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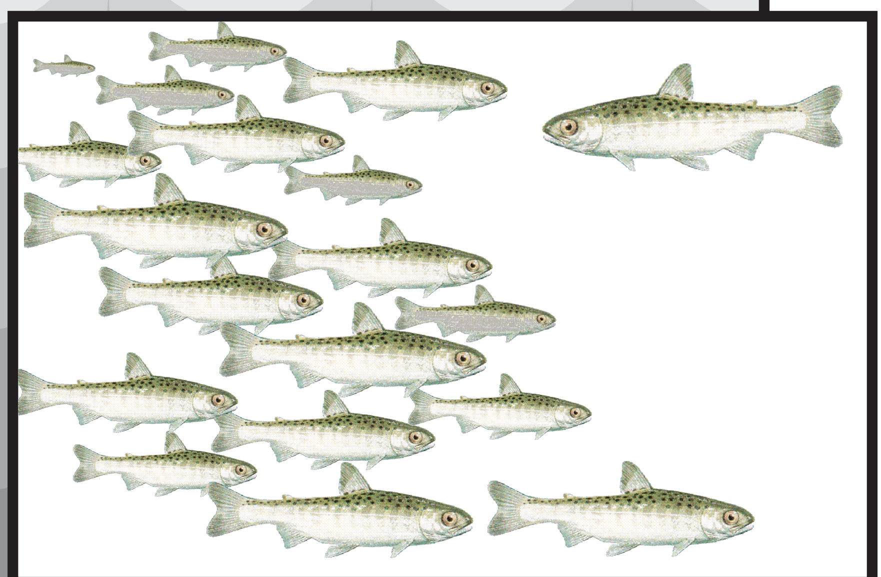
Mid-Hood Canal Juvenile Salmonid Evaluation: Duckabush and Hamma Hamma 2011



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Washington Department of
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Wild Salmon Production/Evaluation

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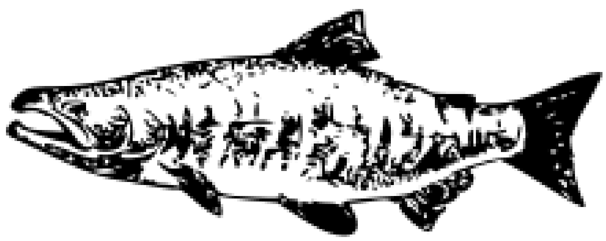

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Acknowledgements

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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 chum and Chinook salmon in 2011. In addition, we derived independent estimates for summer and fall chum salmon stocks in these watersheds. Coho salmon and steelhead smolt catches were too few to expand to an abundance estimate. As expected, no pink salmon fry were captured during the 2011 outmigration period (even-year returns are not observed in these watersheds).

Duckabush River

A floating five-foot screw trap was located at river mile 0.3 (0.48 rkm) and operated by WDFW and LLTK from January 10 to July 26, 2011. The juvenile production of summer chum salmon was ten times larger than fall chum (Table 1). Egg-to-migrant survival for summer and fall chum salmon ranged between 5.1% and 6.8%. The peak of the summer chum outmigration occurred 4 weeks earlier than the peak of the fall chum outmigration. Low numbers of juvenile Chinook were counted despite the fact that no adults were observed spawning in 2010. Based on juvenile abundance, we estimate that the observed production resulted from less than 5 female Chinook spawners.

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 27 to June 26, 2011. Juvenile production of fall chum salmon was nearly 4 times larger than the summer chum salmon (Table 1). Egg-to-migrant survival averaged 14.1% for the fall stock and 6.1% for the summer stock. Juvenile production of Chinook salmon was estimated to be 10,664 sub-yearlings with an egg-to-migrant survival of 6.4%.

TABLE 1.—Production, 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, 2011.

	Duckabush River	Hamma Hamma River
Summer Chum		
Production (CV %)	347,597 (9.8%)	111,633 (17.8%)
Survival	6.8%	6.1%
Avg fork length (±1 S.D., mm)	38.6 (±2.0)	37.8 (±1.6)
Median out-migration date	March 18	March 29
Fall Chum		
Production (CV %)	32,656 (23.2%)	428,368 (7.3%
Survival	5.1%	14.1%
Avg fork length (±1 S.D., mm)	38.6 (±2.0)	37.8 (±1.6)
Median out-migration date	April 4	April 12
Chinook		
Production (CV %)	1,219 (13.6%)	10,664 (15.9%)
Survival	---*	6.4%
Avg fork length (mm)	43.0 (±6.4)	39.1 (±3.8)
Median out-migration date	April 13	February 16

* Egg-to-migrant survival of Chinook salmon in the Duckabush River could not be calculated because no redds were observed and the escapement was estimated to be zero.

Introduction

The Duckabush and Hamma Hamma rivers are adjacent high-gradient watersheds draining into 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 ESU, summer chum populations are part of the Hood Canal summer chum Evolutionary Significant Unit (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 Evolutionary Significant Unit (ESU) listed as *threatened* in 1999 by the National Marine Fisheries Service under the Endangered Species Act (Holtby et al. 1989). 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 (Shared_Strategy_Development_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 (Salo 1998). The Hood Canal summer chum ESU was historically composed of 16 independent populations (Seiler 2005). Summer chum are distinguished from fall and winter chum based on spawn timing and genetics (Ames 2000; Ames et al. 2000; Seiler 2005; Small et al. 2010). 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 to be extinct. Based on the framework developed in the "Summer Chum Salmon Conservation Initiative" (Seiler 2005), harvest of Hood Canal summer chum was greatly reduced and hatchery supplementation was implemented in order to rebuild stocks to harvestable levels. 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) (Weinheimer et al. 2011). 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 (Small et al. 2010). 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 stock resiliency when survival in the marine environment is poor (Weinheimer et al. 2011). 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 2011 outmigration. Throughout this report, the number of juvenile migrants estimated for a given year will be referred to as “freshwater production” 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 2011, the primary objective of this study was to estimate the abundance, survival, and migration timing of juvenile migrants produced by Chinook and chum salmon spawning naturally in the Duckabush and Hamma Hamma rivers. Additional objectives were to enumerate outmigrant catches of all salmonid species in both systems. 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 (5-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 a five-foot circle with a cross sectional area of 9.8-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.

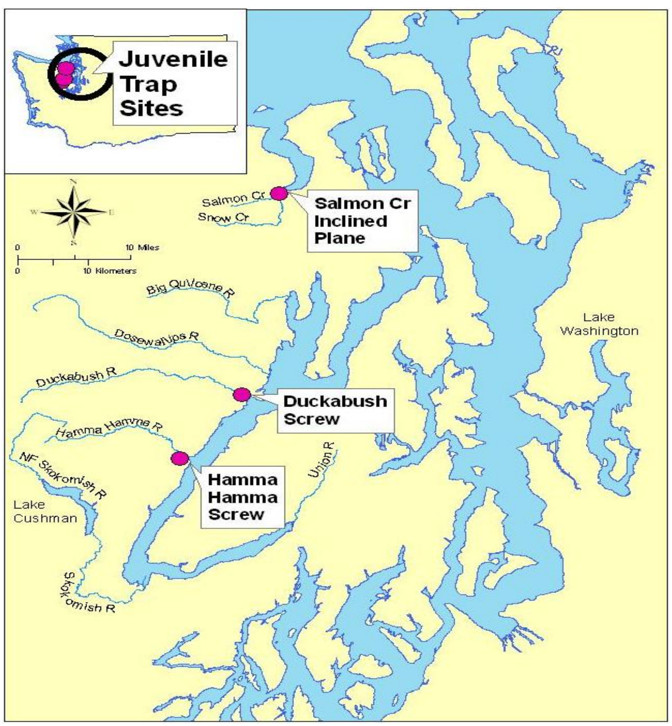

FIGURE 1.─Location of Duckabush and Hamma Hamma screw traps.

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, 2011

Trap	Start Date	End Date	Hours Fished	Total Possible Hours	Percent Fished	Number of Outages	Avg Outage Hrs	St Dev.
Duckabush	1/10	7/26	4,338.25	4,725.50	91.81%	6	64.54	36.1
Hamma	1/26	6/26	2,894.25	3,618.00	80.00%	8	90.47	67.2

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. 2011b). 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 rather than chum salmon. Therefore, the anomalous samples were genotyped using the GAPS Chinook salmon suite of 13 microsatellite DNA markers following protocols detailed in (Small et al. 2011a) and run as described above.

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

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

(2) Efficiency strata. Chum data from the Duckabush River and chum and Chinook data from the Hamma Hamma River were organized into weekly strata (Monday – Sunday) in order to combine catch, efficiency trials, and genetic sampling data. Chinook data from the Duckabush River were organized into time strata based on statistical pooling of the release and recapture data. 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 chum salmon in both rivers and for Chinook salmon in the Hamma Hamma River. Egg-to-migrant survival was the number of 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 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) and 5,000 for Chinook salmon (Healey 1991).

Migration Timing

Migration data was plotted according to statistical week (Sunday – Saturday) 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 ($\hat{u}$ = 45,611) included 38,242 captures in the trap and 7,369 missed catch estimated for trap outages (Appendix B). A total of 2,584 natural-origin chum were marked and released over 32 efficiency trials, ranging between 3 and 105 fish. Mark and recapture data were organized into 21 weekly strata for analysis. Trap efficiency of these strata ranged between 5.8% and 20%.

Chum fry were captured in low numbers on the first day of trapping (January 10), and the last chum was observed on May 31. Chum migration prior to the trapping season was assumed to be minimal (<1% of total migration).

Based on genetic analyses, the catch was predominantly (> 95%) summer chum until the beginning of April when the proportion of fall chum increased in the sample. From April 27 until the end of the trapping season, the sampled catch was mostly fall chum (Table 3). Three of the 400 samples did not contain enough DNA to be identified to a particular stock.

TABLE 3.─Genetic stock identification for juvenile chum salmon migrants caught in the Duckabush screw trap, 2011.

Date	Samples	Summer	Fall	Unknown	% Summer	% Fall
01/24/2011	10	10	0		100.00%	0.00%
01/31/2011	10	10	0		100.00%	0.00%
02/07/2011	20	19	1		95.00%	5.00%
02/14/2011	30	28	1	1	96.55%	3.45%
02/23/2011	30	28	2		93.33%	6.67%
02/28/2011	40	38	2		95.00%	5.00%
03/07/2011	40	39	1		97.50%	2.50%
03/16/2011	40	39	1		97.50%	2.50%
03/21/2011	40	38	2		95.00%	5.00%
03/29/2011	40	34	5	1	87.18%	12.82%
04/07/2011	30	16	14		53.33%	46.67%
04/11/2011	20	14	6		70.00%	30.00%
04/18/2011	15	10	5		66.67%	33.33%
04/27/2011	15	3	11	1	21.43%	78.57%
05/02/2011	10	0	10		0.00%	100.00%
05/10/2011	10	1	9		10.00%	90.00%
Totals	400	327	70	3	82.37%	17.63%

A total of 347,597 ±66,933 (95% C.I.) natural-origin summer chum fry are estimated to have migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 9.8%. A total of 32,656 ±14,868 (95% C.I.) natural-origin fall chum fry are estimated to have migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 23.2%. 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 6.8% for summer chum and 5.1% 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 2011.

Stock	**Juvenile Production**	**Juvenile CV**	**Female Spawners**	**Egg to Migrant Survival**
Summer	347,597	9.8%	2,055	6.8%
Fall	32,656	23.2%	256	5.1%
Total	380,253	9.2%	2,311	6.6%

The entire chum outmigration occurred over a 20 week period between mid January and the end of May (Figure 2). The median migration date for the summer component occurred during statistical week 12 (middle of March), three weeks earlier than the median migration date of the fall component (statistical week 15, early April). The summer chum component of the migration was 95% complete by statistical week 15 (early April). The fall chum component of the migration was 95% complete by statistical week 19 (early May).

The weekly average lengths of chum fry were shorter during the first week of trapping (January 10 to January 16) than the rest of the season (Figure 3, Appendix C). During that week, a high proportion of the chum fry had visible egg yolk sacs attached suggesting they had just emerged from the gravel and were not fully developed when they reached the trap. The average length during that time was 33.7-mm FL and ranged between 31-mm and 39-mm FL. Average lengths after statistical week 3 were similar throughout the rest of the trapping season (January 24 to May 31). The average length during the remainder of the season was 38.7-mm and ranged between 32-mm and 44-mm.

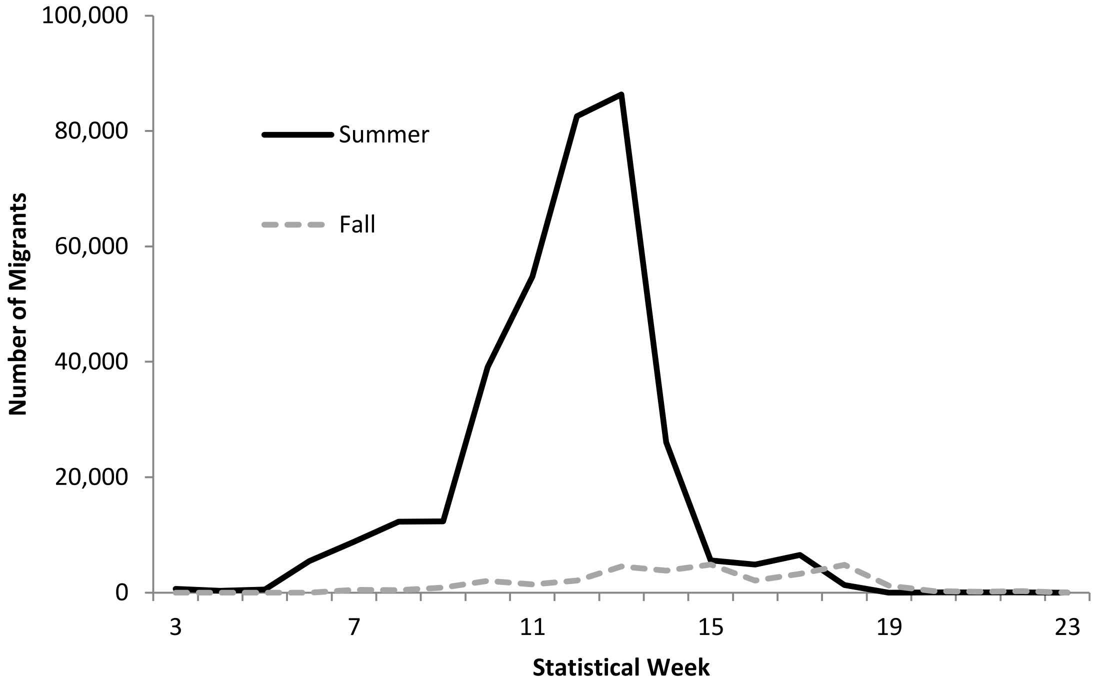

FIGURE 2.—Weekly outmigration of natural-origin chum salmon fry in the Duckabush River, 2011 outmigration.

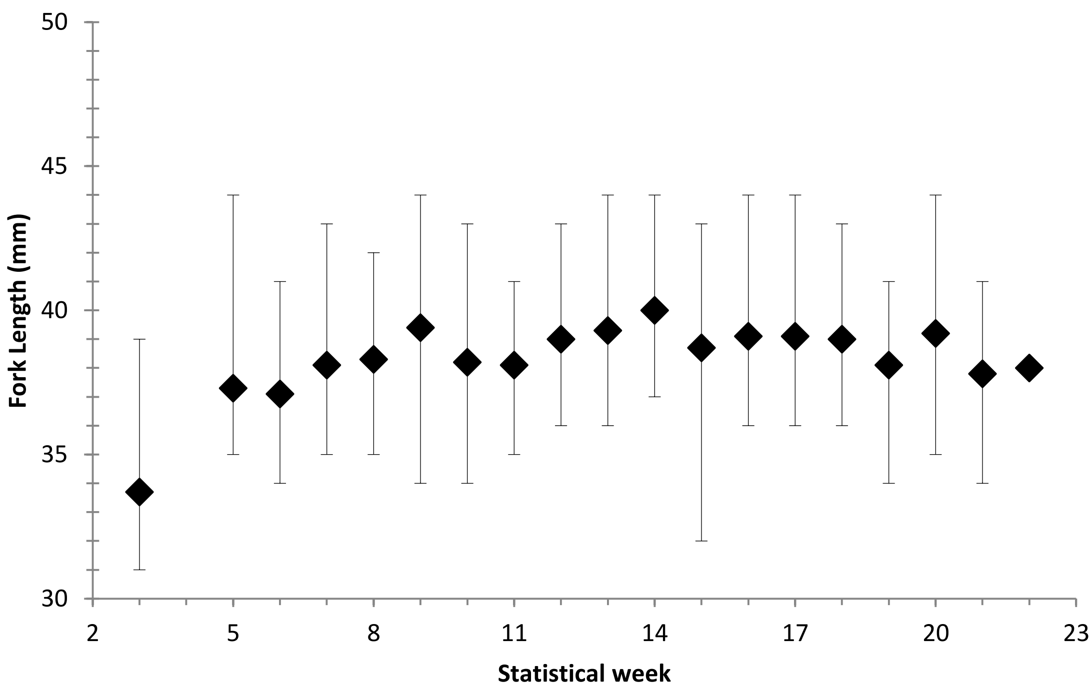

FIGURE 3.—Fork lengths (mm) of chum fry migrants of natural origin captured in the Duckabush River screw trap 2011. Data are mean, minimum, and maximum values by statistical week.

Chinook

Total catch of natural-origin Chinook was 111 juveniles. Due to the low number of Chinook, chum efficiency trials involving chum were used to represent Chinook trap efficiency. The 32 chum efficiency trials were pooled into 6 strata using the *G*-test approach, with trap efficiencies ranging between 6.5% and 20% (Appendix B).

A total of 1,219 ±325 (95% C.I.) natural-origin Chinook fry are estimated to have migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 13.6%.

No adult Chinook spawners were observed in the fall of 2010. Possible explanations for the observance of Chinook fry at the trap and a fry to adult back calculation of escapement are explored in the discussion section of this report.

TABLE 5.—Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Duckabush River, 2011. Release groups were pooled to form 6 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	1/10-1/31	0	0	0.00E+00	31	2	0	1.40E+02
2	2/1-3/11	0	0	0.00E+00	1160	125	0	8.55E+01
3	3/12-3/15	0	0	0.00E+00	105	21	0	2.40E+01
4	3/16-3/17	0	0	0.00E+00	105	9	0	1.22E+02
5	3/18-3/22	2	0	0.00E+00	210	32	13	1.13E+02
6	3/23-7/27	109	0	9.09E-01	973	87	1206	2.70E+04
	Season Total	111	0	9.09E-01	2,584	276	1,219	2.75E+04

The first two Chinook fry were captured on March 21, 2011. Daily migration of Chinook was low and sporadic for most of the season (Figure 4). The median migration date occurred during statistical week 16 (middle of April). The migration was 95% complete by statistical week 29 (middle of July). The last Chinook was captured on July 21, 2011, five days before the end of the trapping season.

Length of natural-origin Chinook fry ranged from 37-mm to 58-mm and averaged 43-mm throughout the trapping season (Figure 5, Appendix C). Average weekly fork lengths of juvenile Chinook began to increase during statistical week 20 (early May).

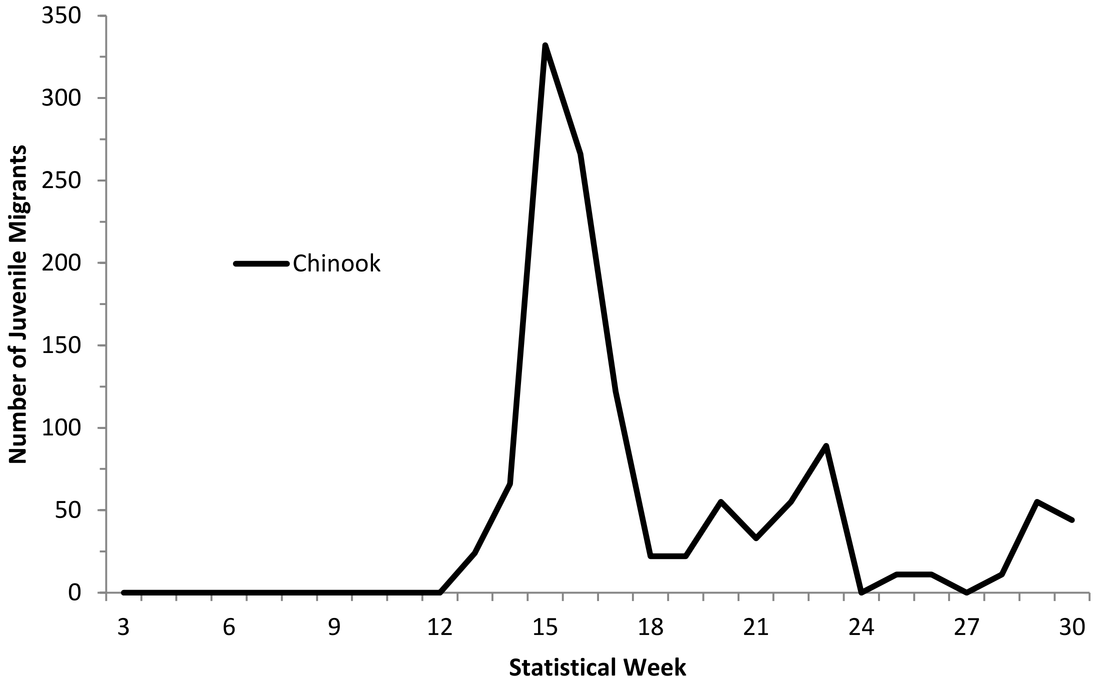

FIGURE 4.─Weekly outmigration of natural-origin Chinook salmon fry in the Duckabush River, 2011 outmigration.

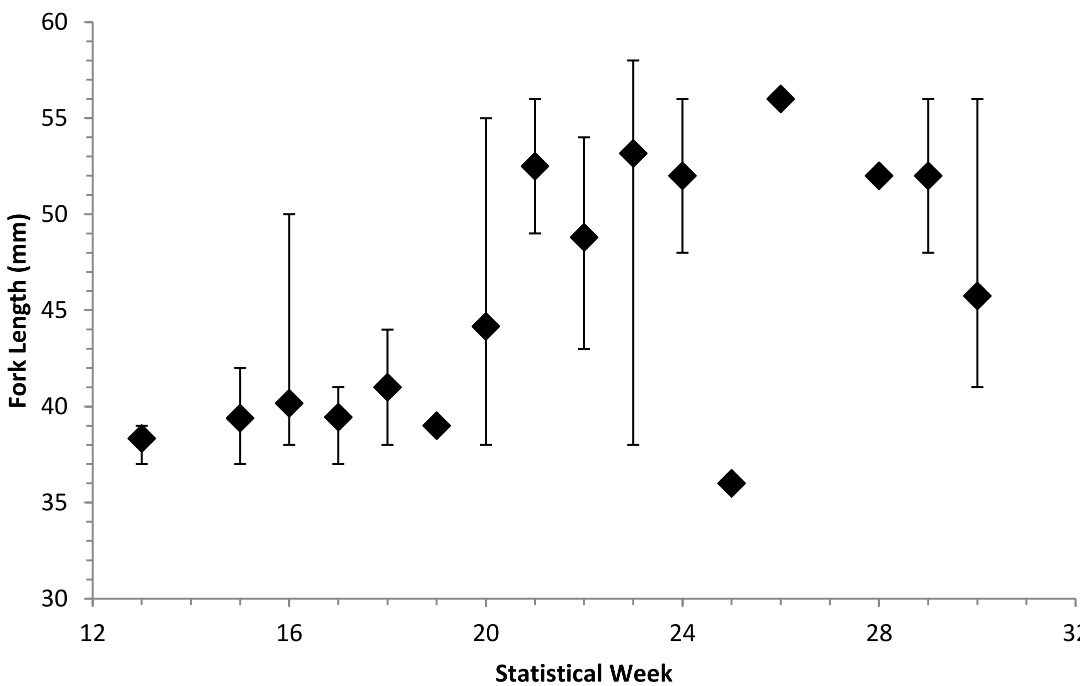

FIGURE 5.─Fork lengths (mm) of juvenile Chinook migrants of natural origin captured in the Duckabush River screw trap 2011. Data are mean, minimum, and maximum values by statistical week.

Other Species

In addition to the species listed above, catch during the trapping season included 410 coho fry, 35 yearling coho, 5 trout parr, 26 steelhead smolts, and 1 ad-marked steelhead smolt. Non-salmonid species captured included sculpin (*Cottus* spp.) and 46 lamprey ammocoetes.

Hamma Hamma Results

Chum

Based on field identification of chum catch, the total estimated catch of natural-origin chum ($\hat{u}$ = 67,992) included 59,639 captures in the trap and 8,353 missed catch estimated for trap outages (Appendix D). However, genetic analyses of chum samples taken throughout the season revealed that some fish, visually identified as chum, were actually juvenile Chinook. By calculating the proportion of Chinook in the genetic samples, the actual estimated catch of natural origin chum was estimated to be $\hat{u}$ = 66,519 during the 2011 season.

A total of 4,913 natural-origin chum were marked and released over 19 efficiency trials, ranging between 53 and 500 fish. Mark and recapture data were organized into 16 weekly strata for analysis. Trap efficiency of these strata ranged between 6% and 19.8%.

Chum fry were captured on the first day of trapping (January 26) and the last chum was observed on May 9. Chum migration prior to the trapping season was assumed to be minimal (<1% of total migration).

Based on genetic analyses, a portion of the fish identified as chum in the field were actually Chinook (Table 6). Misidentifications occurred in 6 of the first 8 weeks of genetic sampling. Field identified "chum" were predominantly summer chum during the first 7 weeks of sampling (>80%), with the exception of week 5 where they comprised less than 20% of the sample. The sampled catch was mostly fall chum from March 19 to the end of the trapping season. Thirty-two samples did not contain enough DNA to be identified to a particular stock.

TABLE 6.─Genetic stock identification for juvenile chum salmon migrants caught in the Hamma Hamma screw trap, 2011.

Date	Samples	Summer	Fall	Chinook	Unknown	% Summer	% Fall	% Chinook
1/31	10	3	0	6	1	100.00%	0.00%	66.67%
2/4	10	4	1	4	1	80.00%	20.00%	44.44%
2/8	20	3	0	17	0	100.00%	0.00%	85.00%
2/17	29	13	3	4	9	81.25%	18.75%	20.00%
2/23	20	3	11	5	1	21.43%	78.57%	26.32%
3/2	40	26	9	0	5	74.29%	25.71%	0.00%
3/9	40	27	12	0	1	69.23%	30.77%	0.00%
3/19	40	10	25	2	3	28.57%	71.43%	5.41%
3/22-3/24	40	8	30	0	2	21.05%	78.95%	0.00%
3/29	39	6	32	0	1	15.79%	84.21%	0.00%
4/8	30	3	26	0	1	10.34%	89.66%	0.00%
4/14	20	3	16	0	1	15.79%	84.21%	0.00%
4/24	15	2	9	0	4	18.18%	81.82%	0.00%
5/1	15	1	13	0	1	7.14%	92.86%	0.00%
5/6	10	1	8	0	1	11.11%	88.89%	0.00%
Totals	378	113	195	38	32	36.69%	63.31%	10.98%

A total of 111,633 ±38,882 (95% C.I.) natural-origin summer chum fry are estimated to have migrated past the screw trap (Table 7). Coefficient of variation for this estimate was 17.8%. A total of 428,368 ±61,526 (95% C.I.) natural-origin fall chum fry are estimated to have migrated past the screw trap (Table 7). Coefficient of variation for this estimate was 7.3%. 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 6.1% for summer chum and 14.1% for fall chum (Table 7).

TABLE 7.─Juvenile production and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin chum salmon in the Hamma Hamma River, 2011.

Stock	Juvenile Production	Juvenile CV	Female Spawners	Egg to Migrant Survival
Summer	111,633	17.8%	736	6.1%
Fall	428,368	7.3%	1,219	14.1%
Total	540,001	6.9%	1,955	11.1%

The entire chum migration occurred over a 15 week period between the end January and the middle of May (Figure 6). The summer component of the migration appeared to have two peak migration periods (March 7-13 and April 18-24) as opposed to the fall component that had a single peak (April 11-17). The median migration date for summer chum occurred during statistical week 14 (end of March), two weeks earlier than the median migration date for fall chum (Statistical week 16, middle of April). The summer chum component of the migration was 95% complete by statistical week 17 (middle of April). The fall chum component of the migration was 95% complete by statistical week 18 (end of April).

The weekly average lengths of natural origin chum fry were similar during the entire trapping season. Average fork length for the entire season was 37.8 mm and ranged between 34 mm and 42 mm (Figure 7, Appendix E).

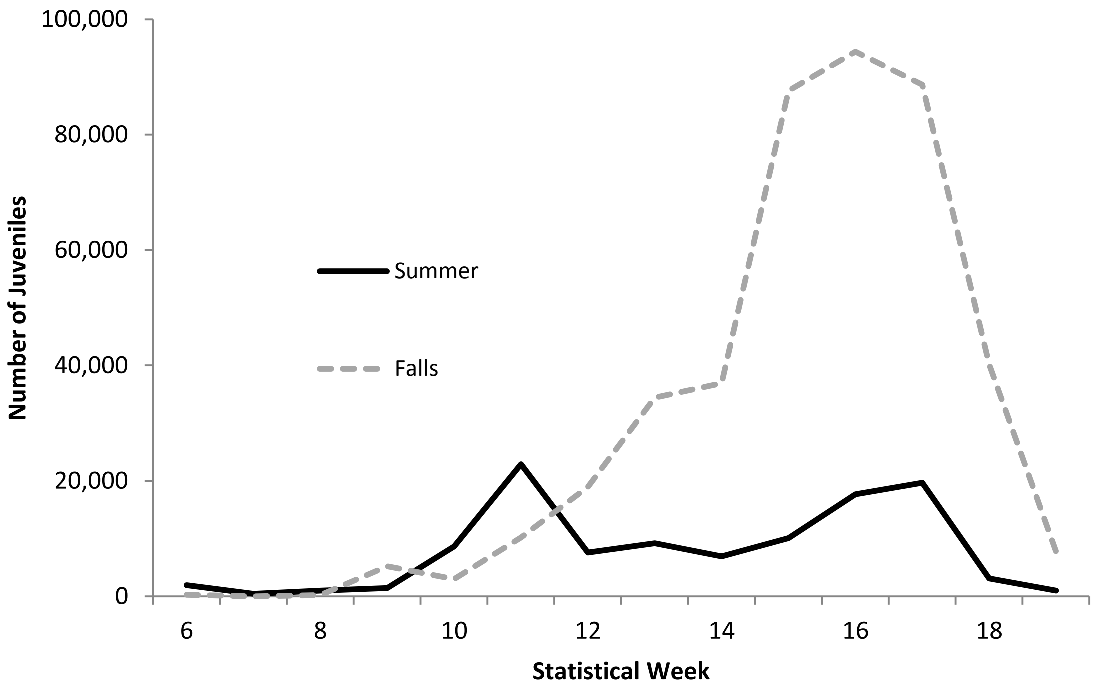

FIGURE 6.—Weekly outmigration of natural-origin chum salmon fry in the Hamma Hamma River, 2011 outmigration

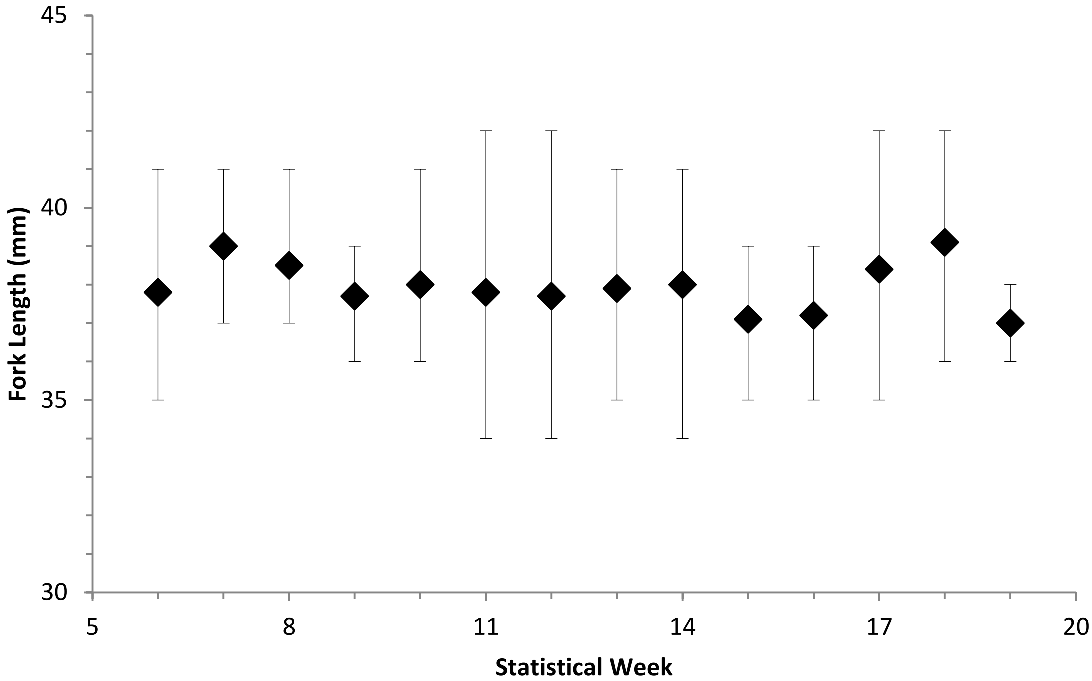

FIGURE 7.─Fork lengths (mm) of chum fry migrants of natural origin captured in the Hamma Hamma River screw trap 2011. Data are mean, minimum, and maximum values by statistical week.

Chinook

Total catch of natural-origin Chinook was 137 captures in the trap and 15 estimated missed catch. Genetic analyses of chum samples revealed that a portion of the visually identified chum catch early in the trapping season (January and February) were actually juvenile Chinook. The number of Chinook estimated to have been misidentified was calculated by applying the proportion of Chinook in the chum genetic samples by the total chum catch for that statistical week. Based on this approach, we estimate that an additional 1,473 natural origin Chinook were captured.

Due to the low number of Chinook, chum efficiency trials were used as a surrogate for Chinook trap efficiency. Between January 29 and March 20, mark and recapture data were organized into 8 weekly strata with trap efficiencies ranging between 10% and 19.8% (Appendix D). The abundance for each strata was adjusted upwards for the proportion of misidentified chum catch. Between January 29 and June 26, mark and recapture data were pooled into 8 strata with trap efficiencies 6.5% and 20%. A total of 10,664 (CV = 15.9%) natural-origin Chinook fry are estimated to have migrated past the screw trap (Table 8). This estimate includes 1,289 ±300 (95% C.I.) migrants estimated from visually identified Chinook and 9,375 ±3,312 (95% C.I.) migrants estimated based on the misidentification rate of chum fry.

Egg-to-migrant survival was estimated to be 6.4% (Table 8).

TABLE 8.─Juvenile production and associated coefficient of variation, female spawning escapement, and egg-to migrant survival for Chinook salmon in the Hamma Hamma River, 2011.

Stock	Juvenile Production	Juvenile CV	Female Spawners	Egg to Migrant Survival
Mis-ID	9,375	18.0%	---	---
Correct ID	1,289	11.9%	---	---
Total	10,664	15.9%	34	6.4%

The first Chinook fry was identified at the trap on February 3, 2011 (statistical week 6). Genetic analyses revealed that Chinook were present in the catch on January 31 (statistical week 5). The majority of Chinook fry were identified after April 1. However, our estimates based on the genetic results suggest that a large percent (>88%) of the production may have migrated prior to April 1 (Figure 8). The migration was 95% complete by statistical week 15 (second week of April). The last Chinook was captured on June 3, 2011, four weeks before the end of the trapping season.

Fork length of natural-origin Chinook fry ranged from 37 mm to 58 mm and averaged 43 mm throughout the trapping season (Figure 9, Appendix E). Average fork length began to increase during statistical week 20 (early May).

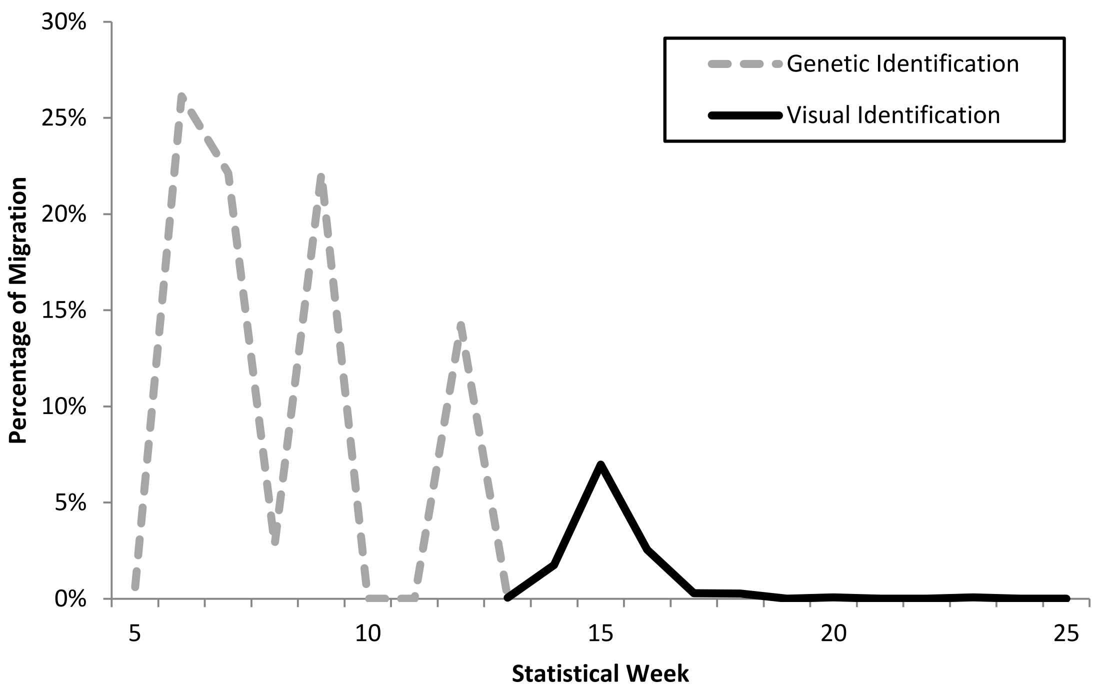

FIGURE 8.─Weekly outmigration of natural-origin Chinook salmon fry in the Hamma Hamma River, 2011 outmigration.

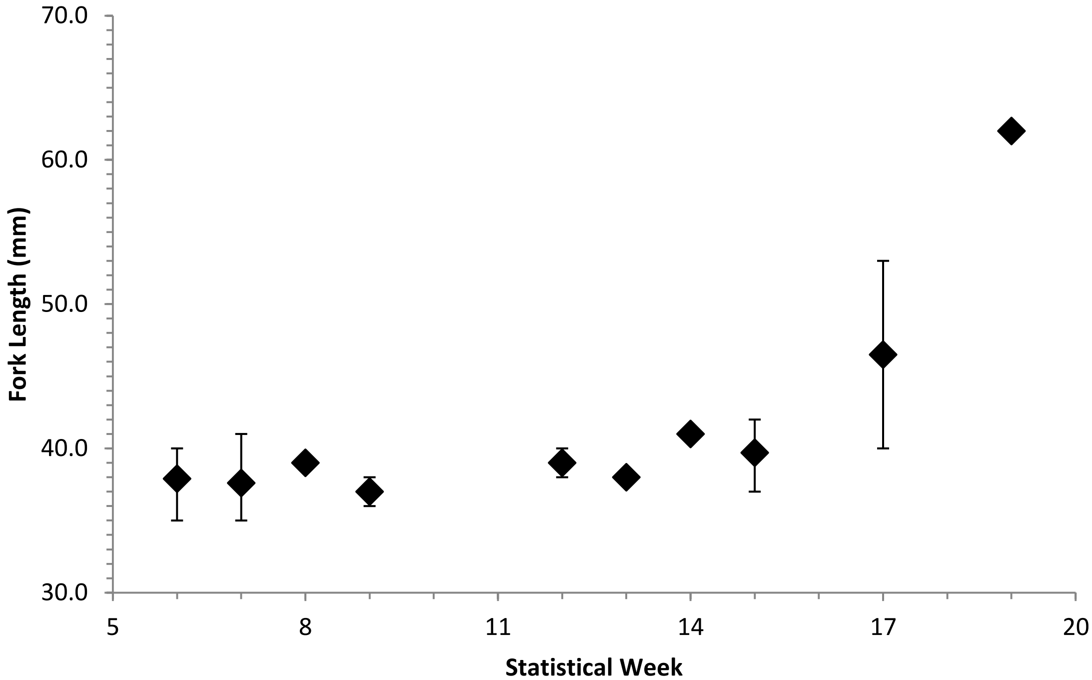

FIGURE 9.—Fork lengths (mm) of Chinook migrants of natural origin captured in the Hamma Hamma River screw trap 2011. Data are mean, minimum, and maximum values by statistical week.

Other Species

In addition to the species listed above, catch during the trapping season included 1,468 ad-marked Chinook fry, 428 coho fry, 92 yearling coho, 3 trout parr, 27 steelhead smolts, 2 cutthroat smolt, 1 cutthroat adult. 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 2011. The 2011 trapping season marked the first 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 (Small et al. 2010). Precision was represented by the coefficient of variation (*CV*) and 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 (Weinheimer et al. 2011) due to the additional analysis step that allotted chum abundance between the summer and fall runs (and between chum and Chinook in the Hamma Hamma). 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 (Topping and Zimmerman 2012). 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 (Holtby et al. 1989; Salo 1998). 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 2011 outmigration of Duckabush summer chum was ten times the number of fall chum outmigrants. This production resulted from the largest observed spawning escapement of Duckabush summer chum salmon (4,110 spawners) and second largest escapement of fall timed chum (512 spawners) since 2007, the first brood year for which juvenile production estimates were derived. Over three years of study, the total production of juvenile chum (summer and fall run) from the Duckabush River does not appear to be correlated with spawner abundance. Although the 2011 outmigration resulted from the highest total chum escapement over the three years of study (no juvenile estimate available for 2010 outmigration), the abundance of juvenile outmigrants in 2011 was just 60% the abundance of the juvenile chum migration in 2009 (Figure 10).

Egg-to-migrant survival of Duckabush summer and fall chum were similar (< 2% different) for the 2011 out-migration, and the differences in freshwater production between the two stocks were due to the fact that the number of summer chum spawners was 8 times larger than the number of fall chum spawners. This correlation suggests that both stocks responded similarly to environmental variables, such as flow, that affect survival in freshwater. When compared to the 2008 and 2009 outmigration years, egg-to-migrant survival of 2011 chum salmon outmigrants (summer and fall run combined) in the Duckabush River was intermediate in value. Peak incubation flows associated with the 2011 outmigration year were also intermediate in value to the 2008 and 2009 outmigration years (Figure 11).

The outmigration timing of Duckabush summer chum peaked four weeks earlier than Duckabush fall chum in 2011. 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 15 of the 21 trapping weeks with a transition to fall chum migrants near the end 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.

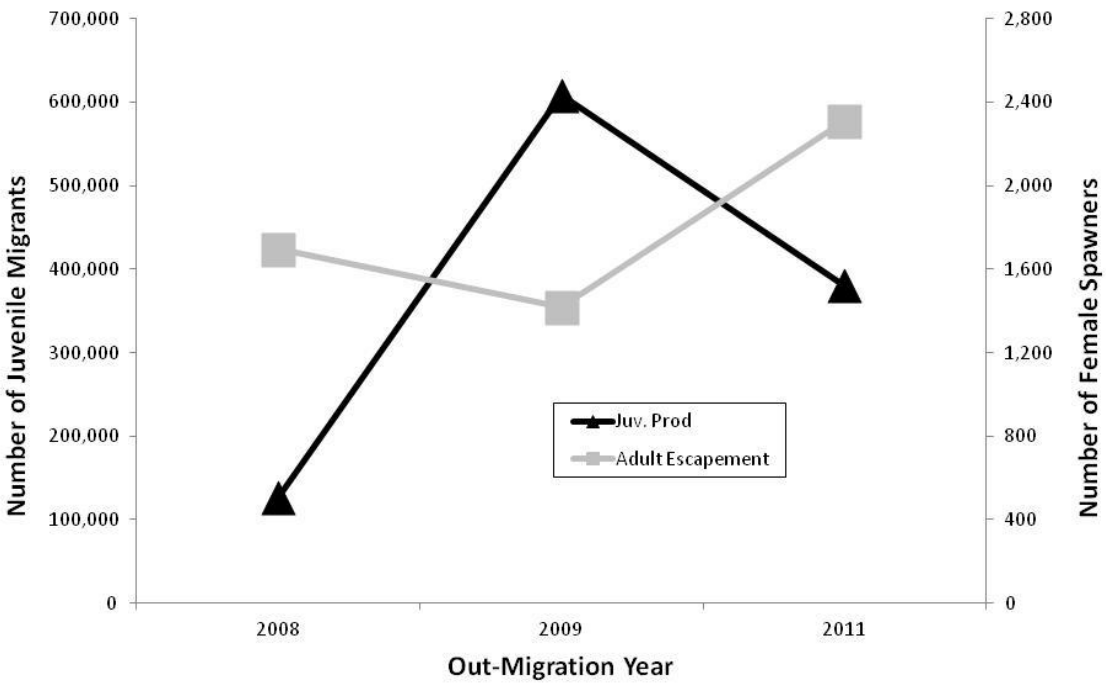

FIGURE 10.—Number of spawners and juvenile migrants by outmigration year for Duckabush River chum salmon (summer and fall run combined), outmigration year 2008, 2009, and 2011. Estimates are not available for 2010 outmigration.

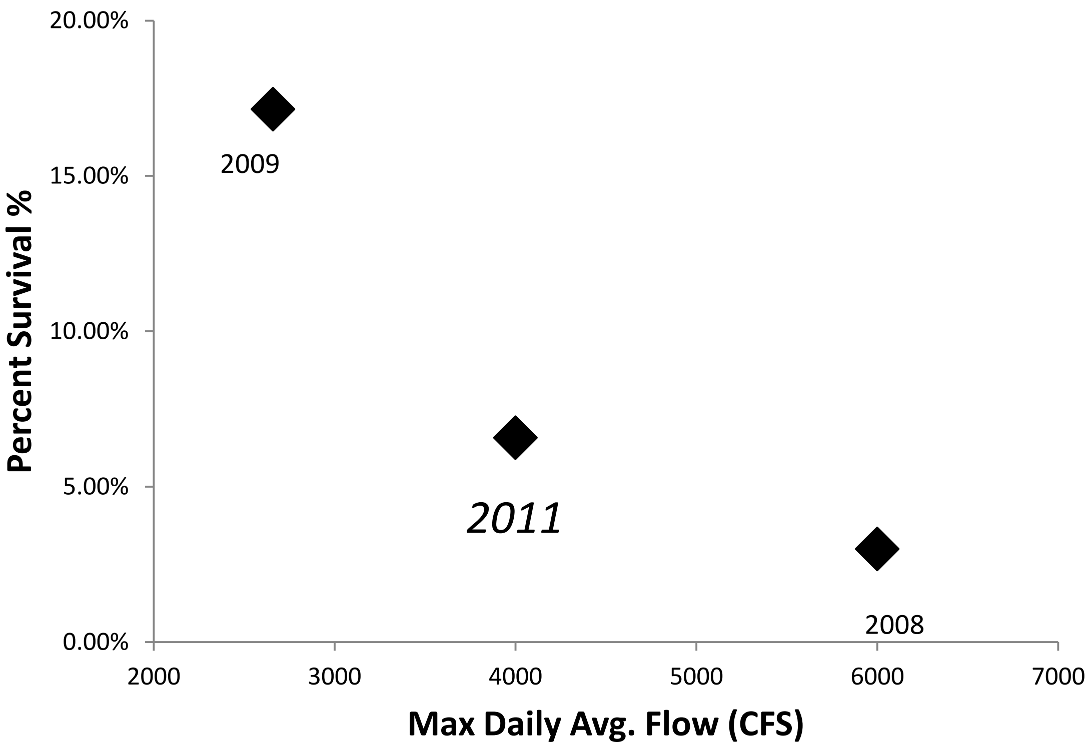

FIGURE 11.—Egg-to-migrant survival for chum salmon (summer and fall run combined) in the Duckabush River (outmigration year 2011) as a function of peak incubation flow. Incubation flow was the maximum daily average flow at USGS gage #12054000 (Duckabush River near Brinnon) between September 1 and December 31.

Duckabush Chinook Salmon

The 2011 season marked the first year since trapping began in 2008 that we were able to estimate juvenile Chinook production in the Duckabush River. The observation of juvenile migrants was initially surprising since no adult Chinook were observed spawning in the Duckabush during the fall of 2010. Among possible explanations for this discrepancy are high turbidity and flows during sampling days, a high abundance of chum in the system, or the entry of a few returning adult Chinook after the 2010 spawning surveys had concluded for the year.

Based on the juvenile production, we back-calculated the possible Chinook escapement with the following assumptions:

1) Fecundity was 5,000 eggs for each female,
2) Equal ratio of females to males, and
3) Comparable egg-to-migrant survival in the Duckabush and Hamma Hamma rivers.

Based on these assumptions, we estimate that five or fewer female Chinook spawned during the fall of 2010 (Table 9). This estimate was based on an assumed 6% egg-to-migrant survival rate. Egg-to-migrant survival of Hamma Hamma Chinook salmon was estimated to be 6% for the 2011 outmigration and we considered this to be a reasonable estimate for the Duckabush. If egg-to-migrant survival was as low as 2%, spawning escapement may have been as high as 24 spawners. If egg-to-migrant survival was as high as 20%, escapement may have been as low as 2 spawners. However, the estimated escapement of Duckabush fall Chinook salmon has not surpassed 20 total spawners since 2001, and we consider it to be unlikely that 24 adult Chinook would have spawned undetected.

TABLE 9.—Back-calculation of juvenile production to potential 2011 Duckabush Chinook spawner escapements based on range of egg-to-migrant survival values. Potential egg deposition, fecundity, male to female ratios were held constant for these calculations.

Juvenile Production	Estimated Survival	Potential Egg Deposition	Fecundity	Number of Females	Total Spawners
1,219	1.0%	121,900	5,000	24	49
1,219	2.0%	60,950	5,000	12	24
1,219	5.0%	24,380	5,000	5	10
1,219	10.0%	12,190	5,000	2	5
1,219	15.0%	8,127	5,000	2	3
1,219	20.0%	6,095	5,000	1	2

The median outmigration date for Duckabush Chinook salmon was two months later than the median outmigration date observed for Hamma Hamma Chinook salmon. A possible explanation for the large difference in outmigration timing is the lack of available rearing habitat. Duckabush Chinook fry began showing signs of freshwater growth during statistical week 16 and continued throughout the remainder of the trapping season. If lengths greater than 45-mm FL represent freshwater growth (Pflug and Mobrand 1989), over 30% of Duckabush Chinook fry showed some sign of growth before being captured in the trap. In comparison, less than 2% of Hamma Hamma Chinook fry showed sign of freshwater growth as they passed the trap. This lack of growth and delayed outmigration timing might suggest that a large majority of fry were unable to find suitable freshwater rearing habitat.

Hamma Hamma Chum Salmon

The 2011 freshwater production of Hamma Hamma fall chum salmon was four times the production of summer chum. This production resulted from a spawning escapement of fall chum (2,438) that was nearly double the number of summer chum (1,472). The total chum escapement (summer and fall run combined) was the lowest observed since juvenile trapping began in 2002 (Figure 12).

Egg-to-migrant survival of fall chum for the 2011 outmigration was nearly two and half times higher than survival of summer chum. Different survival rates for summer and fall chum stocks in the Hamma Hamma River differed from the comparable survival of chum stocks in the

Duckabush River for the same spawning year. . In the Duckabush River, comparable survival rates for summer and fall chum salmon suggested that both stocks were equally impacted by environmental factors during their incubation period. In the Hamma Hamma, the low survival of summer chum compared to fall chum may be explained if summer chum were more susceptible to environmental disturbances based on the timing of peak flows and the spawn timing. Differential survival of chum stocks in the Hamma Hamma River may also be explained if summer chum redds experienced a high rate of superimposition by fall chum spawning. The Hamma Hamma River has an impassable waterfall at river mile 2 that restricts upstream salmonid migration and limits the amount of viable gravel for spawning. This lack of available spawning habitat may restrict fall chum spawning to areas with pre-existing summer chum redds.

In the Hamma Hamma River, no correlation is apparent between egg-to-migrant survival of chum salmon (both stocks combined) and peak average daily flow (Figure 13). The total chum egg-to-migrant survival associated with the 2011 outmigration was the second highest observed since 2002 whereas peak daily average flow was moderate compared to previous trapping seasons. A possible explanation for the lack of correlation between survival and flow may include the relative abundance of spawning stocks and the timing of flow events. Fall chum spawners have historically returned in higher numbers to the Hamma Hamma River than summer chum spawners. Fall chum spawn throughout November and December, which is later than many of the peak flow events associated with the entirety of the chum spawning period. If the Duckabush flow gage (USGS #12054000) can be used as a surrogate for Hamma Hamma flows, most of the peak daily average flow events between 2002 and 2011 have occurred before December 1 of each year. If these flow events occurred before a majority of the fall chum had spawned, then we would not expect peak flow events to have a large impact on the fall chum survival. As additional years of summer versus fall chum production become available, we will be able to further test this hypothesis.

The peak of the 2011 summer chum out-migration occurred five weeks earlier than Hamma Hamma fall chum. A similar pattern was observed on the Duckabush, where the peak of summer chum out-migration occurred four weeks earlier than fall chum. Despite these general similarities, the stock-specific patterns of chum outmigration differed between watersheds. The 2011 out-migration of Hamma Hamma summer chum appeared to have two modes, an initial peak during statistical week 11 (middle of March) and a second peak during statistical week 17 (middle of April). This result contrasted with Duckabush summer chum who exhibited a single peak and a notable drop in abundance following this peak. Also, the median migration dates for summer and fall chum in both systems were also not very correlated. Summer and fall chum in the Duckabush River had median migration dates that were two to three weeks earlier than the Hamma Hamma River. Possible explanations for the differences may include differences in incubation temperatures for a portion of the developing summer chum eggs or a protracted spawning period for summer chum within the Hamma Hamma River. This protracted outmigration was unexpected and will be further examined with genetic sampling of additional years of the juvenile outmigration in the Hamma Hamma River.

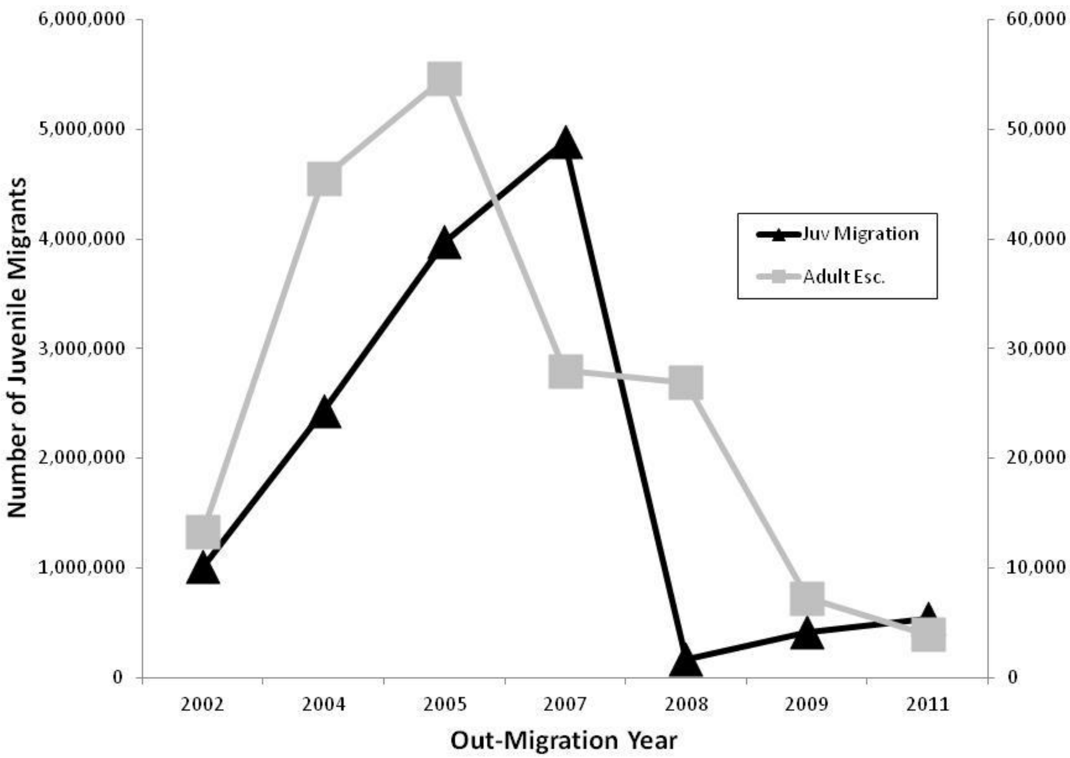

FIGURE 12.─Number of spawners and juvenile migrants by outmigration year for the Hamma Hamma River chum salmon (summer and fall run combined). Estimates are not available for the 2003, 2006, and 2010 outmigration year.

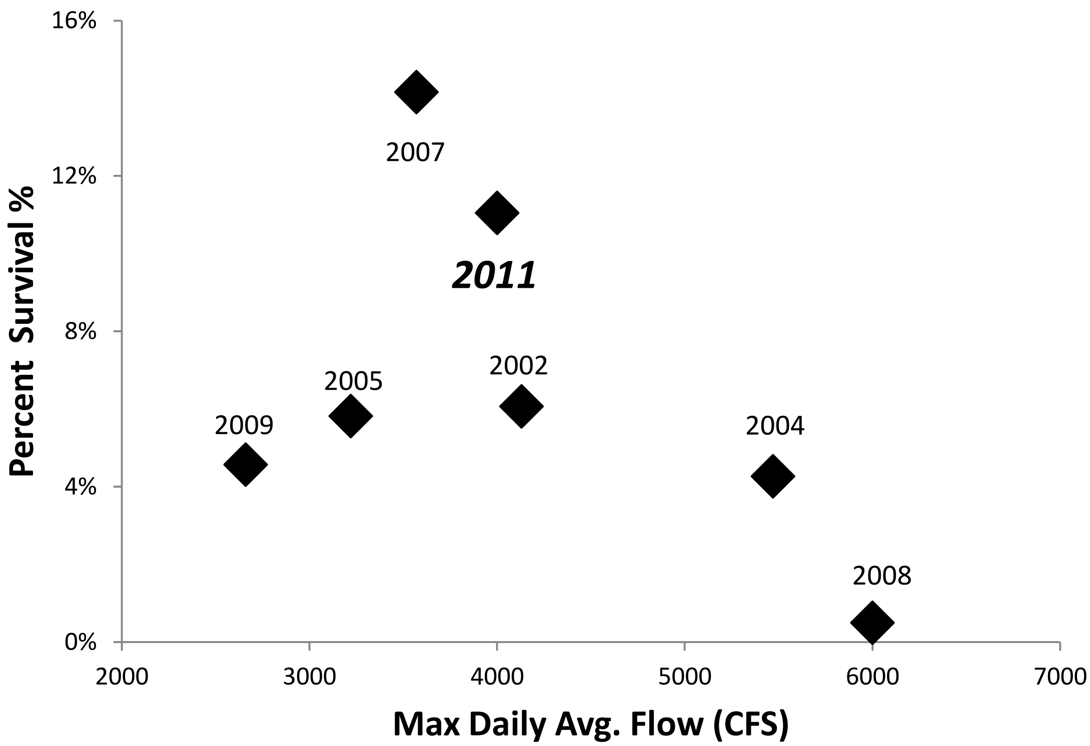

FIGURE 13.—Number of spawners and juvenile migrants by out-migration year for the Hamma Hamma River chum salmon (out-migration year 2002, 2004, 2005, 2007, 2008, 2009 and 2011). Due to the lack of a flow gage on the Hamma Hamma River, incubation flow was approximated as the maximum daily average flow at USGS gage #12054000 (Duckabush River near Brinnon) between September 1 and December 31.

Hamma Hamma Chinook Salmon

A very large portion (88%) of the estimated Chinook production was originally misidentified as chum in the field catches during the early parts of the trapping season. Without the additional information provided by genetic sampling, the misidentification would have resulted in a severely underestimated Chinook production, as well as a slightly overestimated chum production. Therefore, the 2011 Chinook results can not be directly compared to previous years because the error rate in identification is unknown from the previous years. The genetic sampling revealed an issue with the data quality (i.e., species identifications) which is not typically tested in juvenile trapping studies. Based on results from the 2011 season, future estimates of Hamma Hamma Chinook production will be based on both genetic sampling and improvements in the field identification methods.

The peak out-migration and median migration date of Chinook salmon in the Hamma Hamma River occurred during the first half of February (statistical week 6 and 8) in 2011. Over 90% of the Chinook out-migration had occurred by statistical week 15 (early April). This early out-migration timing is very different from what was observed in the Duckabush River. The peak migration on the Duckabush occurred during the middle of April (statistical week 15) and continued through the beginning of July. The median outmigration date of Hamma Hamma Chinook salmon occurred nearly two months earlier than the median migration date of Duckabush Chinook salmon. The difference in migration timing may be explained by spawn timing, incubation temperatures (developmental rate), or the amount of available rearing habitat. The Hamma Hamma River has an impassable barrier (water fall) at river mile 2 whereas rearing habitat for anadromous fish in the Duckabush stretches 7 miles. We hypothesize that the falls on the Hamma Hamma limit the amount of available habitat for juvenile Chinook to rear and grow within the freshwater environment. Hamma Hamma Chinook fry showed very little growth upon outmigration. In contrast, Duckabush Chinook salmon began to show signs of growth within 3 weeks of passing the trap. This suggests that the low numbers of Duckabush Chinook salmon were able to find suitable habitat for some freshwater growth to occur and this resulted in a delay in their migration past the trap. However, freshwater growth of juvenile Chinook salmon in the Duckabush and Hamma Hamma rivers was minimal compared to that observed for fall Chinook salmon populations in Puget Sound, where subyearling Chinook outmigrants average more than 80-mm FL by June and July (Kinsel et al. 2008; Kiyohara and Zimmerman 2012; Topping and Zimmerman 2011).

Recommendations

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

(1) Improve and verify visual identification of Chinook and chum fry throughout the trapping season.
(2) Partition Chinook migrants into their fry (early and small) and parr (late and large) outmigration strategies.
(3) Increase trapping efficiency for yearling migrants to estimate juvenile coho and steelhead smolt production.

Appendix A

Statistical Weeks for 2011

APPENDIX A1.—Statistical Weeks for 2011.

Stat Week	2011
1	Jan 1 - Jan 2
2	Jan 3 - Jan 9
3	Jan 10 - Jan 16
4	Jan 17 - Jan 23
5	Jan 24 - Jan 30
6	Jan 31 - Feb 6
7	Feb 7 - Feb 13
8	Feb 14 - Feb 20
9	Feb 21 - Feb 27
10	Feb 28 - Mar 6
11	Mar 7 - Mar 13
12	Mar 14 - Mar 20
13	Mar 21 - Mar 27
14	Mar 28 - Apr 3
15	Apr 4 - Apr 10
16	Apr 11 - Apr 17
17	Apr 18 - Apr 24
18	Apr 25 - May 1
19	May 2 - May 8
20	May 9 - May 15
21	May 16 - May 22
22	May 23 - May 29
23	May 30 - Jun 5
24	Jun 6 - Jun 12
25	Jun 13 - Jun 19
26	Jun 20 - Jun 26
27	Jun 27 - Jul 3
28	Jul 4 -Jul 10
29	Jul 11 - Jul 17
30	Jul 18 - Jul 24
31	Jul 25 - Jul 31

Appendix B

Duckabush River catches, trap efficiencies, and abundance estimates for 2011

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 2011. 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*	1/10-1/16	30	30	60	8.10E+01	31	2	640	1.09E+05
4*	1/17-1/23	10	21	31	6.24E+01	31	2	331	3.59E+04
5	1/24-1/30	52	0	52	0.00E+00	31	2	555	7.37E+04
6	1/31-/2/6	608	0	608	0.00E+00	179	19	5,472	1.31E+06
7	2/7-2/13	1,026	0	1,026	0.00E+00	351	38	9,260	1.98E+06
8	2/14-2/20	1,026	543	1,569	2.12E+02	210	25	12,733	5.37E+06
9	2/21-2/27	1,629	0	1,629	0.00E+00	210	25	13,220	5.77E+06
10	2/28-3/6	3,703	0	3,703	0.00E+00	210	18	41,123	7.73E+07
11	3/7-3/13	8,281	3,375	11,656	4.77E+05	105	21	56,161	1.20E+08
12	3/14-3/20	7,857	3,398	11,255	1.46E+06	315	41	84,680	2.29E+08
13	3/21-3/27	7,718	0	7,718	0.00E+00	105	8	90,901	7.57E+08
14	3/28-4/3	2,550	0	2,550	0.00E+00	210	17	29,892	4.33E+07
15	4/4-4/10	1,611	0	1,611	0.00E+00	103	15	10,472	5.51E+06
16	4/11-4/17	791	0	791	0.00E+00	184	20	6,968	2.01E+06
17	4/18-4/24	688	0	688	0.00E+00	198	13	9,779	6.05E+06
18	4/25-5/1	417	0	417	0.00E+00	87	5	6,116	5.05E+06
19	5/2-5/8	127	0	127	0.00E+00	56	5	1,207	1.95E+05
20	5/9-5/15	43	0	43	0.00E+00	30	4	267	1.11E+04
21*	5/16-5/22	26	2	28	6.68E-03	3	4	174	4.97E+03
22*	5/23-5/29	47	0	47	0.00E+00	30	4	291	1.31E+04
23*	5/30-6/5	2	0	2	0.00E+00	30	4	12	7.52E+01
Totals		38,242	7,369	45,611	1.93E + 06	2,584	276	380,253	1.26E + 09

APPENDIX B2.—Estimated abundance of summer (U_s) and fall chum (U_f) fry migrants at the Duckabush River screw trap in 2011. 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*	640	1.09E+05	10	1.00	0.00099	10	0.00	0.00475	640	1.09E+05	0	1.43E+03
4*	331	3.59E+04	10	1.00	0.00099	10	0.00	0.00475	331	3.60E+04	0	3.49E+02
5	555	7.37E+04	10	1.00	0.00099	10	0.00	0.00475	555	7.40E+04	0	1.11E+03
6	5,472	1.31E+06	10	1.00	0.00099	10	0.00	0.00475	5,472	1.34E+06	0	1.36E+05
7	9,260	1.98E+06	20	0.95	0.002995	20	0.05	0.004875	8,797	2.04E+06	463	4.13E+05
8	12,733	5.37E+06	29	0.97	0.00153	29	0.03	0.002827	12,294	5.24E+06	439	4.50E+05
9	13,220	5.77E+06	30	0.93	0.002476	30	0.07	0.003729	12,339	5.44E+06	881	6.56E+05
10	41,123	7.73E+07	40	0.95	0.001465	40	0.05	0.002405	39,067	7.22E+07	2,056	4.08E+06
11	56,161	1.20E+08	40	0.98	0.000873	40	0.03	0.001813	54,757	1.17E+08	1,404	5.57E+06
12	84,680	2.29E+08	40	0.98	0.000873	40	0.03	0.001813	82,563	2.24E+08	2,117	1.27E+07
13	90,901	7.57E+08	40	0.95	0.001465	40	0.05	0.002405	86,356	6.94E+08	4,545	1.99E+07
14	29,892	4.33E+07	39	0.87	0.003195	39	0.13	0.004159	26,059	3.56E+07	3,832	4.25E+06
15	10,472	5.51E+06	30	0.53	0.008912	30	0.47	0.010166	5,585	2.50E+06	4,887	2.26E+06
16	6,968	2.01E+06	20	0.70	0.011548	20	0.30	0.013428	4,878	1.52E+06	2,091	8.06E+05
17	9,779	6.05E+06	15	0.67	0.016533	15	0.33	0.01904	6,520	4.17E+06	3,260	2.38E+06
18	6,116	5.05E+06	14	0.21	0.013658	14	0.79	0.016344	1,311	6.74E+05	4,805	3.65E+06
19	1,207	1.95E+05	10	0.00	0.00099	10	1.00	0.00475	0	1.25E+03	1,207	2.01E+05
20	267	1.11E+04	10	0.10	0.01099	10	0.90	0.01475	27	7.70E+02	240	9.87E+03
21*	174	4.97E+03	10	0.10	0.01099	10	0.90	0.01475	17	3.26E+02	156	4.39E+03
22*	291	1.31E+04	10	0.10	0.01099	10	0.90	0.01475	29	9.20E+02	262	1.17E+04
23*	12	7.52E+01	10	0.10	0.01099	10	0.90	0.01475	1	1.62E+00	11	6.21E+01
Totals	380,253	1.E+09	397	-	0	397	-	0	347,597	1.E+09	32,656	6.E+07

APPENDIX B3.—Catch, marked and recaptured fish, and estimated abundance of Chinook fry migrants at the Duckabush River screw trap in 2011. Release groups were pooled to form six strata. Missed catch and associated variance were calculated for periods the trap did not fish.

		Catch					Abundance	
Strata	**Date**	**Actual**	**Missed**	**Variance**	**Marked**	**Recaptured**	**Estimated**	**Variance**
1	1/10-1/31	0	0	0.00E+00	31	2	0	1.40E+02
2	2/1-3/11	0	0	0.00E+00	1,160	125	0	8.55E+01
3	3/12-3/15	0	0	0.00E+00	105	21	0	2.40E+01
4	3/16-3/17	0	0	0.00E+00	105	9	0	1.22E+02
5	3/18-3/22	2	0	0.00E+00	210	32	13	1.13E+02
6	3/23-7/27	109	0	9.09E-01	973	87	1,206	2.70E+04
	Season Total	111	0	0.908944	2,584	276	1,219	2.75E+04

Appendix C

Fork lengths of natural-origin salmon outmigrants in the Duckabush River, 2011

APPENDIX C1.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin chum fry in the Duckabush River screw trap in 2011.

	Statistical Week				Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
3	01/10/2011	01/16/2011	33.7	2.9	31	39	11	640
4	01/17/2011	01/23/2011	-	-	-	-	-	331
5	01/24/2011	01/30/2011	37.3	2.4	35	44	12	555
6	01/31/2011	02/06/2011	37.1	2.1	34	41	31	5,472
7	02/07/2011	02/13/2011	38.1	1.6	35	43	41	9,260
8	02/14/2011	02/20/2011	38.3	1.5	35	42	50	12,733
9	02/21/2011	02/27/2011	39.4	2.0	34	44	50	13,220
10	02/28/2011	03/06/2011	38.2	1.6	34	43	60	41,123
11	03/07/2011	03/13/2011	38.1	1.7	35	41	40	56,161
12	03/14/2011	03/20/2011	39	1.4	36	43	40	84,680
13	03/21/2011	03/27/2011	39.3	1.8	36	44	60	90,901
14	03/28/2011	04/03/2011	40	2.2	37	44	40	29,892
15	04/04/2011	04/10/2011	38.7	1.9	32	43	50	10,472
16	04/11/2011	04/17/2011	39.1	1.6	36	44	40	6,968
17	04/18/2011	04/24/2011	39.1	1.9	36	44	35	9,779
18	04/25/2011	05/01/2011	39	1.9	36	43	35	6,116
19	05/02/2011	05/08/2011	38.1	2.0	34	41	10	1,207
20	05/09/2011	05/15/2011	39.2	2.0	35	44	25	267
21	05/16/2011	05/22/2011	37.8	3.0	34	41	4	174
22	05/23/2011	05/29/2011	38	-	38	38	1	291
23	05/30/2011	06/05/2011	-	-	-	-	-	12
		Season Total	38.6	2.0	31	44	635	380,253

APPENDIX C2.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin 0+Chinook in the Duckabush River screw trap in 2011.

Statistical Week					Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
3	01/10/2011	01/16/2011	-	-	-	-	-	-
4	01/17/2011	01/23/2011	-	-	-	-	-	-
5	01/24/2011	01/30/2011	-	-	-	-	-	-
6	01/31/2011	02/06/2011	-	-	-	-	-	-
7	02/07/2011	02/13/2011	-	-	-	-	-	-
8	02/14/2011	02/20/2011	-	-	-	-	-	-
9	02/21/2011	02/27/2011	-	-	-	-	-	-
10	02/28/2011	03/06/2011	-	-	-	-	-	-
11	03/07/2011	03/13/2011	-	-	-	-	-	-
12	03/14/2011	03/20/2011	-	-	-	-	-	-
13	03/21/2011	03/27/2011	38.3	1.2	37	39	3	24
14	03/28/2011	04/03/2011	-	-	-	-	-	11
15	04/04/2011	04/10/2011	39.4	1.4	37	42	23	365
16	04/11/2011	04/17/2011	40.2	3.0	38	50	24	288
17	04/18/2011	04/24/2011	39.4	1.2	37	41	9	100
18	04/25/2011	05/01/2011	41.0	4.2	38	44	2	44
19	05/02/2011	05/08/2011	39.0	-	-	-	1	11
20	05/09/2011	05/15/2011	44.2	6.2	38	55	6	66
21	05/16/2011	05/22/2011	52.5	4.9	49	56	2	33
22	05/23/2011	05/29/2011	48.8	5.4	43	54	5	55
23	05/30/2011	06/05/2011	53.2	9.9	38	58	6	66
24	06/06/2011	06/12/2011	52.0	5.7	48	56	2	22
25	06/13/2011	06/19/2011	36.0	-	-	-	1	11
26	06/20/2011	06/26/2011	56.0	-	-	-	1	11
27	06/27/2011	07/03/2011	-	-	-	-	-	-
28	07/04/2011	07/10/2011	52.0	-	-	-	1	11
29	07/11/2011	07/17/2011	52.0	3.5	48	56	5	55
30	07/18/2011	07/24/2011	45.8	7.1	41	56	4	44
31	07/25/2011	07/31/2011	-	-	-	-	-	-
		Season Total	43.0	6.4	37	58	95	1,217

Appendix D

Hamma Hamma River catches, trap efficiencies, and abundance estimates for 2011

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 2011. 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. Estimates in this table are based on visual identification of chum in the field and apportioned into chum and Chinook based on genetic results shown in Appendix D2-4.

Week	Dates	n	$\hat{n}$	$\hat{u}$	$V(\hat{u})$	M	m	$\hat{U}$	$V(\hat{U})$
5*	1/27-1/30	12	0	12	0.00E+00	300	30	117	1.36E+03
6	1/31-/2/6	515	0	515	0.00E+00	300	30	5,000	7.43E+05
7	2/7-2/13	522	0	522	0.00E+00	217	40	2,776	1.61E+05
8*	2/14-2/20	209	43	252	4.34E+01	941	157	1,502	2.08E+04
9	2/21-2/27	1,457	0	1,457	0.00E+00	724	117	8,952	6.09E+05
10	2/28-3/6	1,756	0	1,756	0.00E+00	514	77	11,594	1.51E+06
11	3/7-3/13	2,008	2,744	4,752	1.19E+06	500	71	33,066	7.12E+07
12	3/14-3/20	2,056	3,544	5,600	1.59E+06	500	99	28,056	4.66E+07
13	3/21-3/27	7,053	0	7,053	0.00E+00	500	80	43,624	1.97E+07
14*	3/28-4/3	5,152	2,022	7,174	9.87E+05	1,300	212	43,819	4.47E+07
15	4/4-4/10	16,221	0	16,221	0.00E+00	800	132	97,692	5.99E+07
16	4/11-4/17	6,935	0	6,935	0.00E+00	500	30	112,079	3.70E+08
17*	4/18-4/24	8,656	0	8,656	0.00E+00	700	55	108,355	1.91E+08
18	4/25-5/1	5,597	0	5,597	0.00E+00	200	25	43,269	6.07E+07
19	5/2-5/8	1,373	0	1,373	0.00E+00	158	24	8,732	2.52E+06
20*	5/9-5/15	117	0	117	0.00E+00	158	24	744	2.18E+04
Totals		59,639	8,353	67,992	3.77E + 06	4,913	725	549,376	8.69E + 08

APPENDIX D2.— Estimated abundance of Chinook (U_{ch}) and chum (U_d) fry migrants at the Hamma Hamma River screw trap in 2011. Total migrants visually identified as chum in the field (U) were stratified by statistical week. The proportion of Chinook (P_{ch}) and chum (P_d) were based on *n* genetic samples collected during each weekly strata.

Wk	U	V(U)	n	Pch	v(Pch)	n	Pd	v(PU)	Uch	V(Uc)	Ud	V(Uf)
5*	117	1.36E+03	18	0.56	1.45E-02	18	0.44	1.45E-02	65	5.98E+02	52	4.47E+02
6	5,000	7.43E+05	18	0.56	1.45E-02	18	0.44	1.45E-02	2,778	5.82E+05	2,222	4.99E+05
7	2,776	1.61E+05	20	0.85	6.71E-03	20	0.15	6.71E-03	2,359	1.67E+05	416	5.42E+04
8*	1,502	2.08E+04	20	0.20	8.42E-03	20	0.80	8.42E-03	300	1.97E+04	1,202	3.21E+04
9	8,952	6.09E+05	19	0.26	1.08E-02	19	0.74	1.08E-02	2,356	8.99E+05	6,596	1.19E+06
10	11,594	1.51E+06	35	0.00	0.00E+00	35	1.00	0.00E+00	0	0.00E+00	11,594	1.51E+06
11	33,066	7.12E+07	39	0.00	0.00E+00	39	1.00	0.00E+00	0	0.00E+00	33,066	7.12E+07
12	28,056	4.66E+07	37	0.05	1.42E-03	37	0.95	1.42E-03	1,517	1.19E+06	26,539	4.28E+07
13	43,624	1.97E+07	38	0.00	0.00E+00	38	1.00	0.00E+00	0	0.00E+00	43,624	1.97E+07
14*	43,819	4.47E+07	38	0.00	0.00E+00	38	1.00	0.00E+00	0	0.00E+00	43,819	4.47E+07
15	97,692	5.99E+07	29	0.00	0.00E+00	29	1.00	0.00E+00	0	0.00E+00	97,692	5.99E+07
16	112,079	3.70E+08	19	0.00	0.00E+00	19	1.00	0.00E+00	0	0.00E+00	112,079	3.70E+08
17*	108,355	1.91E+08	12	0.00	0.00E+00	12	1.00	0.00E+00	0	0.00E+00	108,355	1.91E+08
18	43,269	6.07E+07	14	0.00	0.00E+00	14	1.00	0.00E+00	0	0.00E+00	43,269	6.07E+07
19	8,732	2.52E+06	9	0.00	0.00E+00	9	1.00	0.00E+00	0	0.00E+00	8,732	2.52E+06
20*	744	2.18E+04	9	0.00	0.00E+00	9	1.00	0.00E+00	0	0.00E+00	744	2.18E+04
Totals	549,376	8.69E+08	374	-	5.64E-02	374	-	5.64E-02	9,375	2.86E+06	540,001	8.65E+08

APPENDIX D3— Estimated abundance of summer (U_s) and fall chum (U_f) fry migrants at the Duckabush River screw trap in 2011. 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.

Wk	U	V(U)	n	Ps	v(Ps)	n	Pf	v(Pf)	Us	V(Us)	Uf	V(Uf)
5*	52	4.47E+02	8	0.88	1.69E-02	8	0.13	2.16E-02	45	3.80E+02	6	5.52E+01
6	2,222	4.99E+05	8	0.88	1.69E-02	8	0.13	2.16E-02	1,945	4.57E+05	278	1.04E+05
7	416	5.42E+04	3	1.00	3.30E-03	3	0.00	1.58E-02	416	5.46E+04	0	1.89E+03
8*	1,202	3.21E+04	16	0.81	1.08E-02	16	0.19	1.31E-02	977	3.64E+04	225	1.97E+04
9	6,596	1.19E+06	14	0.21	1.37E-02	14	0.79	1.63E-02	1,413	6.33E+05	5,183	1.42E+06
10	11,594	1.51E+06	35	0.74	5.90E-03	35	0.26	6.98E-03	8,613	1.62E+06	2,981	1.03E+06
11	33,066	7.12E+07	39	0.69	5.86E-03	39	0.31	6.82E-03	22,892	4.01E+07	10,174	1.37E+07
12	26,539	4.28E+07	35	0.29	6.29E-03	35	0.71	7.36E-03	7,583	7.65E+06	18,957	2.67E+07
13	43,624	1.97E+07	38	0.21	4.75E-03	38	0.79	5.74E-03	9,184	9.82E+06	34,440	2.31E+07
14*	43,819	4.47E+07	38	0.16	3.85E-03	38	0.84	4.84E-03	6,919	8.34E+06	36,900	4.08E+07
15	97,692	5.99E+07	29	0.10	3.65E-03	29	0.90	4.95E-03	10,106	3.53E+07	87,586	9.51E+07
16	112,079	3.70E+08	19	0.16	7.91E-03	19	0.84	9.89E-03	17,697	1.06E+08	94,382	3.83E+08
17*	108,355	1.91E+08	12	0.18	1.43E-02	12	0.82	1.75E-02	19,701	1.72E+08	88,654	3.30E+08
18	43,269	6.07E+07	14	0.07	5.81E-03	14	0.93	8.49E-03	3,091	1.08E+07	40,178	6.77E+07
19	8,732	2.52E+06	9	0.11	1.34E-02	9	0.89	1.76E-02	970	1.02E+06	7,762	3.29E+06
20*	744	2.18E+04	9	0.11	1.34E-02	9	0.89	1.76E-02	83	7.42E+03	661	2.66E+04
Totals	540,001	8.65E+08	326	-	1.47E-01	326	-	1.96E-01	111,633	3.94E+08	428,368	9.85E+08

APPENDIX D4.─Catch, marked and recaptured fish, and estimated abundance of Chinook fry migrants at the Hamma Hamma River screw trap in 2011. Release groups were pooled to form six strata. Missed catch and associated variance were calculated for periods the trap did not fish.

		Catch					Abundance	
Strata	**Date**	**Actual**	**Missed**	**Variance**	**Marked**	**Recaptured**	**Estimated**	**Variance**
1	1/27-2/9	1	0	0.00E+00	377	44	8	1.34E+02
2	2/10-2/20	0	0	0.00E+00	140	26	0	2.81E+01
3	2/21-2/22	0	0	0.00E+00	291	23	0	1.53E+02
4	2/23-3/2	0	0	0.00E+00	633	127	0	2.47E+01
5	3/3-3/18	0	0	0.00E+00	814	115	0	4.97E+01
6	3/19-4/8	81	15	6.13E+01	1,500	289	497	2.78E+03
7	4/9-4/25	49	0	0.00E+00	800	52	741	2.00E+04
8	4/26-6/26	6	0	0.00E+00	358	49	43	3.45E+02
Season Total		137	15	6.13E+01	4,913	725	1,289	2.35E+04

Appendix E

Fork lengths of natural-origin salmon outmigrants in the Hamma Hamma River, 2011

APPENDIX E1.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin chum fry in the Hamma Hamma River screw trap in 2011.

	Statistical Week				Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
5	01/24/2011	01/30/2011	-	-	-	-	-	52
6	01/31/2011	02/06/2011	37.8	1.7	35	41	19	2,222
7	02/07/2011	02/13/2011	39.0	2.0	37	41	3	416
8	02/14/2011	02/20/2011	38.5	1.5	37	41	17	1,202
9	02/21/2011	02/27/2011	37.7	1.0	36	39	15	6,596
10	02/28/2011	03/06/2011	38.0	1.2	36	41	40	11,594
11	03/07/2011	03/13/2011	37.8	1.7	34	42	40	33,066
12	03/14/2011	03/20/2011	37.7	1.9	34	42	38	26,539
13	03/21/2011	03/27/2011	37.9	1.5	35	41	40	43,624
14	03/28/2011	04/03/2011	38.0	1.5	34	41	40	43,819
15	04/04/2011	04/10/2011	37.1	1.1	35	39	30	97,692
16	04/11/2011	04/17/2011	37.2	1.1	35	39	20	112,079
17	04/18/2011	04/24/2011	38.4	2.1	35	42	15	108,355
18	04/25/2011	05/01/2011	39.1	1.8	36	42	15	43,269
19	05/02/2011	05/08/2011	37.0	0.8	36	38	10	8,732
20	05/09/2011	05/15/2011	-	-	-	-	-	744
		Season Total	37.8	1.6	34	42	342	540,001

APPENDIX E2.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin Chinook fry in the Hamma Hamma River screw trap in 2011.

	Statistical Week				Range		Number	Migration
No	**Begin**	**End**	**Average**	**St. Dev**	**Min**	**Max**	**Sampled**	**Estimate**
5	01/24/2011	01/30/2011	-	-	-	-	-	65
6	01/31/2011	02/06/2011	37.9	1.4	35	40	11	2,786
7	02/07/2011	02/13/2011	37.6	1.9	35	41	17	2,359
8	02/14/2011	02/20/2011	39.0	0.0	-	-	3	300
9	02/21/2011	02/27/2011	37.0	1.0	36	38	5	2,356
10	02/28/2011	03/06/2011	-	-	-	-	-	0
11	03/07/2011	03/13/2011	-	-	-	-	-	0
12	03/14/2011	03/20/2011	39.0	1.4	38	40	2	1,517
13	03/21/2011	03/27/2011	38.0	-	-	-	1	5
14	03/28/2011	04/03/2011	41.0	-	-	-	1	186
15	04/04/2011	04/10/2011	39.7	1.2	37	42	21	744
16	04/11/2011	04/17/2011	-	-	-	-	-	273
17	04/18/2011	04/24/2011	46.5	9.2	40	53	2	30
18	04/25/2011	05/01/2011	-	-	-	-	-	29
19	05/02/2011	05/08/2011	62.0	-	-	-	1	0
20	05/09/2011	05/15/2011	-	-	-	-	-	7
21	05/16/2011	05/22/2011	-	-	-	-	-	0
22	05/23/2011	05/29/2011	-	-	-	-	-	0
23	05/30/2011	06/05/2011	-	-	-	-	-	7
24	06/06/2011	06/12/2011	-	-	-	-	-	0
25	06/13/2011	06/19/2011	-	-	-	-	-	0
26	06/20/2011	06/26/2011	-	-	-	-	-	0
		Season Total	39.1	3.8	35	53	64	10,664

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