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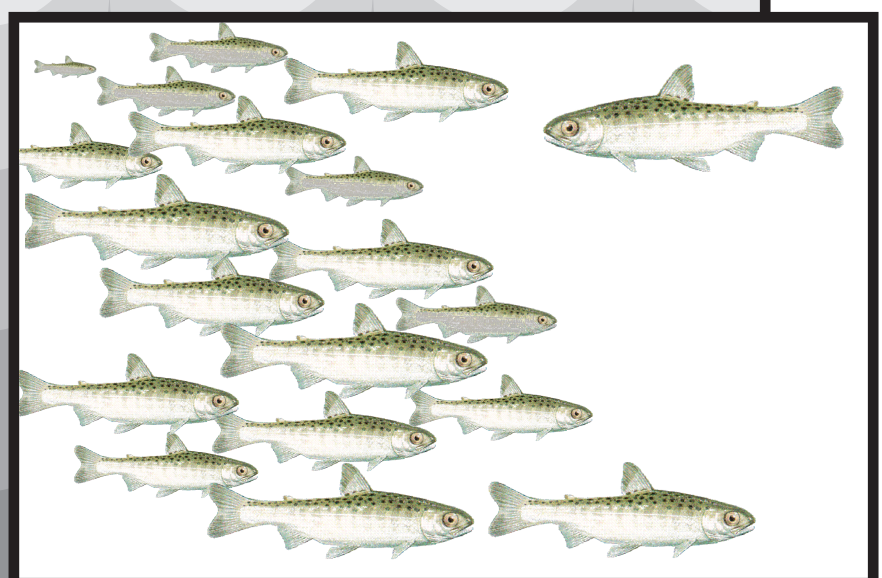
Evaluation of Downstream Migrant Salmon Production in 2008 from the Cedar River and Bear Creek



by Kelly Kiyohara, and Mara Zimmerman

Washington Department of
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Evaluation of Downstream Migrant Salmon Production in 2008 from the Cedar River and Bear Creek

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Success of these projects relied on the hard work of a number of dedicated permanent and temporary Washington Department of Fish and Wildlife (WDFW) personnel. The WDFW Hatcheries Program successfully collected adult sockeye broodstock and incubated eggs, releasing over 2.49 million sockeye fry into the Cedar River. Escapement data were collected and estimates developed by individuals from several agencies: Steve Foley, Larry Lowe, Dan Estell, Loren Brokaw, and Jared Johnson from WDFW; Mike Leslie and Brian Footen from the Muckleshoot Tribe; Karl Burton from SPU; and Hans Berge, Frank Leonetti and Jim Lissa from King County DNRP. WDFW scientific technicians Paul Lorenz, Dan Estell, and Loren Brokaw worked long hours, usually at night, in order to operate the traps, mark, identify, and count fish. WDFW biologists Mike Ackley and Pete Topping provided valuable experience and logistical support. Project management was provided by Paul Faulds from SPU and Hans Berge from King County.

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 incline-plane trap.

The Renton Municipal Airport provided security for the incline-plane trap and other equipment housed at the airport.

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 and Redmond Town Center Security staff provided a measure of security for the crew and trap.

King County Water and Land Resource Division provided continuous flow monitoring.

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Executive Summary

This report describes downstream juvenile migrations of five salmonid species emigrating from two heavily spawned tributaries in the Lake Washington watershed: Cedar River and Bear Creek. Cedar River flows into the southern end of Lake Washington, and Bear Creek flows into the Sammamish River, which flows into the north end of Lake Washington. Juvenile migration abundances are a measure of salmonid production above the trapping location in each basin. In 1992, the Washington Department of Fish and Wildlife (WDFW) initiated monitoring of sockeye fry production in the Cedar River to investigate causes of low adult sockeye returns. In 1999, this annual trapping program was expanded in scope (a second trap) and length in order to estimate production of juvenile Chinook salmon. Production estimates of coho, steelhead, and cutthroat smolts were also made possible by the expanded trapping program.

Juvenile production of sockeye in the Sammamish basin has been evaluated since 1997. In 1997 and 1998, sockeye fry production was estimated from a trap operated in the Sammamish River. In 1999, this monitoring program was moved to Bear Creek in order to concurrently assess Chinook and sockeye production. Since 1999, the Bear Creek study has also provided outmigration estimates of coho, steelhead and cutthroat smolts.

Cedar River

This report documents production and survival of 2007 brood year sockeye as they emigrate from the Cedar River to Lake Washington. These results contribute to a 17-year dataset for the Cedar River. The primary study goal was to estimate total migration of natural-origin Cedar River sockeye fry into Lake Washington in 2008. This estimate was used to calculate survival of the 2007 brood from egg deposition to lake entry. In addition, this estimate provides early life history data useful for calculating survival among other life stages, including juvenile survival within Lake Washington (lake entry to smolt) and marine survival (smolt to returning adults).

A floating incline-plane screen trap, located at river mile (R.M.) 0.7 in the Cedar River, was operated between January 13 and May 17 and captured a portion of sockeye fry migrating from the Cedar River into Lake Washington (Figure 2). Total migration was estimated to be 25.1 million ± 979,000 (95% C.I.) natural-origin sockeye fry. This estimate is based on a total catch of 1,344,757 and trap efficiencies ranging from 1.4% to 14.3%. Based on an estimated deposition of 78.5 million eggs, survival of natural-origin fry from egg deposition to lake entry was 31.2%, the highest survival estimated in the past 17 years. Over the season, 2.49 million hatchery-produced sockeye fry were released into the Cedar River below the incline-plane trap at the Cedar River Trail Park. If survival of hatchery fry released at the Cedar River Trail Park is assumed to be 100%, an estimated 27.6 million sockeye fry entered Lake Washington from the Cedar River in 2008.

Median migration date for natural-origin fry in 2008 (March 16) was six days earlier than the median natural-origin outmigration, and 10 days later than that of hatchery fry. Sockeye outmigration timing is correlated with February stream temperatures. In 2008, temperatures were slightly cooler (5.9°C) than the 17-year average (6.2°C).

Chinook outmigration was evaluated with two different traps. An incline-plane trap, used to assess sockeye fry production, captured the smaller, early-migrating Chinook. A screw trap, operated April 14 through July 19, captured the larger, late-migrating Chinook. A total of 705,583 ± 76,106 (95% C.I.) Chinook are estimated to have passed the incline-plane trap between January 1 and May 17. This estimate is based on a total catch of 31,307 and trap efficiencies ranged from 1.4% to 14.3%. A total of 39,311 ±18,156 (95% C.I.) Chinook are estimated to have passed the screw trap between May 28 and July 19. This estimate is based on a total catch of 741 juvenile Chinook in the screw trap. Screw trap efficiencies ranged from 2.6% to 7.4%. Between May 17 and 28, neither trap operated due to extremely high water. Migration during the outage was estimated to range between 22,068 to 27,726 Chinook.

Between 766,962 and 772,620 0+ Chinook are estimated to have outmigrated from the Cedar River in 2008. Migration timing was bi-modal. Fry emigrated between January and mid-May and comprised between 89.5% and 90.1% of the total migration. Parr emigrated between mid-April and July. Egg-to-migrant survival was estimated at 19%. Age 0+ Chinook increased in size from 34 mm fork length (FL) in January to 121 mm FL by the end of the season.

A total of 13,222 natural-origin coho are estimated to have migrated passed the screw trap in 2008. This total includes 10,404 ± 9,909 (95% CI) coho estimated during the trapped period and 2,962 coho estimated during the trap outage. Steelhead and cutthroat production were not estimated for in 2008 due to low catches (1 steelhead and 26 cutthroat smolts).

Bear Creek

An incline-plane trap installed 100 yards downstream of the Redmond Way Bridge, was operated between February 3 and April 14. A screw trap replaced the incline-plane trap April 14, and fished until July 9. Downstream migrant production was estimated for natural-origin sockeye fry, age 0+ Chinook, coho and cutthroat smolts. Steelhead production was not assessed due to insufficient catch.

A total sockeye fry migration in 2008 is estimated at 251,285 ±58,794 (95% C.I.). This estimate is based on a total catch of 21,802 sockeye fry and trap efficiencies ranging from 6.2% to 12.5%. Juvenile production, applied to deposition of an estimated 18.6 million eggs from the 2007 adult return, yielded a survival rate of 13.5%, the third highest survival since trapping began in 1998.

Chinook outmigration was evaluated from catch in incline-plane and screw traps. A total of 1,172 ± 80 (95% C.I.) Chinook are estimated to have migrated passed the incline-plane trap between February 3 and April 14. This estimate is based on a total catch of 110 Chinook and trap efficiencies of sockeye fry, which were used as a surrogate for Chinook fry migrants. A total of 11,598 ± 2,136 (95% C.I.) Chinook are estimated to have migrated passed the screw trap between April 15 and July 9. This estimate is based on a total catch of 2,772 Chinook and screw trap efficiencies ranging from 18.0% to 41.2%.

A total of 12,770 age 0+ Chinook are estimated to have outmigrated from Big Bear Creek in 2008. Migration timing was bimodal. Fry emigrated between February and April and comprised 9.2% of the total migration. Parr emigrated between May and July. Egg-to-migrant survival was estimated to be 1.0%. Sizes of outmigrating Chinook averaged 37.0 mm FL in February and did not increase to an average of 70.0 mm FL until late May.

A total of 12,208 ±2,401 (95% C.I.) natural-origin coho and 2,751 ±1,091 (95% C.I.) cutthroat are estimated to have outmigrated from Big Bear Creek in 2008. Only one steelhead was caught in the Bear Creek screw trap during the 2008 trapping season.

Introduction

This report describes downstream juvenile migrations of five salmonid species emigrating from two heavily spawned tributaries in the Lake Washington basin: Cedar River and Bear Creek, also referred to as Big Bear Creek. Juvenile migrant abundances are a measure of salmonid production above the trapping location in each watershed. Monitoring efforts have focused on sockeye and Chinook salmon, two species of particular concern in the Lake Washington watershed.

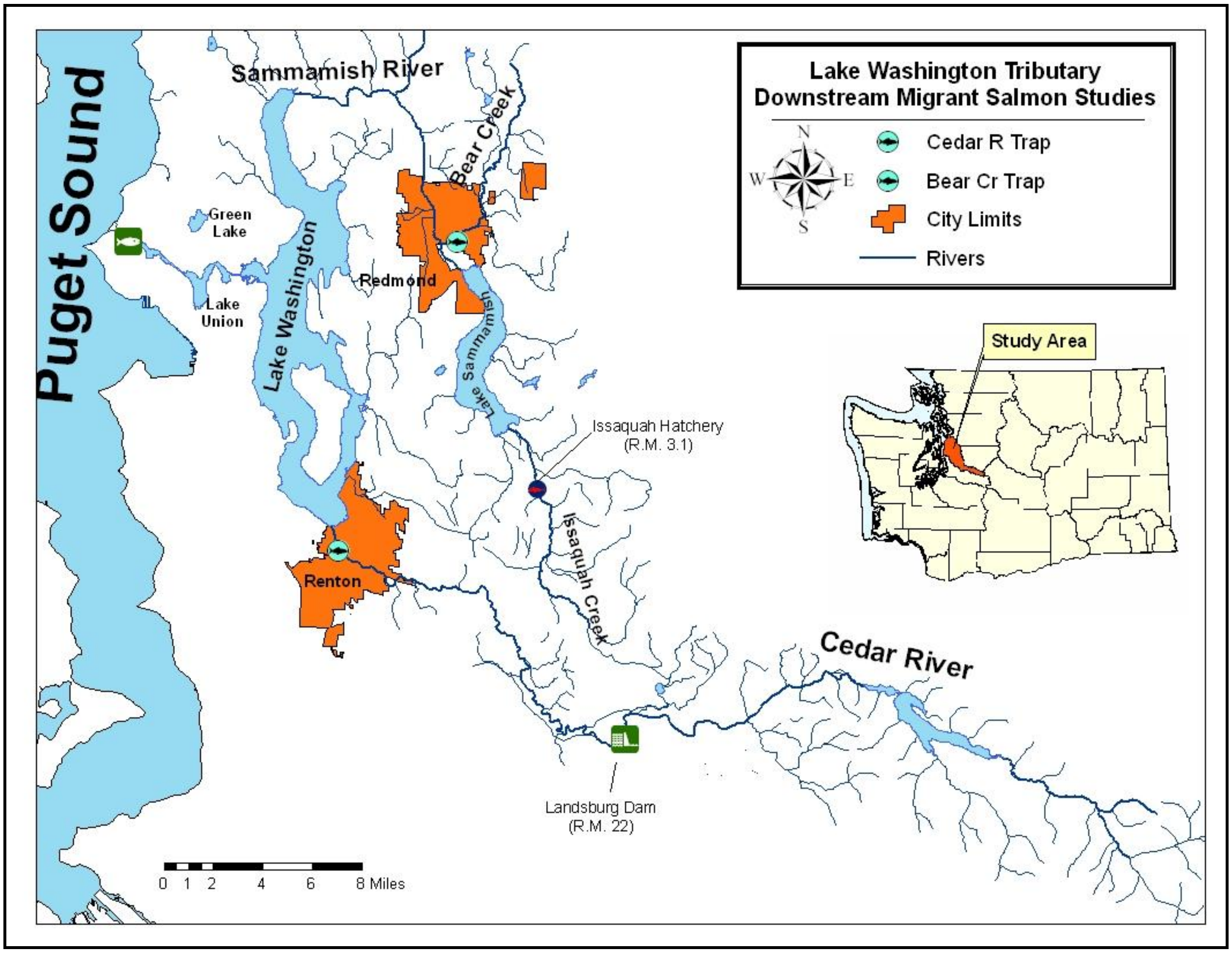


Figure 1. Map of Lake Washington tributary trap sites: Cedar River and Bear Creek, near Renton and Redmond, respectively.

Sockeye salmon have been a management concern in the Lake Washington watershed because of declining returns observed in the mid-1980s to 1991. Although over 500,000 sockeye spawners returned through the Ballard Locks in 1988, by 1991, less than 100,000 sockeye returned. In 1991, a broad-based group was formed to address this decline. Resource managers developed a recovery program that combined population monitoring with artificial production. These efforts continued through 2008 and provide information useful for improving management of Lake Washington sockeye salmon.

Sockeye life history can be partitioned into a freshwater phase and a marine phase. For the 1967 to 1993 broods, marine survival averaged 11% and varied eight-fold (2.6% to 21.4%), with no apparent decline (WDFW unpublished). In contrast, freshwater survival, measured by smolts produced per spawner, declined over this same period. These observations pointed to freshwater survival as an important contributor to the declines of Lake Washington sockeye.

The freshwater phase of sockeye production occurs in two habitats. In the stream habitat, sockeye spawn, eggs incubate, and fry emerge and migrate to the lake. Growth from fry to smolt stages occur in the lake, where virtually all of the juveniles rear for one year before emigrating to the ocean. Partitioning survival between these habitats will help explain causes of population decline. In the Lake Washington watershed, monitoring of natural and hatchery-origin sockeye was initiated in 1992 in the Cedar River and in 1997 in the Sammamish Slough. Monitoring in the Sammamish has continued in Bear Creek since 1999.

Chinook salmon are a management concern in the Lake Washington watershed due to the "threatened" status of Puget Sound Chinook ESU under the Endangered Species Act (March 1999). Increased understanding of habitat requirements, early life history, freshwater productivity and survival of Chinook salmon should improve planning of recovery efforts in the Lake Washington watershed. At the time of listing, baseline information included the number of Chinook spawners; however, adult-to-adult survival provides little insight into life stage-specific survival in freshwater or marine habitat. Combining information on adult spawners and juvenile migrants separates survival into freshwater and marine components and provides a more direct accounting of the role that stream habitats play in regulating salmon production (Seiler *et al.* 1981, Cramer *et al.* 1999). As recovery efforts are often associated with particular life stages (e.g., freshwater rearing habitat versus marine harvest), partitioning of survival among life stages will provide valuable information for the recovery planning process.

Downstream migrant evaluations of Chinook were initiated in 1999 in both the Cedar River and Bear Creek (Seiler *et al.* 2003). Two different gear types were employed in order to sample the entire Chinook migration, which includes an early migration of newly emerged fry and a later migration of larger Chinook (i.e, parr) that rear in the freshwater environment prior to migration. A incline-plane trap gently captures early-timed fry but may be avoided by larger migrants. A screw trap more effectively catches the late-timed parr migration.

Cedar River

Production of sockeye fry at the Landsburg Hatchery on the Cedar River began with the 1991 brood and WDFW has operated a floating incline-plan trap in the lower Cedar River to evaluate the outmigration of natural-origin and hatchery sockeye fry since 1992. All sockeye incubated at the Landsburg Hatchery can be identified with thermally-induced otolith marks (Volk *et al.* 1990). Annual sockeye returns range from 22,000 to 230,000 spawners, and average 98,960 spawners.

Water flow is a key variable influencing survival of hatchery and natural-origin sockeye in the Cedar River. In-river survival of hatchery releases is positively influenced by flow during the release period, as demonstrated in a 1995 study conducted by WDFW (Seiler and Kishimoto 1996). In-river survival of natural-origin sockeye from egg deposition to fry emigration, is negatively correlated with the magnitude of peak flows during egg incubation period, as demonstrated by the seventeen-year data set on Cedar River sockeye obtained and compiled by WDFW. Based on available information, numbers of natural-origin sockeye fry entering Lake Washington are the product of the number of eggs deposited (i.e., spawner returns) and flow-influenced survival rates during incubation and migration.

Bear Creek

Bear Creek is one of the more heavily spawned tributaries in the Sammamish watershed. When the juvenile salmonid study in the Sammamish watershed began in 1997, sockeye were returning to Bear Creek in excess of 50,000 spawners. Over the duration of the juvenile salmonid study, escapement has ranged from 1,080 to 60,000 spawners, with a median return of 8,170 sockeye.

Location of trapping operations has changed over the 12-year study period. In 1997 and 1998, a downstream migrant trap was operated in the Sammamish Slough at Bothell. Catches in this trap were used to estimate the contribution of the Sammamish portion of the watershed to the sockeye fry migration into Lake Washington. While this operation successfully estimated sockeye fry production, velocities in the Sammamish Slough were too low to capture migrants larger than sockeye fry. In 1999, the migrant trapping operation was moved upstream to Bear Creek, a tributary of the Sammamish River, where velocities were high enough to capture larger migrants. In addition to estimating Chinook and sockeye production, higher velocities also enabled measures of coho, steelhead and cutthroat production.

Goals and Objectives

The primary goal of this project is to quantify production of sub-yearling sockeye and Chinook in the Cedar River and Bear Creek. Production estimates are also made for coho salmon and steelhead and cutthroat trout when possible. In addition, information compiled on body size, migration timing, and movement through the Lake Washington system will contribute to the following objectives.

Chinook

1. **Estimate natural production and in-river survival.** In-river survival is estimated from total migrant production and estimated egg deposition. Correlation between in-river survival and variables such as spawner abundance, flows, and habitat condition will improve understanding of in-river survival.
2. **Determine variables contributing to fry and parr productions.** Identifying variables that limit juvenile production will inform management of populations in each watershed.
3. **Estimate lake/marine survival of natural production.** Survival from river outmigration to returning spawners indicates the relative contribution of early riverine survival to lake/locks/marine survival for Chinook abundance.

Sockeye

1. **Estimate natural production and in-river survival**. Overall success of natural spawning sockeye will be determined from natural-origin fry production and estimated egg deposition. 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 environmental variables.
2. **Estimate season total of fry entering the lake**. Rearing survival within the lake can be determined from the combined estimate of natural-origin and hatchery fry entering the lake and smolt production the following spring. This information can be used to evaluate predation and carrying capacity of the lake. Survival through the lake and marine environments can be determined from total fry production estimate and associated brood year adult returns.
3. **Estimate incidence of hatchery fry in the population at lake entry (Cedar River).** Relative survival of hatchery and natural-origin sockeye can be determined from comparing the proportion of hatchery and natural-origin sockeye at the fry life history stage with the incidence of hatchery and natural-origin fish in the sockeye population at later life stages (smolts and adults).
4. **Compare migration timing of natural-origin and hatchery fry.** A comparison of migration timing and subsequent survival of hatchery versus natural-origin sockeye fry will contribute to the adaptive management process guiding Cedar River Hatchery sockeye fry production and release.

Coho, Cutthroat and Steelhead

Estimate production of coho, cutthroat, and steelhead smolts when possible. These estimates provide a measurement of ecosystem health in the Cedar River and Bear Creek. Population levels and ratios between these species are indicative of habitat condition and response to watershed management.

Methods

Fish Collection

Trapping Gear and Operation

Cedar River

Two traps were operated in the lower Cedar River during the spring out-migration period. A small floating incline-plane trap was operated late winter through spring to trap sockeye and Chinook fry emigrating during this period. The design of this trap was chosen to avoid capture of yearling migrants and predation in the trap. A floating rotary screw trap was operated early spring through summer to assess migration of larger sub-yearling Chinook as well as coho, steelhead, and cutthroat smolts. This trap captured larger migrants that were potential predators of sockeye fry; therefore, the live box was designed so as to not retain sockeye fry. Together, these traps provided production estimates for each species while minimizing mortality.

The incline-plane trap consists of one or two low-angle incline-plane screen (scoop) 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 with a perforated aluminum plate (33 - 1/8 in. holes per in^2). The incline-plane trap resembles larger traps used to capture juvenile salmonids in the Chehalis and Skagit rivers, described in Seiler *et al.* 1981. Each scoop trap screens a cross-sectional area of 4 ft^2 when lowered to a depth of 16 inches. 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).

Over the 17-year course of the Cedar River juvenile salmonid study, trapping operations have been modified in response to changes in channel morphology and project objectives. In summer 1998, the lower Cedar River was dredged to reduce flooding potential (USACE 1997). Dredging lowered the streambed, created a wider and deeper channel, and reduced water velocity near the incline-plane trap location to near zero. In response to the change in channel morphology, the incline-plane trap location was moved upstream in 1999 in order to operate under suitable current velocities.

In 2008 the trap was positioned at RM 0.7, just downstream of the South Boeing Bridge. The incline-plane trap fished off the east bank and was repositioned within eight feet of the shoreline in response to changing flows. Two scoop traps were fished in parallel throughout the season except on 21 nights when only one trap was operated due to high flows and debris loads.

The incline-plane trap was operated 86 nights between January 13 and May 17, 2008. During each night of operation, trapping began before dusk and continued past dawn. Trapping was also conducted during periodic daylight intervals to assess daytime movement. Daytime trapping consisted of eleven daytime periods and was conducted nearly once a week from the beginning of February through the end of April. Incline-plane trap operations were discontinued on just four of the scheduled trapping nights due to excessive debris and high stream flows. During these nights, the trap was operated at 10 or 15-minute intervals each hour, except for one night when all trapping was ceased in order to remove a large log that entered the trap. Captured fish were removed from the trap, identified by species, and counted each hour. Large catches of sockeye fry were counted using an electronic counter. Electronic count was divided by an adjustment factor (98.0%) to estimate the actual catch. As in previous years, this adjustment factor was found through hand counting three to five groups of 500 to 1,000 sockeye each, and then running them through the electronic counter. The adjustment factor was the average of the test groups.

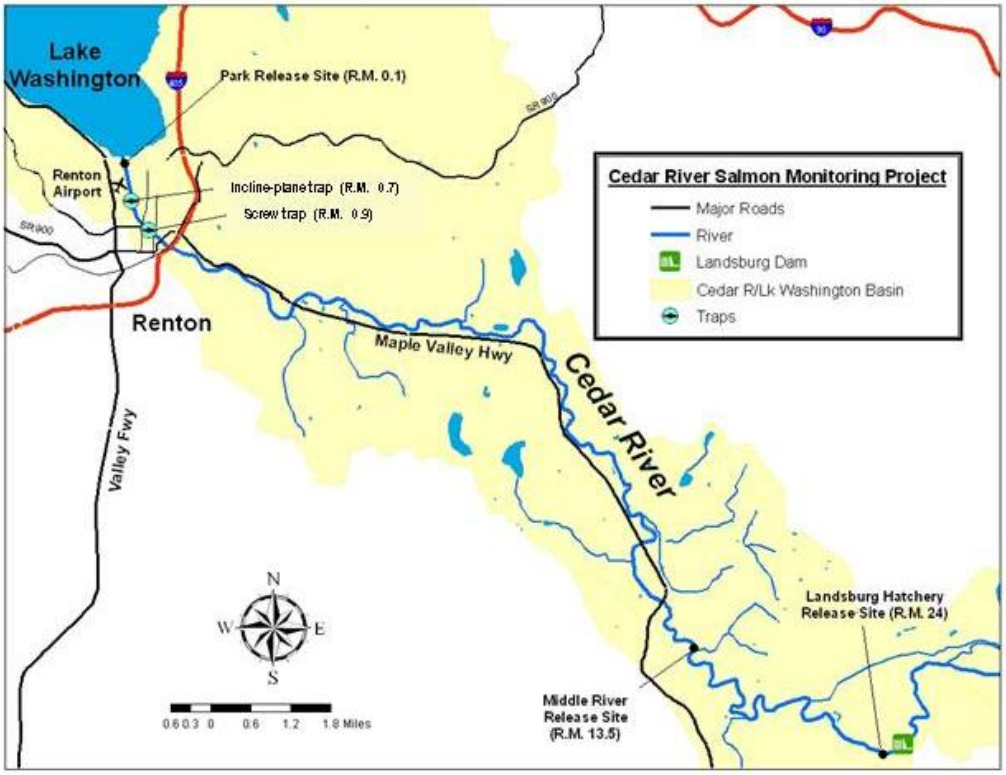


Figure 2. Site map of the lower Cedar River watershed depicting the incline-plane and screw trap locations and hatchery sockeye release sites for the 2008 trapping season.

The trap was located approximately 300 yards downstream of the Logan Street Bridge (approximately RM 0.9). Prior to 2006, the screw trap had been positioned just upstream of the Logan Street Bridge. Bed aggradations during high flow events in early 2006 made this previous location unsuitable for trap operation. Although the site downstream of the bridge did not provide optimal conditions for trapping in 2006 and 2007, no other site was identified on the lower river that would improve trapping conditions, security, and safety of the trap operation.

The screw trap was operated between April 14 and July 19, except during 12 outage periods (April 16, 25, 28, May 6, 13, 29, 30, June 10, 16, 25 and July 6 and 9) due to debris and a 10-day outage (May 15 to 27) due to high flows. 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, FL).

Bear Creek

As with the Cedar River, outmigrating salmonids were captured using two traps in lower Bear Creek. An incline-plane trap, identical to that employed in the Cedar River, was used to capture sockeye and Chinook fry early in the trapping season. This trap was replaced with a 5 ft diameter screw trap in mid April to capture Chinook, coho, steelhead, and cutthroat.

The incline-plane trap was operated between February 3 and April 14. A single scoop trap was suspended from a 30x12 ft steel pontoon barge positioned in the middle of the channel approximately 100 yards downstream of Redmond Way, below the railroad trestle. When the trap was operated, fishing began before dusk and continued past dawn. During trap operations, captured fish were removed from the trap and enumerated; removal occurred at hourly to several hour intervals, depending on migration rates. The incline-plane trap did not fish during daytime hours. On April 15, 2008 the screw trap was hung in place of the incline-plane trap and fished for the remainder of the season.

The screw trap was operated between April 16 and July 9, except during four outage periods (April 25, May 19, 20, and June 10) caused by debris and one outage (May 29) caused by to low water velocity. Low flows were a chronic issue that influenced operation of the screw trap in 2008. Flows were extremely high at the beginning of the trapping season and water backed up into the channel creating little velocity needed for catching juvenile salmonids at the trapping location. Water levels did not recede after a period of no precipitation. Further investigation revealed that three large beaver dams below the trap were impeding the flow of water. Water velocity was low and difficult to trap for the remainder of the season. Following the trap outage on May 29 (screw stopped turning), boards were placed upstream to divert flow into the trap. 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 (FL).

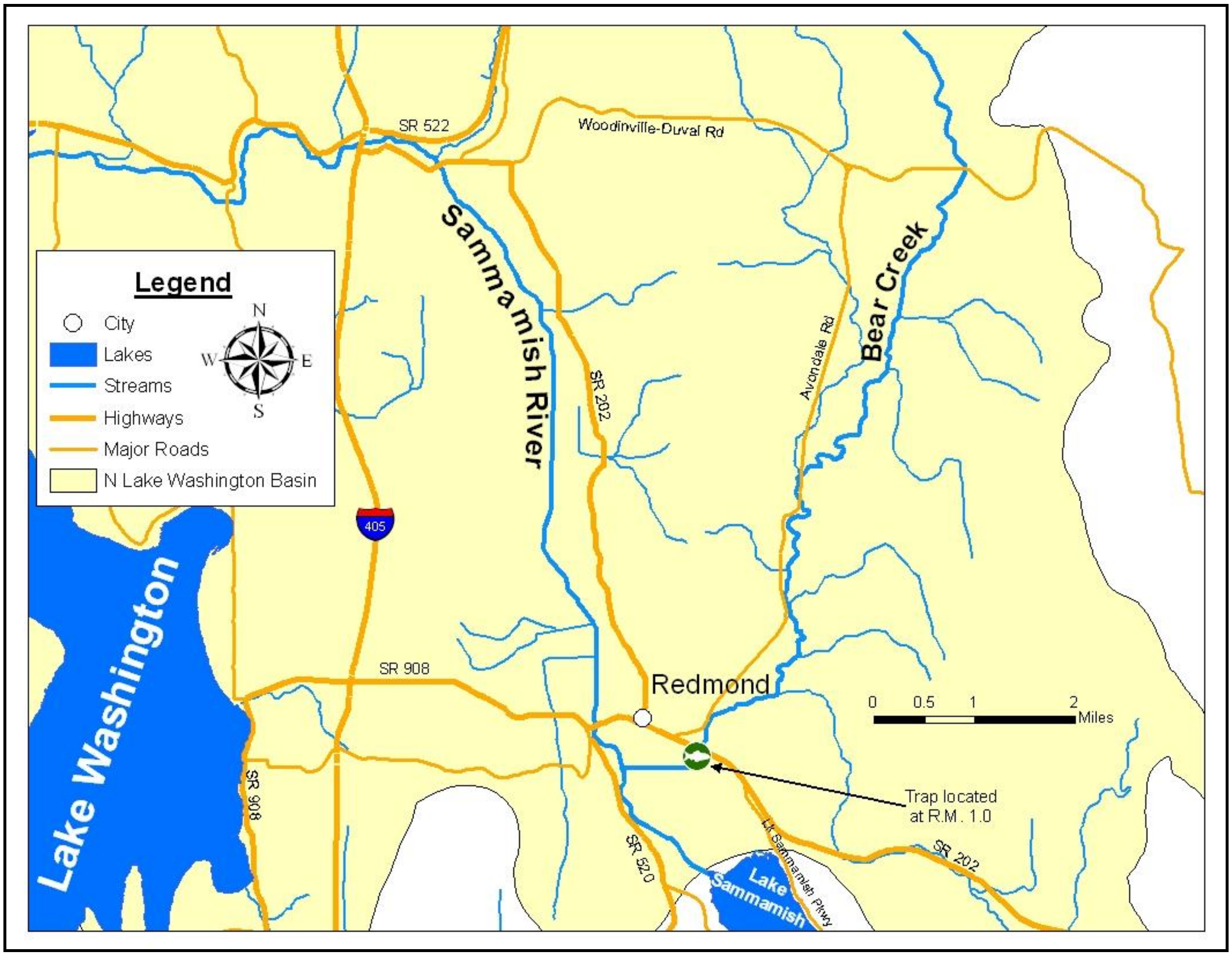


Figure 3. Site map of the Bear Creek watershed in the North Lake Washington Basin depicting trap location for the 2008 trapping season.

Trap Efficiencies

Cedar River

Incline-Plane Trap

Trap efficiencies of the Cedar River incline-plane trap were estimated by marking, releasing, and recapturing groups of marked sockeye fry. Fry captured in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). The health of marked fish was assessed prior to release. All deceased or compromised fish were not included in releases. Release groups ranged from 76 to 3,353 marked sockeye fry, and were released at the Logan Street Bridge (R.M. 1.1) nearly every night the trap operated (76 nights) throughout the season. Marked fry were distributed across the middle of the channel from the bridge. Catches were examined for mark fish and recaptures were noted during each trap checks.

Screw Trap

Trap efficiencies of the Cedar River screw trap were determined for Chinook parr, and coho and cutthroat smolts by recapture of marked and released fish of each species. Fish were anesthetized in a solution of MS-222 and marked with alternating upper and lower, vertical and horizontal partial-caudal fin-clips. Marks were changed on weekly intervals. Marked fish were allowed to recover from the anesthetic during the day in perforated buckets suspended in calm river water. In the evening, groups were released from the Williams Avenue Bridge located roughly 550-yds upstream. Releases occurred over multiple-, one- or two-day intervals throughout each week, varying from 1 to 135 juveniles of each species per release. Due to low catches, adequate numbers of fish were not available for large releases as done in previous years. Catches were examined for marks or tags and recaptures were noted during each trap check.

After May 9, Chinook over 65 mm were tagged with Passive Integrated Transponder tags (PIT tags) and smaller Chinook were fin-clipped and used in mark releases. Similar to fin marks, PIT tags enabled stratified release and recaptures to be evaluated during data analysis. In addition, individual fish could be identified from the PIT tags, providing information on recapture timing for release groups of Chinook parr.

Bear Creek

Incline-Plane Trap

Trap efficiencies for the Bear Creek incline-plane trap were estimated by marking, releasing, and recapturing groups of marked sockeye fry. Release groups, ranging from 22 to 369 sockeye, were released roughly 100 yards upstream, at the Redmond Way Bridge, on 30 nights throughout the season, as adequate numbers of fish were available. Fry captured the previous night or in the early hours of the night were marked in a solution of Bismarck brown dye (14 ppm for 1.5 hours). The health of marked fish was assessed prior to release. All deceased or compromised fish were not included in releases. Catches were examined for marks or tags and recaptures were noted during each trap checks.

Screw Trap

Trap efficiencies for the Bear Creek screw trap were estimated for Chinook, coho, and cutthroat smolts using the same approach described for the Cedar River screw trap. Mark groups, ranging from 1 to 76 individuals of each species, were released from the Union Hill Street Bridge.

Analysis

Production of juvenile salmonids were estimated using one of two methodological approaches. Both approaches, the Petersen estimator with a Chapman modification and Darroch's maximum likelihood estimator were applied to the stratified mark-recapture study design. Petersen estimator is appropriate when recapture of marked fish occurred immediately following release, and was applied to incline-plane trap data for sockeye and Chinook fry. The maximum likelihood estimator is appropriate when recapture of marked fish occurred over a prolonged period, and was applied to screw trap data for Chinook, coho, and trout, According to the Petersen estimate, modified by Chapman (1951), abundance during time period i is estimated as:

Equation 1

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

where:

$\hat{U}_i$ = Migration of unmarked fish passing the trap during time period i
u_i = Unmarked fish caught in the trap during time period i
M_i = Marked fish released above the trap during time period i
m_i = Marked fish recaptured in the trap 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 juvenile salmonid 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

Variance associated with the Petersen estimator was modified to account for variance of the estimated catch during trap outages. If trapping is suspended during the period when only unmarked fish are passing the trap, catch of unmarked fish must be estimated. In this case $\hat{u}_i$ is substituted for u_i in Equation 1. The variance, $V(\hat{U}_i)$, is now estimated using (K. Ryding, Washington Department of Fish and Wildlife, personal communication, see Appendix A for derivation):

Equation 5

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

where:

$Var(\hat{u}_i)$ = variance of estimated unmarked catch during trap outage periods

Population estimates based on Darroch's maximum likelihood estimator for stratified populations were calculated using DARR (Darroch Analysis with Rank Reduction) software developed by Bjorkstedt (2000). DARR v.2.0 was used in this analysis and is an improved version of the original program (Bjorkstedt 2005).

In a time-stratified study design, fish are marked and released in *s* tagging strata. Marked and unmarked fish are recovered in *t* recovery strata. The probability that a marked fish released in the i^{th} period will be captured in the j^{th} period is the joint probability (π_{ij}) that a marked individual is available to be captured (migration probability θ_{ij}) and is captured (capture probability p_j). The joint probability is $\pi_{ij} = \theta_{ij}\, p_j$. Migration probability (θ_{ij}) for a given release and recapture period is determined by a marked individual resuming migration and by migration duration between the release point and the trap. The number of emigrating juvenile fish during the *jth* recovery period, n_j, where $s = t$ and the rows of m,$\{m_i\}$, are mutually independent and:

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

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

Data are arranged in matrices as

$$\mathbf{u} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ \cdots \\ u_t \end{pmatrix} \qquad \mathbf{M} = \begin{pmatrix} M_1 \\ M_2 \\ M_3 \\ \cdots \\ M_s \end{pmatrix} \qquad \mathbf{m} = \begin{pmatrix} m_{11} & m_{12} & \ldots & m_{1t} \\ 0 & m_{22} & \ldots & m_{2t} \\ \ldots & \ldots & \ldots & \ldots \\ 0 & \ldots & 0 & m_{st} \end{pmatrix}$$

Capture probability for each period is estimated as the proportion of marked fish that are recaptured from the matrices:

$$P = m^{-1}M \qquad \text{Equation 6}$$

Counts of unmarked fish are expanded to estimate abundance:

$$\hat{U} = D_u P \qquad \text{Equation 7}$$

where:

m^{-1} = matrix inverse of the recapture matrix
M = vector of marked fish released above the trap for each time period *i*
D_u = matrix with elements of u arranged along a diagonal with zeros elsewhere
$\hat{U}$ = number of unmarked fish passing the trap during the recovery stratum
u = vector of unmarked fish caught in each time period *i*

Total abundance is estimated by summing the estimated number of unmarked individuals.

$$\hat{N} = \sum \hat{U}_j \qquad \text{Equation 8}$$

Estimated variance for the total population estimate is obtained by summing elements of the variance-covariance matrix for stratum-specific abundance estimates:

$$\hat{V}\left(\hat{N}\right) = \sum_i^s \sum_j^t \text{cov}_{ij}\left(\hat{U}\right) \qquad \text{Equation 9}$$

The variance-covariance matrix for U is approximated by:

$$\text{cov}(\hat{U}) \approx D_u \Theta^{-1} D_\mu D_M^{-1} (\theta')^{-1} D_u + D_u (D_P - I) \qquad \text{Equation 10}$$

where:

$$\Theta = D_M^{-1} m D_P \qquad \text{Equation 11}$$

and:

D = matrix with elements of indicated vector arranged along a diagonal with zeros elsewhere

$\mu_i = \sum_j \left(\hat{\Theta}_{ij} / \hat{P}_j\right) - 1$

I = an identity matrix

The matrix Θ describes the probability that an individual marked and released during one period will resume migration during that or another period. Confidence intervals assumed a normal distribution and were calculated from Equation 4.

Data inputs to DARR consisted of a matrix of unmarked captures, marks released, and recaptures by mark groups. DARR groups time periods based on four sequential criteria:

1. Aggregation of time periods minimizes the number of "delayed" recaptures (i.e. those occurring outside the time period when marked fish were released);
2. Aggregation of time periods ensures that at least one fish released in a time period is recaptured in that time period;
3. Aggregation of time periods is necessary if the mean number of recaptures occurring in each time period is less than the ratio of the largest to the smallest number of recaptures; and
4. Aggregation of time periods is necessary to eliminate strata with impossible trap efficiencies (i.e., <0 or >1) (Bjorkstedt 2005).

Cedar River

Incline-Plane Trap

Sockeye

Sockeye migration during each stratum was estimated using Chapman's modification of the Petersen estimate (Equation 1). Variance associated with each migration estimate was calculated using Equation 5. Total catch was the actual catch plus additional estimated catch for periods when the trap did not operate. Estimated catch ($\hat{u}_i$) in Equation 1 and its associated variance ($Var(\hat{u}_i)$) in Equation 5 were calculated for three types of missed catches: 1) entire night periods when trap operations were suspended, 2) partial night periods when trap operations were suspended, and 3) day periods when trap operations were suspended.

Estimated Catch for Entirely Missed Night Samples

When trapping was suspended for entire night periods, a straight-line interpolation between catches on adjacent nights was used to estimate missed night catch. When catch was estimated for a single night, variance of the estimated catch was the variance of catch on adjacent nights (Equation 12). If one or both adjacent night catches were estimates and not actual values, then Equation 13 was used.

Equation 12

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

Equation 13

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

where:

n = number of sample nights used in the interpolation

u_i = actual night catch of unmarked fish used to estimate the un-fished interval

$\overline{u}_i$ = interpolated night catch estimate (mean of adjacent night catches)

$\hat{u}_i$ = estimated night catch of unmarked fish used to estimate the un-fished interval

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

Equation 14

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

Estimated Catch for Partially Missed Nighttime Sampling

Sockeye catch was also estimated for night periods when trap operations were partially suspended. Where the trap was operated intermittently through the night, catch during the un-fished interval(s) ($\hat{u}_z$) was estimated by:

$$\hat{u}_z = T_z \overline{R} \qquad \text{Equation 15}$$

where:

T_z = Hours during non-fishing period z

$\overline{R}$ = Mean catch rate (fish/hour) from adjacent fished periods

Variance associated with $\hat{u}_z$ was estimated by:

$$Var(\hat{u}_z) = T_z^{\ 2} Var(\overline{R}) \qquad \text{Equation 16}$$

Total catch of unmarked fish on night *i* ($\hat{u}_i$) was the sum of actual catches from the fished periods, *f*, and estimated catches from the un-fished periods, *z*. Variance of the total night catch ($Var(\hat{u}_i)$) was the sum of all variances for the un-fished period during night *i*.

Estimated Catch for Missed Daytime Samples

Daytime sockeye catches were estimated by multiplying the night catch by the proportion of the 24-hour catch caught during the day. This proportion, (F_d), was estimated as:

$$F_d = \frac{T_d}{\overline{Q}^{-1} T_n + T_d} \qquad \text{Equation 17}$$

Variance in the day:night catch ratio was:

$$Var(F_d) = \frac{Var(\overline{Q}) T_n^{\ 2} T_d^{\ 2}}{\overline{Q}^4 \left(\frac{1}{\overline{Q}} T_n + T_d \right)^4} \qquad \text{Equation 18}$$

where:

T_n = hours of night during 24 hour period,

T_d = hours of day during 24 hour period, and

$\overline{Q}_d$ = season average day:night catch ratio.

Chinook

Chinook migration during each stratum was estimated using Chapman's modification of the Peterson estimate (Equation 1) and associated variance (Equation 5). Sockeye fry efficiency trials were used as a surrogate for calculating Chinook migrations from Chinook catches. Procedures used to estimate variance associated with missed Chinook catch in the incline-plane trap were identical to those described for sockeye fry.

Screw Trap

Chinook, Coho, and Trout

For Chinook, coho and trout caught in the screw trap, mark groups were stratified by clip type and a catch/release/recapture matrix was input into DARR 2.0. Final efficiency strata were developed using DARR's aggregation algorithm and further adjusted to reflect periods of similar river discharge. Production estimates and their variances were based on Equations 6 – 11.

Bear Creek

Downstream migrant production calculated from incline-plane and screw trap data on Bear Creek were estimated using a similar approach to that used with Cedar River data. Differences applied only to estimating daytime catch. Whereas day catches in the Cedar River were estimated using day:night catch ratios ($\overline{Q}$), missed catches were not estimated for missed daytime sampling in Bear Creek. Previous years' sampling has indicated that day migrations are minimal in Bear Creek. Variances of missed night catches in the incline-plane trap were estimated using Equation 12 or Equation 13.

Egg-to-Migrant Survival

Cedar River

Survival of natural-origin sockeye fry from the Cedar River to lake entry is the natural-origin fry migration divided by the potential egg deposition (PED). PED is based on an Area Under the Curve (AUC) escapement estimate of 45,489 spawners (S. Foley, Washington Department of Fish and Wildlife, personal communication), an assumed even sex ratio, and an average fecundity of 3,450 (C. Cuthbertson, Washington Department of Fish and Wildlife, personal communication). Spawner abundance was calculated and agreed upon in a multi-agency effort of surveying adult returns each year. Fecundity was derived from the average number of eggs per female during 2007 broodstock collection for the Landsburg Hatchery on the Cedar River.

Chinook egg-to-migrant survival was based on 2008 juvenile migrant abundance, 899 Chinook redds in 2007, and an assumed fecundity of 4,500 eggs per female (S. Foley, Washington Department of Fish and Wildlife, personal communication). The number of females was based on annual redd counts conducted by state, local and tribal agencies that assumed one female per redd.

Bear Creek

Egg-to-migrant survival for Bear Creek sockeye and Chinook were similar to methods described in the Cedar River section above.

Sockeye egg deposition is based on an estimated 1,080 adult sockeye spawners returning to Bear Creek in 2007 (S. Foley, Washington Department of Fish and Wildlife, personal communication), an even sex ratio, and the assumption that Bear Creek sockeye have the same fecundity as Cedar River sockeye (3,450 eggs per female).

Chinook egg deposition was based on 276 redds in Bear Creek and an assumed fecundity of 4,500 eggs per female (S. Foley, Washington Department of Fish and Wildlife, personal communication).

Cedar River Results

Sockeye

Catch

A seasonal total of 928,217 natural-origin sockeye fry were caught in the incline-plane trap during trap operations. On the first night of trap operation (January 13), 754 sockeye fry were caught over fifteen hours of trapping. Catch peaked on March 12 when 42,284 sockeye fry were caught. Catches continued to remain high and oscillated between 8,000 and 35,000 through the middle of April before declining.

Diel Migration

An estimated 18,097 fry should have been captured had the trap fished every day, representing 1.4% of the season's total catch. Eleven day intervals were trapped to evaluate daytime migration: February 5, 12, 19, 26, March 4, 12, 19, 25, and April 2, 8, and 24. Flows ranged from 423 cfs to 1,138 cfs and are believed to have accurately captured the range of flows experienced during night operations throughout the season. Day catch rates ranged from 0.56% to 3.29% and averaged 1.96% for the season. The day-fish period on February 12 was not used to calculate day:night migration ratios due a trap outage on one of the surrounding nights.

Catch Expansion

An additional 416,540 sockeye fry should have been caught had the incline-plane trap fished continuously, without high water or debris outages, between January 13 and May 17, 2008. Based on expanded and actual catches, total seasonal catch in the incline-plane trap is estimated to be 1,344,757 sockeye.

Production Estimate

An estimated 27.6 million sockeye fry entered Lake Washington from the Cedar River in 2008 (Table 1, Figure 4). This migration included 25.1 ±979,000 (95% C.I.) million natural-origin fry and 2.5 million hatchery-origin fry. Total migration of natural-origin sockeye include pre-trapping and post-trapping migrations based on logarithmic extrapolation. Pre-season migration, January 1 through January 12, is estimated at 26,392 fry, and the post-season migration, May 18 through June 30, is estimated at 32,813 fry. Both pre- and post-season tails each represent 0.1% of the total natural production.

Total migration was based on capture rates of wild sockeye fry, ranging from 1.4% to 14.3%. Coefficient of variation (CV) associated with the natural-origin migration was 2.0%.

Table 1. Cedar River natural-origin and hatchery sockeye fry migrations entering Lake Washington with 95% confidence intervals, 2008.

Component	Period	Dates	Estimated Migration	CI 95%		CV	Proportion of Total
				Low	High		
Natural Origin	Before Trapping	January 1 - 12	26,392	26,391	26,393	0.0%	0.1%
	During Trapping	January 13- May 17	25,012,936	24,033,931	25,991,940	2.0%	99.8%
	After Trapping	May 18- June 30	32,813	25,582	40,044	11.2%	0.1%
		Subtotal	**25,072,141**	**24,093,109**	**26,051,172**	**2.0%**	
Hatchery	Below Trap	February 7 - April 3	2,496,850				
		Subtotal	**2,496,850**				
TOTAL PRODUCTION			**27,568,991**				

Natural-Origin and Hatchery Timing

Releases of hatchery fry began on February 7 and continued through April 3 (Table 3). Median migration date for hatchery fry released downstream of the incline-plane trap was March 6. Natural-origin fry migration was under way when trapping began on January 13. Natural-origin migration escalated to major peaks on March 13 and April 5 before the migration tapered for the season (Figure 5, Table 2). Median migration date for natural-origin fry was March 16, ten days later than the hatchery median migration date.

February stream temperatures, reflecting egg incubation temperatures, are correlated with median migration timing of natural-origin sockeye fry across years ($R^2 = 0.51$, Figure 6). February stream temperatures averaged 5.9° C in 2008, slightly cooler than the 15-year average (6.2° C) for Cedar River. Median migration date in 2008 was slightly earlier than the 17-year average median migration date (Table 2, Figure 6). The 2001 fry migration was treated as an outlier in the temperature migration regression for various reasons that may have impacted survival of the later-timed portion of fry production. For example, extreme low flows in early 2001 may have facilitated predation. Furthermore, an earthquake in early 2001 triggered a landslide that temporarily blocked stream flow.

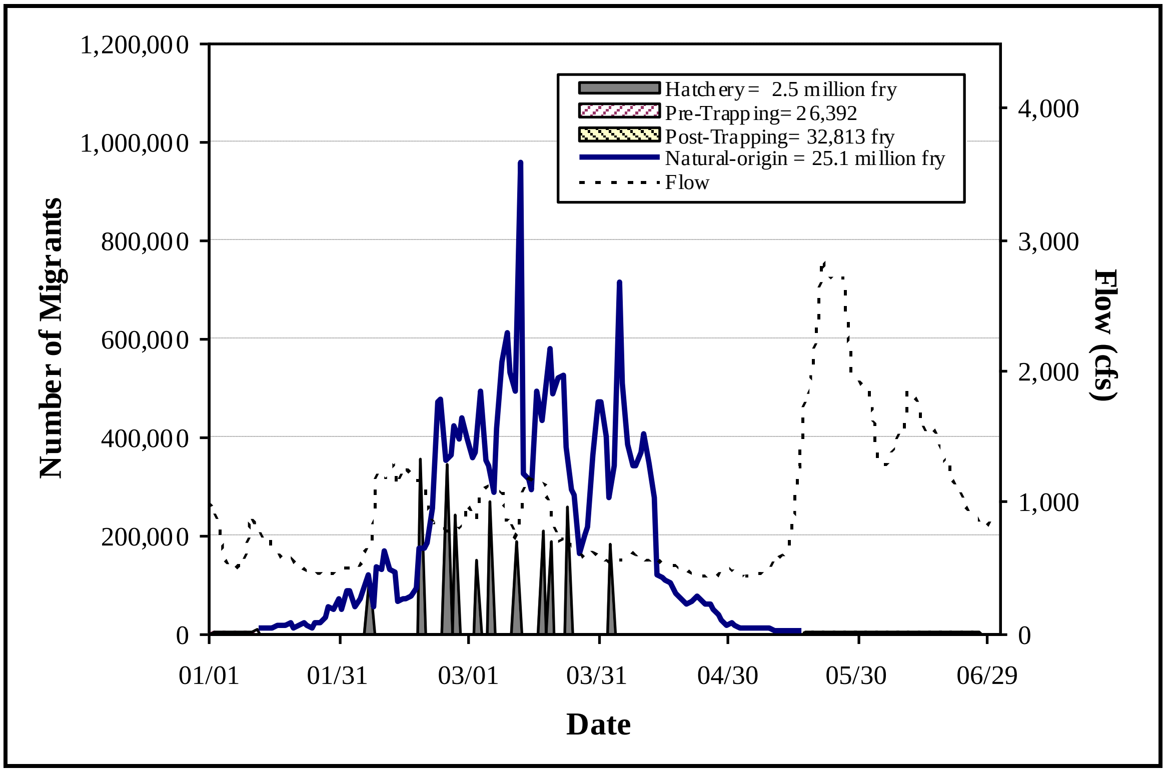


Figure 4. Daily migration of natural-origin and hatchery Cedar River sockeye fry into Lake Washington and daily average flow (USGS Renton gage Station #12119000) in 2008.

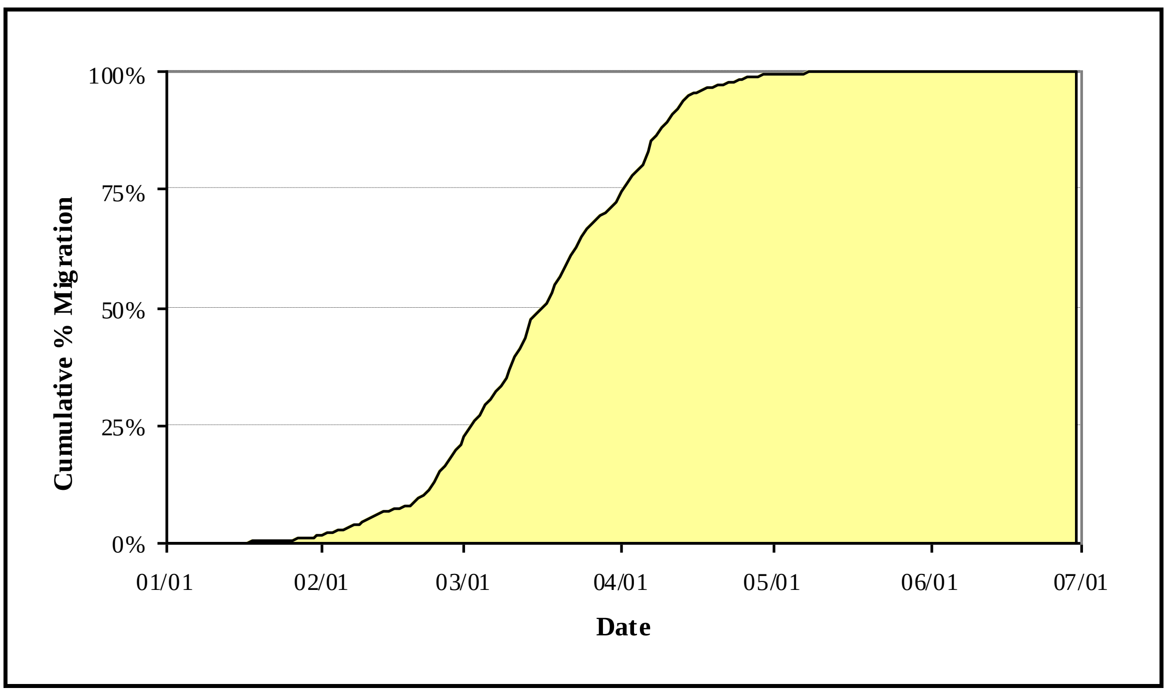


Figure 5. Cumulative migration of natural-origin sockeye fry from the Cedar River into Lake Washington in 2008.

Table 2. Median migration dates of natural-origin, hatchery, and total (combined) sockeye fry populations in the Cedar River for brood years 1991 to 2007.

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
2006	2007	03/23	02/16	03/12	35
2007	2008	03/16	03/06	03/15	10
	Average	03/22	02/26	03/13	24

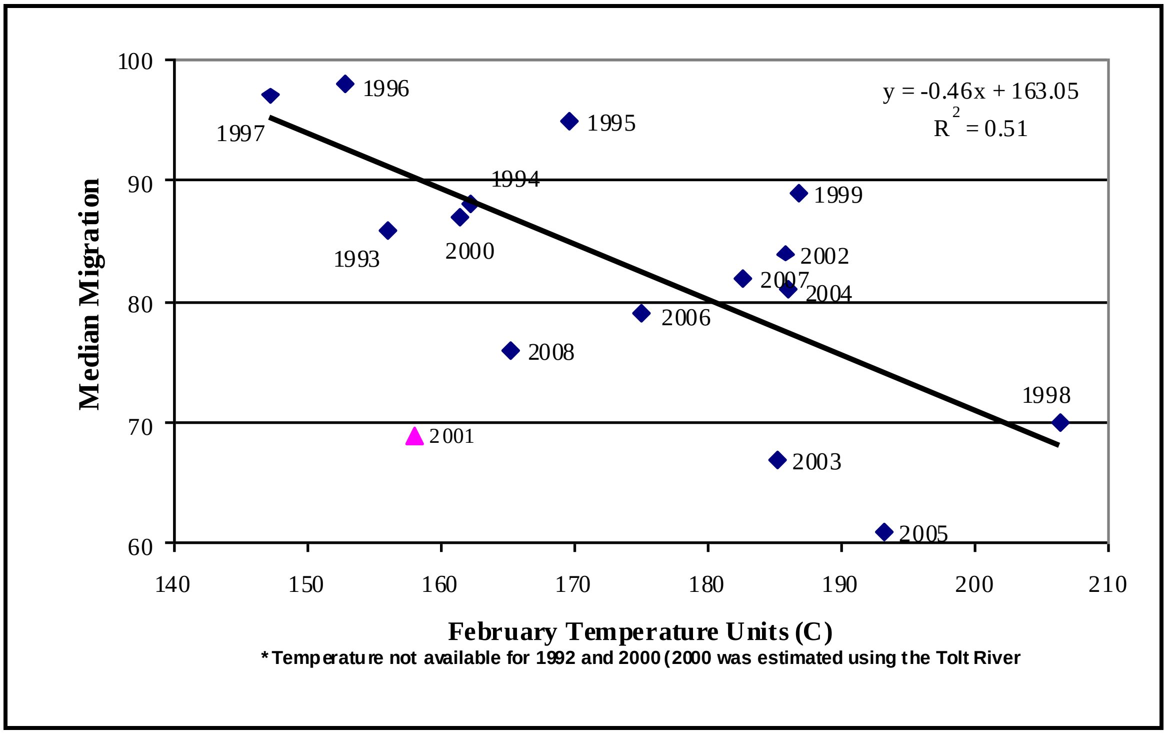


Figure 6. Linear regression of median migration date (Julian Calendar day) for natural-origin Cedar River sockeye fry as a function of the sum of daily average temperatures between February 1 and 28 (USGS Renton gage Station #12119000) for migration years 1993-2008, with 2001 treated as an outlier and not included in analysis.

Table 3. Hatchery sockeye fry released into the Cedar River in 2008 (C. Cuthbertson, Washington Department of Fish and Wildlife, personal communication).

Release Date	Number Released Below Trap (RM 0.1)
02/07/2008	106,000
02/19/2008	369,000
02/25/2008	350,000
02/27/2008	258,000
03/03/2008	153,900
03/06/2008	278,000
03/12/2008	179,550
03/18/2008	232,750
03/20/2008	206,150
03/24/2008	209,700
04/03/2008	153,800
Total	**2,496,850**

Egg-to-Migrant Survival of Natural-Origin Fry

Egg-to-migrant survival of the 2007 brood sockeye was estimated to be 31.95 % (Table 4). Survival was calculated from 25.1 million natural-origin fry surviving from a potential 78.5 million eggs from 22,745 females.

Egg-to-migrant survival was correlated with peak flow during the incubation period for each brood year (R^2 = 0.52, Figure 7). The best fit model for this data series was an decreasing exponential equation ($y = be^{-ax}$). 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, this model and others will continue to be assessed to increase our understanding of the factors affecting natural-origin sockeye fry production from the Cedar River.

Table 4. Egg-to-migrant survival of natural-origin sockeye fry in the Cedar River and peak mean daily flows during egg incubation period for brood years 1991 - 2007. Sockeye spawners were estimated using the area-under-the-curve method. Flow was measured as cubic feet per second (cfs), USGS Renton gage Station #12119000.

Brood Year	**Spawners**	**Females** (@50%)	**Fecundity**	**Potential Egg Deposition**	**Fry Production**	**Survival Rate**	**Peak Incubation Flow** (cfs)	**Date**
1991	77,000	38,500	3,282	126,357,000	9,800,000	7.76%	2,060	01/28/1992
1992	100,000	50,000	3,470	173,500,000	27,100,000	15.62%	1,570	01/26/1993
1993	76,000	38,000	3,094	117,572,000	18,100,000	15.39%	927	01/14/1994
1994	109,000	54,500	3,176	173,092,000	8,700,000	5.03%	2,730	12/27/1994
1995	22,000	11,000	3,466	38,126,000	730,000	1.91%	7,310	11/30/1995
1996	230,000	115,000	3,298	379,270,000	24,390,000	6.43%	2,830	01/02/1997
1997	104,000	52,000	3,292	171,184,000	25,350,000	14.81%	1,790	01/23/1998
1998	49,588	24,794	3,176	78,745,744	9,500,000	12.06%	2,720	01/01/1999
1999	22,138	11,069	3,591	39,748,779	8,058,909	20.27%	2,680	12/18/1999
2000	148,225	74,113	3,451	255,762,238	38,447,878	15.03%	627	01/05/2001
2001	119,000	59,500	3,568	212,296,000	31,673,029	14.92%	1,930	11/23/2001
2002	194,640	97,320	3,395	330,401,400	27,859,466	8.43%	1,410	02/04/2003
2003	110,404	55,202	3,412	188,349,224	38,686,899	20.54%	2,039	01/30/2004
2004	116,978	58,489	3,276	191,609,964	37,027,961	19.32%	1,900	01/18/2005
2005	50,887	25,444	3,065	77,984,328	10,861,369	13.90%	3,860	01/11/2006
2006	106,961	53,481	2,910	155,628,255	9,246,243	5.90%	5,411	11/09/2006
2007	45,489	22,745	3,450	78,468,525	25,072,141	31.95%	1,820	12/03/2007

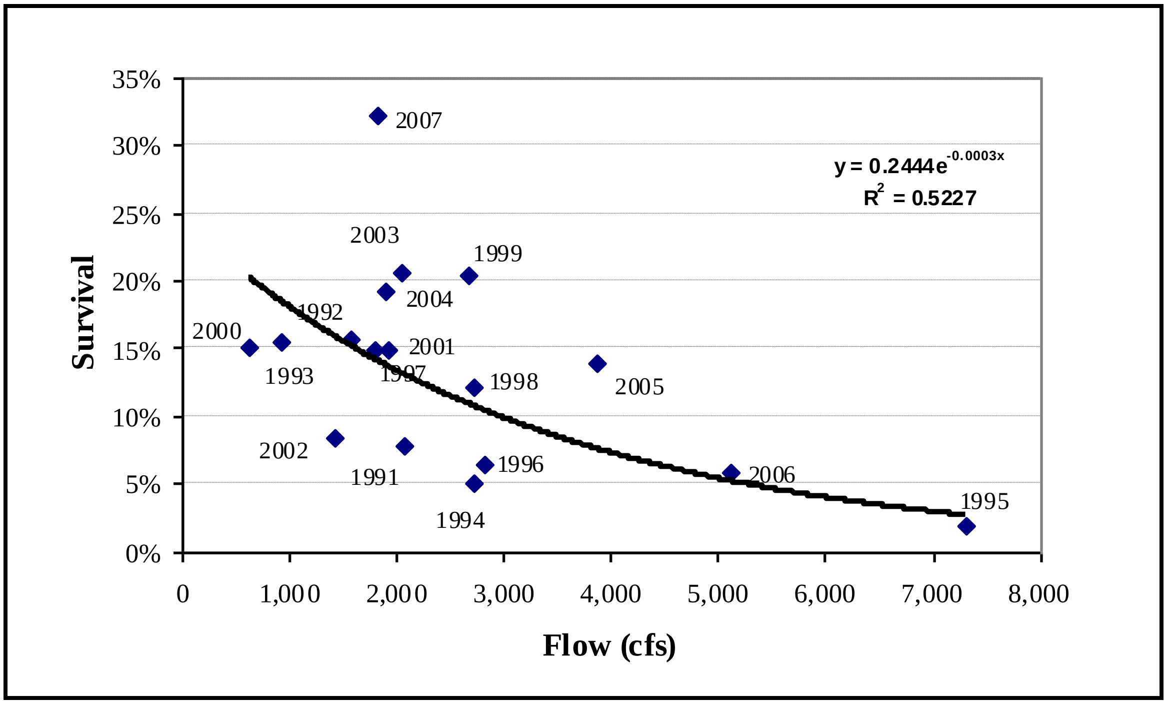


Figure 7. Egg-to-migrant survival of natural-origin sockeye in the Cedar River as a function of peak flow during the winter egg incubation period. Survival for brood years 1991 to 2007 is fit with a decreasing exponential curve.

Chinook

Catch

Incline-Plane Trap

A total of 21,000 Chinook were captured in the incline-plane trap. Sixty-nine Chinook were caught on the first night of incline-plane trap operation (January 13). Catches rapidly increased, with numerous nights' catches over 500 Chinook and peaked at 1,813 fry on March 4. Thereafter, catch declined, but generally remained above 100 Chinook per night through April 8.

Screw Trap

A total of 1,651 natural-origin (unmarked) and 14 hatchery (adipose fin clipped or ad-marked) Chinook were caught in the screw trap. Production estimate was based on natural-origin Chinook catches only. From the first night of trapping to May 15 (4.5 weeks), 269 Chinook were captured, 16% of the total catch. In a 10-day period between May 28 and June 8, 741 natural-origin Chinook parr were caught, 45% of the season total. Nightly catch peaked on June 6, when 104 Chinook parr were caught. The remaining 39% of Chinook parr were caught between June 9 and July 19.

Catch Expansion

Incline-Plane Trap

If the incline-plane trap fished continuously (day and night) between January 13 and May 17, an estimated 10,308 additional fry should have been caught. Missed day catch was estimated using the season average day/night catch ratio (6.60%), which ranged from 0.65% to 37.6%. Catch was partially missed on four nights due to large amounts of debris. Combining expanded and actual catches, total catch was estimated to be 31,307 Chinook in the incline-plane trap.

Screw Trap

The Cedar River experienced record high flows that prevented screw trap operation between May 15 to May 27. Missed catch during this period was not expanded, as the outage occurred near the peak of the Chinook parr migration. Production was estimated using various methods, therefore no catch expansion is reported here.

Production Estimate

Incline-Plane Trap

Chinook migration was estimated to be 704,524 fry between January 13 and May 17, 2008 (Appendix B 2). A migration of 1,095 Chinook fry were estimated to have migrated prior to incline-plane trap operation based on a logarithmic extrapolation between January 1 and 13. This extrapolation combined with the migration estimate during trap operation yields a total migration of 705,538 ±76,106 (95% C.I.) Chinook fry through May 17.

The Chinook estimate between January 13 and May 17 used incline-plane trap catches and efficiency data. Between April 4 and May 17 catch and efficiency data were collected concurrently with the incline-plane trap and screw trap. Trap catches were comparable during the overlapping period with the incline-plane trap catching 61 more Chinook than the screw trap. Estimated migration during this period based on screw trap data was 9,376 Chinook while the estimate using incline-plane trap data was 5,733 Chinook. The difference between these migration estimates is due to mark-release group data. Incline-plane trap mark groups provide a more confident production estimate for the overlapping time period. Incline-plane trap mark releases were conducted using sockeye fry, which were considerably more abundant than Chinook parr and provided a larger sample size for sockeye mark groups and recaptures. Releases of Chinook parr for screw trap efficiency trials were considerably smaller in sample size, with few recaptures. Furthermore, average body size of Chinook migrating during this time was still rather small, increasing confidence that sockeye fry release groups were appropriate for estimating migration during the period of overlap. Therefore, the incline-plane trap estimate of 5,733 Chinook migrants between April 14-May 17 was used in further calculations.

The Cedar River experienced record high flows that prevented the screw trap from fishing between May 15 and 27, 2008 and the incline-plane trap between May 18 and 27, 2008. The incline-plane trap was able to fish short time intervals from May 15 through May 17; however, no efficiency data was collected. Trap efficiency applied during this period was an average of efficiency releases conducted earlier in the season under comparable flows. Between May 18 and 27, flows and large debris increased to a state that was too dangerous for both trap workers and fish, and all trapping was suspended.

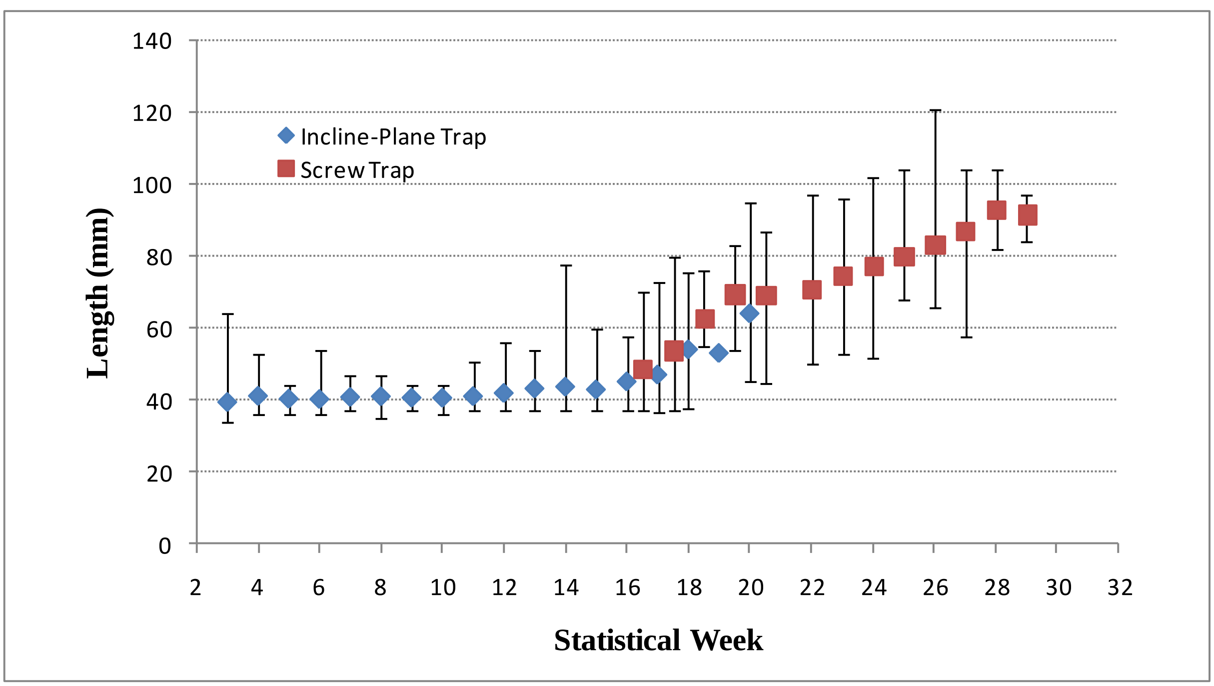


Figure 8. Average and range of fork lengths of Chinook sampled from the Cedar River, 2008.

Screw Trap

Missing information on trap efficiency and catch during the 10-day outage occurred near the peak of the Chinook migration and therefore increased the potential error of the estimate. Several approaches were used to evaluate migration during the extended outage and are further described in the Discussion section. In total, using in season catch data, interpolation and various efficiency and catch data, migration between May 18-May 27 is estimated to be between 22,068 and 27,726 Chinook.

Migration during screw trap operation between May 28 and July 19 was estimated to be 39,311 ±18,156 (95% C.I.) Chinook parr. Marked groups released between May 28 and the end of the season were aggregated into seven strata by DARR 2.0. Each of the final strata had at least two recaptures. Capture rates for the seven groups ranged from 2.6% to 7.4% (Appendix B 3).

In total, 766,962 to 772,620 age 0+ Chinook are estimated to have migrated from the Cedar River into Lake Washington in 2008. This estimate is the combination of the Chinook production estimated from the interpolated pre-trapping period, the incline-plane trap from January 13 through May 17, the range estimate for the period the trap was not fishing, and the estimate from the screw trap for May 28 to July 19 (Table 5).

Table 5. Natural-origin Cedar River juvenile Chinook production estimate and confidence intervals, 2008.

Gear	Period	Actual Catch	Estimated Migration	95% CI Low	95% CI High	CV
Pre-Trapping	January 1 - 12		1,059	927	1,191	6.35%
Incline-Plane Trap	January 13- May 14	21,000	698,531	622,464	774,597	5.56%
Incline-Plane Trap (High Water)	May 15 - May 17	149	5,994	3,517	8,470	21.08%
Total Fry		**21,149**	**705,583**	**629,477**	**781,690**	**5.50%**
Both Traps Out	May 18 - May 27		22,068 - 27,726			
Screw Trap	May 28 - July 19	1,280	39,311	21,155	57,467	23.56%
Total Parr			**61,379 - 67,037**			
	Season Total	**22,429**	**766,962-772,620**			

As in previous seasons, timing of Chinook migration was bi-modal (Figure 9). Migration was 25%, 50%, and 75% complete by roughly February 12, March 4, and March 17, respectively (Figure 10). Juvenile Chinook emigrated mostly as fry, contributing 89.5% to 90.1% of the total migration. This represented the greatest proportion of fry since trapping began in 1998 (Table 6).

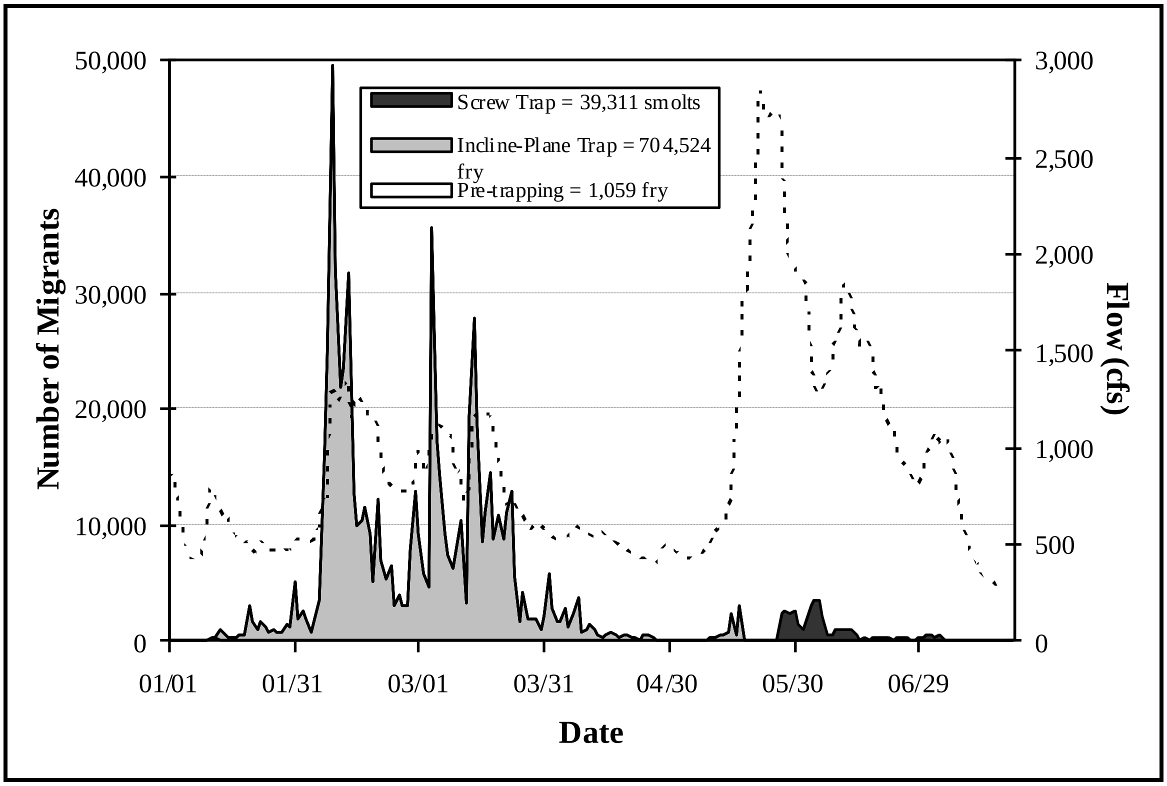


Figure 9. Estimated daily Cedar River Chinook migration from incline-plane and screw trap estimates and mean daily flow (USGS Renton gage Station #12119000) in 2008.

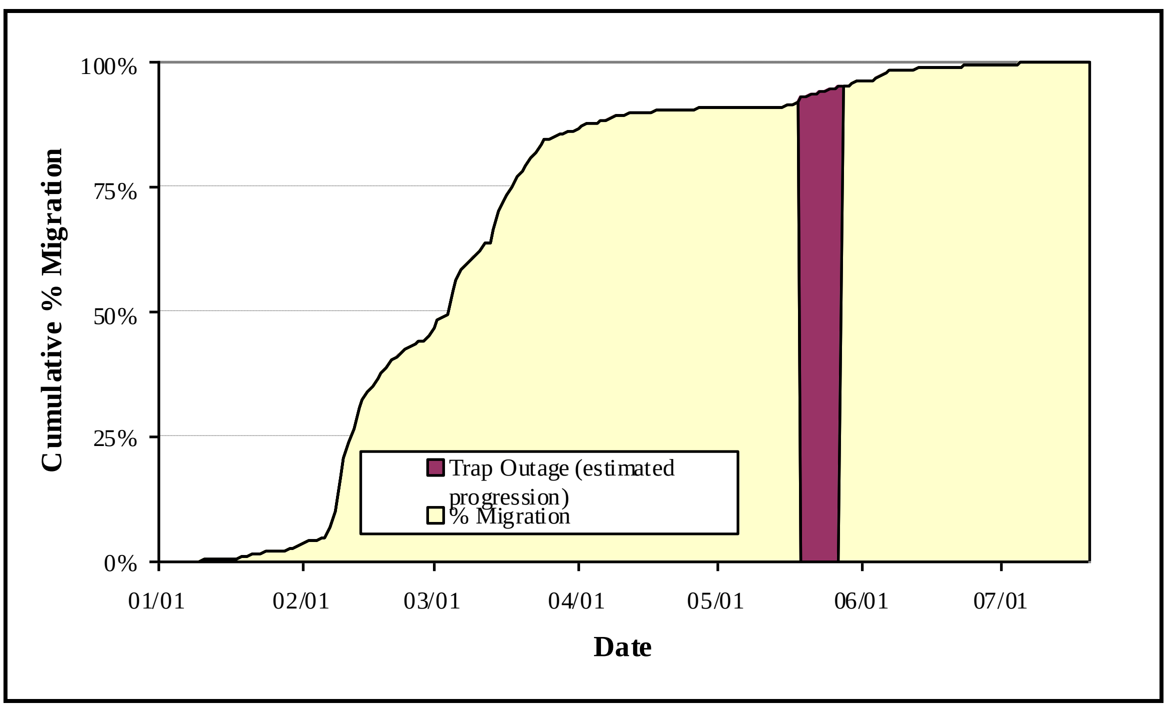


Figure 10. Cumulative percent migration of age 0+ Chinook from the Cedar River in 2008.

Table 6. Production, productivity (production per female), and survival of Chinook fry and parr among brood years. Fry migration was assumed to be January 1 to April 15. Parr migration was assumed to be April 16 through July 13. Productivity was calculated from potential egg deposition (PED) for returning spawners. Data are Cedar River broods 1998 to 2007.

Brood	Estimated Migration			% Migration		Est.	PED	Production/Female			Survival Rates		
Year	Fry	Parr	Total	Fry	Parr	Fem.		Fry	Parr	Total	Fry	Parr	Total
1998	67,293	12,811	80,104	84.0%	16.0%	173	778,500	389	74	463	8.6%	1.6%	10.3%
1999	45,906	18,817	64,723	70.9%	29.1%	180	810,000	255	105	360	5.7%	2.3%	8.0%
2000	10,994	21,157	32,151	34.2%	65.8%	53	238,500	207	399	607	4.6%	8.9%	13.5%
2001	79,813	39,326	119,139	67.0%	33.0%	398	1,791,000	201	99	299	4.5%	2.2%	6.7%
2002	194,135	41,262	235,397	82.5%	17.5%	281	1,264,500	691	147	838	15.4%	3.3%	18.6%
2003	65,875	54,929	120,804	54.5%	45.5%	337	1,516,500	195	163	358	4.3%	3.6%	8.0%
2004	74,292	60,006	134,298	55.3%	44.7%	511	2,299,500	145	117	263	3.2%	2.6%	5.8%
2005	98,085	19,474	117,559	83.4%	16.6%	339	1,525,500	289	57	347	6.4%	1.3%	7.7%
2006	107,796	14,613	122,409	88.1%	11.9%	587	2,641,500	184	25	209	4.1%	0.6%	4.7%
2007	691,216	75,746-81,404	766,962-772,620	89.5-90.1%	9.9-10.5%	899	4,045,500	769	84-90	856-862	17.2%	1.9-2.0%	19.1-19.2%

Egg-to-Migrant Survival

Natural-origin Chinook egg-to-migrant survival for the 2007 brood was estimated to be 19.1% to 19.2% (Table 6). Fall 2007 produced the largest Chinook return to the Cedar River on record (S. Foley, Washington Department of Fish and Wildlife, personal communication). This is the highest egg-to-migrant survival and largest migration of Chinook fry observed since juvenile monitoring began on the Cedar River. Although fry made up a large portion of the 2008 outmigration, the 2008 parr migration was also the largest estimated migration of Chinook parr from the Cedar River.

Size

From January through mid-April, fork lengths (FL) of Chinook fry caught in the incline-plane trap averaged <44 mm each week with the average weekly size increasing less than 5 mm (Table 7, Figure 8). By statistical week 18 (April 27-May 3), weekly average length increased to more than 50 mm; however, the smallest Chinook fry continued to be less than 40 mm. Not until statistical week 20 (May 11-17) did the weekly average size of Chinook grow to be over 60 mm.

Chinook caught in the screw trap increased in size from a weekly average fork length of 48.6 mm in mid-April to 92.7 mm in July (Table 7). Chinook averaged more than 70 mm FL during the last week in May. During screw-trap operation, sizes ranged from 37 mm to 121 mm FL and averaged 73.6 mm FL. The average sizes of Chinook parr caught in 2008 were the shortest observed since juvenile monitoring began on the Cedar River (see Discussion Section, Table 18).

Table 7. Natural-origin Chinook fork length (mm) in Cedar River incline-plane and screw traps in 2008. Data are mean, standard deviation (s.d.), range, sample size, and catch for each statistical week.

Statistical Week			INCLINE-PLANE TRAP						SCREW TRAP					
					Range						Range			
Begin	End	No.	Mean	s.d.	Min	Max	n	Catch	Mean	s.d.	Min	Max	n	Catch
01/13	01/19	3	39.4	5.40	34	64	27	162						
01/20	01/26	4	41.1	3.14	36	53	88	775						
01/27	02/02	5	40.3	2.23	36	44	103	716						
02/03	02/09	6	40.2	2.10	36	54	226	1,517						
02/10	02/16	7	40.8	1.92	37	47	136	2,582						
02/17	02/23	8	41.0	1.88	35	47	200	2,682						
02/24	03/01	9	40.6	1.65	37	44	149	1,696						
03/02	03/08	10	40.6	1.66	36	44	139	3,879						
03/09	03/15	11	41.0	3.05	37	56	72	2,233						
03/16	03/22	12	41.9	3.67	37	56	110	2,187						
03/23	03/29	13	43.1	4.80	37	60	41	1,113						
03/30	04/05	14	43.7	6.55	37	78	60	682						
04/06	04/12	15	42.9	4.34	37	52	39	367						
04/13	04/19	16	45.1	7.92	37	70	75	164	48.6	9.01	37	70	28	29
04/20	04/26	17	47.4	9.60	40	73	73	151	53.8	9.86	37	80	68	72
04/27	05/03	18	57.3	13.18	41	79	11	18	62.5	6.77	55	76	17	17
05/04	05/10	19	53.0	n/a	53	53	1	1	69.4	8.50	54	83	25	25
05/11	05/17	20	63.9	10.61	45	95	35	74	69.0	10.77	45	87	99	166
05/18	05/24	21												
05/25	05/31	22							70.6	9.15	50	97	247	394
06/01	06/07	23							74.3	9.27	53	96	226	478
06/08	06/14	24							77.3	8.13	52	102	167	169
06/15	06/21	25							79.8	7.14	68	104	102	102
06/22	06/28	26							83.2	8.52	66	121	89	98
06/29	07/05	27							86.8	7.56	58	104	68	70
07/06	07/12	28							92.7	7.76	82	104	11	24
07/13	07/19	29							91.5	5.54	84	97	6	7
		Season Totals	42.1	5.79	34	95	1,585	21,000	73.6	12.26	37	121	1,153	1,651

Coho

Catch

A total of 315 natural-origin coho smolts were caught in the screw trap between April 14 and July 19. Catch distribution was variable throughout the season with approximately 68% of the migration passing the trap in May.

Production Estimate

A total of 10 mark groups, ranging in size from 1 to 93 coho, were released. Original mark groups were aggregated into five strata. Recapture rates for the final strata ranged from 1.8% to 14.3% (Appendix B 4).

Total coho production was estimated to be 13,322 smolts (Figure 11). Coho production during trap operation was estimated to be 10,404 ± 9,990 (95% C.I.) smolts (Appendix B 4). An additional 2,962 coho are estimated to have migrated during the 10-day trap outage. Two days before the outage, coho migration increased and may have been the peak migration for the season. On May 14 and 15, an estimated 4,000 coho migrated passed the trap, nearly 40% of the estimated migration for the time period before and after the high water. Because parr-size salmonids are able to hold during high flows and typically resume migration as flows decrease, mark-release groups following the high water period in May may best represent trap efficiency during the extreme flows. Coho migration during the trap outage period was derived from a weighted average of the mark-release groups following high water applied to the interpolated catch of the 10-day outage period.

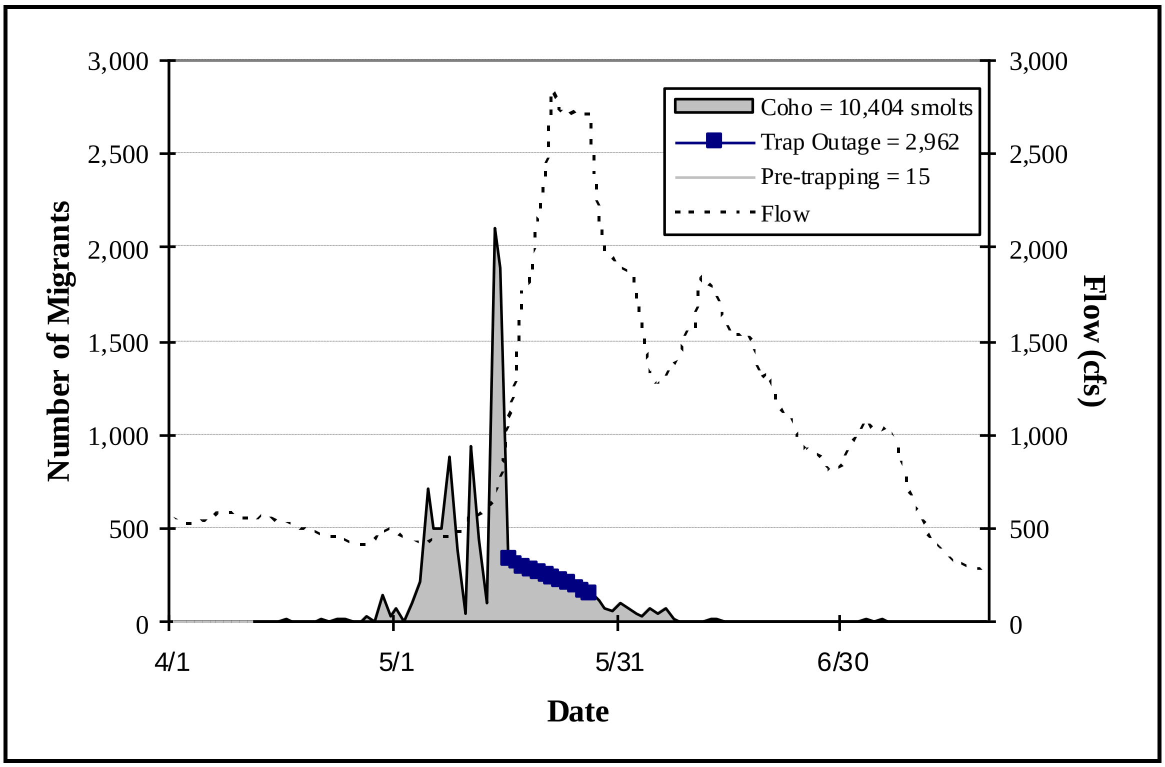


Figure 11. Daily coho smolt migration and daily average flow (USGS Renton gage Station #12119000), Cedar River screw trap, 2008.

Size

Coho smolt fork lengths averaged 105.3 mm, and weekly averages ranging from 88.7 mm to 112.6 mm FL on a weekly basis. Individuals ranged from 81 mm to 168 mm FL (Table 8, Figure 12).

Table 8. Fork length (mm) of coho smolts from the Cedar River screw trap in 2008. Data are mean, standard deviation (s.d.), range, sample size, and catch for each statistical week.

Statistical Week			Mean	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/13	04/19	16	112.6	10.76	94	122	5	5
04/20	04/26	17	111.5	15.80	89	131	8	9
04/27	05/03	18	111.3	13.50	89	168	40	40
05/04	05/10	19	109.7	10.60	90	140	53	59
05/11	05/17	20	103.6	10.80	83	123	40	99
05/18	05/24	21					0	0
05/25	05/31	22	103.5	10.90	84	123	35	47
06/01	06/07	23	101.1	8.57	86	117	23	31
06/08	06/14	24	99.4	13.19	81	125	10	10
06/15	06/21	25	95.5	11.12	84	106	4	4
06/22	06/28	26	92.0	n/a	92	92	1	2
06/29	07/05	27	90.1	3.57	85	96	10	11
07/06	07/12	28	88.7	6.43	84	96	3	3
07/13	07/19	29					0	0
		Season Totals	105.3	12.35	81	168	232	315

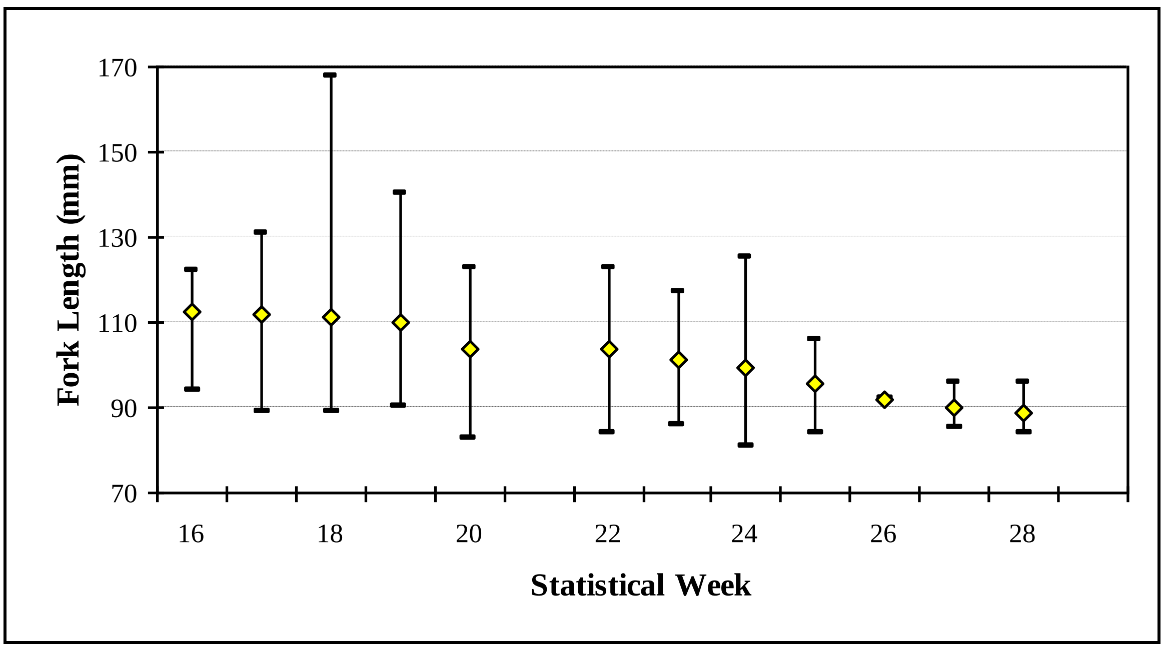


Figure 12. Fork lengths for coho smolts captured in the Cedar River screw trap in 2008. Data are mean, minimum, and maximum lengths.

Trout

Life history strategies used by trout in the Cedar River may include anadromous, ad-fluvial, and resident forms. For simplicity, catches and estimates reported herein are for trout that were visually identified as either cutthroat or steelhead. We acknowledge that cutthroat-rainbow hybrids are included in the reported cutthroat numbers. Furthermore, it is difficult to determine whether juvenile steelhead have adopted the anadromous life form. However, steelhead and rainbow trout are described separately in the Incidental Catch section as "steelhead" appear to have smolted.

Throughout the season, 4 steelhead migrants and 26 cutthroat trout were captured. Catches were too small to develop migration estimates. Cutthroat fork lengths ranged from 131 to 207 mm, and averaged 155.7 mm.

PIT Tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington basin, natural-origin Chinook were tagged with passive integrated transponder (PIT) tags from May 9 to the close of the trapping operation. Tagging occurred three times a week through July 14, 2008 due to low catches of Chinook parr. Chinook were held from the previous day in order to increase the number tagged per day. Over the season a total of 844 natural-origin Chinook parr were tagged (Table 9). This tag group comprised just 1.2% of the estimated Chinook parr production from the Cedar River in 2008.

Table 9. Natural-origin Chinook parr PIT tagged and released from the Cedar River screw trap in 2008.

Stat Week			Wild	Length			Portion of Parr
#	Start	End	Chinook	Mean	Min	Max	Migration Tagged
19	05/06/08	05/10/08	12	76.8	65	86	1.39%
20	05/11/08	05/17/08	53	76.2	65	87	0.67%
22	05/18/08	05/24/08	143	74.7	65	94	1.89%
23	05/25/08	05/31/08	226	78.1	65	96	1.37%
24	06/01/08	06/07/08	138	78.8	66	102	2.29%
25	06/08/08	06/14/08	85	79.8	69	104	4.55%
26	06/15/08	06/21/08	103	82.9	66	121	5.99%
27	06/22/08	06/28/08	43	88.6	77	104	1.60%
28	06/29/08	07/05/08	35	87.3	70	104	10.79%
29	07/06/08	07/12/08	6	91.5	84	97	6.34%
		Season Totals	844	79.4	65	121	1.2%

Mortality

No Chinook mortalities occurred while operating the incline-plane trap.

Five Chinook mortalities resulted from PIT tagging, and 91 Chinook mortalities resulted from heavy debris during screw trap operations.

Incidental Catch

Incidental catches in the incline-plane trap included 11 coho fry, 101 coho smolts, 116 chum fry, 1 sockeye smolt, 1 pink fry, and 8 cutthroat smolts. Other species caught included three-spine stickleback (*Gasterosteus aculeatus*), unspecified sculpin species (*Cottus spp*.), lamprey (*Lampetra spp*.), largescale suckers (*Catostomus macrocheilus*), long-fin smelt (*Spirinchus thaleichthys*), speckled dace (*Rhinichthys osculus*), and brown bullhead catfish (*Ameiurus nebulosus*).

Other salmonids caught in the screw trap include 14 ad-marked hatchery Chinook parr, 1 sockeye smolt, 9 coho parr, and 4 chum fry. Other species caught included three-spine stickleback, unspecified sculpin species, lamprey, large-scale suckers (adult and fry), peamouth (*Mylocheilus caurinus*), speckled dace, and a brown bullhead catfish.

Bear Creek Results

Sockeye

Catch

The incline-plane trap caught 34 sockeye fry on February 3, the first night of trapping. Thereafter, the incline-plane trap fished two to four nights a week, for a total of 41 nights by April 14. Catches peaked on the night of March 23, when 3,035 fry were caught. When incline-plane trap operations concluded on the morning of April 14, catches totaled 11,989 sockeye fry.

A total of 21,802 sockeye fry should have been caught had the trap fished the entire period between February 3 and April 14. This expanded catch includes 9,904 fry estimated for the 31 nights not fished.

Production Estimate

During the period of incline-plane trap operation (February 3 through April 14), 237,059 sockeye fry are estimated to have migrated passed the trap. Recapture rates of mark and release groups ranged from 6.2% to 12.5% (Appendix C 1). At the beginning of the season, catches were so low that there were not enough fish to form a mark group until February 17. Thereafter, mark groups were released every night the trap fished. Some mark-release groups were aggregated for analysis due to low numbers of recaptured fish.

Migration of sockeye fry appeared to be underway when trapping began. Logarithmic extrapolation was used to estimate what may have passed the trap prior to February 3, contributing 4,065 fry to our total estimated migration. The sockeye fry migration was still underway when the screw trap replaced the incline-plane trap on April 14. Rather than attempting to calibrate the screw trap for sockeye fry, the end of the sockeye migration was estimated using logarithmic extrapolation. Migration from April 14 to April 30 was estimated to be 10,161 fry.

A total of 251,285 ±58,794 (95% C.I.) sockeye fry were estimated to have migrated from Bear Creek in 2008, with an associated 11.9% coefficient of variation (Table 10). The estimate includes migration prior to, during, and following incline-plane trap operation.

Egg-to-migrant survival of the 2007 brood was estimated to be 13.5% (Table 11). Survival was 251,285 fry divided by 18.6 million eggs potentially deposited by 540 females.

Table 10. Bear Creek juvenile sockeye fry production estimate and confidence intervals, 2008.

Period	Dates	Est. Migration	CV	95% CI Low	95% CI High
Pre-Trapping	Jan 1-Feb 2	4,065	17.95%	2,635	5,496
Incline-Plane Trap	Feb 3-April 14	237,059	12.64%	178,330	295,789
Post-Trapping	April 15-April 30	10,161	11.81%	7,809	12,512
	Season Totals	251,285	11.94%	192,491	310,079

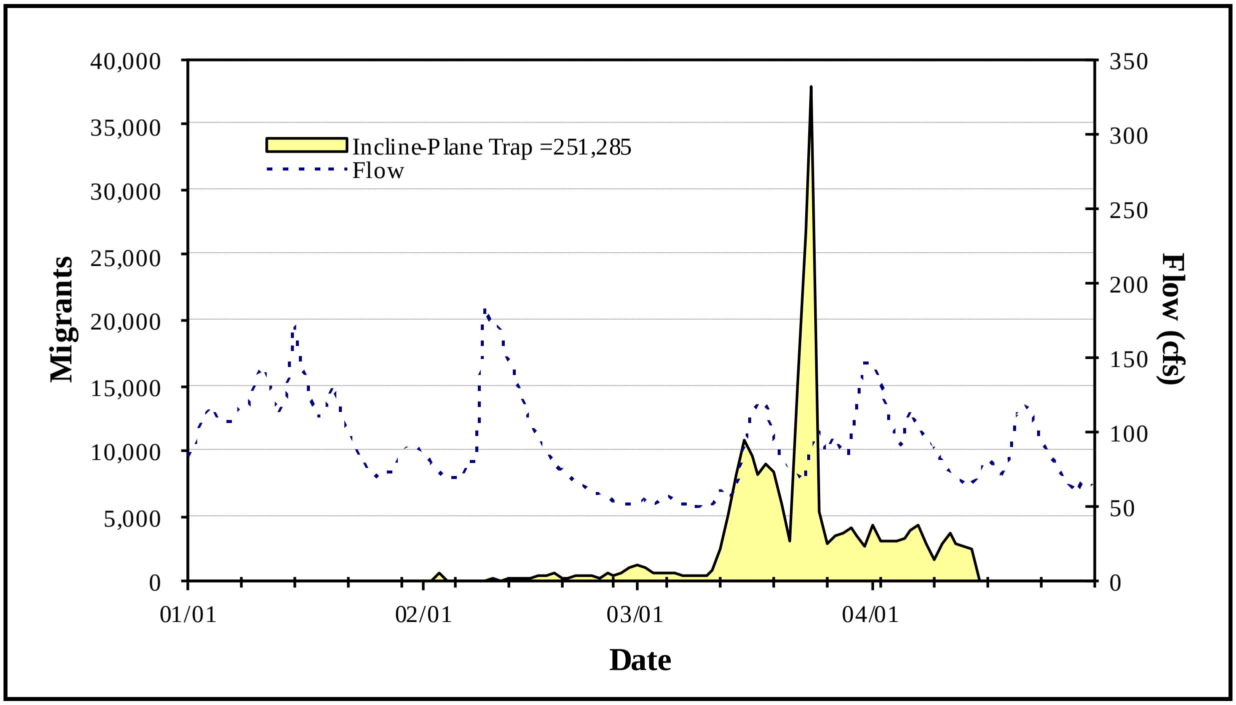


Figure 13. Estimated daily migration of sockeye fry from Bear Creek and daily average flow measured by the King County gaging station at Union Hill Road in 2008.

Table 11. Sockeye egg-to-migrant survival rates by brood year in Bear Creek, based on annually measured sockeye fecundity in the Cedar River.

Brood Year	Spawners	Females (@ 50%)	Fecundity	PED	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1998	8,340	4,170	3,176	13,243,920	1,526,208	11.5%	515	11/26/1998
1999	1,629	815	3,591	2,924,870	189,571	6.5%	458	11/13/1999
2000	43,298	21,649	3,451	74,710,699	2,235,514	3.0%	188	11/27/2000
2001	8,378	4,189	3,568	14,946,352	2,659,782	17.8%	626	11/23/2001
2002	34,700	17,350	3,395	58,903,250	1,995,294	3.4%	222	01/23/2003
2003	1,765	883	3,412	3,011,090	177,801	5.9%	660	01/30/2004
2004	1,449	725	3,276	2,373,462	202,815	8.5%	495	12/12/2004
2005	3,261	1,631	3,065	4,999,015	548,604	11.0%	636	01/31/2005
2006	21,172	10,586	2,910	30,805,260	5,983,651	19.4%	581	12/15/2006
2007	1,080	540	3,450	1,863,000	251,285	13.5%	1,055	12/04/2007

Chinook

Catch

Incline-Plane Trap

The first Chinook fry was caught in the incline-plane trap on February 17, two weeks after trap operations began. Catches were lower than most other seasons with a peak catch of only 20 Chinook on March 13. In total, 57 Chinook fry were captured in the incline-plane trap by the time incline-plane trap operations concluded on the morning of April 14.

A total of 110 Chinook fry should have been caught had the incline-plane trap operated continuously. Total catch includes actual catch plus catch expansion for the 31 nights not fished.

Screw Trap

A total of 2,774 Chinook were caught over the 84 days the screw trap operated. On the first night of screw trap operation, just 2 Chinook were caught. Daily catches through the rest of April averaged less than 2 fish per day. By early May catches began to increase and peaked on May 13, when 436 Chinook were caught. Following this peak, catches sharply declined to average 17 Chinook per day for the remainder of the season. Because of a trap outage, catches on May 18 and 20 (2 Chinook) were not included in the final analysis. A total of 2,772 Chinook were used to estimate production.

Production Estimate

Incline-Plane Trap

Chinook migration was estimated to be 1,172 ±80 (95% C.I.) between February 3 and April 14 (Table 12, Appendix C 2). As the first Chinook was not captured until two weeks into trapping and catches thereafter were scarce, migration prior to trapping is assumed to be zero.

Screw Trap

Chinook migration during screw trap operation was estimated to be 11,598 ±2,136 (95% C.I.) (Appendix C 2). Fifty-three Chinook mark groups released were aggregated into nine strata; capture rates of the screw trap ranged from 18.0% and 41.2%.

Combining information from incline-plane and screw trap estimates yields a total production of 12,770 ±2,158 (95% C.I.) Chinook, with a coefficient of variation of 8.62%. Migration was bi-modal with 9.2% of the migration emigrating as fry and 90.8% emigrating as parr (Table 13, Figure 14).

Table 12. Bear Creek juvenile Chinook production estimate and confidence intervals, 2008.

Gear	Period	Estimated Catch	Estimated Migration	95% CI Low	95% CI High	CV
Incline-Plane Trap	February 2 - April 13	110	1,172	1,092	1,482	13.48%
Screw Trap	April 14 - July 9	2,772	11,598	9,462	13,734	9.23%
	Season Totals	2,882	12,770	10,612	14,929	8.62%

Table 13. Production, productivity (production per female), and survival of natural-origin Chinook in Bear Creek. Fry are assumed to have migrated between February 1 to April 8. Parr are assumed to have migrated between April 9 through June 30. Data are 2000 to 2007 brood years.

Brood Year	Estimated Migration Fry	Estimated Migration Parr	Estimated Migration Total	% Migration Fry	% Migration Parr	Est. Females	Potential Egg Deposition	Production/Female Fry	Production/Female Parr	Production/Female Total	Survival Rates Fry	Survival Rates Parr	Survival Rates Total
2000	419	10,087	10,506	4.0%	96.0%	133	598,500	3	76	79	0.1%	1.7%	1.8%
2001	5,427	15,891	21,318	25.5%	74.5%	138	621,000	39	115	154	0.9%	2.6%	3.4%
2002	645	16,636	17,281	3.7%	96.3%	127	571,500	5	131	136	0.1%	2.9%	3.0%
2003	2,089	21,558	23,647	8.8%	91.2%	147	661,500	14	147	161	0.3%	3.3%	3.6%
2004	1,178	8,092	9,270	12.7%	87.3%	121	544,500	10	67	77	0.2%	1.5%	1.7%
2005	5,764	16,598	22,362	25.8%	74.2%	122	549,000	47	136	183	1.0%	3.0%	4.1%
2006	3,452	13,077	16,529	20.9%	79.1%	131	589,500	26	100	126	0.6%	2.2%	2.8%
2007	1,163	11,543	12,706	9.2%	90.8%	276	1,242,000	4	46	50	0.1%	0.9%	1.0%

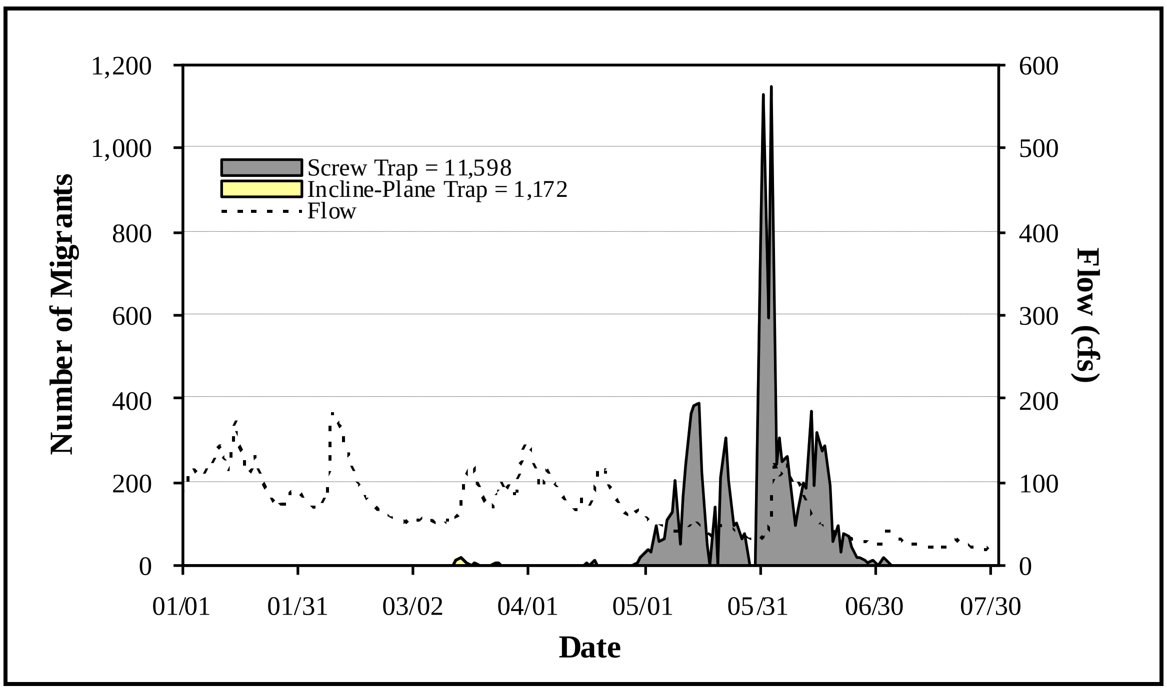


Figure 14. Daily Chinook 0+ migration and daily average flow from Bear Creek, 2008. Daily mean flows were measured at the King County flow gaging station at Union Hill Road.

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2007 brood was estimated to be 1.0% (Table 13). Survival was estimated by dividing 12,770 Chinook by 1,242,000 eggs deposited by 276 females.

Size

From early February through mid- April, sizes of Chinook fry captured in the incline-plane trap averaged 41.0 mm FL, and ranged from 36 mm to 46 mm FL (Table 14).

Fork lengths of Chinook caught in the screw trap ranged from 37 mm to 116 mm, averaging 71.1 mm and increased over the season. In early April, Chinook averaged 44.4 mm FL, with the weekly average remaining below 70 mm FL until mid-May. By the end of the trapping season, weekly average lengths reached 80 mm FL (Table 14, Figure 15). The average parr length in 2008 is much shorter than those observed in the previous seven years (see Discussion Section, Table 18).

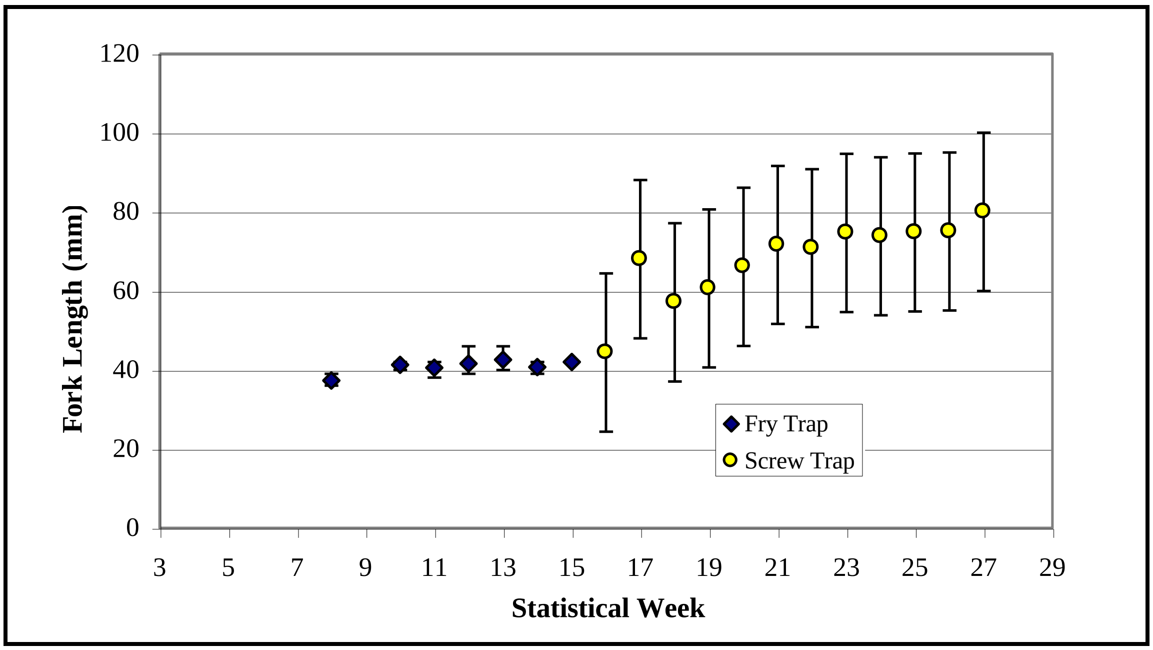


Figure 15. Fork lengths of Chinook 0+ sampled from Bear Creek in 2008. Data are mean, minimum, and maximum lengths each statistical week.

Table 14. Fork lengths of juvenile Chinook and coho in the Bear Creek incline-plane and screw traps in 2008. Data are mean fork lengths (mm), standard deviation (s.d.), ranges, sample sizes, and catch.

Gear	Statistical Week			CHINOOK						COHO					
	Begin	End	No.	Mean	s.d.	Range Min	Range Max	n	Catch	Mean	s.d.	Range Min	Range Max	n	Catch
Incline-Plane Trap	02/03	02/16	6 & 7	0.0	n/a	0	0	0	0						
	02/17	02/23	8	37.7	1.53	36	39	3	3						
	02/24	03/01	9	0.0	0.00	0	0	0	0						
	03/02	03/08	10	41.3	0.96	40	42	4	4						
	03/09	03/15	11	40.5	1.37	38	42	22	22						
	03/16	03/22	12	41.6	2.29	39	46	7	12						
	03/23	03/29	13	42.5	2.16	40	46	11	11						
	03/30	04/05	14	40.7	1.53	39	42	3	3						
	04/06	04/12	15	42.0	n/a	42	42	2	2						
			Totals	41.0	2.01	36	46	52	57						
Screw Trap	04/13	04/19	16	44.4	3.29	39	48	8	8	112.5	3.42	108	116	4	4
	04/20	04/26	17	68.0	36.77	42	94	2	2	124.8	12.54	104	161	21	21
	04/27	05/03	18	57.1	7.42	37	83	52	56	120.5	12.43	97	161	68	204
	05/04	05/10	19	60.6	5.96	38	78	115	140	115.7	10.88	94	146	131	305
	05/11	05/17	20	66.1	6.78	45	82	241	328	115.5	18.44	89	168	103	371
	05/18	05/24	21	71.6	7.83	49	90	188	272	109.1	7.33	95	130	70	159
	05/25	05/31	22	70.8	7.68	54	96	178	219	107.0	8.12	91	121	32	59
	06/01	06/07	23	74.6	7.49	50	96	422	964	111.6	10.75	90	148	66	246
	06/08	06/14	24	73.8	7.27	50	96	227	420	111.7	11.68	92	144	67	182
	06/15	06/21	25	74.7	7.79	52	116	237	264	113.8	12.27	94	141	20	20
	06/22	06/28	26	75.0	5.98	65	90	75	78						0
	06/29	07/12	27 & 28	80.0	4.58	75	84	3	20						2
			Totals	71.1	8.95	37	116	1,748	2,774	114.3	13.03	89	168	582	1,573

Coho

Catch

A total of 1,572 coho smolts were caught in the screw trap over the 84-day trapping season. Coho catches were less than 10 coho per day until May 1, when daily catch increased to 83 coho. Catches remained high the first two weeks of May with nearly fifty-percent of the migration passing during that time period. Catches then decreased and remained below 60 per day until migration suddenly dropped off just as sharply as the beginning of the season.

Production Estimate

Coho production was estimated to be 12,208 ±2,401 (95% C.I.) smolts with a coefficient of variation of 9.9% (Figure 16, Appendix C 4). Production was based on recapture rates of thirteen different mark groups, which were aggregated into seven strata. Final efficiency strata ranged from 7.8% to 28.7%.

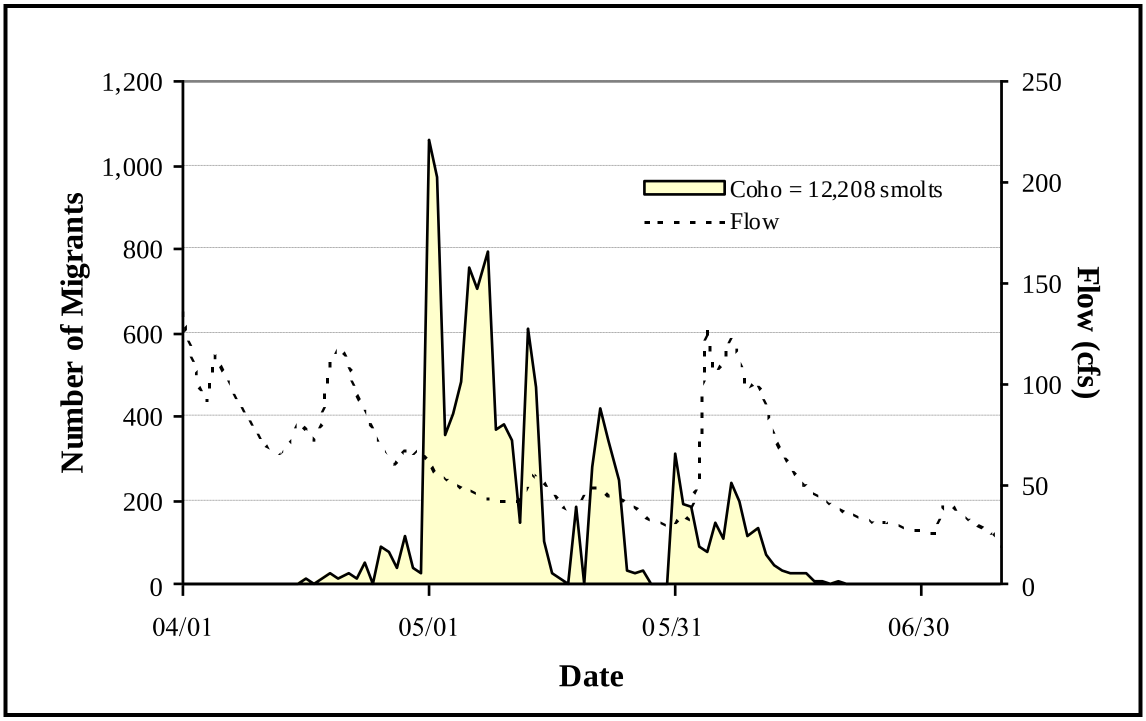


Figure 16. Daily coho smolt migration in Bear Creek and mean daily flows in 2008. Flow data were measured at the King County gaging station at Union Hill Road.

Size

Over the trapping period, fork lengths ranged from 89 mm to 168 mm and averaged 114.3 mm (Figure 17). Weekly mean lengths ranged from 107.0 mm to 124.8 mm FL during screw trap operation (Table 14).

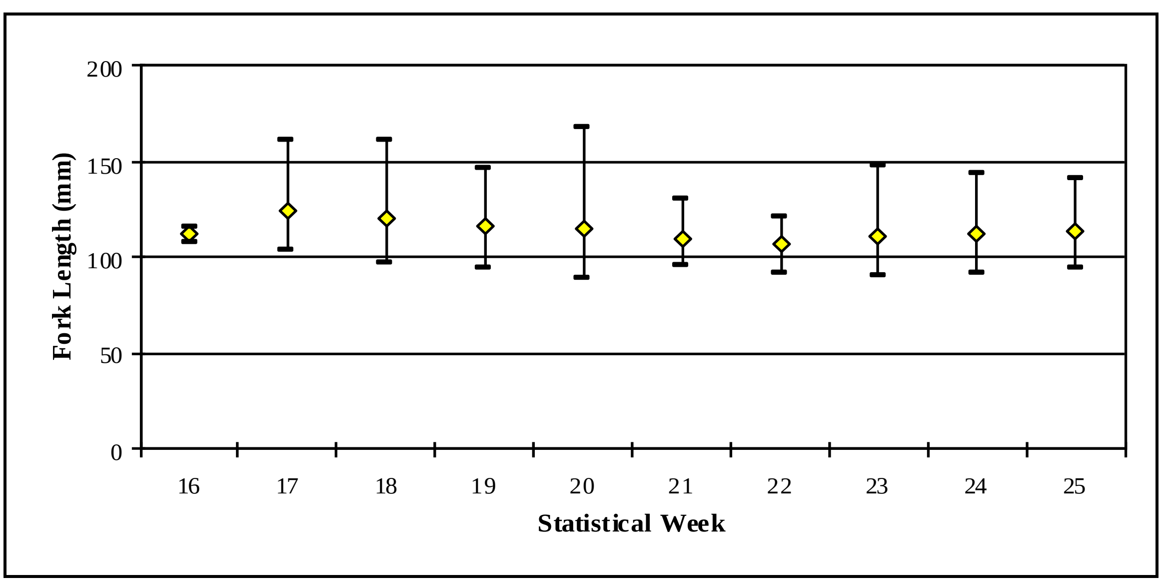


Figure 17. Fork lengths of migrating coho smolts sampled from the Bear Creek screw trap in 2008. Data are mean, minimum, and maximum lengths.

Trout

The identification of trout in Bear Creek poses the same difficulties discussed earlier in the Cedar River section. Based on available visual identification, trout are referred to as cutthroat trout or steelhead outmigrants.

Catch and Production Estimate

One steelhead was captured during the entire 2008 trapping season in Bear Creek.

A total of 320 cutthroat trout were captured in the screw trap. Some of the cutthroat catch may actually be hybrids of rainbow and cutthroat trout if Cedar River results from Marshall *et al* (2006) are indicative of population structure in Bear Creek. Catches at the beginning of the season were under ten per day until mid-May when there was a slight increase to 13. From mid-May through mid-June, catches increased and ranged from 0 to 18 and consisted of 65% of the total catch. Thereafter catches declined to below ten per day for the remainder of the season.

Ten different mark groups of cutthroat were released over the season, ranging from 1 to 56 cutthroat per mark group. Capture rates for these groups ranged from 9.0% to 18.9% yielding an estimated migration of 2,751 ±1,091 cutthroat, with a coefficient of variation of 19% (Figure 18, Appendix C 5), for the trapping period (April 16 through July 9). During the 2000 season, when the screw trap operated from January through June on Bear Creek, 35% of the cutthroat migration occurred prior to April 5. If this time allocation for the migration is applied to cutthroat estimates from the 2008 trapping season, a total of 4,232 cutthroat are estimated to have migrated from Bear Creek.

Cutthroat trout fork lengths averaged 143.2 mm, and ranged from 98 mm to 210 mm throughout the trapping season (Table 15). Average fork lengths showed no consistent trend across weeks.

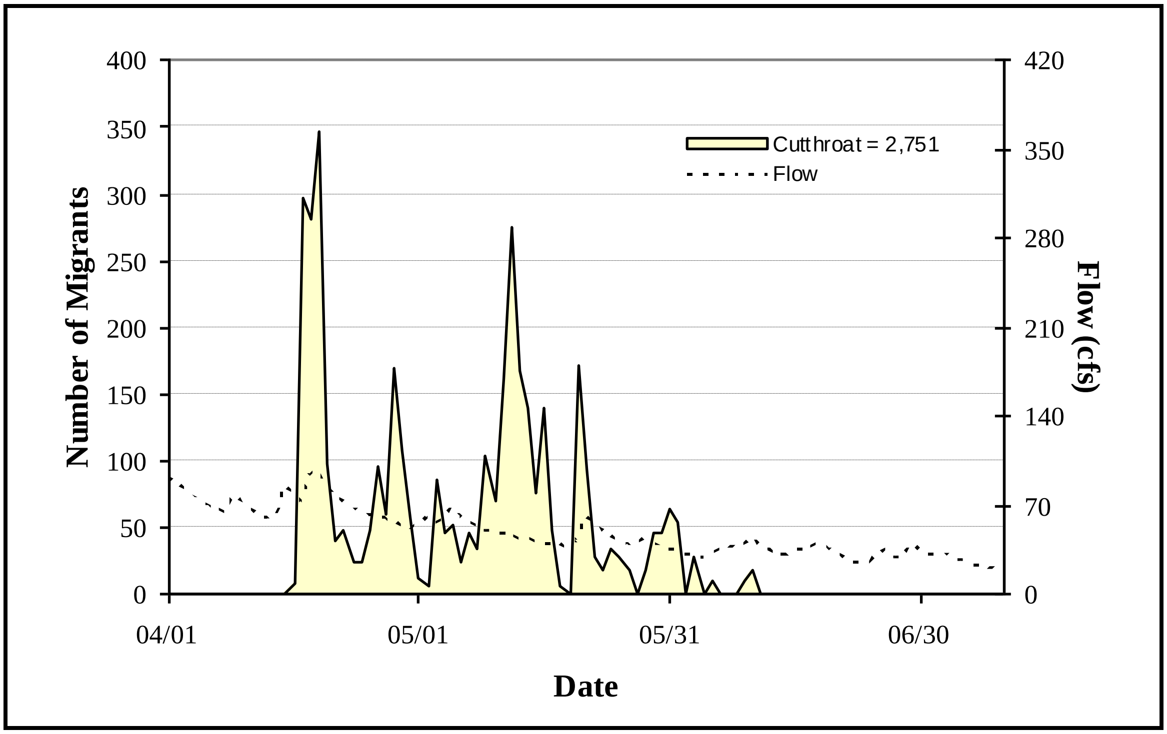


Figure 18. Daily estimated migration of cutthroat trout passing the Bear Creek screw trap in 2008. Flow data were measured at the King County gaging station at Union Hill Road.

Table 15. Cutthroat fork length (mm), standard deviation (s.d.), range, sample size, and catch by statistical week in the Bear Creek screw trap, 2008.

Statistical Week			Avg.	s.d.	Range		n	Catch
Begin	End	No.			Min	Max		
04/14	04/20	16	126.7	24.01	98	141	3	3
04/21	04/27	17	154.9	18.31	121	179	6	6
04/28	05/04	18	156.1	25.91	118	202	15	15
05/05	05/11	19	147.1	15.73	121	181	49	51
05/12	05/18	20	140.3	21.60	103	187	19	58
05/19	05/25	21	139.9	17.81	106	183	50	55
05/26	06/01	22	136.7	11.23	116	166	21	30
06/02	06/08	23	139.1	13.29	112	164	36	47
06/09	06/15	24	144.2	16.09	107	181	27	30
06/16	06/22	25	151.5	28.37	127	210	17	20
06/16	06/22	26	130.0	n/a	130	130	1	1
06/23	07/09	27-28					0	4
		Season Totals	143.2	18.33	98	210	244	320

PIT Tagging

As part of an ongoing multi-agency monitoring of Chinook migrating from the Lake Washington system, PIT tagging also occurred in Bear Creek in 2008. Tagging began on May 9 and occurred three times a week through June 25. Fish were often held overnight to increase the number tagged per day. A total of 1,341 natural-origin Chinook were PIT tagged in Bear Creek throughout the season (Table 16).

Table 16. Natural-origin Chinook parr PIT tagged and released from the Bear Creek screw trap in 2008.

Stat Week			Wild	Length			Portion of
#	Start	End	Chinook	Avg	Min	Max	Migration Tagged
19	05/06	05/10	18	68.2	65	79	2.53%
20	05/11	05/17	156	70.5	65	96	8.56%
21	05/18	05/24	102	74.2	65	90	10.58%
22	05/25	05/31	164	74.8	65	96	15.95%
23	06/01	06/07	385	75.9	65	96	9.76%
24	06/08	06/14	224	75.5	65	106	16.13%
25	06/15	06/21	217	75.4	65	116	17.26%
26	06/22	06/28	75	74.9	65	90	29.33%
Season Totals			**1,341**	**74.7**	**65**	**116**	**0.65%**

Mortality

No Chinook or coho mortalities occurred during incline-plane trapping. Sixteen Chinook mortalities occurred in the screw trap; five of these were due to PIT tagging while the remaining were a result of heavy debris in the live box during trap operation.

Incidental Species

In addition to sockeye and Chinook fry, 9 coho fry were also caught in the incline-plane trap. Other species included lamprey (*Lampetra spp.*), sculpin (*Cottus spp.*), pumpkinseed (*Lepomis gibbosus*), and three-spine sticklebacks (*Gasterosterus aculeatus*). In addition to target species, the screw trap captured sockeye fry, 29 coho fry, and 2 cutthroat adults. Other species caught included lamprey, large-scale suckers (*Catostomus macrocheilus*), three-spine stickleback, sculpin, pumpkinseed, largemouth bass (*Micropterus salmoides*), whitefish (*Prosopium spp.*), peamouth (*Mylocheilus caurinus*), speckled dace (*Rhinichthys osculus*), brown and/or yellow bullhead catfish (*Ameiurus spp.*), bluegill (*Lepomis macrochirus*), and a warmouth (*Lepomis gulosus*).

Discussion

In addition to sockeye and Chinook, five salmonid species were captured as outmigrants of the Cedar River and three salmonid species were captured as outmigrants of Bear Creek. Egg-to-migrant survival of Chinook and sockeye on the Cedar River was higher in 2008 than any previous year when juvenile outmigrations have been evaluated. Lengths of outmigrating Chinook parr were shorter than observed in previous years. Reasons for high survival rates and small body sizes are discussed below. In addition, logistical challenges associated with a long-term trap outage on the Cedar River and low water velocities on Bear Creek are also addressed. Both logistical challenges impacted how production estimates were calculated.

Cedar River

Production Estimates

Chinook

During the 2008 trapping season, the Cedar River experienced unseasonably record high flows during the spring migration period that severely curbed operation of both the incline-plane and the screw trap. Neither trap was operated for a 10-day period, May 18-27, leaving a critical gap in data collection. High flows resulted from a mass of runoff of snowmelt in mid-May that inundated Chester Morse Reservoir, requiring Seattle Public Utilities to evacuate water at unprecedented rates for spring months. The mid-May runoff was unusually high due to a large accumulation of lowland snow during the winter of 2007 and cooler than normal spring temperatures that did not allow for the typical slower snowmelt.

Unfortunately, both traps were disabled close to the second peak of the bimodal Chinook migration. Missed catch could not be predicted from an existing catch versus flow regression because the Cedar River trap has never fished such severe flows during the spring migration. Trap efficiencies were also impossible to estimate. Therefore, previously-used analytic approaches could not be used to estimate migration during the outage period.

A range between 22,068 to 27,276 Chinook was selected to represent migration during the 10-day outage (Table 17). This range reflects estimates from four analytical approaches. One approach was linear interpolation, a method typically employed when estimating catch for periods of trap outages. Based on linear interpolation between May 17 (incline-plane trap) and May 28 (screw trap), migration for the 10-day outage was estimated to be 27,726 Chinook. This approach assumed that the trap efficiencies remained constant regardless of flow fluctuations and that the increase in migration was linear over time. Linear interpolation was also based on the catch of two different gear types, which capture Chinook fry and parr at different rates.

A second method for estimating migration during high water applied trap efficiencies immediately following the outage to catch during a brief screw trap operation period on the night of May 25. In the middle of the prolonged outage, the screw trap was operated for an entire night by means of personnel tending to the trap and managing debris to ensure fish health. A total of 64 Chinook were captured on this night; however, no efficiency release occurred because the captured fish appeared stressed. If catch on May 25 was representative of all nights during the 10-day outage and a recapture rate of 2.7% (based on comparable flows on May 28) is assumed, an estimated 23,703 Chinook migrated during the trap outage period. Alternately, if the May 25 catch was expanded by the recapture rate (2.9%) from statistical week 22, the first full week of trap operation following the outage, Chinook migration was estimated to be 22,068 for the 10-day outage. Both of these methods assume that catch would be similar over a range of flows and that the trap efficiency measured at moderate flows were comparable to high flows.

Table 17. Possible methods for estimating the Chinook migration for a 10-day outage that occurred between May 18 to May 27 as a result of high water.

Methods of Estimating Cedar River Chinook	Estimated Migration
Linear Interpolation	27,726
Actual Catch Expanded by May 28 Efficiency (2.7%)	23,703
Actual Catch Expanded by Week 22 Efficiency (2.9%)	22,068
% Total Migration for May 18-28 from Green River	24,810

The third approach to estimating the total number of Chinook that migrated during the 10-day outage was to compare the Green River Chinook outmigration to the Cedar River outmigration. The two rivers are geographically close and experience similar weather systems, including precipitation amounts and temperatures. In 2008, the Green River experienced unseasonably cool water temperatures and extreme flows comparable to that observed on the Cedar River. Cool water temperatures occurred during the early fry migration and extended into the parr migrations, partially due to the large snowpack that melted early and inundated the rivers with frigid waters. Both watersheds also experienced similar flow fluctuations, including the high water event that halted Cedar River trap operations in late May. Furthermore, Green River Chinook parr migration peaked on June 6, 2008, which corresponds with the assumed peak of the Cedar River Chinook parr migration in 2008. Juvenile traps did not operate on either the Cedar or Green River between May 18 and 19. However, the Green River trap resumed operations on May 20, five days before the Cedar River traps resumed operation. The Green River trap was able to begin fishing just after peak flow and such periods of receding flow have been associated with increased migration in previous years. For the period between May 18 and 27, 3.2% of the total Green River Chinook (2007 brood year) migration occurred (P. Topping, Washington Department of Fish and Wildlife, personal communication). Applying this proportion to the total Cedar River Chinook migration (from trapped periods) suggests that 24,810 Chinook migrated from the Cedar River during the high-water period.

Migration estimates produced by alternate methods were similar to each other and within a reasonable range of each other. Cedar River Chinook migration using in-season data for linear interpolation as well as point catch and efficiency data may provide a more accurate estimate, rather than relying on out-of-basin data (Green River data), as it directly accounts for some of the environmental and species dependent variables that can drive migration timing.

Chinook outmigration in 2008 was nearly three times the largest migration previously observed on the Cedar River since monitoring began in 1998. More specifically, there was an exceptionally large fry migration (89.9%) compared to past years. The exceptionally large proportion of Chinook that migrated as fry, in comparison to parr, suggests that either food or habitat resources were limited and production exceeded the carrying capacity of the Cedar River. Not only was there a large migration of fry but average seasonal fork length of Chinook and weekly average fork length throughout the season were less than previous years. Ward *et al* (2009) suggests that two biotic factors that may explain growth are density and resource availability. In addition, growth and development of juvenile salmon and trout in streams have been linked to food and space availability (Chapman 1966, Jenkins 1969, and Fausch 1984).

The Cedar River experienced unusually cool water temperatures through most of the fry and parr migration period (Figure 19). Lower temperature during rearing periods may have lowered system productivity and limited available food supplies. In addition, greater total abundance of parr in the watershed may also have reduced food availability and contributed to reduced growth during the river-rearing period and earlier movement out of the river. Fry emergence and segregation of size in salmonid species can be due to habitat competition (William Hearn 1987). Fish of similar size often occupy the same types of habitat. As a specific microhabitat becomes scarce, fish move to find available habitat. Even as fish grow, larger fish occupy preferred habitat and smaller, perhaps newly emerged fry, are pushed out of habitat that is optimum for rearing. As a result of such a high abundance, once preferred habitat is occupied by larger, perhaps earlier emerged fry that were rearing in the river, newly emerged fry migrated downstream and eventually to the lake in search of available resources, whether habitat or food and contributed to the large proportion of Chinook that migrated earlier. Although the parr proportion of the total Chinook migration was the lowest observed in 10 years, parr abundance was the largest estimated parr migration since trapping began in 1999.

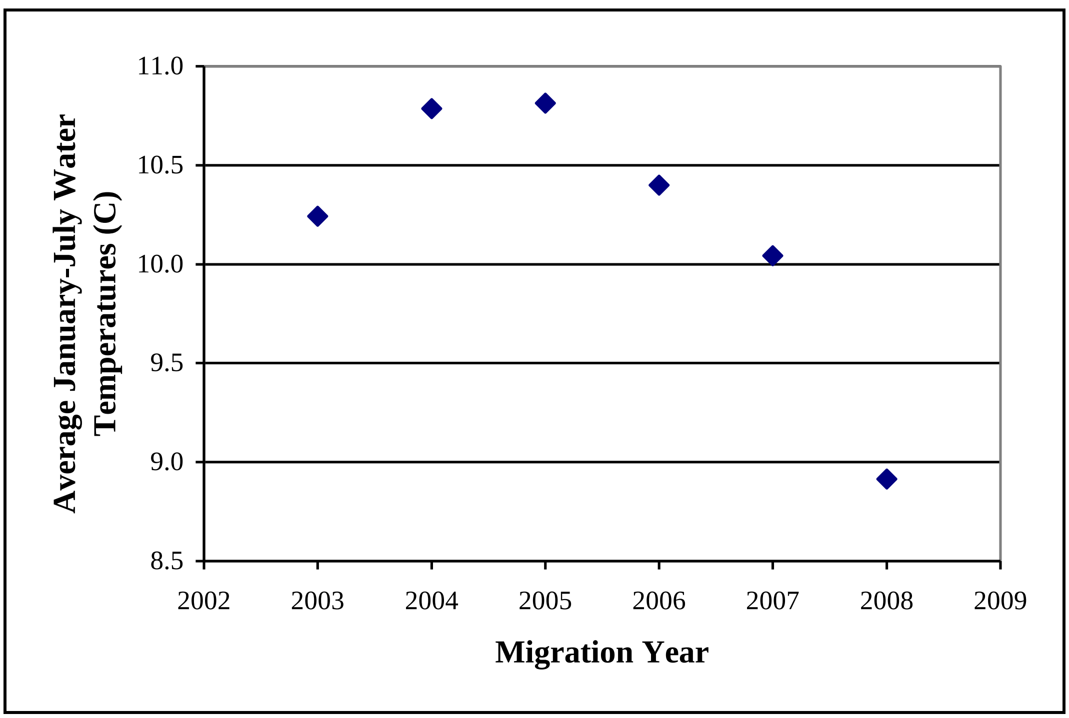


Figure 19. Average water temperature (ºC) in the Cedar River from January to July (USGS Renton gage Station #12119000), 2004-2008.

Coho

Much like the Chinook migration, a number of methods were employed to estimate coho migration missed due to the 10-day outage. Two days prior to high water, the coho migration increased dramatically, possibly indicating the peak or the beginning of the peak of the migration. Unfortunately, the Green River trap experienced low numbers of coho and was unable to make a confident estimate for the missing time period. Between 2002 and 2007, average median migration date for Cedar River coho was May 7 with minimal variation; median migration date ranged from May 2 to May 10. If the 2008 coho migration peaked during the high-water period, peak migration was delayed by nearly 10 days in 2008.

A historical average (2002 to 2007 data) of 14.2% of the coho migration occurred between May 16 and May 27. An estimated 1,736 coho migrated during the high-water event when this rate is applied to the estimated coho migration for the operational trap period. This approach does not take into account the trend and magnitude of the 2008 migration before and after the trap outage. The preferred method for estimating the missed coho migration in 2008 was an interpolation of missed catch expanded by the recapture rate of all mark groups release on or after May 28 (11.3%). This preferred approach yielded an estimate of 2,962 coho migrating during the high-water period and is based on in-season data. This approach encompasses the increase in migration just prior to the trap outage and accounts for coho trap efficiencies during flows that were similar to those that occurred during the outage.

Egg-to-Migrant Survival

The 2007 Cedar River sockeye brood experienced the highest egg-to-migrant survival (32.1%), observed since trapping began in 1992. Survival of natural-origin sockeye was 11.5% greater than any previous year measured. Egg-to-migrant survival of 19.1-19.2% for Chinook in the Cedar River was also extraordinarily high. High survival may have been influenced by flow levels, which were considerably moderate during two vulnerable life history stages, spawning and incubation. Flows averaged 590 cfs during spawning and ranged between 297 cfs and 1,820 cfs during incubation. For a short period (8 days), incubation flows exceeded 1,000 cfs. Substrate in the Cedar River does not begin to move until flows exceed 1,800 to 2,000 cfs at the USGS Renton flow gage (R. Little, Seattle Public Utilities, personal communication). In addition to moderate flows during spawning and egg incubation periods, survival may also have been improved by low sockeye spawner abundance in 2007. Low sockeye returns may increase access to preferred spawning habitat and decrease superimposition of sockeye on both sockeye redds and Chinook redds. Preferred spawning habitat may experience less scour and degradation during high-flow periods.

Chinook Size

Chinook produced by both the Cedar River and Bear Creek were shorter in length than all years when length has been measured (2001 to present). In the Cedar River, average length of Chinook captured throughout the screw-trap season was 73.6 mm, nearly 5 mm shorter than that measured in previous years (Table 18). Mean weekly Chinook fork lengths were consistently shorter than comparable periods in previous years and did not reach 70 mm until statistical week 22 (May 25-31), nearly three weeks later than observed in other years (Figure 20).

Smaller body sizes in 2008 likely resulted from colder water temperatures compared to previous years. Average fork length of Chinook captured in the Cedar River screw trap are positively correlated with the average January-July water temperature in the Cedar River (Figure 21). In the Snake River, growth to parr size of Chinook salmon occurred earlier when water temperatures were warmer rather than cooler, suggesting that size of Chinook salmon increase as water temperature increases (Conner et al, 2002). Banks et al (1971) noted that growth of fall Chinook increases as water temperature increases in the range of 10-18.3 °C as long as food source is not limiting. Average Cedar River water temperature during the months Chinook rear in the river (January to July) was 8.9ºC for the 2008 trapping season, the coldest since 1997. Average water temperature in previous years ranged from 9.3ºC in 2002 to 10.8ºC in 2005 (Figure 19). Cooler waters also typically limit in-river food supplies which directly influence the ability of a migrating fish to grow (Cech et al, 1999).

Table 18. Comparison of natural-origin Chinook sizes measured over seven years (2001-2008) at the Cedar River incline-plane and screw traps.

Migration	**Fry Trap**						**Screw Trap**					
Year	**Avg**	**s.d.**	**Min**	**Max**	**n**	**Catch**	**Avg**	**s.d.**	**Min**	**Max**	**n**	**Catch**
2001	40.3	4.18	34	75	287	687	81.3	14.91	40	121	379	2,872
2002	41.3	7.47	32	92	634	3,781	78.1	21.19	32	131	997	2,592
2003	44.3	10.79	34	90	563	7,186	91.0	13.69	42	128	1,782	3,675
2004	41.9	7.09	34	91	629	2,918	87.4	13.82	42	126	812	6,156
2005	44.7	9.00	36	110	416	4,640	95.7	10.80	42	138	2,260	4,524
2006	45.0	10.70	34	82	496	1,975	82.8	10.92	38	116	701	879
2007	41.8	6.20	34	85	568	2,714	91.7	10.10	45	125	803	878
2008	42.1	5.79	34	95	1,585	21,000	73.6	12.26	37	121	1,153	1,651

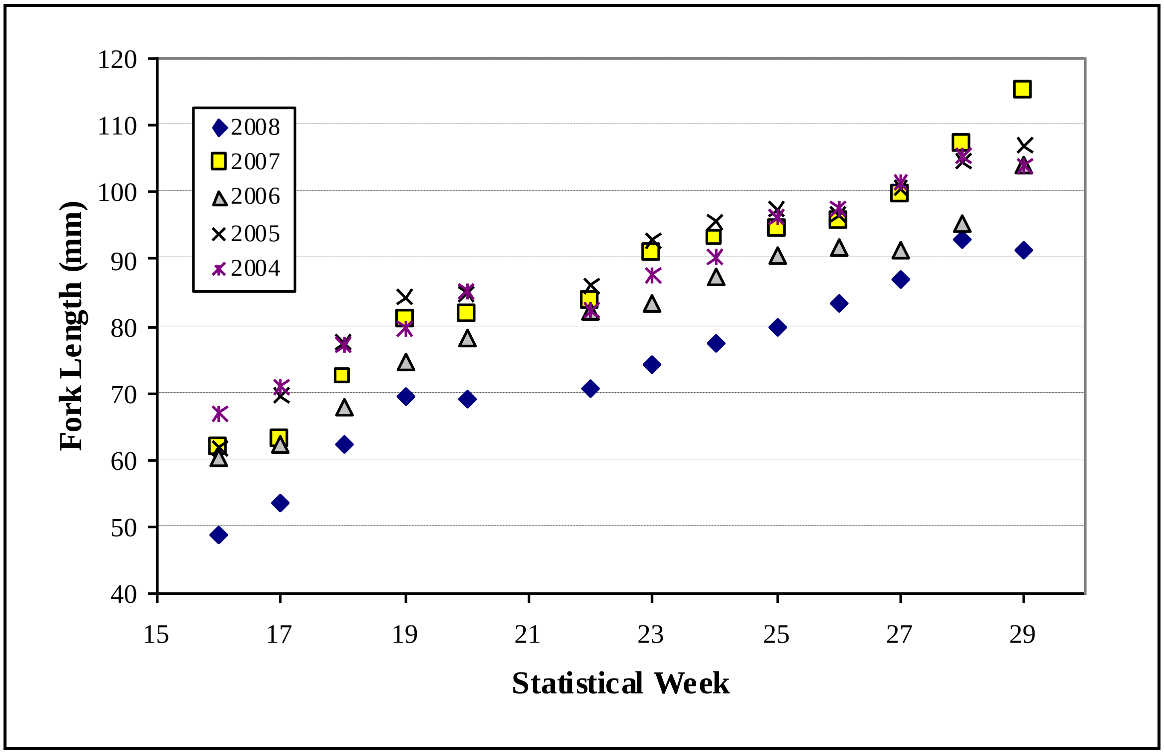


Figure 20. Fork length (mm) of Cedar River Chinook for trap years 2004-2008. Data are means for each statistical week.

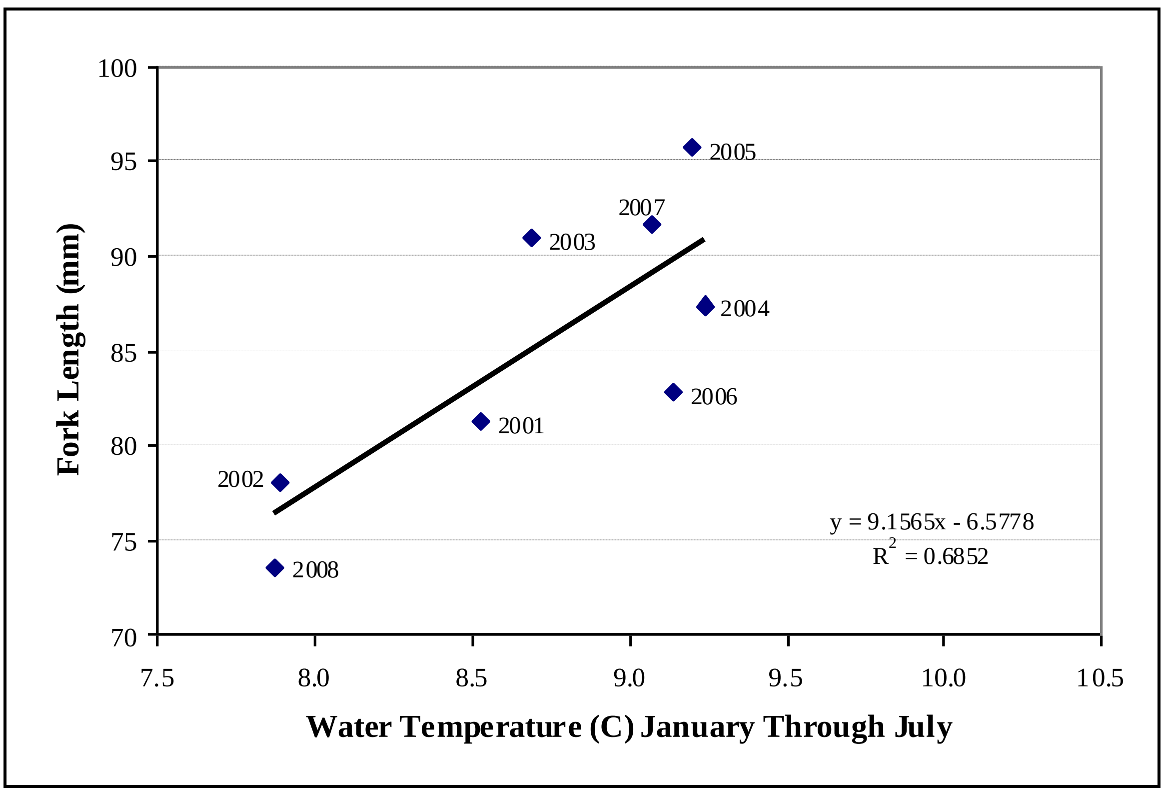


Figure 21. Fork length of Chinook as a function of average water temperature between January and July in the Cedar River. Data are seasonal average lengths from 2001-2008. 1999 and 2000 were not included in the analysis due to incomplete temperature data.

Bear Creek

Production Estimates

Trap operations in Bear Creek in 2008 encountered reduced water velocities caused by beaver dams downstream that potentially impacted the efficiency of both the incline-plane and screw traps. At the beginning of the season, low catches were attributed to high water. Typically efficiency decreases with increased flow because stream hydrology at the trap site does not direct fish towards the trap. After a dry period and continued high water, three beaver dams were found downstream of the trap site. The dams, one of which was nearly 6-feet tall, created a pond and eliminated most of the flow through the trap. As a result, the channel was wider, the noise of water flowing over boulders upstream that previously masked the turning of the screw trap was eliminated, and reduced water velocity decreased the rotations per minute of the screw trap. All three decreased the effectiveness of both traps in 2008.

Over the past two seasons, velocity in Bear Creek has decreased over time. In 2007, it is possible that one or more of these beaver dams were already built and affecting the traps ability to capture fish. Trap efficiencies for the 2007 and 2008 season are lower for all species compared to 2003 to 2006 (Table 19). In response, two flexible pipe pond levelers, designed by Snohomish County Public Utilities District, were installed in the beaver dams during fall 2008 in order to drain water at a base flow rate while allowing fish passage and maintaining habitat for both beavers and fish to rear (Appendix D).

Table 19. Trap efficiencies for Bear Creek 2003-2008. Only two cutthroat mark groups were released in 2003 with no recaptures.

Trap	Sockeye			Chinook			Coho			Cutthroat		
Year	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
2003	6.8%	31.0%	18.8%	31.0%	72.0%	49.1%	14.0%	60.0%	31.0%			
2004	8.7%	20.9%	16.5%	27.0%	85.0%	49.2%	16.0%	70.0%	43.2%	17.0%	33.0%	25.6%
2005	8.7%	28.3%	19.4%	9.8%	96.2%	67.5%	5.4%	72.0%	37.3%	20.0%	30.2%	27.9%
2006	4.0%	20.6%	15.3%	25.7%	64.4%	49.6%	15.0%	46.8%	27.0%	7.5%	21.8%	13.9%
2007	1.5%	13.3%	8.8%	28.6%	52.3%	41.0%	8.1%	27.4%	15.6%	7.3%	18.6%	14.5%
2008	6.2%	12.5%	10.1%	18.0%	42.1%	25.3%	7.8%	28.7%	15.9%	9.0%	18.9%	11.5%

Egg-to-Migrant Survival

Egg deposition on Bear Creek has historically been estimated using either redd-based surveys or the area-under-the-curve (AUC) method (Table 13). The AUC method is an abundance estimator where observations of live fish are collected throughout the season in a specific reach and are plotted on a graph with a line fit through the counts. The area described under the curve is calculated (fish x days), and this value is divided by the assumed average residence time of the fish on the spawning grounds to derive an estimate of total spawner abundance in the surveyed reach. Females are assumed to be 40% of the total return. The second method estimates the numbers of females on redds from direct observations during redd surveys.

In 2008, egg-to-migrant survival of Bear Creek Chinook (2007 brood) was estimated from redd survey data. The total number of redds with females observed near them were multiplied by the number of eggs per female (4,500) to calculate potential egg deposition (PED). Although redd counts began in Bear Creek in 2001, number of females for estimating egg deposition have used either method (redd counts vs. AUC). Table 13 reports egg-to-migrant survival using only the redd count method. The move to using redd count methodology was to provide consistency of data comparison between years. Although survival estimates have changed, bias in either methodology, regarding adult abundance, are not evident. Redd survey data can have problematic gaps for some brood years (2006) because of high water events and poor visibility prohibit accurate counts. Differences in survival calculated with the two methods ranged from –1.43% to 1.73% (Table 20).

Table 20. Difference in egg-to-migrant survival of Chinook between Area Under the Curve (AUC) and Redd based methods of estimating females. The number of females in the 2006 return was estimated by the AUC method due to poor surveying conditions for a duration of time.

Brood Year	Estimated Migration			Estimated Females (Redds)	Survival Redd-Based	Estimated Females (AUC)	Survival AUC-Based	Difference in Survival
	Fry	Smolt	Total					
2001	5,463	15,991	21,454	138	3.45%	276	1.73%	1.73%
2002	655	16,658	17,313	127	3.03%	144	2.67%	0.36%
2003	2,123	21,524	23,647	147	3.57%	105	5.00%	-1.43%
2004	1,175	8,142	9,317	121	1.71%	76	2.72%	-1.01%
2005	4,879	16,589	22,171	122	4.04%	128	3.85%	0.19%
2006	3,976	12,816	16,792	131	2.85%	131	2.85%	0.00%
2007	1,172	11,598	12,770	276	1.03%	276	1.03%	0.00%

Chinook Size

In 2008, Chinook caught in the screw trap averaged 71.1 mm FL. Throughout the season, weekly mean fork lengths were shorter than those of comparable time periods in previous years (with the exception of statistical week 17). Weekly mean lengths did not reach 70 mm FL until week 22, similar to the delayed growth observed for Cedar River Chinook. Water temperatures in Bear Creek, available between 2006 and 2008, were cooler during the 2008 rearing and migration period than the past two seasons. Cool temperature, as cited above, linked to food availability and growth potential, is the likely cause for the small sizes of Chinook observed during the 2008 trapping season (Figure 22).

Table 21. Comparison of natural-origin Chinook sizes measured over eight years (2001-2008) at the Bear Creek incline-plane and screw traps.

Trap	Fry Trap						Screw Trap					
Year	Avg	s.d.	Min	Max	n	Catch	Avg	s.d.	Min	Max	n	Catch
2001	41.1	1.97	34	47	39	63	73.4	11.60	38	105	622	5,131
2002	38.9	3.80	34	52	70	278	81.5	10.83	42	110	885	6,880
2003	40.9	3.20	34	54	78	86	75.9	11.20	35	106	709	8,182
2004	41.6	4.99	38	60	70	102	73.6	11.52	40	107	874	10,613
2005	40.6	2.29	38	47	46	102	78.7	7.06	40	102	1,766	4,612
2006	41.4	4.10	37	64	117	264	76.0	8.82	44	100	907	8,180
2007	41.7	3.30	38	55	75	106	79.8	6.80	40	118	2,978	5,320
2008	41.0	2.01	36	46	52	57	71.1	8.95	37	116	1,748	2,774

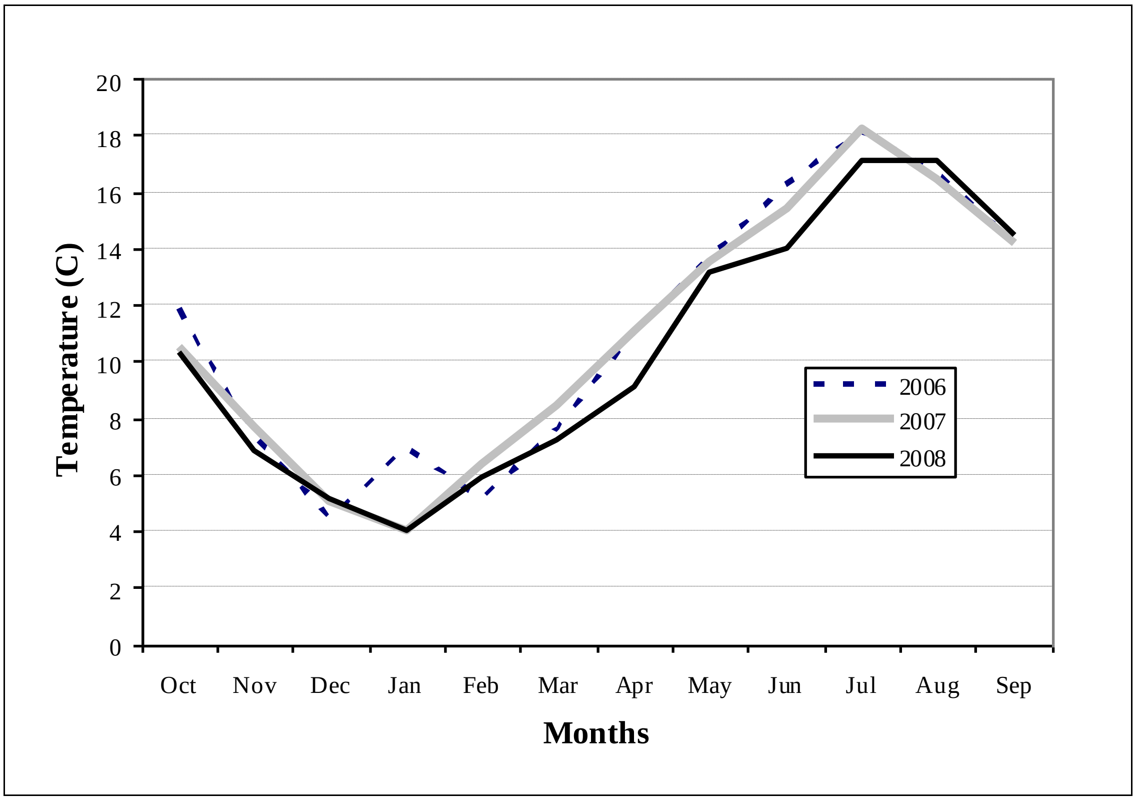


Figure 22. Average water temperature (ºC) in Bear Creek from January to July measured at the King County flow gage station at Union Hill Road, 2006-2008.

Recommendations

The 2008 trapping season in Cedar River and Bear Creek experienced a number of successes. For example, greater catches allowed for larger release groups and contributed to more confident migration estimates. Due to moderate flows and abundant sockeye and Chinook fry catches in the Cedar River, releasing larger groups of marked fish enabled a more robust and confident migration estimate. Abundance of sockeye and Chinook fry were also greater during daylight periods and, paired with more frequent daylight fishing periods, day: night fishing ratios for sockeye and Chinook fry may more accurately represent the proportion that migrate during the day. Although the efficiency of the Bear Creek traps was reduced, larger release groups of Chinook, coho, and cutthroat led to more confident estimates that may have adequately captured the reduction in trap efficiencies at the site.

The 2008 trapping season in Cedar River and Bear Creek also experienced logistical difficulties that affected trap efficiencies via high water in one system and low velocities in the other. Furthermore, when evaluating 2008 data for both systems, a number of assumptions became apparent that could contribute to inaccurate estimates and will be addressed in the 2009 trap season. Addressing these assumptions will improve the accuracy of migration estimates each trap season and more confidently identify contributing factors that affect survival and productivity of salmon in each basin.

Recommendation 1: Move the Cedar River screw trap. Since 2006, the Cedar River screw trap has been located downstream of the Logan Street Bridge. The location of this trap site has resulted in very low catch and recapture rates for larger juvenile salmonids, contributing more uncertainty to migration estimates. Therefore, the trap will be moved upstream near the I-405 overpass for the 2009 trapping season. The process for approving the relocation of the screw trap has been started. The hydrology at the new site provides directed flow, allowing the trap to capture the fastest water where most fish tend to migrate, noise to mask the movement of the screw trap, and velocity to capture and retain larger coho, cutthroat, and steelhead.

Recommendation 2: Restore flow to Bear Creek trap. Efficiencies of both traps in Bear Creek were likely influenced by beaver dams below the trap site, which retained water and reduced the velocity at the traps. In Fall 2008, a cooperative effort of WDFW and King County Natural Resources and Parks staff, with recommendations made by Snohomish County, installed two flexible pipe pond levelers in two of the beaver dams. These pond levelers retain the structure of the dams and important habitat created by beaver dams but still allow for the creek to flow at base flow rates. Although this does not completely restore the creek to a free-flowing state, some velocity should be restored at the trap site.

Recommendation 3: Test assumption that there is very little, or no, sockeye and Chinook fry movement occurring during daylight hours in Bear Creek. Although this assumption was tested in the 1990s, it seems appropriate to periodically retest assumptions to confirm that salmonids are still behaving as expected. The consequence of missing day time catch of juvenile salmonids is an underestimate of the juvenile migration. In 2009, the Bear Creek incline-plane trap will operate periodically throughout the season during daylight hours to assess daylight fry migrations, develop day:night ratios, and to reassess daytime migration.

With such large data sets of juvenile salmonid productivity and survival in both systems, future years provide opportunity to assess how flow, temperature, spawner abundance of both Chinook and sockeye, and the abundance of other salmonid species interact and contribute to sockeye and Chinook productivity in the river habitat.

Appendix A

Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants is estimated.

Kristen Ryding
Statistician
Stock Assessment Unit
Science Division, Fish Program
WDFW

Appendix A. Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants is estimated. Kristen Ryding, WDFW Biometrician.

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

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

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

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

where

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

$E(\hat{u}_i)$ = 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, $Var(\hat{u}_i)$ 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,

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

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

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

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

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

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

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

Note that,

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

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

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

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

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

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

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

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

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

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

Appendix B

Catch and Migration Estimates by Stratum for Cedar River
Sockeye, Chinook, and Coho Salmon, 2008.

Appendix B 1. Catch and migration by stratum for Cedar River natural-origin sockeye fry, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	01/13/08	01/15/08	1,951	7.20%	27,119	4.76E+07
2	01/16/08	01/19/08	3,259	7.00%	46,441	1.23E+08
3	01/20/08	01/20/08	1,181	6.90%	17,209	1.53E+07
4	01/21/08	01/22/08	1,916	8.90%	21,587	2.23E+07
5	01/23/08	01/23/08	1,498	7.00%	21,324	2.02E+07
6	01/24/08	01/24/08	1,567	10.80%	14,476	7.55E+06
7	01/25/08	01/25/08	1,432	14.30%	10,024	2.74E+06
8	01/26/08	01/27/08	3,652	9.60%	38,224	2.73E+07
9	01/28/08	01/28/08	1,698	5.30%	32,262	4.92E+07
10	01/29/08	01/29/08	2,606	5.10%	51,017	8.28E+07
11	01/30/08	01/30/08	3,024	6.60%	45,696	4.93E+07
12	01/31/08	01/31/08	3,371	5.10%	66,521	1.24E+08
13	02/01/08	02/01/08	4,737	10.10%	46,844	2.98E+07
14	02/02/08	02/03/08	9,494	5.80%	164,465	3.72E+08
15	02/04/08	02/04/08	3,914	7.30%	53,560	6.39E+07
16	02/05/08	02/05/08	6,522	9.40%	69,370	9.14E+07
17	02/06/08	02/06/08	6,865	8.40%	81,444	1.27E+08
18	02/07/08	02/08/08	6,366	3.80%	165,914	1.31E+09
19	02/09/08	02/10/08	3,655	1.40%	257,221	5.18E+09
20	02/11/08	02/11/08	3,334	2.00%	163,622	1.52E+09
21	02/12/08	02/13/08	6,525	2.60%	249,869	2.87E+09
22	02/14/08	02/15/08	6,791	5.30%	127,331	7.60E+08
23	02/16/08	02/17/08	8,093	5.60%	144,292	4.38E+08
24	02/18/08	02/18/08	5,436	6.10%	89,382	1.17E+08
25	02/19/08	02/19/08	6,422	3.70%	173,961	7.69E+08
26	02/20/08	02/20/08	11,527	6.70%	171,974	2.70E+08
27	02/21/08	02/22/08	43,716	10.10%	433,421	1.09E+09
28	02/23/08	02/24/08	51,927	5.50%	949,180	1.58E+10
29	02/25/08	02/25/08	29,977	8.60%	347,795	3.81E+08
30	02/26/08	02/26/08	26,649	7.40%	359,401	1.04E+09
31	02/27/08	02/27/08	22,774	5.40%	425,207	2.00E+09
32	02/28/08	02/29/08	54,747	6.60%	823,998	6.23E+09
33	03/01/08	03/02/08	49,999	6.70%	749,526	4.65E+09
34	03/03/08	03/03/08	22,644	6.20%	363,475	7.01E+08
35	03/04/08	03/04/08	25,091	5.10%	490,265	2.86E+09
36	03/05/08	03/05/08	20,288	5.80%	352,726	1.93E+09
37	03/06/08	03/07/08	32,321	5.20%	627,102	4.11E+09
38	03/08/08	03/09/08	51,971	5.40%	968,242	1.77E+10
39	03/10/08	03/10/08	43,684	7.20%	606,584	3.14E+09
40	03/11/08	03/11/08	20,661	3.90%	524,789	6.01E+09
41	03/12/08	03/12/08	42,320	8.60%	492,200	1.57E+09
42	03/13/08	03/14/08	34,248	2.70%	1,269,133	4.01E+10
43	03/15/08	03/16/08	15,736	2.60%	610,927	1.71E+10
44	03/17/08	03/17/08	23,622	4.80%	489,479	3.52E+09
45	03/18/08	03/18/08	21,479	5.00%	429,580	2.12E+09

Table continued next page

Appendix B1. Catch and migration by stratum for Cedar River natural-origin sockeye fry, 2008 (continued).

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
46	03/19/08	03/19/08	24,974	5.20%	477,360	2.93E+09
47	03/20/08	03/21/08	40,470	3.80%	1,062,732	1.34E+10
48	03/22/08	03/23/08	37,308	3.60%	1,030,690	1.18E+10
49	03/24/08	03/24/08	16,462	4.40%	377,033	2.07E+09
50	03/25/08	03/25/08	10,680	3.70%	287,517	1.90E+09
51	03/26/08	03/26/08	12,663	4.50%	283,383	1.10E+09
52	03/27/08	03/28/08	36,605	10.30%	354,320	6.12E+08
53	03/29/08	03/29/08	28,496	7.60%	376,258	1.23E+09
54	03/30/08	03/30/08	17,332	3.40%	508,143	5.20E+09
55	03/31/08	03/31/08	25,303	3.70%	674,878	6.46E+09
56	04/01/08	04/01/08	21,513	5.40%	400,033	1.83E+09
57	04/02/08	04/02/08	64,560	10.60%	609,057	3.02E+09
58	04/03/08	04/03/08	47,516	3.90%	1,221,232	2.02E+10
59	04/04/08	04/04/08	15,179	4.00%	381,689	2.70E+09
60	04/05/08	04/05/08	13,477	4.00%	337,823	2.24E+09
61	04/06/08	04/06/08	13,831	4.10%	336,554	2.93E+09
62	04/07/08	04/07/08	32,270	4.20%	776,962	1.34E+10
63	04/08/08	04/08/08	25,310	4.10%	620,325	6.26E+09
64	04/09/08	04/09/08	30,609	9.20%	333,026	7.84E+08
65	04/10/08	04/10/08	8,415	8.40%	99,806	1.95E+08
66	04/11/08	04/11/08	6,991	8.60%	81,668	1.28E+08
67	04/12/08	04/12/08	10,628	7.80%	136,778	6.37E+08
68	04/13/08	04/13/08	17,535	9.00%	194,094	1.04E+09
69	04/14/08	04/14/08	6,284	8.80%	71,219	1.16E+08
70	04/15/08	04/15/08	5,378	9.10%	59,095	3.63E+07
71	04/16/08	04/16/08	9,138	8.80%	103,984	2.99E+08
72	04/17/08	04/17/08	7,005	9.00%	77,555	1.71E+08
73	04/18/08	04/18/08	1,303	7.70%	17,020	1.34E+07
74	04/19/08	04/19/08	947	8.10%	11,680	7.79E+06
75	04/20/08	04/20/08	2,677	8.20%	32,793	7.91E+07
76	04/21/08	04/21/08	1,109	7.90%	14,047	1.70E+07
		Total	**1,342,658**		**25,012,936**	**2.49E+11**

Appendix B 2. Catch and migration by stratum for Cedar River natural-origin Chinook fry, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	01/13/08	01/15/08	151	7.20%	2,099	3.78E+05
2	01/16/08	01/19/08	130	7.00%	1,853	2.23E+05
3	01/20/08	01/20/08	216	6.90%	3,147	5.43E+05
4	01/21/08	01/22/08	225	8.90%	2,535	3.27E+05
5	01/23/08	01/23/08	115	7.00%	1,637	1.37E+05
6	01/24/08	01/24/08	134	10.80%	1,238	6.39E+04
7	01/25/08	01/25/08	114	14.30%	798	2.16E+04
8	01/26/08	01/27/08	178	9.60%	1,863	1.09E+05
9	01/28/08	01/28/08	38	5.30%	722	3.55E+04
10	01/29/08	01/29/08	74	5.10%	1,449	9.09E+04
11	01/30/08	01/30/08	83	6.60%	1,254	5.35E+04
12	01/31/08	01/31/08	262	5.10%	5,170	8.41E+05
13	02/01/08	02/01/08	204	10.10%	2,017	7.32E+04
14	02/02/08	02/03/08	271	5.80%	4,695	9.64E+05
15	02/04/08	02/04/08	56	7.30%	766	2.21E+04
16	02/05/08	02/05/08	163	9.40%	1,734	7.24E+04
17	02/06/08	02/06/08	296	8.40%	3,512	2.75E+05
18	02/07/08	02/08/08	1,557	3.80%	40,579	1.41E+08
19	02/09/08	02/10/08	1,141	1.40%	80,298	7.51E+08
20	02/11/08	02/11/08	438	2.00%	21,496	2.69E+07
21	02/12/08	02/13/08	1,434	2.60%	54,914	1.40E+08
22	02/14/08	02/15/08	1,205	5.30%	22,594	3.11E+07
23	02/16/08	02/17/08	1,237	5.60%	22,055	1.16E+07
24	02/18/08	02/18/08	561	6.10%	9,224	1.40E+06
25	02/19/08	02/19/08	192	3.70%	5,201	8.16E+05
26	02/20/08	02/20/08	824	6.70%	12,293	1.54E+06
27	02/21/08	02/22/08	1,229	10.10%	12,185	3.30E+06
28	02/23/08	02/24/08	523	5.50%	9,560	1.17E+07
29	02/25/08	02/25/08	336	8.60%	3,898	9.55E+04
30	02/26/08	02/26/08	230	7.40%	3,102	1.18E+05
31	02/27/08	02/27/08	163	5.40%	3,043	1.54E+05
32	02/28/08	02/29/08	1,373	6.60%	20,665	2.90E+07
33	03/01/08	03/02/08	1,010	6.70%	15,141	1.38E+07
34	03/03/08	03/03/08	289	6.20%	4,639	1.92E+05
35	03/04/08	03/04/08	1,818	5.10%	35,523	1.56E+07
36	03/05/08	03/05/08	1,008	5.80%	17,525	5.16E+06
37	03/06/08	03/07/08	1,218	5.20%	23,632	3.08E+07
38	03/08/08	03/09/08	742	5.40%	13,824	5.45E+06
39	03/10/08	03/10/08	557	7.20%	7,734	6.44E+05
40	03/11/08	03/11/08	403	3.90%	10,236	2.56E+06
41	03/12/08	03/12/08	285	8.60%	3,315	1.05E+05
42	03/13/08	03/14/08	1,275	2.70%	47,248	1.20E+08
43	03/15/08	03/16/08	708	2.60%	27,487	1.26E+08
44	03/17/08	03/17/08	528	4.80%	10,941	2.03E+06
45	03/18/08	03/18/08	726	5.00%	14,520	2.78E+06

Table continued next page

Appendix B2. Catch and migration by stratum for Cedar River natural-origin Chinook fry, 2008 (continued).

Stratum	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
46	03/19/08	03/19/08	460	5.20%	8,793	1.14E+06
47	03/20/08	03/21/08	746	3.80%	19,590	8.31E+06
48	03/22/08	03/23/08	869	3.60%	24,007	1.00E+07
49	03/24/08	03/24/08	244	4.40%	5,588	5.84E+05
50	03/25/08	03/25/08	60	3.70%	1,615	9.85E+04
51	03/26/08	03/26/08	192	4.50%	4,297	3.51E+05
52	03/27/08	03/28/08	399	10.30%	3,862	1.12E+05
53	03/29/08	03/29/08	227	7.60%	2,997	6.59E+05
54	03/30/08	03/30/08	75	3.40%	2,199	1.59E+05
55	03/31/08	03/31/08	219	3.70%	5,841	6.47E+05
56	04/01/08	04/02/08	158	5.40%	2,938	1.48E+05
57	04/03/08	04/04/08	343	10.60%	3,236	1.17E+05
58	04/05/08	04/06/08	160	3.90%	4,112	2.68E+06
59	04/07/08	04/07/08	92	4.00%	2,313	1.55E+05
60	04/08/08	04/08/08	150	4.00%	3,760	3.61E+05
61	04/09/08	04/09/08	31	4.10%	754	3.13E+04
62	04/10/08	04/11/08	103	4.20%	2,480	2.88E+05
63	04/12/08	04/13/08	59	4.10%	1,446	2.59E+05
64	04/14/08	04/16/08	159	9.20%	1,730	1.32E+05
65	04/17/08	04/17/08	52	8.40%	617	1.40E+04
66	04/18/08	04/18/08	32	8.60%	374	6.52E+03
67	04/19/08	04/20/08	95	7.80%	1,223	7.86E+04
68	04/21/08	04/23/08	84	9.00%	930	6.35E+04
69	04/24/08	04/24/08	44	8.80%	499	1.04E+04
70	04/25/08	04/25/08	47	9.10%	516	7.72E+03
71	04/26/08	04/27/08	28	8.80%	319	5.63E+04
72	04/28/08	04/30/08	19	9.00%	210	4.47E+03
73	05/01/08	03/01/08	5	7.70%	65	8.64E+02
74	03/02/08	03/02/08	2	8.10%	25	2.58E+02
75	03/03/08	05/06/08	7	8.20%	86	1.41E+03
76	05/07/08	05/14/08	217	7.90%	2,749	1.77E+06
		Total	**31,098**		**698,531**	**1.506E+09**

Appendix B 3. Catch and migration by stratum for Cedar River natural-origin Chinook parr, 2008.

Stratum	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	05/28/08	05/31/08	289	2.90%	9,826	3.12E+07
2	06/01/08	06/07/08	478	2.90%	16,730	4.53E+07
3	06/08/08	06/14/08	169	2.80%	6,021	4.40E+06
4	06/15/08	06/21/08	99	5.30%	1,861	6.54E+05
5	06/22/08	06/28/08	98	5.70%	1,725	5.60E+05
6	06/28/08	07/05/08	70	2.60%	2,730	3.63E+06
7	07/06/08	07/19/08	31	7.40%	418	4.02E+04
		Total	**1,234**		**39,311**	**8.58E+07**

Appendix B 4. Catch and migration by stratum for Cedar River natural-origin coho smolts, 2008.

Stratum	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	04/13/08	05/03/08	50	9.60%	583	1.03E+05
2	05/04/08	05/15/08	158	1.80%	8,795	2.53E+07
3	05/28/08	05/31/08	47	11.80%	400	7.01E+04
4	06/01/08	06/07/08	31	7.30%	424	5.51E+04
5	06/08/08	07/19/08	29	14.30%	203	1.75E+04
		Total	**315**		**10,405**	**2.56E+07**

Appendix C

Catch and Migration Estimates by Stratum for Bear Creek
Sockeye, Chinook, Coho Salmon, and Cutthroat Trout, 2008.

Appendix C 1. Catch and migration by stratum for Bear Creek sockeye, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	02/03/08	02/25/08	366	6.20%	5,917	3.17E+06
2	02/26/08	02/26/08	48	10.80%	444	2.13E+04
3	02/27/08	02/28/08	221	12.50%	1,768	2.85E+05
4	02/29/08	03/03/08	276	8.00%	3,430	1.40E+06
5	03/04/08	03/04/08	81	10.90%	741	4.64E+04
6	03/05/08	03/06/08	116	10.80%	1,073	1.38E+05
7	03/07/08	03/09/08	177	12.00%	1,475	1.89E+05
8	03/10/08	03/10/08	92	10.90%	841	5.92E+04
9	03/11/08	03/11/08	269	10.50%	2,568	4.02E+05
10	03/12/08	03/13/08	1,603	12.10%	13,206	1.18E+07
11	03/16/08	03/16/08	2,298	8.00%	28,725	3.70E+07
12	03/17/08	03/17/08	796	8.80%	9,058	2.35E+06
13	03/18/08	03/18/08	981	11.70%	8,418	1.39E+06
14	03/19/08	03/20/08	987	10.90%	9,015	1.21E+07
15	03/21/08	03/23/08	6,402	8.00%	80,025	7.99E+08
16	03/24/08	03/24/08	532	9.90%	5,373	1.12E+06
17	03/25/08	03/25/08	354	11.90%	2,987	4.09E+05
18	03/26/08	03/27/08	788	10.80%	7,271	1.95E+06
19	03/28/08	03/30/08	864	8.30%	10,368	1.00E+07
20	03/31/08	03/31/08	341	7.80%	4,384	1.56E+06
21	04/01/08	04/01/08	316	10.00%	3,160	7.39E+05
22	04/02/08	04/03/08	616	10.10%	6,072	1.89E+06
23	04/04/08	04/06/08	1,296	11.30%	11,435	4.52E+06
24	04/07/08	04/07/08	227	7.80%	2,894	6.40E+05
25	04/08/08	04/08/08	185	10.70%	1,731	1.59E+05
26	04/09/08	04/10/08	625	9.70%	6,458	3.10E+06
27	04/11/08	04/13/08	945	11.50%	8,222	2.67E+06
		Total	**21,802**		**237,059**	**8.98E+08**

Appendix C 2. Catch and migration by stratum for Bear Creek natural-origin Chinook fry, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	02/03/08	02/25/08	4	6.20%	65	1.17E+03
2	02/26/08	02/26/08	0	10.80%	0	0.00E+00
3	02/27/08	02/28/08	0	12.50%	0	0.00E+00
4	02/29/08	03/03/08	2	8.00%	25	2.44E+02
5	03/04/08	03/04/08	0	10.90%	0	0.00E+00
6	03/05/08	03/06/08	3	10.80%	28	3.33E+02
7	03/07/08	03/09/08	1	12.00%	8	6.05E+01
8	03/10/08	03/10/08	0	10.90%	0	0.00E+00
9	03/11/08	03/11/08	2	10.50%	19	1.49E+02
10	03/12/08	03/13/08	31	12.10%	255	9.08E+03
11	03/16/08	03/16/08	25	8.00%	313	7.42E+03
12	03/17/08	03/17/08	7	8.80%	80	9.25E+02
13	03/18/08	03/18/08	2	11.70%	17	1.27E+02
14	03/19/08	03/20/08	1	10.90%	9	2.22E+02
15	03/21/08	03/23/08	15	8.00%	188	3.33E+03
16	03/24/08	03/24/08	1	9.90%	10	8.38E+01
17	03/25/08	03/25/08	1	11.90%	8	5.60E+01
18	03/26/08	03/27/08	2	10.80%	18	2.27E+02
19	03/28/08	03/30/08	3	8.30%	36	4.43E+02
20	03/31/08	03/31/08	0	7.80%	0	0.00E+00
21	04/01/08	04/01/08	0	10.00%	0	0.00E+00
22	04/02/08	04/03/08	3	10.10%	30	4.40E+02
23	04/04/08	04/06/08	5	11.30%	44	4.39E+02
24	04/07/08	04/07/08	0	7.80%	0	0.00E+00
25	04/08/08	04/08/08	1	10.70%	9	6.86E+01
26	04/09/08	04/10/08	1	9.70%	10	1.57E+02
27	04/11/08	04/13/08	0	11.50%	0	0.00E+00
		Total	**110**		**1,172**	**2.50E+04**

Appendix C 3. Catch and migration by stratum for Bear Creek natural-origin Chinook parr, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	04/16/08	05/03/08	66	42.10%	157	1.69E+03
2	05/04/08	05/10/08	140	19.70%	712	2.52E+04
3	05/11/08	05/17/08	328	18.00%	1,819	9.47E+04
4	05/18/08	05/24/08	270	28.00%	963	3.60E+04
5	05/25/08	05/31/08	831	21.30%	3,899	9.17E+05
6	06/01/08	06/07/08	497	32.90%	1,510	1.83E+04
7	06/08/08	06/14/08	275	29.00%	949	1.82E+04
8	06/15/08	06/21/08	264	21.00%	1,258	7.25E+04
9	06/22/08	07/09/08	101	30.50%	331	4.00E+03
		Total	**2,772**		**11,598**	**1.19E+06**

Appendix C 4. Catch and migration by stratum for Bear Creek natural-origin coho smolts, 2008.

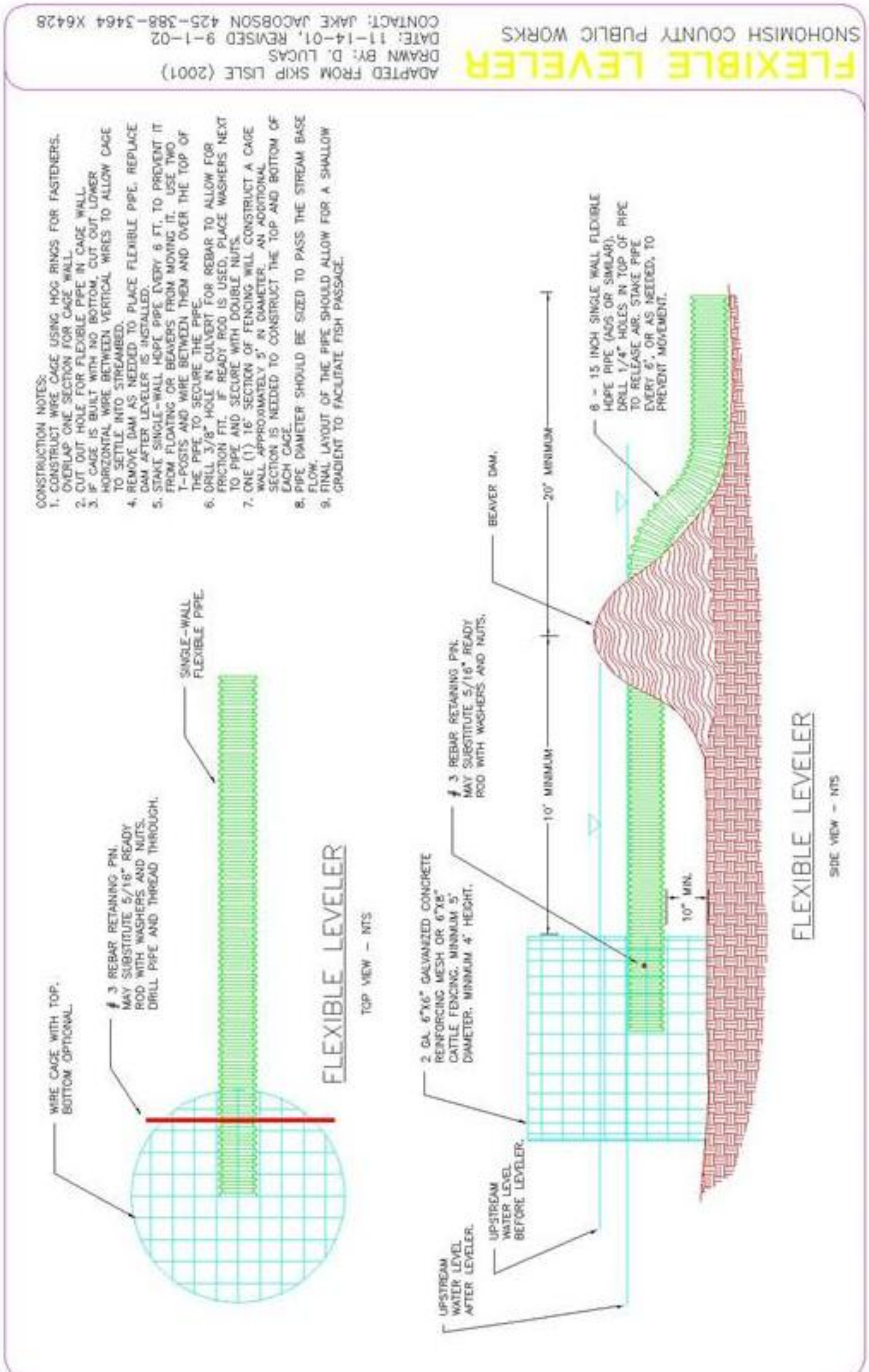
Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	04/16/08	05/10/08	534	7.80%	6,804	1.22E+06
2	05/11/08	05/17/08	371	21.50%	1,728	4.84E+04
3	05/18/08	05/24/08	159	10.70%	1,483	1.63E+05
4	02/25/08	05/31/08	59	14.30%	413	2.89E+04
5	06/01/08	06/07/08	246	23.40%	1,051	2.47E+04
6	06/07/08	06/14/08	182	28.70%	634	5938
7	06/15/08	07/09/08	22	24.00%	91	903
		Total	**1,573**		**12,204**	**1.50E+06**

Appendix C 5. Catch and migration by stratum for Bear Creek cutthroat migrants, 2008.

Stratum	Date Begin	Date End	Total Catch	Recapture Rate	Estimated Migration	Variance
1	04/16/08	05/10/08	78	9.00%	870	1.54E+05
2	05/11/08	05/17/08	58	12.20%	476	3.93E+04
3	05/18/08	05/31/08	85	10.90%	779	8.95E+04
4	06/01/08	06/07/08	47	18.90%	248	9.62E+03
5	06/07/08	07/09/08	55	14.60%	377	1.70E+04
		Total	**323**		**2,750**	**3.10E+05**

Appendix D

Snohomish County Public Utility District's schematics of a flexible pipe pond leveler used to alleviate retained water due to beaver dams in Bear Creek, 2008.


WIRE CAGE WITH TOP. BOTTOM OPTIONAL.
3 REBAR RETAINING PIN. MAY SUBSTITUTE 5/16" READY ROD WITH WASHERS AND NUTS. DRILL PIPE AND THREAD THROUGH.
SINGLE-WALL FLEXIBLE PIPE.
FLEXIBLE LEVELER
TOP VIEW – NTS
CONSTRUCTION NOTES:
1. CONSTRUCT WIRE CAGE USING HOG RINGS FOR FASTENERS. OVERLAP ONE SECTION FOR CAGE WALL.
2. CUT OUT HOLE FOR FLEXIBLE PIPE IN CAGE WALL.
3. IF CAGE IS BUILT WITH NO BOTTOM, CUT OUT LOWER HORIZONTAL WIRE BETWEEN VERTICAL WIRES TO ALLOW CAGE TO SETTLE INTO STREAMBED.
4. REMOVE DAM AS NEEDED TO PLACE FLEXIBLE PIPE. REPLACE DAM AFTER LEVELER IS INSTALLED.
5. STAKE SINGLE-WALL HDPE PIPE EVERY 6 FT. TO PREVENT IT FROM FLOATING OR BEAVERS FROM MOVING IT. USE TWO T-POSTS AND WIRE BETWEEN THEM AND OVER THE TOP OF THE PIPE TO SECURE THE PIPE.
6. DRILL 3/8" HOLE IN CULVERT FOR REBAR TO ALLOW FOR FRICTION FIT. IF READY ROD IS USED, PLACE WASHERS NEXT TO PIPE AND SECURE WITH DOUBLE NUTS.
7. ONE (1) 16' SECTION OF FENCING WILL CONSTRUCT A CAGE WALL APPROXIMATELY 5' IN DIAMETER. AN ADDITIONAL SECTION IS NEEDED TO CONSTRUCT THE TOP AND BOTTOM OF EACH CAGE.
8. PIPE DIAMETER SHOULD BE SIZED TO PASS THE STREAM BASE FLOW.
9. FINAL LAYOUT OF THE PIPE SHOULD ALLOW FOR A SHALLOW GRADIENT TO FACILITATE FISH PASSAGE.
UPSTREAM WATER LEVEL AFTER LEVELER.
UPSTREAM WATER LEVEL BEFORE LEVELER.
2 GA. 6"X6" GALVANIZED CONCRETE REINFORCING MESH OR 6"X8" CATTLE FENCING. MINIMUM 5' DIAMETER. MINIMUM 4' HEIGHT.
3 REBAR RETAINING PIN. MAY SUBSTITUTE 5/16" READY ROD WITH WASHERS AND NUTS.
BEAVER DAM.
10' MINIMUM
20' MINIMUM
6 – 15 INCH SINGLE WALL FLEXIBLE HDPE PIPE (ADS OR SIMILAR). DRILL 1/4" HOLES IN TOP OF PIPE TO RELEASE AIR. STAKE PIPE EVERY 6', OR AS NEEDED, TO PREVENT MOVEMENT.
10" MIN.
FLEXIBLE LEVELER
SIDE VIEW – NTS
FLEXIBLE LEVELER
SNOHOMISH COUNTY PUBLIC WORKS
ADAPTED FROM SKIP LISLE (2001)
DRAWN BY: D. LUCAS
DATE: 11-14-01, REVISED 9-1-02
CONTACT: JAKE JACOBSON 425-388-3464 X6428

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