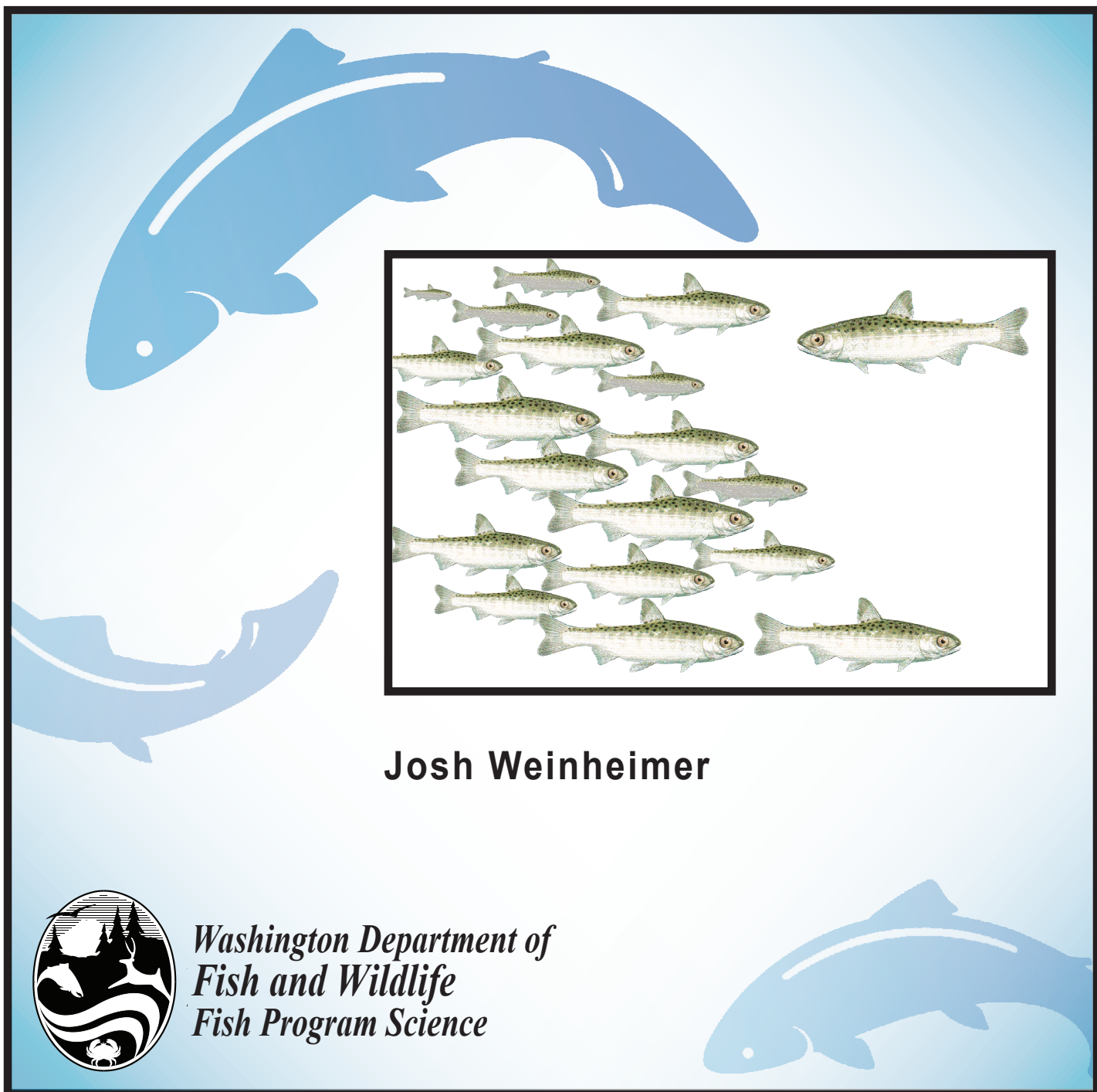


# Mid-Hood Canal Juvenile Salmonid Evaluation: Duckabush River 2017



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2017**



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## Executive Summary

Juvenile salmonid monitoring in Hood Canal, Washington has been a collaborative project between the Washington Department of Fish and Wildlife (WDFW), Long Live the Kings (LLTK), and the Northwest Fisheries Science Center’s (NWFSC) Manchester Research Station. Monitoring of Pacific salmon and steelhead on the Duckabush River, located in central Hood Canal and draining from the Olympic Mountains, began in 2007. This study measures the juvenile abundance and outmigration timing of Chinook salmon, chum salmon, pink salmon (even years only), coho salmon, and steelhead. We derive independent estimates for summer and fall chum salmon stocks in these watersheds via molecular genetic analysis. For those species with adult abundance surveys (chum, Chinook and pink salmon), we also estimate egg to migrant survival.

In 2017, a floating eight-foot screw trap was located at river mile 0.3 (0.48 rkm) and operated by WDFW from January 9 to June 22. The abundance of juvenile summer chum salmon was over four times larger than fall chum (Table 1). Egg-to-migrant survival was higher for summer than fall chum salmon. The median date of summer chum outmigration occurred 2 weeks earlier than the peak of the fall chum outmigration.

TABLE 1.—Abundance, coefficient of variation (CV), egg-to-migrant survival, average fork length and median out-migration date for juvenile salmonids of natural origin leaving the Duckabush River, 2017.

Species	Abundance		Survival	Median migration date	Average fork length
	Estimate	CV			
Summer chum	200,712	3.9%	2.2%	28-Mar	-
Fall chum	44,322	13.3%	1.8%	12-Apr	-
Chinook	577	13.2%	2.3%	21-Mar	39.2
Coho	3,755	31.6%	-	30-Apr	104.9
Steelhead	1,373	32.5%	-	14-May	170.0



## Introduction

The Duckabush is a high-gradient watershed that drains into the western side of Hood Canal, Washington. Large magnitude flow events in this watershed occur twice each year, during rain events in the winter months and snow melt in the spring months. Particularly high flows events occasionally occur during rain-on-snow events in the winter months. The Duckabush system originates in the Olympic Mountains within the Olympic National Park. Human development is minimal with the exception of light logging activity in the upper watershed and residential homes and dikes in the lower part of the river and estuary.

The Duckabush river supports a diverse salmonid community, including Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), coho salmon (*O. kisutch*), and steelhead trout (*Oncorhynchus mykiss*). Three of the salmonid species are federally protected under the Endangered Species Act (ESA). Chinook salmon are part of the Puget Sound Chinook Evolutionary Significant Unit (ESU), summer chum populations are part of the Hood Canal summer chum ESU, and steelhead are part of the Puget Sound steelhead Distinct Population Segment (DPS), as delineated by the National Marine Fisheries Service (NMFS).

Chinook salmon in the Duckabush are part of the Puget Sound Chinook ESU listed as *threatened* in 1999 by NMFS under the Endangered Species Act (NOAA 1999b). Hood Canal has two genetically distinct Chinook salmon populations, one is the Skokomish River stock and the other is the Mid-Hood Canal stock that is composed of the Hamma Hamma, Duckabush, and Dosewallips subpopulations (Committee 2007). Recovery goals for the Mid-Hood Canal population range between 1,325 and 5,200 adults, depending on the rate of freshwater productivity (adults per spawner). Specifically, the Duckabush sub-population recovery goals are between 325 and 1,200 adults. Both the Skokomish and Mid-Hood Canal stocks will need to achieve low risk status for Puget Sound ESU recovery.

Summer chum salmon in the Duckabush river are part of the Hood Canal summer chum ESU listed as *threatened* in 1999 by NMFS (NOAA 1999a). The Hood Canal summer chum ESU was historically composed of 16 independent populations (Ames et al. 2000). Summer chum are distinguished from fall and winter chum based on spawn timing and genetic differentiation (Ames et al. 2000; Crawford and Rumsey 2011). Historically, summer chum stocks in Hood Canal returned in the tens of thousands. By 1980, these returns plummeted to fewer than 5,000 adults and 8 of the 16 stocks were considered extinct. To promote conservation, the WDFW and Point No Point Treaty (PNPT) Tribes developed the Summer Chum Salmon Conservation Initiative which called for reductions in harvest of Hood Canal summer chum and hatchery supplementation in order to rebuild stocks to harvestable levels (Ames et al. 2000). The initiative also called for increased monitoring and improvements to freshwater habitat conditions. The Duckabush summer chum stock is one of the eight extant stocks within Hood Canal. The recovery goals for Duckabush Summer Chum is an total abundance (escapement plus harvest) of 3,290 adults with an escapement of 2,060 adults over a 12 year period, combined with average recruits per spawner  $\geq 1.6$  over the 8 most recent brood years.

Steelhead in the Duckabush are part of the West Hood Canal Winter-Run Steelhead demographically independent population (PSSTRT 2011). The West Hood Canal Winter-Run Steelhead DIP combines winter steelhead from the Hamma Hamma, Duckabush and Dosewallips rivers, and Quilcene River/Dabob Bay. Historic escapement data is lacking for this DIP, but based on recent stream surveys, the population most likely consists of only a few hundred fish. In response to the low estimates, the Hood Canal Steelhead Project was initiated in 2007 by NOAA Fisheries. The goals of the project were to access the benefits of conservation hatchery programs, provide guidance to fisheries managers about steelhead hatchery practices and recovery policies, and attempt to recover three Hood Canal steelhead sub-populations (Duckabush, Dewatto and South Fork Skokomish)(Myers et al. 2015). The project is monitoring 8 streams within Hood Canal that are divided between supplemented and control streams. The Duckabush is one of three streams that was supplemented with hatchery smolts and adults that are the progeny of naturally spawning steelhead in the Duckabush River whose embryos were excavated from redds and reared in the hatchery.

NMFS evaluates the status species listed under the ESA using four viable salmon population (VSP) parameters: abundance, productivity, spatial distribution and diversity (McElhany et al. 2000). A statewide monitoring framework, termed “Fish-In Fish-Out”, was developed by the Governor’s Forum on Monitoring Salmon Recovery and Watershed Health and recommended the coupling of juvenile and adult monitoring for representative populations within each ESU (Crawford 2007). Guidelines for monitoring data needed to assess recovery status were recently published by the National Marine Fisheries Service (Crawford and Rumsey 2011). At the time of listing, little to no information was available on juvenile abundance or freshwater productivity of Chinook, summer chum, or steelhead in Hood Canal. Freshwater productivity (egg-to-migrant survival or smolts per spawner) is an important factor that contributes to population persistence and resilience (McElhany et al. 2000). Without information on juvenile migrants, managers are limited in their ability to assess the contributions of freshwater versus marine environment towards species recovery.

In response to these information needs, a juvenile monitoring study was initiated on the Duckabush River in 2007. The long-term goal for this study is to understand the factors that govern the freshwater productivity and marine survival of salmonid populations in the Duckabush River. The combination of juvenile and spawner abundance allows for brood-specific survival to be partitioned between the freshwater and marine environment. Long-term combination of juvenile and adult abundance data over a range of spawner abundances and flow regimes will provide a measure of freshwater capacity as well as current ranges of freshwater and marine survival.

This report summarizes results from the Duckabush River during the 2017 outmigration. In 2017, the primary objective of this study was to estimate the abundance, productivity and life history diversity of Chinook, Coho, chum and steelhead in the Duckabush River. We conclude by discussing patterns of freshwater survival observed across the 2011-2017 time series.



## Methods

### *Trap Operation*

On the Duckabush River, juvenile migrants were captured in a floating screw trap (8-foot or 1.5 m diameter) located on the right bank at river mile 0.3 (0.48 rkm), approximately 1,600 feet (490 m) upstream of the Highway 101 bridge (Figure 1). The trap consisted of two, four foot wide tapered flights, wrapped 360 degrees around a nine foot long shaft. These flights were housed inside an eight foot diameter cone-shaped frame covered with perforated plating. The shaft was aligned parallel with the flow and was lowered to the water's surface via davits and winches mounted on two 20 ft aluminum pontoons. The trap fished half of an eight foot diameter circle with a cross sectional area of  $16 \cdot \pi = 50.24 \text{ ft}^2$ . Water current acting on the flights caused the trap to rotate, and with every 180 degrees of rotation, a flight entered the water while the other emerged. As the leading edge of a flight emerged from the water it prevented the escape of trapped fish. The fish were gently augured into a solid sided, baffled live box.

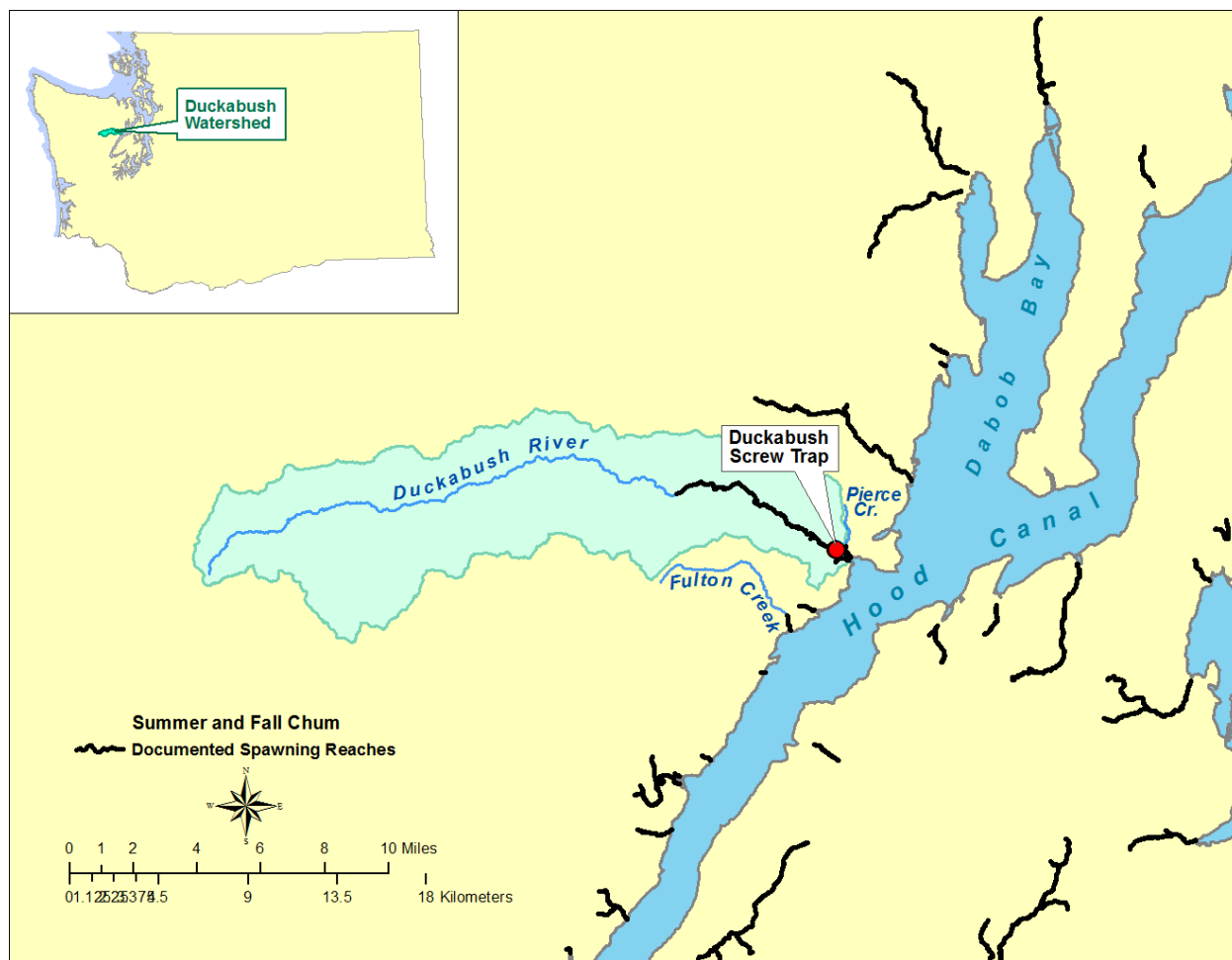


FIGURE 1.—Location of Duckabush screw trap.

The screw trap was fished 24 hours a day, seven days a week, except when flows or debris would not allow the trap to fish effectively (Table 2).

TABLE 2.— Summary of juvenile trap operations for the Duckabush River screw trap, 2017

<b>Trap</b>	<b>Start Date</b>	<b>End Date</b>	<b>Hours Fished</b>	<b>Total Possible Hours</b>	<b>Percent Fished</b>	<b>Number of Outages</b>	<b>Avg Outage Hrs</b>	<b>St Dev.</b>
Duckabush	1/9	6/22	2,816.00	3,929.5	71.66%	15	74.23	50.6

### *Fish Collection*

The trap was checked for fish at dawn each day throughout the trapping season. At each trap check, all captured fish were identified to species and enumerated. A subsample of all captured migrants was measured each week (fork length in mm, FL). Juvenile steelhead were checked for hatchery marks or fin clips (adipose fin). Steelhead of natural origin were sampled for scales and DNA (fin clip).

Tissue was collected from the caudal fin of a subsample of the chum migrants throughout the season (10-40 samples per week). The genetic sampling protocol was designed to estimate a 90% confidence interval within  $\pm 10\%$  of the observed value. This approach maximized sample size during the time intervals where summer and fall stocks were expected to overlap in outmigration timing.

Coho were enumerated as either fry (age-0) or smolts (yearlings  $\geq$  age-1). Defining characteristics of coho fry were a bright orange-brown color, elongated white anal fin ray, small eye and small size (under 60 mm FL). Yearling coho were larger in size (approximately 90-160 mm FL), with silver sides, black tips on the caudal fin and large eye compared to the size of the head.

Trout were enumerated by three different age classes: fry, parr, and smolt. Fry (age-0) were small in size (<40-mm FL), dark brown in color with orange fins, and caught late in the trapping season (after May 1). Parr were trout, other than fry, that were not “smolted” in appearance. Parr were typically between 50 and 150 mm fork length, dark in color (brown with spots on the tale), and caught throughout the trapping season. Smolts were chrome in appearance, larger in size (90 to 350 mm fork length) and with many spots along the dorsal surface and tail. Parr and smolts were assigned as either steelhead or cutthroat based on mouth size and presence or absence of red coloration on the ventral surface of the gill covers. Fry could not be assigned to species and were recorded as “trout”.

Trap efficiency trials were conducted with maiden-caught (i.e., fish captured for the first time) chum fry and coho yearlings throughout the season. Due to low catch of natural origin steelhead, trap efficiency for steelhead was estimated using natural origin coho smolts. No efficiency trials were conducted using Chinook due to very low catches of this species. Chum fry trap efficiency was used as a surrogate for Chinook during the 2017 season. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and fry releases were marked with Bismark-

brown dye and yearling releases were marked with alternating upper and lower caudal fin clips. Marked fish were allowed to recover in freshwater. Marked fry were released at dusk into fast flowing water upstream of a bend in the river, approximately 75 m distance from the trap. Marked yearlings were immediately released upstream of the trap, approximately at river km 3.2. The release site was selected to maximize mixing of marked and unmarked fish while minimizing in-river predation between release and recapture. Trials were conducted every few days to allow adequate time for all marked fish to reach the trap. Most marked fish were caught the day immediately following a release. Dyed and caudal marked fish captured in the trap were recorded as recaptures.

#### *Genetic Identification of Juvenile Chum Salmon*

Juvenile fish were assigned to a baseline consisting of summer- and fall-run chum salmon populations from Hood Canal based on genotypes from 16 microsatellite loci (Small et al. 2009). Baseline collections were combined into reporting groups composed of all summer-run and all fall-run chum salmon collections from Hood Canal. Assignment likelihoods were calculated per reporting group. For further details on genetic methods and assignments, see Small et al. (2009). Four juveniles collected throughout the season were equally likely to have arisen from the summer- and fall-run Chum salmon collections in the baseline suggesting possible mixed ancestry or that their genotypes had alleles that were common to both run groups.

#### *Freshwater Production Estimate*

Freshwater production was estimated using a single partial-capture trap design (Volkhardt et al. 2007). Maiden catch ( $\hat{u}$ ) was expanded by the recapture rate of marked fish ( $M$ ) released above the trap and subsequently recaptured ( $m$ ). Data were stratified by week in order to accommodate for temporal changes in trap efficiency. The general approach was to estimate (1) missed catch, (2) efficiency strata, (3) time-stratified abundance, (4) proportion of summer versus fall migrants (for chum), and (5) total abundance.

(1) Missed catch. Total catch ( $\hat{u}$ ) was the actual catch ( $n_i$ ) for period  $i$  summed with missed catch ( $\hat{n}_i$ ) during periods of trap outages.

**Equation 1**

$$\hat{u}_i = n_i + \hat{n}_i$$

Missed catch for a given period  $i$  was estimated as:

**Equation 2**

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

where:

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

$T_i$  = time (hours) during the missed fishing period.

Variance associated with  $\hat{u}_i$  was the sum of estimated catch variances for this period. Catch variance was:

**Equation 3**

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

where:

**Equation 4**

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

(2) Efficiency strata. Chum data were organized into weekly strata (Monday – Sunday) in order to combine catch, efficiency trials, and genetic sampling data. Chinook were organized into time strata based on statistical pooling of the release and recapture data. Steelhead and coho data were combined into a single stratum that was representative of the entire trapping season. Pooling was performed using a *G*-test (Sokal and Rohlf 1981) to determine whether adjacent efficiency trials were statistically different. Of the marked fish released in each efficiency trial ( $M_i$ ), a portion are recaptured ( $m$ ) and a portion are not seen ( $M - m$ ). If the *seen:unseen* [ $m:(M - m)$ ] ratio differed 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 is identified, the pooled trials are assigned to one strata and the significantly different trial is the beginning of the next stratum.

(3) Time-stratified abundance. Abundance for a given stratum ( $h$ ) was calculated from maiden catch ( $\hat{u}_h$ ), marked fish released ( $M_h$ ), and marked fish recaptured ( $m_h$ ). Abundance was estimated with an estimator appropriate for a single trap design (Carlson et al. 1998; Volkhardt et al. 2007).

**Equation 5**

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

Variance associated with the abundance estimator was modified to account for variance of the estimated catch during trap outages (see Appendix A in Weinheimer et al 2011):

**Equation 6**

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

(4) Proportion of summer versus fall migrants (chum salmon only). The number of summer chum migrants in a weekly strata ( $\hat{U}_h^{summer}$ ) was the juvenile abundance for that strata ( $\hat{U}_h$ ) multiplied by the proportion of stock-specific migrants ( $p_h^{summer}$ ) as identified in the genetic analysis:

**Equation 7**

$$\hat{U}_h^{Summer} = (\hat{U}_h) \cdot p_u^{Summer}$$

Variance for the stock-specific estimate was:

**Equation 8**

$$Var(\hat{U}_h^{Summer}) = \hat{var}(\hat{U}_h) \cdot (\hat{p}^{Summer})^2 + \hat{var}(\hat{p}^{Summer}) \hat{U}_h^2 - \hat{var}(\hat{U}_h) \cdot \hat{var}(\hat{p}^{Summer})$$

$Var(p_h)$  was derived from the proportion of stock-specific migrants ( $p_h$ ) and the number of fish sampled for genetics ( $n_h$ ) in strata  $h$ , and the genetic assignment probability for each stock  $a$ :

**Equation 9**

$$Var(p_h) = \frac{p_h(1 - p_h)}{n_h - 1} + \frac{a(1 - a)}{n_h}$$

Error in the genetic assignment ( $a$ ) was 0.99 for summer chum and 0.95 for fall chum based on Small et al. (2009).

(5) Total abundance. Total abundance of juvenile migrants was the sum of in-season stratified estimates:

**Equation 10**

$$\hat{N}_T = \sum_{h=1}^{h=k} \hat{U}_h$$

Variance was the sum of variances associated with all in-season and extrapolated estimates:

**Equation 11**

$$V(\hat{N}_T) = \sum_{h=1}^{h=k} V(\hat{U}_h)$$

Coefficient of variation was:

**Equation 12**

$$CV = \frac{\sqrt{V(\hat{N}_T)}}{\hat{N}_T}$$

### *Egg-to-Migrant Survival*

Egg-to-migrant survival was estimated for Chinook and chum. Egg-to-migrant survival was the number of female migrants divided by potential egg deposition (P.E.D.). Chum escapement was estimated using an Area-Under-the-Curve estimate based on live fish counts, an assumed stream life of 10 days and a 1.3 male:female ratio (M. Downen, WDFW Region 6, personal communication). Live chum counts were adjusted by a “percent seen” factor based on water clarity, calculated to account for fish not seen during individual surveys. This method was used for both summer and fall chum salmon. Surveys were performed every 7 to 10 days from river mile 2.3 to the mouth. This survey section covers approximately 90% of the available chum spawning habitat. In this report we do not extrapolate for the number fish that are spawning above our survey section. Reported egg to migrant survivals are most likely biased low but still serve as an index when comparing among different years. During the 2010 fall chum survey season, we were only able to perform one spawning ground survey due to high water. Due to only getting in one survey, it is believed the escapement estimate is biased low, so we are omitting it from our egg to migrant survival analysis.

Chinook escapement was estimated using an Area-Under-the-Curve estimate based on observed redds, 1 female per redd, and 1.5 male:female ratio. Potential egg deposition was based on estimated female spawners above the trap site and estimated fecundity of 2,460 for chum (Joy Lee Waltermire, Lilliwaup hatchery, LLTK, personal communication) and 4,250 per female for Chinook salmon (M. Downen, WDFW, personal communication).

### *Migration Timing*

Migration data was plotted according to statistical week (Monday – Sunday). A statistical week begins on a Monday and ends on a Sunday (Appendix A). The first and last week of the trapping season are typically less than 7 days.

### *Freshwater Life History Diversity*

In order to describe abundance and migration of the two subyearling Chinook strategies, the subyearling Chinook production was divided into fry and parr migrants. For a given statistical week, the proportion of Chinook within each size class ( $\leq 40$  mm FL,  $> 40$  mm FL) was applied to the migration estimate for that week.

## Results from 2017

### *Chum*

Total estimated catch of natural-origin chum ( $\hat{u} = 64,250$ ) included 50,186 captures in the trap and an estimated missed catch of 14,064 during trap outages (Appendix B). A total of 4,394 natural-origin chum were marked and released over 22 efficiency trials, ranging between 169 and 210 fish per release group. Mark and recapture data were organized into 24 weekly strata for analysis. Trap efficiency of these strata ranged between 12.6% and 33.7%.

Few chum fry were captured the first day of trapping ( $N = 7$ ), and the last chum was observed on June 8, well before the trap was removed on June 22. Based on these observations, we assumed the trapping season encompassed the entire chum migration, and we made no abundance estimate for the period before trap installation or after trap removal.

Based on genetic analyses, the catch was predominantly ( $> 85\%$ ) summer chum until the end of March when the proportion of fall chum increased in the sample. From April 23 until the end of the trapping season, the sampled catch was mostly fall chum (Table 3). Three vials were empty with no sample collected. One pair of samples had identical genotypes, suggesting that the same individuals had been sampled twice in the field or that the same tissues were extracted twice in the lab. Four of the 400 samples collected throughout the season were equally likely to have arisen from the summer and fall-run chum salmon collections in the baseline suggesting possible mixed ancestry or that their genotypes had alleles that were common to both run groups (Small et al. 2017).

TABLE 3.—Genetic stock identification for juvenile chum salmon migrants caught in the Duckabush River screw trap, 2017.

Date	Samples	Summer	Fall	Unassigned	% Summer	% Fall
2/1/2017	10	8	0	2	100.00%	0.00%
2/7/2017	10	10	0	0	100.00%	0.00%
2/13/2017	20	19	0	1	100.00%	0.00%
2/20/2017	20	19	1	0	95.00%	5.00%
2/26/2017	30	28	1	1	96.55%	3.45%
3/5/2017	30	28	0	2	100.00%	0.00%
3/12/2017	40	35	5	0	87.50%	12.50%
3/22/2017	40	32	7	1	82.05%	17.95%
3/26/2017	40	38	2	0	95.00%	5.00%
4/2/2017	40	33	7	0	82.50%	17.50%
4/11/2017	40	23	17	0	57.50%	42.50%
4/16/2017	40	23	17	0	57.50%	42.50%
4/23/2017	30	13	16	1	44.83%	55.17%
4/30/2017	10	1	9	0	10.00%	90.00%
<b>Totals</b>	400	310	82	8	79.08%	20.92%

A total of  $200,712 \pm 15,482$  (95% C.I.) natural-origin summer chum fry are estimated to have migrated past the screw trap (Table 4). Coefficient of variation for this estimate was 3.9%. A total of  $44,322 \pm 11,578$  (95% C.I.) natural-origin fall chum fry are estimated to have migrated past the screw trap (Table 4). Coefficient of variation for this estimate was 13.3%. Details on the mark-recapture and genetic data used to derive these estimates are provided in Appendix B.

Egg-to-migrant survival was estimated to be 2.2% for summer chum and 1.8% for fall chum (Table 4).

TABLE 4.—Juvenile production and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin chum salmon in the Duckabush River, outmigration year 2017.

<b>Stock</b>	<b>Juvenile Production</b>	<b>Juvenile CV</b>	<b>Female Spawners</b>	<b>Egg to Migrant Survival</b>
Summer	200,712	3.9%	3,683	2.2%
Fall	44,322	13.3%	1,682	1.1%
Total	245,034	4.0%	5,364	1.8%

The entire chum outmigration occurred over a 22-week period between early January and the middle of June (Figure 2). Accounting for seasonal variation in trap efficiency, the median migration date for the summer component occurred on March 28, sixteen days earlier than the median migration date of the fall component on April 12. The summer chum component of the migration was 95% complete by April 18. The fall chum component of the migration was 95% complete by May 2. Chum fry were not measured for body size due to very low variation in fork length (36-45mm).



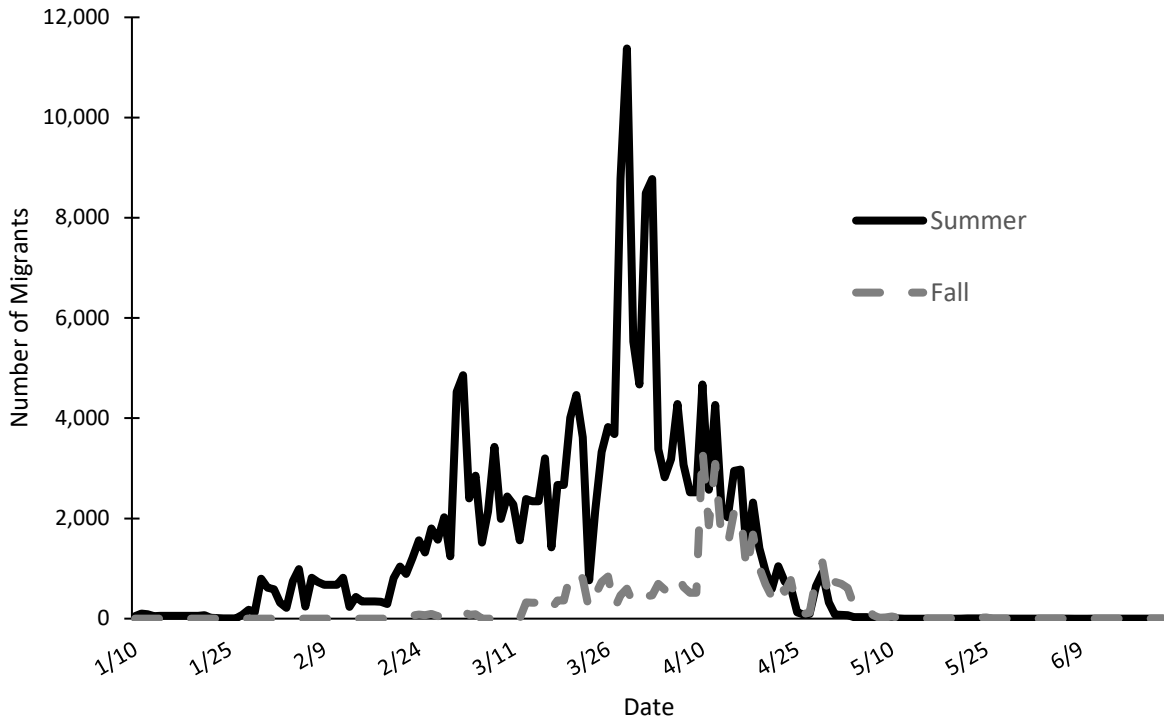


FIGURE 2.—Daily outmigration of natural-origin chum salmon fry in the Duckabush River, 2017 outmigration.

*Chinook*

Total catch of natural-origin Chinook was 81 juveniles. Due to the low number of Chinook, chum efficiency trials were used to represent Chinook trap efficiency. The 22 chum efficiency trials were pooled into 9 strata using the *G*-test approach, with trap efficiencies ranging between 12.6% and 46.3%.

A total of  $577 \pm 148$  (95% C.I.) natural-origin Chinook fry are estimated to have migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 13.2%.

TABLE 5.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Duckabush River, 2017. Chum mark-recapture release groups were used as a surrogate for estimating Chinook salmon trap efficiency and were pooled to form 9 strata. Missed catch and associated variance were calculated for periods the trap did not fish.

Strata	Date	Chinook Catch			Chum Efficiency		Chinook Abundance	
		Actual	Missed	Variance	Marks	Recaptures	Estimated	Variance
1	1/10-1/19	9	8	4.89E-02	169	24	116	1.09E+03
2	2/20-3/2	7	0	0.00E+00	789	251	22	4.80E+01
3	3/3	0	0	0.00E+00	196	45	0	0.00E+00
4	3/4-3/9	2	0	0.00E+00	410	138	6	1.17E+01
5	3/10	1	0	0.00E+00	205	95	2	2.46E+00
6	3/11-3/29	48	31	1.05E+02	578	125	363	4.35E+03
7	3/30-4/11	7	3	1.00E+00	597	178	33	9.33E+01
8	4/12-4/18	2	0	0.00E+00	620	78	16	1.09E+02
9	4/19-6/22	5	0	0.00E+00	830	219	19	5.34E+01
	Season Total	81	42	1.06E+02	4,394	1,153	577	5.75E+03

The first juvenile Chinook was captured on January 30, 2017. Daily migration of Chinook was low and sporadic for most of the season (Figure 3). The median migration date occurred on March 21. The migration was 95% complete by April 14. Based on the minimal catch of Chinook at the beginning and end of the trapping season, we assumed zero migration prior to trap installation and after trap removal.

Length of natural-origin Chinook fry ranged from 35-mm to 48-mm and averaged 39-mm throughout the trapping season (Figure 4). Average weekly fork lengths of juvenile Chinook began to increase during statistical week 18 (end of April).

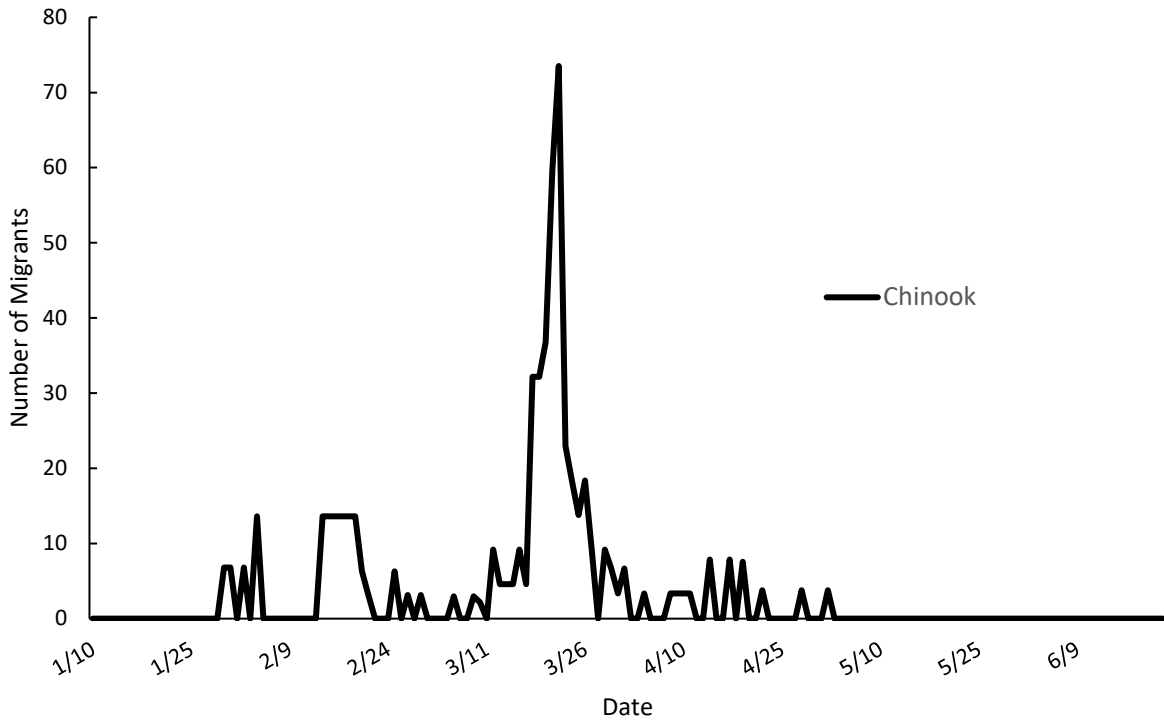


FIGURE 3.—Daily outmigration of natural-origin Chinook salmon fry in the Duckabush River, 2017 outmigration.

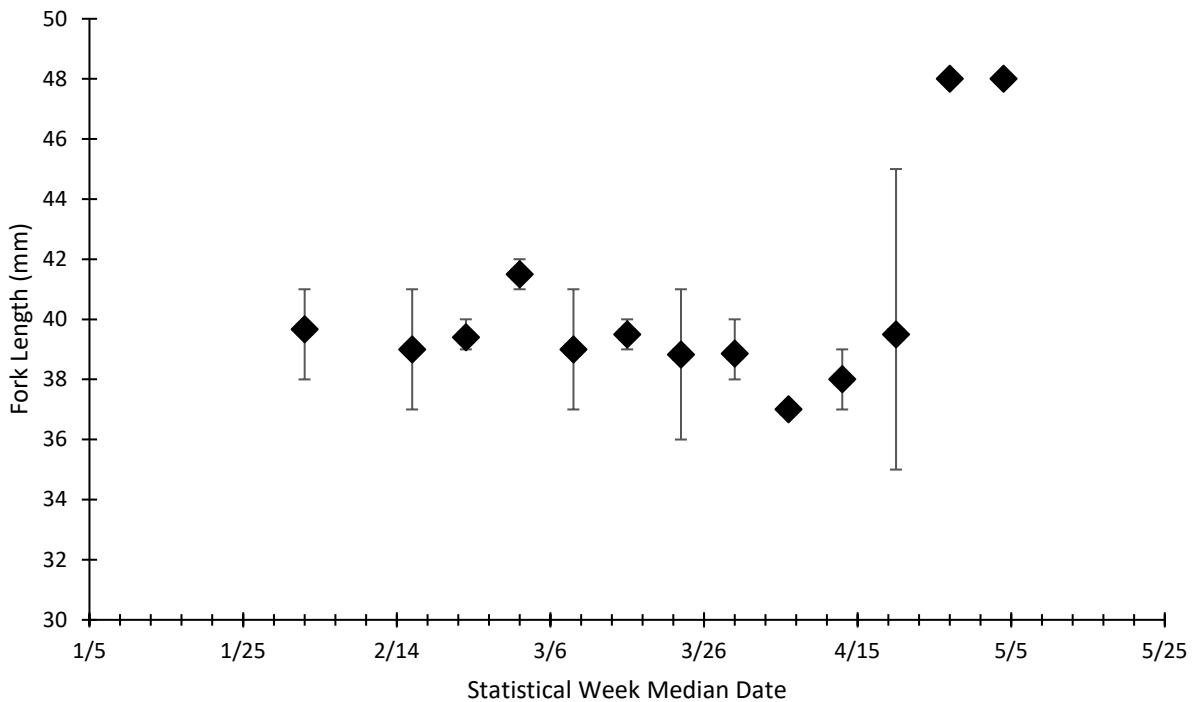


FIGURE 4.—Fork lengths (mm) of juvenile Chinook migrants of natural origin captured in the Duckabush River screw trap 2017. Data are mean, minimum, and maximum values by statistical median date.

*Coho*

Total catch of natural-origin Coho yearlings was 177 juveniles. Coho captured after March 15 were marked and released upstream to estimate trap efficiency. All daily Coho yearling efficiency trials were pooled together to formulate a single stratum for the season. In addition to coho yearlings, we also captured 1,865 coho fry.

A total of  $3,755 \pm 2,328$  (95% C.I.) natural-origin Coho yearlings are estimated to have migrated past the screw trap (Table 7). Coefficient of variation for this estimate was 31.6%.

TABLE 6.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Coho salmon in the Duckabush River, 2017. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

Date	Catch			Marks	Recaptures	Abundance	
	Actual	Missed	Variance			Estimated	Variance
1/9-6/22	177	61	1.47E+02	141	8	3,755	1.41E+06

The first Coho yearling was captured on the first day of trapping. The median migration date occurred on April 30 (Figure 5). The migration was 95% complete by May 25. The last Coho was captured on June 14, 2017, eight days before the end of the trapping season.

Length of natural-origin Coho yearlings ranged from 71-mm to 146-mm and averaged 105-mm throughout the trapping season (Figure 6). Average weekly fork lengths of juvenile Coho began to consistently increase during statistical week 17 (middle of April).

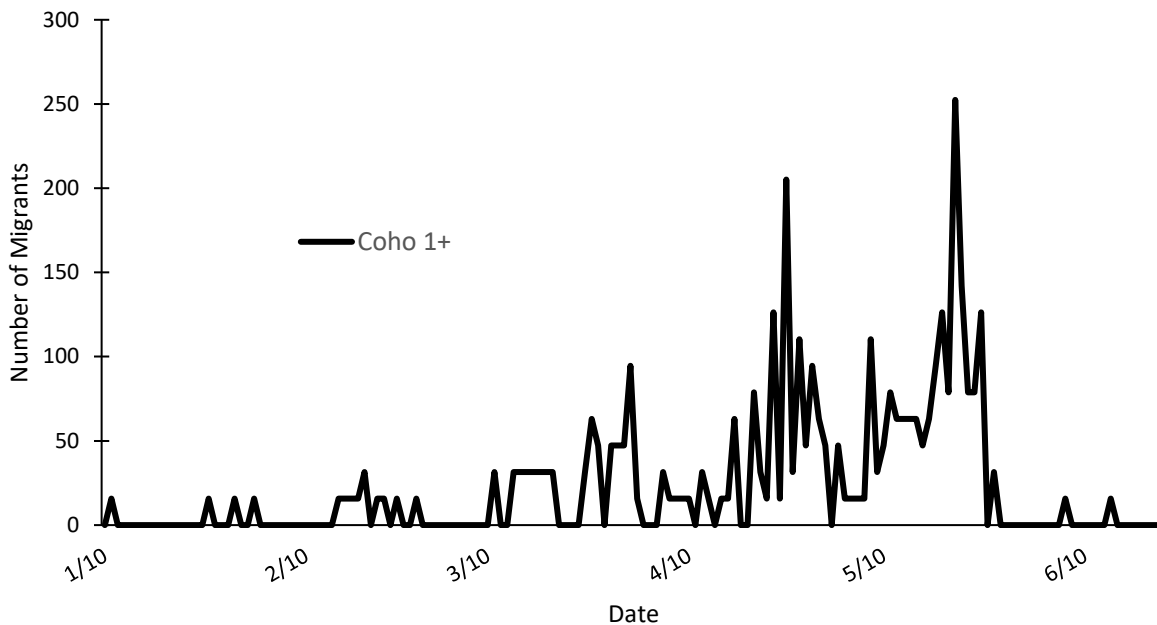


FIGURE 5.—Daily outmigration of natural-origin yearling Coho salmon in the Duckabush River, 2017 outmigration.

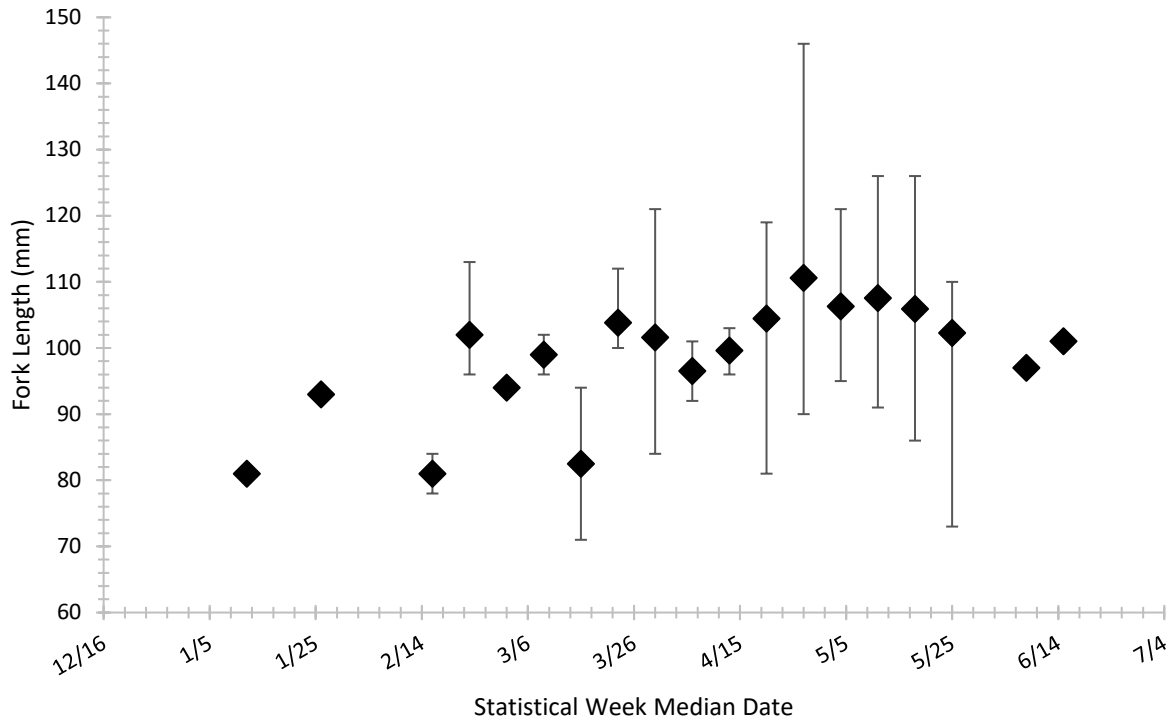


FIGURE 6.—Fork lengths (mm) of juvenile Coho yearling migrants of natural origin captured in the Duckabush River screw trap 2017. Data are mean, minimum, and maximum values by statistical median date.

### Steelhead

Total catch of natural-origin steelhead smolts was 60 juveniles. Due to the low number of natural-origin steelhead, Coho 1+ catch efficiency data was used as a surrogate for steelhead efficiency. All daily Coho yearling efficiency trials were pooled together to formulate a single stratum for the season.

A total of  $1,373 \pm 874$  (95% C.I.) natural-origin steelhead smolts are estimated to have migrated past the screw trap (Table 8). Coefficient of variation for this estimate was 32.5%.

TABLE 7.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for steelhead in the Duckabush River, 2017. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

Date	Catch			Marks	Recaptures	Abundance	
	Actual	Missed	Variance			Estimated	Variance
1/9-6/22	60	27	1.62E+01	141	8	1,373	1.99E+05

The first steelhead smolt was captured on January 30, 2017. The median migration date occurred on May 14 (Figure 7). The migration was 95% complete by June 5. The last steelhead was captured on June 19, 2017, four days before the end of the trapping season.

Length of natural-origin steelhead smolts ranged from 98-mm to 277-mm and averaged 170-mm throughout the trapping season (Figure 8).

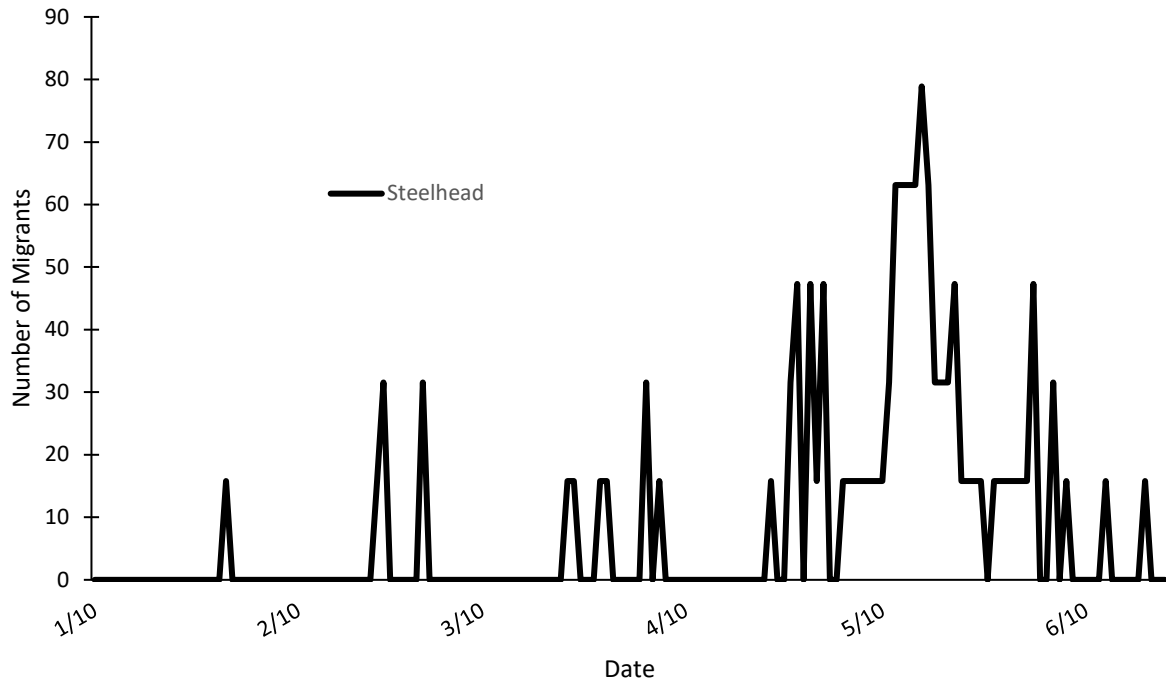


FIGURE 7.—Daily outmigration of natural-origin steelhead smolts in the Duckabush River, 2017.

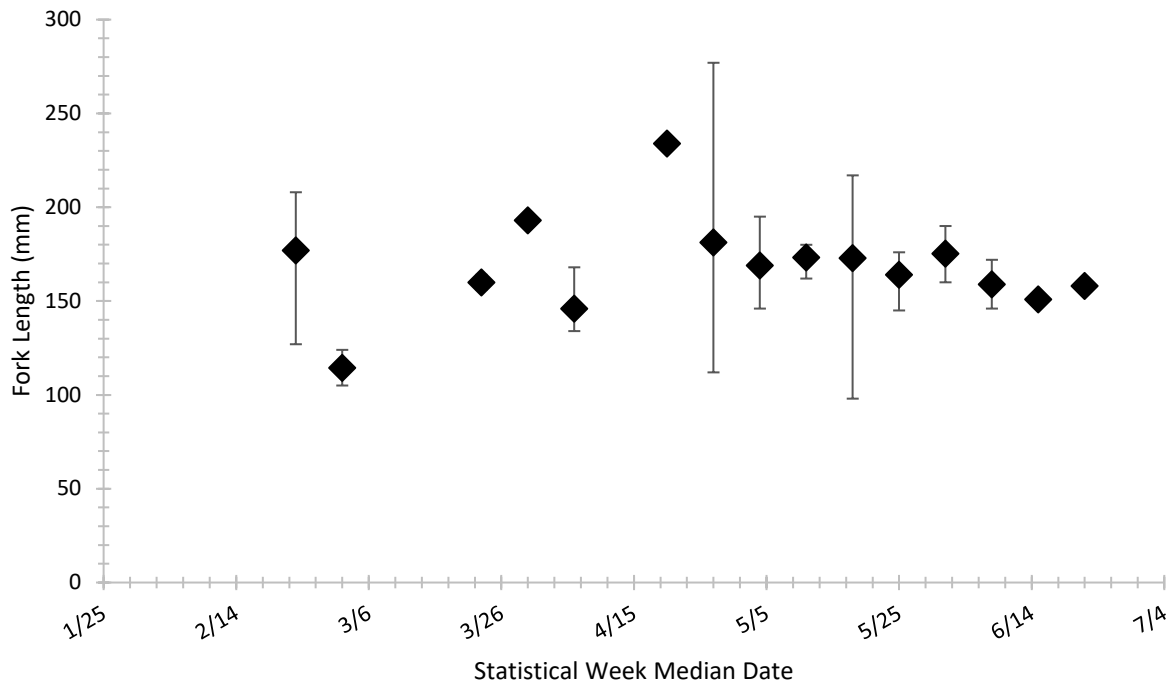


FIGURE 8.—Fork length (mm) of juvenile steelhead smolt migrants of natural origin captured in the Duckabush River screw trap 2017. Data are mean, minimum, and maximum values by statistical median date.

*Other Species*

Non-salmonid species captured included sculpin (*Cottus* spp.) and lamprey ammocoetes.





## Discussion of Data Accumulated 2011-2017

This report provides the freshwater production, survival and out-migration timing for chum and Chinook salmon populations in Hood Canal in 2017. The 2017 trapping season marked the seventh year that genetic samples were collected to distinguish between summer and fall timed chum salmon in the Duckabush River. Based on this study design, we were able to compare juvenile out-migration timing between the two sympatric stocks of chum salmon. In this section, we discuss the Duckabush River juvenile trapping data accumulated to date for summer and fall chum salmon, Chinook salmon, Coho salmon and steelhead.

### *Duckabush Summer Chum Salmon*

The 2017 season marked the highest spawning abundance for summer chum and third highest spawning abundance for fall timed chum since genetic identification of juveniles began in 2011 (Table 8). Juvenile production of summer chum was the third lowest observed. In contrast, fall timed chum juvenile abundance was the second highest in the past seven years.

TABLE 8. —Juvenile production and associated adult escapement and egg-to-migrant survival for summer and fall chum in the Duckabush River, 2011-2017.

Stock	Adult Return Year	Adult Escapement	Juvenile Migration Year	Estimated Juvenile Migration	Egg to Migrant Survival
Summer	2010	4,110	2011	347,597	7.91%
	2011	1,529	2012	290,891	17.79%
	2012	5,241	2013	285,468	5.09%
	2013	3,939	2014	480,202	11.40%
	2014	7,607	2015	130,126	1.60%
	2015	4,905	2016	47,479	0.91%
	2016	8,470	2017	200,712	2.22%
Fall	2010	373*	2011	32,656	5.96%
	2011	2,234	2012	43,053	1.80%
	2012	2,973	2013	42,213	1.33%
	2013	1,144	2014	17,676	1.44%
	2014	4,531	2015	44,595	0.92%
	2015	1,987	2016	41,254	1.94%
	2016	2,323	2017	44,322	1.78%

\*Bias low due to only one adult survey conducted during fall spawning season

We continue to observed higher numbers of summer chum than fall chum in the Duckabush regardless of the number of adults that return for each stock. In our five-year review report for return years 2011-2015, we hypothesized that the differences in productivity and egg to migrant survival could possibly be due to density dependence of adults on the spawning grounds, peak flow events during incubation, the proportion of hatchery origin fish on the spawning grounds or a combination of these variables (Weinheimer 2016). For summer chum, both peak flow and adult spawner abundance (i.e., density dependence) were negatively related to egg to migrant survival (Figures 9,10). Fall chum, on the other hand, showed weaker relationships among these same variables than summer chum, which we postulate is due in part to a much narrower range in survival compared to summer chum (Figure 9,10). Fall chum have experienced lower egg to migrant survival than summer chum each year except for brood year 2015. It is unknown at this time why fall chum survival is consistently lower than summer chum.

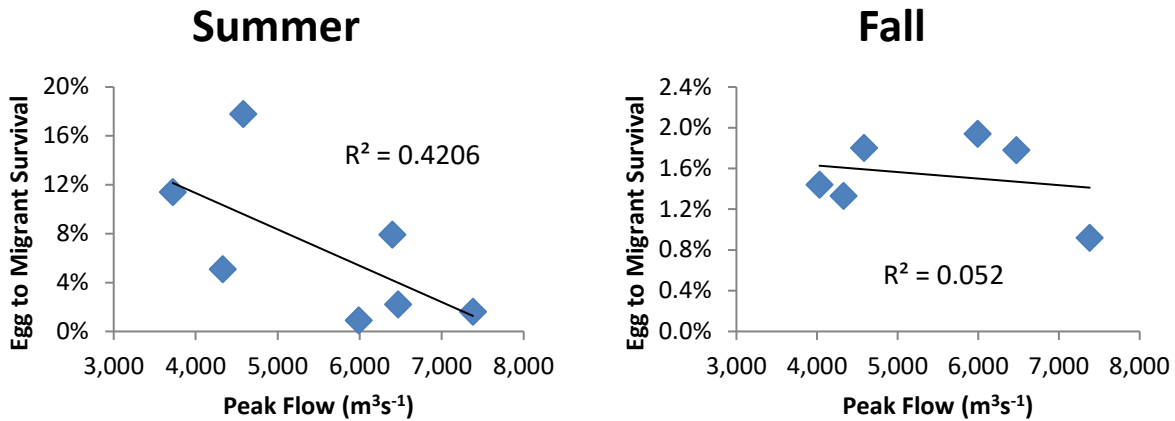


FIGURE 9.—Duckabush summer and fall chum egg to migrant survival vs peak flow ( $m^3s^{-1}$ ), brood years 2010-2016.

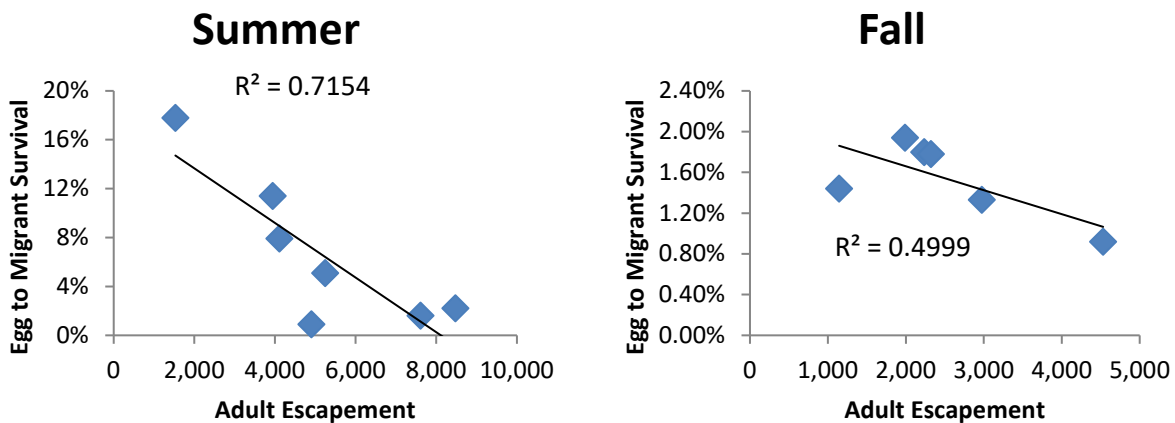


FIGURE 10.—Duckabush summer and fall chum egg to migrant survival vs adult escapement, brood years 2010-2016.

*Duckabush Chinook Salmon*

Freshwater production of Chinook salmon showed a slight drop compared the to the 2016 season (Table 9). The number of adults observed during spawning ground surveys has been higher the past three seasons however egg to migrant survival has been much lower. Prior to 2015, we hypothesized that a larger number of Chinook were spawning in the Duckabush than were estimated due to the above average egg to migrant survivals we were observing. Beginning with 2015, survival rates are within the ranges we observe at other traps sites throughout Puget Sound. We will continue to monitor these results as we accumulate more years of data. Low abundance populations are notoriously difficult to survey, and in this case, a small number of missed adults would substantially alter our estimates of egg to migrant survival.

TABLE 9.—Fry abundance, observed spawning escapement and egg-to-migrant survival for natural-origin Chinook salmon in the Duckabush River, outmigration year 2011-2017.

Out Migration Year	Abundance	Observed Spawning Escapement	Egg-to-Migrant Survival
2011	1,219	0	-
2012	2,788	5	32.8%
2013	5,221	6	51.2%
2014	4,555	7	38.3%
2015	1,179	13	5.3%
2016	686	20	2.0%
2017	577	15	2.3%

We quantified two migration subyearling strategies employed by juvenile Chinook. Fry migrants, which migrate downstream immediately following emergence based on their size at capture ( $\leq 45$  mm), were approximately 89% of the freshwater production that migrated past the Duckabush screw trap in 2017 (Table 10). Parr migrants, which spend some time growing and rearing in freshwater prior to migration ( $> 45$  mm), appear to increase as the total number of subyearling migrants increase (Figure 11). As data accumulate in future years, we will continue to explore this pattern and the possible mechanisms that limit parr production.

TABLE 10. —Migration timing and abundance of two life history strategies (fry and parr) of natural-origin Chinook outmigrants, 2011-2017.

Out Migration Year	Date			Number of Fry	Number of Parr	Percent Fry	Percent Parr	Total Outmigration
	10%	50%	90%					
2011	5-Apr	13-Apr	17-Jun	755	464	61.94%	38.06%	1,219
2012	15-Apr	23-Apr	9-May	1,890	898	67.79%	32.21%	2,788
2013	11-Mar	2-Apr	16-May	4,535	686	86.86%	13.14%	5,221
2014	28-Feb	8-Apr	20-May	3,591	964	78.84%	21.16%	4,555
2015	6-Feb	22-Feb	20-May	858	321	72.77%	27.23%	1,179
2016	18-Feb	28-Feb	25-May	495	191	72.16%	27.84%	686
2017	15-Feb	21-Mar	1-Apr	517	60	89.60%	10.40%	577

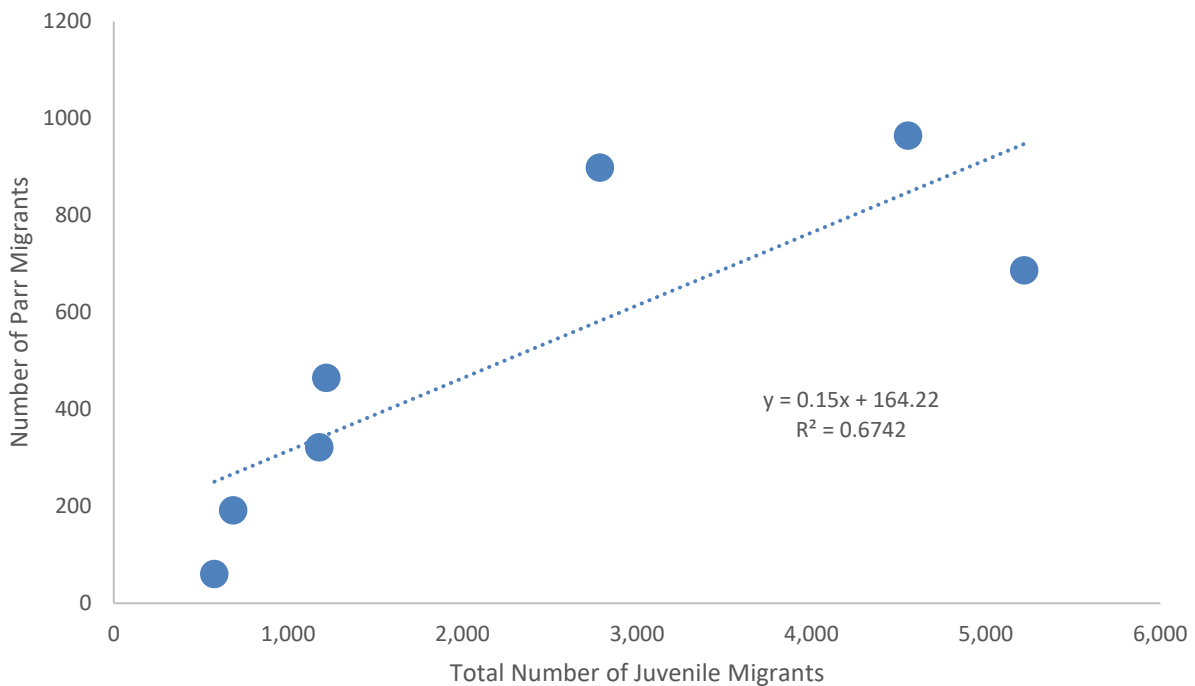


FIGURE 11. Number of Chinook parr migrants vs the total number of subyearling Chinook, Duckabush 2011-2017.

### *Duckabush Coho Salmon*

Freshwater production of Coho yearlings was higher during 2017 than the previous two seasons (Table 11). The lack of production the past 3 seasons compared to the first three seasons (2012-2014) is likely due to a combination of low summer time flows and lack of available habitat. The Duckabush River only has a handful of small tributaries available to returning Coho adults or rearing juveniles, and suspect these are inaccessible or unsuitable for rearing juveniles during low flow years. No adult surveys are conducted for adult Coho so it is unknown whether

escapement numbers were lower for the 2013-2015 broods. We will continue to monitor this trend as we accumulate data in future seasons.

TABLE 11. —Yearling coho production and corresponding upper and lower confidence intervals for the Duckabush River 2012 and 2017.

Out Migration Year	Estimate	Abundance		CV
		Lower CI	Upper CI	
2012	7,082	5,186	8,977	13.70%
2013	6,732	3,811	9,654	22.10%
2014	8,838	4,143	13,532	27.10%
2015	1,844	587	3,100	34.76%
2016	1,121	739	1,504	17.40%
2017	3,755	1,427	6,083	31.63%

### *Duckabush Steelhead*

The 2017 season marked the sixth year since trapping began that we were able to estimate steelhead production in the Duckabush River. Smolt production of steelhead has remained fairly constant for the past three seasons (Table 12), though similar to coho salmon, abundance was lower in 2015 – 2017 than 2012 - 2014. As data accumulate in future years, we will plan to use these data to evaluate the carrying capacity for freshwater production of steelhead smolt outmigrants in the Duckabush River.

TABLE 12.—Steelhead production and corresponding upper and lower confidence intervals for the Duckabush River 2012 through 2017.

Out Migration Year	Estimate	Abundance		CV
		Lower CI	Upper CI	
2012	2,299	1,529	3,068	17.10%
2013	2,422	1,693	3,152	15.40%
2014	2,938	1,879	3,997	18.40%
2015	1,844	587	3,100	34.76%
2016	1,260	646	1,875	24.86%
2017	1,373	498	2,247	32.51%



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**Appendix A**

Statistical Weeks for 2017

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APPENDIX A1.—Statistical Weeks for 2017.

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Stat Week	2017
1	1-Jan
2	Jan 2 - Jan 8
3	Jan 9 - Jan 15
4	Jan 16 - Jan 22
5	Jan 23 - Jan 29
6	Jan 30 - Feb 5
7	Feb 6 - Feb 12
8	Feb 13 - Feb 19
9	Feb 20 - Feb 26
10	Feb 27 - Mar 5
11	Mar 6 - Mar 12
12	Mar 13 - Mar 19
13	Mar 20 - Mar 26
14	Mar 27 - Apr 2
15	Apr 3 - Apr 9
16	Apr 10 - Apr 16
17	Apr 17 - Apr 23
18	Apr 24 - Apr 30
19	May 1 - May 7
20	May 8 - May 14
21	May 15 - May 21
22	May 22 - May 28
23	May 29 - Jun 4
24	Jun 5 - Jun 11
25	Jun 12 - Jun 18
26	Jun 19 - Jun 25
27	Jun 26 - Jul 2

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## **Appendix B**

Duckabush River catches, trap efficiencies, and abundance estimates for 2017

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APPENDIX B1.—Actual catch ( $n$ ), Estimated catch ( $\hat{u}$ ), marked ( $M$ ) and recaptured ( $m$ ) fish, and estimated abundance ( $U$ ) of chum fry migrants at the Duckabush River screw trap in 2017. Release groups were pooled by statistical week. An asterisk (\*) indicates periods with insufficient catch for efficiency trials, so mark-recapture data from outside the given date range were used to estimate abundance. Missed catch and associated variance were calculated for periods that the trap did not fish.

Week	Dates	$n$	$\hat{n}$	$\hat{u}$	$V(\hat{u})$	$M$	$m$	$\bar{U}$	$v(\bar{U})$
3*	1/9-1/15	35	23	58	3.33E+01	169	24	394	8.89E+03
4*	1/16-1/22	3	50	53	8.13E+01	169	24	360	1.02E+04
5*	1/23-1/29	61		61		169	24	415	7.96E+03
6	1/30-2/5	628		628		169	24	4,270	6.22E+05
7*	2/6-2/12	263	417	680	1.53E+03	169	24	4,624	8.00E+05
8*	2/13-2/19	285	410	695	2.64E+03	382	113	2,335	6.88E+04
9	2/20-2/26	2,703		2,703		382	113	9,081	5.25E+05
10	2/27-3/5	6,320		6,320		809	254	20,075	1.12E+06
11	3/6-3/12	5,182		5,182		612	206	15,346	7.80E+05
12*	3/13-3/19	1,463	5,070	6,533	5.86E+04	612	206	19,347	1.74E+06
13	3/20-3/26	4,694	1,203	5,897	3.18E+04	375	81	27,040	7.66E+06
14	3/27-4/2	12,874	3,669	16,543	2.22E+03	394	120	54,004	1.67E+07
15	4/3-4/9	5,833	1,756	7,589	1.38E+05	203	58	26,240	9.89E+06
16	4/10-4/16	3,716	1,025	4,741	9.42E+04	620	78	37,268	2.13E+07
17	4/17-4/23	3,710		3,710		625	160	14,425	9.96E+05
18	4/24-4/30	1,684	144	1,828	1.50E+03	205	59	6,276	4.91E+05
19*	5/1-5/7	685	263	948	5.72E+03	205	59	3,255	1.99E+05
20*	5/8-5/14	32	9	41	2.82E+01	205	59	141	9.03E+02
21*	5/15-5/21	3	3	6	1.06E+01	205	59	21	1.81E+02
22*	5/22-5/28	10	20	30	1.37E+02	205	59	103	2.00E+03
23*	5/29-6/4	0	0	0	0.00E+00	205	59	0	0.00E+00
24*	6/5-6/11	2	2	4	1.12E+00	205	59	14	4.84E+01
25*	6/12-6/18	0	0	0	0.00E+00	205	59	0	0.00E+00
26*	6/19-6/25	0		0		205	59	0	0.00E+00
<b>Totals</b>		50,186	14,064	64,250	3.37E+05	4,394	1,153	245,034	6.29E+07

APPENDIX B2.—Estimated abundance of summer ( $U_s$ ) and fall chum ( $U_f$ ) fry migrants at the Duckabush River screw trap in 2017. Total chum migrants ( $U$ ) were stratified by statistical week. The proportion of summer ( $P_s$ ) and fall chum ( $P_f$ ) were based on  $n$  genetic samples collected during each weekly strata.

Week	$\bar{U}$	$\bar{W}(\bar{U})$	n	$P_s$	$v(P_s)$	n	Pf	$v(P_f)$	$U_s$	$V(U_s)$	Uf	$V(U_f)$
3*	394	8.89E+03	8	1.00	1.24E-03	8	0.00	5.94E-03	394	9.07E+03	0	8.71E+02
4*	360	1.02E+04	8	1.00	1.24E-03	8	0.00	5.94E-03	360	1.03E+04	0	7.11E+02
5*	415	7.96E+03	8	1.00	1.24E-03	8	0.00	5.94E-03	415	8.16E+03	0	9.74E+02
6	4,270	6.22E+05	8	1.00	1.24E-03	8	0.00	5.94E-03	4,270	6.44E+05	0	1.05E+05
7*	4,624	8.00E+05	10	1.00	9.90E-04	10	0.00	4.75E-03	4,624	8.21E+05	0	9.78E+04
8*	2,335	6.88E+04	19	1.00	5.21E-04	19	0.00	2.50E-03	2,335	7.16E+04	0	1.35E+04
9	9,081	5.25E+05	19	0.95	3.16E-03	19	0.05	5.14E-03	8,627	7.33E+05	454	4.22E+05
10	20,075	1.12E+06	29	0.97	1.53E-03	29	0.03	2.83E-03	19,383	1.66E+06	692	1.14E+06
11	15,346	7.80E+05	28	1.00	3.54E-04	28	0.00	1.70E-03	15,346	8.63E+05	0	3.98E+05
12*	19,347	1.74E+06	40	0.88	3.05E-03	40	0.13	3.99E-03	16,928	2.47E+06	2,418	1.51E+06
13	27,040	7.66E+06	39	0.82	4.13E-03	39	0.18	5.09E-03	22,187	8.14E+06	4,853	3.93E+06
14	54,004	1.67E+07	40	0.95	1.47E-03	40	0.05	2.41E-03	51,304	1.93E+07	2,700	7.02E+06
15	26,240	9.89E+06	40	0.83	3.95E-03	40	0.18	4.89E-03	21,648	9.41E+06	4,592	3.62E+06
16	37,268	2.13E+07	40	0.58	6.51E-03	40	0.43	7.45E-03	21,429	1.59E+07	15,839	1.40E+07
17	14,425	9.96E+05	40	0.58	6.51E-03	40	0.43	7.45E-03	8,295	1.68E+06	6,131	1.72E+06
18	6,276	4.91E+05	29	0.45	9.17E-03	29	0.55	1.05E-02	2,813	4.55E+05	3,463	5.57E+05
19*	3,255	1.99E+05	10	0.10	1.10E-02	10	0.90	1.48E-02	325	1.16E+05	2,929	3.15E+05
20*	141	9.03E+02	10	0.10	1.10E-02	10	0.90	1.48E-02	14	2.17E+02	127	1.01E+03
21*	21	1.81E+02	10	0.10	1.10E-02	10	0.90	1.48E-02	2	4.48E+00	19	1.50E+02
22*	103	2.00E+03	10	0.10	1.10E-02	10	0.90	1.48E-02	10	1.15E+02	93	1.75E+03
23*	0	0.00E+00	10	0.10	1.10E-02	10	0.90	1.48E-02	0	0.00E+00	0	0.00E+00
24*	14	4.84E+01	10	0.10	1.10E-02	10	0.90	1.48E-02	1	2.02E+00	12	4.13E+01
25*	0	0.00E+00	10	0.10	1.10E-02	10	0.90	1.48E-02	0	0.00E+00	0	0.00E+00
26*	0	0.00E+00	10	0.10	1.10E-02	10	0.90	1.48E-02	0	0.00E+00	0	0.00E+00
<b>Totals</b>	245,034	6.29E+07	391	-	1.34E-01	391	-	2.00E-01	200,712	6.24E+07	44,322	3.49E+07

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