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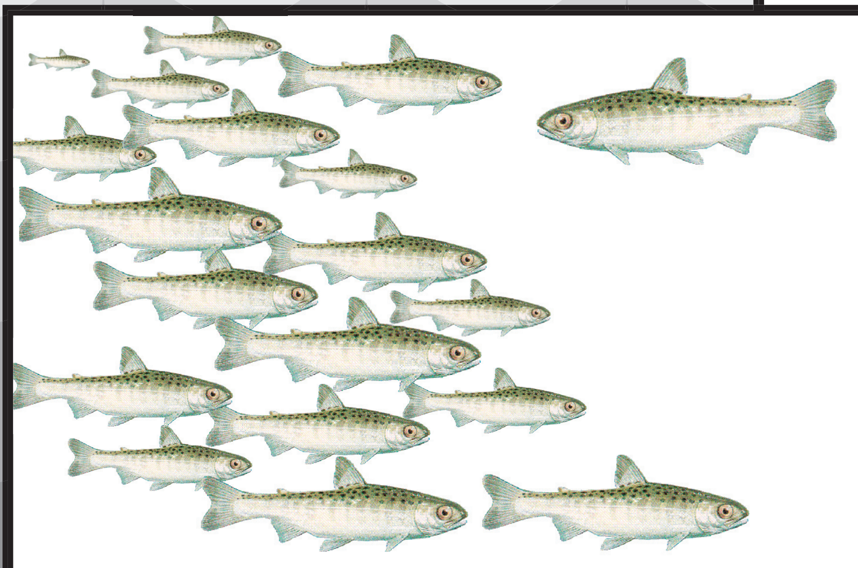
Evaluation of Downstream Migrant Salmon Production in 2006 from the Cedar River and Bear Creek



by Kelly Kiyohara and Greg Volkhardt

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Evaluation of Downstream Migrant Salmon Production in 2006 from the Cedar River and Bear Creek

Kelly Kiyohara
Greg Volkhardt

Washington Department of Fish and Wildlife
Olympia, Washington 98501-1091

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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 6.6 million sockeye fry into the Cedar River. Escapement data were collected and estimates were developed by a number of individuals representing several agencies: Steve Foley and Larry Lowe, WDFW; Mike Leslie and Brian Footen, Muckelshoot Tribe; Karl Burton, SPU; and Hans Berge and Mistie Hammer, King County DNRP. WDFW Scientific Technicians Paul Lorenz, Dan Estelle, and Kelsey Kropp worked long hours, usually at night, operating the traps, marking, identifying and counting fish. WDFW Biologists Mike Ackley and Pete Topping provided valuable experience and logistical support. Paul Faulds provided project management for SPU.

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 2006 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 2006, was expanded in 1999 with the addition of a second downstream migrant trap to estimate the production of juvenile Chinook salmon. With this trap, the production of coho, steelhead and cutthroat smolts were also estimated.

In addition to the Cedar River, downstream migrant production is also measured in the Sammamish basin. A trap was operated in the Sammamish River in 1997 and 1998 to estimate sockeye fry production. This monitoring program was moved to Bear Creek in 1999 to concurrently assess Chinook and sockeye production. Since 1999, as in the Cedar River, this trapping operation has also estimated the populations of coho, steelhead and cutthroat smolts.

Cedar River

Declining adult sockeye salmon returns in the late 1980s and early 1990s prompted an effort to investigate causes for this decline. To determine which life-stages were experiencing poor survival, an evaluation of fry production was undertaken in the Cedar River beginning in 1992. Assessing the sockeye population, at this location and life-stage, separates freshwater production into river and lake components. This report documents our evaluation during 2006, the fifteenth year of this project. The primary study goal was to estimate the season total migration of naturally-produced (wild) Cedar River sockeye fry into Lake Washington. This estimate enables calculation of a survival rate for wild spawners from egg deposition to lake entry, and for production components from lake entry to subsequent life stages of smolts and adults.

Beginning in January and continuing through late May, a floating inclined-plane screen (fry) trap located at river mile (R.M.) 0.7 in the Cedar River was operated to capture a portion of the sockeye fry migrating into Lake Washington (Figure 1). Had the trap fished continuously from January 20 through May 27, total catch was estimated at 665,397 sockeye. Trap efficiency was estimated by releasing dye-marked fry upstream of the trap on 43 nights during trapping season. Capture rates ranged from 1.4% to 11%. Total migration for 2006 was estimated at 10.8 million wild sockeye fry. Survival of wild fry from egg deposition to lake entry was estimated at 13.9%. This rate is the ratio of 10.8 million wild fry to an estimated deposition of 78 million eggs.

Over the season, 6.6 million hatchery produced sockeye fry were released into the Cedar River from three locations. A portion of these fry (2.0 million) was released below the fry trap at the Cedar River Trail Park. Survival of hatchery fry released at the Cedar River Trail Park was assumed to be 100%. The remaining 4.6 million fry were released at two different sites upstream of the trap, 2.8 million released at R.M. 13.5 and 1.8 million released at R.M. 24. Survival of the fry released above the trap was estimated using four different approaches and ranged from 12.7% to 104%. We estimated 2.2 million survived to the trap. With the addition of hatchery sockeye fry, we estimate a total of 15.1 million sockeye fry entered Lake Washington in 2006.

Median migration timing for wild fry in 2006 was only two days earlier than average. February stream temperatures averaged 6.3° C in 2006, slightly warmer than the 12-year average (6.1° C), which in turn produced a median migration date fairly close to the 12-year average median migration date. The median migration date for wild fry was March 20, 25 days later than that of the hatchery fry. This difference was only one day longer than average.

In response to the listing of the Puget Sound Chinook Evolutionary Significant Unit (ESU) under the Endangered Species Act as a threatened species, the existing sockeye fry monitoring program was expanded in 1999 to include an assessment of the wild Chinook production in the Cedar River. The gear operated each year, starting in January, to assess sockeye fry production also captures Chinook fry. To capture the larger, later migrating Chinook smolts, a screw trap was installed at R.M. 0.9 in mid-April, and operated through July. Total catch was estimated at 2,917 Chinook fry. From the start of the season in January through the end of April, mark-recapture data generated with releases of marked sockeye were used to estimate fry trap efficiencies for Chinook migrants. Abundance was estimated at 94,601 Chinook for the period of January 1 through April 30.

Chinook catch from the screw trap totaled 830 smolts. Screw trap efficiency was estimated by releasing groups of fin-marked or PIT tagged Chinook smolts above the trap. Capture rates ranged from 3.1% to 8.4%. Total migration from May 1 through July 16 was estimated at 18,592 Chinook smolts.

Age 0+ Chinook production from the Cedar River was estimated at 117,559 in 2006. Timing was bi-modal with fry emigrating in January through late-April comprising 84% of the total migration. Egg-to-migrant survival was estimated at 7.8%. Over the season, age 0+ Chinook increased in size from less than 34 mm in January to 116 mm by mid-June.

Over the season, based on actual catch and estimates of capture rates we estimated the migrations of coho, steelhead[1] and cutthroat smolts at 38,023, 267, and 2,000, respectively.

[1] We are uncertain if the downstream migrant rainbow trout referred to as steelhead follow an anadromous (saltwater rearing) or ad-fluvial (lake rearing) life history strategy. They are referred to as steelhead in this report since they appear identical to smolted juvenile steelhead from other rivers in western Washington.

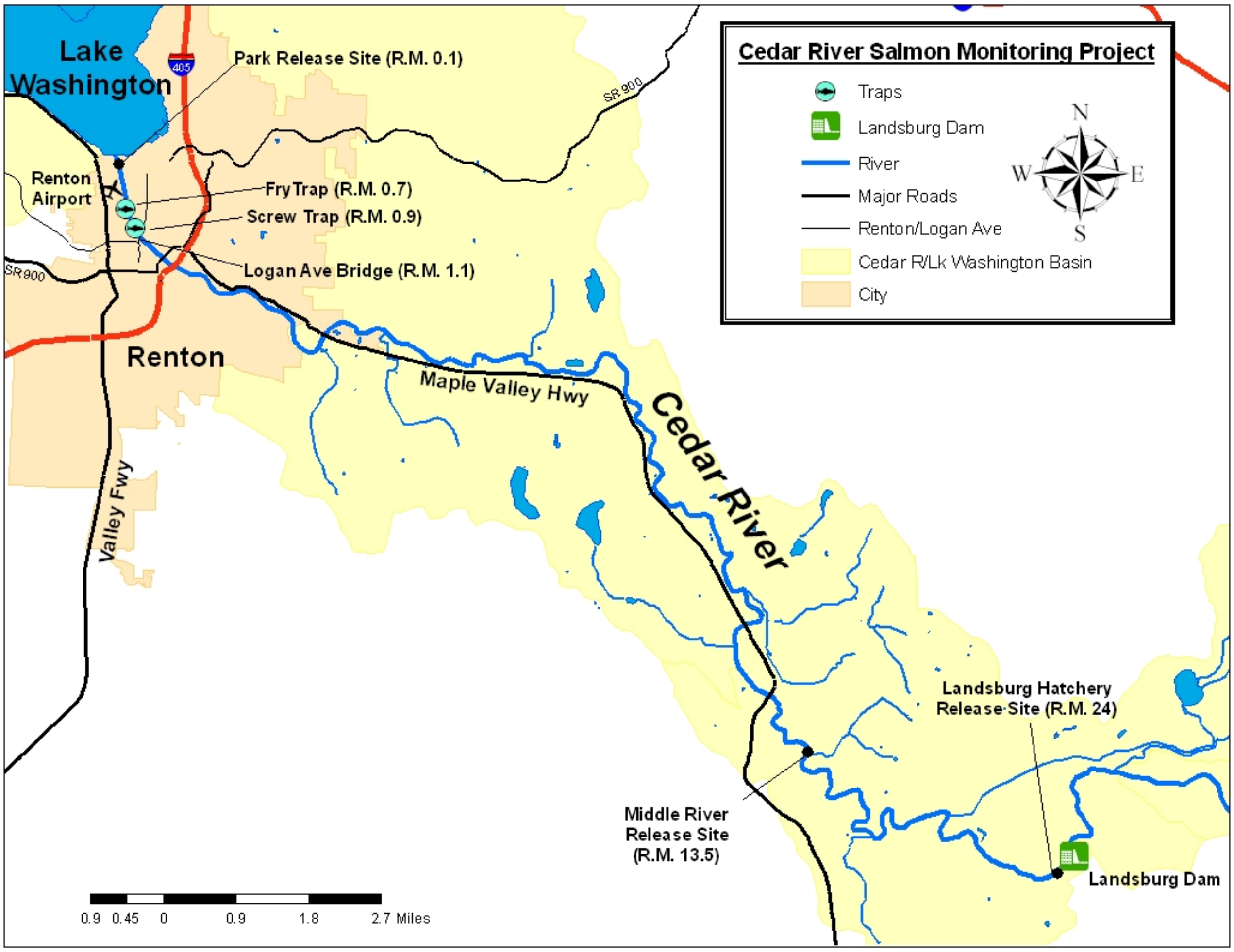

Figure 1. Site map of the lower Cedar River watershed depicting the fry and screw trap locations, hatchery sockeye release sites, and trap efficiency test release sites for the 2006 trapping season.

Bear Creek

A fry trap was installed on Big Bear Creek 100 yards downstream of the Redmond Way Bridge and operated from February through mid April. In April, it was replaced with a screw trap that fished until the end of June. Downstream migrant production was estimated for wild sockeye fry, age 0+ Chinook, coho, steelhead, and cutthroat smolts.

Throughout the fry-trapping season, 22 mark groups were released using sockeye fry. Total catch was estimated at 76,007 sockeye fry. Capture rates ranged from 4.0% to 20.6% and total sockeye production was estimated at 548,604 fry. Relating this production to the estimated deposition of 5.2 million eggs yielded a survival rate of 10.5%.

Migration of age 0+ Chinook during fry trap operation was estimated using sockeye fry mark-recapture data. Total catch was estimated at 498 Chinook fry. Total abundance was estimated at 5,764 Chinook fry. During screw trap operation, 8,179 Chinook smolts were caught. Efficiency for the screw trap was estimated by releasing mark groups above the trap. Capture rates ranged from 25.7% to 64.4%. Chinook abundance during screw trap operation was estimated at 16,598 smolts.

Total production of age 0+ Chinook was estimated at 22,362 in 2006. Migration timing was bimodal with roughly 26% emigrating as fry between February and April, the remaining emigrated as smolts between May and June. Weekly Chinook fork lengths averaged less than 37 mm in February, and grew to 100 mm by late May. Egg-to-migrant survival was estimated at 3.9%.

Coho production was estimated at 46,987 smolts and cutthroat production at 7,855 smolts. During the 2006 trapping season, no steelhead were caught in the Bear Creek screw trap.

Introduction

The decline of sockeye salmon returns to Lake Washington from the mid 1980s to 1991 prompted managers to begin investigating the cause(s). Although over 500,000 fish returned in 1988, by 1991 less than 100,000 sockeye returned through the Ballard Locks. In 1991, a broad-based group was formed to address this decline. Resource managers developed a program involving population monitoring in combination with an artificial production program. Information generated by these efforts, which continued through 2006, will be used to improve management of Lake Washington sockeye salmon.

At a gross-scale, sockeye life history can be partitioned into a freshwater incubation and rearing phase and a marine rearing phase. Existing management information indicated that marine survival had averaged 11%, varying eight-fold (2.6% to 21.4%), for the 1967 to 1993 broods with no apparent decline over the data set (WDFW unpublished data). In contrast, survival in freshwater, as measured by smolts per spawner rates, declined over this same period.

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

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

The downstream migrant evaluations conducted in the Cedar River and Bear Creek in 1999 were the first in the Lake Washington basin directed at estimating the production of wild juvenile Chinook (Seiler et al. 2003). Since the Chinook migration includes newly emerged fry and later, larger smolts, two different gear types were employed. The fry trap gently captures fry but larger migrants can avoid it. For the later-timed smolt migration a rotary screw trap was installed.

Cedar River

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

We have also determined that over the twelve broods measured, survival from egg deposition to fry emigration is largely a function of the severity of peak flows in the Cedar River during the egg incubation period. Therefore, over the range of spawning population levels that have been evaluated thus far, the numbers of naturally-produced sockeye fry entering Lake Washington are the product of the number of eggs deposited and the flow-affected survival rates during incubation and migration.

In the summer of 1998, the lower Cedar River was dredged to reduce the flooding potential (USACE 1997). This project lowered the streambed and created a wider and deeper channel, which reduced the velocity to near zero where the fry trap was located (R.M. 0.25). This dramatic change in the channel required moving the trap location upstream in 1999 and 2000. In addition, the trapping program was extended 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, a different gear type (a screw trap) was operated in faster water. Concurrent operation of the fry and screw traps assessed the capture and size biases of each trap.

Bear Creek

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

Big Bear Creek, also referred to as Bear Creek, is the most heavily spawned tributary in the Sammamish watershed. In past years, sockeye have returned in excess of 50,000 spawners. In more recent years, since trapping began, escapement has ranged from 1,449 to 60,000 spawners, with a median return of 8,170 sockeye. Therefore, in 1999, the migrant trapping operation was moved downstream to the lower end of this stream where velocities were high enough to capture larger migrants. In addition to estimating Chinook and sockeye production, higher velocities also enabled estimating the production of coho, steelhead and cutthroat smolts.

Goals and Objectives

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

Chinook

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

Sockeye

1. **Estimate survival of natural production.** Relating the estimate of wild fry produced to the estimated egg deposition measures the overall success of natural spawning. Significant variation in this rate among broods, as a function of spawner abundance, predator populations, and flows will be evaluated to assess stream carrying capacity and the relative importance of production determinants.
2. **Estimate the season total of fry entering the lake.** Relating the combined estimate of wild and hatchery fry to the smolt production the following spring will measure rearing survival within the lake. Over time this information will help assess predation rates and the lake's carrying capacity. Relating brood year adult returns to the total fry production measures overall survival through the lake and marine environments.
3. **Estimate incidence of hatchery fry in the population at lake entry (Cedar River).** Comparing this rate with the incidence of hatchery fish in the population at later life stages (smolts and adults) will assess relative hatchery and wild survival rates.
4. **Develop migration timing of wild and hatchery fry.** Comparing the difference between wild timing and hatchery fry releases with subsequent survival to return rates will contribute to the adaptive management process guiding Cedar River Hatchery sockeye fry production.

Coho, Cutthroat and Steelhead

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

Methods

Trapping Gear and Operation

Cedar River

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

Fry Trap

The fry trap consists of one or two low-angle inclined-plane screen traps (3 ft wide by 2 ft deep by 9 ft long) suspended from a 40x13 ft steel pontoon barge. Fish are separated from the water via a perforated aluminum plate (33 - 1/8 in. holes per in^2). The structure resembles the larger traps we use to capture smolts in larger river systems throughout the state (Seiler *et al.* 1981). Lowered to a depth of 16 inches, each 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. Trapping began on January 20, during relatively high turbid flow conditions. As in previous years, the trap was initially operated approximately 25 ft off of the west bank. As flows declined, it became apparent that this trapping location had filled in with sediment, reducing our efficiency. Therefore, beginning February 21, and for the remainder of the season the trap was fished off the east bank, between the shoreline and eight feet from the bank. A single inclined-plane trap was fished from the beginning of the season through March 12. A second trap was added after this date to increase the catch and improve trap efficiency. We operated two traps through the remainder of the season.

The traps operated 77 nights from mid-January to late-May. During each night of operation, trapping began before dusk and continued past dawn. Although most of the downstream migration occurred at night, trapping was conducted during several daylight intervals to assess daytime movement. Captured fish were removed from the trap, identified by species, and counted each hour. Large sockeye fry catches were counted using an electronic counter. The electronic count was divided by an adjustment factor (95.9%) to estimate the actual catch. As in previous years, this adjustment factor was found through calibration testing.

Over the season, 6,593,000 hatchery-produced sockeye fry were released into the Cedar River (Table 1). On five nights between February 22 and March 6, 2,795,000 sockeye fry were released from a train trestle at river mile 13.5. Releases at Landsburg occurred on five nights, from February 6 to March 5, totaling 1,772,000 sockeye fry. The remaining 2,026,000 sockeye fry were released below the trap at river mile 0.1.

Screw Trap

The screw trap consisted of a 5 ft diameter rotary screw trap supported by a 12 ft wide by 30 ft long steel pontoon barge (Seiler *et al.* 2003). The trap was located approximately 300 yds downstream of the Logan Street Bridge (approximately RM 0.9). In previous years, the trap had been positioned just upstream of the Logan Street Bridge. Bed aggradations during fall flow events made this location unsuitable for trap operation. After surveying the entire lower Cedar River, the new site afforded the best combination of trapping conditions, security, and safety available for effective trap operation. The screw trap was operated nearly continuously from mid-April through May with seven brief periods of trap in-operation (outages). Five were due to debris stopping the rotation of the trap screw (screw stoppers) and two others occurred when trapping was intentionally suspended due to high debris loads. From late May through July, trapping was suspended during the daylight hours when catch rates were low to avoid any potential hazard to recreational floaters using the river. The catches were enumerated at dusk and in the early morning in order to discern diel movements. All Chinook, coho, steelhead, and cutthroat smolts were enumerated by species and randomly sampled for size (fork length).

Table 1. Hatchery-produced sockeye fry released into the Cedar River in 2006.

Release Date	Number Released by Site		
	Mid-River (RM 13.5)	**Landsburg (RM 24.0)**	**Below Trap (RM 0.1)**
02/06/2006		165,000	
02/14/2006		566,000	
02/21/2006		289,000	
02/22/2006	692,000		
02/23/2006	819,000		
02/27/2006	491,000		
02/28/2006		542,000	
03/02/2006	555,000		
03/05/2006		210,000	
03/06/2006	238,000		
03/13/2006			544,000
03/16/2006			700,000
03/21/2006			446,000
03/29/2006			206,000
04/12/2006			130,000
Total	**2,795,000**	**1,772,000**	**2,026,000**

Note: Shaded dates indicate releases of unfed fry.
12,000 fed fry included in February 28 release.
92,000 fed fry included in April 12 release.

Bear Creek

As with the Cedar River, out-migrating salmonids were captured using two traps in lower Bear Creek. A fry trap was used to capture sockeye and Chinook fry early in the trapping season. This trap was replaced with a screw trap in early April to capture Chinook, coho, steelhead, and cutthroat.

Fry Trap

The fry trap used in Bear Creek was identical to that employed in the Cedar River. A single inclined-plane screen trap was suspended from a 30x12 ft steel pontoon barge positioned approximately 100 yds downstream of Redmond Way, below the railroad trestle in the middle of the channel. Trapping began in early February and ended in early April. On nearly every date the trap was operated, trapping began before dusk and continued past dawn. Captured fish were removed from the trap at hourly to several hour intervals, depending on migration rates, and counted.

Screw Trap

In early April, the fry trap was replaced with a 5 ft diameter screw trap. Screw trap operation began on April 10, and operated continuously through the morning of June 28. 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).

Mark Recapture Groups

Cedar River

Fry Trap

Capture rates for sockeye fry in the Cedar River fry trap were estimated by marking, releasing, and recovering marked fry. Groups varying between 347 and 2,900 marked sockeye fry were released at the Logan Street Bridge (R.M. 1.1) over 43 nights throughout the season. Fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). Marked fry were distributed across the middle of the channel from the bridge.

Screw Trap

Chinook and coho smolts were estimated using mark-recapture data from groups released upstream of the trap. Trap efficiency tests were conducted by aggregating marked fish released and recovered over weekly or shorter time strata. Due to low catches, adequate numbers of fish were not available for large releases as done in previous years. Within each stratum, releases occurred over multiple-, one- or two-day intervals, varying from 1 to 81 smolts of each species per release. Smolts were anesthetized in a solution of MS-222 and marked with alternating partial upper and lower vertical and horizontal partial-caudal fin-clips or tagged with PIT tags (Chinook only). Marks were changed at weekly or shorter time intervals. Marked smolts were allowed to recover from the anesthetic during the day in perforated buckets suspended in calm river water. In the evening, the groups were released from the Logan Street Bridge located roughly 300 yds upstream. During trap checks, catches were examined for marks or tags.

Bear Creek

Fry Trap

In Bear Creek, fry trap capture rates for sockeye were estimated by releasing groups of marked sockeye fry, ranging from 138 to 500 sockeye, from the Redmond Way Bridge on 22 nights over the season. As in the Cedar River, fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours).

Screw Trap

Capture efficiency for the screw trap was estimated for Chinook, coho, and cutthroat smolts using the same approach described for the Cedar River screw trap, however, no PIT tags were applied in Bear Creek. Mark groups ranged from 1 to 100 of each species and were released from the Redmond Way Bridge.

Production Estimate

Production estimates for most species were made using stratified mark-recapture approaches. The Petersen estimate, modified by Chapman (1951), is often used to estimate smolt abundance. Smolt abundance during time period *i* is estimated by;

$$\hat{U}_i = \frac{(u_i + 1)(M_i + 1)}{(m_i + 1)} - 1$$ **Equation 1**

where:

U_i = Migration of unmarked fish past the trap during time period i,

u_i = Catch of unmarked fish during time period i,

M_i = Marked fish released above the trap during time period i, and

m_i = Marked fish recaptured during time period i.

Seber (1982) provides an approximate unbiased estimate of the variance:

$$V(\hat{U}_i) = \frac{(M+1)(u+1)(M-m)(u-m)}{(m+1)^2(m+2)}$$ **Equation 2**

Total production over the entire smolt outmigration is estimated by;

$$\hat{N} = \sum_{i-1}^{n} \hat{U}_i$$ **Equation 3**

Similarly, the variance of *N* is estimated by the sum of the variances for U_i. The normal confidence interval about *N* was calculated using:

$$\hat{N}_{95\%ci} = \hat{N} \pm 1.96\sqrt{V(\hat{N})}$$ **Equation 4**

This approach assumes that marked fish and unmarked fish have the same probability of capture during each fishing period. In some cases, however, recaptures of marked fish may occur during a relatively short period (e.g. a few hours after release), whereas the unmarked catches they represent may occur over a longer period. If trapping is suspended during the period when only unmarked fish are passing the trap, the catch of unmarked fish must be estimated for the abundance estimator to be valid. In this case $\hat{u}_i$ is substituted for u_i in Equation 1. The variance, $V(\hat{U}_i)$, is now estimated using (Ryding pers comm., see Appendix A for derivation);

$$V(\hat{U}_i) = Var(\hat{u}_i)\left(\frac{(M_i+1)(M_i m_i + 3M_i + 2)}{(m_i+1)^2(m_i+2)}\right) + \left(\frac{(M_i+1)(M_i - m_i)\hat{u}_i(\hat{u}_i + m_i + 1)}{(m_i+1)^2(m_i+2)}\right)$$

Equation 5

In other cases, the recapture of marked fish occurred over a prolonged period; including subsequent fishing periods (e.g. *i+1, i+2*, etc.). Where this occurred, the outmigration data was analyzed using the maximum likelihood estimator for stratified populations developed by Darroch (1961) as illustrated by Seber (1982). The software used in this analysis is a program called DARR (Darroch Analysis with Rank Reduction) developed by Bjorkstedt (2000). DARR 2.0 was used in this analysis and is an improved version of the original program (Bjorkstedt 2005).

In a temporally stratified study fish are marked and released in *s* tagging strata, and marked and unmarked fish are recovered in *t* recovery strata. The probability that a fish tagged in the i^{th} period, will be captured in the j^{th} period, is the joint probability (π_{ij}) that an individual released in period *i* will resume migration and is susceptible to capture during period *j* (migration probability θ_{ij}) and is captured during period *j* (capture probability p_j). The joint probability is $\pi_{ij} = \theta_{ij}\, p_j$. Darroch (1961) provided a maximum likelihood estimator for obtaining the number of emigrating smolts during the *jth* recovery period, n_j, where $s = t$ and the rows of $\mathbf{m}, \{m_i\}$, are mutually independent and

$m_i \sim$ multinomial (M_i, π_{ij})
$u_j \sim$ binomial (n_j, p_j)

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

Data are arranged in matrices as

$$\mathbf{u} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix}, \quad \mathbf{M} = \begin{pmatrix} M_1 \\ M_2 \\ M_3 \\ M_4 \end{pmatrix}, \quad \mathbf{m} = \begin{pmatrix} m_{11} & m_{12} & \ldots & m_{1t} \\ 0 & m_{22} & \ldots & m_{2t} \\ \ldots & \ldots & \ldots & \ldots \\ 0 & \ldots & 0 & m_{st} \end{pmatrix}$$

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

$$P = p^{-1} = m^{-1}M$$

Equation 6

Counts of unmarked fish are expanded to estimates of abundance

$$\hat{U} = D_u P$$ **Equation 7**

where:

m^{-1} = the inverse of the recapture matrix,
D_u = the matrix with elements u arranged along the diagonal with zeros elsewhere, and
U = the number of unmarked fish passing the trap during the recovery stratum.

The total abundance is estimated by summing the estimated number of unmarked individuals.

$$\hat{N} = \sum \hat{U}_i$$ **Equation 8**

The matrix Θ, which describes the probability that an individual marked and released during one period will resume migration during that or another period, is estimated by;

$$\hat{\Theta} = D_M^{-1} m D_{\hat{p}}$$ **Equation 9**

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

$$Cov(\hat{U}) \approx D_u \Theta^{-1} D_\mu D_m^{-1} (\theta')^{-1} D_u + D_u (D_p - I)$$ **Equation 10**

where:

D_μ = a diagonal matrix with elements $\mu_i = \left(\sum_j \Theta_{ij} / p_j \right) - 1$, and
I = an identity matrix

The estimated variance is for the total population estimate and is obtained by summing the elements of the variance-covariance matrix for the stratum estimates. Normal confidence limits were calculated from Equation 4.

Initial data inputs to DARR consisted of a matrix of marks released, recaptures, and captures by week. DARR 2.0 applies a series of algorithms to aggregate data to yield an admissible estimate of abundance while preserving as much of the data structure as possible (Bjorkstedt 2005).

Cedar River

Fry Trap

Sockeye

Sockeye mark recaptures always occurred within hours of their release, yet these efficiency tests were used to represent longer fishing periods that often included periods of suspended trapping; therefore, migration during each stratum was estimated using Chapman's modification of the Petersen estimate. Equations 2 and 5 were used for the variance estimates.

To estimate nighttime catch that would have occurred when trapping was suspended, straight-line interpolation based on the catch from adjacent nights was used. 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) (Equation 11). However if one or both nightly catches, u_i, used to interpolate the catch during the unfished period also were estimated then Equation 12 was used.

$$Var(\bar{u}_i) = \frac{\sum (u_i - \bar{u}_i)^2}{n(n-1)}$$

Equation 11

$$Var(\bar{u}_i) = \frac{\sum (\hat{u}_i - \bar{u}_i)^2}{n(n-1)} + \frac{\sum Var(\hat{u}_i)}{n}$$

Equation 12

where:

n = Number of sample nights used in the interpolation,

u_i = Nightly catches of unmarked fish used to estimate the un-fished interval,

$\bar{u}_i$ = Interpolated nightly catch estimate, and

$\hat{u}_i$ = Estimated nightly catches of unmarked fish used to estimate the un-fished interval.

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

$$Var(\hat{u}_i) = \left[\hat{u}_i \left(\frac{\sqrt{Var(\bar{u}_i)}}{\bar{u}_i} \right)^2 \right]$$

Equation 13

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

$$\hat{u}_z = T_z \bar{R}$$

Equation 14

where;

T_z = Hours during non-fishing period z, and

$\bar{R}$ = Mean Catch Rate (fish/hour) from adjacent fished periods.

The variance was estimated by;

$$Var(\hat{u}_z) = T_z^2 Var(\overline{R})$$ **Equation 15**

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

Hatchery and Wild Catch Composition

On hatchery release nights that were fished, natural-origin and hatchery sockeye fry catches were estimated based on one of four methods, listed below in their order of preference (accuracy):

1. During hatchery releases on March 5 and 6, otolith samples were taken. The number of hatchery sockeye in the nightly catch was estimated by:

$$\hat{u}_{hi} = \frac{O_{hi} u_i M_i}{m_i}$$ **Equation 16**

where:

$\hat{u}_{hi}$ = Estimated number of hatchery sockeye caught during night i, and

O_{hi} = The proportion of otolith marked hatchery sockeye in the sample from night i.

Natural-origin sockeye were estimated by subtracting the estimated hatchery catch, $\hat{u}_{hi}$, from the actual catch of unmarked sockeye, u_i.

2. For hatchery release nights when otolith sampling was not conducted, the catch of natural-origin sockeye from the previous and following nights were used to interpolate the wild catch on the hatchery release night. Hatchery catch was then estimated by subtracting wild catch from the total nightly catch. This approach was used where naturally-produced sockeye catches were generally consistent from night to night and estimates of hatchery catch were greater than zero. This method was applied to hatchery releases occurring on February 6, 14, and 28, and March 2.

3. Where straight-line interpolation yielded hatchery catches less than zero, we estimated hatchery and wild catch by comparing the nightly timing distributions between hatchery release nights and the surrounding nights when only wild fish were migrating. Recognizing that there is a delay between when the nightly migration of wild fish began to when the hatchery fish reached the trap, we compared the early evening catch of wild sockeye to the total catch of wild sockeye from nights adjacent to the hatchery release night. This proportion was applied to the early evening wild sockeye catches on hatchery release nights to estimate the expected nightly catch of wild sockeye. The catch of hatchery sockeye was estimated by subtracting the estimated wild catch from the actual total nightly catch. This approach was taken on February 23 and 27.

4. Recognizing that the survival of hatchery sockeye is affected by stream discharge (Seiler and Kishimoto 1996), the last approach used a flow-based hatchery release survival model developed from previous years data (1995, 2001-2003) when intensive otolith sampling was

conducted to estimate hatchery fry survival. This approach was used when otolith sampling, interpolation, and hourly proportioning were not appropriate due to erroneous estimated hatchery catches. This final approach was applied on February 21 and 22.

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

$$F_d = \frac{T_d}{\frac{1}{\overline{Q}} T_n + T_d}$$

Equation 17

and its variance by;

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

Equation 18

where;

T_n = Hours of night during 24 hour period,

T_d = Hours of day during 24 hour period, and

$\overline{Q}_d$ = Average day/night catch ratio.

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

$$Var(\hat{u}_d) = \hat{u}_i^{\,2} Var(F_d) + Var(\hat{u}_i) F_d^{\,2} - Var(\hat{u}_i) Var(F_d)$$

Equation 19

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).

Chinook

Efficiency tests conducted with sockeye fry were used to estimate efficiencies for Chinook catches in the fry trap. Therefore, procedures used to estimate the juvenile Chinook migration during fry trap operation were identical to those described for sockeye fry.

Screw Trap

Chinook, Coho, and Trout

Trap efficiency tests were conducted using marked or tagged Chinook, coho, and trout. Since these tests were conducted on a daily or nearly daily schedule and recoveries were protracted over periods of up to two weeks, we used Darroch's maximum likelihood estimator for stratified populations to estimate abundances for these species. Alternating upper and lower caudal vertical and horizontal clips were changed at approximately weekly intervals until early May. On May 8, we began PIT tagging Chinook three days per week and fin marking on the other days. The PIT tags enabled identification of individually tagged fish enabling stratification to be evaluated post-season.

Mark strata were combined in some weeks due to low numbers of recoveries prior to developing matrices for input into DARR 2.0. While DARR can aggregate (re-stratify) data itself, we opted to evaluate stream discharge for adjacent initial strata to help make re-stratification decisions. Matrices were developed based on the flow-based re-stratification prior to analysis using DARR 2.0. Production estimates and their variances were developed using Equations 6 – 10.

Bear Creek

Procedures used to estimate downstream migrant production for the fry trap and screw trap were nearly identical to those used on the Cedar River. Differences applied only to estimating the daytime catch. Whereas day catches in the Cedar River were estimated using day/night catch rate ratios ($\overline{Q}$), day catches in the Bear Creek fry trap were minimal and not estimated. The variances of interpolated catches were estimated using Equation 11 or 12.

Cedar River Results

Sockeye

Trap Operation

Fry trap operation began on January 20, and operated on 77 nights through the season until the last night of trapping on May 27. Two daytime trapping intervals were fished on March 10 and March 17.

On three of the scheduled trapping nights, the trap did not operate continuously through the night due to excessive debris or stream flow. During those nights, the trap was operated at 10 or 15-minute intervals each hour.

Catch

During the first night of trap operation (January 20), 117 sockeye fry we caught during the nine hours trapped. Nightly catches increased and wild catch peaked on March 23, with 20,239 wild sockeye fry caught. Catches decreased thereafter, until the last night of trapping (May 27), when 5 fry were caught. The combined nightly catches of wild sockeye for the season totaled 435,590 fry.

Diel Migration

While the vast majority of sockeye fry migrate at night, daytime trapping indicated small numbers of fry migrated during daylight. There were two daylight intervals trapped, one with a day to night catch rate ratio of 2.68% and the other of 0.48% (Table 2). The average day catch rate to night catch rate ratio (1.58%) was used to estimate daytime migrations.

Table 2. Day-to-night catch rate ratios of sockeye fry estimated using the night before and the night after the daytime interval, Cedar River fry trap, 2006.

NIGHTTIME					DAYTIME					DAY:NIGHT	
Date Down	Time	Hours Fished	Catch	Catch/ Hour	Date Down	Time	Hours Fished	Catch	Catch/ Hour	Ratio (D/N)	Flow (cfs)
03/09	18:00	12.50	3,924	313.92	03/10	7:00	10	74	7.4	2.68%	857
03/10	18:00	12.50	2,989	239.12							
	Sum	25.00	6,913	276.52							
03/16	18:00	13.00	16,337	1,256.69	03/17	7:00	11	66	6	0.48%	566
03/17	18:00	12.50	15,458	1,236.64							
	Sum	25.50	31,795	1,246.86							
				Average						1.58%	
				Variance						2E-05	

Catch Expansion

An estimate was made for the number of sockeye that may have been caught for the day and night periods not fished. Daytime migration was estimated by using the average (1.58%) ratio of day/night catch rates measured during operation of the fry trap. Due to large amounts of debris, partial catches were expanded on three nights. Had the trap fished continuously (day and night) from January 20 through May 27, we estimate an additional 229,807 fry would have been caught. With the addition of these fish to the actual catches, season catch total is projected at 665,397 sockeye in the fry trap.

Production Estimate

In nearly all of 43 mark release groups, recaptures occurred within a few hours of release. One release, however, had a single recapture the night after. Therefore, we aggregated this group with the following night's group into a single release in order to reduce analytical complications. Our final data set consisted of 42 different strata including one combine mark group (Appendix B 1).

We calculated 15.1 million sockeye fry entered Lake Washington from the Cedar River in 2006 (Table 3, Figure 2). The total included 10.9 million wild fry and 4.2 million hatchery-produced fry. Capture rates ranged from 1.4% to 11%. Logarithmic extrapolation was used to estimate fry migration before trapping started, January 1 to January 20, which resulted in an additional 48,000 wild sockeye fry. Addition of this estimate accounts for approximately 0.4% of the total wild estimate. Logarithmic extrapolation was also used to estimate migration through July 31, which totaled 20,000 fry, only 0.2% of the total wild estimate. Our estimated coefficient of variation (CV) for the wild migration was 2.0% with a 95% confidence interval of 10,362,832 to 11,222,656 sockeye fry.

Table 3. Estimated 2006 Cedar River wild and hatchery sockeye fry migrations entering Lake Washington with 95% confidence intervals.

Component	Period	Dates	Estimated Migration	95% CI Low	95% CI High	CV	Prop. of Total
Wild	Before Trapping	January 1 - 19	48,093	42,330	53,856	6.1%	0.3%
	During Trapping	January 20 - May 27	10,792,744	10,362,832	11,222,656	2.0%	71.4%
	After Trapping	May 27 - July 1	27,299	20,644	33,953	12.4%	0.2%
		Subtotal	10,868,135	10,438,133	11,298,138	2.0%	
Hatchery	Above Trap	February 6 - March 6	2,218,930			n/a	14.7%
	Below Trap	March 13 - April 12	2,026,000			n/a	13.4%
		Subtotal	4,244,930				
		Season Total	**15,113,065**				

Wild and Hatchery Timing

Releases of hatchery-produced fry began on February 6, and continued through April 12 (**Table 1**). The median migration date for hatchery fry was February 23. The wild fry migration was under way when trapping began on January 20, peaked during mid-March, and declined through April to low levels in May when trapping ended (Figure 3, Table 4). Median migration dates for wild fry occurred on March 20.

Stream temperatures influence the length of the incubation period. After evaluating temperature data throughout the period of fry incubation and migration, it appears February stream temperatures best explain observed variation in migration timing ($r^2 = 0.58$) (Figure 4). February stream temperatures averaged 6.3° C in 2006, slightly warmer than the 12-year average (6.1° C), which in turn produced a median migration date fairly close to the 12-year average median migration date (Table 4, Figure 4). The 2001 fry migration was treated as an outlier due to extreme low flows that facilitated predation and an earthquake, which triggered a landslide that temporarily blocked flow and may have caused a significant mortality in the later-timed portion of the fry production.

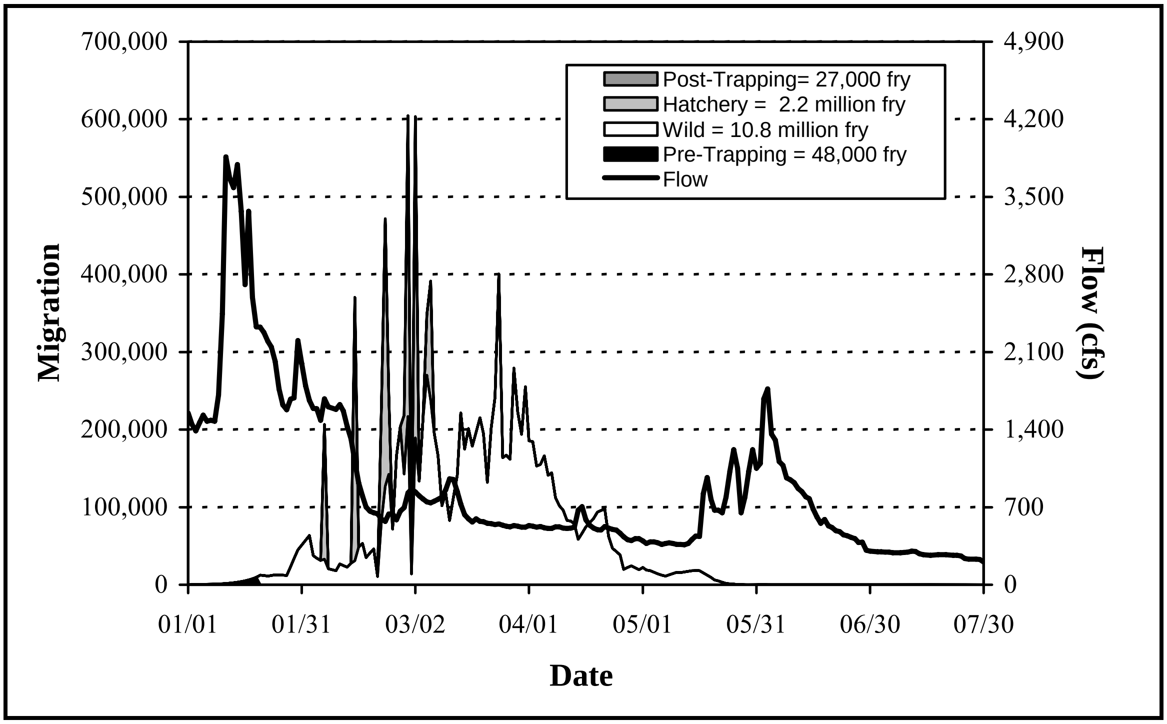

Figure 2. Estimated daily migration of wild and hatchery Cedar River sockeye fry into Lake Washington and daily average flow, 2006.

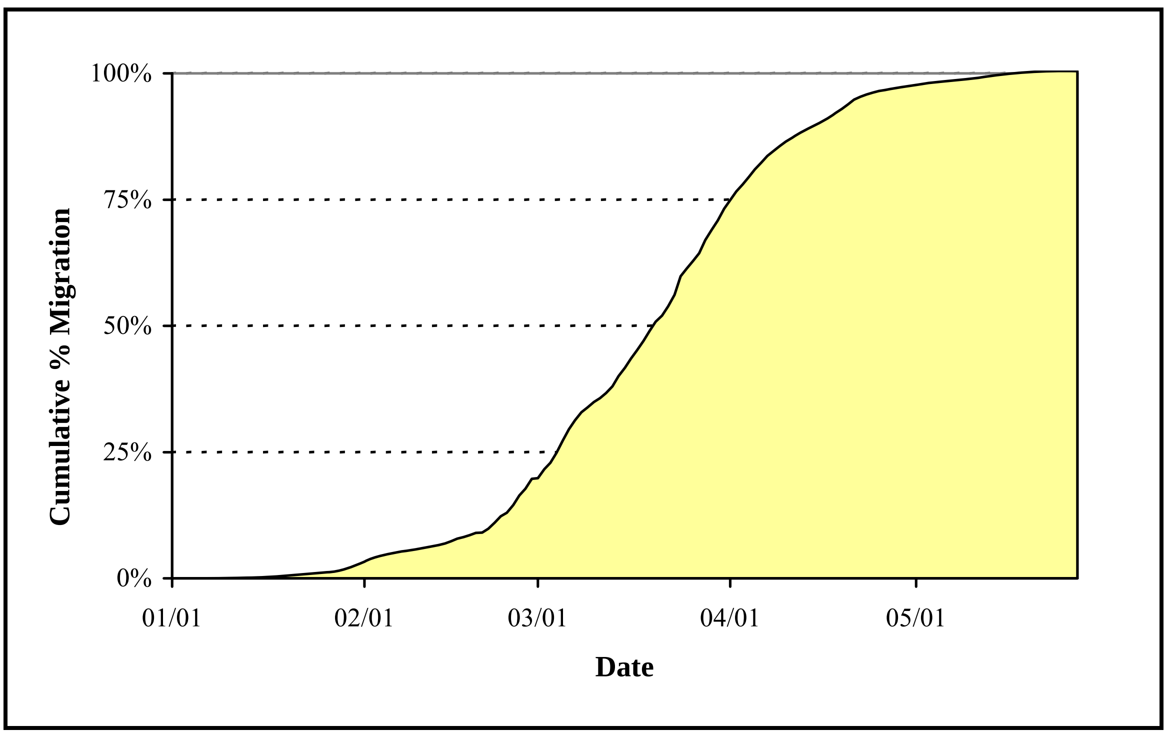

Figure 3. Cumulative wild sockeye fry migration timing, Cedar River 2006.

Table 4. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River.

Brood Year i	Trap Year i+1	Median Migration Date Wild	Hatchery	Combined	Difference (days) W-H
1991	1992	03/18	02/28	03/12	19
1992	1993	03/27	03/07	03/25	20
1993	1994	03/29	03/21	03/26	8
1994	1995	04/05	03/17	03/29	19
1995	1996	04/07	02/26	02/28	41
1996	1997	04/07	02/20	03/16	46
1997	1998	03/11	02/23	03/06	16
1998	1999	03/30	03/03	03/15	27
1999	2000	03/27	02/23	03/20	32
2000	2001	03/10	02/23	03/08	15
2001	2002	03/25	03/04	03/19	21
2002	2003	03/08	02/24	03/03	12
2003	2004	03/21	02/23	03/15	26
2004	2005	03/02	02/01	02/28	29
2005	2006	03/20	02/23	03/14	25
	Average	03/22	02/27	03/13	24

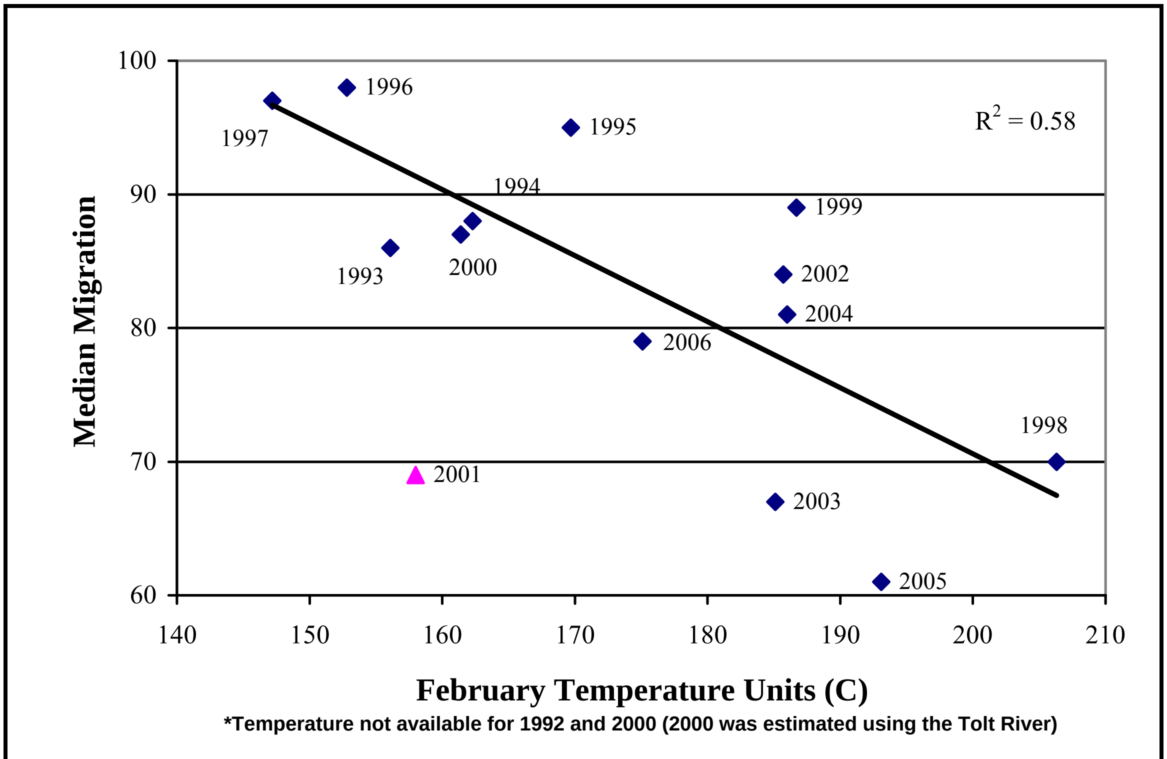

Figure 4. Linear regression of median migration Julian Calendar date for wild Cedar River sockeye fry as a function of the sum of daily average temperatures from February 1-28 (USGS Renton Gaging Station #12119000) for migration years 1993-2006, with 2001 as an outlier.

Survival of Hatchery Release Groups

Survival rates estimated for the groups of fry released above the trap ranged from 12% to 104%, and averaged 54.1% (Table 5). Average survival of fed fry groups released above the trap was 57.8%. Survival of emergent fry groups averaged 45.6%. When these survival rates were weighted by group size, rates for unfed, fed, and all sockeye fry released above the trap averaged 46.9% 49.6%, and 48.6%, respectively. Fry survival rates were greatly influenced by the poor survival of groups released on February 23 and February 27, which survived at less than 20%. Factors causing the poor performance of these groups are unknown, but may include high in-river predation rates, poor condition or inaccurate counts at release, or inaccurate estimation of hatchery and wild catch composition. If these two estimates are considered outliers, survival of fed an unfed fry increases to 64.6% and 59.4% respectively, and overall average survival would increase to 62.6%.

A variety of methods were used to estimate the number of hatchery fry in the nightly catch. Otolith sampling was the best method. It directly estimates hatchery and wild fish in the catch. However, funding was not sufficient to analyze otolith samples for every release. For releases where otolith analysis was not conducted, we used the most precise indirect method available that provided a plausible estimate (e.g. survival between zero and about 100%).

The most accurate approach, otolith sampling, was used for the fed fry releases on March 5 and 6 (see Hatchery and Wild Catch Composition, Method 1). A previous release of fed fry on February 23 appeared to survive poorly (12.7%), so we opted to otolith sample these releases to provide a better assessment of migration patterns for fed fry releases. Survival was estimated at 37.1% and 64.6%, respectively with nearly all of the fed fry emigrating on the night of release.

Interpolation of the natural-origin catch was used on four nights, February 6, 14, and 28, and March 2, and estimated the survival of those hatchery releases at 104.2%, 60.2%, 71.5% and 74.6%, respectively (see Hatchery and Wild Catch Composition, Method 2). This approach was considered the most precise of the indirect methods, as it only assumed wild migration rates were intermediary between those of the day preceding and following the release.

Estimating natural-origin and hatchery components through analysis of the nightly migration timing distribution was applied to data for two nights, February 23 and 27 (see Hatchery and Wild Catch Composition, Method 3). This approach estimated survival of hatchery fish at 12.7% and 15.5%, respectively. This approach assumed the nightly hourly migration timing of naturally-produced fish was consistent over several days, which we felt was less certain than the assumption for the interpolation approach.

A flow-based regression model (Figure 5) was used to estimate survival for releases on February 21 and 22 (see Hatchery and Wild Catch Composition, Method 4). This approach estimated survival at 51.2% and 49.9% respectively. While this model was developed using otolith estimated survival rates, it performed poorly with some of the catch data from this year (e.g. actual catch less than predicted catch); therefore, we preferred using the in-season data rather than the model for most hatchery survival estimates.

Survival of hatchery releases below the trap were assumed to be 100%.

Table 5. In-river survival estimates of hatchery sockeye fry released above the trap, Cedar River 2006.

Release Date	Sockeye Released	Daily Avg. Flow	Estimated Daily Migration	Estimated Daily Survival
02/06	165,000	1,679	171,888	104.17%
02/14	566,000	1,112	340,620	60.18%
02/21	289,000	591	148,042	51.23%
02/22	692,000	573	345,039	49.86%
02/23	819,000	639	103,908	12.69%
02/27	491,000	695	75,912	15.46%
02/28	542,000	828	387,730	71.54%
03/02	555,000	838	414,025	74.60%
03/05	210,000	749	78,005	37.15%
03/06	238,000	740	153,761	64.61%
Sum	4,567,000		2,218,930	
Average				54.1%

Note: Shaded dates indicate releases of unfed fry.
February 28 release total included 12,000 fed fry.

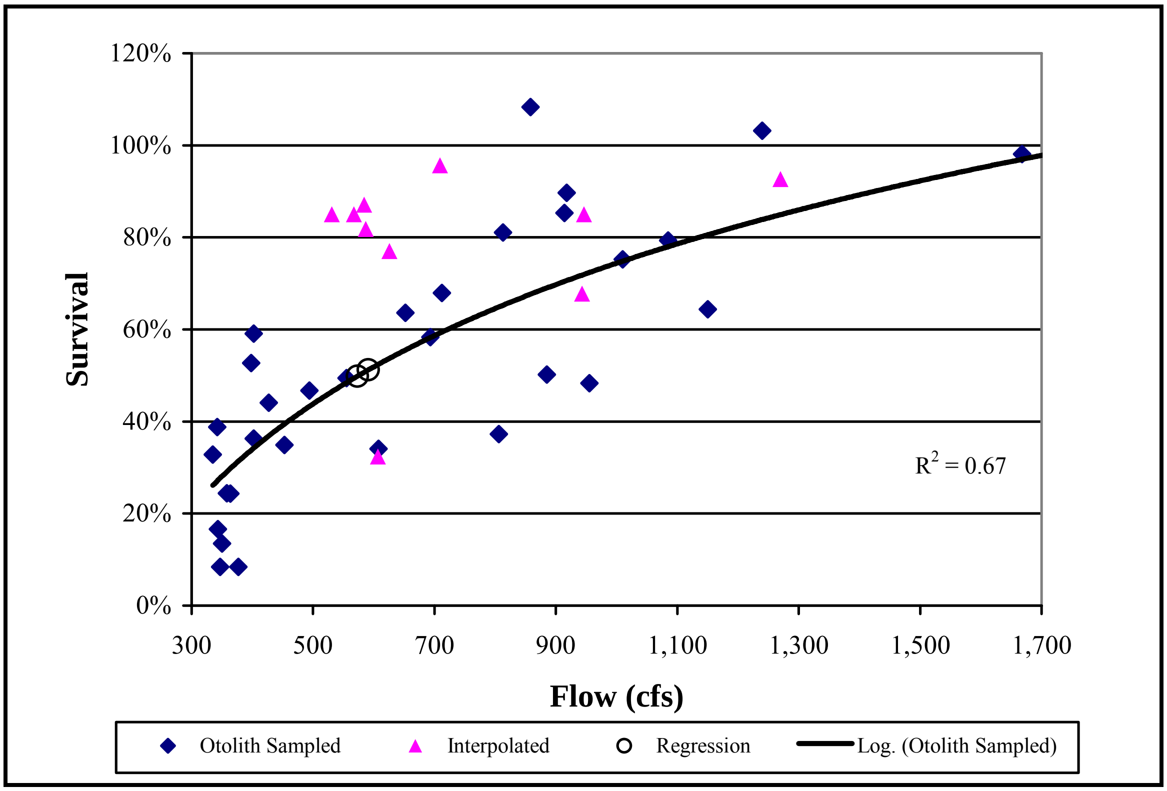

Figure 5. Survival of hatchery fry released from Landsburg as a function of daily mean flow using data collected from the Cedar River in 1995, and 2001 - 2003. Also shown are survival rates estimated in 2004 (interpolated) and in 2006 (regression).

Egg-to-Migrant Survival of Naturally-Produced Fry

Overall egg-to-migrant survival of the 2005 brood sockeye was estimated at 13.9 %. This rate is the ratio of 10.8 million wild fry to an estimated potential egg deposition (PED) of 77.9 million eggs. This PED is based on a escapement estimate of 50,887 spawners, an assumed even sex ratio and an average fecundity of 3,065 (Figure 6). The estimate of fecundity was derived from the average number of eggs per female estimated during broodstock collection (Antipa pers. comm.).

Regressing the survival estimates on peak brood year incubation flow resulted in a correlation coefficient of 53% (Figure 6). The best fit for this data series was derived from fitting the data to an exponential equation ($y = ba^x$). This function generally describes an exponential decay in egg-to-migrant survival with increasing peak stream flow during the incubation period. As additional data are generated, we will continue to assess this model and others, to increase our understanding of the factors affecting wild sockeye fry production from the Cedar River.

Table 6. Estimated egg-to-migrant survival of naturally-produced sockeye fry (using the AUC method to estimate spawners) in the Cedar River relative to peak mean daily flows during the incubation period as measured at the USGS Renton gage, brood years 1991-2005.

Brood Year	Spawners	Females (@50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1991	77,000	38,500	3,282	126,357,000	9,800,000	7.8%	2,060	01/28/1992
1992	100,000	50,000	3,470	173,500,000	27,100,000	15.6%	1,570	01/26/1993
1993	76,000	38,000	3,094	117,572,000	18,100,000	15.4%	927	01/14/1994
1994	109,000	54,500	3,176	173,092,000	8,700,000	5.0%	2,730	12/27/1994
1995	22,000	11,000	3,466	38,126,000	730,000	1.9%	7,310	11/30/1995
1996	230,000	115,000	3,298	379,270,000	24,390,000	6.4%	2,830	01/02/1997
1997	104,000	52,000	3,292	171,184,000	25,350,000	14.8%	1,790	01/23/1998
1998	49,588	24,794	3,176	78,745,744	9,500,000	12.1%	2,720	01/01/1999
1999	22,138	11,069	3,591	39,748,779	8,058,909	20.3%	2,680	12/18/1999
2000	148,225	74,113	3,451	255,762,238	38,447,878	15.0%	627	01/05/2001
2001	119,000	59,500	3,568	212,296,000	31,673,029	14.9%	1,930	11/23/2001
2002	194,640	97,320	3,395	330,401,400	27,859,466	8.4%	1,410	02/04/2003
2003	110,404	55,202	3,412	188,349,224	38,686,899	20.5%	2,039	01/30/2004
2004	116,978	58,489	3,276	191,609,964	37,027,961	19.3%	1,900	01/18/2005
2005	50,887	25,444	3,065	77,984,328	10,861,369	13.9%	3,860	01/11/2006

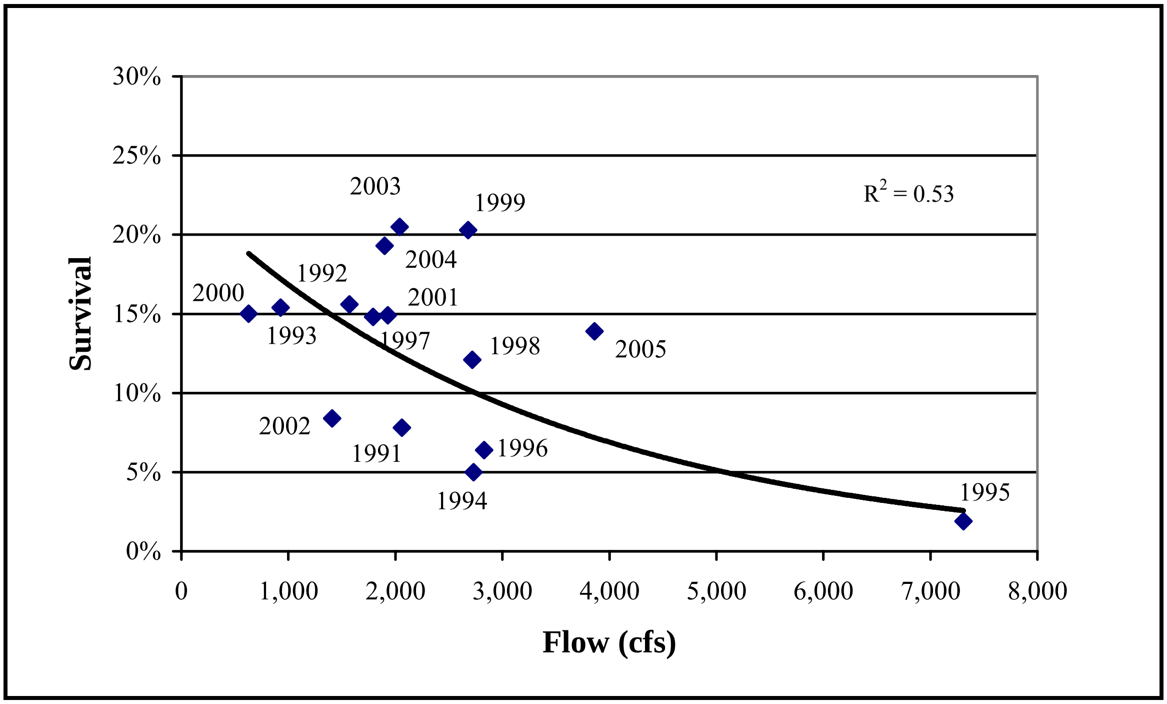

Figure 6. Exponential regression of wild sockeye egg-to-migrant survival from brood years 1991 to 2005 as a function of peak flow during the winter egg incubation period, Cedar River.

Chinook

Catch

Fry Trap

On the first night of fry trap operation (January 20), 13 Chinook fry were caught. Catches through mid-February were low, and averaged less than 25 per night. Between mid-February and mid-March, catches briefly climbed to over 100 Chinook fry, and nightly catches peaked on February 23 at 242 fry. Thereafter, catch declined to average less than 10 Chinook fry per day for the remainder of the season. Two daytime intervals were fished throughout the season. Day to night catch rate ratios ranged from 0% to 3.3% and averaged 1.67% (Table 7). Over the season, a total of 1,975 Chinook were captured in the fry trap.

Screw Trap

Over the 97-day interval that the screw trap operated (April 10 through July 16), 879 unmarked wild and 47 hatchery adipose-marked Chinook we caught. From the first night of trapping to April 30, nightly catches totaled 48 Chinook, comprising only 5% of our season's total catch. During May and June, 816 wild Chinook smolts were caught (93% of the season total). Nightly catches peaked on May 9 when 48 Chinook smolts were caught. The remaining 2% of Chinook smolts were caught in July.

Table 7. Day to night catch rate ratios of Chinook fry estimated at the Cedar River fry trap, 2006.

Nighttime Start Date	Nighttime Start Time	Nighttime Hours	Nighttime Catch	Nighttime Catch/Hr	Daytime Start Date	Daytime Start Time	Daytime Hours	Daytime Catch	Daytime Catch/Hr	D:N Ratio	Flow (cfs)
03/09	18:00	12.50	30	2.4	03/10	7:00	10.00	1	0.10	3.33%	857
03/10	18:00	12.50	45	3.6							
	Sum	25.00	75	3.0							
03/16	18:00	13.00	24	1.8	03/17	7:00	11.00	0	0.00	0.00%	566
03/17	18:00	12.50	8	0.6							
	Sum	25.50	32	1.3							
				Average						1.67%	
				Variance						4.63E-05	

Catch Expansion

Fry Trap

An estimate was made for the number of Chinook that may have been caught for the day and night periods not fished. Daytime migration was estimated by using the average (1.67%) ratio of day/night catch rates measured during operation of the fry trap. Due to large amounts of debris, partial catches were expanded on three nights. Had the trap fished continuously (day and night) from January 20 through May 27, we estimate an additional 1,360 fry would have been caught. With the addition of these fish to the actual catches, season catch total is projected at 3,335 Chinook in the fry trap.

Production Estimate

Fry Trap

Capture rates for Chinook fry were assumed to be equivalent to that of marked sockeye fry released upstream of the trap, therefore sockeye mark-recapture data was used to estimate Chinook fry migration. As in the sockeye fry estimate, estimated catches, $\hat{u}$, were substituted for u in the equation. Fry migration was estimated at 94,601 Chinook fry for the period of January 20 through April 30 (Appendix B 2).

The fry trap and screw trap ran concurrently between April 10 and May 27, which provided independent daily estimates of Chinook migration. Daily estimates from each trap were summed by week and tested for equality using a Z-test. Differences were significant in six of the seven weeks tested ($\alpha = 0.05$) (Table 8). During the weeks of concurrent operation, the estimated fry trap migrations were larger than the screw trap migrations through Week 18. This trend reversed itself beginning in Week 19, when the screw trap estimates were larger in all remaining weeks except Week 21. Similarly, mean Chinook fork lengths were similar through week 18 (Figure 7). Mean screw trap fork lengths were significantly larger than those from the fry trap (2 sample t-test, α=0.05) beginning in Week 19, which is less efficient for larger-sized migrants. Due to these differences we elected to use fry trap migration estimates through Week 18 and use screw trap estimates beginning Week 19 through the remainder of the season.

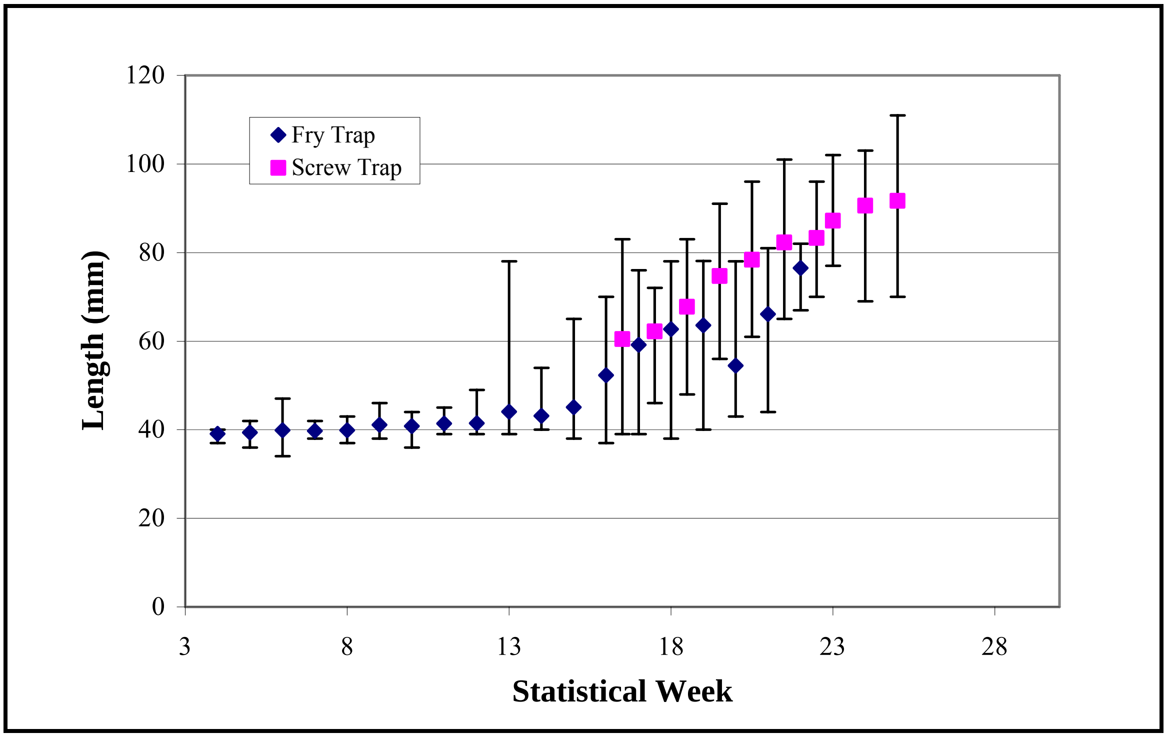

Figure 7. Average and range of fork lengths of Chinook sampled from the Cedar River, 2006.

Screw Trap

Over the entire season 32 mark groups were released. Groups were marked with either upper or lower horizontal or vertical partial caudal clips or PIT tags. There was concern that PIT tagged fish would be captured at different rates compared to non-PIT tagged fish. However, subsequent analysis showed that differences in recapture rates between fin marked and PIT tagged fish were not significant (2 sample t-test, $\alpha = 0.05$).

Many of these mark groups were small with few or no recaptures; therefore, the original groups were aggregated into four strata based on flow. Each of the final strata had at least three recaptures. Capture rates for the four groups ranged from 3.1% to 8.4% (Appendix B 3). DARR estimated migration during screw trap operation at 18,592 Chinook smolts.

Combining the Chinook production estimated from the fry trap for January 20 through April 30 and the estimate from the screw trap for May 1 through July 16, a total migration over this interval was estimated at 113,193 age 0+ Chinook (Table 9). Migration prior to fry trap operation was estimated by logarithmic extrapolation from January 1 to 19, adding 4,366 migrants for a total migration of 117,559 Chinook.

Table 8. Independent weekly estimates of Chinook migration, N_w, from the fry and screw traps with results from a Z-test comparison of the weekly estimates, Cedar River 2006**.**

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)	
04/10	04/16	16	607	3.02E+03	139	2.96E+02	y
04/17	04/23	17	439	4.13E+02	128	6.99E+01	y
04/24	04/30	18	179	4.11E+02	85	8.25E+01	y
05/01	05/07	19	515	4.30E+02	1,190	7.01E+03	y
05/08	05/14	20	394	2.25E+02	3,028	2.62E+04	y
05/15	05/21	21	4,102	1.74E+05	3,568	1.32E+05	n
05/22	05/28	22	1,984	5.40E+04	3,536	8.18E+04	y

Table 9. Cedar River juvenile Chinook production estimate and confidence intervals, 2006.

Gear	Period	Estimated		95% CI		CV
		Catch	Migration	Low	High	
Pre-Trapping	January 1 - 19		4,366	2,553	6,179	21.2%
Fry Trap	January 20- April 30	2,917	94,601	78,472	110,731	8.7%
Screw Trap	May 1 - July 16	830	18,592	10,931	26,963	21.59%
	Season Total	3,747	117,559	101,326	133,792	7.05%

As in the previous six seasons, emigration timing was clearly bi-modal (Figure 8). We estimate that the migration was 25%, 50%, and 75% complete by February 1, February 22, and March 9, respectively (Figure 9). Juvenile Chinook emigrated mostly as fry, with 84% of the total migration. Only 16% of the total migration were smolts. This is the second greatest proportion of fry since we began trapping in 1998 (Table 10).

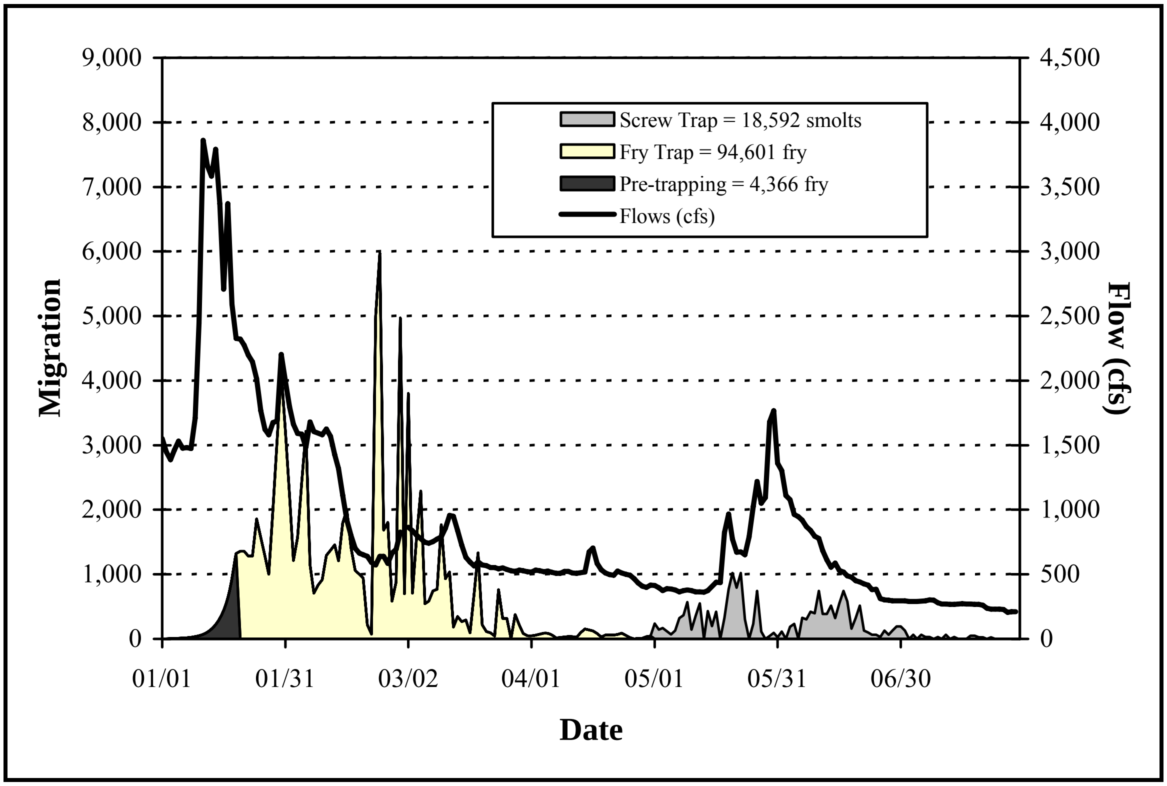

Figure 8. Estimated daily Cedar River Chinook migration from fry and screw trap estimates and flow (USGS Renton Gage), 2006.

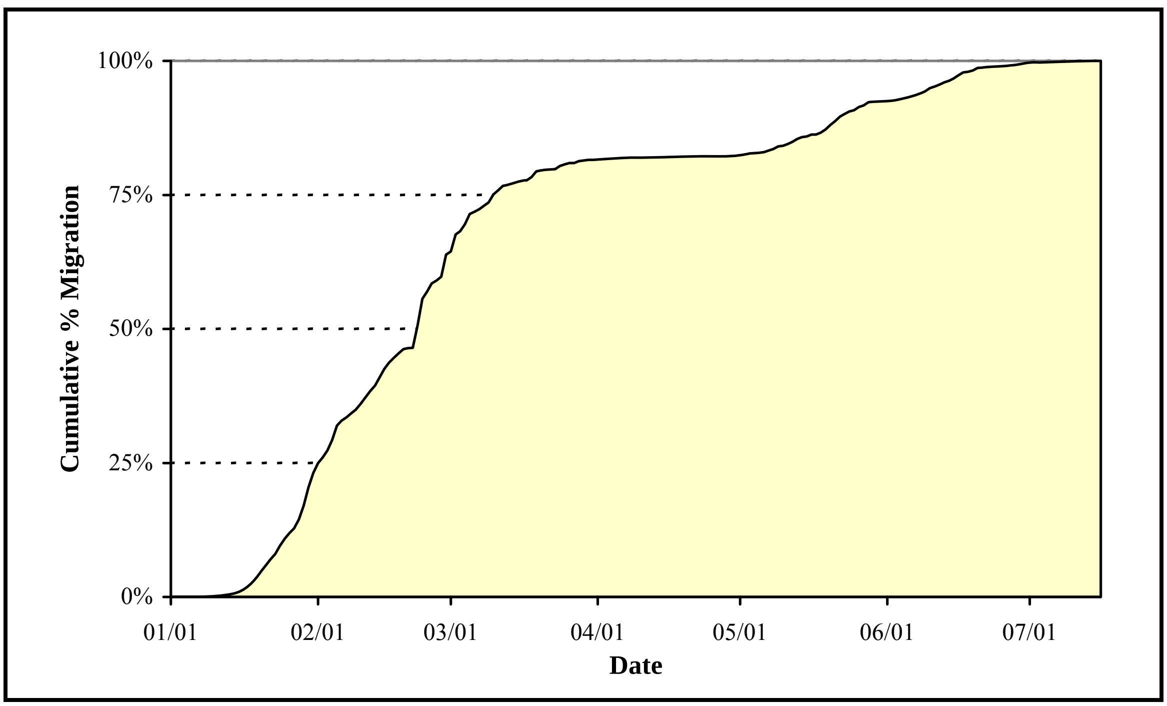

Figure 9. Cumulative percent migration of age 0+ Chinook, Cedar River 2006.

Table 10. Comparison of fry and smolt components between brood years for wild Chinook production, standardized by assuming a January 1 to July 13 migration period, Cedar River broods 1998 to 2005.

Brood Year	Migration			% Migration	
	Fry Jan 1-Apr 15	Smolt Apr 16-Jul 13	Total Jan 1-Jul 13	Fry Jan 1-Apr 15	Smolt Apr 16-Jul 13
1998	67,293	12,811	80,104	84%	16%
1999	45,906	18,817	64,723	71%	29%
2000	10,994	21,157	32,151	34%	66%
2001	79,813	39,326	119,139	67%	33%
2002	194,135	41,262	235,397	82%	18%
2003	65,875	54,929	120,804	55%	45%
2004	74,292	60,569	134,861	55%	45%
2005	98,226	18,865	117,082	84%	16%

Egg-to-Migrant Survival

Relating juvenile Chinook production from the Cedar River to estimates of annual egg deposition yields brood year egg-to-migrant survival rates (Table 11). For the 2005 brood, the wild Chinook egg-to-migrant survival rate was estimated at 7.7% based on an escapement of 339 females (Burton *et al.* 2006) and an assumed fecundity of 4,500 eggs per female.

Table 11. Wild age 0+ chinook egg-to-migrant survival estimates for brood years 1998-2005, Cedar River.

Brood Year	Estimated Migration	Estimated Females	Potential Egg Deposition	Production/ Female	Survival Rates
1998	80,932	173	778,500	468	10.4%
1999	64,723	180	810,000	360	8.0%
2000	32,249	53	238,500	608	13.5%
2001	119,674	398	1,791,000	301	6.7%
2002	235,397	281	1,264,500	838	18.6%
2003	120,876	337	1,516,500	359	8.0%
2004	134,604	511	2,299,500	263	5.9%
2005	117,559	339	1,525,500	347	7.7%

Size

From January through mid April, the weekly mean fork lengths of Chinook fry caught in the fry trap increased 6 mm from 39.1 mm to 45.1 mm, and averaged 41.3 mm (Table 12, Figure 7). The weekly average increased to over 60 mm by late April. The smallest Chinook fry captured each week was consistently 40 mm or less through early May, but increased afterwards indicating the end of the incubation period.

Chinook caught in the screw trap increased in size from a weekly average fork length of 60.5 mm in mid-April to 107.7 mm near the end of trapping (Table 12). During screw trap operation, sizes ranged from 38 mm to 116 mm and averaged 82.8 mm.

Table 12. Mean Chinook fork length (mm), standard deviation, range, sample size, and catches in the Cedar River fry and screw traps, 2006.

Statistical Week			FRY TRAP						SCREW TRAP					
Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
01/16	01/22	4	39.1	1.19	37	40	13	31						
01/23	01/29	5	39.4	1.75	36	42	16	40						
01/30	02/05	6	39.9	2.38	34	47	56	92						
02/06	02/12	7	39.7	1.08	38	42	65	121						
02/13	02/19	8	39.9	1.41	37	43	52	129						
02/20	02/26	9	41.1	1.43	38	46	54	400						
02/27	03/05	10	40.8	1.45	36	44	52	476						
03/06	03/12	11	41.4	1.50	39	45	18	178						
03/13	03/19	12	41.5	2.30	39	49	22	175						
03/20	03/26	13	44.1	9.03	39	78	18	90						
03/27	04/02	14	43.1	3.43	40	54	15	38						
04/03	04/09	15	45.1	7.73	38	65	21	24						
04/10	04/16	16	52.3	12.06	37	70	10	25	60.5	11.48	39	83	14	19
04/17	04/23	17	59.2	11.39	39	76	15	18	62.2	19.90	46	72	18	18
04/24	04/30	18	62.7	14.68	38	78	7	7	67.8	11.68	48	83	12	12
05/01	05/07	19	63.6	10.02	40	78	20	20	74.7	8.24	56	91	74	100
05/08	05/14	20	54.5	11.95	43	78	11	11	78.4	7.33	61	96	143	171
05/15	05/21	21	66.1	11.17	44	81	17	70	82.3	7.27	65	101	113	153
05/22	05/28	22	76.5	4.99	67	82	14	30	83.3	6.37	70	96	78	104
05/29	06/04	23							87.2	6.54	77	102	28	30
06/05	06/11	24							90.6	6.93	69	103	77	97
06/12	06/18	25							91.7	7.14	70	111	87	101
06/19	06/25	26							91.5	8.05	74	108	38	38
06/26	07/02	27							95.4	7.30	80	108	15	26
07/03	07/09	28							104.0	n/a	104	104	1	7
07/10	07/16	29							107.7	8.50	99	116	3	3
		Season Totals	45.0	10.70	34	82	496	1,975	82.8	10.92	38	116	701	879

Coho

Catch

A total of 795 wild coho smolts were caught in the screw trap between April 10 and July 16. Approximately 76% of the catch occurred during May. Catch distribution was uni-modal with the peak catch of 79 smolts occurring on May 9.

Production Estimate

Mark groups were released almost daily with fin marks rotating weekly. A total of 12 mark groups ranging in size from 3 to 199 coho were released. Mark groups had few to no recaptures; therefore the original groups were aggregated into five strata based on flow. Capture rates for the final strata ranged from 1.5% to 7.5% (Appendix B 4).

Coho production over the trapping season was estimated at 37,701 smolts using Darroch's maximum likelihood estimator (Appendix B 4). Assuming a starting migration date of April 1, 322 additional smolts were estimated to have migrated before trapping began on April 10, using linear extrapolation.

Total coho production was estimated at 38,023 smolts with a coefficient of variation of 28.9% and a 95% confidence interval of 16,416 to 59,629 smolts (Figure 10). The poor precision measured for this estimate was primarily the result of poor capture rates experience at this site.

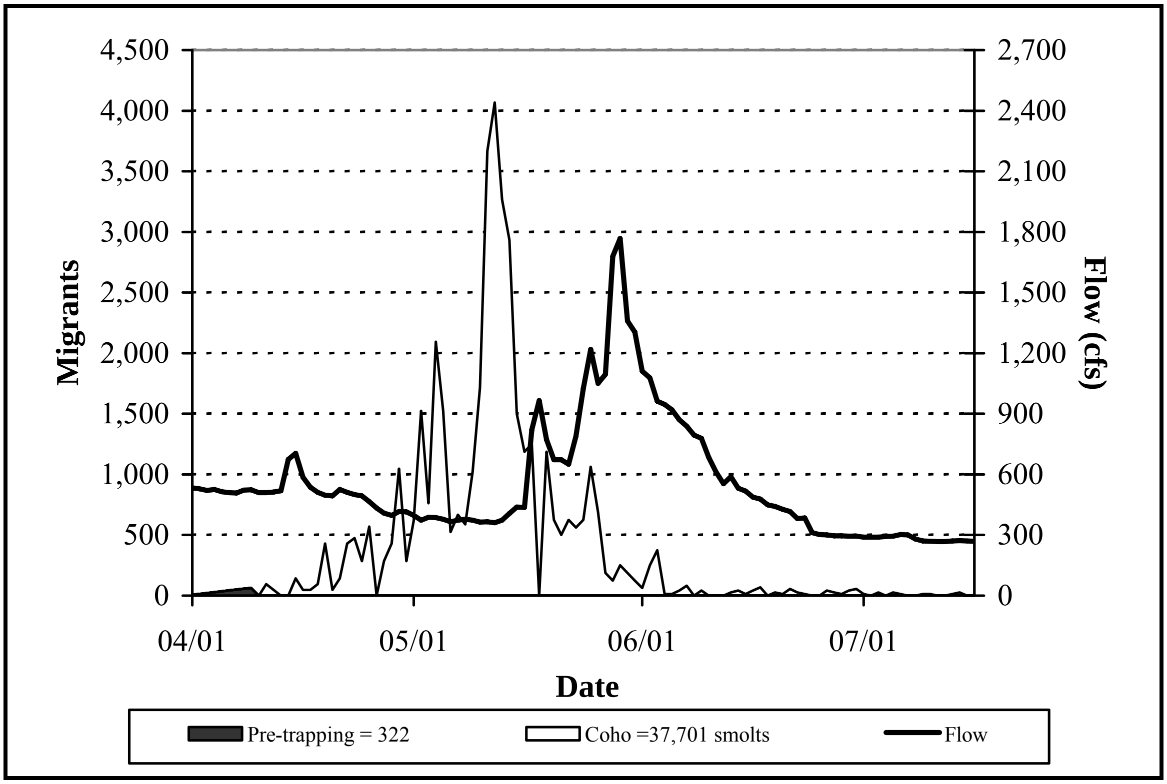

Figure 10. Estimate of daily coho smolt migration and daily average flow, Cedar River screw trap, 2006.

Size

Over the season, weekly coho smolt fork lengths averaged 107.7 mm and individuals ranged from 84 mm to 141 mm (Table 13, Figure 11). Weekly mean size ranged from 92 mm to 116 mm.

Table 13. Weekly mean fork length (mm), standard deviation, range, sample size and catches for coho smolts from the Cedar River screw trap, 2006.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/10	04/16	16	116.0	11.38	104	134	8	8
04/17	04/23	17	112.8	9.40	99	141	35	40
04/24	04/30	18	111.3	6.87	94	128	54	68
05/01	05/07	19	110.5	6.98	97	125	74	176
05/08	05/14	20	108.8	8.47	93	141	80	315
05/15	05/21	21	105.6	7.89	90	123	67	86
05/22	05/28	22	102.8	7.23	94	118	16	29
05/29	06/04	23	95.8	10.02	84	114	10	18
06/05	06/11	24	92.0	5.72	87	104	7	9
06/12	06/18	25	100.4	7.78	84	116	16	16
06/19	06/25	26	99.8	6.39	93	113	8	11
06/26	07/02	27	99.9	11.50	86	125	9	13
07/03	07/09	28	97.0	1.41	96	98	2	4
07/10	07/16	29	106.0	7.07	101	111	2	2
		Season Totals	107.7	9.19	84	141	388	796

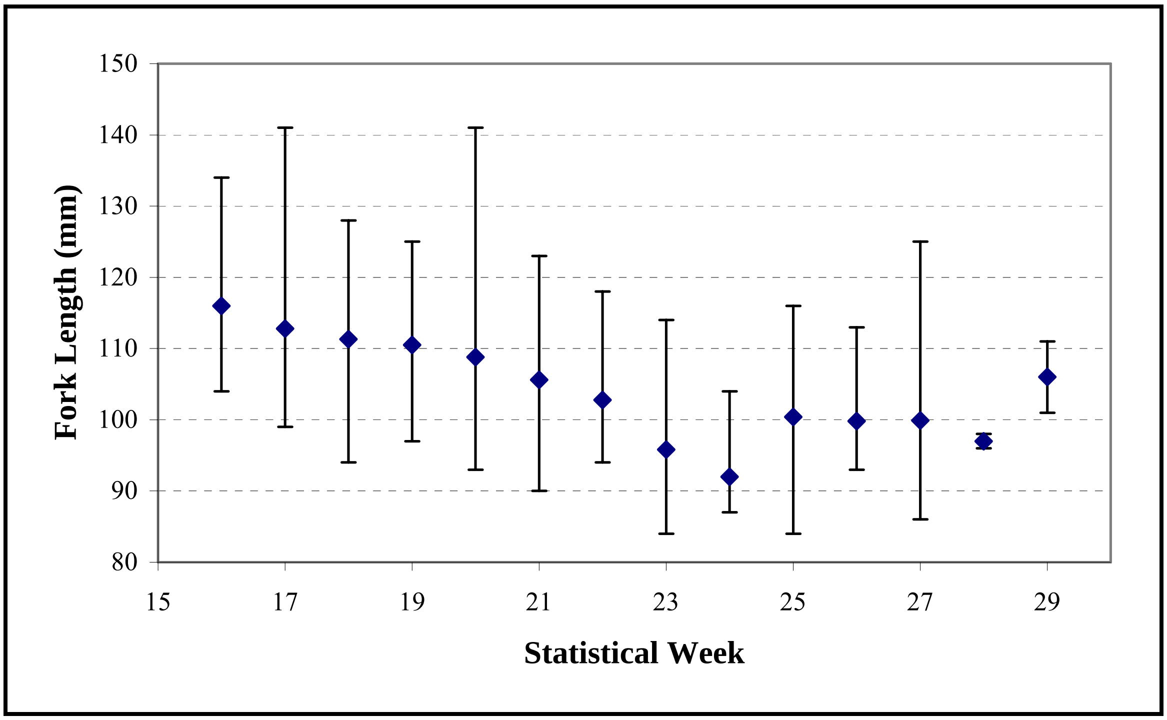

Figure 11. Weekly ranges and mean fork lengths for coho smolts captured in the Cedar River screw trap, 2006.

Trout

The variety of life history strategies used by trout in the Cedar River may include anadromous, ad-fluvial, and resident forms. For simplicity, the catches and estimates reported herein are for trout that were visually identified in the field as either cutthroat or steelhead. We acknowledge that cutthroat-rainbow hybrids are included in the reported cutthroat numbers. Furthermore, we are uncertain whether the reported steelhead were truly the anadromous life-form; yet we reported these separately from the resident rainbows described in the Incidental Catch section, below, since they appeared smolted.

Catch

Throughout the season, a total of 4 steelhead migrants and 29 cutthroat trout were sporadically trapped. An additional 1 cutthroat was estimated to have passed the trap during outages.

Production Estimate

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

During evaluation of downstream migrant passage in the Toutle, Green, and White Salmon Rivers, we captured steelhead smolts at rates that were 79%, 54%, and 47%, respectively, of the rates that marked coho were recaptured (Seiler and Neuhauser 1985, Seiler *et al.* 1992). The average of these rates (60%) indicates a steelhead-to-coho capture rate. Applying this rate to our average coho smolt catch rate (2.54%) estimates a steelhead capture rate in the Cedar River screw trap of 1.5%. Although the trapping operations on the Toutle, Green, and White Salmon Rivers employed scoop traps, from which steelhead can more easily escape, Bear Creek screw trap data corroborates the 60% rate. In 2006, the capture rates in Bear Creek for coho and cutthroat averaged 27.1% and 13.9%, resulting in a cutthroat-to-coho capture rate of 51.3%. As cutthroat migrants in the Cedar River averaged 165.5 mm, similar in size to steelhead migrants, we consider them an acceptable surrogate.

Application of a capture rate of 1.5% to the catch of 4 steelhead estimates a total migration of 267 migrants. Applying this rate to the expanded catch of 30 cutthroat estimates the total cutthroat migration during the trapping period at 2,000 cutthroat. No confidence intervals were developed for these estimates, which apply only to the period of screw trap operation (April 10 through July 16). While cutthroat migration likely occurred before and after this interval, no migration timing trends were evident from the catch data, which would help to define the start or end of this migration. Therefore, there was no expansion of the 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.

Based on limited sampling, Marshall et al. (2006) estimated 12% of the field-identified cutthroat were, in fact, cutthroat/rainbow hybrids. Assuming this rate has remained constant, we estimate approximately 1,760 cutthroat and 240 hybrid trout passed the traps.

Size

Steelhead fork lengths ranged from 158 to 180 mm, and averaged 168.7 mm. Cutthroat trout fork lengths averaged 165.5 mm, and ranged from 127 to 206 mm throughout the trapping season (Table 14).

Table 14. Weekly mean cutthroat fork length (mm), standard deviation, range, sample size and catches, Cedar River screw trap 2006.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/10	04/16	16	165.0	n/a	165	165	1	1
04/17	04/23	17	155.8	26.91	127	204	6	8
04/24	04/30	18	160.0	12.73	151	169	3	2
05/01	05/14	19-20					0	1
05/15	05/21	21	154.0	n/a	154	154	1	1
05/22	06/04	22-23					0	1
06/05	06/11	24	170.0	19.29	148	184	3	3
06/12	06/18	25	168.8	14.40	156	194	6	7
06/19	06/25	26	174.0	n/a	174	174	1	1
06/26	07/02	27					0	0
07/03	07/09	28	206.0	n/a	206	206	1	1
07/10	07/16	29	171.7	13.65	156	181	3	3
Season Totals			165.5	20.29	127	206	26	29

PIT tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington basin, we began tagging Chinook with passive integrated transponder (PIT) tags on May 4. Due to lower than usual trap efficiency and lower numbers of fish, tagging only occurred three times a week through June 30. Chinook were held from the previous day in order to increase the number tagged per day. Over the season a total of 573 wild Chinook smolts were tagged (Table 15). This tag group comprised only 3.1% of the estimated Chinook smolt production from the Cedar River in 2006.

Table 15. Wild Chinook smolts PIT tagged and released from the Cedar River screw trap, 2006.

Stat Week			Wild	Length			Portion of
#	Start	End	Chinook	Avg	Min	Max	Migration Tagged
19	05/01	05/07	23	73.3	64	91	1.93%
20	05/08	05/16	140	78.1	64	96	5.79%
21	05/15	05/25	58	82.5	67	95	1.65%
22	05/22	06/03	139	82.7	65	101	5.75%
23	05/29	06/12	10	83.5	77	96	1.43%
24	06/05	06/21	54	90.9	77	103	2.10%
25	06/12	06/30	81	91.5	80	111	2.49%
26	06/19	07/09	54	91.0	74	110	4.40%
27	06/26	07/18	14	93.2	80	100	1.67%
Season Totals			573	84.3	64	111	3.10%

Mortality

Over the season, three Chinook fry died in the fry trap.

In the screw trap there were 12 Chinook mortalities. Five mortalities were due to PIT tagging, while 7 were due to screw stoppers.

Incidental Catch

Additional catch in the fry trap, other than sockeye and Chinook fry, included 149 coho fry, 112 coho smolts, 121 chum fry, 5 pink fry, and 6 cutthroat smolts. Other species caught included three-spine stickleback, sculpin, lamprey, largescale suckers, long-fin smelt fry and spawned out adults, and Northern pikeminnow.

Other salmonids caught in the screw trap include 47 hatchery ad-marked Chinook smolts, 1 hatchery ad-marked coho, 5 sockeye smolts, 1 ad-marked rainbow trout and 1 ad-marked steelhead. Other species caught included three-spine stickleback, sculpin, lamprey, large-scale suckers (adult and fry), peamouth, dace, and a bullhead catfish.

Bear Creek Results

Sockeye

Catch

On the first night of trapping, February 8, 235 sockeye fry were caught in the fry trap. Thereafter, through the morning of April 8, the trap fished two to four nights a week for a total of 34 nights. Catches peaked on the night of March 24 when 4,444 fry were caught. When trapping concluded on the morning of April 7, catches totaled 42,250 sockeye fry.

Expanding catches for the 25 nights not fished estimates that there would have been an additional 33,757 sockeye fry caught during those nights. Should the trap have fished continuously from February 8 to April 7, a total of 76,007 fry would have been caught. In previous years no sockeye fry were caught during daylight intervals fished. Therefore, migration during daylight hours was considered minimal and not estimated.

Production Estimate

Twenty-two mark groups were released, roughly one a week, above the trap over the season. Since recaptures were sufficient for all mark-release groups, no aggregating of the efficiency strata was necessary. Capture rates ranging from 4.0% to 20.6% (Appendix C 1). During the period of fry trap operation (February 8 through April 8), we estimate 535,858 sockeye fry passed the trap. The sockeye fry migration appeared to already be underway when we began trapping. Logarithmic extrapolation was used to estimate what may have passed the trap prior to February 8, and added 8,991 fry to our total estimated migration. The sockeye fry migration was still underway when the screw trap replaced the fry trap on April 8. Rather than attempting to calibrate the screw trap, the tail end of the migration was estimated using logarithmic extrapolation. Migration from April 8 to April 15, was estimated at 3,755 fry. A total of 548,604 sockeye fry was estimated to have migrated from Bear Creek in 2006 with a CV of 3.9% and a 95% confidence interval of 506,538 to 590,669 (Table 16).

Egg-to-migrant survival of the 2005 brood was estimated at 10.5% (Table 17). This rate is the ratio of 548,604 fry to an estimate of 5.2 million eggs potentially deposited. Egg deposition is based on an estimated 3,261 sockeye adults in Bear Creek (Foley[a] pers. comm.), an even sex ratio, and an assumed fecundity of 3,200 eggs per female. This is the third highest survival since trapping began at this location in 1999.

Table 16. Estimated 2006 Bear Creek sockeye fry migration entering Lake Washington with 95% confidence intervals.

Period	Dates	Est. Migration	CV	95% CI Low	95% CI High	Variance
Pre-Trapping	February 1 - February 7	8,991	10.1%	7,219	10,763	8.17E+05
Fry Trap	February 8- April 8	535,858	4.0%	493,878	577,837	4.59E+08
Post-Trapping	April 9 - April 15	3,755	27.4%	2,724	4,786	1.06E+06
	Season Totals	548,604	3.9%	506,538	590,669	4.61E+08

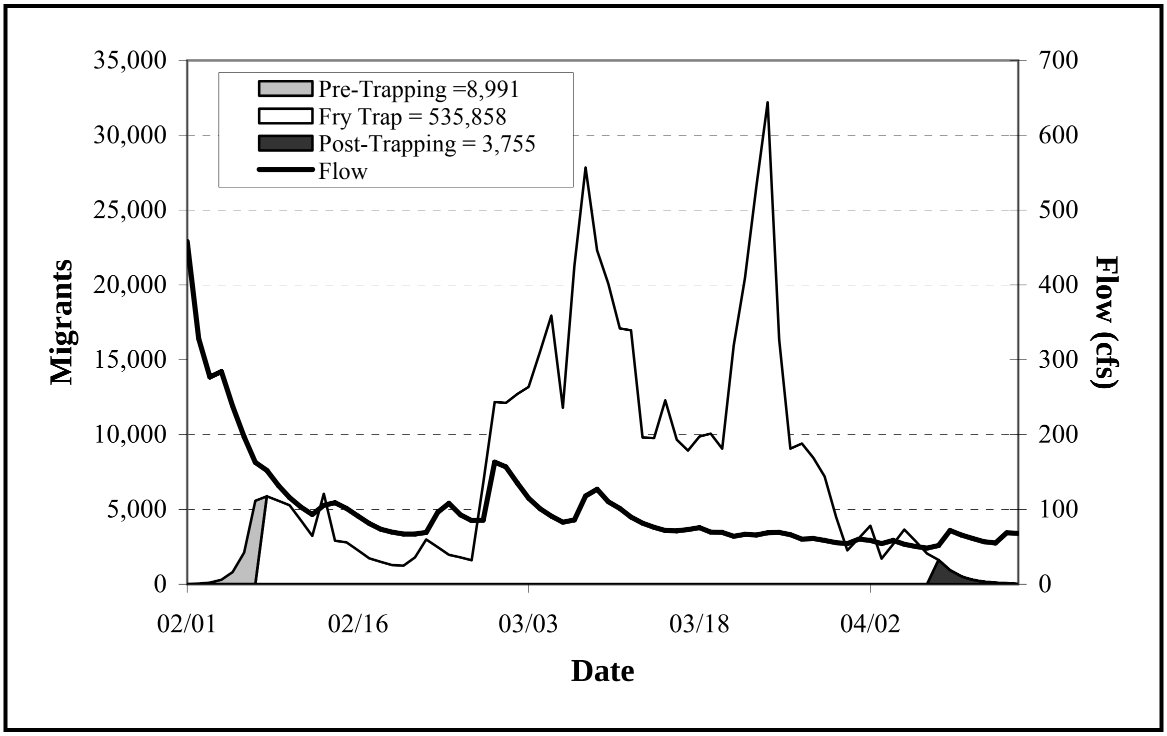

Figure 12. Estimated daily migration of sockeye fry from Bear Creek and daily average flow, 2006.

Table 17. 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	8,340	4,170	3,200	13,344,000	1,526,208	11.4%	515	11/26/1998
1999	1,629	815	3,200	2,606,400	189,571	7.3%	458	11/13/1999
2000	43,298	21,649	3,200	69,276,800	2,235,514	3.2%	188	11/27/2000
2001	8,378	4,189	3,200	13,404,800	2,659,782	19.8%	626	11/23/2001
2002	34,700	17,350	3,200	55,520,000	1,995,294	3.6%	222	01/23/2003
2003	1,765	883	3,200	2,824,000	177,801	6.3%	660	01/30/2004
2004	1,449	725	3,200	2,318,400	202,815	8.7%	495	12/12/2004
2005	3,261	1,631	3,200	5,217,600	548,604	10.5%	636	01/31/2005

Chinook

Catch

Fry Trap

On the first night of trapping, February 8, 15 Chinook fry were captured. Catches peaked on the night of March 8, with 102 Chinook fry captured. In total, 269 Chinook fry were captured in the fry trap by the time trapping ended on the morning of April 8.

Catch expansion for the 25 nights not fished resulted in an additional estimated catch of 229 Chinook fry, bringing the total estimated catch to 498 Chinook fry caught in the fry trap.

Screw Trap

The fry trap was replaced with the screw trap on April 8, and began fishing April 10. It fished continuously through June 29. On the first night of trapping, only 1 Chinook was caught. Daily migrations in April averaged less than 25 Chinook. By mid-May catches began to increase and peaked on May 22, when 564 Chinook were caught. Catches then sharply declined to average 56 Chinook per day for the remainder of the season. A total of 8,179 Chinook were caught over the 80 days trapped.

Production Estimate

Fry Trap

Chinook migration timing, as indicated by catch, suggested most Chinook reared to smolt size before migrating. Too few Chinook fry were captured during fry trapping to directly estimate efficiency. Therefore, fry trap capture rates for marked sockeye were assumed to be equivalent to that of Chinook fry and were used to estimate Chinook fry migration. As in the sockeye fry estimate, estimated catches of unmarked Chinook fry were used to estimate abundance during each fishing stratum. Over the entire fry migration period, abundance was estimated at 4,929 Chinook (Appendix C 2). When we began trapping operations, the Chinook fry migration was already underway. We estimated that 835 Chinook fry migrated passed the trap prior to February 8. Total abundance for the fry trapping period was estimated at 5,764 Chinook fry.

Screw Trap

Chinook mark groups were released nearly daily and fin marks rotated weekly during screw trap operation. Originally 16 different fin-mark groups were released. DARR aggregated these into 14 strata, estimating capture rates between 25.7% and 64.4% and producing a smolt migration estimate of 16,598 Chinook (Appendix C 3). Combining the fry and screw trap Chinook production estimates a total juvenile production of 22,362 Chinook with a coefficient of variation of 3.9% and a 95% confidence interval of 20,647 to 24,077 juveniles. As in the past, migration is clearly bi-modal with 26% of the migration emigrating as fry and the remaining 74% emigrating as smolts (Figure 13) (Table 19).

Table 18. Bear Creek juvenile Chinook production estimate and confidence intervals, 2006.

Gear	Period	Estimated		95% CI		CV
		Catch	Migration	Low	High	
Pre-Trapping	February 1- February 7		835	600	1,070	14.4%
Fry Trap	February 8 - April 8	269	4,929	3,435	6,423	15.5%
Screw Trap	April 9 - June 29	8,179	16,598	16,187	17,009	4.9%
	Season Totals	8,448	22,362	20,647	24,077	3.9%

Table 19. Comparison of fry and smolt components between brood years, for wild Chinook production, standardized by assuming a February 1 to June 30 migration period, Bear Creek broods 2000 to 2005.

Brood Year	Migration			% Migration	
	Fry Feb 1-Apr 8	**Smolt** Apr 9-Jun 30	**Total** Jan 1-Jul 13	**Fry** Feb 1-Apr 8	**Smolt** Apr 9-Jun 30
2000	419	10,087	10,506	4%	96%
2001	5,427	15,891	21,318	25%	75%
2002	645	16636	17,281	4%	96%
2003	2,089	21,558	23,647	9%	91%
2004	1,178	8,092	9,270	13%	87%
2005	5,764	16,598	22,362	26%	74%

Egg-to-migrant survival of the 2005 brood was estimated at 3.9% (Table 20). This rate is the ratio of 22,362 Chinook to an estimate of 576,000 eggs deposited. Egg deposition is based on 128 spawning females in Bear Creek (Foley[a] pers. comm.) and an assumed fecundity of 4,500 eggs per female. In addition, based on carcass recovery, hatchery-produced Chinook comprised 78.8% of the spawners sampled (Foley[b] pers comm.).

Table 20. Age 0+ Chinook production and egg-to-migrant survival estimates for Bear Creek broods 1998 to 2005.

Brood Year	Estimated Migration	Estimated Females	Potential Egg Deposition	Production/ Female	Survival Rates
1998	15,002	159	715,500	94	2.1%
1999	32,220	293	1,318,500	110	2.4%
2000	10,588	133	598,500	80	1.8%
2001	21,454	276	1,242,000	78	1.7%
2002	17,313	144	648,000	120	2.7%
2003	23,647	105	472,500	225	5.0%
2004	9,317	76	342,000	123	2.7%
2005	22,362	128	576,000	175	3.9%

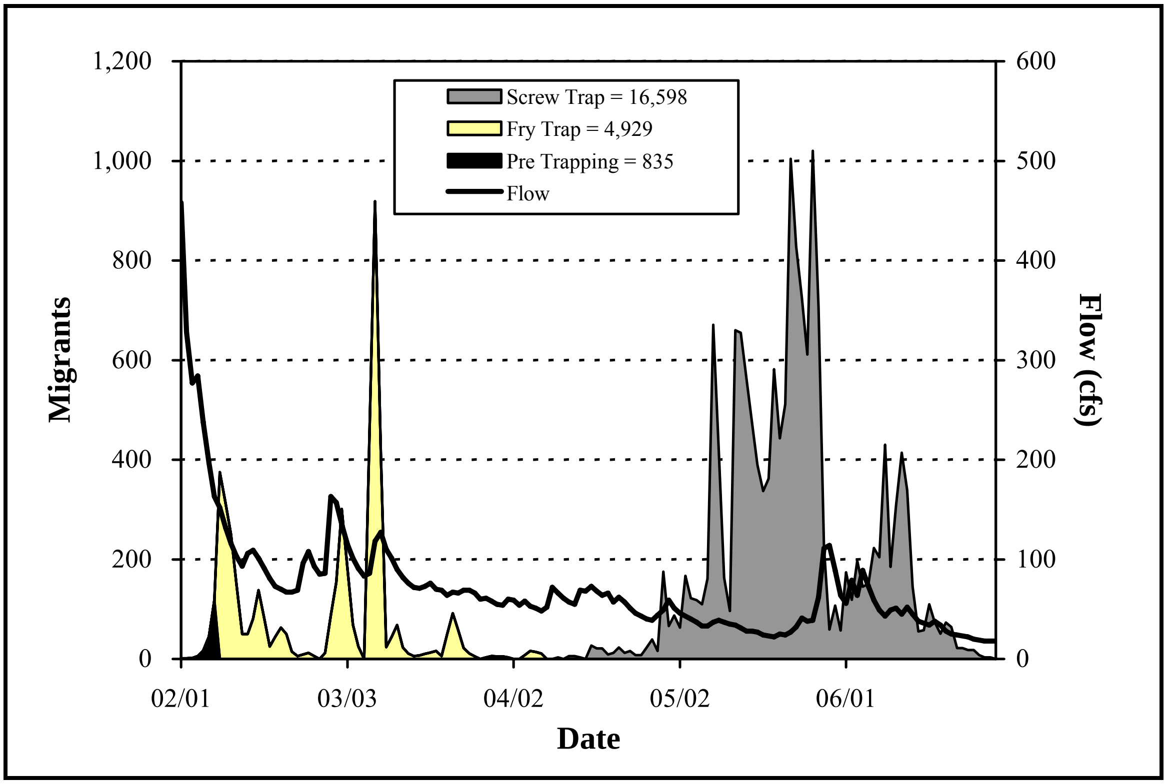

Figure 13. Estimated daily Chinook 0+ migration and daily average flow from Bear Creek, 2006.

Size

From early February through early April, the sizes of Chinook fry captured in the fry trap ranged from only 37 mm to 64 mm, and averaged 41.4 mm (Table 21).

Weekly average fork lengths during screw trap operation increased throughout the season. Chinook averaged 61.2 mm in early April, and grew to average 78.8 mm by mid June (Table 21, Figure 14). Fork lengths over the screw trapping period ranged from 44 mm to 100 mm.

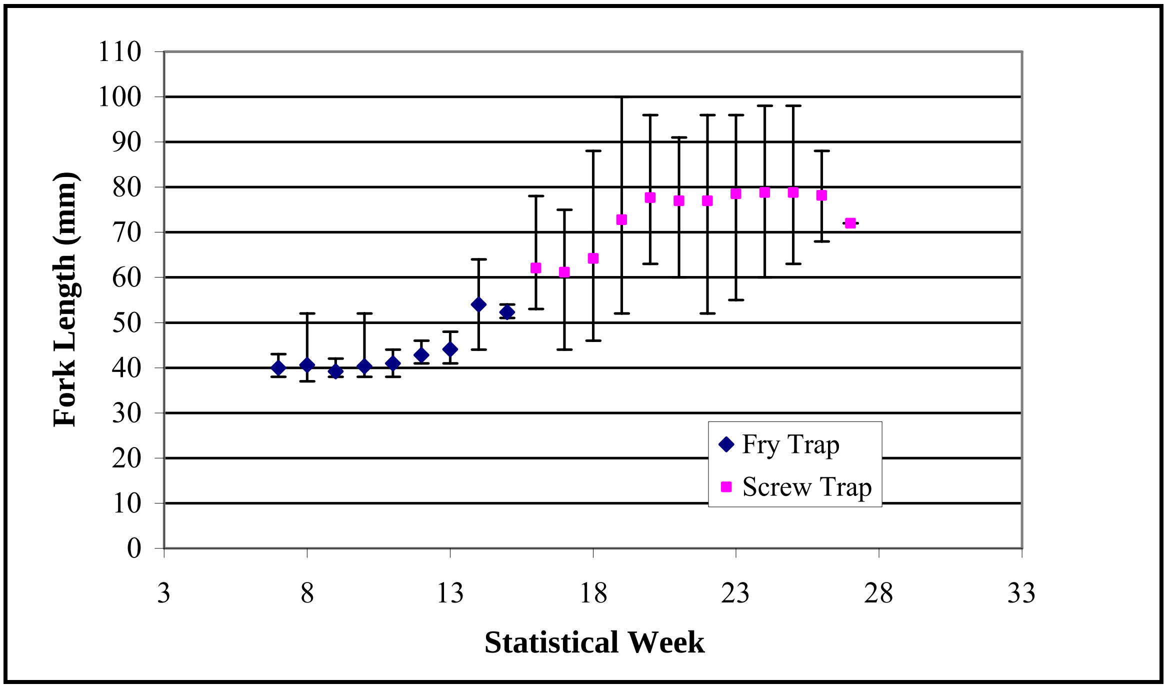

Figure 14. Average and range of Chinook 0+ fork lengths sampled from Bear Creek, 2006.

Table 21. Chinook and coho smolt mean fork lengths (mm), standard deviations, ranges, sample sizes, and catches in the Bear Creek fry and screw traps, 2006.

Gear	Statistical Week			CHINOOK						COHO					
	Begin	End	No.	Avg.	s.d.	Range Min	Range Max	n	Catch	Avg.	s.d.	Range Min	Range Max	n	Catch
Fry Trap	02/06	02/12	7	40.0	1.43	38	43	22	28						
	02/13	02/19	8	40.6	4.18	37	52	19	21						
	02/20	02/26	9	39.2	1.83	38	42	6	7						
	02/27	03/05	10	40.3	3.02	38	52	27	62						
	03/06	03/12	11	41.0	1.41	38	44	21	116						
	03/13	03/19	12	42.8	1.75	41	46	8	9						
	03/20	03/26	13	44.1	2.25	41	48	8	19						
	03/27	04/02	14	54.0	14.14	44	64	2	2						
	04/03	04/09	15	52.3	1.25	51	54	4	5						
			Totals	41.4	4.05	37	64	117	269						
Screw Trap	04/10	04/16	16	62.1	7.39	53	78	15	14	129.2	15.95	98	170	29	40
	04/17	04/23	17	61.2	8.91	44	75	28	34	123.7	11.68	94	168	76	280
	04/24	04/30	18	64.2	9.80	46	88	43	86	117.4	12.04	92	148	114	1,598
	05/01	05/07	19	72.8	8.06	52	100	74	434	112.6	13.34	91	147	115	3,216
	05/08	05/14	20	77.7	6.64	63	96	116	2,021	108.3	10.20	87	144	132	3,643
	05/15	05/21	21	77.0	5.88	60	91	160	1,815	106.1	10.95	88	144	130	1,601
	05/22	05/28	22	77.0	7.77	52	96	129	2,036	107.8	12.44	82	140	100	664
	05/29	06/04	23	78.5	8.76	55	96	120	395	122.6	12.45	80	184	99	285
	06/05	06/11	24	78.8	8.83	60	98	90	839	116.7	14.26	90	151	39	63
	06/12	06/18	25	78.8	7.29	63	98	80	403	108.6	16.55	86	134	19	39
	06/19	06/25	26	78.2	5.43	68	88	51	100	96.3	3.20	94	101	4	10
	06/26	07/02	27	72.0	n/a	72	72	1	2						0
			Totals	76.0	8.82	44	100	907	8,179	113.8	13.98	80	184	857	11,439

Coho

Catch

During the first week of screw trap operation, only 17 coho smolts were captured. Thereafter, catches steadily increased until May 8, when it peaked at 1,013 smolts. Catches then declined, and by May 25, daily catches dropped below 100 coho and averaged 16 smolts per day. Over the entire 80-day trapping season, ending on the morning of June 29, a total of 11,439 coho smolts were caught.

Production Estimate

Coho mark groups were released nearly daily and fin marks were rotated weekly. Sixteen different mark groups were released over the season. DARR aggregated mark groups into fifteen strata and estimated capture rates ranging from 15% to 47%. DARR estimated coho production at 46,987 smolts with a coefficient of variation of 9.7% and a 95% confidence interval of 44,658 to 49,316 smolts (Figure 15, Appendix C 4).

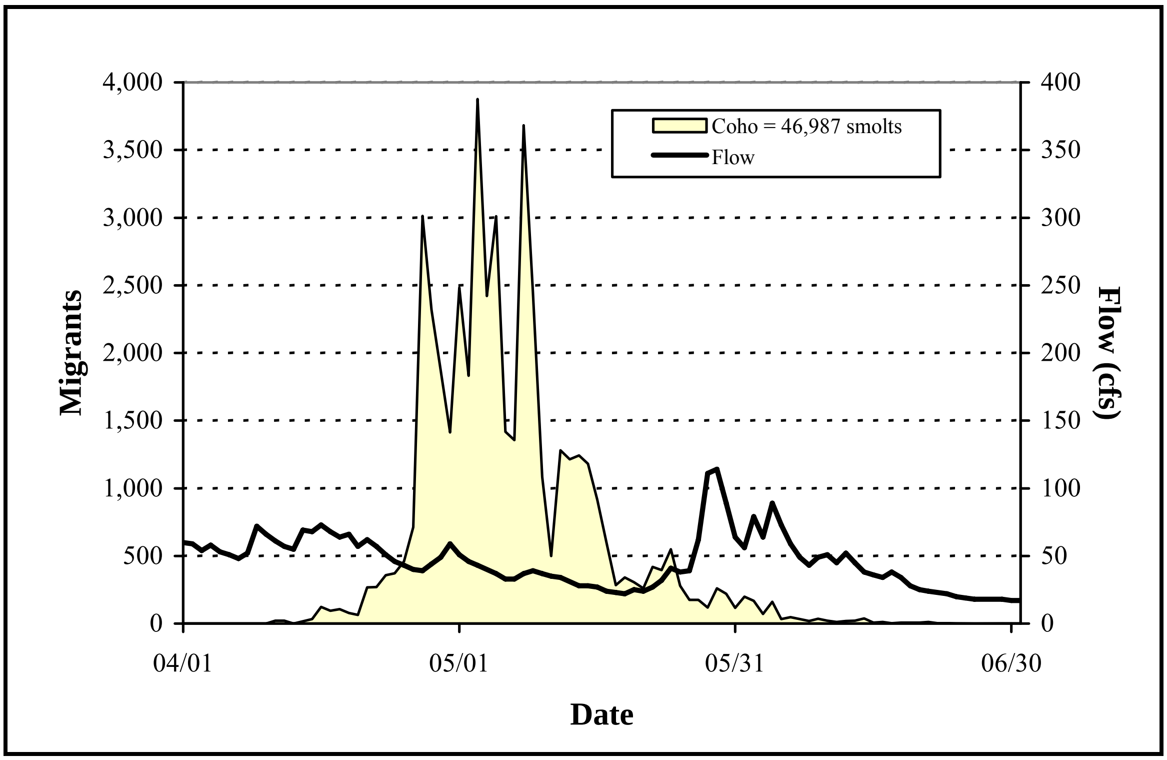

Figure 15. Estimated daily coho smolt migration, Bear Creek screw trap 2006**.**

Size

Over the trapping period, fork lengths ranged from 80 mm to 184 mm and averaged 113.8 mm (Figure 16). Weekly mean size ranged from 96.3 mm to 129.2 mm over the season (Table 21).

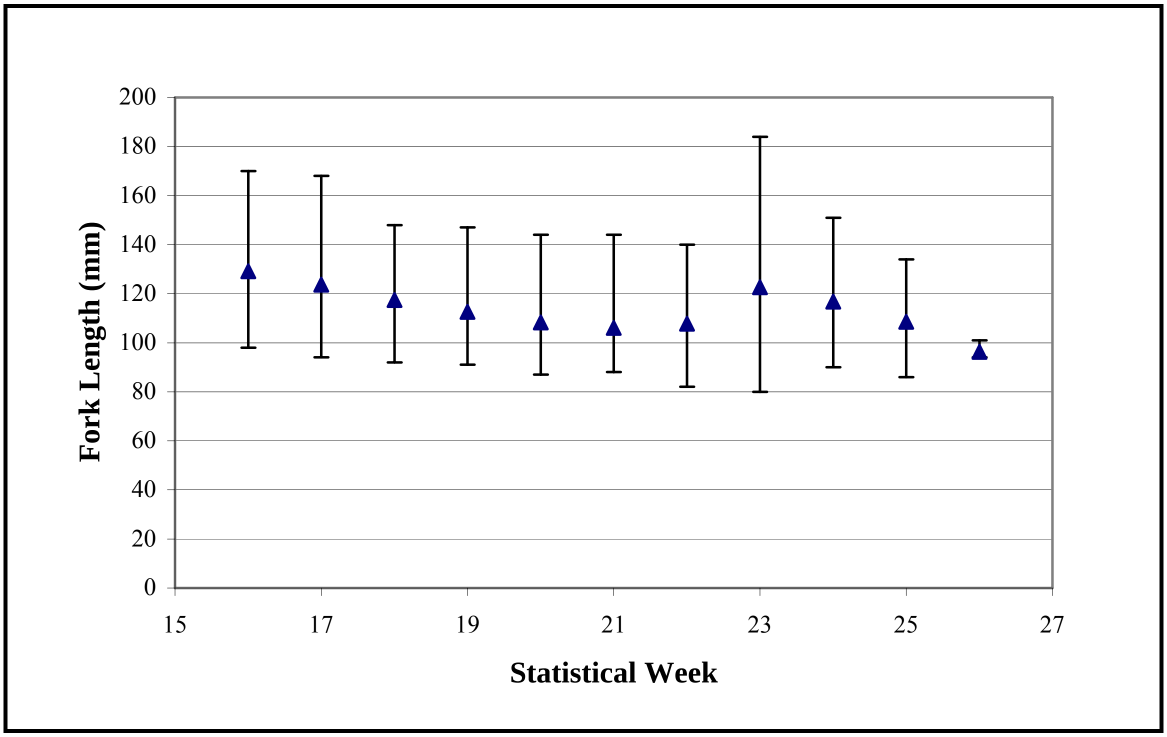

Figure 16. Average and range of fork lengths from coho smolts sampled from Bear Creek, 2006.

Trout

The identification of trout in Bear Creek poses the same difficulties as was discussed earlier in the Cedar River section. For these reasons, we refer to trout as cutthroat trout or steelhead out migrants, based on visual identification.

Catch and Production Estimate

There were no steelhead captured throughout the 2006 trapping season in Bear Creek.

A total of 623 cutthroat trout were captured in the screw trap. Migration was mostly uni-modal with daily catch peaking May 8, when 38 cutthroat were captured. Sixteen different mark groups were released over the season. Outside of the peak migration periods, some of the mark groups were small and recoveries were few. In aggregating adjacent mark groups, we considered stream flows since previous years' data has shown some correlation between trap efficiency and discharge. We also aggregated the mark groups with the goal of having a minimum of three recaptures per stratum. Eight strata were formed from the 16 release groups and used as input for DARR. DARR output capture rates ranged from 7.5% to 21.8% and estimated production at 5,106 cutthroat, with a coefficient of variation of 26.9% and a 95% confidence interval of 4,403 to 5,805 smolts (Figure 17, Appendix C 5). This estimate applies only to the interval trapped (April 10 through June 28). During the 2000 season, when the screw trap operated from January through June, 35% of the cutthroat migration occurred prior to April 5. Applying this timing to the cutthroat estimated during the 2006 trapping season estimates that a total of 7,855 cutthroat migrated from Bear Creek.

Based on limited sampling, Marshall et al. (2006) estimated 8.5% of the field-identified cutthroat were, in fact, cutthroat/rainbow hybrids. Applying this rate estimates that approximately 7,187 cutthroat and 668 hybrid trout passed the traps.

Cutthroat trout fork lengths averaged 163.8 mm, and individuals varied from 111 mm to 310 mm throughout the trapping season (Table 22).

Table 22. Mean cutthroat fork length (mm), standard deviation, range, sample size, and catch by statistical week, Bear Creek screw trap 2006.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/10	04/16	16	145.3	21.60	112	176	6	8
04/17	04/23	17	177.1	23.02	118	223	42	58
04/24	04/30	18	174.0	26.64	131	310	71	116
05/01	05/07	19	158.6	21.17	111	206	62	117
05/08	05/14	20	162.9	22.17	124	221	54	145
05/15	05/21	21	154.3	20.55	120	204	32	57
05/22	05/28	22	160.1	19.05	124	218	35	41
05/29	06/04	23	161.5	15.96	139	189	27	34
06/05	06/11	24	154.9	11.26	136	175	12	17
06/12	06/18	25	151.6	11.58	132	168	16	24
06/19	06/25	26-27					0	6
		Season Totals	163.8	22.97	111	310	357	623

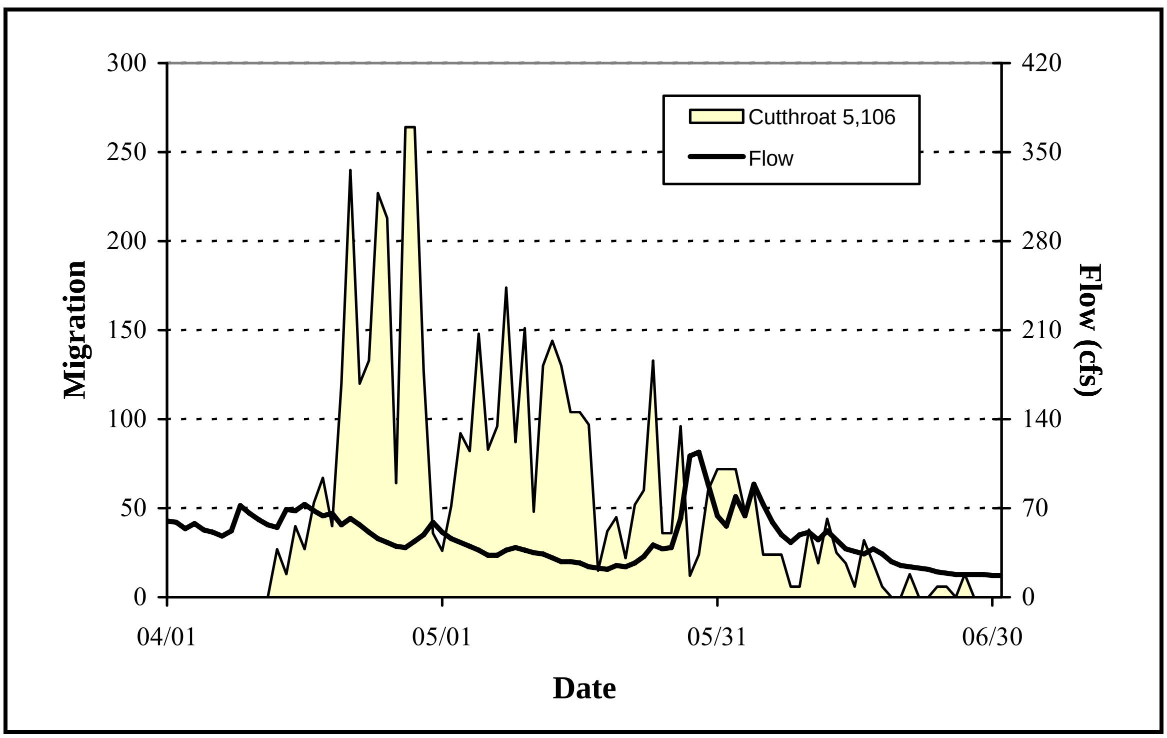

Figure 17. Daily estimated migration of cutthroat trout and flow, Bear Creek screw trap 2006.

Mortality

During the fry trapping season, three Chinook died in the trap. In the screw trap, three Chinook and four coho smolts died over the trapping season.

Incidental Species

In addition to sockeye and Chinook fry caught in the fry trap, 8 coho fry, 10 cutthroat smolts, and 31 pink fry were also caught. Other species included lamprey, sculpin, three-spine sticklebacks, pumpkinseed, large mouth bass, dace, and Northern pikeminnow. In addition to the species estimated for the screw trap, we also caught sockeye fry, one sockeye smolt, 9 coho fry, 2 chum fry, 17 resident rainbow trout, and 2 cutthroat adults. Other species caught included lamprey, large-scale suckers, three-spine stickleback, sculpin, pumpkinseed, small and large mouth bass, whitefish, warmouth, peamouth, dace, catfish, and Northern pikeminnow.

Appendix A

Variance of total unmarked smolt numbers, $\hat{U}_i$,
when the number of unmarked smolts, $\hat{u}_i$ is estimated.

Kristen Ryding
WDFW Biometrician

Variance of total unmarked smolt numbers, $\hat{U}_i$, when the number of unmarked smolts, $\hat{u}_i$ is estimated.

by Kristen Ryding, WDFW Biometrician

The estimator for $\hat{U}_i$ is,

$$\hat{U}_i = \frac{\hat{u}_i\left(M_i+1\right)}{\left(m_i+1\right)}$$

the estimated variance of $\hat{U}_i$, $Var\left(U_i\right)$ is as follows,

$$Var\left(\hat{U}_i\right) = Var\left(\hat{u}_i\right)\left(\frac{\left(M_i+1\right)\left(M_i m_i+3M_i+2\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}\right)+Var\left(\hat{U}_i\middle|E\left(\hat{u}\right)\right)$$

$$\text{where } Var\left(\hat{U}_i\middle|E\left(\hat{u}\right)\right)=\frac{\left(M_i+1\right)\left(M_i-m_i\right)E\left(\hat{u}_i\right)\left(E\left(\hat{u}_i\right)+m_i+1\right)}{\left(m_i+1\right)^2\left(m_i+2\right)},$$

$E\left(\hat{u}_i\right)$ = the expected value of $\hat{u}_i$ either in terms of the estimator (equation for $\hat{u}_i$) or just substitute in the estimated value and, $Var\left(\hat{u}_i\right)$ depends on the sampling method used to estimate $\hat{u}_i$.

Derivation:

Ignoring the subscript i for simplicity, the derivation of the variance estimator is based on the following unconditional variance expression,

$$Var\left(\hat{U}\right)=Var\left(E\left(\hat{U}\middle|u\right)\right)+E\left(Var\left(\hat{U}\middle|u\right)\right).$$

The expected value and variance $\hat{U}$ given u is as before, respectively,

$$E\left(\hat{U}_i\middle|u\right)=\frac{u_i\left(M_i+1\right)}{\left(m_i+1\right)} \text{ and,}$$

$$Var\left(\hat{U}\middle|u\right)=\frac{u\left(u+m+1\right)\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}.$$

Substituting in $\hat{u}$ for u gives the following,

$$Var\left(\hat{U}\right)=Var\left(\frac{\hat{u}\left(M+1\right)}{\left(m+1\right)}\right)+E\left[\frac{\left(M+1\right)\left(M-m\right)\hat{u}\left(\hat{u}+m+1\right)}{\left(m+1\right)^2\left(m+2\right)}\right]$$

$$Var\left(\hat{U}\right)=\left(\frac{\left(M+1\right)}{\left(m+1\right)}\right)^2 Var\left(\hat{u}\right)+\frac{\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}\left[E\left(\hat{u}^2\right)+E\left(\hat{u}\right)\left(m+1\right)\right]$$

Note that,

$$E\left(\hat{u}^2\right)=Var\left(\hat{u}\right)+\left(E\hat{u}\right)^2$$

Substituting in this value for $E\left(\hat{u}^2\right)$,

$$Var\left(\hat{U}\right)=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u})+\left(E(\hat{u})\right)^2+E(\hat{u})(m+1)\right]$$

$$=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u})+E(\hat{u})\left[E(\hat{u})+m+1\right]\right]$$

$$Var\left(\hat{U}\right)=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}Var(\hat{u})+\frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u})+m+1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2}+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right)+\frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u})+m+1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2}+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=\frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{(M+1)(m+2)}{(m+2)}+\frac{(M-m)}{(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=\frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{Mm+2M+m+2+M-m}{(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)(Mm+3M+2)}{(m+1)^2(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

Appendix B

Catch and Migration Estimates by Stratum
for Cedar River Sockeye, Chinook, and Coho Salmon, 2006.

Appendix B 1. Estimated catch and migration by stratum for Cedar River wild sockeye fry, 2006.

Stratum	Date Begin	Date End	Total Estimated Catch	Capture Rate	Estimated Migration	Variance
1	01/20	02/06	7,105	1.40%	497,121	6.96E+09
2	02/07	02/14	4,585	2.40%	189,763	6.70E+08
3	02/15	02/19	3,805	1.70%	223,951	4.21E+09
4	02/20	02/23	14,847	4.10%	360,119	1.28E+09
5	02/24	02/24	5,235	7.30%	72,112	5.84E+07
6	02/25	02/26	15,158	4.10%	372,177	2.61E+09
7	02/27	02/27	4,855	3.40%	142,659	1.95E+08
8	02/28	02/28	7,590	3.50%	218,059	1.14E+09
9	03/01	03/02	8,143	4.00%	205,970	7.55E+08
10	03/03	03/03	6,014	4.50%	134,278	2.81E+08
11	03/04	03/05	18,403	3.80%	483,469	3.58E+09
12	03/06	03/06	7,846	3.30%	234,320	1.30E+09
13	03/07	03/07	8,986	4.60%	194,512	5.27E+08
14	03/08	03/09	10,463	3.90%	265,380	1.42E+09
15	03/10	03/10	3,063	2.60%	116,394	4.56E+08
16	03/11	03/12	11,144	5.70%	195,020	5.64E+08
17	03/13	03/13	7,753	5.50%	141,215	3.17E+08
18	03/14	03/14	12,183	5.50%	222,127	3.55E+08
19	03/15	03/16	30,870	8.20%	378,696	1.47E+09
20	03/17	03/19	51,394	8.70%	591,826	1.10E+09
21	03/20	03/20	14,413	7.40%	193,991	4.50E+08
22	03/21	03/21	13,730	10.40%	132,210	1.32E+08
23	03/22	03/23	37,659	8.50%	440,712	1.55E+09
24	03/24	03/24	15,227	3.80%	396,116	2.02E+09
25	03/25	03/26	31,411	9.50%	329,935	7.34E+08
26	03/27	03/27	13,583	8.40%	162,539	1.99E+08
27	03/28	03/28	17,883	6.40%	278,215	6.25E+08
28	03/29	03/30	29,578	7.10%	416,397	2.00E+09
29	03/31	03/31	15,321	6.00%	256,578	7.51E+08
30	04/01	04/02	30,333	8.20%	372,145	9.28E+08
31	04/03	04/03	11,182	7.30%	152,981	1.83E+08
32	04/04	04/04	17,066	11.00%	154,548	1.31E+08
33	04/05	04/06	27,365	8.90%	308,296	7.72E+08
34	04/07	04/07	11,106	7.70%	145,058	1.93E+08
35	04/08	04/09	19,478	9.10%	213,011	3.22E+08
36	04/10	04/11	15,190	8.50%	179,137	3.25E+08
37	04/12	04/12	7,050	8.60%	81,503	5.57E+07
38	04/13	04/18	31,905	7.20%	441,836	2.59E+09
39	04/19	04/21	20,102	7.00%	287,012	1.01E+09
40	04/22	04/30	26,505	8.90%	296,685	2.29E+09
41	05/01	05/09	9,561	6.80%	141,324	5.18E+08
42	05/10	05/27	10,307	5.90%	173,345	1.08E+09
		Total	**665,397**		**10,792,744**	**4.81E+10**

Appendix B 2. Estimated catch and migration by stratum for Cedar River Chinook fry, 2006.

Stratum	Date Begin	Date End	Total Estimated Catch	Capture Rate	Estimated Migration	Variance
1	01/20	02/06	493	1.40%	34,494	4.70E+07
2	02/07	02/14	230	2.40%	9,519	2.05E+06
3	02/15	02/19	109	1.70%	6,415	3.97E+06
4	02/20	02/23	462	4.10%	11,206	1.00E+07
5	02/24	02/24	123	7.30%	1,694	5.26E+04
6	02/25	02/26	98	4.10%	2,406	1.61E+06
7	02/27	02/27	30	3.40%	882	3.17E+04
8	02/28	02/28	174	3.50%	4,999	7.15E+05
9	03/01	03/02	180	4.00%	4,553	4.84E+05
10	03/03	03/03	32	4.50%	714	2.24E+04
11	03/04	03/05	147	3.80%	3,862	8.34E+05
12	03/06	03/06	18	3.30%	538	2.13E+04
13	03/07	03/07	27	4.60%	584	1.63E+04
14	03/08	03/09	59	3.90%	1,496	8.05E+04
15	03/10	03/10	46	2.60%	1,748	1.60E+05
16	03/11	03/12	112	5.70%	1,960	1.00E+05
17	03/13	03/13	10	5.50%	182	3.57E+03
18	03/14	03/14	19	5.50%	346	6.76E+03
19	03/15	03/16	46	8.20%	564	1.04E+04
20	03/17	03/19	186	8.70%	2,142	4.22E+05
21	03/20	03/20	16	7.40%	215	3.18E+03
22	03/21	03/21	12	10.40%	116	1.10E+03
23	03/22	03/23	12	8.50%	140	3.86E+03
24	03/24	03/24	29	3.80%	754	2.56E+04
25	03/25	03/26	60	9.50%	630	8.60E+03
26	03/27	03/27	1	8.40%	12	1.72E+02
27	03/28	03/28	24	6.40%	373	6.49E+03
28	03/29	03/30	21	7.10%	296	2.07E+04
29	03/31	03/31	3	6.00%	50	8.69E+02
30	04/01	04/02	9	8.20%	110	1.54E+03
31	04/03	04/03	5	7.30%	68	9.49E+02
32	04/04	04/04	10	11.00%	91	7.91E+02
33	04/05	04/06	13	8.90%	146	2.51E+03
34	04/07	04/07	1	7.70%	13	2.11E+02
35	04/08	04/09	5	9.10%	55	7.55E+02
36	04/10	04/11	6	8.50%	71	8.97E+02
37	04/12	04/12	2	8.60%	23	2.99E+02
38	04/13	04/18	45	7.20%	623	1.97E+04
39	04/19	04/21	12	7.00%	171	2.84E+03
40	04/22	04/30	30	8.90%	336	8.61E+03
		Total	**2,917**		**94,601**	**6.77E+07**

Appendix B 3. Total catch and migration by stratum for Cedar River wild Chinook smolts, 2006

Stratum	Date Begin	Date End	Total Catch	Capture Rate	Estimated Migration	Variance
1	05/01	05/11	221	8.40%	2,624	3.92E+05
2	05/10	05/14	60	5.10%	1,185	3.32E+05
3	05/15	06/09	339	4.30%	7,923	8.38E+06
4	06/10	07/16	210	3.10%	6,860	7.60E+06
		Total	**830**		**18,592**	**1.67E+07**

Appendix B 4. Total catch and migration by stratum for Cedar River wild coho smolts, 2006.

Stratum	Date Begin	Date End	Total Catch	Capture Rate	Estimated Migration	Variance
1	04/10	05/06	265	2.10%	12,879	3.25E+07
2	04/07	05/09	153	4.60%	3,328	2.64E+06
3	05/10	05/13	165	1.50%	10,945	3.93E+07
4	05/14	06/02	155	1.60%	9,765	4.69E+07
5	06/03	07/16	57	7.30%	784	1.42E+05
		Total	**795**		**37,701**	**1.21E+08**

Appendix C

Catch and Migration Estimates by Stratum
for Bear Creek Sockeye,
Chinook and Coho Salmon, and Cutthroat Trout, 2006.

Appendix C 1. Estimated catch and migration by stratum for Bear Creek sockeye, 2006.

Stratum	Date Begin	Date End	Total Estimated Catch	Capture Rate	Estimated Migration	Variance
1	02/08	02/13	1,210	4.00%	30,030	5.77E+07
2	02/14	02/20	1,097	8.00%	13,762	1.18E+07
3	02/21	02/27	3,211	16.60%	19,343	5.39E+06
4	02/28	03/01	2,214	9.10%	24,300	1.22E+07
5	03/02	03/02	1,728	13.60%	12,712	1.61E+06
6	03/03	03/05	7,470	16.00%	46,688	3.65E+07
7	03/06	03/06	1,629	13.80%	11,804	1.72E+06
8	03/07	03/08	5,450	11.10%	49,050	8.91E+07
9	03/09	03/10	5,343	12.60%	42,320	2.85E+07
10	03/11	03/12	5,006	14.70%	34,013	1.30E+07
11	03/13	03/13	1,264	12.90%	9,807	1.42E+06
12	03/14	03/15	3,838	17.40%	22,057	1.08E+07
13	03/16	03/17	3,826	20.60%	18,573	3.16E+06
14	03/18	03/19	3,789	19.00%	19,942	3.38E+06
15	03/20	03/20	1,632	18.00%	9,067	9.28E+05
16	03/21	03/22	5,171	14.20%	36,415	3.52E+07
17	03/23	03/24	8,118	13.80%	58,826	7.20E+07
18	03/25	03/26	4,778	18.80%	25,415	5.81E+07
19	03/27	03/27	1,656	17.60%	9,409	8.37E+05
20	03/28	03/29	2,673	17.10%	15,629	3.89E+06
21	03/30	03/31	1,236	18.30%	6,752	5.56E+06
22	04/01	04/08	3,668	18.40%	19,942	5.90E+06
		Total	**76,007**		**535,858**	**4.59E+08**

Appendix C 2. Estimated catch and migration by stratum for Bear Creek Chinook fry, 2006.

Stratum	Date Begin	Date End	Total Estimated Catch	Capture Rate	Estimated Migration	Variance
1	02/08	02/13	48	4.00%	1,191	1.23E+05
2	02/14	02/20	40	8.00%	502	2.58E+04
3	02/21	02/27	11	16.60%	66	4.90E+02
4	02/28	03/01	22	9.10%	241	7.66E+03
5	03/02	03/02	41	13.60%	302	2.72E+03
6	03/03	03/05	44	16.00%	275	4.50E+03
7	03/06	03/08	153	13.80%	1,377	2.53E+05
8	03/09	03/10	56	11.10%	444	1.57E+05
9	03/11	03/12	17	12.60%	116	1.35E+03
10	03/13	03/13	3	14.70%	23	1.57E+02
11	03/14	03/15	3	12.90%	17	1.15E+02
12	03/16	03/17	4	17.40%	19	8.15E+01
13	03/18	03/19	6	20.60%	32	1.46E+02
14	03/20	03/20	1	19.00%	6	2.47E+01
15	03/21	03/22	20	18.00%	141	2.81E+03
16	03/23	03/24	11	14.20%	80	1.85E+03
17	03/25	03/26	3	13.80%	16	9.71E+01
18	03/27	03/29	2	18.80%	12	6.46E+01
19	03/30	03/31	2	17.60%	11	4.80E+01
20	04/01	04/08	11	17.10%	60	3.70E+02
		Total	**498**		**4,929**	**5.81E+05**

Appendix C 3. Total catch and migration by stratum for Bear Creek Chinook smolts, 2006.

Stratum	Date Begin	End	Total Catch	Capture Rate	Estimated Migration	Variance
1	04/10	04/20	36	33.20%	108	9.90E+02
2	04/21	04/30	99	25.70%	385	5.83E+03
3	05/01	05/05	274	49.20%	557	1.45E+03
4	05/06	05/09	805	59.00%	1,364	5.91E+03
5	05/10	05/14	1376	64.40%	2,138	8.44E+03
6	05/15	05/18	951	60.80%	1,564	7.31E+03
7	05/19	05/23	1894	56.20%	3,369	3.40E+04
8	05/24	05/29	1024	30.60%	3,342	8.28E+04
9	05/30	06/02	184	40.20%	457	2.52E+03
10	06/03	06/07	519	56.40%	920	2.52E+03
11	06/08	06/12	643	38.40%	1,674	1.70E+04
12	06/13	06/17	250	56.60%	442	5.66E+02
13	06/18	06/22	105	45.50%	231	3.92E+02
14	06/23	06/28	19	40.00%	48	8.43E+01
		Total	**8,179**		**16,598**	**1.70E+05**

Appendix C 4. Total catch and migration by stratum for Bear Creek coho smolts, 2006.

Stratum	Date Begin	End	Total Catch	Capture Rate	Estimated Migration	Variance
1	04/10	04/20	105	19.80%	554	1.34E+04
2	04/21	04/25	414	24.00%	1,723	5.05E+04
3	04/26	04/30	1,399	15.00%	9,327	1.22E+06
4	05/01	05/05	2,453	18.00%	13,628	2.81E+06
5	05/06	05/09	2,448	27.50%	8,902	1.04E+06
6	05/10	05/14	1,958	36.80%	5,325	1.95E+05
7	05/15	05/18	1,176	39.50%	2,977	6.61E+04
8	05/19	05/23	806	46.80%	1,722	1.26E+04
9	05/24	05/29	340	21.80%	1,558	3.83E+04
10	05/30	06/02	159	22.70%	700	1.21E+04
11	06/03	06/07	103	29.70%	347	2.65E+03
12	06/08	06/12	35	34.00%	103	6.16E+02
13	06/13	06/17	31	37.50%	83	3.04E+02
14	06/18	06/28	11	30.80%	36	2.36E+02
		Total	**11,439**		**46,987**	**5.46E+06**

Appendix C 5. Total catch and migration by stratum for Bear Creek cutthroat migrants, 2006.

Stratum	Date Begin	End	Total Catch	Capture Rate	Estimated Migration	Variance
1	04/10	04/25	99	7.50%	1,320	2.67E+05
2	04/26	04/30	83	11.00%	756	5.59E+04
3	05/01	05/05	78	19.60%	398	1.24E+04
4	05/06	05/09	96	21.80%	441	6.56E+03
5	05/10	05/14	88	14.60%	602	2.33E+04
6	05/15	05/23	72	13.40%	537	2.22E+04
7	05/24	06/07	66	8.30%	792	9.51E+04
8	06/08	06/28	41	15.80%	260	9.24E+03
		Total	**623**		**5,106**	**4.92E+05**

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