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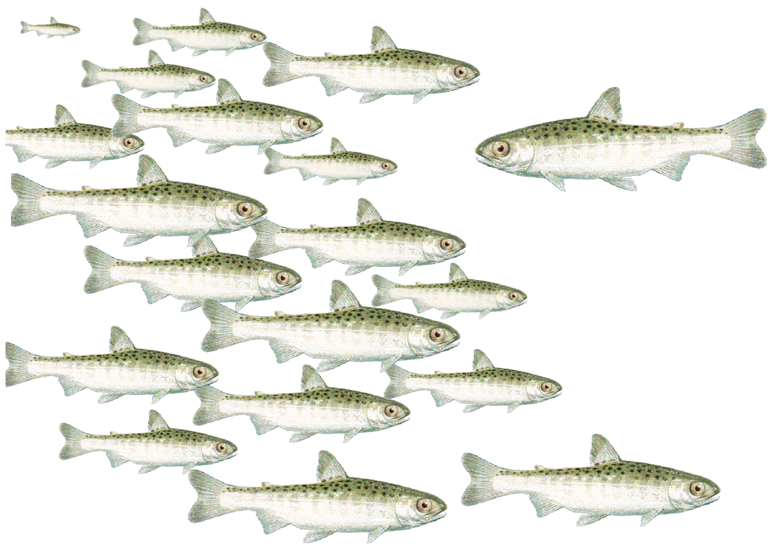
May 2024

Newaukum River Smolt Production, 2022



by Daniel Olson, Devin West, and Marisa Litz

Washington Department of FISH & WILDLIFE

FPA 24-06

Newaukum River Smolt Production, 2022

Washington Department of Fish and Wildlife

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Executive Summary

This report provides the results from the 2022 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 trout (*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 Chinook (*O. tshawytscha*), coho salmon (*O. kisutch*), and steelhead trout. Based on the location and timing of our study, the 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.

To meet the study objectives, a 1.5-meter (5–foot) rotary screw trap was operated near river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River from March 11 to July 12, 2022.

Coho outmigrants were predominately of the yearling (or "1+") age class (96.3%). Scale age data indicated that there was a small 2+ year-old component of the coho out-migration (2.0%) 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 (1.7%) that started in late June. The average fork length of all outmigrant coho was 119.0 mm (± 10.5 mm SD). The average fork length of subyearlings was 101.9 mm (± 10.8 mm SD), yearlings were 119.8 mm (± 10.4 mm SD), and two-year-old outmigrants were 125.8 mm (± 10.8 mm SD). Abundance of wild coho outmigrants in 2022 was estimated to be 51,031 ± 10,667 SD with a CV of 20.2%.

Steelhead outmigrants were predominately one (54.0%) and two (42.0%) years of age. A small proportion (4.0%) of steelhead were three years of age. Fork length averaged 150.2 mm (± 26.3 mm SD) for Age-1, 155.9 mm (± 20.9 mm SD) for Age-2, and 185.8 mm (± 29.1 SD) for Age-3. The average fork length for all measured steelhead was 151.9 mm (± 28.3 mm SD). We were not able to produce an estimate of abundance in 2022 due to not trapping over the entirety of the steelhead out-migration period.

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, our goal was to estimate the subyearling (> 45 mm fork length) component of the Chinook out-migration that generally occurs from March – July. Fork length of Chinook subyearlings increased steadily throughout the trapping period and averaged 45.9 mm (± 4.5 mm, standard deviation SD) and 95.7 mm (± 6.0 mm SD) in the first and last sampled week of trapping, respectively. Roughly 90.5% of the total catch of wild Chinook outmigrants were > 45 mm. Abundance of wild Chinook subyearling outmigrants in 2022 was estimated to be 40,638 ± 2,750 SD with a coefficient of variation (CV) of 6.7%.

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, thus providing limited information on freshwater production of other salmonid species, including Chinook (*O. tshawytscha*) and steelhead trout (*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 spring and fall Chinook salmon, coho salmon, and steelhead trout and is known to support a relatively large proportion (2000 – 2021 average =28%) (Ronne et al. 2023) of the spring Chinook spawning population in the Chehalis River Basin. 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. Specifically, we describe the abundance, timing, and diversity (body size, age structure, run timing) of juvenile outmigrants for wild Chinook salmon, coho salmon, steelhead, and cutthroat trout (*O. clarkii*). Based on the location and timing of our study, the 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 11 to July 12, 2022. This report includes results from the 2022 field season.

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 from the foothills of the Cascade mountains. The main stem Newaukum enters the Chehalis River at approximately river kilometer 121 (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 spring and fall Chinook salmon, coho salmon, winter steelhead, 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 the adult returns as determined from otoliths (Campbell et al. 2017; 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 sub yearlings. 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]), which are individuals that out-migrate almost immediately after emergence. Fry are observed at the smolt trap beginning in mid-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). The second pulse of Chinook outmigrants are termed ‘subyearlings’, which are individuals that grow in freshwater for weeks to months after emergence and are observed at the smolt trap between the months of March and July. Subyearlings are the focus of our production estimates in the Newaukum River.

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 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 2021, it was estimated that 89.4% of adult spring and fall Chinook salmon spawned upstream of the trap site producing the subyearling outmigrants in 2021 (Ronne et al. 2023). For adult coho salmon and steelhead that reproduced in 2020, 100% of all coho and 100% of all steelhead spawning activity was estimated to occur upstream of the trapping site (Ronne et al. 2023).

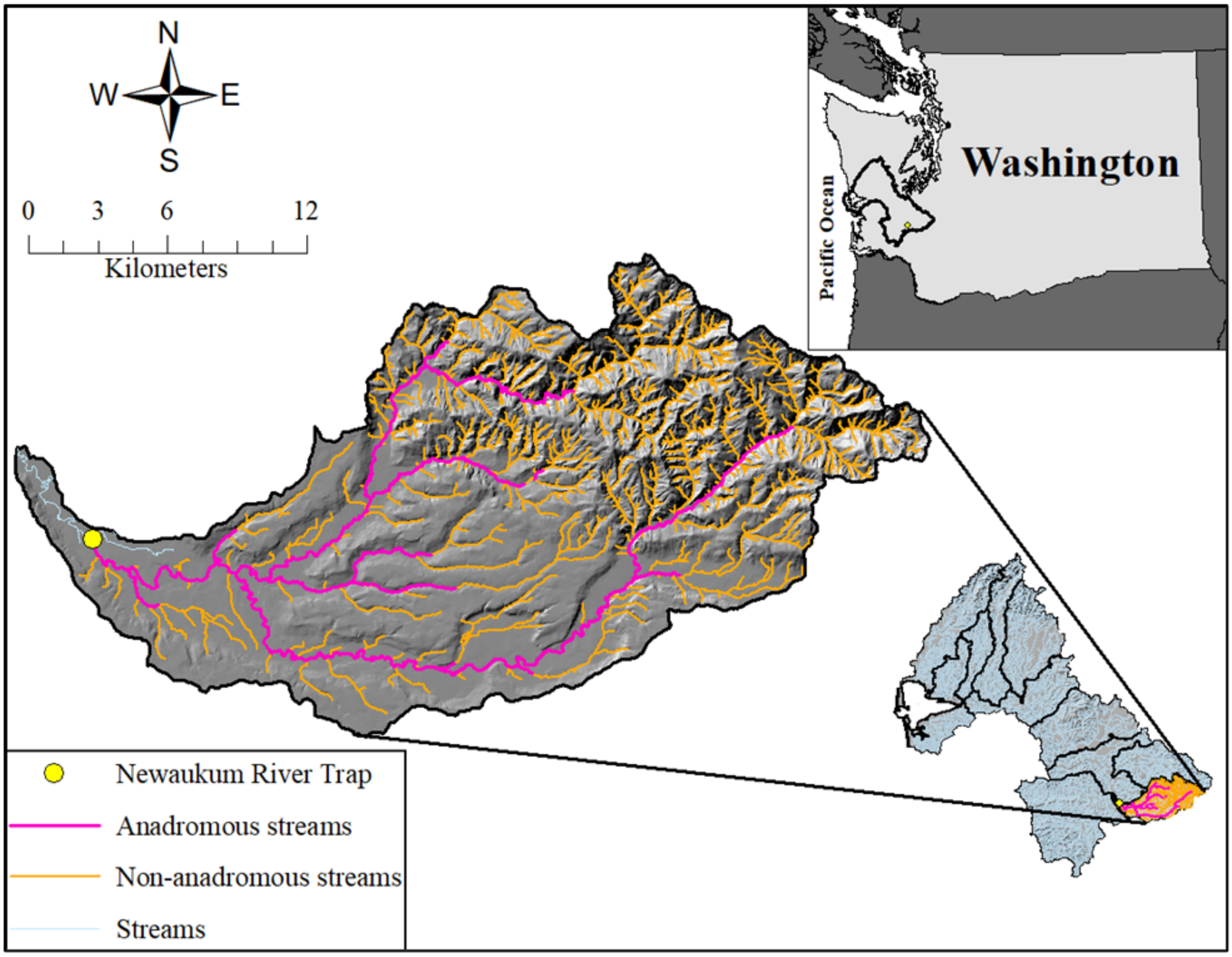

Figure 1. Newaukum River rotary screw trap location. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (112.5 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the Newaukum River rotary screw trap. Non-anadromous streams represent stream habitat outside the predicted coho salmon range of occurrence (565.7 km) upstream of the trap location. Marked fish were released 3.9 kilometers 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 kilometer 9.35 of the Newaukum River (Figure 2). In 2022, the trap was scheduled to operate continuously from March 7 through July 25, 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-min 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. Chinook, coho, and steelhead 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).

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

Sample Type	Species	Fry	Parr	Transitional/Smolt
Fork Length	Chinook	1st 10 per day	1st 10 per day	1st 10 per day
	Coho	1st 10 per week	1st 10 per day	All efficiency marked individuals 100 per day
	Steelhead	1st 10 per week[a]	1st 10 per day	All efficiency marked individuals 100 per day
	Cutthroat	---	All individuals encountered	All individuals encountered
Scales	Chinook[b]	---	---	---
	Coho	---	---	1st 5 per day
	Steelhead	---	---	1st 5 per day
	Cutthroat	---	All individuals encountered	All individuals encountered

[a] Trout fry included both steelhead/rainbow trout and cutthroat.
[b] No scale samples were collected from Chinook.

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 1-, 2-, and 3- year-old 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

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 Chinook, coho, and steelhead. All trap efficiency trials were conducted with wild (adipose fin intact) fish. 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. 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 for coho and steelhead because it was assumed that these life stages were not actively out-migrating. 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 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
Chinook	Wild	T, S	SY	FL ≥ 45 mm
Coho	Wild	T, S	Y, SY	
Steelhead	Wild	T, S	Y	

Marked fish were released 3.9 kilometers 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 (rkm)
Chinook	VIE	Weekly	5 weeks	Bridge	3.9
Coho	PIT	Individual	Individual	Bridge	3.9
Steelhead	PIT	Individual	Individual	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 Chinook, coho, and steelhead were generated using the R package Bayesian Time-Stratified Population Analysis System (BTSPAS), developed by Bonner and Schwarz (2014), using R version 2021.1.1 (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 proportion of time sampled each week was included to adjust for missed catch. For Chinook estimates in 2022, a time strata period was added to the beginning and end of the trapping season to allow the BTSPAS model to estimate the start and end of the run.

There were no missed trapping periods lasting more than 24 hours. However, 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 100,000 draws with the first 50,000 discarded as warmup. 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 25,000 simulations. 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 >2000, and Rhat was less than 1.1 for all parameters (Gelman et al. 2004).

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. Prior to analysis, marks were removed if the trap did not continuously fish for 48 hours after release because those marks were not available for recapture.

Results

Summary of Fish Species Encountered

A diverse assemblage of fish species was encountered throughout the 2022 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 (*Entosphenus tridentatus*), brook lamprey (*Lampetra planeri*), 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 7 to July 25, 2022. There were thirteen occurrences of trap outages (Appendix B). For four of the thirteen 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 1–3, 5–6, and 9–12 (nine total) were due to a log stopping the cone. The non-planned outages averaged 3.9 hours; six were less than 2 hours in duration, and the other two each lasted eight hours.

Assumption Testing Trials

In 2022, results indicated that mark/tag retention was high based on trials that lasted 24 hours. The estimated mark retention was 89.3% (Micro-Ject, 184 out of 206 marked) for Chinook, 100% (PIT tags, 185 out of 185 tagged) for coho, and 100% for steelhead (PIT tags, 25 out of 25 tagged). This resulted in few steelhead being available for tag retention evaluation. We also found that mark/tag related mortality was low. Estimated survival over a 24-hour holding period was 99.0% (Micro-Ject 204 out of 206 marked) for Chinook, 100% (PIT tag, 185 out of 185 tagged) for coho, and 96.0% for steelhead (PIT tags, 24 out of 25 tagged).

Differences in initial capture probabilities due to body size were tested using a Kolmogorov–Smirnov test for Chinook salmon. For coho and salmon, logistic regression was used. The fork length of maiden captures did not differ significantly for Chinook recaptures ($D = 0.22$, $p = 0.08$). Similarly, the relationship between probability of recapture and fork length was not significant for coho or steelhead ($p = 0.48$ and $p= 0.29$, respectively).

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 ($n < 200$) the first five weeks of trapping (beginning March 7, trapping period 1), peaked in early June, and declined to low numbers again by the last week of trapping (ending July 25, trapping period 20).

Scale age data were not collected from Chinook in 2022 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 45.9 mm (± 4.5 mm SD) and 95.5 mm (± 6.7 mm SD) in the first and last sampled week of trapping, respectively (Figure 3).

A total of 4,567 Chinook subyearling outmigrants (not including fry or parr) were captured: 3,403 were marked and 439 were recaptured for an overall recapture rate of 9.3% (Appendix C). Modeled weekly trap efficiencies ranged from 5.6.% to 24.1% (Figure 4).

Abundance of wild Chinook subyearling outmigrants (not including fry or parr) was estimated to be 40,638 ± 2,750 SD with a coefficient of variation (CV) of 6.7% (Figure 5, Table 7). The Rhat value for Chinook was 1.001, suggesting good model convergence. Chinook smolt production in the Newaukum River contributed 16.4% to the total Chinook smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap in 2022.

In 2021, the total number of adult spring Chinook spawners in the Newaukum River upstream of the trap site, was estimated to be 500 and adult fall Chinook was estimated to be 365, producing an overall smolt-per-spawner estimate of 47.0 for the 2021 brood year of naturally spawning Chinook (Ronne et al. 2023).

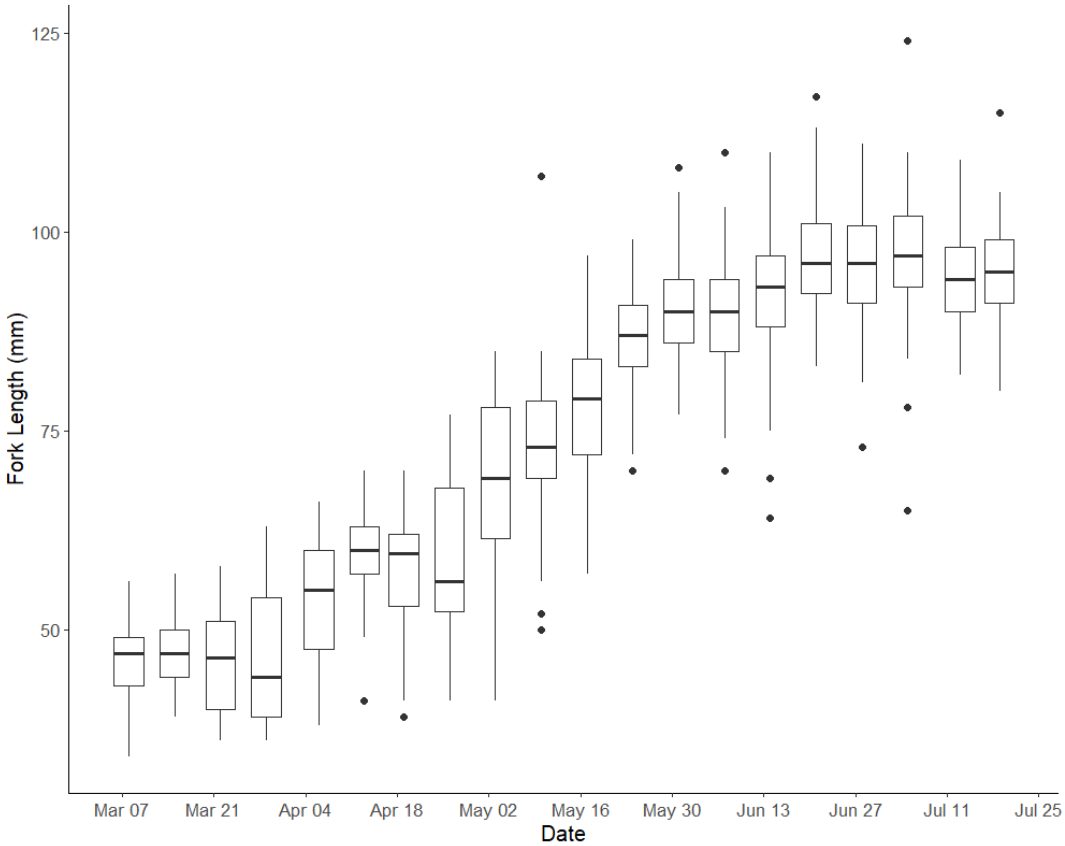

Figure 3. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Newaukum River screw trap, 2022. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

Table 7. Final outmigrant abundance estimate.

Year	Trap	Species	Origin	Life Stage(s)	Age	Abundance	CV
2022	Newaukum River	Chinook	Wild	Smolts and transitionals	Subyearling	40,638	6.7%
2022	Newaukum River	Coho	Wild	Smolts and transitionals	Yearling	51,031	20.2%
2022	Newaukum River	Steelhead	Wild	Smolts and transitionals	Yearling+	NA	NA

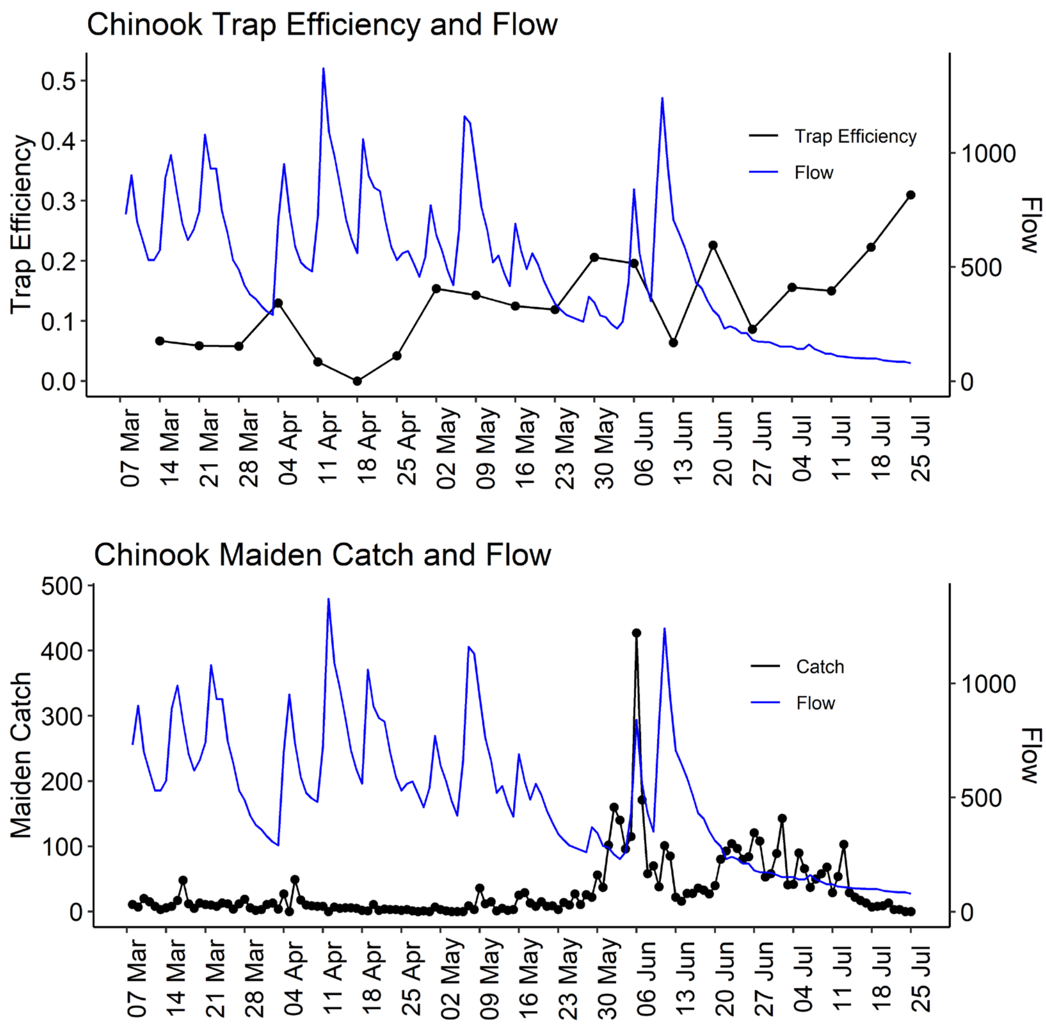

Figure 4. Wild Chinook transitional and smolt raw trap efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Newaukum River smolt trap.

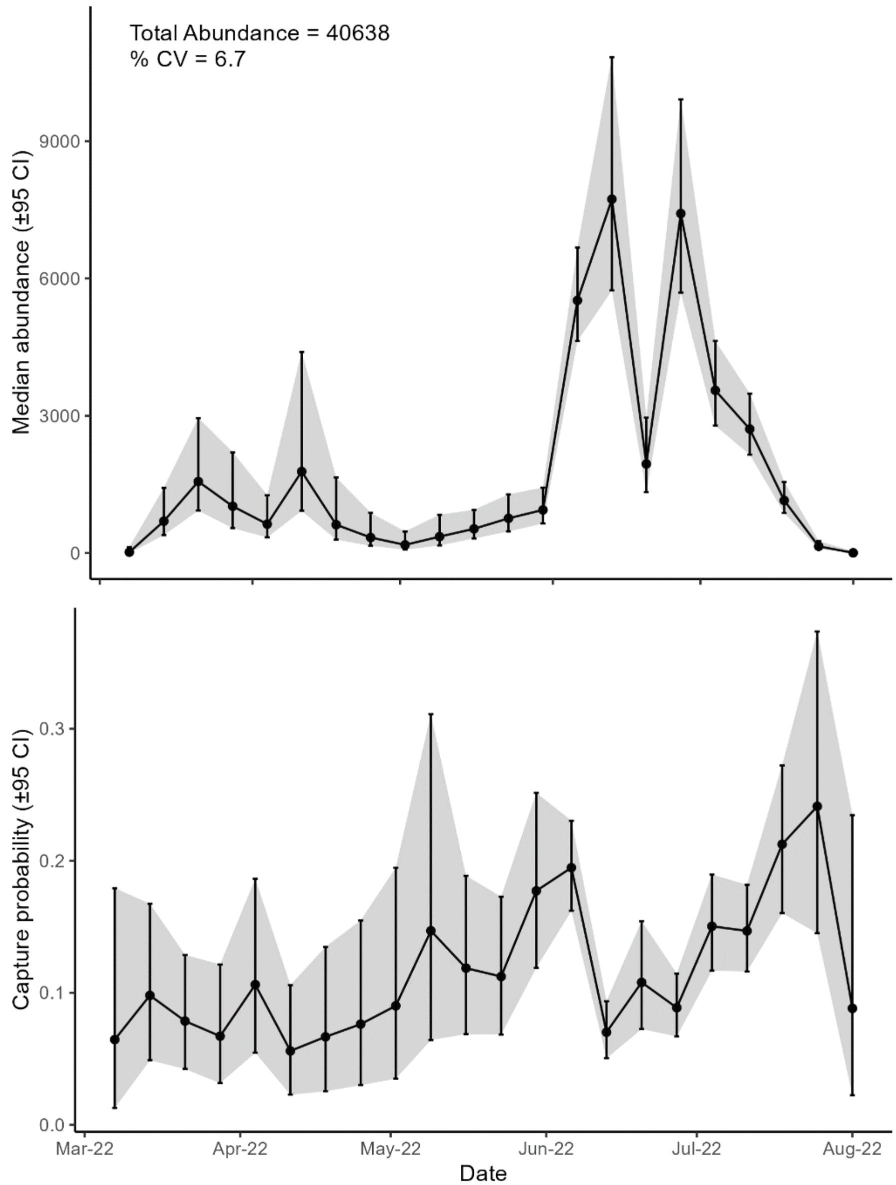

Figure 5. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Newaukum River smolt trap in 2022. Error bars and shading around point estimates represent 95% confidence intervals.

Coho

The coho outmigrant estimate in 2022 included both subyearlings and yearlings in transitional and smolt life stages. Approximately 98.5% of the outmigrants observed at the trap were categorized as the 'smolt' phenotype whereas 1.5% were categorized as the 'transitional' phenotype. Coho outmigrants were observed in low numbers in the first week of trapping during the second week of March (beginning March 7, trapping period 1), peaked in early May, and were last observed on July 21 (trapping period 21).

Scale age data indicated that there was a subyearling component (1.7%) and a two-year-old component of the coho out-migration in 2022 (2.0%) (Figure 6, Table 8). The fork length of known sub-yearling outmigrants averaged 101.9 mm (± 2.5 mm SD), the average fork length of known yearling outmigrants averaged 119.8 mm (± 9.4 mm SD), and the fork length of known two-year old outmigrants averaged 125.8 mm (± 16.5 mm SD). Fork length for all measured outmigrants averaged 119.0 mm (± 10.5 mm SD).

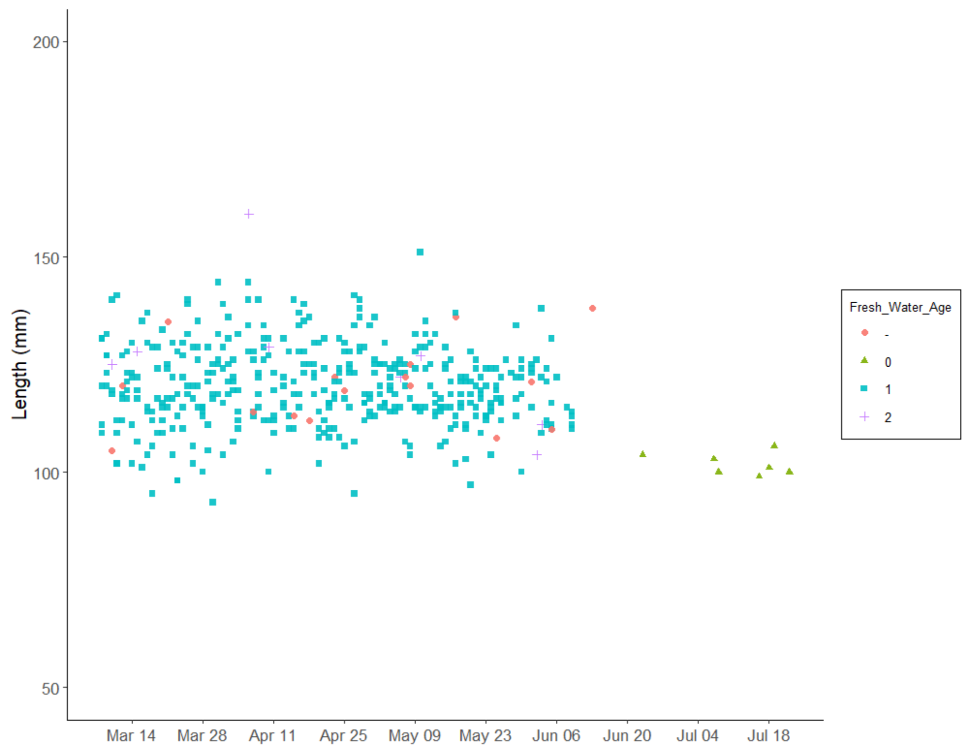

Figure 6. Plot of length and age by date for wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2022.

In 2022, a total of 3,368 coho outmigrants were captured, 1,939 coho were marked, and 64 were recaptured for an overall recapture rate of 3.3% (Appendix D). Modeled weekly trap efficiencies ranged from 2.6 to 4.6%.

Abundance of 2022 wild coho outmigrants was estimated to be 51,031 ± 10,667 SD with a CV of 20.2% (Figure 7, Table 7). The Rhat value for coho was 1.003, suggesting good model convergence. In 2022, coho smolt production in the Newaukum River contributed 31.2% to the total coho smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap.

In 2020, the total number of adult coho spawners in the Newaukum River upstream of the trap site was estimated to be 2,768 (Ronne et al. 2022), producing a smolt-per-spawner estimate of 18.4 for the 2020 brood year of naturally spawning coho.

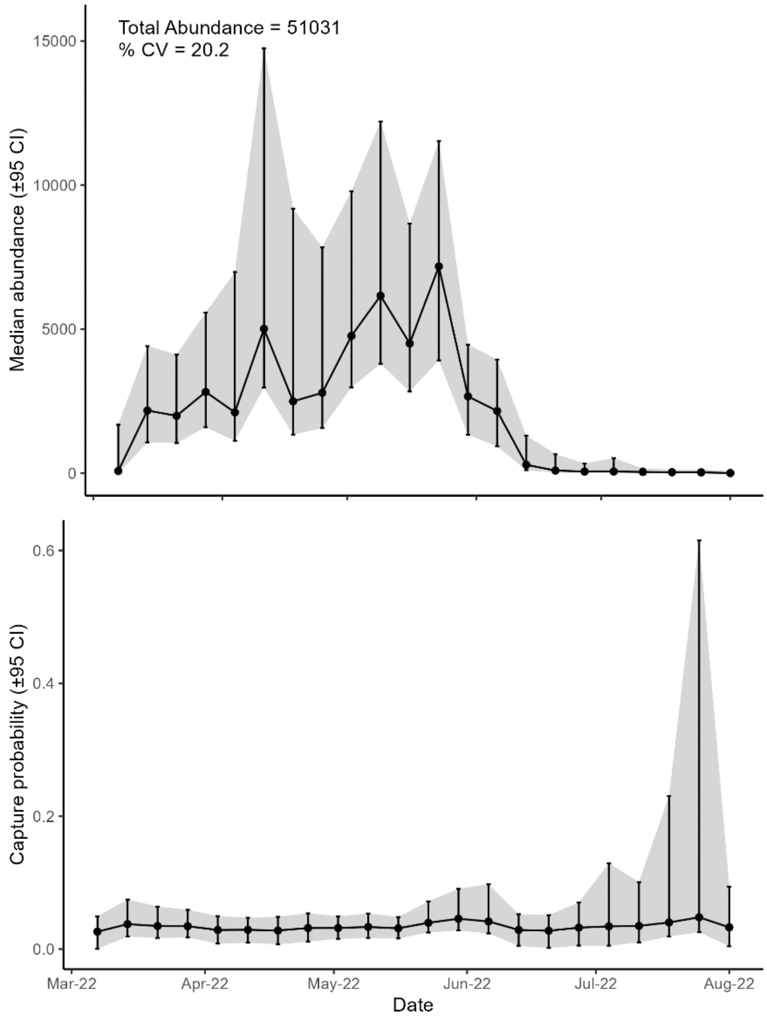

Figure 7. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho yearlings produced above the Newaukum River smolt trap in 2022. Error bars and shading around point estimates represent 95% confidence intervals.

Table 8. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2022. 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	3/7	3/13	35		32	1	2
2	3/14	3/20	31		29	1	1
3	3/21	3/27	35		35		
4	3/28	4/3	35		35		
5	4/4	4/10	30		27	2	1
6	4/11	4/17	26		24		2
7	4/18	4/24	35		33		2
8	4/25	5/1	35		35		
9	5/2	5/8	35		31	1	3
10	5/9	5/15	33		32	1	
11	5/16	5/22	35		34		1
12	5/23	5/29	26		25		1
13	5/30	6/5	21		17	2	2
14	6/6	6/12	6		5		1
15	6/13	6/19	0				
16	6/20	6/26	1	1			
17	6/27	7/3	0				
18	7/4	7/10	2	2			
19	7/11	7/17	2	2			
20	7/18	7/24	2	2			

Steelhead

The goal was to generate an unbiased abundance estimate of the steelhead smolt and transitional outmigration. However, due to environmental conditions and duration of trapping, the first assumption of trapping over the entirety of the out-migration was violated. For example, some of the largest total maiden captures occurred during the first and second week of the trapping season. Thus, at minimum, the ascending limb of the outmigration was missed, which made it difficult to determine when the run started and when the peak of outmigration occurred. Therefore, the estimate of abundance for steelhead was unreportable in 2022 (Table 7).

Scale age data indicated that sampled steelhead were Age-1, Age-2, and Age-3 (Figure 8, Table 9). Fork length averaged 150.24 mm (± 226.1 mm SD) for Age-1, 155.9 mm (± 20.8 mm SD) for Age-2, 185.8 mm (± 29.1 mm SD) for Age-3, and 151.9 mm (± 28.3 mm SD) overall.

In 2022, a total of 387 steelhead outmigrants were captured, 365 steelhead were marked, and 15 were recaptured for an overall recapture rate of 4.1% (Appendix E).

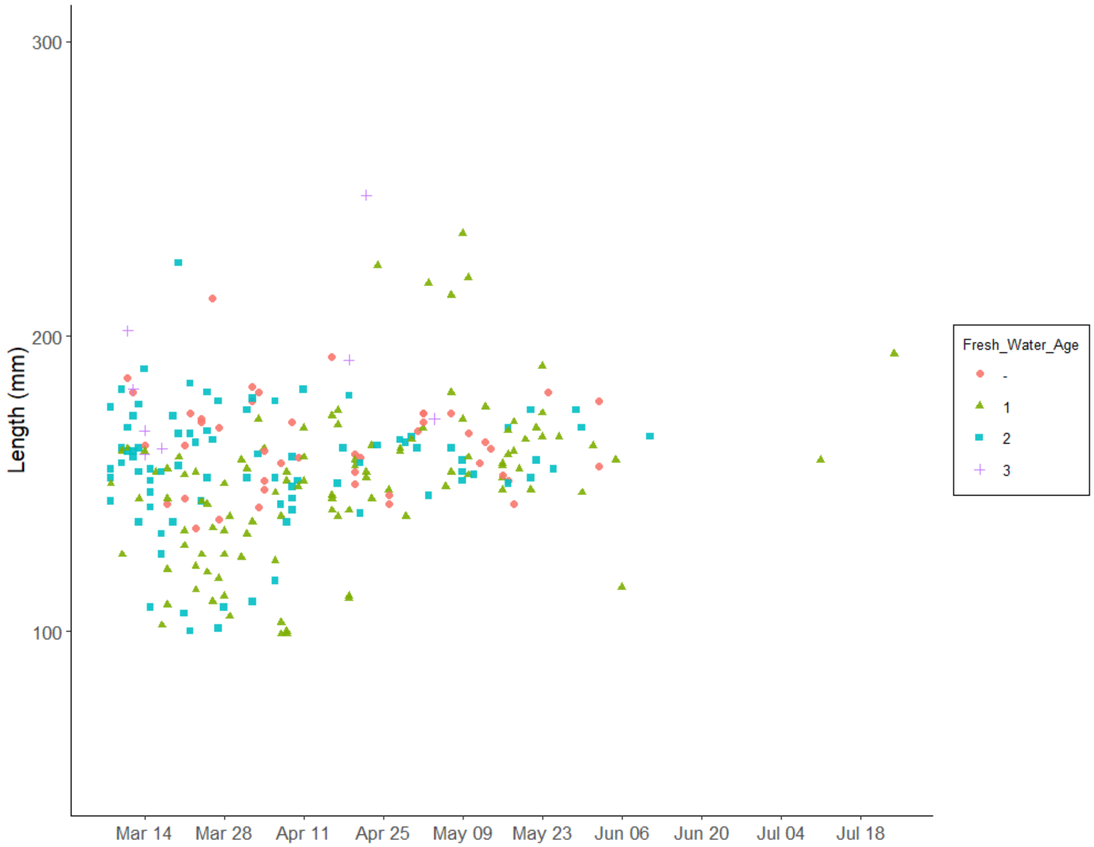

Figure 8. Plot of length and age by date for wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2022.

Table 9. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2022. 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	3/7	3/13	30		6	17	4	3
2	3/14	3/20	28		10	14	1	3
3	3/21	3/27	33		14	12		7
4	3/28	4/3	21		9	5		7
5	4/4	4/10	27		13	11		3
6	4/11	4/17	10		7	2		1
7	4/18	4/24	20		10	4	2	4
8	4/25	5/1	16		6	4		6
9	5/2	5/8	14		7	5	1	1
10	5/9	5/15	14		8	1		5
11	5/16	5/22	18		11	5		2
12	5/23	5/29	6		2	3		1
13	5/30	6/5	5		3			2
14	6/6	6/12	1			1		
15	6/13	6/19	0					
16	6/20	6/26	0					
17	6/27	7/3	0					
18	7/4	7/10	1		1			
19	7/11	7/17	0					
20	7/18	7/24	1		1			

Cutthroat

While cutthroat trout were not a focus of our study, they were encountered at the trap. Of the one fish successfully aged, scale age data indicated that it was Age-2 (100%) (Figure 9, Table 10).

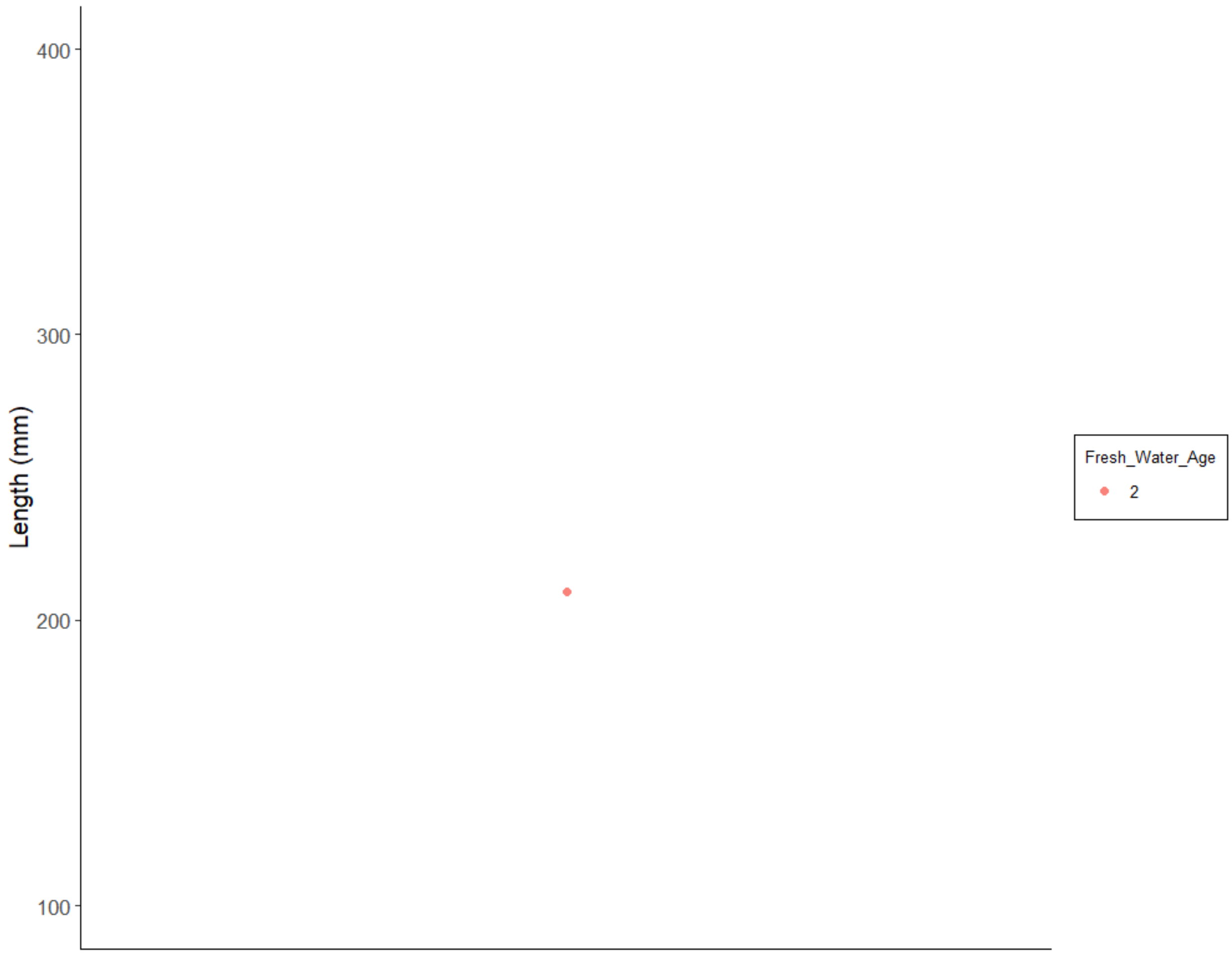

Figure 9. Plot of length and age by date for wild cutthroat the Newaukum River screw trap, 2022.

Table 10. Freshwater ages of wild cutthroat at the Newaukum River screw trap, 2022. 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	ND
1	3/7	3/13	0					0
2	3/14	3/20	0					0
3	3/21	3/27	0					0
4	3/28	4/3	0					0
5	4/4	4/10	0					0
6	4/11	4/17	0					0
7	4/18	4/24	0					0
8	4/25	5/1	0					0
9	5/2	5/8	0					0
10	5/9	5/15	0					0
11	5/16	5/22	0					0
12	5/23	5/29	0					0
13	5/30	6/5	1			1		0
14	6/6	6/12	0					0
15	6/13	6/19	0					0
16	6/20	6/26	0					0
17	6/27	7/3	0					0
18	7/4	7/10	0					0
19	7/11	7/17	0					0
20	7/18	7/24	0					0

Discussion

Basin-wide Context

This report presents results from the 2022 salmon and steelhead smolt out-migration of the Newaukum River, the fourth 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 kilometer 9.35. 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 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 in 2016 (Campbell et al. 2017) found that 95% (37 out of 39) 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 2022 Chinook estimate saw a 75.0% decrease from the 2021 estimate (40,638 versus 163,146) and the CV increased from 4.4% to 6.7% (Figure 10). This decrease in wild Chinook production corresponded with decreased adult returns: there were 1,763 Chinook spawners in the Newaukum in 2020, but only 968 in 2021 (Ronne et al. 2022, 2023). The 2021 adult return (n=968) was similar to the return in 2019 (n=1,033, Ronne et al. 2021). Despite this similarity in adult returns, the corresponding smolt production estimates in 2020 and 2022 were drastically different (129,682 compared to 40,639). 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.

The 2022 juvenile coho estimate decreased by 12.6% from the 2021 estimate (51,031 compared to 57,417) and the CV increased from 12.4% in 2021 to 20.1% in 2022 (Figure 11). This decrease in wild coho production occurred despite an increase in adult returns: 1,988 coho returned to the Newaukum in 2019 compared to 2,770 in 2020 (Ronne et al. 2021, 2022). It is uncertain why the smolt estimate for 2022 decreased from 2021 despite an increase in adult returns during their respective brood years. It is possible that the heat dome of June 2021 resulted in increased juvenile mortality during the summer rearing period. In addition, like Chinook, the high flow during winter 2021–2022 may have flushed the yearlings out of the system prior to trap installation.

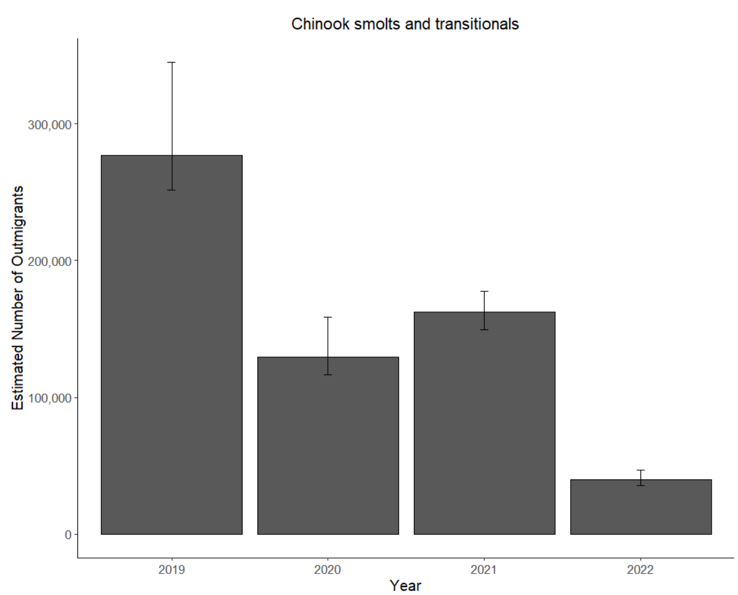

Figure 10. Time series of 2019–2022 estimates with 95% confidence intervals of wild Chinook juvenile outmigrants at the Newaukum River smolt trap.

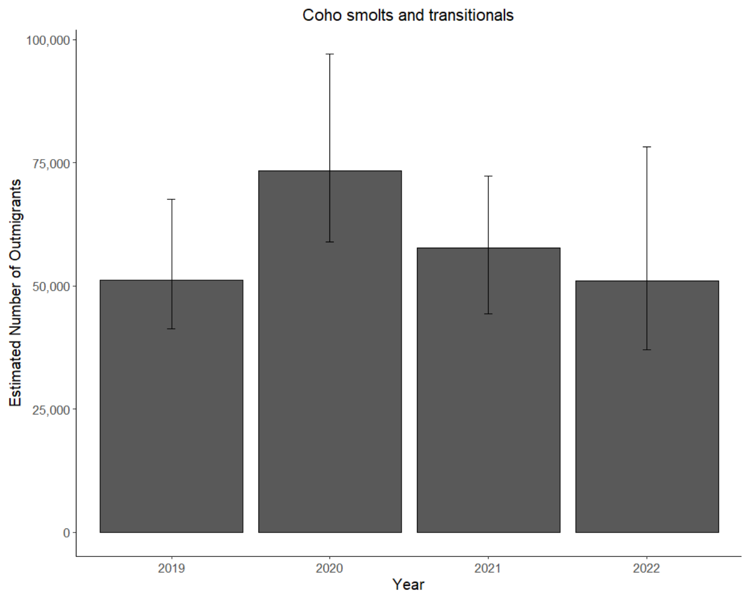

Figure 11. Time series of 2019–2022 estimates with 95% confidence intervals of wild coho juvenile outmigrants at the Newaukum River smolt trap.

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 mile 52 averaged ~320,000 (Olson et. al. unpublished data). Therefore, the area above river mile 52 contributes to roughly 15% of the coho smolt production in the basin. In 2022 specifically, coho smolt abundance at the mainstem Chehalis River smolt trap was estimated to be 163,354. Therefore, in 2022, the Newaukum River coho abundance estimate (51,031) represents approximately 31% of the coho production above river mile 52 of the mainstem Chehalis River. This is an increase from 28% of total production in 2021 (Olson et al. 2023). Above river mile 52, 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).

In 2022, an estimate of wild juvenile steelhead outmigrants was unreportable due to missing the early portion of the out-migration window. There will be an attempt in future seasons to deploy the trap at an earlier date to capture the early out-migration. Interestingly, in 2022 an unbiased steelhead smolt abundance estimate was generated for the Chehalis Mainstem trap located approximately 31 river miles downstream of the Newaukum trap (36,236 ± 25,121 SD). Despite not generating an abundance estimate, distinct age-classes of wild steelhead were observed in the

Neaukum (Age-1 through Age-3), providing improved understanding of life history diversity in this sub-basin.

Next Steps

The Newaukum River presents many challenges to smolt trapping operations. In 2022, these challenges included high flows and debris. This was particularly problematic for steelhead, which migrated slightly earlier than coho in 2022 and resulted in an unreportable estimate. 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 resulted in three trap outages in March, six in April, and two in May. To reduce the duration of these outages, a cellular trail camera was used to monitor the trap in 2022 and helped identify precisely when a stoppage occurred, reducing lost data. These cameras will continue to be used in future years.

Within trapping seasons, mean monthly stream temperatures steadily increased from 7–10°C in March, to approximately 16–22°C in July (Table 11). Between years, 2022 was warmer than both 2021 and 2020 during March, but cooler than either for the remainder of the season, except for July, when 2022 was warmer than 2020 and 2021. Most notably in 2022, mean monthly temperature in May was 2.5℃ to 3.6℃ cooler than in 2020 and 2021, respectively.

Stream flow in 2022 was the highest and most variable since trapping operations began in 2019 (Figure 12). The Newaukum River peaked over 1,000 cfs on five separate occasions during the trapping season and spent much of the season over 500 cfs. These frequent changes in flow necessitated frequent trap moves to maintain accessibility to the trap. It is believed that these consistently high flows were a cause of low overall catch numbers and low trapping efficiency. In 2023, the trap will be accessed from the opposite bank used in previous seasons. The left bank is considerably higher than the right bank where the trap is currently accessed. The expectation is that the higher access will reduce the number moves needed to maintain trap operations during periods of variable flow.

The Chinook subyearling outmigration in 2022 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 11.5 ℃ to 14.8 ℃ to 21.3 ℃, respectively (Table 11). During this timeframe, fish were processed earlier in the morning when stream temperatures were coolest.

Table 11. Time series of mean monthly stream temperatures °C recorded at Newaukum River smolt trap near river km 9.35 from 2019 - 2022.

Year Month	2019 Mean (°C)	2020 Mean (°C)	2021* Mean (°C)	2022 Mean (°C)
March		7.1	7.2	8.4
April		10.7	11.6	9.0
May		14.0	15.1	11.5
June	16.5	15.1	20.2	14.8
July	21.8	18.6	-	21.3

*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.

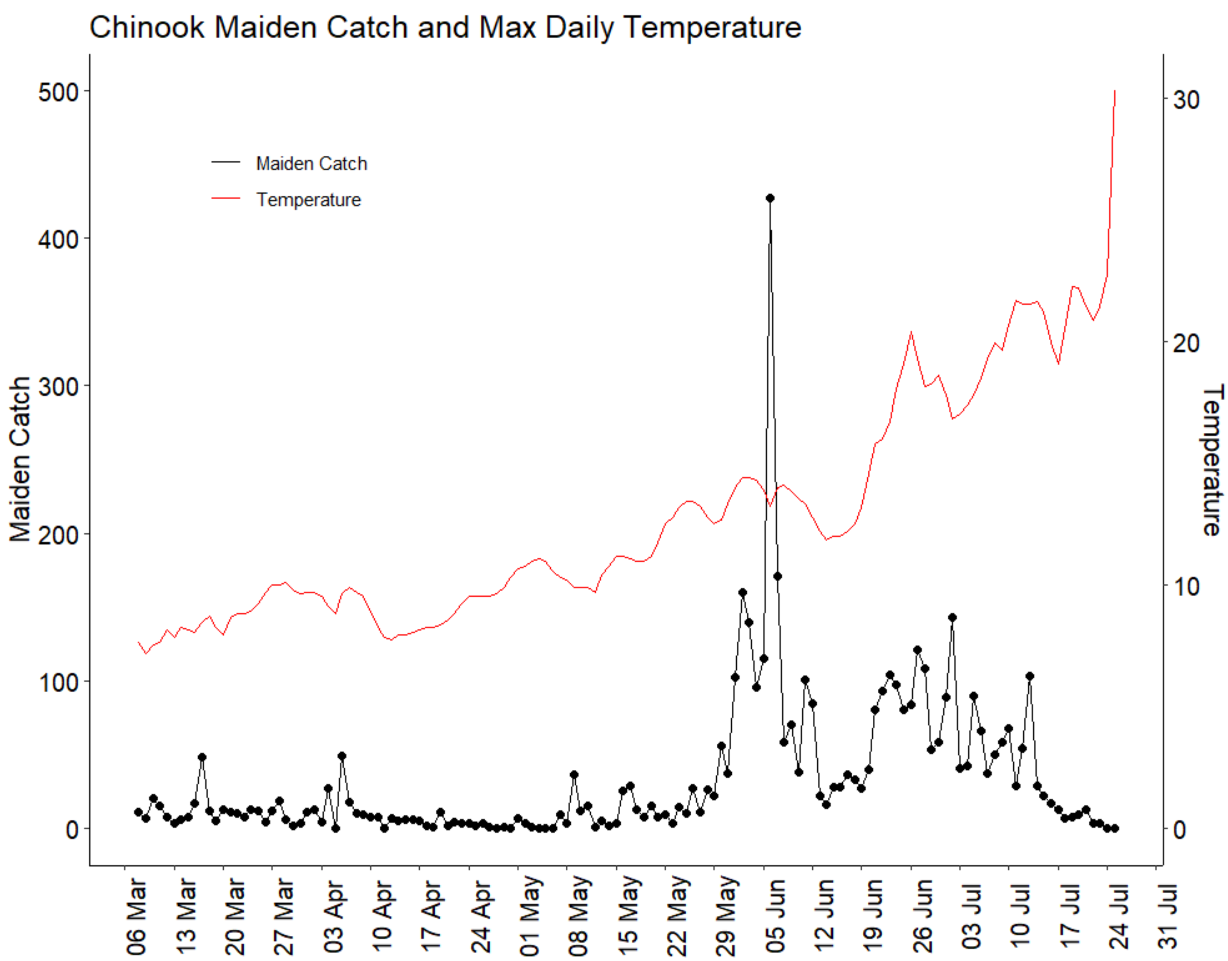

Figure 12. Chinook maiden catch and maximum daily stream temperature (°C) at the Newaukum River smolt trap in 2022.

In the 2022 season, Chinook marks changed from visible implant elastomer (VIE) to Micro-Ject. While this marking technique worked well, overall catch numbers were low, limiting meaningful comparison with VIE marked Chinook at the Upper Chehalis trap. Micro-Ject will continue to be evaluated as a marking method in 2023.

In summary, 2022 represents the fourth year for which wild Chinook, coho and steelhead out-migrations have been described from any location in the Newaukum River in three decades. The 2023 season will benefit from refinements resulting from this year. Unbiased and precise estimates of abundance were generated for Chinook and coho in 2022, but the steelhead estimates were unreportable due to failure to trap over the entirety of the outmigration. 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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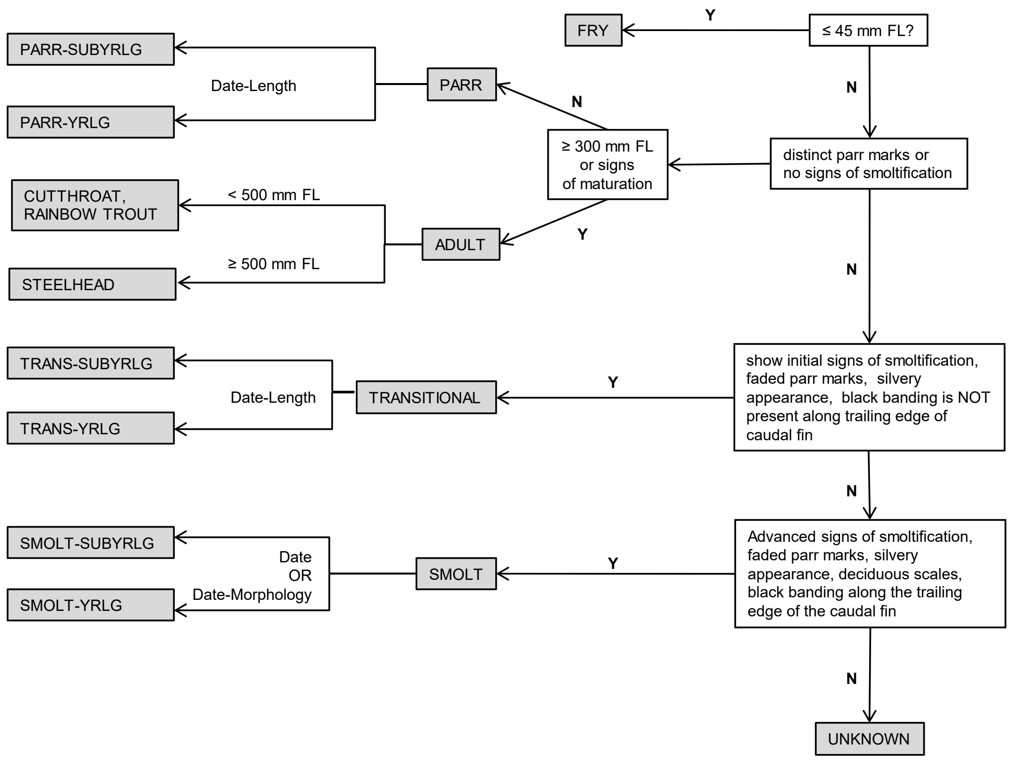
Appendices

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 2022.

Last Time Observed Fishing	Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Resume Fishing	Comments
3/8 1200	8 hr	Visual	3/9 0830	Screw Stopper
3/14 1220	1.1 hr	Trail Camera	3/14 1430	Screw Stopper
3/15 2329	0.6 hr	Trail Camera	3/16 0005	Screw Stopper
4/4 1245	18.25 hr	Scheduled	4/5 0700	High Debris Loads
4/6 2100	1.5 hr	Trail Camera	4/6 2230	Screw Stopper
4/7 0300	5.5 hr	Trail Camera	4/7 0830	Screw Stopper
4/11 2015	20.5 hr	Scheduled	4/12 1640	High Debris Loads
4/20 1107	3.4 hr	Scheduled	4/20 1426	Trap Maintenance
4/30 0816	1.25 hr	Visual	4/30 0931	Screw Stopper
4/30 1201	0.66 hr	Trail Camera	4/30 1241	Screw Stopper
5/7 2100	8 hr	Visual	5/8 0802	Screw Stopper
5/15 2301	1.75 hr	Trail Camera	5/16 0045	Screw Stopper
6/8 0931	1.1 hr	Scheduled	6/8 1035	Trap Maintenance

Appendix C. 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	3/1	3/7	0	NA	0	0.001
2	3/8	3/14	60	4	70	1.00
3	3/15	3/21	101	6	124	1.00
4	3/22	3/28	69	4	68	1.00
5	3/29	4/4	51	7	66	1.00
6	4/5	4/11	71	0	88	0.86
7	4/12	4/18	28	0	38	0.86
8	4/19	4/25	24	1	26	1.00
9	4/26	5/2	13	2	15	1.00
10	5/3	5/9	6	2	46	0.86
11	5/10	5/16	72	9	63	1.00
12	5/17	5/23	101	12	85	1.00
13	5/24	5/30	107	22	166	1.00
14	5/31	6/6	500	98	1077	1.00
15	6/7	6/13	500	32	545	1.00
16	6/14	6/20	190	23	208	1.00
17	6/21	6/27	500	43	659	1.00
18	6/28	7/4	339	53	534	1.00
19	7/5	7/11	407	61	398	1.00
20	7/12	7/18	188	42	245	1.00
21	7/19	7/25	42	13	36	1.00
22	7/26	8/1	0	NA	0	0.001

Comments: Total captures are wild Chinook. All marks and recaptures are wild Chinook caught in the Newaukum trap to which a VIE 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.

Appendix D. Mark-recapture data for wild coho outmigrants (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	3/1	3/7	0	NA	0	0.001
2	3/8	3/14	82	2	85	1.00
3	3/15	3/21	68	3	69	1.00
4	3/22	3/28	93	3	97	1.00
5	3/29	4/4	49	1	59	1.00
6	4/5	4/11	110	0	146	0.86
7	4/12	4/18	51	1	68	0.86
8	4/19	4/25	87	4	87	1.00
9	4/26	5/2	147	5	151	1.00
10	5/3	5/9	115	3	206	0.86
11	5/10	5/16	132	4	140	1.00
12	5/17	5/23	282	8	287	1.00
13	5/24	5/30	118	9	123	1.00
14	5/31	6/6	87	2	93	1.00
15	6/7	6/13	6	0	7	1.00
16	6/14	6/20	1	0	1	1.00
17	6/21	6/27	1	1	1	1.00
18	6/28	7/4	0	0	0	1.00
19	7/5	7/11	2	0	2	1.00
20	7/12	7/18	1	1	2	1.00
21	7/19	7/25	3	2	3	1.00
22	7/26	8/1	1	NA	0	0.001

*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.

Appendix E. Mark-recapture data for wild steelhead 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). 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	3/1	3/7	0	NA	0	0.001
2	3/8	3/14	91	5	109	1.00
3	3/15	3/21	53	2	51	1.00
4	3/22	3/28	39	2***	40	1.00
5	3/29	4/4	19	1	23	1.00
6	4/5	4/11	32	1	49	0.86
7	4/12	4/18	9	0	11	0.86
8	4/19	4/25	23	3	22	1.00
9	4/26	5/2	10	0	14	1.00
10	5/3	5/9	7	0	19	0.86
11	5/10	5/16	12	1	16	1.00
12	5/17	5/23	21	0	18	1.00
13	5/24	5/30	7	0	6	1.00
14	5/31	6/6	6	0	5	1.00
15	6/7	6/13	2	0	1	1.00
16	6/14	6/20	0	0	0	1.00
17	6/21	6/27	0	0	1	1.00
18	6/28	7/4	0	0	0	1.00
19	7/5	7/11	0	0	1	1.00
20	7/12	7/18	1	0	0	1.00
21	7/19	7/25	0	0	1	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 start and end one day before the recapture dates.

*** Includes one PIT scar only fish.