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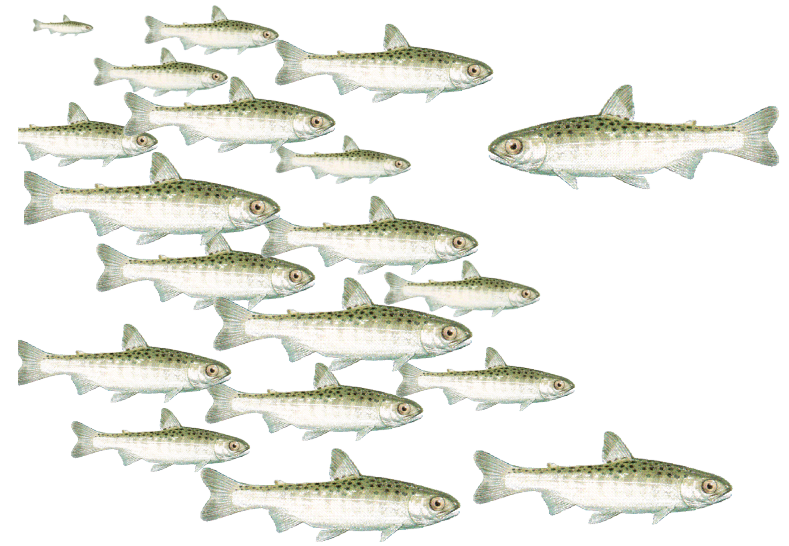
Evaluation of Juvenile Salmon Production in 2018 from the Cedar River and Bear Creek



by Peter Lisi

Washington Department of
Fish and Wildlife
Fish Program
Science Division

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Evaluation of Juvenile Salmon Production in 2018 from the Cedar River and Bear Creek

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Introduction

This report describes the emigration of five salmonid species from two tributaries in the Lake Washington watershed. The Cedar River tributary flows into the southern end of Lake Washington and Bear Creek flows into the Sammamish River, which in turn 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 sources 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 abundance 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 operated in the Sammamish River during the downstream sockeye migration. In 1999, the monitoring site was relocated to Bear Creek to evaluate Chinook and sockeye production. Since 1999, the Bear Creek juvenile monitoring study estimates coho production and movement of steelhead and cutthroat trout.

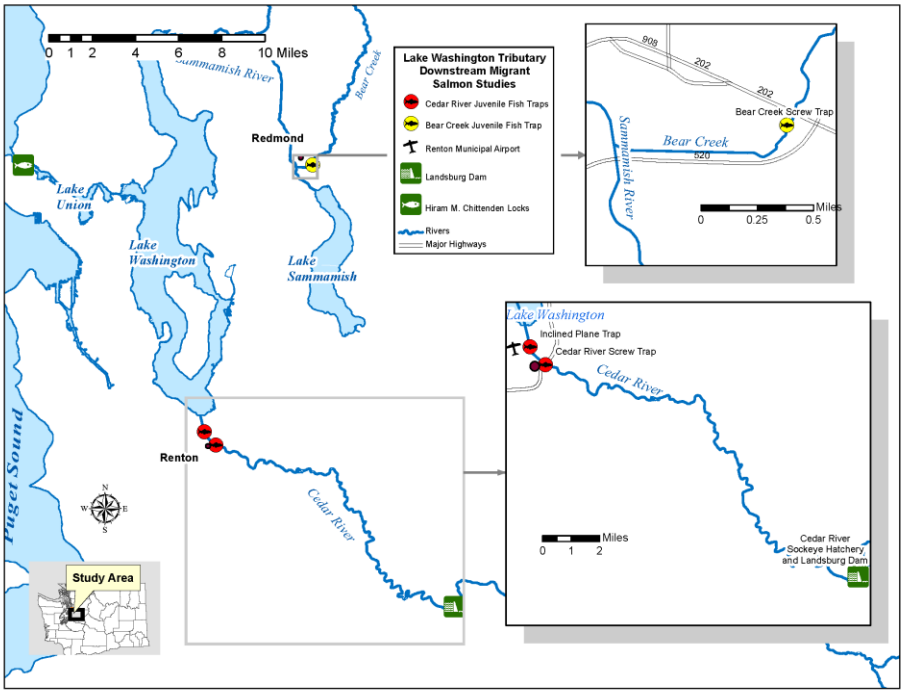

Figure 1. Map of Lake Washington trap sites used to monitor abundance of juvenile migrant salmonids in the Cedar River and Bear Creek, near Renton and Redmond, respectively.

The primary goal of this study was to estimate the abundance of natural-origin sockeye fry, natural-origin Chinook, and natural-origin coho migrating from the Cedar River and Bear Creek into Lake Washington in 2018. These data allow an estimate of egg to fry survival of the 2017 brood. Daily abundance estimates also characterized the migration timing of each species into Lake Washington.

Methods

Fish Collection

Trapping Gear and Operation

Cedar River

A rotary screw trap operated in the lower Cedar River during the late winter and spring out migration period to assess migration of sockeye and Chinook fry, larger sub-yearling Chinook, coho, steelhead, and resident cutthroat. The Cedar River screw trap is a 5-ft diameter rotary scrap trap supported by a 12-ft x 30-ft steel pontoon barge (Seiler et al., 2003). The screw trap operated at river mile (R.M) 1.6, under the I-405 Bridge (Figure 1) continuously for the entire migration period from mid-January through mid-July. The trap did not fish during 14 daylight and 17 night periods due to high river flows or public safety concerns. The trap also did not operate on 10 day and night periods to avoid catch of hatchery released sockeye salmon, which are extremely abundant and compromise our ability to count natural-origin fry when present. Debris jams stopped the trap from fishing during five daylight and 14 night periods. Catches were enumerated by species at dusk and dawn in order to discern diel movements. Fork lengths were randomly sampled on a weekly basis from all sockeye, Chinook, coho, and cutthroat.

Over the duration of the Cedar River juvenile monitoring study, trapping operations moved in response to changes in channel morphology. From 1992 to 2016, a small floating inclined-plane trap operated nightly from January through early April (Seiler et al., 2003). In the summer of 1998, dredging in the lower Cedar River forced the inclined-plane trap location to relocate in 1999 from R.M 0.25 to R.M 0.8 in order to operate under suitable river velocities. Beginning in 1999, WDFW also began operating a rotary screw trap at R.M 1.6 for the period April to July to enumerate Chinook salmon.

In contrast to previous years, during 2017 and 2018, we operated only a single rotary screw for the duration of the season at R.M 1.6. We made this change for three reasons. First, dredging in 2016 resulted in major channel modifications in the lower Cedar River that compromised the inclined-plane trapping site. Second, for the purposes of data comparability, we sought to use a single gear type over the course of the trapping season rather than one gear type early (incline plane) and different gear type late (rotary screw). Finally, the rotary screw trap simplifies trap staffing because unlike the incline plane trap, it does not require a trap operator to be present during all hours of operation. Thus, the inclined-plane trap was retired.

The Cedar River Hatchery at Landsburg releases sockeye fry into the Cedar River during the winter and spring to contribute to sockeye returns to the Cedar River and to help promote Lake Washington fisheries. The hatchery released 6.95 million sockeye fry into the Cedar River over 9 nights throughout the 2018 migration period. Hatchery staff released fry at three separate locations and often at two locations on the same night. In total, seven releases occurred at the lower location (R.M. 2.1), six from the middle location (R.M. 13.5), and five releases at upper location (R.M. 21.8). To avoid complications estimating hatchery and natural-origin components, the trap did not operate on hatchery release nights. We estimated missed catch of natural-origin sockeye during

hatchery nights when the trapped was pulled out of the water. Residual hatchery sockeye can migrate for up to three nights after a hatchery release (Kiyohara, 2013). Since hatchery sockeye fry are not externally identifiable as hatchery fish, we are unable to assess the rate of contribution of hatchery fry to natural origin catch and abundance. In some instances, larger fry size is indication of when fry are fed before their release. True abundance and survival of natural origin sockeye is likely lower than reported if hatchery fish delay their migration by one or more nights after a release.

Bear Creek

A rotary screw trap operated from January 25 to July 10, 2018, ~100 yards downstream of the Redmond Way Bridge at the railroad trestle (Figure 1). The trap fished continuously, except for 14 periods when high flows and debris stopped the trap, and for six night or day periods, when the trap was pulled due to an extreme abundance of peamouth chub (*Mylocheilus caurinus*) during their spawning aggregations. Technicians enumerated the catch by species daily at dawn and dusk. Fork lengths were randomly sampled on a weekly basis from all Chinook, coho, and cutthroat.

Similar to the Cedar River, trapping operations changed in response to flow conditions, project objectives, and safety concerns. From January to April, an inclined-plane trap operated 100 yards downstream of the Redmond Way Bridge in years 1999 through 2011. A rotary screw trap fished for the remainder of the season from April to July. The inclined-plane trap was retired after 2011. The rotary screw trap now operates in late January to cover the early fry migration period as well as the spring parr and smolt migrations.

PIT Tagging

During screw trap operation at both sites, a portion of natural-origin Chinook migrants and Steelhead smolts received passive integrated transponder (PIT) tags. Tagging occurred three to five times a week, between late April and June, and following standard protocols outlined by the Columbia River basin by the PIT Tag Steering Committee (2014). Chinook longer than 65 mm that displayed good physical health received a PIT tag. Fish were released the same day of capture or held overnight in perforated buckets suspended off the stern of the trap. Hatchery Chinook sub-yearlings were also PIT tagged at Issaquah Hatchery. 1,000 fish per week were released into Issaquah Creek covering three weeks: May 1, 8, and 24. All fish were tagged and held at the Issaquah hatchery one to two weeks in advance of their release.

The Hiram Chittenden Locks demarcate the freshwater to marine boundary between the Lake Washington watershed and Puget Sound (Figure 1). The locks have several PIT tag detection antennas in four smolt flumes and the adult fish ladder. One of two filling culverts in the large lock received a PIT tag antenna array in the fall of 2015. The following analysis includes detections from the filling culvert array. Here, the median migration date is the median date of all detected fish at all detection locations. The average travel time is the difference between release date and detection date. The survival rate is the total unique detections relative to the total released at each site.

Trap Efficiencies

Throughout the season, mark and recapture of sockeye fry, Chinook, and coho provide an estimate of trap efficiency. Fry were marked in a solution of Bismarck brown dye (14 ppm for 1 hour) in an aerated bucket of stream water. Only healthy, marked fry were released above the trapping site while deceased or injured fish were removed. The trap efficiency for a day or night period is the total recaptured fish relative to the total number of released fish. In the Cedar River, efficiency trials were occasionally supplemented with hatchery sockeye fry to increase the size of release groups.

Larger Chinook parr were PIT tagged while coho were marked with alternating upper and lower, vertical and horizontal partial-caudal fin clips. A dilute solution of MS-222 and stream water anesthetized parr before clipping. Marks alternated on weekly intervals or more frequently with significant changes in river discharge. Beginning April 24, Chinook parr larger than 65 mm FL received PIT tags. Similar to fin clips, PIT tags enable stratified releases and recaptures. Before releasing, clipped Coho and PIT tagged Chinook fish recovered from marking in perforated buckets suspended behind the trap in calm river water.

Trap efficiency trials occurred every other night, with frequency determined by the catch of each species. Releases of fry, smolt, and parr in the Cedar River occurred 2 km upstream of the trap at the Maplewood Roadside Park. Fry were released 100 meters upstream of the Bear River trap at the Redmond Way Bridge and smolts 700 m upstream at the Union Hill Bridge.

Analysis

The abundance of juvenile migrant salmonids is estimated using a mark-recapture approach and a single trap design (Volkhardt et al. 2007). The analysis is stratified by time in order to account for heterogeneity in capture rates throughout the season. The general approach is 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* is the actual catch (*n*) summed with estimated missed catch ($\hat{n}$) during trap outages. Missed catch is estimated using one of three different approaches depending on when a trap outage occurred because migration rates differ between the day and night: 1) entire missed night periods, 2) partial day or night periods, and 3) entire day periods when trap operations suspended.

Missed Catch for Entire Night Periods

For night outages, missed catch is a straight-line interpolation between catches on adjacent nights. This approach assumes that abundance of migrating fish during the adjacent nights are similar to the outage period. When the outage occurred on a single night, variance of the estimated catch is the variance of the mean catch on adjacent nights (Equation 1). When the outages occur

on consecutive nights, then missed catch is estimated from one or both adjacent night catches (Equation 2).

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 interpolates between two or more consecutive nights, variance for each interpolated catch estimate is scaled by 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 trap operated intermittently, missed catch during the un-fished interval ($\hat{n}_i$) 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 $\hat{n}_i$ estimated by:

Equation 5

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

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

Equation 6

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

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) estimated as:

Equation 7

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

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

Equation 8

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

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 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 size. 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).

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 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 is based on the first and last five days of the catch. 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 is the sum of the stratified abundance estimates for all k strata and the extrapolated migration estimates. Confidence intervals and coefficient of variation associated with abundances are calculated from the variance:

Equation 13

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

Egg-to-Migrant Survival and Productivity

Egg-to-migrant survival is the abundance natural-origin juvenile migrants (age 0+) relative to the previous fall egg deposition by female adult spawners. The potential egg deposition (PED) is the product of the number of female spawners and their fecundity. Weekly fall spawning surveys estimate the number of sockeye spawners (assuming 50% are female) in Cedar River and Bear Creek. Cedar River sockeye fecundity during the broodstock collection for the hatchery was 3,050 eggs per female in 2017 (Sedgwick, 2018). The fecundity of Bear Creek sockeye are assumed to be the same as the fecundity of Cedar River broodstock sockeye.

Productivity for Chinook in both the Cedar River and Bear Creek is the number of age 0+ out migrants produced per female spawner. Two life-history forms of sub-yearling Chinook salmon are observed in Puget Sound: small fry that migrate immediately after emergence and larger parr that spend several weeks to months rearing in freshwater streams. Fry are defined as fish emigrating between January and early April (8^{th}) and larger parr are defined as fish emigrating between early April (9^{th}) and July. Here, Chinook freshwater productivity is the number of migrants (both fry and parr combined) per female. The number of female Chinook is based on weekly fall redd counts and assumed to represent one female per redd. Average fecundity for the Cedar River and Bear Creek is assumed to be similar to the fecundity of Soos Creek Hatchery Chinook on the Green River (4,500 eggs per female). In recent years, the survival rate of Chinook appears high (e.g. 61.9% in 2011 Cedar). A possible source of overestimating the survival rate is underestimating fecundity. We measured fecundity in the Lake Washington basin at the Issaquah hatchery from 2014 to 2016 (N = 280 females). Average fecundity during this period exceeded 4,500 eggs per female (Issaquah median = 5,222; mean = 5,265; standard deviation = 1,316). Fecundity in each female typically varies as a function of body size and age. The relationship between female body size (POH in mm) and fecundity can be explained using a power function

(Fecundity = 0.0438*POHmm$^{1.8021}$, R^2 =0.44). For each year and stream, we estimated fecundity for each carcass on the spawning ground based on the POH length (carcass length data provided by A. Bosworth) and then calculated the average fecundity for the population based on the 2014 – 2016 measurements.

Cedar River

Sockeye

Production Estimate

We estimated 8,725,471 ± 1,434,498 (± 95% CI) natural-origin sockeye fry entered Lake Washington from the Cedar River in 2018 (Table 1, Appendix A1). This estimate includes a small pre-season estimate of 16,500 fry between January 1 and January 12. Fry migration began prior to our first day of trapping as noted by sockeye catches on the first night (Figure 2). The majority of the fry migrated between March 1st to the 23rd (Figure 2). The median migration date for natural-origin sockeye was March 11th. Cedar River sockeye fry are migrating earlier over the last 3 decades (-9.6 days per decade, Table). However, the 2018 run was 4 days later relative to the average run timing observed over the last 10 years (March 7th).

Efficiency data were aggregated into four release strata from twelve efficiency trials of sockeye fry (Table 1, Appendix A). Weekly recapture rates of the screw trap during the winter season appear consistent from year to year with the change in methods to a single gear type. Average efficiency rates in 2018 were 2.43%. This rate closely matches efficiency rates observed in 2017 (2.82%).

Table 1. Abundance of natural-origin sockeye fry entering Lake Washington from the Cedar River in 2018. Table includes; total catch (actual plus estimated), abundance of fry migrants, 95% confidence intervals (C.I.), coefficient of variation (*CV*), and trap efficiency.

Dates	Total catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Pre trapping Jan 1-12	--	16,500	14,142	18,858	7.3%	--
Jan 12- Feb 2	6,206	137,911	88,777	187,045	18.2%	4.50%
Feb 3- Mar 23	175,591	7,153,257	6,255,335	8,051,179	6.4%	2.45%
Mar 24- Mar 30	20,709	516,112	366,679	665,545	14.8%	4.01%
Mar 31- July 15	9,704	901,691	566,041	1,237,341	19.0%	1.08%
Total	212,210	8,725,471	7,290,974	10,159,969	5.68%	2.43%

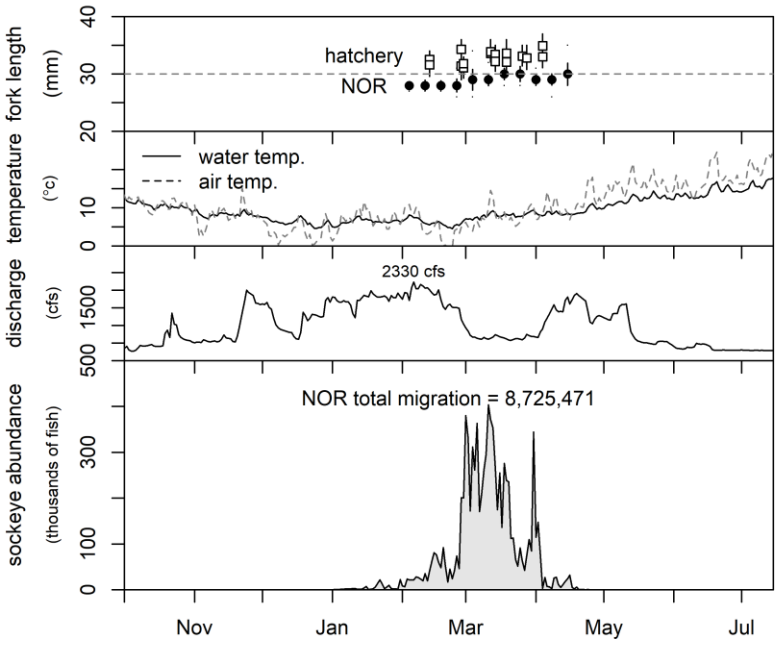

Figure 2. Estimated daily migration of natural-origin sockeye fry migrating from the Cedar River into Lake Washington between January 1 and July 15, 2018. Pre-trapping migration estimates are included (Jan. 1 - Jan. 12). Top panel displays changes in average fork length of natural-origin fry with vertical lines as ± 1 standard deviation. Fork lengths of hatchery fry were taken at the holding ponds before their release. Middle panels show daily river flow and water temperature (or air) during this period (USGS gage #12119000, air temperature in Renton, King County 31N).

The Cedar River Sockeye Hatchery released 6,947,607 million sockeye from February 18, 2018 through April 4, 2018 on nine nights (Table 2). Seven releases occurred at the lower location (River mile, R.M. 2.1), six from the middle location (R.M. 13.5) and five releases at the upper location (R.M. 21.8). The screw trap did not operate during release nights and part of the following day to reduce the impact on these fish and because their abundance can compromise our ability to accurately estimate natural-origin sockeye. Hatchery sockeye median migration date was March 14th, 3 days later than the median migration date of naturally produced sockeye in 2018 (Table 3). Hatchery fry were 3 to 5 mm longer in fork length (data from the hatchery) when they were released compared to natural origin fry captured at the trap (Figure 2).

Table 2. Release schedule of 6,947,607 million hatchery sockeye from the Cedar River Sockeye Hatchery released at three different release points along the Cedar River in 2018: lower (river mile, R.M. 2.1), middle (R.M. 13.5) and upper location (R.M. 21.8)

Release Date	Lower	Middle	Upper
14-Feb	130,326	485,977	242,328
27-Feb	225,343	327,793	167,236
28-Feb	720,163		248,132
12-Mar	439,582	346,448	
14-Mar	413,410	730,934	275,299
19-Mar		772,041	429,073
26-Mar	694,580		
28-Mar	193,129		
4-Apr		105,813	
	2,816,533	2,769,006	1,362,068

Table 3. Median migration dates of natural-origin, hatchery, and average combined sockeye fry from the Cedar River for trap years 1992 to 2018.

Trap year	Natural	Hatchery	Combined	Diff (H-N)
1992	03/18	02/28	03/12	19
1993	03/27	03/07	03/25	20
1994	03/29	03/21	03/26	8
1995	04/05	03/17	03/29	19
1996	04/07	02/26	02/28	41
1997	04/07	02/20	03/16	46
1998	03/11	02/23	03/06	16
1999	03/30	03/03	03/15	27
2000	03/27	02/23	03/20	33
2001	03/10	02/23	03/08	15
2002	03/25	03/04	03/19	21
2003	03/08	02/24	03/03	12
2004	03/21	02/23	03/15	27
2005	03/02	02/23	03/01	7
2006	03/20	03/06	03/16	14
2007	03/23	02/20	02/26	31
2008	03/16	03/06	03/15	10
2009	03/19	03/06	03/13	13
2010	03/07	03/08	03/07	-1
2011	03/25	02/18	03/01	35
2012	03/22	03/08	03/18	14
2013	03/07	03/06	03/07	1
2014	03/02	03/11	03/04	-9
2015	03/07	03/12	03/07	-5
2016	03/07	03/14	03/14	-7
2017	02/28	03/08	03/03	-8
2018	03/11	03/14	03/13	-3

Egg-to-Migrant Survival of Natural-Origin Fry

Egg-to-migrant survival of the 2017 brood Cedar River sockeye was 18.29% (Table 4). Survival was based on 8.725 million natural-origin fry from a potential 47.7 million eggs deposited by 15,645 females (A. Bosworth, Washington Department of Fish and Wildlife, personal communication). Average fecundity for the 2017 brood was 3,050 eggs per female sockeye (M. Sedgwick, Washington Department of Fish and Wildlife, personal communication).

Salmon eggs and alevins incubating within streambed redds are susceptible to flooding and scour, so peak winter discharges often explain annual variation in egg to fry survival. River flows surpassed known scouring thresholds (2,200 ft^3 sec^{-1}, Gendaszek et al. 2017) during egg incubation (November through February). Peak flows during December 2017 were at scour thresholds of 2,310 ft^3 sec^{-1}. Peak discharge on February 6th reached 2330 ft^3 sec^{-1} (Table 4). Trap technicians noticed fry with eggs attached (alevins) throughout February during higher flows. An unusual mortality event of 127 fry was observed on February 2nd and the fry submitted to the WDFW pathology lab. All appeared to have died from coagulated yolk syndrome, suggesting a scour event killed them. The majority of the migration occurred when daily flows were more moderate (500-1,100 ft^3 s^{-1}) in mid-March (Figure 2).

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 - 2017. Incubation period is defined as November 1 to February 28. USGS monitors river flow continuously in Renton at station 12119000.

Brood yr	Spawners	Females	Fecundity	Egg deposition	Fry	Survival	Peak flow	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	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
2015	7,191	3,596	3,070	11,038,185	2,163,843	19.60%	4,661	12/7/2015
2016	7,573	3,787	3,144	11,904,756	2,530,668	21.26%	2,140	2/10/2017
2017	31,290	15,645	3,050	47,717,250	8,725,471	18.29%	2,330	2/6/2018

Chinook

Production Estimate

The total production of Chinook sub-yearling (parr and fry) in 2018 was 524,378 ± 78,450 (±95% C.I.). Here, Chinook fry are defined as those fish emigrating from January to April 8th and Chinook parr are defined as fish emigrating after April 9th (Figure 3). During the transition period in April, the overall migration decreases and larger size parr start to appear in the catch (Figure 3). The fry component was 94% of all natural Chinook production. Because trap efficiencies are not statistically different between sockeye and Chinook, sockeye releases were used to help estimate trap efficiency of Chinook fry (Kiyohara 2016). Trap efficiencies averaged 2.46% for sockeye fry.

An estimated 31,804 natural-origin Chinook parr passed the screw trap in 2018 (Table 5). This estimate is based on a total catch of 1,943 Chinook parr and trap efficiency of 6.11%. Parr made up only 6% of the total sub-yearling migration. Chinook fry migration increased quickly over the season to one prominent peak in early March then slowly decreased for the remainder of season (Figure 3). Parr displayed sporadic movements in June that averaged 1,000 fish per day in late May and early June (Figure 3).

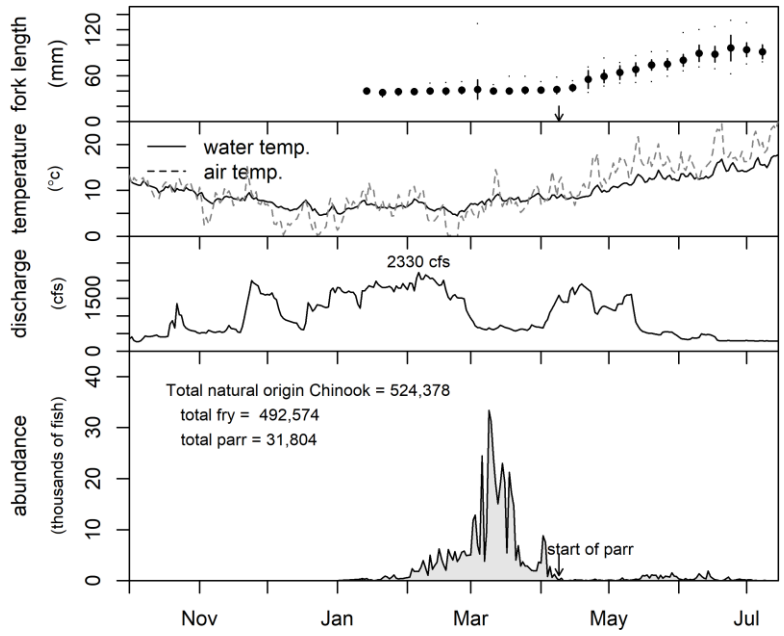

Figure 3**.** Bottom panel: Estimated daily migration of Chinook fry and parr from the Cedar River from January 1 to July 12, 2018. Pre-trapping migration estimates cover January 1-12. Parr life history type designation starts on April 9th (plot arrow). Middle panels: Time series of mean daily water and air temperatures. River discharge from the USGS gaging station in Renton (Station 12119000). Top panel: Mean weekly Chinook body fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length.

Table 5. Abundance of Chinook migrants from Cedar River in 2018. Table includes total catch, abundance of fry and parr life history types, 95% confidence intervals (C.I.), coefficient of variation (*CV*) and trap efficiencies (*Eff.*)

Life history	Period	Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Fry	Jan 1-12 pre trapping	--	1,637	1,410	1,864	7.1%	
Fry	Jan 13-Feb 2	443	9,844	6,484	13,204	17.4%	4.50%
Fry	Feb 3- Mar 23	10,653	433,986	385,346	482,626	5.7%	2.45%
Fry	Mar 24 –Mar 30	712	17,745	13,194	22,296	13.1%	4.01%
Fry	Mar 31- April 8	316	29,362	18,117	40,607	19.5%	1.08%
Parr	April 9-July 15	1,943	31,804	21,377	42,231	16.7%	6.11%
	Fry total:	12,124	492,574	424,551	560,597	5.2%	2.47%
	Parr total:	1,943	31,804	21,377	42,231	16.7%	6.11%
	Chinook total:	14,067	524,378	445,928	602,828	5.0%	2.68%

Size

Chinook migrant fork length (FL) ranged from 36 to 132 mm (Figure 3). Average fork length increased as water temperatures increased (Figure 3). Weekly average size of fry was 38 mm increasing to 42 mm FL by the first week in April (Figure 3). Chinook parr averaged 44 mm during the second week of April and increased to 96 mm by the first week in July.

Productivity

Egg-to-migrant survival of the 2017 brood Cedar River Chinook was 14.2% (Table 6). Survival was based on 524,378 sub-yearling migrants and 3.69 million eggs from 819 female spawners (A. Bosworth, Washington Department of Fish and Wildlife, personal communication). The number of juvenile Chinook migrants produced per female (640) is near the 50th percentile relative to the last 20 years (median = 571 migrants per female, Table 6). The 2017 egg-to-migrant survival assuming 4,500 eggs per female is above 2025 goals (13.8%) for the Cedar (WRIA 8 Conservation plan 2017). Egg-to-fry survival rates were encouragingly high during 2011-2015 brood years (survival rate range: 30-62%), but the 2017 brood year appeared to have a lower survival (14.2%) despite moderate flows. Cedar River discharge approached scouring thresholds (2,200 ft^3 sec^{-1}, Gendaszek et al. 2017) during egg incubation (November through February). Peak flows during November and December 2017 were 2,070 and 2,310 ft^3 sec^{-1} (respectively). Peak discharge on February 6th reached 2,330 ft^3 sec^{-1} (Figure 3).

We calculated an alternative egg-to-migrant survival estimate using the relationship between body size and fecundity for adult females. From 2001-2017, we estimated average Chinook fecundity on the spawning grounds based on the post-orbital eye to hypural plate length (POH) of female carcasses (Issaquah average = 5,265; SD= 1,316, carcass length data at the spawning ground provided by A. Bosworth and A. David, Appendix A 4). This alternative formulation can produce a lower annual survival rate estimate than if we assume fecundity is 4,500 eggs per female. For instance, the Cedar River survival estimate in 2011 drops 16% from 61.9% to 45.9% under a POH based estimate of fecundity because larger sized females were found on the spawning ground (Table 6). For years when the survival rate is lower, the difference between the two calculations is

less noticeable (<1.5%), but not negligible. The survival rate for the 2017 brood would be 12.0% instead of 14.2 % and therefore, slightly below WRIA conservation plan 2025 goals.

Table 6. Abundance of Chinook fry and parr and productivity (juveniles per female) among brood years 1998 to 2017. Productivity is based on 4,500 eggs per females and weekly fall redd surveys. An alternative survival estimate uses Chinook fecundity on the spawning ground based on the post-orbital eye to hypural plate length (POH) of female carcasses (data provided by A. Bosworth and A. David).

Brood	Fry	Parr	Total	±95%CI	%Fry	%Parr	Redds	Fry per Female	Parr per Female	Total per Female	Egg Survival	Alt. Egg Survival
1998	63,702	17,230	80,932	7,732	79%	21%	173	368	100	468	10.4%	--
1999	46,500	18,223	64,723	5,609	72%	28%	182	255	100	356	7.9%	--
2000	10,833	21,416	32,249	5,220	34%	66%	53	204	404	608	13.5%	--
2001	79,799	39,875	119,674	41,349	67%	33%	398	201	100	301	6.7%	6.3%
2002	194,657	40,740	235,397	51,485	83%	17%	281	693	145	838	18.6%	14.8%
2003	65,752	55,124	120,876	2,518	54%	46%	337	195	164	359	8.0%	6.0%
2004	74,292	60,006	134,298	42,912	55%	45%	511	145	117	263	5.8%	4.4%
2005	98,967	18,592	117,559	16,233	84%	16%	339	292	55	347	7.7%	6.1%
2006	110,961	14,225	125,186	16,912	89%	11%	587	189	24	213	4.7%	3.7%
2007	705,583	64,208	769,791	76,106	92%	8%	899	785	71	785	19.0%	15.5%
2008	127,064	12,388	139,452	38,399	91%	9%	599	212	21	233	5.2%	3.8%
2009	115,474	36,916	152,390	13,058	76%	24%	285	405	130	535	11.9%	8.7%
2010	177,803	10,003	187,806	63,560	95%	5%	266	668	38	706	15.7%	11.0%
2011	863,595	38,919	902,514	165,973	96%	4%	324	2,665	120	2,786	61.9%	45.9%
2012	874,658	19,219	893,877	77,993	98%	2%	433	2,020	44	2,064	45.9%	41.3%
2013	1,426,631	32,130	1,458,761	390,039	98%	2%	740	1,928	43	1,971	43.8%	33.1%
2014	326,901	20,762	347,663	90,223	94%	6%	232	1,409	89	1,499	33.3%	29.4%
2015	941,443	31,198	972,641	408,314	97%	3%	723	1,302	43	1,345	29.9%	23.6%
2016	151,262	23,457	174,719	37,722	87%	13%	418	362	56	418	9.3%	8.1%
2017	492,574	31,804	524,378	78,450	94%	6%	819	601	39	640	14.2%	12.0%

Coho

Production Estimate

Total coho age 1+ smolt production was 179,946 ± 52,442 (± 95% C.I.) migrants (Table 7). The median migration date was May 7th, the peak migration day when we estimated more than 30,000 coho smolts. Production estimate for Coho was the most on record and is progressively increasing (Table 8). In comparison, the median run size between 2000 to 2017 was 60,621 smolts. Total catch (actual and estimated missed) of coho migrants in the screw trap was 5,848. We observed two life history forms in the Cedar River: typical 1+ yearling coho and sub-yearling coho fry and parr (62 total). Seven weeks of efficiency trials were aggregated into one strata with an efficiency of 3.25% (Table 7). This estimate includes only yearlings that moved past the screw trap (Figure 4). Fry and parr were not included in the estimate as their catch was very small.

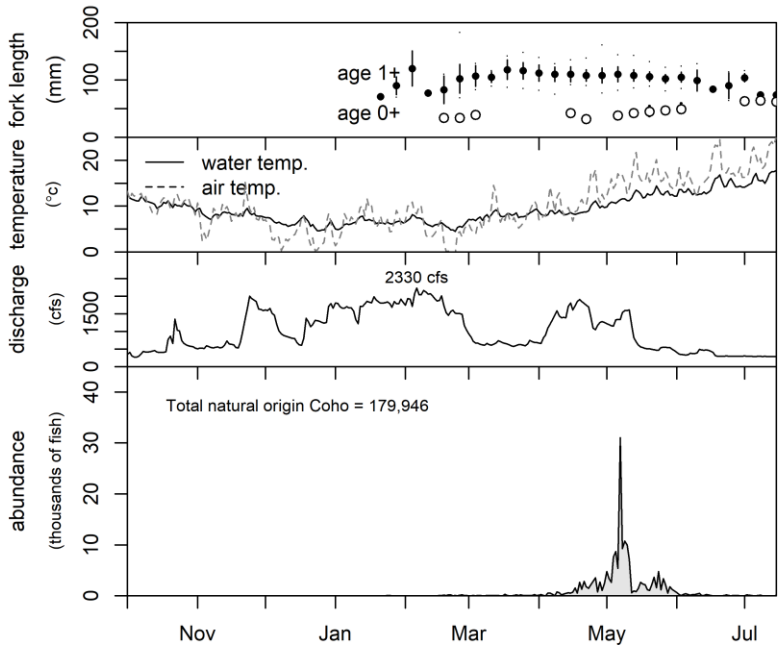

Figure 4. Bottom panel: Estimated daily migration of yearling coho from the Cedar River in 2018 based on screw trap estimates from January 1 to July 12. Middle panels: Time series of mean daily air and water temperatures and river discharge from the USGS gaging station in Renton (Station 12119000). Top panel: Mean weekly Coho body fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length. Age 1+ smolts in filled points and age 0+fry and parr in open points.

Table 7. Abundance of coho smolt migrants from Cedar River in 2018. Table includes abundance of yearling migrants, 95% confidence intervals (C.I.), coefficient of variation (*CV*) and trap efficiency.

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Jan 12 - July 15	5,848	179,946	127,504	232,388	14.87%	3.25%

Size

Average fork length of all measured coho migrants smolts was 102 mm; weekly averages ranged from 84 mm to 114 mm. Smolt migrants ranged from 76 mm to 149 mm FL (Figure 4). Sub-yearlings coho (fry and parr) ranged from 35 to 40mm between February 2nd and April 9th. Subyearling coho grew from an average of 40 to 74 mm between April 16th and July 9th.

Table 8. Annual catch, abundance estimate, and 95% C.I. of natural-origin juvenile coho smolts emigrating from Cedar River from brood years 1997 to 2016.

Brood	Trap	Total Catch	Start	End	Abundance	Lower CI	Upper CI	*CV*
1997	1999	5,018	03/18	07/27	39,088	35,241	42,935	5.00%
1998	2000	2,446	04/27	07/13	32,169	30,506	33,833	--
1999	2001	6,262	04/08	07/22	82,462	60,293	104,661	13.70%
2000	2002	3,716	04/01	07/22	60,513	50,286	70,740	8.60%
2001	2003	3,964	04/10	07/12	74,507	58,947	90,067	10.70%
2002	2004	2,808	04/14	07/20	70,044	46,735	93,353	17.00%
2003	2005	2,918	04/01	07/28	72,643	42,725	102,561	21.40%
2004	2006	795	04/01	07/16	38,023	16,416	59,629	28.90%
2005	2007	482	04/01	07/20	33,994	8,291	59,697	40.80%
2006	2008	315	04/14	07/19	13,322	3,392	23,372	--
2007	2009	5,805	04/21	07/18	52,691	45,600	49,781	6.87%
2008	2010	6,528	04/22	07/04	83,060	70,049	96,071	7.99%
2009	2011	4,930	04/27	07/16	52,458	44,645	60,271	7.60%
2010	2012	2,912	04/18	07/14	48,168	38,493	57,843	10.25%
2011	2013	4,623	04/17	07/17	115,185	90,688	139,682	10.90%
2012	2014	8,071	04/16	07/16	129,666	104,393	154,940	9.94%
2013	2015	5,209	04/08	07/08	107,874	91,047	124,701	7.96%
2014	2016	2,720	04/14	07/14	60,621	41,862	79,379	15.79%
2015	2017	2,798	01/12	07/12	91,295	61,769	120,821	16.50%
2016	2018	5,848	01/12	07/15	179,946	127,504	232,388	14.87%

Trout

Life history strategies used by trout in the Cedar River include anadromous, adfluvial, fluvial, and resident forms. Catches and estimates reported herein are for trout that were visually identified as either *Oncorhynchus clarki* (cutthroat trout) or *Oncorhynchus mykiss* (steelhead/rainbow trout). Steelhead smolts were identified when the fish had silver coloration upon capture. We did not identify trout fry to species or life-history type.

Six steelhead smolts, 120 juvenile cutthroat trout, 16 unidentifiable trout fry, and 4 adult cutthroat trout were captured in the screw trap. Catches were too few to estimate migrant abundance. Steelhead fork lengths ranged from 160 to 180 mm and averaged 166 mm. Juvenile cutthroat fork lengths ranged from 73 mm to 226 mm and averaged 151 mm.

Incidental Catch

Twenty-three species of fish were documented in the Cedar River over the last 3 years. Other salmonids caught in the screw trap during 2018 include 259 hatchery Chinook parr and 16 pink fry (*Oncorhynchus gorbuscha*). Non-salmonid fishes encountered in the trap during 2018 include 47 lamprey (*Lampetra* spp.), 78 three-spine stickleback (*Gasterosteus aculeatus*), 183 sculpin (*Cottus* spp.), 7 large-scale suckers (*Catostomus macrocheilus*), 4 peamouth chub (*Mylocheilus caurinus*), 1 whitefish *(Prosopium spp.)*, and 9 longnose dace (*Rhinichthys cataractae*). See Appendix A5 for the full species catch over the last three years.

Bear Creek

Sockeye

Production Estimate

An estimated 1,385,897 ± 144,039 (± 95% CI) natural-origin sockeye fry migrated past the Bear Creek in 2018 (Figure 5, Table 9). This estimate includes a small pre-season run of 955 fry from January 1st to the 24th. Median migration date for natural-origin sockeye was March 15th. Total catch (actual and estimated missed) in the Bear Creek screw trap was 146,946 sockeye fry during the trapping period (Table 9). Eleven efficiency trails from February 19 to April 1 were aggregated into two final strata of 11.27% and 8.52% (Table 9, Appendix B1). Several larger sub-yearling fry (50-70mm FL) were caught in the trap in May and June.

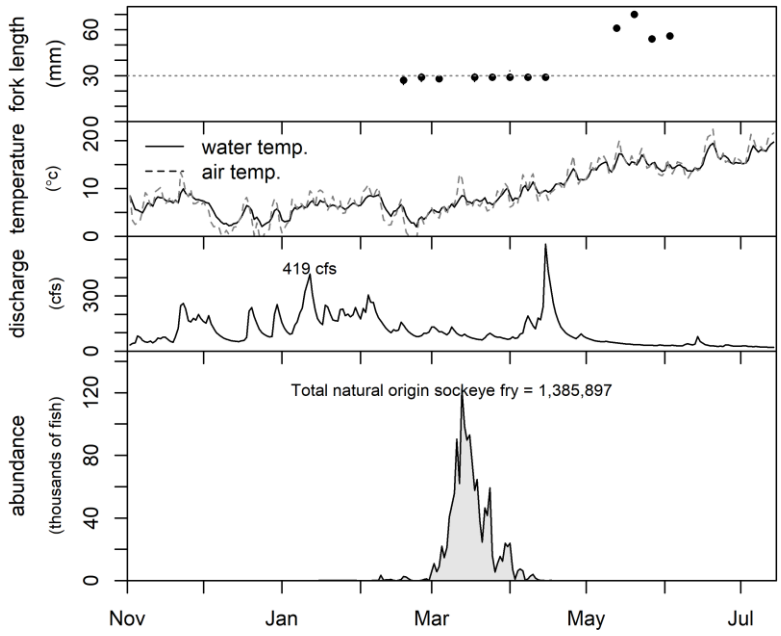

Figure 5. Estimated daily migration of sockeye fry from Bear Creek in 2018 (bottom panel), daily average flow, water and air temperature (middle panels). Top panel: Mean weekly Sockeye fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length.

Table 9. Abundance of sockeye fry migrants from Bear Creek in 2018. Table includes 95% confidence intervals (C.I.) of abundance, coefficient of variation (*CV*) and trap efficiency for the period.

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Jan 1-Jan 24 Pre trap		955	743	1,167	11.3%	
Jan 25- Mar 20	117,949	1,043,795	943,509	1,144,081	4.9%	11.27%
Mar 21 - July 10	28,997	341,147	297,606	384,688	6.5%	8.52%
Total	146,946	1,385,897	1,241,858	1,529,936	4.0%	

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2017 brood of Bear Creek sockeye was 52.8% (Table 10). The survival estimate is based on 1,385,857 fry migrants and a potential egg deposition (PED) of 2.6 million eggs from 861 female sockeye spawning in Bear Creek in 2017. Survival was the highest on record, continuing a recent trend of increasing egg-to-fry survival of sockeye in Bear Creek over the last decade (Table 10). Peak flows during the egg incubation were moderate, 419 ft^3 s^{-1} on January 12, 2018 (median high flows 1998-2018 = 481 ft^3 s^{-1}).

Table 10. Egg-to-migrant survival of Bear Creek sockeye by brood year. Potential egg deposition (PED) is based on fecundity of sockeye broodstock in the Cedar River. Median run date based on a cumulative distribution when 50% of the migration passed.

Brood yr	Spawners	Females	Fecundity	Egg deposition	Fry production	Egg Survival	Peak Flow	Flow date	Run timing
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	3/22/2001
2001	8,378	4,189	3,568	14,946,352	2,659,782	17.8%	626	11/23/2001	3/13/2002
2002	34,700	17,350	3,395	58,903,250	1,995,294	3.4%	222	1/23/2003	3/15/2003
2003	1,765	883	3,412	3,011,090	177,801	5.9%	660	1/30/2004	3/11/2004
2004	1,449	725	3,276	2,373,462	202,815	8.5%	495	12/12/2004	3/10/2005
2005	3,261	1,631	3,065	4,999,015	548,604	11.0%	636	1/31/2005	3/10/2006
2006	21,172	10,586	2,910	30,805,260	5,983,651	19.4%	581	12/15/2006	3/18/2007
2007	1,080	540	3,450	1,863,000	251,285	13.5%	1,055	12/4/2007	3/20/2008
2008	577	289	3,135	904,448	327,225	36.2%	546	1/8/2009	3/28/2009
2009	1,568	784	3,540	2,775,360	129,903	4.7%	309	11/27/2009	3/16/2010
2010	12,527	6,264	3,075	19,260,263	8,160,976	42.4%	888	12/13/2010	3/14/2011
2011	911	455	3,318	1,509,690	266,899	17.7%	348	11/23/2011	3/26/2012
2012	4,219	2,110	3,515	7,414,893	1,553,602	21.0%	467	1/10/2013	3/18/2013
2013	2,003	1,001	3,362	3,365,362	438,534	13.0%	244	1/12/2014	3/20/2014
2014	2,130	1,065	3,368	3,586,920	1,590,812	44.4%	206	2/7/2015	2/19/2015
2015	414	207	3,070	635,490	81,125	12.8%	350	1/29/2016	3/4/2016
2016	1,031	516	3,144	1,622,304	512,651	31.6%	645	2/10/2017	3/21/2017
2017	1,721	861	3,050	2,626,050	1,385,897	52.8%	419	1/12/2018	3/15/2018

Chinook

Production Estimate

Two life-history forms of sub-yearling Chinook salmon are commonly observed in Puget Sound: small fry that migrate immediately after emergence while parr are those that rear and grow before migrating. Within the Lake Washington juvenile monitoring project, a timeframe traditionally defines the fry and parr run. We acknowledge there may be some parr sized fish included in the fry estimation and fry sized fish in the parr component. Weekly lengths of sub-yearling Chinook migrants averaged 39 mm to 43 mm from February and March. Average fork length increased to 60 mm by April. In May, parr ranged in size from 46 mm to 108 mm. By the end of June Chinook averaged 101 mm in length (Figure 6).

The total production of Chinook sub-yearling (parr and fry) was 52,620 ± 6,145 (±95% C.I., Table 11). Fry represented 46% of the total migration (24,193 ± 2,709). Parr represent 54% of total production in Bear Creek in 2018 (28,427 ± 3,436; Figure 6). The median date of the fry and parr migration was March 11th and May 17th (respectively, Figure 6). Parr migrated out of Bear Creek rapidly as average daily air and water temperatures exceeded 20 ºC in early June (Figure 6).

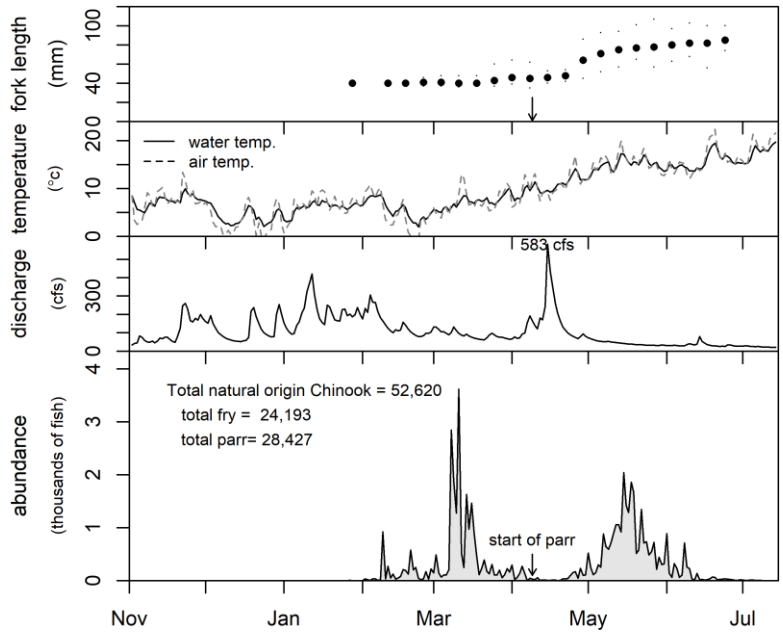

Figure 6. Estimated daily migration of Chinook fry and parr from Bear Creek in 2018 based on screw trap estimates from January 25 to July 10. Parr life history type designation starts on April 9th with the onset of larger average body size of rearing Chinook. Middle panels: Time series of mean daily water, air temperatures, and river discharge from the King County gaging station at Union Hill Road. Top panel: Mean weekly Chinook body fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length.

The Chinook abundance estimate was based on a total catch (actual plus estimated missed) of 2,403 Chinook fry and 11,058 parr. Trap efficiencies for the fry period was 11.3% and 8.5%, pooled from 11 surrogate sockeye fry efficiency trials from the start of the season through April 1. Efficiency strata from 17 Chinook parr efficiency trials were pooled into one final strata of 38.9% (Table 11).

Table 11. Abundance of natural-origin sub-yearling Chinook emigrating from Bear Creek in 2018. Table includes abundance of juvenile migrants, 95% confidence intervals (C.I.), coefficient of variation (*CV*), and efficiency strata for each period and life history type (*Eff.*).

Period	Life History	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Jan 25 – March 20	Fry	2,403	21,263	19,071	23,455	5.3%	11.3%
March 21- April 8	Fry	249	2,930	2,413	3,447	9.0%	8.5%
April 9-July 10	Parr	11,058	28,427	24,991	31,863	6.2%	38.9%
	Fry total:	2,652	24,193	21,484	26,902	4.6%	11.0%
	Parr total:	11,058	28,427	24,991	31,863	6.2%	38.9%
	Chinook total:	13,710	52,620	46,475	58,765	4.0%	26%

Productivity

Egg-to-migrant survival of the 2017 brood of Bear Creek Chinook was 7.3% (Table 12). The survival estimate is based on 52,620 sub-yearling migrants and a potential egg deposition (PED) of eggs deposited in 160 Chinook redds assuming 4,500 eggs per female. The 2017 brood of Bear Creek Chinook produced moderate numbers of fry and parr per female. For 8 of the last 10 years, egg survival rate in Bear exceeded the 2025 WRIA 8 goals for this population (>4.4% egg survival).

As an alternative approach to estimating egg-to-migrant survival, we also estimated the average Chinook fecundity on the spawning ground based on the post-orbital eye to hypural plate length (POH) of female carcasses (data provided by A. Bosworth and A. David, Appendix B4). This formulation can be a more conservative estimate of annual survival rate relative to our previous estimate of fecundity of 4,500 eggs per female. For instance in 2013, Bear Creek spawners were quite large (Appendix B4) and fecundity averaged 5,976 eggs per spawner (Table 12, Appendix B4). Our survival estimate drops from 29.1% to 22.8% for brood-year 2013. For years when the survival rate is lower, the difference between the two calculations is less noticeable (<1%). The majority of Bear Chinook arrived at a small body size in 2017, and therefore had fewer predicted eggs per spawner (4,459). This alternative survival estimate of 7.5% closely matches the survival formulation assuming 4,500 eggs per spawner (7.3%).

Table 12. Abundance and productivity (juveniles per female) of natural-origin Chinook in Bear Creek. Fry are assumed to have migrated between January 1 and April 8. Parr are assumed to have migrated between April 9 and July 30. Data are for 2000 to 2017 brood years. Egg survival based off 4,500 eggs per female spawner. We provide an alternative estimate of survival by adjusting fecundity according to the length of fish observed on the spawning ground that year.

brood year	fry	parr	total	% fry	% parr	female spawners	fry per female	parr per female	Total / female	egg survival	alt. egg survival
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%	2.8%
2002	645	16,636	17,281	3.7%	96.3%	127	5	131	136	3.0%	2.5%
2003	2,089	21,558	23,647	8.8%	91.2%	147	14	147	161	3.6%	2.8%
2004	1,178	8,092	9,270	12.7%	87.3%	121	10	67	77	1.7%	1.3%
2005	5,764	16,598	22,362	25.8%	74.2%	122	47	136	183	4.1%	3.2%
2006	3,452	13,077	16,529	20.9%	79.1%	131	26	100	126	2.8%	2.2%
2007	1,163	11,543	12,706	9.2%	90.8%	89	13	130	143	3.2%	2.9%
2008	14,243	50,959	65,202	21.8%	78.2%	132	108	386	494	11.0%	8.3%
2009	1,530	7,655	9,185	16.7%	83.3%	48	32	159	191	4.3%	3.3%
2010	901	16,862	17,763	5.1%	94.9%	60	15	281	296	6.6%	5.2%
2011	4,000	18,197	22,197	18.0%	82.0%	55	73	331	404	9.0%	6.8%
2012	24,776	19,823	44,599	55.6%	44.4%	147	169	135	303	6.7%	6.1%
2013	24,266	38,509	62,775	38.7%	61.3%	48	506	802	1,308	29.1%	22.8%
2014	25,500	7,233	32,733	77.9%	22.1%	60	425	121	546	12.1%	10.6%
2015	23,753	20,371	44,124	53.8%	46.2%	138	172	148	320	7.1%	6.5%
2016	21,672	14,037	35,709	60.7%	39.3%	115	188	122	311	6.9%	6.7%
2017	24,193	28,427	52,620	46.0%	54.0%	160	151	178	329	7.3%	7.5%

Coho

Total catch (actual and estimated missed) in the Bear Creek screw trap was 4,667 yearling coho. This included an actual catch of 3,946 coho migrants and 721 estimated missed catch of coho due to trap outages. Less than 1% of the total catch were sub-yearlings (45 total). The median migration date was May 7th.

Production Estimate

The total production of coho juvenile smolts was 37,631 ± 9,326 (95% C.I., Table 13, Figure 7). The 2018 run was above the above the average migration for Bear Creek (average = 30,268, high= 62,970 in 1999, low= 6,004 in 2017, Table 14). The abundance estimate is based on total catch of 4,667 coho migrants. Fourteen efficiency trials were aggregated into a single stratum of 12.4%. The run peaked shortly after receding flood conditions in early April.

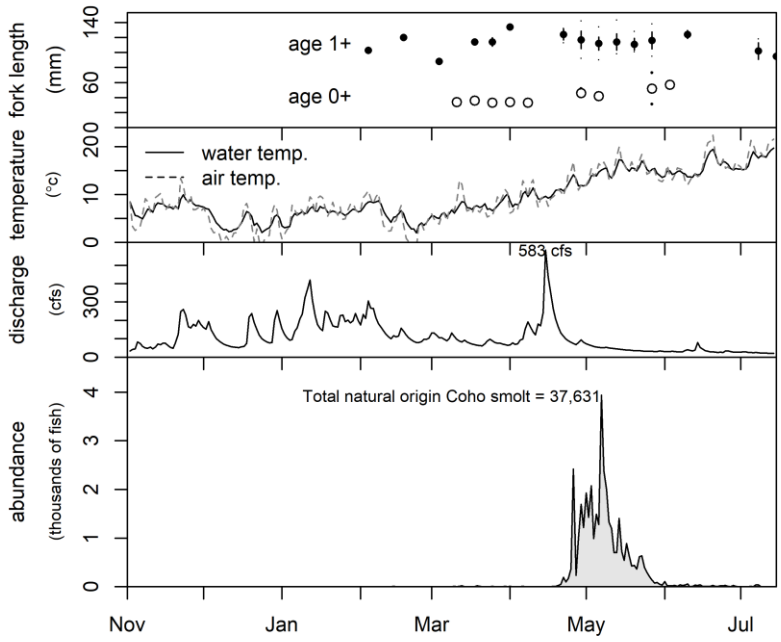

Figure 7. Bottom panel: Daily sub-yearling and yearling coho migration at the Bear Creek screw trap in 2018. Middle panels: Daily average flow and temperature at the Bear Creek King County gage 02a at Union Hill Road. Top panel: Mean weekly Coho body fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length. Age 1+ smolts in filled points and age 0+fry and parr in open points.

Table 13. Abundance of natural-origin juvenile coho emigrating from Bear Creek in 2018, 95% confidence intervals (C.I.), coefficient of variation (*CV*) and trap efficiency (*Eff.*) for the period. Sub-yearling were excluded from the abundance estimate.

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*
Jan25- July 10	4,667	37,631	28,305	46,957	12.6%	12.4%

Table 14. Annual catch, abundance estimate, and 95% C.I. of natural-origin juvenile coho smolts emigrating from Bear Creek from brood years 1997 to 2016.

Brood year	Trap	Total Catch	Start	End	Abundance	Lower CI	Upper CI	*CV*
1997	1999	14,934	02/23	07/13	62,970	50,645	75,295	10.00%
1998	2000	7,737	01/24	07/13	28,142	26,133	30,151	3.64%
1999	2001	6,617	04/10	07/12	21,665	18,947	24,383	6.40%
2000	2002	17,381	04/12	07/15	58,212	52,791	63,633	4.80%
2001	2003	15,048	04/09	07/08	48,561	42,304	54,818	6.60%
2002	2004	9,111	04/05	06/26	21,085	18,641	23,529	5.90%
2003	2005	16,191	04/08	07/14	43,725	43,638	43,813	0.10%
2004	2006	11,439	04/08	06/29	46,987	44658	49316	9.70%
2005	2007	2,802	04/15	07/11	25,143	20,220	30,066	9.90%
2006	2008	1,572	04/16	07/09	12,208	9,807	14,609	9.90%
2007	2009	3,926	04/22	06/30	33,395	26,840	39,951	10.02%
2008	2010	1,954	04/22	07/04	13,100	11,427	14,773	6.52%
2009	2011	4,871	04/27	07/16	34,513	25,700	43,326	13.03%
2010	2012	3,989	01/25	07/14	16,059	14,734	17,384	4.21%
2011	2013	1,288	01/28	07/10	17,752	9,986	25,518	22.30%
2012	2014	4,682	01/28	07/09	36,119	28,866	43,371	10.25%
2013	2015	5,205	01/28	07/01	30,544	30,025	31,064	0.87%
2014	2016	1,848	01/28	07/14	11,545	8,717	14,343	12.50%
2015	2017	439	01/31	07/10	6,004	2,142	9,866	32.80%
2016	2018	4,667	01/25	07/11	37,631	28,305	46,957	12.64%

Size

Over the trapping period, fork lengths of sub-yearling and yearling coho ranged from 32 mm to 143 mm. Weekly mean lengths of age 1+ coho ranged from 88 mm to 124 mm in April and May (Figure 7). Fork length of age 1+ coho were smaller in July; weekly averages ranged between 102 to 95 mm suggesting that larger coho migrate out earlier than smaller coho. Age 0+ fry emerged at 33 to 40 mm, and grew to 57 to 73 mm by June as river temperatures approached 20 ºC.

Trout

Trout in Bear Creek were identified to species when possible. The cutthroat estimate is a measure of the number of cutthroat moving past the trap, but does not necessarily represent the number of cutthroat migrating downstream towards Lake Washington. The Bear screw trap caught 1,325 juvenile cutthroat trout. Sporadic catches precluded trap efficiency trials and abundance estimation. The Bear screw trap also caught 12 cutthroat adults, and 3 unidentifiable trout fry. Among the cutthroat adults, the largest fish was 389 mm. Juvenile cutthroat trout averaged 157 mm over the season and ranged between 87 mm to 246 mm (

Table 15). Average fork lengths showed no consistent trend across weeks.

Table 15. Mean cutthroat fork length (mm), range in fork length (maximum and minimum), standard deviation (SD) sample size (N), and catch by statistical week in the Bear Creek screw trap.

Week	End Week	Mean FL	Max. FL	Min. FL	SD	N	Catch
4	1/28/2018	190	351	123	84.5	8	11
5	2/4/2018	154	291	114	41.5	16	26
6	2/11/2018	134	197	91	20.1	30	47
7	2/18/2018	128	162	109	19.2	6	16
8	2/25/2018	175	330	89	72	11	28
9	3/4/2018	144	218	87	30.3	42	49
10	3/11/2018	152	305	86	52.1	14	17
11	3/18/2018	154	211	84	35	21	31
12	3/25/2018	146	204	78	32.6	14	29
13	4/1/2018	153	204	113	33.5	6	17
14	4/8/2018	170	385	94	44.7	43	87
15	4/15/2018	151	215	98	39	6	12
16	4/22/2018	--	--	--	--	--	20
17	4/29/2018	181	389	104	51.8	24	118
18	5/6/2018	176	226	100	27.5	40	134
19	5/13/2018	172	246	105	30.2	42	255
20	5/20/2018	151	208	92	28.4	34	192
21	5/27/2018	150	178	126	15.3	12	133
22	6/3/2018	166	171	160	5.1	4	54
23	6/10/2018	143	160	127	12.2	5	25
24	6/17/2018	167	209	130	24.3	7	23
25	6/24/2018	--	--	--	--	--	7
26	7/1/2018	--	--	--	--	--	3
27	7/8/2018	--	--	--	--	--	3
	Season total	158	243	106	35	385	1,337

Incidental Species

In addition to target species, the screw trap captured 59 hatchery sized trout, likely from Cottage Lake that escaped shortly after planting. Other species caught included 842 lamprey (*Lampetra* spp), 487 three-spine stickleback (*Gasterosteus aculeatus*), 573 sculpin (*Cottus* spp.), 59 green sunfish (*Lepomis cyanellus*), 1,934 peamouth (*Mylocheilus caurinus*), 5 dace (*Rhinichthys* spp), 21 bluegill (*Lepomis macrochirus*), 26 large-scale suckers (*Catostomus macrocheilus*), 11 pumpkinseed (*Lepomis gibbosus*), 3 northern pikeminnow *(Ptychocheilus oregonensis)*, 6 rock bass (*Ambloplites rupestris*), 1 warmouth (*Lepomis gulosus*),3 whitefish (*Prosopium* spp.), and 18 brown bullhead catfish (*Ameiurus nebulosus*) (Appendix B5).

PIT Tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington watershed, a small percentage (Tables 16 and 17) of natural-origin Chinook received passive integrated transponder (PIT) tags. Tagging occurred three to five times a week during the parr migration. Chinook parr were kept from the previous day if the catch was low in order to increase the number of tags released per day.

From April 25 through June 25, 2018, 700 natural-origin Chinook parr were PIT tagged in the Cedar River (Table 16). Of these 700 fish, 47 Chinook (6.7%) were detected at the Chittenden Locks. The median migration date to the Locks was June 20, with the first Chinook was detected on May 27 and the last on July 10. Individual travel times from the Cedar River to the Locks averaged 24 days (SD = 9.7) and ranged from 5 days to 41 days. Detection rates appear to be trending lower over the past 5 years (Table 17).

In Bear Creek, 2,578 Chinook parr were tagged between April 25 and June 23, 2018 (Table 16). There were 279 of 2,578 Chinook (10.8%) detected at the Chittenden Locks. The first Chinook was detected on May 17 and the last was detected July 4 (Table 16). Individual travel times from Bear Creek to the Locks averaged 22 days and ranged from 6 days to 54 days. Detections declined rapidly over the course of the 2018 season (Table 16) from 19.6% per week in early May to as low as 1.5% by June. Unlike the Cedar River tagging site, detection rates of Bear Creek Chinook at the Locks have not decreased from year to year (Table 17 and Table 18).

Over three weeks in May, 3,001 hatchery Chinook were released with PIT tags from the Issaquah Hatchery (Table 16). Tagging occurred 11 to 13 days prior to release. Although the length of fish at release is unknown, we assume our sample is representative of the hatchery population. Healthy tagged Chinook were placed back into the general hatchery population before releasing on three days (May 1, May 8, and May 24, 2018). The lock antennas detected Issaquah Hatchery Chinook from May 16 to June 27, 2018. Average travel time was 20 days and ranged from 15 to 54 days. Detections declined rapidly over the course of the season (Table 16), from 14.1% to 8.6% to 2.6% for the first, second, and third release groups. Overall detection rate of Issaquah hatchery Chinook was 8.4%. The average detection rate in 2018 was twice the rate compared to previous years (Table 19).

Over the history of the PIT tagging effort in Lake Washington, PIT tagged salmonids can pass through the Ballard lock system undetected across several potential exit routes (DeVries 2017). One hypothesis is that Chinook avoid warmer surface water flumes as Lake Union stratifies and therefore fish are forced to find cooler and deeper passages through the locks that are not instrumented. The installation of antennas in one of two large-lock filling culvert offers a chance to test whether or not this is true. In both 2017 and 2016, less than 1% of all unique fish recorded at the Locks were detected in the filling culvert. In 2018, 3.7% (22 of the 579) of all Chinook recorded at the locks were detected in the filling culvert. The reason for the increase in detections at the filling culvert from 2016 and 2017 to 2018 is unknown at this point. All detections on the large lock occurred in the afternoon, while surface exits through the flumes were primarily in the morning around dawn. It is possible that Chinook avoided the flumes during the afternoon when surface water temperatures are warmer and were more likely to exit through deeper passage in the

filling culverts. Nonetheless, the results so far suggest that this particular filling culvert (one of two in the large locks) is probably not a major route for smolts to exit Lake Washington.

We feel we did not miss a significant number of tagged fish due to the operational period of the flumes. The first and last tag detections occurred a number of days following the start of operations and prior to the end of operations. Since 2000, smolt flumes operate seasonally in spillway bays 4 and 5. In 2018, USACE replace the older tunnel style flumes with two "slide" flumes. One of these smolt slide style flumes operated from April 24th and through July 25th in spill bay 4 (reader ID 30). A second antenna was operational by May 11th until the 22nd of July in spill bay 5 (reader ID 10). The adult ladder antennas operate continuously throughout the year since 2004. The large lock filling culvert operates continuously since November 2015 (reader ID 5). As of April 2018, all antennas are now linked remotely to an online server (Biologic, by Biomark Corp., Boise, Idaho), which allowed closer monitoring of voltage, current, and detections in real time.

Table 16. Weekly releases and detections of natural-origin Chinook parr PIT tagged from the Cedar River and Bear Creek screw traps and hatchery origin Chinook tagged fish at the Issaquah hatchery in 2018.

		N. Tagged			N. Detected			% Detected		
Week		Bear	Cedar	Issaquah	Bear	Cedar	Issaquah	Bear	Cedar	Issaquah
4/23	4/29	51	1		10	0		19.6%		
4/30	5/6	128	4	1,001	25	0	141	19.5%		14.1%
5/7	5/13	540	22	1,000	89	2	86	16.5%	9.1%	8.6%
5/14	5/20	600	123		84	12		14.0%	9.8%	
5/21	5/27	652	168	1,000	51	10	26	7.8%	6.0%	2.6%
5/28	6/3	246	158		16	16		6.5%	10.1%	
6/4	6/10	260	48		4	1		1.5%	2.1%	
6/11	6/17	52	125		0	5		0.0%	4.0%	
6/18	6/24	49			0			0.0%		
6/25	7/1		51			1			2.0%	
Total		2,578	700	3,001	279	47	254	10.8%	6.7%	8.4%

Table 17. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Cedar River screw trap, tag years 2010 to 2018. Detection data is from the Hiram Chittenden Locks.

	N.	Length (mm)			% of Parr	N.	%	Travel	First	Last	Median Detection
Year	Tagged	Ave	Min	Max	Migration	Detected	Detected	Days	Detection	Detection	Date
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
2016	1,372	87.0	65	138	4.4%	128	9.3%	22.5	05/19	07/15	06/04
2017	823	85.8	65	113	3.5%	36	4.4%	22.5	06/04	07/22	06/17
2018	700	80.2	64	103	2.5%	47	6.7%	24.0	05/27	07/10	06/20

Table 18. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Bear Creek screw trap, tag years 2010 to 2018. Detection data is from the Hiram Chittenden Locks.

	N.	Length (mm)			% of Parr	N.	%	Travel	First	Last	Median
Year	Tagged	Ave	Min	Max	Migration	Detected	Detected	Days	Detection	Detection	Date
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
2016	2,766	83.3	65	108	14.5%	287	10.4%	23.2	05/07	06/29	05/31
2017	3,211	80.9	65	108	22.9%	387	12.1%	22.0	05/21	07/05	06/09
2018	2,578	78.1	63	107	9.0%	279	10.8%	22.0	05/17	07/04	06/05

Table 19. PIT tag and migration timing of natural-origin Chinook released from Issaquah hatchery, years 2014 to 2018. Detection data is from the Hiram Chittenden Locks.

Year	Release Date	N. Tagged	N. Detected	% Detected	Travel Days	First Detection	Last Detection
2014	23-May	5,000	137	2.74%	34	06/08	07/27
2015	1-May	1,193	60	5.03%	26	05/21	06/13
2015	4-May	1,186	49	4.13%	24	05/18	06/13
2015	8-May	1,189	33	2.78%	21	05/21	06/13
2016	1-May	999	55	5.51%	31	5/19	6/28
2016	8-May	999	27	2.70%	25	5/19	6/27
2016	18-May	995	12	1.21%	25	6/7	6/27
2017	7-May	1,000	49	4.90%	22	5/28	6/24
2017	15-May	734	21	2.86%	22	6/4	6/19
2017	22-May	999	20	2.00%	23	6/7	6/23
2018	1-May	1,001	141	14.09%	29	5/16	6/24
2018	8-May	1,000	86	8.60%	33	5/28	6/27
2018	24-May	1,000	26	2.60%	28	6/9	6/27

Appendix A

Catch of Fishes and Migration Estimates by Strata for Cedar River Sockeye, Chinook, and Coho Salmon in 2018

Appendix A1. Total catch and migration by strata for Cedar River natural-origin sockeye fry, 2018.

Dates	Total catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Jan 1-Jan 12	Pre trapping	16,500	14,142	18,858	7.5%		1.45E+06
Jan 13- Feb 2	6,206	137,911	88,777	187,045	18.2%	4.50%	6.28E+08
Feb 3- Mar 23	175,591	7,153,257	6,255,335	8,051,179	6.4%	2.45%	2.10E+11
Mar 24- Mar 30	20,709	516,112	366,679	665,545	14.8%	4.01%	5.81E+09
Mar 31- July 15	9,704	901,691	566,041	1,237,341	19.0%	1.08%	2.93E+10
Total	212,210	8,725,471	7,290,974	10,159,969	5.68%	2.43%	2.46E+11

Appendix A2. Total catch and migration by strata for Cedar River natural-origin Chinook, 2018.

Life history	Period	Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Fry	Jan 1-12 pre trapping	--	1,637	1,410	1,864	7.08%		1.34E+04
Fry	Jan 13-Feb 2	443	9,844	6,484	13,204	17.41%	4.50%	2.94E+06
Fry	Feb 3- Mar 23	10,653	433,986	385,346	482,626	5.72%	2.45%	6.16E+08
Fry	Mar 24 –Mar 30	712	17,745	13,194	22,296	13.08%	4.01%	5.39E+06
Fry	Mar 31- April 8	316	29,362	18,117	40,607	19.54%	1.08%	3.29E+07
Parr	April 9-July 15	1,943	31,804	21,377	42,231	16.73%	6.11%	2.83E+07
	Fry total:	12,124	492,574	424,551	560,597	5.22%	2.47%	6.57E+08
	Parr total:	1,943	31,804	21,377	42,231	16.73%	6.11%	2.83E+07
	Chinook total:	14,067	524,378	445,928	602,828	4.99%	2.68%	6.85E+08

Appendix A3. Total catch and migration by strata for Cedar River natural-origin coho age 1+ smolt, 2018

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Jan 12 - July 15	5,848	179,946	127,504	232,388	14.87%	3.25%	2.51E+06

Appendix A4. Alternate estimation of the egg to juvenile survival rate of Cedar River Chinook estimated by the average post orbital eye to hypural length (POH mm) of female carcasses.

Brood	♀ POH (mm)	♀Carcasses	Est. Fecundity	♀ Spawners	Egg Deposition	Juvenile Prod.	Est. Survival
2001	623	124	4,758	398	1,893,684	119,674	6.3%
2002	685	165	5,645	281	1,586,245	235,397	14.8%
2003	705	136	5,946	337	2,003,802	120,876	6.0%
2004	707	232	5,976	511	3,053,736	134,298	4.4%
2005	690	122	5,720	339	1,939,080	117,559	6.1%
2006	692	239	5,749	587	3,374,663	125,186	3.7%
2007	678	323	5,542	899	4,982,258	769,791	15.5%
2008	716	199	6,114	599	3,662,286	139,452	3.8%
2009	720	78	6,176	285	1,760,160	152,390	8.7%
2010	736	65	6,425	266	1,709,050	187,806	11.0%
2011	713	75	6,068	324	1,966,032	902,514	45.9%
2012	640	109	4,994	433	2,162,402	893,877	41.3%
2013	706	146	5,961	740	4,411,140	1,458,761	33.1%
2014	647	60	5,093	232	1,181,576	347,663	29.4%
2015	688	185	5,690	723	4,113,870	972,641	23.6%
2016	650	67	5,136	418	2,146,848	174,719	8.1%
2017	664	172	5,337	819	4,371,003	524,378	12.0%

Appendix A5: Actual catch of all species and salmon life-history types in the 2018 Cedar River screw trap with reference to the catch in 2017 screw trap and 2016 (screw trap + inclined-plane trap catch).

Common name	Genus	2018	2017	2016
sockeye fry (natural)	*Oncorhynchus nerka*	167,717	41,250	7,925
Chinook fry (natural)	*Oncorhynchus tshawytcha*	9,868	2,766	3,601
coho smolt (wild)	*Oncorhynchus kisutch*	5,537	2,618	2,597
Chinook parr (natural)	*Oncorhynchus tshawytcha*	1,770	1,362	1,799
Chinook parr (hatchery)	*Oncorhynchus tshawytcha*	259	85	40
sculpin: general	*Cottus spp.*	183	221	93
cutthroat juvenile	*Oncorhynchus clarkii clarkii*	120	197	48
3 spine stickleback	*Gasterosteus aculeatus*	78	26	191
coho fry	*Oncorhynchus kisutch*	56	17	3
lamprey	*Lampetra spp.*	47	82	27
pink salmon	*Oncorhynchus gorbuscha*	19	0	1
trout fry 0+	*Oncorhynchus mykiss/clarkii*	16	1	0
longnose dace	*Rhinichthys cataractae*	9	2	3
coho parr (wild)	*Oncorhynchus kisutch*	8	15	28
largescale sucker	*Catostomus macrocheilus*	7	14	7
steelhead smolt (wild)	*Oncorhynchus mykiss*	6	8	17
coho smolt (hatchery)	*Oncorhynchus kisutch*	5	0	0
cutthroat adult	*Oncorhynchus clarkii clarkii*	4	2	1
peamouth chub	*Mylocheilus caurinus*	4	6	5
Chinook age 1+	*Oncorhynchus tshawytcha*	1	0	0
pumpkinseed	*Lepomis gibbosus*	1	1	0
whitefish	*Prosopium spp.*	1	2	10
speckled dace	*Rhinichthys osculus*	0	1	2
rock bass	*Ambloplites rupestris*	0	0	1
warmouth	*Lepomis gulosus*	0	0	4
bluegill	*Lepomis macrochirus*	0	0	1
smallmouth bass	*Micropterus dolomieu*	0	0	1
chum fry	*Oncorhynchus keta*	0	0	1

Appendix B

Catch of all Fishes and Migration Estimates by Strata for Bear Creek Sockeye, Chinook, and Coho Salmon 2018.

Appendix B1 Catch and migration by strata for Bear Creek natural-origin sockeye, 2018.

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Jan 1- Jan 24 Pre trap		955	743	1,167	11.3%		1.17E+04
Jan 25 - Mar 20	117,949	1,043,795	943,509	1,144,081	4.9%	11.3%	2.62E+09
Mar 21 - July 10	28,997	341,147	297,606	384,688	6.9%	8.5%	4.93E+08
Total	146,946	1,385,897	1,241,858	1,529,936	4.0%		3.11E+09

Appendix B2. Catch and migration by strata for Bear Creek natural-origin Chinook, 2018.

Period	Life History	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Jan 25 – March 20	Fry	2,403	21,263	19,071	23,455	5.3%	11.3 %	1.25E+06
March 21- April 8	Fry	249	2,930	2,413	3,447	9.0%	8.5%	6.95E+04
April 9 - July 10	Parr	11,058	28,427	24,991	31,863	6.2%	38.9%	3.07E+06
	Fry total:	2,652	24,193	21,484	26,902	4.6%	11.0%	1.25E+06
	Parr total:	11,058	28,427	24,991	31,863	6.2%	38.9%	3.14E+06
	Chinook total:	13,710	52,620	46,475	58,765	4.0%	26.1%	4.39E+06

Appendix B3. Catch and migration by strata for Bear Creek natural-origin coho smolts, 2018.

Period	Total Catch	Abundance	Lower CI	Upper CI	*CV*	*Eff.*	*Variance*
Jan 25- July 10	4667	37,631	28,305	46,957	12.6%	12.4%	2.26E+07

Appendix B4. Alternate estimation of the egg to juvenile survival rate for Bear Creek Chinook estimated by the average post-orbital eye to hypural plate length (POH mm) of female carcasses on the spawning ground.

Brood	♀POH (mm)	♀Carcasses	Est. Fecundity	♀Spawners	Egg Deposition	Juvenile Prod.	Egg. Survival
2001	670	121	5,424	138	748,512	21,318	2.8%
2002	674	174	5,483	127	696,341	17,281	2.5%
2003	691	83	5,735	147	843,045	23,647	2.8%
2004	699	73	5,855	121	708,455	9,270	1.3%
2005	687	138	5,675	122	692,350	22,362	3.2%
2006	685	103	5,645	131	739,495	16,529	2.2%
2007	641	74	5,009	89	445,801	12,706	2.9%
2008	704	79	5,930	132	782,760	65,202	8.3%
2009	698	6	5,840	48	280,320	9,185	3.3%
2010	690	55	5,720	60	343,200	17,763	5.2%
2011	707	27	5,976	55	328,680	22,197	6.8%
2012	636	85	4,938	147	725,886	44,599	6.1%
2013	691	19	5,735	48	275,280	62,775	22.8%
2014	650	22	5,136	60	308,160	32,733	10.6%
2015	635	78	4,924	138	679,512	44,124	6.5%
2016	613	29	4,621	115	531,415	35,709	6.7%
2017	597	78	4,406	160	704,960	52,620	7.5%

Appendix B5. Actual catch composition of salmonids and incidental species in Bear Creek 2018, 2017, and 2016. The screw trap documented 23 unique species as well as several life history types within a species.

Common name	Genus species	2018	2017	2016
sockeye fry (natural)	*Oncorhynchus nerka*	145,059	25,656	3,564
Chinook parr (natural)	*Oncorhynchus tshawytcha*	9,795	6,792	4,852
coho smolt (wild)	*Oncorhynchus kisutch*	3,946	427	1,675
Chinook fry (natural)	*Oncorhynchus tshawytcha*	2,712	677	1,180
peamouth chub	*Mylocheilus caurinus*	1,934	639	1,825
cutthroat (juvenile)	*Oncorhynchus clarkii*	1,323	1,110	674
lamprey	*Lampetra sp.*	842	645	910
sculpin	*Cottus spp*	573	304	285
3 spine stickleback	*Gasterosteus aculeatus*	487	558	188
green sunfish	*Lepomis cyanellus*	59	128	306
rainbow trout (hatchery)	*Oncorhynchus mykiss*	59	24	2
coho fry	*Oncorhynchus kisutch*	40	11	3
largescale sucker	*Catostomus macrocheilus*	27	10	16
bluegill	*Lepomis macrochirus*	21	7	19
brown bullhead	*Ameiurus nebulosus*	16	22	23
cutthroat (adult)	*Oncorhynchus clarkii*	12	21	47
pumpkinseed	*Lepomis gibbosus*	11	6	22
rock bass	*Ambloplites rupestris*	6	13	3
smallmouth bass	*Micropterus dolomieu*	6	0	1
coho (parr)	*Oncorhynchus kisutch*	5	2	8
coho (hatchery)	*Oncorhynchus kisutch*	4	0	0
longnose dace	*Rhinichthys cataractae*	4	3	0
trout 0+	*Oncorhynchus mykiss*	3	8	7
northern pikeminnow	*Ptychocheilus oregonensis*	3	1	1
whitefish	*Prosopium spp*	3	1	1
warmouth	*Lepomis gulosus*	1	11	13
sockeye smolt natural	*Oncorhynchus nerka*	1	0	0
speckled dace	*Rhinichthys osculus*	1	3	2
yellow perch	*Perca flavescens*	0	2	1
steelhead smolt (wild)	*Oncorhynchus mykiss*	0	1	2

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