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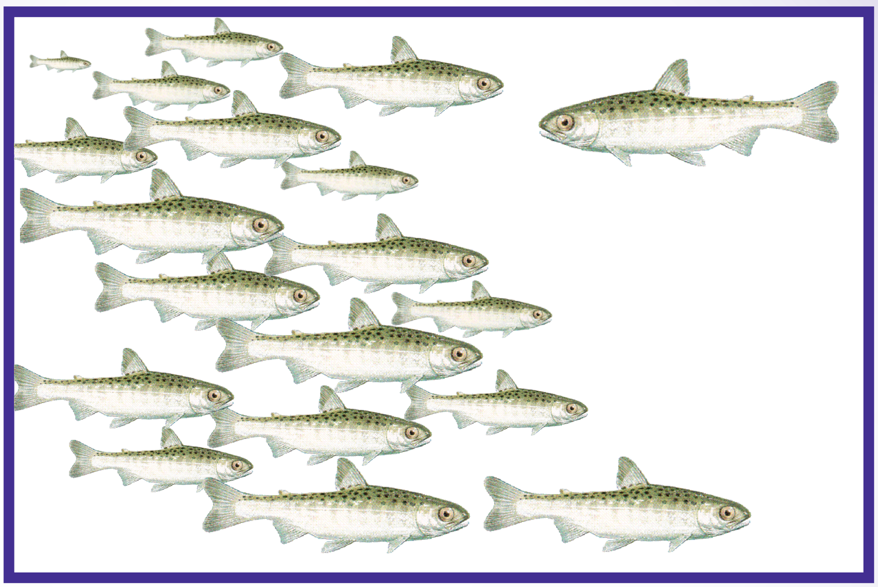
Mid-Hood Canal Juvenile Salmonid Evaluation: Duckabush River 2019



Josh Weinheimer

Washington Department of Fish and Wildlife
Fish Program Science

FPA 20-08

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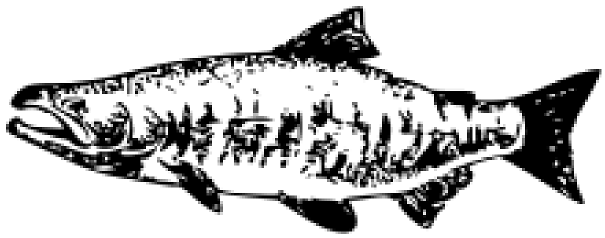

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Acknowledgements

Measuring juvenile salmonid production from large systems like the Duckabush River involves a tremendous amount of work. In 2019, the Duckabush River juvenile trap was operated by dedicated scientific technician Eric Kummerow from the Washington Department of Fish and Wildlife (WDFW). Much of the data reported here relied on the conscientious efforts of WDFW technician Phil Aurdal, who operated the trap in previous years. Logistical support was provided by Wild Salmon Production Evaluation Unit biologist Pete Topping.

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

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

Between 2011 and 2019, the Duckabush juvenile trap project was funded by Washington State General Funds, the Salmon Recovery Funding Board (SRFB) and Long Live the Kings. We thank the Washington State Recreation and Conservation Office, in particular Keith Dublanica, for administering the SRFB grant and the SRFB Monitoring Panel for their feedback on Fish In / Fish Out monitoring.

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Executive Summary

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

In 2019, a floating eight-foot screw trap was located at river mile 0.3 (0.48 rkm) and operated by WDFW from January 8 to June 23. The abundance of juvenile summer chum salmon was over 8 times larger than fall chum (Table 1). Egg-to-migrant survival was higher for summer than fall chum salmon. The median date of summer chum outmigration occurred 4 weeks earlier than the median of the fall chum outmigration.

TABLE 1.—Abundance, coefficient of variation (CV), egg-to-migrant survival, average fork length and median out-migration date for juvenile salmonids of natural origin leaving the Duckabush River, 2019.

	Abundance				
Species	**Estimate**	**CV**	**Survival**	**Median migration date**	**Average fork length**
Summer chum	379,002	6.21%	29.55%	3/17	-
Fall chum	42,919	17.68%	5.35%	4/14	-
Chinook	832	10.30%	-	3/28	42.6
Coho	1,525	24.79%	-	5/8	98.5
Steelhead	419	27.39%	-	5/8	162.9

Introduction

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

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

Chinook salmon in the Duckabush River are part of the Puget Sound Chinook ESU listed as *threatened* in 1999 by NMFS under the Endangered Species Act (NOAA 1999b). Hood Canal has two genetically distinct Chinook salmon populations, one in the Skokomish River and a Mid-Hood Canal population composed of the Hamma Hamma, Duckabush, and Dosewallips subpopulations (Ruckelhaus et al. 2006). Recovery goals for the Mid-Hood Canal population range between 1,325 and 5,200 adults, depending on the rate of freshwater productivity (adults per spawner). Specifically, the Duckabush sub-population recovery goals are between 325 and 1,200 adults. Both the Skokomish and Mid-Hood Canal stocks will need to achieve low risk status for Puget Sound ESU recovery.

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

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

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

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

This report summarizes results from the Duckabush River during the 2019 outmigration. In 2019, the primary objective of this study was to estimate the abundance, productivity and life history diversity of Chinook salmon, coho salmon, chum salmon and steelhead trout in the Duckabush River. We conclude by discussing patterns of freshwater survival observed across the 2011-2019 time series.

Methods

Trap Operation

On the Duckabush River, juvenile migrants were captured in a floating screw trap (8-foot or 1.5 m diameter) located on the right bank at river mile 0.3 (0.48 rkm), approximately 1,600 feet (490 m) upstream of the Highway 101 bridge (Figure 1). The trap consisted of two tapered flights, each four feet wide, wrapped 360 degrees around a nine foot long shaft. These flights were housed inside an eight foot diameter cone-shaped frame covered with perforated plating. The shaft was aligned parallel with the flow and was lowered to the water's surface via davits and winches mounted on two 20 ft aluminum pontoons. The trap fished half of an eight foot diameter circle with a cross sectional area of 16*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.

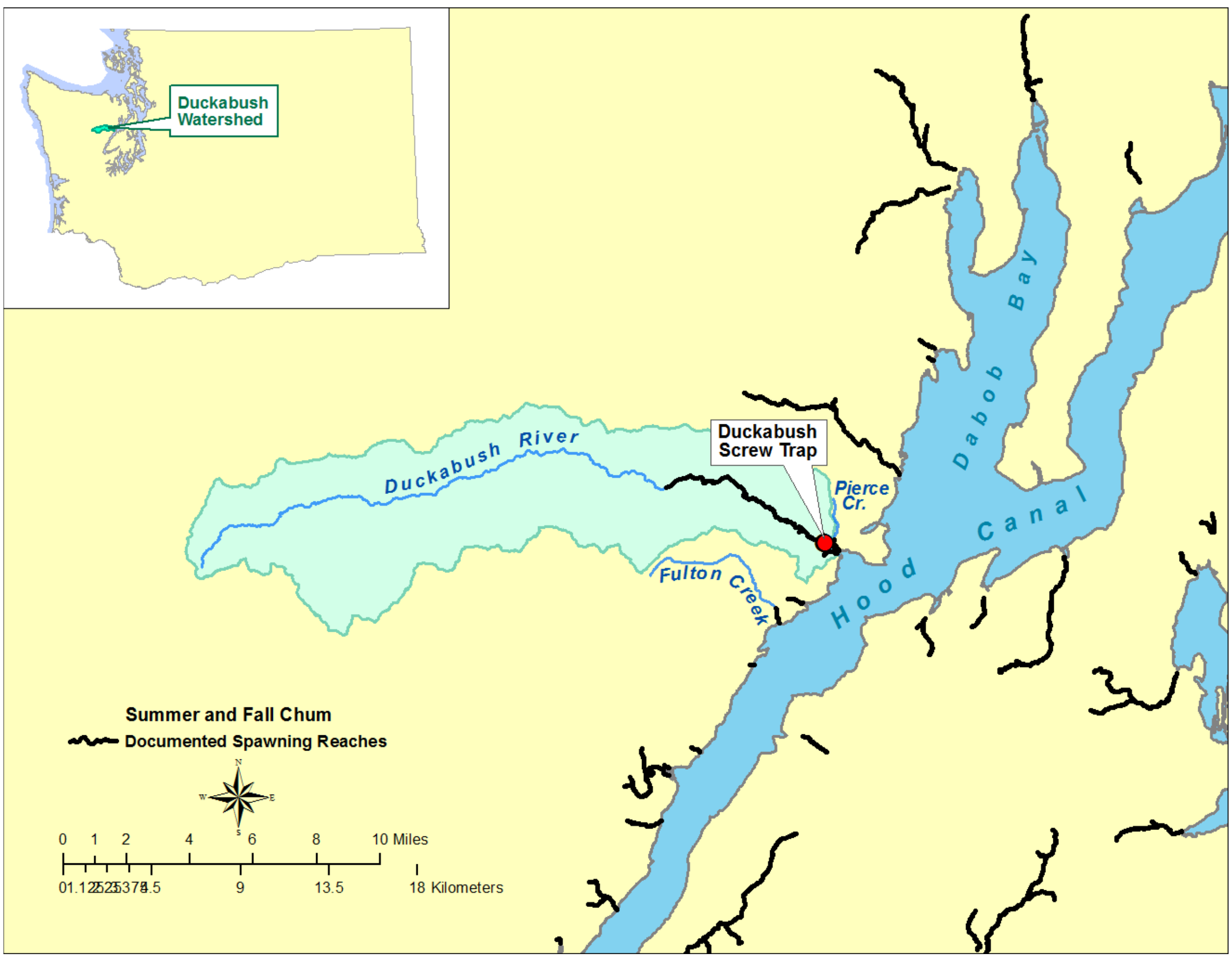

FIGURE 1.─Location of Duckabush screw trap.

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 2).

TABLE 2.─ Summary of juvenile trap operations for the Duckabush River screw trap, 2019

Trap	Start Date	End Date	Hours Fished	Total Possible Hours	Percent Fished	Number of Outages	Avg Outage Hrs	St Dev.
Duckabush	1/8	6/23	3,430.50	3,980.00	86.19%	5	109.9	36.0

Fish Collection

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

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

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

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

Trap efficiency trials were conducted with maiden-caught (i.e., fish captured for the first time) chum fry and coho yearlings throughout the season. Due to low catch of natural origin steelhead, trap efficiency for steelhead was estimated using natural origin coho smolts. No efficiency trials were conducted using Chinook due to very low catches of this species. Chum fry trap efficiency was used as a surrogate for Chinook during the 2019 season. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and fry releases were marked with Bismarkbrown dye whereas yearling releases were marked with alternating upper and lower caudal fin clips. Marked fish were allowed to recover in freshwater. Marked fry were released at dusk into fast flowing water upstream of a bend in the river, approximately 75 m distance from the trap. Marked yearlings were immediately released upstream of the trap, approximately at river km 3.2, a distance of 2.7 river km. The release site was selected to maximize mixing of marked and unmarked fish while minimizing in-river predation between release and recapture. Efficiency trials were conducted every few days to allow adequate time for all marked fish to reach the trap. Most marked fish were caught the day immediately following a release. Dyed and caudal marked fish captured in the trap were recorded as recaptures.

Genetic Identification of Juvenile Chum Salmon

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

Freshwater Production Estimate

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

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

Equation 1

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

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

Equation 2

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

where:

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

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

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

Equation 3

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

where:

Equation 4

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

<u>(2) Efficiency strata.</u> Chum data were organized into weekly strata (Monday – Sunday) in order to combine catch, efficiency trials, and genetic sampling data. Chinook were organized into time strata based on statistical pooling of the release and recapture data. Steelhead and coho data were combined into a single stratum that was representative of the entire trapping season. Pooling was performed using a *G*-test (Sokal and Rohlf 1981) to determine whether adjacent efficiency trials were statistically different. Of the marked fish released in each efficiency trial (M_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 (see Appendix A in Weinheimer et al 2011):

Equation 6

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

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

Equation 7

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

Variance for the stock-specific estimate was:

Equation 8

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

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

Equation 9

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

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

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

Equation 10

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

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

Equation 11

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

Coefficient of variation was:

Equation 12

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

Egg-to-Migrant Survival

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

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

Migration Timing

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

Chum

Total estimated catch of natural-origin chum ($\hat{u}$ = 80,320) included 75,418 captures in the trap and an estimated missed catch of 4,902 during trap outages (Appendix B). A total of 2,479 natural-origin chum were marked and released over 21 efficiency trials, ranging between 104 and 129 fish per release group. Mark and recapture data were organized into 24 weekly strata for analysis. Trap efficiency of these strata ranged between 4.4% and 29.1%.

Few chum fry were captured the first day of trapping (N = 3), and the last chum was observed on June 14, eight days before the trap was removed on June 20. Based on these observations, we assumed the trapping season encompassed the entire chum migration, and we made no abundance estimate for the period before trap installation or after trap removal.

Based on genetic analyses, the catch was predominantly summer chum until the end of March when the proportion of fall chum increased in the sample. From April 9 until the end of the trapping season, the sampled catch was mostly fall chum (Table 3). Two vials were empty with no tissue collected, accounting for the unassigned samples.

TABLE 3.─Genetic stock identification for juvenile chum salmon migrants caught in the Duckabush River screw trap, 2019.

Date	Samples	Summer	Fall	Unassigned	% Summer	% Fall
2/5/2019	10	9	0	1	100.00%	0.00%
2/14/2019	20	20	0	0	100.00%	0.00%
2/18/2019	30	30	0	0	100.00%	0.00%
2/24/2019	40	39	0	1	100.00%	0.00%
3/3/2019	40	40	0	0	100.00%	0.00%
3/10/2019	40	40	0	0	100.00%	0.00%
3/17/2019	40	39	1	0	97.50%	2.50%
3/24/2019	40	36	4	0	90.00%	10.00%
3/31/2019	40	26	14	0	65.00%	35.00%
4/9/2019	40	17	23	0	42.50%	57.50%
4/14/2019	30	1	29	0	3.33%	96.67%
4/21/2019	20	1	19	0	5.00%	95.00%
4/29/2019	10	0	10	0	0.00%	100.00%
Totals	400	298	100	2	74.87%	25.13%

A total of 379,002 ± 46,142 (95% C.I.) natural-origin summer chum fry are estimated to have migrated past the screw trap (Table 4). Coefficient of variation for this estimate was 6.21%. A total of 42,919 ± 14,875 (95% C.I.) natural-origin fall chum fry are estimated to have migrated past the screw trap (Table 4). Coefficient of variation for this estimate was 17.68%. 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 29.6% for summer chum and 5.4% for fall chum (Table 4).

TABLE 4.─Juvenile production and associated coefficient of variation, female spawning escapement, and egg-to-migrant survival for natural-origin chum salmon in the Duckabush River, outmigration year 2019.

Stock	Juvenile Production	Juvenile CV	Female Spawners	Egg to Migrant Survival
Summer	379,002	6.2%	521	29.6%
Fall	42,919	17.7%	326	5.35%
Total	421,921	5.9%	847	20.2%

The entire chum outmigration occurred over a 22-week period between early January and the middle of June (Figure 2). Accounting for seasonal variation in trap efficiency, the median migration date for the summer component occurred on March 17, twenty nine days earlier than the median migration date of the fall component on April 14. The summer chum component of the migration was 95% complete by March 31. The fall chum component of the migration was 95% complete by May 3. Chum fry were not measured for body size due to very low variation in fork length (36-45mm).

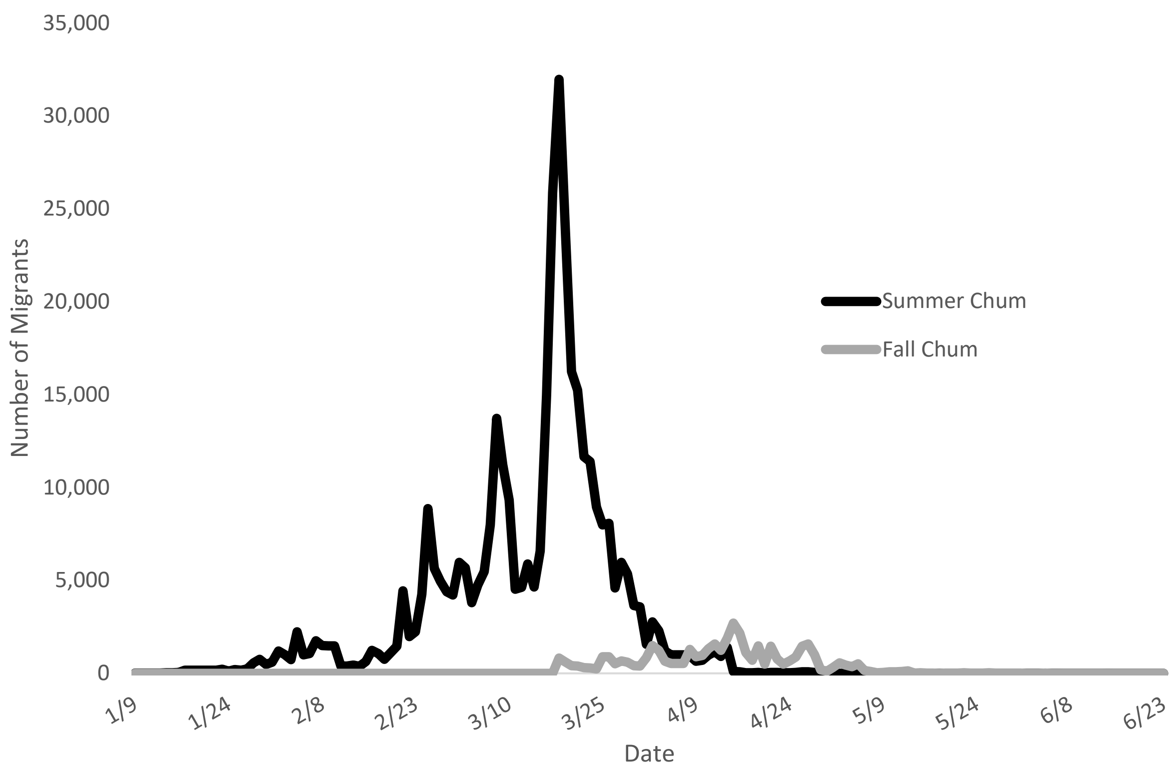

FIGURE 2.─Daily outmigration of natural-origin chum salmon fry in the Duckabush River, 2019 outmigration.

Chinook

Total catch of natural-origin Chinook was 157 juveniles. Due to the low number of Chinook, chum efficiency trials were used to represent Chinook trap efficiency. The 20 chum efficiency trials were pooled into eight strata using the *G*-test approach, with trap efficiencies ranging between 4.4% and 42.5%.

A total of 832 ± 168 (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 10.3%.

TABLE 5.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Chinook salmon in the Duckabush River, 2019. Chum mark-recapture release groups were used as a surrogate for estimating Chinook salmon trap efficiency and were pooled to form eight strata. Missed catch and associated variance were calculated for periods the trap did not fish.

		Chinook Catch			Chum Efficiency		Chinook Abundance	
Strata	Date	Actual	Missed	Variance	Marks	Recaptures	Estimated	Variance
1	1/9-2/6	0	0	0.00E+00	355	89	0	0.00E+00
2	2/7-2/14	0	0	0.00E+00	113	5	0	0.00E+00
3	2/15-2/16	0	0	0.00E+00	112	14	0	0.00E+00
4	2/17-3/1	0	0	0.00E+00	465	105	0	0.00E+00
5	3/2-3/15	0	0	0.00E+00	361	47	0	0.00E+00
6	3/16-3/19	32	0	0.00E+00	120	51	74	1.57E+02
7	3/20-5/1	108	8	1.23E+00	704	116	699	6.98E+03
8	5/2-6/23	17	0	0.00E+00	129	37	58	1.99E+02
	Season Total	157	8	1.23E+00	2359	464	832	7.34E+03

The first juvenile Chinook was captured on March 18, 2019. Daily migration of Chinook was low and sporadic for most of the season (Figure 3). Based on the minimal catch of Chinook at the beginning and end of the trapping season, we assumed zero migration prior to trap installation and after trap removal.

Length of natural-origin Chinook fry ranged from 36-mm to 86-mm and averaged 43-mm throughout the trapping season (Figure 4). Average weekly fork lengths of juvenile Chinook began to increase during statistical week 15 (middle of April).

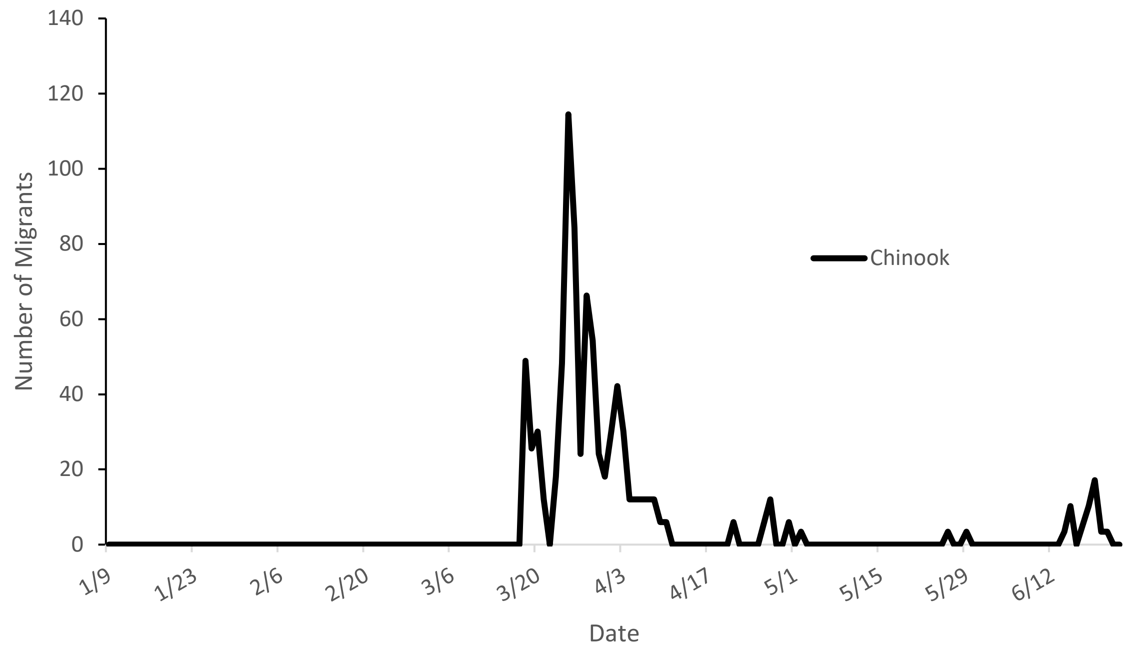

FIGURE 3.─Daily outmigration of natural-origin Chinook salmon fry in the Duckabush River, 2019 outmigration.

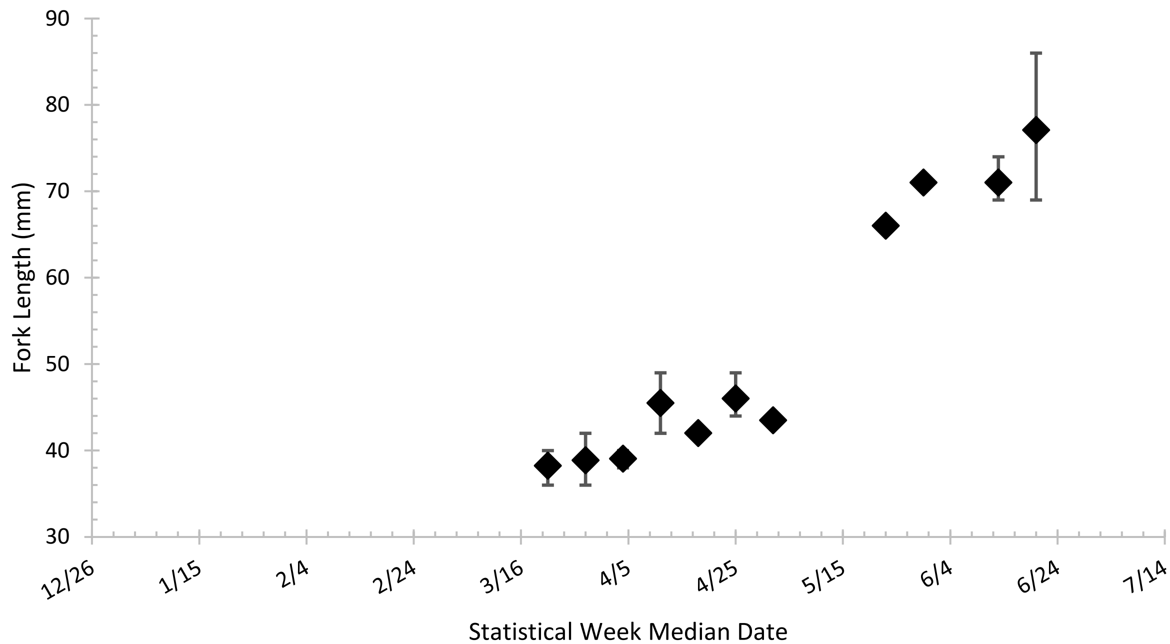

FIGURE 4.─Fork length (mm) of juvenile Chinook migrants of natural origin captured in the Duckabush River screw trap 2019. Data are mean, minimum, and maximum values by statistical median date.

Coho

Total catch of natural-origin coho yearlings was 151 juveniles. Coho captured after March 15 were marked and released upstream to estimate trap efficiency. All daily coho yearling efficiency trials were pooled together to formulate a single stratum for the season. In addition to coho yearlings, we also captured 4,208 coho fry.

A total of 1,525 ± 741 (95% C.I.) natural-origin coho yearlings are estimated to have migrated past the screw trap (Table 6). Coefficient of variation for this estimate was 24.8%.

TABLE 6.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for Coho salmon in the Duckabush River, 2019. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

	Catch					Abundance	
Date	**Actual**	**Missed**	**Variance**	**Marks**	**Recaptures**	**Estimated**	**Variance**
1/9-6/23	151	9	6.68E+00	142	14	1,525	1.43E+05

The first coho yearling was captured on January 9th. The median migration date occurred on May 8 (Figure 5). The migration was 95% complete by June 8. The last coho was captured on June 15, 2019, eight days before the end of the trapping season.

Length of natural-origin coho yearlings ranged from 63-mm to 125-mm and averaged 99-mm throughout the trapping season (Figure 6). Average weekly fork lengths of juvenile coho began to consistently increase during statistical week 16 (middle of April).

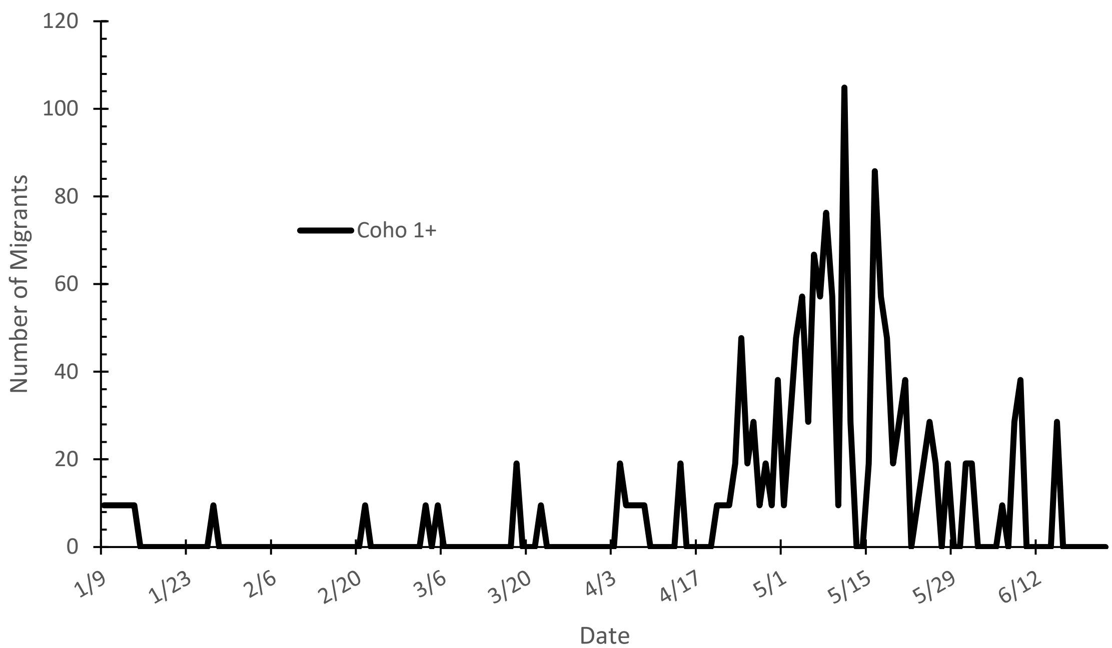

FIGURE 5.─Daily outmigration of natural-origin yearling coho salmon in the Duckabush River, 2019 outmigration.

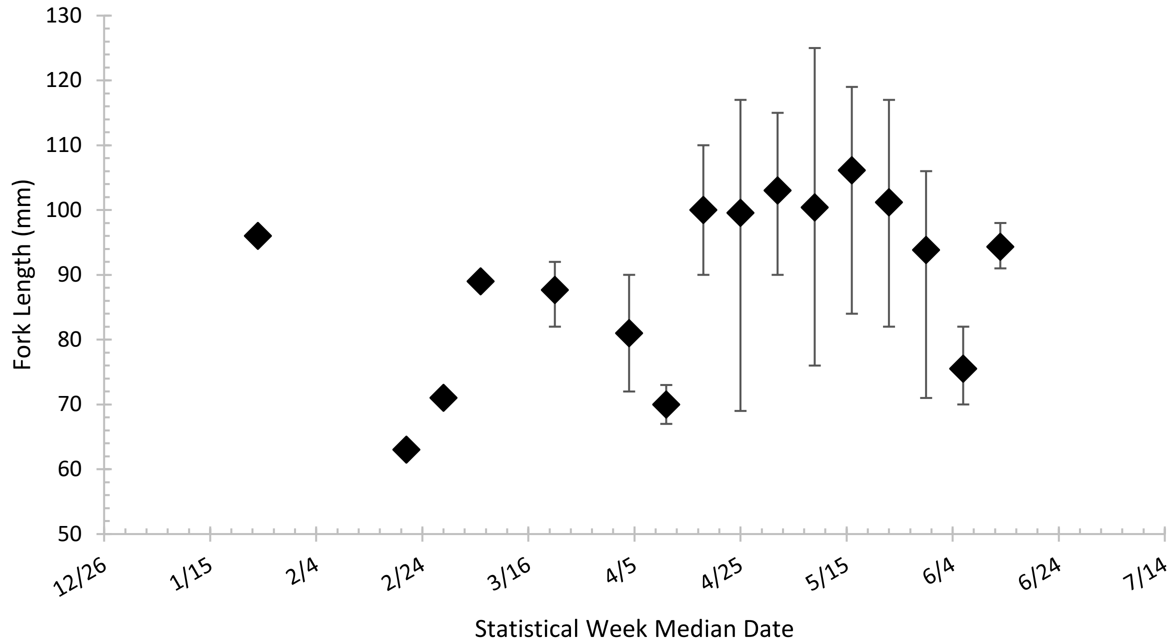

FIGURE 6.─Fork length (mm) of juvenile coho yearling migrants of natural origin captured in the Duckabush River screw trap 2019. Data are mean, minimum, and maximum values by statistical median date.

Steelhead

Total catch of natural-origin steelhead smolts was 44 juveniles. Due to low catches of steelhead, coho efficiency trials were used as a surrogate for steelhead efficiency. All coho efficiency trials were pooled together to formulate a single stratum for the season.

A total of 419 ± 225 (95% C.I.) natural-origin steelhead smolts are estimated to have migrated past the screw trap (Table 7). Coefficient of variation for this estimate was 27.4%.

TABLE 7.─Juvenile catch, marked and recaptured fish, and estimated abundance and associated variance for steelhead in the Duckabush River, 2019. Release groups were pooled into one strata. Missed catch and associated variance were calculated for periods the trap did not fish.

	Catch					Abundance	
Date	Actual	Missed	Variance	Marks	Recaptures	Estimated	Variance
1/9-6/23	44	0	0.00E+00	142	14	419	1.32E+04

The first steelhead smolt was captured on March 26, 2019. The median migration date occurred on May 8 (Figure 7). The migration was 95% complete by May 25. The last steelhead was captured on June 1, 2019, twenty two days before the end of the trapping season.

Length of natural-origin steelhead smolts ranged from 91-mm to 206-mm and averaged 163-mm throughout the trapping season (Figure 8).

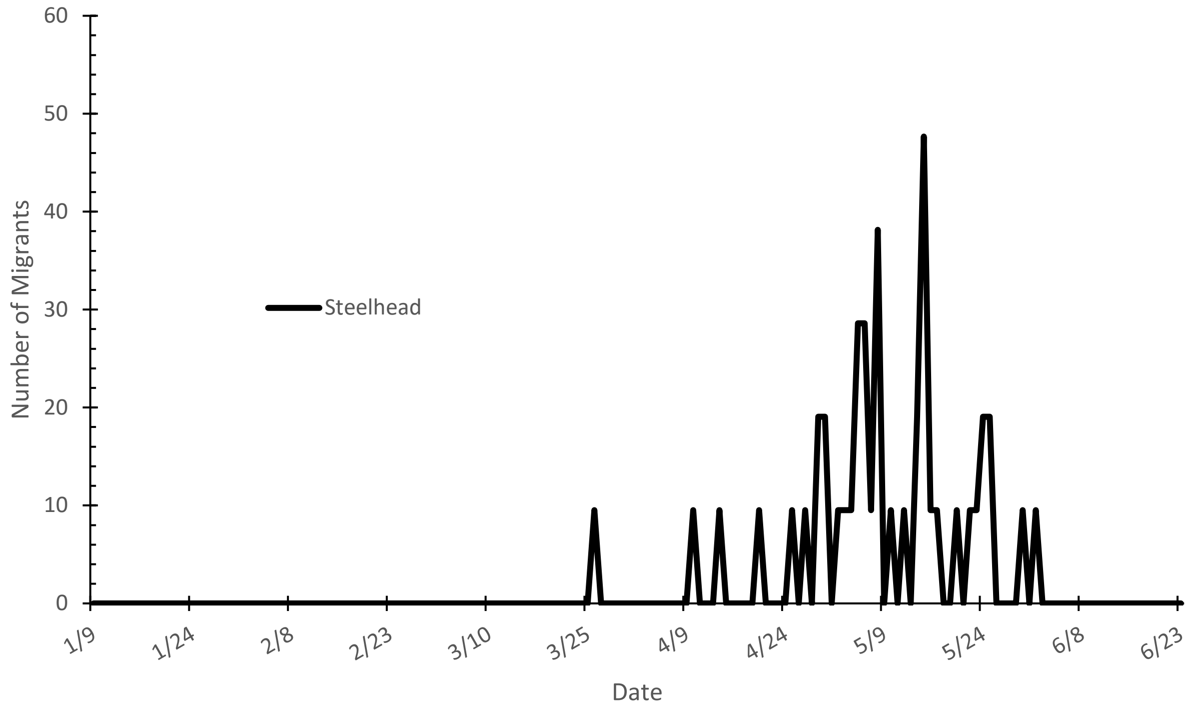

FIGURE 7.─Daily outmigration of natural-origin steelhead smolts in the Duckabush River, 2019.

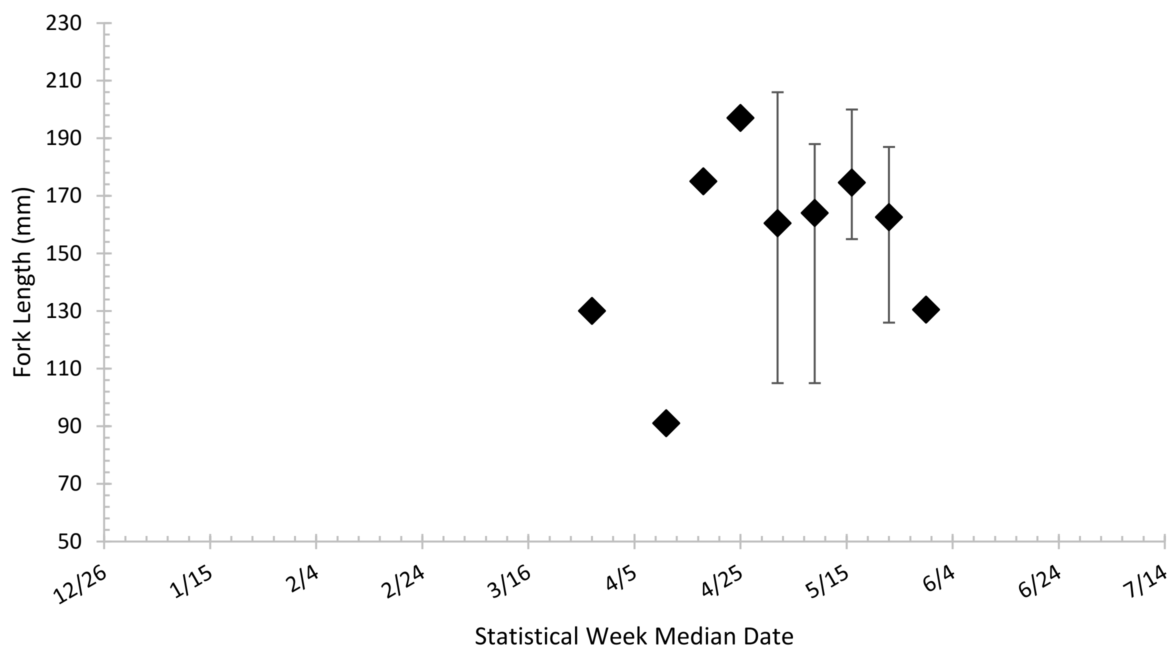

FIGURE 8.─Fork length (mm) of juvenile steelhead smolt migrants of natural origin captured in the Duckabush River screw trap 2019. Data are mean, minimum, and maximum values by statistical median date.

Other Species

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

Discussion of Data Accumulated 2011-2019

This report provides the freshwater production and out-migration timing for chum salmon, Chinook salmon, pink salmon, coho salmon and steelhead populations in the Duckabush River during in 2019. The 2019 trapping season marked the ninth year that genetic samples were collected to distinguish between summer and fall timed chum salmon in the Duckabush River. Based on this study design, we were able to compare juvenile out-migration timing between the two sympatric stocks of chum salmon. In this section, we discuss the Duckabush River juvenile trapping data accumulated to date for summer and fall chum salmon, Chinook salmon, coho salmon and steelhead.

Duckabush Summer Chum Salmon

The 2019 season was the lowest spawning abundance for both summer and fall chum since genetic identification of juveniles began in 2011 (Table 8). Juvenile production of summer chum was the second highest observed. Fall timed chum juvenile abundance was the fifth highest in the past nine years.

TABLE 8. ─Juvenile production and associated adult escapement and egg-to-migrant survival for summer and fall chum in the Duckabush River, 2011-2019.

Stock	Adult Return Year	Adult Escapement	Juvenile Migration Year	Estimated Juvenile Migration	Egg to Migrant Survival
Summer	2010	4,110	2011	347,597	7.91%
	2011	1,529	2012	290,891	17.79%
	2012	5,241	2013	285,468	5.09%
	2013	3,939	2014	480,202	11.40%
	2014	7,607	2015	130,126	1.60%
	2015	4,905	2016	47,479	0.91%
	2016	8,470	2017	200,712	2.22%
	2017	6,720	2018	365,203	5.08%
	2018	1,199	2019	379,002	29.55%
Fall	2010	373*	2011	32,656	5.96%
	2011	2,234	2012	43,053	1.80%
	2012	2,973	2013	42,213	1.33%
	2013	1,144	2014	17,676	1.44%
	2014	4,531	2015	44,595	0.92%
	2015	1,987	2016	41,254	1.94%
	2016	2,323	2017	44,322	1.78%
	2017	2,019	2018	99,741	4.62%
	2018	326	2019	42,919	5.35%

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

Summer chum continue to numerically dominate fall chum in the Duckabush. Egg to migrant survival of summer timed chum was the highest we have observed since this project began. In previous annual Duckabush reports, we have hypothesized this trend could be due to density dependence and/or peak flow events during spawning and incubation (Weinheimer 2016; Weinheimer 2018). As we continue to accumulate years of data, density dependence appears to be more closely correlated with egg to migrant survival than peak flow events (Figure 9).

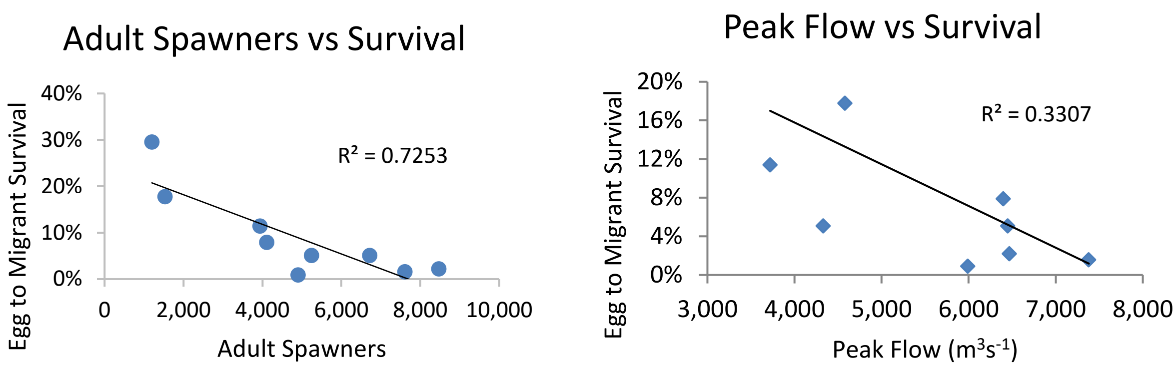

FIGURE 9. ─Summer chum egg to migrant survival vs total adult spawners and peak flow (Sept 1 – Jan 30, m^3s^{-1}), brood years 2010-2018.

The fall chum 2019 fry outmigration had the largest observed egg to migrant survival for fall timed chum over the course of the time series. This high survival corresponded to the lowest adult escapement during our project. Similar to summer chum, fall timed chum egg to migrant survival appears to be more correlated with adult escapement than peak river flows during incubation (Figure 10). Fall chum continue to lag behind summer chum in survival, adult escapement and total juvenile production.

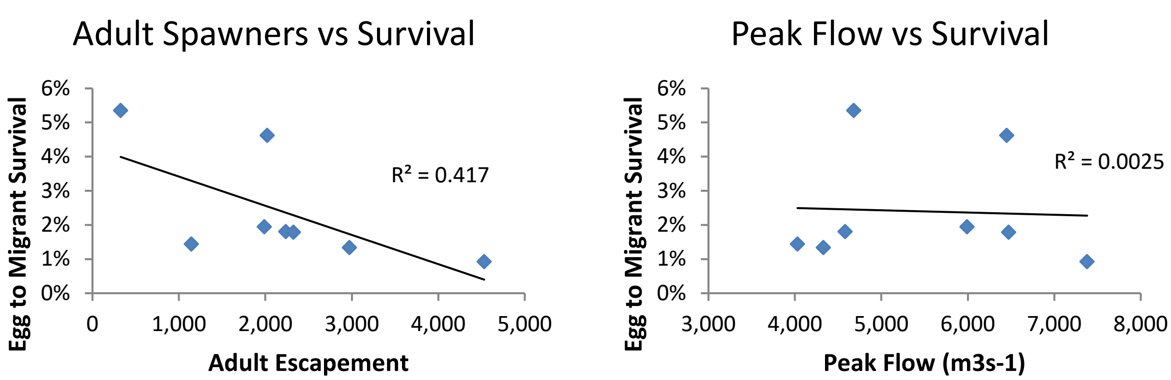

FIGURE 10. ─Fall chum egg to migrant survival vs total adult spawners and peak flow (Oct 15 – Mar 15,m^3s^{-1}), brood years 2011-2018.

In addition to freshwater survival and productivity, we have been collecting scales from returning adults to describe the age composition of spawners. Using this age information coupled with adult and juvenile abundance data, we can calculate marine survival rates for each brood (Table 9). So far, we only have 4 complete brood years. Survival for summer chum is ranging between 1.1% and 2.3% and fall timed fish between 4.4% and 14.1%.

TABLE 9.─Brood Year, outmigration year, fry abundance, adult returns by age and marine survival for natural-origin Summer and Fall Chum salmon in the Duckabush River, outmigration year 2011-2017.

Stock	Brood Year	Outmigration Year	Freshwater Production	Estimated Adult Return by Age Class				Total Adults	Marine Survival
				2	3	4	5		
Summer	2010	2011	347,597	66	1,057	6,460	314	7,897	2.27%
	2011	2012	290,891	0	1,070	2,167	43	3,280	1.13%
	2012	2013	285,468	0	2,424	3,235	246	5,905	2.07%
	2013	2014	480,202	0	3007	5,860	89	8,956	1.87%
	2014	2015	130,126	0	615	711		1,326	1.02%*
	2015	2016	47,479	0	400			400	0.84%*
	2016	2017	200,712	0				0	0.00%*
Fall	2010	2011	32,656	0	192	4,131	302	4,625	14.16%
	2011	2012	43,053	0	267	1,511	104	1,882	4.37%
	2012	2013	42,213	0	181	1749	125	2,055	4.87%
	2013	2014	17,676	0	470	1,223	0	1,693	9.58%
	2014	2015	44,595	0	502	409		911	2.04%*
	2015	2016	41,254	0	316			316	0.77%*
	2016	2017	44,322	0				0	0.00%*

*Incomplete marine survival estimates

Duckabush Chinook Salmon

Freshwater production of Chinook fry was the fourth lowest we have observed since 2011 (Table 10). The number of adults observed during spawning ground surveys was the third lowest reported for the same time frame. The estimated egg to migrant survival for 2019 was 6 to 10 times higher than the estimates from the previous three seasons. We continue to estimate very low numbers of adult Chinook on the spawning grounds each season. Low abundance populations are notoriously difficult to survey, and in this case, a small number of missed adults would substantially alter our estimates of egg to migrant survival. We will continue to monitor these results as we accumulate more years of data.

TABLE 10.─Fry abundance, observed spawning escapement and egg-to-migrant survival for natural-origin Chinook salmon in the Duckabush River, outmigration year 2011-2019.

Out Migration Year	Juvenile Abundance	Observed Spawning Escapement	Egg-to-Migrant Survival
2011	1,219	0	-
2012	2,788	5	32.80%
2013	5,221	6	51.20%
2014	4,555	7	38.30%
2015	1,179	13	5.30%
2016	686	20	2.00%
2017	577	15	2.30%
2018	43	2	1.06%
2019	832	4	12.24%

Duckabush Coho Salmon

Freshwater production of coho yearlings was well below the 7 year average (4,641) production since 2011 (Table 11). The lack of production the past 5 seasons compared to the first three seasons (2012-2014) is likely due to low summer flows, resulting in a reduction in available habitat. During August 2018, when the 2019 yearling smolts experienced summer rearing conditions, median flow was the second lowest (84 cfs) since 2011. By comparison, during the 2011-2013 summers, average flow during August was 249 cfs. The Duckabush River only has a handful of small tributaries available to returning coho adults or rearing juveniles, and we suspect these are inaccessible or unsuitable for rearing juveniles during low flow years. No adult surveys are conducted for adult coho so it is unknown whether escapement numbers were lower for the 2013-2015 broods.

TABLE 11. ─Yearling coho production and corresponding upper and lower confidence intervals for the Duckabush River 2012-2019.

		Abundance			
Out Migration Year	Estimate	Lower CI	Upper CI	CV	Average August Flow
2012	2,299	1,529	3,068	17.10%	409
2013	2,422	1,693	3,152	15.40%	202
2014	2,938	1,879	3,997	18.40%	137
2015	1,844	587	3,100	34.76%	93
2016	1,260	646	1,875	24.86%	70
2017	1,373	498	2,247	32.51%	87
2018	1,127	543	1,712	26.46%	135
2019	419	194	645	27.39%	84

Duckabush Steelhead

The 2019 season marked the eighth year since trapping began that we were able to estimate steelhead production in the Duckabush River, though low catch forced us to use coho trap efficiency estimates as a surrogate. The Duckabush has been part of the Hood Canal Steelhead Project led by NOAA and Long Live the Kings. The goal of the project is to test the effects of hatchery supplementation on natural populations. For the study, the Duckabush was supplemented with both hatchery reared smolts and hatchery adult releases groups from 2011-2018. Initially, we saw higher abundances of steelhead when the supplementation began but smolt production of steelhead has continued to decline since 2014 (Table 12). As these data accumulate, they will help inform the freshwater carrying capacity for steelhead smolt outmigrants in the Duckabush River.

TABLE 12.─Steelhead production and corresponding upper and lower confidence intervals for the Duckabush River 2012 through 2019.

		Abundance		
Out Migration Year	**Estimate**	**Lower CI**	**Upper CI**	**CV**
2012	2,299	1,529	3,068	17.10%
2013	2,422	1,693	3,152	15.40%
2014	2,938	1,879	3,997	18.40%
2015	1,844	587	3,100	34.76%
2016	1,260	646	1,875	24.86%
2017	1,373	498	2,247	32.51%
2018	1,127	543	1,712	26.46%
2019	419	194	645	27.39%

Appendix A

Statistical Weeks for 2019

APPENDIX A1.–Statistical Weeks for 2019.

Stat Week	2019
1	Jan 1 - Jan 6
2	Jan 7 - Jan 13
3	Jan 14 - Jan 20
4	Jan 21 - Jan 27
5	Jan 28 - Feb 3
6	Feb 4 - Feb 10
7	Feb 11 - Feb 17
8	Feb 18 - Feb 24
9	Feb 25 - Mar 3
10	Mar 4 - Mar 10
11	Mar 11 - Mar 17
12	Mar 18 - Mar 24
13	Mar 25 – Mar 31
14	Apr 1 - Apr 7
15	Apr 8 - Apr 14
16	Apr 15 - Apr 21
17	Apr 22 - Apr 28
18	Apr 29 - May 5
19	May 6 - May 12
20	May 13 - May 19
21	May 20 - May 26
22	May 27 - Jun 2
23	Jun 3 - Jun 9
24	Jun 10 - Jun 16
25	Jun 17 - Jun 23
26	Jun 24 – Jun 30
27	Jul 1 - Jul 7

Appendix B

Duckabush River catches, trap efficiencies, and abundance estimates for 2019

APPENDIX B1.–Actual catch (n), Estimated catch ($\hat{u}$), marked (M) and recaptured (m) fish, and estimated abundance (U) of chum fry migrants at the Duckabush River screw trap in 2019. Release groups were pooled by statistical week. An asterisk (*) indicates periods with insufficient catch for efficiency trials, so mark-recapture data from outside the given date range were used to estimate abundance. Missed catch and associated variance were calculated for periods that the trap did not fish.

Week	Dates	n	$\hat{n}$	$\hat{u}$	$V(\hat{u})$	M	m	$\hat{U}$	$V(\hat{U})$
2*	1/9-1/13	3	20	23	1.05E+01	355	89	91	4.99E+02
3*	1/14-1/20	60	135	195	4.86E+01	355	89	771	7.91E+03
4*	1/21-1/27	185	140	325	5.35E+01	355	89	1,286	1.82E+04
5	1/28-2/3	1,355		1,355		355	89	5,360	2.52E+05
6	2/4-2/10	397	156	553	2.00E+00	113	5	10,507	1.51E+07
7	2/11-2/17	671	244	915	3.27E+00	227	45	4,535	3.67E+05
8	2/18-2/24	3,582		3,582		230	50	16,224	4.00E+06
9	2/25-3/3	6,099		6,099		240	36	39,726	3.54E+07
10	3/4-3/10	7,908		7,908		120	16	56,286	1.52E+08
11	3/11-3/17	16,602	3,088	19,690	1.46E+01	241	70	67,112	4.44E+07
12	3/18-3/24	23,416		23,416		240	45	122,679	2.60E+08
13	3/25-3/31	7,774		7,774		240	42	43,571	3.56E+07
14*	4/1-4/7	2,147	822	2,969	1.43E+04	240	42	16,640	5.70E+06
15	4/8-4/14	1,821	297	2,118	5.61E+03	224	29	15,885	7.48E+06
16*	4/15-4/21	1,398		1,398		224	29	10,485	3.14E+06
17*	4/22-4/28	961		961		224	29	7,208	1.50E+06
18	4/29-5/5	733		733		129	37	2,508	1.20E+05
19*	5/6-5/12	182		182		129	37	623	8.50E+03
20*	5/13/5/19	68		68		129	37	233	1.53E+03
21*	5/20-5/26	35		35		129	37	120	5.43E+02
22*	5/27-6/2	14		14		129	37	48	1.55E+02
23*	6/3-6/9	6		6		129	37	21	5.61E+01
24*	6/10-6/16	1		1		129	37	3	8.28E+00
25*	6/17-6/23	0		0		129	37	0	0.00E+00
Totals		75,418	4,902	80,320	2.01E+04	2,359	464	421,921	5.64E+08

APPENDIX B2.–**Estimated abundance of summer (U_s) and fall chum (U_f) fry migrants at the Duckabush River screw trap in 2019. Total chum migrants (U) were stratified by statistical week. The proportion of summer (P_s) and fall chum (P_f) were based on *n* genetic samples collected during each weekly strata.**

Week	U	V(U)	n	Ps	v(Ps)	n	Pf	v(Pf)	Us	V(Us)	Uf	V(Uf)
2*	91	4.99E+02	9	1.00	1.10E-03	9	0.00	5.28E-03	91	5.08E+02	0	4.11E+01
3*	771	7.91E+03	9	1.00	1.10E-03	9	0.00	5.28E-03	771	8.55E+03	0	3.10E+03
4*	1,286	1.82E+04	9	1.00	1.10E-03	9	0.00	5.28E-03	1,286	2.00E+04	0	8.63E+03
5	5,360	2.52E+05	9	1.00	1.10E-03	9	0.00	5.28E-03	5,360	2.83E+05	0	1.50E+05
6	10,507	1.51E+07	9	1.00	1.10E-03	9	0.00	5.28E-03	10,507	1.52E+07	0	5.03E+05
7	4,535	3.67E+05	20	1.00	4.95E-04	20	0.00	2.38E-03	4,535	3.77E+05	0	4.80E+04
8	16,224	4.00E+06	30	1.00	3.30E-04	30	0.00	1.58E-03	16,224	4.09E+06	0	4.10E+05
9	39,726	3.54E+07	39	1.00	2.54E-04	39	0.00	1.22E-03	39,726	3.58E+07	0	1.88E+06
10	56,286	1.52E+08	40	1.00	2.48E-04	40	0.00	1.19E-03	56,286	1.52E+08	0	3.58E+06
11	67,112	4.44E+07	40	1.00	2.48E-04	40	0.00	1.19E-03	67,112	4.55E+07	0	5.30E+06
12	122,679	2.60E+08	40	0.98	8.73E-04	40	0.03	1.81E-03	119,612	2.60E+08	3,067	2.70E+07
13	43,571	3.56E+07	40	0.90	2.56E-03	40	0.10	3.50E-03	39,214	3.36E+07	4,357	6.87E+06
14*	16,640	5.70E+06	40	0.65	6.08E-03	40	0.35	7.02E-03	10,816	4.06E+06	5,824	2.60E+06
15	15,885	7.48E+06	40	0.43	6.51E-03	40	0.58	7.45E-03	6,751	2.95E+06	9,134	4.30E+06
16*	10,485	3.14E+06	30	0.03	1.44E-03	30	0.97	2.69E-03	350	1.57E+05	10,136	3.22E+06
17*	7,208	1.50E+06	20	0.05	3.00E-03	20	0.95	4.88E-03	360	1.55E+05	6,847	1.60E+06
18	2,508	1.20E+05	10	0.00	9.90E-04	10	1.00	4.75E-03	0	6.11E+03	2,508	1.49E+05
19*	623	8.50E+03	10	0.00	9.90E-04	10	1.00	4.75E-03	0	3.75E+02	623	1.03E+04
20*	233	1.53E+03	10	0.00	9.90E-04	10	1.00	4.75E-03	0	5.21E+01	233	1.78E+03
21*	120	5.43E+02	10	0.00	9.90E-04	10	1.00	4.75E-03	0	1.37E+01	120	6.08E+02
22*	48	1.55E+02	10	0.00	9.90E-04	10	1.00	4.75E-03	0	2.12E+00	48	1.65E+02
23*	21	5.61E+01	10	0.00	9.90E-04	10	1.00	4.75E-03	0	3.62E-01	21	5.78E+01
24*	3	8.28E+00	10	0.00	9.90E-04	10	1.00	4.75E-03	0	3.39E-03	3	8.30E+00
25*	0	0.00E+00	10	0.00	9.90E-04	10	1.00	4.75E-03	0	0.00E+00	0	0.00E+00
Totals	421,921	5.64E+08	398	-	3.55E-02	398	-	9.93E-02	379,002	5.54E+08	42,919	5.76E+07

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