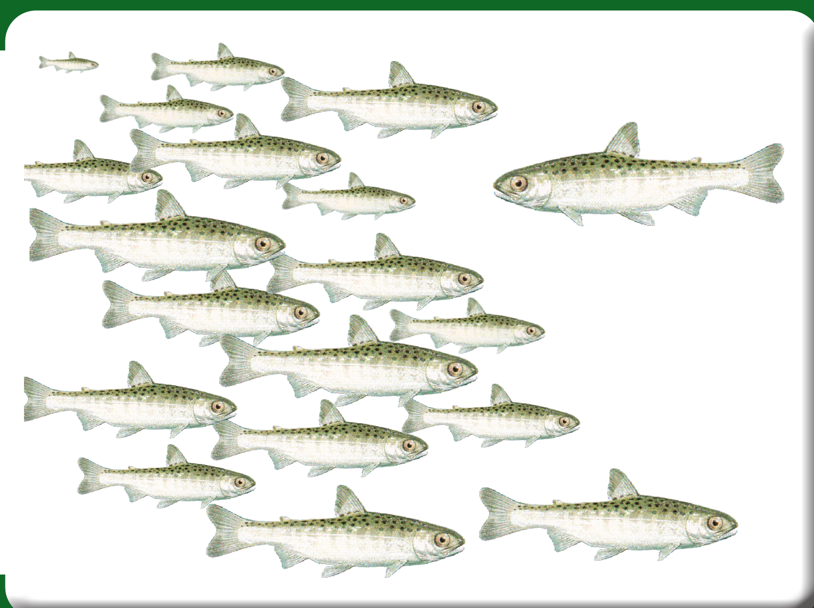
STATE OF WASHINGTON

June 2021

Newaukum River Smolt Production, 2020



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

Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 21-05

Newaukum River Smolt Production, 2020

Washington Department of Fish and Wildlife

Daniel Olson, Devin West, John Winkowski, and Marisa Litz

Fish Science Division

1111 Washington Street SE, Olympia WA 98501

June 2021

Acknowledgements

We would like to thank Justin Miller-Nelson and Fred Bodine for field operations. We would like to thank Eric Walther for providing maps in this report, the WDFW Ageing Lab for reading our scale samples, and Lea Ronne and Curt Holt for providing adult spawner estimates above the trap. We would like to thank a private landowner for allowing access to our trapping site.

This project was funded by the Washington State Legislature through the Department of Ecology's Office of Chehalis Basin.

Recommended citation: Olson, D.R., West, D., J. Winkowski, and M. Litz. 2021. Newaukum River Smolt Production, 2020, FPA 21-05. Washington Department of Fish and Wildlife, Olympia, Washington.

Table of Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

This report provides the results from the 2020 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) 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 13 to July 24, 2020.

Chinook outmigrants were 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 55.7 mm (± 3.8 mm, standard deviation SD) and 91.9 mm (± 7.5 mm SD) in the first and last sampled week of trapping, respectively. Roughly 96% of the total catch of wild Chinook outmigrants were > 45 mm. Abundance of wild Chinook subyearling outmigrants in 2020 was estimated to be 129,682 ± 11,112 SD with a coefficient of variation (CV) of 8.4%.

Coho outmigrants were predominately of the yearling (or "1+") age class (98.3%). Scale age data also indicated that there is a small subyearling ("0+") component of the coho out-migration (1.4%) that starts near the beginning of June. Average fork length of all outmigrant coho was 114.6 mm (± 10.2 mm SD). Fork length of known yearling outmigrants averaged 105.0 mm (± 12.9 mm SD) whereas fork length of known subyearling outmigrants averaged 75.5 mm (± 7.9 mm SD). Abundance of wild coho outmigrants in 2020 was estimated to be 73,416 ± 10,042 SD with a CV of 13.5%.

Steelhead outmigrants were predominately one (47.7%) and two (50.8%) years of age. A small proportion of steelhead were three (1.5%) years of age. Fork length averaged 142.1 mm (± 20.7 mm SD) for Age-1, 175.0 mm (± 19.5 mm SD) for Age-2, 182.5 mm (± 3.5 SD) for Age-3, and 161.0 mm (± 27.5 mm SD) for all captured steelhead. We were not able to produce an estimate of abundance in 2020 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 1,018 smolts mi^{-2} [393 smolts km^{-2}]) than any other western Washington watershed for which data currently exists (Litz 2021). 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 freshwater production among multiple species of salmonids across multiple locations within the Chehalis Basin. Beginning in 2021, this expanded effort will become a long term component of the integrated monitoring program used to evaluate salmon and steelhead responses to changes in the riverine environment as a result of habitat restoration and protection actions and climate change (M&AMT 2021). In 2019, the Newaukum River was selected to monitor smolt production to collect baseline information prior to early action restoration projects focused on enhancing salmon and steelhead rearing habitat in the basin. The Newaukum River supports runs of fall and spring run Chinook salmon, coho salmon, and steelhead trout. The Newaukum River is known to support a relatively large proportion (~25%) (WDFW, unpublished data) 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 along all coast Lead Entity areas (http://www.chehalisleadentity.org/our-work/). Several restoration projects are currently being implemented and 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) of juvenile outmigrants for wild Chinook salmon, coho salmon, 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. This report includes results from the 2020 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 (*O. clarkii*). 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 are 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 is described by West et al. (2020). In 2019, it was estimated that 90% of adult spring and fall Chinook salmon spawned upstream of the trap site producing the subyearling outmigrants in 2020 (Ronne et al. 2021). For adult coho salmon and steelhead that reproduced in 2018, all spawning activity was estimated to occur upstream of the trapping site (C. Holt, WDFW personal communication).

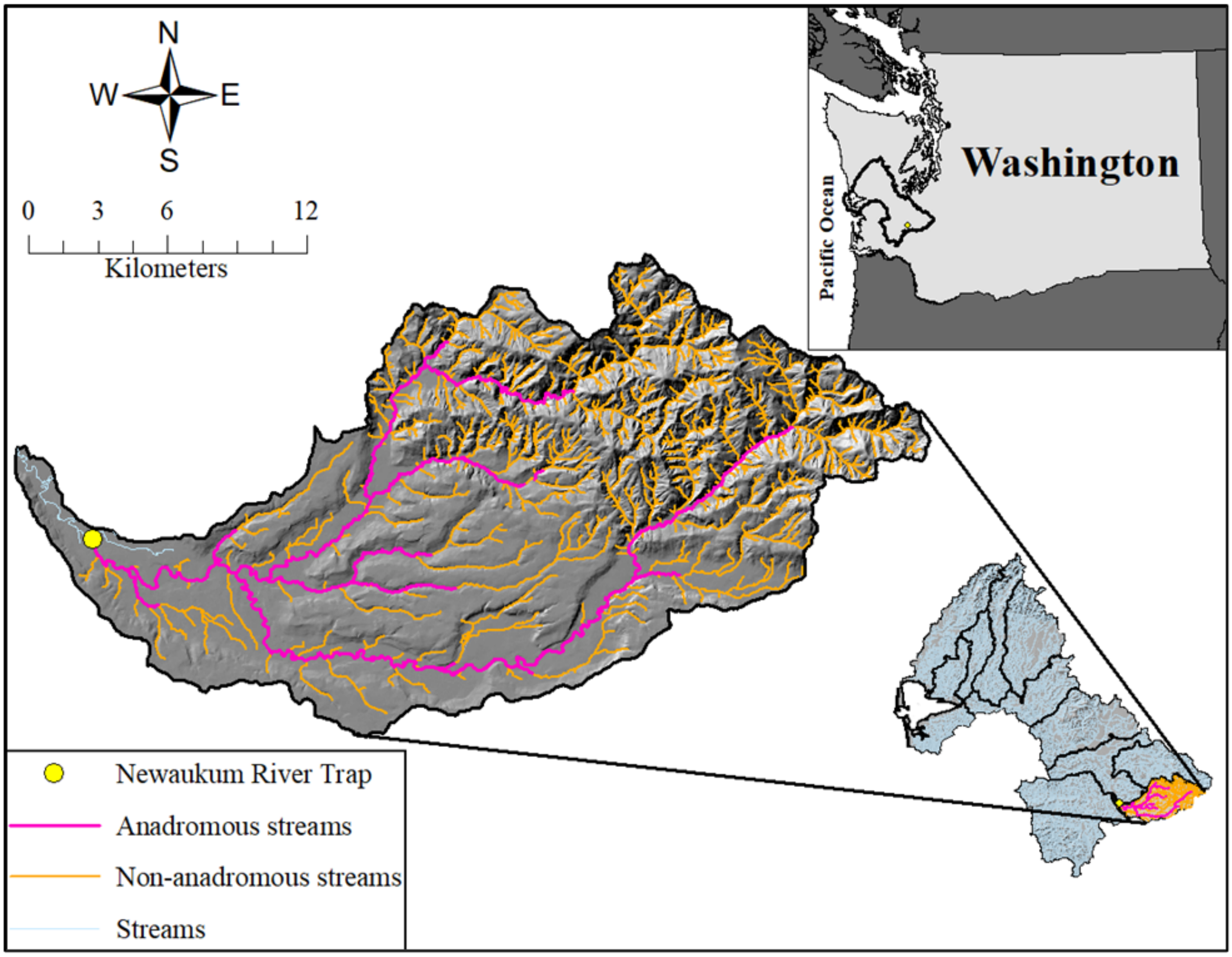


Figure 1. Newaukum River rotary screw trap location. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (112.5 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the Newaukum River rotary screw trap. Non-anadromous streams represent 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 2020, the trap was scheduled to operate continuously from March 13 through July 24, although unscheduled trap outages did occur due to high flow, warm (> 18°C) water temperatures, debris, and trap malfunctions. The trap was not operated from March 25 to April 14 due to the COVID-19 pandemic.

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 (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
Scales	Chinook[b]	---	---	---
	Coho	---	---	1st 5 per day
	Steelhead	---	---	1st 5 per day

[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 were 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 salmon.

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 salmon.

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 et al. 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 2020, a time strata period was added to the beginning and end of the trapping season to allow the BTSPAS model to estimate the tails of the run.

We were unable to trap from March 25 to April 14, 2020 because of the COVID-19 pandemic. 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 modified BTSPAS diagonal model (T. Buehrens, WDFW personal communication) with model arguments as follows: number of chains = 4, iterations = 20,000, burn-in = 10,000, simulations = 1,000, and thin rate = 10. Model convergence was evaluated 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.

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 v.3.4.1 (R Core Team, 2017) using the package BTSPAS (Bonner and Schwarz 2014).

Results

Summary of Fish Species Encountered

We encountered a diverse assemblage of fish species throughout the 2020 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*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), rock bass (*Ambloplites rupestris*), pumpkinseed (*Lepomis gibbosus*) and yellow bullhead (*Ameiurus natalis*).

Trap operation

We operated the trap from March 12 to July 24, 2020. There were six occurrences of trap outages (Appendix B). For three 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 flows and debris, COVID-19, or furlough. The first of these events, due to COVID-19, began on March 25 and lasted 21 days (through April 14). The second and third outages were due to a log stopping the cone before the crew had arrived onsite so exact time stopped is unknown; these events occurred on June 9 and June 15 respectively. Both events lasted less than 24 hours. The fourth outage (June 15 – 19) was due to high flow and debris and lasted for 39.3 hours. The fifth outage (June 28 – 30) was due to a mandatory staff furlough and lasted 46.2 hours. The sixth outage (July 4 – 5) was due to a log stopping the cone prior to the crew arriving onsite, so the exact time stopped is unknown.

Assumption Testing Trials

In 2020, results indicated that mark/tag retention was high based on trials that lasted 24 hours. Estimated mark retention was 100% (VIE, 174 out of 174 marked) for Chinook and 100% (PIT tags, 91 out of 91 marked) for coho and 83% for steelhead (PIT tags, 5 out of 6 tagged). The COVID-19 lockdown caused three weeks of the steelhead out-migration to be missed (Appendix B). This resulted in few steelhead being available for tag retention evaluation. We also found that mark/tag related mortality was low. Estimated survival was 82% (VIE, 143 out of 174 marked) for Chinook, 100% (PIT tag, 91 out of 91 marked) for coho, and 100% for steelhead (PIT tags, 6 out of 6 tagged) over the 24-hour holding period. It is suspected that Chinook survival was influenced by unanticipated excessive velocity in the fish holding apparatus as opposed to tag related mortality. Alternative holding methods will be explored in 2021. 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 for Chinook ($D = 0.26$, $p = 0.06$). However, using logistic regression, the relationship between probability of recapture and fork length was significant for coho ($p = 0.02$, e.g., smaller fish were more likely to be recaptured compared to larger fish). This relationship was not observed for steelhead ($p = 0.60$) 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 numbers (n < 100) the first week of trapping (beginning March 16, trapping period 1), peaked in early June, and declined to low numbers again by the last week of trapping (ending July 24, trapping period 18, Appendix C).

Scale age data were not collected from Chinook in 2020 as all juvenile fish were assumed to be subyearlings. Fork length of Chinook subyearlings increased steadily throughout the trapping period with an average of 55.7 mm (± 3.68 mm SD) and 91.9 mm (± 7.50 mm) in the first and last sampled week of trapping, respectively (Figure 3).

A total of 14,272 Chinook subyearling outmigrants were captured: 4,866 were marked and 814 were recaptured for an overall recapture rate of 16.7% (Appendix C; Periods 1 – 18). Modeled weekly trap efficiencies ranged from 2.0 to 21.6% (Figure 3).

Abundance of wild Chinook subyearling outmigrants was estimated to be 129,682 ± 11,112 SD with a coefficient of variation (CV) of 8.4% (Figure 5, Table 9). The Rhat value for Chinook was 1.05, suggesting good model convergence.

In 2019, the total number of adult spring Chinook spawners in the Newaukum River upstream of the trap site was estimated to be 157 and adult fall Chinook was estimated to be 770, producing an overall smolt per spawner estimate of 139.9 for the 2019 brood year of naturally spawning Chinook.

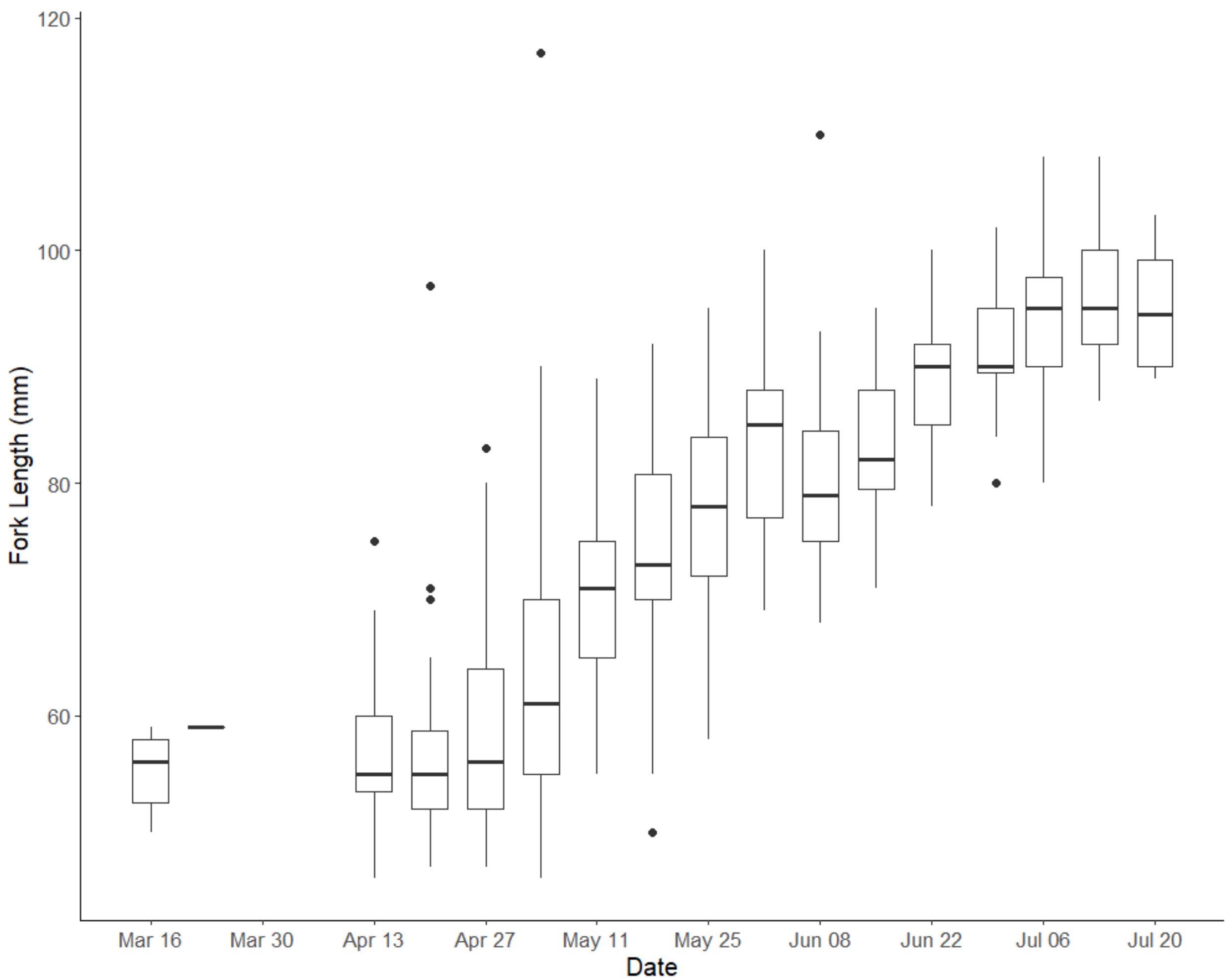


Figure 4. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Newaukum River screw trap, 2020. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

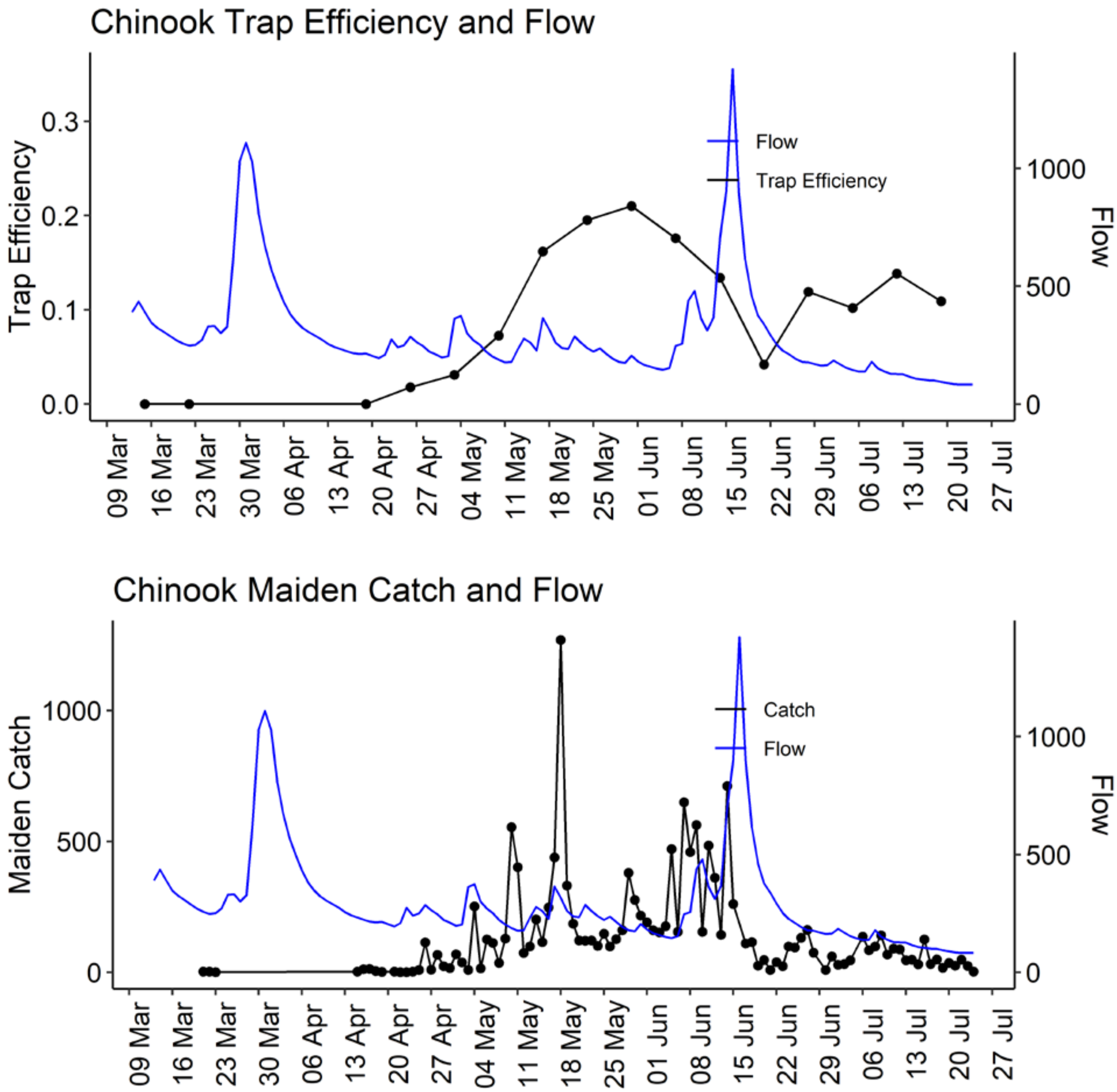


Figure 5. Chinook wild transitional and smolt trap raw efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Newaukum smolt trap.

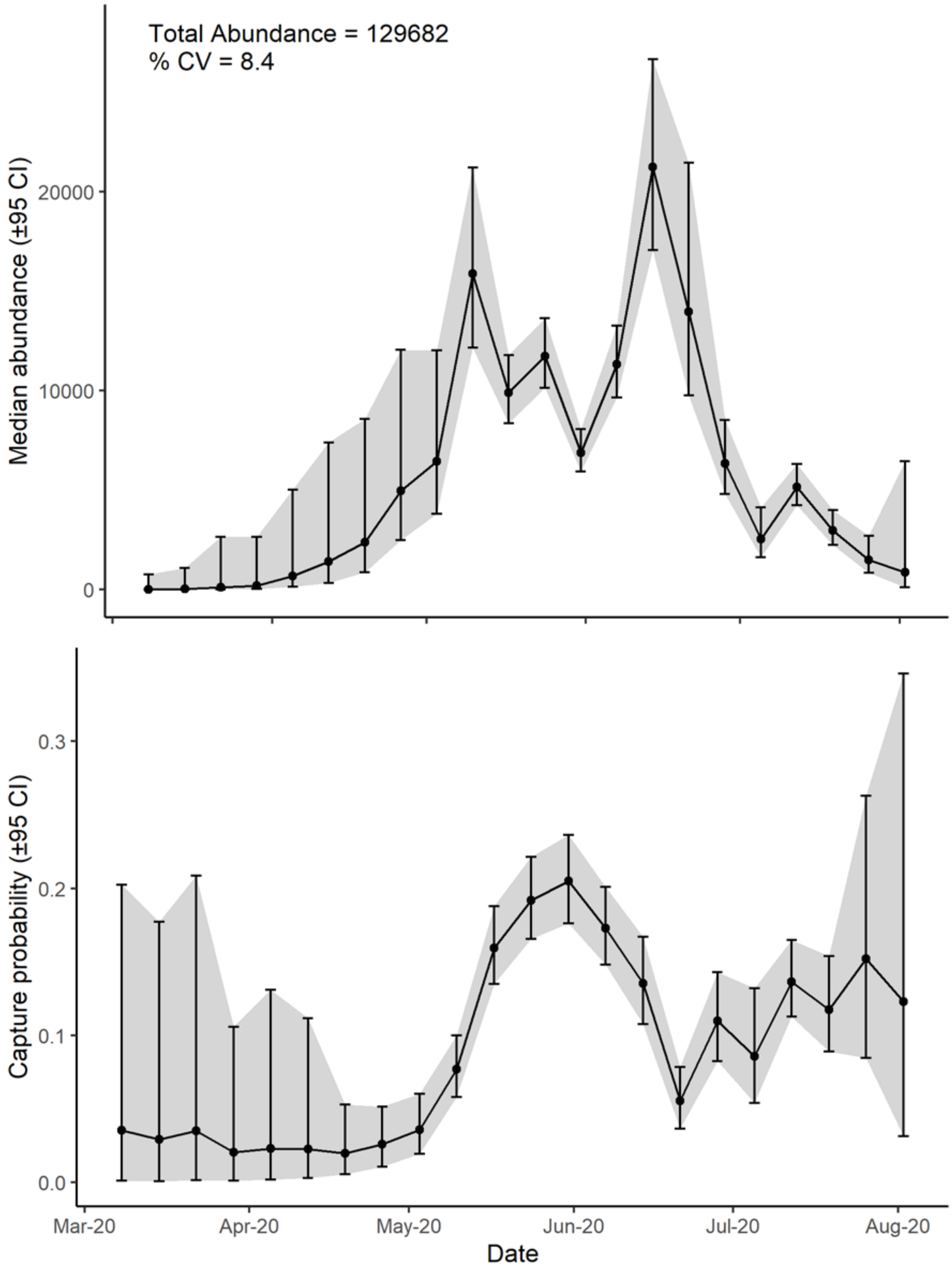


Figure 6. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Newaukum River smolt trap in 2020. Error bars and shading around point estimates represent 95% confidence intervals.

Coho

The coho outmigrant estimate in 2020 included both subyearlings and yearlings in transitional and smolt life stages. Approximately 92% of the outmigrants observed at the trap were categorized as the ‘smolt’ phenotype whereas 8% were categorized as the ‘transitional’ phenotype. Coho outmigrants were observed in low numbers the first week of trapping (beginning March 19, trapping period 1), peaked in early May, and were last observed on June 20 (trapping period 20, Figure 6, Appendix D).

Scale age data indicated a subyearling component of the coho out-migration starting the first week of June. Prior to this date, almost all sampled outmigrants were one year of age (Figure 7, Table 7). Fork length of known yearling outmigrants averaged 112.8 mm (± 10.9 mm) whereas fork length of known subyearling outmigrants averaged 99.0 mm (± 5.7 mm). Fork length for all measured outmigrants averaged 114.6 mm (±10.2 mm).

In 2020, a total of 2,581 coho outmigrants were captured, 2,321 coho were marked, and 95 were recaptured for an overall recapture rate of 4.1% (Appendix D). Modeled weekly trap efficiencies ranged from 2.7 to 11.7%.

Abundance of 2020 wild coho outmigrants was estimated to be 73,416 ± 10,112 SD with a CV of 13.5%. The Rhat value for coho was 1.03, suggesting good model convergence.

In 2018, the total number of adult coho spawners in the Newaukum River upstream of the trap site was estimated to be 5,186, producing a smolt per spawner estimate of 14.2 for the 2018 brood year of naturally spawning coho (Table 9).

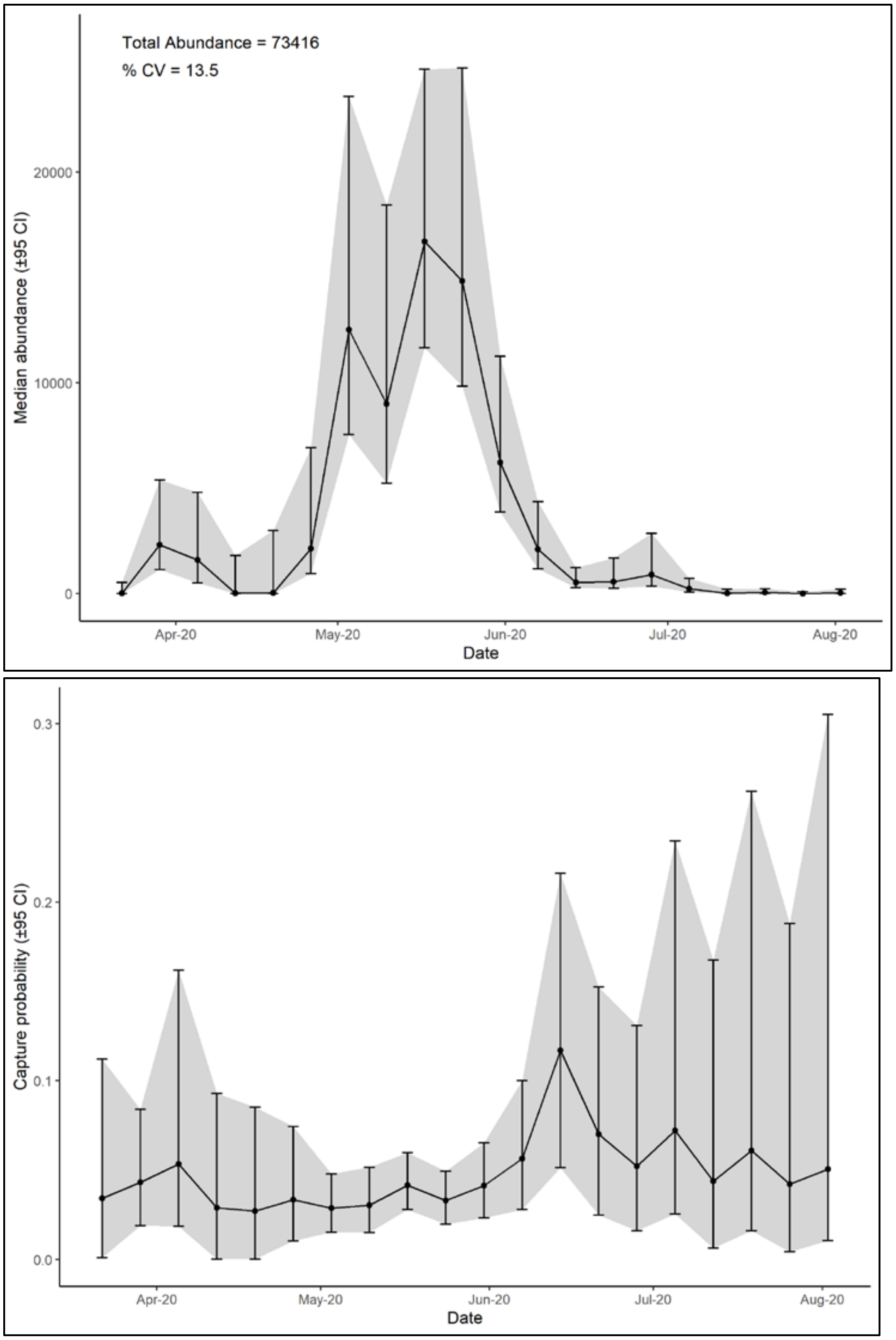


Figure 7. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho subyearlings produced above the Newaukum River smolt trap in 2020. Error bars and shading around point estimates represent 95% confidence intervals. Data provided in Appendix D.

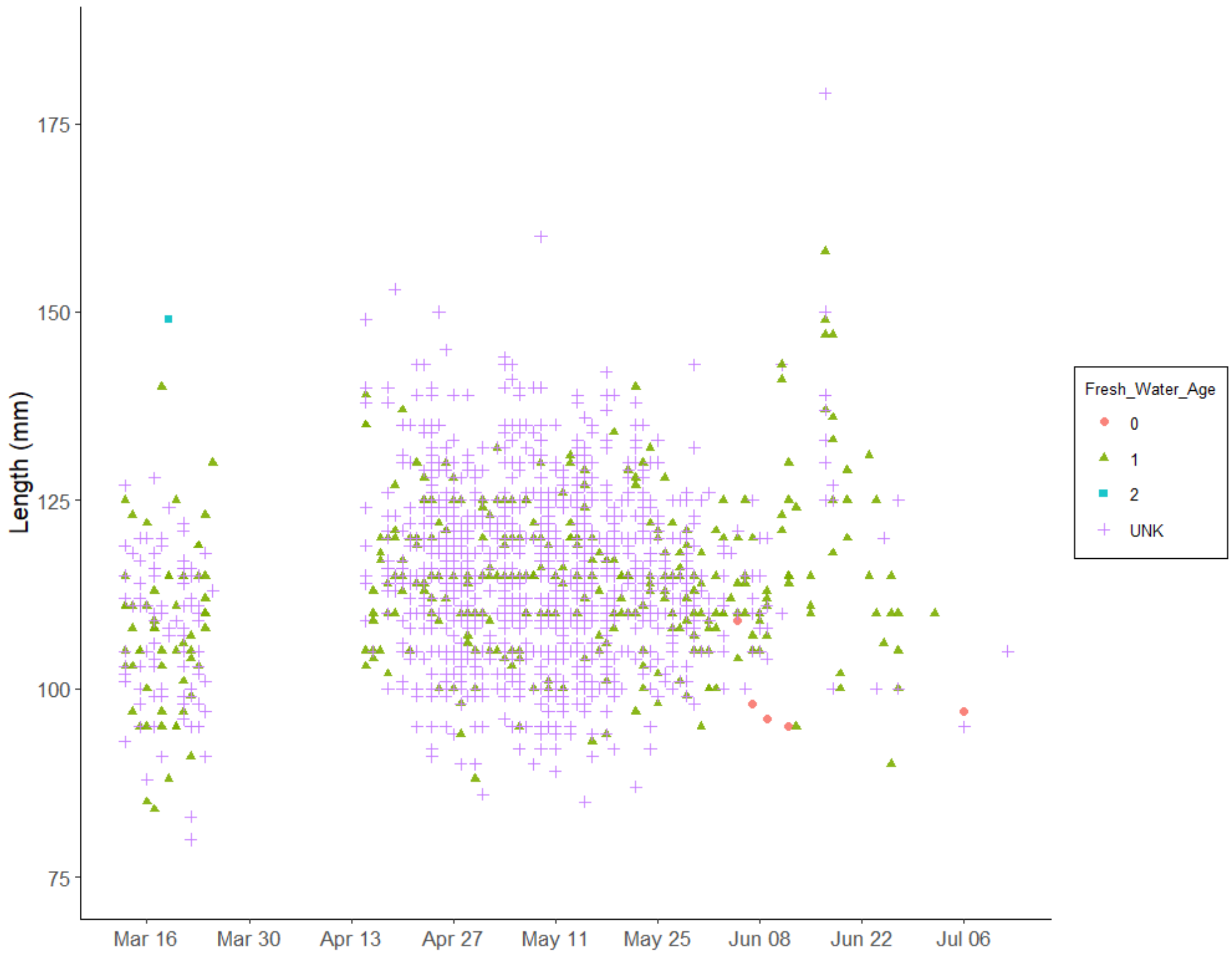


Figure 8. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2020.

Table 7. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2020. 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	3/09	3/15	17	0	15	0	0	0	2
2	3/16	3/22	35	0	34	1	0	0	0
3	3/23	3/29	12	0	11	0	0	0	1
4	3/30	4/05	NA	NA	NA	NA	NA	NA	NA
5	4/06	4/12	NA	NA	NA	NA	NA	NA	NA
6	4/13	4/19	24	0	23	0	0	0	1
7	4/20	4/26	35	0	31	0	0	0	4
8	4/27	5/03	35	0	31	0	0	0	4
9	5/04	5/10	35	0	34	0	0	0	1
10	5/11	5/17	35	0	31	0	0	0	4
11	5/18	5/24	35	0	34	0	0	0	1
12	5/25	5/31	35	0	34	0	0	0	1
13	6/01	6/07	32	2	27	0	0	0	3
14	6/08	6/14	23	2	19	0	0	0	2
15	6/15	6/21	18	0	17	0	0	0	1
16	6/22	6/28	14	0	11	0	0	0	3
17	6/29	7/05	1	0	1	0	0	0	0
18	7/06	7/12	3	1	0	0	0	0	2

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 2020 (Table 9).

Scale age data indicated that sampled steelhead were Age-1, Age-2, and Age-3 (Figure 8. , Table 8.). Fork length averaged 142.1 mm (± 20.7 mm) for Age-1, 175.0 mm (± 19.5 mm) for Age-2, 182.5 mm (± 3.54) for Age-3, and 161.0 mm (± 27.5 mm SD) for all captured steelhead.

In 2020, a total of 212 steelhead outmigrants were captured, 207 steelhead were marked, and 18 were recaptured for an overall recapture rate of 8.7% (Appendix E).

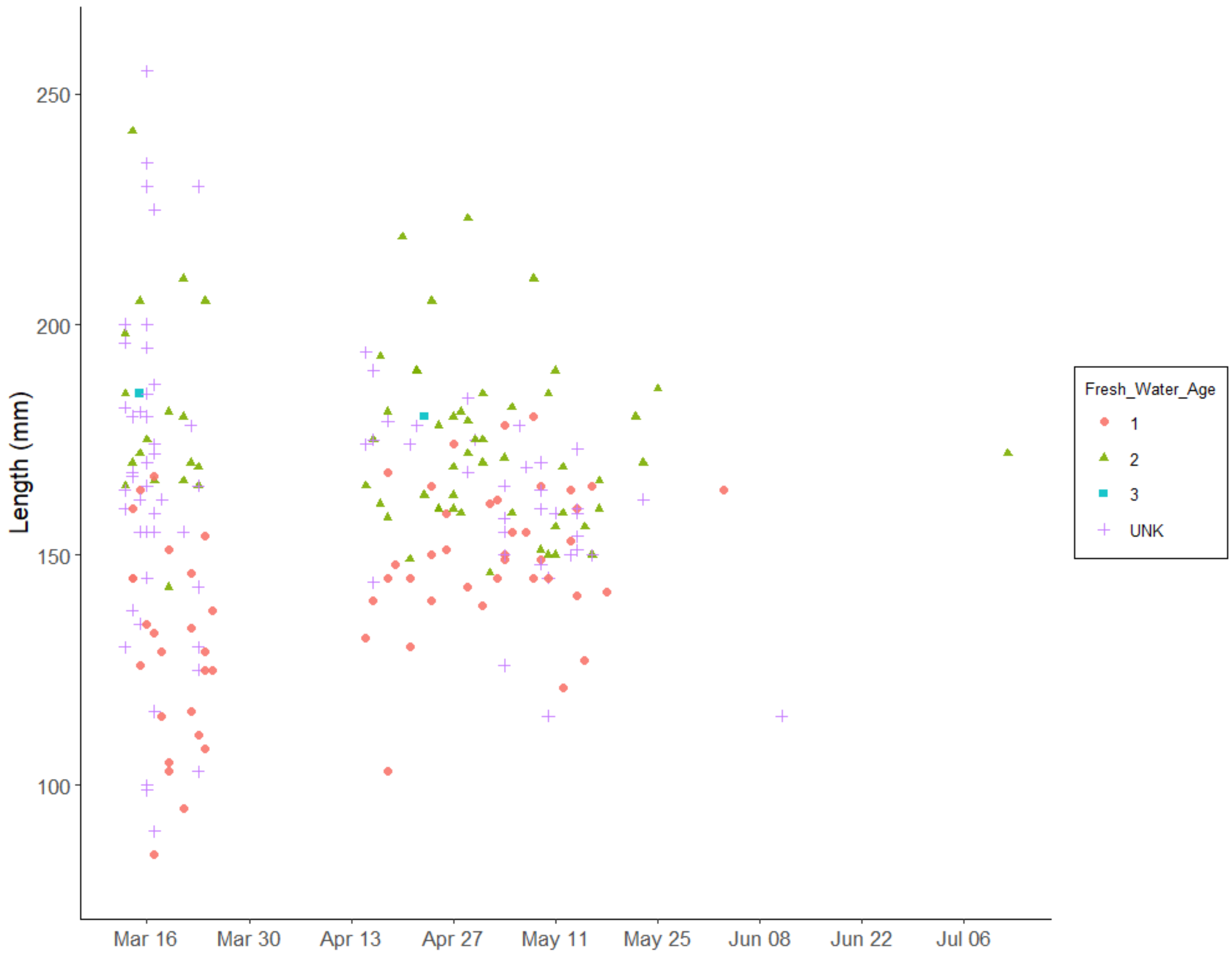


Figure 9. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2020.

Table 8. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2020. 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	3/09	3/15	15	0	5	7	1	0	2
2	3/16	3/22	27	0	13	8	0	0	6
3	3/23	3/29	12	0	7	3	0	0	2
4	3/30	4/05	NA	NA	NA	NA	NA	NA	NA
5	4/06	4/12	NA	NA	NA	NA	NA	NA	NA
6	4/13	4/19	17	0	6	6	0	0	5
7	4/20	4/26	19	0	7	9	1	0	2
8	4/27	5/03	22	0	6	14	0	0	2
9	5/04	5/10	24	0	10	7	0	0	7
10	5/11	5/17	22	0	7	9	0	0	6
11	5/18	5/24	4	0	1	2	0	0	1
12	5/25	5/31	1	0	0	1	0	0	0
13	6/01	6/07	1	0	1	0	0	0	0
14	6/08	6/14	0	0	0	0	0	0	0
15	6/15	6/21	0	0	0	0	0	0	0
16	6/22	6/28	0	0	0	0	0	0	0
17	6/29	7/05	0	0	0	0	0	0	0
18	7/06	7/12	1	0	0	1	0	0	0

Table 9. Final Outmigrant Abundance Estimate

Year	Trap	Species	Origin	Life Stage(s)	Age	Abundance	CV
2020	Newaukum River	Coho	Wild	Smolts and transitionals	Yearling	73,416	13.5%
2020	Newaukum River	Steelhead	Wild	Smolts and transitionals	Yearling	NA	NA
2020	Newaukum River	Chinook	Wild	Smolts and transitionals	Subyearling	129,682	8.4%

Discussion

Basin-wide Context

This report presents results from the 2020 salmon and steelhead smolt out-migration of the Newaukum River, the second 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 2020 Chinook estimate saw a 53% decrease from the 2019 estimate (129,682 versus 277,109) and the CV increased from 8.4% to 11.8%. This decrease in wild Chinook production corresponds with reduced adult returns: 1,494 in 2018 versus 927 in 2019. Conversely, the 2020 juvenile coho estimate increased 43% over the 2019 estimate (73,416 versus 51,228) and the CV was consistent year to year (13.5% and 13.1%). This increase in wild coho production corresponds with increased adult returns: 2,876 in 2017 versus 5,186 in 2018.

Previous studies (Campbell et al. 2017; Thompson et al. 2019) have demonstrated that spring-, fall-, and heterozygous run-types of Chinook salmon spawn in the Newaukum River. However, out-migration timing of offspring of these run types remains unknown. Our estimate of juvenile Chinook abundance in 2020 presumably included all run types, but more research is needed to differentiate among them. One promising technique for identified spring run Chinook salmon involves genetic analysis of the *GREB1-L* gene. In 2021, we will be collecting samples for genetic analysis with the goal of determining the relative proportion of spring-run, fall-run, and heterozygous run-types among subyearling juvenile outmigrants. Other efforts are ongoing to determine the run-timing and abundance of adult Chinook.

By operating multiple smolt traps in the basin, we were able to partition smolt abundance estimates to specific locations providing a finer scale resolution of freshwater production in the basin. 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 2021). From 2017-2020, coho smolt abundance estimated in the Chehalis main stem at river mile 52 averaged ~350,000 (West et al. 2021). Therefore, the area above river mile 52 contributes to roughly 18% of the coho smolt production in the basin. In 2020 specifically, coho smolt abundance at the Chehalis River smolt trap was estimated to be 463,566 (West et al. 2021). Therefore, in 2020, the Newaukum River coho abundance estimate (73,416) represents approximately 16% of the coho production above river mile 52 of the mainstem Chehalis River. This is an increase from 14% of total production in 2019. 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 2020, 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 2020 we were able to produce an unbiased steelhead smolt abundance estimate for the Chehalis main stem trap located approximately 31 river miles downstream of the Newaukum trap (38,647 ± 10,746 SD). The main stem trap became operational 6 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 3 distinct age-classes of wild steelhead (Age-1 through Age-3), 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 2020, these challenges included high flows, warm stream temperatures, and COVID-19. The COVID-19 lockdown necessitated a trap outage from March 25 to April 14 during the coho and steelhead out-migration period (March-April) and increased uncertainty of our estimates during that period. This was particularly problematic for steelhead, which migrate slightly earlier than coho and resulted in an unreportable estimate for steelhead in 2020. Challenges in trap operation 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 the increased flows. These issues caused three outages in June and one in July.

Generally speaking, within trapping seasons, mean monthly stream temperatures steadily increase from 6-7°C in March, to approximately 18-20°C in July. Between years, 2020 was cooler than 2019 during each month of the season. Most notably in 2020, mean monthly temperatures were 1.4°C, 3.2°C, and 1.7°C cooler in June, July, and August, In 2020, 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 2020 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 14.0℃ to 15.1℃, respectively (Table 10, Figure 9). 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 2021. 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 10. Mean monthly stream temperatures ℃ recorded at Newaukum River smolt trap near river km 9.35 in 2020.

Month	Mean (℃)
March	7.1
April	10.7
May	14.0
June	15.1
July	18.6

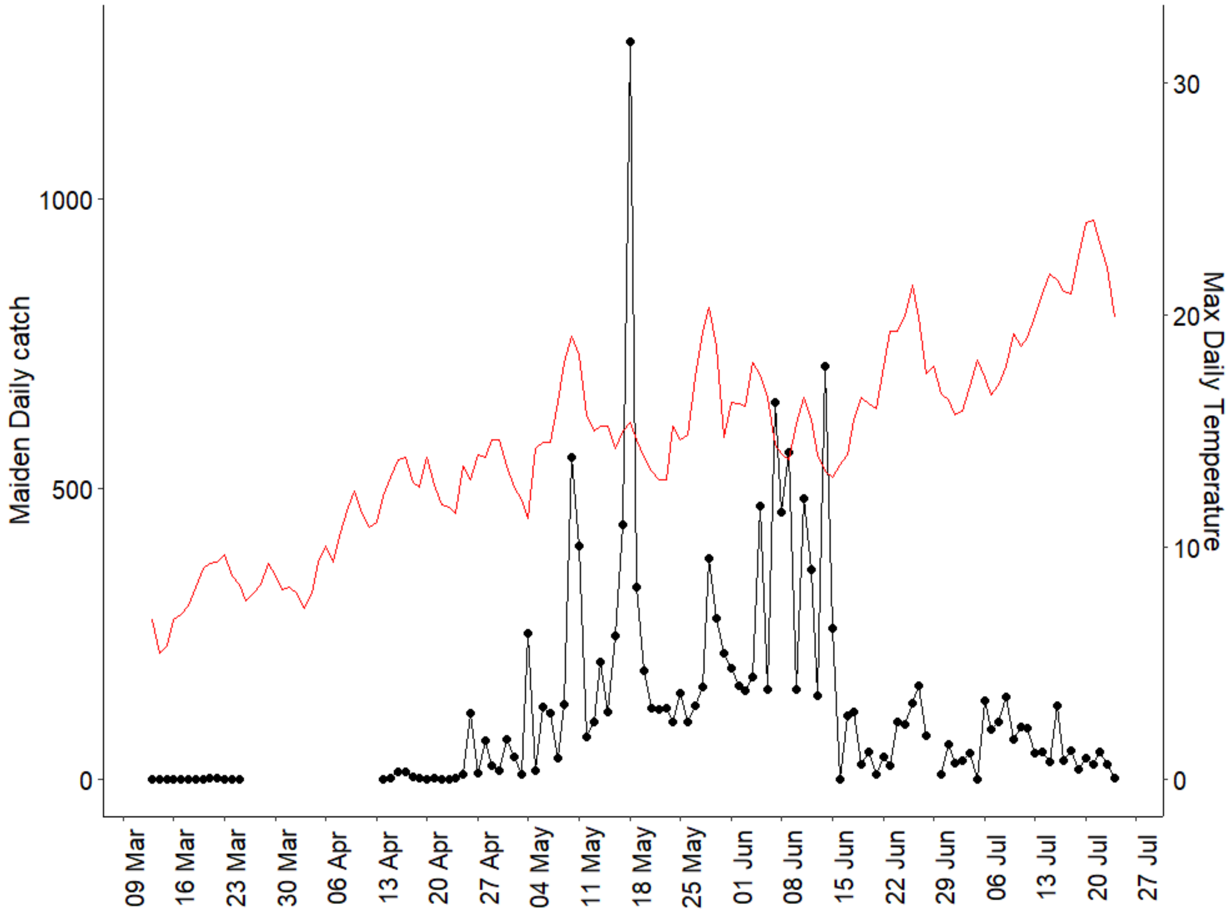


Figure 10. Chinook maiden catch and maximum daily stream temperature (°C) at the Newaukum River smolt trap in 2020.

In summary, 2020 represents the second year for which wild Chinook, coho and steelhead out-migrations have been described from any location in the Newaukum River in three decades. Our 2021 season will benefit from refinements resulting from this year. For Chinook and coho, we generated unbiased and precise estimates of smolt abundance in 2020, 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.

References

Anderson, J. H., and P. C. Topping. 2018. Juvenile life history diversity and freshwater productivity of Chinook Salmon in the Green River, Washington. North America Journal of Fisheries Management **38**:180-193.

ASRPSC (Aquatic Species Restoration Plan Steering Committee). 2019. Chehalis Basin Strategy: Aquatic Species Restoration Plan – Phase I. Office of the Chehalis Basin. Publication #19-06-009. November 2019.

Beamer, E. M., A. McBride, C. M. Greene, R. Henderson, G. M. Hood, K. Wolf, K. Larsen, C. Rice, and K. L. Fresh. 2005. Skagit River Chinook Recovery Plan. Appendix D. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations., http://www.skagitcoop.org/index.php/documents/.

Bonner, S.J. and Schwarz, C.J., 2011. Smoothing population size estimates for time-stratified mark–recapture experiments using Bayesian P-splines. *Biometrics*, *67*(4), pp.1498-1507.

Bonner, S.J. and Schwarz, C.J., 2014. BTSPAS: Bayesian Time Stratified Petersen Analysis System. *R package version*.

Campbell, L. A., A. M. Claiborne, S. Ashcraft, M. S. Zimmerman, and C. Holt. 2017. Final Report: Investigating Juvenile Life History and Maternal Run Timing of Chehalis River Spring and Fall Chinook Salmon Using Otolith Chemistry, FPT 17-15. Washington Department of Fish and Wildlife, Olympia, Washington, https://wdfw.wa.gov/publications/01985/.

Chehalis Basin Strategy. 2020. www.chehalisbasinstrategy.com

Chehalis Lead Entity. 2020. www.chehalisleadentity.org

Greene, C. M., D. W. Jensen, G. R. Pess, E. A. Steel, and E. Beamer. 2005. Effects of environmental conditions during stream, estuary, and ocean residency on Chinook salmon return rates in the Skagit River, Washington. Transactions of the American Fisheries Society **134**:1562-1581.

Groot, C. and Margolis, L. eds., 1991. Pacific Salmon Life Histories. UBC Press.

Kiyohara, K., and M. S. Zimmerman. 2012. Evaluation of juvenile salmon production in 2011 from the Cedar River and Bear Creek, FPA 12-01. Washington Department of Fish and Wildlife, Olympia, Washington, https://wdfw.wa.gov/publications/01380/.

Litz, M.L. 2021. 2020 wild coho forecasts for Puget Sound, Washington Coast, and Lower Columbia., Washington Department of Fish and Wildlife, Olympia, Washington.

M&AMT (Monitoring and Adaptive Management Team). 2021. Aquatic Species Restoration Plan Monitoring and Adaptive Management Plan. Office of the Chehalis Basin.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ronne L., N. VanBuskirk, M. Litz, and M. Scharpf. 2021. Newaukum Adult Salmon and Steelhead Spawner Abundance, 2019-2020, Washington Department of Fish and Wildlife, Olympia, Washington. FPT 21-01.

Sandell, T., J. Fletcher, A. McAninch, and M. Wait. 2014. Grays Harbor Juvenile Fish Use Assessment: 2013 Annual Report. Wild Fish Conservancy, prepared for the Chehalis Basin Habitat Work Group, http://wildfishconservancy.org/projects/grays-harbor-juvenile-salmon-fish-community-study.

Thompson, T. Q., S. M. O'Rourke, S. K. Brown, T. Seamon, M. Zimmerman, and M. M. Miller 2019. Run-Type Genetic Markers and Genomic Data Provide Insight for Monitoring Spring-Run Chinook Salmon in the Chehalis Basin, Washington. University of California, Davis, CA.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 *in* D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Walther, EJ. 2021. Salmonid Distribution Models to Support Restoration Planning Across the Fragmented Chehalis River basin, WA. MS Thesis, University of Alaska Fairbanks.

West. D.C., J. Winkowski, M. Litz. 2021 Chehalis River Smolt Production 2020. Washington Department of Fish and Wildlife, Olympia, Washington.

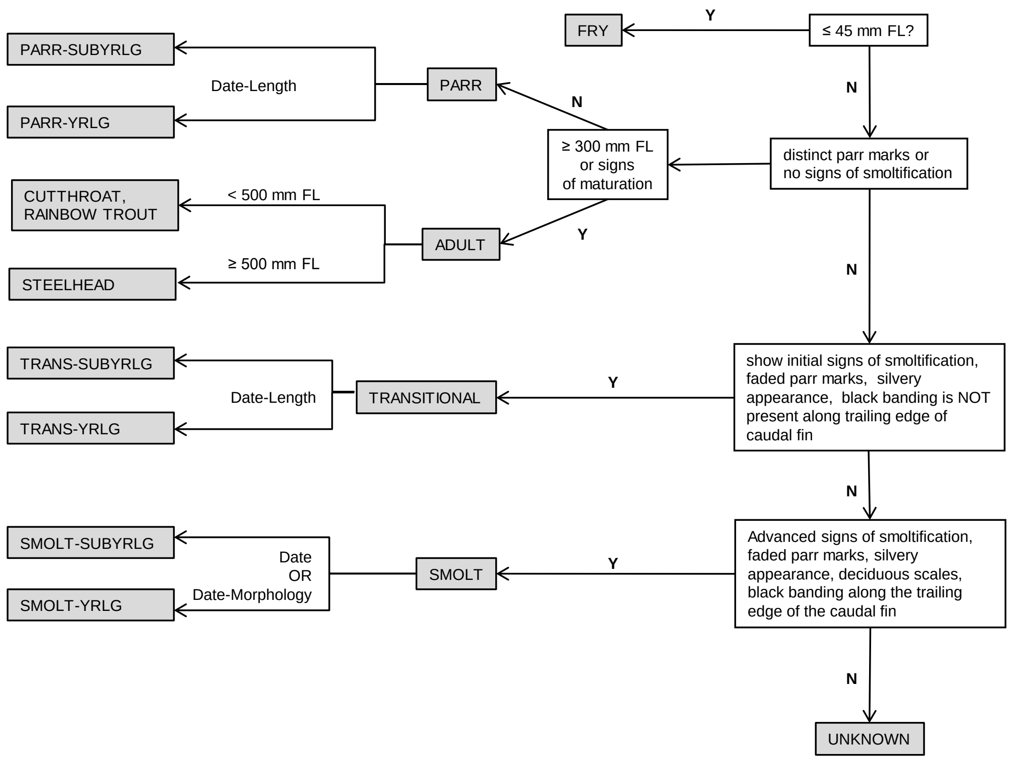
Winkowski, J., and M. S. Zimmerman. 2018. Chehalis River Smolt Production, 2018. Washington Department of Fish and Wildlife, Olympia, Washington. FPA 19-01. https://wdfw.wa.gov/publications/02042/.

Winkowski, J. J., E. J. Walther, and M. S. Zimmerman. 2018. Summer Distribution and Movements of Juvenile Salmonids in the South Fork Newaukum River, 2016. Washington Department of Fish and Wildlife. Olympia, Washington. FPT 18-05.

Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor, and D. E. Pflug. 2015. Abundance, survival, and life history strategies on juvenile migrant Chinook Salmon in the Skagit River, Washington. Transactions of the American Fisheries Society **144**:627-641.

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 2020. All missed trapping periods occurred by staff pulling the trap.

Last Time Observed Fishing	Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
3/25/2020 0933	512 hrs	Scheduled Plan	4/14/2020 1730	COVID-19 Shutdown
6/9/2020 0834	UNK	Visual	06/10/2020	Trap Stopper
6/15/2020 0804	UNK	Visual	6/15/2020 1700	Trap Stopper
6/15/2020 1700	39.3 hrs	Scheduled Plan	6/16/2020	High Debris
6/28/2020 0849	46.2 hrs	Scheduled Plan	6/30/2020 0600	Furlough
7/4/2020 0910	UNK	Visual	7/5/2020 1018	Trap Stopper

Appendix C. Mark-recapture data for wild Chinook outmigrants (transitionals, smolts) organized by time 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 time period (Prop Fished).

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Captured	Prop Fished
1	3/09	3/15	0	0	0	0.48
2	3/16	3/22	6	0	6	1.00
3	3/23	3/29	1	0	1	0.34
4	3/30	4/05	0	0	0	0.00
5	4/06	4/12	0	0	0	0.00
6	4/13	4/19	35	0	35	0.75
7	4/20	4/26	114	2	132	1.00
8	4/27	5/03	219	13	233	1.00
9	5/04	5/10	605	49	1225	1.00
10	5/11	5/17	670	101	1580	1.00
11	5/18	5/24	717	157	2252	1.00
12	5/25	5/31	709	135	1409	1.00
13	6/01	6/07	710	118	1957	1.00
14	6/08	6/14	501	64	2876	1.00
15	6/15	6/21	382	17	569	0.73
16	6/22	6/28	336	41	626	0.91
17	6/29	7/05	147	18	177	1.00
18	7/06	7/12	629	86	708	1.00
19	7/13	7/19	312	33	351	1.00
20	7/20	7/26	36	6	138	0.61

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 time 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 time period (Prop Fished).

Period	**Start Date***	**End Date***	**Total Mark**	**Total Recap**	**Total Capture**	**Prop fished**
1	3/09	3/15	43	2	43	0.48
2	3/16	3/22	100	4	100	1.00
3	3/23	3/29	20	2	29	0.34
4	3/30	4/05	0	0	0	0.00
5	4/06	4/12	0	0	0	0.00
6	4/13	4/19	54	2	54	0.75
7	4/20	4/26	323	8	363	1.00
8	4/27	5/03	273	7	274	1.00
9	5/04	5/10	521	22	694	1.00
10	5/11	5/17	474	14	491	1.00
11	5/18	5/24	258	10	258	1.00
12	5/25	5/31	120	7	120	1.00
13	6/01	6/07	62	11	62	1.00
14	6/08	6/14	34	3	39	1.00
15	6/15	6/21	30	1	35	0.73
16	6/22	6/28	10	2	15	0.91
17	6/29	7/05	1	0	1	1.00
18	7/06	7/12	3	1	3	1.00
19	7/13	7/19	0	0	0	1.00
20	7/20	7/26	0	0	1	0.61

*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 time 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 time 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	3/09	3/15	27	6	27	0.48
2	3/16	3/22	45	5	45	1.00
3	3/23	3/29	14	2	17	0.34
4	3/30	4/05	0	0	0	0.00
5	4/06	4/12	0	0	0	0.00
6	4/13	4/19	18	0	18	0.75
7	4/20	4/26	19	0	19	1.00
8	4/27	5/03	23	1	23	1.00
9	5/04	5/10	30	2	31	1.00
10	5/11	5/17	24	1	24	1.00
11	5/18	5/24	4	1	4	1.00
12	5/25	5/31	1	0	1	1.00
13	6/01	6/07	1	0	1	1.00
14	6/08	6/14	1	0	1	1.00
15	6/15	6/21	0	0	0	0.73
16	6/22	6/28	0	0	0	0.91
17	6/29	7/05	0	0	0	1.00
18	7/06	7/12	1	0	1	1.00
19	7/13	7/19	0	0	0	1.00
20	7/20	7/26	0	0	0	0.61

*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.

This program receives Federal financial assistance from the U.S. Fish and Wildlife Service Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972. The U.S. Department of the Interior and its bureaus prohibit discrimination on the bases of race, color, national origin, age, disability and sex (in educational programs). If you believe that you have been discriminated against in any program, activity or facility, please contact the WDFW ADA Program Manager at P.O. Box 43139, Olympia, Washington 98504, or write to

Department of the Interior
Chief, Public Civil Rights Division
1849 C Street NW
Washington D.C. 20240