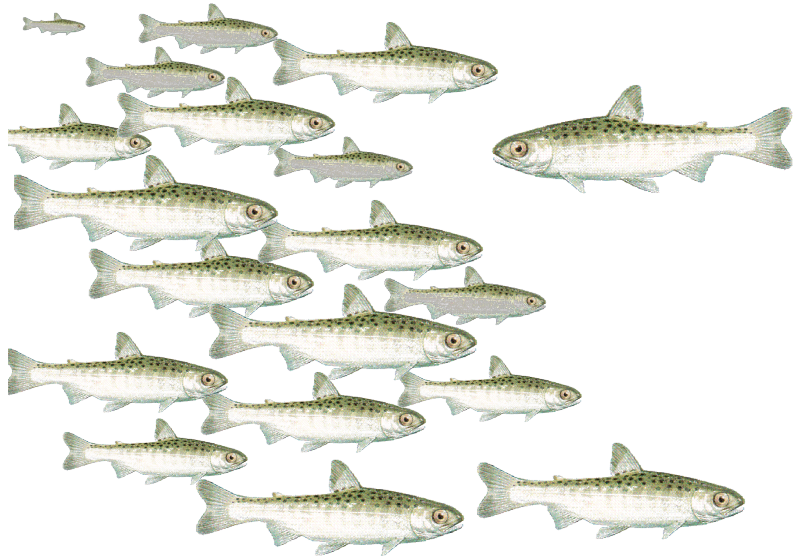


# Evaluation of Juvenile Salmon Production in 2015 from the Cedar River and Bear Creek



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Fish and Wildlife  
Fish Program  
Science Division*

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## Introduction

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This report describes the emigration of five salmonid species from two 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 estimates of coho production and described ancillary data on movement patterns of steelhead and cutthroat trout.

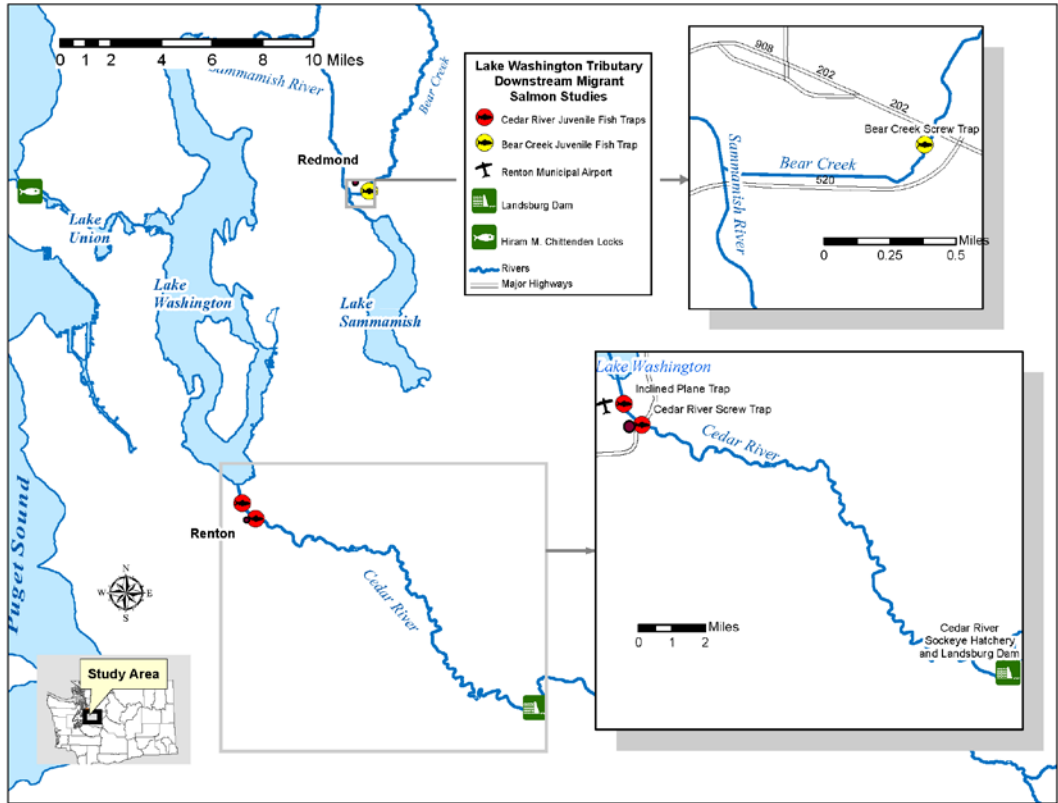


Figure 1. Map of Lake Washington trap sites used to monitor abundance of juvenile migrant salmonids in the Cedar River and Bear Creek, near Renton and Redmond, respectively.

The primary study goal of this program in 2015 was to estimate the number of juvenile sockeye fry, and 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 2014 brood from egg deposition to lake/river entry and to describe the migration timing of each species. Cutthroat and steelhead movements were assessed through catch totals but no abundance estimates were made. Biological data representing each population is also summarized.

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# Methods

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## 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 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 30 x13 ft steel pontoon barge. Fish are separated from the water with a perforated aluminum plate (33 - 1/8 in. holes per in<sup>2</sup>). The inclined-plane trap resembles larger traps used to capture juvenile salmonids in the Chehalis and Skagit rivers, described by Seiler et al. (1981). Each scoop trap screens a cross-sectional area of 4 ft<sup>2</sup> 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 24 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 in the City of Renton (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 2015, 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. Only one trap was fished for the entire season.

The inclined-plane trap began operating on the night of January 14, 2015 and was operated 106 nights between January 14 and April 29. During each night of operation, trapping began before dusk and continued past dawn. Trapping was also conducted during 7 day-light periods between early February and the end of March. Each hour, captured fish were removed from the trap, identified by species, and counted. 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 sixteen nights throughout the season; four releases at the lower site (R.M. 2.1), six releases occurred at the middle release location (R.M. 13.5) and six releases at upper location (R.M. 21.8). The trap operated during one lower river release and all middle and upper river releases for a total of 13 releases.

In 2015, the screw trap was operated at R.M 1.6, just under the I-405 Bridge (Figure 1), on 89 nights between the evening of April 8 and July 8. There were periods when the trap did not operate during daylight periods due to public safety concerns and warm water temperatures. Catches were identified by species and 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 from January 27 to July 1, 2015. The trap was fished for 5 night periods and 6 day periods each week from January 27 to April 4, then fished continuously except for 4 periods when debris stopped the trap, and between June 26 to June 28 when high water temperatures restricted handling of ESA-listed species.

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 (Figure 1). 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 April 29 and July 3, 2015. Fish were often held from the previous day to be tagged to increase the total number of fish tagged per day. Fish were never held for more than 2 days total prior to release. 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 PIT Tag Steering Committee (2014).

In 2015, a portion of Issaquah Hatchery Chinook were also tagged and released on three different release dates, May 1, 4, and 8. Survival and detection data are included and compared to that of Bear Creek and Cedar River.

At the Hiram Chittenden Locks facility demarcating the boundary between the Lake Washington watershed from the marine waters of Puget Sound, PIT tag antennas were positioned in the four smolt flumes and the adult fish ladder. Median migration date was the median date of all detected fish at all detection locations at the Hiram Chittenden Locks. Average travel times were calculated using tag date and subsequent detection date at the Hiram Chittenden Locks.

## **Trap Efficiencies**

### **Cedar River**

#### ***Inclined-Plane Trap***

Trap efficiencies for sockeye in the Cedar River inclined-plane trap were estimated from recaptures of marked natural or hatchery origin sockeye fry released above the trap. Natural origin sockeye captured in the early hours of the night were used for efficiency trials. Some releases were augmented with hatchery sockeye to create larger release groups. 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, marked fry were distributed across the middle of the channel using a swinging bucket on a rope. Catches were examined for marked fish and recaptures were noted during each trap check. In 2015, unlike previous years, Chinook catches were consistently large enough to form regular efficiency trials. Trap efficiencies for Chinook in the Cedar River were estimated from recaptures of marked Chinook fry rather than sockeye fry as has been the practice in previous trap seasons when Chinook are not abundant enough to form efficiency trials.

#### ***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 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). Beginning May 17, the release location moved upstream to R.M. 2.6 near the Maplewood Roadside Park because the Riviera location became difficult to access due to low flows. 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. 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. Chinook fry were not

sufficiently abundant to form efficiency trial groups. Sockeye fry were assumed adequate surrogates for estimating trap efficiencies of Chinook fry.

Trap efficiencies of Chinook parr, coho, and cutthroat in Bear Creek screw trap were estimated 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 periods during the adjacent nights were 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

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

Equation 2

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

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,



$\bar{n}_i$  = 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

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

## 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:

Equation 4

$$\hat{n}_i = T_i * \bar{R}$$

where:

$T_i$  = Hours during non-fishing period  $i$

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

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

Equation 5

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

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

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

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:

Equation 7

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

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

Equation 8

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

where:

$T_n$  = hours of night during 24 hour period,

$T_d$  = hours of day during 24 hour period, and

$\bar{Q}_d$  = 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:

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

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

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 thirteen of sixteen nights when releases occurred upstream from the trap. Abundance was estimated using a time stratified sampling approach and calcein dye with otolith validation to identify hatchery presence in catches. A portion of each release was marked with calcein and all sockeye released from the Cedar River Hatchery were otolith marked. Trap operations were altered to note catches in 1 and 9 minutes periods iteratively to create 10 minute trapping periods. All catch was interrogated for a calcein mark and totals for each 1 and 9 minute sampling period were recorded. One minute periods were held as a sample for otolith analysis. The true presence of hatchery fish was validated through otolith analysis for eight releases and the remaining five releases abundance were determined by the presence of a calcein mark.

Total hatchery abundance 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 and Productivity**

Egg-to-migrant survival estimates are the measured survival between egg deposition and migration of juveniles into Lake Washington. Survival was estimated by dividing the 2015 abundance of natural-origin juvenile migrants by the 2014 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 in a multi-agency collaborative effort. This estimate assumed an even sex ratio for sockeye. Cedar River sockeye fecundity was estimated by the average number of eggs per female during 2014 sockeye brood-stock collection for the Cedar River Sockeye Hatchery (Shoblom 2015). Fecundity of Bear Creek sockeye was assumed to be the same as the fecundity of Cedar River sockeye.

Productivity for Chinook in both Cedar River and Bear Creek was measured by the number of migrants produced per female spawner that contributed to the outmigrating brood year. We acknowledge that there are two life-history forms of sub yearling Chinook salmon observed in Puget Sound: small fry migrating immediately after emergence and larger parr that spend some time rearing in freshwater. The small fry are defined as fish emigrating between January and mid-April and larger parr are defined as fish emigrating between mid-April and July. Because there is an unknown in-river mortality rate during the fry to parr transition, we have chosen to report Chinook freshwater productivity as the number of migrants (both fry and parr combined) per female. We suggest that reporting fry and parr survival separately, as was calculated in previous reports, underestimates the true fry survival because it does not include the fish that migrated as parr (which obviously survived the fry stage). Productivity is further divided into the number of fry and parr per female. 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. 2015). Fecundity for Cedar River and Bear Creek (4,500 eggs per female) is assumed to be similar to the fecundity of Soos Creek Hatchery Chinook on the Green River.



# Cedar River

## Sockeye

### *Production Estimate*

Total catch (actual and estimated missed) in the inclined-plane trap was 184,500 sockeye fry. A total of 122,564 natural-origin sockeye fry were caught in the inclined-plane trap during trap operations. We estimated a missed catch of an additional 61,935 sockeye fry for all night trap outages between January 17 and April 29, 2015. Seven day intervals were trapped to evaluate day-time migration: February 9 and 23, and March 2, 9, 16, 23, and 30. Flows on these days ranged from 454 cfs to 1,495 cfs at the Cedar River USGS gage (#12119000). Day-to-night catch ratios ranged from 0.40% to 34.69%. We estimated a missed catch of 10,382 fry for all day-time trap outages.

Table 1. Abundance of natural-origin sockeye fry entering Lake Washington from the Cedar River in 2015. Table includes abundance of fry migrants, 95% confidence intervals (C.I.), and coefficients of variation (CV).

Component	Period	Dates	Fry Abundance	95% C.I.		CV
				Low	High	
Natural Origin	Pre Trapping	January 1 - 13	14,309	8,604	20,014	20.34%
	During Trapping	January 14-April 29	13,780,877	12,055,991	15,505,763	6.39%
	Post Trapping	April 30- June 30	83,746	41,731	125,762	19.04%
		<b>Total</b>	<b>13,878,932</b>	<b>12,153,525</b>	<b>15,604,339</b>	<b>6.34%</b>

A total of 48 efficiency trials were conducted in 2015. Efficiency data were aggregated into 17 strata. Capture rates for these strata ranged from 0.36% to 3.02% (Appendix B).

An estimated 13.9 million natural-origin sockeye fry entered Lake Washington from the Cedar River in 2015 (Table 1, Appendix A 1). This estimate includes pre-season and post-season estimates of 98,055 fry total, as well as the estimated abundance of fry during the trapping period of 13.8 million fry. Both pre- and post-season tails each represent less than 1% of the total natural production. Coefficient of variation (CV) associated with the natural-origin migration was 6.34%.

Migration began prior to our first day of trapping as noted by sockeye catches on the first night. Migration began moderately with a few notable peaks in the month of March which is usually when the majority of sockeye migrate. Migration then declined for the remainder of the season (Figure 2). Median migration date for natural-origin sockeye was March 7 (Table 2). Hatchery fish migrated later (five days) than naturally produced fish in 2015 (Table 2). The median migration date for hatchery sockeye does not include releases when the trap was not fished, particularly the three Riviera releases. If these lower releases survived similarly to the

March 12 Riviera release, median migration date of hatchery fish would be earlier at March 3, changing the median date to be slightly earlier than the natural migration.

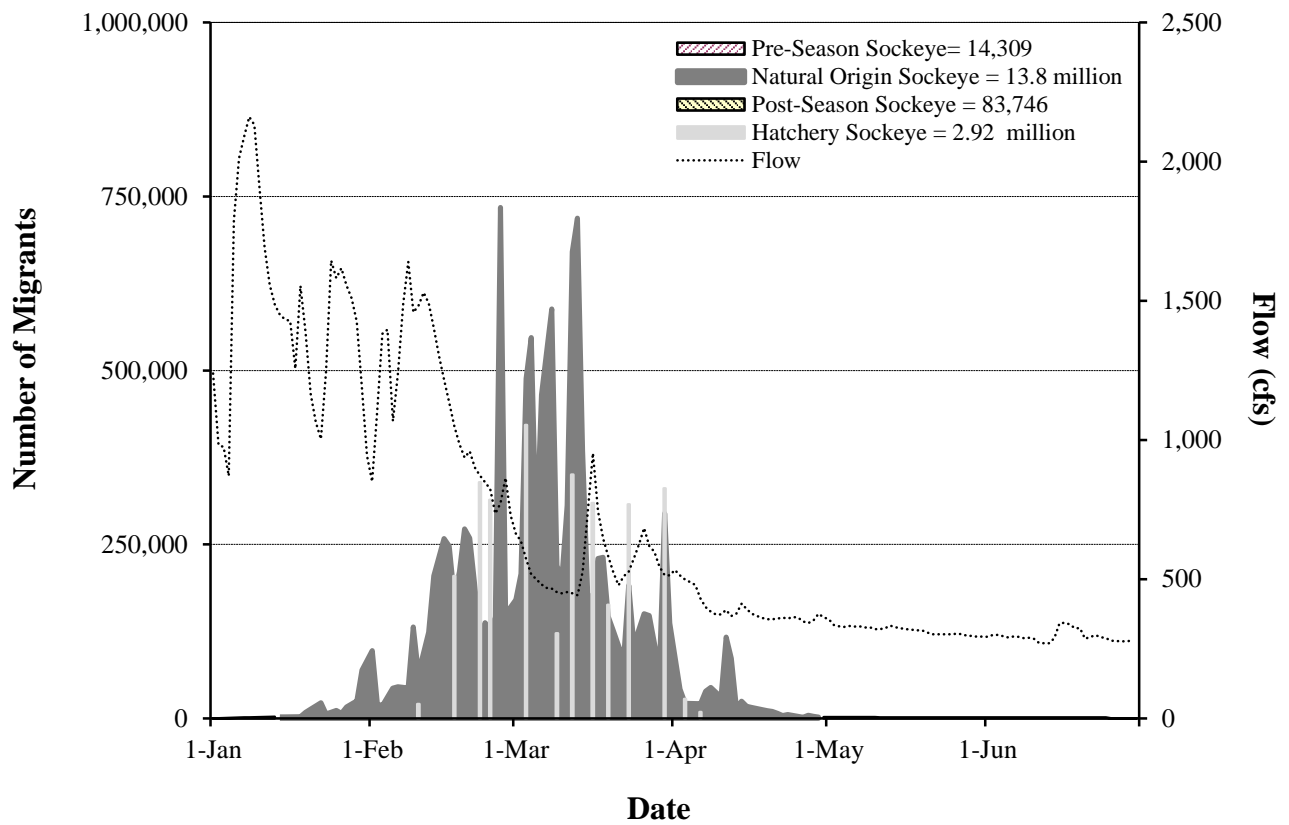


Figure 2. Estimated daily migration of natural-origin and hatchery sockeye fry migrating from the Cedar River into Lake Washington between January 14 and April 29, 2015. Pre- and post-trapping migration estimates are included. Graph includes daily average flows during this period (USGS Renton gage Station #12119000).



Table 2. Median migration dates of natural-origin, hatchery, and total (combined) sockeye fry from the Cedar River for brood years 1991 to 2014. 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 i	Trap Year i+1	February Thermal Units	Median Migration Date			Difference (days) W-H
			Wild	Hatchery	Combined	
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	02/23	03/01	7
2005	2006	184	03/20	03/06	03/16	14
2006	2007	193	03/23	02/20	02/26	31
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	03/08	03/07	-1
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
2013	2014	160	03/02	03/11	03/04	-9
2014	2015	222	03/07	03/12	03/07	-5
	<b>Average</b>		03/19	03/02	03/11	17

### ***Hatchery Abundance and Survival***

Over the season a total of 5.03 million hatchery-produced sockeye were released into the Cedar River (Table 3). On four separate nights, a total of 2.14 million sockeye were released at R.M. 2.1. An additional 1.97 million hatchery fry were released at R.M. 13.5 on six separate nights and a total of 0.92 million fry were released at the Cedar River Sockeye Hatchery (R.M. 21.8) on six different nights (Table 3). The inclined-plane trap operated on all upper and middle river release nights and one lower river release (March 12). Due to trap staffing constraints and our historical inability to assess the lower river releases due to trap location, efforts were focused on continued monitoring of the upper and middle river releases.

Estimates were formed using a time-stratified sampling method to obtain a sample to estimate the presence of hatchery fish in catches. Calcein dye was used to mark a portion of each hatchery release from the upper and middle release locations and one release (March 12) from the lower location. Catches were interrogated for a calcein mark and some samples were

submitted for otolith analysis to validate the presence of hatchery fish and validity of the calcein mark. Survival ranged from 17.4% to 181.0%. We recognize that survival over 100% is unreasonable however rates below 100% are within the confidence intervals of those estimates. Indeed, the two releases with the highest estimated survival (Feb 17 and Feb 22) also had the greatest range in 95% confidence interval (Table 3). We estimated a total of 2.9 million hatchery fry entering the lake with an overall survival of 58.1%. The actual number of hatchery sockeye entering Lake Washington in 2015 is greater. These estimates do not include survival of the remaining three lower river releases (Riviera location) that were not fished totaling 1.7 million hatchery sockeye. If all releases that occurred at the Riviera survived similarly to the one Riviera release that was monitored (March 12 survived at 82.2%), total hatchery fish reaching the lake would increase by 1.4 million to total 4.3 million hatchery fish. Overall survival of hatchery fish released would increase to 86.0%.

Table 3. Estimated hatchery sockeye abundance, variance, survival, and method used to estimate 2015 releases. Releases where no estimate is provided are nights the trap did not operate. Flow data was measured at the USGS Renton gage, Station #12119000.

Date Released	Daily Average Flow (cfs)	Estimate Method	Sockeye Released	Release Location	Estimated Hatchery Sockeye			95% CI + / -
					Abundance	Variance	Survival	
2/10/2015	1,483	Otolith	121,029	Upper	20,533	2.4x10 <sup>7</sup>	17.4%	8.1%
2/17/2015	1,049	Otolith	151,685	Middle	204,392	1.1x10 <sup>9</sup>	137.5%	43.8%
2/18/2015	985	n/a	342,581	Lower				
2/22/2015	873	Otolith	189,638	Upper	339,183	2.6x10 <sup>9</sup>	181.7%	53.5%
2/24/2015	824	Otolith	326,076	Middle	313,848	1.1x10 <sup>9</sup>	98.1%	20.3%
2/25/2015	735	n/a	901,025	Lower				
3/3/2015	573	Calcein	375,790	Middle	421,670	1.3x10 <sup>9</sup>	113.1%	18.9%
3/9/2015	454	Otolith	282,259	Upper	122,133	6.4x10 <sup>7</sup>	43.7%	5.6%
3/12/2015	499	Calcein	429,571	Lower	350,447	2.2x10 <sup>9</sup>	82.2%	21.4%
3/16/2015	952	Calcein	417,907	Middle	309,328	1.9x10 <sup>9</sup>	74.6%	20.4%
3/19/2015	582	Calcein	242,668	Upper	163,257	4.1x10 <sup>8</sup>	68.1%	16.5%
3/23/2015	527	Otolith	323,083	Middle	307,761	1.5x10 <sup>9</sup>	96.3%	23.4%
3/25/2015	625	n/a	464,296	Lower				
3/30/2015	514	Otolith	373,692	Middle	330,714	1.5x10 <sup>9</sup>	89.2%	20.7%
4/3/2015	499	Otolith	49,615	Upper	27,945	1.9x10 <sup>7</sup>	60.8%	18.6%
4/6/2015	431	Calcein	36,888	Upper	9,039	1.7x10 <sup>6</sup>	26.7%	7.6%
<b>Season Total</b>			<b>5,027,803</b>		<b>2,920,251</b>		<b>58.1%</b>	

### **Egg-to-Migrant Survival of Natural-Origin Fry**

Egg-to-migrant survival of the 2014 brood Cedar River sockeye was estimated to be 79.9% (Table 4). Survival of the 2014 brood was the highest observed since monitoring began. The previous highest survival was estimated at 56.6% (brood 2009). There are two possible sources of error that could contribute to this higher than expected estimate: the sockeye fry estimate or the spawner abundance estimate. We account for error in our juvenile sockeye estimates, but

would still expect survival to be 69% if estimated using the lower bound of the 95% confidence interval. We do not believe that we have consistently violated any of the assumptions associated with the mark recapture approach of estimating fry abundance. Violations of these assumptions could bias the 2014 brood egg-to-migrant survival to be higher than actual survival. Incubation flows were low and stable, ideal for maximizing survival. The previously highest egg-to-migrant survival (2009, 56.6%) is also associated with low incubation flows and the second lowest spawner abundance.

High egg to migrant survival might also be expected at low spawner abundances if the population is released from density dependent processes. Indeed, spawner abundance in 2014 was the lowest observed across the 1991 – 2014 time series. Although we found minimal difference in the fit of a density dependent and a density independent model (Figure 3), maximum fry per spawner will typically be observed at low spawner abundances. In the density dependent model, fry per spawner decreases at higher spawner abundances, whereas fry per spawner remain constant at higher spawner abundances in the density independent model. Most importantly, the 2014 brood does not appear to be an outlier under either model and falls within the range of other observations when depicted in the standard spawner-recruit plot (Figure 3).

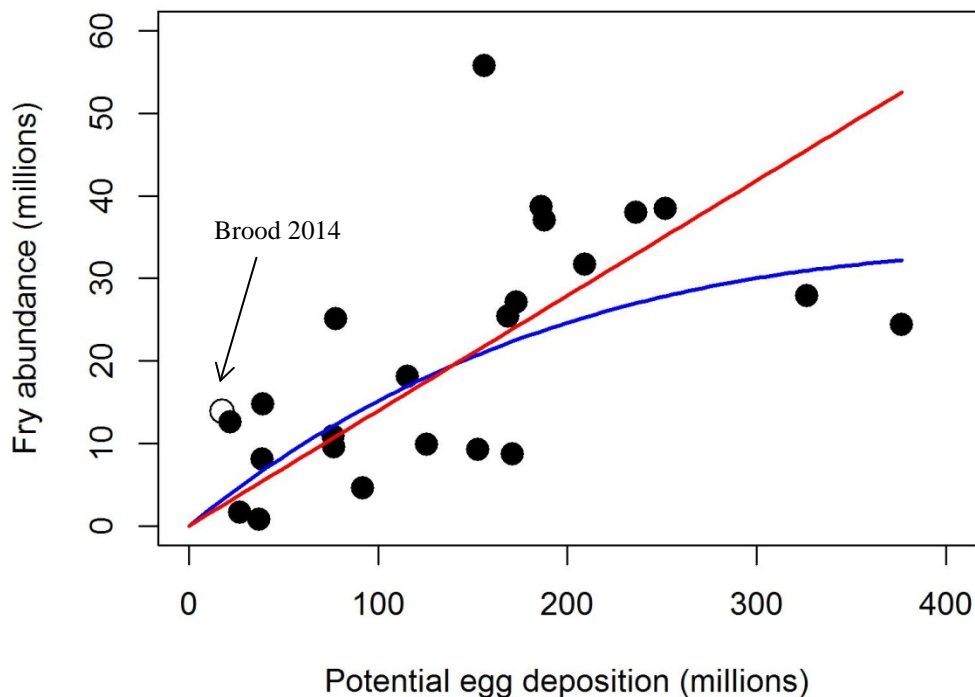


Figure 3. Cedar River fry production from 1991 to 2014 brood as a function of potential egg deposition, with brood year 2014 highlighted by the open circle. The blue line depicts a Ricker density-dependent fit to these data ( $\ln(\text{fry}/\text{spawner}) \sim a + b \cdot \text{spawners}$ ), whereas the red line depicts a density independent straight line through the origin ( $\ln(\text{fry}/\text{spawner}) \sim a$ ). These two models performed similarly based on Akaike’s Information Criterion corrected for small sample sizes ( $\text{AICc} = 65.1$  for Ricker model,  $\text{AICc} = 63.8$  for straight line model).

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 - 2014. Incubation period is defined from November to February. 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)	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	88,974	44,487	3,515	156,371,805	55,793,120	35.68%	1,513	12/7/2012
2013	140,682	70,341	3,362	236,486,442	37,975,769	16.06%	1,762	11/20/2013
2014	10,450	5,225	3,368	17,597,800	13,878,932	78.87%	2,162	1/8/2015

## Chinook

### *Production Estimate*

Production of natural-origin Chinook was estimated to be  $347,663 \pm 90,067$  ( $\pm 95\%$  C.I.) sub yearlings, based on operation of both the inclined-plane and screw traps. Between January 1 and April 7, 2015  $326,901 \pm 89,717$  ( $\pm 95\%$  C.I.) natural-origin Chinook were estimated to have passed the inclined-plane trap (Table 6, Appendix A 2). This includes an estimate for a pre-trapping period from January 1 to 13 of 13,309 fry and an estimate of 313,592 Chinook fry during the time the inclined-plane trap was operating from January 14 to April 7. This estimate was based on a total catch of 6,277 and Chinook trap efficiency strata ranging from 1.7% to 10.2%. 2015 was the second year the trap has captured sufficient Chinook to conduct trap efficiency trials consistently throughout the season. Trap efficiency estimates for the two species were not statistically significantly different from each other, though Chinook capture rates were always higher than sockeye capture rates (Table 5). Application of sockeye trap efficiencies for Chinook fry abundance produces an estimate of 658,000 Chinook fry, nearly doubling the abundance estimate for the same time period. We chose to apply Chinook trap efficiencies to estimate Chinook fry abundance in 2015 (Table 5). The fry migration showed a broad, consistent

movement in the month of February with two prominent peaks at the end of February and in mid-March (Figure 3).

Table 5. Sockeye and Chinook inclined-plane trap efficiencies during 2015.

Date	Flow (cfs)	Trap Efficiencies	
		Sockeye	Chinook
01/27/15	1,555	0.93%	2.17%
01/30/15	1,189	1.90%	2.54%
02/02/15	1,106	0.95%	0.95%
02/03/15	1,382	0.66%	1.12%
02/06/15	1,242	0.17%	0.61%
02/09/15	1,459	0.83%	0.93%
02/13/15	1,401	0.54%	1.56%
02/16/15	1,135	0.53%	0.74%
02/20/15	960	1.13%	1.59%
02/24/15	824	1.88%	2.01%
02/27/15	865	1.87%	1.89%
03/01/15	664	1.98%	4.00%
03/03/15	573	2.03%	3.94%
03/09/15	454	2.98%	10.20%

Between April 8 and July 8, 2015,  $20,725 \pm 7,932$  ( $\pm 95\%$  C.I.) natural-origin Chinook were estimated to have passed the screw trap (Table 6, Figure 5, Appendix A 3). This estimate is based on a total catch of 1,150 natural-origin juvenile Chinook parr in the screw trap and trap efficiency ranging from 5.6% to 7.5%. Post-trapping Chinook migration was estimated at 37 Chinook. The parr portion of the migration was much less prominent than the fry component and displayed sporadic movements with one daily peak of 1,600 Chinook near the end of May.

We estimated the abundance of two life-history forms of sub yearling Chinook salmon observed in Puget Sound: small fry migrating immediately after emergence and larger parr that spend some time rearing and growing in freshwater. The small fry are defined as fish emigrating between January and mid-April and comprised 94% of all sub yearlings. The larger parr are defined as fish emigrating between mid-April and July and comprised 6% of the total migration (Table 8). In 2015, nearly 60% of the fry migration occurred in February which is a month earlier than what is typically observed. Warmer than usual fall and winter winter temperatures may have contributed to this pattern by increasing incubation rates.

Table 6. Abundance of natural-origin juvenile migrant Chinook in the Cedar River in 2015. Data are total catch, abundance, 95% confidence intervals (C.I.), and coefficient of variation (CV).

Capture Method	Period	Total Catch	Abundance	95% C.I.		CV
				Low	High	
Pre-trapping	January 1 - 13		13,309	7,521	19,098	22.19%
Fry Trap	January 14 - April 7	6,277	313,592	223,905	403,279	14.59%
Fry Trap subtotal		6,277	326,901	237,028	416,774	14.03%
Screw Trap	April 8 - July 8	1,150	20,725	12,793	28,657	19.53%
Post Trapping	July 9 - July 13		37	1	72	50.30%
Screw Trap subtotal		1,150	20,762	12,830	28,694	19.49%
<b>TOTAL</b>		<b>7,427</b>	<b>347,663</b>	<b>257,440</b>	<b>437,886</b>	<b>13.24%</b>

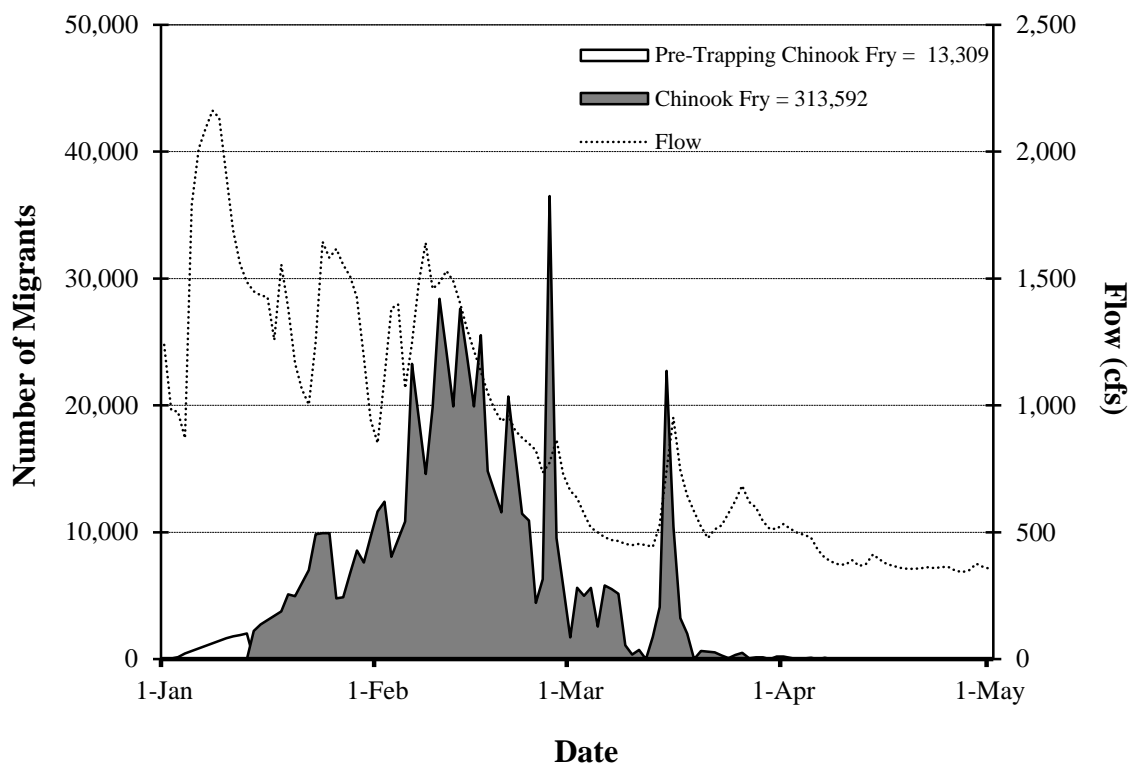


Figure 4. Estimated daily migration of Chinook fry from the Cedar River in 2015 based on inclined-plane trap estimates from January 1 to April 7. Pre-trapping migration estimate included. Graph includes mean daily flows during this time period (USGS Renton gage, Station #12119000) in 2015.

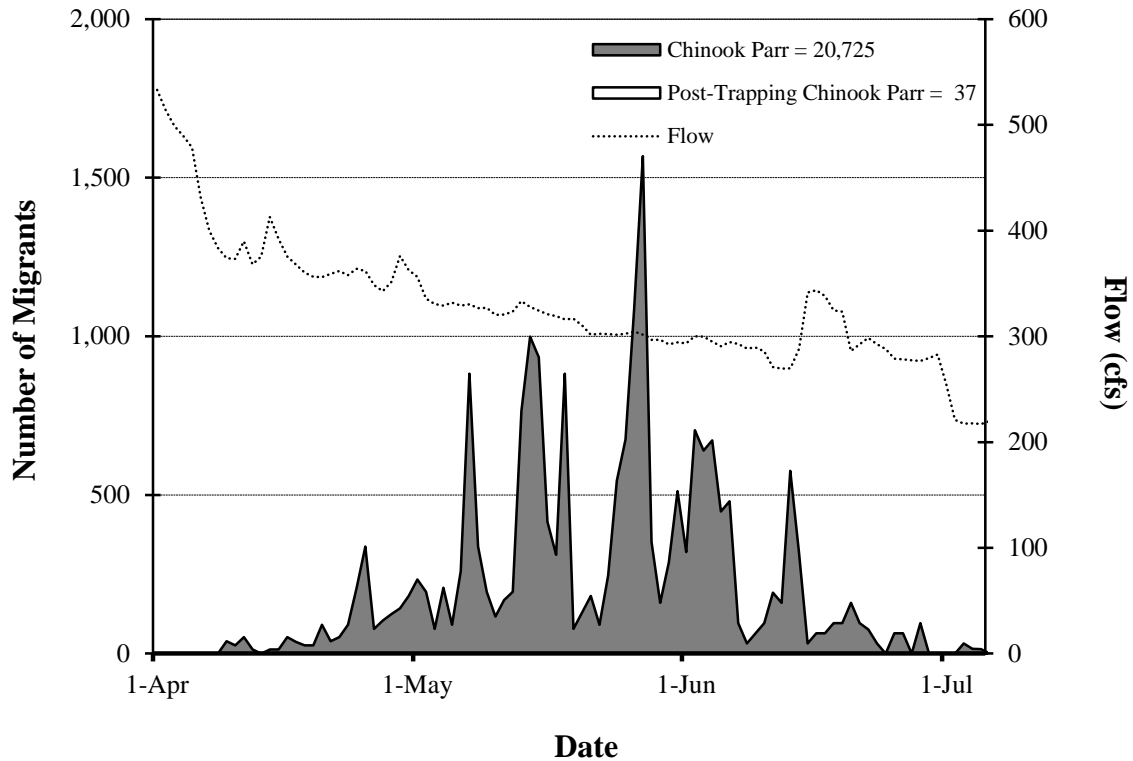


Figure 5. Estimated daily migration of Chinook parr from the Cedar River in 2015 based on screw trap estimates from April 8 to July 13. Graph includes mean daily flows during this time period (USGS Renton gage, Station #12119000) in 2015.

## ***Productivity***

The number of juvenile Chinook migrants produced per female spawner was the fourth highest observed from the Cedar River at 1,499 migrants per female (Table 7). The number of fry per female is also the fourth highest (1,409) however the number of parr per female is the seventh lowest since monitoring began. Incubation flows were moderate with one flow event peaking at 2,162 cfs in Renton in mid-January. Aside from that particular event, flows stayed well below 2,000 cfs and averaged 1,272 cfs in Renton from November through the end of February. These moderate flows may have been a large contributor to the large juvenile abundance calculated from a smaller adult return. Productivity was based on 232 female spawners (Burton et al. 2015).

Table 7. Abundance of Chinook fry and parr and productivity (juveniles per female) among brood years. Fry migration estimates were made using inclined-plane trap data. Chinook parr estimates were formed using screw trap data for the remainder of the season. Transition date represents the date which the change from inclined-plane to screw trap data was used to form Chinook estimates. Data are Cedar River broods 1998 to 2014.

Brood Year	Trapping Dates		Juvenile Abundance		95% CI(±)	Percent Abundance		Est. Fem.	Juveniles/Female		Egg to Migrant Survival			
	Start	Transition	End	Fry		Parr	Total		Fry	Parr		Fry	Parr	Total
1998	23-Jan	18-Mar	27-Jul	63,702	17,230	80,932	7,732	79%	21%	173	368	100	468	10.4%
1999	20-Jan	27-Apr	13-Jul	46,500	18,223	64,723	5,609	72%	28%	182	255	100	356	7.9%
2000	18-Jan	9-Apr	22-Jul	10,833	21,416	32,249	5,220	34%	66%	53	204	404	608	13.5%
2001	25-Jan	15-Apr	22-Jul	79,799	39,875	119,674	41,349	67%	33%	398	201	100	301	6.7%
2002	21-Jan	21-Apr	12-Jul	194,657	40,740	235,397	51,485	83%	17%	281	693	145	838	18.6%
2003	18-Jan	14-Apr	20-Jul	65,752	55,124	120,876	2,518	54%	46%	337	195	164	359	8.0%
2004	21-Jan	11-Apr	29-Jul	74,292	60,006	134,298	42,912	55%	45%	511	145	117	263	5.8%
2005	20-Jan	1-May	16-Jul	98,967	18,592	117,559	16,233	84%	16%	339	292	55	347	7.7%
2006	18-Jan	18-Apr	20-Jul	110,961	14,225	125,186	16,912	89%	11%	587	189	24	213	4.7%
2007	13-Jan	18-May	19-Jul	705,583	61,379 - 67,037	766,962 - 772,620	76,106	89.5-90.1%	9.9-10.5%	899	785	68-75	853-859	19.0% - 19.1%
2008	1-Feb	22-Apr	18-Jul	127,064	12,388	139,452	38,399	91%	9%	599	212	21	233	5.2%
2009	17-Jan	16-Apr	4-Jul	115,474	36,916	152,390	13,058	76%	24%	285	405	130	535	11.9%
2010	30-Jan	10-May	16-Jul	177,803	10,003	187,806	63,560	95%	5%	266	668	38	706	15.7%
2011	22-Jan	11-May	14-Jul	863,595	38,919	902,514	165,973	96%	4%	324	2,665	120	2,786	61.9%
2012	24-Jan	30-Apr	17-Jul	874,658	19,219	893,877	77,993	98%	2%	433	2,020	44	2,064	45.9%
2013	17-Jan	3-May	16-Jul	1,426,631	32,130	1,458,761	390,039	98%	2%	740	1,928	43	1,971	43.8%
2014	14-Jan	8-Apr	8-Jul	326,901	20,762	347,663	89,751	94%	6%	232	1,409	89	1,499	33.3%



## Size

Weekly average lengths of sub yearling Chinook increased from 38.5 mm fork length (FL) in January to 102.9 mm FL by July (Figure 6). Chinook caught in the inclined-plane trap ranged from 36 mm FL to 77 mm FL and averaged 41.7 mm FL. Chinook caught in the screw trap increased in size from 52 mm FL to 115 mm FL and averaged 86.6 mm FL.

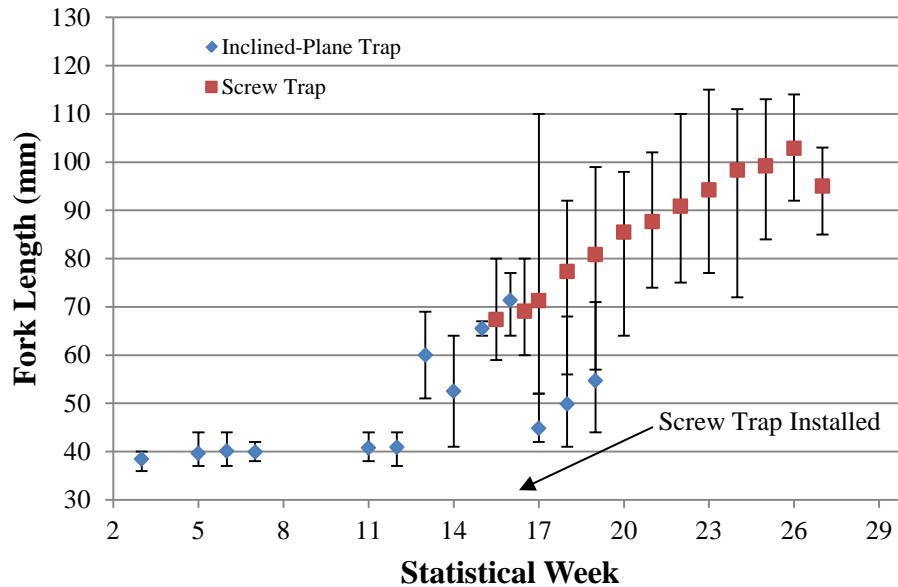


Figure 6. Fork lengths of natural-origin juvenile Chinook sampled from the Cedar River, 2015. Graph shows average, minimum, and maximum lengths by statistical week.

## Coho

### ***Production Estimate***

During inclined-plane trap operations from January 14 to April 29, 126 coho fry and 161 coho smolts were caught. Catches were too few to form efficiency trials and abundance estimates were not made for the period prior to screw trap operations (April 8).

Total catch (actual and missed) of all coho migrants captured in the screw trap was 5,209 coho smolts. This included 5,098 natural-origin coho caught in the screw trap between April 8 and July 8 and an estimated missed catch of 111 coho due to trap outages. Only 172 sub yearling coho were caught, constituting 3.3% of the total catch.

A total of 47 efficiency trials were conducted. Efficiency trials were aggregated into one stratum for a season long capture rate of 4.8% (Appendix A 4). Total coho production was estimated to be  $107,874 \pm 16,827$  ( $\pm 95\%$  C.I.) migrants for the period the trap was operating with a coefficient of variation of 7.96% (Table 8, Appendix A 4). This estimate includes both yearling

and sub yearlings that moved past the trap during screw trap operations (Figure 7). We acknowledge that there are two life history forms observed in the Cedar River: typical 1+ yearling coho but also a component that is visually noted as sub yearling coho, further confirmed by scale analysis. We are unable to determine if these sub yearling coho exit to marine waters the same year they migrate out of the Cedar River. This abundance estimate represents total abundance of coho exiting the Cedar River into Lake Washington.

Table 8. Abundance of coho migrants from Cedar River in 2015. Table includes abundance of sub yearling and yearling migrants, 95% confidence intervals (C.I.), and coefficient of variation (CV).

Capture Method	Dates	Total Catch	Abundance	CV	95% C.I.	
					Low	High
Screw Trap	April 8 - July 8	5,209	107,874	7.96%	91,047	124,701

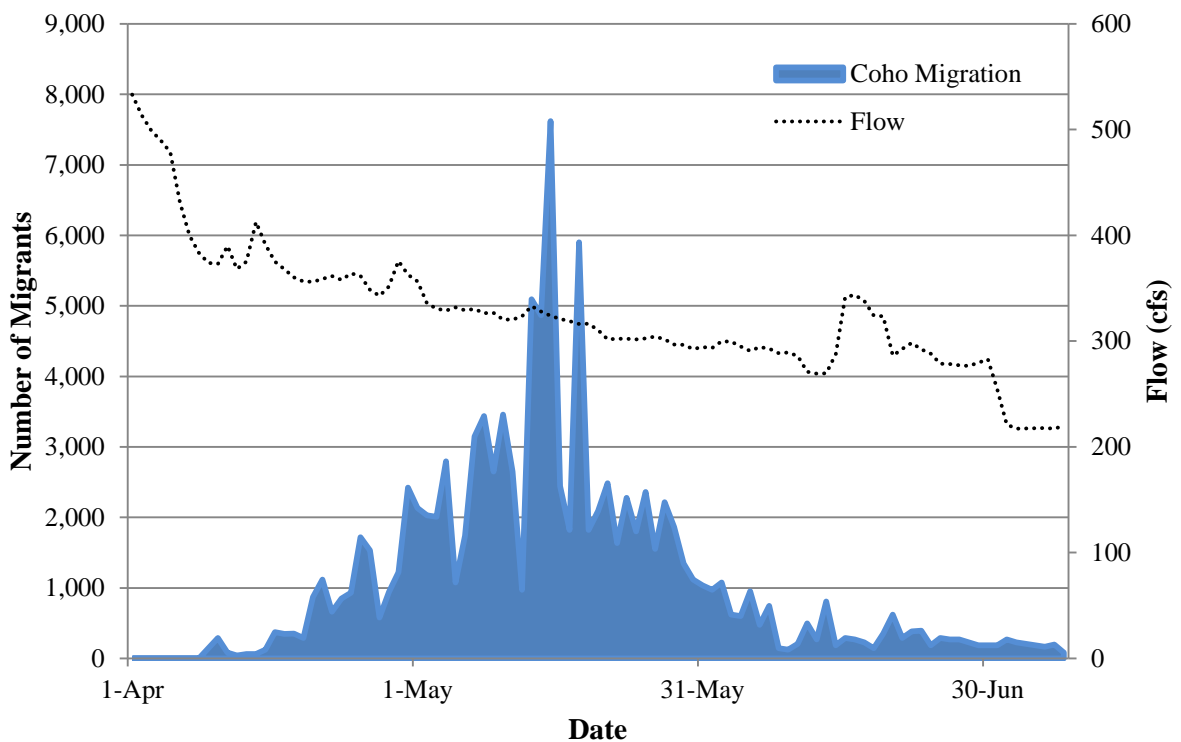


Figure 7. Daily coho migration and daily average flow (USGS Renton gage Station #12119000) at the Cedar River screw trap, 2015. Coho abundance includes both sub yearling and yearling coho caught in the Cedar River screw trap.

## Size

Average fork length of all measured coho migrants, both yearlings and sub yearlings, was 105.7 mm FL; weekly averages ranged from 94.5 mm to 114.3 mm FL. Individual migrants ranged from 48 mm to 147 mm FL (Figure 8).

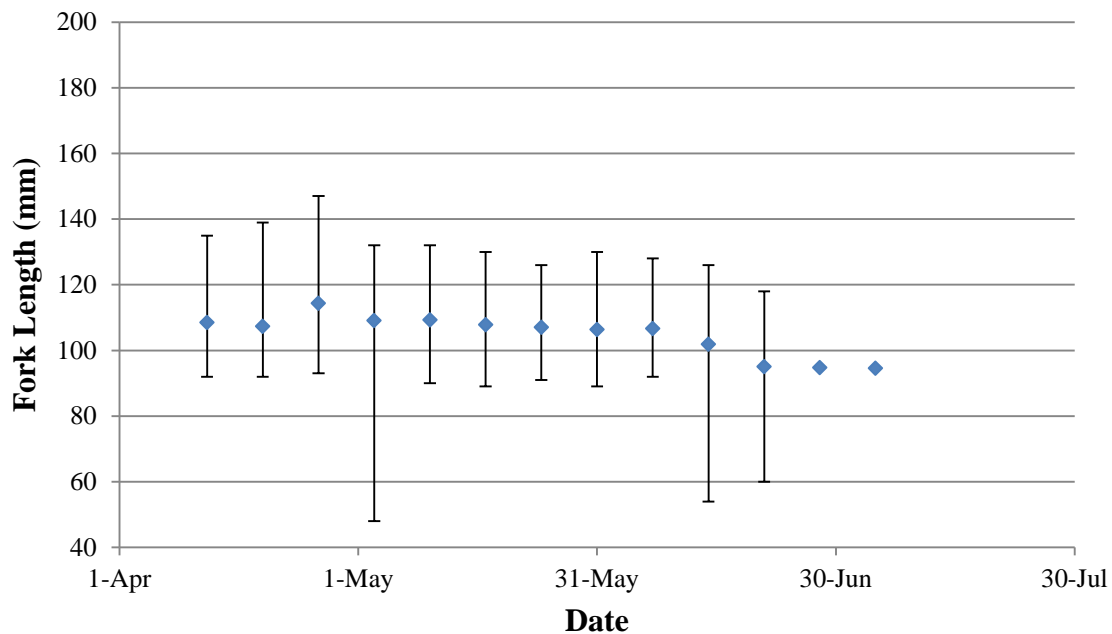


Figure 8. Fork lengths for coho migrants captured in the Cedar River screw trap in 2015. Data are mean, minimum, and maximum lengths.

## 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) caught in the inclined plane and screw trap. Cutthroat-rainbow hybrids may be included but are difficult to identify in the field. 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.

One rainbow trout and 4 cutthroat trout were captured in the inclined-plane trap. The cutthroat trout fork lengths ranged from 67 mm to 135 mm. No measurement was taken on the *O. mykiss*. Catches were too few to make abundance estimates.

A total of 7 unidentifiable trout fry, 12 steelhead migrants and 123 cutthroat trout were captured in the screw trap. Catches were too few to estimate migrant abundance. *O. mykiss* fork lengths ranged from 160 mm to 220 mm FL and averaged 182.3 mm FL. Cutthroat fork lengths ranged from 77 mm to 200 mm FL, and averaged 152.9 mm FL. Three adult cutthroat trout were also captured.

## Incidental Catch

Incidental catches in the inclined-plane trap included, 1 pink fry, and 3 chum fry. Other species caught included three-spine stickleback (*Gasterosteus aculeatus*), unspecified sculpin

species (*Cottus* spp.), lamprey (*Lampetra* spp.), speckled dace (*Rhinichthys osculus*), and large-scale sucker (*Catostomus macrocheilus*).

Other salmonids caught in the screw trap include 179 ad-marked hatchery Chinook parr, 2 sockeye smolts and 285 sockeye fry. Other species caught included three-spine stickleback, unspecified sculpin species, large-scale suckers, peamouth (*Mylocheilus caurinus*), longnose dace (*Rhinichthys cataractae*), pumpkinseed (*Lepomis gibbosus*), brown bullhead (*Ameiurus nebulosus*), lamprey (*Lampetra* spp.), and black crappie (*Pomoxis nigromaculatus*).

# Bear Creek

## Sockeye

### *Production Estimate*

Total catch (actual and estimated missed) in the Bear Creek screw trap was 77,166 sockeye fry during the trapping period from January 28 to July 1. This included an actual catch of 49,946 sockeye fry and an estimated missed catch of 27,220 sockeye fry. Trap outages included 20 full days early in the season due to staffing constraints and 8 periods in which heavy debris stopped the trap from fishing. In late-June water temperatures began to increase to a level where the handling of ESA listed species is not permitted. We intentionally stopped trap operations from June 26 to June 28 to prevent further stress on fish, as temperatures exceeded the safe handling limits of ESA-listed species. No sockeye were estimated for these additional 2 days.

Nineteen efficiency trials using sockeye fry were conducted during the season and aggregated into eight final strata, with capture rates ranging from 1.6% to 11.0% (Appendix B1). Catches were initially low and the first efficiency group was not released until March 8. Efficiency releases continued nearly twice or more weekly until April 10 when catches declined near the end of migration.

We estimated a total abundance of  $1,590,812 \pm 375,752$  ( $\pm 95\%$  C.I.) sockeye fry emigrating from Bear Creek in 2015 (Table 9, Figure 9). This estimate includes 1,388 sockeye estimated prior to the beginning of trapping (January 1 to January 27) and 1,589,424 sockeye that migrated during trapping efforts (January 28 to July 1).

Table 9. Abundance of sockeye fry migrants from Bear Creek in 2015. Table includes abundance of fry migrants, 95% confidence intervals (C.I.), and coefficient of variation (CV).

Capture Method	Dates	Total Catch	Fry Abundance	CV	95% C.I.	
					Low	High
Pre-trapping	Jan 1 - Jan 27		1,388	47.60%	94	2,682
Screw Trap	Jan 28 - July 1	77,166	1,589,424	12.1%	1,215,060	1,966,564
<b>Season Totals</b>		<b>77,166</b>	<b>1,590,812</b>	<b>12.1%</b>	<b>1,215,061</b>	<b>1,966,563</b>

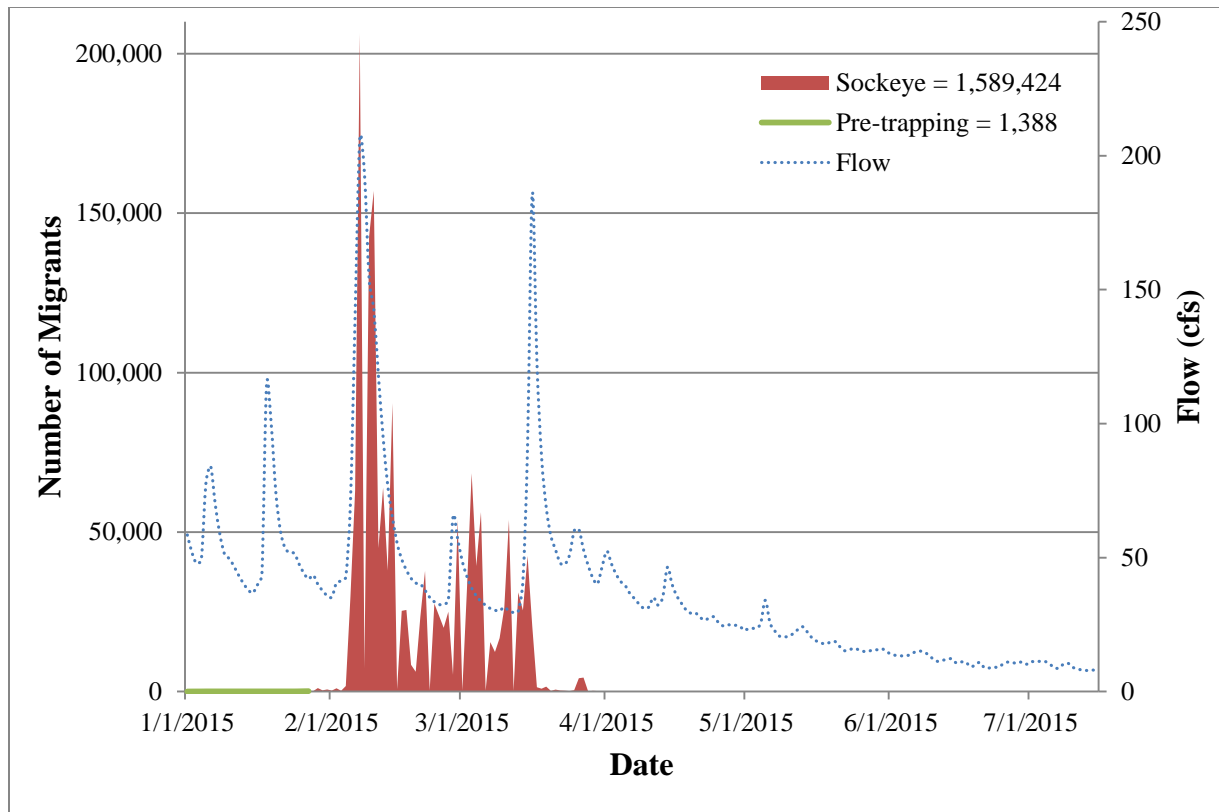


Figure 9. Estimated daily migration of sockeye fry from Bear Creek and daily average flow measured by the King County gage 02a at Union Hill Road in 2015 (<http://green.kingcounty.gov/wlr/waterres/hydrology>).

### **Egg-to-Migrant Survival**

Egg-to-migrant survival of the 2014 brood of Bear Creek sockeye was estimated to be 44.4% (Table 10). Survival was based on 1,590,812 fry migrants and a PED of 3,586,920 eggs. PED was estimated based on 1,065 females in 2014 (B. Craig, Washington Department of Fish and Wildlife, personal communication) and an average fecundity of 3,368 eggs per female based on the data from the Cedar River Sockeye Hatchery from brood year 2014 (Shoblom 2015). Similarly to the Cedar River, sockeye egg-to-migrant survival in 2015 was the highest observed since monitoring began.

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)	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
2013	2,003	1,001	3,362	3,365,362	438,534	13.0%	244	1/12/2014
2014	2,130	1,065	3,368	3,586,920	1,590,812	44.4%	206	2/7/2015

## Chinook

Total catch (actual and estimated missed) in the Bear Creek screw trap was 2,493 Chinook during the trapping period of January 28 to July 1. This included actual catch of 2,212 Chinook and an estimated missed catch of 281 Chinook during 22 full days and 8 periods when the trap was stopped by debris. This includes estimates for the two days in June when high water temperatures required trapping and handling of ESA listed species to cease.

### ***Production Estimate***

For the period between January 28 and May 3, sockeye trap efficiencies were used to estimate Chinook fry abundance because Chinook catches were insufficient for efficiency trials (Figure 10). From May 4 forward, a total of 21 efficiency trials were conducted with Chinook sub yearlings. Chinook sub yearling trials were aggregated into 2 strata; capture rates of these strata were 27.8% and 55.5%. Chinook migration during screw trap operation was estimated to be  $33,759 \pm 13,287$  ( $\pm 95\%$  C.I.) (Table 11, Appendix B2). This estimate includes 346 Chinook estimated to have migrated before trap operations began (January 1 to 27) and 33,413 Chinook that migrated during trap operations from January 28 to July 1.

Table 11. Abundance of natural-origin juvenile Chinook emigrating from Bear Creek in 2015. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), and coefficient of variation (CV).

Capture Method	Period	Total Catch	Abundance	95% C.I.		CV
				Low	High	
Pre-Trapping	January 1 - January 27		346	129	563	31.90%
Screw Trap	January 28 - July 1	2,493	33,413	20,128	46,698	20.30%
<b>Season Totals</b>			33,759	20,472	47,046	20.00%

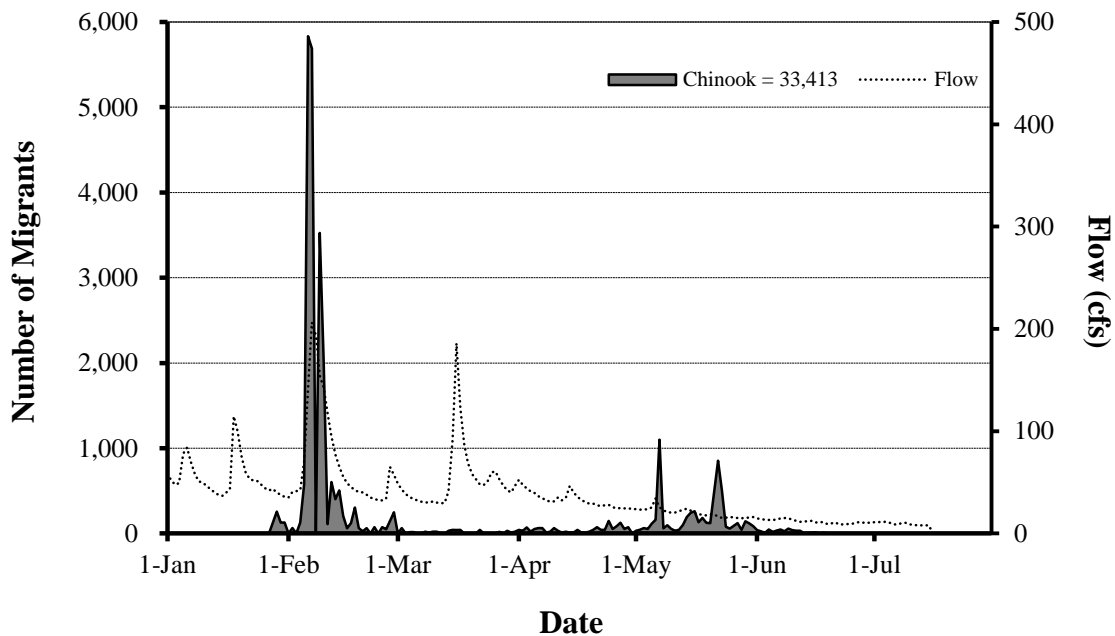


Figure 10. Daily migration of sub yearling Chinook and daily average flow from Bear Creek, 2015. Daily mean flows were measured at King County gage 02a at Union Hill Road in 2015 (<http://green.kingcounty.gov/wlr/waterres/hydrology>).

We estimated the abundance of two life-history forms of sub yearling Chinook salmon observed in Puget Sound: small fry migrating immediately after emergence and larger parr that spend some time rearing and growing in freshwater. Small fry migrants, defined by their emigration between January and April, comprised 78.5% of the total migration (Table 12). Large parr migrants, defined by emigration between May and July, represented 21.5% of total production in Bear Creek during 2015. Although fry and parr are defined by a timeframe, we do acknowledge that there are some annual variations in size during the defined timeframes. As a result there may be some parr sized fish included in the fry component and fry sized fish in the parr component. This was only the second time since monitoring began in 1999 when the fry component outnumbered the parr component in Bear Creek (Table 12). The larger than usual fry component may be driven by the higher flows that occurred in early February. Between February 6 and 10 over 20,000 Chinook fry were estimated to have migrated out of Bear Creek (Figure 9). In addition to being less numerous than the fry, the parr migration was also considerably smaller in abundance than most previous years (Table 12).



## Productivity

The 2014 brood of Bear Creek Chinook produced the second highest fry per female yet the fifth lowest parr per female since monitoring began. Productivity was based on 60 female spawners which is well below the average return (B. Craig, Washington Department of Fish and Wildlife, personal communication).

Table 12. Abundance and productivity (juveniles per female) 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 2014 brood years.

Brood Year	Juvenile Abundance			% Abundance		Est. Females	Juveniles/Female			Overall Survival
	Fry	Parr	Total	Fry	Parr		Fry	Parr	Total	
2000	419	10,087	10,506	4.0%	96.0%	133	3	76	79	1.8%
2001	5,427	15,891	21,318	25.5%	74.5%	138	39	115	154	3.4%
2002	645	16,636	17,281	3.7%	96.3%	127	5	131	136	3.0%
2003	2,089	21,558	23,647	8.8%	91.2%	147	14	147	161	3.6%
2004	1,178	8,092	9,270	12.7%	87.3%	121	10	67	77	1.7%
2005	5,764	16,598	22,362	25.8%	74.2%	122	47	136	183	4.1%
2006	3,452	13,077	16,529	20.9%	79.1%	131	26	100	126	2.8%
2007	1,163	11,543	12,706	9.2%	90.8%	89	4	143	147	3.2%
2008	14,243	50,959	65,202	21.8%	78.2%	132	108	386	494	11.0%
2009	1,530	7,655	9,185	16.7%	83.3%	48	32	159	191	4.3%
2010	901	16,862	17,763	5.1%	94.9%	60	15	281	296	6.6%
2011	4,000	18,197	22,197	18.0%	82.0%	55	73	331	404	9.0%
2012	24,776	19,823	44,599	55.6%	44.4%	147	169	135	303	6.7%
2013	24,266	38,509	62,775	38.7%	61.3%	48	506	802	1,308	29.1%
2014	25,500	7,233	32,733	77.9%	22.1%	60	425	121	546	12.1%

## Size

The minimum weekly average lengths of sub yearling Chinook migrants was less than 50.0 mm FL until early April then increased to average greater than 80 mm FL by late May with some fish over 100 mm. In early May Chinook ranged in size from 62 mm to 108 mm FL. By the end of June Chinook averaged 87.8 mm FL. (Figure 11).

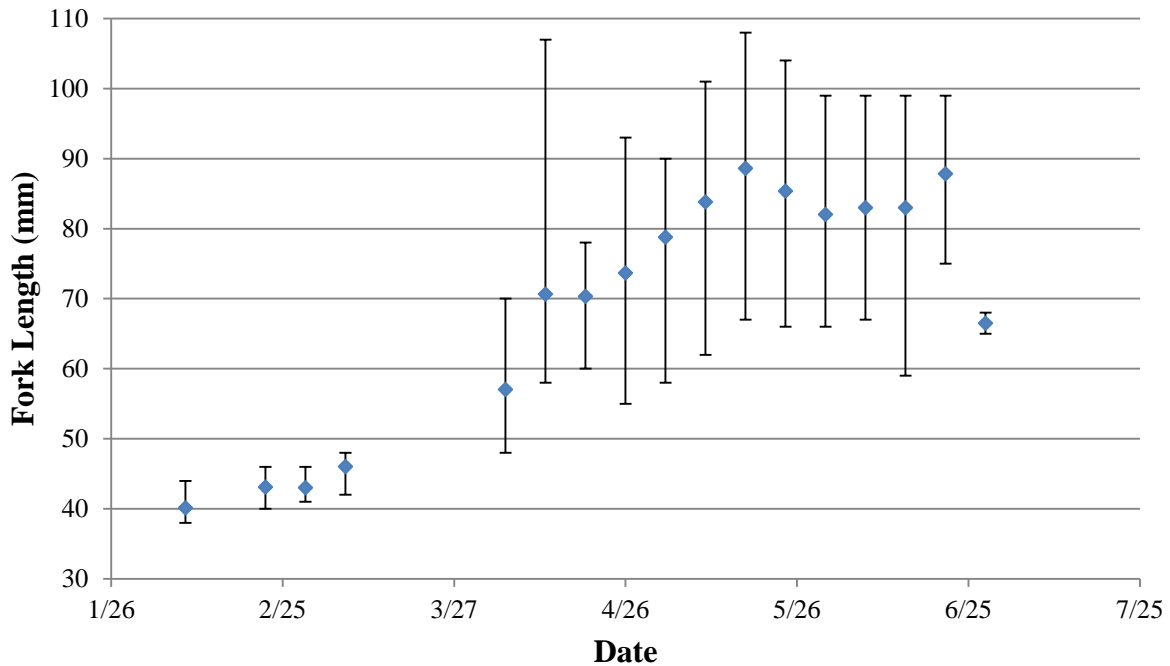


Figure 11. Fork lengths of sub yearling Chinook sampled from Bear Creek in 2015. Data are mean, minimum, and maximum lengths for each statistical week.

## Coho

Total catch (actual and estimated missed) in the Bear Creek screw trap was 5,205 sub yearling and yearling coho. This included an actual catch of 5,053 coho migrants and an estimated missed catch of 152 coho due to trap outages. Only 10 coho sub yearlings were caught, primarily fry, and contributed less than 0.2% of the total catch.

## Production Estimate

Abundance of coho was based on total catch and 44 efficiency trials, which were aggregated into 3 strata. Capture rates of efficiency strata ranged from 14.7% to 18.1%. Coho production was estimated to be  $30,544 \pm 520$  ( $\pm 95\%$  C.I.) smolts (Table 13, Figure 12, Appendix B 3). Similar to the Cedar River, coho fry and sub yearlings may exit Bear Creek and rear downstream for an unknown period of time before migrating to the marine waters of Puget Sound. Coho abundance is a measurement of total coho exiting Bear Creek in any given year.

Table 13. Abundance of natural-origin juvenile coho emigrating from Bear Creek in 2015. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), and coefficient of variation (CV).

Capture Method	Period	Total Catch	Abundance	95% C.I.		CV
				Low	High	
Screw Trap	January 28 - July 1	5,205	30,544	30,025	31,064	0.87%

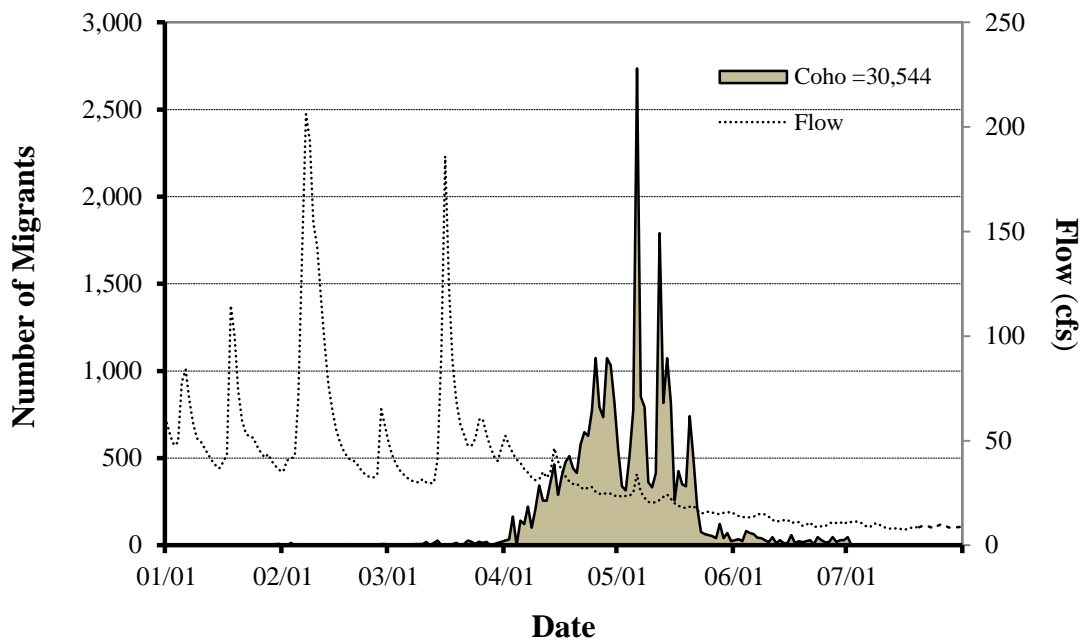


Figure 12. Daily migration of coho smolts in Bear Creek from January 28 to July 1, 2015. Graph also shows mean daily flows during this period. Flow data were measured at King County gage 02a at Union Hill Road in 2015 (<http://green.kingcounty.gov/wlr/waterres/hydrology>).

## Size

Over the trapping period, fork lengths of sub yearling and yearling coho ranged from 55 mm to 164 mm FL and averaged 113.3 mm FL (Figure 13). Weekly mean lengths ranged from 92.5 mm to 129.1 mm FL during trap operation.

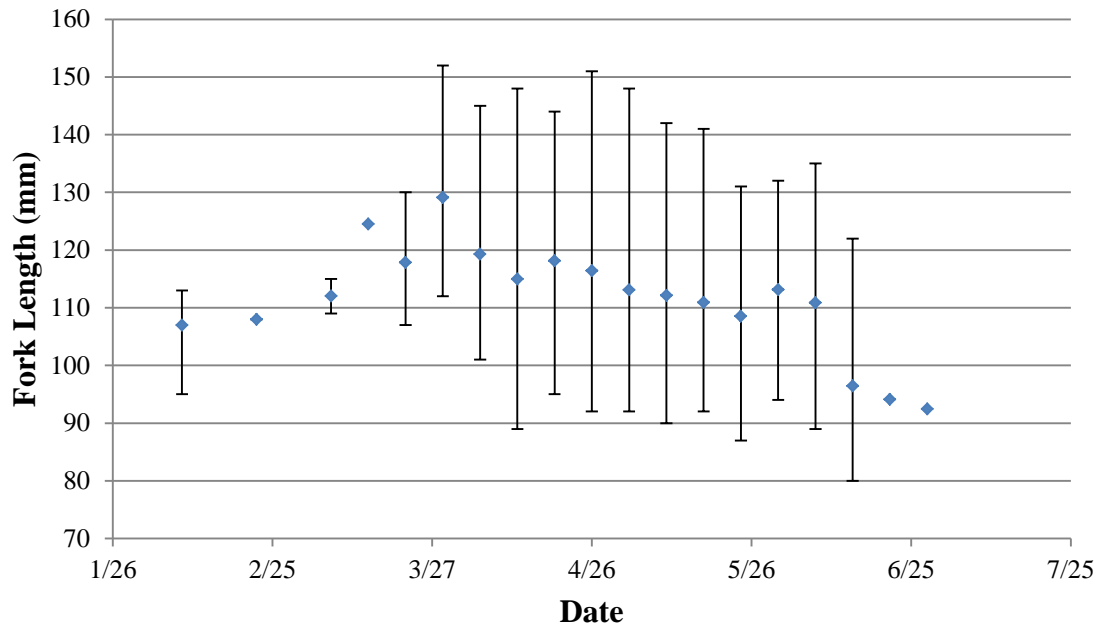


Figure 13. Fork lengths of migrating coho smolts caught at the Bear Creek screw trap in 2015. Data are statistical week mean, minimum, and maximum lengths.

## Trout

The identification of trout in Bear Creek poses the same difficulties discussed earlier in the Cedar River section. Trout were identified to species when possible based on visual identification. 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 necessarily the number of cutthroat migrating downstream towards Lake Washington and the marine waters of Puget Sound.

### ***Production Estimate***

No steelhead were captured during the entire 2015 trapping season in Bear Creek. Seven unidentifiable trout fry were also captured.

Total catch of cutthroat trout was 1,037. Catch was sporadic, making it difficult to conduct trap efficiency trials. A total of 11 trials, which released 345 cutthroat total, recaptured 48 fish (13.9%) over the entire season. Due to the low number of releases and sporadic small groups with low recaptures, we did not estimate cutthroat movement.

### ***Size***

Cutthroat trout fork lengths averaged 162.4 mm FL and ranged between 72 mm to 291 mm FL throughout the trapping season (Table 14). Average fork lengths showed no consistent trend across weeks.

Table 14. Cutthroat fork length (mm), standard deviation (SD), range, sample size (n), and catch by statistical week in the Bear Creek screw trap, 2015.

Statistical Week			Fork Length (mm)				n	Catch
Begin	End	No.	Avg.	SD	Range			
					Min	Max		
01/25	01/31	5	139.7	69.6	98	220	3	11
02/01	02/07	6						23
02/08	02/14	7	140.2	31.5	95	192	16	27
02/15	02/21	8	139.9	20.2	92	178	19	32
02/22	02/28	9	125.3	32.3	72	170	11	13
03/01	03/07	10	144.3	36.4	91	210	14	15
03/08	03/14	11	168.4	29.0	92	272	38	79
03/15	03/21	12	172.3	20.3	136	204	17	55
03/22	03/28	13	158.5	27.5	122	212	11	17
03/29	04/04	14	185.2	25.4	153	228	11	27
04/05	04/11	15	171.8	32.0	107	291	75	218
04/12	04/18	16	166.6	20.5	132	245	61	111
04/19	04/25	17	173.4	26.6	123	244	34	70
04/26	05/02	18	168.5	25.7	134	242	37	77
05/03	05/09	19	161.5	22.5	114	216	38	97
05/10	05/16	20	155.7	18.9	114	184	19	58
05/17	05/23	21	154.6	24.5	117	194	16	69
05/24	05/30	22	134.0	n/a	134	134	1	9
05/31	06/06	23	150.3	10.9	134	157	4	9
06/07	06/13	24	132.7	20.9	109	170	7	12
06/14	06/20	25	157.0	na/	157	157	1	3
06/21	06/27	26	125.0	19.8	111	139	2	2
06/28	07/04	27						3
<b>Season Totals</b>			<b>162.4</b>	<b>29.2</b>	<b>72</b>	<b>291</b>	<b>435</b>	<b>1,037</b>

## Incidental Species

In addition to target species, the screw trap captured 9 hatchery coho smolts, 7 trout fry, 22 hatchery trout plants from Cottage Lake and 43 cutthroat adults (larger than 250 mm). Other species caught included lamprey (*Lampetra* spp.), green sunfish (*Lepomis cyanellus*), three-spine stickleback (*Gasterosteus aculeatus*), sculpin (*Cottus* spp.), whitefish (*Prosopium* spp.), peamouth (*Mylocheilus caurinus*), dace (*Rhinichthys* spp), bluegill (*Lepomis macrochirus*), large-scale suckers (*Catostomus macrocheilus*), small mouth bass (*Micropterus dolomieu*), pumpkinseed (*Lepomis gibbosus*), northern pike (*Esox lucius*), rock bass (*Ambloplites rupestris*), and brown bullhead catfish (*Ameriurus nebulosus*).



## PIT Tagging

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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 April 29 through July 3, 2015. Over the season, a total of 861 natural-origin Chinook parr were PIT tagged at the Cedar River screw trap (Table 15). This tag group comprised 4.2% of the estimated Chinook parr production from the Cedar River in 2015. A total of 63 Chinook PIT tags (7.3%) were detected as they moved through the smolt flumes at the Chittenden Locks while exiting Lake Washington. This is the lowest proportion of Chinook detected at the Locks since the analysis began. The first Chinook was detected on May 21, 2015 and the last on June 21, 2015 (Table 16). Median migration date of Chinook detected moving through the Locks was May 29, 2015. Individual travel times from the Cedar River to the Locks averaged 19.5 days (SD = 7.5). Average fork length of Chinook PIT tagged during the season was 88.2 mm and ranged from 64 mm to 115 mm. Average fork length of Chinook detected at the Chittenden Locks during the sample period was 87.6 mm, with a range of 75 mm to 102 mm.

In Bear Creek tagging occurred from May 4 through June 17, 2015. A total of 1,414 Chinook were tagged throughout the season and represented 19.4% of estimated Chinook parr production. A total of 114 Chinook PIT tags (8.1%) were detected as they moved through the smolt flumes at the Chittenden Locks (Table 15). The first Chinook was detected at the Locks was May 19, 2015 and the last was detected June 18, 2015 (Table 17). Individual travel times from Bear Creek to the Locks averaged 17.7 days (SD = 7.4). Average fork length of Chinook PIT tagged at Bear Creek was 84.7 mm and ranged from 65 mm to 108 mm. Average fork length of Chinook detected at the Chittenden Locks was 87.8 mm and ranged from 70 mm to 101 mm.

In 2015, 3,568 hatchery Chinook were PIT tagged at Issaquah Hatchery between April 20 and May 4. These fish comprised three similar size groups to represent each of the three Chinook hatchery releases scheduled for 2015. Fork lengths of Chinook at tagging ranged from 63 mm to 97 mm and averaged 79.6 mm. The tagging occurred roughly 5 to 9 days prior to release, so the length of fish at release is unknown but assumed to accurately represent the hatchery population. Healthy Chinook were placed back into the general hatchery population before releases that occurred on three separate days: May 1, 4, and 8, 2015. According to hatchery records, the average length of Chinook at release was 85.4mm, 82.8mm, and 81.2 mm respectively. Issaquah Hatchery Chinook were first detected at the Chittenden Locks on May 18 and continued through June 13, 2015. Average travel time was 31.7 days. Detection rate was 3.8%, considerably lower than both Cedar River and Bear Creek Chinook, yet similar to the 2014 detection rate of the Issaquah Hatchery group (2.7%). It is unclear where along the migration route the loss of hatchery Chinook was highest. Installation of PIT tag antenna along the migration corridor may help identify mortality hotspots. One alternative is that hatchery Chinook simply chose an alternate route through the Chittenden Locks at a higher rate than the natural-origin Chinook from Cedar River and Bear Creek, or that hatchery Chinook residualize

in either Lake Sammamish or Lake Washington resulting in lower detections of hatchery Chinook than natural-origin Chinook.

The portion of PIT tagged Chinook detected at the Locks from the Cedar River in 2015 appears to be the lowest since 2010. However detection rates at the Locks for Bear Creek Chinook appear to be similar to previous years (Table 16, Table 17). The 2015 median migration date for both locations is the earliest since 2010. The period between the first and last detections is also truncated compared to previous years, lasting only four weeks in 2015 compared to the average of ten weeks in previous years. Detections of 2015 Issaquah Hatchery Chinook also display a rather truncated migration period of three weeks relative to the seven week period observed during 2014.

In 2015, the smolt flumes were operational from April 20 to July 7 however a variety of issues prevented continuous operation of the PIT tag antenna within the flumes. These issues may have contributed to the lower than expected detection rates. Construction at the Chittenden Locks facility caused power outages and damage to fiber optic cables, leading to communication outages during outmigration. Prior to May 8 only one flume was fully operational. Damaged cables prevented full detection capabilities until May 8. Due to a power supply issue on June 3 and 4 we believe we missed some detection of outmigrating fish through the smolt flumes on those days. Only five fish were detected on June 1 and two fish on June 9, the detections bracketing the known outage on June 3 and 4. With such few fish detected on surrounding days, it's unlikely that missed detections on June 3 and 4 would significantly alter detection. Due to the unknown number of tagged fish that migrated through the Locks facility during these outages, the 2015 data likely has a lower overall detection rate compared to recent years.

Another possible factor affecting detection rates of out-migrating Chinook salmon could be the use of other routes to exit Lake Washington. Due to low water supply in 2015, only one flume was operated during most of the outmigration season. The lack of flow attraction to the flume may have cause Chinook to use alternative routes, such as through the large or small locks. Extremely warm surface water temperatures may have also contributed to flume avoidance as the flumes draw surface water to operate.



Table 15. Natural-origin Chinook parr PIT tagged from the Cedar River and Bear Creek screw traps in 2015.

Statistical Week			Cedar River Screw Trap						Bear Creek Screw Trap							
Begin	End	No.	# Tagged	Length (mm)			Portion of Parr Migration	# Detected @ Locks	% of Tags Detected	# Tagged	Length (mm)			Portion of Parr Migration	# Detected @ Locks	% of Tags Detected
				Avg	Min	Max					Avg	Min	Max			
27-Apr	3-May	18	39	78.0	64	90	3.7%	8	0.0%	382	82.8	65	108	24.7%	66	0.0%
4-May	10-May	19	154	82.1	64	99	7.4%	8	5.2%	233	88.7	67	108	18.9%	33	17.3%
11-May	17-May	20	216	86.0	65	102	5.7%	22	10.2%	514	85.3	66	104	23.5%	15	14.2%
18-May	24-May	21	142	89.6	75	110	6.6%	23	16.2%	120	82.0	66	99	20.9%		2.9%
25-May	31-May	22	147	90.5	75	101	3.2%	8	5.4%	73	83.0	67	99	31.1%		0.0%
1-Jun	7-Jun	23	102	94.2	77	115	3.0%	1	1.0%	80	83.3	70	99	58.1%		0.0%
8-Jun	14-Jun	24	32	98.3	72	111	2.2%	1	3.1%	12	87.8	75	99	67.1%		0.0%
15-Jun	21-Jun	25	22	99.2	84	113	3.6%		0.0%							0.0%
22-Jun	28-Jun	26	6	98.7	85	114	1.8%		0.0%							0.0%
29-Jun	5-Jul	27	1	103.0	103	103	1.6%		0.0%							0.0%
<b>Season Total</b>			<b>861</b>	<b>88.2</b>	<b>64</b>	<b>115</b>	<b>4.2%</b>	<b>63</b>	<b>7.3%</b>	<b>1,414</b>	<b>84.7</b>	<b>65</b>	<b>108</b>	<b>19.4%</b>	<b>114</b>	<b>8.1%</b>

Table 16. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Cedar River screw trap, tag years 2010 to 2015. 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	6.1%	482	21.6%	29.9	05/24	08/25	06/24
2011	594	87.3	65	118	5.8%	116	19.5%	19.3	05/26	08/27	06/07
2012	1,671	84.0	64	123	4.3%	212	12.7%	30.0	05/29	09/14	07/08
2013	711	81.3	58	108	3.7%	209	29.4%	17.3	05/26	07/17	06/19
2014	1,944	83.8	65	122	5.9%	172	8.8%	24.8	05/24	07/29	06/13
2015	861	88.2	64	115	4.2%	63	7.3%	19.5	05/21	06/21	05/29

Table 17. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Bear Creek screw trap, tag years 2010 to 2015. 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	7.8%	103	17.5%	26.1	06/06	07/07	06/23
2011	2,316	79.9	65	102	26.3%	337	14.6%	15.1	05/23	07/29	06/05
2012	2,721	75.2	62	97	12.2%	316	11.6%	31.3	05/22	08/13	06/21
2013	1,858	79.3	58	102	9.8%	518	27.9%	12.3	05/16	07/20	06/12
2014	1,968	77.6	62	103	4.8%	324	16.5%	23.9	05/20	07/14	06/12
2015	1,414	84.7	65	108	19.4%	114	8.1%	17.7	05/19	06/18	05/28

Table 18. PIT tag and migration timing of hatchery-origin Chinook released from Issaquah hatchery, years 2014 and 2015. Detection data is from the Hiram Chittenden Locks.

Tag Year	Release Date	# Tagged	# Detected @ Locks	% of Tags Detected	Avg Travel Time (days)	First Detection	Last Detection
2014	23-May	5000	137	2.74%	34	06/08	07/27
2015	1-May	1193	60	5.03%	26	05/21	06/13
2015	4-May	1186	49	4.13%	24	05/18	06/13
2015	8-May	1189	33	2.78%	21	05/21	06/13

## **Appendix A**

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Catch and Migration Estimates by Strata for Cedar River  
Sockeye, Chinook, and Coho Salmon, 2015.

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Appendix A 1. Catch and migration by strata for Cedar River natural-origin sockeye fry, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
Pre Trap	1/1/2014	1/13/2015			14,309	8.5x10 <sup>6</sup>
1	1/14/2015	2/5/2015	6,760	1.22%	532,047	1.15x10 <sup>10</sup>
2	2/6/2015	2/16/2015	8,323	0.54%	1,488,800	6.63x10 <sup>10</sup>
3	2/17/2015	2/23/2015	15,582	1.13%	1,361,777	2.39x10 <sup>10</sup>
4	2/24/2015	2/25/2015	5,181	1.88%	272,801	1.14x10 <sup>9</sup>
5	2/26/2015	2/26/2015	3,098	0.34%	734,221	8.96x10 <sup>10</sup>
6	2/27/2015	3/3/2015	21,531	1.82%	1,176,318	5.85x10 <sup>9</sup>
7	3/4/2015	3/8/2015	25,439	1.01%	2,384,241	3.86x10 <sup>11</sup>
8	3/9/2015	3/11/2015	21,919	3.00%	728,361	1.22x10 <sup>10</sup>
9	3/12/2015	3/14/2015	32,515	1.80%	1,774,124	1.27x10 <sup>11</sup>
10	3/15/2015	3/15/2015	928	0.26%	178,653	1.06x10 <sup>10</sup>
11	3/16/2015	3/18/2015	8,363	1.30%	632,019	7.21x10 <sup>9</sup>
12	3/19/2015	3/22/2015	9,711	2.08%	460,752	2.99x10 <sup>9</sup>
13	3/23/2015	3/29/2015	12,208	1.34%	900,216	1.18x10 <sup>10</sup>
14	3/30/2015	4/2/2015	5,394	0.95%	562,738	6.49x10 <sup>9</sup>
15	4/3/2015	4/10/2015	4,182	1.75%	236,664	5.71x10 <sup>8</sup>
16	4/11/2015	4/12/2015	728	0.24%	202,912	1.03x10 <sup>10</sup>
17	4/13/2015	5/3/2015	2,639	1.67%	154,233	6.08x10 <sup>8</sup>
Post Trap	5/4/2015	6/30/2015			83,746	4.60x10 <sup>8</sup>
<b>Total</b>			<b>184,500</b>	<b>1.67%</b>	<b>13,878,932</b>	<b>7.74x10<sup>11</sup></b>

Appendix A 2. Catch and migration by strata for Cedar River natural-origin Chinook fry, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
Pre Trap	1/1/2014	1/13/2015			13,309	8.72x10 <sup>6</sup>
1	1/14/2015	3/8/2015	5,683	1.85%	300,558	2.07x10 <sup>9</sup>
2	3/9/2015	3/15/2015	325	10.20%	2,705	1.06x10 <sup>6</sup>
3	3/16/2015	4/7/2015	269	1.75%	10,329	2.66x10 <sup>7</sup>
<b>Total</b>			<b>6,277</b>		<b>326,901</b>	<b>2.09x10<sup>9</sup></b>

Appendix A 3. Catch and migration by strata for Cedar River natural-origin Chinook parr, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	4/8/2015	5/25/2015	844	7.5%	10,956	2.90x10 <sup>6</sup>
2	5/26/2015	7/8/2015	306	2.6%	9,769	1.35x10 <sup>7</sup>
Post Trap	7/9/2015	7/13/2015			37	3.40x10 <sup>2</sup>
<b>Total</b>			<b>1,150</b>		<b>20,762</b>	<b>1.64x10<sup>7</sup></b>

Appendix A 4. Catch and migration by strata for Cedar River natural-origin coho migrants, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	4/8/2015	7/8/2015	5,209	4.8%	107,874	$7.4 \times 10^7$
<b>Total</b>			<b>5,209</b>		<b>107,874</b>	<b><math>7.4 \times 10^7</math></b>

## **Appendix B**

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Catch and Migration Estimates by Strata for Bear Creek  
Sockeye, Chinook, Coho Salmon, and Cutthroat Trout, 2015.

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Appendix B 1 Catch and migration by strata for Bear Creek sockeye, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
Pre Trap	1/1/2015	1/26/2015			1,388	4.36x10 <sup>5</sup>
1	1/27/2015	2/10/2015	9,536	1.56%	612,357	3.17x10 <sup>10</sup>
2	2/11/2015	2/15/2015	13,011	5.47%	238,013	7.92x10 <sup>8</sup>
3	2/16/2015	2/17/2015	5,848	11.49%	50,903	2.02x10 <sup>7</sup>
4	2/18/2015	2/18/2015	358	4.27%	8,377	4.37x10 <sup>6</sup>
5	2/19/2015	2/22/2015	5,411	7.98%	67,804	2.49x10 <sup>8</sup>
6	2/23/2015	3/1/2015	6,320	4.06%	155,523	2.26x10 <sup>9</sup>
7	3/2/2015	3/7/2015	13,429	6.33%	212,184	1.09x10 <sup>9</sup>
8	3/8/2015	7/1/2015	23,252	9.52%	244,263	6.24x10 <sup>8</sup>
<b>Total</b>			<b>77,166</b>		<b>1,590,812</b>	<b>4.00x10<sup>10</sup></b>

Appendix B 2. Catch and migration by strata for Bear Creek natural-origin Chinook, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
Pre Trap	1/1/2015	1/26/2015			346	1.23x10 <sup>4</sup>
1	1/27/2015	2/10/2015	348	1.56%	22,318	4.54x10 <sup>7</sup>
2	2/11/2015	2/15/2015	100	5.47%	1,827	1.92x10 <sup>5</sup>
3	2/16/2015	2/17/2015	21	11.49%	183	1.65x10 <sup>3</sup>
4	2/18/2015	2/18/2015	13	4.27%	304	1.19x10 <sup>4</sup>
5	2/19/2015	2/22/2015	12	7.98%	150	2.42x10 <sup>3</sup>
6	2/23/2015	3/1/2015	24	4.06%	593	2.26x10 <sup>4</sup>
7	3/2/2015	3/7/2015	6	6.33%	95	1.76x10 <sup>3</sup>
8	3/8/2015	5/3/2015	180	9.52%	1,888	3.60x10 <sup>4</sup>
9	5/4/2015	6/3/2015	1,600	28.00%	5,714	2.24x10 <sup>5</sup>
10	6/4/2015	7/1/2015	190	55.93%	340	1.04x10 <sup>3</sup>
<b>Total</b>			<b>2,493</b>		<b>33,759</b>	<b>5.00x10<sup>7</sup></b>

Appendix B 3. Catch and migration by strata for Bear Creek natural-origin coho smolts, 2015.

Strata	Date		Total Catch	Recapture Rate	Estimated Migration	Variance
	Begin	End				
1	1/27/2015	4/18/2015	697	11.9%	4,694	2.86x10 <sup>5</sup>
2	4/19/2015	4/25/2015	857	37.9%	4,558	2.71x10 <sup>5</sup>
3	4/26/2015	7/1/2015	3,650	12.7%	21,293	2.39x10 <sup>6</sup>
<b>Total</b>			<b>5,205</b>		<b>30,544</b>	<b>2.94x10<sup>6</sup></b>



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