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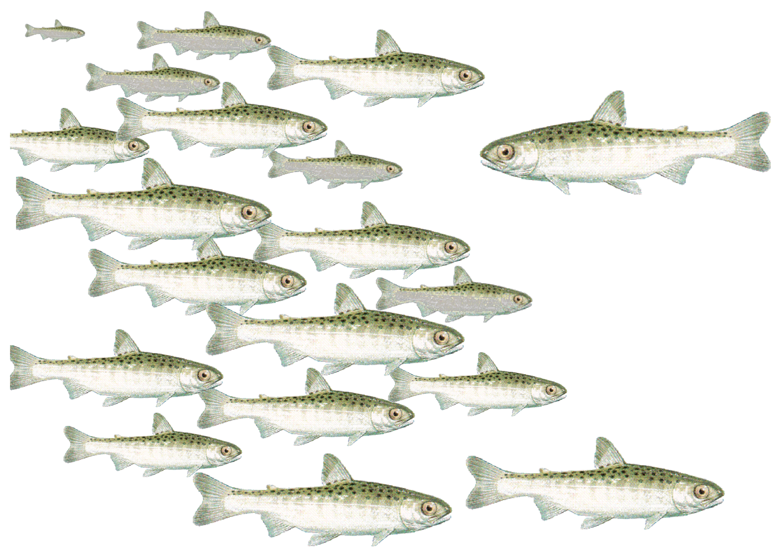
Evaluation of Juvenile Salmon Production in 2017 from the Cedar River and Bear Creek



by Peter Lisi

Washington Department of Fish and Wildlife
Fish Program
Science Division

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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 on 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, monitoring site moved 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.

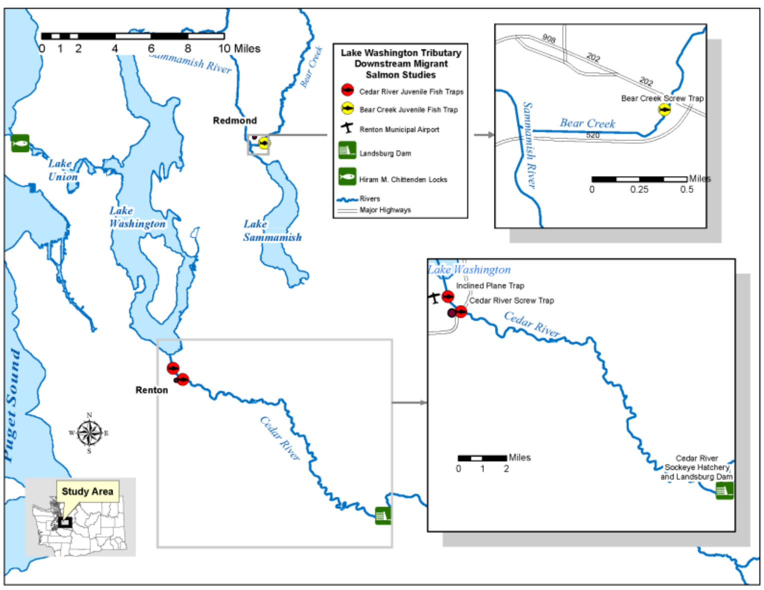

Figure 1. Map of Lake Washington trap sites used to monitor abundance of juvenile migrant salmonids in the Cedar River and Bear Creek, near Renton and Redmond, respectively.

The primary goal of this study is 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 2017. These data allow an estimate of egg to fry survival of the of the 2016 brood. Daily abundance estimates also characterize 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 to 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 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 Chinook, coho, and cutthroat smolts.

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 RM 1.6 for the period April to July to enumerate Chinook salmon.

In contrast to previous years, during 2017, we operated 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 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 while fishing. 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 4.3 million sockeye fry into the Cedar River on 10 nights throughout the 2017 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) and middle location (R.M. 13.5), and three 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 in coordination with hatchery staff. 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. True abundance and survival of natural origin sockeye is likely lower than reported if hatchery fish delay their migration by a night after a release.

Bear Creek

A rotary screw trap operated from January 30 to July 10, 2017, ~100 yards downstream of the Redmond Way Bridge at the railroad trestle (Figure 1). The trap fished continuously, except for 17 periods when high flows and debris stopped the trap. 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 smolts.

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 migration.

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 April 26 and July 7, 2017, following standard protocols outlined by the Columbia River basin by the PIT Tag Steering Committee (2014). Chinook longer than 65 mm and 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. Natural origin Chinook were also tagged at the Landsburg Hatchery forebay in the upper Cedar River watershed during dewatering for annual cleaning (N = 6). A total of 3,211 migrants were tagged at Bear Creek and 823 tagged at the Cedar River.

Nearly 3,000 (n=2,733) hatchery Chinook sub-yearlings were PIT tagged at Issaquah Hatchery. These fish were released into Issaquah Creek covering three weeks: May 8, 15, and 22. All were tagged and held at the Issaquah hatchery two-three weeks in advance of their release.

The Hiram Chittenden Locks demarcate the freshwater to marine boundary between 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 analysis include 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 at each of stream release locations. 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 hours) in an aerated bucket of stream water. Only healthy, marked fry were released above the trapping site while deceased or injured fish were removed. Releases occurred across the middle of the channel using a swinging bucket on a rope. The trap efficiency for a day or night period is the total recaptured fish relative to the total number of released fish.

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 smolt and parr in the Cedar River occurred 2000 meters upstream of the trap at the Maplewood Roadside Park while fry were released 800 m upstream at the Rivera Apartments. 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

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

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 (α = 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 (derivation in Appendix A):

Equation 10

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

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

Extrapolate Migration Prior to and Post Trapping

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

Equation 11

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

Variance of the extrapolation 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 sockeye spawners (assuming 50% are female) in Cedar River and Bear Creek. Cedar River sockeye fecundity during the broodstock collection for the hatchery was 3,144 eggs per female in 2016 (Sedgwick, 2017). The fecundity of Bear Creek sockeye are assumed to be the same as the fecundity of Cedar River brood stock sockeye.

Productivity for Chinook in both 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 a 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 red. Average fecundity for 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).

Cedar River

Sockeye

Production Estimate

An estimated 2.53 ± 0.52 million (± 95% CI) natural-origin sockeye fry entered Lake Washington from the Cedar River in 2017 (Table 1, Appendix A 1). This estimate includes a small pre-season estimate of 21,048 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). There were notable peaks on morning of February 13 (before a hatchery release) and March 1 of 108,700 and 95,000 sockeye respectively (Figure 2). Sockeye fry continued to be trapped into the first week of July.

Median migration of natural-origin sockeye occurred on February 28th. Notably, this is the earliest migration of fry out of the Cedar River on record and is part of a long-term trend toward earlier migration over the last 3 decades (Table 3). To put this in perspective, the 2017 sockeye migration is 27 days earlier than the average run timing from 1992-2000, 17 days later than the 2000's, and 11 days earlier than average timing during the last 6 years (March 7). In the Cedar River, a higher take of hatchery brood stock from of earlier migrating adults may accentuate long-term behavioral shifts in earlier spawning and migration of natural origin sockeye.

Efficiency groups of natural origin sockeye were supplemented with hatchery sockeye fry to increase the total number of sockeye released. Efficiency data were aggregated into two strata of 3.34% and 2.77% from twelve efficiency trails of sockeye fry (Table 1, Appendix A).

Table 1. Abundance of natural-origin sockeye fry entering Lake Washington from the Cedar River in 2017. Table includes; total catch (actual plus estimated), abundance of fry migrants, 5% and 95% confidence intervals (C.I.), coefficient of variation (CV), and trap efficiency.

Capture Method	Dates	Total catch	Abundance	5% CI	95% CI	*CV*	*Eff.*
Pre-trapping	Jan 1-Jan 12		21,048	20,203	21,893	2.0%	
Screw Trap	Jan 12- Feb 2	10,275	313,003	261,549	364,457	8.4%	3.34%
Screw Trap	Feb 3- July 12	60,953	2,196,617	1,731,904	2,661,330	10.8%	2.77%
	Total	71,411	2,530,668	2,013,657	3,047,679	9.4%	

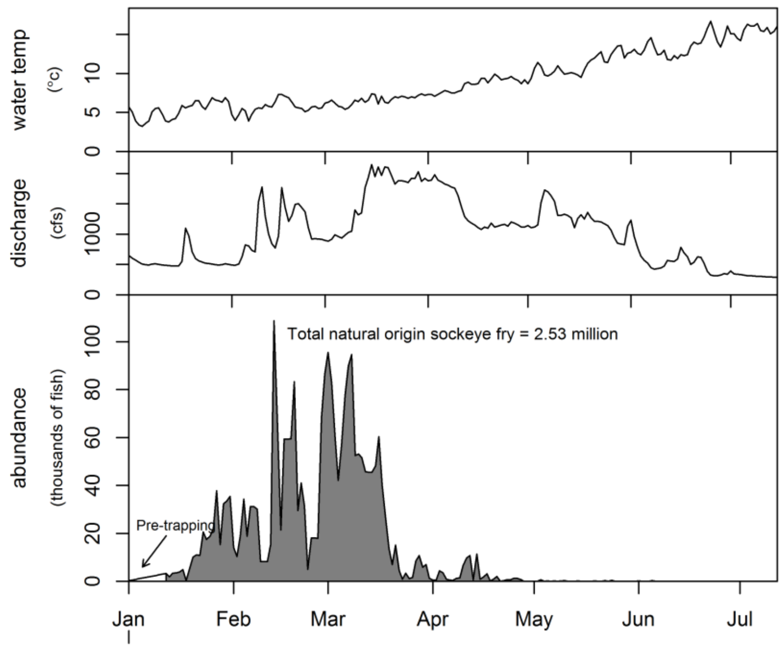

Figure 2. Estimated daily migration of natural-origin sockeye fry migrating from the Cedar River into Lake Washington between January 1 and July 12, 2017. Pre-trapping migration estimates are included (Jan. 1-Jan. 12). Top panel reference changes in daily river flow and water temperature during this period (USGS Renton gage Station #12119000).

The Cedar River Sockeye Hatchery released 4.32 million sockeye from February 13, 2017 through April 12, 2017 on ten nights at three locations above the trap (Table 2). In total, seven releases occurred at the lower location (River mile, R.M. 2.1) and middle location (R.M. 13.5) and three releases at upper location (R.M. 21.8). The screw trap did not fish 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 8th, 8 days later than the median migration date of naturally produced sockeye in 2017 (Table 3).

Table 2. Release schedule of 4.315 million hatchery sockeye from the Cedar River Sockeye Hatchery released at three different release points along the Cedar River in 2017: lower (river mile, R.M. 2.1), middle (R.M. 13.5) and upper location (R.M. 21.8) . Data courtesy of Michael Sedgwick, Cedar River Hatchery Manager.

Release Date	Lower	Middle	Upper
13-Feb	285,779	118,032	
15-Feb	88,332	339,765	
17-Feb		100,605	277,910
6-Mar		297,862	230,733
8-Mar	562,268		
13-Mar		661,743	
15-Mar	390,095		253,992
28-Mar	156,243	238,840	
3-Apr	69,771	70,171	76,666
12-Apr	33,514		62,987
Total	1,586,002	1,827,018	902,288

Table 3. Median migration dates of wild natural-origin, hatchery, and average combined sockeye fry from the Cedar River for trap years 1992 to 2017.

Trap year	Wild	Hatchery	Combined	Diff (H-W)
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

Egg-to-Migrant Survival of Natural-Origin Fry

Egg-to-migrant survival of the 2016 brood Cedar River sockeye was 21.26% (Table 4). Survival was based on 2.53 million natural-origin fry from a potential 11.9 million eggs deposited by 3,787 females (A. Bosworth, Washington Department of Fish and Wildlife, personal communication). Average fecundity for the 2016 brood was 3,144 eggs per female sockeye (M. Sedgwick, Washington Department of Fish and Wildlife, personal communication).

Salmon eggs incubating within streambeds redds are susceptible to flooding and scour, so peak winter discharges often explain lower egg to fry survival. River flows did not surpass known scouring thresholds (2200 $ft^3 sec^{-1}$, Gendaszek et al. 2017) during egg incubation (November through February). Peak flows during November and December 2016 were moderate (1460, 1680 $ft^3 sec^{-1}$ respectively). Flow on February 10^{th} reached 2140 $ft^3 sec^{-1}$ (Table 4). Only after the most of the fry migration passed, flows passed scour levels (2,500 $ft^3 sec^{-1}$) 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 - 2016. Incubation period is from November to February. 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

Chinook

Production Estimate

Two life-history forms of sub-yearling Chinook salmon migrate out of Puget Sound streams and rivers: small fry migrating immediately after emergence and larger parr that spend several weeks to months rearing and growing in freshwater streams. Here, Chinook fry are defined as those fish emigrating from January to April 8th and parr are defined as fish emigrating between April 9th and July (Figure 3). During the transition period in April, the overall migration decreases and larger size fish start to appear in the catch (Figure 3).

The total production of Chinook sub-yearling (parr and fry) in 2017 was 174,719 ± 37,722 (±95% C.I.). The fry component was 151,262 ± 31,111 or 87% of all natural origin Chinook sub-yearling. Chinook fry efficiency trials occurred regularly from the start of the season, though early season catches were low. Because trap efficiencies are not statistically different between sockeye and Chinook, sockeye releases were used to help estimate trap efficiency of Chinook fry from Feb

3 to April 8th (Kiyohara 2016). Trap efficiencies ranged from 2.77% to 5.1%. An estimated 23,457± 6,611 (±95% C.I.) natural-origin Chinook parr passed the screw trap (Table 5). This estimate is based on a total catch of 1,453 Chinook parr and trap efficiency of 6.20%. Parr made up only 13% of the total sub-yearling migration. Chinook fry migration increased quickly over the season to one prominent peak in early February then slowly decreased for the remainder of season (Figure 3). Parr displayed sporadic movements in June that averaged 1000 fish per day (Figure 3).

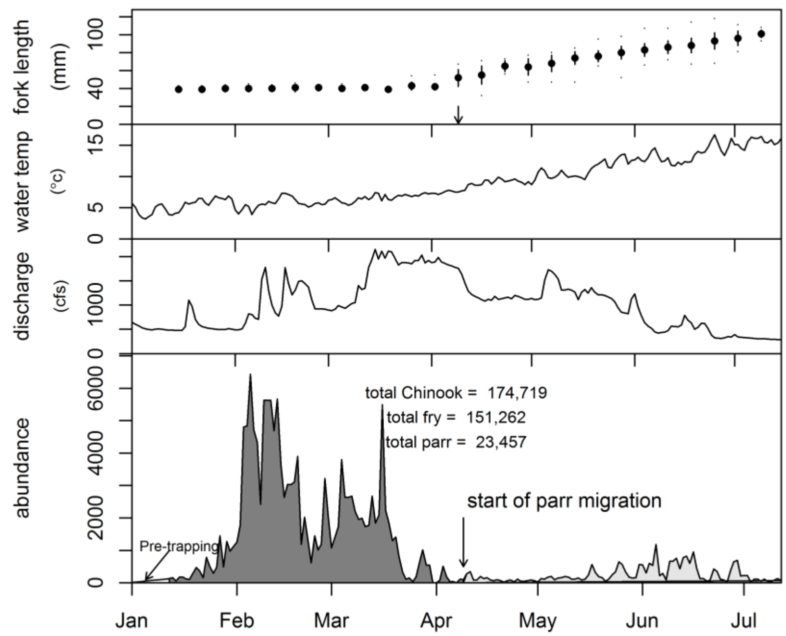

Figure 3**.** Bottom panel: Estimated daily migration of Chinook fry and parr from the Cedar River from January 1 to July 12, 2017. Pre-trapping migration estimates cover January 1-12. Parr life history type designation starts on April 9th. Middle panels: Time series of mean daily water temperatures and 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 2017. Table includes total catch, abundance of fry and parr life histories, 95% confidence intervals (C.I.), coefficient of variation (*CV*) and trap efficiencies (*Eff*.)

Life history	Period	Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*
Fry	Jan 1-12 pre trapping		826	677	975	9.2%	
Fry	Jan 12-Feb 2	637	12,495	7,347	17,643	21.0%	5.09%
Fry	Feb 3- April 8	3,821	137,941	112,127	163,755	9.5%	2.77%
Parr	April 9-July 12	1,453	23,457	16,846	30,068	14.4%	6.20%
	Fry total:	4,458	151,262	120,151	182,373	8.9%	
	Parr total:	1,453	23,475	16,846	30,068	14.4%	
	Chinook total:	5,911	174,719	136,997	212,441	7.9%	

Size

Chinook migrant fork length (FL) ranged from 36 to 128 mm (Figure 3). Average fork length increased as water temperatures increased (Figure 3).Weekly average size of fry was 38 mm increasing to 50 mm FL by the first week in April (Figure 3). Chinook parr averaged 57 mm during the second week of April to 113 mm by the first week in July.

Productivity

Egg-to-migrant survival of the 2016 brood Cedar River Chinook was 9.3% (Table 6). Survival was based on 174,719 sub-yearling migrants and 1.845 million eggs from 418 female spawners (A. Bosworth, Washington Department of Fish and Wildlife, personal communication). The number of juvenile Chinook migrants produced per female is low relative to the last 20 years (6th lowest, Table 6). The 2017 egg-to-migrant survival is below 2025 goals (13.8%) for the Cedar (WRIA Conservation plan 2017). Although egg survival rates were encouragingly high during 2011-2015 brood years (survival rate range: 30-61%), the 2016 brood year appeared to have much lower survival (9.3%) despite moderate flows in the Cedar. Peak flows in November, and December 2016 were moderate (1460, 1680 ft^3 sec^{-1} respectively). In early February, flows before the fry migration reached 2140 ft^3 sec^{-1} (Figure 3).

Table 6. Abundance of Chinook fry and parr and productivity (juveniles per female) among brood years 1998 to 2016. Productivity is based on 4500 eggs per females and weekly fall redd surveys.

Brood yr	Fry	Parr	Total	±95%CI	%Fry	%Parr	Female Spawners	Fry per Female	Parr per Female	Total per Female	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%
2002	1,94,657	40,740	235,397	51,485	83%	17%	281	693	145	838	18.6%
2003	65,752	55,124	120,876	2,518	54%	46%	337	195	164	359	8.0%
2004	74,292	60,006	134,298	42,912	55%	45%	511	145	117	263	5.8%
2005	98,967	18,592	117,559	16,233	84%	16%	339	292	55	347	7.7%
2006	110,961	14,225	125,186	16,912	89%	11%	587	189	24	213	4.7%
2007	705,583	64,208	769,791	76,106	92%	8%	899	785	71	785	19.0%
2008	127,064	12,388	139,452	38,399	91%	9%	599	212	21	233	5.2%
2009	115,474	36,916	152,390	13,058	76%	24%	285	405	130	535	11.9%
2010	177,803	10,003	187,806	63,560	95%	5%	266	668	38	706	15.7%
2011	863,595	38,919	902,514	165,973	96%	4%	324	2,665	120	2,786	61.9%
2012	874,658	19,219	893,877	77,993	98%	2%	433	2,020	44	2,064	45.9%
2013	1,426,631	32,130	1,458,761	390,039	98%	2%	740	1,928	43	1,971	43.8%
2014	326,901	20,762	347,663	90,223	94%	6%	232	1,409	89	1,499	33.3%
2015	941,443	31,198	972,641	408,314	97%	3%	723	1,302	43	1,345	29.9%
2016	151,262	23,457	174,719	37,722	87%	13%	418	362	56	418	9.3%

Coho

Production Estimate

Total coho age 1+ smolt production was 91,295 ± 29,526 (± 95% C.I.) migrants (Figure 4. Bottom panel: Estimated daily migration of yearling coho migration from the Cedar River in 2017 based on screw trap estimates from January 1 to July 12. Middle panels: Time series of mean daily 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). Total catch (actual and missed) of coho migrants in the screw trap was 2,798. We observed two life history forms in the Cedar River: typical 1+ yearling coho and a few sub-yearling coho fry and parr (40 total). Eighteen efficiency trials were aggregated into one strata of 3.1% (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. The median migration date was May 9th.

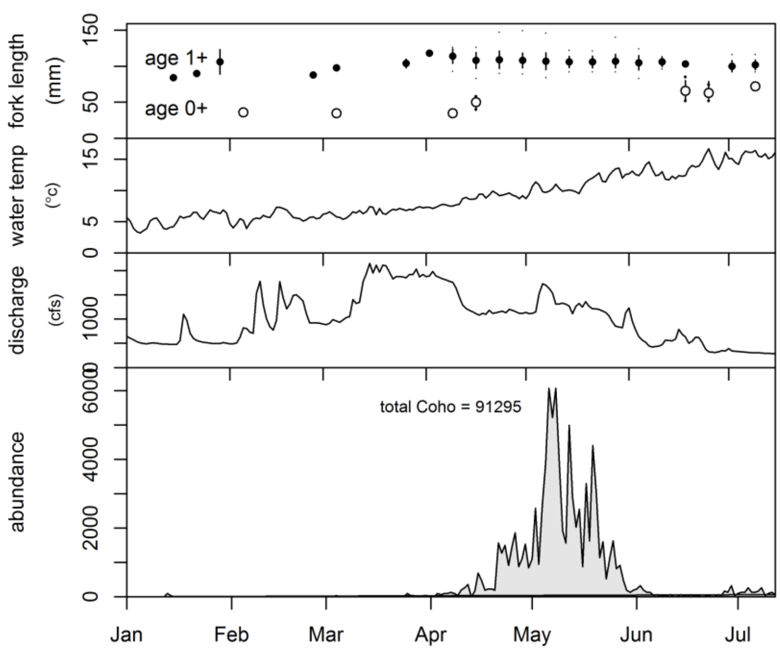

Figure 4. Bottom panel: Estimated daily migration of yearling coho migration from the Cedar River in 2017 based on screw trap estimates from January 1 to July 12. Middle panels: Time series of mean daily water temperatures and river discharge from the USGS gaging station in Renton (Station 12119000). 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 2016. Table includes abundance of yearling migrants, 5% and 95% confidence intervals (C.I.), coefficient of variation (*CV*) and trap efficiency.

Period	Total Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*
Jan 12 - July 12	2,798	91,295	61,769	120,821	16.5%	3.07%

Size

Average fork length of all measured coho migrants smolt 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 to April 9 and then grew to 40 to 74 mm between April 16 to July 9th.

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 smolt were identified when the fish had silver coloration upon capture. We did not identify trout fry to species or life-history type.

Eight steelhead smolts, 197 juvenile cutthroat trout, one unidentifiable trout fry, and two adult cutthroat trout were captured in the screw trap. Catches were too few to estimate migrant abundance. Steelhead fork lengths ranged from 141 to 223 mm and averaged 185 mm FL. Juvenile cutthroat fork lengths ranged from 98 mm to 238 mm FL and averaged 149 mm FL.

Incidental Catch

Other salmonids caught in the screw trap include 85 hatchery Chinook parr. Non-salmonid fishes in the trap include lamprey (*Lampetra* spp.), three-spine stickleback (*Gasterosteus aculeatus*), sculpin (*Cottus* spp.), large-scale sucker (*Catostomus macrocheilus*), peamouth chub (*Mylocheilus caurinus*), whitefish *(Prosopium spp.)*, longnose dace (Rhinichthys cataractae), pumpkinseed sunfish *(Lepomis gibbosus)*, speckled dace (*Rhinichthys osculus)*. Six species were absent from the catch in 2017, but were present in 2016 (Pink and Chum salmon, smallmouth bass, bluegill, warmouth, and rock bass, Appendix A4).

Bear Creek

Sockeye

Production Estimate

An estimated 512,651 ± 75,888 (± 95% CI) natural-origin sockeye fry entered Lake Washington from Bear Creek in 2017 (Table 8). This estimate includes a very small pre-season run of 1,212 from January 1st to the 30th. Median migration date for natural-origin sockeye was March 21st. Total catch (actual and estimated missed) in the Bear Creek screw trap was 28,213 sockeye fry during the trapping period (Table 8). Twenty-three efficiency trails from March 3 to April 11 were aggregated into two final strata of 5.95% and 3.95% (Table 8, Appendix B1).

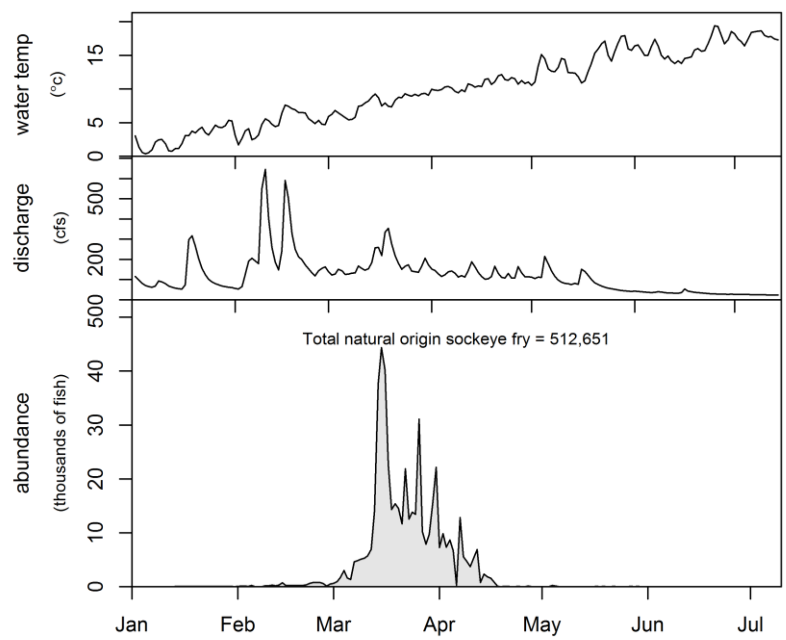

Figure 5. Estimated daily migration of sockeye fry from Bear Creek in 2017 (bottom panel), daily average flow (middle panel), and temperature (top panel) King County gage at Union Hill Road.

Table 8. Abundance of sockeye fry migrants from Bear Creek in 2017. Table includes 95% confidence intervals (C.I.) of abundance, coefficient of variation (*CV*) and trap efficiency for the period.

Period	Total Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*
Jan 1-Jan 30 Pre trap		1,212	18,715	1,480	11.3%	
Jan31- Mar 30	23,877	401,883	349,967	453,227	6.6%	5.95%
Mar 31 - July 10	4,336	109,842	85,852	133,832	11.1%	3.95%
Total	28,213	512,651	454,534	588,539	5.7%	

Egg-to-Migrant Survival

Egg-to-migrant survival of the 2016 brood of Bear Creek sockeye was 31.6 % (Table 9). The survival estimate is based on 512,651 fry migrants and a potential egg deposition (PED) of 1.6 million eggs from 516 female sockeye estimated to have spawned in Bear Creek in 2016. Survival was the 4th highest on record, continuing a recent trend of increasing egg-to-fry survival of sockeye in Bear Creek over the last decade (Table 9).

Table 9. Egg-to-migrant survival of Bear Creek sockeye by brood year. Potential egg deposition (PED) is based on fecundity of sockeye brood stock in the Cedar River.

Brood yr	Spawners	Females	Fecundity	Egg deposition	Fry production	Egg Survival	Peak Flow	Flow date
1998	8,340	4,170	3,176	13,243,920	1,526,208	11.5%	515	11/26/1998
1999	1,629	815	3,591	2,924,870	189,571	6.5%	458	11/13/1999
2000	43,298	21,649	3,451	74,710,699	2,235,514	3.0%	188	11/27/2000
2001	8,378	4,189	3,568	14,946,352	2,659,782	17.8%	626	11/23/2001
2002	34,700	17,350	3,395	58,903,250	1,995,294	3.4%	222	1/23/2003
2003	1,765	883	3,412	3,011,090	177,801	5.9%	660	1/30/2004
2004	1,449	725	3,276	2,373,462	202,815	8.5%	495	12/12/2004
2005	3,261	1,631	3,065	4,999,015	548,604	11.0%	636	1/31/2005
2006	21,172	10,586	2,910	30,805,260	5,983,651	19.4%	581	12/15/2006
2007	1,080	540	3,450	1,863,000	251,285	13.5%	1,055	12/4/2007
2008	577	289	3,135	904,448	327,225	36.2%	546	1/8/2009
2009	1,568	784	3,540	2,775,360	129,903	4.7%	309	11/27/2009
2010	12,527	6,264	3,075	19,260,263	8,160,976	42.4%	888	12/13/2010
2011	911	455	3,318	1,509,690	266,899	17.7%	348	11/23/2011
2012	4,219	2,110	3,515	7,414,893	1,553,602	21.0%	467	1/10/2013
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
2015	414	207	3,070	635,490	81,125	12.8%	350	1/29/2016
2016	1,031	516	3,144	1,622,304	512,651	31.6%	645	2/10/2016

Chinook

Production Estimate

Two life-history forms of sub-yearling Chinook salmon in Puget Sound: small fry that migrate immediately after emergence while parr are those that rear and grow before migrating. 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.

The total production of Chinook sub-yearling (parr and fry) was 35,709 ± 13,019 (±95% C.I.), Fry represented 60.7% of the total migration (21,672 ±11,114). An estimated 25% of the total fry migration (5,355) may have occurred during the pre-trapping period of January 1st to January 30th. Parr represent 39.3% of total production in Bear Creek in 2017 (14,037 ± 1,905, Figure 6, Table 10). The median date of the fry and parr migration was February 19th and May 28th (respectively, Figure 6). Parr migrated out of Bear Creek rapidly as average daily temperatures approached 20 ºC in early June (Figure 6).

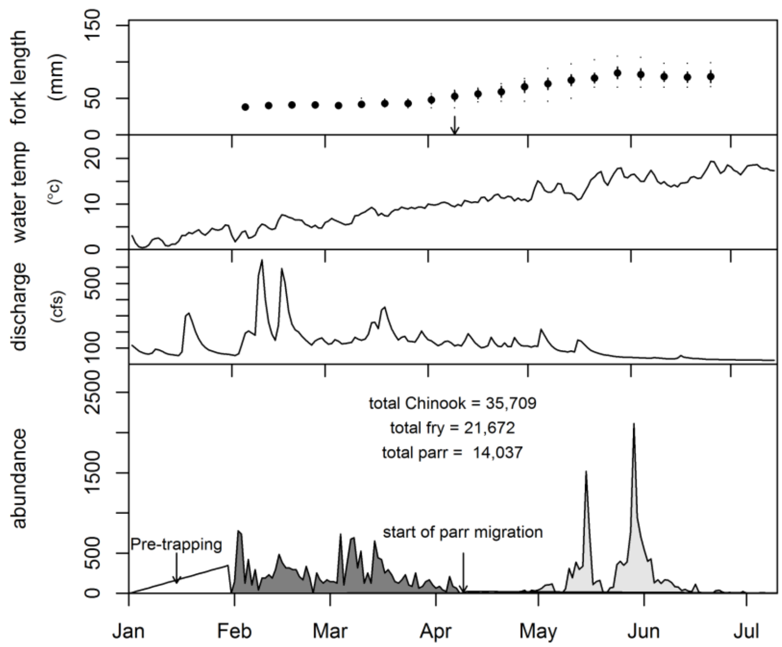

Figure 6. Estimated daily migration of Chinook fry and parr from the Bear Creek in 2017 based on screw trap estimates from January 1 to July 10. Pre-trapping migration estimates cover January 1 to the 30th. Parr life history type designation starts on April 9th with the onset of larger average body size of rearing Chinook. Middle panels: Time series of mean daily water 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 and estimated missed) of 777 Chinook fry and 7,246 parr. Trap efficiencies for the fry period was 4.76%, pooled from six Chinook fry efficiency trials from the start of the season through March 12. Efficiency strata from 22 Chinook efficiency trials were pooled into two final strata of 42.0% and 55.4% (Table 10)

Table 10. Abundance of natural-origin sub-yearling Chinook emigrating from Bear Creek in 2017. 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	5% CI	95% CI	*CV*	*Eff.*
Pre trap Jan 1-30	Fry		5355	3,802	6,908	14.8%	
Jan 31- April 8	Fry	777	16,317	6,756	25,878	29.9%	4.76%
April 9-May 15	Parr	2,003	3,833	2,768	4,898	14.2%	42.0%
May 16-July 10	Parr	5,243	10,204	9,363	11,045	4.2%	55.2%
	Fry total:	777	21,672	10,588	32,785	22.8%	
	Parr total:	7,246	14,037	12,132	15,942	4.9%	
	Chinook total:	8,023	35,709	22,690	48,728	14.0%	

Size

Weekly average lengths of sub-yearling Chinook migrants averaged 39mm to 43mm 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 FL. By the end of June Chinook averaged 101 mm FL (Figure 6).

Productivity

Egg-to-migrant survival of the 2016 brood of Bear Creek Chinook was 6.9 % (Table 11). The survival estimate is based on 35,709 sub-yearling migrants and a potential egg deposition (PED) of 517,500 eggs deposited in 115 observed Chinook redds. The 2016 brood of Bear Creek Chinook produced moderate numbers of fry and parr per female. For 7 of the last 10 years, egg survival rate in Bear exceeded the 2025 WRIA 8 goals for this population (>4.4% egg survival).

Table 11. 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 2016 brood years.

brood year	fry	parr	total	% fry	% parr	female spawners	fry per female	parr per female	Total / female	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%
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	13	130	143	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%
2015	23,753	20,371	44,124	53.8%	46.2%	138	172	148	320	7.1%
2016	21,672	14,037	35,709	60.7%	39.3%	115	188	122	311	6.9%

Coho

Total catch (actual and estimated missed) in the Bear Creek screw trap was 439 sub-yearling and yearling coho. This included an actual catch of 427 coho migrants and only 12 estimated missed catch of coho due to trap outages. Less than 0.5% of the total catch were sub-yearlings (13 total). The median migration date was May 16th.

Production Estimate

The total production of coho juvenile migrants was 6,004 ±3,982 (95% C.I., Table 12, Figure 7). The abundance estimate is based on total catch 427 coho migrants. Five efficiency trials were aggregated into a single stratum of 7.32%. The migration is typically 30,000 migrants in Bear Creek (max= 62,970 in 1999) and the 2017 migration year is the lowest in the history of the project.

Table 12. Abundance of natural-origin juvenile coho emigrating from Bear Creek in 2017, 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	5% CI	95% CI	*CV*	*Eff.*
Jan31- July 10	427	6,004	2,142	9,866	32.8%	7.32%

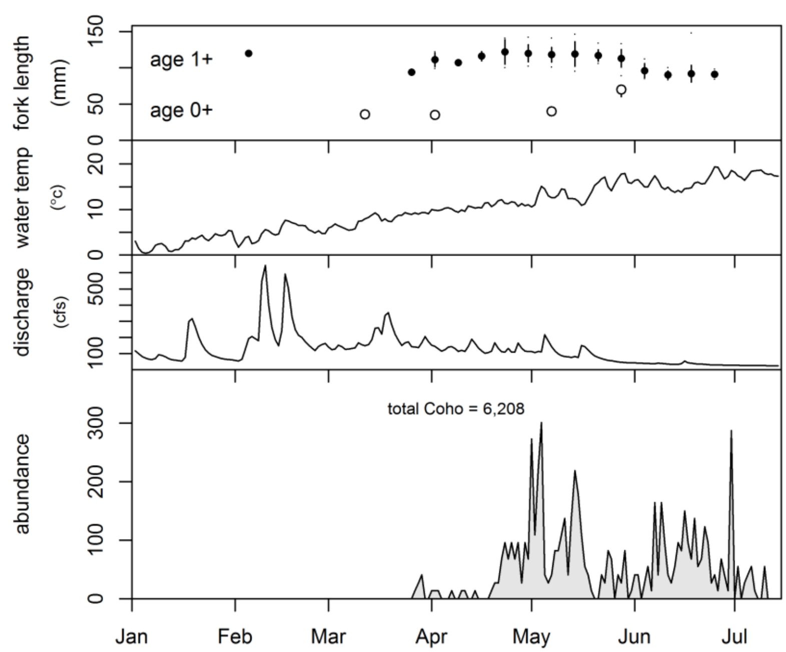

Figure 7. Bottom panel: Daily sub-yearling and yearling coho migration at the Bear Creek screw trap in 2017. Middle planes: Daily average flow and temperature at the Bear Creek at King County gage 02a at Union Hill Road. Top panel: Mean weekly Coho body fork length with vertical lines as ± 1 standard deviation and '.' ± maximum and minimum weekly fork length. Age 1+ smolts in filled points and age 0+fry and parr in open points.

Size

Over the trapping period, fork lengths of sub-yearling and yearling coho ranged from 35 mm to 148 mm FL. Weekly mean lengths of age 1+ coho ranged from 91 mm to 122 mm FL in April and May (Figure 7). Body size of age 1+ coho were smaller in June and July; weekly averages ranged between 90 to 96 mm suggesting that larger Coho migrate out first. Age 0+ fry emerged 35 and 40mm fork length and grow to 68 to 70mm by late May and July as the river temperatures approach 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 1,110 juvenile cutthroat trout. Sporadic catches preventing forming larger trap efficiency trials and estimating abundance. The Bear screw trap also caught twenty-one cutthroat adults, one steelhead smolt, and eight unidentifiable trout fry.

Size

The juvenile steelhead was 187 mm. Among the cutthroat adults, the largest fish was 448 mm FL. Juvenile cutthroat trout averaged 157 mm FL over the season and ranged between 87 mm to 249 mm FL (Table 13). Average fork lengths showed no consistent trend across weeks.

Table 13. Average cutthroat fork length (mm), range in fork length, 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
5	2/5/2017	130	448	74	64.5	44	71
6	2/12/2017					0	50
7	2/19/2017					0	23
8	2/26/2017	144	173	113	17.6	13	33
9	3/5/2017	126	178	88	27.3	18	30
10	3/12/2017	109	121	89	17.7	3	37
11	3/19/2017	209	368	138	107.7	4	20
12	3/26/2017	164	202	138	18.5	9	25
13	4/2/2017	143	178	109	28.4	6	27
14	4/9/2017	138	178	89	24.8	12	33
15	4/16/2017	220	220	220		1	10
16	4/23/2017	135	176	100	32.9	4	47
17	4/30/2017	165	245	131	28.7	27	54
18	5/7/2017	152	172	129	14.3	11	34
19	5/14/2017	157	260	117	25.6	46	129
20	5/21/2017	153	212	128	16	32	184
21	5/28/2017	163	214	132	19.9	23	58
22	6/4/2017	145	158	123	10.3	13	158
23	6/11/2017	154	198	126	23.2	10	60
24	6/18/2017	146	242	112	29.8	16	17
25	6/25/2017					0	1
26	7/2/2017					0	4
27	7/9/2017					0	4
28	7/16/2017					0	1
	Season total	153	219	120	30	292	1110

Incidental Species

In addition to target species, the screw trap captured 24 hatchery trout, likely from Cottage Lake. Other species caught included 645 lamprey (*Lampetra* spp), 558 three-spine stickleback

(*Gasterosteus aculeatus*), 304 sculpin (*Cottus* spp.), 128 green sunfish (*Lepomis cyanellus*), 639 peamouth (*Mylocheilus caurinus*), 3 dace (*Rhinichthys* spp), 7 bluegill (*Lepomis macrochirus*), 10 large-scale suckers (*Catostomus macrocheilus*), 6 pumpkinseed (*Lepomis gibbosus*), 1 northern pikeminnow *(Ptychocheilus oregonensis)*, 13 rock bass (*Ambloplites rupestris*), 2 yellow perch (*Perca flavescens)*, 11 warmouth (*Lepomis gulosus*), 1 whitefish (*Prosopium* spp.), and 22 brown bullhead catfish (*Ameiurus nebulosus*) (Appendix B 4). We erroneously reported (Kiyohara 2016) that the screw trap captured its first Northern Pike (*Esox lucis*) in 2016. Instead, this fish was a juvenile Northern Pikeminnow (confirmed by Dan Estell, trap technician).

PIT Tagging

To support the ongoing, multi-agency evaluation of salmonid survival within the Lake Washington watershed, 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 26 through July 7, 2017, 823 natural-origin Chinook parr were PIT tagged in the Cedar River. This total includes 6 Chinook tagged and released at the Landsburg Dam on June 13, 2017 (Table 14). The combined tag group was 3.5% of the estimated Chinook parr production from the Cedar River in 2016. Of these 823 fish, only 36 Chinook (4.4%) were detected at the Chittenden Locks. The median migration date to the locks was June 17, with the first Chinook was detected on June 4 and the last on July 22. Individual travel times from the Cedar River to the Locks averaged 22.5 days (SD = 6.7) and ranged from 10 days to 57 days. This is the lowest rate of detection rate relative to the last seven years (Table 15), which previously ranged from 21.6-7.3%.

In Bear Creek, 3,211 Chinook parr were tagged between April 26 to June 23, 2017 (Table 14), representing 22.9% of the Chinook parr production. There were 387 of 3,211 Chinook (12.1%) detected at the Chittenden Locks. Four of these Chinook passed through the large lock filling culvert. The first Chinook was detected on May 21 and the last was detected July 05 (Table 14). Individual travel times from Bear Creek to the Locks averaged 22 day and ranged from 5 days to 49 days. Detection rates of Chinook at the locks have not decreased from year to year in Bear Creek compared to the other release sites (Table 16).

Over three weeks in May, 2,733 hatchery Chinook were released with PIT tags from the Issaquah Hatchery (Table 17). 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 7, May 15, and May 22, 2017). The lock antennas detected Issaquah Hatchery Chinook from May 28 to June 23, 2017. Average travel time was 22 days and ranged from 16 to 47 days. Overall detection rate of Issaquah hatchery Chinook was 3.29%, and ranged from 1.2% to 5.5% for individual release groups. Detections declined rapidly over the course of the season (Table 17). Average detection rate in 2017 (3.29%,) were similar to the detection rates in 2015 and 2016 (3.8%, 3.1% respectively, Table 17).

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 the large-lock filling culvert offers a chance to test whether or not this is true. In 2017, only 4 of 513 (0.9%) fish detected at the locks were detected in the filling culvert. All four fish originated from Bear Creek and entered the filling culvert in June (11th, 16th, 22nd and 27th). In 2016, a similar ratio of fish (N=4 of 509) were detected in the filling culvert relative to the other stations (previously reported only 3 detections, Kiyohara 2016;

N=2 Cedar, N=1 Bear, an unreported N=1 from Issaquah). The results so far suggest that this particular filling culvert (one of two in the large locks) is probably not a major route for fish to exit Lake Washington. Filling culverts on the small locks are screened so that no fish pass through them (S. Pozarycki, USACE, personal communication).

Since 2000, four smolt flumes operate seasonally in spillway bays 4 and 5. In 2017, smolt flume antenna were installed in late April through July. Since the first and last tag detections occurred a number of days following the start of operations and prior to the end of operations, we feel we did not miss a significant number of tagged fish due to the operational period of the flumes. A new slide style flume in bay 4 (SB4b) was installed April 28 to August 3rd. Spillway 5 (SB5b) tunnel style flume operated from April 25 to July 18. Spillway SB5c tunnel style flume operated from April 21 to June 13. The adult ladder fish ladder antennas operates continuously since June 2004. The large lock filling culvert operates continuously since November 2015. North side (SB4a) slide style flume was not installed in 2017 (information courtesy of Scott Pozarycki at USACE).

Table 14. 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 2017.

Statistical Week		N. Tagged			N. Detected			% Detected		
		Bear	Cedar	Issaquah	Bear	Cedar	Issaquah	Bear	Cedar	Issaquah
4/23	4/29	10	1		2	0		20.0%	--	
4/30	5/6	91	14		18	3		19.8%	21.4%	
5/7	5/13	302	22	1000	54	5	49	17.9%	22.7%	4.9%
5/14	5/20	596	58	734	108	8	21	18.1%	13.8%	2.9%
5/21	5/27	508	83	999	81	3	20	15.9%	3.6%	2.0%
5/28	6/3	1226	94		119	7		9.7%	7.4%	
6/4	6/10	338	172		5	4		1.5%	2.3%	
6/11	6/17	123	248		0	5		0.0%	2.0%	
6/18	6/24	17	62		0	1		0.0%	1.6%	
6/25	7/1	0	62			0			0.0%	
7/2	7/8	0	7			0			0.0%	
7/9	7/15	0	0							
	Total	3211	823	2733	387	36	90	12.1%	4.4%	3.3%

Table 5. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Cedar River screw trap, tag years 2010 to 2017. Detection data is from the Hiram Chittenden Locks.

Year	N. Tagged	Length (mm) Ave	Min	Max	% of Parr Migration	N. Detected	% Detected	Travel Days	First Detection	Last Detection	Median Detection Date
2010	2232	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	1671	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	1944	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	1372	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

Table 6. Biological and migration timing data of PIT tagged natural-origin Chinook released from the Bear Creek screw trap, tag years 2010 to 2017. Detection data is from the Hiram Chittenden Locks.

Year	N. Tagged	Length (mm) Ave	Min	Max	% of Parr Migration	N. Detected	% Detected	Travel Days	First Detection	Last Detection	Median Date
2010	589	77.9	65	99	7.8%	103	17.5%	26.1	06/06	07/07	06/23
2011	2316	79.9	65	102	26.3%	337	14.6%	15.1	05/23	07/29	06/05
2012	2721	75.2	62	97	12.2%	316	11.6%	31.3	05/22	08/13	06/21
2013	1858	79.3	58	102	9.8%	518	27.9%	12.3	05/16	07/20	06/12
2014	1968	77.6	62	103	4.8%	324	16.5%	23.9	05/20	07/14	06/12
2015	1414	84.7	65	108	19.4%	114	8.1%	17.7	05/19	06/18	05/28
2016	2766	83.3	65	108	14.5%	287	10.4%	23.2	05/07	06/29	05/31
2017	3211	80.9	65	108	22.9%	387	12.1%	22.0	05/21	07/05	06/09

Table 7. PIT tag and migration timing of natural-origin Chinook released from Issaquah hatchery, years 2014 and 2017. 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	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
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	1000	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

Appendix A

Catch of Fishes and Migration Estimates by Strata for Cedar River Sockeye, Chinook, and Coho Salmon in 2017

Appendix A 1. Total catch and migration by strata for Cedar River natural-origin sockeye fry, 2017.

Period	Total catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Jan 1-12 pre trapping		21,048	20,203	21,893	2.0%		$1.86x10^{5}$
Jan 12- Feb 2	10,275	313,003	261,549	364,457	8.4%	3.34%	$6.89x10^{8}$
Feb 3- July 12	60,953	2,196,617	1,731,904	2,661,330	10.8%	2.77%	$5.62x10^{10}$
Total	71,411	2,530,668	2,013,657	3,047,679	9.4%		$5.69x10^{10}$

Appendix A 2. Total catch and migration by strata for Cedar River natural-origin Chinook, 2017.

Life history	Period	Total catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Fry	Jan 1-12 pre trapping		826	677	975	9.2%		$5.75x10^{3}$
Fry	Jan 12-Feb 2	637	12,495	7,347	17,643	21.0%	5.09%	$6.90x10^{6}$
Fry	Feb 3- Aril 8	3,821	137,941	112,127	163,755	9.5%	2.77%	$1.73x10^{8}$
Parr	April 9-July 12	1,453	23,457	16,846	30,068	14.4%	6.20%	$1.14x10^{7}$
	Fry total:	4,458	151,262	120,151	182,373	8.9%		$1.80x10^{8}$
	Parr total:	1,453	23,457	16,846	30,068	14.4%		$1.14x10^{7}$
	Chinook total:	5,911	174,719	136,997	212,441	7.9%		$1.92x10^{8}$

Appendix A 3. Total catch and migration by strata for Cedar River natural-origin coho migrants age 1+ smolt, 2017.

Life history	Period	Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Smolt	Jan 12 - July 12	2,618	91,295	61,769	120,821	16.5%	3.07%	$2.27x10^{8}$

Appendix A 4: Actual catch of all species and salmon life-history types in the 2017 Cedar River screw trap with reference to the catch in 2016 (screw trap + inclined plane trap catch).

Common name	*Genus species*	2017	2016
Sockeye Fry (natural)	*Oncorhynchus nerka*	41,250	7,925
Chin Fry (natural)	*Oncorhynchus tshawytcha*	2,766	3,601
Coho Smolt (wild)	*Oncorhynchus kisutch*	2,618	2,597
Chin Parr (natural)	*Oncorhynchus tshawytcha*	1,362	1,799
Sculpin: General	*Cottus spp.*	221	93
Cutthroat Juv.	*Oncorhynchus clarkii*	197	48
Chinook parr (hatchery)	*Oncorhynchus tshawytcha*	85	40
Lamprey	*Lampetra spp.*	82	27
3 Spine Stickleback	*Gasterosteus aculeatus*	26	191
Coho Fry	*Oncorhynchus kisutch*	17	3
Coho Parr (wild)	*Oncorhynchus kisutch*	15	28
Largescale Sucker	*Catostomus macrocheilus*	14	7
Steelhead Smolt (wild)	*Oncorhynchus mykiss*	8	17
Peamouth Chub	*Mylocheilus caurinus*	6	5
Cutthroat Adult	*Oncorhynchus clarkii*	2	1
Whitefish	*Prosopium spp.*	2	10
Longnose Dace	*Rhinichthys cataractae*	2	3
Trout fry 0+	*Oncorhynchus mykiss/clarkii*	1	0
Pumpkinseed	*Lepomis gibbosus*	1	0
Speckled Dace	*Rhinichthys osculus*	1	2
Rock Bass	*Ambloplites rupestris*	0	1
Warmouth	*Lepomis gulosus*	0	4
Bluegill	*Lepomis macrochirus*	0	1
Smallmouth Bass	*Micropterus dolomieu*	0	1
Chum fry	*Oncorhynchus keta*	0	1
Pink fry	*Oncorhynchus gorbusha*	0	1

Appendix B

Catch of all Fishes and Migration Estimates by Strata for Bear Creek Sockeye, Chinook, Coho Salmon, and Cutthroat Trout, 2017.

Appendix B 1 Catch and migration by strata for Bear Creek sockeye, 2017.

Period	Total Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Jan 1-Jan 30 Pre trap		1,212	18,715	1,480	11.3%		1.87×10^{4}
Jan31- Mar 30	23,877	401,883	349,967	453,227	6.6%	5.95%	6.94×10^{8}
Mar 31 - July 10	4,336	109,842	85,852	133,832	11.1%	3.95%	1.50×10^{8}
Total	28,213	512,651	454,534	588,539	5.7%		8.84×10^{8}

Appendix B 2. Catch and migration by strata for Bear Creek natural-origin Chinook, 2017.

Period	Life History	Total Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Pre trap Jan 1-30	Fry		5355	3,802	6,908	14.8%		6.27×10^{5}
Jan 31- April 8	Fry	777	16,317	6,756	25,878	29.9%	4.76%	2.38×10^{7}
April 9-May 15	Parr	2,003	3,833	2,768	4,898	14.2%	42.0%	2.95×10^{5}
May 16-July 10	Parr	5,243	10,204	9,363	11,045	4.2%	55.2%	1.84×10^{5}
	Fry total:	777	21,672	10,588	32,785	22.8%		2.44×10^{7}
	Parr total:	7,246	14,037	12,132	15,942	4.9%		4.79×10^{5}
	Chinook total:	8,023	35,709	22,690	48,728	14.0%		2.49×10^{7}

Appendix B 3. Catch and migration by strata for Bear Creek natural-origin coho smolts, 2017.

Period	Total Catch	Abundance	5% CI	95% CI	*CV*	*Eff.*	*Variance*
Jan31- July 10	427	6,004	2,142	9,866	32.8%	7.32%	3.88×10^{6}

Appendix B 4. Actual catch composition of salmonids and incidental species in Bear Creek 2017 and 2016. The screw trap did not capture a Northern Pike (*Esox lucis*) in 2016 even though it was previously reported in Kiyohara 2016 (personal communication Dan Estell trap technician).

Common name	*Genus species*	2017	2016
Sockeye Fry (natural)	*Oncorhynchus nerka*	25,656	3,564
Chin Parr (natural)	*Oncorhynchus tshawytcha*	6,792	4,852
Cutthroat (juvenile)	*Oncorhynchus clarkii*	1,110	674
Chin Fry (natural)	*Oncorhynchus tshawytcha*	677	1,180
Lamprey	*Lampetra sp.*	645	910
Peamouth Chub	*Mylocheilus caurinus*	639	1,825
3 Spine Stickleback	*Gasterosteus aculeatus*	558	188
Coho Smolt (wild)	*Oncorhynchus kisutch*	427	1,675
Sculpin: General	*Cottus spp*	304	285
Green Sunfish	*Lepomis cyanellus*	128	306
Rainbow Trout (hatchery)	*Oncorhynchus mykiss*	24	2
Brown Bullhead	*Ameiurus nebulosus*	22	23
Cutthroat (adult)	*Oncorhynchus clarkii*	21	47
Rock Bass	*Ambloplites rupestris*	13	3
Warmouth	*Lepomis gulosus*	11	13
Coho Fry	*Oncorhynchus kisutch*	11	3
Largescale Sucker	*Catostomus macrocheilus*	10	16
Trout 0+	*Oncorhynchus mykiss*	8	7
Bluegill	*Lepomis macrochirus*	7	19
Pumpkinseed	*Lepomis gibbosus*	6	22
Speckled Dace	*Rhinichthys osculus*	3	2
Yellow Perch	*Perca flavescens*	2	1
Coho Parr	*Oncorhynchus kisutch*	2	8
Northern Pikeminnow	*Ptychocheilus oregonensis*	1	1
Steelhead Smolt (wild)	*Oncorhynchus mykiss*	1	2
Whitefish	*Prosopium spp*	1	1
Black Crappie	*Pomoxis nigromaculatus*	0	3
Smallmouth Bass	*Micropterus dolomieu*	0	1

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