days from February 6 through March 20, we also operated the trap during daytime intervals.

Catch

Nightly catches increased from 3,834 sockeye on the first night of trapping, January 18 to exceed 135,000 on March 7. Catches exceeded 100,000 fry on eight nights between February 21 and March 13. On five of these nights hatchery produced sockeye fry released at the Riviera site contributed to the high catches. Over the remaining season, catches generally declined and on our last night of trapping, June 3, we caught only 210 fry. For the 115 nights trapped over the season, our combined catch of wild and hatchery fry totaled 3,964,944 sockeye

Catches during the nights of February 28, and March 18 and 19, were expanded due to intermittent trapping. Trapping the night of February 28 was suspended early for heavy debris caused by the landslide approximately eight miles upstream triggered by the earthquake that morning. We estimated an additional 29,398 fry would have been caught had trapping continued through the night, for a nightly projected total of 45,457. On March 3, trapping did not begin until 2145 hours, 4 hours after dusk. We estimated the missed catch from 1800 to 2145, at 17,498 fry. The nights of March 18 and March 19 had projected nightly catches of 76,160 and 58,837 fry, respectively (Table 2).

Addition of these projections (94,545 fry) and estimated catch for nights not fished to the actual night catches increased the total expanded nightly catches to 4,129,441 fry (Appendix A).

Over the 50.5 daylight hours trapped we caught a total of 1,905 sockeye fry.

Table 2. Sockeye fry catch expansions for partial nights fished using cumulative percents, Cedar River fry trap 2001.

DATE	PERIOD FISHED Begin	End	CATCH Total	Period	Proportion Fished	DATE	EXPANDED CATCH Period	Nightly
02/26	19:00	1:00	64,733	45,449	70.2%			
02/27	19:00	1:00	58,589	43,390	74.1%			
03/01	19:00	1:00	83,277	61,004	73.3%			
03/02	19:00	1:00	74,767	50,586	67.7%			
Average					71.3%	02/28	32,408	45,457
03/01	23:00	7:00	83,277	56,201	67.5%			
03/02	23:00	7:00	74,767	50,217	67.2%			
03/04	23:00	7:00	37,586	29,176	77.6%			
03/05	23:00	7:00	124,359	83,237	66.9%			
Average					69.8%	03/03	43,907	62,902
03/16	19:00	1:00	36,284	27,271	75.2%			
03/17	19:00	1:00	47,911	34,602	72.2%			
03/20	19:00	1:00	77,938	57,829	74.2%			
03/21	19:00	1:00	82,603	52,217	63.2%			
Average					71.2%	03/18	54,225	76,160
03/16	21:00	5:00	36,284	31,585	87.0%			
03/17	21:00	5:00	47,911	40,905	85.4%			
03/20	21:00	5:00	77,938	66,823	85.7%			
03/21	21:00	5:00	82,603	68,118	82.5%			
Average					85.2%	03/19	50,104	58,837

Trap Efficiency

Marked sockeye fry were released at Logan Street on 69 nights from January 21 through May 24 to determine capture efficiency of the trap. Recapture rates ranged from 3.5% to 17% for these efficiency tests (Table 3). Nightly average flows among the 69 nights that trap efficiency tests were conducted, however, varied within the relatively narrow range of 338 to 882 cfs. Over the entire trapping season, flows varied just slightly more, from 319 to 996 cfs.

After an exceptionally dry winter, on March 19 flows finally increased enough to allow us to move our screw trap barge, which had been moored against the left bank three hundred yards upstream of the fry trap, to its fishing position just upstream of the Logan Street Bridge. After we moved this 30 by 15 ft steel barge, it was apparent that the former current vectors, which it had caused, were gone. Comparison of the capture rate data between pre and post move intervals with ANOVA determined that trap efficiency was significantly lower after moving the screw trap. In addition, since nearly all of the variation in flow occurred on and after March 19, correlating capture rates with flow for this period found a significant although weak relationship. However, given the poor predictive power of this marginal relationship, we elected to split the capture rates after March 19 into three strata and computed average values for each. For the low flow (<500 cfs), medium flow (500- 700 cfs) and high flow (>700 cfs) strata, capture rates averaged 9.1%, 7.5% and 4.6%, respectively. In comparison, capture rates before moving the screw trap barge averaged 10.4% (Table 3, Figure 2).

Table 3. Trap efficiency test summary using sockeye fry released from the Logan Street Bridge by screw trap position upstream and flow, Cedar River fry trap 2001.

Strata	Flow Range Min	Flow Range Max	# Release Groups	Efficiency Min	Efficiency Max	Efficiency Average	Variance
Screw Trap Position 1	338	493	28	7.4%	17.0%	10.4%	1.5E-05
Screw Trap Position 2							
Flows 300-500 cfs	349	493	31	4.9%	13.8%	9.1%	1.2E-05
Flows 501-700 cfs	506	681	8	4.7%	9.2%	7.5%	4.8E-05
Flows 701+ cfs	808	882	2	3.5%	5.7%	4.6%	1.2E-04

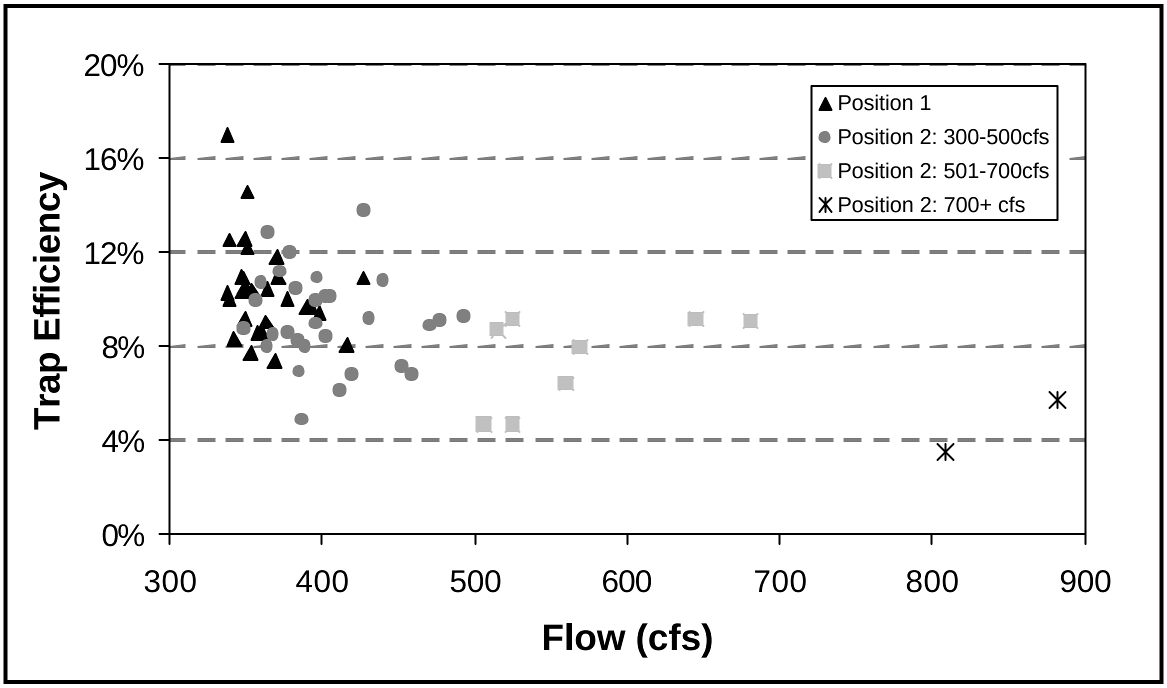

Figure 2. Trap efficiency plotted with flow, indicating which tests were conducted before and after the screw trap barge was moved which changed the flow vectors, Cedar River fry trap 2001.

Otolith Sampling

Fry were collected for otolith analysis on 21 nights over the sixty-day interval (January 22 through March 22) that included releases from the Landsburg Hatchery. Sampling was focused on the 11 nights of and nights following fry releases from the hatchery. Exceptions to this plan occurred on the first release (January 22) and the eighth release, February 28. We did not operate the trap on January 23, the night following the first release. The February 28 earthquake caused a landslide that blocked the river and when flow was restored the heavy debris load precluded trapping through the night.

Over the 21 nights that otolith samples were analyzed, hatchery fry comprised between 0% and 73% of the samples. Of the 3,151 sockeye otoliths that were analyzed, 23% were hatchery fry (Table 4). Sampling occurred on five nights following Riviera releases, which in combination with the total migration estimates for these nights, allowed us to estimate the proportion of these releases that migrate the second night.

Only one potential anomaly in the otolith samples was observed. One marked fry was recovered either 15 days after release or two days before its scheduled release. On March 21, one of the 150 otoliths sampled was identified as a late release group from Riviera. The only release dates for that group were March 6 and 23. We surmise that some fry either escaped from the hatchery on or about March 20 or remained in the river from the earlier release.

Table 4. Sockeye fry otolith sampling results, Cedar River 2001.

Sample Date	Number Sampled	Number Marked	Percent Marked	Variance	Release Code	Release Location
01/22	150	32	21.3%	0.001126	E1	Landsburg
01/29	150	27	18.0%	0.000991	E1	Landsburg
01/30	150	67	44.7%	0.001659	E1	Landsburg
02/05	150	63	42.0%	0.001635	E1	Landsburg
02/06	150	22	14.7%	0.000840	E1	Landsburg
02/07	150	16	10.7%	0.000640	E1	Landsburg
02/08	150	23	15.3%	0.000871	E1	Landsburg
02/15	150	15	10.0%	0.000604	E2	Riviera
		95	63.3%	0.001559	E4	Riviera
02/16	150	2	1.3%	0.000088	E1	Landsburg
		1	0.7%	0.000044	E2	Riviera
		95	63.3%	0.001559	E4	Riviera
02/22	150	2	1.3%	0.000088	M1	Landsburg
		6	4.0%	0.000258	E4	Riviera
02/23	150	1	0.7%	0.000044	M1	Landsburg
		46	30.7%	0.001427	E4	Riviera
02/24	150	0	0.0%	0.000000		
02/25	150	3	2.0%	0.000132	M1	Landsburg
		1	0.7%	0.000044	999	Hat. Unknown
02/26	150	24	16.0%	0.000902	M1	Landsburg
02/27	151	5	3.3%	0.000213	M1	Landsburg
03/07	150	33	22.0%	0.001144	L4	Riviera
03/08	150	83	55.3%	0.001648	L4	Riviera
03/10	150	13	8.7%	0.000531	L1	Landsburg
03/11	150	12	8.0%	0.000494	L1	Landsburg
03/21	150	29	19.3%	0.001047	L1	Landsburg
		1	0.7%	0.000044	L2	Riviera
03/22	150	20	13.3%	0.000776	L1	Landsburg
Total	3,151	737	23.4%			

Diel Migration

In previous years, trapping during limited daytime intervals indicated low migration rates relative to nighttime hours. In 1998 and 1999, daytime catch rates were based on two daytime intervals which estimated the daytime catch rate to nighttime catch rate ratio (D:N ratio) of 10%. In 2000, the D:N ratio of 5% was based on four daytime intervals. During the 2001 season, to better assess diel migration rates, we fished 12 daytime intervals (Table 5). The time intervals that we trapped ranged from a half-hour to 11 hours. D:N ratios ranged from 0.09% to 13.2%, although the 13.2% was based on only a half-hour daytime fishing interval. Not including the D:N ratio of 13.2%, the ratios ranged from 0.09% to 2.3%. The average D:N ratio (.68%) was used to estimate daily daytime migration.

Table 5. Day:night catch ratios of sockeye fry catches in the Cedar River fry trap, 2001.

NIGHTTIME					DAYTIME						DAY:NIGHT	
Trap Down Date	Trap Down Time	Hours Fished	Catch	Catch/ Hour	Date	Time Down	Time Up	Hours Fished	Catch	Catch/ Hour	Ratio (D/N)	Flow (cfs)
02/05	17.00	15.0	32,438	2,163	02/06	8.00	17.00	9.0	264	29.3	1.51%	390
02/06	17.00	15.0	25,837	1,722								
		30.0	58,275	1,943								
02/09	17.50	13.5	19,138	1,418	02/10	14.00	17.50	3.5	4	1.1	0.09%	369
02/10	18.00	13.0	16,397	1,261								
		26.5	35,535	1,341								
02/18	18.00	13.0	67,112	5,162	02/19	14.00	18.00	4.0	36	9.0	0.18%	362
02/19	18.00	14.0	65,109	4,651								
		27.0	132,221	4,897								
02/19	18.00	14.0	65,109	4,651	02/20	14.00	17.00	3.0	25	8.3	0.20%	351
02/20	17.00	15.0	55,749	3,717								
		29.0	120,858	4,168								
02/20	17.00	15.0	55,749	3,717	02/21	14.00	17.00	3.0	33	11.0	0.18%	348
02/21	17.00	15.0	131,322	8,755								
		30.0	187,071	6,236								
02/21	17.00	15.0	131,322	8,755	02/22	14.00	18.00	4.0	122	30.5	0.40%	347
02/22	18.00	14.0	89,441	6,389								
		29.0	220,763	7,613								
02/22	18.00	14.0	89,441	6,389	02/23	14.00	18.00	4.0	86	21.5	0.31%	340
02/23	18.00	13.0	99,878	7,683								
		27.0	189,319	7,012								
02/25	17.00	14.0	96,805	6,915	02/26	7.00	18.00	11.0	59	5.4	0.09%	335
02/26	18.00	14.0	64,733	4,624								
		28.0	161,538	5,769								
02/28	18.00	6.0	32,408	5,401	03/01	12.00	14.00	2.0	170	85.0	1.36%	422
03/01	18.50	12.5	83,277	6,662								
		18.5	115,685	6,253								
03/05	18.00	13.0	124,359	9,566	03/06	14.50	18.00	3.5	254	72.6	0.74%	351
03/06	18.00	13.0	130,237	10,018								
		26.0	254,596	9,792								
03/18	18.00	7.0	54,225	7,746	03/19	13.67	14.17	0.5	427	854.0	13.2%	882
03/19	19.83	9.2	50,104	5,464								
		16.2	104,329	6,452								
03/19	19.83	9.2	50,104	5,464	03/20	15.00	18.00	3.0	425	141.7	2.34%	515
03/20	18.00	12.0	77,938	6,495								
		21.2	128,042	6,048								
Season Total		308.3	1,708,232	5,540				50.5	1,905	37.7	0.68%	

Total Production Estimate

We estimated 43.2 million sockeye fry migrated past the Cedar River fry trap in 2001 (Table 6, Figure 3). Addition of the 8.8 million hatchery sockeye fry that were released below the trap results in 52.0 million sockeye fry entering Lake Washington from the Cedar River in 2001. This total included 38.5 million wild fry and 13.5 million hatchery fry. The 38.1 million wild fry estimated during the trapping season was expanded to include the estimated migration occurring before and after the trapping season. Linear extrapolation from January 1 to January 17 resulted in the addition of 300,522 wild fry, and from June 3 to July 1 resulted in the addition of 32,403 wild fry.

Table 6. Estimated 2001 Cedar River wild and hatchery sockeye fry migrations entering Lake Washington with 95% confidence intervals.

Component	Trapping Period	Dates	Estimated Migration	95% CI Low	95% CI High	CV	Prop. of Total
Wild	Before	January 1 - 17	300,522	274,648	326,396	4.4%	0.6%
	During	January 18 - June 3	38,114,953	35,957,167	40,272,739	2.9%	73.4%
	After	June 3 - July 1	32,403	31,951	32,855	0.7%	0.1%
		Subtotal	38,447,878	36,289,936	40,605,820	2.9%	74.0%
Landsburg	During	January 22-March 27	845,609	717,120	974,098	7.8%	1.6%
Riviera	During	January 22-March 27	3,880,427	3,404,815	4,356,039	6.3%	7.5%
Below Trap	During	January 22-March 27	8,788,000	8,788,000	8,788,000	0.0%	16.9%
		Subtotal	13,514,036	12,981,741	14,046,331	2.0%	26.0%
		Total	51,961,914	49,495,732	54,428,096	2.4%	100.0%

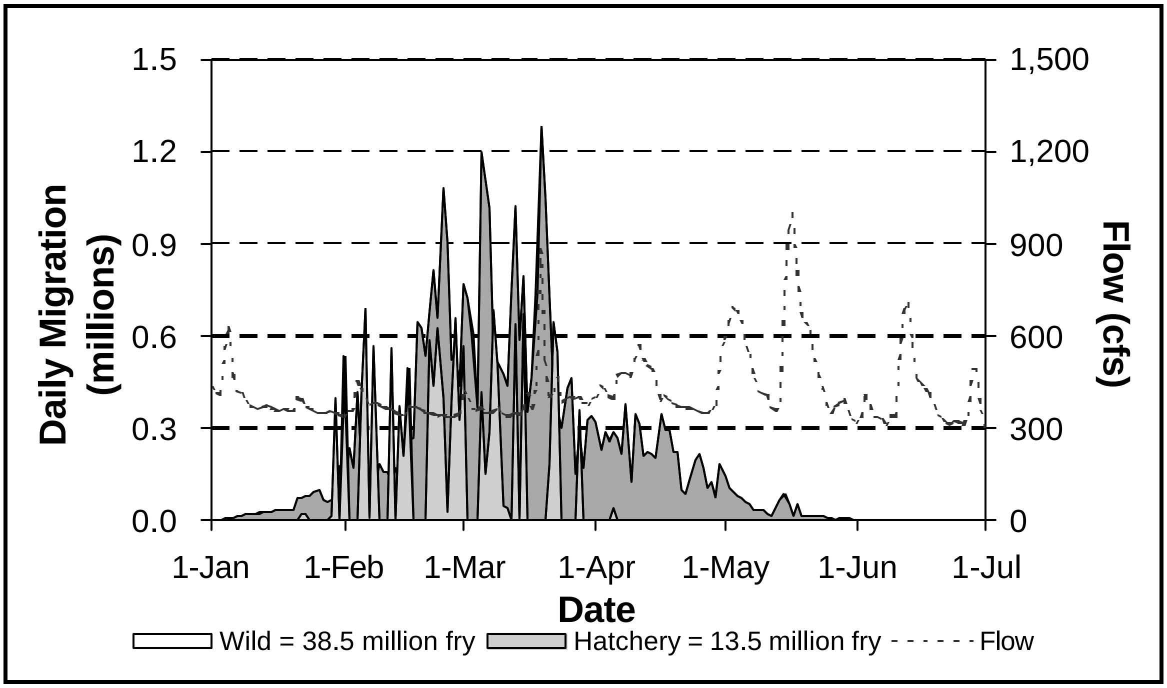

Figure 3. Estimated daily migration of wild and hatchery Cedar River sockeye fry into Lake Washington and flow, 2001.

Wild and Hatchery Timing

The wild migration, which was under way when we began trapping on January 18, increased sharply within several weeks to the first peak in excess of one million fry on the night of February 24. During March, the nightly wild migration exceeded 1 million fry on five nights before declining to low levels by mid-May. Releases of hatchery-produced fry began on January 22 and continued through April 5. Median migration dates for hatchery and wild fry passing the trap occurred on February 26 and March 10 (Table 7, Figure 4).

Table 7. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River.

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

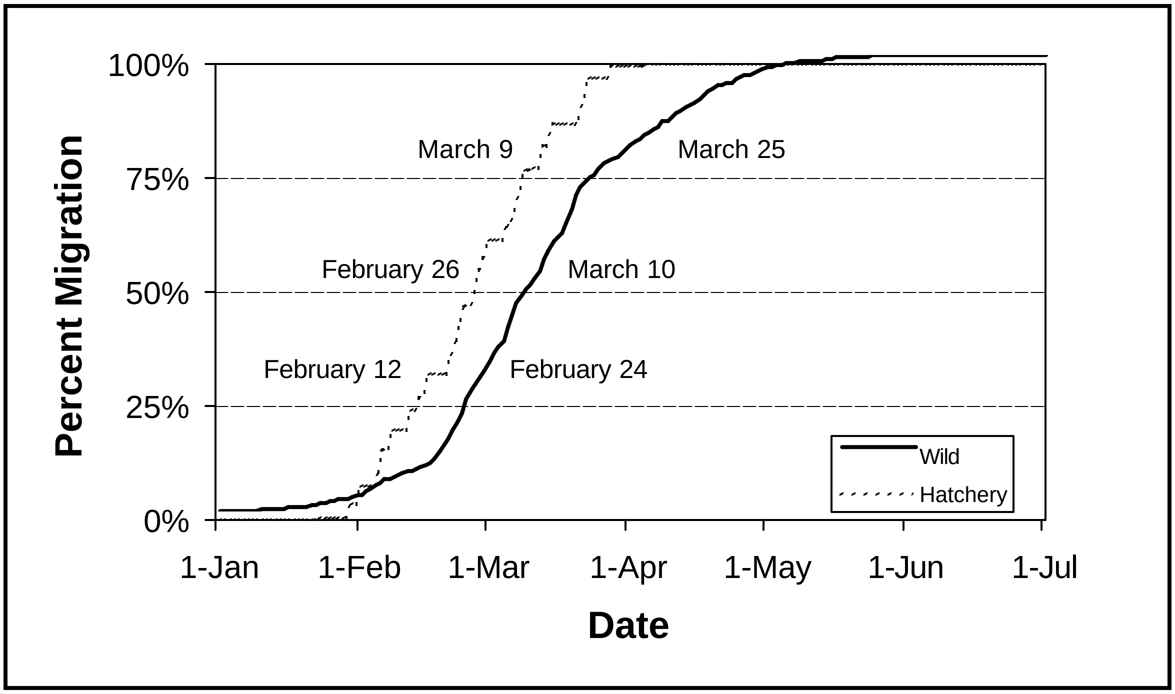

Figure 4. Cumulative wild and hatchery sockeye fry migration timing, Cedar River 2001.

The median migration date for wild fry in 2001 was one day earlier than the earliest median date observed over the previous nine years. Inter-annual variation in migration timing over these nine broods is explained by a negative correlation with temperature units during February (Seiler *et al*. 2002). Timing of the 2001 sockeye fry migration, however, did not correlate with this temperature based timing model. Given the temperature units during February 2001 of 158 (C), the regression model predicted a median migration date of April 2, 23 days later than the measured date of March 10. We believe that this deviation results from relatively high survival early in the season followed by lower survival beginning in March. This deviation likely results from a number of factors which combined to increase survival of the early portion of the migration and decrease survival of the later portion.

February stream temperatures best predicted migration timing ($r^2 = 0.62$) when temperature data was evaluated from throughout the period of fry incubation and migration from previous years (Figure 5). Due to abnormal environmental conditions during the 2001 season, we chose to consider 2001 as an outlier. Environmental pressures, other than temperature, likely caused the early migration observed in 2001. The earthquake on February 28 triggered a landslide eight miles upstream of the trap that actually dammed the river. After an hour or so flow was restored, which transported large amounts of sediment and debris downriver. At the trap, 16 to 18 inches of fine sediment was deposited in the main channel. Approximately 20% of the sockeye spawned below the landslide. Moreover, the later portion of the run spawns in this reach. The earthquake may have caused mortality to sockeye eggs and alevins throughout the Cedar River. We expect however, that mortality in the lower reach was higher than above the landslide as a result of the flow interruption followed immediately by the heavy sediment load, which suffocated eggs and alevins. Any earthquake related mortality would appear as earlier migration timing.

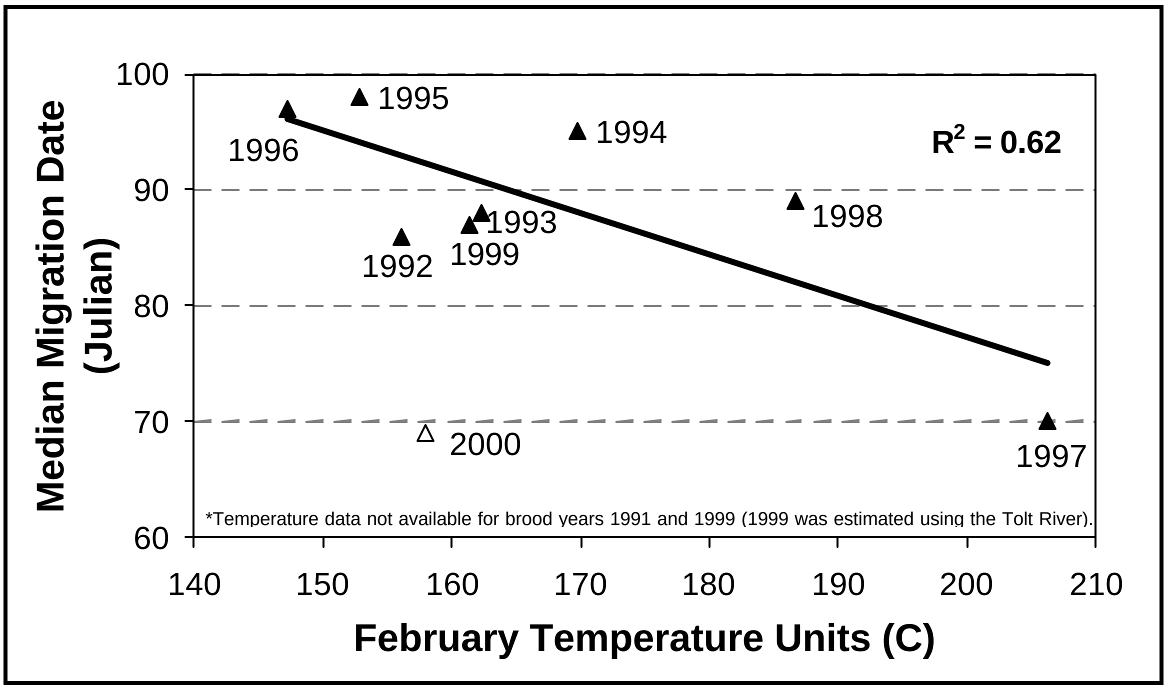

Figure 5. Linear regression of median migration Julian Calendar date for wild Cedar River sockeye fry as a function of the sum of February 1-28 daily average temperature as measured at the USGS Renton Gaging Station #12119000 for brood years 1992-1999, with 2000 as an outlier.

Survival of Hatchery Release Groups

Fry survival from the hatchery release sites to the trap was assessed for hatchery groups released from Landsburg and Riviera sites. Hatchery fry released at Landsburg were caught the night of and after releases, while Riviera releases typically migrated past the trap within the night released. Otolith sampling did reveal however that at least for two releases from Riviera fry were caught on subsequent nights. One release group was represented in the sample taken two nights after release.

Estimated survival of the fry released at Landsburg ranged from 8% to 53% and averaged 26%. Survival for the groups released in the lower river at the Riviera site was estimated to average 75%, nearly three times higher than the fry released at Landsburg (Table 8, Table 9). Nightly hatchery migrations estimated from otolith sampling had coefficients of variation (CVs) ranging from 7.2% to 57%, and migrations estimated using interpolation had CVs ranging from 11% to 65%. Survival of two Riviera releases (February 14 and 21) was estimated with both otolith sampling and interpolation. This was due to delayed migration of those release groups. The February 14 release had an estimated survival of 72% with a CV of 12.9%, and the February 21 release had an estimated survival of 97.6% with a CV of 22.7%.

Table 8. In-river survival estimates of hatchery sockeye fry released from Landsburg, Cedar River 2001.

Release Timing	Release Date	Sockeye Released	Recovery Date(s)	Estimated Migration	Estimated Survival	95% CI +/-	CV
Early	01/22	79,000	01/22	19,418			
			01/23	22,186			
			Total	41,604	52.66%	61.97%	60.04%
	01/29	193,000	01/29	15,122			
			01/30	31,894			
			Total	47,016	24.36%	4.19%	8.78%
	02/05	380,000	02/05	131,171			
			02/06	36,477			
			Total	167,648	44.12%	7.91%	9.15%
	02/07	307,000	02/05	8,755			
			02/08	17,030			
			Total	25,785	8.40%	2.51%	15.22%
	02/15	61,000	02/15	0			
			02/16	10,133			
			Total	10,133	16.61%	16.41%	50.39%
Middle	02/22	213,000	02/22	11,488			
			02/23	6,425			
			Total	17,913	8.41%	9.47%	57.42%
	02/24	64,000	02/24	0			
			02/25	[a]24,836			
			Total	24,836	38.81%	37.57%	49.39%
	02/26	361,000	02/26	99,795			
			02/27	18,709			
			Total	118,504	32.83%	11.24%	17.47%
	02/28	273,000	02/28	31,622			
			03/01	36,129			
			Total [b]	67,751	24.82%	17.71%	36.41%
Late	03/10	614,000	03/10	45,223			
			03/11	37,782			
			Total	83,005	13.52%	5.11%	19.30%
	03/21	665,000	03/21	175,931			
			03/22	65,483			
			Total	241,414	36.30%	9.74%	13.68%
Total		3,210,000		845,609	26.34%	3.64%	7.05%

[a] Includes one hatchery with unknown code, assumed to be from Landsburg.

[b] Hatchery migration estimated using Landsburg sample average survival rate.

Table 9. In-river survival estimates of hatchery sockeye fry released from Riviera, Cedar River 2001.

Release Timing	Release Date	Sockeye Released	Recovery Date(s)	Estimated Migration	Estimated Survival	95% CI +/-	CV
Early	02/14	560,000	02/14[a]	369,627			
			02/15	28,368			
			02/16	5,067			
			Total	403,062	71.98%	18.14%	12.86%
	02/15	293,000	02/15	179,661	61.32%	8.68%	7.22%
	02/16	615,000	02/16	481,321	78.26%	11.38%	7.42%
	02/21	638,000	02/21[a]	588,194			
			02/22	34,454			
			Total	622,648	97.59%	43.49%	22.73%
	02/23	309,000	02/23	295,368	95.59%	23.99%	12.80%
Late	03/06	553,000	03/06[a]	147,425	26.66%	33.97%	65.01%
	03/07	598,000	03/07	287,361	48.05%	14.86%	15.78%
	03/08	653,000	03/08	681,315	104.34%	16.81%	8.22%
	03/09	648,000	03/09[a]	507,980	78.39%	16.58%	10.79%
			03/21[b]	6,073			
	03/23	284,000	03/23[a]	268,213	94.44%	45.07%	24.35%
Total		5,151,000		3,880,427	75.33%	8.27%	5.60%

[a] Hatchery migration estimates were made by subtracting the wild migration estimate (interpolated) from the total migration estimate.

[b] These otolith marked fry were not associated with a specific group, releases with that otolith code were released on 3/6 and 3/23.

Survival of individual Landsburg release groups ranged from 8.4% to 52.7% (Table 8). The weighted average survival was 26.3%. Survival was estimated using otolith samples for all release nights, and the nights after releases except January 23. The night of January 23 was not trapped and the average proportion of hatchery fry migrating the second night was used to estimate hatchery migration on that night.

Survival of individual Riviera release groups ranged from 26.7% to 104.3% (Table 9). The weighted average survival was 75.3%. Survival of Riviera fry was estimated using otolith samples on eight nights, and by subtracting the interpolated wild migration from the total nightly migration estimate on five nights. These survival estimates do not include fry caught on March 21, which were not associated with a specific release. The specific otolith code on the fry caught only occurred on fry that were released on March 6 and 23. The fry in the otolith sample either remained upstream for 15 days before migrating into the trap, or was inadvertently released two days early along with a Landsburg release.

In the past, the majority of the hatchery sockeye fry migrated downstream rapidly. However, due to low flows during the 2001 season, delayed migration was exhibited in all Landsburg release groups and in two of the Riviera release groups. Many release groups shared the same otolith code, making it impossible to distinguish individual release groups. The possibility exists that the migration of each individual Landsburg group lasted longer than two days. If a significant portion of the group did not pass the trap within two nights then survival rates were underestimated for some groups and overestimated for others. The Riviera groups were interpolated to represent that the release group migrated downstream past the trap in one night, and this also could under-estimate or over-estimate individual release groups. In order to more accurately represent survival rates, each release strategy from the two release locations were combined (Table 10). The three release strategies from Landsburg, early, middle and late, had survival rates ranging from 25.1% to 28.6% with CVs ranging from 7.0% to 20.4%. The two release strategies from Riviera, early and late, had survival rates of 82.1% (CV = 8.7%) and 69.4% (CV = 8.2%), respectively.

Confidence intervals and CVs only account for the precision of trap-based estimates. The error associated with the estimates of the number of hatchery fry released is not included. The precision of these estimates is unknown. Over-estimation and under-estimation of fish released in a group would manifest itself in under and overestimating survival, respectively.

Table 10. Survival from release to the trap of pooled early, middle, and late Landsburg and Riviera release groups, Cedar River 2001.

Release Location	Strategy	# Released	Est. Migration at Trap	Percent Survival	95% CI +/-	CV
Landsburg	Early	1,020,000	292,186	28.65%	3.93%	7.00%
	Middle	911,000	229,004	25.14%	10.05%	20.41%
	Late	1,279,000	324,419	25.37%	5.71%	11.48%
Riviera	Early	2,415,000	1,982,060	82.07%	14.03%	8.72%
	Late	2,736,000	1,898,367	69.38%	11.15%	8.20%

Egg-to-Migrant Survival of Naturally-Produced Fry

Survival-to-lake-entry of 2000 brood sockeye fry resulting from the PED from natural spawners was estimated at 11.3% (Table 11). This rate represents an overall average value that is the ratio of 38.5 million fry to an estimated PED of 339.5 million eggs. The estimated spawning population of 196,730 was derived largely from Ballard Locks counts as described in Seiler *et al.* 2002. The fecundity was estimated at 3,451 eggs per female (Brodie Antipa WDFW, pers. comm.).

Regressing survival on peak incubation flow for the ten broods measured thus far indicates substantial correlation. The highest r^2 found for the data series was derived from fitting the data to the first exponential equation ($y = ba^x$). Fitting the data to this equation resulted in an r^2 of 0.85 (Figure 6). It generally describes an exponential decay in egg-to-migrant survival with increasing peak stream flow during the incubation period.

Survival of the 2000 brood was lower than expected considering the record low peak incubation flow. The flow-survival relationship developed through the 1999 brood year and the peak incubation flow of 627 cfs predicts a survival of 13%. This difference, though only 1.7% higher, translates into nearly six million sockeye fry. We attribute this difference to two main factors: low flows throughout most of the season which enabled higher predation rates, and a landslide caused by the earthquake on February 28 which resulted in dewatering and siltation in the lower eight miles of the river.

Table 11. 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 1991-2000.

Brood Year	Spawners	Females (@50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Date
1991	75,196	37,598	3,282	123,396,636	9,800,000	7.94%	2,060	01/28/1992
1992	184,854	92,427	3,470	320,721,690	27,100,000	8.45%	1,570	01/26/1993
1993	100,684	50,342	3,094	155,758,148	18,100,000	11.62%	927	01/14/1994
1994	123,663	61,832	3,176	196,376,844	8,700,000	4.43%	2,730	12/27/1994
1995	26,627	13,314	3,466	46,144,591	730,000	1.58%	7,310	11/30/1995
1996	308,014	154,007	3,298	507,915,086	24,390,000	4.80%	2,830	01/02/1997
1997	118,883	59,442	3,292	195,681,418	25,350,000	12.95%	1,790	01/23/1998
1998	79,174	39,587	3,176	125,728,312	9,500,000	7.56%	2,720	01/01/1999
1999	47,395	23,698	3,591	85,097,723	8,058,909	9.47%	2,680	12/18/1999
2000	196,730	98,365	3,451	339,457,615	38,447,878	11.33%	627	01/06/2001

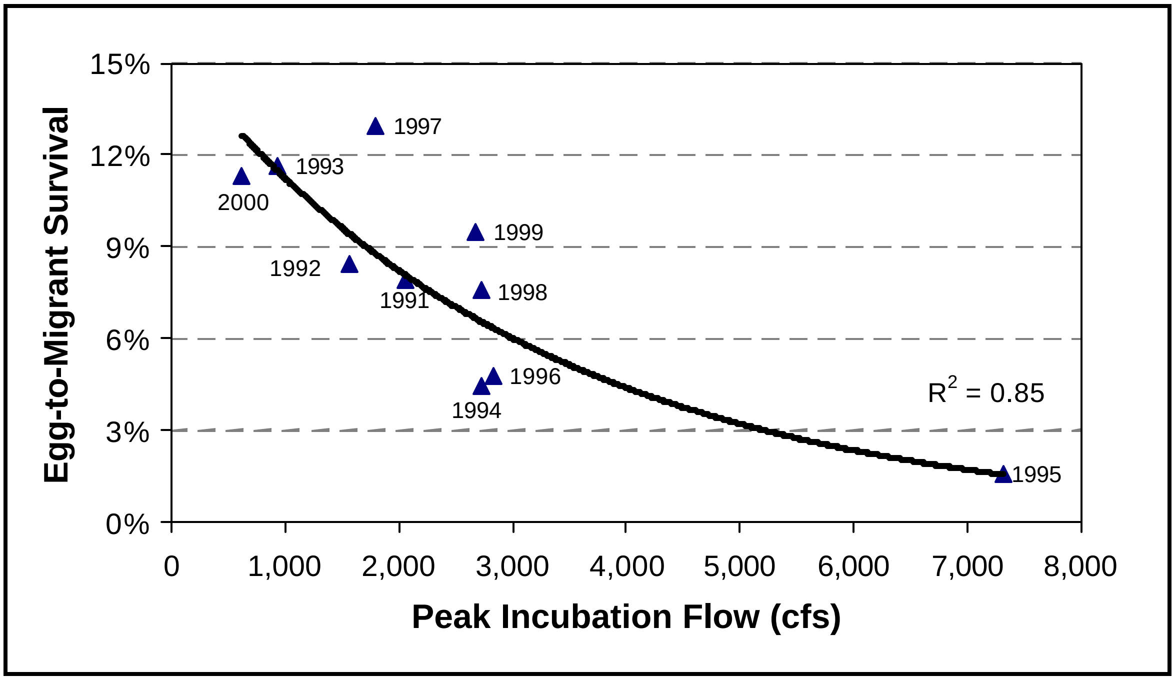

Figure 6. Exponential regression of wild sockeye egg-to-migrant survival from brood years 1991 to 2000 as a function of peak flow during the winter egg incubation period, Cedar River.

Chinook

Catch

Fry Trap

On the first night of fry trap operation (January 18), we caught zero chinook fry. The first chinook were caught during the night of January 27, when four fry entered the trap. From the first night of trapping through March, nightly catches varied from a low of zero to a high of 100 fry. Through March, we caught a total of 655 chinook fry, 96% of the season total. Catches totaled only 32 fry from April to June 3. We fished during 12 daytime intervals in order to estimate migration during daylight hours not fished, and day to night catch rate ratios ranged from 0% to 251% (Table 12). Over the season, a total of 687 fry were captured in the fry trap.

Table 12. Day/night catch ratios estimated at the Cedar River fry trap, 2001.

NIGHTTIME				DAYTIME						DAY:NIGHT	
Dates	Hours Fished	Catch	Catch/ Hour	Date	Time Down	Time Up	Hours Fished	Catch	Catch/ Hour	Ratio (D/N)	Flow (cfs)
02/05-02/06	30.0	23	0.77	02/06	08:00	17:00	9.0	2	0.22	29.0%	390
02/09-02/10	26.5	15	0.57	02/10	14:00	18:00	4.0	0	0	0.0%	369
02/18-02/19	27.0	19	0.70	02/19	14:00	18:00	4.0	0	0	0.0%	362
02/19-02/20	28.0	18	0.64	02/20	14:00	18:00	4.0	1	0.25	38.9%	351
02/20-02/21	29.0	7	0.24	02/21	14:00	17:00	3.0	0	0	0.0%	348
02/21-02/22	30.0	27	0.90	02/22	14:00	18:00	4.0	0	0	0.0%	347
02/22-02/23	27.0	37	1.37	02/23	14:00	18:00	4.0	0	0	0.0%	340
02/25-02/26	28.0	61	2.18	02/26	07:00	18:00	11.0	3	0.27	12.5%	335
02/28-03/01	15.8	23	1.45	03/01	12:10	14:10	2.0	7	3.50	240.9%	422
03/05-03/06	26.0	35	1.35	03/06	14:30	18:00	3.5	0	0	0.0%	351
03/18-03/19	12.7	118	9.31	03/19	13:40	14:10	0.5	0	0	0.0%	882
03/19-03/20	18.7	114	6.11	03/20	15:00	18:00	3.0	0	0	0.0%	515
Average			2.13						0.35	16.6%	

Screw Trap

Over the 105-day interval that we operated the screw trap (April 8 through July 22), we captured 2,872 wild and 76 hatchery chinook. From the first night of trapping through April 29, nightly catches varied slightly and ranged from zero to eight chinook. During May and June, we caught a total of 2,729 wild chinook smolts, 95% of the season total. The highest nightly catch, 278 chinook smolts, occurred on May 28. During the 25 days that we operated the trap 24-hours, almost all chinook were captured at night. Over these dates, D:N ratios ranged from 0% to 113%, but averaged only 3.8%.

Throughout the trapping season, we tagged 1,553 wild and 67 hatchery chinook smolts with passive integrated transponder (PIT) tags. Smolts surviving to the Ballard Locks were interrogated as they pass through detectors fitted to the smolt flumes. This passage data has been compiled and will be further analyzed with adult recoveries beginning in 2004.

Catch Expansion

Chinook fry catches in the scoop trap were estimated for days and nights not fished. Nighttime intervals not fished were estimated using interpolation of catch rates from the previous and following nights fished. Daytime migration was estimated by using the average (16.6%) ratio of day/night catch rates measured during operation of the fry trap (Table 12). Due to large amounts of debris, catches during three nights of partial trapping (February 28, and March 18 and 19) were expanded by hourly interpolation. We estimated the fry trap would have caught an additional 223 chinook fry had we fished it continuously from January 18 to June 3.

Screw trap catch data was also expanded to estimate the number of chinook we would have caught had we fished the trap continuously. Expansion resulted in the addition of 195 wild chinook to the catch. This catch expansion included daytime migration estimates when we did not fish, and for seven trapping intervals when we found the screw stopped by debris. This increase represented 6% of the combined total catch estimate.

Size

From February through April, the weekly mean fork length of chinook fry caught in the fry trap increased 3-mm, and averaged 40-mm (Table 13). By early-May, the lower end of the size range had increased slightly to around 44-mm. While the catch included individuals as large as 75-mm and mean fork length increased to 55-mm, catches were very low by mid-April (Figure 9). We attribute the decline in capture rates to the increased swimming ability of larger chinook migrants.

Chinook caught in the screw trap increased in size from a weekly average fork length of 53 mm in mid-April to 112 mm in mid-July (Table 13, Figure 7).

Table 13. Mean chinook fork length, standard deviation, range, sample size, and catches in the Cedar River fry and screw traps, 2001.

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
01/22	01/28	4	35.3	1.5	34	37	4	4						
01/29	02/04	5	38.0	n/a	38	38	1	23						
02/05	02/11	6	38.6	1.1	37	41	41	50						
02/12	02/18	7	39.0	1.2	37	41	20	37						
02/19	02/25	8	39.2	1.3	37	41	49	134						
02/26	03/04	9	39.4	1.8	35	43	59	114						
03/05	03/11	10	39.6	2.3	36	43	16	43						
03/12	03/18	11	39.3	2.5	34	46	35	84						
03/19	03/25	12	39.5	1.8	36	44	38	161						
03/26	04/01	13	41.3	4.0	39	46	3	6						
04/02	04/08	14	41.0	n/a	41	41	1	1						
04/09	04/15	15	45.2	7.7	39	61	13	18	52.7	7.6	40	66	23	23
04/16	04/22	16	42.0	n/a	42	42	1	1	59.5	20.5	45	74	2	2
04/23	04/29	17					0	0	64.6	9.7	47	78	17	19
04/30	05/06	18	55.4	9.0	44	65	5	7	70.5	8.6	42	86	87	117
05/07	05/13	19					0	0	79.4	7.4	66	96	44	84
05/14	05/20	20	75.0	n/a	75	75	1	4	84.3	7.3	74	96	7	394
05/21	05/27	21						0	88.4	6.7	72	98	20	348
05/28	06/03	22						0	89.0	7.7	69	107	106	1,000
06/04	06/10	23							90.8	6.0	81	104	45	293
06/11	06/17	24							87.9	9.3	75	101	7	402
06/18	06/24	25							101.5	7.1	96	116	8	86
06/25	07/01	26											0	54
07/02	07/08	27							110.5	7.6	99	121	6	27
07/09	07/15	28							112.0	5.8	104	119	7	13
07/16	07/22	29											0	10
		Totals	40.3	4.2	34	75	287	687	81.3	14.9	40	121	379	2,872

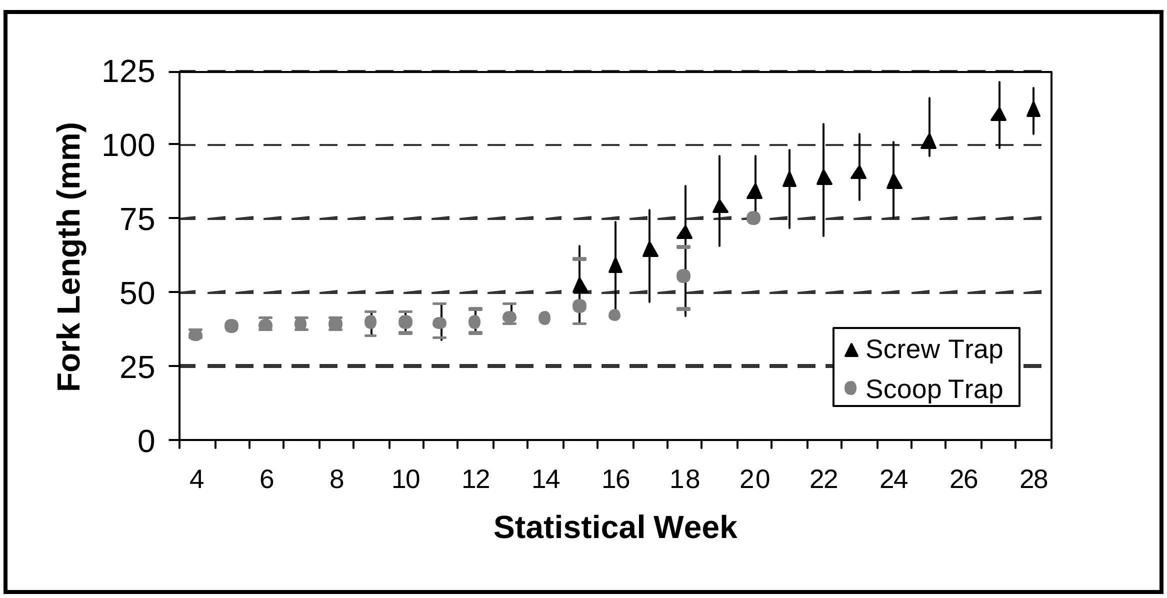

Figure 7. Average and range of fork lengths from age 0+ chinook sampled from the Cedar River, 2001.

Trap Efficiency

Capture efficiency for chinook fry caught in the fry trap was assumed to be equal to that estimated with marked sockeye fry released upstream of the trap and subsequently recapturing them (see Cedar River Results-Sockeye- Trap Efficiency section). We used the average of the tests prior to March 19, and split the capture rates after March 19 into three flow strata and computed average values for each. For the low flow (<500 cfs), medium flow (500- 700 cfs) and high flow (>700 cfs) strata, capture rates averaged 9.14%, 7.46% and 4.61%, respectively (Table 3, Figure 2).

Capture rate of chinook in the screw trap was estimated by releasing 15 mark-recapture groups between May 1 and June 30. Trap efficiencies for these groups ranged from 0 to 38.5%; however, the estimates at the ends of the range were from small groups (Table 14). Because confidence in the results of tests using small numbers of marked fish was low, we combined groups from adjacent tests to develop test groups of at least 50 marked migrants. The combining of tests with small numbers of fish resulted in more comparable test groups.

Table 14. Estimated chinook smolt recapture rate from screw trap efficiency tests, Cedar River 2001.

Date(s)	Flow (cfs)	NUMBER Released	Recaptured	Recapture Rate	Variance
Actual Test Groups					
05/01	589	10	2	20.0%	0.01600
05/05	649	8	1	12.5%	0.01367
05/06	560	5	0	0.0%	0.00000
05/09	419	6	1	16.7%	0.02315
05/12	368	22	2	9.1%	0.00376
05/13	356	5	0	0.0%	0.00000
05/19	671	47	4	8.5%	0.00166
05/22	525	29	3	10.3%	0.00320
05/26	354	63	8	12.7%	0.00176
05/27	371	75	13	17.3%	0.00191
05/29	393	100	15	15.0%	0.00128
06/02	340	100	15	15.0%	0.00128
06/03	405	100	18	18.0%	0.00148
06/23	323	13	5	38.5%	0.01821
06/30	357	7	1	14.3%	0.01749
	Total	590	88		
	Average			13.9%	
	Variance			0.00054	
Combined Test Groups					
05/01-05/13	356-649	56	6	10.7%	0.00171
05/19-05/22	525-671	76	7	9.2%	0.00110
05/26	354	63	8	12.7%	0.00176
05/27	371	75	13	17.3%	0.00191
05/29	393	100	15	15.0%	0.00128
06/02	340	100	15	15.0%	0.00128
06/03-06/30	323-405	120	24	20.0%	0.00133
	Total	590	88		
	Average			14.3%	
	Variance			0.00020	

A scatter plot using all release groups did not yield a significant relationship between mean daily flow and trap efficiency ($p>0.05$). The results may have been affected by the small size of some of the release groups. However, flow also did not explain variation when five release groups of 50 or more fish per group were analyzed. Mean daily stream flow during these five tests ranged from 340 to 405 cfs, which was not enough variation to adequately assess the flow relationship. Because these analyses failed to develop a significant relationship with flow, mean trap efficiency from the seven combined tests (14.3%) was used to estimate the capture rate in the screw trap over the entire period of operation.

Total Production Estimate

During the period of fry trap operation (January 18 through June 3), we estimate that 11,421 chinook fry passed the trap. This estimate is based on our expanded catch of 910 chinook fry and the average trap efficiency to the corresponding stratum. During the period of screw trap operation (April 8 through July 22), we estimate that 21,416 age 0+ chinook passed the trap. This estimate is based on our expanded catch of 3,059 migrants, and the estimated average trap efficiency of 14.3%.

The fry trap and screw trap ran concurrently between April 8 and June 3 providing independent daily estimates of chinook migration from each trap. Daily estimates from each trap were summed for each gear type by week and tested for equality using a Z-test. In the first two weeks there was no difference between the estimates. Thereafter, however the screw trap estimated significantly more chinook each week ($p<0.05$) (Table 15). Given the large difference in chinook size (Table 13, Figure 7) captured in the two traps it became obvious that as chinook grew they were able to avoid the fry trap.

Combining the chinook production estimated from the fry trap for January 18 through April 8, with the estimate from the screw trap for April 9 through July 22, yielded a total migration over this interval of 32,249 naturally produced age 0+ chinook (Table 16, Figure 8). We did not estimate chinook migration prior to trapping because no chinook were caught during the first week of trapping.

Table 15. Independent weekly estimates of chinook migration, N_w, from the fry and screw traps with results from Z-test comparison of the weekly estimates, Cedar River 2001.

Statistical Week			Fry Trap		Screw Trap		Significant Difference? (Yes/No)
Begin	End	Number	Estimated Migration (N_w)	$V(N_w)$	Estimated Migration (N_w)	$V(N_w)$	
04/09	04/15	15	239	1,881	161	1,318	No
04/16	04/22	16	11	17	14	12	No
04/23	04/29	17	0	0	301	4,074	Yes
04/30	05/06	18	174	808	826	8,255	Yes
05/07	05/13	19	0	0	679	3,159	Yes
05/14	05/20	20	164	708	2,863	85,356	Yes
05/21	05/27	21	0	0	2,513	45,402	Yes
05/28	06/03	22	0	0	7,352	262,736	Yes

Table 16. 2001 Cedar River juvenile chinook production estimate with 95% confidence intervals.

Gear	Period	Estimated Catch	Estimated Migration	95% CI Low	95% CI High	CV
Fry Trap	January 18 - April 8	880	10,833	7,703	13,963	14.7%
Screw Trap	April 9 - July 22	3,059	21,416	17,239	25,593	10.0%
	Total	3,939	32,249	27,029	37,469	8.3%

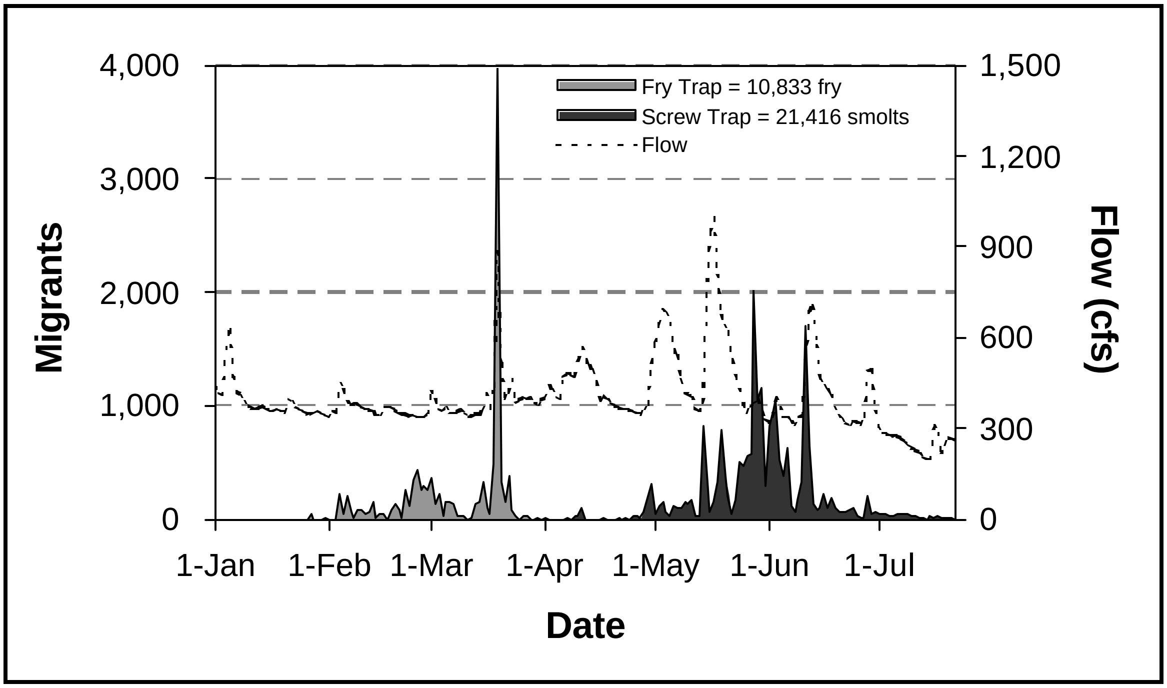

Figure 8. Estimated daily Cedar River 0+ chinook migration from fry and screw trap estimates and flow (USGS Renton Gage), 2001.

Juvenile chinook exhibited a bimodal migration pattern. Fry migrated in February and March while smolts migrated primarily in May and June (Fig. 2,Table 17). In the previous two years, more chinook emigrated as fry than smolts. Due to the anomalously low and steady flows in 2001, relatively low numbers of chinook fry were flushed downstream. Other than the migration of nearly 4,000 fry on the one flow spike (March 19), more chinook were able to rear for several months before migrating as larger smolts. Over the entire season, we estimate that the migration was 25%, 50%, and 75% complete by March 19, May 23, and June 2, respectively (Figure 9).

Table 17. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a January 1 to July 13 migration period, Cedar River brood years 1998 to 2000.

Brood Year	Estimated Migration thru Apr 15	Estimated Migration Apr 16-Jul 13	Estimated Migration Total	Percent Migration thru Apr 15	Percent Migration 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%

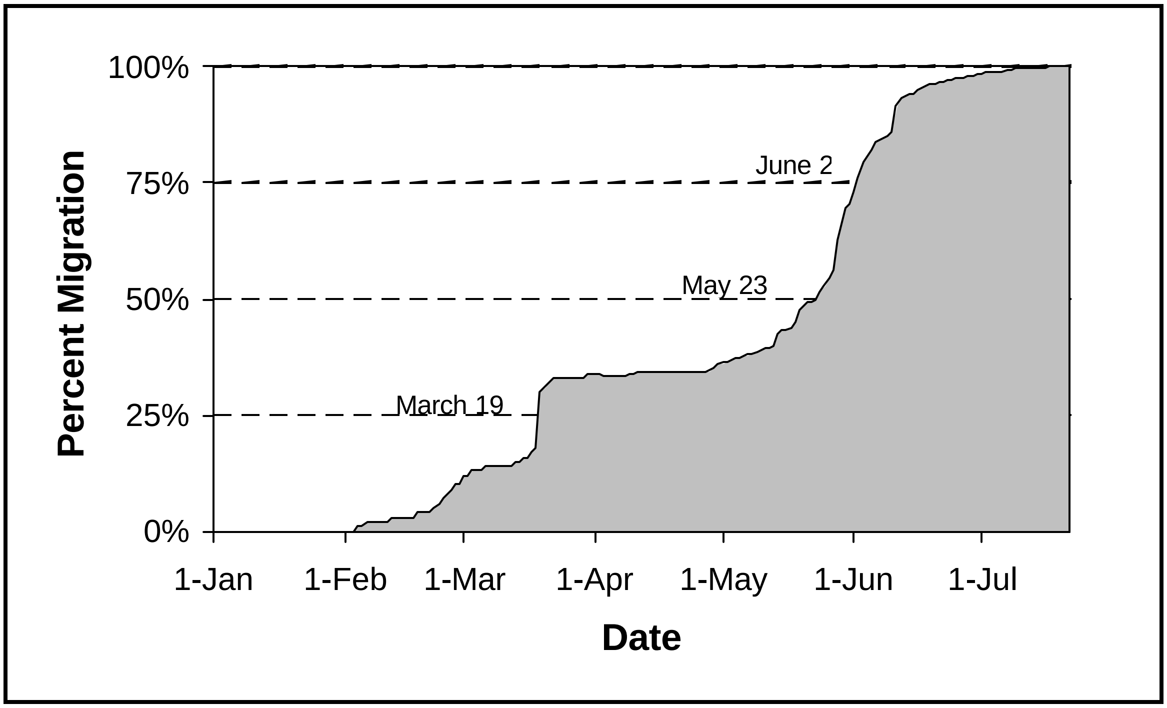

Figure 9. Cumulative percent migration of age 0+ chinook, Cedar River 2001.

Egg-to-Migrant Survival

Relating our overall estimates of juvenile chinook production from the Cedar River to estimates of annual egg deposition yields an estimate of egg-to-migrant survival. For the 2000 brood, we estimated a wild chinook egg-to-migrant survival of 13.5% based on an escapement of 53 females and an average fecundity of 4,500 (Table 18).

Table 18. Age 0+ chinook production and egg-to-migrant survival estimates for Cedar River broods 1998 to 2000.

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%

Coho

Catch

We captured a total of 5,927 wild and three hatchery coho smolts in the screw trap between April 8 and July 22. Over 91% of the catch occurred between April 23 and June 4. Catch distribution was unimodal with the peak daily catch of 530 on May 14.

Over the period of both daytime and nighttime screw trap operation, D:N ratios for coho smolts averaged 0.7%. Weekly average D:N ratios were somewhat higher early and late in the trapping season when few fish were migrating (Figure 10). Catch was highest during weeks 18 (beginning on April 30) through 20 (ending on May 20). During this period, weekly day/night catch rate ratios averaged less than 2%.

Throughout the trapping season, we tagged 1,236 coho smolts with PIT tags.

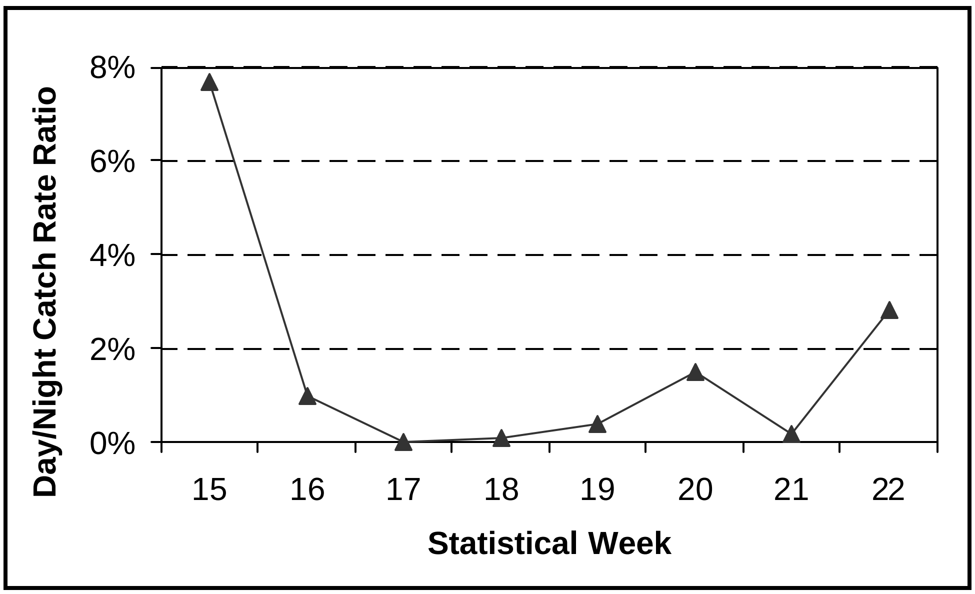

Figure 10. Ratio of daytime to nighttime coho catch rates by statistical week, Cedar River screw trap 2001.

Size

Over the season, coho smolt fork lengths averaged 112 mm (Table 19, Figure 11). Mean fork length varied little between weeks.

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 335 coho. This addition represents an increase of 5.7% to the actual catch.

Table 19. Weekly mean fork length, standard deviation, range, sample size and catches for coho from the Cedar River screw trap, 2001.

Statistical Week			COHO					
					Range			
Begin	End	No.	Avg.	s.d.	Min	Max	n	Catch
04/09	04/15	15	111.6	10.5	88	150	72	167
04/16	04/22	16	113.7	10.2	92	143	84	259
04/23	04/29	17	115.7	12.1	60	143	94	476
04/30	05/06	18	112.1	9.5	87	138	96	1,339
05/07	05/13	19	112.5	10.7	89	165	125	794
05/14	05/20	20	108.0	12.2	84	135	56	1,969
05/21	05/27	21	110.6	10.8	87	132	26	519
05/28	06/03	22	106.9	10.0	85	132	67	320
06/04	06/10	23					0	36
06/11	06/17	24					0	36
06/18	06/24	25					0	4
06/25	07/01	26					0	2
07/02	07/08	27					0	2
07/09	07/15	28					0	1
07/16	07/22	29	172.0	n/a	172	172	1	3
		Totals	112.0	11.2	60	172	621	5,927

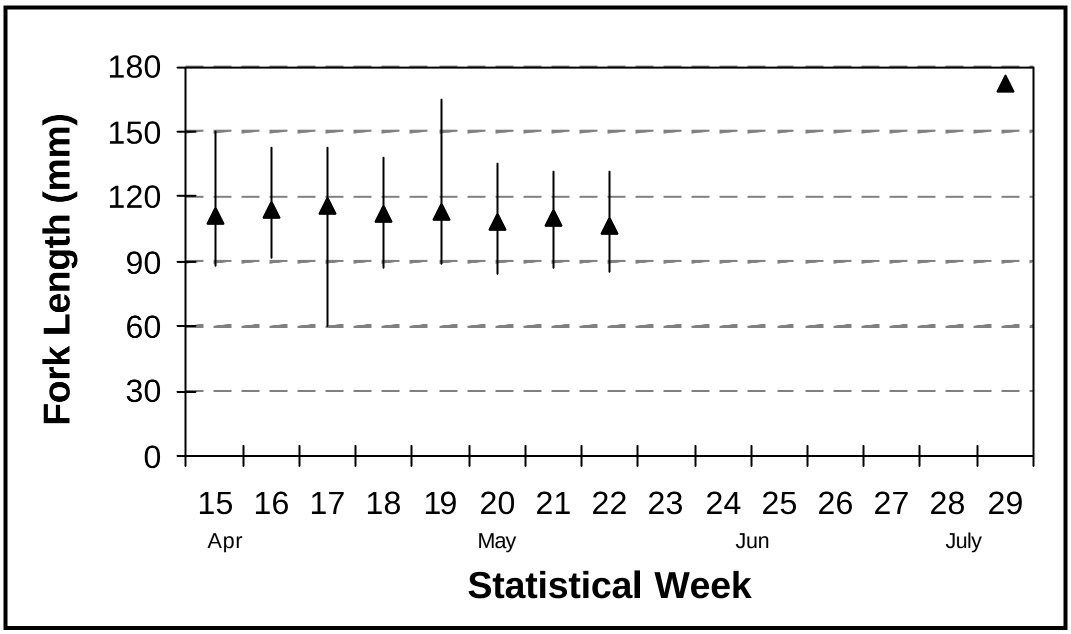

Figure 11. Weekly ranges and mean fork lengths for coho smolts captured in the Cedar River screw trap, 2001.

Trap Efficiency

Twenty-nine mark-recapture tests were conducted to measure trap efficiency for coho. Recapture rates for individual groups ranged from 0% to 24% and averaged 7.4%. As was done with the chinook tests, we combined small release groups (less than 40 marked coho released) with adjacent releases to form groups of at least 40 individuals. This adjustment reduced the number of mark-recapture tests from 29 to 26, but increased our confidence in the results from individual tests. Trap efficiency in the resulting 26 tests averaged 7.8% (Table 20). As with chinook, regression analysis failed to find a significant flow effect on trap efficiency ($p>0.05$).

Table 20. Estimated coho smolt recapture rates from screw trap efficiency tests from groups combined to include greater than 40 individuals, Cedar River 2001.

Date(s)	Flow(s) (cfs)	NUMBER Released	Recaptured	Recapture Rate	Variance
Combined Test Groups					
04/23-04/24	360-365	61	5	8.2%	0.000020
04/25	357	64	8	12.5%	0.002256
04/26	349	68	8	11.8%	0.001611
04/28	364	48	6	12.5%	0.002256
04/29	378	75	3	4.0%	0.001407
04/30	519	63	4	6.3%	0.000196
05/01	589	102	2	2.0%	0.003352
05/02	645	100	1	1.0%	0.004557
05/03	693	100	14	14.0%	0.003905
05/04	681	100	4	4.0%	0.001407
05/05	649	71	2	2.8%	0.002434
05/06	560	78	1	1.3%	0.004184
05/09	419	58	2	3.4%	0.001851
05/10	412	60	3	5.0%	0.000757
05/12	368	100	11	11.0%	0.001056
05/13	356	100	7	7.0%	0.000056
05/17	996	50	6	12.0%	0.001806
05/19	671	100	5	5.0%	0.000757
05/20	640	101	14	13.9%	0.003734
05/20	640	100	6	6.0%	0.000307
05/21	618	100	5	5.0%	0.000757
05/22	525	99	14	14.1%	0.004084
05/26	354	62	4	6.5%	0.000169
05/27	371	46	11	23.9%	0.026122
05/31	329	69	0	0.0%	0.006007
06/02-06/12	340-690	72	6	8.3%	0.000034
Total		2,047	152		
Average				7.8%	
Variance				0.00012	

Total Production Estimate

Application of the average coho smolt trap efficiency to the expanded catch of 6,262 smolts estimates a production of 80,795 smolts during the trapping season. Using logarithmic expansion, we estimated that an additional 1,667 smolts would have been caught had we begun trapping on March 15. Total coho production was estimated at 82,462 smolts with a coefficient of variation of 13.7% and a 95% confidence interval of 60,263 to 104,661 smolts (Figure 12).

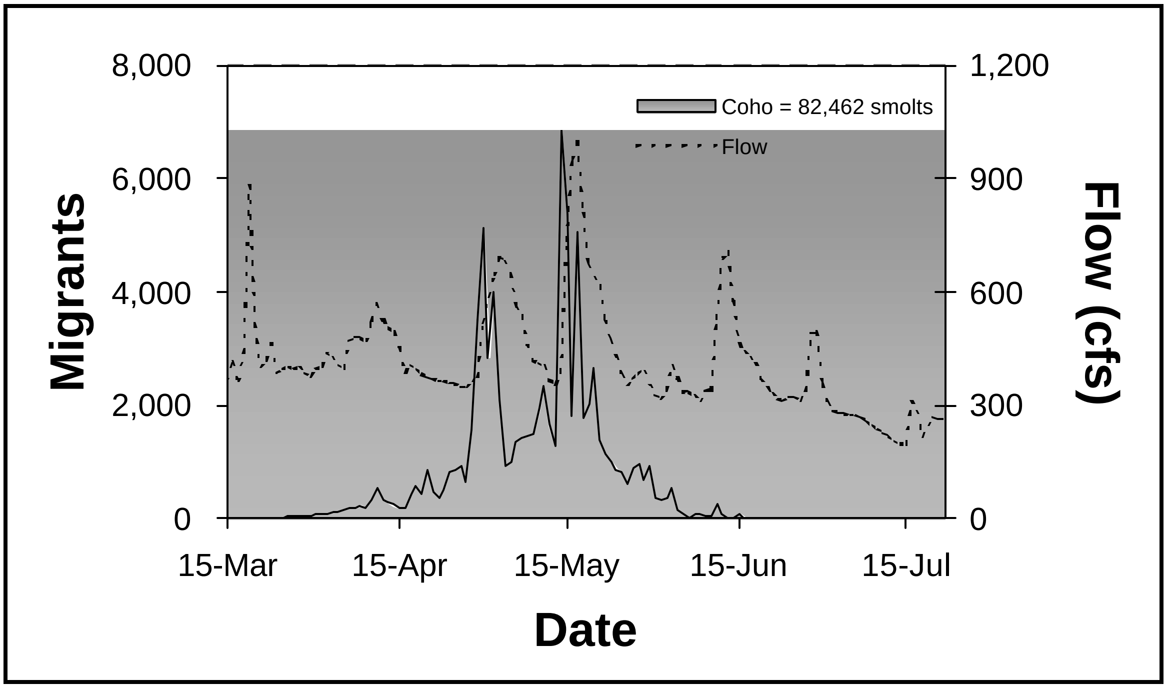

Figure 12. Estimate of daily coho smolt migration and flow (USGS Renton Gage), Cedar River screw trap, 2001.

Steelhead and Cutthroat

Catch

A total of 91 steelhead smolts were captured between April 9 and July 13. Daily catch peaked on April 30 with 24 steelhead caught during rising flows. Due to the low catches, there was no definable timing pattern during the period of trap operation. Steelhead were not observed in any of the daytime catches. We tagged 22 steelhead with PIT tags over the trapping season.

A total of 132 cutthroat trout were captured in the screw trap between April 9 and July 22. Due to the low catches, there was no definable timing pattern during the period of trap operation. Cutthroat were not observed in any of the daytime catches.

Size

Over the season, steelhead smolt fork lengths averaged 201 mm and varied little from week to week (Table 21). Cutthroat trout fork lengths averaged 163 mm, and varied from 99 to 225 mm throughout the trapping season (Table 21).

Table 21. Weekly mean steelhead and cutthroat fork length, standard deviation, range, sample size and catches, Cedar River screw trap 2001.

Statistical Week			STEELHEAD						CUTTHROAT					
Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
04/09	04/15	15	200.6	35.7	165	255	6	6	163.3	30.1	110	225	28	32
04/16	04/22	16					0	1	145.0	26.3	105	192	11	12
04/23	04/29	17	201.0	8.5	195	207	2	2	148.3	28.5	99	177	6	4
04/30	05/06	18	207.8	27.6	157	277	36	40	176.3	45.5	130	221	3	16
05/07	05/13	19	176.8	8.7	164	183	4	9	168.3	33.1	134	200	3	10
05/14	05/20	20	189.0	15.9	171	217	6	18	191.7	25.5	167	218	3	9
05/21	05/27	21	188.0	27.2	155	217	4	8					0	4
05/28	06/03	22	170.0	n/a	170	170	1	3					0	12
06/04	06/10	23					0	1	146.0	n/a	146	146	1	3
06/11	06/17	24											0	12
06/18	06/24	25											0	5
06/25	07/01	26											0	7
07/02	07/08	27					0	2					0	1
07/09	07/15	28					0	1					0	1
07/16	07/22	29											0	4
		Totals	200.6	27.3	155	255	59	91	163.3	31.2	99	225	55	132

Catch Expansion

Expansions of the actual catch to represent the number of steelhead and cutthroat that would have been caught if the trap had fished continuously resulted in the addition of only two steelhead and two cutthroat smolts on May 7.

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 ratio. Applying this ratio to our average coho smolt catch rate (7.8%) estimates a steelhead capture rate in the Cedar River screw trap of 4.68%. This rate may underestimate the steelhead catch rate in the screw trap because the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape. Therefore, we selected a trap efficiency value of 5% for estimating steelhead and cutthroat migration in the Cedar River in 2001.

Total Production Estimate

Application of a catch rate of 5% to the expanded catch of 93 steelhead estimates a total migration of 1,860 smolts (Figure 13). Applying this rate to the expanded catch of 134 cutthroat estimates the total cutthroat migration during the trapping period at 2,680 smolts (Figure 14). No confidence intervals were developed for these estimates, which apply only to the period of screw trap operation (April 9 through July 22). While cutthroat migration very likely occurred before and after this interval, no migration timing trends were evident from the catch data, which would help to define the start or end of this migration. Therefore, we did not attempt to expand our cutthroat estimate beyond the trapping period. The estimate of cutthroat migration during the trapping season represents an unknown portion of the total production of downstream migrant cutthroat from the Cedar River.

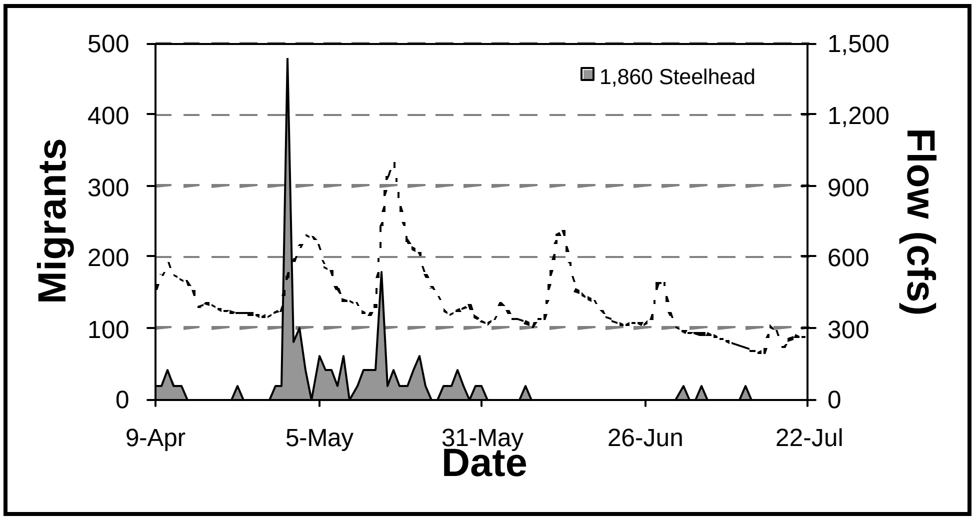

Figure 13. Estimated daily steelhead smolt migration and flow, Cedar River screw trap 2001.

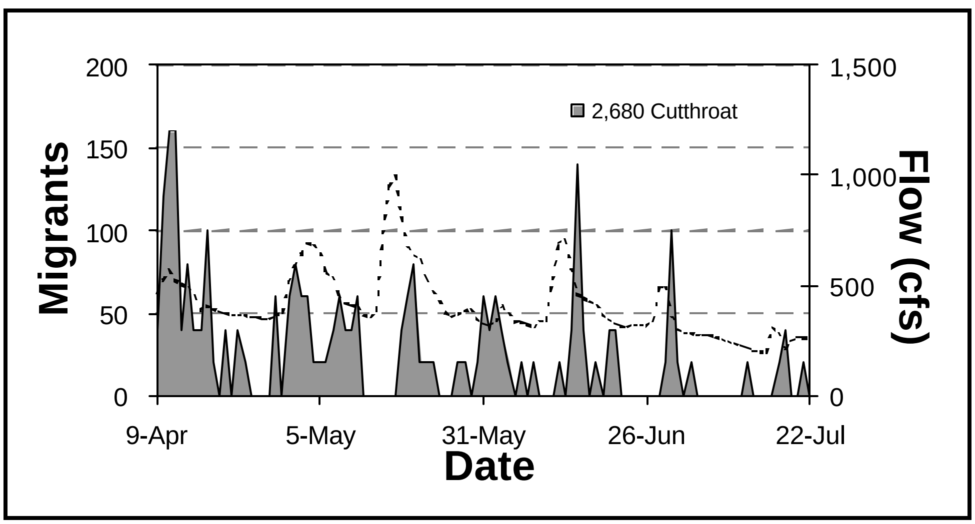

Figure 14. Estimated daily cutthroat migration and flow, Cedar River screw trap 2001.

Mortality

Over the season, no chinook fry mortalities occurred in the fry trap.

Over the season, three cutthroat, six steelhead, 175 coho, and 40 chinook smolts were found dead in the screw trap. Coho and chinook mortality rates were 3.0% and 1.4%, while steelhead was 6.6%. Most of the mortalities occurred when large woody debris jammed the screw trap. These rates are high compared to previous years, and the majority of the deaths occurred during the night of May 15.

During that night, heavy winds and rain caused debris to fill up one side of the screw but it did not stop turning. By morning, four steelhead, 172 coho, and 30 chinook were dead. Although most of the observed chinook mortalities occurred after late-May (by which time mean size exceeded 75 mm), mortality earlier in the season when chinook were smaller may be underestimated for two reasons. First, larger migrants, particularly cutthroat, often eat fry in the collection box. Second, dead fry could be removed from the trap by the debris drum, which cycles detritus from the trap. Therefore, chinook fry mortalities may be somewhat higher than counted.

Mortality also occurred as a result of passive integrated transponder (PIT) tags used to mark chinook and coho smolts. Mortality was estimated by holding sample groups for 24-hours. As a result, we estimate that 16 chinook and 24 coho mortalities occurred from PIT tagging the smolts.

Incidental Species

In addition to the salmonids estimated above, we also caught five age 1+ coho, 15 coho fry, and 81 chum fry in the fry trap. We also caught 56 coho fry, 3 hatchery coho smolts, 76 hatchery chinook smolts, and 30 chum fry in the screw trap. Other species caught included long-fin smelt, three-spine sticklebacks, sculpin, large-scale suckers, pea-mouth, and lampreys.

Bear Creek Results

Sockeye

Catch

Fry Trap

On the first night of fry trap operation, January 27, we caught 18 sockeye fry. Given the low catch, we fished every other night until February 26. Thereafter, the trap was fished nightly through April 9. Catches remained very low until the flow finally increased in mid-March. The peak catch, 56,600 fry, occurred on the night of March 18 as flows increased. In total, we caught 312,487 sockeye fry through the morning of April 10. Trapping during two daytime intervals, 7 hours on February 22 and three hours on March 20, resulted in catches of just two and three sockeye fry.

Screw Trap

Screw trap operation began the morning of April 10 and continued through the morning of July 13. On the first day of trapping we caught 12,570 sockeye fry. The last catch of 11 sockeye fry occurred on April 27. To minimize predation in the trap, we frequently removed fry during the night. From April 10 through April 27, we caught 28,624 sockeye fry.

Trap Efficiency

Capture rates of the 36 groups of marked sockeye fry released upstream of the fry trap averaged 15% and ranged from 4.1% to 25.5%. Linear regression analysis using all release groups did not yield a significant relationship between mean daily flow and trap efficiency ($p>0.05$) (Figure 15). Because this analysis failed to develop a significant relationship with flow, mean trap efficiency (15%) was used to estimate the capture rate in the fry trap over the entire period of operation.

Capture rate in the screw trap was estimated with four mark groups between April 14 and April 19. Recovery rates of these groups ranged from 18% to 23.1% (Figure 15) and averaged 20.9%.

Total Production Estimate

During the period of fry trap operation (January 27 through April 9), we estimate that 2,098,529 sockeye fry passed the trap (Appendix C). This estimate is based on our catch, the season average trap efficiency of 15%, and estimated migration for the 15 nights early in the season when trapping did not occur every night. During the period of screw trap operation (April 10 through April 23), we estimate that 136,985 sockeye fry passed the trap. This estimate is based on our catch of 28,624 fry and the estimated average trap efficiency of 20.9%.

For the entire 2001 migration, we estimate that 2,235,514 sockeye fry migrated from Bear Creek (Figure 16). The confidence interval (95%) for this estimate ranges from 2,048,890 to 2,422,138 fry.

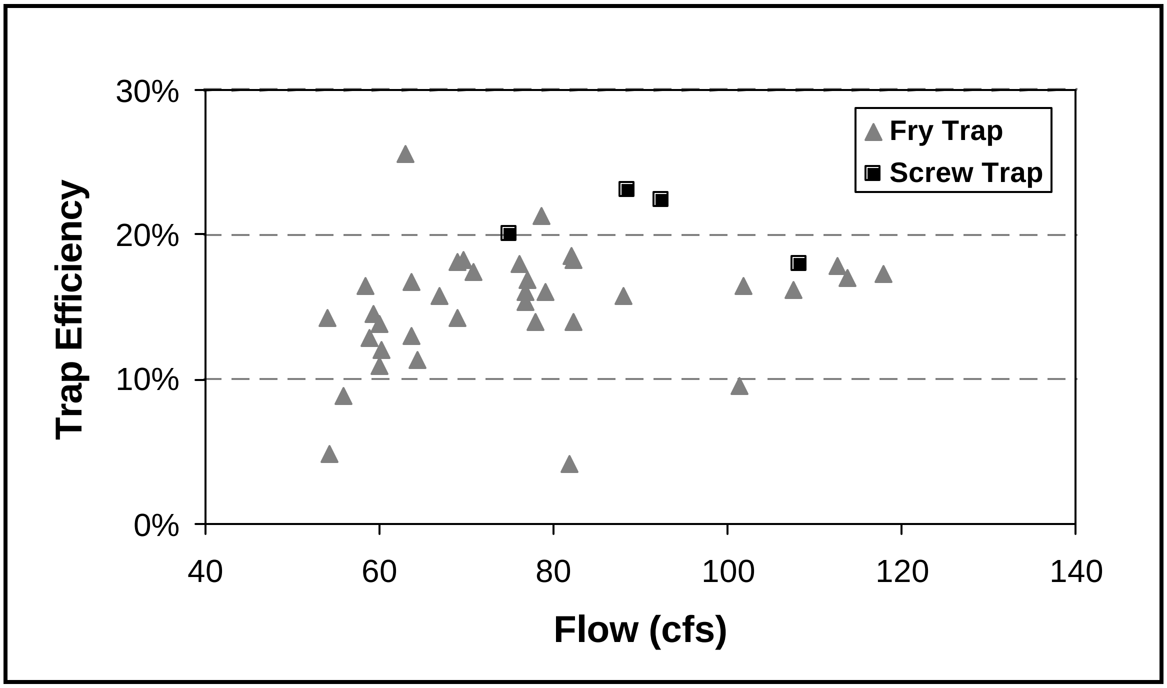

Figure 15. Trap efficiency tests and mean daily flow for Bear Creek fry and screw traps using sockeye fry, 2001.

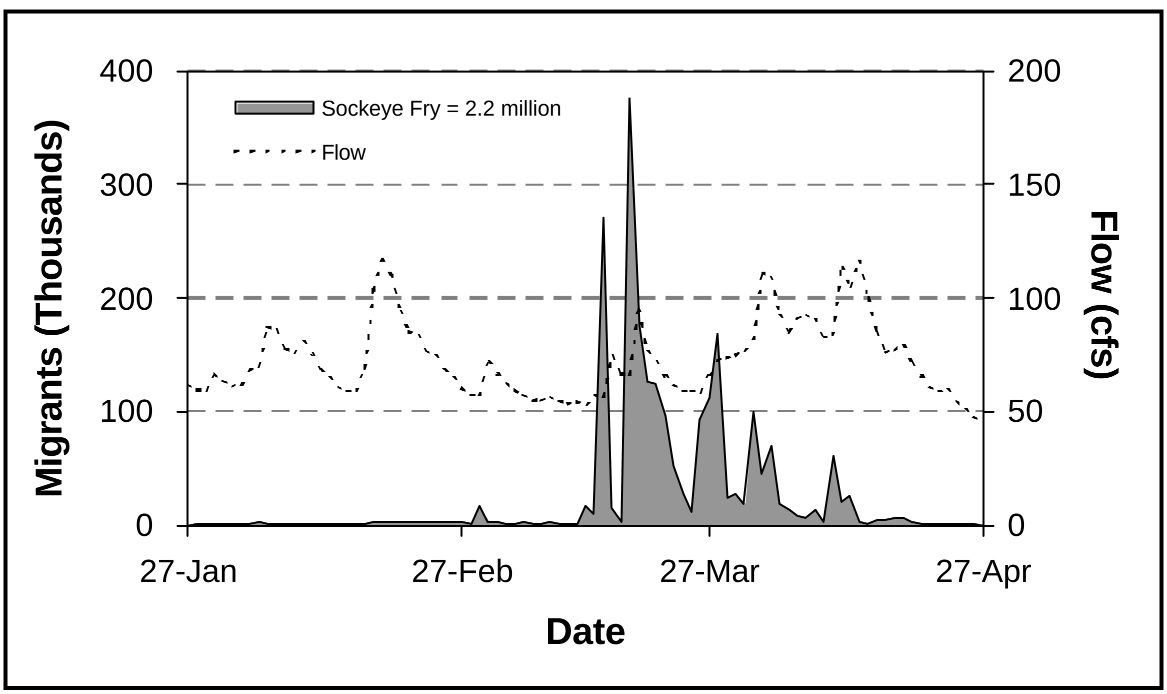

Figure 16. Estimated daily migration of Bear Creek sockeye fry into Lake Washington and flow, 2001.

Egg-to-Migrant Survival

Survival from egg deposition to fry migration is estimated at 3.2%. This rate is the ratio of 2.2 million fry to an estimated deposition of 68.8 million eggs (Table 22). Over the three broods evaluated thus far, the 2000 brood had the highest escapement, the lowest peak incubation flow, and the lowest survival. Apparently, peak incubation flows in Bear Creek are not the primary determinant of egg to migrant survival as observed in the Cedar River.

Flows through most of the 2001 season were anomalously low. Nightly migration rates were also very low through February and early March. Considering the high egg deposition and lack of high flows during incubation, we expected very large nightly migrations beginning in February. As the season progressed and very few fry were caught, we began investigating. In the Cedar River, over many years we have documented a positive correlation between migration flows and fry survival. Therefore, given the low flows, we expected high predation rates in Bear Creek.

To assess predation rates in Bear Creek, before daylight on the morning of March 14 Roger Tabor (USFWS) collected a sample of cutthroat, coho, and sculpin upstream of the trap. Analysis of stomach contents determined that on average each cutthroat, coho, and torrent sculpin contained 17, four, and one freshly consumed sockeye fry, respectively. These consumption rates, in conjunction with our population estimates for cutthroat and coho, provided insight into total nightly sockeye fry losses due to predation during low flows.

On March 15 and again on March 18, flows increased following the first significant precipitation. Sharp increases in the sockeye fry migration coincided with these moderate flow increases. These observations lead us to conclude that flow levels regulate predation rates, which in turn determines survival of sockeye fry in Bear Creek.

Table 22. Sockeye egg-to-migrant survival rates by brood year, Bear Creek.

Brood Year	Spawners	Females (@50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1998	8,300	4,150	3,200	13,280,000	1,523,208	11.47%	515	11/26/1998
1999	1,600	800	3,200	2,560,000	189,571	7.42%	458	11/13/1999
2000	43,000	21,500	3,200	68,800,000	2,235,514	3.20%	188	11/27/2000

Chinook

Catch

Fry Trap

The first chinook fry was caught on the night of March 4. The peak nightly catch of 20 fry occurred on March 18 with the first significant increase in flow. Catches totaled only 63 fry from March 4 through April 9.

Screw Trap

Over the continuous 94 days that we operated the screw trap (April 10 through July 12) the wild chinook catch totaled 5,131 smolts. Catches increased through May and peaked at 428 chinook smolts on May 29.

Throughout the trapping season, we tagged 2,131 wild chinook smolts with passive integrated transponder (PIT) tags.

Size

Chinook increased in size from around 40 mm in March to 90 mm in mid-July (Table 23, Figure 17).

Table 23. Mean chinook fork length, standard deviation, range, sample size, and catches in the Bear Creek fry and screw traps, 2001.

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
02/26	03/04	9	42.0	n/a	42	42	1	1						
03/05	03/11	10					0	0						
03/12	03/18	11	40.6	1.7	38	44	17	28						
03/19	03/25	12	40.4	2.2	37	44	12	17						
03/26	04/01	13	42.8	1.5	40	45	8	15						
04/02	04/09	14	42.0	n/a	42	42	1	2						
04/09	04/15	15							41.8	2.4	38	46	17	19
04/16	04/22	16							43.5	2.7	40	47	6	8
04/23	04/29	17							47.0	7.5	41	67	16	20
04/30	05/06	18							68.4	4.9	62	78	8	32
05/07	05/13	19							73.4	5.4	51	86	80	149
05/14	05/20	20							70.6	11.0	50	93	116	822
05/21	05/27	21							76.4	8.1	56	91	45	938
05/28	06/03	22							80.6	7.3	55	96	78	1,727
06/04	06/10	23							75.5	8.1	56	105	103	663
06/11	06/17	24							72.8	7.2	52	91	70	473
06/18	06/24	25							79.2	6.9	65	97	54	158
06/25	07/01	26							80.2	4.6	71	89	16	83
07/02	07/08	27							88.8	4.6	82	95	13	35
07/09	07/15	28											0	4
		Totals	41.0	2.0	37	45	39	63	73.4	11.6	38	105	622	5,131

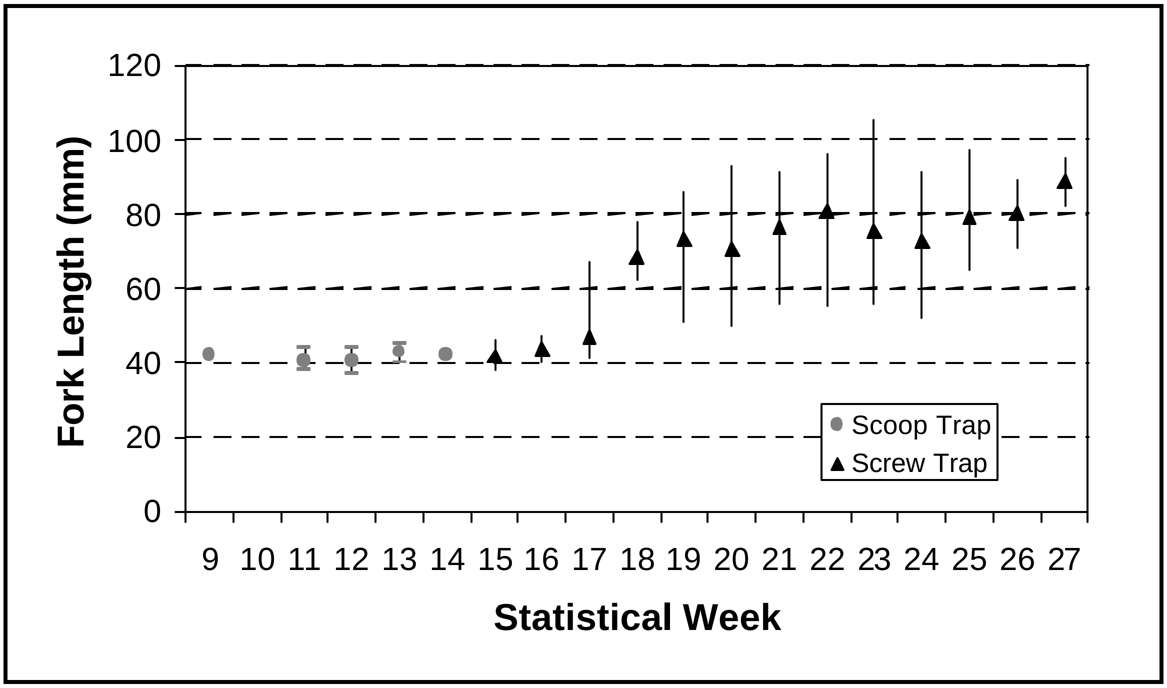

Figure 17. Average and range of fork lengths from age 0+ chinook sampled from the Bear Creek, 2001.

Trap Efficiency

We assumed that chinook fry were captured in the fry trap at the same rate as sockeye fry (15%).

To estimate the capture rate of the screw trap we released 27 groups of marked chinook between May 5 and June 19. Recapture rates ranged from 0 to 82.6%; however, the estimates at the ends of the range were from very small release groups. Because confidence in the results of tests using small numbers of marked fish was low, we combined groups from adjacent tests to develop larger groups (Table 24). Although the trap was moved three times during the season, chinook efficiency tests were not significantly different between trap positions ($p>.20$). Due to the weak flow correlation (Figure 18), the average of the grouped efficiency tests (50.5%) was used to estimate migration.

Total Production Estimate

During the period of fry trap operation (January 27 through April 9), we estimate that only 419 chinook fry passed the trap. This estimate is based on our catch of 63 chinook fry and the average trap efficiency of 15%. During the period of screw trap operation (April 10 through July 12), we estimate that 10,169 age 0+ chinook passed the trap. This estimate is based on our catch of 5,131 migrants, and the average trap efficiency estimated using grouped efficiency tests.

Combining the chinook production estimated from the fry and screw traps for January 27 through July 12 yielded a total migration of 10,588 age 0+ chinook (Table 25, Figure 19). We did not estimate chinook migration prior to trapping because no chinook were caught during the first month of trapping.

Table 24. Grouped recapture rates of chinook smolts released above the screw trap, Bear Creek 2001.

Date(s)	Average Flow (cfs)	NUMBER Released	NUMBER Recaptured	Recapture Rate
05/05-05/11	51.9	45	18	40.0%
05/12-05/15	47.8	68	33	48.5%
05/16	101.5	70	16	22.9%
05/18-05/19	58.1	63	32	50.8%
05/20	49.3	69	48	69.6%
05/22-05/23	38.1	63	24	38.1%
05/24	32.2	48	30	62.5%
05/25	30.1	98	67	68.4%
05/26	28.8	44	31	70.5%
05/30	28.5	100	61	61.0%
05/31	28.5	94	49	52.1%
06/02	40.9	77	41	53.2%
06/03-06/05	61.4	134	23	17.2%
06/06	51.3	45	27	60.0%
06/09	45.7	85	38	44.7%
06/11-06/19	71.8	77	37	48.1%
	Total	1,180	575	
	Average			50.5%
	Variance			0.00151

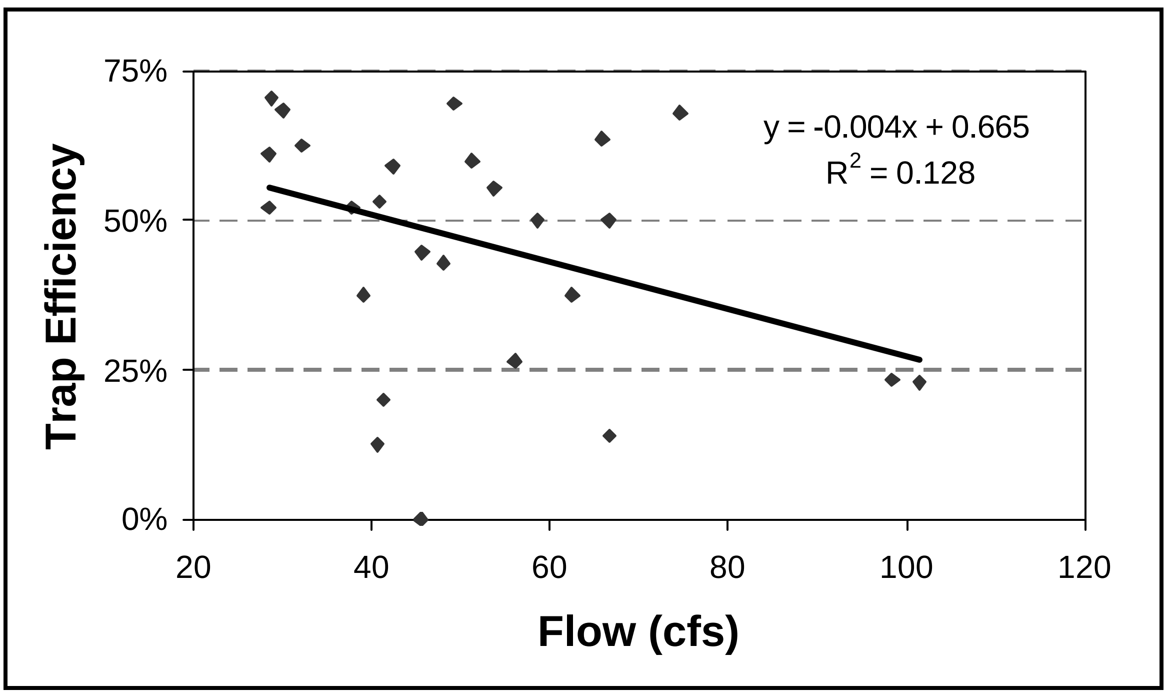

Figure 18. Linear regression analysis between chinook trap efficiency tests and daily mean flow, Bear Creek screw trap 2001.

Table 25. 2001 Bear Creek juvenile chinook production estimate and confidence intervals.

Gear	Period	Catch	Estimated Migration	95% CI Low	95% CI High	CV
Fry Trap	January 27 - April 9	63	419	382	456	4.5%
Screw Trap	April 10 - July 12	5,131	10,169	8,635	11,703	7.7%
	Total	5,194	10,588	9,054	12,122	7.4%

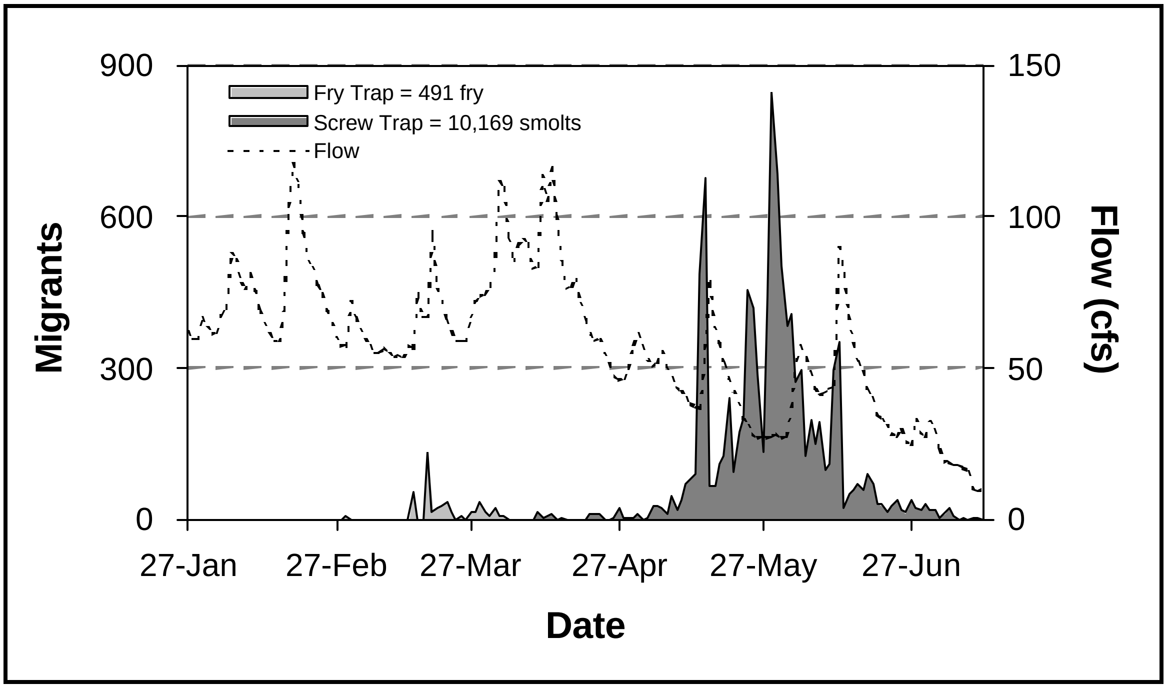

Figure 19. Estimated daily Bear Creek 0+ chinook migration from fry and screw trap estimates and flow, 2001.

The majority (96%) of juvenile chinook emigrated as smolts between May and June (Table 26). The extreme low flows of the season and the lack of rain allowed the fry to remain in the creek longer than in the previous two years. We estimate that the total migration was 25%, 50%, and 75% complete by May 20, May 29, and June 3, respectively (Figure 20).

Table 26. Comparison of fry and smolt components between years for wild chinook production standardized by assuming a January 24 to July 13 migration period, Bear Creek brood years 1998 to 2000.

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

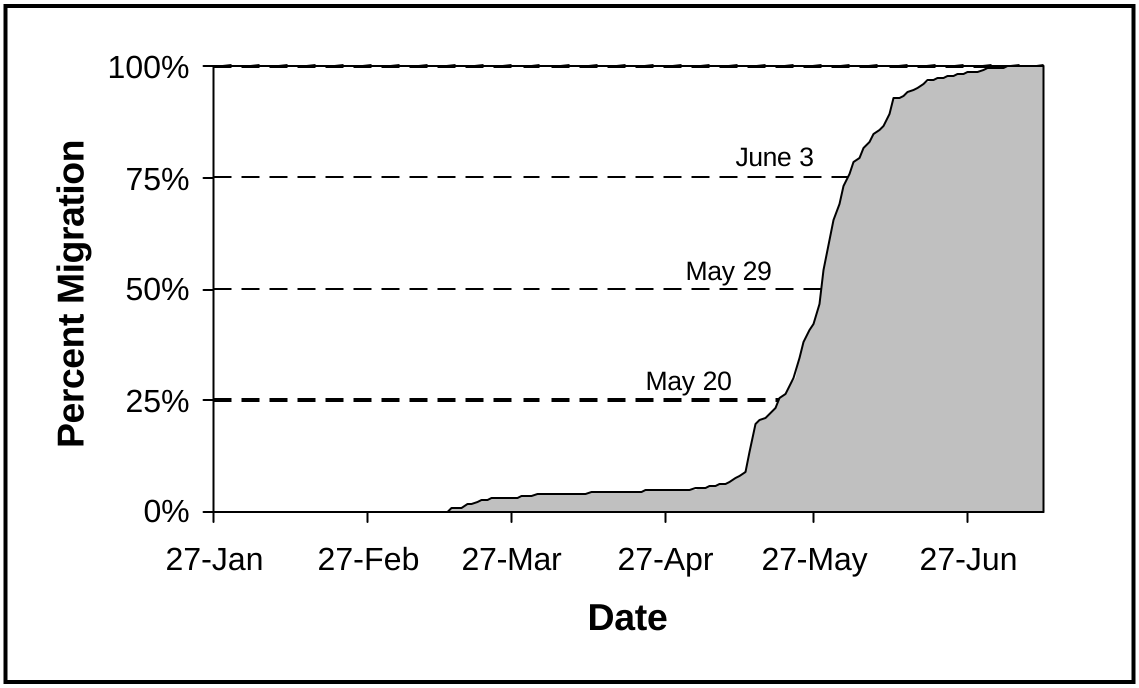

Figure 20. Cumulative percent migration of age 0+ chinook, Bear Creek 2001.

Egg-to-Migrant Survival

Relating our overall estimates of juvenile chinook emigrating from Bear Creek to respective estimates of egg deposition yields egg-to-migrant survival rates. For the 2000 brood, we estimated this survival rate at 1.8% based on an escapement of 133 females and an assumed average fecundity of 4,500 eggs per female (Table 27). While this rate is slightly lower than estimated for the previous two broods, a higher proportion of the production emigrated as smolts.

Table 27. Age 0+ chinook production and egg-to-migrant survival estimates for Bear Creek broods 1998 to 2000.

Brood Year	Estimated Migration	Estimated Females	Potential Egg Deposition	Production/ Female	Survival Rates
1998	15,002	159	715,500	94.4	2.1%
1999	32,220	293	1,318,500	110.0	2.4%
2000	10,588	133	598,500	79.6	1.8%

Coho

Catch

Over the screw trap season, April 10 through July 12, we captured a total of 6,617 wild coho smolts. Over 76% of this catch occurred between May 3 and May 24. Catches increased through April and peaked at 581 on May 14.

Throughout the trapping season, we tagged 1,011 wild and 12 hatchery coho smolts with PIT tags.

Size

Over the season, coho smolts averaged 116 mm fork length. Over the eight week migration, weekly mean size generally declined (Table 28, Figure 21).

Table 28. Weekly mean fork length, standard deviation, range, sample size and catches for wild coho from the Bear Creek screw trap, 2001.

Statistical Week			COHO					
					Range			
Begin	End	No.	Avg.	s.d.	Min	Max	n	Catch
04/09	04/15	15	128.6	8.9	107	142	11	9
04/16	04/22	16	123.8	10.7	105	148	29	38
04/23	04/29	17	121.7	10.8	95	146	113	263
04/30	05/06	18	116.1	9.5	101	133	38	1,005
05/07	05/13	19	117.9	10.2	99	146	104	2,361
05/14	05/20	20	108.7	10.8	81	137	120	1,425
05/21	05/27	21	107.8	11.0	87	132	26	833
05/28	06/03	22	111.1	9.4	97	126	14	358
06/04	06/10	23					0	223
06/11	06/17	24					0	62
06/18	06/24	25					0	27
06/25	07/01	26	164.0	48.1	130	198	2	10
07/02	07/08	27					0	3
07/09	07/15	28						0
		Totals	116.3	12.6	81	198	457	6,617

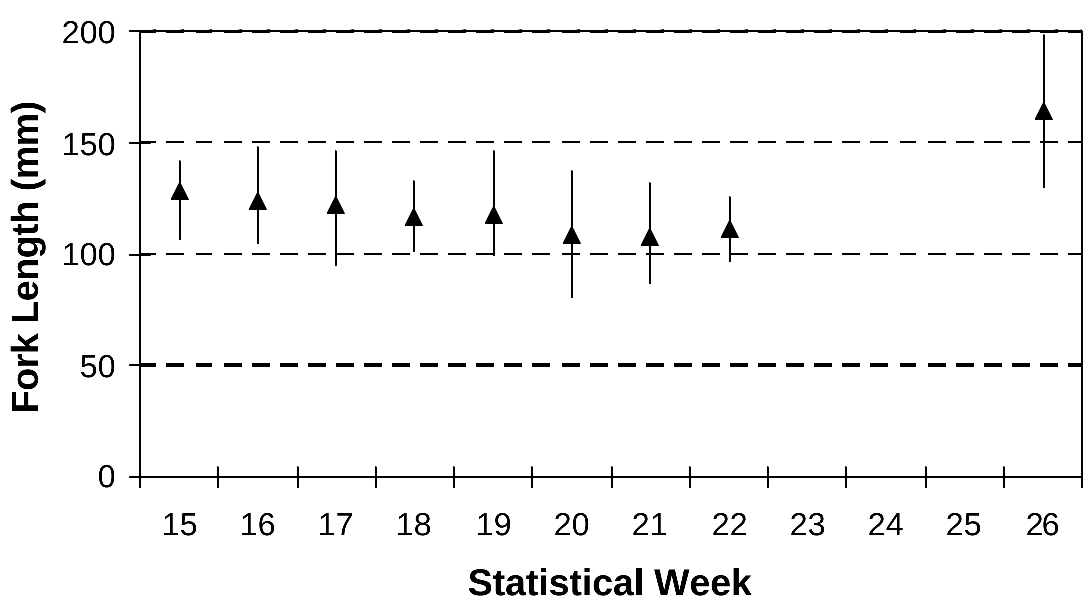

Figure 21. Weekly ranges and mean fork lengths for coho smolts captured in the Bear Creek screw trap, 2001.

Trap Efficiency

Thirty-nine mark-recapture tests were conducted to measure trap efficiency for coho. Recapture rates for individual groups ranged from 0% to 78.6% and averaged 32.6%. Capture rates were not significantly correlated with variation in flow ($p>0.05$) but were affected by the trap location. As flow declined, the rotation of the screw trap slowed and larger fish were observed swimming out of the trap. In order to maximize rotational speed, we adjusted the lateral position of the trap twice, on May 8 and May 23. Small release groups were combined with adjacent groups to create release groups of at least 40 fish. Average capture rates of the groups for each screw trap position were used to estimate daily migrations for respective trap positions (Table 29).

Table 29. Estimated coho smolt recapture rates from grouped screw trap efficiency tests by trap position, Bear Creek 2001.

Trap Position	Date(s)	Average Flow (cfs)	Number		Average Efficiency
			Released	Recaptured	
Original	04/21-04/25	59	68	17	25.0%
	04/26-04/27	48	44	6	13.6%
	04/28-04/29	49	57	14	24.6%
	04/30	72	60	14	23.3%
	05/01	66	99	24	24.2%
	05/03	54	53	11	20.8%
	05/05	66	75	17	22.7%
	05/06	59	100	22	22.0%
	05/07	53	100	6	6.0%
	Average				20.2%
	Variance				0.00045
1st Move	05/08	48	100	35	35.0%
	05/09	46	114	64	56.1%
	05/11	41	100	19	19.0%
	05/12	39	99	32	32.3%
	05/13	38	100	43	43.0%
	05/14	43	100	36	36.0%
	05/15-05/16	84	100	17	17.0%
	05/18	62	88	28	31.8%
	05/19	54	93	34	36.6%
	05/20	49	73	31	42.5%
	05/22	41	50	14	28.0%
	Average				34.3%
	Variance				0.00110
2nd Move	05/23-05/24	34	82	42	51.2%
	05/25-05/26	29	70	34	48.6%
	05/29-05/31	29	90	44	48.9%
	06/04	64	71	22	31.0%
	Average				44.9%
	Variance				0.00219

Total Production Estimate

Application of the average coho smolt trap efficiency for each position to respective catches estimates the production of coho at 21,665 smolts. Confidence intervals (95%) around this estimate range from 18,947 to 24,383 smolts and the coefficient of variation is 6.4% (Figure 22).

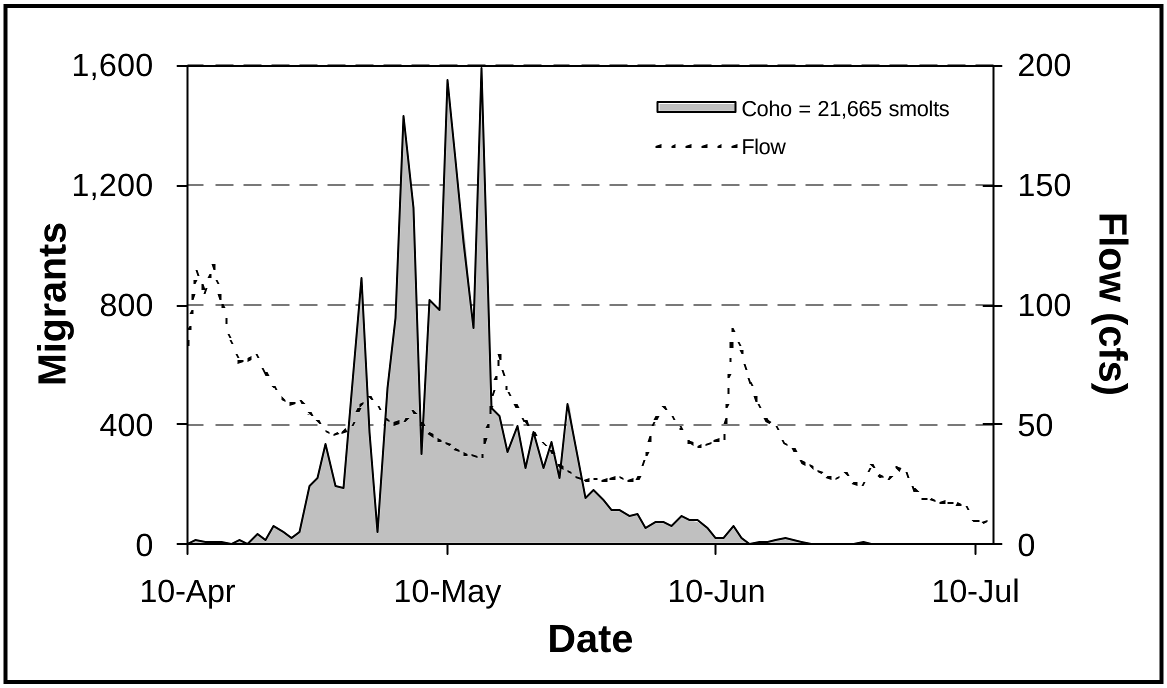

Figure 22. Estimate of daily coho smolt migration and flows, Bear Creek screw trap, 2001.

Steelhead and Cutthroat

Catch

Over the season, we caught 99 steelhead smolts of which 77 were ad-marked. Daily catch peaked on April 24, 26, and 29, with 12 steelhead caught on each day. We tagged three steelhead with PIT tags.

A total of 548 cutthroat trout were captured in the screw trap. The peak daily catch of 39 cutthroat occurred on April 25. After this date, cutthroat catches declined to low levels by early June.

Size

Over the season, steelhead smolt fork lengths averaged 213 mm and ranged from 160 to 280 mm (Table 30). Cutthroat trout fork lengths averaged 195 mm, and varied from 81 to 321 mm throughout the trapping season (Table 30).

Table 30. Weekly mean unmarked steelhead and cutthroat smolt fork lengths, standard deviations, ranges, sample sizes and catches, Bear Creek screw trap 2001.

Statistical Week			STEELHEAD						CUTTHROAT					
Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
04/09	04/15	15	230.7	26.1	210	260	3	3	200.7	24.7	132	260	30	31
04/16	04/22	16	250.0	42.4	220	280	2	2	207.0	35.0	133	280	18	21
04/23	04/29	17	201.5	24.5	160	227	6	10	208.0	33.8	160	321	38	121
04/30	05/06	18	210.7	19.9	189	228	3	3	183.2	25.9	125	228	15	90
05/07	05/13	19					1	2	167.8	30.7	105	224	11	110
05/14	05/20	20	236.0	n/a	236	236	1	1	158.5	109.6	81	236	2	42
05/21	05/27	21						0					0	47
05/28	06/03	22	192.0	n/a	192	192	1	1	192.0	n/a	192	192	1	44
06/04	06/10	23						0					0	28
06/11	06/17	24						0	81.0	n/a	81	81	1	11
06/18	06/24	25						0						0
06/25	07/01	26						0					0	3
07/02	07/08	27						0						0
07/09	07/15	28						0						0
		Totals	213.1	30.7	160	280	17	22	194.5	36.3	81	321	116	548

Trap Efficiency

As in the Cedar River, daily catches of steelhead and cutthroat trout were too low to use in mark-recapture trap efficiency experiments. Efficiency was estimated by applying the 60% average steelhead to coho capture rate, derived from the Toutle, Green, and White Salmon Rivers (refer to page 43), to the average coho smolt catch rates estimated for each screw trap position. By position, resulting capture rates were estimated at 12.1%, 20.6%, and 26.9%, respectively. These rates may underestimate the actual catch rates in the screw trap because the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape. Therefore, we selected to round trap efficiencies to values of 15%, 25%, and 30% for estimating steelhead and cutthroat migration from Bear Creek in 2001.

Total Production Estimate

Application of these catch rates to the actual catches during each trap position yields a total steelhead migration estimate of 619 steelhead smolts (Figure 23). Relating this estimate to the 6,650 hatchery steelhead fry released into Bear Creek in September 1999 estimates an average survival to smolt stage of 9.3%. This estimate assumes that the unmarked steelhead smolts were also from the hatchery release.

Total cutthroat migration during the trapping period is estimated at 2,869 smolts (Figure 24). To approximate the total cutthroat migration, we analyzed the timing data generated in 1999 and 2000 when we operated the screw trap from February to mid- July. In these two seasons, 30% and 36% of the migration occurred before April 10. Expanding by the average of these two seasons, 33% estimates that 1,413 cutthroat migrated before we began trapping in 2001. Addition of this estimate yields a total cutthroat migration of 4,282 for 2001.

Given the assumption used to estimate capture rate, we did not calculate confidence intervals for these estimates.

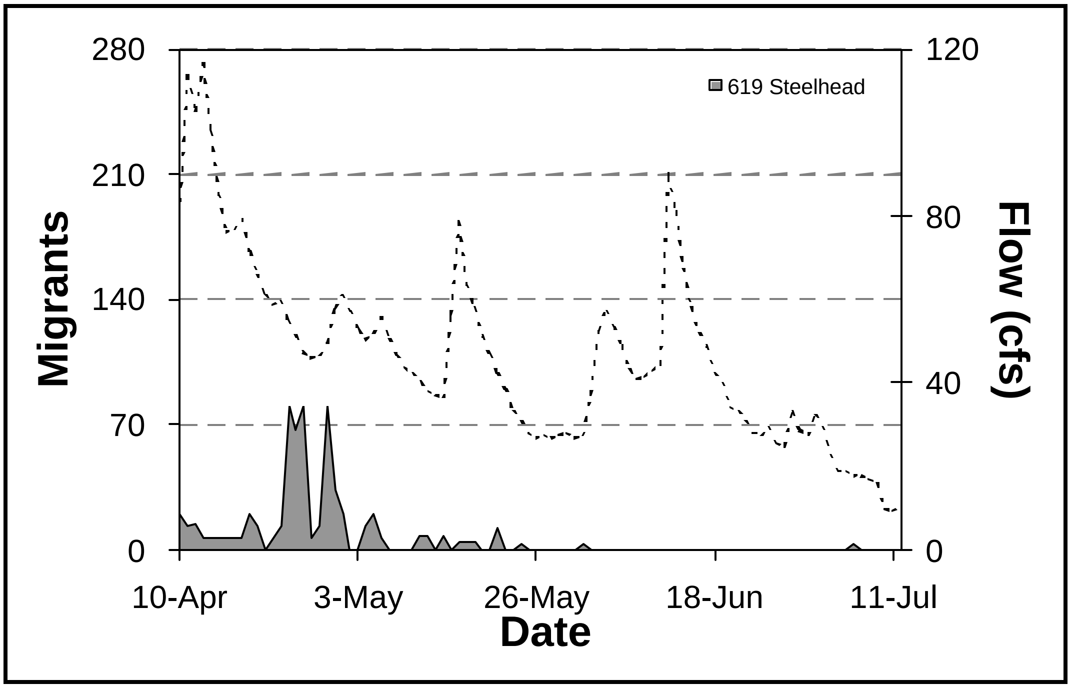

Figure 23. Estimated daily steelhead migration and flow, Bear Creek screw trap 2001.

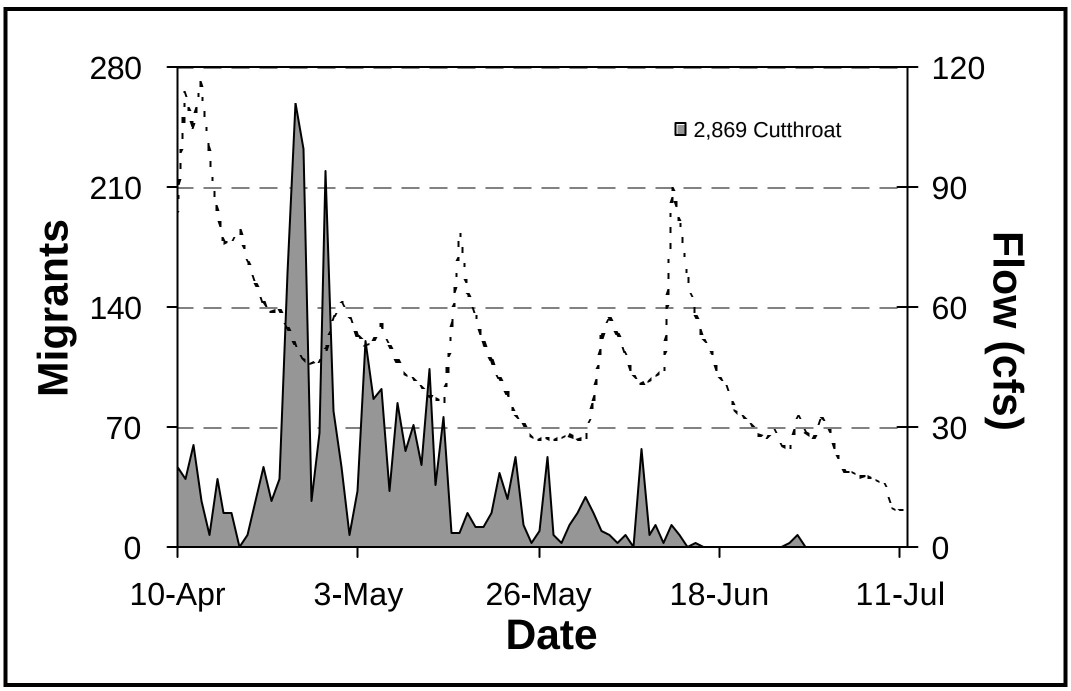

Figure 24. Estimated daily cutthroat migration and flow, Bear Creek screw trap 2001.

Mortality

Three chinook mortalities occurred during fry trap operation. One chinook was dead upon entering the trap, and another had predator bite marks. During screw trap operation, mortalities included 11 chinook 0+, one coho fry, five coho smolts, and two cutthroat smolts.

Mortality also occurred as a result of applying passive integrated transponder (PIT) tags to chinook and coho smolts. Mortality was estimated by holding sample groups for 24-hours. In total, we estimate that 54 chinook and 35 coho mortalities occurred from the PIT tagging process.

Incidental Species

In addition to the four species discussed above, in the fry trap we also caught one wild chinook age 1+, eight coho fry, nine coho smolts, 33 age 1+ and six adult cutthroat trout. In the screw trap we also caught nine wild and one hatchery chinook age 1+, 137 coho fry, 114 hatchery coho smolts, and seven cutthroat adults. Non-salmonid species caught included three-spine sticklebacks, sculpin, large-scale suckers, pea-mouth, sunfish, pumpkinseeds, and lamprey.

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Appendix A:

Daily Estimated Cedar River Wild and Hatchery
Sockeye Fry Migration into Lake Washington, 2001

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2001.

Date	Actual Catch	Flow (cfs)	Trap Efficiency	HATCHERY RELEASES Landsburg	Riviera	Below Trap	Daily Migration Wild	Hatchery
01/18	3,834	363	10.4%				36,909	0
01/19		358					35,365	0
01/20	3,511	354	10.4%				33,802	0
01/21	7,337	398	10.4%				70,634	0
01/22	9,459	390	10.4%	79,000			71,612	19,418
01/23		371					76,656	22,186
01/24	8,484	364	10.4%				81,681	0
01/25		357					89,017	0
01/26	10,008	348	10.4%				96,353	0
01/27	6,932	348	10.4%				66,741	0
01/28	6,531	349	10.4%				62,925	0
01/29	8,723	358	10.4%	193,000			68,889	15,122
01/30	7,419	349	10.4%			367,000	39,508	398,894
01/31	18,045	345	10.4%				173,738	0
02/01	13,315	338	10.4%			535,000	128,198	535,000
02/02	24,550	357	10.4%				236,365	0
02/03	17,667	354	10.4%				170,161	0
02/04	43,165	451	10.4%				415,732	0
02/05	32,438	427	10.4%	380,000		288,000	181,141	419,171
02/06	25,837	390	10.4%			654,000	212,277	690,477
02/07	8,518	377	10.4%	307,000			73,262	8,755
02/08	11,535	382	10.4%			550,000	94,022	567,030
02/09	19,138	379	10.4%				184,478	0
02/10	16,387	369	10.4%				158,031	0
02/11	16,698	365	10.4%				160,821	0
02/12	11,973	360	10.4%			559,000	115,358	559,000
02/13	17,989	354	10.4%				173,258	0
02/14	51,362	342	10.4%		560,000		124,257	369,627
02/15	29,453	343	10.4%	61,000	293,000		75,640	208,029
02/16	78,793	371	10.4%		615,000		263,445	496,521
02/17	28,000	371	10.4%				269,899	0
02/18	67,112	370	10.4%				647,197	0
02/19	65,109	362	10.4%				627,328	0
02/20	55,749	351	10.4%				536,738	0
02/21	131,322	348	10.4%		638,000		676,146	588,194
02/22	89,480	347	10.4%	213,000		388,000	815,545	433,942
02/23	99,878	340	10.4%		309,000	322,000	661,379	623,792
02/24	111,904	342	10.4%	64,000		396,000	1,079,949	396,000
02/25	96,819	338	10.4%				906,413	24,836
02/26	64,733	335	10.4%	361,000		282,000	523,917	381,795
02/27	58,589	339	10.4%			640,000	546,299	658,709
02/28	16,059	381	10.4%	273,000		294,000	438,362	325,622
03/01	83,277	422	10.4%			532,000	767,122	568,129
03/02	74,767	393	10.4%				721,369	0
03/03	45,404	364	10.4%				606,893	0
03/04	37,586	358	10.4%				362,828	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2001 (cont'd.).

Date	Actual Catch	Flow (cfs)	Trap Efficiency	HATCHERY RELEASES Landsburg	Riviera	Below Trap	Daily Migration Wild	Hatchery
03/05	124,359	369	10.4%			414,000	1,199,258	414,000
03/06	130,237	351	10.4%		553,000		1,108,515	147,425
03/07	135,308	349	10.4%		598,000		1,018,808	287,361
03/08	127,596	353	10.4%		653,000		549,981	681,315
03/09	105,836	364	10.4%		648,000		513,503	507,980
03/10	54,104	350	10.4%	614,000			476,537	45,223
03/11	48,971	339	10.4%				434,469	37,782
03/12	77,542	340	10.4%				747,778	0
03/13	106,019	348	10.4%			637,000	1,023,430	637,000
03/14	60,648	347	10.4%				585,451	0
03/15	82,197	363	10.4%			672,000	793,931	672,000
03/16	36,284	416	10.4%				349,902	0
03/17	47,911	365	10.4%				462,028	0
03/18	46,146	440	10.4%				734,804	0
03/19	41,202	882	4.6%				1,283,012	0
03/20	77,938	515	7.5%				1,051,625	0
03/21	82,603	402	9.1%	665,000			727,962	182,004
03/22	44,583	420	9.1%			582,000	425,650	647,483
03/23	57,199	465	9.1%		284,000	280,000	361,262	548,213
03/24	27,015	385	9.1%				297,595	0
03/25	39,305	394	9.1%				433,234	0
03/26	41,906	402	9.1%				462,189	0
03/27	13,847	396	9.1%				152,721	0
03/28	25,520	402	9.1%			357,000	281,126	357,000
03/29	15,206	384	9.1%				167,516	0
03/30	29,683	379	9.1%				326,988	0
03/31	30,849	394	9.1%				339,835	0
04/01	28,975	403	9.1%				319,569	0
04/02	20,569	440	9.1%				227,013	0
04/03	25,891	428	9.1%				285,219	0
04/04	23,367	405	9.1%				257,719	0
04/05	26,077	397	9.1%			39,000	287,615	39,000
04/06	24,297	471	9.1%				267,983	0
04/07	19,585	481	9.1%				216,497	0
04/08	34,529	478	9.1%				380,828	0
04/09	11,489	470	9.1%				126,797	0
04/10	25,476	525	7.5%				344,657	0
04/11	23,288	569	7.5%				314,821	0
04/12	15,591	525	7.5%				210,716	0
04/13	16,667	506	7.5%				225,152	0
04/14	19,638	493	9.1%				216,901	0
04/15	18,098	453	9.1%				200,060	0
04/16	31,508	389	9.1%				348,010	0
04/17	26,510	407	9.1%				292,923	0
04/18	26,873	396	9.1%				296,818	0
04/19	20,309	383	9.1%				224,310	0

Appendix A. Daily estimated Cedar River wild and hatchery sockeye fry migration into Lake Washington, 2001 (cont'd.).

Date	Actual Catch	Flow (cfs)	Trap Efficiency	HATCHERY RELEASES Landsburg	Riviera	Below Trap	Daily Migration Wild	Hatchery
04/20	20,254	373	9.1%				223,708	0
04/21	9,074	368	9.1%				100,610	0
04/22	7,566	366	9.1%				83,637	0
04/23	12,150	365	9.1%				134,304	0
04/24	18,019	360	9.1%				199,185	0
04/25	19,559	357	9.1%				216,212	0
04/26	15,345	349	9.1%				169,704	0
04/27	9,691	349	9.1%				107,220	0
04/28	11,516	364	9.1%				127,497	0
04/29	6,865	378	9.1%				75,890	0
04/30	13,487	519	7.5%				182,194	0
05/01		589					142,600	0
05/02	7,600	645	7.5%				102,992	0
05/03		693					92,350	0
05/04	6,026	681	7.5%				81,694	0
05/05		649					70,502	0
05/06	4,380	560	7.5%				59,310	0
05/07		538					51,175	0
05/08	3,171	459	9.1%				35,116	0
05/09		419					34,667	0
05/10	3,092	412	9.1%				34,208	0
05/11		404					22,991	0
05/12	1,061	368	9.1%				11,753	0
05/13		356					37,491	0
05/14	5,708	387	9.1%				63,218	0
05/15		735					87,883	0
05/16		950					50,563	0
05/17	606	996	4.6%				13,285	0
05/18	2,415	808	4.6%				52,968	0
05/19	1,181	671	7.5%				16,017	0
05/20		640					16,004	0
05/21		618					15,990	0
05/22		525					15,977	0
05/23		473					13,033	0
05/24	1,174	431	9.1%				13,000	0
05/25		379					10,188	0
05/26		354					7,376	0
05/27	412	371	9.1%				4,563	0
05/28		383					5,023	0
05/29		393					5,482	0
05/30	535	353	9.1%				5,931	0
05/31		329					4,115	0
06/01	207	319	9.1%				2,298	0
06/02		340					2,320	0
06/03	210	405	9.1%				2,331	0
TOTAL	3,964,944			3,210,000	5,151,000	8,788,000	38,114,953	13,514,036

Appendix B:

Estimated Chinook, Coho, Steelhead and Cutthroat
Smolt Daily Migrations, Cedar River 2001

Appendix B. Estimated chinook, coho, steelhead and cutthroat smolt daily migrations, Cedar River 2001.

Date	Flow (cfs)	Chinook		Coho	Steelhead	Cutthroat
		Scoop	Screw			
01/18	363	0				
01/19	358	0				
01/20	354	0				
01/21	398	0				
01/22	390	0				
01/23	371	0				
01/24	364	0				
01/25	357	0				
01/26	348	0				
01/27	348	38				
01/28	349	0				
01/29	358	0				
01/30	349	0				
01/31	345	10				
02/01	338	0				
02/02	357	0				
02/03	354	0				
02/04	451	221				
02/05	427	38				
02/06	390	211				
02/07	377	67				
02/08	382	10				
02/09	379	86				
02/10	369	77				
02/11	365	48				
02/12	360	67				
02/13	354	144				
02/14	342	10				
02/15	343	48				
02/16	371	48				
02/17	371	0				
02/18	370	77				
02/19	362	125				
02/20	351	77				
02/21	348	10				
02/22	347	259				
02/23	340	115				
02/24	342	336				
02/25	338	432				
02/26	335	259				
02/27	339	288				
02/28	350	259				
03/01	422	355				
03/02	393	134				
03/03	364	221				

Appendix B. Estimated chinook, coho, steelhead and cutthroat smolt daily migrations, Cedar River 2001 (cont'd.).

Date	Flow (cfs)	Chinook Scoop	Chinook Screw	Coho	Steelhead	Cutthroat
03/04	358	19				
03/05	369	153				
03/06	351	153				
03/07	349	125				
03/08	353	29				
03/09	364	29				
03/10	350	19				
03/11	339	0				
03/12	340	10				
03/13	348	125				
03/14	347	153				
03/15	363	326				
03/16	416	105				
03/17	365	38				
03/18	440	479				
03/19	882	3,966				
03/20	515	322				
03/21	402	153				
03/22	420	372				
03/23	465	88				
03/24	385	22				
03/25	394	0				
03/26	402	22				
03/27	396	22				
03/28	402	0				
03/29	384	0				
03/30	379	11				
03/31	394	0				
04/01	403	11				
04/02	440	0				
04/03	428	0				
04/04	405	0				
04/05	397	0				
04/06	471	0				
04/07	481	11				
04/08	478	0				
04/09	470	0	35	219	20	40
04/10	525	121	28	323	20	120
04/11	569	40	98	555	40	160
04/12	525	54	0	323	20	160
04/13	506	13	0	310	20	40
04/14	493	11	0	245	0	80
04/15	453	0	0	181	0	40
04/16	389	0	0	194	0	40
04/17	407	0	7	439	0	100

Appendix B. Estimated chinook, coho, steelhead and cutthroat smolt daily migrations, Cedar River 2001 (cont'd.).

Date	Flow (cfs)	Chinook		Coho	Steelhead	Cutthroat
		Scoop	Screw			
04/18	396	0	0	568	0	20
04/19	383	0	0	439	0	0
04/20	373	11	0	877	0	40
04/21	368	0	7	477	0	0
04/22	366	0	0	348	20	40
04/23	365	0	14	503	0	20
04/24	360	0	0	826	0	0
04/25	357	0	21	877	0	0
04/26	349	0	21	942	0	0
04/27	349	0	7	645	0	0
04/28	364	0	56	1,561	20	60
04/29	378	0	182	3,496	20	0
04/30	519	67	301	5,135	480	60
05/01	589	54	49	2,838	80	80
05/02	645	40	112	3,987	100	60
05/03	693	13	154	2,077	40	60
05/04	681	0	63	929	0	20
05/05	649	0	35	1,006	60	20
05/06	560	0	112	1,342	40	20
05/07	538	0	98	1,419	40	40
05/08	459	0	91	1,458	20	60
05/09	419	0	147	1,484	60	40
05/10	412	0	126	1,935	0	40
05/11	404	0	168	2,335	20	60
05/12	368	0	21	1,651	40	0
05/13	356	0	28	1,290	40	0
05/14	387	0	819	6,851	40	0
05/15	735	43	322	5,380	180	0
05/16	950	43	70	1,806	20	0
05/17	996	65	147	5,070	40	0
05/18	808	0	329	1,768	20	40
05/19	671	13	791	2,013	20	60
05/20	640	0	385	2,671	40	80
05/21	618	0	203	1,393	60	20
05/22	525	0	49	1,148	20	20
05/23	473	0	168	993	0	20
05/24	431	0	504	877	0	0
05/25	379	0	462	813	20	0
05/26	354	0	553	606	20	0
05/27	371	0	574	903	40	20
05/28	383	0	2,017	968	20	20
05/29	393	0	1,057	684	0	0
05/30	353	0	1,156	916	20	20
05/31	329	0	294	348	20	60
06/01	319	0	826	335	0	40

Appendix B. Estimated chinook, coho, steelhead and cutthroat smolt daily migrations, Cedar River 2001 (cont'd.).

Date	Flow (cfs)	Chinook Scoop	Chinook Screw	Coho	Steelhead	Cutthroat
06/02	340	0	959	374	0	60
06/03	405	0	1,043	555	0	40
06/04	372		518	155	0	20
06/05	336		378	65	0	0
06/06	336		623	26	0	20
06/07	325		119	65	20	0
06/08	311		56	65	0	20
06/09	339		168	52	0	0
06/10	340		329	39	0	0
06/11	529		1,702	271	0	0
06/12	690		644	65	0	20
06/13	705		140	13	0	0
06/14	575		84	0	0	40
06/15	461		91	65	0	140
06/16	444		224	26	0	40
06/17	427		105	26	0	0
06/18	411		182	0	0	20
06/19	371		91	0	0	0
06/20	345		70	0	0	40
06/21	331		70	26	0	40
06/22	316		56	0	0	0
06/23	312		77	13	0	0
06/24	323		91	13	0	0
06/25	321		21	0	0	0
06/26	315		14	0	0	0
06/27	341		7	0	0	0
06/28	491		196	13	0	0
06/29	493		49	0	0	20
06/30	357		63	0	0	100
07/01	304		42	13	0	20
07/02	285		49	13	20	0
07/03	281		42	0	0	20
07/04	277		28	13	0	0
07/05	275		21	0	20	0
07/06	275		42	0	0	0
07/07	267		49	0	0	0
07/08	257		42	0	0	0
07/09	246		49	0	0	0
07/10	236		35	0	0	0
07/11	228		28	0	0	0
07/12	219		7	0	20	20
07/13	205		7	13	0	0
07/14	197		0	0	0	0
07/15	197		28	0	0	0
07/16	311		14	0	0	0

Appendix B. Estimated chinook, coho, steelhead and cutthroat smolt daily migrations, Cedar River 2001 (cont'd.).

Date	Flow (cfs)	Chinook		Coho	Steelhead	Cutthroat
		Scoop	Screw			
07/17	286		21	0	0	20
07/18	219		14	13	0	40
07/19	250		7	0	0	0
07/20	267		7	0	0	0
07/21	263		7	13	0	20
07/22	262		0	13	0	0
TOTAL		11,421	21,416	80,795	1,860	2,680

Appendix C:

Estimated Juvenile Sockeye, Chinook, Coho, Steelhead and Cutthroat Daily Migrations, Bear Creek 2001

Appendix C. Estimated juvenile sockeye, chinook, coho, steelhead and cutthroat daily migrations, Bear Creek 2001.

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
FRY TRAP						
01/27	61.9	120	0			
01/28	59.5	333	0			
01/29	59.5	545	0			
01/30	66.6	479	0			
01/31	63.4	406	0			
02/01	61.1	505	0			
02/02	61.9	605	0			
02/03	68.2	1,224	0			
02/04	69.7	1,842	0			
02/05	87.6	1,782	0			
02/06	85.9	1,716	0			
02/07	77.8	1,244	0			
02/08	76.2	771	0			
02/09	81.0	632	0			
02/10	75.3	492	0			
02/11	69.0	412	0			
02/12	65.0	333	0			
02/13	61.1	299	0			
02/14	58.8	266	0			
02/15	58.8	718	0			
02/16	69.0	1,164	0			
02/17	103.5	1,955	0			
02/18	117.3	2,740	0			
02/19	110.4	2,614	0			
02/20	94.2	2,487	0			
02/21	85.1	2,514	0			
02/22	83.5	2,541	0			
02/23	77.0	2,840	0			
02/24	74.5	3,133	0			
02/25	69.0	2,707	0			
02/26	65.0	2,281	0			
02/27	60.3	1,869	0			
02/28	57.2	1,403	0			
03/01	57.2	16,640	7			
03/02	72.1	3,192	0			
03/03	66.6	2,614	0			
03/04	62.7	572	0			
03/05	59.5	1,403	0			
03/06	57.2	2,228	0			
03/07	54.9	738	0			
03/08	54.9	1,018	0			
03/09	56.5	2,068	0			
03/10	54.9	1,516	0			
03/11	53.4	885	0			

Appendix C. Estimated juvenile sockeye, chinook, coho, steelhead and cutthroat daily migrations, Bear Creek 2001 (cont'd.).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
FRY TRAP						
03/12	54.2	1,403	0			
03/13	53.4	16,953	0			
03/14	57.2	8,972	0			
03/15	56.5	271,084	53			
03/16	74.5	14,658	0			
03/17	66.6	3,305	0			
03/18	66.6	376,432	133			
03/19	95.1	176,098	13			
03/20	76.2	126,218	20			
03/21	72.1	123,770	27			
03/22	65.8	95,565	33			
03/23	61.9	51,676	13			
03/24	58.8	27,215	0			
03/25	58.8	11,486	7			
03/26	58.8	92,100	0			
03/27	66.6	112,378	13			
03/28	72.1	167,745	13			
03/29	73.7	23,710	33			
03/30	74.5	27,361	13			
03/31	77.0	18,157	7			
04/01	81.8	98,930	20			
04/02	111.2	44,474	7			
04/03	109.5	68,908	7			
04/04	92.6	17,658	0			
04/05	85.1	12,597	0			
04/06	90.9	7,901	0			
04/07	92.6	6,717	0			
04/08	90.9	13,807	0			
04/09	82.7	3,405	0			
SCREW TRAP						
04/10	83.5	60,156	16	0	20	47
04/11	113.8	20,243	4	15	13	40
04/12	105.2	25,192	6	10	14	60
04/13	116.4	3,226	8	10	7	27
04/14	100.1	1,378	0	10	7	7
04/15	85.1	3,742	4	5	7	40
04/16	76.2	4,915	0	15	7	20
04/17	77.0	5,585	0	5	7	20
04/18	79.4	5,551	0	40	7	0
04/19	71.3	2,752	0	15	20	7
04/20	65.8	1,125	0	64	13	27
04/21	61.1	1,072	8	44	0	47
04/22	58.8	536	10	25	7	27
04/23	59.5	148	10	44	13	40

Appendix C. Estimated juvenile sockeye, chinook, coho, steelhead and cutthroat daily migrations, Bear Creek 2001 (cont'd.).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
SCREW TRAP						
04/24	54.9	732	0	207	80	160
04/25	51.1	388	0	232	67	260
04/26	47.4	191	2	356	80	233
04/27	45.9	53	20	207	7	27
04/28	46.7		4	198	13	67
04/29	49.6		2	529	80	220
04/30	58.0		2	943	33	80
05/01	61.1		8	400	20	47
05/02	57.2		0	44	0	7
05/03	52.7		2	553	0	33
05/04	50.4		24	800	13	120
05/05	51.9		24	1,512	20	87
05/06	55.7		20	1,186	7	93
05/07	50.4		8	321	0	33
05/08	46.7		44	872	0	84
05/09	43.7		18	831	0	56
05/10	42.2		36	1,650	0	72
05/11	40.1		69	1,364	8	48
05/12	37.9		81	1,073	8	104
05/13	37.2		89	770	0	36
05/14	36.5		487	1,694	8	76
05/15	56.5		674	484	0	8
05/16	78.6		65	458	4	8
05/17	63.4		65	332	4	20
05/18	58.0		109	420	4	12
05/19	51.1		127	271	0	12
05/20	46.7		240	399	0	20
05/21	42.2		95	271	12	44
05/22	38.6		174	364	0	28
05/23	33.0		200	216	0	53
05/24	30.9		454	450	3	13
05/25	28.1		418	283	0	3
05/26	26.8		289	147	0	10
05/27	27.5		131	178	0	53
05/28	26.8		444	145	0	7
05/29	27.5		848	114	0	3
05/30	28.1		684	111	0	13
05/31	26.8		501	91	0	20
06/01	27.5		384	100	3	30
06/02	37.2		408	53	0	20
06/03	52.7		271	71	0	10
06/04	57.2		297	71	0	7
06/05	53.4		125	58	0	3
06/06	48.9		198	89	0	7

Appendix C. Estimated juvenile sockeye, chinook, coho, steelhead and cutthroat daily migrations, Bear Creek 2001 (cont'd.).

Date	Flow (cfs)	Sockeye	Chinook	Coho	Steelhead	Cutthroat
SCREW TRAP						
06/07	43.0		149	80	0	0
06/08	40.8		194	76	0	57
06/09	41.5		97	53	0	7
06/10	43.0		109	24	0	13
06/11	44.4		295	22	0	3
06/12	90.1		351	60	0	13
06/13	81.0		20	22	0	7
06/14	67.4		50	0	0	0
06/15	58.0		57	11	0	3
06/16	51.9		71	7	0	0
06/17	48.9		59	13	0	0
06/18	42.2		89	18	0	0
06/19	40.1		71	13	0	0
06/20	34.4		30	11	0	0
06/21	33.0		28	4	0	0
06/22	30.9		14	0	0	0
06/23	28.1		24	2	0	0
06/24	27.5		36	4	0	0
06/25	29.5		18	2	0	0
06/26	25.4		12	4	0	0
06/27	24.8		36	9	0	3
06/28	33.0		22	0	0	7
06/29	28.8		18	2	0	0
06/30	27.5		30	2	0	0
07/01	32.3		18	2	0	0
07/02	29.5		18	0	0	0
07/03	22.8		4	0	0	0
07/04	18.9		8	2	0	0
07/05	18.9		20	2	0	0
07/06	17.7		6	0	3	0
07/07	17.7		0	0	0	0
07/08	17.0		4	0	0	0
07/09	15.8		0	0	0	0
07/10	9.9		2	0	0	0
07/11	9.3		2	0	0	0
07/12	9.9		0	0	0	0
TOTAL		2,235,514	10,588	21,665	619	2,869