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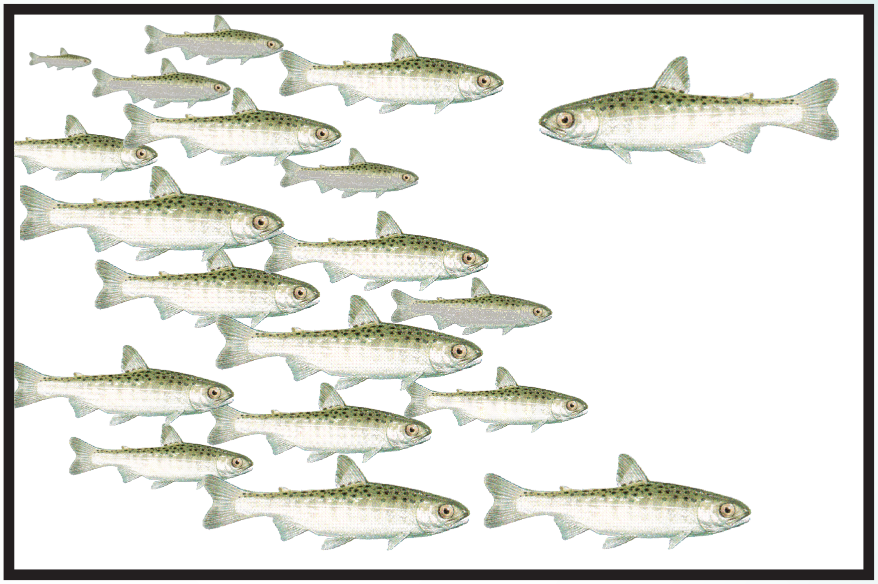
Mid-Hood Canal Juvenile Salmonid Evaluation: Duckabush River 2014



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Washington Department of Fish and Wildlife
Fish Program Science

FPA 15-05

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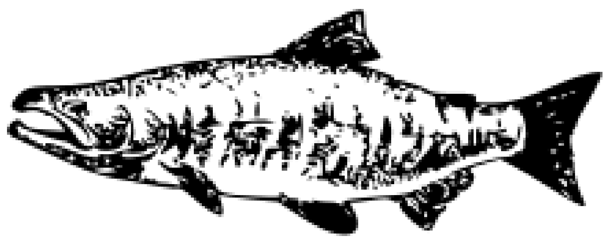

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Acknowledgements

Measuring juvenile salmonid production from large systems like the Duckabush River involves a tremendous amount of work. The Duckabush River juvenile trap was operated by dedicated scientific technician Phil Aurdal from the Washington Department of Fish and Wildlife (WDFW). Logistical support was provided by Wild Salmon Production Evaluation Unit biologist Pete Topping.

Mo Small (WDFW) conducted genetic analysis of juvenile chum samples. Kris Ryding (WDFW) consulted on the study design and estimator variance for the genetic sampling protocol.

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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 2014, a floating eight-foot screw trap was located at river mile 0.3 (0.48 rkm) and operated by WDFW from January 8 to June 25. The abundance of juvenile summer chum salmon was over twenty seven times larger than fall chum (Table 1). Egg-to-migrant survival was higher for summer than fall chum salmon. The peak of the summer chum outmigration occurred 5 weeks earlier than the peak of the fall chum outmigration. Pink salmon were by far the most abundant salmonid species emigrating from the Duckabush River in 2014 (Table 1).

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, 2014.

	Abundance				
Species	**Estimate**	**CV**	**Survival**	**Median migration date**	**Average fork length**
Summer chum	480,202	5.7%	11.2%	March 3	-
Fall chum	17,676	48.5%	1.4%	April 11	-
Chinook	4,555	8.8%	30.4%	April 8	41.9
Pink	2,401,896	6.1%	3.23%	April 12	-
Coho	8,838	27.1%	-	March 3	83.5
Steelhead	2,938	18.4%	-	April 24	171.8

Introduction

The Duckabush is a high-gradient watershed that drains into the western side of Hood Canal, Washington. Peak flow events in this watershed occur twice each year, during rain-on-snow events in the winter months and snow melt in the spring 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 abundance of 3,290 adults with an escapement of 2,060 adults over a 12 year period and have at least an average recruits per spawner of 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 populations (Duckabush, Dewatto and South Fork Skokomish). The project is monitoring 8 streams within Hood Canal that are divided between supplemented and control streams. The Duckabush is one of three supplemented streams and receives hatchery smolts and adults that are the progeny of excavated natural origin steelhead redds from the Duckabush.

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 2014 outmigration. In 2014, the primary objective of this study was to estimate the abundance, productivity and life history diversity of Chinook, Coho, pink, chum and steelhead in the Duckabush River. We conclude by discussing patterns of freshwater survival observed across the 2010-2014 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 a 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*pi = 50.24 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.

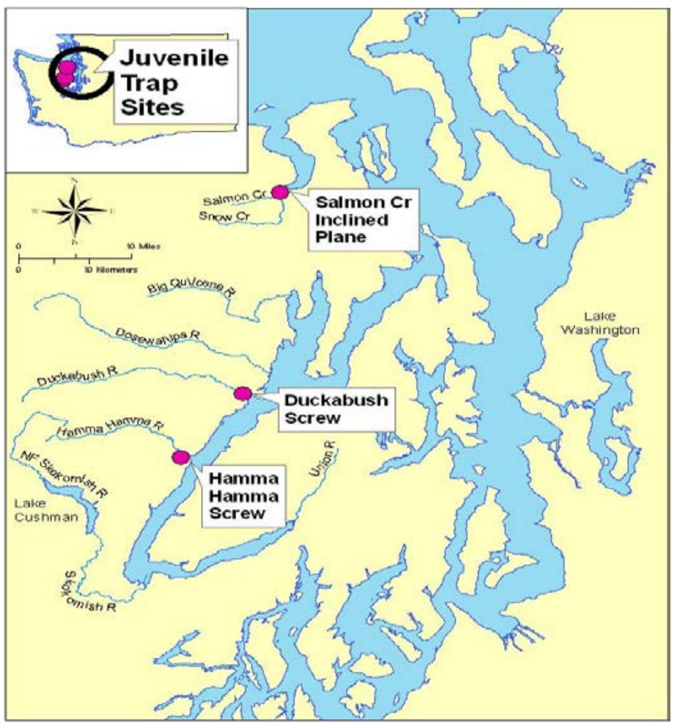

FIGURE 1.─Location of Duckabush screw trap.

Screw traps were 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, 2014

Trap	Start Date	End Date	Hours Fished	Total Possible Hours	Percent Fished	Number of Outages	Avg Outage Hrs	St Dev.
Duckabush	1/8	6/25	3,586.83	4,027.00	89.07%	7	62.88	47.9

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 ±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 ≥ 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 and pink fry throughout the season. Due to low catch of natural origin steelhead, trap efficiency for steelhead was estimated using hatchery surrogates. A known number of hatchery ad-marked steelhead were released upstream by Long Live the Kings in late April and early May. We estimated our steelhead trap efficiency based on the percentage of captured ad-marked steelhead (captured hatchery steelhead divided by total released). 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 2014 season. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and marked with Bismark-brown dye. Marked fish were allowed to recover in freshwater. Marked fish were released at dusk into fast flowing water upstream of a bend in the river, approximately 75 m distance from the trap. 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 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). Some of the juvenile samples, identified as chum in the field, produced anomalous genotypes (failed at some loci and alleles were out of range for chum salmon). These anomalies suggested that the samples may have been Chinook or pinks rather than chum salmon. The non-chum samples were not further analyzed to determine species.

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.

<u>(1) Missed catch</u>. 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

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

where:

$\overline{R}$ = 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

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

where:

Equation 4

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

<u>(2) Efficiency strata.</u> Chum data were organized into weekly strata (Monday – Sunday) in order to combine catch, efficiency trials, and genetic sampling data. Chinook and pink data were organized into time strata based on statistical pooling of the release and recapture data. Steelhead and coho data was 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_1), 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.

<u>(3) Time-stratified abundance</u>. 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 ($\widehat{U}_h^{summer}$) was the juvenile abundance for that strata ($\widehat{U}_h$) multiplied by the proportion of stock-specific migrants (p_h^{summer}) as identified in the genetic analysis:

Equation 7

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

Variance for the stock-specific estimate was:

Equation 8

$$Var\left(\hat{U}_h^{Summer}\right) = V\hat{a}r\left(\hat{U}_h\right) \cdot \left(\hat{p}^{Summer}\right)^2 + V\hat{a}r\left(\hat{p}^{Summer}\right)\hat{U}_h^2 - V\hat{a}r\left(\hat{U}_h\right) \cdot V\hat{a}r\left(\hat{p}^{Summer}\right)$$

$Var(p_h)$ 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, chum and pink. 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 Pink escapement was also estimated using an Area-Under-the-Curve and a 1 to 1 male:female ratio (Groot and Margolis 1991). 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 2,500 for chum (Joy Lee Waltermire, Lilliwaup hatchery, LLTK, personal communication), 1,800 for Pink (Heard 1991) and 5,000 for Chinook salmon (Healey 1991).

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 (< 40 mm FL, > 40 mm FL) was applied to the migration estimate for that week.

Results from 2014

Chum

Total estimated catch of natural-origin chum ($\hat{u}$ = 103,027) included 81,015 captures in the trap and an estimated missed catch of 22,012 during trap outages (Appendix B). A total of 2,718 natural-origin chum were marked and released over 28 efficiency trials, ranging between 26 and 105 fish per release group. Mark and recapture data were organized into 27 weekly strata for analysis. Trap efficiency of these strata ranged between 1.94% and 37.1%.

Few chum fry were captured the first day of trapping (N = 40 January 8), and the last chum was observed on June 12, well before the trap was removed on June 25. 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 21 until the end of the trapping season, the sampled catch was mostly fall chum (Table 3). One of the 400 samples had allele frequencies that did not meet the assignment threshold. Five of the samples could not be positively identified as chum or did not contain sufficient DNA to analyze.

TABLE 3.—Genetic stock identification for juvenile chum salmon migrants caught in the Duckabush River screw trap, 2014.

Date	Samples	Summer	Fall	Unassigned	Unknown	% Summer	% Fall
01/27/2013	10	10	0			100.00%	0.00%
02/03/2013	10	10	0			100.00%	0.00%
02/10/2013	10	10	0			100.00%	0.00%
02/17/2013	20	20	0			100.00%	0.00%
02/24/2013	20	18	1	1		94.74%	5.26%
03/03/2013	30	30	0			100.00%	0.00%
03/10/2013	30	30	0			100.00%	0.00%
03/17/2013	40	39	1			97.50%	2.50%
03/24/2013	40	40	0			100.00%	0.00%
03/31/2013	40	33	5		2	86.84%	13.16%
04/07/2013	40	28	11		1	71.80%	28.20%
04/14/2013	40	24	14		2	63.16%	36.84%
04/21/2013	40	5	35			12.50%	87.50%
04/28/2013	20	1	19			5.00%	95.00%
05/05/2013	10	2	8			20.00%	80.00%
Totals	400	300	94	1	5	66.07%	34.19%

A total of 480,202 ± 53,838 (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 5.7%. A total of 17,676 ± 16,810 (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 48.5%. 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 11.2% for summer chum and 1.4% 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 2014.

Stock	Juvenile Production	Juvenile CV	Female Spawners	Egg to Migrant Survival
Summer	480,202	5.7%	1,713	11.2%
Fall	17,676	48.5%	497	1.4%
Total	497,879	5.78%	2,210	9.0%

The entire chum outmigration occurred over a 24 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 4, five weeks earlier than the median migration date of the fall component on April 11. The summer chum component of the migration was 95% complete by April 2. The fall chum component of the migration was 95% complete by May 5. Chum fry were not measured due to very low variation in total length (36-45mm).

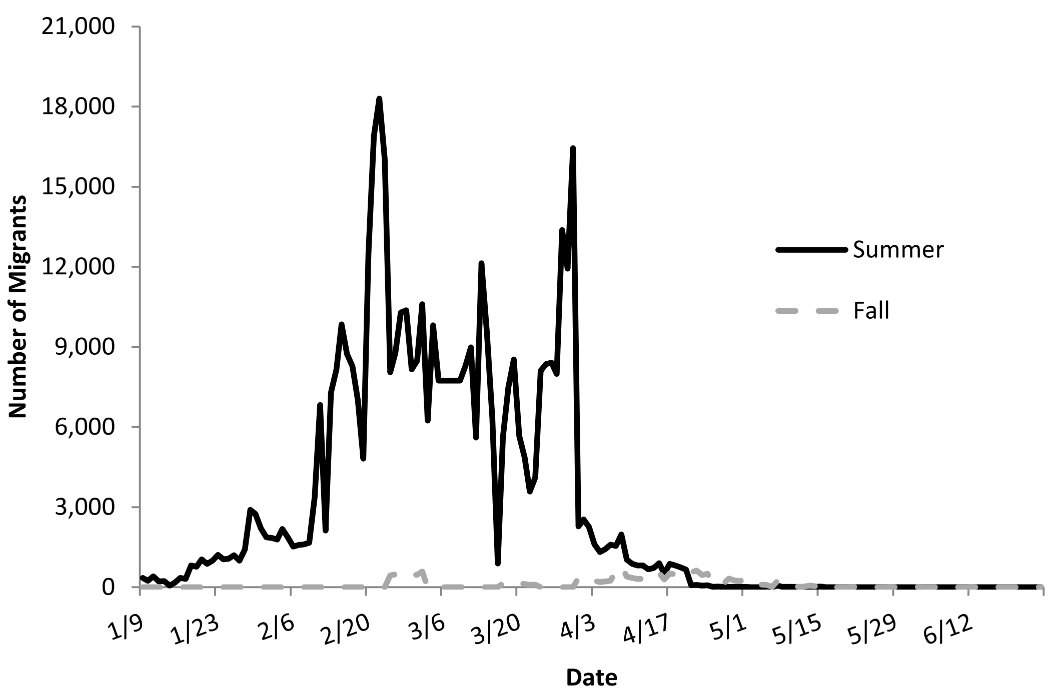

FIGURE 2.—Daily outmigration of natural-origin chum salmon fry in the Duckabush River, 2014 outmigration.

Chinook

Total catch of natural-origin Chinook was 757 juveniles. Due to the low number of Chinook, chum efficiency trials were used to represent Chinook trap efficiency. The 28 chum efficiency trials were pooled into 7 strata using the *G*-test approach, with trap efficiencies ranging between 1.9% and 29.0%.

A total of 4,555 ± 786 (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 8.8%.

Egg-to-migrant survival was estimated to be 30.37% for Duckabush Chinook salmon in 2014 (Table 6).

TABLE 5.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Duckabush River, 2014. Release groups were pooled to form 7 strata. Missed catch and associated variance were calculated for periods the trap did not fish.

		Catch					Abundance	
Strata	**Date**	**Actual**	**Missed**	**Variance**	**Marks**	**Recaptures**	**Estimated**	**Variance**
1	1/9-2/24	29	8	1.89E+00	1,013	150	248	1.84E+03
2	2/25-3/20	189	36	1.12E+01	523	146	802	5.31E+03
3	3/21-3/24	35	0	0.00E+00	105	16	218	3.30E+03
4	3/25-3/26	14	0	0.00E+00	103	2	485	6.94E+04
5	3/27-3/31	17	19	1.09E+01	105	23	159	1.52E+03
6	4/1-4/14	233	0	0.00E+00	418	121	800	5.62E+03
7	4/15-6/25	240	37	4.83E+02	451	67	1,841	7.36E+04
	Season Total	757	100	5.07E+02	2,718	525	4,555	1.61E+05

TABLE 6.─Juvenile abundance and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin Chinook salmon in the Duckabush River, outmigration year 2014.

Stock	**Juvenile Abundance**	**Juvenile CV**	**Female Spawners**	**Egg to Migrant Survival**
Chinook	4,555	8.8%	3	30.4%

The first Chinook fry was captured on January 31, 2014. Daily migration of Chinook was low and sporadic for most of the season (Figure 3). The median migration date occurred on April 8. The migration was 95% complete by June 7. One Chinook was captured on June 25, 2014, the last day of the trapping season. 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 34-mm to 83-mm and averaged 42-mm throughout the trapping season (Figure 4). Average weekly fork lengths of juvenile Chinook began to increase during statistical week 19 (middle of May).

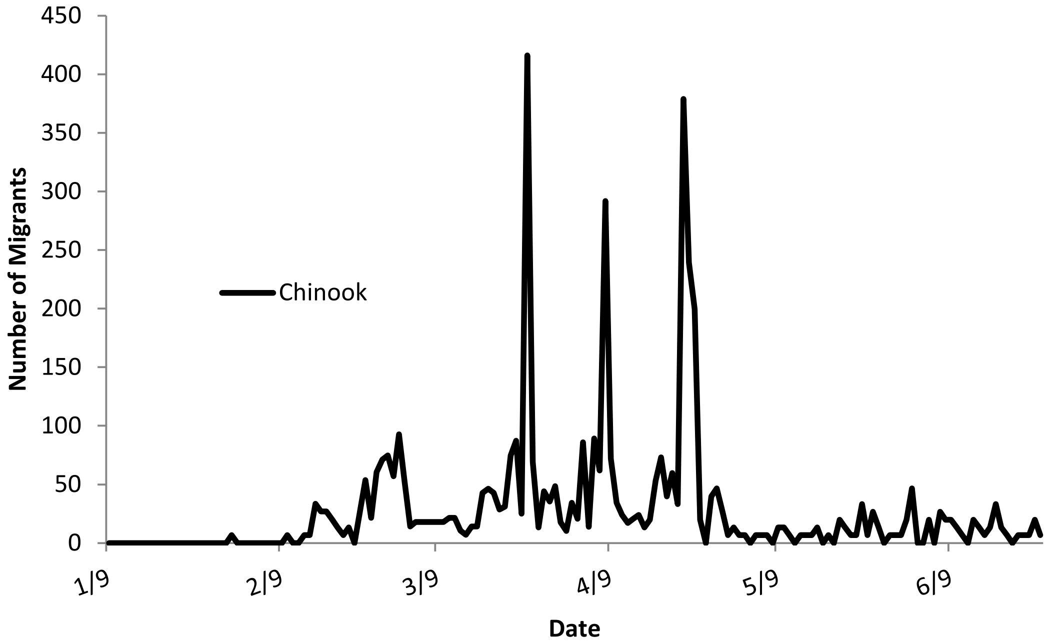

FIGURE 3.—Daily outmigration of natural-origin Chinook salmon fry in the Duckabush River, 2014 outmigration.

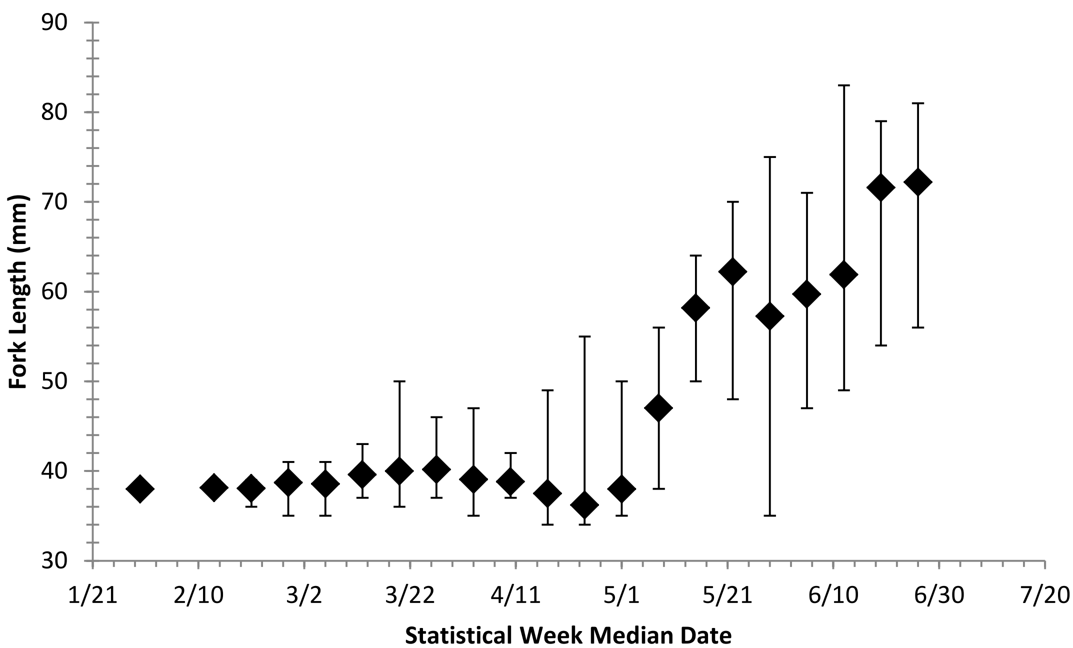

FIGURE 4.—Fork lengths (mm) of juvenile Chinook migrants of natural origin captured in the Duckabush River screw trap 2014. Data are mean, minimum, and maximum values by statistical median date.

Pink

Total catch of natural-origin pink was 403,644 juveniles. The 20 pink efficiency trials were pooled into 9 strata using the *G*-test approach, with trap efficiencies ranging between 4.9% and 29.5%.

Eleven pink fry were captured on the first day of trapping (January 9), and the last pink was observed on June 19. Pink migration prior to and after the trapping season was assumed to be minimal (<1% of total migration).

A total of 2,401,896 ± 288,867 (95% C.I.) natural-origin pink fry are estimated to have migrated past the screw trap (Table 7). Coefficient of variation for this estimate was 6.1%.

TABLE 7.―Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for pink salmon in the Duckabush River, 2014. Release groups were pooled to form 9 strata. Missed catch and associated variance were calculated for periods the trap did not fish.

		Catch					Abundance	
Strata	Date	Actual	Missed	Variance	Marks	Recaptures	Estimated	Variance
1	1/9-3/11	16,104	10,724	1.38E+06	210	48	115,525	2.31E+08
2	3/12-3/17	7,877	0	0.00E+00	103	11	68,267	3.18E+08
3	3/18-3/20	7,420	0	0.00E+00	105	31	24,579	1.28E+07
4	3/21-3/24	3,382	0	0.00E+00	104	17	19,728	1.71E+07
5	3/25-3/26	5,643	0	0.00E+00	102	5	96,872	1.26E+09
6	3/27-4/10	147,857	25,040	5.26E+07	419	96	748,626	5.39E+09
7	4/11-4/29	203,487	17,892	4.16E+06	518	90	1,262,590	1.44E+10
8	4/30-5/8	11,417	628	7.91E+04	294	58	60,225	5.06E+07
9	5/9-6/25	457	0	0.00E+00	155	12	5,484	2.03E+06
	Season Total	403,644	54,284	5.82E+07	2,010	368	2,401,896	2.17E+10

Egg-to-migrant survival was estimated to be 3.2% for Duckabush pink salmon in 2014 (Table 8).

TABLE 8.―Juvenile abundance and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin pink salmon in the Duckabush River, outmigration year 2014.

Stock	Juvenile Abundance	Juvenile CV	Female Spawners	Egg to Migrant Survival
Pink	2,401,896	6.14%	41,276	3.23%

Pink salmon fry were captured during the first night of trapping. The entire pink outmigration occurred over a 24 week period between early January and the middle of June (Figure 5). The median migration date occurred on April 12. The pink fry migration was 95% complete by April 27.

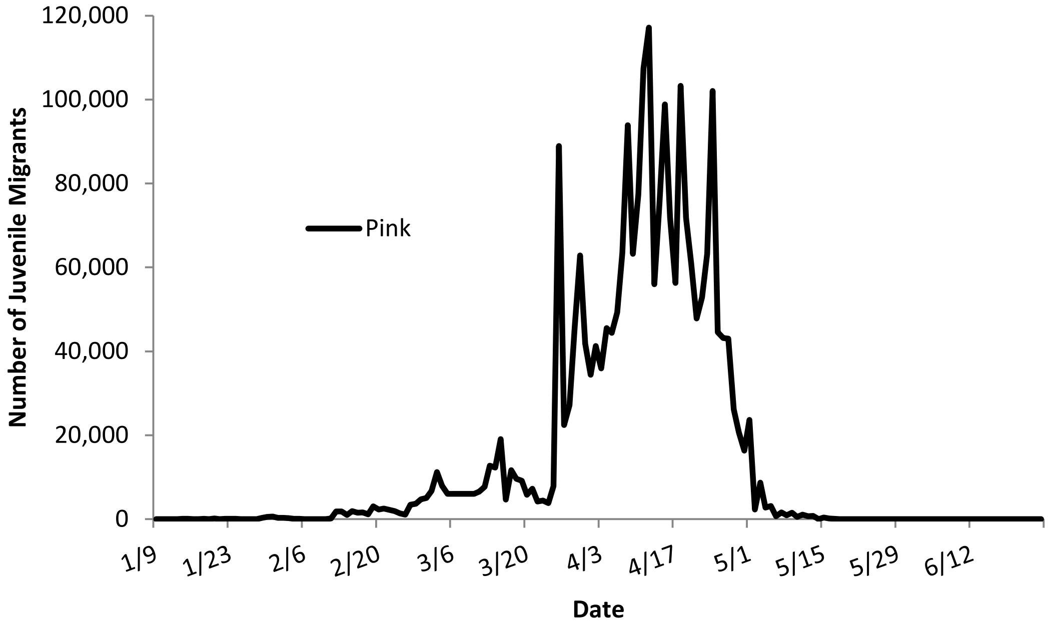

FIGURE 5.—Daily outmigration of natural-origin pink salmon fry in the Duckabush River, 2014 outmigration.

Coho

Total catch of natural-origin Coho yearlings was 522 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 1,744 coho fry.

A total of 8,838 ± 4,695 (95% C.I.) natural-origin Coho yearlings are estimated to have migrated past the screw trap (Table 9). Coefficient of variation for this estimate was 27.1%.

TABLE 9.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Coho salmon in the Duckabush River, 2014. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

	Catch					Abundance	
Date	**Actual**	**Missed**	**Variance**	**Marks**	**Recaptures**	**Estimated**	**Variance**
1/9-7/9	522	84	1.37E+02	174	11	8,838	5.74E+06

The first Coho yearling was captured on the first day of trapping, January 9, 2014. The median migration date occurred on March 3 (Figure 6). The migration was 95% complete by May 20. The last Coho was captured on June 20, 2014, five days before the end of the trapping season.

Length of natural-origin Coho yearlings ranged from 49-mm to 132-mm and averaged 84-mm throughout the trapping season (Figure 7). Average weekly fork lengths of juvenile Coho began to consistently increase during statistical week 15 (middle of April).

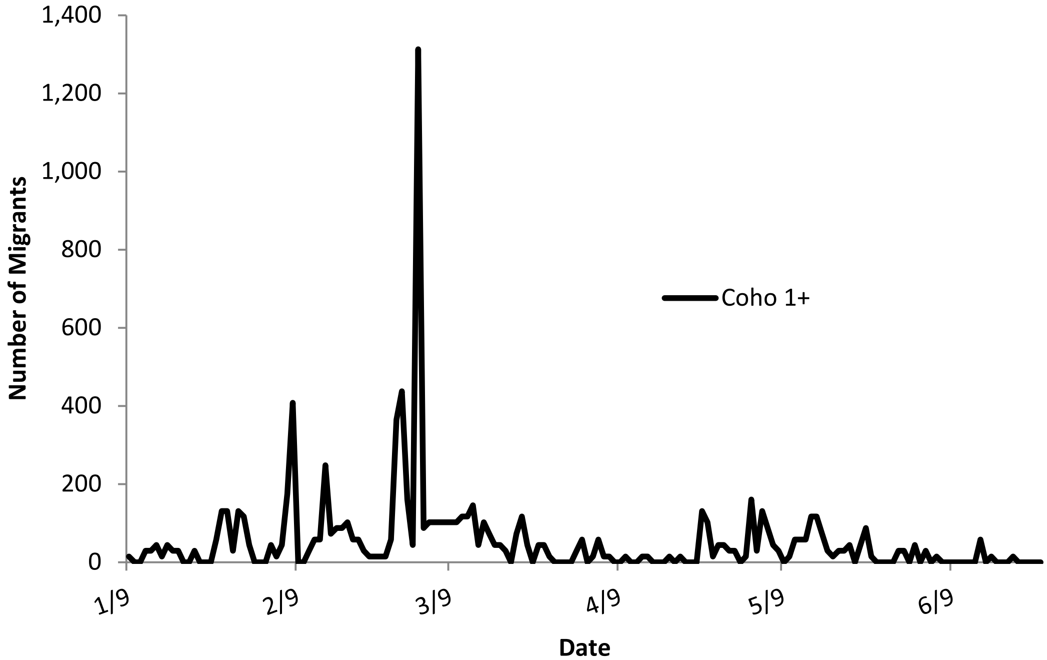

FIGURE 6.—Daily outmigration of natural-origin yearling Coho salmon in the Duckabush River, 2014 outmigration.

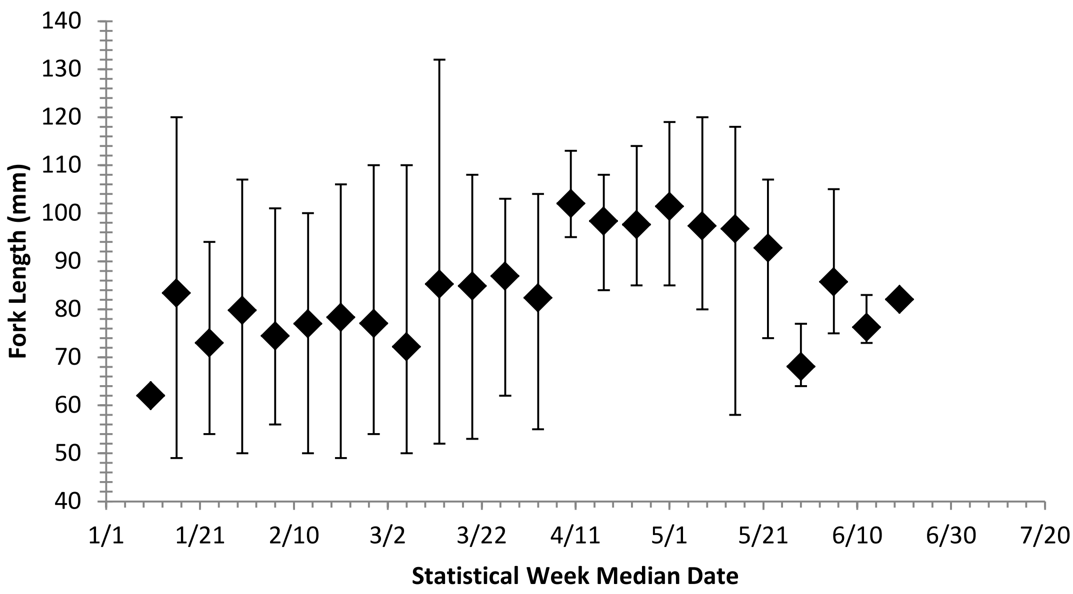

FIGURE 7.—Fork lengths (mm) of juvenile Coho yearling migrants of natural origin captured in the Duckabush River screw trap 2014. Data are mean, minimum, and maximum values by statistical median date.

Steelhead

Total catch of natural-origin steelhead smolts was 42 juveniles. Due to the low number of natural-origin steelhead, catch of ad-marked hatchery steelhead released upstream from the trap were used to estimate steelhead smolt trap efficiency. We captured 85 ad-marked steelhead over the course of the season. The 7 hatchery steelhead efficiency trials were pooled together to formulate a single stratum for the season.

A total of 2,938 ± 1,059 (95% C.I.) natural-origin steelhead smolts are estimated to have migrated past the screw trap (Table 10). Coefficient of variation for this estimate was 18.4%.

TABLE 10.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for steelhead in the Duckabush River, 2014. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

	Catch					Abundance	
Date	**Actual**	**Missed**	**Variance**	**Marks**	**Recaptures**	**Estimated**	**Variance**
1/9-6/25	42	17	2.11E+01	4,282	85	2,938	2.92 E+05

The first steelhead smolt was captured on January 10, 2014. The median migration date occurred on April 24 (Figure 8). The migration was 95% complete by May 23. The last steelhead was captured on May 27, 2014, twenty nine days before the end of the trapping season.

Scale samples were collected on 39 of the 42 natural-origin steelhead smolts captured. The sample included 28 readable and 11 regenerated or upside down samples. Scale sample results from the 28 readable samples showed that age 2 smolts were the dominant age class captured at the trap in 2014 (Table 11).

Table 11.—Steelhead smolt age data for the Duckabush River 2012 through 2014.

Out Migration Year	Number Sampled	Freshwater Age 1+	2+	3+
2012	52	15.38%	63.46%	21.15%
2013	43	6.98%	76.74%	16.28%
2014	28	0.00%	75.00%	25.00%

Length of natural-origin steelhead smolts ranged from 138-mm to 208-mm and averaged 172-mm throughout the trapping season (Figure 9).

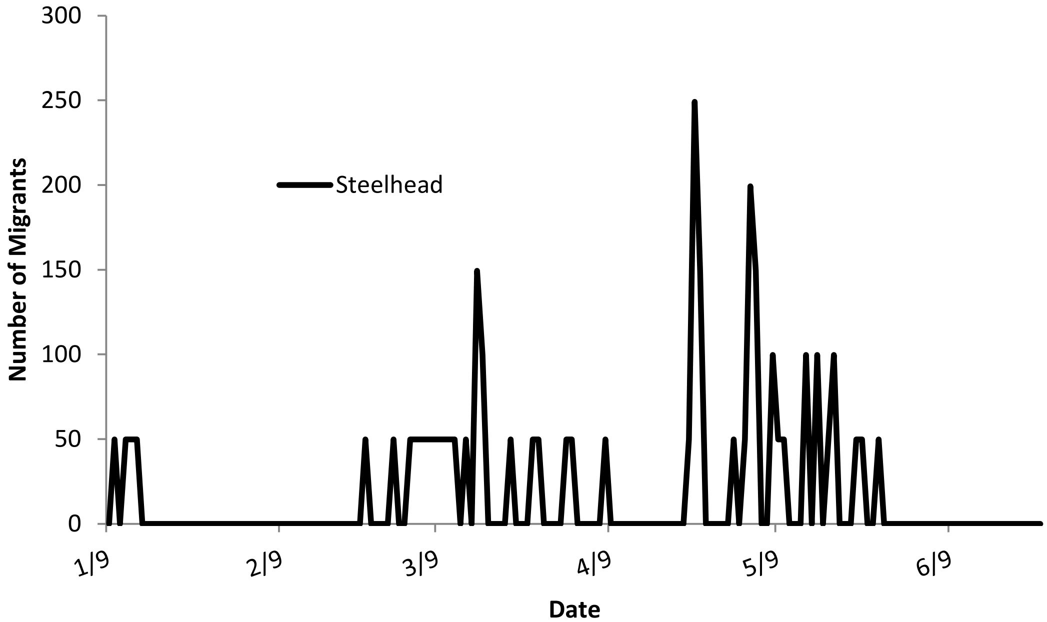

FIGURE 8.—Daily outmigration of natural-origin steelhead smolts in the Duckabush River, 2014.

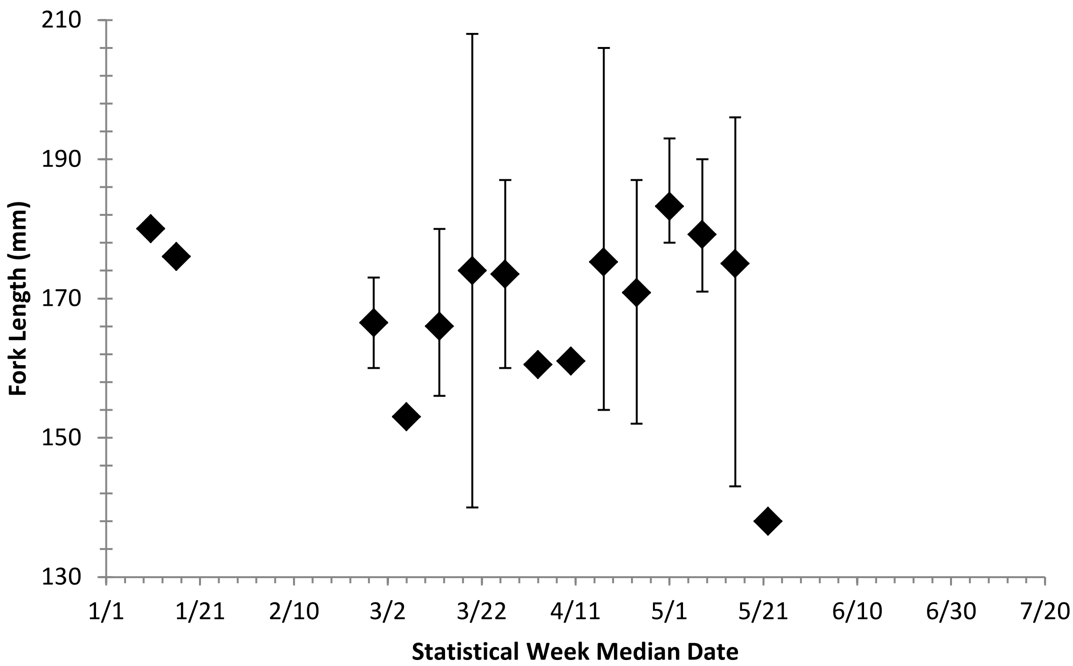

FIGURE 9.—Fork lengths (mm) of juvenile steelhead smolt migrants of natural origin captured in the Duckabush River screw trap 2014. Data are mean, minimum, and maximum values by statistical median date.

Other Species

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

Discussion of Data Accumulated 2011-2014

This report provides the freshwater production, survival and out-migration timing for chum and Chinook salmon populations in Hood Canal in 2014. The 2014 trapping season marked the fourth 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, pink salmon, Coho salmon and steelhead.

Precision and Accuracy of Mark-Recapture Estimates

Precision of the juvenile abundance estimates provided in this report were within or slightly higher than the NMFS guidelines recommended for monitoring of ESA-listed species (Crawford and Rumsey 2011) . Precision, represented by the coefficient of variation (*CV*), represents the ability of a value to be consistently reproduced. The precision of a mark-recapture estimate is a function of both catch and recapture rates (i.e., trap efficiency; Robson and Regier 1964) as well as the uncertainty in the proportions attributed to each sample. The uncertainty of the genetic proportions in a given time period is influenced by the proportion value and the number of fish sampled. Now that the migration timing for each stock is better understood, we should be able to further improve precision of the estimate by maximizing tissue sampling during periods of overlap between summer and fall chum salmon.

The accuracy of the juvenile abundance estimates provided in this report were assessed with respect to five assumptions of the mark-recapture estimator (Hayes et al. 2007; Seber 1973). Accuracy represents how well the derived estimate matches the true value. An estimate derived from a mark-recapture study design is considered to be accurate (i.e., unbiased) when the estimator assumptions are met. Therefore, the Duckabush River juvenile monitoring study was designed to minimize violation of these assumptions.

<u>Assumption 1. Population is closed with no immigration or emigration and no births or deaths.</u> The emigration assumption is technically violated because the trap catches downstream migrants that are emigrating from the river. However, we assume that the entire cohort is leaving the system within a defined period and that the abundance of juveniles can be estimated at a fixed station during this migration. This assumption is supported by the modality of downstream movement.

Two potential sources of deaths are mark-related mortality and in-river predation. Stress associated with handling or marking is minimized by gentle handling and dying by trained staff. Mortalities in response to handling or marking was minimal based on periodic evaluations of fish held for 24-hour periods after the marking process. Mortality between release and recapture due to in-river predation or live box predation is expected to be an important issue for the small fry migrants (Chinook, chum). The release site above the trap was selected to be close enough to the trap to minimize in-river predation but far enough from the trap to maximize mixing of marked and unmarked fish (assumption #4 below). Predation within the live box is a potential source of mortality, especially later in the season when catch of yearling migrants increase.

<u>Assumption 2. All animals have the same probability of being caught.</u> This assumption would be violated if trap efficiency changes over time, if capture rates within a species are different for small and large fish, or if a portion of the presumed "migrants" are not moving in a downstream direction. Temporal changes in trap efficiency are accommodated by stratifying the migration estimate into different time periods. Size-biased capture rates are unlikely for chum and Chinook salmon that migrate at relatively small sizes (30-45 mm fork length). It is possible that larger (>45mm) Chinook could evade capture better than smaller sized migrants. Due to low catches of Chinook, we are unable at this time to have mark-recapture tests using larger Chinook migrants to test this hypothesis. Equal probability of capture would also be violated if a portion of the juvenile fish were caught because they were redistributing in the river rather than in process of a downstream migration. The location of the traps near the mouth of each river, the recapture of marked sub-yearlings within one day of release, and the modality of the outmigration do not support the idea that the fry migrants caught in this study were simply redistributing in the river.

<u>Assumption 3. Marking does not affect catchability.</u> This assumption would be violated if marked fish were better able to avoid the trap or were more prone to capture than maiden-caught fish. Trap avoidance of marked fish was more likely for Coho or steelhead than the smaller sub-yearling Chinook or chum salmon. However, behavioral differences between maiden captures and recaptured fish are currently unknown. Handling and marking the fish may also make them more prone to capture if the stress of handling compromises fish health. To minimize this effect, fish held for release were monitored for the 10+ hours between initial capture and release. During this period, fish are held in a perforated bucket that allows water to be exchanged between bucket and stream. Fish that do not appear to be healthy or swimming naturally were not included in the release group.

<u>Assumption 4. Marked fish mix at random with unmarked fish.</u> This assumption would be violated if marked and unmarked fish were spatially or temporally distinct in their downstream movements. The locations of the trap and release sites were selected to minimize violations of this assumption. The traps are located in the fast-moving thalweg used by juvenile fish (marked and unmarked) to ease downstream transport. The release sites were selected at the outset of study on both rivers and have been consistent over time. Release locations in both watersheds were selected in order to maximize mixing of marked and unmarked sub yearlings while minimizing in-river predation. The assumption of equal mixing can be tested by pairing releases from different locations upstream of the trap (Tynan 1997). This type of comparison will be planned for future evaluation of this assumption.

<u>Assumption 5. No marks are lost and all marks are detected.</u> This assumption would be violated if dye or fin clips were not retained or recognized on recaptured fish. This assumption

was likely met. Bismark Brown dye is known to retain its coloration of fish throughout the recapture period of several days (unpublished data). The frequency of undetected marks should also have been low given the highly-trained staff performing both the marking procedure and collecting the recapture data.

Assumptions for Missed Catch

The accuracy of each abundance estimate depends, in part, on accurate estimates of missed catch during periods that the trap did not fish. The linear interpolation method used to estimate in-season missed catch assumed that no major changes occurred in fish migration during the outage period. Drops or spikes in migration rates during high flows would violate this assumption but are nearly impossible to verify.

A second type of missed catch occurred prior to or after the trapping season. Chum salmon have the most extended migration of any species in the Duckabush juvenile evaluations and low levels of catch were occurring at the beginning of the trapping season. Emergence timing of summer and fall chum is expected to vary as a function of adult spawn timing, incubation temperatures, and total days in the gravel (NOAA 1999a; NOAA 1999b). The combination of these factors changes from year to year and leads to some variability in the timing of emergence for all species in a system. This variability in emergence made migration prior to trap installation difficult to estimate. Although the onset of the chum migration is unknown, the extremely low catches observed during the first few days of trapping suggest a longer trapping season would not substantially alter our estimates.

Duckabush Chum Salmon

The 2014 season marked the second lowest spawning abundance for both summer and fall chum since genetic identification of juveniles began in 2011. Juvenile production of summer and fall chum varied significantly from one another. Summer chum were estimated at close to half a million juvenile migrants, the highest observed during the past four seasons. In contrast, juvenile production of fall chum was nearly two times smaller than the previous low observed in 2011 (Table 11). Egg to migrant survival for summer chum was more than double of the estimated survival for the 2013 summer chum. Fall chum have exhibited similar survival for the past three seasons.

TABLE 12. Juvenile production and associated adult escapement and egg-to-migrant survival for summer and fall chum in the Duckabush River, 2011-2014.

Stock	Adult Return Year	Adult Escapement	Juvenile Migration Year	Estimated Juvenile Migration	Egg to Migrant Survival
Summer	2010	4,110	2011	347,597	7.78%
	2011	1,529	2012	290,891	17.50%
	2012	5,241	2013	285,468	5.01%
	2013	3,939	2014	480,202	11.22%
Fall	2010	373*	2011	32,656	8.05%
	2011	2,234	2012	43,053	1.77%
	2012	2,973	2013	42,213	1.31%
	2013	1,144	2014	17,676	1.42%

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

The 2014 season set a new high for summer chum juvenile abundance despite having the second lowest spawning abundance. Years of greater adult abundance of summer chum have resulted in a lower egg to migrant survival (Figure 10). This trend suggests that production of summer chum could be constrained by density dependent factors. Fall chum on the other hand, have ranged between 1,000 to 2,900 spawners the past three seasons and have had consistent survival rates around 1% to 2% (Figure 11). It is unknown at this time why fall chum egg to migrant survival is consistently lower than summer chum.

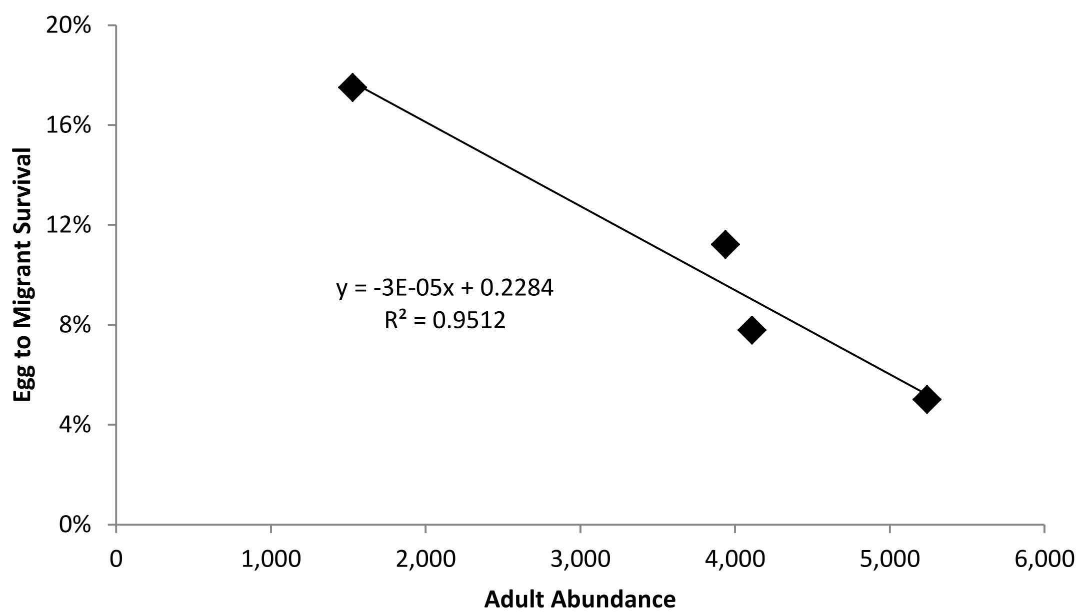

FIGURE 10.—Egg-to-migrant survival vs number of spawners of Duckabush summer chum, 2011-2014.

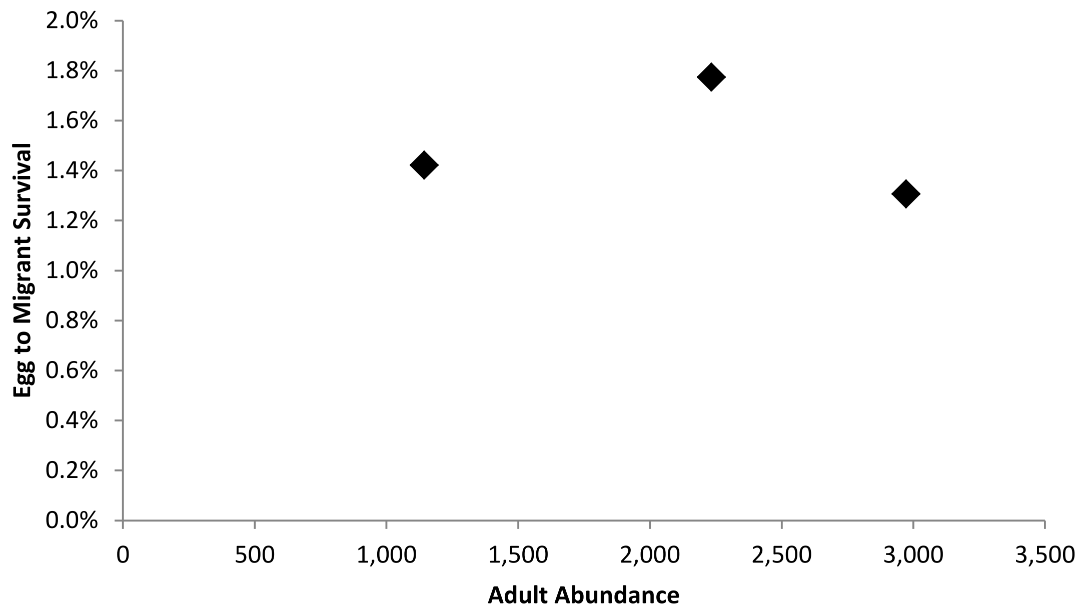

FIGURE 11. ─ Egg-to-migrant survival vs number of spawners of Duckabush fall chum, 2011-2014.

Duckabush Chinook Salmon

Freshwater production of Chinook salmon showed a slight drop compared the to the 2013 season (Table 12). Adult abundance has continued to remain very low. Given the number of juvenile Chinook migrants and associated survival estimates, we continue to suspect that adult Chinook surveys consistently underestimate spawning escapement. 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 13.─Fry abundance, observed spawning escapement, estimated spawning escapement and egg-to-migrant survival for natural-origin Chinook salmon in the Duckabush River, outmigration year 2011-2014.

Out Migration Year	Abundance	Observed Spawning Escapement	Egg-to-Migrant Survival
2011	1,219	0	-
2012	2,788	5	22%
2013	5,221	6	52%
2014	4,555	7	30%

We quantified two migration subyearling strategies employed by juvenile Chinook. Fry migrants, which migrate downstream immediately following emergence, were approximately 78.8% of the freshwater production that migrated past the Duckabush screw trap in 2014 (Table 13). Parr migrants, which spend some time growing and rearing in freshwater prior to migration, appear to decrease as the total number of subyearling migrants increase (Figure 12). One possible explanation for this pattern is a limited capacity of rearing habitat in the mainstem Duckabush River. Long term monitoring on the Skagit River has shown that density dependent production of parr but density independent production of fry (Zimmerman 2015). As data accumulate in future years, we will continue to explore this pattern and the possible mechanisms that limit parr production.

TABLE 14. ─Migration timing and abundance of two life history strategies (fry and parr) of natural-origin Chinook outmigrants, 2011-2014.

Out Migration Year	Date 10%	Date 50%	Date 90%	Number of Fry	Number of Parr	Percent Fry	Percent Parr	Total Outmigration
2011	4/5	4/13	6/17	755	464	61.9%	38.1%	1,219
2012	4/15	4/23	5/9	1,890	898	67.8%	32.2%	2,788
2013	3/11	4/2	5/16	4,535	686	86.9%	13.1%	5,221
2014	2/28	4/8	5/20	3,590	964	78.8%	21.2%	4,555

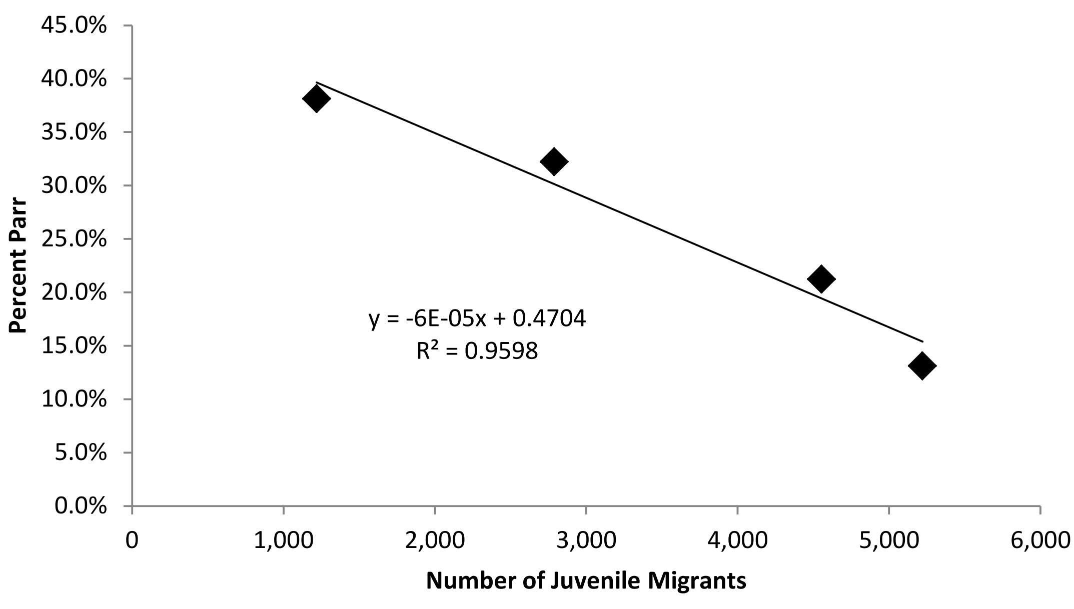

FIGURE 12. Percent of Chinook parr migrants vs the total number of subyearling Chinook, Duckabush 2011-2014.

Duckabush Pink

In 2014, the estimate of adult pink salmon escapement was over 20 times higher than either of the two previous pink return years (Table 14). Juvenile outmigration was 5 times as large as 2012. Egg to migrant survival was approximately 10% for the 2013 return compared to the 2011 return. One possible explanation for the decrease in egg to migrant survival is the large abundance of adult pink salmon on the spawning grounds, which may have led to an elevated rate of redd superimposition. Redd superimposition has been found to increase mortality during incubation when high densities of adult pink spawners are present, and is a direct mechanism for density-dependent productivity (Fukushima et al. 1998) . As additional years of data become available, we will be able to further evaluate the factors that influence egg to migrant survival for Duckabush pink salmon.

TABLE 15.-Adult escapement, juvenile migration and egg to migrant survival for Duckabush pink salmon, 2009, 2011 and 2013 brood.

Adult Return Year	Adult Escapement	Juvenile Migration	Egg to Migrant Survival
2009	3,567	35,788	1.11%
2011	4,103	512,637	13.88%
2013	82,551	2,401,896	3.23%

Duckabush Coho Salmon

Freshwater production of Coho yearlings has remained fairly consistent for the past three seasons (Table 15). This trend suggests that the rearing habitat may limit the production of Coho yearlings. The Duckabush River only has a handful of small tributaries that are accessible to returning Coho adults or rearing juveniles. We will continue to monitor this trend as we accumulate data in future seasons.

TABLE 16. —Yearling coho production and corresponding upper and lower cofindence intervals for the Duckabush River 2012 and 2014.

	Abundance			
Out Migration Year	Estimate	Lower CI	Upper CI	CV
2012	7,082	5,186	8,977	13.7%
2013	6,732	3,811	9,654	22.1%
2014	8,838	4,143	13,532	27.1%

Duckabush Steelhead

The 2013 season marked the third 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 16). 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 17.—Steelhead production and corresponding upper and lower confidence intervals for the Duckabush River 2012 through 2014.

	Abundance			
Out Migration Year	**Estimate**	**Lower CI**	**Upper CI**	**CV**
2012	2,299	1,529	3,068	17.1%
2013	2,422	1,693	3,152	15.4%
2014	2,938	1,879	3,997	18.4%

Appendix A

Statistical Weeks for 2014

APPENDIX A1.–Statistical Weeks for 2014.

Stat Week	2014
1	Jan 1 - Jan 5
2	Jan 6 - Jan 12
3	Jan 13 - Jan 19
4	Jan 20 - Jan 26
5	Jan 27 - Feb 2
6	Feb 3 - Feb 9
7	Feb 10 - Feb 16
8	Feb 17 - Feb 23
9	Feb 24 - Mar 2
10	Mar 3 - Mar 9
11	Mar 10 - Mar 16
12	Mar 17 - Mar 23
13	Mar 24 - Mar 30
14	Mar 31 - Apr 6
15	Apr 7 - Apr 13
16	Apr 14 - Apr 20
17	Apr 21 - Apr 27
18	Apr 28 - May 4
19	May 5 - May 11
20	May 12 - May 18
21	May 19 - May 25
22	May 26 - Jun 1
23	Jun 2 - Jun 8
24	Jun 9 - Jun 15
25	Jun 16 - Jun 22
26	Jun 23 - Jun 29

Appendix B

Duckabush River catches, trap efficiencies, and abundance estimates for 2014

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 2014. 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	$\hat{U}$	$V(\hat{U})$
2*	1/9-1/12	113	25	138	3.00E+02	70	7	1,225	1.82E+05
3	1/13-1/19	280	26	306	3.26E+02	70	7	2,716	7.74E+05
4	1/20-1/26	1,236		1,236		210	34	7,451	1.32E+06
5	1/27-2/2	2,333		2,333		209	34	13,998	4.60E+06
6	2/3-2/9	1,630		1,630		209	27	12,225	4.54E+06
7	2/10-2/16	5,677	1,319	6,996	2.82E+04	105	15	46,349	1.09E+08
8	2/17-2/23	12,170	1,333	13,503	2.88E+04	210	33	83,798	1.70E+08
9	2/24-3/2	18,454		18,454		210	56	68,312	5.89E+07
10	3/3-3/9	4,586	11,060	15,646	1.75E+06	104	29	54,761	9.12E+07
11	3/10-3/16	9,199	4,608	13,807	7.62E+05	104	27	51,776	7.89E+07
12	3/17-3/23	9,881		9,881		210	50	40,880	2.45E+07
13	3/24-3/30	5,754	3,530	9,284	9.54E+04	208	25	74,629	1.87E+08
14	3/31-4/6	4,856		4,856		209	67	14,996	2.23E+06
15	4/7-4/13	2,829		2,829		209	54	10,802	1.57E+06
16	4/14-4/20	1,311		1,311		208	32	8,303	1.75E+06
17	4/21-4/27	402	98	500	8.51E+02	159	26	2,963	3.05E+05
18	4/28-5/4	182		182		84	9	1,547	2.03E+05
19*	5/5-5/11	68	13	81	6.56E+01	84	9	689	4.78E+04
20*	5/12-5/18	42		42		84	9	357	1.27E+04
21*	5/19-5/25	3		3		84	9	26	2.26E+02
22*	5/26-6/1	4		4		84	9	34	3.25E+02
23*	6/2-6/8	3	0	3	0.00E+00	84	9	26	2.26E+02
24*	6/9-6/15	2	0	2	0.00E+00	84	9	17	1.39E+02
Totals		81,015	22,012	103,027	2.67E+06	3,292	586	497,879	7.37E+08

APPENDIX B2.–Estimated abundance of summer (U_s) and fall chum (U_f) fry migrants at the Duckabush River screw trap in 2014. 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	U	V(U)	n	Ps	v(Ps)	n	Pf	v(Pf)	Us	V(Us)	Uf	V(Uf)
2*	1,225	1.82E+05	10	1.00	9.90E-04	10	0.00	4.75E-03	1,225	1.84E+05	0	6.26E+03
3	2,716	7.74E+05	10	1.00	9.90E-04	10	0.00	4.75E-03	2,716	7.81E+05	0	3.14E+04
4	7,451	1.32E+06	10	1.00	9.90E-04	10	0.00	4.75E-03	7,451	1.38E+06	0	2.57E+05
5	13,998	4.60E+06	10	1.00	9.90E-04	10	0.00	4.75E-03	13,998	4.79E+06	0	9.09E+05
6	12,225	4.54E+06	10	1.00	9.90E-04	10	0.00	4.75E-03	12,225	4.69E+06	0	6.88E+05
7	46,349	1.09E+08	10	1.00	9.90E-04	10	0.00	4.75E-03	46,349	1.11E+08	0	9.69E+06
8	83,798	1.70E+08	20	1.00	4.95E-04	20	0.00	2.38E-03	83,798	1.73E+08	0	1.63E+07
9	68,312	5.89E+07	19	0.95	3.29E-03	19	0.05	5.27E-03	64,717	6.80E+07	3,595	2.44E+07
10	54,761	9.12E+07	30	1.00	3.30E-04	30	0.00	1.58E-03	54,761	9.22E+07	0	4.60E+06
11	51,776	7.89E+07	30	1.00	3.30E-04	30	0.00	1.58E-03	51,776	7.98E+07	0	4.12E+06
12	40,880	2.45E+07	40	0.98	8.73E-04	40	0.03	1.81E-03	39,858	2.47E+07	1,022	3.00E+06
13	74,629	1.87E+08	40	1.00	2.48E-04	40	0.00	1.19E-03	74,629	1.89E+08	0	6.39E+06
14	14,996	2.23E+06	38	0.87	3.35E-03	38	0.13	4.34E-03	13,023	2.43E+06	1,973	1.00E+06
15	10,802	1.57E+06	39	0.72	5.58E-03	39	0.28	6.55E-03	7,755	1.45E+06	3,047	8.78E+05
16	8,303	1.75E+06	38	0.63	6.55E-03	38	0.37	7.54E-03	5,244	1.14E+06	3,059	7.44E+05
17	2,963	3.05E+05	40	0.13	3.05E-03	40	0.88	3.99E-03	370	3.06E+04	2,593	2.68E+05
18	1,547	2.03E+05	20	0.05	3.00E-03	20	0.95	4.88E-03	77	7.07E+03	1,470	1.93E+05
19*	689	4.78E+04	10	0.20	1.88E-02	10	0.80	2.25E-02	138	9.91E+03	551	4.02E+04
20*	357	1.27E+04	10	0.20	1.88E-02	10	0.80	2.25E-02	71	2.66E+03	286	1.07E+04
21*	26	2.26E+02	10	0.20	1.88E-02	10	0.80	2.25E-02	5	1.70E+01	20	1.54E+02
22*	34	3.25E+02	10	0.20	1.88E-02	10	0.80	2.25E-02	7	2.86E+01	27	2.26E+02
23*	26	2.26E+02	10	0.20	1.88E-02	10	0.80	2.25E-02	5	1.70E+01	20	1.54E+02
24*	17	1.39E+02	10	0.20	1.88E-02	10	0.80	2.25E-02	3	8.38E+00	14	9.24E+01
Totals	497,879	7.37E+08	474	-	1.46E-01	474	-	2.05E-01	480,202	7.55E+08	17,676	7.36E+07

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