Newaukum River Smolt Production, 2023

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Authors

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Executive Summary

This report provides the results from the 2023 juvenile salmonid monitoring study on the Newaukum River main stem near Centralia, Washington. The primary objective of this study is to describe the freshwater production (e.g., smolt abundance) of Pacific salmon (*Oncorhynchus* spp.) and steelhead (*O. mykiss*) in the Newaukum River. Specifically, we describe the abundance, timing, and diversity (body size, age structure, run timing) of juvenile outmigrants for wild coho salmon (*O. kisutch*), steelhead, and Chinook (*O. tshawytscha*). Based on the location and timing of the study, the results reflect juveniles that completed their freshwater rearing phase in habitats upstream of a rotary screw trap operated in the main stem Newaukum River.

To meet the study objectives, a 1.5-meter (5–foot) rotary screw trap was deployed near river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River from March 9 to July 10, 2023.

Coho outmigrants were predominately of the yearling (or “1+”) age class (95.3%). Scale age data indicated that there was a small 2+ year-old component of the coho out-migration (3.9%) that started near the middle of March. Scale age data also indicated that there was a small subyearling (“0” age class) component of the coho out-migration (0.8%) that started in early June. The average fork length of all outmigrant coho was 111.7 mm (± 11.9 mm standard deviation SD). The average fork length of known subyearlings was 94.0 mm (± 2.6 mm SD), known yearlings was 111.8 mm (± 10.6 mm SD), and two-year-old outmigrants averaged 121.7 mm (± 11.6 mm SD). Abundance of wild coho outmigrants in 2023 was estimated to be 75,630 (95% CI: 63,042 – 92,116) with a coefficient of variation (CV) of 9.8%.

Steelhead outmigrants ranged from Age-1 to Age-3 based on scales (54.5%, 39.4% and 6.1% for Age-1 through Age-3, respectively), indicating three different juvenile life histories. Outmigrant timing was concurrent for all age classes. The average fork length for all measured steelhead was 140.0 mm (± 29.5 mm SD). Fork length averaged 127.8 mm (± 21.3 mm SD) for Age-1, 165.1 mm (± 16.3 mm SD) for Age-2, and 176.8 mm (± 10.0 SD) for Age-3. Abundance of wild steelhead outmigrants was estimated to be 11,443 (95% CI = 8,028 – 17,169) with a CV of 20.1%.

Chinook salmon in coastal Washington begin their downstream migration as Age-0 fish (fry, parr, and transitional/smolt subyearlings). Typically, the majority of Chinook fry (≤ 45 mm fork length) out-migrate when flow conditions are not suitable for smolt trapping in the Chehalis Basin (e.g., January and February). Therefore, the goal was to estimate the subyearling smolt (> 45 mm fork length) component of the Chinook out-migration that generally occurs from March – July. Fork length of all Chinook subyearlings increased steadily throughout the trapping period and averaged 41.8 mm (± 3.1 mm SD) and 84.6 mm (± 5.6 mm SD) in the first and last sampled week of trapping, respectively. Approximately 89.8% of the total catch of wild Chinook outmigrants were > 45 mm. Abundance of wild Chinook subyearling smolt outmigrants in was estimated to be 64,472 (95% CI = 59,777 – 73,289) with a CV of 10.7%.

Introduction

The Washington Department of Fish and Wildlife (WDFW) has monitored freshwater production of juvenile Pacific salmon (*Oncorhynchus* spp.) in the Chehalis River since the early 1980s. Over this time, the work has focused on wild coho salmon (*O. kisutch*) and estimates of wild coho smolt abundance have been generated at the basin scale. Results from the monitoring program have demonstrated that the Chehalis River has a higher density of wild coho smolts (average 1,003 smolts mi^{-2} [387 smolts km^{-2}]) than any other western Washington watershed for which data currently exists (Litz 2023). Previously, smolt abundance estimates from individual tributaries throughout the Chehalis River Basin were generated in the 1980s and 1990s but were not evaluated during the next two decades. Earlier estimates only focused on coho, providing limited information on freshwater production of other salmonid species, including Chinook (*O. tshawytscha*) and steelhead (*O. mykiss*). Recent efforts under the Chehalis Basin Strategy (http://chehalisbasinstrategy.com/) to develop a monitoring and adaptive management plan (M&AMT 2021) as part of the larger Aquatic Species Restoration Plan (ASRPSC 2019) have highlighted the need for annual smolt (or juvenile outmigrant) data that will be critical for evaluating variability and trends in juvenile freshwater production over time.

The Newaukum River was selected for intense monitoring of smolt and adult abundance in 2019 to collect baseline information prior to early action restoration projects focused on enhancing salmon and steelhead rearing habitat in the basin. Importantly, the Newaukum River supports runs of coho salmon, steelhead, spring and fall Chinook salmon, and cutthroat trout, and is known to support a relatively large proportion (2000 – 2021 average = 28%) of the spring Chinook spawning population in the Chehalis River Basin (Ronne et al. 2023). Additionally, in 2015 the Newaukum River was designated as a “pilot watershed” by Chehalis Lead Entity to guide restoration among all coast Lead Entity areas; http://www.chehalisleadentity.org/our-work/. Several restoration projects are currently being implemented within the Newaukum River basin. For these reasons, accurate and precise estimates of salmon and steelhead smolt populations (e.g., freshwater production) in the Newaukum River are critical for monitoring status and trends of salmon and steelhead populations and responses to habitat restoration.

Objectives

The primary objective of this study is to describe the freshwater production of salmon and steelhead in the Newaukum River. Abundance, timing, and diversity (body size, age structure, run timing) of juvenile coho salmon, steelhead, Chinook salmon, and cutthroat trout (*O. clarkii*) are also described. Based on the location and timing of the study, these results reflect juveniles that completed their freshwater rearing phase in habitats upstream of river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River between March 9 to July 10, 2023.

Methods

Study Site

The Newaukum River is a major sub-basin of the Chehalis River, a large coastal drainage in Southwest Washington State. The Newaukum River is comprised of three forks (North, Middle, and South Fork), multiple smaller tributaries, and a main stem that drains approximately 450 square kilometers (km) from the foothills of the Cascade mountains. The main stem Newaukum enters the Chehalis River at approximately river km 121 (river mile 75.2), just south of the city of Centralia. The Newaukum River is relatively low elevation (~48 to 909 m) and low gradient with a rain dominant hydrology. Land use in the basin is predominately industrial timber production in the headwater locations and private residential and agricultural in lower elevation locations. Native anadromous salmonids in the Newaukum River include coho salmon, winter steelhead, spring and fall Chinook salmon, and cutthroat trout. A hatchery program for coho and steelhead is operated by the Onalaska School District in the South Fork Newaukum upstream of the smolt trap.

Like other rivers in western Washington, juvenile Chinook salmon in the Chehalis River have a protracted out-migration period during their first year of life. Yearlings are rarely observed at the Chehalis main stem smolt trap or in adult returns as determined from otoliths (Campbell et al. 2017 & 2023; Winkowski and Zimmerman 2018). The Chehalis main stem trap is downstream of the Newaukum trap, therefore juvenile Chinook salmon in the Newaukum presumably exhibit a similar life history behavior of out-migrating as subyearlings. There are two predominant freshwater rearing strategies observed for juvenile Chinook salmon at both the Chehalis main stem and Newaukum smolt traps, and they are distinguishable as bimodal out-migration peaks. The first pulse of outmigrants is termed ‘fry’ (defined as juveniles ≤ 45 mm fork length [FL]) and consists of individuals that out-migrate almost immediately after emergence. Fry are observed at the smolt trap beginning in early March but have been presumably out-migrating since January, based on other smolt traps in the Puget Sound and other areas (Anderson and Topping 2018; Groot and Margolis 1991; Kiyohara and Zimmerman 2012; Zimmerman et al. 2015, 2023). The second pulse of Chinook outmigrants are termed ‘subyearlings’ and consist of individuals that grow in freshwater for weeks to months after emergence that are observed at the smolt trap between the months of March and July. Subyearlings are the focus of these production estimates.

The trapping location (Figure 1) on the Newaukum River (46°37’0.56 N, 122°56’12.51 W) was selected for multiple reasons, including ease of access for installation, operation, and removal, water velocity, river depth and width, and location within the stream network, described by West et al. (2020). In 2022, it was estimated that 87% of adult spring Chinook and 58% of fall Chinook salmon in the Newaukum River spawned upstream of the trap site producing the subyearling outmigrants in 2023 (Ronne et al. 2024). In 2021, 100% of adult coho salmon spawned upstream of the trap, producing the yearling outmigrants in 2023. Likewise, all adult steelhead that spawned in the Newaukum from 2020-2022, producing Age-1, Age-2, and Age-3 smolts, were identified upstream of the trap site.

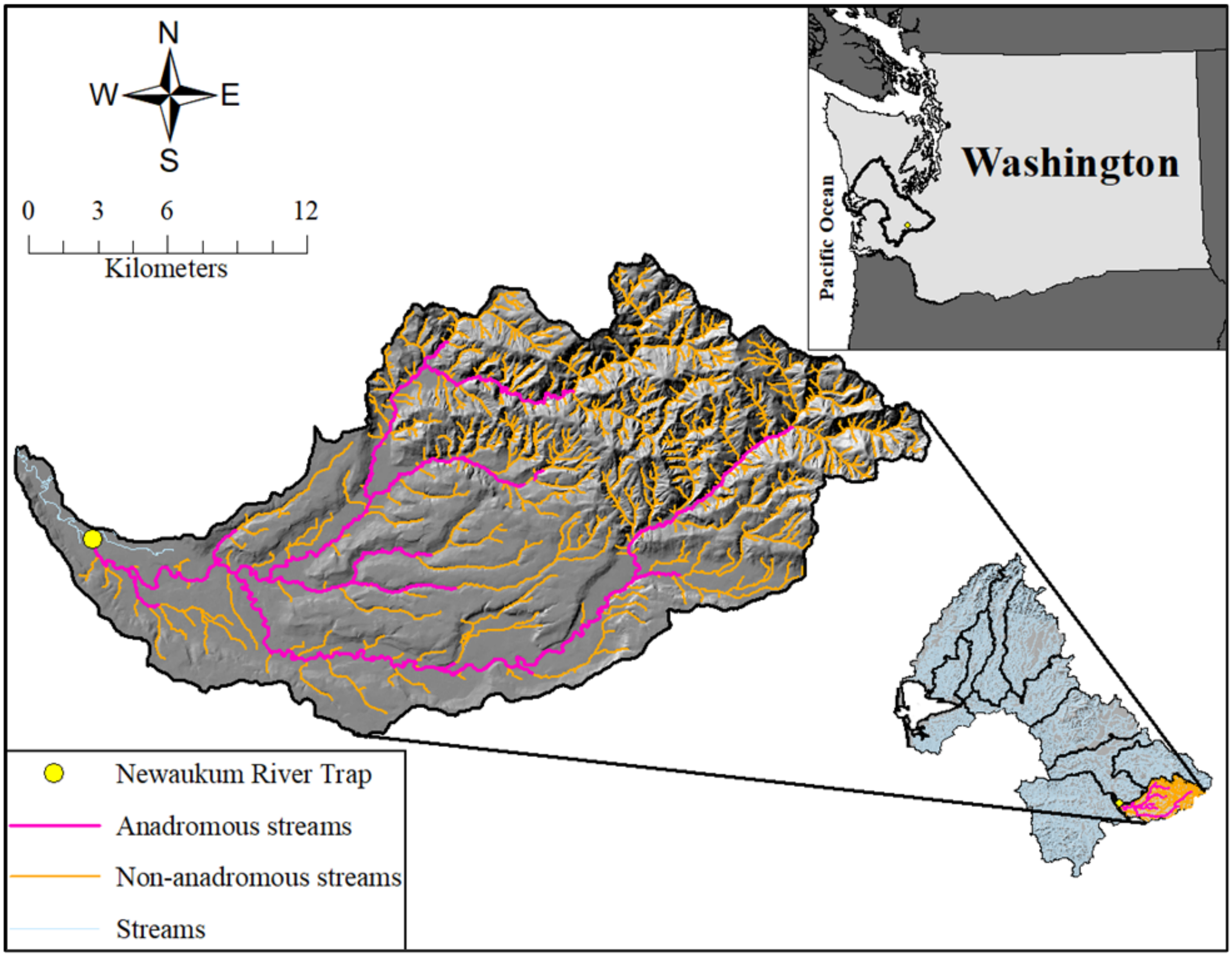

Figure 1. Newaukum River rotary screw trap location. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (112.5 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the Newaukum River rotary screw trap. Non-anadromous streams represent stream habitat outside the predicted coho salmon range of occurrence (565.7 km) upstream of the trap location. Marked fish were released 3.9 km upstream of the trap location at the Rush Road bridge on the right bank, directly under the bridge.

Trap Operation

A 1.5 m (5-foot) diameter rotary screw trap (RST) was operated near river km 9.35 of the Newaukum River in 2023 (Figure 2). The trap was scheduled to operate continuously from March 9 through July 10, 2023, although unscheduled trap outages did occur due to high flow and debris. None of these outages lasted longer than 24 hours.

Stream temperature and trap status information (e.g., fishing or not fishing, cone revolutions per minute) were collected daily at the start of each sampling event. Water temperatures in fish holding containers were monitored throughout sampling events. Stream temperature was also monitored with a temperature data logger (HOBO 64K Pendant) deployed adjacent to the trap and cabled to the bank that collected and logged temperature at 30-minute intervals. Data loggers were calibrated according to

Winkowski et al. (2018). Stream flow is monitored by the USGS discharge gage Newaukum River near Chehalis, Washington (USGS 12025000), which is located 2.7 km downstream of the trap site.

Figure 2. Newaukum River trap site.

Fish Collection

Fish sampling commenced each morning daily and was adjusted to earlier times as stream temperatures increased to > 18°C throughout the season. Crews monitored river flows and weather several times daily and modified operations in response to environmental conditions, such as earlier or multiple checks to minimize temperature impacts on fish health. Fish were removed from the live box and moved to small dish tubs for sampling. Fish were anaesthetized with tricaine methanesulfonate (MS-222) prior to enumeration and biological sampling. An anaesthetizing solution was created by diluting 10 – 25 ml of a MS-222 solution (5 g of MS-222 dissolved in 500 ml of water in a 500 ml container) into 2 – 3 L of water. This solution was replaced as necessary. Samplers continually evaluated fish response to the solution and targeted the lowest dosages needed to complete biological sampling.

During sampling, all fish were identified to species and enumerated. Coho, steelhead, Chinook, cutthroat, and lamprey (*Entospenus tridentus* and *Lampetra planeri*) were further categorized by life stage and age class as described below. Marks associated with trap efficiency trials (see Trap Efficiency Trials section) and hatchery origin (clipped adipose fin) were examined on all Chinook, coho, and steelhead. Fork length (mm) and scales were systematically collected from a subsample of wild (adipose fin intact) coho and steelhead, and all cutthroat (Table 1). No scales were collected from Chinook (only fork lengths). Genetic samples were collected from Chinook to help better understand life history diversity. Fin clips were also collected from lamprey for an unrelated population genetics study.

Table 1. Sample rates for biological data collection from wild juvenile salmonids.

Sample Type	Species	Fry	Parr	Transitional/Smolt
Fork Length	Coho	1st 10 daily	1st 10 daily	1st 10 daily
	Steelhead	1st 10 daily[a]	1st 10 daily	All efficiency marked individuals (≤ 100 daily)
	Chinook	1st 10 daily	1st 10 daily	1st 10 daily
	Cutthroat	---	---	All individuals encountered[b]
Scales	Coho	---	---	1st 5 daily
	Steelhead	---	---	1st 5 daily
	Chinook[c]	---	---	All > 150mm
	Cutthroat	---	---	All[b]
DNA	Coho	---	---	---
	Steelhead	---	---	---
	Chinook	1st 10 daily up to 50 per week	---	1st 10 daily up to 50 per week
	Cutthroat	---	---	---
	Lamprey	---	---	1st 10 per life stage per week

[a] Trout fry included both steelhead/rainbow trout and cutthroat.

[b] Includes adults

[c] No scale samples were collected from Chinook or cutthroat.

Life stage categories followed WDFW protocols developed for the Lower Columbia ESU monitoring program (see Appendix A for life stage decision tree). The five life stage categories include fry, parr, transitional, smolt, and adult. Fry and adults were assigned based on length criteria (fry ≤ 45 mm FL and adults ≥ 300 mm FL [cutthroat], 300 – 499 mm FL [rainbow], or ≥ 500 mm FL [steelhead]). Parr, transitional, and smolt life stages were assigned based on phenotypic traits. Parr had distinct parr marks or showed no signs of smoltification, transitionals showed initial signs of smoltification (i.e., silvery appearance and faded parr marks), and smolts showed advanced signs of smoltification (i.e., faded parr marks, deciduous scales, silvery appearance, black banding along the trailing edge of the caudal fin, and translucent pectoral and pelvic fins).

Age class represented the number of years in freshwater as measured from scale samples. Most out-migrating Chinook salmon in the Newaukum River were subyearlings. However, individuals ≥ 150 mm were typically larger than the fork length range of subyearling outmigrants and were thus labeled as yearlings (Table 2). For coho salmon, all fry and parr were classified as subyearlings, and all smolts and transitionals were classified as yearlings (Table 3). For steelhead, the field-assigned ‘yearlings’ were a mix of Age-1, Age-2, and Age-3 fish that could not be distinguished by length in the field (Table 4). Therefore, the age composition of steelhead was further described using scale data.

Table 2. Date and length criteria used for field calls of juvenile Chinook.

Life Stage	Age Class	Date Range	Length Range (mm FL)
Fry	---	Start – End	≤ 45
Parr, Transitional, Smolt	Subyearling	Start – End	> 45
Transitional, Smolt	Yearling	Start – End	> 150

Table 3. Date and length criteria used for field calls of juvenile coho.

Life Stage	Age Class	Date Range	Length Range (mm FL)
Fry	---	Start – End	≤ 45
Parr	Subyearling	Start – End	> 45
Transitional, Smolt	Yearling	Start – End	> 45

Table 4. Date and length criteria used for field calls of juvenile steelhead trout.

Life Stage	Age Class	Date Range	Length Range (mm FL)
Fry	---	Start – End	≤ 45
Parr	NA	Start – End	> 45
Transitional, Smolt	Yearling (+)	Start – End	90 – 299
Adult*	NA	Start – End	300 – 499
Adult**	NA	Start – End	≥ 500

*Cutthroat/ Resident Rainbow **Steelhead

Genetics

Genetic samples were collected from subyearling migrant Chinook captured at the screw trap to document diversity at Single Nucleotide Polymorphism (SNP) loci highly correlated with run timing of adult Chinook within the Chehalis basin (Thompson et al. 2019). Fin clips were collected from Chinook fry (juveniles ≤ 45 mm FL) and subyearlings (juveniles > 45 mm FL in the transitional or smolt life stage). However, the fry samples were collected to help supplement another fry trapping study (Zimmerman et al. 2023). Only subyearling smolt and transitional genetics are included in the current study. The first 10 Chinook encountered daily were sampled for genetics, up to 50 per week. Tissue was collected from the caudal fin and placed on DNA collection blotter paper and stored in plastic bags with desiccant beads until sent to the lab for processing.

Genomic DNA was isolated from fish tissue with Machery-Nagle silica-based column extraction kits following the manufacturers protocol for animal tissues. Chinook salmon-specific SNPs were genotyped using a cost-effective method based on a custom amplicon sequencing called Genotyping in Thousands (GTseq) (Campbell et al. 2015). For each sample, pools were sequenced, de-multiplexed, and genotyped by generating a ratio of allele counts. The process had four segments: extraction, library preparation, sequencing, and genotyping. The GTseq SNP panel used to infer adult run timing phenotype had 298 autosomal SNP loci, one sex ID SNP locus, and 33 run timing SNP loci. Run timing SNP loci comprise the two used in previous genetic analysis of Chehalis Chinook salmon (Thompson et al. 2019) and 31 additional run timing markers identified as important markers by Koch and Narum (2020) and Thompson et al. (2020).

Trap Efficiency Trials

A single trap, mark-recapture study design stratified by week was used to estimate juvenile salmon and steelhead abundance (Volkhardt et al. 2007). The mark-recapture design consisted of counting maiden caught fish (maiden captures) in the trap and marking a known number of the captured fish for release at an upstream location (marks). Marked fish that were recaptured in the trap after release (recaptures) were enumerated to calculate trap efficiency. Maiden captures, marks, and recaptures were stratified by week to account for heterogeneity in trap efficiency throughout the season. Weekly estimate periods began on Monday and ended on Sunday.

Trap efficiency trials were conducted with predetermined species, origin, and life stage groups to estimate outmigrant abundance (Table 5). Species included in the trap efficiency trials were coho, steelhead, and Chinook. All trap efficiency trials were conducted with wild (adipose fin intact) fish. For coho and steelhead, trap efficiency trials were conducted with transitional and smolt life stages. Fry and parr life stages were not included in the trap efficiency trials because it was assumed that these life stages were not actively out-migrating. For Chinook, trap efficiency trials were conducted with transitional and smolt life stages because those were the life stages for which an abundance estimate was desired. The trap did not operate for the full duration of the early-timed fry out-migration period; therefore, no estimate was generated for Chinook fry and this life stage was not included in the trap efficiency trials. Fish in good physical condition were selected for efficiency trials whereas fish in poor physical condition were enumerated and released downstream. The goal was to mark a maximum of 100 fish per species per day and up to 500 per species per week for efficiency trials; however, the actual number varied based on fish capture rates throughout the season.

Table 5. Abundance estimate groups defined by species, origin, life stage, and age class. Life stages included in the estimates were transitional (T), and smolt (S). Age classes included in the estimates were subyearling (SY) and yearling (Y). FL = fork length.

Abundance Group	Origin	Life Stage	Age Class	Note
Coho	Wild	T, S	Y, SY	
Steelhead	Wild	T, S	Y	
Chinook	Wild	T, S	SY	FL > 45 mm

Marked fish were released 3.9 km upstream of the trap location at the Rush Road bridge on the right bank, directly under the bridge.

Mark types and rotation schedules allowed the data to be stratified by week for the purpose of analysis. Different mark types were used for salmon and steelhead (Table 6). Releases generally occurred within 1 to 3 hours of the start of a trap check.

Table 6. Trap efficiency marks and release locations for each abundance estimate group. Efficiency marks were visible implant elastomer tag (VIE) and passive integrated transponder tag (PIT).

	Trap Efficiency Marks			Release location	
Abundance Group	Mark Types	Rotation Schedule	Mark Rotation	Description	Distance upstream of trap (river km)
Coho	PIT	Individual	Individual	Bridge	3.9
Steelhead	PIT	Individual	Individual	Bridge	3.9
Chinook	VIE	Weekly	4 weeks	Bridge	3.9

Assumption Testing

The six basic assumptions that must be met for unbiased estimates in mark-recapture studies include: 1) the population is closed, 2) marks are not lost, 3) marking does not affect behavior, 4) initial capture probabilities are homogenous, 5) the second sample is a random representative sample (i.e., marked and unmarked fish are completely mixed), and 6) mark status is reported correctly (Volkhardt et al. 2007). Throughout the season, multiple trials were conducted to reduce the probability of any assumption violations. These included mark/tag retention trials to ensure marks/tags were not lost, mark/tag detection trials to ensure that marks/tags were not missed and were reported correctly, and mark-related mortality trials to ensure marking/tagging did not affect behavior or survival.

Analysis

Estimates of abundance for coho, steelhead, and Chinook were generated using the R package Bayesian Time-Stratified Population Analysis System (BTSPAS), developed by Bonner and Schwarz (2014), using R version 2021.11.2 (R Core Team, 2021). The method uses Bayesian P-splines and hierarchical modeling of trap efficiencies to determine abundance with known precision through time, which allows for estimation during missed trapping days and for time strata with minimal efficiency data (Bonner and Schwarz 2011). Data for the analysis were stratified by week and included the total catch of unmarked fish (i.e., maiden captures), marks released, marks recaptured, and proportion of time sampled. The model assumed all marks were recaptured during the time strata period (i.e., week) in which they were released. This assumption was mostly supported by the collected data. Marks, marks released, and marks recaptured were removed as needed prior to analysis to account for missed trapping periods. The proportion of time sampled each week was included to adjust for missed catch. To model the initial tail of the run, one, three, and zero periods were added for coho, steelhead, and Chinook, respectively. To model the final tail of the run, two periods were added for Chinook as catches had not reached zero by the end of the trapping season.

For missed trapping periods, the BTSPAS model produced estimates with known precision using the entire season's dataset by fitting a spline through those dates. For coho and Chinook estimates, the BTSPAS diagonal model was used with model arguments as follows: each model was run with four Markov chain Monte Carlo (MCMC) chains and each chain had a total 50,000 draws (iterations) with the first 25,000 discarded as warmup (burn-in). A thinning rate of two was used to reduce autocorrelation in MCMC draws of the posterior distribution of each model parameter and to limit the file size due to computer memory limitations, for a total of 12,500 simulations. The steelhead estimate used the following arguments: number of chains = 4, iterations = 100,000, burn-in = 50,000, sims = 25,000, and thin rate = 2. Model convergence was assessed by visually inspecting the trace plots and using the Brooks-Gelman-Rubin (BGR; Rhat) statistic. Models were considered to have converged if MCMC chains were fully mixed based on visual inspection, the smallest number of effective draws was >1000, and Rhat was less than 1.1 for all parameters (Gelman et al. 2004).

Results

Summary of Fish Species Encountered

A diverse assemblage of fish species was encountered throughout the 2023 trapping season. Native fishes included juvenile Chinook and coho salmon, steelhead and cutthroat trout, mountain whitefish (*Prosopium williamsoni*), redside shiner (*Richardsonius balteatus*), longnose dace (*Rhinichthys cataractae*), speckled dace (*R. osculus*), largescale sucker (*Catostomus macrocheilus*), three-spine stickleback (*Gasterosteus aculeatus*), northern pikeminnow (*Ptychocheilus oregonensis*), Pacific lamprey, brook lamprey, and sculpin species (Cottidae). Non-native fishes included bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), rock bass (*Ambloplites rupestris*), and yellow bullhead (*Ameiurus natalis*).

Trap Operation

The trap operated from March 9 to July 10, 2023. There were eleven trap outages (Appendix B). For four of the eleven outages, the outage time was known exactly because the trap stopped fishing when staff intentionally lifted the cone during periods of high debris loads or trap maintenance. Outages 1 – 2, 4 – 5, 7, and 9 – 10 (seven total) were due to a log stopping the cone. The non-planned outages averaged 6.0 hours; four were 3.0 hours or less in duration, and the other three lasted 7.58, 12.0, and 14.3 hours in duration.

Assumption Testing Trials

Results indicated that mark/tag retention was high based on trials that lasted 24 hours. The estimated mark retention was 100% (PIT tags, 210 out of 210 tagged) for coho, 100% for steelhead (PIT tags, 46 out of 46 tagged), and 85.2% (Micro-Ject, 190 out of 223 marked) and 100% (VIE, 95 out of 95 marked) for Chinook. We also found that mark/tag related mortality was low. Estimated survival over a 24-hr holding period was 100% for coho (PIT tag, 210 out of 210 tagged), 100% for steelhead (PIT tags, 46 out of 46 tagged), and 93.7% (Micro-Ject 209 out of 223 marked) and 100% (VIE 95 out of 95) for Chinook.

Differences in initial capture probabilities due to body size in coho and steelhead were tested using logistic regression. For Chinook salmon, a Kolmogorov-Smirnov test was used. The relationship between probability of recapture and fork length was not significant for coho or steelhead ($p = 0.18$ and $p = 0.12$, respectively). The fork length of maiden captures did not differ significantly for Chinook recaptures ($D = 0.09$, $p = 0.88$).

Coho

The coho outmigrant estimate included both subyearlings and yearlings in transitional and smolt life stages. Approximately 84.3% of the outmigrants observed at the trap were categorized as the ‘smolt’ phenotype whereas 15.6% were categorized as the ‘transitional’ phenotype. Coho outmigrants were observed in low numbers in the first week of trapping during the third week of March (beginning March 23, trapping period 3), peaked in mid-May, and were last observed on July 9 (trapping period 18) (Appendix C).

Scale age data indicated most smolt were Age-1 (95.3%), with a small subyearling component (0.8%) and a two-year-old component for the coho out-migration (3.9%) (Figure 3, Table 7). The fork length of known sub-yearling outmigrants averaged 94.0 mm (± 2.6 mm SD), the average fork length of known yearling outmigrants averaged 111.8 mm (± 10.6 mm SD), and the fork length of known two-year old outmigrants averaged 121.7 mm (± 11.6 mm SD). Fork length for all measured outmigrants averaged 111.7 mm (± 11.9 mm SD).

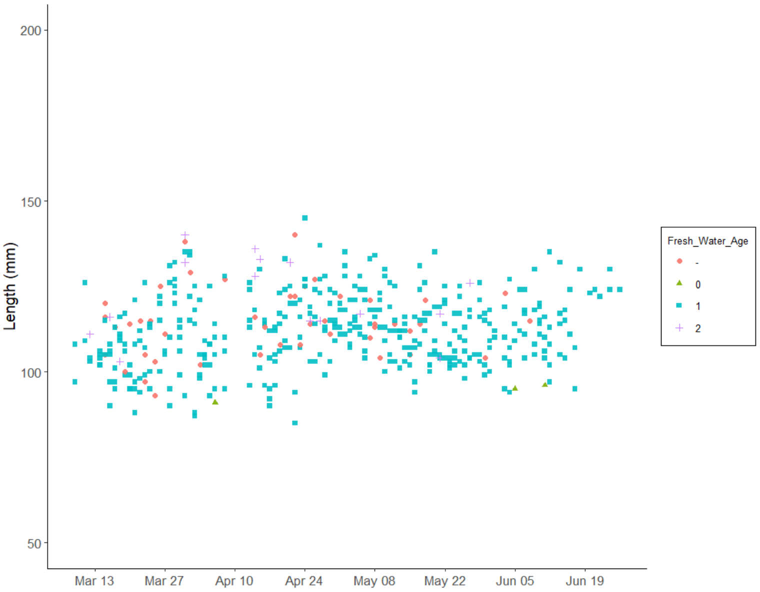

Figure 3. Plot of length and age by date for wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2023.

Table 7. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2023. Data are scale ages of sampled juveniles by week. ND indicates no data.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	ND
1	3/6	3/13	4		4		
2	3/14	3/20	29		22	3	4
3	3/21	3/27	32		24		8
4	3/27	4/3	33		27	2	4
5	4/4	4/9	30	1	27		2
6	4/10	4/16	15		10	3	2
7	4/17	4/23	35		29	1	5
8	4/24	4/30	35		27	2	6
9	5/1	5/6	30		28	1	1
10	5/7	5/13	35		29		6
11	5/14	5/20	35		31		4
12	5/21	5/27	35		33	2	
13	5/28	6/3	23		21	1	1
14	6/4	6/10	25	1	22		2
15	6/11	6/17	24	1	23		
16	6/18	6/24	6		6		
17	6/25	7/1	3		3		
18	7/2	7/8	0				
19	7/9	7/15	0				

The dataset used to generate an estimate of abundance had a total of 3,506 maiden coho outmigrants. In addition, 2,585 coho were marked and 138 recaptured (Appendix C). Modeled weekly trap efficiencies ranged from 3.2% to 11.8%.

Abundance of 2023 wild coho outmigrants was estimated to be 75,630 (95% CI = 63,042 - 92,116) with a coefficient of variation (CV) of 9.8% (Figure 4, Table 8). The Rhat value for coho was 1.001, suggesting good model convergence. In 2023, coho smolt production in the Newaukum River contributed 19.8% to the total coho smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap.

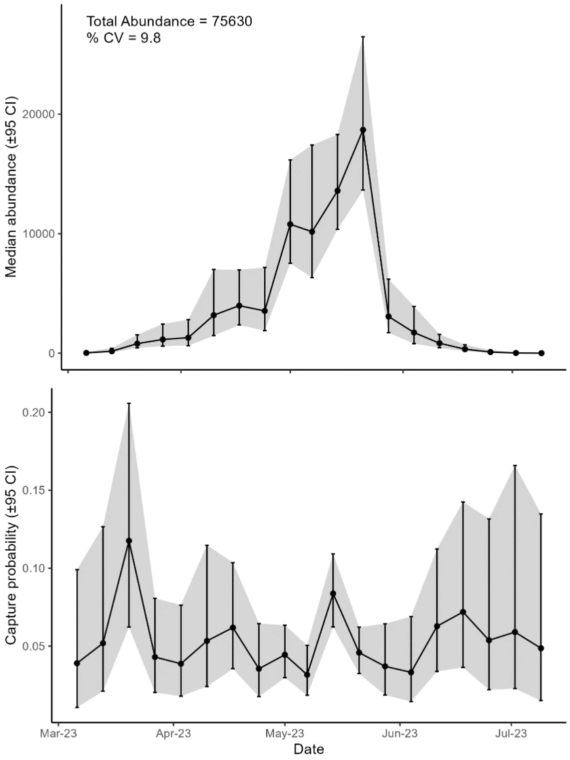

Figure 4. Number of out-migrants (top panel) and trap efficiency (bottom panel) by week for wild coho yearlings produced above the Newaukum River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

Table 8. Final outmigrant abundance estimates.

Species	Origin	Life Stage(s)	Age	Abundance (95% CI)	CV (%)
Coho	Wild	Smolts and transitionals	1	75,630 (63,042 – 92,116)	9.8
Steelhead	Wild	Smolts and transitionals	1+	11,443 (8,028 -17,169)	20.1
Chinook	Wild	Smolts and transitionals	0	64,472 (59,777 -73,289)	10.7

In 2021, the total number of adult coho spawners in the Newaukum River upstream of the trap site was estimated to be 5,594 (Ronne et al. 2022), producing a smolt-per-spawner estimate of 13.5 for the 2021 brood year of naturally spawning coho. This was the lowest value for brood years 2019-2021.

Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Of these life stages, approximately 65.1% of outmigrants observed were classified as the smolt phenotype, compared to 34.9% transitional. Steelhead outmigrant numbers were low during the first week of trapping, March 9 (trapping period 1), peaked in early April, and were last observed the week of June 18 (trapping period 16) (Figure 5, Table 9, Appendix D).

Table 9. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2023. Data are scale ages of sampled juveniles by week. ND indicates no data.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Age-3	ND
1	3/6	3/13	11		2	5	1	3
2	3/14	3/20	22		12	4	2	4
3	3/21	3/27	34		16	8	1	9
4	3/27	4/3	30		10	14	4	2
5	4/4	4/9	30		17	10	1	2
6	4/10	4/16	15		8	3		4
7	4/17	4/23	24		14	7		3
8	4/24	4/30	35		8	15	2	10
9	5/1	5/6	10		7	1		2
10	5/7	5/13	19		8	6	1	4
11	5/14	5/20	8		5	2		1
12	5/21	5/27	1			1		
13	5/28	6/3						
14	6/4	6/10	2		1	1		
15	6/11	6/17	1			1		
16	6/18	6/24						
17	6/25	7/1						
18	7/2	7/8						
19	7/9	7/15						

Scale age data indicated that sampled steelhead were Age-1 (54.5%), Age-2 (39.4%), and Age-3 (6.1%) (Figure 6, Table 9). Fork length averaged 127.8 mm (± 21.3 mm SD) for Age-1, 165.1 mm (± 16.3 mm SD) for Age-2, 176.8 mm (± 10.0 mm SD) for Age-3, and 140.0 mm (± 29.5 mm SD) for all.

The dataset used to generate an estimate of abundance had a total of 564 maiden steelhead outmigrants. In addition, 490 steelhead were marked and 30 recaptured. Modeled weekly trap efficiencies ranged from 3.1% to 7.9% (Appendix D). The abundance of wild steelhead outmigrants was estimated to be 11,443 (95% CI = 8,028 – 17,169) with a CV of 20.1%.

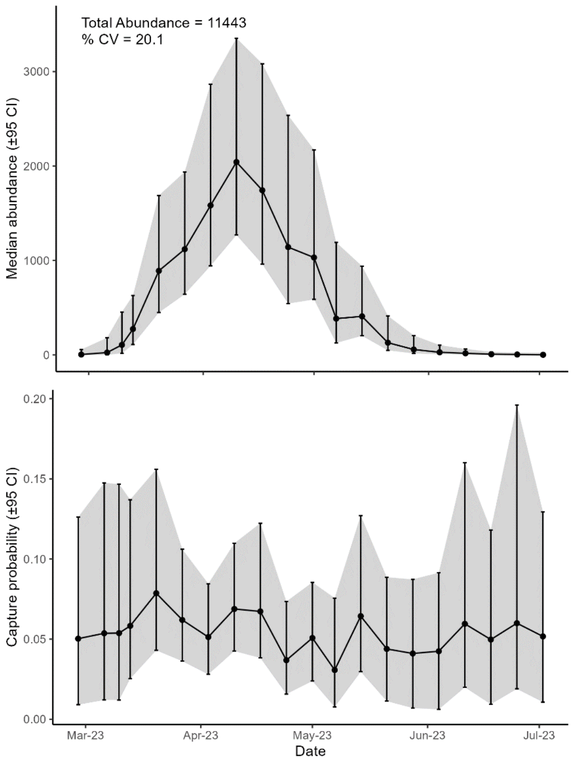

Figure 5. Number of out-migrants (top panel) and trap efficiency (bottom panel) by week for wild steelhead smolts produced above the Newaukum River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

Steelhead contributing to the 2023 smolt outmigration came from the 2020 through 2022 brood years. For the 2020 brood, there were 1,103 spawners above the trap. Based on scale ages, it was determined that 5,054 smolts from that brood out-migrated at Age-1 in 2021, 2,785 at Age-2 in 2022, and 698 at Age-3 in 2023, for a total smolt production of 8,537. This produced a total smolt-per-spawner estimate of 7.7 for the 2020 brood year, although this estimate may be biased low due to not capturing the entire outmigration of steelhead smolts in 2021 and 2022. Estimating steelhead productivity above the trap through time is a project goal.

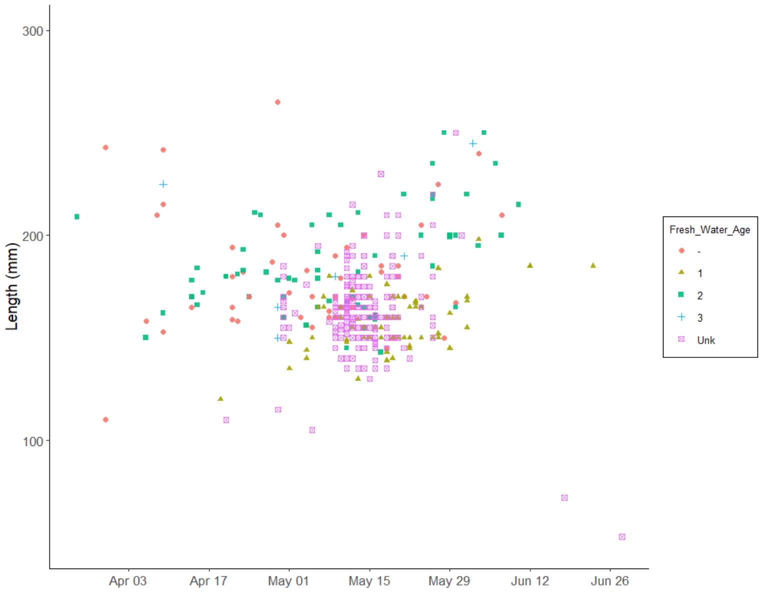

Figure 6. Plot of length and age by date for wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2023.

Chinook

The Chinook outmigrant estimate was derived for the 'subyearling' life history that included transitionals and smolts. Chinook outmigrants were observed in low weekly numbers (n < 250) the first seven weeks of trapping (beginning March 11, trapping period 1), peaked in early June, and declined to low numbers again by the last week of trapping (ending July 9, trapping period 18) (Appendix E).

Scale age data were not collected from Chinook as all juvenile fish were assumed to be subyearlings. Fork length of Chinook subyearlings (fry, parr, transitionals and smolts) increased steadily throughout the trapping period with an average of 41.8 mm (± 3.1 mm SD) and 84.6 mm (± 5.6 mm SD) in the first and last sampled week of trapping, respectively (Figure 7).

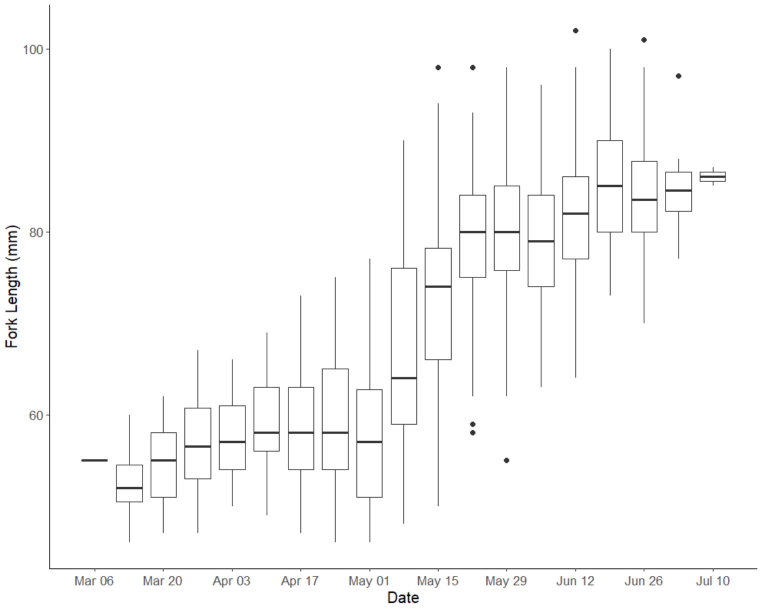

Figure 7. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Newaukum River screw trap, 2023. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

The dataset used to generate an estimate of abundance had a total of 12,458 Chinook subyearling maiden outmigrants (not including fry or parr) In addition, 4,996 Chinook were marked and 1,071 recaptured (Appendix E). Modeled weekly trap efficiencies ranged from 5.5.% to 33.8%.

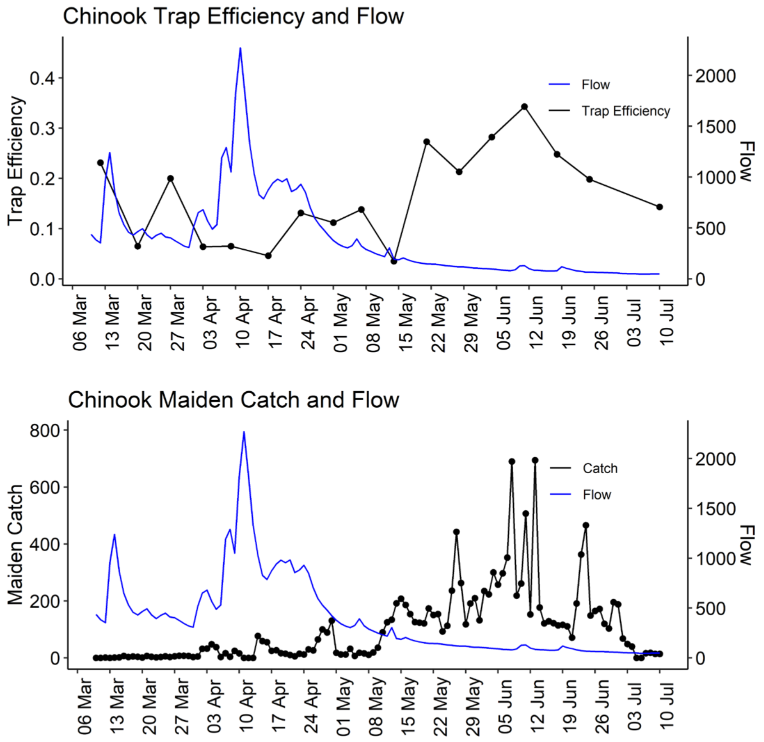

Figure 8. Wild Chinook transitional and smolt raw trap efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Newaukum River smolt trap.

Abundance of wild Chinook subyearling outmigrants (not including fry or parr) was estimated to be 64,472 (95% CI = 59,777 – 73,289) with a CV of 10.7% (Figure 9, Table 8). The Rhat value for Chinook was 1.007, suggesting good model convergence. Chinook smolt production in the Newaukum River contributed 19.0% to the total Chinook smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap in 2023.

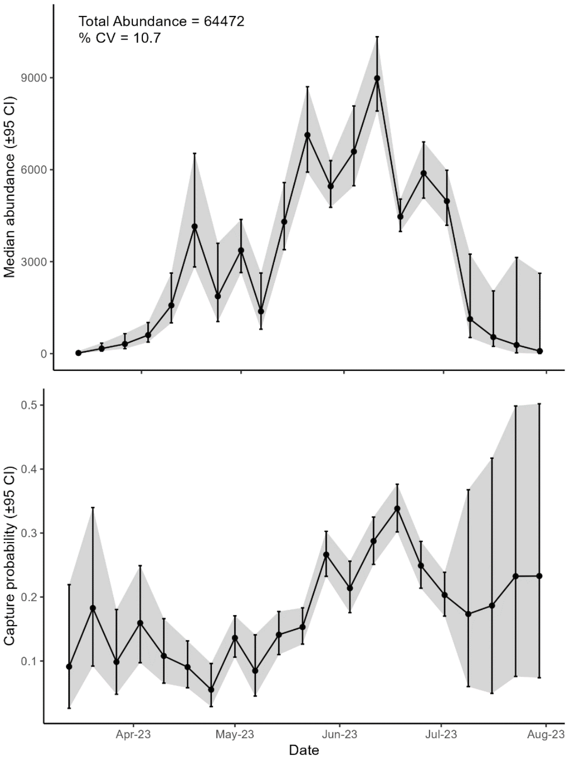

Figure 9. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Newaukum River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

The total number of adult spring Chinook spawners in the Newaukum River in 2022 upstream of the trap site was estimated to be 253, and adult fall Chinook was estimated to be 223 (total Chinook spawners = 476, Ronne et al. 2024), producing an overall smolt-per-spawner estimate of 135.4 for the 2022 brood year of naturally spawning Chinook. This was the second highest value for brood years 2019-2022.

Chinook Run Types

A total of 801 juvenile Chinook tissue samples from the Newaukum River smolt trap were sent to the lab for processing in 2023. Of those, SNP genotypes were successfully obtained from 587 samples (73.3%). Chinook subyearlings had one of three genotypes associated with run-timing: homozygous spring (two copies of a spring allele), homozygous fall (two copies of a fall allele), or heterozygote (one spring allele and one fall allele, unknown run timing). Proportions of spring, fall, and heterozygote genotypes by week were apportioned according to the weekly abundance estimates with known precision based on results from the mark-recapture study (Figure 10, Table 10, Table 11). No fish were sampled in the first or final three weeks of trapping; however, the model predicted abundance during those periods, so proportions in these weeks were based on determinations from the next week or the week prior. If the correlation of the SNP genotype and adult run timing phenotype still holds, the Chinook subyearling outmigration abundance estimate consisted of an estimated 13,522 (21.4%) homozygous spring Chinook, 34,595 (54.7%) homozygous fall Chinook, and 15,167 (24.0%) of heterozygous spring-fall Chinook with unknown run timing.

Table 10. Chinook genetic sample sizes by period.

Start Date	End Date	Period	Spring	Heterozygote	Fall	Total
7-Mar	13-Mar	1	NA	NA	NA	NA
14-Mar	20-Mar	2	7	3	1	11
21-Mar	27-Mar	3	18	0	0	18
28-Mar	3-Apr	4	9	3	1	13
4-Apr	10-Apr	5	16	3	6	25
11-Apr	17-Apr	6	21	5	7	33
18-Apr	24-Apr	7	14	5	19	38
25-Apr	1-May	8	10	10	18	38
2-May	7-May	9	10	11	23	44
8-May	14-May	10	16	19	18	53
15-May	21-May	11	19	13	22	54
22-May	28-May	12	17	14	18	49
29-May	4-Jun	13	9	12	35	56
5-Jun	11-Jun	14	0	13	31	44
12-Jun	18-Jun	15	0	14	32	46
19-Jun	25-Jun	16	1	6	29	36
26-Jun	2-Jul	17	0	4	15	19
3-Jul	9-Jul	18	1	2	7	10
10-Jul	16-Jul	19	NA	NA	NA	NA
17-Jul	23-Jul	20	NA	NA	NA	NA
24-Jul	30-Jul	21	NA	NA	NA	NA
		Totals	**168**	**137**	**282**	**587**

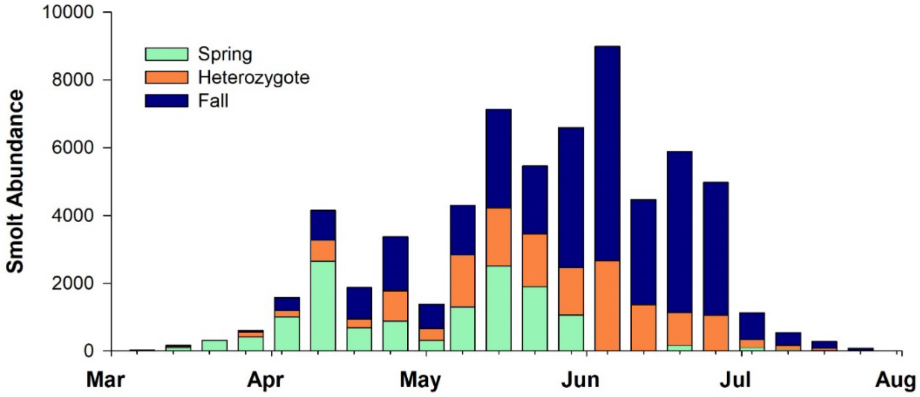

Figure 10. Chinook subyearling SNP genotype estimates from the Newaukum River trap by date. Genotypes are associated with adult run timing in Chehalis Chinook salmon (Thompson et al. 2019).

Table 11. Chinook subyearling genetic estimates by period and run type at the Newaukum River screw trap.

Start Date	End Date	Period	Spring	Heterozygote	Fall	Total
7-Mar	13-Mar	1	14	6	2	22
14-Mar	20-Mar	2	106	46	15	167
21-Mar	27-Mar	3	316	0	0	316
28-Mar	3-Apr	4	420	140	47	606
4-Apr	10-Apr	5	1,009	189	378	1,576
11-Apr	17-Apr	6	2,640	629	880	4,149
18-Apr	24-Apr	7	689	246	936	1,871
25-Apr	1-May	8	887	887	1,596	3,370
2-May	7-May	9	313	345	721	1,379
8-May	14-May	10	1,299	1,542	1,461	4,302
15-May	21-May	11	2,509	1,716	2,905	7,130
22-May	28-May	12	1,894	1,560	2,005	5,459
29-May	4-Jun	13	1,060	1,413	4,121	6,593
5-Jun	11-Jun	14	0	2,654	6,329	8,983
12-Jun	18-Jun	15	0	1,360	3,107	4,467
19-Jun	25-Jun	16	163	981	4,741	5,885
26-Jun	2-Jul	17	0	1,047	3,927	4,974
3-Jul	9-Jul	18	113	225	789	1,127
10-Jul	16-Jul	19	54	108	378	540
17-Jul	23-Jul	20	28	57	198	283
24-Jul	30-Jul	21	9	17	60	85
			13,522 **(21.4%)**	**15,167** **(24.0%)**	**34,595** **(54.7%)**	**63,284** **(100%)**

Cutthroat

While cutthroat trout were not a focus of the study, they were encountered at the trap, and although efficiency trials were not conducted, the total number of fish caught equaled 16. Of these, 14 scales were sampled and 13 successfully aged (Figure 11 and Table 12).

The cutthroat outmigration included both transitional and smolt life stages. Of these life stages, approximately 87.5% of outmigrants observed were classified as the smolt phenotype, compared to 12.5% transitional. Cutthroat outmigrant numbers were low during the first week of trapping, March 11 (trapping period 1), peaked in mid-March, and were last observed June 25 (trapping period 17).

Scale age data indicated that sampled cutthroat were Age-1 (44.4%), Age-2 (33.3%), and Age-3 (22.2%) (Figure 11, Table 12). Fork length averaged 127.8 mm (± 21.3 mm SD) for Age-1, 165.1 mm (± 16.3 mm SD) for Age-2, 176.8 mm (± 10.0 mm SD) for Age-3, and 140.0 mm (± 29.5 mm SD) overall.

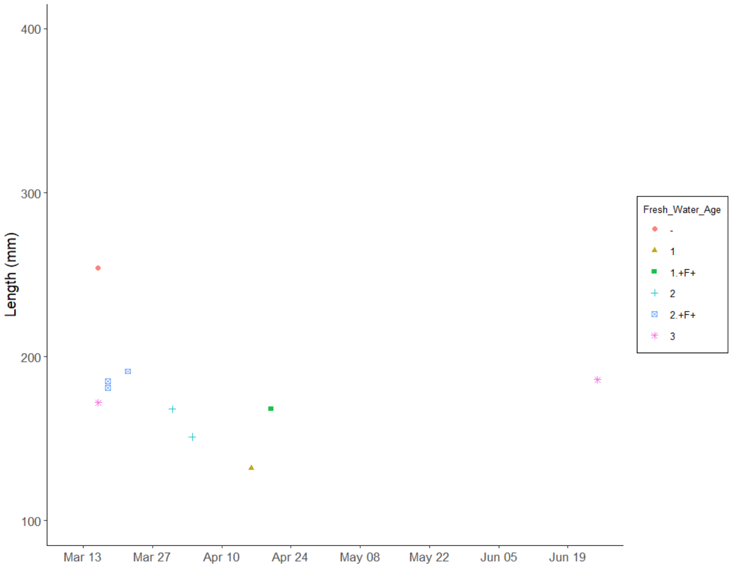

Figure 11. Plot of length and age by date for wild cutthroat the Newaukum River screw trap, 2023.

Table 12. Freshwater ages of wild cutthroat at the Newaukum River screw trap, 2023. Data are scale ages of sampled individuals by week. ND indicates no data.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Age-3	Age-4	Adult	ND
1	3/6	3/13	1		1					
2	3/14	3/20	5			1	1		2*	1
3	3/21	3/27	2		1				1*	
4	3/27	4/3	1			1				
5	4/4	4/9	2		1	1				
6	4/10	4/16	0							
7	4/17	4/23	2		1				1**	
8	4/24	4/30	0							
9	5/1	5/6	0							
10	5/7	5/13	0							
11	5/14	5/20	0							
12	5/21	5/27	0							
13	5/28	6/3	0							
14	6/4	6/10	0							
15	6/11	6/17	0							
16	6/18	6/24	0							
17	6/25	7/1	1				1			
18	7/2	7/8	0							
19	7/9	7/15	0							

Comments:

* Scale age 2.+F+ ** Scale age 1.+F+

Discussion

Basin-wide Context

This report presents results from the 2023 salmon and steelhead smolt out-migration of the Newaukum River, the fifth year since 1988 when any smolt monitoring has been conducted in this sub-basin. The abundance estimates provided in this report represent juvenile salmonids that completed their freshwater rearing in habitats upstream of the trap location, specifically production from upstream of river km 9.35 (river mile 5.8). However, some juveniles emerge from the gravel upstream of the trap location and redistribute to areas downstream of the trap location during their freshwater rearing period and are not included in these estimates. This caveat is especially true for coho salmon which are known to redistribute in a downstream direction during the fall months in search of suitable overwintering habitat (Winkowski et al. 2018).

The 2023 juvenile coho estimate was the highest of the time series and an increase of 48.2% from the 2022 estimate (75,630 compared to 51,031). The CV decreased from 20.1% in 2022 to 9.8% in 2023, indicating lower variance in the estimate (Figure 12). This increase in wild coho production coincided with an increase in adult returns: 2,770 coho returned to the Newaukum in 2020 compared to 5,594 in 2021 (Ronne et al. 2022, 2023). It is encouraging that coho production rebounded after a steady decline since 2020. It may indicate good survival during the vulnerable periods of freshwater rearing, including the summer parr period in 2022 and overwinter period in 2022 and 2023.

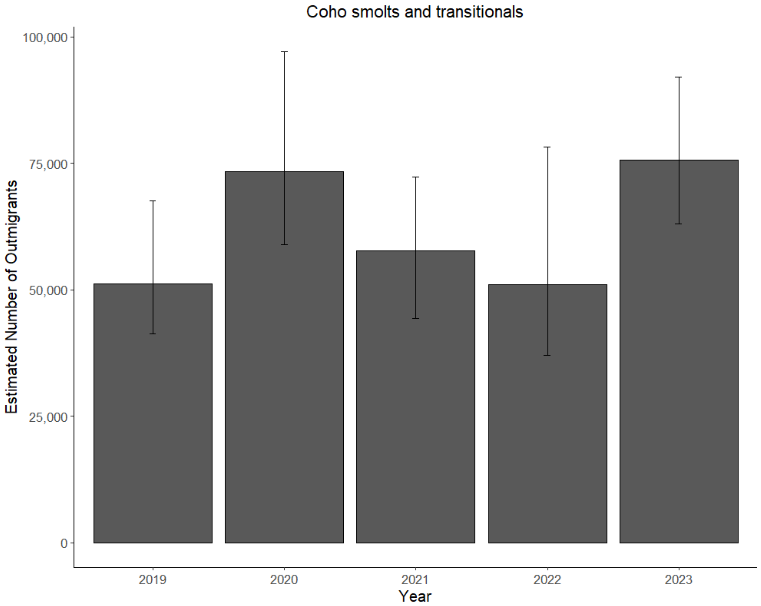

Figure 12. Time series of 2019–2023 estimates with 95% confidence intervals of wild coho juvenile outmigrants at the Newaukum River smolt trap.

From 2019 - 2022, an estimate of wild juvenile steelhead outmigrants was unreportable due to missing the early portion of the out-migration. For the first time in the history of the operation of the Newaukum River Rotary Screw trap, a reportable steelhead production estimate was generated (Figure 13). Factors that may have contributed to the generation of a steelhead production estimate include accessing the trap from the opposite bank than was previously used, which allowed fishing the thalweg through the season, combined with a later than usual out-migration peak. It is a goal to use further reportable estimates to generate a correction factor to apply to previous out migrations to generate production estimates for 2019 – 2022.

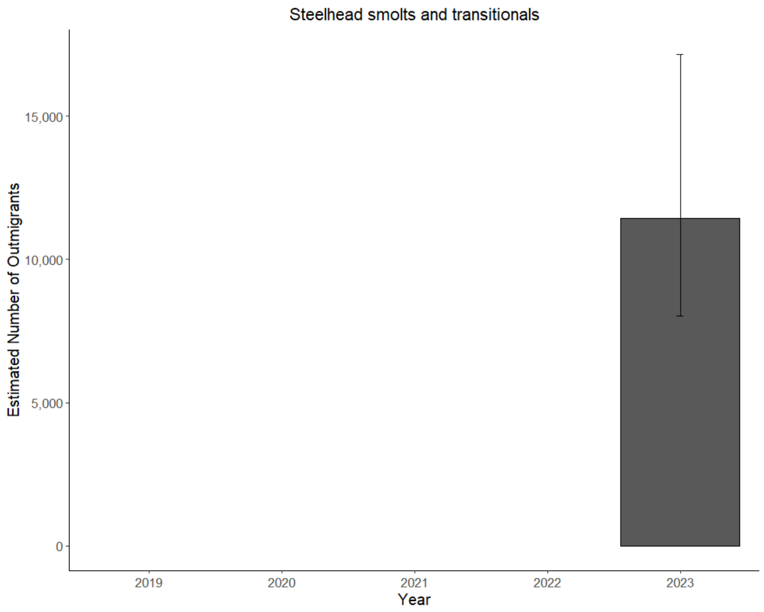

Figure 13. Times series of 2019 - 2023 estimates with 95% confidence intervals of wild steelhead juvenile outmigrants at the Newaukum River smolt trap. Note that the 2019 - 2022 estimates are not considered reportable.

The abundance estimate for Chinook salmon represents the subyearling component of the out-migration upstream of the trap location and does not include the earlier timed fry migrants. However, the subyearling estimate is relevant to habitat restoration planning because the subyearling component of the out-migration represents the numbers of juveniles that are supported by freshwater habitats upstream of the trap site. Fry migrants spend less time rearing in freshwater habitats. Fry migrants move downstream shortly after emergence and make extensive use of estuary and nearshore growing environments prior to entering the ocean (Beamer et al. 2005, Sandell et al. 2014). Other studies in western Washington have observed that, within a watershed, the numbers of subyearling Chinook outmigrants are relatively consistent from year to year and have concluded that abundance of this life history reflects a freshwater rearing capacity (Anderson and Topping 2018, Zimmerman et al. 2015). Moreover, evaluation of otoliths from adult Chinook returning to the Newaukum River (Campbell et al. 2017 & 2023) found that most (> 95%) adults out-migrated as subyearlings. If rearing capacity is reached, additional juvenile Chinook may migrate downstream as fry in response to density-dependence (Greene et al. 2005). Extending this density-dependent migration hypothesis to the Newaukum River will require additional years of juvenile monitoring coupled with adult Chinook spawner data above the trap location.

The 2023 Chinook estimate saw a 58.6% increase from the 2022 estimate (64,472 vs. 40,639) and the CV increased from 6.7% in 2022 to 10.7% in 2023 (Figure 14). Contradictorily, this increase in wild Chinook production corresponded with decreased adult returns: there were 865 Chinook spawners in the Newaukum in 2021, but only 476 in 2022 (Ronne et al. 2022 & 2023). Despite this, the smolt production estimate increased. Smolt production estimates in 2021 and 2022 were drastically different (129,682 and 40,639, respectively). The winter of 2021 – 2022 saw multiple high water flow events in the Chehalis Basin, including record flooding in the Newaukum River. These high flows could have caused the decline, leading to increased mortality, and/or flushing fry out of the Newaukum sub-basin prior to trap installation in 2022. It is encouraging to see Chinook production start to rebound following the sharp decline from 2021 to 2022 (162,269 and 40,639, respectively). While this isn't a full recovery to the 2019 – 2021 average (189,686), it is a step in the right direction.

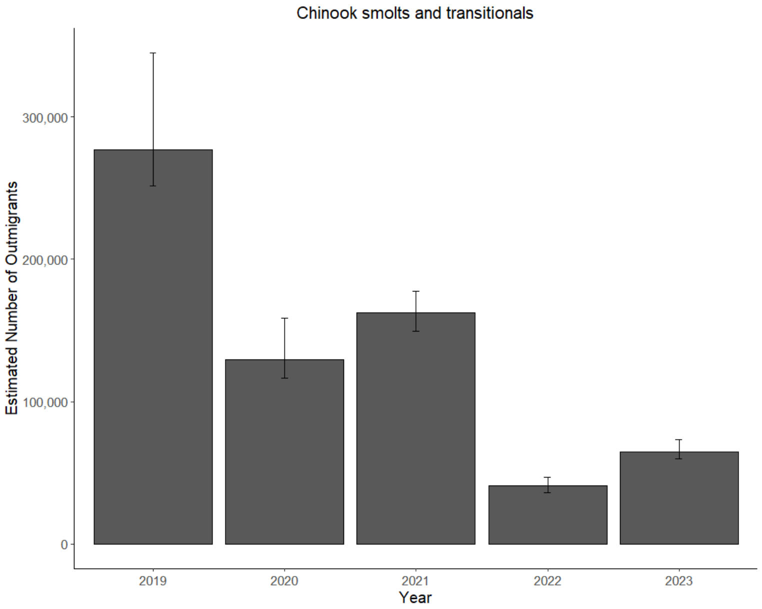

Figure 14. Time series of 2019–2023 estimates with 95% confidence intervals of wild Chinook juvenile outmigrants at the Newaukum River smolt trap.

This was the second year that genetic samples were taken from subyearling Chinook > 45 mm. Results indicate that proportions of run types were similar to 2021 (20.5% spring, 61.6% fall, and 17.9% heterozygote), indicating relatively stable proportions of run types among years. These results confirm other observations that the Newaukum produces a higher proportion of spring Chinook than other tributaries of the Chehalis River (Gilbertson et al. 2021) and could be a place to prioritize conservation or restoration to support this vulnerable run type. Interestingly, juvenile Chinook production in the Newaukum in 2023 contained a higher overall number of smolts (n = 64,472) than fry (n = 33,785) as determined in a complementary study (Zimmerman et al. 2023) and could indicate that Chinook rearing habitat in the Newaukum is not fully seeded.

Operating multiple smolt traps in the Chehalis basin allows comparison of smolt abundance estimates from specific locations, providing a finer scale resolution of freshwater production at the sub-basin level. Annual freshwater production of wild coho smolts in the Chehalis River Basin has averaged 2.2 million (range = 0.5 to 3.7 million) since WDFW began monitoring in the 1980s (Litz 2023). From 2017–2022, coho smolt abundance in the Chehalis Mainstem above river km 84 (river mile 52) averaged ~330,000 (Olson and Litz 2024). Therefore, the area above river km 84 contributes to roughly 15% of the coho smolt production in the basin. In 2023 specifically, coho smolt abundance at the mainstem Chehalis River smolt trap was estimated to be 381,223. Therefore, in 2023, the Newaukum River coho abundance estimate (75,630) represents approximately 19.8% of the coho production above river km 84 of the mainstem Chehalis River. This is an increase from 11.2% of total production in 2022 (Olson et al. 2024). Above river km 84, the Newaukum Basin only represents approximately 8% of the available anadromous stream segments, suggesting it produces a disproportionally high percentage of coho from this area of the Chehalis Basin (Walther 2021). This information is critical for conservation and restoration planning and for understanding status and trends of salmon smolt abundance in different locations in the basin and how they could be influenced by changes to the physical environment (e.g., restoration or climate change).

Next Steps

The Newaukum River presents many challenges to smolt trapping operations. In 2023, these challenges included high flows and debris. Challenges in trap operations began when river flows exceeded 800 cubic feet per second (cfs, USGS Stream Gage 1202500). This was primarily because of the increased debris load that accompanies increased flows. High flows and debris loads resulted in four trap outages in March, five in April, one in May, and one in June. To reduce the duration of these outages, a cellular trail camera continued to be used to monitor the trap in 2023 and helped identify precisely when a stoppage occurred, reducing missed data. These cameras will continue to be used in future years and their use on other traps is recommended.

Within trapping seasons, mean monthly stream temperatures steadily increased from 6 – 8°C in March, to approximately 18 – 22°C in July (Table 13). Between years, 2023 was cooler than previous years in both March and April, above average in May and June, and warmer that previous in July.

Prior to 2023, changes in river flow necessitated frequent trap moves to maintain trap access and good fishing position. In 2023, access was gained from the opposite, higher bank. This change in access point allowed the trap to remain in the thalweg for the entirety of the season. This may have contributed to capture the entirety of the steelhead out-migration, enabling the generation of a reportable production estimate. This access point will continue to be used in future years so long as landowner permission is maintained.

The Chinook subyearling outmigration peaked in early June, limiting handling fish during stressful high stream temperatures. As catch of subyearling Chinook increased from May to June to July, mean monthly stream temperatures increased from 15.2℃ in May to 17.7℃ in June to 22.1℃ in July (Table 13). During this time, fish were processed earlier in the morning when stream temperatures were coolest.

Table 13. Time series of mean monthly stream temperatures ℃ recorded at Newaukum River smolt trap near river km 9.35 from 2019 - 2023.

Year Month	2019 Mean (℃)	2020 Mean (℃)	2021* Mean (℃)	2022 Mean (℃)	2023 Mean (℃)
March	-	7.1	7.2	8.4	6.6
April	-	10.7	11.6	9.0	8.7
May	-	14.0	15.1	11.5	15.2
June	16.5	15.1	20.2	14.8	17.7
July	21.8	18.6	-	21.3	22.1

*Temperature data at Newaukum River trap site during 2021 trapping season are unavailable. Temperature data are from Stan Hedwall Park, 5.85 Rkm below trap site.

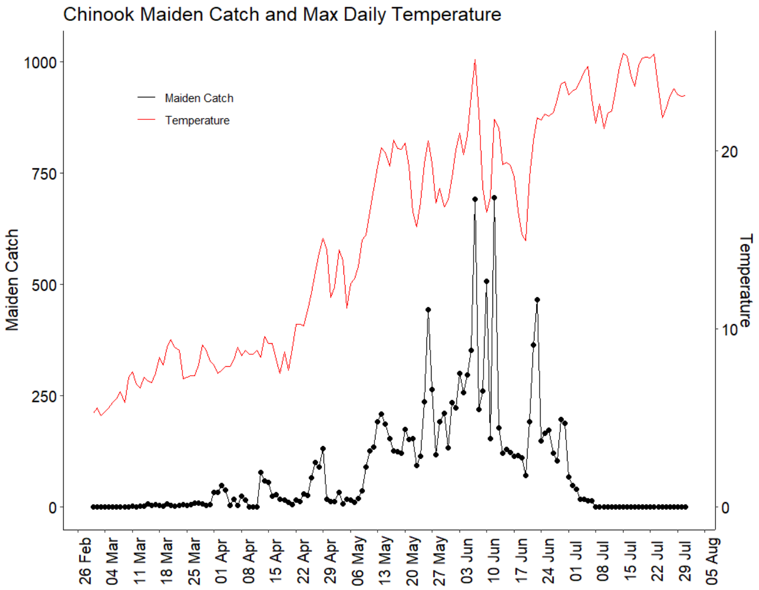

Figure 15. Chinook maiden catch and maximum daily stream temperature (°C) at the Newaukum River smolt trap in 2023.

In the 2022 season, the Chinook marking method changed from visible implant elastomer (VIE) to Micro-Ject. Micro-Ject was not as effective in 2023 as it was in 2022. Challenges encountered included frequent marker breakdown, marker clogging, fin blowout, and overall difficulty obtaining good marks. Due to these persistent challenges, the marking method was changed back to VIE in June 2023. It is not believed that either trap efficiency or production estimates were meaningfully impacted by this change. It is planned to continue the use of VIE in the future.

In summary, 2023 represents the fifth year for which wild coho, steelhead, and Chinook out-migrations have been described from any location in the Newaukum River in three decades. The 2024 season will benefit from refinements resulting from this year. Unbiased and precise estimates of abundance were generated for coho and Chinook in 2023, and for the first time, a production estimate for steelhead. For all three species, biological diversity was described (timing, age structure, and size) for outmigrants, as these characteristics reflect how the existing habitat contributes to freshwater production of salmon and steelhead. Continuation of this monitoring in future years will provide understanding of variability and trends in freshwater production over time. As part of a larger, integrated monitoring effort associated with the Aquatic Species Restoration Plan, this baseline information should also inform future questions on the influence of habitat restoration projects or climate change impacts on freshwater production of salmon and steelhead in the Newaukum River.

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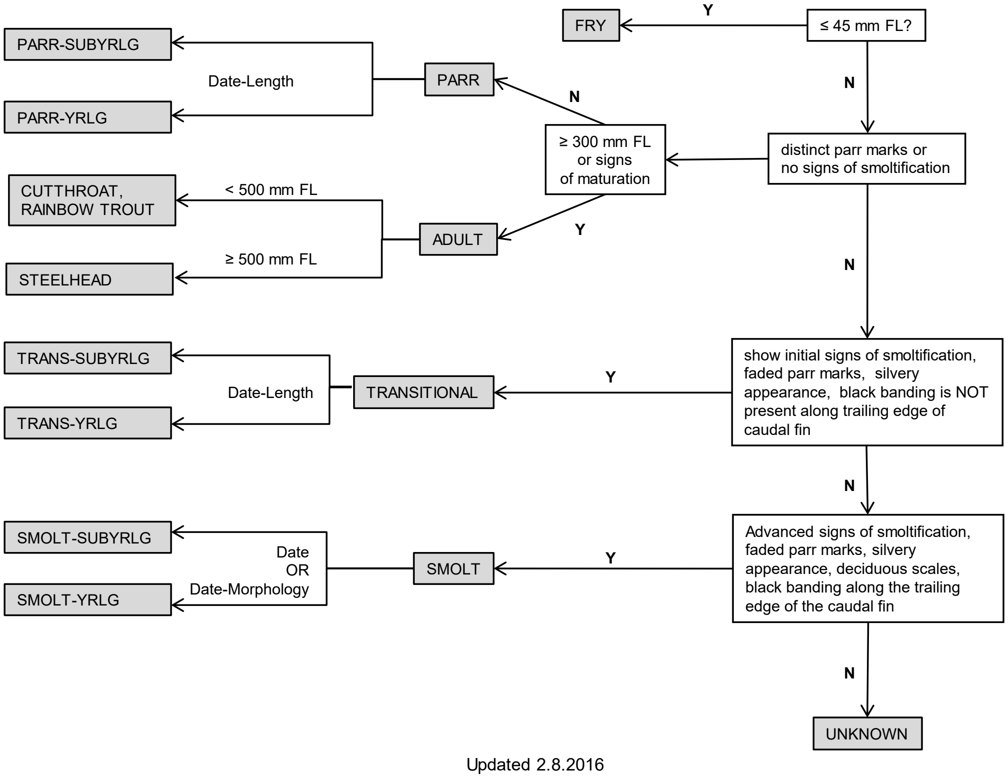
Appendices

Appendix A. Decision tree for assigning life stages of juvenile outmigrants developed by the Washington Department of Fish and Wildlife to ensure consistency in data collection protocols across juvenile trapping projects.



Updated 2.8.2016

Appendix B. Newaukum River missed trapping periods 2023.

Last Time Observed Fishing	Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Resume Fishing	Comments
3/9 1930	12 hr	visual	3/10 0915	Screw stopper
3/13 1400	3 hr	visual	3/13 1700	Screw stopper
3/13 1900	14.5 hr	scheduled	3/14 0930	Pulled due to debris
3/14 1720	14.3 hr	visual	3/15 0938	Screw stopper
4/6 0800	1.17 hr	Trail Camera	4/6 0910	Screw stopper
4/7 2113	9.25 hr	Scheduled	4/8 0715	Pulled due to debris and collar failure
4/8 1500	2.5 hr	Trail Camera	4/8 1730	Screw stopper
4/10 0600	77.33 hr	Scheduled	4/13 1120	Trap pulled
4/23 1900	1.33 hr	Trail Camera	4/23 2020	Screw stopper
5/6 0145	7.58 hr	visual	5/6 0920	Screw stopper

Appendix C. Mark-recapture data for wild coho out-migrants (transitionals, smolts) organized by period. Data are the combined counts of subyearling and yearling coho. Dataset includes total marks released (Total Mark), total marks recaptures (Total Recap), total maiden captures (Total Captures), and the proportion of time the trap fished during the period (Prop Fished).

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/7	3/13	2	0	8	0.86
2	3/14	3/20	58	9	68	0.71
3	3/21	3/27	49	1	50	1.00
4	3/28	4/3	43	2	35	0.71
5	4/4	4/10	0	0	73	0.43
6	4/11	4/17	100	8	140	0.57
7	4/18	4/24	132	6	123	1.00
8	4/25	5/1	435	18	481	1.00
9	5/2	5/7**	317	8	277	0.86
10	5/8	5/14	474	41	1139	1.00
11	5/15	5/21	661	26	860	1.00
12	5/22	5/28	166	7	112	1.00
13	5/29	6/4	37	1	56	1.00
14	6/5	6/11	66	6	52	1.00
15	6/12	6/18	36	4	25	1.00
16	6/19	6/25	6	0	6	1.00
17	6/26	7/2	3	1	1	1.00
18	7/3	7/9	0	0	0	0.71

*Start and End Date reflect the dates of maiden captures to which the release and recapture data were applied for estimation. Release dates start and end one day before the recapture dates.

** Shifted marking period to start one day prior.

Appendix D. Mark-recapture data for wild steelhead out-migrants (transitionals, smolts) organized by period. Dataset includes total marks released (Total Mark), total marks recaptures (Total Recap), total maiden captures (Total Captures), and the proportion of time the trap fished during the period (Prop Fished). No estimate was produced from data due to low recapture numbers and violating the assumption of trapping over the entirety of the out-migration.

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop Fished
1	3/7	3/13	5	2	15	1.00
2	3/14	3/20	44	4	52	0.71
3	3/21	3/27	67	6	69	1.00
4	3/28	4/3	67	3	81	1.00
5	4/4	4/10	114	9	121	0.85
6	4/11	4/17	30	4	84	0.71
7	4/18	4/24	59	1	41	1.00
8	4/25	5/1	61	1	54	1.00
9	5/2	5/7**	7	0	8	0.85
10	5/8	5/14	24	0	30	1.00
11	5/15	5/21	8	0	5	1.00
12	5/22	5/28	1	0	1	1.00
13	5/29	6/4	0	0	0	1.00
14	6/5	6/11	1	0	2	1.00
15	6/12	6/18	1	0	0	1.00
16	6/19	6/25	0	0	1	1.00
17	6/26	7/2	1	0	0	1.00

*Start and End Date reflect the dates of maiden captures to which the release and recapture data are applied for estimation. Release dates should start and end one day before the recapture dates.

** Shifted marking period to start one day prior stat/ recap period.

Appendix E. Mark-recapture data for wild Chinook outmigrants (transitionals, smolts) organized by period. Dataset includes total marks released (Total Mark), total marks recaptures (Total Recap), total maiden captures (Total Captures), and the proportion of time the trap fished during the period (Prop Fished).

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop Fished
1	3/7	3/13	0	0	1	0.86
2	3/14	3/20	13	3	23	0.71
3	3/21	3/27	25	2	31	1.00
4	3/28	4/3	55	11	96	1.00
5	4/4	4/10	86	8	147	0.86
6	4/11	4/17	185	12	216	0.57
7	4/18	4/24	109	4	102	1.00
8	4/25	5/1	374	51	459	1.00
9	5/2	5/7**	98	11	97	0.86
10	5/8	5/14	356	51	607	1.00
11	5/15	5/21	576	88	1093	1.00
12	5/22	5/28	600	164	1453	1.00
13	5/29	6/4	366	78	1409	1.00
14	6/5	6/11	553	159	2583	1.00
15	6/12	6/18	600	206	1510	1.00
16	6/19	6/25	500	124	1467	1.00
17	6/26	7/2	500	99	1012	1.00
18	7/3	7/9	0	0	138	0.71
19	7/10	7/16	0	0	14	0.14

Comments: Total captures are wild Chinook. All marks and recaptures are wild Chinook caught in the Newaukum trap to which a MicroJect mark was applied for trap efficiency trials.

*****Start and End Date reflect the dates of maiden captures to which the release and recapture data are applied for estimation. Release dates start and end one day before the recapture dates.

** Shifted marking period to start one day prior stat/ recap period.