# Upper Chehalis River Smolt Production, 2023


**Washington Department of Fish and Wildlife**

# Upper Chehalis River Smolt Production, 2023

Justin Miller-Nelson, Jonathan Schroeder, and Marisa Litz

Fish Science Division

1111 Washington Street SE, Olympia WA 98501

**Acknowledgements**

We would like to thank Charlotte Gruninger, Tyler Gustafson, and Bryan Blazer for field operations. We would like to thank Eric Walther for providing maps in this report, the WDFW Ageing Lab for reading the scale samples, John Winkowski for temperature data, and Curt Holt for providing adult spawner estimates.

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

**Recommended citation:** Miller-Nelson, J., J. Schroeder, and M. Litz. 2024. Upper Chehalis River Smolt Production, 2023. FPA 24-13. 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 third year of results from a juvenile salmonid monitoring study on the Upper Chehalis River main stem near Pe Ell, Washington in 2023. The primary objective of this study is to describe the freshwater production (e.g., smolt abundance) of Pacific salmon (*Oncorhynchus* spp.) and steelhead trout (*O. mykiss*) in the Upper Chehalis 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 trout. Based on the location and timing of our study, the results reflect juveniles that completed their freshwater rearing phase in habitats upstream of river kilometer (rkm) 151.7 (river mile 94.3) of the main stem Chehalis River.

To meet the study objectives, a 1.5-meter (5–foot) rotary screw trap was operated near rkm 151.7 (river mile 94.3) of the main stem Chehalis River from March 7 through July 16, 2023.

Scale age data indicated the presence of two age classes, one-, and two-year-olds. Coho outmigrants were predominately of the yearling (or "1+") age class (98.5%). Scale age data indicated that there was a small 2+ year-old component of the coho out-migration (1.5%). The average fork length of known yearlings was 114.1 mm (± 10.7 mm SD), and two-year-old outmigrants was 114.2 mm (± 10.8 mm SD). Abundance of wild coho outmigrants in 2023 was estimated to be 26,028 (95% confidence intervals, CI = 18,177 – 39,266) with a coefficient of variation (CV) of 20.2%.

Steelhead outmigrants were Age-1 through Age-3, based on scales. Age-1 steelhead represented 33.7% of juveniles, Age-2 represented 65.3% of juveniles, and Age-3 represented 1.0% of the juveniles. A total of 20.4% of the scales sampled were unreadable and therefore age could not be determined from those fish. Fork length averaged 153.7 mm (± 20.6 mm SD) for Age-1, 160.2 mm (± 21.7 mm SD) for Age-2, and 201.5 mm (± 25.2 mm SD) for Age-3. Abundance of wild steelhead outmigrants was estimated to be 11,247 (95% CI = 8,050 – 16,206) with a CV of 18.2%.

The Chinook salmon outmigrants quantified were subyearlings, not fry. The majority of Chinook fry (≤ 45 mm fork length) out-migrate when flow conditions are not suitable for smolt trapping in the Chehalis River (e.g., January and February). Therefore, the goal was to estimate the subyearling (> 45 mm fork length) component of the Chinook outmigration that generally occurs from March through July. Fork length of Chinook subyearlings increased steadily throughout the trapping period with an average of 54.1 mm (± 3.3 mm SD) and 85.9 mm (± 5.5 mm SD) in the first and last sampled week of trapping, respectively. During this time roughly 98.5% of the total catch of wild Chinook outmigrants were > 45 mm. Abundance of wild Chinook subyearling outmigrants was estimated to be 79,900 (95% CI = 72,245 – 88,792) with a CV of 5.3%.

# 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 generating wild coho salmon (*O. kisutch*) estimates of smolt abundance at a basin scale. Results from this monitoring program have demonstrated that the Chehalis River has a higher density of wild coho smolts (average 1,021 smolts $mi^{-2}$ or 394 smolts $km^{-2}$) than any other western Washington watershed for which data currently exists (Litz 2024). In the 1980s and 1990s, smolt abundance estimates from individual tributaries throughout the Chehalis River were also generated, however, prior to 2019, smolt abundance estimates had not been evaluated for nearly two decades. Furthermore, because the current method for basin scale population estimation utilizes back calculation, estimates are not readily available until returning adults are sampled for coded wire tags (CWT) approximately 18 months following outmigration. Therefore, there is limited information on freshwater production of other salmonid species, including Chinook (*O. tshawytscha*) and chum salmon (*O. keta*) and steelhead trout (*O. mykiss*) in the Chehalis River basin. 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 freshwater production over time in response to freshwater restoration.

Smolt monitoring activities by WDFW were expanded in 2019 to develop a more comprehensive understanding of freshwater production among multiple species of salmonids across different ecological regions in the Chehalis River basin (e.g., Olympic and Cascade mountains, Willapa Hills). Beginning in 2021, this expanded effort became a long-term component of an integrated status and trends monitoring program used to evaluate salmon and steelhead abundance in the riverine environment in response to habitat restoration, protection actions, and environmental change (M&AMT 2021). Also in 2021, the Upper Chehalis River was selected as an area to monitor smolt production, collect baseline information to better inform restoration projects, and evaluate potential impacts of a proposed Flood Retention Expandable (FRE) facility in the basin. The Upper Chehalis River supports runs of fall and spring run Chinook salmon, coho salmon, and steelhead trout. In fact, the Upper Chehalis River is known to support a relatively large proportion (~15%) of the steelhead population in the entire Chehalis River Basin (Ronne et al. 2020). Additionally, the proposed location for a FRE facility in the main stem Chehalis River at river kilometer (rkm) 174 (river mile 108.2) has highlighted the need for research to fill data gaps about species composition, abundance, distribution, and life history diversity. For these reasons, accurate and unbiased estimates of juvenile salmon and steelhead abundance (e.g., freshwater production) in the Upper Chehalis River are critical for monitoring status and trends of salmon and steelhead populations and their response to habitat alterations.

## Objectives

The primary objective of this study was to estimate the freshwater production of salmon and steelhead in the Upper Chehalis River. Specifically, goals were to 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 the study, results reflect juveniles that completed their

freshwater rearing phase in habitats upstream of rkm 151.7 (river mile 94.3) of the main stem Upper Chehalis River. This report includes results from the third field season in 2023.

# Methods

## Study Site

The Chehalis River is a large coastal watershed in western Washington that drains approximately 6,889 $km^2$ from the Willapa Hills, Cascade Mountains, and Olympic Mountains into Grays Harbor. The Upper Chehalis River sub-basin has a rain dominant hydrology and arises in the East Fork and West Fork. Primary tributaries to the Upper Chehalis include Thrash, Crim, Rock, and Elk creeks. Land use in the sub-basin is predominately timber production in headwater locations and private residential and agricultural in lower elevation locations. Timber lands are often characterized by steep sloped banks and drainages. River flows in the sub-basin can fluctuate annually from ~18,000 cubic feet per second (cfs or 510 $m^3s^{-1}$) down to ~20 cfs (0.6 $m^3s^{-1}$) with sudden and abrupt changes in flows being common. Native anadromous salmonids in the Chehalis River include fall and spring Chinook salmon, coho salmon, winter steelhead, and cutthroat trout (*O. clarkii*). Chum salmon are present in the basin but occur downstream of the smolt trap location in this study. A WDFW acclimation pond is located on Eight Creek, a tributary to Elk Creek. This pond is located upstream of the trapping site and releases approximately 100,000 adipose clipped fin coho and 25,000 to 30,000 adipose clipped fin steelhead from Skookumchuck hatchery annually (M. Scharpf WDFW, personal communication). Juvenile research is also conducted annually approximately 25 km upstream of the trap site by the Chehalis tribe operating a 5 ft rotary screw trap. Further downstream of this site, rotary screw traps are also operated by WDFW in the Newaukum River at rkm 9.35 and in the main stem Chehalis River at rkm 84.

Like other rivers in western Washington, juvenile Chinook salmon in the Chehalis River migrate downstream over a protracted outmigration 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; Olson et al. 2023; West et al. 2024). The Chehalis main stem trap is downstream of the Upper Chehalis trap, therefore juvenile Chinook salmon in the Upper Chehalis presumably exhibit a similar life history observed lower in the system. There are two predominant freshwater rearing strategies observed for juvenile Chinook salmon and these are both documented at the Chehalis main stem smolt trap as a bimodal outmigration. The first pulse of outmigrants represent '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 fry and smolt traps in the Chehalis River, Puget Sound, and other areas (Anderson and Topping 2018; Gilbertson et al. 2021; Groot and Margolis 1991; Kiyohara and Zimmerman 2012; Zimmerman et al. 2015). The second pulse of Chinook outmigrants represent 'subyearlings', which are individuals > 45 mm FL that grow in freshwater for weeks to months after emergence and are observed at the smolt trap between the months of April and July.

The trapping location on the Upper Chehalis River (46°38'5.06 N, 123°10'4.47 W) is located at rkm 151.7, approximately 22.4 km downstream of a proposed FRE facility and was selected for multiple reasons (Figure 1). Site selection considerations were typical for selecting a rotary screw trapping site and included fine scale physical characteristics (e.g., access for installation, operation, and removal, water

velocities, river depth and width, anchoring locations), broad scale site location implications (e.g., sites location in the basin and proximity to other trap locations), and landowner permission for access. Site selection was finalized after considering multiple options in the Upper Chehalis River. The location has optimal physical conditions (e.g., flow, depth) within the basin and access was granted for trapping operations.

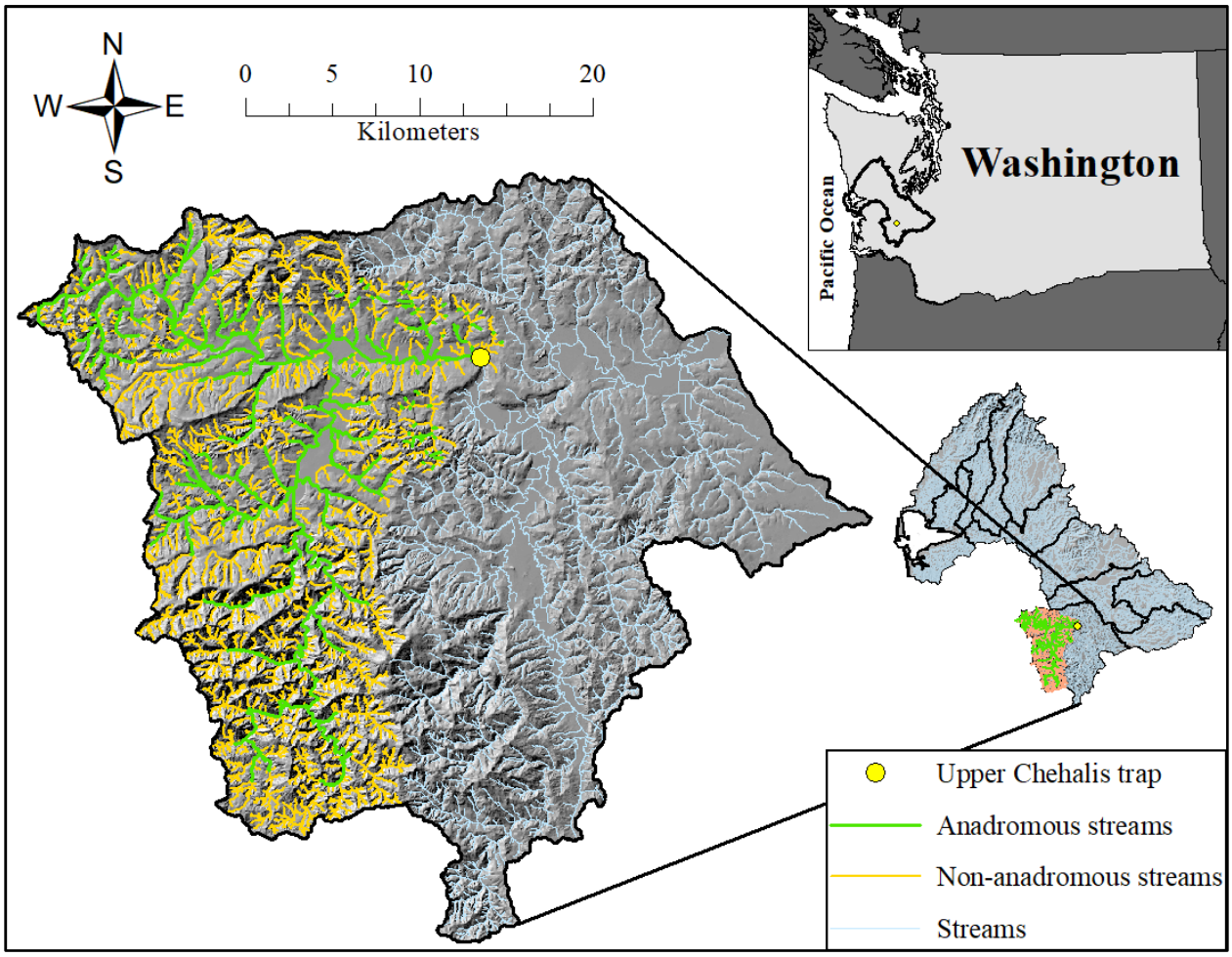



Figure 1. Upper Chehalis rotary screw trap (46.634747, -123.167972). Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (299.8 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the upper Chehalis River rotary screw trap. Non-anadromous streams represent stream habitat outside the predicted coho salmon range of occurrence (919.4 km) upstream of the trap location.

## Trap Operation

A 1.5 m (5-foot) diameter rotary screw trap (RST) was operated near rkm 151.7 of the Chehalis River. The screw trap used internal flights rotating by water pressure to capture downstream migrants and funnel them into a holding area (livebox) at the back of the trap where fish were held until sampling. In

2023, the trap was scheduled to operate continuously from March 7 through June 29, 2023, although unscheduled trap outages did occur due to high flows (Appendix B).

Instantaneous water temperature and trap status information (e.g., fishing or not fishing, cone revolutions per minute) were collected at each fish sampling event ("trap check"). 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 temperature at 30-minute intervals. Data loggers were calibrated according to Winkowski et al. (2018). Stream flow was monitored by the USGS discharge gage near Doty, Washington located in the main stem Chehalis River 13.4 km upstream of the trap (USGS 12020000).


Figure 2. Upper Chehalis River trap site.

# Fish Collection

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

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

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

| Sample Type | Species | Fry | Parr | Transitional/Smolt |
|---|---|---|---|---|
| Fork Length | Coho | 1st 10 daily | 1st 10 daily | 1st 10 daily |
| | Steelhead | 1st 10 daily[a] | 1st 10 daily | All efficiency marked individuals (≤ 100 daily) |
| | Chinook | 1st 10 daily | 1st 10 daily | 1st 10 daily |
| | Cutthroat | --- | --- | All individuals encountered[b] |
| Scales | Coho | --- | --- | 1st 5 daily |
| | Steelhead | --- | --- | 1st 5 daily |
| | Chinook[c] | --- | --- | All > 150mm |
| | Cutthroat | --- | --- | All[b] |

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

[b] Includes adults

[c] 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 rearing years in freshwater as measured from scale samples. Over the 35 years of trapping at the main stem Chehalis site, beginning in 1986, yearling Chinook salmon have rarely been observed. Furthermore, the vast majority of juvenile Chinook identified in the field are assigned to the subyearling age class based on fork length age (Table 2). While extremely rare, individuals > 150 mm are encountered that are outside of the fork length range of subyearling outmigrants and get categorized as yearlings in the field. These individuals are often opportunistically sampled for scales to verify. We assume Chinook in the Upper Chehalis follow a similar life history as the mainstem Chehalis River. 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' could be any of 1-, 2-, or 3-year-old individuals that could not be distinguished by length in the field (Table 4). Therefore, the age composition of steelhead was further described using scale data.

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

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

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

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

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

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

*Cutthroat/ Resident Rainbow
**Steelhead

## Trap Efficiency Trials

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

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

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

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

Marked fish were released 1.43 kilometers upstream of the trap location at the intersection of River Rd and State Route 6.

Mark types and rotation schedules allowed the data to be stratified by week for the purpose of analysis. This was irrelevant for coho and steelhead, however, because they were marked using individual PIT tags. The different mark types for each species are listed below (Table 6). Releases generally occurred within 1 to 3 hours of the start of a trap check.

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

| | Trap Efficiency Marks | | | Release location | |
|---|---|---|---|---|---|
| Abundance Group | Mark Types | Rotation Schedule | Mark Rotation | Description | Distance upstream of trap (rkm) |
| Coho | PIT | Individual | Individual | Intersection | 1.43 |
| Steelhead | PIT | Individual | Individual | Intersection | 1.43 |
| Chinook | VIE | Weekly | 1 weeks | Intersection | 1.43 |

# Assumption Testing

The six basic assumptions needed 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 (Volkhardt et al. 2007). Throughout the season multiple trials were conducted to reduce the probability of any assumption violations. These included mark/tag retention trials to ensure marks/tags were not lost, mark/tag detection trials to ensure that mark/tags were not missed and that they were reported correctly, and mark-related mortality trials to ensure marking/tagging did not affect behavior or survival.

# Analysis

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

No trapping occurred from March 12 to March 15, 2023, and from April 6 to April 13, 2023, due to high river flows. However, for the missed trapping periods, the BTSPAS model produced estimates with known precision using the entire season's dataset by fitting a spline through those dates. Prior to analysis, marks were removed during periods when the trap did not continuously fish for 48 hours after release because those marks were not available for recapture. For all species, the first and last periods were set to 0 to allow the model to estimate the beginning and tail of each run. For Chinook estimates, a BTSPAS

diagonal model was used. The model arguments were as follows: number of chains = 4, iterations = 200,000, burn-in = 100,000, sims = 50,000 and a thin rate of 2. For both coho and steelhead. The model arguments were as follows: number of chains = 4, iterations = 100,000, burn-in = 50,000, sims = 25,000 and a thin rate of 2. Model convergence was assessed by visually inspecting the trace plots and using the potential scale reduction statistic, or Rhat. The Rhat statistic measures the ratio of the average variance 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 1.001 for all parameters (Gelman et al. 2004). The BTSPAS analysis was executed using R version 2021.1.1 (R Core Team 2021) and the BTSPAS package (Bonner and Schwarz 2014).

# Results

## Summary of Fish Species Encountered

A diverse assemblage of fish species was encountered throughout the 2023 trapping season. Native fish included juvenile Chinook and coho salmon, steelhead, rainbow and cutthroat trout, redside shiner (*Richardsonius balteatus*), smallmouth bass (*Micripterus dolomieu*), unidentified dace species (*Rhinichthys spp.*), speckled dace (*R. osculus*), longnose dace (*R. cataractae*), sucker species (*Catostomus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), Pacific lamprey, brook lamprey (*L. planeri*), and sculpin (Cottidae). Non-native fish included rock bass (*Ambloplites rupestris*).

## Trap Operation

The trap was operated from March 07, 2023, to June 29, 2023. There were ten occurrences of trap outages (Appendix B). For all ten events, the outage time was known exactly because the trap stopped fishing either when staff lifted the cone during periods of high flows, debris and maintenance, or the outage was indicated by trail camera video footage. All events except for three were under 4 hours in duration. The first event was planned on March 12, 2023, and lasted for three days due to high flows. The next outage began sometime around midnight on April 1, 2023, due to a log in the cone, when technicians arrived at the site in the morning, they fixed the problem and got the trap fishing again. However, in the early evening hours of April 1st the trap was pulled again due to heavy debris loads and was not reset until the following morning. The last major outage was on April 6, 2023, due to predicted high flows and lasted for seven and a half days, this outage was planned, and the trap was moved to the far bank.

## Assumption Testing Trials

In 2023, results from the mark retention trails indicated that mark/tag retention was high based on trials that lasted 24 hours. Estimated mark retention was 100% (visible implant elastomer = VIE, 74 tagged) for Chinook and 100% (passive integrated transponder = PIT tag, 21 tagged) for coho and 100% (PIT tag, 20 tagged) for steelhead. A double tag/mark experiment with steelhead and coho also indicated that mark retention was high at 97% for steelhead (43 total recaps, 40 with PIT tag and scar present at time of recapture) and 100% for coho (29 total recaps, 29 with PIT tag and scar present at time of recapture). For

all trials, mark/tag related mortality was zero. Estimated survival was 100% (VIE, 74 out of 74 tagged) for Chinook, 100% for coho (PIT tag, 21 out of 21 tagged), and 100% for steelhead (PIT tag, 20 out of 20 tagged) over the 24-hour holding period. Differences in initial capture probabilities due to body size were also tested using a Kolmogorov–Smirnov test, which found that the fork length of maiden captures compared to recaptures did not differ significantly for Chinook during the peak in period 16 ($D = 0.12$, $p < 0.50$). PIT tagging coho and steelhead also allowed for logistic regression analysis to assess probability of recapture by fork length. The relationship for coho between probability of recapture and fork length was significant ($p = 0.04$) and the relationship for steelhead was also significant ($p = 0.23$), indicating that tagged coho and steelhead may be more susceptible to recapture than non-tagged fish.

# Coho

The coho outmigrant estimate included both subyearlings and yearlings in transitional and smolt life stages. Approximately 48.8% of the outmigrants observed at the trap were categorized as the 'smolt' phenotype whereas 51.2% were categorized as the 'transitional' phenotype. Coho outmigrants were observed in low numbers in the first three weeks of trapping (beginning March 7, 2023, trapping period 1), peaked in mid-May, and were last observed on June 12, 2023 (trapping period 15) (Appendix C).

Scale age data indicated two age classes of the coho juvenile outmigration. A total of 274 scale samples were collected and 95.6% were successfully aged. Age-1 coho were the dominant age class (98.5%) and Age-2 were much less prevalent (1.5%) (Figure 3, Table 7). The fork length of known yearling outmigrants averaged 114.1 mm (± 10.7 mm SD), and the fork length of known Age-2 outmigrants averaged 114.2 mm (± 10.8 mm SD). Fork length for all measured outmigrants averaged 115.6 mm (± 10.4 mm SD).

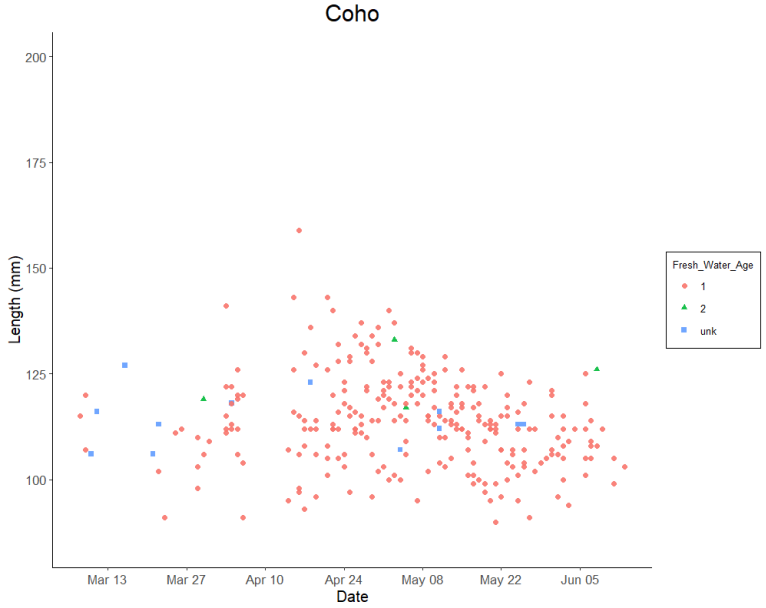



Figure 3. Plot of length and age by date for wild coho outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2023.

Table 7. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2023. Data are scale ages of sampled juveniles by week.

| Period | Start Date | End Date | No. Scales | Age-1 | Age-2 | Age-3 | Not Determined |
|---|---|---|---|---|---|---|---|
| 1 | 3/07 | 3/12 | 4 | 2 | | | 2 |
| 2 | 3/13 | 3/19 | 1 | | | | 1 |
| 3 | 3/20 | 3/26 | 6 | 4 | | | 2 |
| 4 | 3/27 | 4/02 | 6 | 5 | 1 | | |
| 5 | 4/03 | 4/09 | 18 | 17 | | | 1 |
| 6 | 4/10 | 4/16 | 10 | 10 | | | |
| 7 | 4/17 | 4/23 | 28 | 27 | | | 1 |
| 8 | 4/24 | 4/30 | 35 | 35 | | | |
| 9 | 5/01 | 5/07 | 35 | 32 | 2 | | 1 |
| 10 | 5/08 | 5/14 | 35 | 33 | | | 2 |
| 11 | 5/15 | 5/21 | 35 | 35 | | | |
| 12 | 5/22 | 5/28 | 28 | 26 | | | 2 |
| 13 | 5/29 | 6/04 | 18 | 18 | | | |
| 14 | 6/05 | 6/11 | 14 | 13 | 1 | | |
| 15 | 6/12 | 6/18 | 1 | 1 | | | |
| 16 | 6/19 | 6/25 | 0 | | | | |

Table 8. Final outmigrant abundance estimates.

| Species | Origin | Life Stage(s) | Age | Abundance (95% CI) | CV (%) |
|---|---|---|---|---|---|
| Coho | Wild | Smolts and transitionals | 1 | 26,028 (18,177 – 39,266) | 20.2 |
| Steelhead | Wild | Smolts and transitionals | 1+ | 11,247 (8,050 – 16,206) | 18.2 |
| Chinook | Wild | Smolts and transitionals | 0 | 79,900 (59,777 – 73,289) | 5.3 |

A total of 820 coho outmigrants were captured, 805 coho were marked, and 29 were recaptured (Appendix C). Modeled weekly trap efficiencies ranged from 2.3% to 4.9%.

Abundance of 2023 wild coho outmigrants was estimated to be 26,028 (95% CI = 18,177 – 39,266) with a coefficient of variation (CV) of 20.2% (Figure 4, Table 8). The Rhat value for coho was 1.001, suggesting good model convergence. In 2023, coho smolt production in the Upper Chehalis River contributed 6.8% to the total coho smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap.

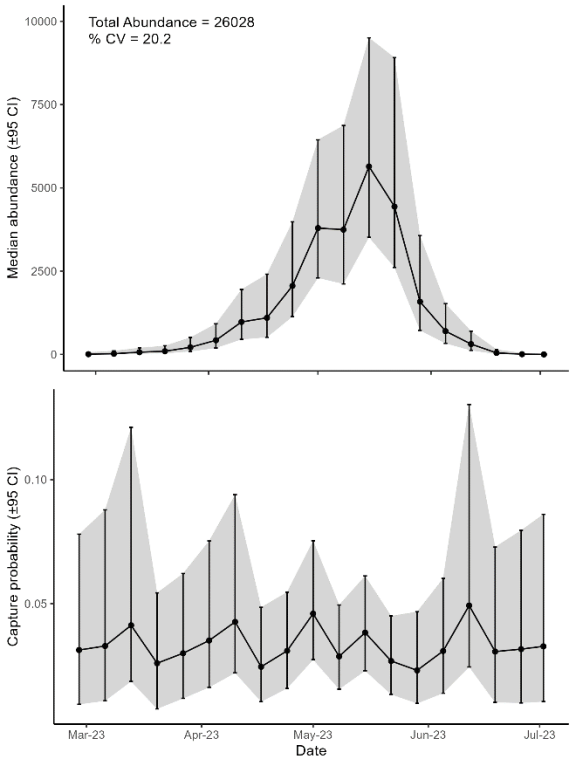



Figure 4. Number of out-migrants (top panel) and trap efficiency (bottom panel) by week for wild coho yearlings produced above the Upper Chehalis River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

In 2021, the total number of adult coho spawners in the Upper Chehalis River upstream of the trap site was estimated to be 4,404, producing a smolt-per-spawner estimate of 5.9 for the 2021 brood year of naturally spawning coho. Estimates of coho smolts-per-spawner fluctuated from 6.0 for brood year 2019 to 18.2 in brood year 2020, a year when adult abundance was low in the upper Chehalis (n = 1,340). Tracking smolts-per-spawner as a metric of coho productivity is a project goal going forward.

# Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Of these life stages, approximately 34% of outmigrants observed were classified as the smolt phenotype, compared to 66% transitional. Steelhead outmigrant numbers were low during the first week of trapping, March 7, 2023 (trapping period 1), peaked in late April, and were last observed the week of June 12, 2023 (trapping period 15) (Figure 5, Appendix D).

Table 9. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2023. Data are scale ages of sampled juveniles by week.

| Period | Start Date | End Date | No. Scales | Age-0 | Age-1 | Age-2 | Age-3 | Not Determined |
|---|---|---|---|---|---|---|---|---|
| 1 | 3/07 | 3/12 | 5 | | 3 | | | 2 |
| 2 | 3/13 | 3/19 | 13 | | 11 | 1 | | 1 |
| 3 | 3/20 | 3/26 | 32 | 7 | 19 | | | 6 |
| 4 | 3/27 | 4/02 | 26 | 4 | 15 | | | 7 |
| 5 | 4/03 | 4/09 | 20 | 10 | 5 | | | 5 |
| 6 | 4/10 | 4/16 | 14 | 6 | 6 | | | 2 |
| 7 | 4/17 | 4/23 | 30 | 5 | 18 | 1 | | 6 |
| 8 | 4/24 | 4/30 | 35 | 7 | 18 | | | 10 |
| 9 | 5/01 | 5/07 | 29 | 8 | 16 | | | 5 |
| 10 | 5/08 | 5/14 | 26 | 7 | 14 | | | 5 |
| 11 | 5/15 | 5/21 | 16 | 10 | 5 | | | 1 |
| 12 | 5/22 | 5/28 | 2 | 2 | | | | |
| 13 | 5/29 | 6/04 | 1 | 1 | | | | |
| 14 | 6/05 | 6/11 | 0 | | | | | |
| 15 | 6/12 | 6/18 | 1 | | | | | 1 |
| 16 | 6/19 | 6/25 | 0 | | | | | |

Scale age data indicated that the sampled steelhead were Age-1 (33.7%), Age-2 (65.3%), and Age-3 (1.0%) (Figure 6, Table 9). Fork length averaged 153.7 mm (± 20.6 mm SD) for Age-1, 160.2 mm (± 21.7 mm SD) for Age-2, and 201.5 mm (± 25.2 mm SD) for Age-3. Fork length for all measured outmigrants averaged 157.1 mm (± 22.5 mm SD).

A total of 591 steelhead outmigrants were captured, 561 steelhead were marked, and 43 were recaptured (Appendix D). The abundance of wild steelhead outmigrants was estimated to be 11,247 with a CV of 18.2%. (95% CI = 8,050 – 16,206). Modeled weekly trap efficiencies ranged from 3.0% to 11.1%.

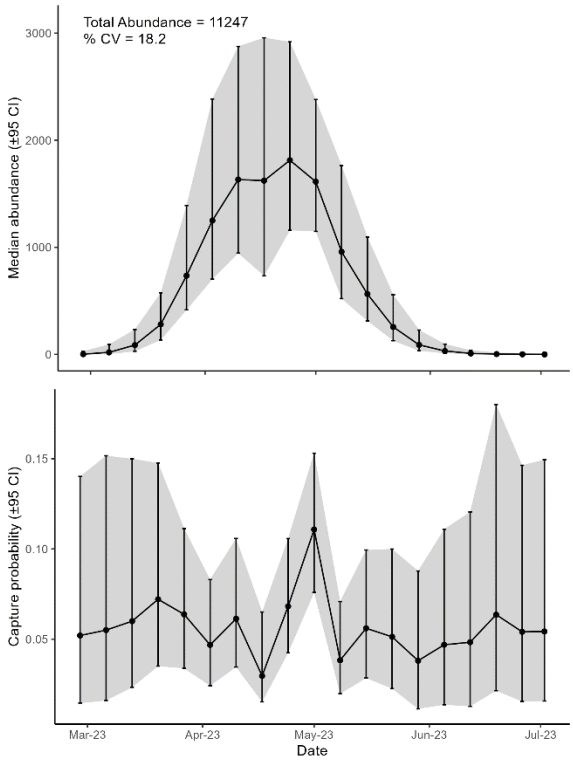



Figure 5. Number of out-migrants (top panel) and trap efficiency (bottom panel) by week for wild steelhead yearlings produced above the Upper Chehalis River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

Steelhead contributing to the 2023 smolt outmigration came from the 2020 through 2022 brood years. For the 2020 brood, there were 917 spawners above the trap. Based on scale ages, it was determined that 6,952 smolts from that brood out-migrated at Age-1 in 2021, 6,138 at Age-2 in 2022, and 112 at Age-3 in 2023, for a total smolt production of 13,202. This produced the first smolt-per-spawner estimate for this trap valued at 14.4 for the 2020 brood year. Tracking smolts-per-spawner as a metric of steelhead productivity is a project goal going forward.

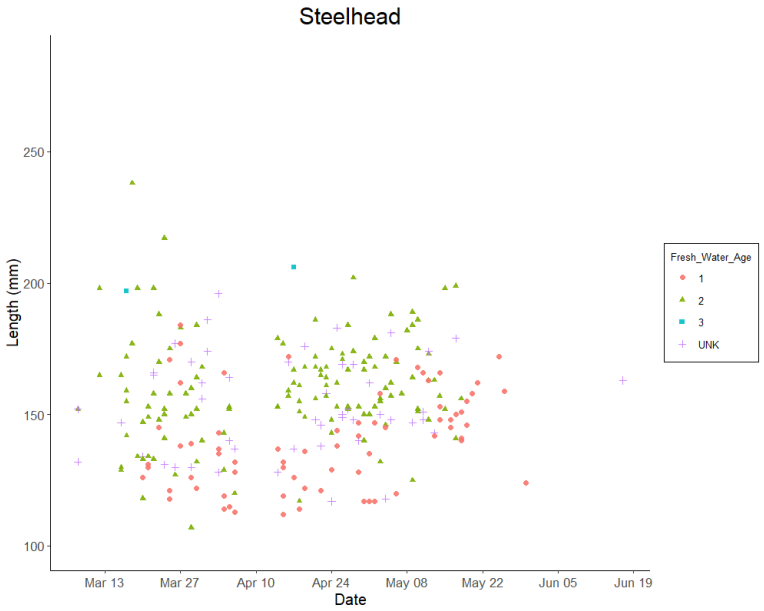



Figure 6. Plot of length and age by date for wild steelhead outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2023.

# Chinook

The Chinook outmigrant estimate was derived for the 'subyearling' life history that included transitionals and smolts. Chinook outmigrants were observed in low weekly numbers ($n < 20$) during the first nine weeks of trapping, peaked in mid-May, and declined to low numbers again by the last week of trapping (trapping period 17) (Appendix E).

Scale age data were not collected from Chinook as all juvenile fish were assumed to be subyearlings. Fork length of Chinook subyearlings (fry, parr, transitionals and smolts) increased steadily throughout the trapping period with an average of 54.1 mm (± 3.3 mm SD) and 85.9mm (± 5.5 mm SD) in the first and last sampled week of trapping, respectively (Figure 7).

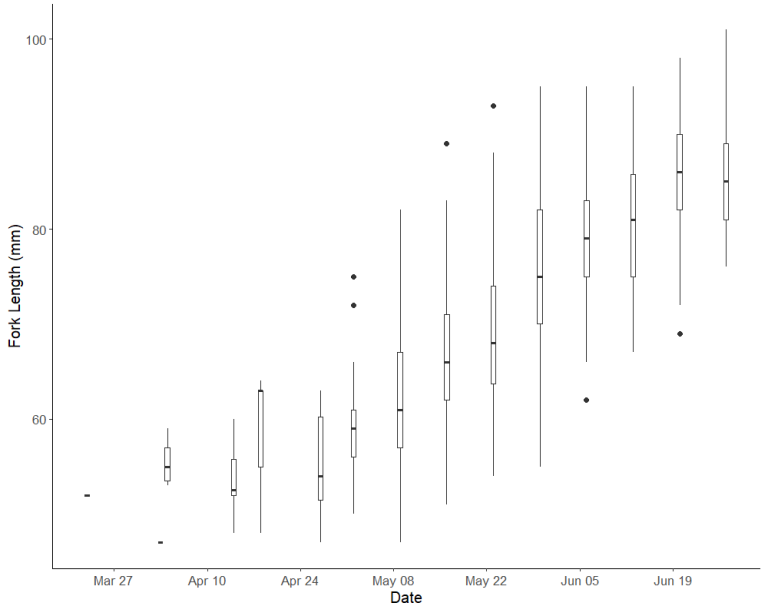



Figure 7. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Upper Chehalis River screw trap, 2023. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

A total of 7,723 Chinook subyearling outmigrants (not including fry or parr) were captured: 3,824 were marked and 369 were recaptured (Appendix E).

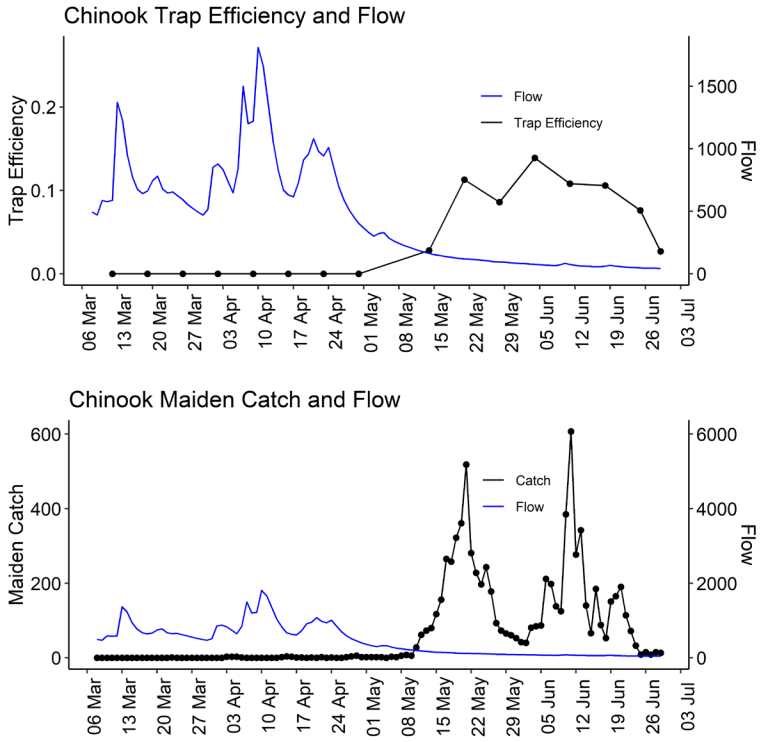



Figure 8. Wild Chinook transitional and smolt raw trap efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Upper Chehalis River smolt trap.

Abundance of wild Chinook subyearling outmigrants (not including fry or parr) was estimated to be 79,900 (95% CI = 72,245 – 88,792) with a coefficient of variation (CV) of 5.3% (Figure 9, Table 8). The Rhat value for Chinook was 1.001, suggesting good model convergence. Modeled weekly trap efficiencies ranged from 7.6% to 11.7%. Chinook smolt production in the Upper Chehalis River contributed 23.5% to the total Chinook smolt production in the Chehalis River Basin above the Mainstem Chehalis smolt trap in 2023.

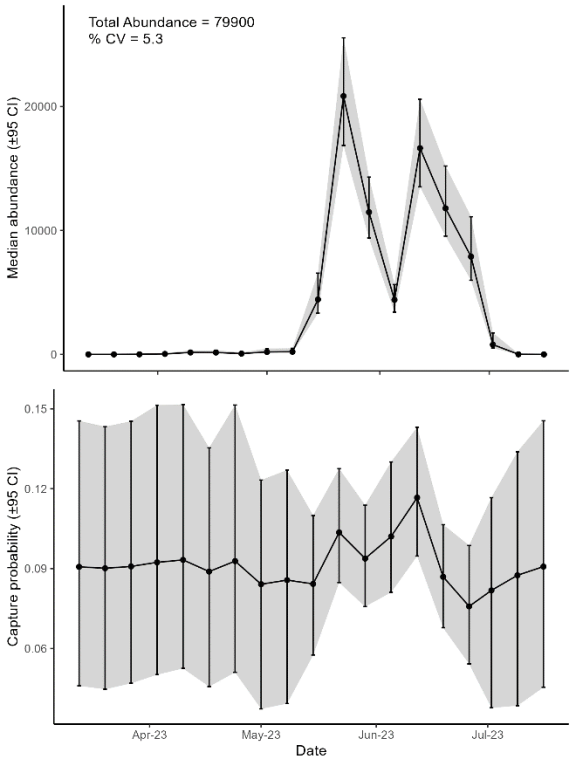



Figure 9. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Upper Chehalis River smolt trap in 2023. Error bars and shading around point estimates represent 95% confidence intervals.

The total number of adult spring Chinook spawners in the Upper Chehalis River in 2022 upstream of the trap site was estimated to be 55, and adult fall Chinook was estimated to be 609, producing an overall smolt-per-spawner estimate of 120.3 for the 2022 brood year of naturally spawning Chinook.

# Discussion

## Basin-wide Context

This report presents results from the 2023 salmon and steelhead smolt outmigration for the Upper Chehalis River and includes the third year of smolt monitoring estimates produced for this portion of the 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 rkm 151.7. The smolt trap in the Upper Chehalis is one of four juvenile monitoring programs in the Chehalis Basin. By operating multiple smolt traps in the basin, smolt abundance estimates can be partitioned to specific locations, providing finer scale resolution of freshwater production. Habitat upstream of the trap is characterized predominately by timber land, but also includes agricultural land. This area has several tributaries including Elk Creek, Dunn Creek, and Crim Creek. In addition to freshwater production from these tributaries, some juveniles emerge from the gravel upstream of the trap location and redistribute to areas downstream during their freshwater rearing period. These fish were not included in the estimates,

especially 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).

Due to a proposed Flood Retention Expandable (FRE) facility at rkm 174.1, there has been increased interest in salmon and steelhead abundance and production in the Upper Chehalis. A study completed in 2019 reported that spring Chinook, fall Chinook, coho, and steelhead spawners above the FRE facility represented 1.24%, 3.37%, 2.72% and 15.43% of the total spawners in the Chehalis River Basin, respectively (Ronne et al. 2020). The upper basin is particularly important for steelhead. In fact, steelhead spawners upstream of the smolt trap contributed anywhere from 12 to 23% of the total basin steelhead abundance from 2013-2019, despite having only 4% of the basin's suitable steelhead spawning habitat (Ronne et al. 2020). This work estimating juvenile steelhead production from the upper basin will be an important element for determining the impacts of the proposed FRE on steelhead production in the Chehalis Basin and provide valuable information on stock status for conservation and management purposes. For example, in 2022, the Secretary of Commerce received a petition to list Olympic Peninsula steelhead Distinct Population Segment (DPS) under the Endangered Species Act (ESA). Steelhead in the Chehalis are part of the Southwest Washington DPS that is not listed, but should that ever change, juvenile production estimates will be important for examining productivity trends.

Estimates of annual freshwater production of wild coho smolts in the Chehalis River Basin averaged 2.2 million (0.5 to 3.8 million) since WDFW began monitoring smolt production in the 1980s (Litz 2024). The proportion of coho habitat upstream of our trapping location represents approximately 6.6% of the rearing habitat relative to the entire basin (Walther 2021). The proportion of juvenile coho salmon from upstream of the trapping location relative to basin-wide production was estimated to be quite low at 1.1% in 2023. Based on this information, it may be that a relatively small proportion of all wild coho in the Chehalis River watershed complete their freshwater rearing in the upper Chehalis, Elk Creek, and other small tributaries upstream of the trap site. Conversely, a larger proportion of wild coho appear to complete their freshwater rearing in the main stem and tributaries downstream of the trap location, which make up approximately 93.4% of coho salmon habitat in the Basin (Walther 2021). Spawning and rearing areas downstream of the trap location include off-channel sloughs and ponds along the main stem river, major tributaries such as the Black, Satsop, Wishkah, and Hoquaim rivers, and smaller tributaries including Porter and Cloquallum Creek.

Our estimate of juvenile coho production in the Upper Chehalis River basin in 2023 was 26,028. This number is 6.5% higher than 2022 estimate (n = 24,434) and represents 6.8% of the estimate for coho production above our Lower Chehalis mainstem trap site in 2023. Generating an unbiased and precise estimate for coho at this new location has mainly been possible due to learning how the equipment operates best at this location and adapting field protocols. If rearing habitat is a limiting factor for coho in the Chehalis Basin, as suggested in other streams in western Washington (Reeves et al. 1989), then restoration activities targeting rearing habitat should increase the productivity of coho in the Chehalis Basin, consistent with the goals of the Aquatic Species Restoration Plan (ASRPSC 2019).

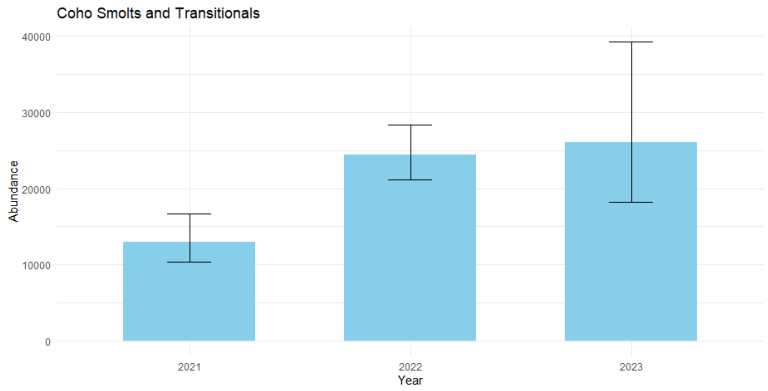



Figure 10. Time series of 2021–2023 estimates with 95% confidence intervals of wild coho juvenile outmigrants at the Upper Chehalis River smolt trap.

This report provides the third reportable estimate of wild steelhead smolt production from the Upper Chehalis River basin upstream of rkm 151.7. The proportion of steelhead caught at the Upper trap site relative to the main stem trap was 31.5% in 2021 and 28.1% in 2022 but is unreportable in 2023 due to low catches and recaptures of steelhead at the main stem trap.

The estimate of 11,247 steelhead outmigrants in 2023 from the roughly 299.8 anadromous rkm upstream of the trap (Walther 2021) corresponds to 37.5 wild steelhead smolts $km^{-1}$. This smolt density is low compared to other western Washington watersheds where steelhead smolt estimates are available, such as the Coweeman River (average 243 smolts $km^{-1}$) or the Wind River (average 240 smolts $km^{-1}$) (T. Buehrens WDFW, personal communication). The reasons for these differences are not yet apparent and may reflect the difference between available versus suitable rearing habitat upstream of the Upper Chehalis River trap. Of note, some studies (Ashcraft et al. 2017, Ronne et al. 2018) identified the Upper Chehalis sub-basin as a particularly productive steelhead spawning area. Over five years of monitoring, surveyors estimated 600-1,000 redds (or 900-1,800 steelhead spawners) in this area of the basin. The Upper Chehalis sub-basin has high gradient, and coarse substrate habitat typically associated with rearing of juvenile steelhead. Another possible explanation is that steelhead parr have the option of rearing downstream of the trap; however, rearing areas downstream of the trap are generally low gradient main stem reaches, off-channel sloughs, and ponds along the main stem river. These habitat types are not considered high quality juvenile steelhead rearing habitat (Burnett et al. 2007).

Steelhead smolt age shifted from predominantly Age-1 in 2021 to predominantly Age-2 in 2022 and 2023. Unlike the 2021 season, when scale results indicated a higher proportion of Age-1 steelhead (71.4%), this year's data was more consistent with other Chehalis Basin traps (33.7% Age-1), showing a higher percentage of Age-2 steelhead (65.3%). Future studies will show if the higher percentage of Age-1 steelhead in 2021 was an anomaly or a reoccurring trend for steelhead in the upper Chehalis Basin. The majority of smolt and transitional steelhead captured were PIT tagged prior to release. Recoveries of PIT tagged adults in future years could provide insight into marine survival or repeat spawning events. Ideally, installation of a PIT array below the trap could be used to track tagged juvenile and adult returns to further research survival and life history diversity of natural origin steelhead.

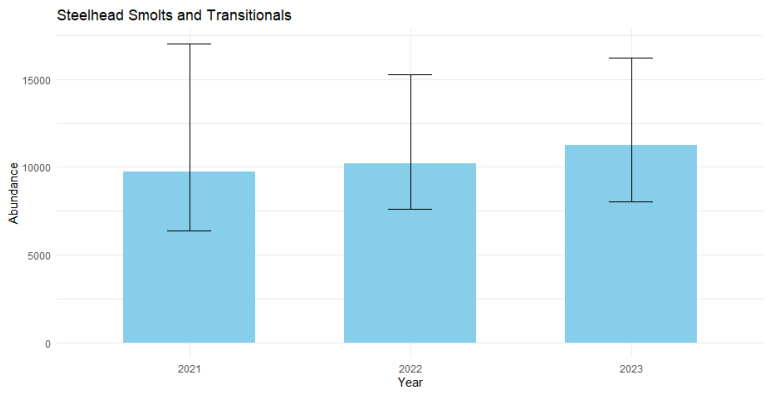



Figure 11. Times series of 2021 - 2023 estimates with 95% confidence intervals of wild steelhead juvenile outmigrants at the Upper Chehalis River smolt trap.

The estimate of Chinook subyearling outmigrants represents a portion of the total freshwater production of Chinook upstream of the trap location in 2023 since it does not include the earlier timed fry migrants. The subyearling estimate of 79,900 Chinook is the third reportable estimate produced for this portion of the Chehalis basin. The Chinook production estimate from the Upper Chehalis trap increased by 75.1% between 2022 (19,870) and 2023 (79,900). The large influx in Chinook out-migrants could be contributed to ideal water levels in the upper Chehalis Basin during the time when fry began to emerge. In 2022, two high-water events, occurring in early January and early March, may have led to lower Chinook outmigrant numbers for that year. The proportion of Chinook caught at the Upper trap site relative to the main stem trap in 2023 was 23.5%, which was much higher than production coming from the upper Chehalis relative to the downstream trap in 2022 (8.0%).

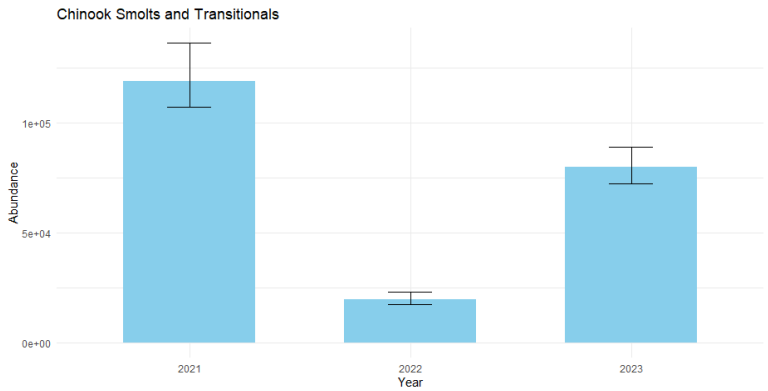



Figure 12. Time series of 2021–2023 estimates with 95% confidence intervals of wild Chinook juvenile outmigrants at the Upper Chehalis River smolt trap.

# Next Steps

The Upper Chehalis River estimates represented here provide critical information for salmon and steelhead smolt production in the basin but trapping in this location presents many challenges. Temperature concerns are prevalent later in the season at this location in the Chehalis River. For example, maximum daily river temperatures during May and June 2021 peaked at 20.3°C and 30.6°C, respectively, which was

concurrent with one of the largest global heatwave events ever recorded (Thompson et al. 2022) and increasing Chinook catch (Figure 13, Table 10). The 2022 season saw on average water temperatures much lower than the year of 2021, and rarely exceeded 18°C. When river temperatures did exceed 18°C, sampling protocols were minimized to reduce fish stress.

Similarly to the 2022 season, a major challenge faced during the 2023 trapping season was the difference in river flows throughout the season. The Upper Chehalis trap experiences frequent fluctuations in flows ranging from above 1000 cfs to as low as 300 cfs within the same week, causing the crew to regularly move the trap to accommodate these changes in flow. At the start of the 2023 season, the Chehalis River flows near Doty averaged 584 cfs, and when the season concluded, flows dropped to 43 cfs. Flows in the Upper Chehalis dropped to record low levels in June, causing the season to end earlier than the last two previous seasons. Despite pulling the trap early, estimates were produced for coho, steelhead, and Chinook. There were also two in-season high water events which caused a few days of outages due to flows exceeding the threshold for fishing. The two outage times occurred on March 12 through March 15, 2023, and April 6 through April 13, 2023. Flows in 2022 were consistently higher than in 2023 and there were two major events prior to the trapping season which may have negatively affected juvenile Chinook numbers. Unlike the 2022 season however, flows stayed within the average cfs range from March to early May. In late May and the entire month of June, flows dropped to well below historical averages.

Despite the daily low flow averages in the later part of the season, juvenile Chinook numbers increased from the previous year and were consistent with the Chinook numbers observed in the 2021 seasons. Given the extreme flow conditions of the river in January and February when Chinook fry out-migrate, there are no plans to fish the trap during the early-timed fry migration in 2024 as changes in flow make it difficult to maintain minimal trapping positions throughout the outmigration.

Table 10. Mean monthly stream temperatures recorded at Upper Chehalis River smolt trap near river km 151.7, 2021–2023.

| 2021 | | 2022 | | 2023 | |
|---|---|---|---|---|---|
| **Month** | **Mean (°C)** | **Month** | **Mean (°C)** | **Month** | **Mean (°C)** |
| April | 12.7 | April | 8.2 | April | 13.76 |
| May | 14.5 | May | 10.61 | May | 16.48 |
| June | 18.8 | June | 14.18 | June | 17.88 |
| July | 22.1 | July | 17.75 | | |

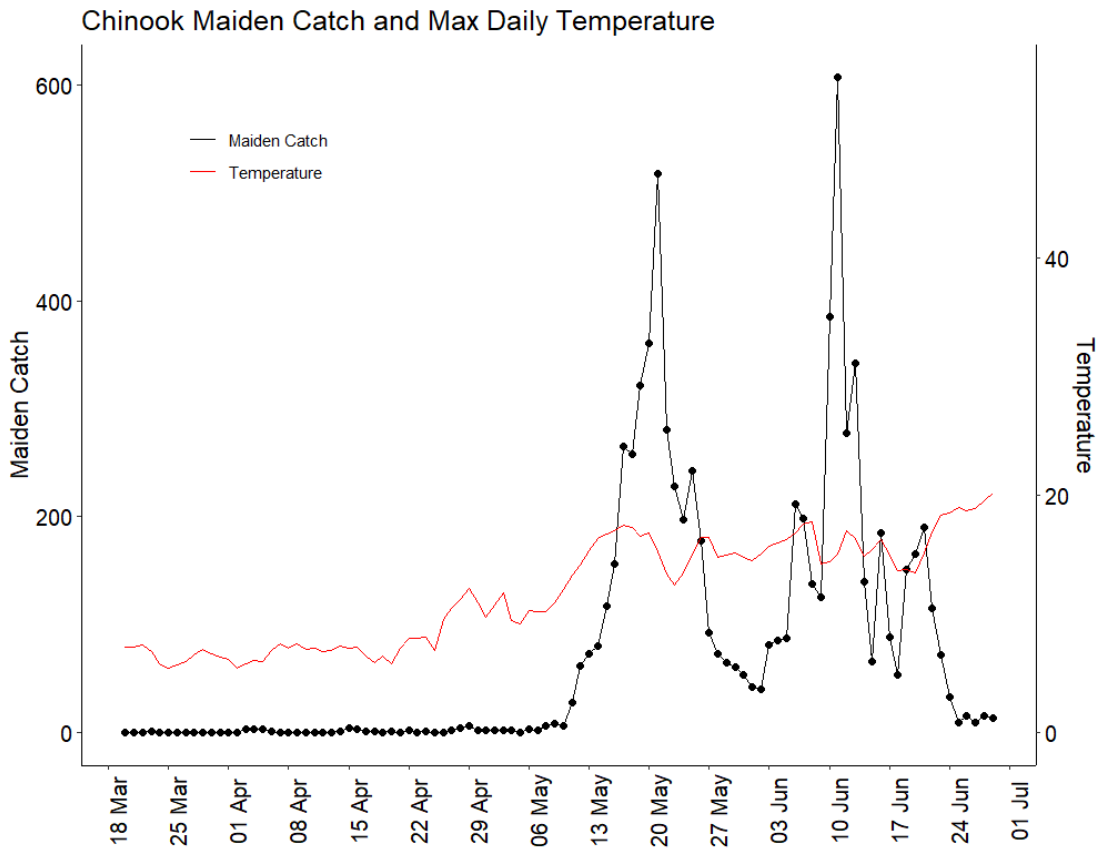



Figure 13. Chinook maiden catch and average daily stream temperature (°C) at the Upper Chehalis River smolt trap, 2023.

In summary, 2023 represents the third year for which wild juvenile Chinook, coho, and steelhead production has been described from this location of the Upper Chehalis River. For all three species, unbiased and precise estimates of smolt abundance were generated and history characteristics described, including genetic run timing of Chinook, and size and age of the outmigrants. Life history strategies reflect how the existing habitat contributes to freshwater production of salmon and steelhead. Continued monitoring will provide even greater understanding of how variability in habitat and environmental conditions affects freshwater production over time.

# 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.

Ashcraft, S., C. Holt, M. Scharpf, M. Zimmerman, and N. VanBuskirk. 2017. Spawner Abundance and Distribution of Salmon and Steelhead in the Upper Chehalis River, 2013-2017, FPT 17-12. Washington Department of Fish and Wildlife, Olympia, Washington.

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/

Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17(1):66-80.

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

Campbell, N.R., S.A. Harmon, and S.R. Narum. 2015. Genotyping-in-Thousands by sequencing (GT-seq): A cost effective SNP genotyping method based on custom amplicon sequencing. Molecular Ecology Resources 15(4): 855-867.

Campbell, L.A., A.M. Claiborne, S. Ashcraft, M.S. Zimmerman, and C. Holt. 2017.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.

Chehalis Basin Strategy. 2020. www.chehalisbasinstrategy.com

Chehalis Lead Entity. 2020. www.chehalisleadentity.org

Gelman, A., J. Carlin, A. Stern, and D. B. Rubin. 2004. Bayesian Data Analysis, 2nd Edition. Chapman and Hall/CRC Press. Boca Raton, FL.

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 L. Margolis, 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.

Koch, I.J., and S.R. Narum. 2020. Validation and association of candidate markers for adult migration timing and fitness in Chinook Salmon. Evolutionary Applications 13(9): 2316-2332.

Litz, M.N.C. 2024. 2024 Wild Coho Forecasts for Puget Sound, Washington Coast, and Lower Columbia, Washington Department of Fish and Wildlife, Olympia, Washington FPA 24-03.

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

Olson, D., D. West., J. Winkowski, T. Seamons, and M. Litz. 2023. Chehalis River Smolt Production, 2021. Washington Department of Fish and Wildlife, Olympia, Washington FPA 23-06.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Reeves, G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-245. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p

Ronne, L., N. Vanbuskirk, C. Holt, and M. Zimmerman. 2018. Spawner Abundance and Distribution of Salmon and Steelhead in the Upper Chehalis River, 2017-2018, FPT 18-09. Washington Department of Fish and Wildlife, Olympia, Washington.

Ronne L., N. VanBuskirk, and M. Litz. 2020. Spawner Abundance and Distribution of Salmon and Steelhead in the Upper Chehalis River, 2019 and Synthesis of 2013-2019, FPT 20-06 Washington Department of Fish and Wildlife, Olympia, Washington.

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.

Thompson, N.F., E.C. Anderson, A.J. Clemento, M.A. Campbell, D.E. Pearse, J.W. Hearsey, A.P. Kinziger, and J.C. Garza. 2020. A complex phenotype in salmon controlled by a simple change in migratory timing. Science 370(6516): 609-613.

Thompson, T.Q., S.M. O'Rourke, S.K. Brown, T. Seamons, 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. UC Davis, WDFW.

Thompson, V., A.T. Kennedy-Asser, E. Vosper, Y.T. E. Lo, C. Huntingford, O. Andrews, M. Collins, G.C. Hegerl, and D. Mitchell. 2022. The 2021 western North America heat wave among the most extreme events ever recorded globally. Science Advances 8, eabm6860.

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

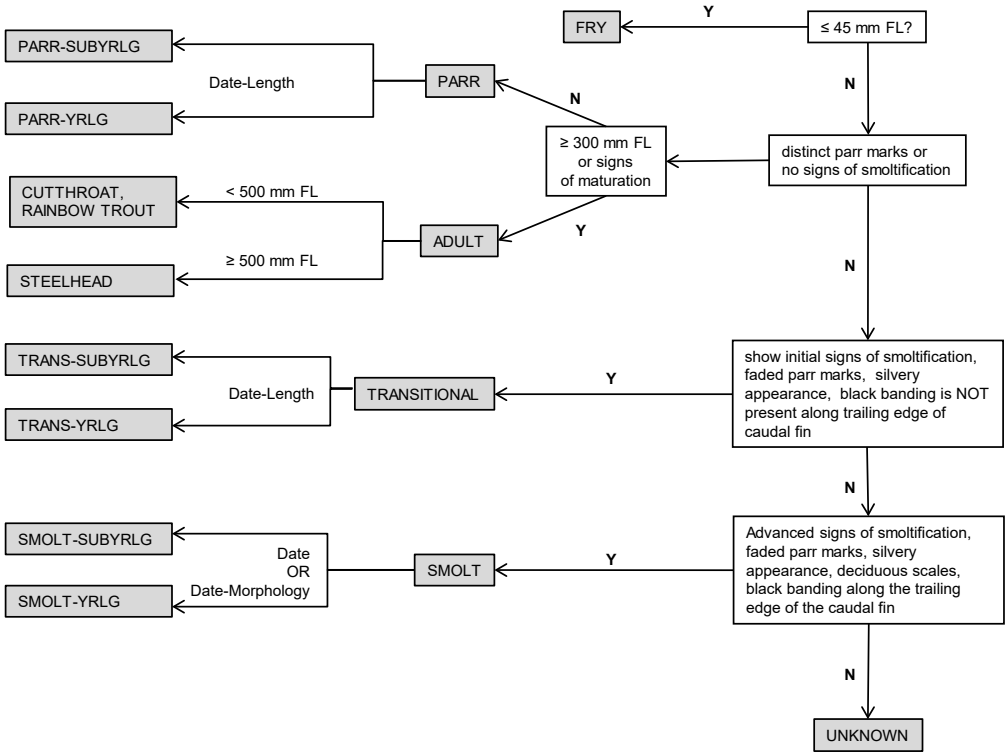
West, D., J. Winkowski, T. Seamons, and M. Litz. 2021. Chehalis River Smolt Production, 2020, FPA 21-06. Washington Department of Fish and Wildlife, Olympia, Washington.

Winkowski, J.J., E.J. Walther, and M.S. Zimmerman. 2018. Summer riverscape patterns of fish, habitat, and temperature across the Chehalis River basin. FPT 18-01. Washington Department of Fish and Wildlife. Olympia, Washington.

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. Upper Chehalis River missed trapping periods 2023.

| Last Time Observed Fishing | Time Stopped Fishing | Method to Determine Trap Not Fishing | Time Resume Fishing | Comments |
|---|---|---|---|---|
| 3/12/2023 0815 | 75hrs | Trap Pulled | 3/15/2023 1115 | Trap pulled for high flows. |
| 3/27/23 0949 | Unknown | Trap Stopper Visual | 3/28/23 0912 | Trap was stopped upon arrival. Wasn't fishing long. |
| 4/1/23 0000 | 8hrs 40mins | Trap Stopper Trail Cam | 4/01/23 0840 | Trap stopped sometime around midnight due to stopper. |
| 4/01/23 1644 | 17hrs 56mins | Trap Pulled Visual | 4/02/23 0940 | Pulled overnight due to stoppers. Put back in to monitor debris and try to fish again. |
| 4/02/23 1910 | 1hr 10mins | Trap Stopper Trail Cam | 4/02/23 2030 | Not fishing between these times due to stopper. |
| 4/06/23 0933 | 173hrs 53mins | Trap Pulled Planned | 4/13/23 1520 | Trap pulled and moved to far bank for highwater event. |
| 4/20/23 0845 | 2hrs 50mins | Trap Pulled Visual | 4/20/23 1135 | Beaver in live box on arrival. Foam collar chewed up and back of trap was lowered into water to remove beaver. |
| 5/7/23 0915 | 1hr 31mins | Trap Pulled Visual | 5/7/23 1046 | Moved trap upstream roughly 60 feet into main flow to increase catches and rpms. |
| 5/28/23 0858 | 38mins | Trap Pulled Planned | 5/28/23 0936 | Moved trap further into flow by 10 ft due to low flow/rpms. Had to move river right anchor further upstream. |
| 6/12/23 0751 | 2hr 51mins | Trap Stopper Trail Cam | 6/12/23 0942 | Trap not fishing due to stopper |
| 6/29/23 1141 | NA | Trap Pulled Planned | NA | End of season. |

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

| Period | Start Date* | End Date* | Total Mark | Total Recap | Total Capture | Prop fished |
|---|---|---|---|---|---|---|
| 1 | 3/7 | 3/13 | 4 | 0 | 5 | 0.99 |
| 2 | 3/14 | 3/20 | 1 | 0 | 1 | 0.98 |
| 3 | 3/21 | 3/27 | 6 | 0 | 6 | 1.00 |
| 4 | 3/28 | 4/3 | 6 | 1 | 13 | 0.84 |
| 5 | 4/4 | 4/10 | 15 | 1 | 19 | 0.43 |
| 6 | 4/11 | 4/17 | 10 | 0 | 17 | 0.69 |
| 7 | 4/18 | 4/24 | 56 | 2 | 63 | 1.00 |
| 8 | 4/25 | 5/1 | 171 | 10 | 176 | 1.00 |
| 9 | 5/2 | 5/8 | 119 | 4 | 106 | 0.80 |
| 10 | 5/9 | 5/15 | 175 | 6 | 219 | 1.00 |
| 11 | 5/16 | 5/22 | 164 | 0 | 122 | 1.00 |
| 12 | 5/23 | 5/29 | 39 | 1 | 34 | 1.00 |
| 13 | 5/30 | 6/5 | 21 | 2 | 20 | 1.00 |
| 14 | 6/6 | 6/12 | 17 | 2 | 18 | 1.00 |
| 15 | 6/13 | 6/19 | 1 | 0 | 1 | 1.00 |
| 16 | 6/20 | 6/26 | 0 | 0 | 0 | 1.00 |
| 17 | 6/27 | 7/2 | 0 | 0 | 0 | 0.57 |

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

| Period | Start Date* | End Date* | Total Mark | Total Recap | Total Capture | Prop Fished |
|---|---|---|---|---|---|---|
| 1 | 3/7 | 3/13 | 3 | 1 | 5 | 0.99 |
| 2 | 3/14 | 3/20 | 15 | 3 | 20 | 0.98 |
| 3 | 3/21 | 3/27 | 47 | 2 | 49 | 1.00 |
| 4 | 3/28 | 4/3 | 41 | 0 | 50 | 0.84 |
| 5 | 4/4 | 4/10 | 32 | 3 | 43 | 0.43 |
| 6 | 4/11 | 4/17 | 26 | 1 | 31 | 0.69 |
| 7 | 4/18 | 4/24 | 99 | 8 | 124 | 1.00 |
| 8 | 4/25 | 5/1 | 198 | 24 | 181 | 1.00 |
| 9 | 5/2 | 5/8 | 47 | 0 | 37 | 0.80 |
| 10 | 5/9 | 5/15 | 33 | 1 | 33 | 1.00 |
| 11 | 5/16 | 5/22 | 16 | 0 | 14 | 1.00 |
| 12 | 5/23 | 5/29 | 2 | 0 | 2 | 1.00 |
| 13 | 5/30 | 6/5 | 1 | 0 | 1 | 1.00 |
| 14 | 6/6 | 6/12 | 0 | 0 | 0 | 1.00 |
| 15 | 6/13 | 6/19 | 1 | 0 | 1 | 1.00 |
| 16 | 6/20 | 6/26 | 0 | 0 | 0 | 1.00 |
| 17 | 6/27 | 7/2 | 0 | 0 | 0 | 0.57 |

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

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

| Period | Start Date* | End Date* | Total Mark | Total Recap | Total Capture | Prop Fished |
|---|---|---|---|---|---|---|
| 1 | 3/7 | 3/13 | 0 | 0 | 0 | 0.99 |
| 2 | 3/14 | 3/20 | 0 | 0 | 0 | 0.98 |
| 3 | 3/21 | 3/27 | 1 | 0 | 1 | 1.00 |
| 4 | 3/28 | 4/3 | 0 | 0 | 3 | 0.84 |
| 5 | 4/4 | 4/10 | 4 | 0 | 7 | 0.43 |
| 6 | 4/11 | 4/17 | 9 | 0 | 10 | 0.69 |
| 7 | 4/18 | 4/24 | 4 | 2 | 5 | 1.00 |
| 8 | 4/25 | 5/1 | 13 | 0 | 16 | 1.00 |
| 9 | 5/2 | 5/8 | 13 | 1 | 17 | 0.80 |
| 10 | 5/9 | 5/15 | 249 | 18 | 374 | 1.00 |
| 11 | 5/16 | 5/22 | 612 | 66 | 2161 | 1.00 |
| 12 | 5/23 | 5/29 | 666 | 63 | 1077 | 1.00 |
| 13 | 5/30 | 6/5 | 424 | 48 | 449 | 1.00 |
| 14 | 6/6 | 6/12 | 688 | 88 | 1942 | 1.00 |
| 15 | 6/13 | 6/19 | 606 | 51 | 1025 | 1.00 |
| 16 | 6/20 | 6/26 | 498 | 32 | 599 | 1.00 |
| 17 | 6/27 | 7/2 | 37 | 0 | 37 | 0.57 |

**Comments:**

* 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 Civil Rights Coordinator at 833-885-1012, email: CivilRightsTeam@dfw.wa.gov or by mail at P.O. Box 43139, Olympia, WA 98504, or write to:

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