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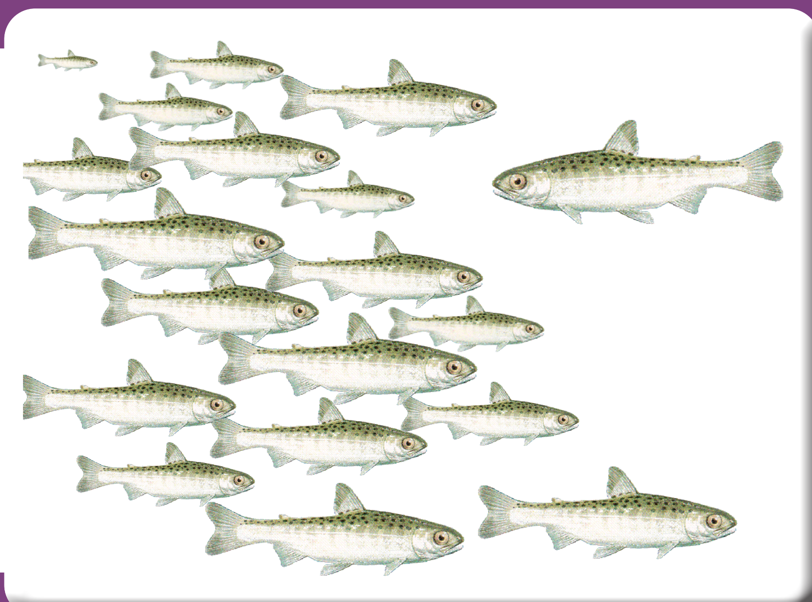
May 2023

Newaukum River Smolt Production, 2021



by Daniel Olson, Devin West, John Winkowski, Todd Seamons, and Marisa Litz

Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 23-05

Newaukum River Smolt Production, 2021

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Executive Summary

This report provides the results from the 2021 juvenile salmonid monitoring study on the Newaukum River main stem near Centralia, WA. 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 Chinook (*O. tshawytscha*), coho salmon (*O. kisutch*), and steelhead. 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, 2021.

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 54.2 mm (± 5.2 mm, standard deviation SD) and 86.6 mm (± 7.0 mm SD) in the first and last sampled week of trapping, respectively. Roughly 88% of the total catch of wild Chinook outmigrants were > 45 mm. Abundance of wild Chinook subyearling outmigrants in 2021 was estimated to be 163,146 ± 7,235 SD with a coefficient of variation (CV) of 4.6%.

Coho outmigrants were predominately of the yearling (or "1+") age class (98.3%). Scale age data indicated that there was a small 2+ year-old component of the coho out-migration (1.6%) that started near the middle of April. Average fork length of all outmigrant coho was 113.6 mm (± 9.6 mm SD). Fork length of known yearling outmigrants averaged 113.3 mm (± 9.3 mm SD) whereas fork length of known two-year-old outmigrants averaged 114.6 mm (± 10.4 mm SD). Abundance of wild coho outmigrants in 2021 was estimated to be 57,714 ± 7,145 SD with a CV of 12.4%.

Steelhead outmigrants were predominately one (51.2%) and two (40.1%) years of age. A small proportion of steelhead were three (8.3%) and 4 (0.4%) years of age. Fork length averaged 156.1 mm (± 29.7 mm SD) for Age-1, 142.4 mm (± 22.5 mm SD) for Age-2, 166.6 mm (± 21.4 SD) for Age-3, 188.2 mm for Age-4, and 157.1 mm (± 27.4 mm SD) for all captured steelhead. We were not able to produce an estimate of abundance in 2021 due to not trapping over the entirety of the steelhead out-migration period.

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 and Agha 2022). Previously, smolt abundance estimates from individual tributaries throughout the Chehalis River Basin were generated in the 1980s and 1990s but have not been evaluated for nearly two decades. These earlier estimates were also only focused on coho, thus 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.

Smolt monitoring activities by WDFW were recently expanded to develop a more comprehensive understanding of salmonid freshwater production across multiple locations within the Chehalis Basin. Beginning in 2021, this expanded effort became a long-term component of the integrated monitoring program used to evaluate salmon and steelhead responses to changes in the riverine environment due to habitat restoration and protection actions and climate change (M&AMT 2021). In 2019, the Newaukum River was selected to monitor smolt production and 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. The Newaukum River is known to support a relatively large proportion (~25%) (Ronne et al. 2022) of the spring Chinook 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 planned 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 was 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 (*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, 2021. This report includes results from the 2021 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. Our site selection process was described by West et al. (2020). In 2020, it was estimated that 94.9% of adult spring and fall Chinook salmon spawned upstream of the trap site producing the subyearling outmigrants in 2020 (Ronne et al. 2022). For adult coho salmon and steelhead that reproduced in 2019, 99.8% of all coho and 100% of all steelhead spawning activity was estimated to occur upstream of the trapping site (Ronne et al. 2021).

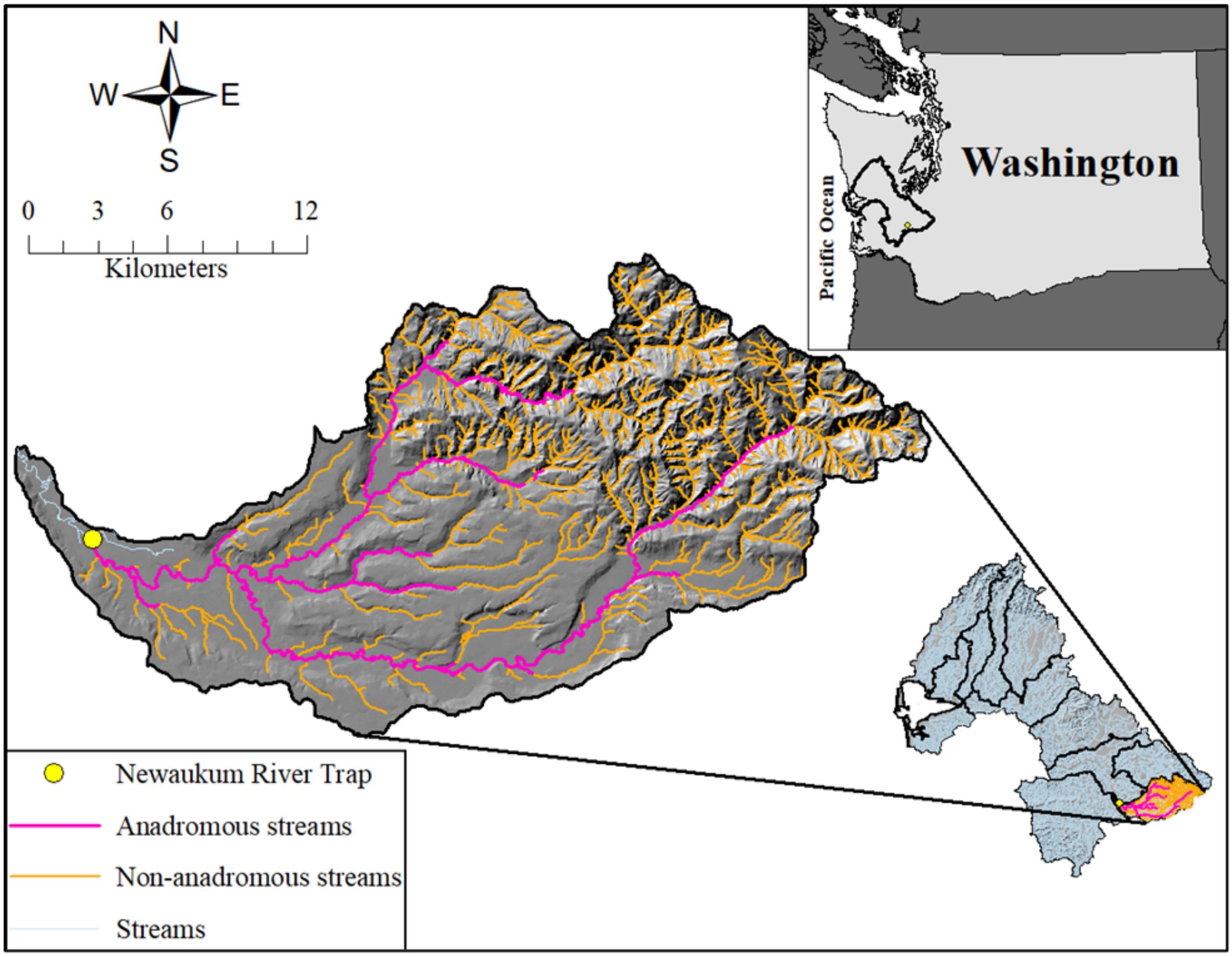


Figure 1. Newaukum River rotary screw trap location. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (112.5 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the Newaukum River rotary screw trap. Non-anadromous streams represent 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 1). In 2021, the trap was scheduled to operate continuously from March 11 through July 12, although unscheduled trap outages did occur due to high flow, warm (> 18°C) water temperatures, and debris. The trap was not operated from June 26 to June 28 due to high water temperatures.

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 (5g 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 and scales were systematically collected from a subsample of wild (adipose fin intact) coho and steelhead, and all cutthroat (Table 1). Only fork lengths were collected from Chinook (no scales).

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-, 3-, and 4-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

We used a single trap, mark-recapture study design stratified by week 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 species, origin, and life stages for which we intended 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 these were the life stages for which we intended to generate an abundance estimate. 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 we 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. Our 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 (Table 6).

Mark types and rotation schedules allowed the data to be stratified by week for the purpose of analysis. We used different mark types for salmon and steelhead (Table 6). Releases generally occurred within 1-3 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 to 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. Throughout the season, we conducted multiple trials 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

We used the Bayesian Time-Stratified Population Analysis System (BTSPAS, Bonner and Schwarz 2014) to estimate abundance of Chinook, coho, and steelhead (Table 6). 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 2021, 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 tail of the run.

We were unable to trap from June 26 to June 28, 2021, because of high water temperatures. For the missed trapping period, however, 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, we used the BTSPAS nondiagonal model with model arguments as follows: number of chains = 4, iterations = 2,500, burn-in = 1,250, simulations = 1,250, and thin rate = 1. Model convergence was assessed by visually inspecting the trace plots and using the potential scale reduction statistic, or Rhat ($\hat{R}$). The Rhat statistic measures the ratio of the average variance of draws within each chain to the variance of the pooled draws across chains; if all chains are at equilibrium, these will be the same and Rhat will be 1. If the chains have not converged to a common distribution, the Rhat statistic will be > 1. Models were considered to have converged if MCMC chains were fully mixed based on visual inspection, and Rhat was less than 1.1 for all parameters (Gelman et al. 2004).

We 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 the analysis, we removed any marks for which the trap did not continuously fish for 48 hours after release because these marks were not available for recapture. The BTSPAS analysis was executed in R version 2021.1.1 (R Core Team, 2021) using the package BTSPAS (Bonner and Schwarz 2014).

Genetics

Genetic samples were collected from subyearling migrant Chinook from upstream of our trapping location on the Newaukum River (river mile 5.8) to document diversity at SNP (Single Nucleotide Polymorphism) loci highly correlated with run timing of adult Chinook within the Chehalis basin (Thompson et al. 2019). Fin clips were collected from Chinook subyearlings (e.g., juveniles > 45 mm FL in the transitional or smolt life stage). The first 10 Chinook subyearling 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 Single Nucleotide Polymorphisms (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).

Results

Summary of Fish Species Encountered

We encountered a diverse assemblage of fish species throughout the 2021 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

We operated the trap from March 11 to July 12, 2021. There were six occurrences of trap outages (Appendix B). For two of the six outages, the outage time was known exactly because the trap stopped fishing when staff intentionally lifted the cone during periods of high-water temperature. The first through fourth of these outages were due to a log stopping the cone before the crew had arrived onsite so exact stoppage duration is unknown; these events occurred on April 1, May 14, June 13, and June 18 respectively. All these events lasted less than 24 hours. The fifth and sixth outages were scheduled due to high water temperatures. The fifth was from June 21 to June 22 and lasted twenty-two hours and eight minutes. The sixth outage was from June 26 to June 28 and lasted sixty hours and twenty minutes.

Assumption Testing Trials

In 2021, results indicated that mark/tag retention was high based on trials that lasted 24 hours. Estimated mark retention was 100% (PIT tags, 135 out of 135 tagged) for coho, 100% for steelhead (PIT tags, 33 out of 33 tagged), and 98.7% (VIE, 158 out of 160 marked) for Chinook. This resulted in few steelhead being available for tag retention evaluation. We also found that mark/tag related mortality was low. Estimated survival was 99.3% (PIT tag, 134 out of 135 tagged) for coho, 100% for steelhead (PIT tags, 33 out of 33 tagged), and 94.4% (VIE, 151 out of 160 marked) for Chinook over the 24-hour holding period. It is suspected that Chinook survival was influenced by unanticipated excessive water velocity in the fish holding apparatus as opposed to tag related mortality. To test this, we also evaluated holding Chinook in a larger live box located in slower river flow. During this trial, Chinook survival was better in the live box compared to the screen bucket (97.4% versus 88.7%) over a twenty-four-hour period. The five-day mark retention trial on Chinook indicated improved retention over the trial period for the Micro-ject group (63 out 66 marked, 95.5%) when compared to VIE group (61 out of 66 tagged, 92.4%) (Table 12). The Micro-ject group also had better survival (66 out of 66, 100%) versus the VIE group (63 out of 66, 95.5%); an unmarked control group had a 98.4% survival (61 out of 62 individuals) (Table 13).

We also tested for differences in initial capture probabilities due to body size. Using a Kolmogorov–Smirnov test, the fork length of maiden captures versus recaptures did not differ significantly for Chinook ($D = 0.14$, $p = 0.41$). However, using logistic regression, the relationship between probability of recapture and fork length was significant for coho ($p = 0.01$, e.g., smaller fish were more likely to be recaptured compared to larger fish). This relationship was not observed for steelhead ($p = 0.70$) as recapture probability was similar across fork lengths of tagged fish.

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 ($n < 100$) the first five weeks of trapping (beginning March 11, trapping period 1), peaked in early May, and declined to low numbers again by the last week of trapping (ending July 11, trapping period 18, Appendix C).

Scale age data were not collected from Chinook in 2021 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 46.3 mm (± 6.8 mm SD) and 92.3 mm (± 5.6 mm) in the first and last sampled week of trapping, respectively (Figure 3).

A total of 24,583 Chinook subyearling outmigrants (not including fry or parr) were captured: 5,195 were marked and 838 were recaptured for an overall recapture rate of 16.1% (Appendix C; Periods 1 – 18). Modeled weekly trap efficiencies ranged from 8.5% to 28.8% (Figure 4).

Abundance of wild Chinook subyearling outmigrants (not including fry or parr) was estimated to be 163,146 ± 7,586 SD with a coefficient of variation (CV) of 4.6% (Figure 5, Table 11). The Rhat value for Chinook was 1.003, suggesting good model convergence. We estimate that Chinook smolt production in the Newaukum River contributed 37.2% of the total Chinook smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap in 2021.

In 2020, the total number of adult spring Chinook spawners in the Newaukum River upstream of the trap site was estimated to be 653 and adult fall Chinook was estimated to be 1,020, producing an overall smolt per spawner estimate of 97.5 for the 2020 brood year of naturally spawning Chinook (Ronne et. al. 2022).

Chinook subyearling abundance by run type

A total of 758 juvenile Chinook tissue samples from the Newaukum River smolt trap were sent to the lab for processing in 2021. Of those, SNP genotypes were successfully obtained from 699 samples (92%). 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), and 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 median abundance estimates with known precision based on results from the mark-recapture study (Table 7, Figure 6). No fish were sampled in the first or final week 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 33,091 (20.5%) spring Chinook, 99,538 (61.6%) fall Chinook, and 28,990 (17.9%) of unknown run timing (i.e., heterozygotes).

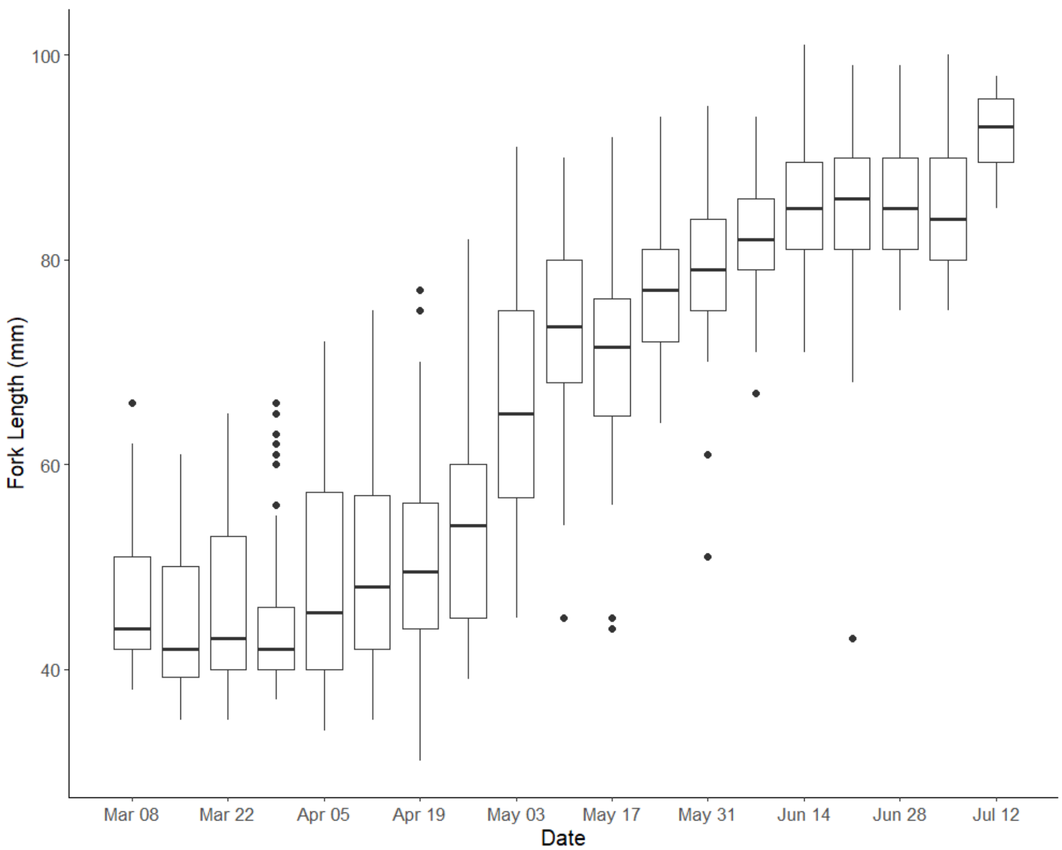


Figure 3. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Newaukum River screw trap, 2021. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

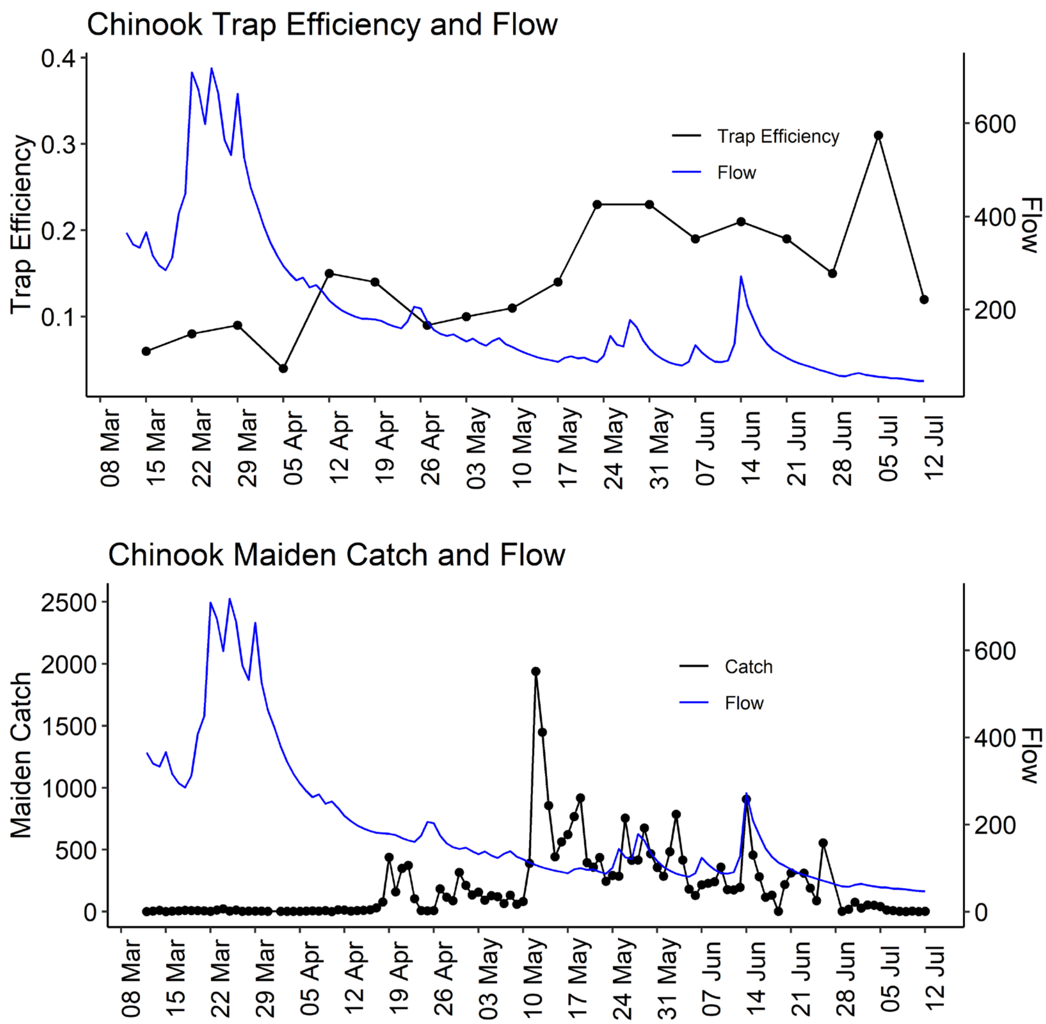
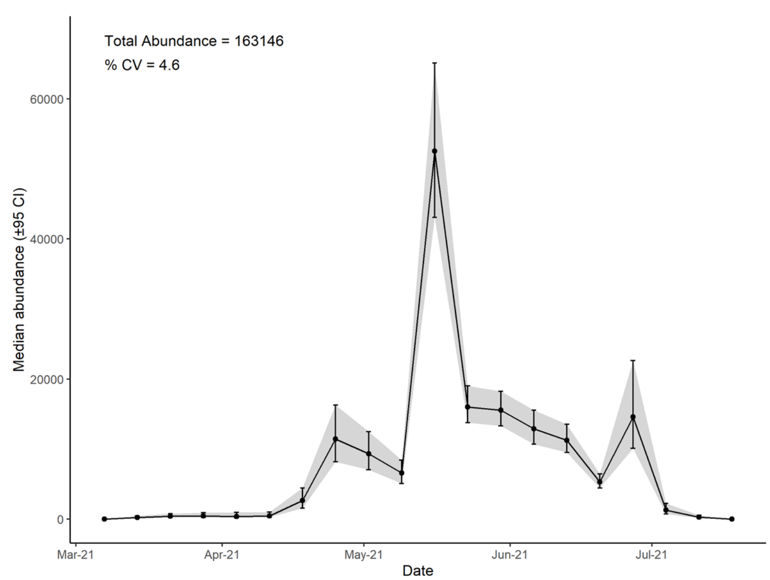


Figure 4. Wild Chinook transitional and smolt raw trap efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Newaukum River smolt trap.



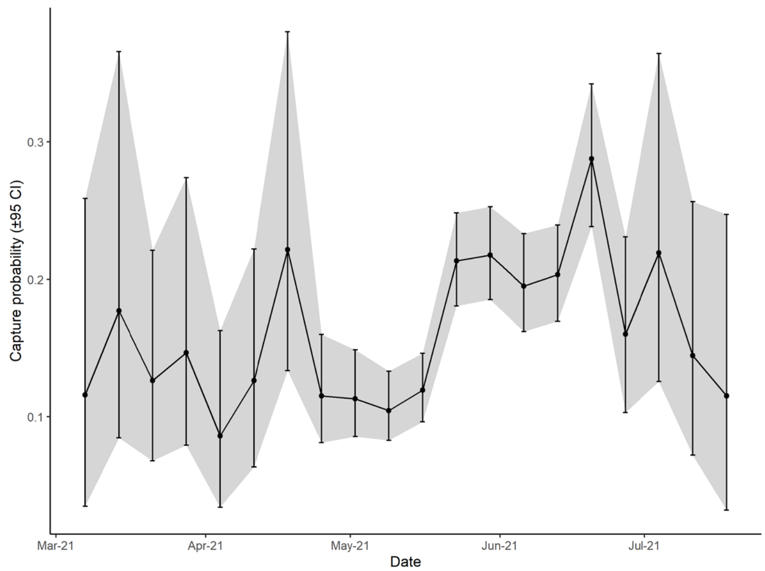


Figure 5. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Newaukum River smolt trap in 2021. Error bars and shading around point estimates represent 95% confidence intervals.

Table 7. Chinook subyearling genetic estimates by period and run type at the Newaukum River screw trap.

Period	Start Date	End Date	Spring	Heterozygote	Fall	Total
1	1-Mar	7-Mar	5	1	2	8
2	8-Mar	14-Mar	145	18	54	217
3	15-Mar	21-Mar	359	37	12	408
4	22-Mar	28-Mar	380	56	28	464
5	29-Mar	4-Apr	154	123	92	369
6	5-Apr	11-Apr	306	93	80	479
7	12-Apr	18-Apr	992	771	881	2,644
8	19-Apr	25-Apr	4,054	1,192	6,200	11,445
9	26-Apr	2-May	2,480	1,335	5,532	9,347
10	3-May	9-May	1,741	1,838	2,999	6,578
11	10-May	16-May	14,491	10,869	27,171	52,531
12	17-May	23-May	2,884	3,205	9,935	16,023
13	24-May	30-May	4,350	2,486	8,700	15,535
14	31-May	6-Jun	526	2,628	9,723	12,876
15	7-Jun	13-Jun	225	1,126	9,910	11,261
16	14-Jun	20-Jun	0	451	4,854	5,305
17	21-Jun	27-Jun	0	2,734	11,846	14,580
18	28-Jun	4-Jul	0	0	1,267	1,267
19	5-Jul	11-Jul	0	26	247	273
20	12-Jul	18-Jul	0	1	5	6
Totals			**33,091 (20.5%)**	**28,990 (17.9%)**	**99,538 (61.6%)**	**161,619**

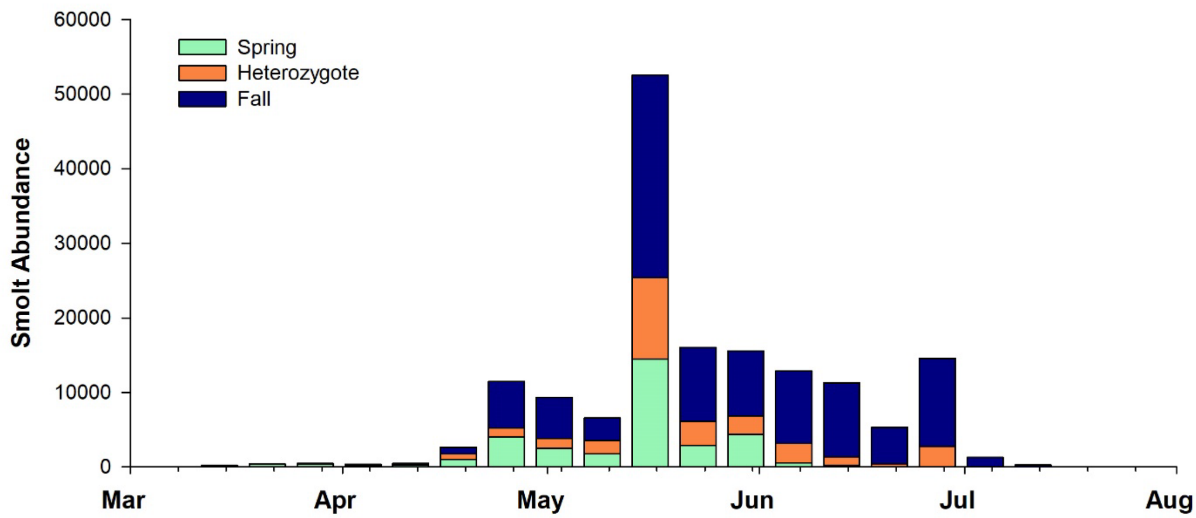


Figure 6. Chinook subyearling SNP genotype estimates from the Newaukum River trap by date. SNP genotypes are associated with adult run timing in Chehalis Chinook salmon (Thompson et al. 2019).

Coho

The coho outmigrant estimate in 2021 included both subyearlings and yearlings in transitional and smolt life stages. Approximately 80% of the outmigrants observed at the trap were categorized as the 'smolt' phenotype whereas 20% were categorized as the 'transitional' phenotype. Coho outmigrants were observed in low numbers the first week of trapping (beginning March 11, trapping period 1), peaked in late April, early May, and were last observed on June 25 (trapping period 16, Appendix D).

Scale age data did not indicate that there was a subyearling component of the coho out-migration in 2021; however, scale age data did indicate that there was a two-year-old component (1.7%) (Figure 8, Table 8). Fork length of known yearling outmigrants averaged 114.6 mm (± 10.4 mm) whereas fork length of known two-year old outmigrants averaged 125.9 mm (± 10.4 mm). Fork length for all measured outmigrants averaged 113.6 mm (± 9.6 mm).

In 2021, a total of 2,937 coho outmigrants were captured, 2,274 coho were marked, and 136 were recaptured for an overall recapture rate of 6.0% (Appendix D). Modeled weekly trap efficiencies ranged from 2.1 to 16.7%.

Abundance of 2021 wild coho outmigrants was estimated to be 57,417 ± 7,145 SD with a CV of 12.4% (Figure 7, Table 11). The Rhat value for coho was 1.059, suggesting good model convergence. We estimated that in 2021, coho smolt production in the Newaukum River contributed 28.2% of the total coho smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap.

In 2019, the total number of adult coho spawners in the Newaukum River upstream of the trap site was estimated to be 1,984 (Ronne et al. 2021), producing a smolt per spawner estimate of 28.9 for the 2019 brood year of naturally spawning coho.

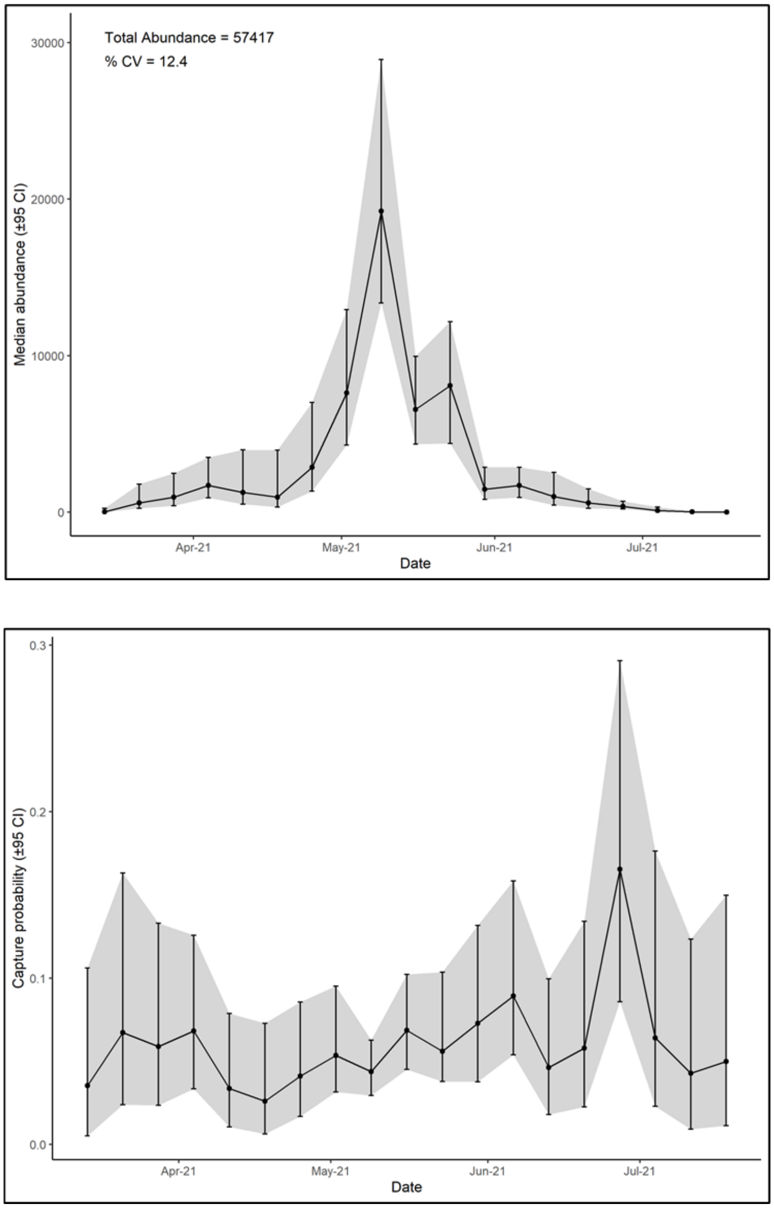


Figure 7. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho yearlings produced above the Newaukum River smolt trap in 2021. Error bars and shading around point estimates represent 95% confidence intervals. Data provided in Appendix D.

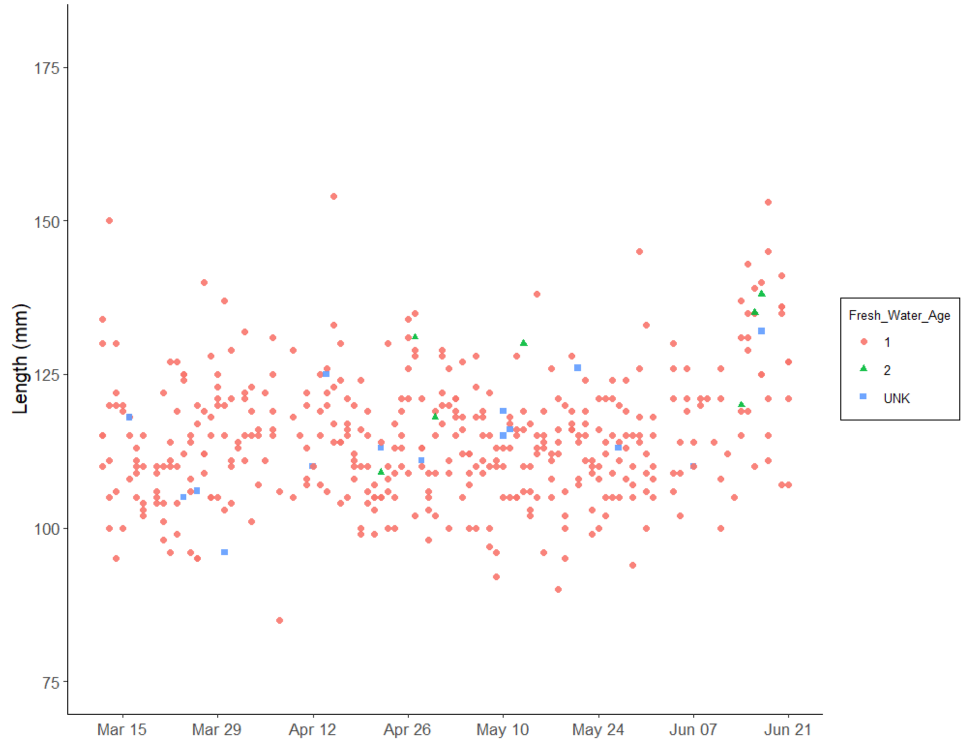


Figure 8. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2021.

Table 8. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2021. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	ND
1	3/8	3/14	15		15		
2	3/15	3/21	27		26		1
3	3/22	3/28	35		33		2
4	3/29	4/4	29		28		1
5	4/5	4/11	18		18		
6	4/12	4/18	31		29		2
7	4/19	4/25	35		33	1	1
8	4/26	5/2	35		32	2	1
9	5/3	5/9	35		35		
10	5/10	5/16	35		31	1	3
11	5/17	5/23	35		34		1
12	5/24	5/30	35		34		1
13	5/31	6/6	21		21		
14	6/7	6/13	13		12		1
15	6/14	6/20	30		26	3	1
16	6/21	6/27	5		5		
17	6/28	7/4	0				
18	7/5	7/11	0				

Steelhead

Our goal was to generate an unbiased abundance estimate of the steelhead smolt and transitional outmigration. However, due to environmental conditions and duration of our trapping, we violated Assumption 1 of trapping over the entirety of the out-migration. For example, some of our largest total maiden captures were in the first and second week of the trapping season. Thus, at minimum, we missed the ascending limb of the outmigration and cannot discern a peak of the outmigration. Therefore, our estimate of abundance for steelhead is unreportable in 2021 (Table 11).

Scale age data indicated that sampled steelhead were Age-1, Age-2, Age-3, and Age-4 (Figure 9 , Table 9). Fork length averaged 142.4 mm (± 22.5 mm) for Age-1, 166.6 mm (± 21.4 mm) for Age-2, 188.2 mm (± 44.1 mm) for Age-3, 232 mm (1 individual) for Age-4, and 157.1 mm (± 27.4 mm) for all captured steelhead.

In 2021, a total of 430 steelhead outmigrants were captured, 421 steelhead were marked, and 22 were recaptured for an overall recapture rate of 5.2% (Appendix E).

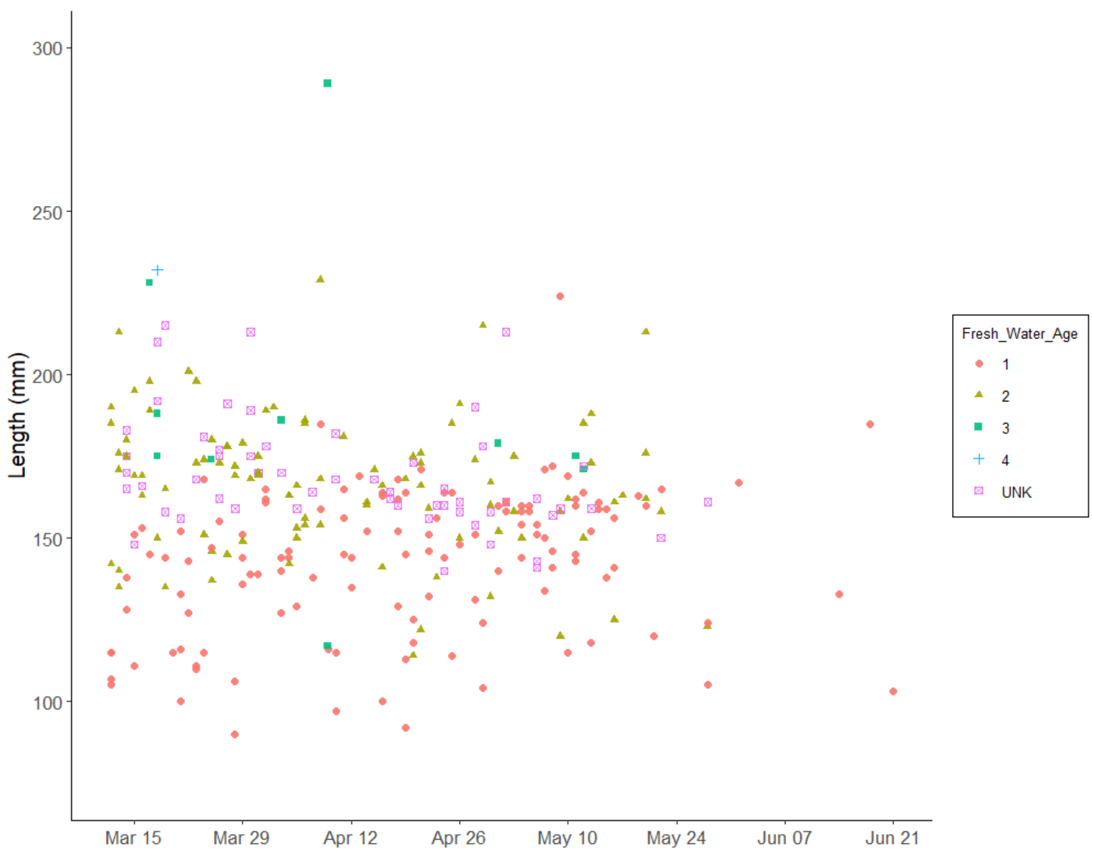


Figure 9. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2021.

Table 9. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2021. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Age-3	Age-4	ND
1	3/8	3/14	20		6	10			4
2	3/15	3/21	31		10	10	3	1	7
3	3/22	3/28	32		10	14	1		7
4	3/29	4/4	31		13	11	1		6
5	4/5	4/11	27		10	11	2		4
6	4/12	4/18	21		11	5			5
7	4/19	4/25	31		15	10			6
8	4/26	5/2	27		9	8	1		9
9	5/3	5/9	25		15	5			5
10	5/10	5/16	26		15	7	2		2
11	5/17	5/23	10		4	5			1
12	5/24	5/30	4		2	1			1
13	5/31	6/6	1		1				
14	6/7	6/13	0						
15	6/14	6/20	2		2				
16	6/21	6/27	1		1				
17	6/28	7/4	0						
18	7/5	7/11	0						

Cutthroat

While cutthroat are not a focus of our study, they were encountered at our trap. Of the six fish successfully aged, scale age data indicated that four were Age-2 (66.7%), one was Age-3 (16.7%), and one was Age-3+F+ (16.7%) (Figure 10, Table 10).

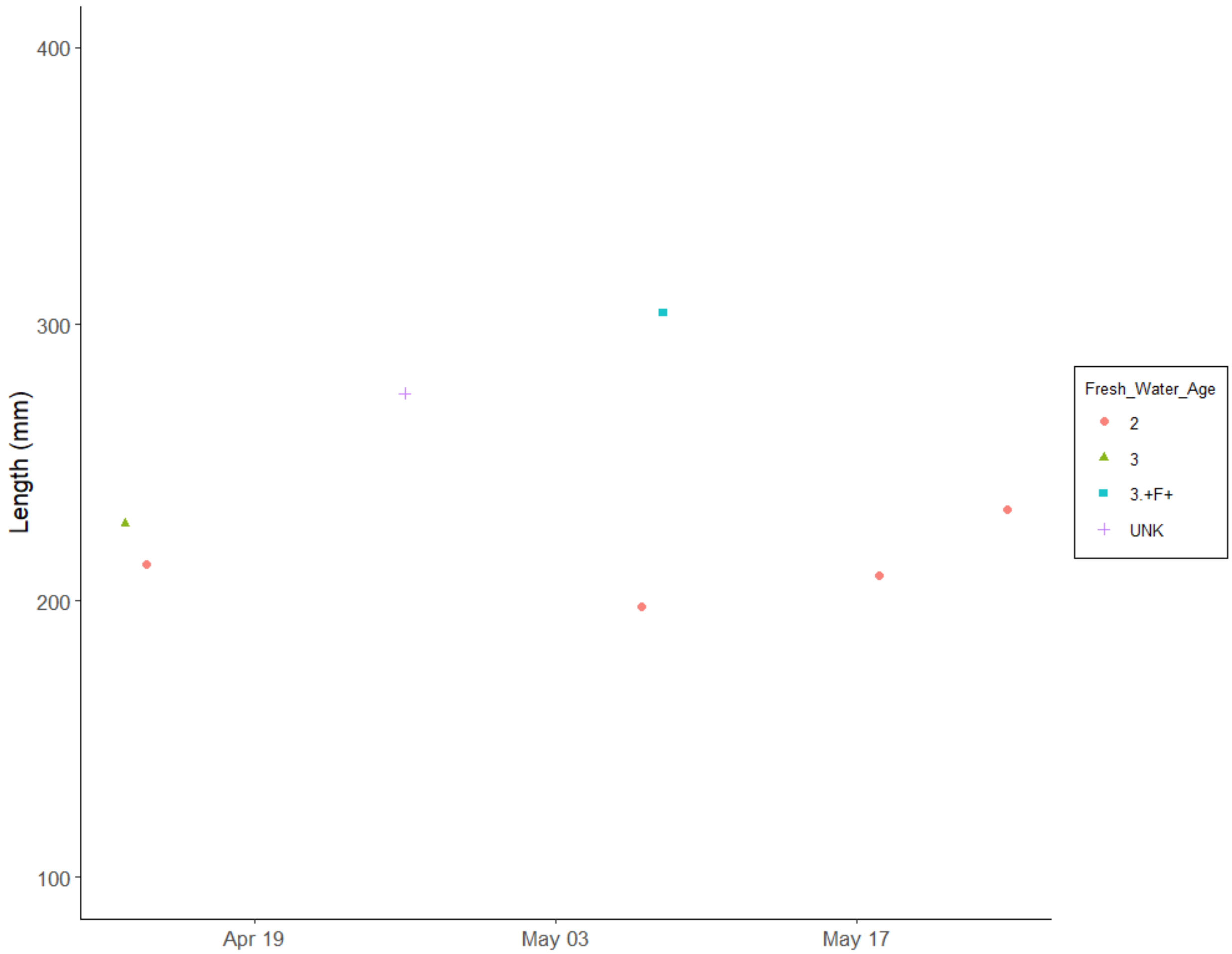


Figure 10. Plot of date-length-age data from wild cutthroat the Newaukum River screw trap, 2021.

Table 10. Freshwater ages of wild cutthroat at the Newaukum River screw trap, 2021. Data are scale ages of sampled individuals by week.

Period	**Start Date**	**End Date**	**No. Scales**	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**Age-4**	**Adult**	**ND**
1	3/8	3/14	0							
2	3/15	3/21	0							
3	3/22	3/28	0							
4	3/29	4/4	0							
5	4/5	4/11	0							
6	4/12	4/18	2			1	1			
7	4/19	4/25	0							
8	4/26	5/2	1							1
9	5/3	5/9	2			1			1 (3.+F+)	
10	5/10	5/16	0							
11	5/17	5/23	1			1				
12	5/24	5/30	1			1				
13	5/31	6/6	0							
14	6/7	6/13	0							
15	6/14	6/20	0							
16	6/21	6/27	0							
17	6/28	7/4	0							
18	7/5	7/11	0							

Table 11. Final Outmigrant Abundance Estimate

Year	Trap	Species	Origin	Life Stage(s)	Age	Abundance	CV
2021	Newaukum River	Coho	Wild	Smolts and transitionals	Yearling	57,417	12.4%
2021	Newaukum River	Steelhead	Wild	Smolts and transitionals	Yearling	NA	NA
2021	Newaukum River	Chinook	Wild	Smolts and transitionals	Subyearling	163,146	4.6%

Discussion

Basin-wide Context

This report presents results from the 2021 salmon and steelhead smolt out-migration of the Newaukum River, the third 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. We acknowledge that 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 the estimate. 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).

Our abundance estimate of 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 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 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) 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 2021 Chinook estimate saw a 25.8% increase from the 2020 estimate (163,146 versus 129,682) and the CV decreased from 11.8% to 4.6% (Figure 11). This increase in wild Chinook production corresponded with increased adult returns: 1,673 in 2020 versus 927 in 2019 (Ronne et al. 2022). Conversely, the 2021 juvenile coho estimate decreased 21.4% from the 2020 estimate (57,417 versus 73,416) and the CV decreased from 13.5% in 2020 to 12.4% 2021 (Figure 12). This decrease in wild coho production corresponds with decreased adult returns: 1,984 in 2019 versus 5,186 in 2018 (Ronne et al. 2021).

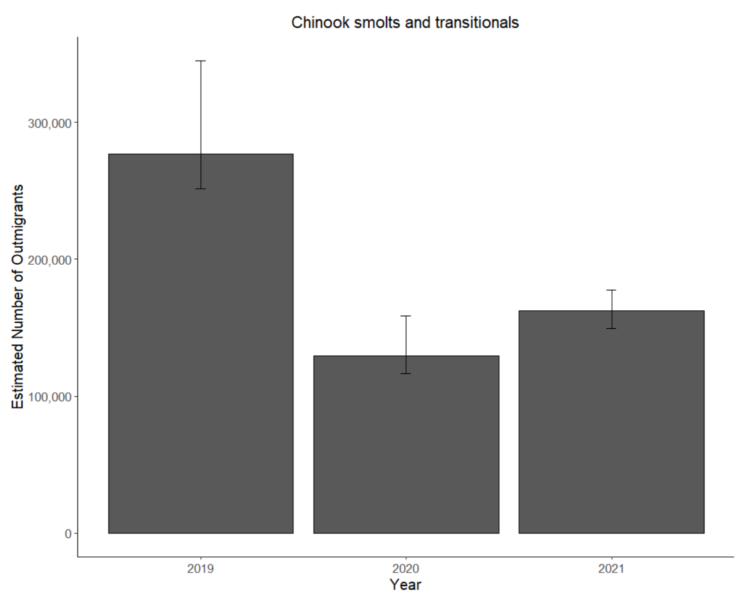


Figure 11. Time series of 2019 - 2021 estimates of wild Chinook juvenile outmigrants at the Newaukum River smolt trap.

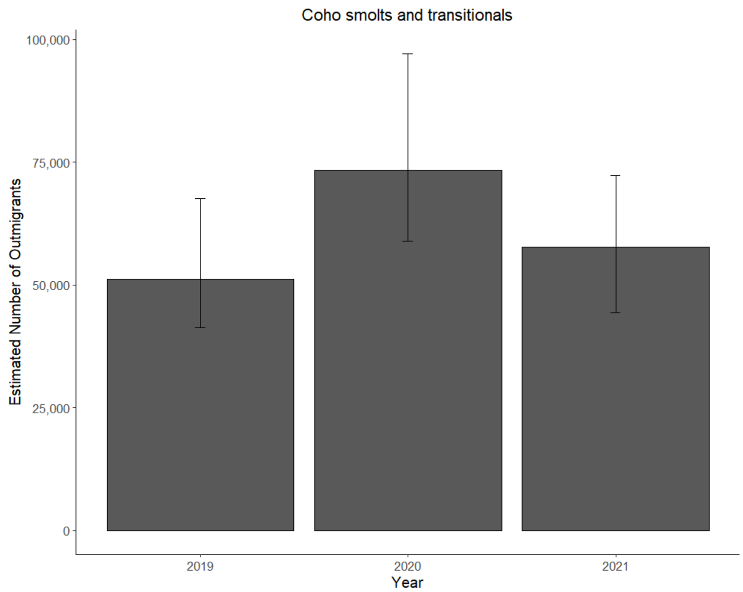


Figure 12. Time series of 2019 - 2021 estimates of wild coho juvenile outmigrants at the Newaukum River smolt trap.

Combining a genetic approach with our abundance estimates, we successfully estimated the abundance of outmigrating Chinook salmon having three genotypes associated with adult run timing with known precision. Our results suggest that the fall run genotype represents the largest component of the outmigration (61.6%) followed by the spring run type (20.5%), and those of unknown run timing (i.e., heterozygotes; 17.9%) (Table 12). The proportion of estimated spring Chinook outmigrants relative to the total estimated Chinook outmigrants was greater from the Newaukum River smolt trap compared to the Mainstem Chehalis River smolt trap (20.5% versus 6.6%). Interestingly, the estimate of spring Chinook outmigrants from the Newaukum River smolt trap was also greater than the amount estimated from the Mainstem Chehalis River smolt trap (33,091 versus 28,526). These results indicate that there could be a significant loss of juvenile spring Chinook originating from the Newaukum River occurring in the mainstem Chehalis River downstream of the Newaukum smolt trap.

The run timing of heterozygotes in the Chehalis Basin is unknown. Genotypes of voucher samples of known timing spring and fall run adult samples were used to verify our SNP markers, although those adult samples had almost no heterozygotes (Thompson et al. 2019). Heterozygotes are believed to show intermediate run timing (i.e., summer), but this is unverified in the Chehalis Basin. Future efforts could include work to verify the run timing of heterozygote adults. Our analysis is valuable because it now allows us to track abundance trends in all run types and proportional trends among run types which is critical information when determining if habitat restoration, protection, or climate change are impacting run types disproportionately. Finally, this information is particularly important for the spring Chinook component considering populations are low and declining (Curt Holt, WDFW personal communication).

Table 12. Chinook genetic sample sizes by period.

Period	**Fall**	**Heterozygote**	**Likely Fall**	**Likely Heterozygote**	**Likely Spring**	**No Data**	**Partial Heterozygote**	**Spring**	**Grand Total**
2	3	1	1			4		8	17
3	1	3			1	10		29	44
4	2	4		1	1	10	1	27	46
5	3	4				11		5	23
6	6	7			1	3		23	40
7	16	14		1		1		18	50
8	26	5				1		17	49
9	29	7	1					13	50
10	31	19						18	68
11	30	12				1	1	16	60
12	31	10						9	50
13	28	8						14	50
14	37	10				1		2	50
15	44	5						1	50
16	43	4				3			50
17	13	3	2			2			20
18	9					1			10
19	28	3							31
Total	**380**	**119**	**4**	**2**	**3**	**48**	**2**	**200**	**758**

By operating multiple smolt traps in the Chehalis basin, we were able to partition smolt abundance estimates to 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 averaged 2.2 million (0.5 to 3.7 million) since WDFW began monitoring smolt production in the 1980s (Litz and Agha 2022). From 2017-2021, coho smolt abundance estimated in the Chehalis Mainstem above river mile 52 averaged ~350,000 (Olson et al. 2022). Therefore, the area above river mile 52 contributes to roughly 18% of the coho smolt production in the basin. In 2021 specifically, coho smolt abundance at the Mainstem Chehalis River smolt trap was estimated to be 220,194 (Olson et al. 2022). Therefore, in 2021, the Newaukum River coho abundance estimate (62,159) represents approximately 28% of the coho production above river mile 52 of the mainstem Chehalis River. This is an increase from 16% of total production in 2020. This is the second consecutive year that the proportion of Newaukum coho in the Mainstem Chehalis River coho outmigrant estimate has increased. 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 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 2021, we were unable to produce an estimate of wild juvenile steelhead outmigrants due to missing the early portion of the out-migration window. In future seasons we may attempt to deploy the trap at an earlier date to capture the early out-migration period. Interestingly, in 2021 we were able to produce an unbiased steelhead smolt abundance estimate for the Chehalis Mainstem trap located approximately 31 river miles downstream of the Newaukum trap (30,942 ± 3,799 SD). The main stem trap became operational 7 days after the Newaukum trap, suggesting that the wild steelhead smolts were not rapidly moving downstream. Moreover, despite not generating an abundance estimate, we were able to observe 4 distinct age-classes of wild steelhead (Age-1 through Age-4), which improves understanding of life history diversity in the Newaukum sub-basin.

Next Steps

The Newaukum River presents many challenges to smolt trapping operations. In 2021, these challenges included high flows, warm water temperatures, and debris. This was particularly problematic for steelhead, which migrated slightly earlier than coho in 2021 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 is primarily because of the increased debris load that accompanies increased flows. These issues caused one outage in April, one in May, and four in June (two due to debris and two due to water temperature).

Within trapping seasons, mean monthly stream temperatures steadily increase from 6-7°C in March, to approximately 18-20°C in July. Between years, 2021 was warmer than 2020 during each month of the season. Most notably in 2021, mean monthly temperatures were 1.1°C and 5.1°C warmer in May and June than during the same months in 2020. In 2021, stream flow consistently stayed between 100 and 500 cfs throughout the season, except for two spikes over 1000 cfs, one in March and one in June. After the cfs spike in June, flows steadily decreased until the season ended.

The Chinook subyearling out-migration in 2021 peaked in early June, which presented some challenges with fish handling under relatively high stream temperatures. As catch of subyearling Chinook increased from May to June, mean monthly stream temperatures increased from 15.1℃ to 20.2℃, respectively (Table 13, Figure 13). During this timeframe, we adjusted our fish processing to earlier in the morning when stream temperatures were lowest. We will follow a similar model in 2022. Also, as was previously noted in this report, our estimate of the Chinook out-migration represents the subyearling component of the out-migration and did not include fry outmigrants. Given the extreme flow conditions of the river in January and February when fry out-migrate, we do not currently have plans to fish the trap during the early-timed fry migration.

Table 13. Time series of mean monthly stream temperatures °C recorded at Newaukum River smolt trap near river km 9.35 from 2019 - 2021.

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

*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.

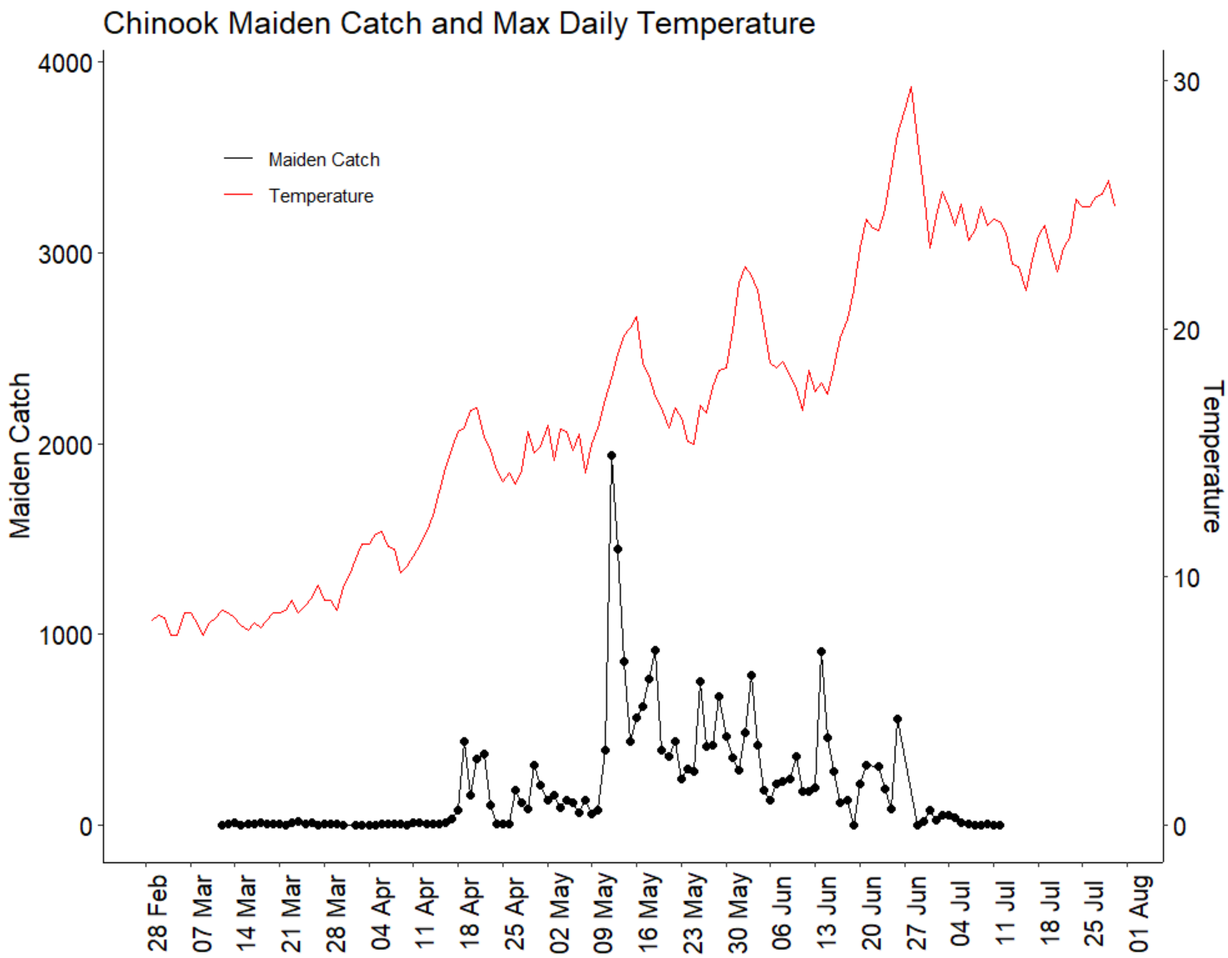


Figure 13. Chinook maiden catch and maximum daily stream temperature (C) at the Newaukum River smolt trap in 2021

In 2021, we evaluated an alternative device for holding fish for our mark retention trials. In previous years, we used perforated screen buckets to hold fish overnight for mark retention and survival studies. While these screen buckets worked, the size of the bucket limited how many fish could be held at a time. Additionally, if not careful, fish mortality can be an issue if too much water turbulence is present, particularly with Chinook. To alleviate these issues, we evaluated using a live box instead. Chinook held in the live box had better survival than those held in the screen buckets (97.4% versus 86.7%) (Table 14, Appendix F). Given these results, we will switch to using a live box in 2022.

Table 14. Cumulative results of 24-hour mark survival trials for 2021 trapping season at the Newaukum River smolt trap.

		Alive	Dead
Coho	Screen Bucket	106	1
	Live Box	28	0
Steelhead	Screen Bucket	33	0
	Live Box	0	0
Chinook	Screen Bucket	39	6
	Live Box	112	3

We also evaluated the use of Micro-ject on subyearling Chinook. Micro-ject has been used on yearling coho in the past but given the size difference between subyearling Chinook and yearling coho, there was concern about its suitability on subyearling Chinook. To address this concern, sixty-six Chinook marked with Micro-ject were held simultaneously with sixty-six VIE marked Chinook for a period of five days. An unmarked group of sixty-two Chinook were also held during the same period. Over the course of the five-day trial, the Micro-ject group had both better retention (95.5% versus 92.4%) and better survival (100% versus 95.5%) than the VIE group; the unmarked group had a 98.4% survival rate (Table 15, Appendix G). Two advantages Micro-ject has over VIE include producing less waste (via needles and unused paint) and marking the less sensitive anal fin (VIE fish are marked either behind the eye or on the operculum). These results suggest that Micro-ject is a viable marking option for Chinook. To evaluate this further, in 2022 we will use Micro-ject at the Newaukum River trap and VIE at the Upper Chehalis trap. This will give us an entire season worth of data with which to compare the two marking techniques.

Table 15. Results of 5-day Chinook VIE and Micro-ject retention and survival trial at the Newaukum River smolt trap.

		Alive		Dead	
		With Tags	W/O Tags	With Tags	W/O Tags
Start 5/18/21	VIE	66	0	0	0
	Microject	66	0	0	0
	Unmarked	0	62	0	0
5/19/21	VIE	61	3	0	2
	Microject	65	1	0	0
	Unmarked	0	61	0	1
5/21/21	VIE	61	3	0	2
	Microject	64	2	0	0
	Unmarked	0	61	0	1
End 5/23/21	VIE	59	4	1	2
	Microject	63	3	0	0
	Unmarked	0	61	0	1

In summary, 2021 represents the third year for which wild Chinook, coho and steelhead out-migrations have been described from any location in the Newaukum River in three decades. Our 2022 season will benefit from refinements resulting from this year. For Chinook and coho, we generated unbiased and precise estimates of smolt abundance in 2021, but the steelhead estimates were unreportable due to failure to trap over the entirety of the out-migration. For all three species, we described the biological diversity (timing, age structure, and size) of the outmigrants, as these are additional characteristics that 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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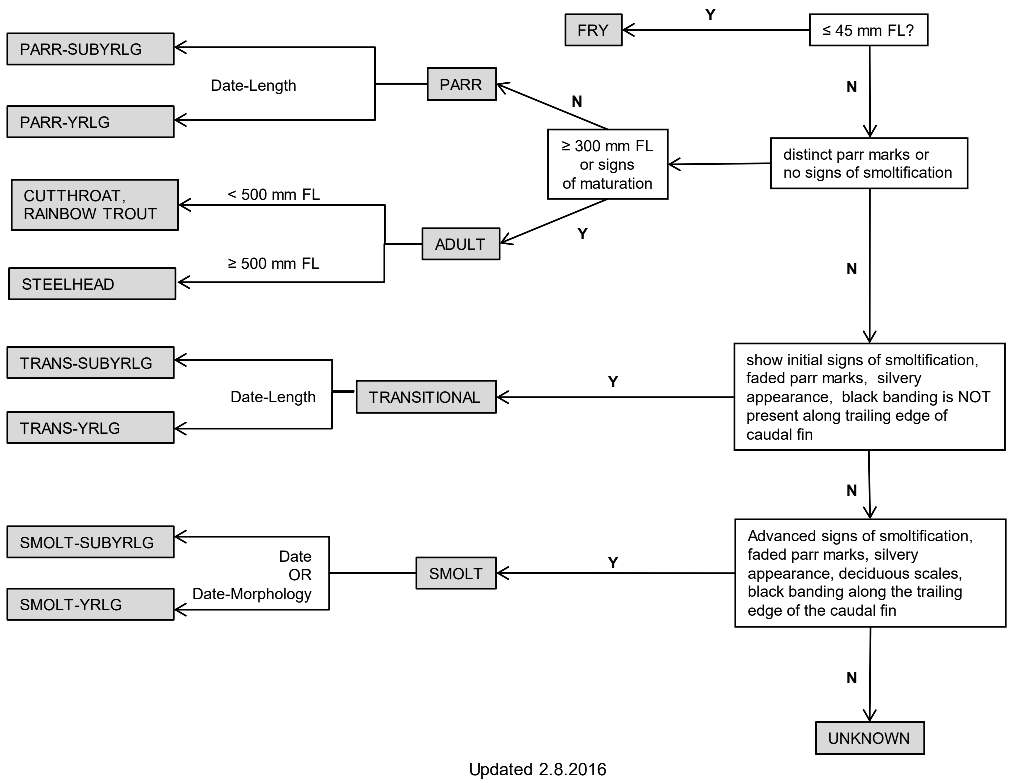
Appendices

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.



Appendix B. Newaukum River missed trapping periods 2021.

Last Time Observed Fishing	Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
4/1/21 1030	Unk	Visual	4/2/21 0825	Cone Stopper
5/14/21 1042	Unk	Visual	5/15/21 0725	Cone Stopper
6/13/21 0900	Unk	Visual	6/14/21 0755	2 Cone Stoppers
6/18/21 1007	Unk	Visual	6/19/21 0730	Cone Stopper
6/21/21 0842	22 hr 8 min	Scheduled	6/22/21 0650	Heat Outage
6/26/21 0740	60 hr 20 min	Scheduled	6/28/21 2100	Heat Outage

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 Captured**	**Prop Fished**
1	3/8	3/14	18	3	20	0.50
2	3/15	3/21	51	4	53	1.00
3	3/22	3/28	67	8	69	1.00
4	3/29	4/4	23	1	31	1.00
5	4/5	4/11	41	8	59	1.00
6	4/12	4/18	128	21	589	1.00
7	4/19	4/25	488	58	1321	1.00
8	4/26	5/2	494	50	1057	1.00
9	5/3	5/9	613	71	688	1.00
10	5/10	5/16	582	57	6267	1.00
11	5/17	5/23	544	120	3420	1.00
12	5/24	5/30	500	112	3372	1.00
13	5/31	6/6	500	101	2508	1.00
14	6/7	6/13	499	105	2290	1.00
15	6/14	6/20	495	88	1526	1.00
16	6/21	6/27	100	15	1145	0.49
17	6/28	7/4	26	8	277	1.00
18	7/5	7/11	25	3	40	1.00

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	3/8	3/14	16	0	21	0.50
2	3/15	3/21	59	3	57	1.00
3	3/22	3/28	108	8	117	1.00
4	3/29	4/4	59	2	42	1.00
5	4/5	4/11	22	0	23	1.00
6	4/12	4/18	83	3	117	1.00
7	4/19	4/25	268	10	408	1.00
8	4/26	5/2	509	18	846	1.00
9	5/3	5/9	353	26	448	1.00
10	5/10	5/16	432	22	456	1.00
11	5/17	5/23	112	15	105	1.00
12	5/24	5/30	151	11	153	1.00
13	5/31	6/6	24	1	46	1.00
14	6/7	6/13	13	0	34	1.00
15	6/14	6/20	75	12	60	1.00
16	6/21	6/27	0	0	4	0.49
17	6/28	7/4	0	0	0	1.00
18	7/5	7/11	0	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 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 Captured	Prop Fished
1	3/8	3/14	18	2	33	0.50
2	3/15	3/21	51	2	32	1.00
3	3/22	3/28	67	3	72	1.00
4	3/29	4/4	23	4	57	1.00
5	4/5	4/11	41	3	28	1.00
6	4/12	4/18	128	0	37	1.00
7	4/19	4/25	488	0	34	1.00
8	4/26	5/2	494	4	44	1.00
9	5/3	5/9	613	0	32	1.00
10	5/10	5/16	582	1	33	1.00
11	5/17	5/23	544	1	9	1.00
12	5/24	5/30	500	0	4	1.00
13	5/31	6/6	500	0	1	1.00
14	6/7	6/13	499	0	1	1.00
15	6/14	6/20	495	0	2	1.00
16	6/21	6/27	100	0	2	0.49
17	6/28	7/4	26	0	0	1.00
18	7/5	7/11	25	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 start and end one day before the recapture dates.

Appendix F. Pictures showing live box and screen buckets used during 2021 season.

Appendix G. Pictures illustrating quality range of Micro-ject marks and VIE tags.

Micro-ject	VIE