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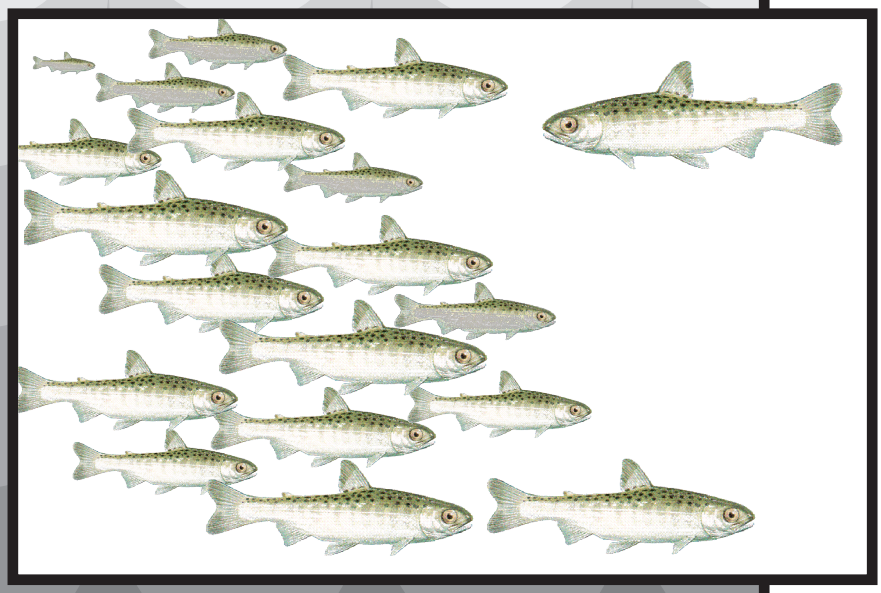
Evaluation of Juvenile Salmon Production in 2013 from the Cedar River and Bear Creek



by Kelly Kiyohara

Washington Department of
FISH AND WILDLIFE
Fish Program
Science Division
Wild Salmon Production/Evaluation

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Evaluation of Juvenile Salmon Production in 2013 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 Washington Department of Fish and Wildlife (WDFW) personnel. Escapement data were collected and estimates developed by individuals from several agencies: Aaron Bosworth, Bethany Craig, Dan Estell, David Baisch, April Bosley, Dave Smith and Kenny Shapiro from WDFW; Jesse Nitz from the Muckleshoot Tribe; Karl Burton, Dwyane Paige, and David Chapin from SPU; and Hans Berge, Dan Lantz, Chris Gregersen, and Jim Lissa from King County DNRP. WDFW scientific technicians Paul Lorenz, Dan Estell, and Ben Nelson worked long hours in order to operate juvenile traps, and identify, count, and mark, juvenile salmon. WDFW biologist Pete Topping provided valuable experience and logistical support for the juvenile trapping operation. The WDFW Hatcheries Program successfully collected adult sockeye brood stock and incubated eggs, releasing over 18.8 million sockeye fry into the Cedar River. Project management was provided by Paul Faulds and Michele Koehler from SPU and Hans Berge from DNRP.

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 inclined-plane trap.

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

The City of Renton Parks Department and the Washington State Department of Transportation 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 changes in flow due to dam operation.

Bear Creek

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

King County DNRP provided continuous flow monitoring.

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Introduction

This report describes the emigration of five salmonid species 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; Bear Creek flows into the Sammamish River, which flows into the north end of Lake Washington (Figure 1). In each watershed, the abundance of juvenile migrants is the measure of freshwater production upstream from the trapping location.

In 1992, the Washington Department of Fish and Wildlife (WDFW) initiated an evaluation of sockeye fry migrants in the Cedar River to investigate the causes of low adult sockeye returns. In 1999, the Cedar River juvenile monitoring study was expanded in scope in order to include juvenile migrant Chinook salmon. This new scope extended the trapping season to a six month period and, as a consequence, also allowed estimation of coho production, and assessment of steelhead and cutthroat trout movement.

In 1997, WDFW initiated an evaluation of sockeye fry migrants in the Sammamish watershed. In 1997 and 1998, a juvenile trap was operated in the Sammamish River during the downstream sockeye migration. In 1999, this monitoring study was moved to Bear Creek in order to simultaneously evaluate Chinook and sockeye production. Since 1999, the Bear Creek juvenile monitoring study has also provided production estimates to be derived for coho, and described ancillary data on movement patterns of steelhead and cutthroat trout.

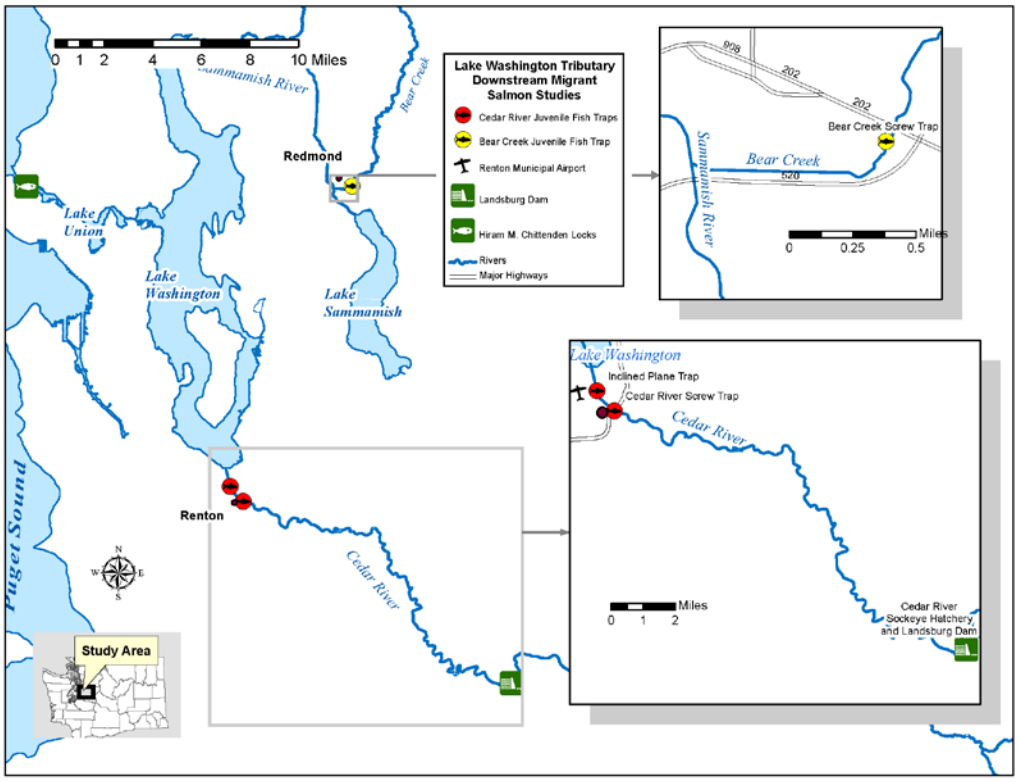

Figure 1. Map of Lake Washington trap sites used to monitor abundance of juvenile migrant salmonids in the Cedar River and Bear Creek, near Renton and Redmond, respectively.

The primary study goal of this program in 2013 was to estimate the number of juvenile sockeye fry, natural-origin Chinook and coho migrating from the Cedar River and Bear Creek into Lake Washington. This estimate was used to calculate survival of the 2012 brood from egg deposition to lake/river entry and to describe the migration timing of each species. Cutthroat and steelhead movement is assessed as catch and data are available. Biological data representing each population is also summarized.

Methods

Fish Collection

Trapping Gear and Operation

Cedar River

Two traps were operated in the lower Cedar River during the late winter/spring out migration period. A small floating inclined-plane trap was operated late winter through spring to trap sockeye and Chinook fry. This trap was designed to minimize predation in the trap by reducing capture of yearling migrants. A floating rotary screw trap was operated early spring through summer to assess migration of larger sub yearling Chinook as well as coho, steelhead/rainbow, 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 trap-related mortality.

The inclined-plane trap consists of one or two low-angle inclined-plane screen (scoop) traps (3-ft wide by 2-ft deep by 9-ft long) suspended from a 30x13 ft steel pontoon barge. Fish are separated from the water with a perforated aluminum plate (33 - 1/8 in. holes per in^2). The inclined-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 22 years that the Cedar River juvenile monitoring study has been conducted, 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 at the inclined-plane trap location to nearly zero. In response, the inclined-plane trap location was moved upstream in 1999 to river mile 0.8 in order to operate under suitable current velocities.

In 2013, the inclined-plane trap was anchored at RM 0.8, just downstream of the South Boeing Bridge (Figure 1). This trap was positioned off the east bank and repositioned within eight feet of the shoreline in response to changing flows. Two scoop traps were fished in parallel throughout the season except on 47 nights when only one trap was operated due to high flows, debris loads or excess catches of either hatchery or naturally produced sockeye.

The inclined-plane trap began operating on the night of January 24 was operated 91 nights between January 24 and May 17. During each night of operation, trapping began before dusk and continued past dawn. Trapping was also conducted during seven day-light periods between the beginning of February through the middle of April. Captured fish were removed from the trap, identified by species, and counted each hour. Fork lengths were randomly sampled on a weekly basis from all salmonid species, except for sockeye.

The Cedar River Sockeye Hatchery released hatchery reared sockeye fry into the Cedar River above the trap on fifteen nights throughout the season; seven fry releases occurred at R.M. 13.5 and eight releases at R.M. 21.8. The trap was operating during all but two of the hatchery releases that occurred above the trap, April 3 and April 30, due to lack of staffing. Survival of hatchery fry was estimated for releases that occurred during trap operations using the nightly timing approach.

In 2013, the screw trap was operated at R.M 1.6, just under the I-405 Bridge (Figure 1), on 82 nights between the evening of April 17 and July 17. There were periods when the trap did not fish due to high debris loads or day periods when trapping was intentionally halted due to public safety concerns or high flows and heavy debris. Catches were enumerated at dusk and in the early morning in order to discern diel movements. Fork length was measured from a weekly random sample of all Chinook, coho, steelhead/rainbow, and cutthroat smolts.

Bear Creek

A rotary screw trap was operated 100 yards downstream of the Redmond Way Bridge, the entire season, from January 28 to July 10, 2013. The screw trap is identical to that employed in the Cedar River and was positioned in the middle of the channel approximately 100 yards downstream of Redmond Way, below the railroad trestle (**Error! Reference source not found.**). Catches were identified to species and enumerated at dusk and in the early morning. Fork lengths were randomly sampled on a weekly basis from all Chinook, coho, and cutthroat smolts.

PIT Tagging

During screw trap operation at both sites, a portion of natural-origin Chinook migrants were tagged with Passively Integrated Transponder (PIT) tags. Captured steelhead were tagged as well. Tagging occurred two to three times a week, depending on catches, between May 1 and July 17, 2013. Fish were often held from the previous day to be tagged to increase the total number of fish tagged per day. Fish were held in partially-perforated buckets suspended in the river off the stern of the trap or in the live box. Chinook longer than 65-mm that displayed good physical health were considered for tagging. Fork lengths were measured for all PIT tagged fish. Protocols for tagging follow those outlined for the Columbia River basin by the Columbia Basin Fish and Wildlife Authority and the PIT Tag Steering Committee (1999).

Upon exiting the Lake Washington watershed through the Hiram Chittenden Locks facility, tagged fish could be detected by a PIT tag antenna if they used one of four smolt flumes or the adult fish ladder. Median migration date was the median date of all detected fish at the smolt flumes at the Hiram Chittenden Locks. Average travel times were calculated using tag date and subsequent detection date at the smolt flumes at the Hiram Chittenden Locks.

Trap Efficiencies

Cedar River

Inclined-Plane Trap

Trap efficiencies of the Cedar River inclined-plane trap were estimated from recaptures of marked natural-origin sockeye fry released above the trap. Fish captured in the early hours of the night were used for efficiency trials. All fry used for efficiency trials 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. Deceased or compromised fish were not included in releases. Fish were transported in buckets with battery operated aerators if needed. At the release location, a swinging bucket on a rope distributed marked fry across the middle of the channel. Catches were examined for marked fish and recaptures were noted during each trap check. Sockeye fry were used as surrogates for Chinook fry trap efficiencies due to low numbers of Chinook that precluded us from releasing large groups of Chinook.

Screw Trap

Trap efficiencies of the Cedar River screw trap were determined for Chinook, coho, and cutthroat from recaptures of marked fish released above the trap. Trap efficiency trials were conducted for 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 or more frequently when there was a significant change in river discharge. Beginning May 1, Chinook parr larger than 65-mm FL were tagged with Passive Integrated Transponder tags (PIT tags) while smaller Chinook continued to be fin clipped. Similar to fin marks, PIT tags enabled stratified releases 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.

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 approximately 800-yards upstream of the trap (Riviera release location). Efficiency trial releases were conducted every night or every other night, with frequency driven by the availability of each species in the days catch. Catches were examined for marks or tags and recaptures were noted during each trap check.

Bear Creek

Similarly to the Cedar River inclined plane trap, sockeye efficiencies for the Bear Creek screw trap were estimated from recaptures of marked sockeye fry released above the trap, approximately 100 yards upstream of the trap at the Redmond Way Bridge. Fry releases occurred when adequate numbers of fish were available. Fry captured the previous 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 and recaptures were noted during each trap check. When Chinook fry were not abundant enough to form efficiency trial groups, sockeye fry were assumed adequate surrogates for estimating trap efficiencies.

Trap efficiencies of Chinook parr, coho, and cutthroat in Bear Creek screw trap were estimated for using the same approach described for similar species at the Cedar River screw trap. Efficiency trial releases were conducted every night or every other night, with frequency driven by the availability of each species in the day's catch.

Analysis

The abundance of juvenile migrant salmonids was estimated using a mark-recapture approach and a single trap design (Volkhardt et al. 2007). The analysis was stratified by time in order to account for heterogeneity in capture rates throughout the season. The general approach was to estimate (1) missed catch, (2) efficiency strata, (3) abundance for each strata, (4) extrapolated migration prior to and post trapping, and (5) total production.

Missed Catch

Total catch ($\hat{u}_i$) during period *i* was the actual catch (*n*) summed with estimated missed catch ($\hat{n}$) during trap outages. Missed catch was estimated using three different approaches depending on what type of trap outage occurred: 1) entire night periods when trap operations were suspended, 2) partial day or night periods when trap operations were suspended, and 3) entire day periods when trap operations were suspended. Three approaches were used because salmonid catch rates differ between the day and night time hours.

Missed Catch for Entire Night Periods

When the trap operations were suspended for entire night periods, missed catch was estimated using a straight-line interpolation between catches on adjacent nights. This approach assumes that the fishing period during the adjacent nights was the same as the outage period. When the outage occurred on a single night, variance of the estimated catch was the variances of the mean catch on adjacent nights (Equation 1). When the outage occurred on multiple consecutive nights, then one or both adjacent night catches were estimates and Equation 2 was used.

Equation 1

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

Equation 2

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

where:

k = number of sample nights used in the interpolation,

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

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

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

When 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 3

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

Missed Catch for Partial Day and Night Periods

When the inclined-plane trap was operated intermittently through the night or the screw trap operated intermittently, missed catch during the un-fished interval ($\hat{n}_i$) was estimated by:

$$\hat{n}_i = T_i * \overline{R}$$ Equation 4

where:

T_i = Hours during non-fishing period *i*

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

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

$$Var(\hat{n}_i) = T_i^2 * Var(\overline{R})$$ Equation 5

Variance of the mean catch rate ($\overline{R}$) for *k* adjacent fishing periods was:

$$Var(\overline{R}) = \frac{\sum_{i=1}^{i=k} (R_i - \overline{R})^2}{k(k-1)}$$ Equation 6

Missed Catch for Entire Day Periods

Missed day-time catches in the inclined-plane trap were estimated by multiplying the previous night catch by the proportion of the 24-hour catch caught during the day. This proportion (F_d) was estimated as:

$$\hat{F}_d = \frac{T_d}{\overline{Q}^{-1} T_n + T_d}$$ Equation 7

Variance in the day-to-night catch ratio was:

$$Var(\hat{F}_d) = \frac{Var(\overline{Q})T_n{}^2 T_d{}^2}{\overline{Q}^4\left(\frac{1}{\overline{Q}}T_n + T_d\right)^4}$$ Equation 8

where:

T_n = hours of night during 24 hour period,

T_d = hours of day during 24 hour period, and

$\overline{Q_d}$ = bi-weekly day-to-night catch ratio.

Efficiency Strata

Stratification of the capture and recapture data was necessary to accommodate for changes in trap efficiency over the season. These changes result from a number of factors including river flows, turbidity, and fish sizes. However, when using a mark-recapture approach to estimate abundance, precision of the estimate increases with the number of recaptures. A manufactured drawback of stratification can be a large variance associated with the estimate. Therefore, a *G*-test was used to determine whether to pool or hold separate adjacent efficiency trials (Sokal and Rohlf 1981).

Of the marked fish (*M*) released in each efficiency trial, a portion are recaptured (*m*) and a portion are not seen (*M*-*m*). If the seen:unseen [*m*:(*M*-*m*)] ratio differs between trials, the trial periods were considered as separate strata. However, if the ratio did not differ between trials, the two trials were pooled into a single stratum. A *G*-test determined whether adjacent efficiency trials were statistically different ($\alpha = 0.05$). Trials that did not differ were pooled and the pooled group compared to the next adjacent efficiency trial. Trials that did differ were held separately. Pooling of time-adjacent efficiency trials continued iteratively until the seen:unseen ratio differed between time-adjacent trials. Once a significant difference was identified, the pooled trials were assigned to one strata and the significantly different trial indicated the beginning of the next strata.

Abundance for Each Strata

The abundance of juvenile migrants for a given strata *h* was calculated from maiden catch (actual and missed, $\hat{u}_h$), marked fish released in that strata (M_h), and marked fish recaptured in that strata (m_h). Abundance was estimated using a Bailey estimator appropriate for single trap designs (Carlson et al. 1998, Volkhardt et al 2007):

Equation 9

$$\hat{U}_h = \frac{\hat{u}_h(M_h + 1)}{m_h + 1}$$

Variance associated with the Bailey estimator was modified to account for variance of the estimated catch during trap outages (derivation in Appendix A):

Equation 10

$$V(\hat{U}_h) = V(\hat{u}_h)\left(\frac{(M_h+1)(M_h m_h + 3M_h + 2)}{(m_h+1)^2(m_i+2)}\right) + \left(\frac{(M_h+1)(M_h - m_h)\hat{u}_h(\hat{u}_h + m_h + 1)}{(m_h+1)^2(m_h+2)}\right)$$

Maiden catch ($\hat{u}_h$) was the sum of all actual and estimated catch during strata *h*. Variance of the catch [$V(\hat{u}_h)$] was the sum of all estimated catch variances during strata *h*.

Extrapolate Migration Prior to and Post Trapping

Modality of the trap catches suggested that migration outside the period of trap operation was minimal. Pre- and post-trapping migrations were estimated using linear extrapolation.

Equation 11

$$\hat{N}_e = \frac{\sum_{d=1}^{d=k} \hat{N}_d}{k} * \frac{t}{2}$$

Variance of the extrapolation was estimated as:

Equation 12

$$V(\hat{N}_e) = \frac{\sum_{d=1}^{d=k} (\hat{N}_d - \overline{N})^2}{k(k-1)} * \left(\frac{t}{2}\right)^2$$

where:

$\hat{N}_d$ = Daily migration estimates,

k = Number of daily migration estimates used in calculation, and

t = Number of days between assumed start/end of migration and the first/last day of trapping.

Pre- and post-season migration was based on the first and last five days of measured migration. The assumed migration for sockeye was January 1 to June 30 on the Cedar River and January 1 to April 30 on Bear Creek. The assumed migration for Chinook in both watersheds was January 1 to July 13. Pre- and post-season migration was not estimated for coho or cutthroat.

Total Production

Total production was the sum of the stratified abundance estimates for all *k* strata and the extrapolated migration estimates:

Equation 13

$$\hat{N} = \hat{N}_{before} + \sum_{h=1}^{h=k} \hat{U}_h + \hat{N}_{after}$$

Total variance was the sum of stratified abundance variances and extrapolated migration variances. Confidence intervals and coefficient of variation associated with abundances were calculated from the variance.

Hatchery Catch and Survival

Hatchery catch and survival was estimated for fifteen nights when releases occurred above the trap. Hatchery fish were released from the Cedar River Sockeye Hatchery at R.M. 21.8 on eight occasions, and from the Trestle site (R.M. 13.5) on seven occasions. Due to the inability to visually distinguish hatchery and natural-origin sockeye, the portion of each in the catch is unknown on hatchery release nights. Therefore, on nights of releases, natural-origin nightly migration timing was assumed to be similar to surrounding nights (i.e. hourly catch proportion), and a nightly timing method was applied to estimate natural-origin catch on hatchery release nights. Hatchery catch was the actual catch minus the expected hourly catch. Remaining catch in excess of the expected catch was assumed to be hatchery sockeye. Total hatchery migration was estimated by expanding estimated hatchery catch by the measured nighttime efficiency. If an efficiency trial was not conducted on a hatchery release night, then the appropriate strata efficiency was applied. Survival of releases above the trap was calculated by dividing estimated hatchery abundance at the trap by total number of sockeye released above the trap.

Egg-to-Migrant Survival

Egg-to-migrant survival for sockeye and Chinook was the survival between egg deposition and migration of juveniles into Lake Washington. Survival was estimated by dividing the 2013 abundance of natural-origin juvenile migrants by the 2012 potential egg deposition (PED) for each species and watershed. PED was the product of the number of female spawners and their fecundity. Sockeye spawner abundances in the Cedar River and Bear Creek were Area-Under-the-Curve estimates that were calculated and agreed upon in a multi-agency effort. This estimate assumed an even sex ratio for sockeye. Cedar River sockeye fecundity was the average number of eggs per female during 2012 sockeye brood stock collection for the Cedar River Sockeye Hatchery (Shoblom 2014). Fecundity of Bear Creek sockeye was assumed to be the same as the fecundity of Cedar River sockeye.

The number of female Chinook was based on annual redd counts conducted by state and local agencies and assumed to represent one female per redd (Burton et al. 2013). Chinook fecundity was based on a long-term average fecundity at the Soos Creek Hatchery (M. Wilson, Washington Department of Fish and Wildlife, personal communication). Further partitioning of Chinook survival is calculated to estimate the survival and productivity of the fry and parr components.

Cedar River

Sockeye

Production Estimate

Total catch (actual and estimated missed) in the inclined-plane trap was 1,048,315 sockeye fry. A total of 690,461 natural-origin sockeye fry were caught in the inclined-plane trap during trap operations. We estimated a missed catch of an additional 309,088 sockeye fry for all night trap outages between January 24 and May 16, 2013. Seven day intervals were trapped to evaluate day-time migration: February 8, 22, March 1, 6, 20, 27, and April 1. Flows on these days ranged from 851 cfs to 2,260 cfs at the Cedar River USGS gage (#12119000) and were representative of flows throughout the season. Day-to-night catch ratios ranged from 2.58% to 78.67%. We estimated an additional missed catch of 49,415 fry for all day-time trap outages. Missed day-time catch represented 4.7% of the season's total catch.

Table 1. Abundance of natural-origin and hatchery sockeye fry entering Lake Washington from the Cedar River in 2013. Table includes abundance of fry migrants, 95% confidence intervals (C.I.), and coefficients of variation (*CV*). Hatchery sockeye totals are adjusted to reflect estimated survival of releases above the trap on nights the trap operated.

Component	Period	Dates	Fry Abundance	95% C.I.		*CV*
				Low	High	
Natural Origin	Pre Trapping	January 1 - 23	1,093,110	706,116	1,480,103	18.06%
	During Trapping	January 24-May 16	53,633,075	52,766,504	54,499,646	3.33%
	Post Trapping	May 17- June 30	1,092,422	980,932	1,203,912	5.21%
		Subtotal	**55,818,607**	**52,299,452**	**59,337,761**	**0.42%**
Hatchery	Above Trap		4,587,159	3,152,890	6,021,427	15.95%
	Below Trap		7,862,441			
		Subtotal	**12,449,600**			
		Total	**68,268,206**	**64,467,999**	**72,068,414**	**2.84%**

A total of 55 efficiency trials were conducted in 2013. Efficiency data were aggregated into fourteen strata. Capture rates for these strata ranged from 0.79% to 3.74% (Appendix B).

An estimated 55.8 million natural-origin sockeye fry entered Lake Washington from the Cedar River in 2013 (Table 1, Appendix A 1). This estimate includes pre- and post-season estimates of 1.1 million fry each, as well as the estimated abundance of fry during the trapping period of 53.6 million fry. Both pre- and post-season tails each represent less than 2% of the total natural production. Coefficient of variation (*CV*) associated with the natural-origin migration was 0.42%. Migration began strong and continued well into April before slowing for the remainder of the season (Figure 2). Median migration date for natural-origin sockeye was March 7 (Table 2).

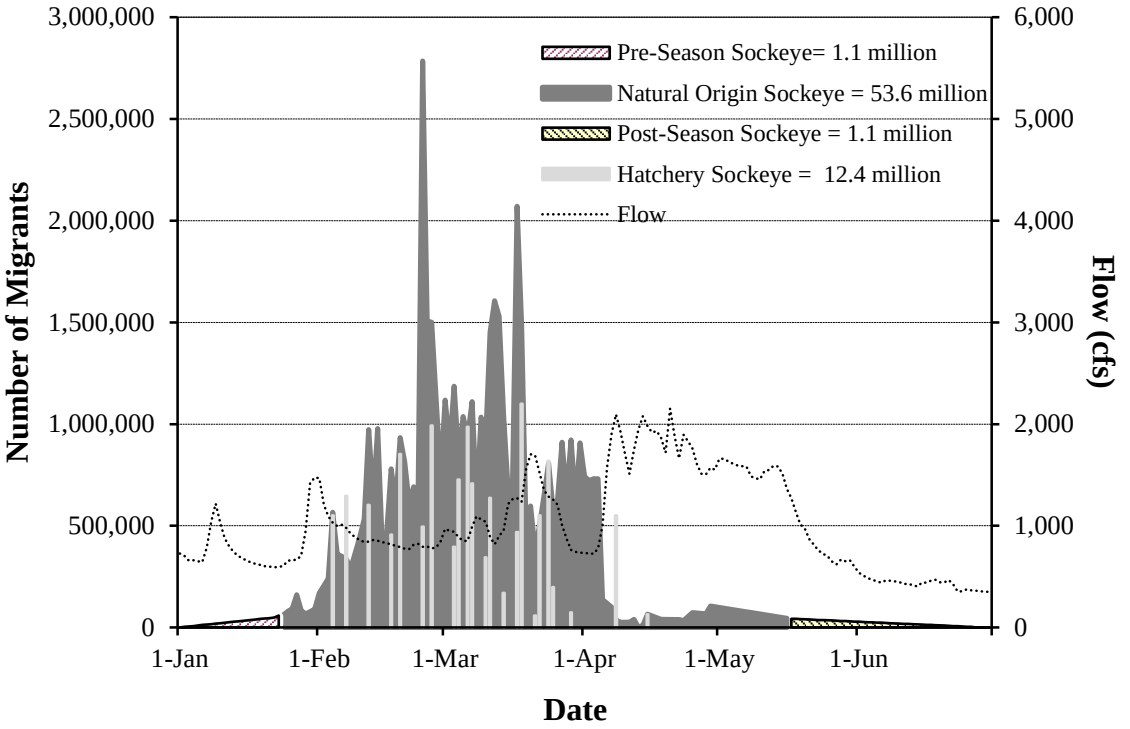

Figure 2. Estimated daily migration of natural-origin and hatchery sockeye fry migrating from the Cedar River into Lake Washington between January 24 and May 16, 2013. Pre- and post-trapping migration estimates are included. Graph includes daily average flows during this period (USGS Renton gage Station #12119000).

Table 2. Median migration dates of natural-origin, hatchery, and total (combined) sockeye fry from the Cedar River for brood years 1991 to 2012. Total thermal units for February were measured in degrees Celsius at the USGS Renton gage, Station #12119000. Temperature was not available for the 1991 brood year.

Brood Year	Trap Year	February	Median Migration Date			Difference
i	i+1	Thermal Units	Wild	Hatchery	Combined	(days) W-H
1991	1992		03/18	02/28	03/12	19
1992	1993	156	03/27	03/07	03/25	20
1993	1994	162	03/29	03/21	03/26	8
1994	1995	170	04/05	03/17	03/29	19
1995	1996	153	04/07	02/26	02/28	41
1996	1997	147	04/07	02/20	03/16	46
1997	1998	206	03/11	02/23	03/06	16
1998	1999	187	03/30	03/03	03/15	27
1999	2000	161	03/27	02/23	03/20	32
2000	2001	158	03/10	02/23	03/08	15
2001	2002	186	03/25	03/04	03/19	21
2002	2003	185	03/08	02/24	03/03	12
2003	2004	186	03/21	02/23	03/15	26
2004	2005	193	03/02	02/01	02/28	29
2005	2006	184	03/20	02/23	03/14	25
2006	2007	193	03/23	02/16	03/12	35
2007	2008	170	03/16	03/06	03/15	10
2008	2009	187	03/19	03/06	03/13	13
2009	2010	219	03/07	03/04	03/05	3
2010	2011	163	03/25	02/18	03/01	35
2011	2012	170	03/22	03/08	03/18	14
2012	2013	184	03/07	03/06	03/07	1
	Average		03/20	02/27	03/12	21

Hatchery Abundance and Survival

Over the season a total of 18.8 million hatchery-produced sockeye were released into the Cedar River. On 10 separate nights, a total of 7.86 million sockeye were released at R.M. 0.1. Releases at this location are assumed to have 100% survival from point of release to lake entry. An additional 5.41 million were released at R.M. 13.5 on 7 separate nights (Table 4). A total of 5.23 million fry were released at the Cedar River Sockeye Hatchery (R.M. 21.8) on 8 different nights. Of those 15 nights hatchery sockeye were released upstream of the trap, 13 releases occurred on nights when the inclined-plane trap was operating and hatchery sockeye abundance and survival were estimated. Abundance and survival were not estimated for the remaining two nights, April 3 (968,508 sockeye released at R.M. 13.5) and April 30 (39,160 sockeye released at R.M. 24), and are not included in any season totals below as an unknown portion of the release survived to lake entry. Hatchery abundance and survival was calculated using the nightly timing approach as it is the only approach that provided consistent reasonable estimates (greater than 0% and less than 100% survival). Accounting for in-river loss of hatchery fish released above the trap on 13 of the releases that were monitored, hatchery sockeye fry abundance for all upstream releases was estimated at 4.6 million fry. Total in-river survival of hatchery sockeye planted upstream of the trap is estimated to be 46.3% with survival ranging from 10.3% to 90.6% for individual releases (Table 4). Accounting for in-river loss, total hatchery sockeye entering Lake Washington is estimated to be 12.4 million fish.

Table 3. Date, location, and total number of hatchery sockeye fry released into the Cedar River in 2013 (Shoblom 2013).

Release Date	Lower R.M. 0.1	Middle R.M. 13.5	Upper R.M. 21.8
02/04/2013			783,862
02/07/2013	647,116		
02/12/2013		820,162	
02/17/2013			807,907
02/19/2013	852,724		
02/24/2013		786,475	
02/26/2013	992,774		
03/03/2013			677,262
03/04/2013	726,828		
03/06/2013	986,010		
03/07/2013			781,081
03/10/2013		594,235	
03/11/2013	637,171		
03/14/2013			1,238,341
03/17/2013		986,698	
03/18/2013	1,099,808		
03/21/2013			457,553
03/22/2013	551,166		
03/24/2013	818,555		
03/25/2013		977,101	
03/29/2013			715,695
04/03/2013		968,508	
04/08/2013	550,289		
04/15/2013		280,137	
04/30/2013			39,160
Grand Total	7,862,441	5,413,316	5,500,861

Table 4. Estimated hatchery sockeye abundance, variance, and survival for releases conducted above the Cedar River inclined-plane trap, 2013. Estimates were developed using the nightly timing approach. Flow data was measured at the USGS Renton gage, Station #12119000.

Date Released	Daily Average Flow (cfs)	Sockeye Released	Release Location	Estimated Hatchery Sockeye		
				Abundance	Variance	Survival
4-Feb	1,028	783,862	Upper	551,472	4.14E+09	70.35%
12-Feb	845	820,162	Middle	602,767	4.88E+11	73.49%
17-Feb	819	807,907	Upper	456,053	3.73E+07	56.45%
24-Feb	792	786,475	Middle	495,830	3.75E+07	63.04%
3-Mar	942	677,262	Upper	396,356	6.51E+09	58.52%
7-Mar	988	781,081	Upper	707,970	1.65E+10	90.64%
10-Mar	1,040	594,235	Middle	344,087	4.53E+09	57.90%
14-Mar	956	1,238,341	Upper	169,390	2.00E+08	13.68%
17-Mar	1,271	986,698	Middle	468,300	1.21E+10	47.46%
21-Mar	1,695	457,553	Upper	58,909	8.93E+08	12.87%
25-Mar	1,258	977,101	Middle	198,290	1.58E+09	20.29%
29-Mar	762	715,695	Upper	73,821	7.44E+08	10.31%
15-Apr	1,982	280,137	Middle	63,915	1.98E+08	22.82%
	Season Total	**9,906,509**		**4,587,159**	**5.36E+11**	**46.30%**

Egg-to-Migrant Survival of Natural-Origin Fry

Egg-to-migrant survival of the 2012 brood Cedar River sockeye was estimated to be 36.4% (Table 5). Survival was based on 55.8 million natural-origin fry surviving from a potential 153 million eggs deposited by 43,573 females (A. Bosworth, Washington Department of Fish and Wildlife, personal communication). Average fecundity for the 2012 brood was 3,515 eggs per female sockeye (Shoblom 2014). This is the third highest egg-to-migrant survival observed since juvenile monitoring began in the Cedar River.

Table 5. 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 - 2012. Flow was measured at the USGS Renton gage, Station #12119000.

Brood Year	Spawners	Females (@50%)	Fecundity	Potential Egg Deposition	Fry Production	Survival Rate	Peak Incubation Flow (cfs)	Peak Incubation Flow Date
1991	76,592	38,296	3,282	125,687,226	9,800,000	7.80%	2,060	1/28/1992
1992	99,849	49,924	3,470	173,237,755	27,100,000	15.64%	1,570	1/26/1993
1993	74,677	37,338	3,094	115,524,700	18,100,000	15.67%	927	1/14/1994
1994	107,767	53,883	3,176	171,133,837	8,700,000	5.08%	2,730	12/27/1994
1995	21,443	10,721	3,466	37,160,483	730,000	1.96%	7,310	11/30/1995
1996	228,391	114,196	3,298	376,616,759	24,390,000	6.48%	2,830	1/2/1997
1997	102,581	51,291	3,292	168,848,655	25,350,000	15.01%	1,790	1/23/1998
1998	48,385	24,193	3,176	76,835,676	9,500,000	12.36%	2,720	1/1/1999
1999	21,755	10,877	3,591	39,060,930	8,058,909	20.63%	2,680	12/18/1999
2000	146,060	73,030	3,451	252,025,754	38,447,878	15.26%	627	1/5/2001
2001	117,225	58,613	3,568	209,129,787	31,673,029	15.15%	1,930	11/23/2001
2002	192,395	96,197	3,395	326,590,484	27,859,466	8.53%	1,410	2/4/2003
2003	109,164	54,582	3,412	186,233,926	38,686,899	20.77%	2,039	1/30/2004
2004	114,839	57,419	3,276	188,106,200	37,027,961	19.68%	1,900	1/18/2005
2005	49,846	24,923	3,065	76,388,804	10,861,369	14.22%	3,860	1/11/2006
2006	105,055	52,527	2,910	152,854,370	9,246,243	6.05%	5,411	11/9/2006
2007	45,066	22,533	3,450	77,738,114	25,072,141	32.25%	1,820	12/3/2007
2008	17,300	8,650	3,135	27,118,177	1,630,081	6.01%	9,390	1/8/2009
2009	12,501	6,250	3,540	22,125,910	12,519,260	56.58%	2,000	11/19/2009
2010	59,795	29,898	3,075	91,935,489	4,517,705	4.91%	5,960	1/18/2011
2011	23,655	11,827	3,318	39,243,121	14,763,509	37.62%	2,780	1/30/2012
2012	87,145	43,573	3,515	153,157,338	55,793,120	36.43%	1,513	12/7/2012

Chinook

Production Estimate

Production of natural-origin Chinook was estimated to be 893,877 ± 78,268 (±95% C.I.) sub-yearlings, based on operation of both the inclined-plane and screw traps. Between January 1 and April 29, 2013 874,658 ± 77,845 (±95% C.I.) natural-origin Chinook were estimated to have passed the inclined-plane trap (Figure 3, Appendix A 2). This includes an estimate for a pre-trapping period from January 1 to 21 of 55,367 fry and an estimate of 819,291 Chinook during the time the inclined plane trap was operating from January 24 to April 29. This estimate was based on a total catch of 16,572 and sockeye trap efficiencies ranging from 0.79% to 3.74%. Sockeye trap efficiencies have been assumed to be an adequate surrogate for Chinook trap

efficiencies due to low Chinook catches until recently. Between April 30 and July 17, 2013, 19,219 ± 8,053 (±95% C.I.) natural-origin Chinook were estimated to have passed the screw trap (Table 6, Figure 4, Appendix A 3). This estimate is based on a total catch of 1,144 natural-origin juvenile Chinook in the screw trap and trap efficiency of 5.7%. Migration was assumed completed and no post trapping was extrapolated as no Chinook were caught during the final week of trapping.

Migration timing was bi-modal. The small fry are defined as fish emigrating between January and mid-April and comprised 97% of all sub-yearlings. The larger parr are defined as fish emigrating between mid-April and July and comprised 3% of the total migration (Table 7).

Table 6. Abundance of natural-origin juvenile migrant Chinook in the Cedar River in 2013. Data are total catch, abundance, 95% confidence intervals (C.I), and coefficient of variation (*CV*).

Gear	Period	Total Catch	Abundance	95% C.I. Low	95% C.I. High	*CV*
Pre-Trapping	January 1 - 21		55,367	18,964	91,770	33.55%
Inclined-Plane Trap	January 24-April 29	16,573	819,291	750,482	888,100	4.29%
Total Fry		**16,573**	**874,658**	**796,812**	**952,503**	**4.54%**
Screw Trap	April 30- July 17	1,144	19,219	11,166	27,272	21.38%
	Season Total	**17,717**	**893,877**	**815,609**	**972,131**	**4.47%**

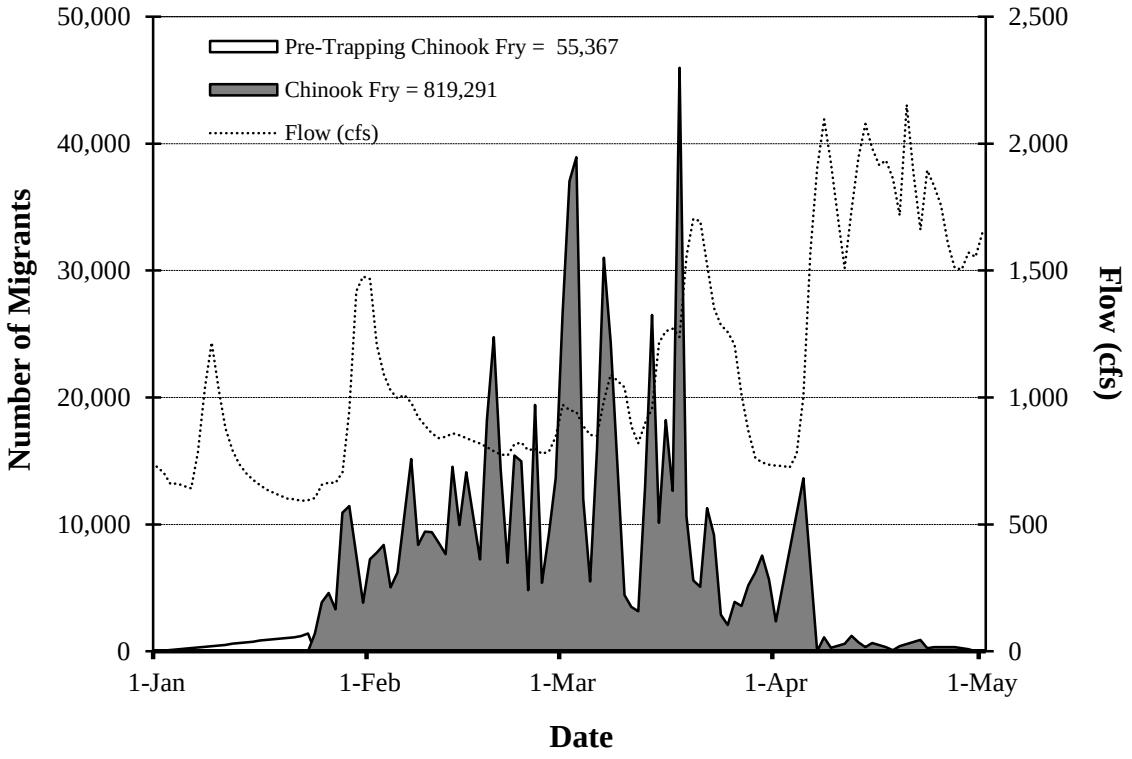

Figure 3. Estimated daily migration of Chinook fry from the Cedar River in 2013 based on inclined-plane trap estimates from January 1 to April 29. Graph includes mean daily flows during this time period (USGS Renton gage, Station #12119000) in 2013.

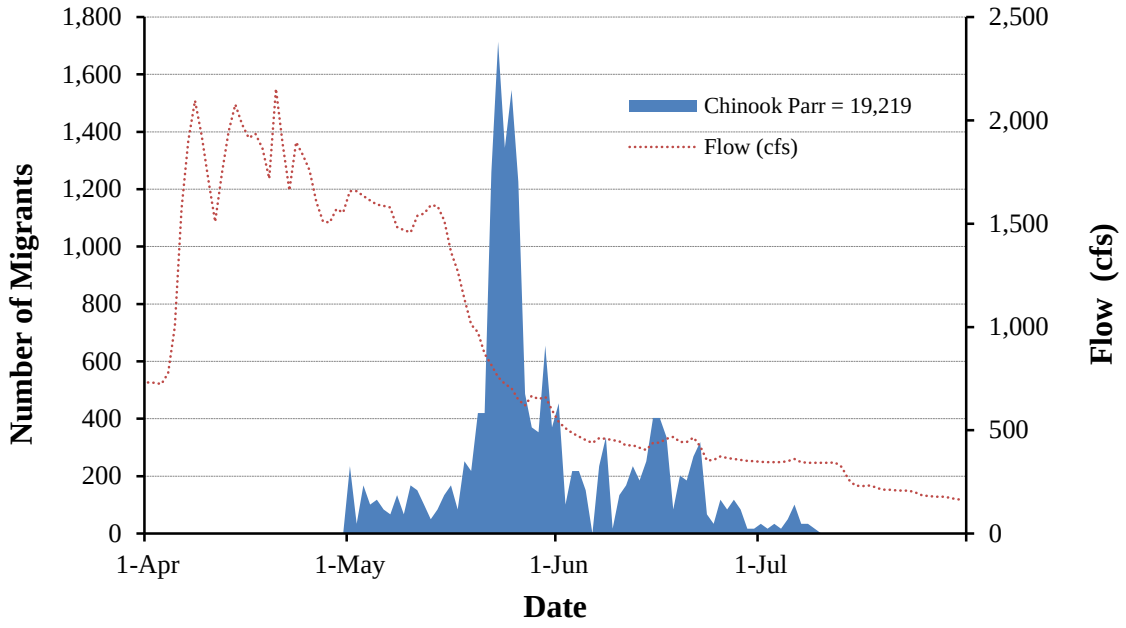

Figure 4. Estimated daily migration of Chinook parr from the Cedar River in 2013 based on screw trap estimates from April 30 to July 31. Graph includes mean daily flows during this time period (USGS Renton gage, Station #12119000) in 2013.

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2012 brood of Cedar River Chinook was estimated to be 45.9% (Table 6). Survival was based on 893,870 natural-origin sub-yearlings surviving from an estimated 1.95 million eggs deposited by 433 female spawners (Burton et al. 2013). Average fecundity for the 2012 brood was assumed to be 4,500 eggs per female.

Table 7. Abundance, productivity (juveniles 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. Egg-to-migrant survival was calculated from potential egg deposition (PED) for returning spawners. Data are Cedar River broods 1998 to 2012.

Brood	Trapping Dates		Juvenile Abundance			95%	Percent Abundance		Est.	Survival		
Year	Start	End	Fry	Parr	Total	CI (±)	Fry	Parr	Fem.	Fry	Parr	Total
1998	23-Jan	27-Jul	67,293	12,811	80,104	7,732	84%	16%	173	8.6%	1.6%	10.3%
1999	20-Jan	13-Jul	45,906	18,817	64,723	5,609	71%	29%	182	5.6%	2.3%	7.9%
2000	18-Jan	22-Jul	10,994	21,157	32,151	5,220	34%	66%	53	4.6%	8.9%	13.5%
2001	25-Jan	22-Jul	79,813	39,326	119,139	41,349	67%	33%	398	4.5%	2.2%	6.7%
2002	21-Jan	12-Jul	194,135	41,262	235,397	51,485	82%	18%	281	15.4%	3.3%	18.6%
2003	18-Jan	20-Jul	65,875	54,929	120,804	25,418	55%	45%	337	4.3%	3.6%	8.0%
2004	21-Jan	29-Jul	74,292	60,006	134,298	42,912	55%	45%	511	3.2%	2.6%	5.8%
2005	18-Jan	20-Jul	98,085	19,474	117,559	16,233	83%	17%	339	6.4%	1.3%	7.7%
2006	20-Jan	16-Jul	107,796	14,613	122,409	16,912	88%	12%	587	4.1%	0.6%	4.7%
2007	13-Jan	19-Jul	691,216	75,746-81,404	766,962-772,620	76,106	89.5-90.1%	9.9-10.5%	899	17.2%	1.9-2.0%	19.1-19.2%
2008	1-Feb	18-Jul	124,655	14,883	139,538	38,399	89%	11%	599	4.6%	0.6%	5.2%
2009	17-Jan	4-Jul	115,474	36,916	152,390	13,058	76%	24%	285	9.0%	2.9%	11.9%
2010	30-Jan	16-Jul	153,126	34,680	187,806	63,560	82%	18%	266	12.8%	2.9%	15.7%
2011	22-Jan	14-Jul	836,886	64,710	901,596	165,973	93%	7%	324	57.4%	4.4%	61.8%
2012	23-Jan	17-Jul	869,117	24,753	893,870	77,993	97%	3%	433	44.6%	1.3%	45.9%

Size

Weekly average lengths of sub yearling Chinook increased from 39.1-mm fork length (FL) in January to 98.2-mm FL by July (Figure 5). Chinook caught in the inclined-plane trap ranged from 34-mm FL to 112-mm FL and averaged 40.7-mm FL. Chinook caught in the screw trap increased in size from 40-mm FL to 111-mm FL and averaged 77.2-mm FL.

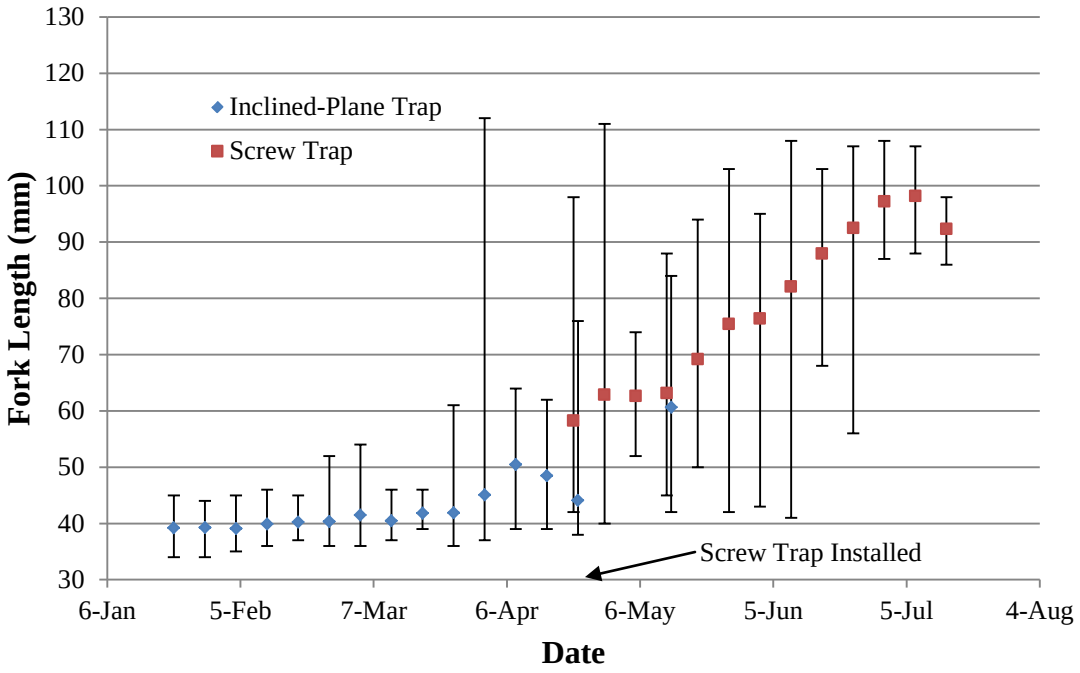

Figure 5. Fork lengths of natural-origin juvenile Chinook sampled from the Cedar River, 2013. Graph shows average, minimum, and maximum lengths by statistical week.

Coho

Production Estimate

Total catch (actual and missed) of all coho migrants captured in the screw trap was 4,623 coho smolts. This included 4,201 natural-origin coho caught in the screw trap between April 17 and July 17 and an estimated missed catch of 422 coho due to trap outages.

A total of 21 efficiency trials were conducted. Efficiency trials were aggregated into one stratum. Capture rate for the season was 3.97% (Appendix A 4). Total coho production was estimated to be 115,185 ± 24,497 (±95% C.I.) migrants for the period the trap was operating with a coefficient of variation of 10.85% (Table 9, Appendix A 4).

Table 8. Abundance of coho migrants from Cedar River in 2013. Table includes abundance of sub-yearling and yearling migrants, 95% confidence intervals (C.I.), and coefficient of variation (*CV*).

Period	Dates	Total Catch	Abundance	*CV*	95% C.I.	
					Low	High
Screw Trap	April 17 - July 17	4,623	115,185	10.85%	90,688	139,682

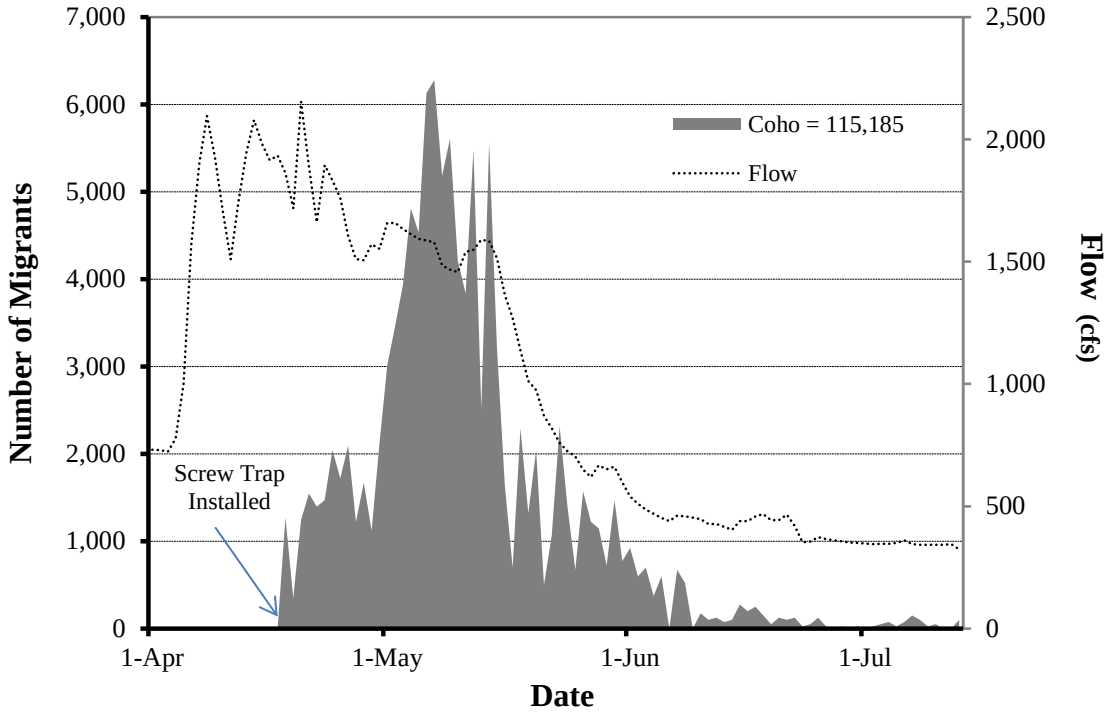

Figure 6. Daily coho migration and daily average flow (USGS Renton gage Station #12119000) at the Cedar River screw trap, 2013. Coho abundance includes both sub-yearling and yearling coho caught in the Cedar River screw trap.

Size

Average fork length of all measured coho migrants, both yearlings and sub-yearlings, was 101.4-mm FL; weekly averages ranged from 75.2-mm to 106.3-mm FL. Individual migrants ranged from 45-mm to 149-mm FL (Figure 7).

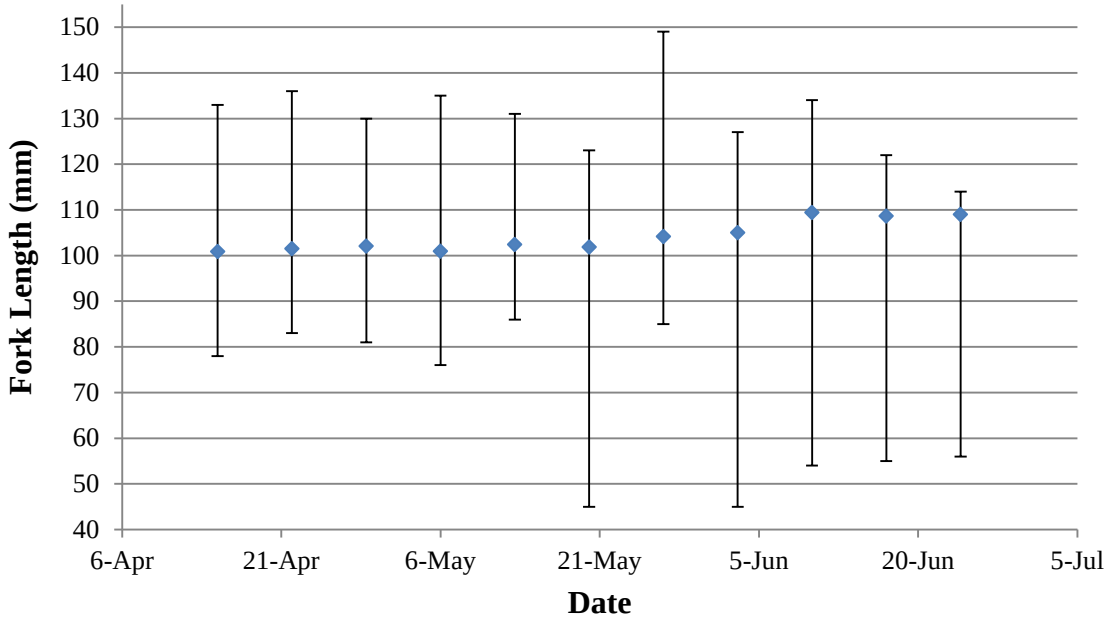

Figure 7. Fork lengths for coho migrants captured in the Cedar River screw trap in 2013. Data are mean, minimum, and maximum lengths.

Trout

Life history strategies used by trout in the Cedar River include anadromous, adfluvial, fluvial, and resident forms. For simplicity, catches and estimates reported herein are for trout that were visually identified as either *Oncorhynchus clarki* (cutthroat trout) or *Oncorhynchus mykiss* (steelhead/rainbow trout). Cutthroat-rainbow hybrids are included and indistinguishable in these numbers. Furthermore, it is difficult to determine whether juvenile *O. mykiss* have adopted the anadromous life form. The juvenile anadromous life history strategy, or "smolt," was assigned to *O. mykiss* that had a silver coloration upon capture. Those that did not display smolt-like characteristics were assigned as rainbow trout.

A total of 4 steelhead migrants and 91 cutthroat trout were captured in the screw trap. No rainbow trout were caught. Catches were too few to develop migration estimates. *O. mykiss* fork lengths ranged from 146-mm to 240-mm FL and averaged 191-mm FL. Cutthroat fork lengths ranged from 92-mm to 214-mm FL, and averaged 145.3-mm FL.

Incidental Catch

Incidental catches in the inclined-plane trap included 132 coho fry, 209 coho smolts, 7 chum fry, and 35 cutthroat trout. Other species caught included three-spine stickleback (*Gasterosteus aculeatus*), unspecified sculpin species (*Cottus* spp.), lamprey (*Lampetra* spp.), speckled dace (*Rhinichthys osculus)*, longfin smelt (*Spirinchus thaleichthys),* and large-scale sucker (*Catostomus macrocheilus*).

Other salmonids caught in the screw trap include 10 ad-marked hatchery Chinook parr, 4 sockeye smolt, 564 sockeye fry, and 3 trout fry. Other species caught included three-spine stickleback, unspecified sculpin species, large-scale suckers, peamouth (*Mylocheilus caurinus*), longnose dace (*Rhinichthys cataractae)*, largemouth bass *(Micropterus salmoides)* and lamprey.

Bear Creek

Sockeye

Production Estimate

Total catch (actual and estimated missed) in the Bear Creek screw trap was153, 254 sockeye fry during the trapping period from January 28 to July 10, This included an actual catch of 112,874 sockeye fry and an estimated missed catch of 40,380 sockeye fry during the 23 full days when the trap was intentionally not fished, and 5 night and 2 day periods when the trap was stopped due to heavy debris.

Twenty efficiency trials using sockeye fry were conducted during the season and aggregated into seven final strata, with capture rates ranging from 5.83% and 15.4% (Appendix B1). Catches were low and the first efficiency group was not released until February 21. Efficiency releases continued nearly twice or more weekly until April 4 when catches declined near the end of migration.

We estimated a total abundance of 1.55 million ± 173,985 (±95% C.I.) sockeye fry emigrating from Bear Creek in 2013 (Table 9, Figure 8). Due to low catch at the beginning of the season, there was no pre-trapping catch estimated.

Table 9. Abundance of sockeye fry migrants from Bear Creek in 2013. Table includes abundance of fry migrants, 95% confidence intervals (C.I.), and coefficient of variation (*CV*).

Period	Dates	Total Catch	Fry Abundance	*CV*	95% C.I.	
					Low	High
Screw Trap	Jan 28-July 10	153,254	1,553,602	5.7%	1,379,617	1,727,587

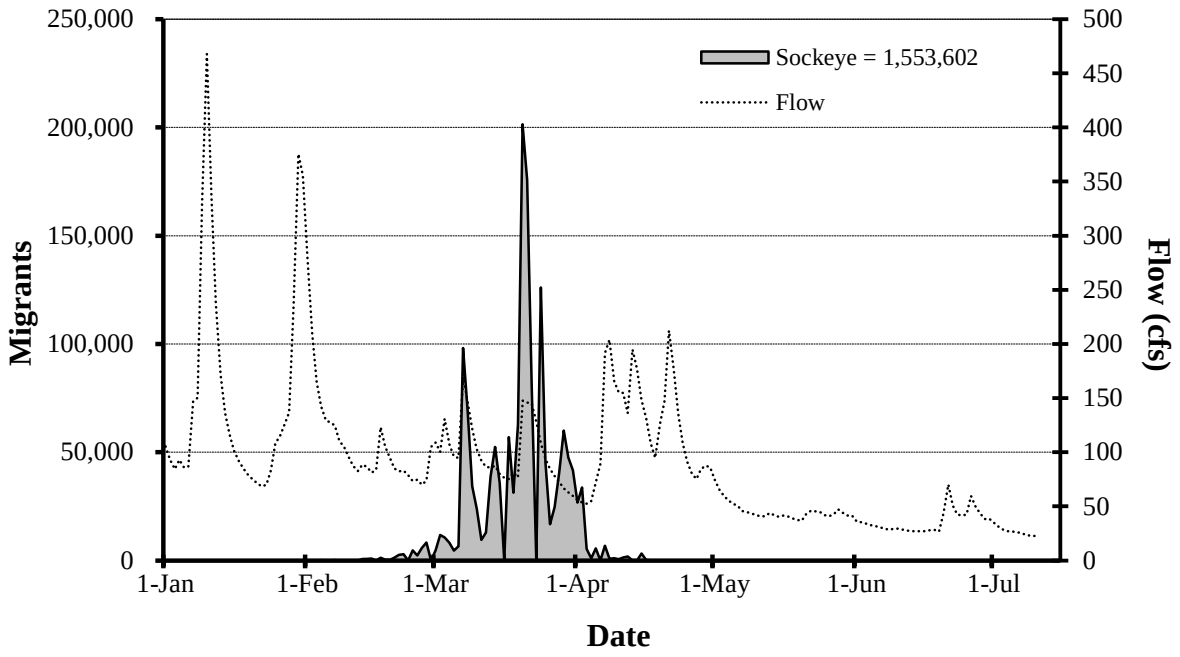

Figure 8. Estimated daily migration of sockeye fry from Bear Creek and daily average flow measured by the King County gage 02a at Union Hill Road in 2013 (http://green.kingcounty.gov/wlr/waterres/hydrology).

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2012 brood of Bear Creek sockeye was estimated to be 20.95% (Table 10). Survival was based on 1,553,602 fry migrants and a PED of 7,414,893 million eggs. PED was estimated based on 2,110 females in 2012 (A. Bosworth, Washington Department of Fish and Wildlife, personal communication) and an average fecundity of 3,515 eggs per female based on the data from the Cedar River Sockeye Hatchery from brood year 2012 (Shoblom 2014).

Table 10. Egg-to-migrant survival of Bear Creek sockeye by brood year. Potential egg deposition (PED) was based on fecundity of sockeye brood stock in the Cedar River.

Brood Year	Spawners	Females (@ 50%)	Fecundity	PED	Fry Abundance	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	1/23/2003
2003	1,765	883	3,412	3,011,090	177,801	5.9%	660	1/30/2004
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	1/31/2005
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	12/4/2007
2008	577	289	3,135	904,448	327,225	36.2%	546	1/8/2009
2009	1,568	784	3,540	2,775,360	129,903	4.7%	309	11/27/2009
2010	12,527	6,264	3,075	19,260,263	8,160,976	42.4%	888	12/13/2010
2011	911	455	3,318	1,509,690	266,899	17.7%	348	11/23/2011
2012	4,219	2,110	3,515	7,414,893	1,553,602	21.0%	467	1/10/2013

Chinook

Total catch (actual and estimated missed) in the Bear Creek screw trap was 6,022 Chinook during the trapping period of January 28 to July 10. This included actual catch of 5,175 Chinook and an estimated missed catch of 847 Chinook during 23 full days when the trap was intentionally not fished and 5 night and 2 day periods when the trap was stopped due to heavy debris.

Production Estimate

For the period between January 28 and April 21, sockeye trap efficiencies were used to estimate Chinook fry abundance because Chinook catches were too low to form efficiency trials. From April 21 forward, a total of 26 efficiency trials were conducted with Chinook sub-yearlings. Trials were aggregated into eight strata; capture rates of these strata ranged between 2.8% and 48.8%. Chinook migration during screw trap operation was estimated to be 44,599 ± 6,618 (±95% C.I.) (Table 11, Appendix B2).

Table 11. Abundance of natural-origin juvenile Chinook emigrating from Bear Creek in 2013. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), and coefficient of variation (*CV*).

Gear	Period	Total Catch	Abundance	95% C.I.		*CV*
				Low	High	
Screw Trap	January 28 - July 10	6,022	44,599	37,981	50,002	7.57%

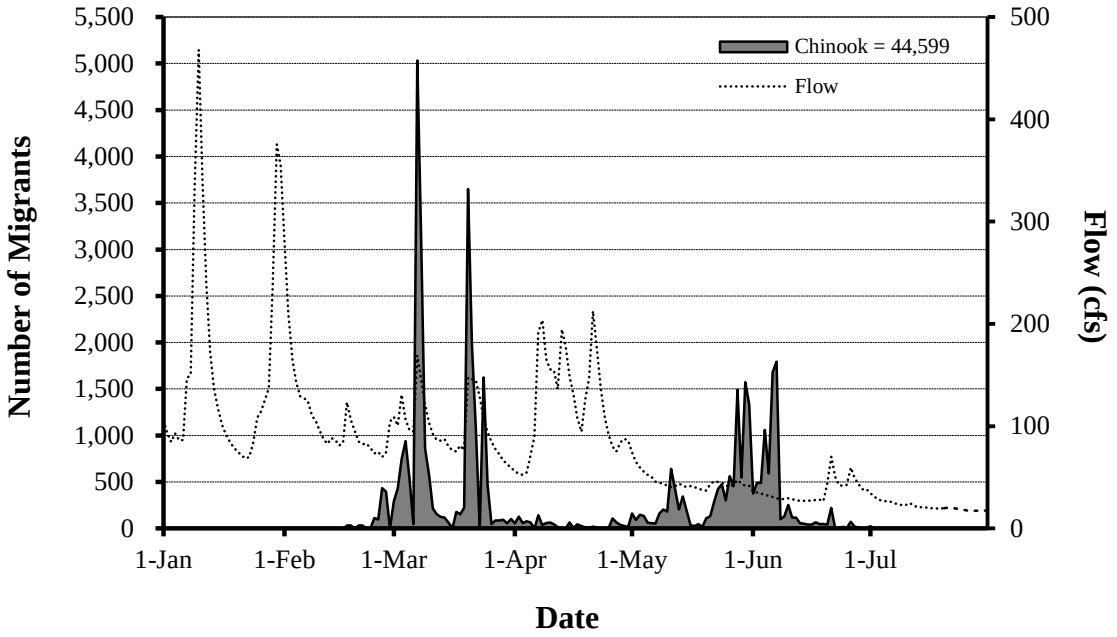

Figure 9. Daily migration of sub yearling Chinook and daily average flow from Bear Creek, 2013. Daily mean flows were measured at King County gage 02a at Union Hill Road in 2013 (http://green.kingcounty.gov/wlr/waterres/hydrology).

Migration timing of sub yearling Chinook was bimodal. Small fry migrants, defined by their emigration between February and April, comprised 55.6% of the total migration. Large parr migrants, defined by emigration between May and July, represented 44.4% of total production in Bear Creek during 2013.

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2012 brood of Bear Creek Chinook was estimated to be 6.7% (Table 12). Survival was based on 44,599 sub yearling migrants and a PED of 661,500 eggs. The PED was estimated based on 147 female spawners (A. Bosworth, Washington Department of Fish and Wildlife, personal communication) and an assumed fecundity of 4,500 eggs per female.

Table 12. Abundance, productivity (juveniles per female), and egg-to-migrant survival of natural-origin Chinook in Bear Creek. Fry are assumed to have migrated between February 1 and April 8. Parr are assumed to have migrated between April 9 and June 30. Data are 2000 to 2012 brood years.

Brood	Juvenile Abundance			% Abundance		Est.	PED	Juveniles/Female			Survival		
Year	Fry	Parr	Total	Fry	Parr	Females		Fry	Parr	Total	Fry	Parr	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%	89	400,500	4	143	147	0.3%	2.9%	3.2%
2008	14,243	50,959	65,202	21.8%	78.2%	132	594,000	108	386	494	2.4%	8.6%	11.0%
2009	1,530	7,655	9,185	16.7%	83.3%	48	216,000	32	159	191	0.7%	3.5%	4.3%
2010	901	16,862	17,763	5.1%	94.9%	60	270,000	15	281	296	0.6%	6.1%	6.7%
2011	4,000	18,197	22,197	18.0%	82.0%	55	247,500	73	331	404	1.6%	7.4%	9.0%
2012	24,776	19,823	44,599	55.6%	44.4%	147	661,500	169	135	303	3.7%	3.0%	6.7%

Size

The minimum weekly average lengths of sub yearling Chinook migrants was 40.0-mm FL in February and increased to an average of 87.2-mm FL by early July. From early February through mid- April, weekly averages of Chinook fry ranged from 40.5-mm FL to 46.5-mm FL. By late April Chinook grew to a weekly average 51.8-mm FL and continued to grow to average 81.8-mm FL by late June (Figure 10). Although average FL increased quickly, some Chinook migrants were still measuring less than 65-mm FL in mid-June.

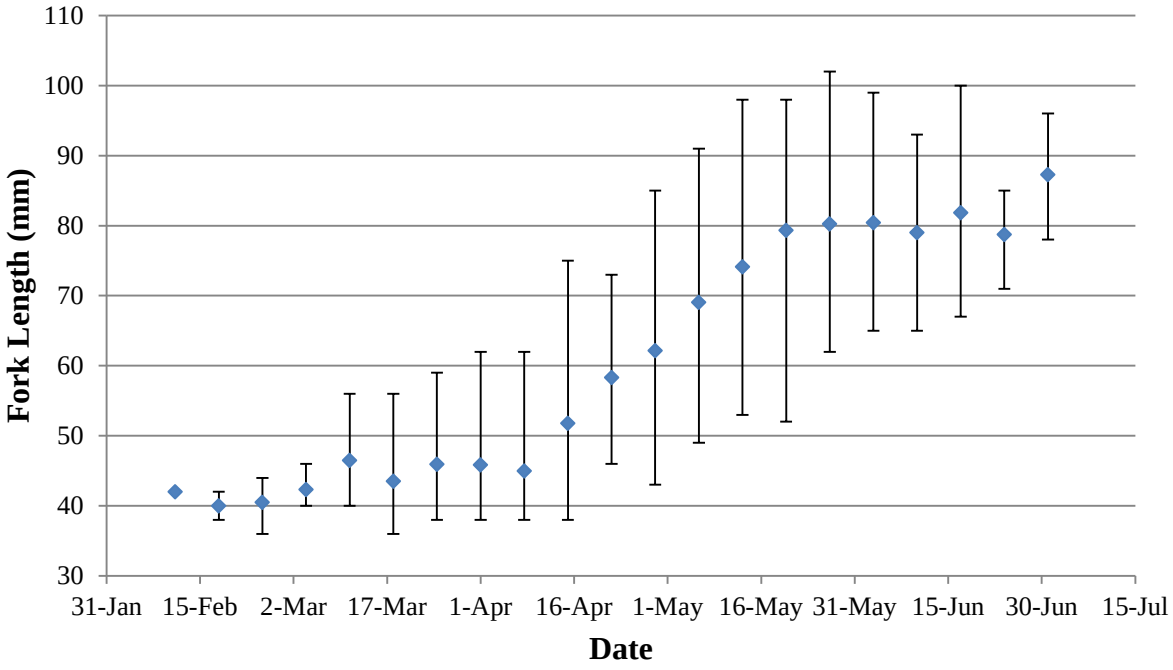

Figure 10. Fork lengths of sub yearling Chinook sampled from Bear Creek in 2013. Data are mean, minimum, and maximum lengths for each statistical week.

Coho

Total catch (actual and estimated missed) in the Bear Creek screw trap was 1,288 sub-yearling and yearling coho. This included an actual catch of 1,240 coho migrants and an estimated missed catch of 48 coho due to trap outages.

Production Estimate

Abundance of coho was based on total catch and 12 efficiency trials, which were aggregated into three strata. Capture rates of efficiency strata ranged from 3.3% to 13.9%. Coho production was estimated to be 17,752 ± 7,766 (±95% C.I.) smolts (Table 13, Figure 11, Appendix B 3).

Table 13. Abundance of natural-origin juvenile coho emigrating from Bear Creek in 2013. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), and coefficient of variation (*CV*).

Gear	Period	Total Catch	Abundance	95% C.I.		*CV*
				Low	High	
Screw Trap	January 28 - July 10	1,288	17,752	9,986	25,518	22.30%

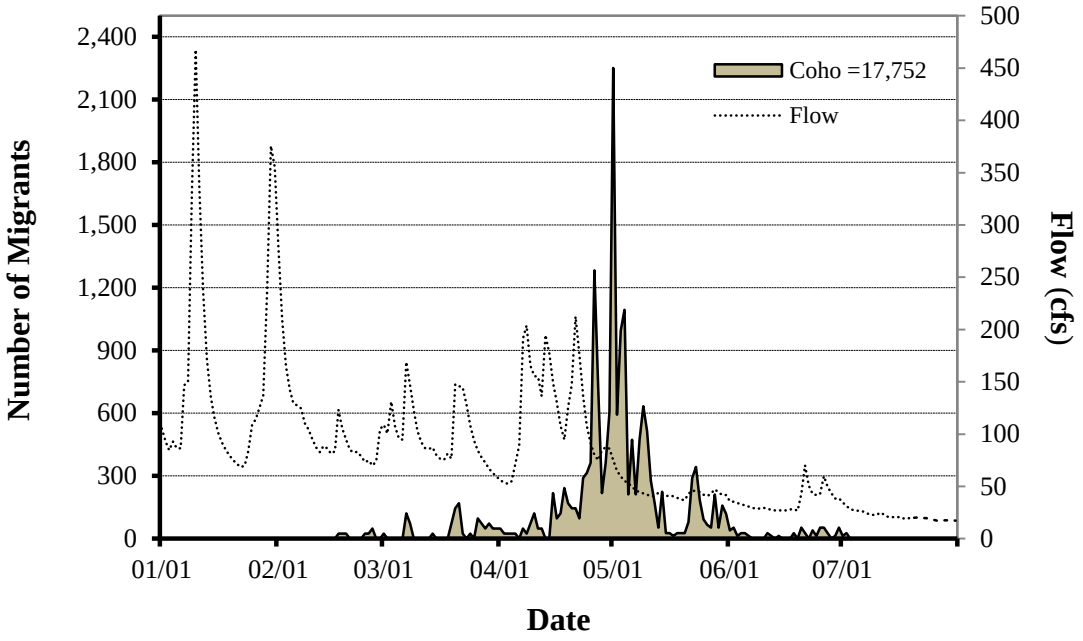

Figure 11. Daily migration of coho smolts in Bear Creek from January 28 to July 10, 2013. Graph also shows mean daily flows during this period. Flow data were measured at King County gage 02a at Union Hill Road in 2013 (http://green.kingcounty.gov/wlr/waterres/hydrology).

Size

Over the trapping period, fork lengths of sub-yearling and yearling coho ranged from 38-mm to 143-mm FL and averaged 114.4-mm FL (Figure 12). Weekly mean lengths ranged from 44.0-mm to 129.5-mm FL during trap operation.

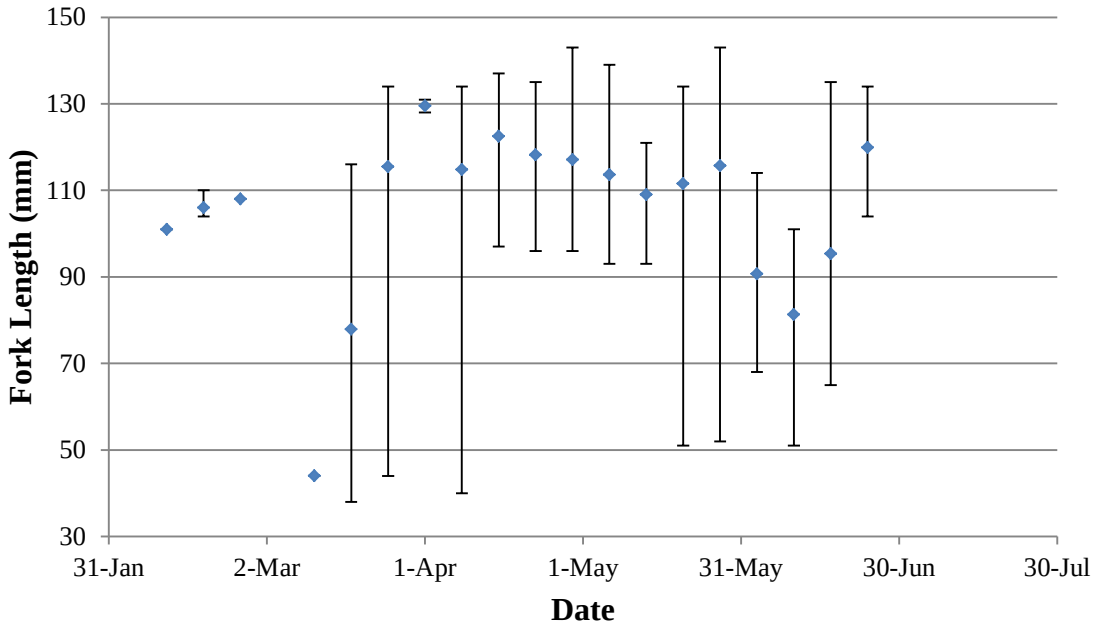

Figure 12. Fork lengths of migrating coho smolts caught at the Bear Creek screw trap in 2013. Data are statistical week mean, minimum, and maximum lengths.

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/rainbow migrants. The cutthroat estimate does not differentiate migration for different life history strategies and is a measure of the number of cutthroat moving past the trap, not cutthroat production.

Production Estimate

No steelhead were captured during the entire 2013 trapping season in Bear Creek.

Total catch (actual and missed) of cutthroat trout was 1,051, and consisted of 894 actual captures and 157 estimated missed catch for trap outages. Thirteen different efficiency trials of cutthroat were conducted over the season. Trials were aggregated into one stratum with a capture rate of 11.8%. Migration was estimated to be 8,551 ± 3,319 (±95% C.I.) cutthroat, with a coefficient of variation of 19.8% (Figure 13, Table 14, Appendix B 4) for the trapping period. Movement was already occurring when trapping began January 28. Trout movement was variable throughout the season and displayed no apparent trend or pattern. Peak abundance of 350 trout was estimated on April 26 (Figure 13).

Table 14. Abundance of natural-origin cutthroat trout moving in Bear Creek in 2013. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), and coefficient of variation (*CV*).

Gear	Period	Total Catch	Abundance	95% C.I.		*CV*
				Low	High	
Screw Trap	January 28 - July 10	1,051	8,551	5,232	11,870	19.80%

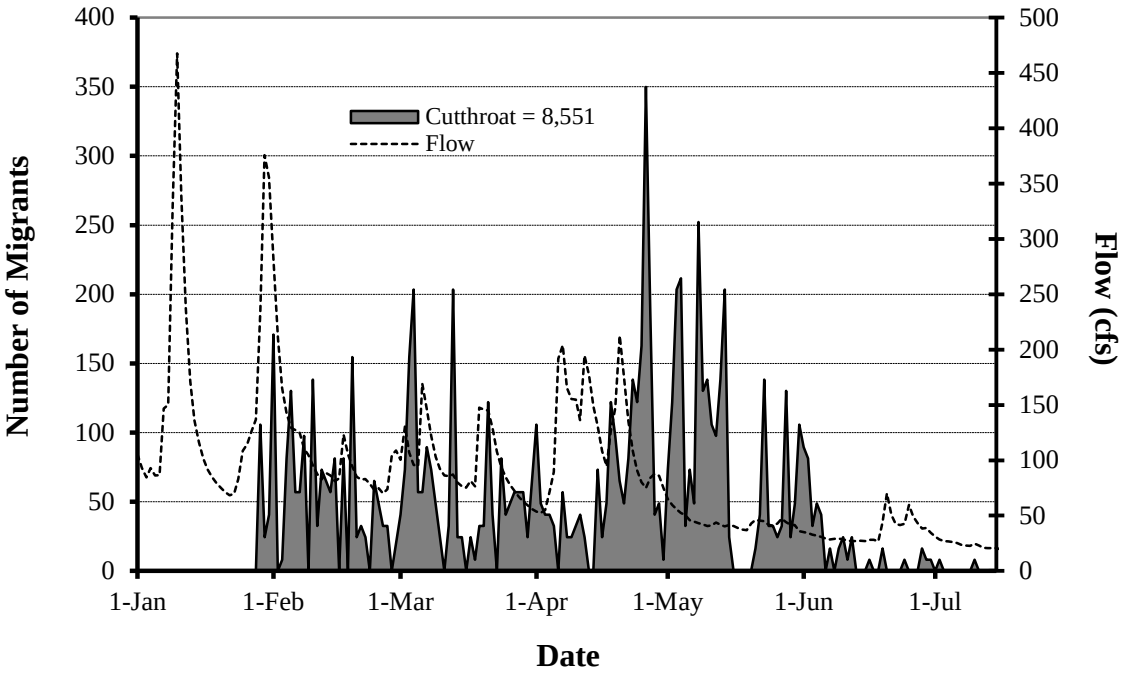

Figure 13. Daily migration of cutthroat trout passing the Bear Creek screw trap in 2013. Flow data were measured at the King County gaging station at Union Hill Road. (http://green.kingcounty.gov/wlr/waterres/hydrology).

Size

Cutthroat trout fork lengths averaged 152.1-mm FL and ranged between 71-mm and 328-mm FL throughout the trapping season (Table 15). Average fork lengths showed no consistent trend across weeks.

Table 15. Cutthroat fork length (mm), standard deviation (SD), range, sample size (n), and catch by statistical week in the Bear Creek screw trap, 2013.

Statistical Week			Fork Length (mm)					
			Avg.	SD	Range		n	Catch
Begin	End	No.			Min	Max		
01/28	02/03	5	127.6	23.0	71	181	41	41
02/04	02/10	6	123.2	29.8	72	204	44	46
02/11	02/17	7	141.2	29.5	89	194	31	31
02/18	02/24	8	141.0	30.0	90	209	33	33
02/25	03/03	9	150.9	30.1	92	204	46	47
03/04	03/10	10	145.0	29.7	91	208	31	31
03/11	03/17	11	145.2	31.0	92	219	21	35
03/18	03/24	12	161.0	27.9	121	212	18	33
03/25	03/31	13	159.8	37.4	112	328	34	34
04/01	04/07	14	163.9	23.5	120	208	16	26
04/08	04/14	15	177.4	22.2	135	206	7	14
04/15	04/21	16	170.8	29.3	96	219	41	59
04/22	04/28	17	165.2	20.2	106	209	75	116
04/29	05/05	18	161.0	22.3	110	243	83	88
05/06	05/12	19	155.9	20.5	109	216	97	112
05/13	05/19	20	147.5	19.4	118	188	25	28
05/20	05/26	21	151.9	15.5	122	198	34	36
05/27	06/02	22	150.9	15.2	113	190	58	62
06/03	06/09	23	149.0	23.5	118	208	12	19
06/10	06/16	24	159.3	38.5	121	204	4	5
06/17	06/23	25	146.8	26.8	122	198	10	3
Season Totals			**152.1**	**27.7**	**71**	**328**	**761**	**904**

Incidental Species

In addition to target species, the screw trap captured 1 hatchery coho smolt, 17 trout fry, 8 hatchery trout plants from Cottage Lake and 17 cutthroat adults. Other species caught included lamprey (*Lampetra* spp.), green sunfish (*Lepomis cyanellus*), three-spine stickleback (*Gasterosterus aculeatus*), sculpin (*Cottus* spp.), whitefish (*Prosopium* spp.), peamouth (*Mylocheilus caurinus*), dace (*Rhinichthys* spp), bluegill (*Lepomis macrochirus*), large-scale suckers (*Catostomus macrocheilus*), and brown bullhead catfish (*Ameriurus nebulosus*).

PIT Tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington watershed, natural-origin Chinook were tagged with passive integrated transponder (PIT) tags. Tagging occurred two to three times a week. Due to low catches of Chinook parr, fish were held from the previous day in order to increase the number of tags released per day. Only the Chinook parr migrants were represented in the tag groups.

Tagging occurred in the Cedar River from May 6 through July 10, 2013. Over the season, a total of 711 natural-origin Chinook parr were PIT tagged at the Cedar River screw trap (Table 16). This tag group comprised 3.7% of the estimated Chinook parr production from the Cedar River in 2013. A total of 209 Chinook PIT tags (29.4%) were detected as they moved through the smolt flumes at the Chittenden Locks while exiting Lake Washington. The first Chinook was detected on May 26, 2013 and the last on July 17, 2013 (Table 17). Median migration date of Chinook detected at the Locks was June 19, 2013. Individual travel times averaged 17.3 days (SD = 10.6).

In Bear Creek tagging occurred from May 1 through July 5, 2013. A total of 1,869 Chinook were tagged throughout the season and represented 9.75% of estimated Chinook parr production. A total of 518 Chinook PIT tags (27.7%) were detected as they moved through the smolt flumes at the Chittenden Locks (Table 16). The first Chinook was detected at the Locks was May 16, 2013 and the last was detected July 20, 2013 (Table 18). Individual travel times averaged 12.3 days (SD = 7.6).

In 2013, the portion of PIT tagged Chinook detected at the Locks from both Cedar River and Bear Creek was the largest since 2010 and exhibited the quickest travel time from tagging to exiting Lake Washington through the Chittenden Locks (Table 17, Table 18)

Table 16. Natural-origin Chinook parr PIT tagged from the Cedar River Bear Creek screw traps in 2013.

Statistical Week			Cedar River Screw Trap							Bear Creek Screw Trap						
				Length (mm)							Length (mm)					
Begin	End	No.	# Tagged	Avg	Min	Max	Portion of Parr Migration	# Detected @ Locks	% of Tags Detected	# Tagged	Avg	Min	Max	Portion of Parr Migration	# Detected @ Locks	% of Tags Detected
28-Apr	4-May	18								17	69.3	58	82	2.7%	5	29.4%
5-May	11-May	19	8	70.4	65	76	1.0%	1	12.5%	185	74.7	65	91	10.7%	55	29.7%
12-May	18-May	20	14	74.4	65	94	1.4%	5	35.7%	114	76.4	65	98	13.3%	21	18.4%
19-May	25-May	21	368	77.6	65	97	4.6%	109	29.6%	400	79.8	65	98	17.5%	127	31.8%
26-May	1-Jun	22	109	78.5	58	95	3.9%	29	26.6%	526	80.4	65	102	8.4%	189	35.9%
2-Jun	8-Jun	23	47	84.2	68	108	4.0%	16	34.0%	406	80.4	65	99	7.0%	95	23.4%
9-Jun	15-Jun	24	78	87.8	68	103	4.4%	31	39.7%	165	79	65	93	24.4%	22	13.3%
16-Jun	22-Jun	25	58	93.5	78	107	4.0%	16	27.6%	46	81.8	67	100	10.5%	4	8.7%
23-Jun	29-Jun	26	20	97.2	87	108	4.3%	2	10.0%	6	78.8	71	85	4.6%		0.0%
30-Jun	6-Jul	27	6	98.2	88	107	2.1%		0.0%	4	87.3	78	96	9.5%		0.0%
7-Jul	13-Jul	28	3	92.3	86	98	6.0%		0.0%							
Season Total			711	81	58	108	3.7%	209	29.4%	1,869	79.3	58	102	9.8%	518	27.7%

Table 17. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Cedar River screw trap, tag years 2010 to 2013. Detection data is from the Hiram Chittenden Locks.

Tag Year	# Tagged	Length (mm)			Portion of Parr Migration	# Detected @ Locks	% of Tags Detected	Avg Travel Time (days)	First Detection	Last Detection	Median Date
		Avg	Min	Max							
2010	2,232	84.2	65	127	6.10%	482	21.59%	29.9	05/24	08/25	06/24
2011	594	87.3	65	118	5.80%	116	19.53%	19.3	05/26	08/27	06/07
2012	1,671	84.0	64	123	4.29%	212	12.69%	30.0	05/29	09/14	07/08
2013	711	81.3	58	108	3.70%	209	29.40%	17.3	05/26	07/17	06/19

Table 18. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Bear Creek screw trap, tag years 2010 to 2013. Detection data is from the Hiram Chittenden Locks.

Tag Year	# Tagged	Length (mm)			Portion of Parr Migration	# Detected @ Locks	% of Tags Detected	Avg Travel Time (days)	First Detection	Last Detection	Median Date
		Avg	Min	Max							
2010	589	77.9	65	99	7.80%	103	17.49%	26.1	06/06	07/07	06/23
2011	2,316	79.9	65	102	26.30%	337	14.55%	15.1	05/23	07/29	06/05
2012	2,721	75.2	62	97	12.2%	316	11.61%	31.3	05/22	08/13	06/21
2013	1,858	79.3	58	102	9.75%	518	27.88%	12.3	05/16	07/20	06/12

Appendix A

Catch and Migration Estimates by Strata for Cedar River Sockeye, Chinook, and Coho Salmon, 2013.

Appendix A 1. Catch and migration by strata for Cedar River natural-origin sockeye fry, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/24/2013	1/26/2013	8,780	3.74%	231,943	7.84E+08
2	1/27/2013	2/13/2013	147,532	2.48%	5,944,076	1.07E+11
3	2/14/2013	2/14/2013	18,356	1.86%	977,725	1.02E+10
4	2/15/2013	2/18/2013	80,869	3.55%	2,259,113	4.22E+10
5	2/19/2013	2/20/2013	42,013	2.36%	1,747,918	6.88E+10
6	2/21/2013	2/23/2013	53,531	2.72%	1,952,549	7.42E+10
7	2/24/2013	3/2/2013	153,039	1.88%	8,095,486	5.41E+11
8	3/3/2013	3/13/2013	182,613	1.48%	12,257,412	9.67E+11
9	3/14/2013	3/16/2013	45,532	1.86%	2,437,789	6.92E+10
10	3/17/2013	3/24/2013	56,156	0.79%	6,959,781	7.64E+11
11	3/25/2013	3/27/2013	41,831	1.95%	2,114,987	1.46E+11
12	3/28/2013	3/30/2013	81,680	3.71%	2,191,674	2.09E+10
13	3/31/2013	4/14/2013	111,473	2.52%	4,379,011	1.75E+11
14	4/15/2013	5/16/2013	25,558	1.17%	2,083,611	1.95E+11
		Total	**1,048,964**		**53,633,075**	**3.18E+12**

Appendix A 2. Catch and migration by strata for Cedar River natural-origin Chinook fry, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/24/2013	1/26/2013	313	3.74%	8,268	1.58E+06
2	1/27/2013	2/13/2013	3,773	2.48%	152,015	1.02E+08
3	2/14/2013	2/14/2013	356	1.86%	18,962	4.82E+06
4	2/15/2013	2/18/2013	1,584	3.55%	44,250	2.59E+07
5	2/19/2013	2/20/2013	988	2.36%	41,105	9.01E+07
6	2/21/2013	2/23/2013	897	2.72%	32,718	4.98E+07
7	2/24/2013	3/2/2013	2,047	1.88%	108,283	8.83E+07
8	3/3/2013	3/13/2013	2,525	1.48%	169,484	4.76E+08
9	3/14/2013	3/16/2013	831	1.86%	44,492	1.88E+07
10	3/17/2013	3/24/2013	867	0.79%	107,452	3.27E+08
11	3/25/2013	3/27/2013	251	1.95%	12,691	1.11E+07
12	3/28/2013	3/30/2013	617	3.71%	16,556	2.63E+06
13	3/31/2013	4/14/2013	1,449	2.52%	56,901	3.23E+07
14	4/15/2013	4/29/2013	75	1.17%	6,114	2.29E+06
		Total	**16,573**		**819,291**	**1.23E+09**

Appendix A 3. Catch and migration by strata for Cedar River natural-origin Chinook parr, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	4/30/2013	7/17/2013	1,144	5.70%	19,219	1.69E+07
		Total	**1,144**		**19,219**	**1.69E+07**

Appendix A 4. Catch and migration by strata for Cedar River natural-origin coho migrants, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	4/17/2013	7/17/2013	4,623	3.97%	115,185	1.56E+08
Total			**4,623**		**115,185**	**1.56E+08**

Appendix B

Catch and Migration Estimates by Strata for Bear Creek Sockeye, Chinook, Coho Salmon, and Cutthroat Trout, 2013.

Appendix B 1 Catch and migration by strata for Bear Creek sockeye, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/28/2013	2/26/2013	1,529	5.83%	24,566	3.64E+07
2	2/27/2013	3/6/2013	7,106	12.95%	54,680	1.59E+07
3	3/7/2013	3/19/2013	58,822	11.15%	525,736	2.41E+09
4	3/20/2013	3/25/2013	45,298	7.14%	628,719	4.68E+09
5	3/26/2013	4/1/2013	32,941	12.71%	257,823	6.79E+08
6	4/2/2013	4/2/2013	3,163	9.20%	33,716	2.18E+07
7	4/3/2013	7/10/2013	4,395	15.40%	28,362	3.56E+07
		Total	**153,254**		**1,553,602**	**7.88E+09**

Appendix B 2. Catch and migration by strata for Bear Creek natural-origin Chinook, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/28/2013	2/26/2013	48	5.83%	771	5.72E+04
2	2/27/2013	3/6/2013	442	12.95%	3,398	1.61E+05
3	3/7/2013	3/19/2013	1,208	11.15%	10,797	5.74E+06
4	3/20/2013	3/25/2013	633	7.14%	8,786	1.11E+06
5	3/26/2013	4/1/2013	67	12.71%	524	4.90E+03
6	4/2/2013	4/2/2013	12	9.20%	128	1.52E+03
7	4/3/2013	4/21/2013	115	15.40%	742	1.49E+04
8	4/22/2013	5/10/2013	754	48.81%	1,538	1.14E+04
9	5/11/2013	5/12/2013	115	10.19%	1,069	6.50E+04
10	5/13/2013	5/24/2013	683	29.71%	2,282	4.37E+04
11	5/25/2013	6/4/2013	1,245	13.67%	8,980	1.19E+06
12	6/5/2013	6/5/2013	143	23.26%	592	1.39E+04
13	6/6/2013	6/7/2013	151	2.94%	3,473	2.94E+06
14	6/8/2013	6/14/2013	290	34.90%	823	7.85E+03
15	6/15/2013	7/10/2013	116	15.09%	696	4.39E+04
		Total	**6,022**		**44,599**	**1.14E+07**

Appendix B 3. Catch and migration by strata for Bear Creek natural-origin coho smolts, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/28/2013	5/1/2013	389	3.33%	9414	1.44E+07
2	5/2/2013	5/8/2013	574	13.93%	4052	2.95E+05
3	5/9/2013	7/10/2013	325	7.14%	4286	1.05E+06
		Total	**1,288**		**17,752**	**1.57E+07**

Appendix B 4. Catch and migration by strata for Bear Creek natural-origin cutthroat smolts, 2013.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/28/2013	7/10/2013	1,051	11.80%	8,551	2.87E+06
		Total	**1,051**		**8,551**	**2.87E+06**

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