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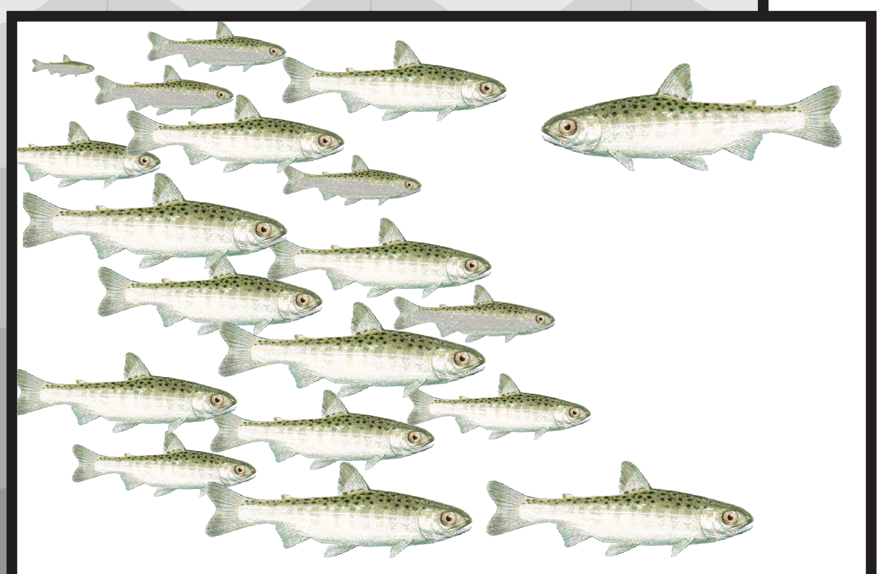
Mid-Hood Canal Juvenile Salmonid Evaluation: Duckabush and Hamma Hamma 2012



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Washington Department of
FISH AND WILDLIFE
Fish Program
Science Division
Wild Salmon Production/Evaluation

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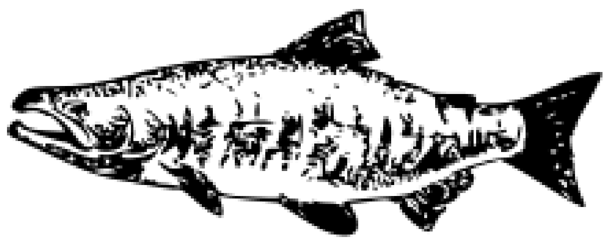

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Acknowledgements

Measuring juvenile salmonid production from large systems like the Duckabush and Hamma Hamma Rivers involves a tremendous amount of work. We would like to thank Long Live the Kings (LLTK) biologists Joy Lee Waltermire and Rick Endicott for operating the Hamma Hamma River juvenile trap. The Duckabush River juvenile trap was operated by dedicated scientific technician Phil Aurdal from the Washington Department of Fish and Wildlife. Logistical support was provided by Wild Salmon Production Evaluation Unit biologists Pete Topping and Mike Ackley.

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 central Hood Canal, Washington began in 2002 on the Hamma Hamma River and in 2007 on the Duckabush River. This work 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. This report describes the juvenile abundance, egg-to-migrant survival, and outmigration timing of Chinook, chum and pink salmon. We also derived independent estimates for summer and fall chum salmon stocks in these watersheds via molecular genetic analysis. In addition, coho salmon and steelhead smolt abundance estimates were derived for the Duckabush.

Duckabush River

A floating five-foot screw trap was located at river mile 0.3 (0.48 rkm) and operated by WDFW from January 10 to July 9, 2012. The abundance of juvenile summer chum salmon was over six times larger than fall chum (Table 1). Egg-to-migrant survival for summer and fall chum salmon ranged between 15.2% and 1.3%. The peak of the summer chum outmigration occurred 6 weeks earlier than the peak of the fall chum outmigration. Abundance of juvenile Chinook salmon was estimated to be 2,788 sub-yearlings with an egg-to-migrant survival of 22.3%. Abundance of juvenile pink salmon was over 14 times larger than estimates from 2008 and. The 2012 season marked the first season that abundance of yearling coho (7,082) and steelhead (2,299) were estimated.

Hamma Hamma River

A floating eight-foot screw trap was located at river mile 0.5 (0.8 rkm) and operated by LLTK from January 30 to July 9, 2012. Juvenile fall chum salmon abundance was 3 times larger than the summer chum salmon abundance (Table 1). Egg-to-migrant survival averaged 0.9% for the fall stock and 2.7% for the summer stock. Abundance of juvenile Chinook salmon was estimated to be 12,306 sub-yearlings with an egg-to-migrant survival of 1.8%. Abundance of juvenile pink salmon was estimated to be 49,314 with an egg-to-migrant survival of 0.7%.

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 and Hamma Hamma Rivers, 2012.

	Duckabush River	Hamma Hamma River
Summer Chum		
Abundance (CV %)	290,891 (5.4%)	26,079 (13.3%)
Survival	15.2%	2.7%
Avg fork length (±1 S.D., mm)	-	-
Median out-migration date	3/15	3/12
Fall Chum		
Abundance (CV %)	43,053 (12.6%)	83,107 (16.1%)
Survival	1.3%	0.9%
Avg fork length (±1 S.D., mm)	-	-
Median out-migration date	4/24	4/1
Chinook		
Abundance (CV %)	2,788 (16.5%)	12,306 (12.7%)
Survival	22.3%	1.8%
Avg fork length (mm)	40.0 (±5.8)	-
Median out-migration date	4/23	3/27
Pink		
Abundance (CV %)	512,637 (12.7%)	49,314 (25.0%)
Survival	13.9%	0.7%
Avg fork length (±1 S.D., mm)	-	-
Median out-migration date	4/18	4/13
Coho		
Abundance (CV %)	7,082 (13.7%)	-
Survival	-	-
Avg fork length (±1 S.D., mm)	90.9 (±14.0)	-
Median out-migration date	4/23	-
Steelhead		
Abundance (CV %)	2,299 (17.1%)	-
Survival	-	-
Avg fork length (±1 S.D., mm)	173.5 (±23.4)	-
Median out-migration date	4/29	-

Introduction

The Duckabush and Hamma Hamma rivers are adjacent high-gradient watersheds draining into the western side of Hood Canal, Washington. Peak flow events in these watersheds occur twice each year, during rain-on-snow events in the winter months and snow melt in the spring months. Both systems originate in the Olympic Mountains within the Olympic National Park. Human development is minimal on both systems 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 and Hamma Hamma rivers support 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 in these watersheds are federally protected under the Endangered Species Act. 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 ESU, as delineated by the National Marine Fisheries Service.

Chinook salmon in the Duckabush and Hamma Hamma rivers are part of the Puget Sound Chinook ESU listed as *threatened* in 1999 by the National Marine Fisheries Service 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). Under the recovery plan, Hamma Hamma and Duckabush stocks are roughly half of the Mid-Hood Canal population.

Summer chum salmon in the Duckabush and Hamma Hamma rivers 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, 2000 #1411;Ames, 2000 #1411;Crawford, 2011 #1412}. 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, harvest of Hood Canal summer chum was greatly reduced and hatchery supplementation was implemented 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 and Hamma Hamma summer chum stocks are two of the eight extant stocks within Hood Canal.

Under NMFS Listing Status Decision Framework, listing status of a species under the Endangered Species Act (ESA) will be evaluated based on biological criteria (abundance, productivity, spatial distribution and diversity) and threats to population viability (e.g., harvest, habitat) (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, juvenile monitoring studies were initiated on the Hamma Hamma River in 2002 and on the Duckabush River in 2007. The Hamma Hamma juvenile trapping project was initiated in 2002 by Long Live the Kings (LLTK), a regional enhancement group, with a focus on freshwater production and survival of Chinook salmon. This project has also provided data needed to assess freshwater production of summer and fall chum and pink salmon. The Duckabush River juvenile trapping project was initiated in 2007 by Long Live the Kings with a focus on wild steelhead production. In 2008, the Duckabush trapping season was expanded to include summer and fall chum, Chinook, and pink salmon and became a joint effort between Washington Department of Fish and Wildlife and Long Live the Kings. Steelhead smolt evaluations from both systems are part of the Hood Canal Steelhead Project led by the NWFSC Manchester Research Station.

This report summarizes results from both watersheds for the 2012 outmigration. Throughout this report, the number of juvenile migrants estimated for a given year will be referred to as "freshwater abundance" because they are the offspring of naturally spawning salmon in the Hamma Hamma and Duckabush Rivers. The combination of juvenile and spawner abundance for the Duckabush and Hamma Hamma populations allows for brood-specific survival to be partitioned between the freshwater and marine environment. Spawner abundance is currently derived by staff from WDFW Region 6 and LLTK. Long-term combination of juvenile and adult abundance data over a range of spawner abundances and flow regimes should provide a measure of freshwater capacity as well as current ranges of freshwater and marine survival.

Objectives

In 2012, the primary objective of this study was to estimate the abundance, survival, and migration timing of juvenile migrants produced by Chinook, chum and pink salmon spawning naturally in the Duckabush and Hamma Hamma rivers. Additional objectives were to estimate the abundance of yearling coho and steelhead. The long-term goal for this study is to understand the factors that limit productivity of salmonid populations in the Duckabush and Hamma Hamma rivers.

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 five-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-feet^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.

On the Hamma Hamma River, juvenile migrants were captured in an 8-foot (2.8-m diameter) floating screw trap located on the right bank at river mile 0.5 (0.8 rkm), approximately 2,640 foot (805-m) upstream of the river mouth (Figure 1). Similar to the Duckabush trap, fish were gently guided into a solid sided, baffled live box.

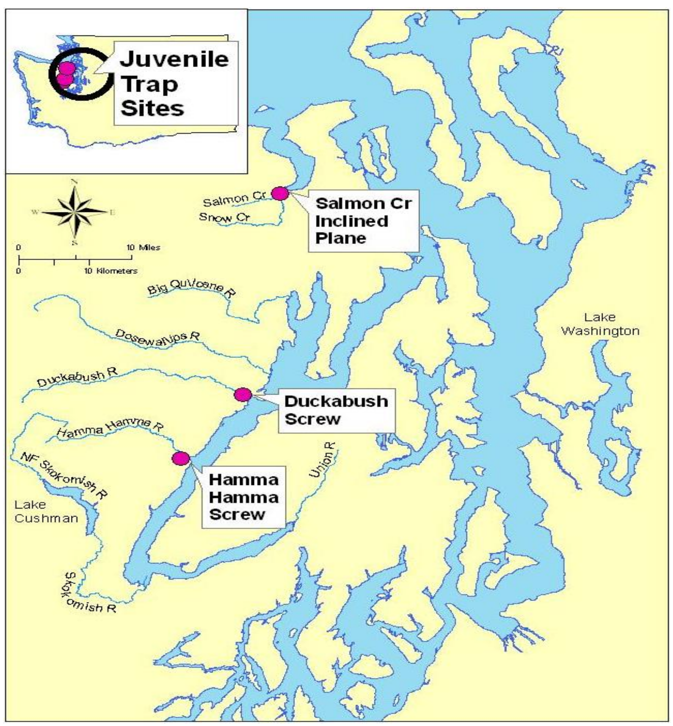

FIGURE 1.─Location of Duckabush and Hamma Hamma screw traps.

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 and Hamma Hamma River screw traps, 2012

Trap	Start Date	End Date	Hours Fished	Total Possible Hours	Percent Fished	Number of Outages	Avg Outage Hrs	St Dev.
Duckabush	1/9	7/9	3,873.92	4,366	88.73%	10	49.21	38.1
Hamma	1/30	7/9	3,383.50	3,861	87.63%	4	119.38	39.6

Fish Collection

On both rivers, the traps were 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 to have a 90% probability of estimating the proportion of outmigrants within ±10% (absolute error). This approach maximized sample size during the time intervals where summer and fall stocks were expected to overlap in their outmigration.

Coho were enumerated as either fry or smolts (yearlings). 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 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 (fish captured for the first time) chum fry of natural origin throughout the season. No efficiency trials were conducted using Chinook due to very low catches of this species. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and marked with Bismark-brown dye. Marked fish were allowed to recover in freshwater. On the Duckabush, marked fish were released at dusk into fast flowing water upstream of a bend in the river, approximately 75-m distance from the trap. On the Hamma Hamma, marked fish were released at dusk 100-m upstream of the trap. The release sites were 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

A complete description of the genetic methods and assignment is provided in (Small et al. 2010). DNA was extracted from fin clips with a silica membrane protocol and genotypes were assessed at 16 microsatellite loci (detailed in Small et al. 2009). Juvenile fish were assigned to a baseline consisting of summer- and fall-run chum salmon populations from Hood Canal (from 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. 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

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

(2) Efficiency strata. Chum data from the Duckabush and Hamma Hamma River 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 (α = 0.05). Trials that did not differ were pooled and the pooled group compared to the next adjacent efficiency trial. Trials that did differ were held separately. Pooling of time-adjacent efficiency trials continued iteratively until the *seen:unseen* ratio differed between time-adjacent trials. Once a significant difference 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. 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:*

Equation 9

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

Error in the genetic assignment was considered to be minimal to none 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 salmon in both rivers. Egg-to-migrant survival was the number of female migrants divided by potential egg deposition (P.E.D.). Chum and pink escapement was estimated using an Area-Under-the-Curve estimate based on live fish counts and an assumed stream life of 10 days (M. Downen, WDFW Region 6, personal communication). Live fish counts were adjusted by a “percent seen” factor, calculated to account for fish not seen during individual surveys. 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) for both river systems. A statistical week begins on a Monday and ends on a Sunday (Appendix A). The first and last week of the year are typically less than 7 days.

Duckabush Results

Chum

Total estimated catch of natural-origin chum ($\hat{u}$ = 73,205) included 61,726 captures in the trap and 11,479 missed catch estimated for trap outages (Appendix B). A total of 3,587 natural-origin chum were marked and released over 27 efficiency trials, ranging between 45 and 300 fish. Mark and recapture data were organized into 25 weekly strata for analysis. Trap efficiency of these strata ranged between 9.6% and 30.5%.

Chum fry were captured in low numbers on the first day of trapping (January 10), and the last chum was observed on June 29. Chum migration prior to the trapping season was assumed to be minimal (<1% of total migration).

Based on genetic analyses, the catch was predominantly (> 90%) summer chum until the beginning of April when the proportion of fall chum increased in the sample. From April 17 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. Two of the samples could not be positively identified as chum.

TABLE 3.─Genetic stock identification for juvenile chum salmon migrants caught in the Duckabush screw trap, 2012.

Date	Samples	Summer	Fall	Unassigned	Unknown	% Summer	% Fall
01/30/2012	10	10	0	0	0	100.00%	0.00%
02/06/2012	10	9	0	0	1	100.00%	0.00%
02/13/2012	10	10	0	0	0	100.00%	0.00%
02/20/2012	20	20	0	0	0	100.00%	0.00%
02/27/2012	30	29	1	0	0	96.67%	3.33%
03/05/2012	40	40	0	0	0	100.00%	0.00%
03/12/2012	40	40	0	0	0	100.00%	0.00%
03/19/2012	40	37	3	0	0	92.50%	7.50%
03/26/2012	40	39	1	0	0	97.50%	2.50%
04/02/2012	40	36	3	1	0	92.31%	7.69%
04/10/2012	40	27	12	0	1	69.23%	30.77%
04/17/2012	30	5	25	0	0	16.67%	83.33%
04/25/2012	20	0	20	0	0	0.00%	100.00%
04/30/2012	20	0	20	0	0	0.00%	100.00%
05/07/2012	10	1	9	0	0	10.00%	90.00%
Totals	400	303	94	1	2	76.32%	23.68%

A total of 290,891 ± 31,032 (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 5.4%. A total of 43,053 ± 10,588 (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 12.6%. 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 15.2% for summer chum and 1.3% 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 2012.

Stock	Juvenile Production	Juvenile CV	Female Spawners	Egg to Migrant Survival
Summer	290,891	5.4%	765	15.2%
Fall	43,053	12.6%	1,313	1.3%
Total	333,944	5.0%	2,078	6.4%

The entire chum outmigration occurred over a 25 week period between early January and the end of June (Figure 2). The median migration date for the summer component occurred on March 15, six weeks earlier than the median migration date of the fall component on April 24. The summer chum component of the migration was 95% complete by April 9. The fall chum component of the migration was 95% complete by May 31.

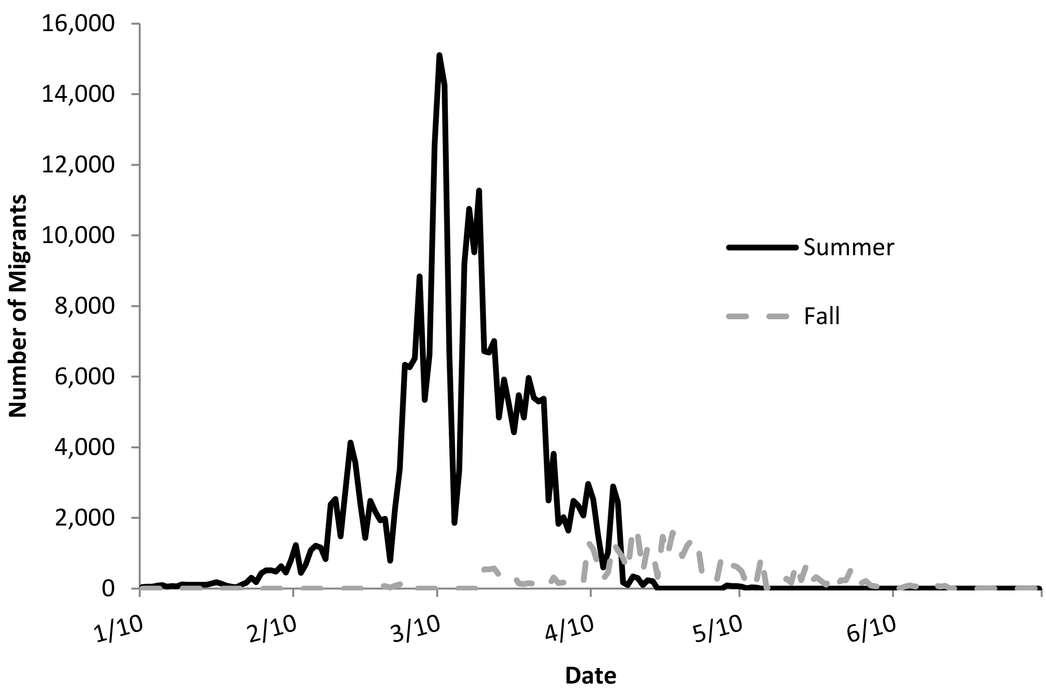

FIGURE 2.─Daily outmigration of natural-origin chum salmon fry in the Duckabush River, 2012 outmigration.

Chinook

Total catch of natural-origin Chinook was 352 juveniles. Due to the low number of Chinook, chum efficiency trials involving chum were used to represent Chinook trap efficiency. The 27 chum efficiency trials were pooled into 7 strata using the *G*-test approach, with trap efficiencies ranging between 9.6% and 46.7%.

A total of 2,788 ± 903 (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 16.5%.

Egg-to-migrant survival was estimated to be 22.3% for Duckabush Chinook salmon in 2012 (Table 6).

TABLE 5.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Duckabush River, 2012. 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	1/10-3/4	9	0	0.00E+00	930	241	35	1.02E+02
2	3/5-3/22	0	0	0.00E+00	808	135	0	0.00E+00
3	3/23-4/15	63	1	2.67E-01	1,177	288	261	9.81E+02
4	4/16-4/30	206	15	4.39E+01	200	20	2,115	2.04E+05
5	5/1-5/2	30	0	0.00E+00	105	49	64	1.12E+02
6	5/3-5/25	24	3	6.46E+00	315	76	111	5.68E+02
7	5/26-7/9	20	3	5.78E-02	52	5	203	6.60E+03
	Season Total	352	22	5.07E+01	3,587	814	2,788	2.12E+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 2012.

Stock	**Juvenile Abundance**	**Juvenile CV**	**Female Spawners**	**Egg to Migrant Survival**
Chinook	2,788	16.5%	3	22.3%

The first Chinook fry was captured on February 2, 2012. Daily migration of Chinook was low and sporadic for most of the season (Figure 3). The median migration date occurred on April 23. The migration was 95% complete by June 3. The last Chinook was captured on June 30, 2012, nine days before the end of the trapping season.

Length of natural-origin Chinook fry ranged from 32-mm to 65-mm and averaged 40-mm throughout the trapping season (Figure 4, Appendix C). Average weekly fork lengths of juvenile Chinook began to increase during statistical week 17 (middle of April).

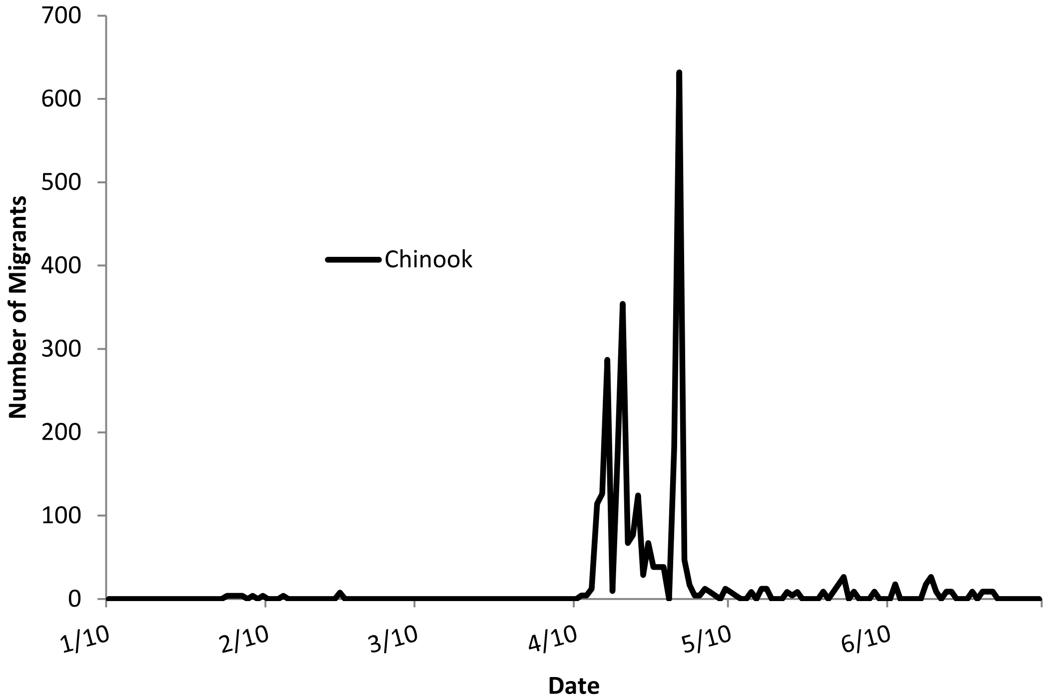

FIGURE 3.—Daily outmigration of natural-origin Chinook salmon fry in the Duckabush River, 2012 outmigration.

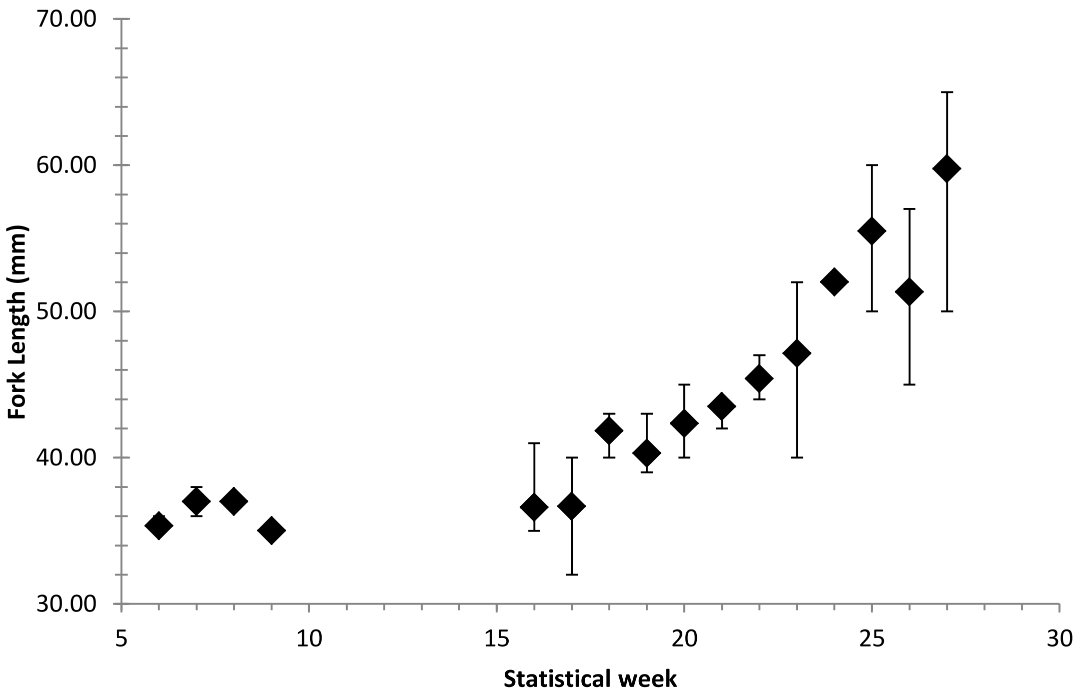

FIGURE 4.—Fork lengths (mm) of juvenile Chinook migrants of natural origin captured in the Duckabush River screw trap 2012. Data are mean, minimum, and maximum values by statistical week.

Pink

Total catch of natural-origin pink was 72,081 juveniles. Efficiency trials involving chum were used to represent pink trap efficiency. The 27 chum efficiency trials were pooled into 7 strata using the *G*-test approach, with trap efficiencies ranging between 9.6% and 46.7%.

The first pink fry was captured on the first day of trapping (January 10), and the last pink was observed on June 1. Pink migration prior to the trapping season was assumed to be minimal (<1% of total migration).

A total of 512,637 ± 127,418 (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 12.7%.

TABLE 7.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for pink salmon in the Duckabush River, 2012. 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	1/10-3/4	546	19	5.16E+01	930	241	2,174	2.13E+04
2	3/5-3/22	2,279	477	1.15E+05	808	135	16,394	5.79E+06
3	3/23-4/15	36,740	5,243	1.83E-06	1,177	288	171,128	1.07E+07
4	4/16-4/30	28,753	3,657	2.02E+06	200	20	310,210	4.11E+09
5	5/1-5/2	1,409	0	0.00E+00	105	49	2,987	9.57E+04
6	5/3-5/25	2,345	10	1.03E+02	315	76	9,665	9.37E+05
7	5/26-7/9	9	0	0.00E-00	52	5	80	1.33E+03
	Season Total	72,081	9,406	5.07E+01	3,587	814	512,637	4.00E+09

Egg-to-migrant survival was estimated to be 13.9% for Duckabush pink salmon in 2012 (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 2012.

Stock	**Juvenile Abundance**	**Juvenile CV**	**Female Spawners**	**Egg to Migrant Survival**
Pink	512,637	12.34%	2,052	13.88%

Pink salmon fry were captured during the first night of trapping. The entire pink outmigration occurred over a 21 week period between early January and the beginning of June (Figure 5). The median migration date occurred on April 18. The pink fry migration was 95% complete by April 29.

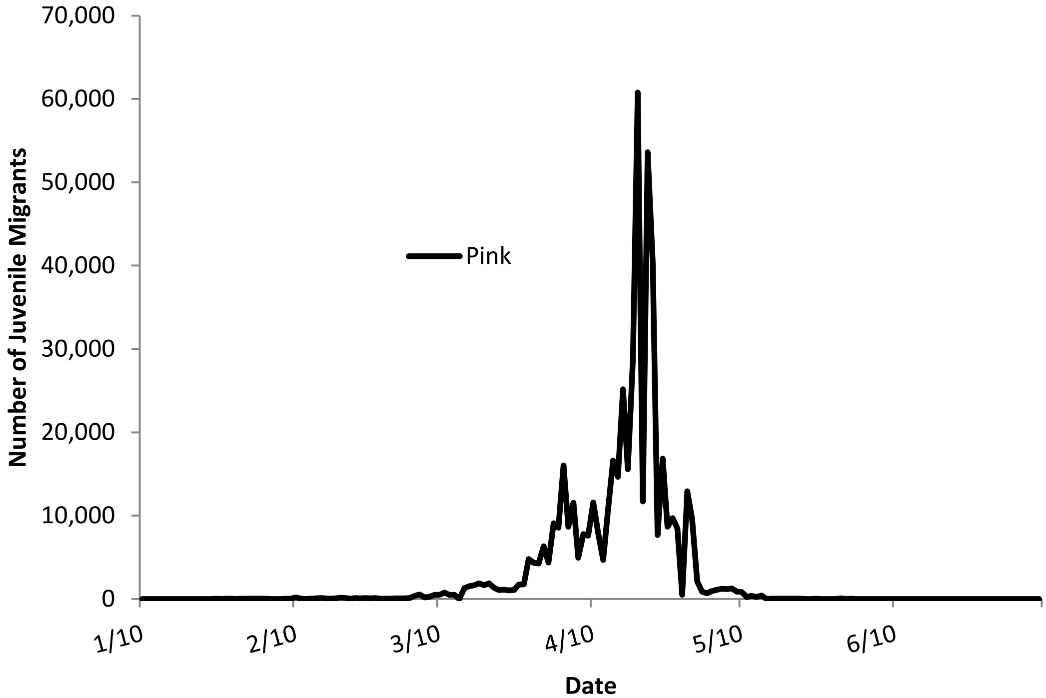

FIGURE 5.─Daily outmigration of natural-origin pink salmon fry in the Duckabush River, 2012 outmigration.

Coho

Total catch of natural-origin Coho yearlings was 230 juveniles. Due to the low number of natural-origin yearling Coho, steelhead efficiency trials involving ad-marked hatchery steelhead were used to represent Coho yearling trap efficiency. The 6 hatchery steelhead efficiency trials were pooled together to formulate a single stratum for the season.

A total of 7,082 ± 1,895 (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 13.7%.

TABLE 9.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Coho salmon in the Duckabush River, 2012. 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	230	38	5.30E+01	1,743	65	7,082	9.35E+05

The first five Coho yearlings were captured on January 11, 2012. The median migration date occurred on April 23 (Figure 6). The migration was 95% complete by May 22. The last Coho was captured on June 10, 2012, twenty-nine days before the end of the trapping season.

Length of natural-origin coho fry ranged from 56-mm to 130-mm and averaged 91-mm throughout the trapping season (Figure 7, Appendix C). Average weekly fork lengths of juvenile coho began to increase during statistical week 15 (Early April).

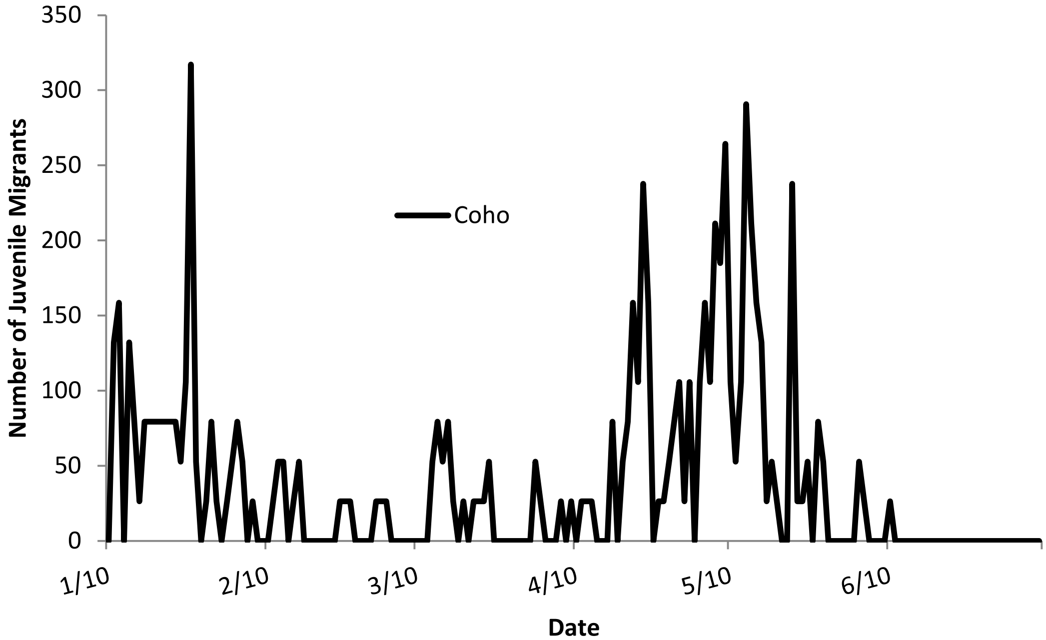

FIGURE 6.—Daily outmigration of natural-origin yearling Coho salmon in the Duckabush River, 2012 outmigration.

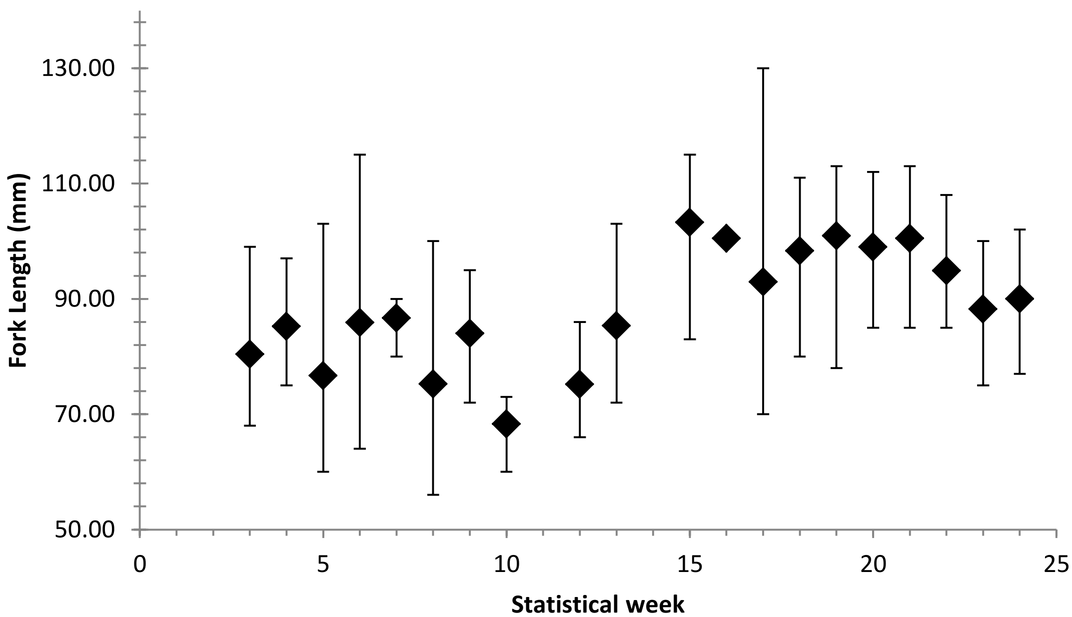

FIGURE 7.—Fork lengths (mm) of juvenile Coho yearling migrants of natural origin captured in the Duckabush River screw trap 2012. Data are mean, minimum, and maximum values by statistical week.

Steelhead

Total catch of natural-origin yearling steelhead was 68 juveniles. Due to the low number of natural-origin steelhead, steelhead efficiency trials involving ad-marked hatchery steelhead were used to represent steelhead yearling trap efficiency. The 6 hatchery steelhead efficiency trials were pooled together to formulate a single stratum for the season.

A total of 2,299 ± 769 (95% C.I.) natural-origin steelhead yearlings are estimated to have migrated past the screw trap (Table 10). Coefficient of variation for this estimate was 17.1%.

TABLE 10.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for steelhead in the Duckabush River, 2012. 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	68	19	2.92E+01	1,743	65	2,299	1.54E+05

The first yearling steelhead was captured on January 13, 2012. The median migration date occurred on April 29 (Figure 8). The migration was 95% complete by June 4. The last yearling steelhead was captured on July 1, 2012, eight days before the end of the trapping season.

Length of natural-origin steelhead ranged from 127-mm to 230-mm and averaged 174-mm throughout the trapping season (Figure 9, Appendix C).

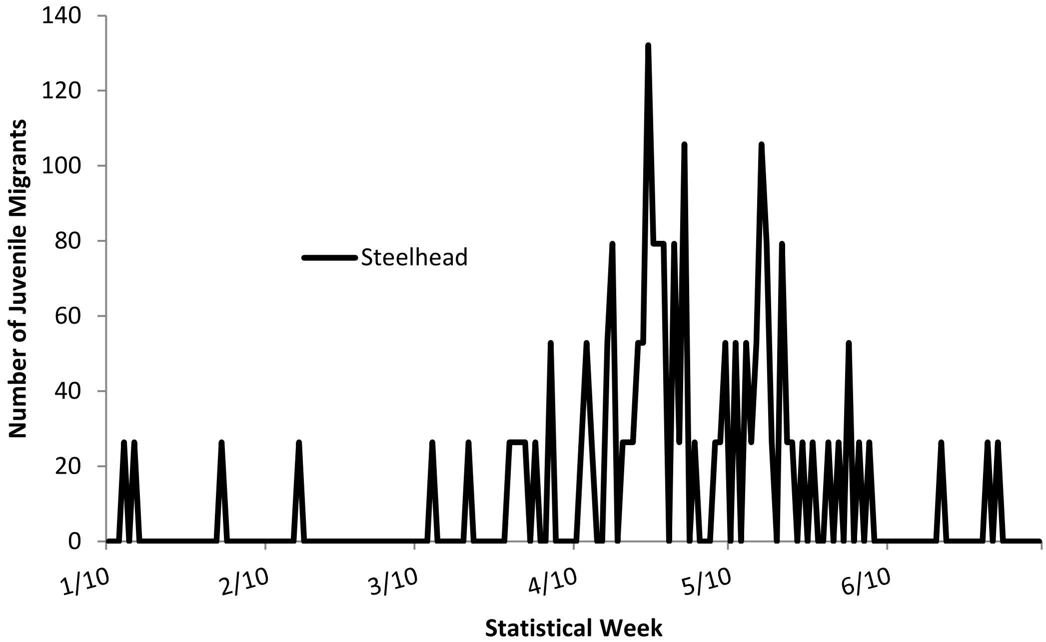

FIGURE 8.—Daily outmigration of natural-origin yearling steelhead in the Duckabush River, 2012 outmigration.

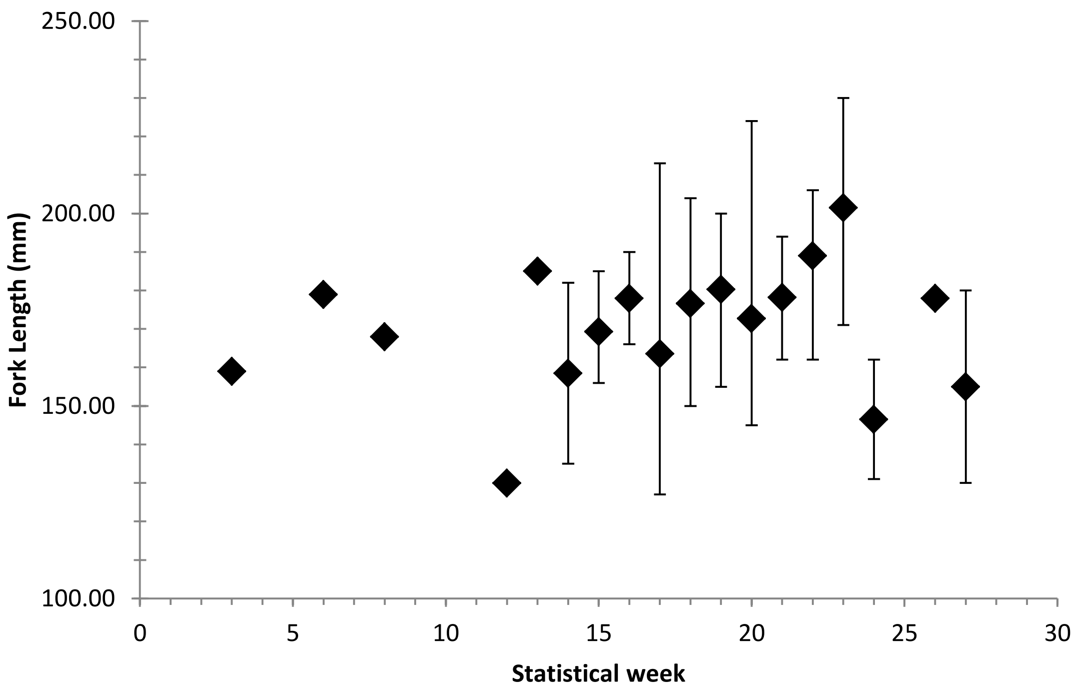

FIGURE 9.—Fork lengths (mm) of juvenile steelhead yearling migrants of natural origin captured in the Duckabush River screw trap 2012. Data are mean, minimum, and maximum values by statistical week.

Other Species

In addition to the species listed above, catch during the trapping season included 13,082 coho fry, 1 ad-marked yearling coho, 4 cutthroat smolt, 1 cutthroat parr, 247 trout parr, and 65 ad-marked steelhead smolt. Non-salmonid species captured included sculpin (*Cottus* spp.) and 163 lamprey ammocoetes.

Hamma Hamma Results

Chum

Based on field identification of chum catch, the total estimated catch of natural-origin chum ($\hat{u}$ = 12,148) included 10,349 captures in the trap and 1,799 missed catch estimated for trap outages (Appendix D). A total of 621 natural-origin chum were marked and released over 4 efficiency trials, ranging between 36 and 255 fish. Trap efficiency of these strata ranged between 5.3% and 49.4%.

Chum fry were captured on the first day of trapping (January 31) and the last chum was observed on May 22. Chum migration prior to the trapping season was assumed to be minimal (<1% of total migration).

Based on genetic analyses, the catch was predominantly (> 90%) summer chum until the end of April when the proportion of fall chum increased in the sample. From March 22 until the end of the trapping season, the sampled catch was mostly fall chum (Table 11). Eleven of the 400 samples had allele frequencies that failed to meet the assignment threshold and twenty-eight of the samples could not positively be identified as chum.

TABLE 11.─Genetic stock identification for juvenile chum salmon migrants caught in the Hamma Hamma screw trap, 2012.

Date	Samples	Summer	Fall	Unassigned	Unknown	% Summer	% Fall
1/31	10	10	0	0	0	100.00%	0.00%
2/7-2/8	20	19	0	1	0	100.00%	0.00%
2/13	30	28	0	0	2	100.00%	0.00%
2/21	40	38	0	1	1	100.00%	0.00%
2/27	40	37	0	1	2	100.00%	0.00%
3/4	40	38	0	0	2	100.00%	0.00%
3/13	40	38	0	0	2	100.00%	0.00%
3/22	40	12	21	3	4	36.36%	63.64%
3/28	30	1	25	1	3	3.84%	96.16%
4/4	30	7	21	0	2	25.00%	75.00%
4/10	20	2	15	0	3	11.76%	88.24%
4/17	20	0	16	1	3	0.00%	100.00%
4/25	20	1	13	2	4	7.14%	92.86%
5/2	10	0	9	1	0	0.00%	100.00%
5/8-5/15	10	3	7	0	0	30.00%	70.00%
Totals	400	234	127	11	28	64.82%	35.18%

A total of 26,079 ± 6,787 (95% C.I.) natural-origin summer chum fry are estimated to have migrated past the screw trap (Table 12). Coefficient of variation for this estimate was 13.3%. A total of 83,107 ± 26,290 (95% C.I.) natural-origin fall chum fry are estimated to have migrated past the screw trap (Table 12). Coefficient of variation for this estimate was 16.1%. Details of the mark-recapture and genetic data used to derive these estimates are provided in Appendix D.

Egg-to-migrant survival was estimated to be 2.7% for summer chum and 0.9% for fall chum (Table 12).

TABLE 12.—Juvenile abundance and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin chum salmon in the Hamma Hamma River, 2012.

Stock	Juvenile abundance	Juvenile CV	Female Spawners	Egg to Migrant Survival
Summer	26,079	13.3%	386	2.7%
Fall	83,107	16.1%	3,844	0.9%
Total	109,186	11.9%	4,230	1.0%

The entire chum migration occurred over a 15 week period between the end January and the end of May (Figure 10). The summer component of the migration appeared to have two peak migration periods (March 5-11 and April 2-8) as opposed to the fall component that had a single peak (March 26 – April 1). The median migration date for summer chum occurred on March 12, two weeks earlier than the median migration date for fall chum (April 1). The summer chum component of the migration was 95% complete by April 9. The fall chum component of the migration was 95% complete by May 1.

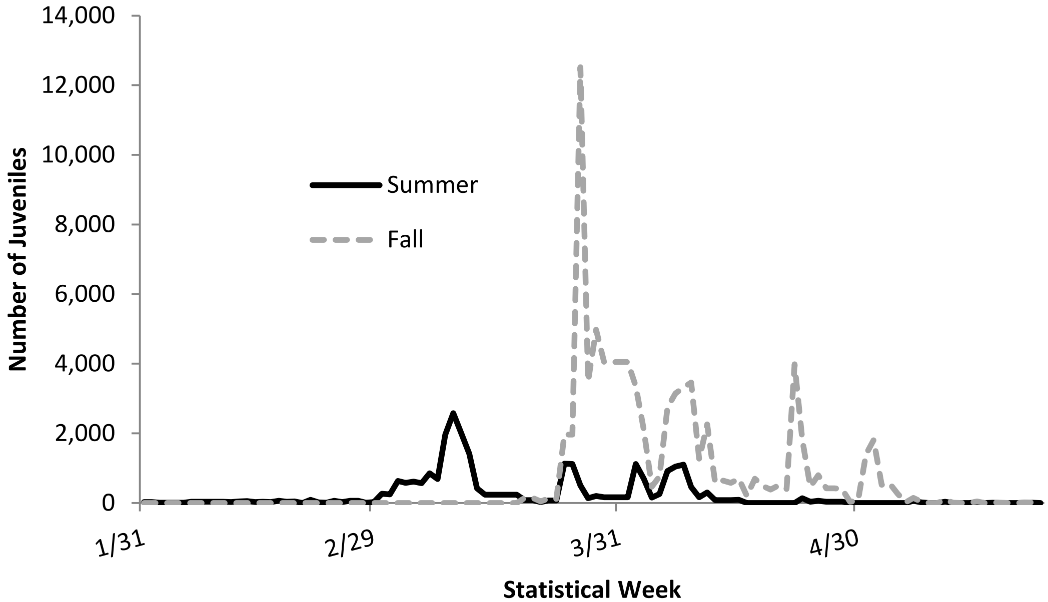

FIGURE 10.─Daily outmigration of natural-origin chum salmon fry in the Hamma Hamma River, 2012 outmigration

Chinook

Total catch of natural-origin Chinook was 1,743 juveniles with an estimated missed catch of 392 fish. Due to the low number of Chinook, chum efficiency trials involving chum were used to represent Chinook trap efficiency. The 4 chum efficiency trials were pooled into 3 strata using the *G*-test approach, with trap efficiencies ranging between 5.9% and 42.0%.

A total of 12,306 ± 3,051 (95% C.I.) natural-origin Chinook fry are estimated to have migrated past the screw trap (Table 13). Coefficient of variation for this estimate was 12.7%.

Two hundred seventy-three adult Chinook spawners were observed in the fall of 2011.

Egg-to-migrant survival was estimated to be 1.8% (Table 14).

TABLE 13.─ Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Hamma Hamma River, 2012. Release groups were pooled to form 3 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	1/31-3/7	757	0	0.00E+00	355	149	1,797	1.48E+04
2	3/8-3/26	724	266	2.26E+03	159	36	4,281	4.28E+05
3	3/27-7/9	262	126	2.68E+02	304	18	6,228	1.98E+06
	Season Total	1,743	392	2.53E+03	818	203	12,306	2.42E+06

TABLE 14.—Juvenile abundance and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin Chinook salmon in the Hamma Hamma River, outmigration year 2012.

Stock	Juvenile Abundance	Juvenile CV	Female Spawners	Egg to Migrant Survival
Chinook	12,306	12.34%	137	1.80%

Chinook fry were captured during the first night of the season. The migration was 95% complete by April 10. The last Chinook was captured on May 18, 2012, seven weeks before the end of the trapping season.

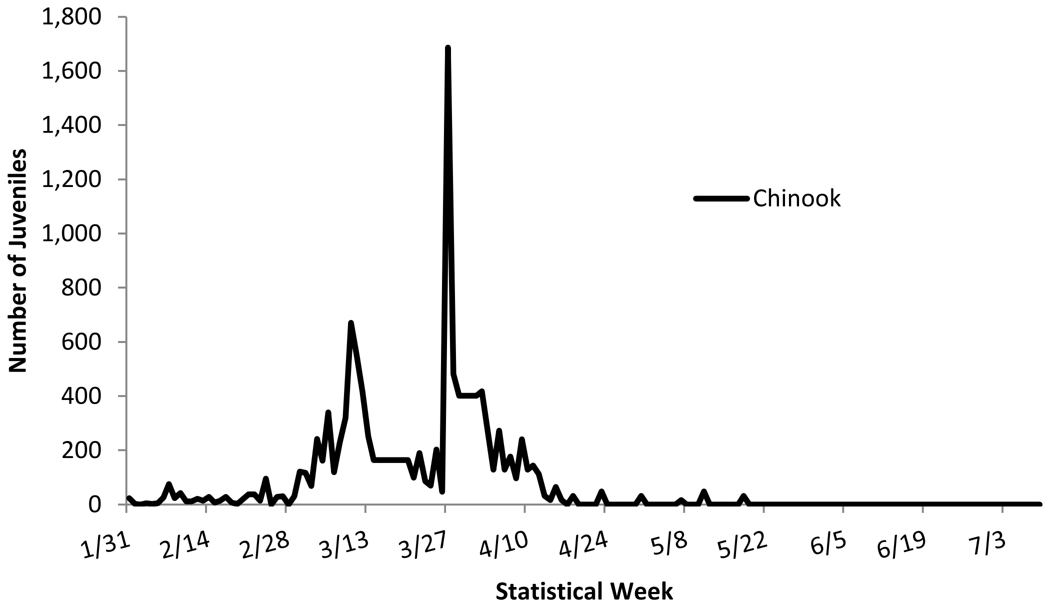

FIGURE 11.—Daily outmigration of natural-origin Chinook salmon fry in the Hamma Hamma River, 2012 outmigration.

Pink

Total catch of natural-origin pink was 7,056 juveniles with an estimated missed catch of 1,440 fish. A total of 103 natural-origin pink were marked and released over 2 efficiency trials, ranging between 21 and 82 fish. The 2 pink efficiency trials were pooled into 2 strata using the *G*-test approach, with trap efficiencies ranging between 8.5% and 19.0%.

A total of 49,314 ± 24,162 (95% C.I.) natural-origin pink fry are estimated to have migrated past the screw trap (Table 15). Coefficient of variation for this estimate was 25.0%.

Two thousand eight hundred seventy-three adult pink spawners were observed in the fall of 2011. Egg-to-migrant survival was estimated to be 0.7% (Table 16).

TABLE 15.— Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for pink salmon in the Hamma Hamma River, 2012. Release groups were pooled to form 2 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	1/31-4/18	5,156	1,343	1.35E+05	21	4	28,596	1.08E+08
2	4/19-7/9	1,900	97	2.94E+03	82	7	20,719	4.36E+07
	Season Total	7,056	1,440	1.38E+05	103	11	49,314	1.52E+08

TABLE 16.—Juvenile abundance and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin pink salmon in the Hamma Hamma River, outmigration year 2012.

Stock	Juvenile abundance	Juvenile CV	Female Spawners	Egg to Migrant Survival
Pink	49,314	24.72%	1,437	0.69%

Pink fry were captured during the first night of the season. The migration was 95% complete by April 23. The last pink was captured on May 7, 2012, nine weeks before the end of the trapping season.

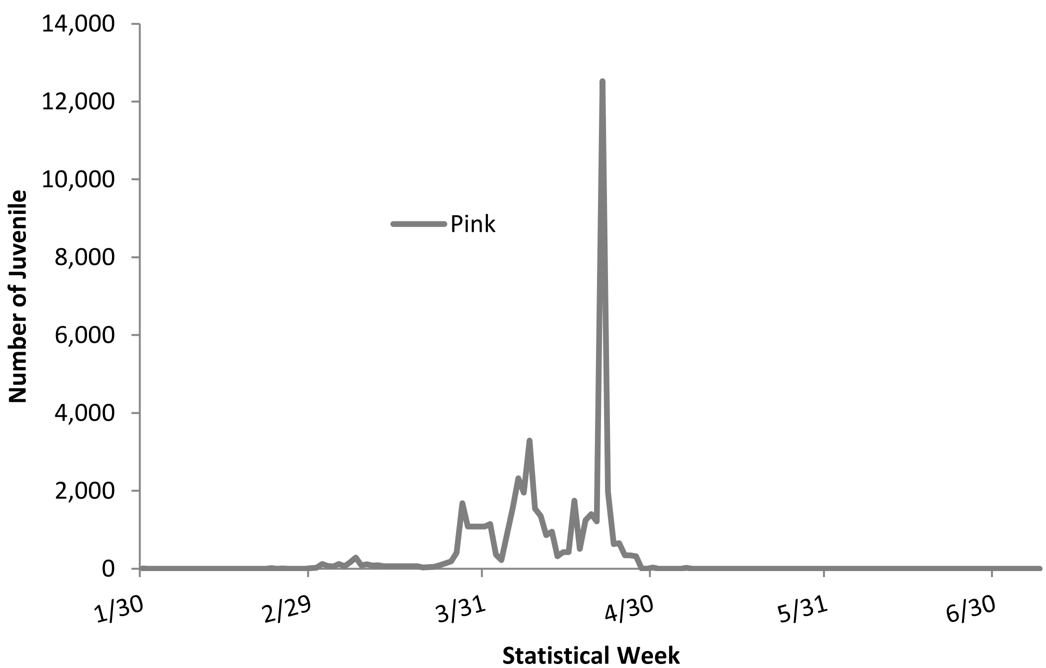

FIGURE 12.—Daily outmigration of natural-origin pink salmon fry in the Hamma Hamma River, 2012 outmigration.

Other Species

In addition to the species listed above, catch during the trapping season included 10,049 ad-marked Chinook fry, 1,579 coho fry, 168 yearling coho, 27 trout parr, 64 steelhead smolts, 3 cutthroat smolt. Non-salmonid species captured included sculpin (*Cottus* spp.) and lamprey ammocoetes.

Discussion

This report provides the freshwater production, survival and out-migration timing for chum and Chinook salmon populations in Hood Canal in 2012. The 2012 trapping season marked the second year that genetic samples were collected to distinguish between summer and fall timed chum salmon in the Duckabush and Hamma Hamma Rivers. Based on this study design, we were able to compare juvenile out-migration timing between the two stocks of chum salmon that coexist in each watershed.

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. In 2011, *CV* values (lower precision) were higher than in earlier years of study (McElhany et al. 2000) due to the additional analysis step that allotted chum abundance between the summer and fall runs. The uncertainty of the genetic proportions in a given time period can be influenced by the proportion value and the number of fish sampled. Now that the timing of out-migration for each stock in each watershed is better understood, we should be able to improve our future sampling protocols (number of fish per week) in order to further improve precision of the estimate.

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 Hamma Hamma and Duckabush River juvenile monitoring studies were designed to minimize violating 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. Mortalities 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, pink). 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.

Assumption 2. All animals have the same probability of being caught. 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). 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.

Assumption 3. Marking does not affect catchability. 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, chum or pink 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.

Assumption 4. Marked fish mix at random with unmarked fish. 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.

Assumption 5. No marks are lost and all marks are detected. 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 and Hamma Hamma 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. As the onset and termination of the chum migration is unknown, a more complete abundance estimate would only be possible by increasing the length of the trapping season.

Duckabush Chum Salmon

The 2012 outmigration of Duckabush summer chum was nearly 7 times the number of fall chum outmigrants despite the larger adult escapement abundance estimate for fall chum (2,626) relative to summer chum (1,529) the previous fall. Over the two years of the study that we collected genetic samples (2011 and 2012), the abundance of juveniles summer and fall chum appears to track with spawner abundance (Figure 13 and 14). The number of spawners decreased for 2011 brood of summer chum and resulted in fewer freshwater outmigrants than the 2010 spawners. The inverse of this relationship was true for fall chum increased spawning abundance resulted in more outmigrants for the 2011 brood.

Egg-to-migrant survival of Duckabush summer and fall chum were very different from each other (>13% different) for the 2012 out-migration. The fall component had nearly two times as many spawners as the summer component but had less than 15% the number of outmigrants the following spring. This large difference in egg-to-migrant survival might suggest that the fall timed stock responded differently to environmental variables, such as flow, that affect survival in freshwater. When compared to the 2011 outmigration year, egg-to-migrant survival of 2012 chum salmon outmigrants (summer and fall combined) in the Duckabush was similar in value. Peak incubation flows associated with the 2012 outmigration year were low compared to the 2011 outmigration year (Figure 15).

The outmigration timing of Duckabush summer chum peaked six weeks earlier than Duckabush fall chum in 2012. Summer chum dominated the chum out-migration for 14 of the 25 trapping weeks with a transition to fall chum migrants near the middle of April. Differences in outmigration timing and the variation in timing of marine entry for these stocks will continue to be tracked and compared in future years of study.

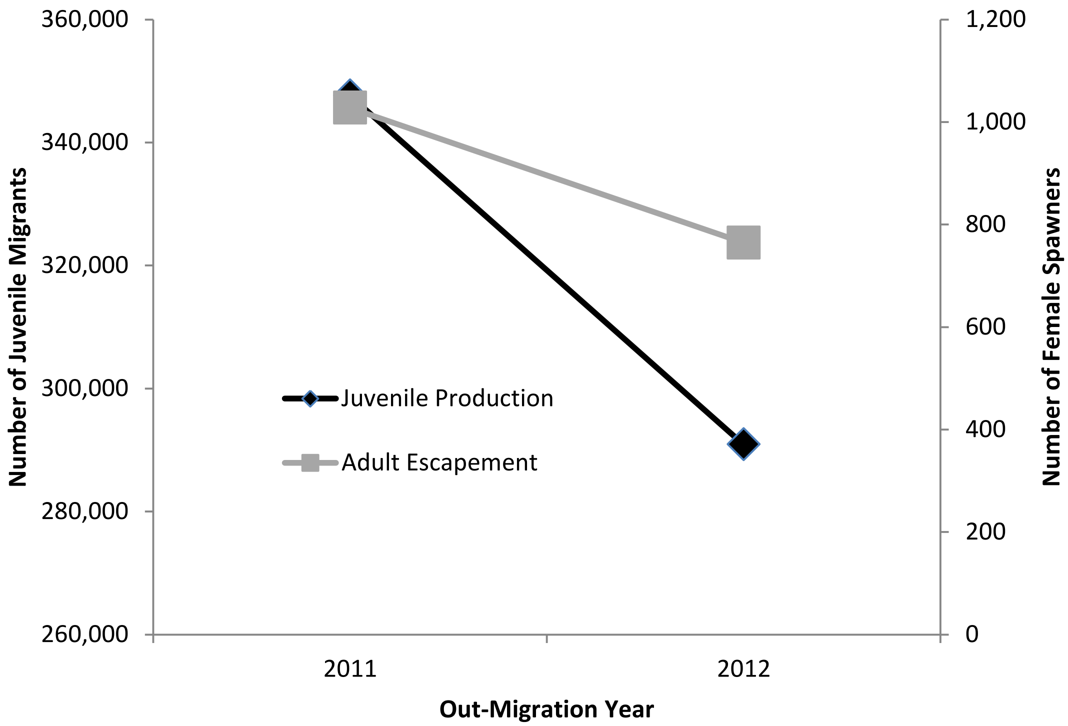

FIGURE 13.─ Number of spawners and juvenile migrants by outmigration year for Duckabush River summer chum salmon, 2011 and 2012.

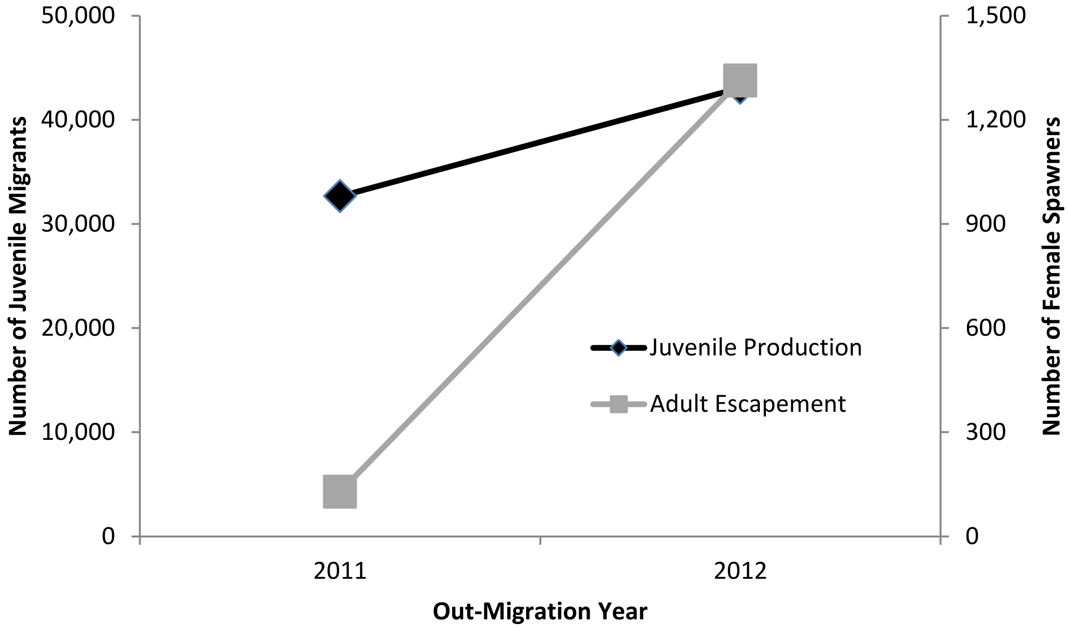

FIGURE 14.—Number of spawners and juvenile migrants by outmigration year for Duckabush River fall chum salmon, 2011 and 2012.

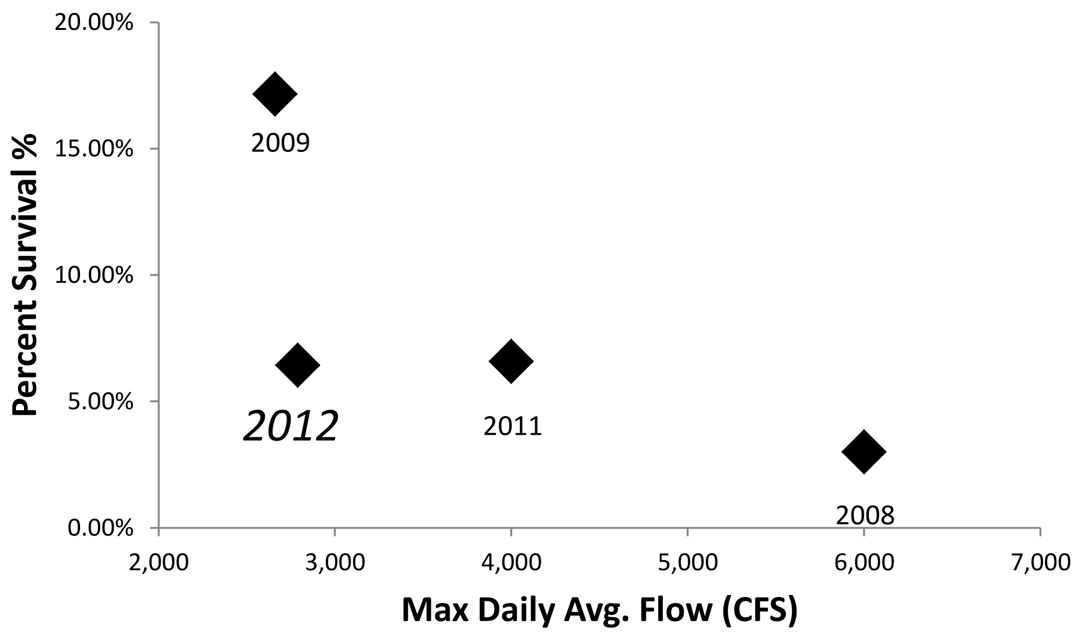

FIGURE 15.—Egg-to-migrant survival for chum salmon (summer and fall run combined) in the Duckabush River (outmigration year 2012) as a function of peak incubation flow. Incubation flow was the maximum daily average flow at USGS gage #12054000 (Duckabush River near Brinnon) between September 1 and December 31.

Duckabush Chinook Salmon

Freshwater production of Chinook salmon in 2012 was more than double the estimated production for the 2011 trapping season (Table 17). Over the two years of study, it appears that total production of juvenile Chinook from the Duckabush River is positively correlated with spawner abundance. During the 2010 spawning ground surveys, zero Chinook were observed in the system. Assuming that Chinook survived at a similar rate to chum in 2011 (6%), it was estimated that up to 5 female Chinook spawned in 2010 (Weinheimer and Zimmerman 2012). The 2011 fall surveys witnessed 5 adult Chinook spawning and an estimated egg-to-migrant survival of 21%. This egg-to-migrant survival rate is higher than the range of values observed in other Pacific Northwest river systems (Kinsel et al. 2007; Lister and Walker 1966). It seems unlikely that Duckabush Chinook would have survived at such a high rate while other salmonid species in the system did not achieve similar survival benchmarks. This suggests that more than 5 Chinook spawned during the fall of 2011. Possible explanations include unseen spawners during surveys or entry of adult Chinook into the system after spawning surveys were complete for the year.

TABLE 17.—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 and 2012.

Out-Migration Year	Fry Abundance	Observed Spawning Escapement	Estimated Spawning Escapement	Egg-to-Migrant Survival
2011	1,219	0	5	-
2012	2,788	5	-	22%

The median out-migration date for Duckabush Chinook in 2012 was 4 weeks later than the median out-migration date observed for Hamma Hamma Chinook salmon. This is similar to the trend observed during the 2011 out-migration, when median out-migration of Duckabush Chinook was two months later than the median date for Hamma Hamma Chinook (Weinheimer and Zimmerman 2012). It was hypothesized in the 2011 report that the lack of available rearing habitat in the Hamma Hamma River might explain the early marine entry timing. Less than 2% of Hamma Hamma Chinook fry showed signs of freshwater growth compared to the 30% of Duckabush Chinook fry that showed freshwater growth in 2011. In 2012, 10% of Duckabush Chinook fry showed signs of freshwater growth as they passed the trap. Length data was not collected for Hamma Hamma Chinook in 2012. This hypothesis will continue to be tested as future years of data are collected.

Duckabush Pink Salmon

We found much higher abundance of Duckabush pink salmon in 2012 than previous years, despite the relatively similar spawning escapement estimates across years (Figure 16). Egg-to-migrant survival also increased 13-fold compared to the two prior pink out-migrations. This increase in pink egg-to-migrant survival and production was unique to only the Duckabush River in 2012. Egg-to-migrant survival for Hamma Hamma pink salmon continued to remain very low (0.69%), consistent with what has been observed since trapping began in 2002. It is unknown at this time why such a large difference in survival would occur between the two river systems. As additional years of data become available, we will be able to further investigate the factors that influence egg-to-migrant survival in both the Duckabush and Hamma Hamma Rivers.

The out-migration timing of Duckabush pink peaked during statistical week 17 (middle of April). Over 90% of the pink out-migration had occurred by statistical week 18 (end of April). A similar pattern was observed on the Hamma Hamma, where the peak migration occurred during statistical week 17 and 90% of the out-migration was complete by statistical week 18. Similarities in out-migration timing between the two watersheds will continue to be tracked and compared in future years of study.

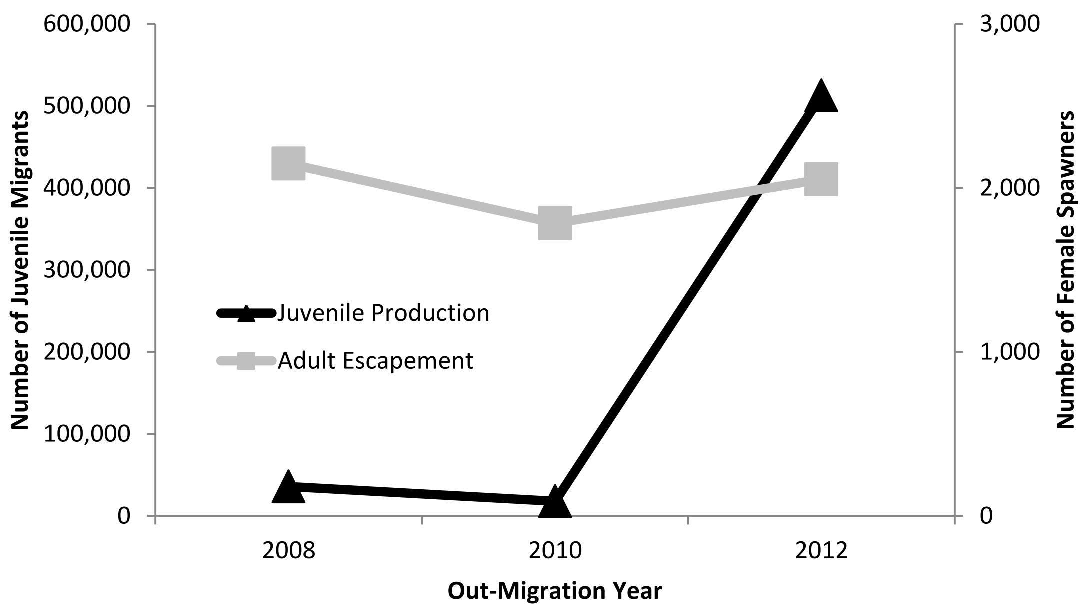

FIGURE 16.—Number of spawners and juvenile migrants by outmigration year for Duckabush River fall pink salmon, 2008, 2010 and 2012.

Duckabush Coho Salmon and Steelhead

The 2012 season marked the first year since trapping began that we were able to estimate yearling coho and steelhead production in the Duckabush River. Prior to the 2012 season, we were unable to recapture enough marked natural-origin yearling coho and steelhead that we released above the trap to estimate production. In 2012, Long Live the Kings released 1,743 ad-marked hatchery steelhead 2 miles upstream of the trap, to help supplement the natural-origin population of steelhead. We successfully recaptured 65 of those fish and used these data to estimate trap efficiency for yearling-sized out-migrants. In the future, we plan to continue marking all maiden capture natural-origin coho and steelhead in addition to any released hatchery ad-marked fish to calculate yearling trap efficiency.

Hamma Hamma Chum Salmon

The 2012 freshwater abundance of Hamma Hamma fall chum salmon was three times the abundance of summer chum. This production resulted from a spawning escapement of fall chum (7,687) that was ten times the number of summer chum (772). The fall chum escapement was the highest observed since 2007 and the summer chum escapement was the second lowest since trapping began in 2002 (Figure 17).

Egg-to-migrant survival of summer chum for the 2012 out-migration was nearly four times higher than survival of fall chum. A similar pattern was observed in the Duckabush, where summer chum survived at a much higher rate than fall-timed fish. In the Hamma Hamma, the low survival of fall-timed chum may be explained by low average flows that lead to a lack of available spawning gravel and possible redd superimposition from high densities of spawning adult fall chum. The 2011 Hamma Hamma fall chum out-migration survived at a much higher rate (14%) and had only one-third as many spawners (2,437) as the 2012 out-migration (Weinheimer and Zimmerman 2012). Average flows during the month of December were higher for the 2011 out-migration parents than the 2012 out-migrants (Figure 18). The lack of available spawning habitat due to low flow and high spawning escapement may have restricted a majority of fall chum to spawn in areas with pre-existing chum redds.

The out-migration timing of Hamma Hamma summer chum peaked four weeks earlier than Hamma Hamma fall chum in 2012. In contrast, peak spawn timing for summer and fall chum stocks is generally six to eight weeks apart. Summer chum dominated the chum out-migration for 8 of the 16 trapping weeks with a transition to fall chum migrants near the end of March. Differences in outmigration timing and the variation in timing of marine entry for these stocks will continue to be tracked and compared in future years of study.

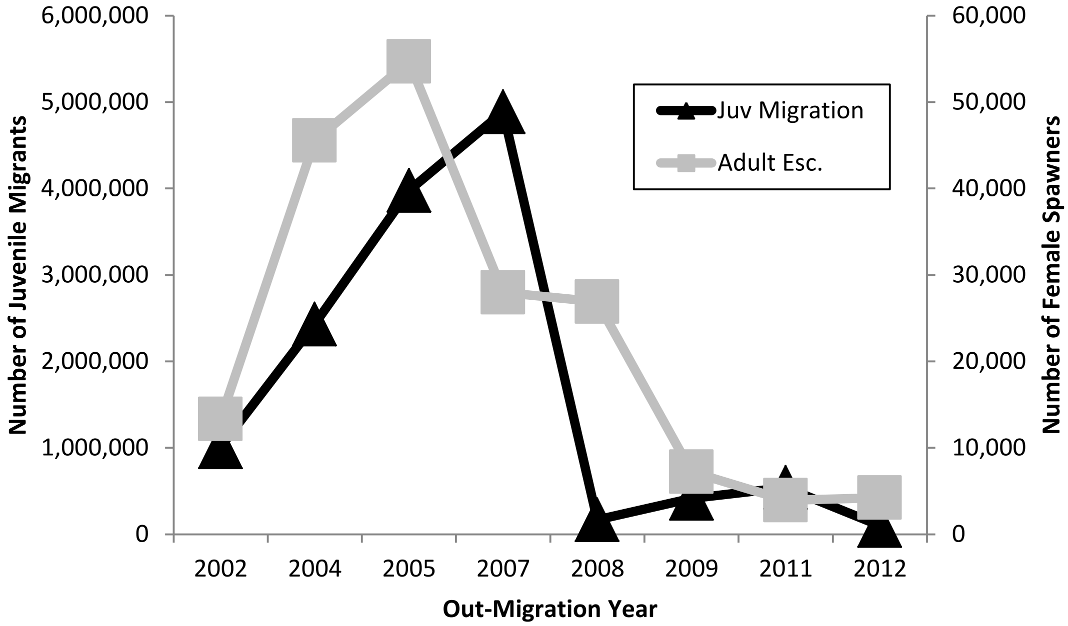

FIGURE 17.─Number of spawners and juvenile migrants by outmigration year for the Hamma Hamma River chum salmon (summer and fall run combined). Estimates are not available for the 2003, 2006, and 2010 outmigration years.

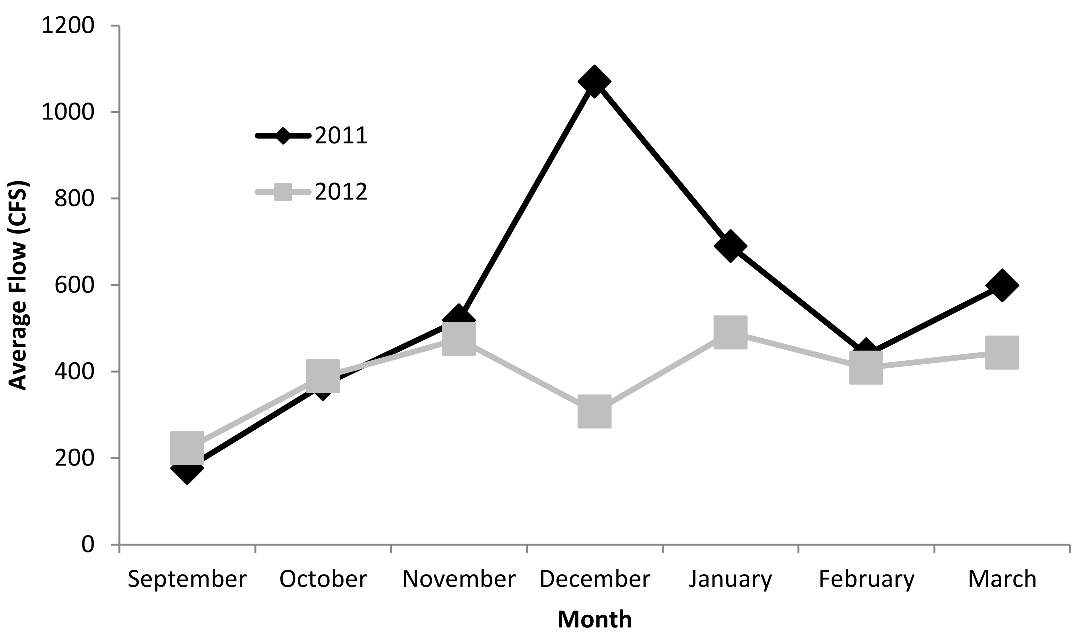

FIGURE 18.─Average river flow (CFS) by out-migration year for the Hamma Hamma River chum salmon. Due to the lack of a flow gage on the Hamma Hamma River, incubation flow was approximated as the average monthly flow at USGS gage #12054000 (Duckabush River near Brinnon) between September 1 and March 31.

Hamma Hamma Chinook Salmon

Freshwater production of Hamma Hamma Chinook salmon in 2012 was nearly identical to the estimated production for the 2011 trapping season. This production resulted from the highest spawning escapement (273 spawners) since trapping began in 2002. Egg-to-migrant survival was nearly four times less than the 2011 season despite the fact the 2012 out-migration had four times as many adult spawners (Table 18). This might suggest that density dependent factors are influencing Hamma Hamma Chinook production. As additional years of data become available, we will be able to further investigate the factors that influence egg-to-migrant survival in both the Duckabush and Hamma Hamma Rivers.

The out-migration timing of Hamma Hamma Chinook peaked during statistical week 14 (end of March). Over 90% of the Chinook out-migration had occurred by statistical week 15 (early April). Out-migration timing of juvenile Hamma Hamma Chinook continues to be earlier than Duckabush Chinook. The peak out-migration on the Duckabush occurred during the middle of April (statistical week 17) and continued through the middle of June. The median out-migration date of Hamma Hamma Chinook occurred nearly 4 weeks earlier than the median migration date of Duckabush Chinook. The difference in migration timing may be explained by spawn timing, incubation temperatures (developmental rate), or the amount of available rearing habitat. Differences in out-migration timing between the two watersheds will continue to be tracked and compared in future years of study.

TABLE 18.─Freshwater production, observed spawning escapement, estimated spawning escapement and egg-to-migrant survival for natural-origin Chinook salmon in the Duckabush River, outmigration year 2011 and 2012.

Out-Migration Year	Juvenile Abundance	Observed Spawning Escapement	Egg-to-Migrant Survival
2011	10,664	67	6.4%
2012	12,306	273	1.8%

Hamma Hamma Pink Salmon

The 2012 season marked the second highest freshwater abundance of Hamma Hamma pink salmon since trapping began in 2002. Egg-to-migrant survival continues to be less than 1% despite an increase in adult spawners (Table 19). It is unknown why pinks continue to exhibit very low survival levels in the Hamma Hamma River. As additional years of data become available, we hope to further investigate what factors might be impacting pink salmon egg-to-migrant survival.

The out-migration timing of Hamma Hamma pink peaked during statistical week 17 (middle of April). Over 90% of the pink out-migration had occurred by statistical week 18 (end of April). A similar pattern was observed on the Duckabush, where the peak migration occurred during statistical week 17 and 90% of the out-migration was complete by statistical week 18. Similarities in out-migration timing between the two watersheds will continue to be tracked and compared in future years of study.

TABLE 19.—Freshwater production, observed spawning escapement, estimated spawning escapement and egg-to-migrant survival for natural-origin pink salmon in the Hamma Hamma River, outmigration year 2002 through 2012.

Out-Migration Year	Freshwater Production	Observed Spawning Escapement	Egg-to-Migrant Survival
2002	236,329	49,880	0.53%
2004	42,111	8,903	0.53%
2008	4,387	3,362	0.14%
2010	1,473	2,165	0.08%
2012	49,314	2,873	0.69%

Recommendations

The following recommendations should improve future assessments of juvenile production and survival in the Duckabush and Hamma Hamma Watersheds:

(1) Partition Chinook migrants into their fry (early and small) and parr (late and large) outmigration strategies.
(2) Increase trapping efficiency for yearling migrants to estimate juvenile coho and steelhead smolt production.

Appendix A

Statistical Weeks for 2012

APPENDIX A1.—Statistical Weeks for 2012.

Stat Week	2012
1	Jan 1
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 4
11	Mar 5 - Mar 11
12	Mar 12 - Mar 18
13	Mar 19 - Mar 25
14	Mar 26 - Apr 1
15	Apr 2 - Apr 8
16	Apr 9 - Apr 15
17	Apr 16 - Apr 22
18	Apr 23 - April 29
19	Apr 30 - May 6
20	May 7 - May 13
21	May 14 - May 20
22	May 21 - May 27
23	May 28 - Jun 3
24	Jun 4 - Jun 10
25	Jun 11 - Jun 17
26	Jun 18 - Jun 24
27	Jun 25 - Jul 1
28	Jul 2 -Jul 8
29	Jul 9 - Jul 15

Appendix B

Duckabush River catches, trap efficiencies, and abundance estimates for 2012

APPENDIX B1.—Catch (u), marked (M) and recaptured (m) fish, and estimated abundance (U) of chum fry migrants at the Duckabush River screw trap in 2012. Release groups were pooled by statistical week. An asterisk (*) indicates periods when efficiency trials were used to estimate abundance from a different week. 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	$\hat{U}$	$V(\hat{U})$
3	1/9-1/15	116	0	116	0.00E+00	45	13	381	7.55E+03
4*	1/16-1/22	41	167	208	1.04E+03	45	13	683	3.48E+04
5	1/23-1/29	186	33	219	2.00E+02	53	15	739	2.66E+04
6	1/30-/2/5	569	0	569	0.00E+00	202	51	2,221	7.56E+04
7	2/6-2/12	1,285	134	1,419	5.31E+01	209	62	4,730	2.56E+05
8	2/13-2/19	2,843	0	2,843	0.00E+00	206	54	10,700	1.53E+06
9	2/20-2/26	4,127	0	4,127	0.00E+00	215	46	18,967	5.93E+06
10	2/27-3/4	3,176	0	3,176	0.00E+00	208	27	23,707	1.69E+07
11	3/5-3/11	12,563	0	12,563	0.00E+00	600	108	69,269	3.60E+07
12	3/12-3/18	7,966	4,865	12,831	4.75E+06	200	48	52,633	1.23E+08
13	3/19-3/25	9,856	0	9,856	0.00E+00	402	89	44,133	1.68E+07
14	3/26-4/1	5,331	4,884	10,215	5.75E+05	83	23	35,753	3.73E+07
15	4/2-4/8	4,637	0	4,637	0.00E+00	400	105	17,542	2.16E+06
16	4/9-4/15	2,696	329	3,025	3.79E+04	292	43	20,144	9.49E+06
17	4/16-4/22	2,025	0	2,025	0.00E+00	607	139	8,794	4.51E+05
18*	4/23-4/29	782	1,022	1,804	7.38E+04	607	139	7,835	1.76E+06
19	4/30-5/6	1,571	0	1,571	0.00E+00	315	96	5,118	1.97E+05
20	5/7-5/13	1,032	0	1,032	0.00E+00	105	29	3,646	3.16E+05
21*	5/14-5/20	348	25	373	6.04E+02	157	34	1,684	7.96E+04
22	5/21-5/27	277	0	277	0.00E+00	52	5	2,447	7.75E+05
23*	5/28-6/3	178	0	178	0.00E+00	52	5	1,572	3.24E+05
24*	6/4-6/10	53	9	62	8.57E-01	52	5	548	4.18E+04
25*	6/11-6/17	51	0	51	0.00E+00	52	5	451	2.87E+04
26*	6/18-6/24	16	11	27	1.30E+01	52	5	239	9.95E+03
27*	6/25-7/1	1	0	1	0.00E+00	52	5	9	6.92E+01
Totals		61,726	11,479	73,205	4.92E+06	5,263	1,164	333,945	2.54E+08

APPENDIX B2.—Estimated abundance of summer (U_s) and fall chum (U_f) fry migrants at the Duckabush River screw trap in 2012. 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)
3*	381	7.55E+03	10	1.00	0.00099	10	0.00	0.00475	381	7.69E+03	0	6.54E+02
4*	683	3.48E+04	10	1.00	0.00099	10	0.00	0.00475	683	3.52E+04	0	2.05E+03
5*	739	2.66E+04	10	1.00	0.00099	10	0.00	0.00475	739	2.72E+04	0	2.47E+03
6	2,221	7.56E+04	10	1.00	0.00099	10	0.00	0.00475	2,221	8.04E+04	0	2.31E+04
7	4,730	2.56E+05	9	1.00	0.0011	9	0.00	0.005278	4,730	2.80E+05	0	1.17E+05
8	10,700	1.53E+06	10	1.00	0.00099	10	0.00	0.00475	10,700	1.64E+06	0	5.37E+05
9	18,967	5.93E+06	20	1.00	0.000495	20	0.00	0.002375	18,967	6.11E+06	0	8.40E+05
10	23,707	1.69E+07	30	0.97	0.001441	30	0.03	0.002694	22,916	1.66E+07	790	1.49E+06
11	69,269	3.60E+07	40	1.00	0.000248	40	0.00	0.001188	69,269	3.72E+07	0	5.66E+06
12	52,633	1.23E+08	40	1.00	0.000248	40	0.00	0.001188	52,633	1.24E+08	0	3.14E+06
13	44,133	1.68E+07	40	0.93	0.002026	40	0.08	0.002966	40,823	1.83E+07	3,310	5.82E+06
14	35,753	3.73E+07	40	0.98	0.000873	40	0.03	0.001813	34,859	3.66E+07	894	2.27E+06
15	17,542	2.16E+06	39	0.92	0.002122	39	0.08	0.003087	16,192	2.49E+06	1,349	9.56E+05
16	20,144	9.49E+06	39	0.69	0.00586	39	0.31	0.006824	13,946	6.87E+06	6,198	3.60E+06
17	8,794	4.51E+05	30	0.17	0.005119	30	0.83	0.006373	1,466	4.06E+05	7,329	8.03E+05
18	7,835	1.76E+06	20	0.00	0.000495	20	1.00	0.002375	0	2.95E+04	7,835	1.90E+06
19	5,118	1.97E+05	20	0.00	0.000495	20	1.00	0.002375	0	1.29E+04	5,118	2.58E+05
20	3,646	3.16E+05	10	0.10	0.01099	10	0.90	0.01475	365	1.46E+05	3,282	4.48E+05
21*	1,684	7.96E+04	10	0.00	0.00099	10	1.00	0.00475	0	2.73E+03	1,684	9.27E+04
22*	2,447	7.75E+05	10	0.00	0.00099	10	1.00	0.00475	0	5.16E+03	2,447	8.00E+05
23*	1,572	3.24E+05	10	0.00	0.00099	10	1.00	0.00475	0	2.13E+03	1,572	3.34E+05
24*	548	4.18E+04	10	0.00	0.00099	10	1.00	0.00475	0	2.56E+02	548	4.30E+04
25*	451	2.87E+04	10	0.00	0.00099	10	1.00	0.00475	0	1.72E+02	451	2.96E+04
26*	239	9.95E+03	10	0.00	0.00099	10	1.00	0.00475	0	4.65E+01	239	1.02E+04
27*	9	6.92E+01	10	0.00	0.00099	10	1.00	0.00475	0	8.75E-03	9	6.92E+01
Totals	333,944	2.54E+08	497	-	0	497	-	0	290,891	2.51E+08	43,053	2.92E+07

Appendix C

Fork lengths of natural-origin salmon outmigrants in the Duckabush River, 2012

APPENDIX C1.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin Chinook fry in the Duckabush River screw trap in 2012.

	Statistical Week				Range		Number	Migration
No	Begin	End	Average	St. Dev	Min	Max	Sampled	Estimate
3	1/9/12	1/15/12	-	-	-	-	-	0
4	1/16/12	1/22/12	-	-	-	-	-	0
5	1/23/12	1/29/12	-	-	-	-	-	0
6	1/30/12	2/5/12	35.33	0.58	35	36	3	15
7	2/6/12	2/12/12	37.00	1.41	36	38	2	8
8	2/13/12	2/19/12	37.00	-	37	37	1	4
9	2/20/12	2/26/12	35.00	0.00	35	35	2	8
10	2/27/12	3/4/12	-	-	-	-	-	0
11	3/5/12	3/11/12	-	-	-	-	-	0
12	3/12/12	3/18/12	-	-	-	-	-	0
13	3/19/12	3/25/12	-	-	-	-	-	0
14	3/26/12	4/1/12	-	-	-	-	-	0
15	4/2/12	4/8/12	-	-	-	-	-	0
16	4/9/12	4/15/12	36.61	1.05	35	41	61	261
17	4/16/12	4/22/12	36.68	1.63	32	40	25	1,091
18	4/23/12	4/29/12	41.83	0.83	40	43	12	392
19	4/30/12	5/6/12	40.30	1.22	39	43	20	724
20	5/7/12	5/13/12	42.33	1.75	40	45	6	29
21	5/14/12	5/20/12	43.50	1.00	42	44	4	33
22	5/21/12	5/27/12	45.40	1.14	44	47	5	21
23	5/28/12	6/3/12	47.13	3.40	40	52	8	71
24	6/4/12	6/10/12	52.00	-	52	52	1	9
25	6/11/12	6/17/12	55.50	5.26	50	60	4	35
26	6/18/12	6/24/12	51.33	6.03	45	57	3	53
27	6/25/12	7/1/12	59.75	6.70	50	65	4	35
28	7/2/12	7/8/12	-	-	-	-	-	0
29	7/9/12	7/15/12	-	-	-	-	-	0
		Season Total	40	5.8	32	65	161	2,788

APPENDIX C2.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin coho 1+ in the Duckabush River screw trap in 2011.

	Statistical Week				Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
3	1/9/12	1/15/12	80.39	9.06	68	99	23	502
4	1/16/12	1/22/12	85.25	10.08	75	97	4	502
5	1/23/12	1/29/12	76.71	13.69	60	103	21	634
6	1/30/12	2/5/12	85.91	16.10	64	115	11	317
7	2/6/12	2/12/12	86.67	5.77	80	90	3	106
8	2/13/12	2/19/12	75.25	18.46	56	100	4	132
9	2/20/12	2/26/12	84.00	11.53	72	95	3	79
10	2/27/12	3/4/12	68.33	7.23	60	73	3	79
11	3/5/12	3/11/12	-	-	-	-	-	0
12	3/12/12	3/18/12	75.17	7.68	66	86	6	291
13	3/19/12	3/25/12	85.33	12.53	72	103	6	159
14	3/26/12	4/1/12	-	-	-	-	-	0
15	4/2/12	4/8/12	103.25	14.10	83	115	4	106
16	4/9/12	4/15/12	100.50	0.71	100	101	2	106
17	4/16/12	4/22/12	92.93	14.98	70	130	15	476
18	4/23/12	4/29/12	98.33	9.95	80	111	12	581
19	4/30/12	5/6/12	100.95	9.54	78	113	22	608
20	5/7/12	5/13/12	98.97	7.29	85	112	34	1,216
21	5/14/12	5/20/12	100.50	8.08	85	113	18	608
22	5/21/12	5/27/12	94.88	7.56	85	108	16	423
23	5/28/12	6/3/12	88.25	10.28	75	100	4	53
24	6/4/12	6/10/12	90.00	12.53	77	102	3	106
25	6/11/12	6/17/12	-	-	-	-	-	0
26	6/18/12	6/24/12	-	-	-	-	-	0
27	6/25/12	7/1/12	-	-	-	-	-	0
28	7/2/12	7/8/12	-	-	-	-	-	0
29	7/9/12	7/15/12	-	-	-	-	-	0
		Season Total	90.9	14.0	56	130	214	7,082

APPENDIX C3.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin steelhead in the Duckabush River screw trap in 2012.

	Statistical Week				Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
3	1/9/12	1/15/12	159.00	1.41	158	160	2	53
4	1/16/12	1/22/12	-	-	-	-	-	0
5	1/23/12	1/29/12	-	-	-	-	-	0
6	1/30/12	2/5/12	179.00	-	179	179	1	26
7	2/6/12	2/12/12	-	-	-	-	-	0
8	2/13/12	2/19/12	168.00	-	168	168	1	26
9	2/20/12	2/26/12	-	-	-	-	-	0
10	2/27/12	3/4/12	-	-	-	-	-	0
11	3/5/12	3/11/12	-	-	-	-	-	0
12	3/12/12	3/18/12	130.00	-	130	130	1	26
13	3/19/12	3/25/12	185.00	-	185	185	1	26
14	3/26/12	4/1/12	158.50	-	135	182	2	106
15	4/2/12	4/8/12	169.33	14.64	156	185	3	79
16	4/9/12	4/15/12	178.00	16.97	166	190	2	106
17	4/16/12	4/22/12	163.60	31.41	127	213	10	264
18	4/23/12	4/29/12	176.63	20.48	150	204	8	502
19	4/30/12	5/6/12	180.33	15.96	155	200	6	159
20	5/7/12	5/13/12	172.75	24.29	145	224	8	211
21	5/14/12	5/20/12	178.20	10.50	162	194	10	370
22	5/21/12	5/27/12	189.00	19.97	162	206	4	106
23	5/28/12	6/3/12	201.50	30.32	171	230	4	106
24	6/4/12	6/10/12	146.50	21.92	131	162	2	53
25	6/11/12	6/17/12	-	-	-	-	-	0
26	6/18/12	6/24/12	178.00	-	178	178	1	26
27	6/25/12	7/1/12	155.00	35.36	130	180	2	53
28	7/2/12	7/8/12	-	-	-	-	-	0
29	7/9/12	7/15/12	-	-	-	-	-	0
		Season Total	173.5	23.4	127	230	68	2,299

Appendix D

Hamma Hamma River catches, trap efficiencies, and abundance estimates for 2012

APPENDIX D1.─Catch (u), marked (M) and recaptured (m) fish, and estimated abundance (U) of chum fry migrants at the Hamma Hamma River screw trap in 2012. Release groups were pooled by statistical week. A * indicates periods when efficiency trials were used to estimate abundance from a different week. 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	$\hat{U}$	$V(\hat{U})$
6*	1/31-2/5	41	0	41	0.00E+00	255	126	83	1.10E+02
7*	2/6-2/12	115	0	115	0.00E+00	255	126	232	4.45E+02
8*	2/13-2/19	137	0	137	0.00E+00	255	126	276	5.79E+02
9*	2/20-2/26	162	0	162	0.00E+00	255	126	327	7.49E+02
10	2/27-3/4	1,017	0	1,017	0.00E+00	255	126	2,050	1.86E+04
11	3/5-3/11	2,327	0	2,327	0.00E+00	159	36	10,063	2.08E+06
12*	3/12-3/18	98	324	422	9.48E+03	159	36	1,825	2.54E+05
13*	3/19-3/25	2,292	54	2,346	1.58E+03	159	36	10,145	2.15E+06
14	3/26-4/1	512	1,240	1,752	2.99E+04	171	9	30,134	8.78E+07
15*	4/2-4/8	1,200	0	1,200	0.00E+00	171	9	20,640	3.68E+07
16*	4/9-4/15	423	0	423	0.00E+00	171	9	7,276	4.64E+06
17	4/16-4/22	1,139	0	1,139	0.00E+00	36	4	8,429	1.03E+07
18*	4/23-4/29	198	181	379	9.54E+03	36	4	2,805	1.75E+06
19*	4/30-5/6	645	0	645	0.00E+00	36	4	4,773	3.31E+06
20*	5/7-5/13	24	0	24	0.00E+00	36	4	178	5.49E+03
21*	5/14-5/20	19	0	19	0.00E+00	36	4	141	3.60E+03
Totals		10,349	1,799	12,148	5.05E + 04	2,445	785	99,377	1.49E + 08

Wk	U	V(U)	n	Ps	v(Ps)	n	Pf	v(Pf)	Us	V(Us)	Uf	V(Uf)
6*	83	1.10E+02	10	1.00	0.00099	10	0.00	0.00475	83	1.17E+02	0	3.22E+01
7*	232	4.45E+02	19	1.00	0.00052	19	0.00	0.00250	232	4.73E+02	0	1.33E+02
8*	276	5.79E+02	28	1.00	0.00035	28	0.00	0.00170	276	6.05E+02	0	1.28E+02
9*	327	7.49E+02	38	1.00	0.00026	38	0.00	0.00125	327	7.77E+02	0	1.33E+02
10	2,050	1.86E+04	37	1.00	0.00027	37	0.00	0.00128	2,050	1.97E+04	0	5.37E+03
11	10,063	2.08E+06	38	1.00	0.00026	38	0.00	0.00125	10,063	2.11E+06	0	1.24E+05
12*	1,825	2.54E+05	38	1.00	0.00026	38	0.00	0.00125	1,825	2.55E+05	0	3.85E+03
13*	10,145	2.15E+06	33	0.36	0.00753	33	0.64	0.00867	3,689	1.04E+06	6,456	1.74E+06
14	30,134	8.78E+07	26	0.04	0.00186	26	0.96	0.00331	1,159	1.66E+06	28,975	8.39E+07
15*	20,640	3.68E+07	28	0.25	0.00730	28	0.75	0.00864	5,160	5.14E+06	15,480	2.41E+07
16*	7,276	4.64E+06	17	0.12	0.00707	17	0.88	0.00928	856	4.06E+05	6,420	4.06E+06
17	8,429	1.03E+07	16	0.00	0.00062	16	1.00	0.00297	0	3.76E+04	8,429	1.05E+07
18*	2,805	1.75E+06	14	0.07	0.00581	14	0.93	0.00849	200	4.45E+04	2,605	1.56E+06
19*	4,773	3.31E+06	9	0.00	0.00110	9	1.00	0.00528	0	2.14E+04	4,773	3.41E+06
20*	178	5.49E+03	10	0.30	0.02432	10	0.70	0.02808	53	1.13E+03	125	3.43E+03
21*	141	3.60E+03	10	0.30	0.02432	10	0.70	0.02808	42	7.20E+02	99	2.22E+03
Totals	99,377	1.49E+08	371	8.44	0.08285	371	7.56	0.11679	26,016	1.07E+07	73,361	1.29E+08

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