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Duckabush Chinook Salmon 6 Year Review: 2011-2016

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Washington Department of Fish and Wildlife
Fish Program Science

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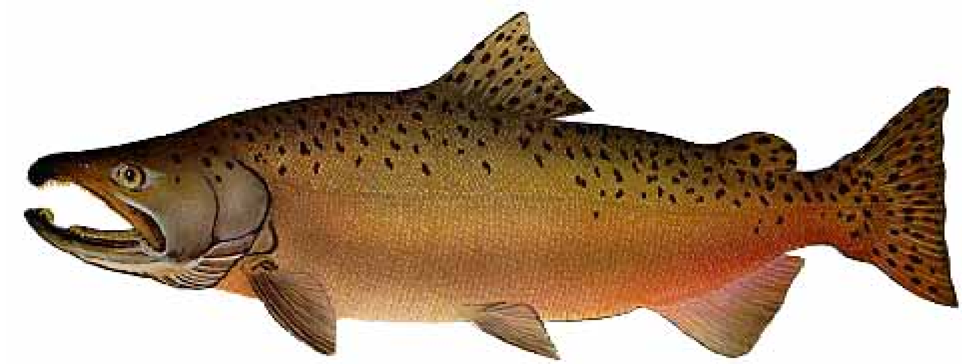

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Acknowledgements

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

A number of other individuals and agencies contributed to these projects. Diane Henry and Kurt Hanan, the adjacent landowners, provided access to the trap site. Mark Downen and Rick Ereth, WDFW Region 6, provided adult spawner counts and estimates.

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Executive Summary

This report summarizes the results from the juvenile monitoring study on the Duckabush River from 2011 to 2016. We evaluated freshwater productivity, juvenile outmigration timing, adult abundance and egg to migrant survival of Chinook salmon. Adult Chinook abundance was very low (≤ 20 adults) across all 6 cohorts in our study. Juvenile abundance was also low, ranging from 686 to 5,221 migrants. The majority of the juvenile captured at the trap were fry sized migrants (<40 mm) and showed very little instream growth following emergence. Parr sized migrants (>40 mm) composed roughly 13 to 38% of the outmigration and ranged in size from 41 to 85 mm. Juvenile outmigration timing was fairly uniform from the middle of January until the trap was removed either in late June or July. Egg to migrant survival varied 25-fold and only two of the five years were within the range of survivals observed at the Green and Skagit Rivers for Chinook salmon. Based on the results of this study, Duckabush Chinook appear to not be meeting the adult abundance criteria listed in the Puget Sound Salmon Recovery Plan.

Introduction

The Duckabush River is located on the Olympic Peninsula in Washington State and drains east into Hood Canal. The river is home to a number of anadromous fish species, including Chinook salmon (*Oncorhynchus tshawytscha),* summer and fall timed chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), coho salmon (*O. kisutch*), and steelhead trout (*Oncorhynchus mykiss*). Three of these salmonid species (Chinook, Summer Chum and Steelhead) are federally protected under the Endangered Species Act (ESA). For this report, we focus on Chinook salmon.

Chinook salmon in the Duckabush River are part of the Puget Sound Chinook Evolutionary Significant Unit (ESU) listed as *threatened* in 1999 by National Marine Fisheries Service (NMFS)(NOAA 1999). The Puget Sound Chinook salmon ESU is composed of all naturally spawning populations of Chinook and twenty-six artificial propagation programs from the Elwha River east, including Hood Canal, South Sound, North Sound and the Strait of Georgia. The NMFS Puget Sound Technical Review Team (TRT) identified 5 biogeographical regions within the ESU based on physical and ecological differences that allowed for groups of salmon to evolve in common (Ruckelhaus et al. 2006). These regions are the Strait of Georgia, Strait of Juan de Fuca, Whidbey basin, Central/South Sound and Hood Canal. Within the Hood Canal region, two populations of Chinook are independently recognized, the Skokomish River Chinook and Mid-Hood Canal stocks (Ruckelhaus et al. 2006). The Mid-Hood Canal stock is a combination of Chinook from the Hamma Hamma River, Duckabush River and Dosewallips River.

Following the listing, NMFS was required to formulate a recovery plan for the conservation of Chinook salmon within the Puget Sound ESU. Local, state and tribal agencies throughout Puget Sound put together a series of draft recovery plans for their regional areas. NOAA, in conjunction with the TRT and Shared Salmon Strategy, reviewed and combined these plans into a single recovery document, titled the Puget Sound Salmon Recovery Plan (National Marine Fisheries Service 2006). Recovery objectives and criteria for individual stocks are based on long term population viability. Population viability is defined as a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity over a 100 year time frame (McElhany et al. 2000). The TRT evaluates population viability using the Viable Salmon Population (VSP) metrics: abundance, productivity, spatial distribution and diversity(McElhany et al. 2000). Included in the plan, the TRT determined that in order for the Puget Sound Chinook ESU to maintain long term viability, two independent Chinook populations within Hood Canal must reach their recovery benchmarks. Using the VSP metrics, the TRT calculated planning targets for population abundance (adult escapement) and productivity (adult recruits per spawner) for each sub-population of the Mid-Hood Canal Chinook stock (Hamma Hamma, Duckabush and Dosewallips) to achieve recovery. The TRT lists both a high productivity and low productivity escapement target because a more productive population with less spawners has the same level of risk as populations with low productivity with more spawners. The Duckabush high productivity recovery targets calls for an escapement of 325 adults with a productivity of three adult returners per spawner and the low productivity target escapement of 1,200 adults with a productivity of one adult return per spawner. The plan lays out a series of harvest reduction measures, hatcheries reintroduction and supplementation strategies, and habitat preservation and restoration measures needed to achieve recovery.

Adult escapement estimates for the Duckabush only go back to 1990 and were chronically low (<10) between 1990 and 1997. In an attempt to increase adult returns of Chinook to the Duckabush, a hatchery supplementation program was operated from 1995 to 1999. Chinook that were released came from the George Adams hatchery on the Skokomish River. The George Adams Chinook stock was originally derived from the Green River, Soos Creek hatchery. Adult returns increased during the period of supplementation (range 12-151) but immediately fell back to pre-supplementation levels when the program ended. Genetic testing has revealed that most of the Chinook present in the Hood Canal region are similar and appear to reflect influence from hatchery releases in the region, mostly from the Green River broodstock (Myers et al. 1998).

This report is a six year review that covers juvenile migration years 2011 to 2016. We investigate the differences in timing of juvenile outmigration, freshwater productivity, adult abundance and fry vs parr abundance for Duckabush River Chinook. In addition, we compare our observations of Duckabush Chinook with what is being observed in other Puget Sound Chinook populations.

Methods

Study Site

The Duckabush is a high-gradient watershed that drains into the western side of Hood Canal, Washington. The Duckabush system originates in the Olympic Mountains within Olympic National Park. The river is classified as a transitional watershed with large magnitude flow events typically occurring twice each year, during rain events in the winter months and snow melt in the spring months. Human development is minimal relative to much of the Puget Sound region 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. Anadromous fish can only access the lower reach of the Duckabush due to an impassable waterfall at river mile 8 (river km 13). In addition to Chinook salmon, steelhead trout, summer and fall chum salmon, coho salmon, pink salmon and cutthroat trout are present in the Duckabush River. Juvenile trap catches are described in previous reports (Weinheimer 2015; Weinheimer 2016).

Trap Operation

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

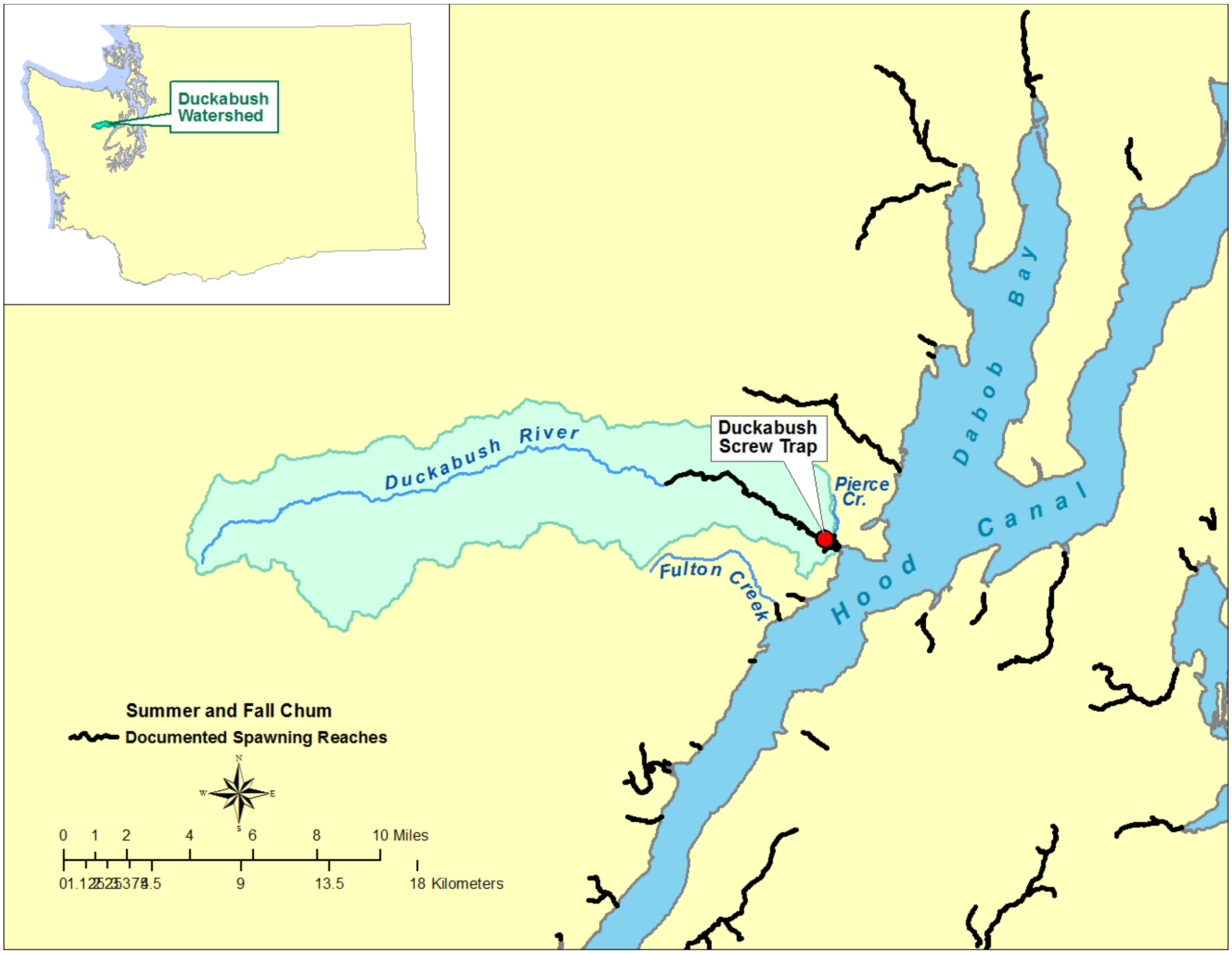

Figure 1. Location of Duckabush screw trap.

The screw trap was fished 24 hours a day, seven days a week, except when flows or debris would not allow the trap to fish effectively (Table 1).

Table 1. Summary of juvenile trap operations for the Duckabush River screw trap, 2011-2016.

Trap Year	Start Date	End Date	Hours Fished	Total Possible Hours	Percent Fished	Number of Outages	Avg Outage Hours	Std. Dev Outage Hours
2011	10-Jan	26-Jul	4,388.25	4,725.50	91.81%	6	64.54	36.1
2012	9-Jan	9-Jul	3,873.92	4,366.00	88.73%	10	49.21	38.1
2013	10-Jan	2-Jul	3,845.50	4,125.50	93.21%	6	46.67	21.5
2014	8-Jan	25-Jun	3,586.83	4,027.00	89.07%	7	62.88	47.9
2015	9-Jan	28-Jun	3,613.75	4,075.75	88.66%	8	57.75	41.9
2016	12-Jan	26-Jun	2,881.67	3,977.00	72.46%	13	84.26	79.7

Fish Collection

The trap was checked for fish at dawn each day throughout the trapping season. At each trap check, all captured fish were identified to species and enumerated. A subsample of all captured migrants was measured each week (fork length in mm, FL).

Trap efficiency trials were conducted with maiden-caught (i.e., fish captured for the first time) chum fry throughout the season. Due to low numbers of Chinook in our catch, we were unable to use them for mark-recapture tests during any of the six seasons. Chum fry are similar in size and were used as a surrogate to estimate trap efficiency. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and marked with Bismark-brown dye. Marked fish were allowed to recover in freshwater. Marked fish were released at dusk into fast-flowing water upstream of a bend in the river, approximately 75 meters from the trap. The release site was selected to maximize mixing of marked and unmarked fish while minimizing in-river predation between release and recapture. Trials were conducted every few days to allow adequate time for all marked fish to reach the trap. Most marked fish were caught the day immediately following a release. Dyed fish captured in the trap were recorded as recaptures.

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 and (4) total abundance. We did not estimate abundance before the trap was installed or after it was removed.

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

Equation 1

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

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

Equation 2

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

where:

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

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

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

Equation 3

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

where:

Equation 4

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

<u>(2) Efficiency strata.</u> Due to the low numbers of Chinook in the daily catch, chum efficiency trials were used as a surrogate for Chinook trap efficiency. Chum data 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.

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

Equation 5

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

Variance associated with the abundance estimator was modified to account for variance of the estimated catch during trap outages:

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

Equation 7

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

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

Equation 8

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

Coefficient of variation was:

Equation 9

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

Adult Escapement

Chinook salmon escapement was estimated using an Area-Under-the-Curve estimate based on redd counts and/or live fish counts (M. Downen, WDFW Region 6, personal communication). Live Chinook counts were adjusted by a visibility factor based on water clarity in order to account for fish not seen during individual surveys. Surveys were performed every 7 to 10 days. On the Duckabush, surveys were conducted from river mile 2.7 to the mouth. Jacks are not included in the estimates.

Egg-to-Migrant Survival

Egg-to-migrant survival was the number of female migrants divided by potential egg deposition (P.E.D.). Potential egg deposition was based on estimated female spawners above the trap site and estimated fecundity of 4,250 per female Chinook salmon and 1.5 males per female (M. Downen, WDFW, personal communication).

Freshwater Life History: Fry vs Parr

To describe the two different life history strategies utilized by sub yearling Chinook, we divided the entire outmigration into either fry or parr migrants based on size at the trap. For a given statistical week, the proportion of Chinook within each age class (≤ 40 mm FL, > 40 mm FL) was applied to the migration estimate for that week.

Results

Adult Abundance

Historical Duckabush Chinook escapement estimates date back to 1990 (Figure 2). Average returns during years we would expect supplemented hatchery fish to return (1998-2003) were 50 adults. Average returns during non-supplementation years (1990-1996 and 2004-2015) were 7 adults. No escapement data was available for 1997.

Chinook salmon escapement averaged 9 adults per year between 2010 and 2015 (Table 2). Zero Chinook were observed in the fall of 2010 and the largest estimated adult escapement during our juvenile monitoring study was 20 adults in 2015.

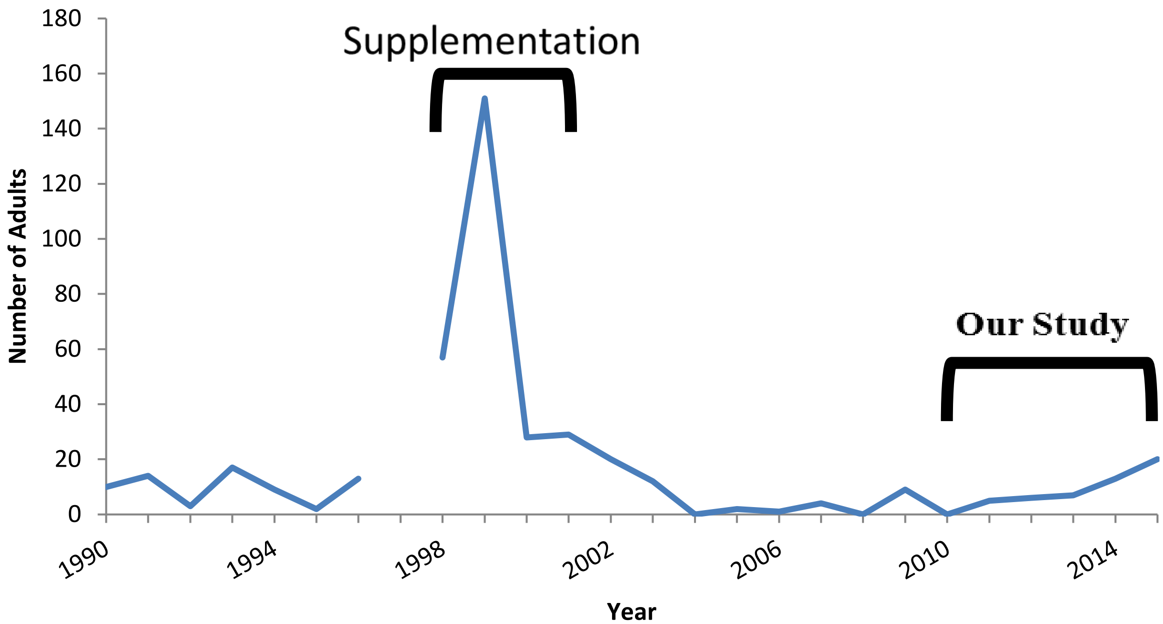

Figure 2. Adult escapement estimates for Duckabush fall Chinook, brood year 1990-2015.

Table 2. Adult escapement of Duckabush fall Chinook, return year 2010-2015.

Year	Escapement
2010	0
2011	5
2012	6
2013	7
2014	13
2015	20

Freshwater Productivity

Chinook abundance past the trapping site ranged 7 fold between 2011 and 2016 (Table 3). Freshwater production averaged 2,608 over the course of our 6 year study. Juvenile Chinook were captured in 2011 despite the fact that zero adult Chinook were observed in the river in the fall of 2010.

Table 3. Chinook freshwater abundance and coefficient of variation of Duckabush fall Chinook outmigration years 2011-2016.

Juvenile Migration Year	Estimated Freshwater Abundance	Estimated Juvenile Abundance CV
2011	1,219	13.49%
2012	2,788	16.51%
2013	5,221	6.23%
2014	4,555	8.80%
2015	1,179	9.75%
2016	686	0.66%

Fry vs Parr Abundance

Fry were more abundant than parr during the past 6 trappings seasons (Table 4). Parr migrants represented between 13 and 38% of the freshwater production. A higher proportion of fry migrants were captured during our highest total abundance outmigration years.

Table 4. Chinook fry and parr abundance and percent of migration from the Duckabush River, outmigration years 2011-2016.

	Juvenile Migrants				
Juvenile Migration Year	Fry		Parr		Total
	Abundance	% of Migration	Abundance	% of Migration	
2011	755	61.9%	464	38.1%	1,219
2012	1,890	67.8%	898	32.2%	2,788
2013	4,535	86.9%	686	13.1%	5,221
2014	3,591	78.8%	964	21.2%	4,555
2015	858	72.8%	321	27.2%	1,179
2016	495	72.2%	191	27.8%	686

Juvenile Timing

For 5 out of 6 years, the first Chinook migrants to the trap were captured during the month of January or early February (Table 5). The 2011 trapping season did not encounter its first Chinook until late March. The days between median fry and median parr migration ranged from 11 to 86 days. The median parr migration occurred in late April through May during all 6 years. Chinook migrants were captured on the last day of trapping in 2013 and 2014 (Table 5).

Table 5. First and last Chinook migrants and fry and parr arrival timing to smolt trap on Duckabush River, outmigration years 2011-2016.

Outmigration Year	First Chinook at Trap	Fry 50%	Parr 50%	Last Chinook at Trap
2011	3/21	4/13	5/29	7/21
2012	2/2	4/19	4/30	6/30
2013	2/4	4/2	5/26	7/2*
2014	1/31	4/6	5/16	6/25*
2015	1/10	2/21	5/17	6/2
2016	2/8	2/27	5/16	6/25

*Chinook captured on last day of trapping

Egg to Migrant

Egg to migrant survival averaged just over 20% between brood years 2010 and 2015 (Table 6). The 2010 brood had zero estimated females return to spawn therefore we were unable to estimate egg to migrant survival.

Table 6. Estimated number of females, potential egg deposition and egg to migrant survival for Duckabush River Chinook, brood years 2010-2015.

Brood Year	Estimated Number of Females	Potential Egg Deposition	Egg to Migrant %
2010	0	0	-
2011	2	9,239	30.18%
2012	3	11,087	47.09%
2013	3	12,935	35.21%
2014	6	24,022	4.91%
2015	9	36,957	1.86%

Discussion

Adult Abundance

Adult escapement during our study was well below the recovery objectives laid out by the TRT for Mid-Hood Canal Chinook. These estimates do not account for any terminal or marine fishery impacts that could remove potential returning adults. Exploitation rates for Mid-Hood Canal Chinook have ranged between 20 and 26% from return year 2010 to 2014 (personal communication, Jon Carey WDFW). The 2015 exploitation rate for Mid-Hood Canal Chinook was not available at the time of this publication. The exploitation rate represents the percentage of returning age 3 through 5 year olds for a given year that are assumed to have been impacted by fishing prior to reaching the spawning grounds. Using these rates, we can estimate that pre-terminal fisheries removed between 2 and 6 returning adults per year from 2011 to 2014 (Table 7). Even without any fishing mortality, Duckabush Chinook would still be returning at extremely low levels.

Table 7. Duckabush Chinook escapement, exploitation rate and expected additional adults if not fishing for brood years 2010 through 2014.

Year	Escapement	Exploitation Rate	No fishing, additional adults
2010	0	16.4%	-
2011	5	26.8%	2
2012	6	21.3%	2
2013	7	21.4%	2
2014	13	27.2%	6

Freshwater Productivity and Egg to Migrant Survival

The Duckabush is the only river of the three rivers (Dosewallips, Hamma Hamma and Duckabush Rivers) that make up the Mid-Hood Canal Chinook population that is currently monitored for Chinook freshwater productivity. The estimated number of Chinook that passed our trap during our study was very low. Freshwater abundance estimates ranged between 686 and 5,221 migrants and averaged less than 2,700 migrants during the past 6 seasons. The lack of juvenile production in the Duckabush was not a totally unexpected outcome given the low abundance of adult spawners.

It is possible that these estimates are conservative and may not encompass the entire outmigration for a given season due to the trap being taken out at the end of June as opposed to the end of July. During the 2011 season, the trap was fished until July 26 and nearly 10% of the entire outmigration was estimated to have passed the trap in the month of July. The remainder of the seasons (2012 through 2016) had ending dates ranging from June 25th to July 9th. Additional fish may have been encountered if trapping had continued to the end of July. Other Chinook stocks in Puget Sound that are derived from the Green River Chinook stock also exhibit juvenile Chinook migration in July and August. One example is the Nisqually River located in south Puget Sound. A rotary screw trap has been operated on the Nisqually since 2009, with the trap fishing from early January to the middle or end of August. Chinook migrants are routinely captured during the month of July (M. Klungle WDFW, personal communication). Between outmigration years 2011 and 2015, the percentage of July timed migrants ranged between 19 – 60% of the entire natural origin Chinook outmigration in the Nisqually River. Given that we captured Chinook in July during 2011 and what has been observed on the Nisqually River, it seems possible a portion of the Duckabush juvenile Chinook are outmigrating after trapping operations have ceased for the year.

Using the available spawning escapement and juvenile production numbers, we attempted to formulate egg to migrant survival estimates. We were only able to formulate estimates for 5 of the 6 years (brood years 2011 through 2015) due to no adults being observed during spawning ground surveys in the fall of 2010. Only two of the estimates (2014 and 2015) fall within the range of estimated Chinook egg to migrant survivals from the Skagit and Green Rivers (Table 8). The 2011 through 2013 brood years' survival estimates were all nearly 2 times higher than anything observed in the Skagit and Green. It seems unlikely that Duckabush Chinook would survive at such high levels compared to other Puget Sound Chinook populations. One hypothesis to explain the high survivals is that adult abundance was underestimated. Surveys are only performed from river mile 2.7 to the mouth each week through the season. Adult Chinook could be quickly moving through the survey reach area and are not being counted. Diminished visibility during surveys could also be impacting the ability for surveyors to see Chinook in deep holes. Furthermore, low abundance populations are notoriously difficult to accurately enumerate. A combination of these factors could be impacting the estimated number of adults spawning in the river, resulting egg to migrant survival rates that are biased high. Expanding the survey reach for Chinook in conjunction with continued smolt trapping could help refine future estimates and give further insight about Duckabush Chinook freshwater survival.

Table 8. Chinook egg to migrant survival estimates for Green River (outmigration year 2000 through 2015) and Skagit River (outmigration year 1993 through 2008).

Year	Stock	Range of egg to migrant survivals	Reference
1993-2008	Skagit	4.5% - 21.5%	Zimmerman et al. (2015)
2000-2015	Green	1.6% - 12.6%	Topping and Anderson (2016)

Fry vs Parr

Juvenile Chinook have been documented utilizing various life history strategies throughout Puget Sound (Topping and Anderson 2016; Zimmerman et al. 2015). These life history strategies are defined by the size, timing and age at which juvenile Chinook migrate out of the freshwater environment. We have categorized these phenotypes into three juvenile life history strategies; 1) fry, 2) parr and 3) yearlings. Fry and parr age-0 Chinook while smolts are fish that spent at least one winter in freshwater before migrating and are age-1 when entering the marine environment.

We did not encounter any yearling Chinook during our study so we will focus our analysis on fry and parr.

A majority of the Chinook that migrated past our trap we classified as fry (<40 mm). Fry sized migrants emerge from the gravel and immediately migrate downstream towards the estuary with little to no freshwater growth. By examining at the size distribution across years, the 36-40 mm fry size class predominates, and there appears to be a parr mode at approximately 60 mm (Figure 3). Given that the Duckabush only has 8 miles of habitat that is available to returning adults, it seems plausible that the prevalence of fry sized migrants could be due to the lack of rearing habitat.

In contrast to fry migrants, fish that exhibit the parr life history have reared in freshwater for 1 to 6 months following emergence from the gravel and subsequently are larger upon leaving the river. A majority of our parr migrants (> 72%) were in the 41 to 60 mm class with very few (< 2%) greater than 80 mm. We expected to see larger size parr Chinook similar to what is observed in other parts of Puget Sound. Each year the Green River typically sees some parr exceeding 100 mm (P. Topping WDFW, personal communication). Our largest parr during the past 6 seasons was 85 mm.

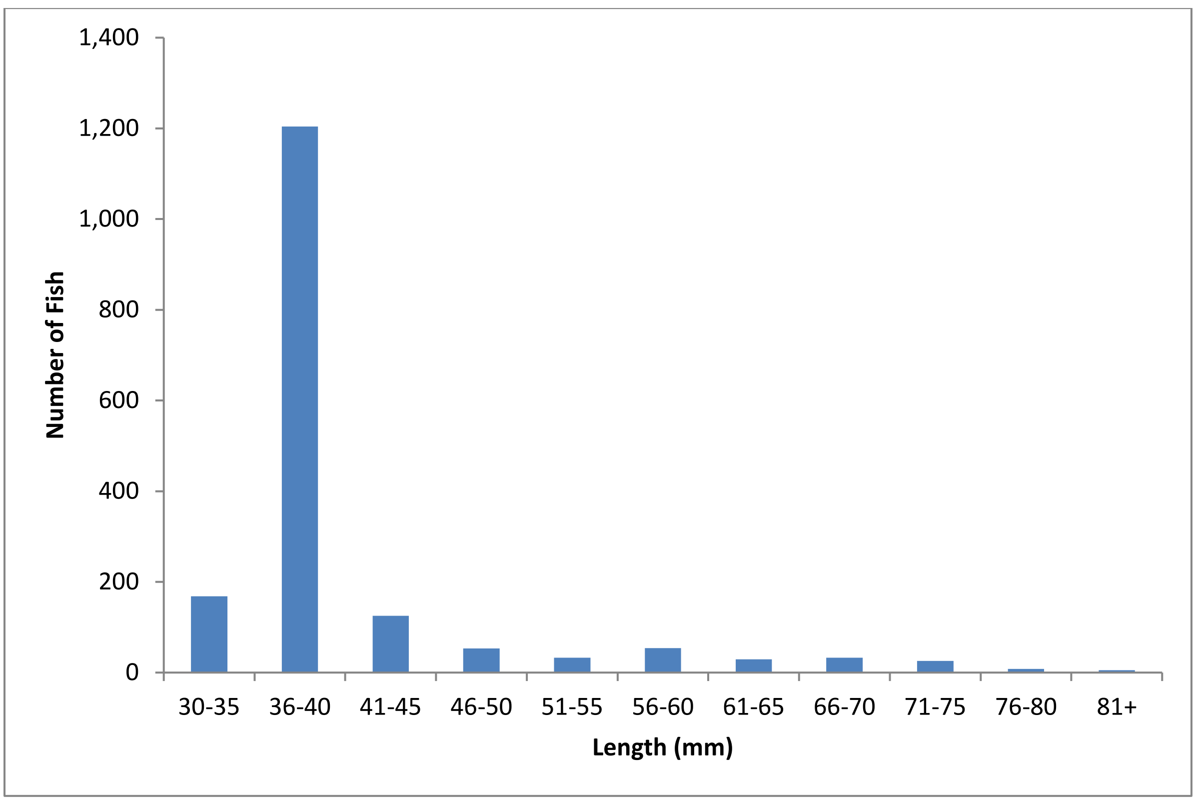

Figure 3. Duckabush River juvenile Chinook lengths measured at the smolt trap, outmigration years 2011 through 2016

Migration Timing

Juvenile Chinook outmigration timing did not appear to match the bimodal pattern that has been observed in other Puget Sound Chinook watersheds including the Skagit, Green and Nisqually Rivers (M. Klungle WDFW, personnal communication; Topping and Anderson 2016; Zimmerman et al. 2015). In those systems, a peak fry migration occurs during early spring (February - March) followed by another peak in late spring (May-June). Instead, Duckabush Chinook were observed starting their migration in the middle of January with a peak observed during the month of April, followed by a declining number of fish until the end of the trapping season (Figure 4). The lack of a distinct second peak comprised of parr size appears to be absent in the Duckabush. This could be due to the lack of available rearing habitat for juvenile Chinook once they emerge from the gravel. We will continue to monitor the fry-parr relationship for Duckabush Chinook in the future.

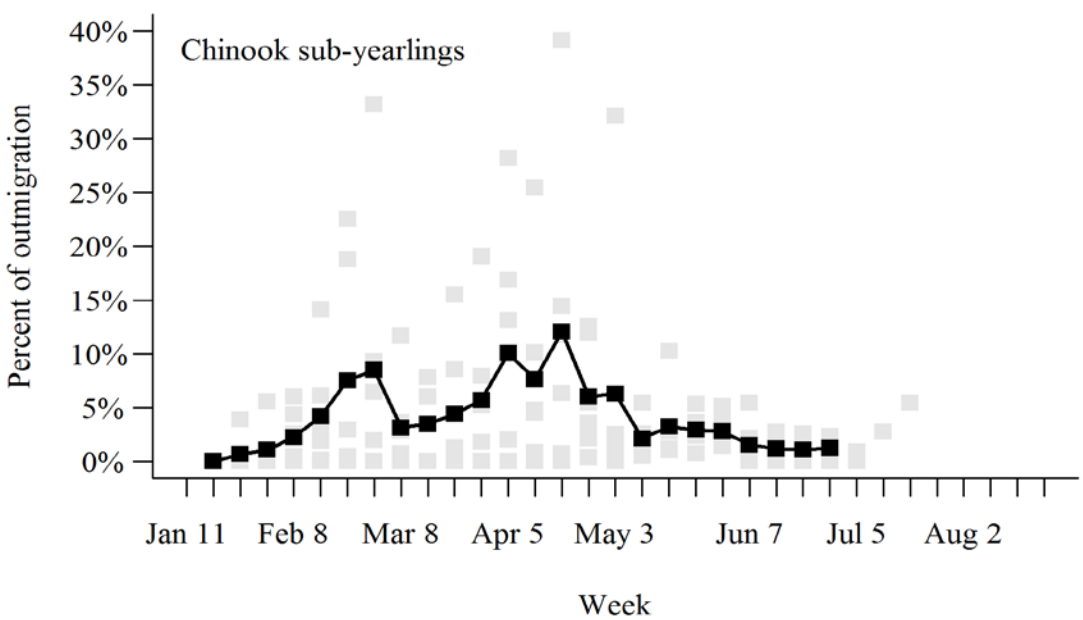

Figure 4. Daily outmigration timing of Duckabush Chinook, years 2011 through 2016.

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