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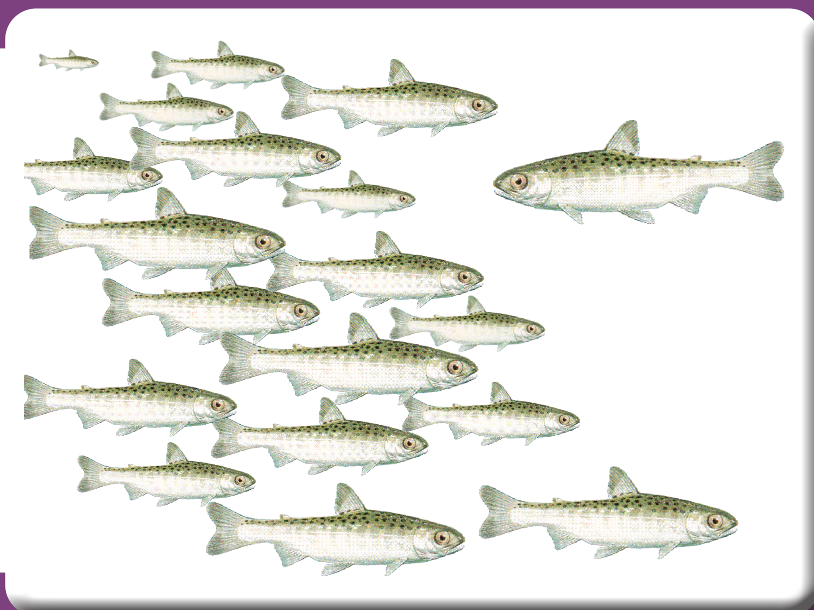
May 2023

Chehalis River Smolt Production, 2021



by Daniel Olson, Devin West,
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Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 23-06

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Executive Summary

This report provides the 2021 results from the juvenile salmonid smolt monitoring study on the Chehalis River main stem near Rochester, 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 Chehalis River. Specifically, we describe the timing and diversity (body size, age structure, genetics) and estimates of abundance of juvenile outmigrants for wild coho salmon (*O. kisutch*), steelhead, and Chinook salmon (O. *tshawytscha*). 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 84 (river mile 52) of the main stem Chehalis River.

To meet the study objectives, a 2.4-meter (8–foot) rotary screw trap was operated near river kilometer 84 (river mile 52) of the main stem Chehalis River from March 18 to July 8, 2021.

Coho outmigrants were predominately of the yearling (or “1+”) age class (95.6%) with rare occurrences of subyearlings (or “0+”) and 2-year-old outmigrants (1.2% and 3.2%, respectively). Fork length averaged 118.5 mm (± 8.5 mm standard deviation, SD) for subyearlings, 129.0 mm (± 15.3 mm SD) for yearlings, and 143.5 mm (± 26.2 mm SD) for 2-year-olds. Abundance of wild coho outmigrants was estimated to be 220,194 ± 10,646 SD with a coefficient of variation (CV) of 4.8% (Table 1).

Steelhead outmigrants were one, two, and three years of age (51.9%, 45.6% and 2.5%, respectively), indicating three different juvenile life histories. Fork lengths averaged 160.5 mm (± 17.1 mm SD) for fish that were 1-year-old, 181.8 mm (± 24.0 mm SD) for 2-year-old, and 243.8 mm (± 26.3 mm SD) for 3-year-old. Abundance of wild steelhead outmigrants was estimated to be 30,942 ± 3,799 SD with a CV of 12.2% (Table 1).

Chinook outmigrants were subyearlings. Fork length of Chinook transitional and smolt subyearlings increased steadily throughout the trapping period with an average of 48.8 mm (± 7.0 mm SD) and 98.3 mm (± 4.3 mm SD) in the first and last full week of trapping, respectively. Abundance of wild Chinook subyearling outmigrants was estimated to be 438,032 ± 30,752 SD with a CV of 7.0% (Table 1).

Table 1. Abundance of coho, steelhead, and Chinook outmigrants that completed their freshwater rearing phase upstream of river kilometer 84 (river mile 52) of the main stem Chehalis River.

Abundance Group	Origin	Life Stage	Age Class	Abundance ± Standard Deviation	Coefficient of Variation (%)
Coho	Wild	Transitional, Smolt	Yearling	220,194 ± 10,646	4.8
Steelhead	Wild	Transitional, Smolt	Yearling	30,942 ± 3,799	12.2
Chinook	Wild	Transitional, Smolt	Subyearling	438,032 ± 30,752	7.0

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 this monitoring program have demonstrated that the Chehalis River has a higher density of wild coho smolts (average 1,003 smolts mi^{-2} or 387 smolts km^{-2}) than any other western Washington watershed for which data currently exists (Litz and Agha 2022). Previously, smolt abundance estimates from individual tributaries throughout the Chehalis River Basin were generated in the 1980s and 1990s and prior to 2017, had not been evaluated for nearly two decades. Furthermore, the method for basin scale population estimation uses back calculation, meaning that estimates are not readily available until returning adults are sampled for coded wire tags (CWT). Finally, there is currently limited information on freshwater production of other salmonid species, including Chinook salmon (*O. tshawytscha*), chum salmon (*O. keta*), and steelhead (*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 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 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 the integrated status and trends monitoring program used to evaluate salmon and steelhead responses to changes in the riverine environment as the result of habitat restoration, protection actions, and climate change (M&AMT 2021). Operating a smolt trap in a large river comes with significant operational challenges associated with maintaining both staff safety and fish health under dynamic environmental conditions. A pilot study was conducted in 2017 that tested a new trap design and multi-species trapping protocols. Since then, field seasons have benefited from refinements in the operational protocols, trap modifications, and analysis techniques (West et al. 2020).

Objectives

The primary objective of this study was to describe the freshwater production of salmon and steelhead in the Chehalis River. Specifically, we describe the abundance, timing, and diversity (body size, age structure, genetics) of juvenile outmigrants for wild coho salmon, steelhead, and Chinook salmon. 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 84 (river mile 52) of the main stem Chehalis River. An additional objective in 2021 was to quantify the life history of subyearling Chinook salmon throughout their outmigration. Our research questions were: 1) can we partition subyearling Chinook population estimates by spring, fall, and heterozygote run types; and 2) how do proportions of these run types vary across the outmigration? This report includes results from the 2021 field season.

Methods

Study Site

The Chehalis River is a large coastal watershed in western Washington that drains approximately 6,889 square kilometers from the Willapa Hills, Cascade Mountains, and Olympic Mountains into Grays Harbor. The Chehalis River is relatively low elevation (~1 – 1,350 m) and low gradient with a rain dominant hydrology. Land use in the basin is predominately timber production in headwater locations and private residential and agricultural in lower elevation locations. Some National Forest land is present in high elevation locations draining the Olympic Mountains. 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.

Like other rivers in western Washington, juvenile Chinook salmon in the Chehalis River have a protracted outmigration period in their first year of life. Yearlings are rarely observed at the smolt trap or in the adult returns as determined from otoliths (Campbell et al. 2017). There are two predominant freshwater rearing strategies observed for juvenile Chinook salmon and these are observed at the smolt trap as a bimodal outmigration. The first pulse of outmigrants is termed 'fry' (defined as juveniles ≤ 45 mm fork length, FL), which are individuals that out-migrate almost immediately after emergence. Fry are observed at the smolt trap as soon as it is installed in mid-March but have been presumably outmigrating since January, based on observed data from 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.

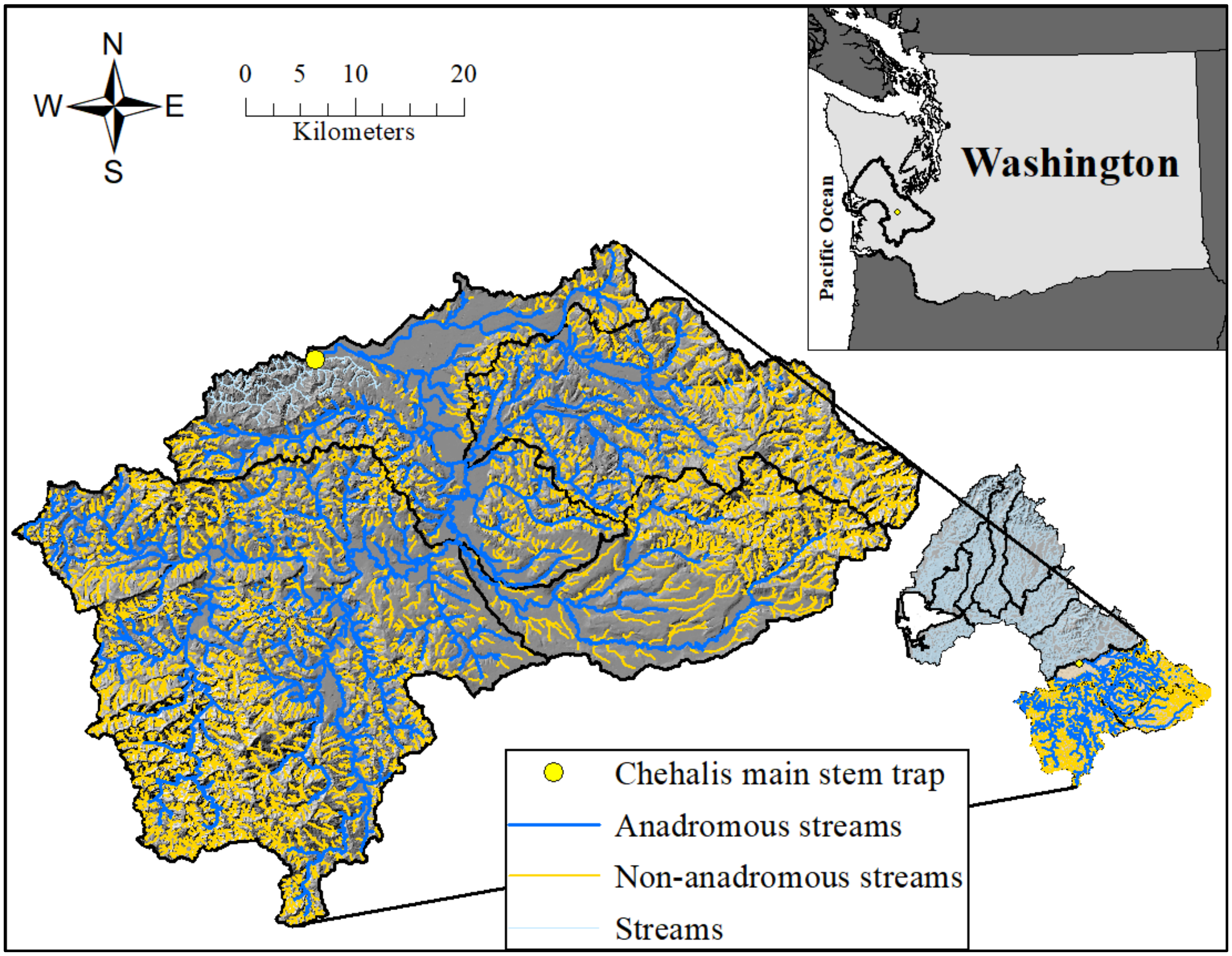


Figure 1. Main stem Chehalis River rotary screw trap. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (1,390 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the main stem Chehalis River rotary screw trap. Non-anadromous streams represent stream habitat outside the predicted coho salmon range of occurrence (3,358 km) upstream of the trap location.

Trap Operation

A 2.4 m (8-foot) diameter rotary screw trap (RST) was operated near river kilometer 84 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 (live box) at the back of the trap where fish were held until sampling. This site was selected because it is the most downstream point in the main stem with suitable characteristics to maximize RST efficiency throughout the trapping period. Due to the location of this trap, our estimates represent a portion of the freshwater production in the Chehalis Basin as additional freshwater habitat occurs downstream (e.g., main stem, Black River, Satsop River, Wynoochee River, Wishkah River, and Hoquaim River). The trap was scheduled to operate continuously although unscheduled trap outages did occur due to high flow, high water temperatures, and debris.

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 is monitored by the USGS discharge gage in Grand Mound, Washington located in the main stem Chehalis River 12.3 km upstream of the trap location (USGS 12027500).

Figure 2. Chehalis River screw trap under low flow fishing conditions.

Fish Collection

Fish collection commenced on March 18, 2021, with the trap operating 24 hours per day, seven days per week. Typically, after June 1 stream temperatures and algae growth increase the risk of fish mortality. Therefore, after June 1 through the remainder of the season, staff monitored the live box 24 hours a day, but fish collection was minimized to Monday - Friday. During this time, monitoring was conducted hourly and often more frequently if needed to maintain fish health. For typical fish sampling events (pre-June 1), fish were removed from the live box once per day using a dip net and transferred to a trough with flowing river water. Fish were anaesthetized with tricaine methanesulfonate (MS-222) prior to enumeration and biological sampling. For each sampling event, five grams of MS-222 were diluted with water in a 500-ml container and approximately 15-

25 ml of this diluted MS-222 solution was combined with 2 L of freshwater prior to sampling the fish. Samplers continually evaluated fish response to the solution and aimed for the lowest dosages needed to complete biological sampling.

During sampling, all fish were identified to species and enumerated. Coho, steelhead, and Chinook were further categorized by life stage and age class, as described in Appendix A. Marks associated with trap efficiency trials (see *Trap Efficiency Trials* section) and hatchery origin (clipped adipose fin) were examined on all coho, steelhead, and Chinook as we expected to capture hatchery origin coho and steelhead, which get released from multiple locations upstream of the trap site (e.g., Skookumchuck hatchery). Fork length (FL) and scales were collected from a subsample of wild (adipose fin intact) coho, steelhead, and Chinook (Table 2). Genetic samples were also collected from Chinook subyearlings to achieve the secondary objective of this study of quantifying the run timing proportions of subyearling Chinook salmon throughout their outmigration (Table 2).

Table 2. 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 encounterd*
Scales	Coho	---	---	1st 5 daily
	Steelhead	---	---	1st 5 daily
	Chinook[b]	---	---	---
	Cuttthroat	---	---	---
DNA	Coho	---	---	---
	Steelhead	---	---	---
	Chinook	---	---	1st 10 daily up to 50 weekly
	Cutthroat	---	---	---

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

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 [cutthroat], 301 – 499 mm FL [rainbow], or ≥ 500 mm [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. For coho salmon, all fry and parr were classified as subyearling and all smolts and transitionals were classified as yearling (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.

Over the twenty-two years of trapping at the main stem Chehalis site, beginning in 1999, yearling Chinook salmon have rarely been observed and the vast majority of juvenile Chinook identified in the field get assigned to the subyearling age class based on fork length. While extremely rare, individuals > 150 mm are encountered that are outside of the fork length range of subyearling outmigrants and are categorized as yearlings in the field. These individuals are often opportunistically sampled for scales to verify age (Table 5, Table 10).

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 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	> 45
Adult (Resident RBT)	NA	Start – end	300 - 499
Adult (STLH kelt)	NA	Start – end	> 500

Table 5. 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	46 - 150
Transitional, Smolt	Yearling (+)	Start – end	> 150

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 6). 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 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. We did not conduct efficiency trials on Chinook fry outmigrants as we did not operate the trap for the full duration of the early timed outmigration; therefore, no estimate was generated for the Chinook fry life stage. 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 outmigrating. 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 one hundred fish per species per day and five hundred per species per week for efficiency trials. However, this number varied based on fish capture rates throughout the season.

Table 6. 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 estimate 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 4.5 km upstream of the trap location at the Independence Road bridge on the right bank, roughly 20 m upstream of the bridge (Table 7). Mark types and rotation schedules allowed fish data to be organized by week for the purpose of analysis. This was irrelevant for steelhead, however, because they were marked using individual PIT tags. The different mark types for each species are listed below (Table 7). All releases occurred within 1-3 hours of a trap check. Prior to June 1, all efficiency trials were conducted by marking 7 days per week and fishing the trap 24 hours per day. After June 1, trapping operation was reduced to 5 days per week and implementing minimum hourly trap checks 24 hours a day. Thus, fish were marked daily Tuesday through Thursday and the trap was monitored for recaptures Wednesday through Saturday morning. This continued for two weeks until the algae load diminished. At this point, we resumed trap operation seven days a week for the remainder of the season, allowing normal efficiency trials. Missed trapping periods were accounted for via our statistical analyses described below.

Table 7. Trap efficiency marks and release locations for each abundance estimate group. Efficiency marks were coded wire tag (CWT), passive integrated transponder tag (PIT), and partial caudal fin clip (PCC).

	Trap Efficiency Marks			Release location	
Abundance Group	Mark Types	Rotation Schedule	Mark Rotation	Description	Distance upstream of trap (rkm)
Coho	CWT, PCC	Weekly	2 weeks	Bridge	4.5
Steelhead	PIT	Individual	Individual	Bridge	4.5
Chinook	PCC	Weekly	2 weeks	Bridge	4.5

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. Throughout the season we conducted multiple trails to reduce the probability of any assumption violations. These included mark/tag retention trails 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

We used the Bayesian Time-Stratified Population Analysis System (BTSPAS, Bonner and Schwarz 2014) to estimate abundance of coho, steelhead, and Chinook (Table 1). The method uses Bayesian p-splines and hierarchical modeling of trap efficiencies to determine abundances 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 used in 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 during trap outages.

Prior to analysis, we removed any marks for which the trap did not continuously fish for forty-eight hours after release because those marks were not available for recapture. For each species, we added one period prior to our trapping season, which had the total maiden catch set to zero to allow the model to estimate the initial tail of each run. Historically, we have observed very few outmigrants in March and thus felt this was a valid assumption. Additionally, for Chinook, we added one period to the end of our trapping season with the total maiden catch set to zero to allow the model to estimate final tail of the run. For coho, steelhead, and Chinook estimates, we used the BTSPAS nondiagonal version 2021 model with model arguments as follows: number of chains = 4, iterations = 2,500, burn-in = 1,250, simulations = 1,2500, and thin rate = 1. Model convergence was assessed by visually inspecting the trace plots and using the potential scale reduction statistic, or Rhat. The Rhat statistic measures that ratio of the average variance of draws within each chain to the variance of the pooled draws across chains; if all chains are at equilibrium, these will be the same and Rhat will be 1. If the chains have not converged to a common distribution, the Rhat statistic will be > 1. Models were considered to have converged if MCMC chains were fully mixed based on visual inspection, and Rhat was less than 1.1 (Gelman et al. 2014). The BTSPAS analysis was executed in R v.2021.1.1 (R Core Team, 2021) using the package BTSPAS (Bonner and Schwarz 2014).

Genetics

Genetic samples were collected from subyearling migrant Chinook from upstream of our trapping location on the mainstem Chehalis River (river mile 52) to document diversity at SNP (Single Nucleotide Polymorphism) loci highly correlated with run timing of adult Chinook within the Chehalis basin (Thompson et al. 2019). Fin clips were collected from Chinook subyearlings (e.g., juveniles > 45 mm FL in the transitional or smolt life stage). The first 10 Chinook subyearling encountered daily were sampled for genetics, up to 50 per week. Tissue was collected from the caudal fin and placed on DNA collection blotter paper and stored in plastic bags with desiccant beads until sent to the lab for processing.

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

Results

Summary of Fish Species Encountered

We encountered a diverse assemblage of fish species throughout the 2021 trapping season. Native fishes included juvenile coho and Chinook salmon, steelhead and cutthroat and rainbow trout, mountain whitefish (*Prosopium williamsoni*), redside shiner (*Richardsonius balteatus*), dace species (*Rhinichthys spp.*), largescale sucker (*Catostomus macrocheilus*), three-spine stickleback (*Gasterosteus aculeatus*), peamouth chub (*Mylocheilus caurinus*), northern pikeminnow (*Ptychocheilus oregonensis*), Pacific lamprey (*Entosphenus tridentatus*), western brook lamprey (*Lampetra richardsoni*), and sculpin species (Cottidae). Non-native fishes included American shad (*Alosa sapidissima*), bluegill (*Lepomis macrochirus*), pumpkinseed (*L.* gibbosus), black crappie (*Pomoxis nigromacula*), brown bullhead (*Ameiurus nebulosus*), yellow bullhead (*A. natalis),* largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), and rock bass (*Ambloplites rupestris*).

Trap operation

We operated the trap from March 18 to July 8, 2021. There were nine occurrences of trap outages; of which, only two were unscheduled (e.g., debris stopping the trap) (Appendix B). For scheduled outages, the outage time was known exactly because the trap stopped fishing when staff lifted the cone during periods of high flows, high water temperatures, or heavy debris loads. Operations then resumed daily until the first trapping period in June, when our schedule was adjusted to five days per week for the next two weeks; at which point, we resumed operations seven days per week for the remainder of the season

Assumptions Testing Trials

In 2021, results from the mark retention trials indicated that mark/tag retention was high based on trials that lasted 24 hours. Estimated mark retention was 78.6% (coded wire tag = CWT, 1,010 out of 1,285 marked) for coho tested. This is an average of all technicians who were tagging. One technician struggled while all others had 100% tag retention. Once it was discovered that this technician was struggling with tag retention, that technician stopped CWT tagging coho until 100% tag retention during a CWT tag retention trial was achieved. This occurred early in the season, so it is believed that actual CWT tag retention of coho put out is closer to 100%. PIT tag retention for steelhead was 99.4% (passive integrated transponder = PIT tag, 176 out of 177 marked) for steelhead. We found that mark/ tag related mortality was low. Estimated survival was 99.9% (CWT, 1,284 out of 1,285 marked) for coho and 94.9% for steelhead (PIT tag, 168 out of 177 tagged) over the 24-hour holding period. Steelhead survival was 100% until the last two trials of the season in May. It is believed that these mortalities were related to water temperature and not tagging. There for it is believed that actual tagged steelhead survival was closer to 100%.

We also tested for differences in initial capture probabilities due to body size. Using a Kolmogorov–Smirnov test, the fork length of maiden captures versus recaptures did not differ significantly for coho during period 13 ($D = 0.19$, $p = 0.06$), or for Chinook during period 12 ($D = 0.16$, $p = 0.28$). PIT tagging allowed for logistic regression analysis of probability of recapture by fork length. The relationship between probability of recapture and fork length was not significant ($p = 0.30$)

Coho

The coho outmigrant estimate in 2021 included yearlings in both transitional and smolt life stages. Of these life stages, 99.9% of outmigrants observed were classified as the smolt phenotype, compared to transitional. Coho outmigrants were observed in low numbers the first week of trapping (beginning March 18, trapping period 2), peaked in late April, early May, and declined through June (ending trapping period 18, Figure 3, Appendix C).

Scale age data indicated a small subyearling component of the coho outmigration that began near the third week of May. Prior to this date, all scale sampled coho outmigrants were yearlings, except for some two-year-old individuals. A total of 381 scale samples were collected and 89.5% were aged successfully. Age-1 coho were the dominant age class (95.6%), and subyearling and age 2 were rare (1.2% and 3.2%, respectively) (Figure 4, Table 8).

A total of 29,290 coho outmigrants were captured throughout the season (Appendix C). A total of 3,649 coho were marked and 512 were recaptured. Modeled weekly trap efficiencies ranged from 5.3% to 20.2%.

Trap efficiency and maiden catches can both be affected by river flows. In 2021 however, river flows were relatively consistent over the duration of the coho outmigration (Figure 5). Trap efficiencies and maiden catches can also be affected by water temperature. However, neither seem to have affected coho outmigration in a significant way (Figure 5 and Figure 6).

Abundance of wild coho outmigrants was estimated to be 220,194 ± 10,646 (SD) with a CV of 4.8%. On a basin wide scale, the coho estimates from the Newaukum River and Upper Chehalis traps contributed 28.2% and 5.9%, respectively.

In 2019, the total number of adult coho spawners in the Chehalis River upstream of the trap site was estimated to be 8,521 (370 hatchery origin = HOR and 8,151 natural origin = NOR, C. Holt, WDFW, personal communication), producing a smolt-per-spawner estimate of 27.0 for the 2019 brood year of naturally spawning coho. Estimating coho productivity through time is a goal of this study going forward.

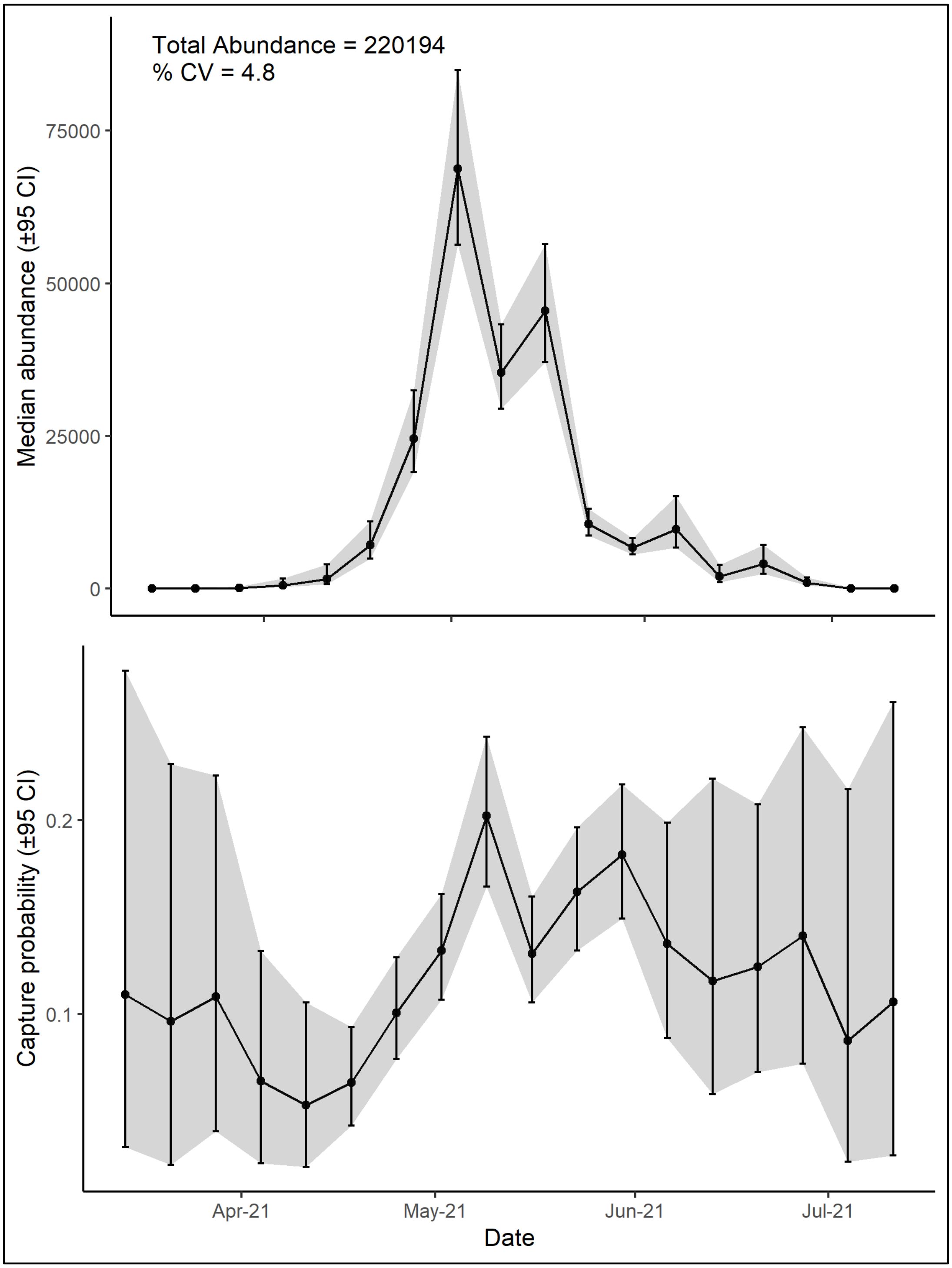


Figure 3. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho smolts and transitionals produced above the Chehalis River smolt trap in 2021**.** Error bars around trap efficiency estimates and shading around abundance estimates represent 95% confidence intervals. Data provided in Appendix C.

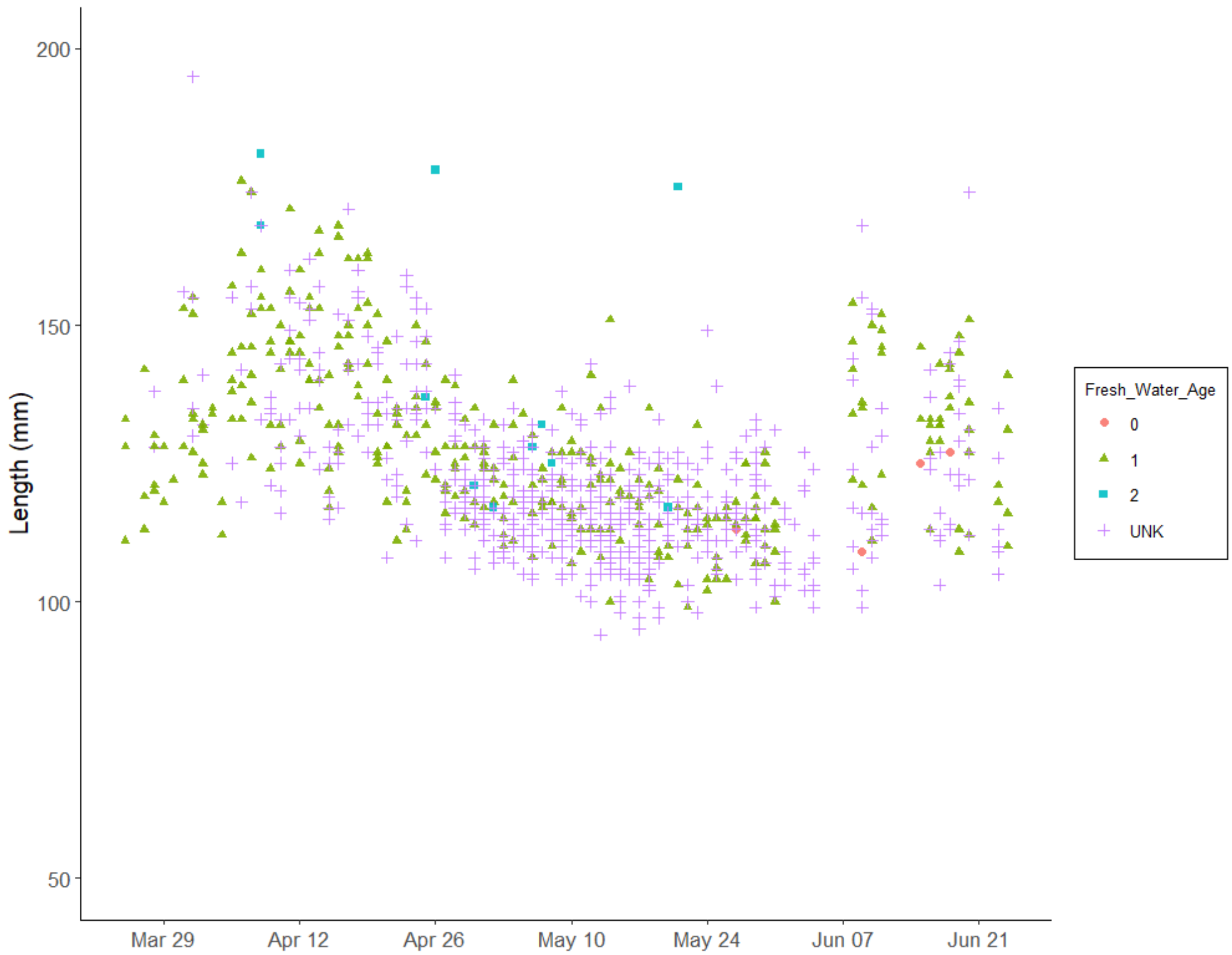
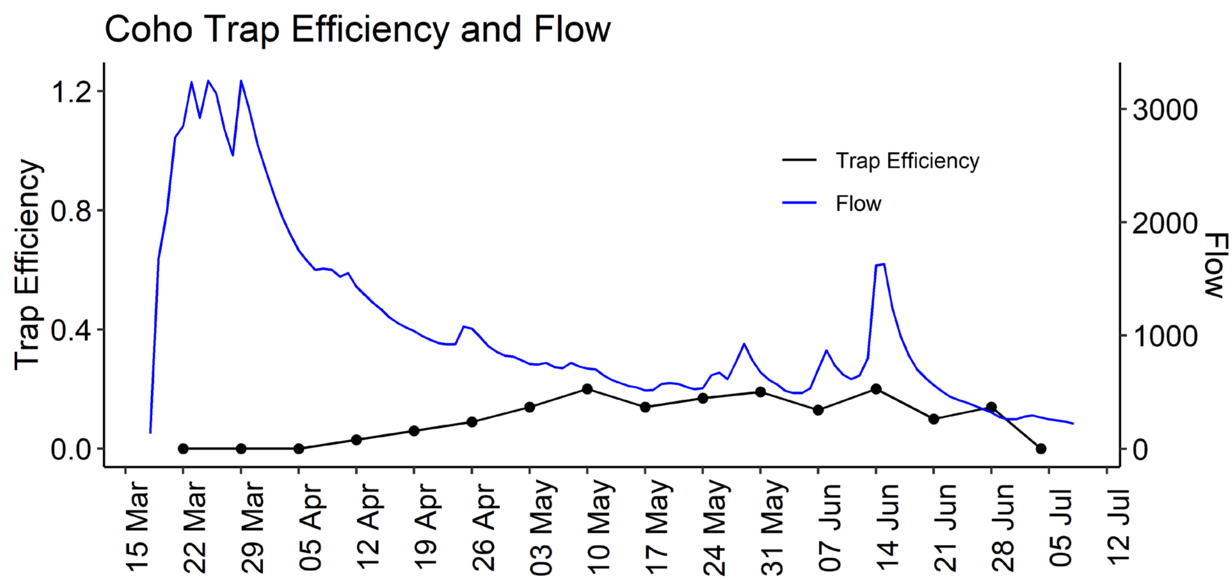


Figure 4. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2021.



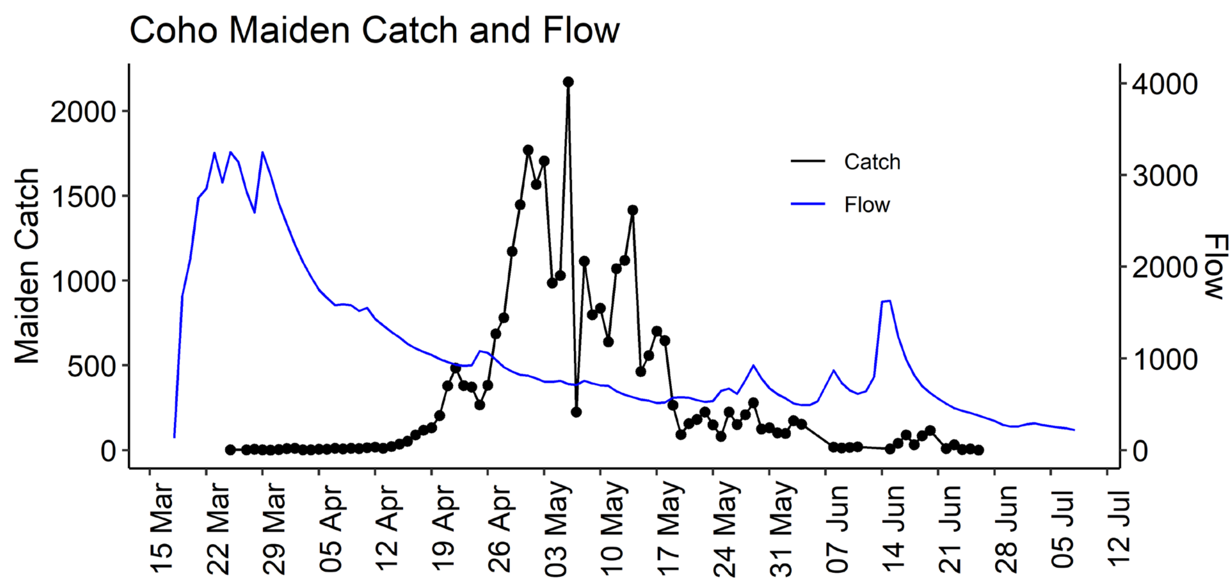
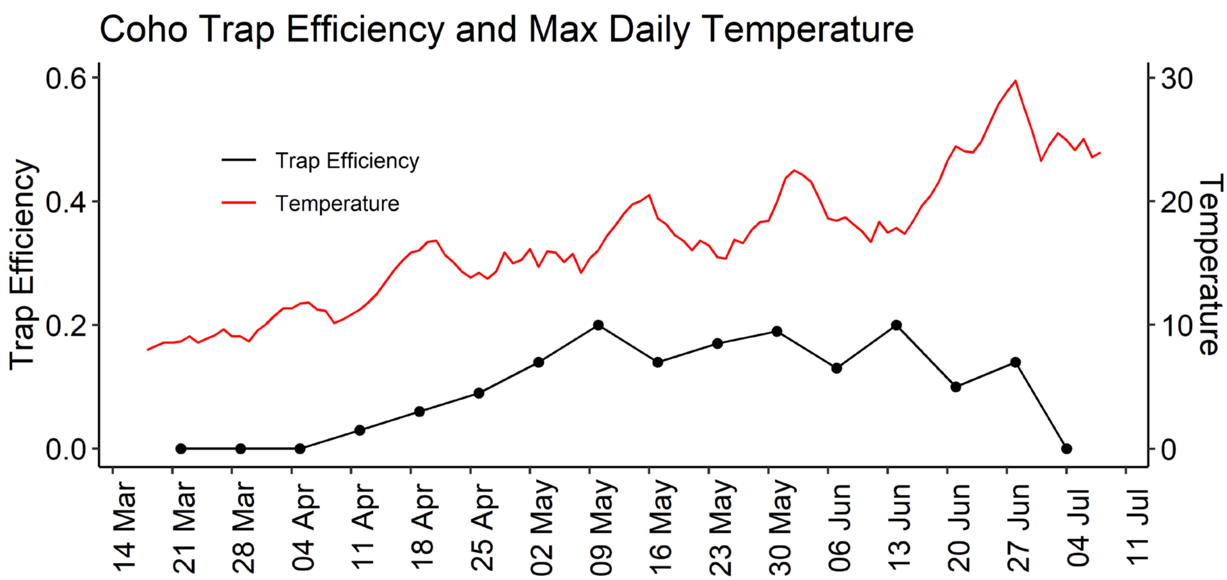


Figure 5. Wild coho transitional and smolt efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Chehalis smolt trap in 2021.



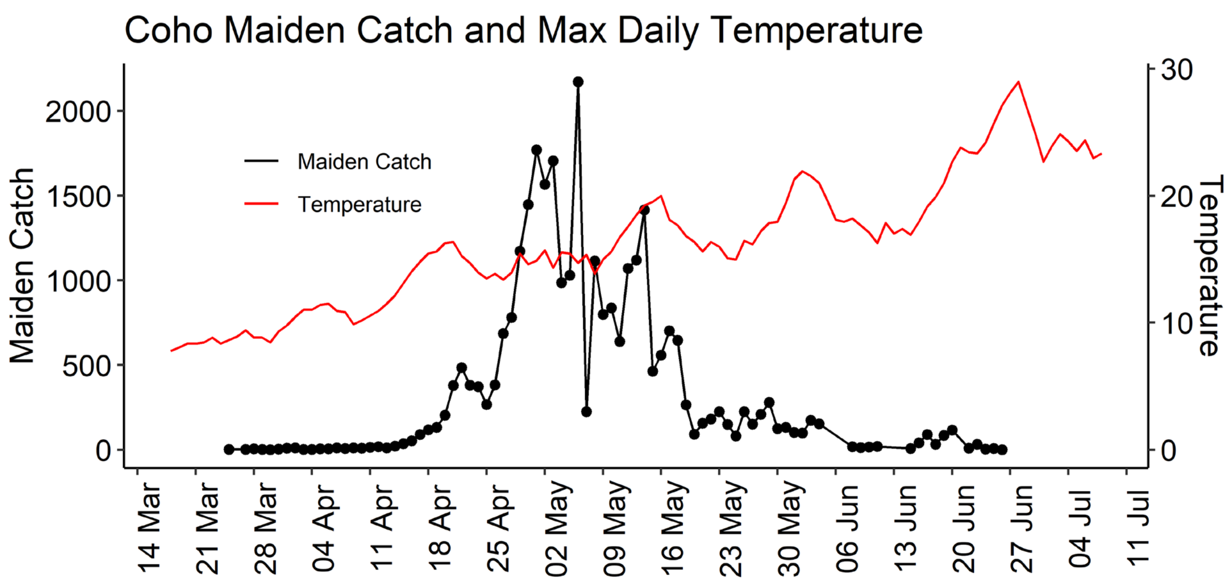


Figure 6 Wild coho transitional and smolt efficiency (top), maiden catch (bottom) and temperature (°C, top & bottom) as a function of period at the Chehalis smolt trap in 2021

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

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
1	3/8	3/14	N/A				
2	3/15	3/21	0				
3	3/22	3/28	11		10		1
4	3/29	4/4	22		19		3
5	4/5	4/11	37		33	2	2
6	4/12	4/18	37		36		1
7	4/19	4/25	35		31	1	3
8	4/26	5/2	36		32	3	1
9	5/3	5/9	35		28	3	4
10	5/10	5/16	36		31		5
11	5/17	5/23	35		26	2	7
12	5/24	5/30	35	1	28		6
13	5/31	6/6	5		5		
14	6/7	6/13	20	1	16		3
15	6/14	6/20	28	2	25		1
16	6/21	6/27	9		6		3
17	6/28	7/4	0				
18	7/5	7/11	0				

Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Of these life stages, approximately 97.4% of outmigrants observed were classified as the smolt phenotype, compared to transitional. Steelhead outmigrant numbers were low during the first week of trapping, March 15 (trapping period 3), peaked the first week of May, and were last observed the week of June 21 (trapping period 16) (Figure 7).

Scale age data indicated that steelhead were 1-, 2-, and 3- years-old (Figure 8, Table 9. A total of 303 scale samples were collected and 79.5% were successfully aged. Fork lengths averaged 160.8 mm (± 16.0 mm SD), 181.8 mm (± 24.0 mm SD), and 243.8 mm (± 26.6 mm SD) for fish that were 1-, 2-, and 3-years-old, respectively. Age composition of successfully aged steelhead was 51.9% Age-1, 45.6% Age-2, and 2.5% Age-3.

A total of 1,910 steelhead outmigrants were captured throughout the season (Appendix D). A total of 1,591 steelhead were marked and 113 were recaptured. Modeled weekly trap efficiencies ranged from 3.1% to 9.2%.

Trap efficiency and maiden catches can both be affected by river flows. However, in 2021 river flows were relatively consistent over the duration of the steelhead outmigration (Figure 9).

Abundance of wild steelhead outmigrants was estimated to be 30,942 ± 3,799 (SD) with a CV of 12.2%

Steelhead contributing to the 2021 smolt outmigration came from the 2018 through 2020 brood years. Spawners from these years were estimated to be 1,733, 2,014, and 2,888 for these years, respectively (C. Holt, WDFW, personal communication). The smolt-per-spawner estimate for adults that escaped in the 2017-2018 run year was 20.2. Smolt abundance for the 2018 brood year was 35,044. We will continue to estimate smolt abundance by brood year and smolt-per-spawner by run year as our monitoring efforts continue.

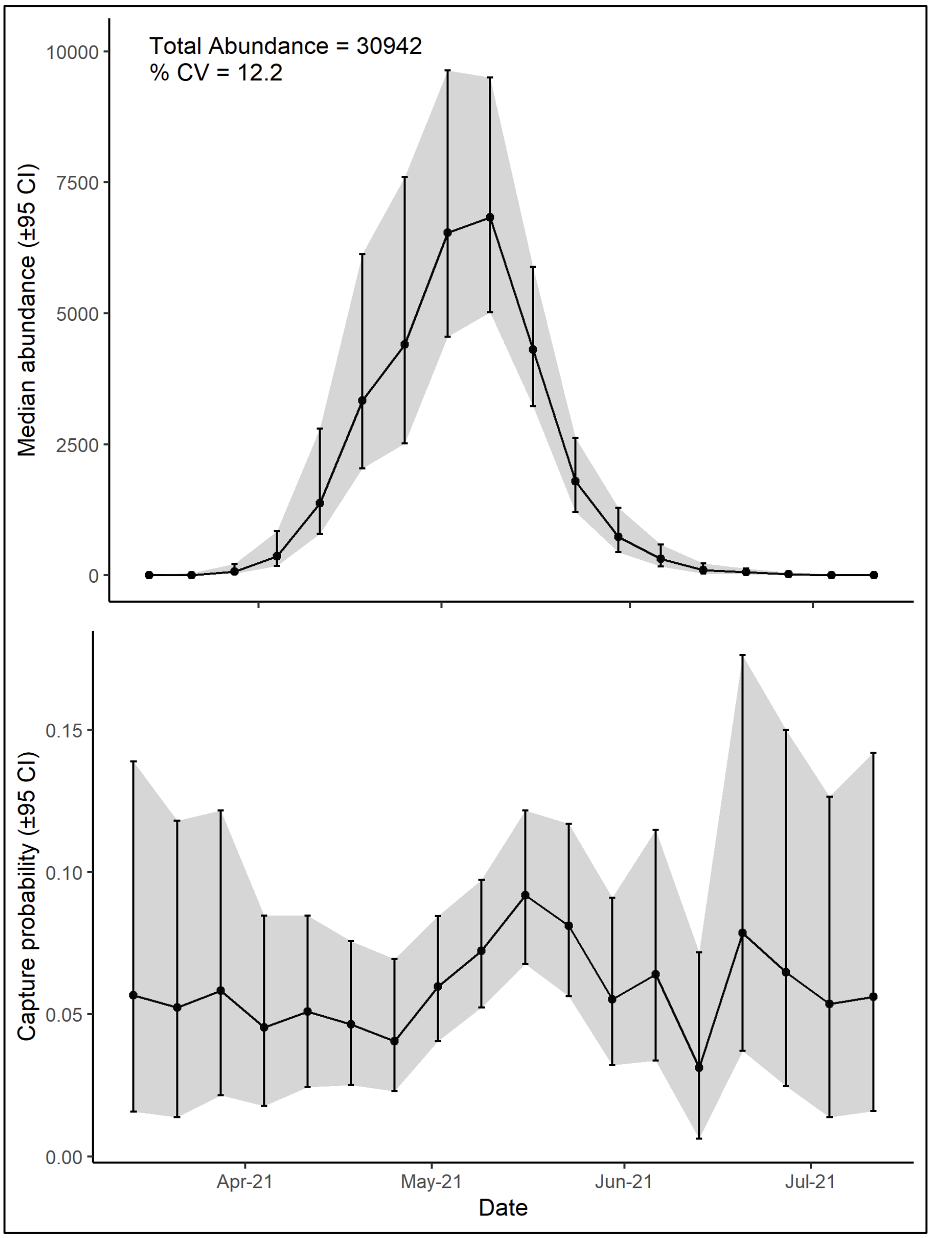


Figure 7. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild steelhead smolts and transitionals produced above the Chehalis River smolt trap in 2021. Error bars around trap efficiency estimates and shading around abundance estimates represent 95% confidence intervals.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

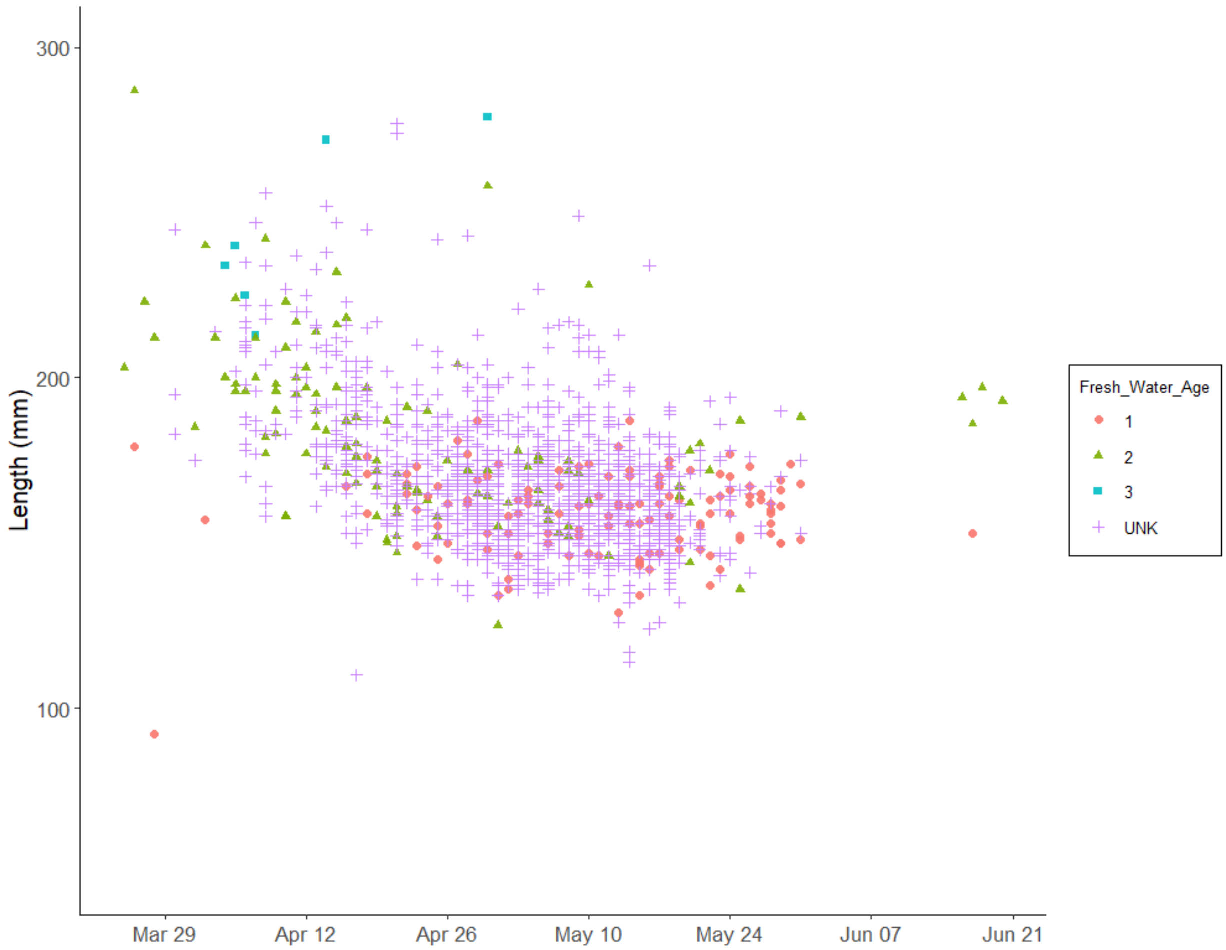
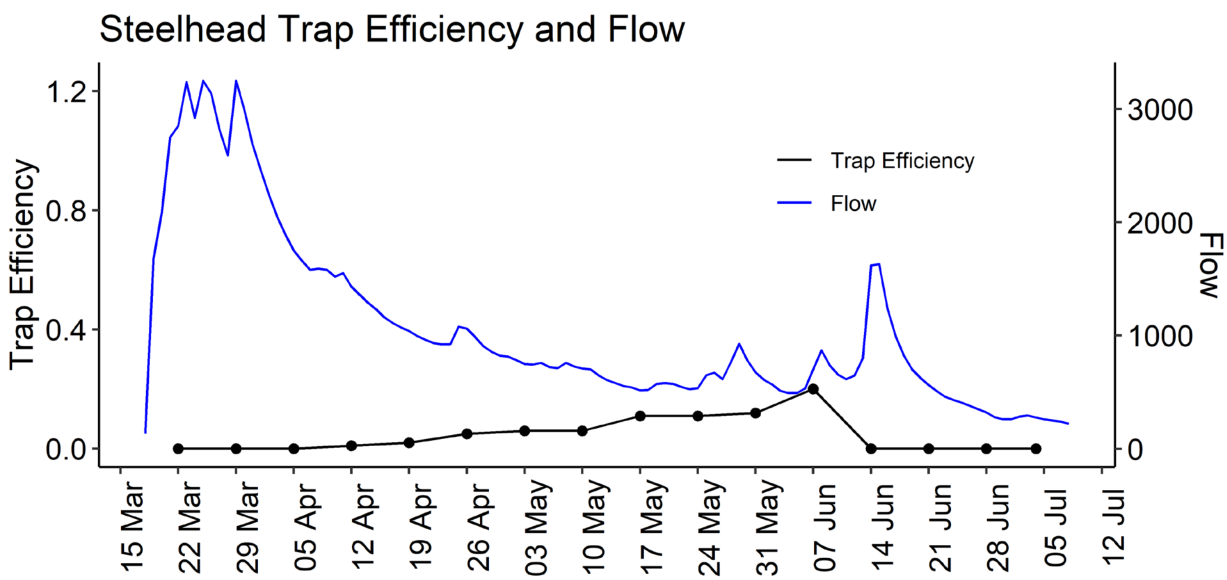


Figure 8. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2021.



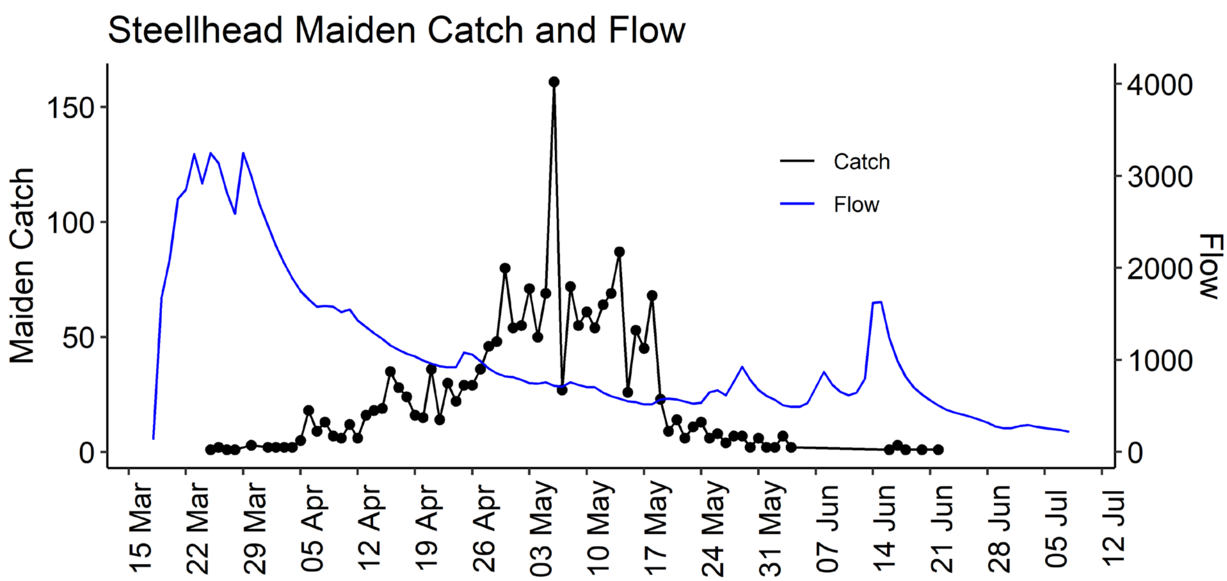
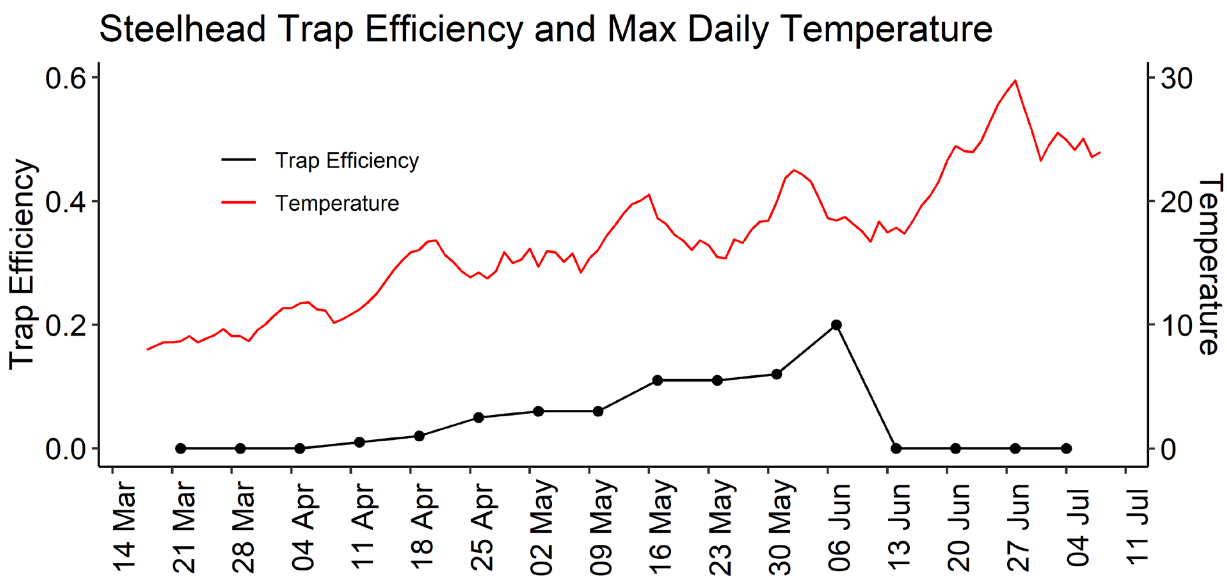


Figure 9. Steelhead wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow CFS (top & bottom) as a function of period at Chehalis smolt trap in 2021.



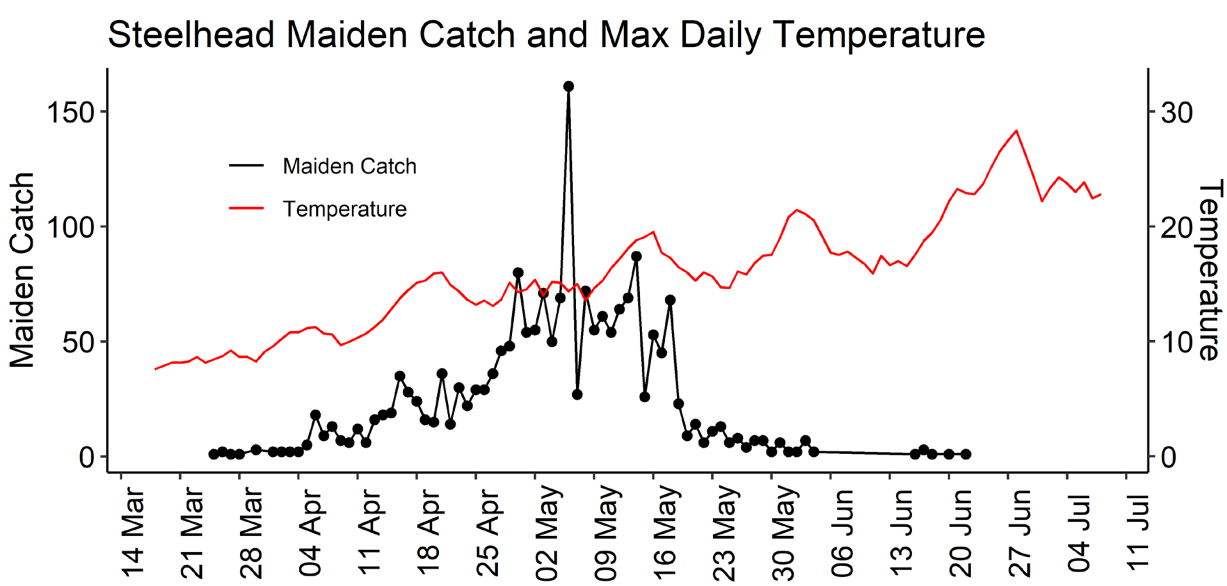


Figure 10. Wild steelhead transitional and smolt efficiency (top), maiden catch (bottom) and temperature (°C, top & bottom) as a function of period at the Chehalis smolt trap in 2021.

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

Period	Start Date	End Date	No. Scales	Age-1	Age-2	Age-3	Not Determined
2	3/15	3/21	0				
3	3/22	3/28	1	2	4		
4	3/29	4/4	3	1	4	1	5
5	4/5	4/11	8		20	3	11
6	4/12	4/18	26	4	21	1	9
7	4/19	4/25	23	10	20		6
8	4/26	5/2	23	17	10	1	9
9	5/3	5/9	19	16	14		6
10	5/10	5/16	17	26	3		6
11	5/17	5/23	3	23	7		5
12	5/24	5/30	1	23	2		4
13	5/31	6/6	0	2	1		1
14	6/7	6/13	0				
15	6/14	6/20	0	1	4		
16	6/21	6/27	0				
17	6/28	7/4	0				
18	7/5	7/11	0				

Chinook

The Chinook outmigrant estimate was derived for the subyearling life history and included transitionals and smolts. Chinook outmigrants were observed in low numbers the first week of trapping March 18 (trapping period 2), peaked around second week of May, and declined through the rest of the trapping season (Figure 11).

Generally, all Chinook outmigrants were assumed to be Age-0. Scale age data were opportunistically collected from two larger Chinook. These individuals were confirmed yearlings and fork lengths measured 142 mm and 154 mm, respectively (Table 10). Subyearling Chinook (including fry and parr) ranged from 31-106 mm. Fork length of Chinook increased steadily throughout the season with an average of 48.7 mm (± 6.9 mm SD) and 98.3 mm (± 4.3 mm SD) in the first and last full week of trapping, respectively (Figure 12).

In 2021, a total of 42,915 Chinook subyearling (not including fry and parr) outmigrants were captured, 4,518 were marked, and 533 were recaptured (Appendix E; Periods 1 – 22). Modeled weekly trap efficiencies ranged from 5.2% to 19.0%.

Trap efficiency and maiden catches can both be affected by river flows. However, river flows in 2021 were relatively consistent over the duration of the Chinook outmigration (Figure 13).

Abundance of wild Chinook subyearling outmigrants was estimated to be 438,032 ± 30,752 (SD) with a CV of 7.0%.

In 2020, the total number of adult spring Chinook that spawned in the Chehalis River above our trap site was estimated to be 2,788 (all NOR) and adult fall Chinook was estimated to be 4,788 (24 HOR and 4,606 NOR), producing an overall smolt-per-adult estimate of 90.5 for the 2020 brood year of naturally spawning Chinook. Estimating subyearling Chinook productivity through time is a goal of this study going forward.

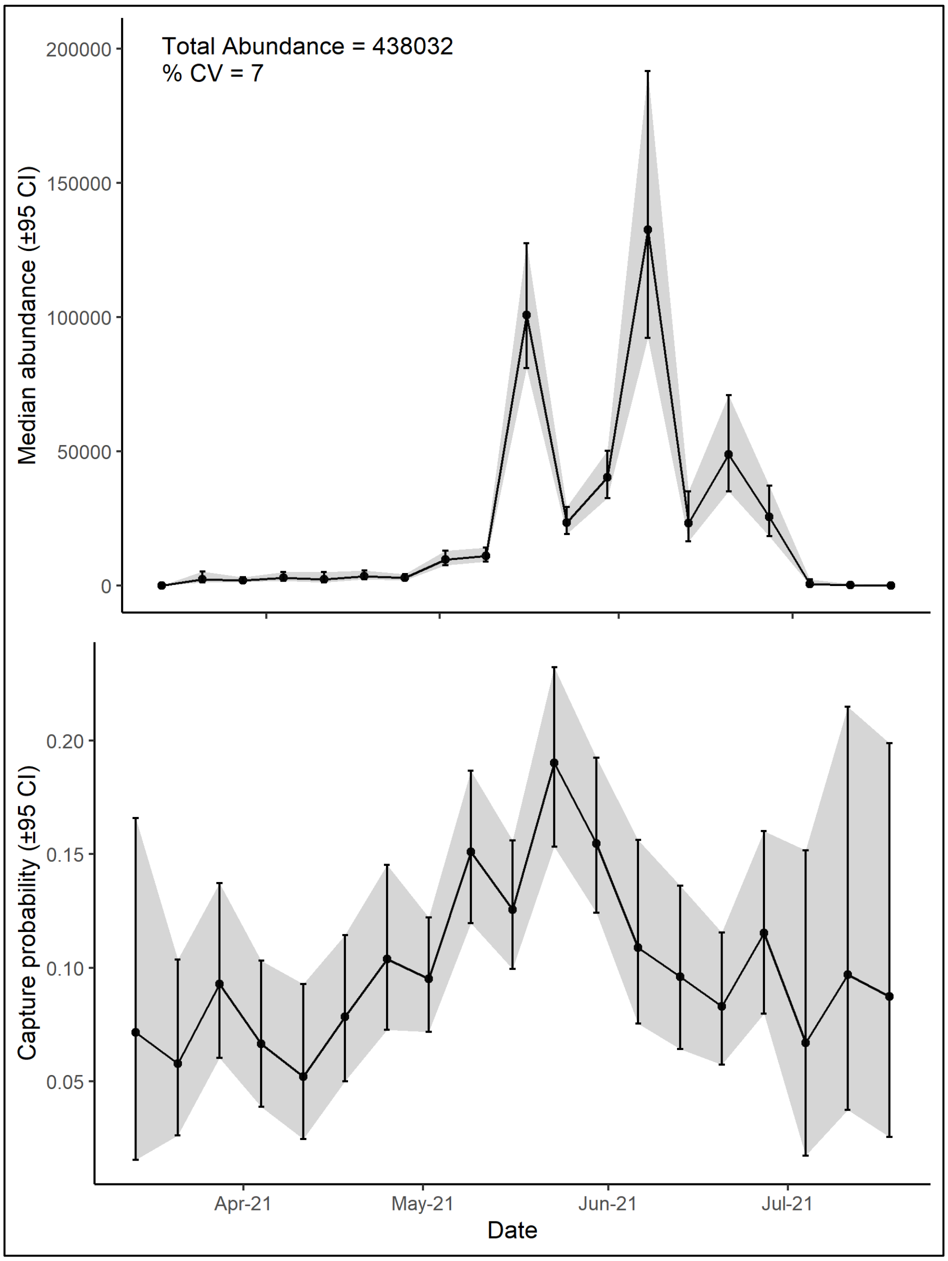


Figure 11 Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Chehalis River smolt trap in 2021. Error bars and shading represent 95% confidence intervals.

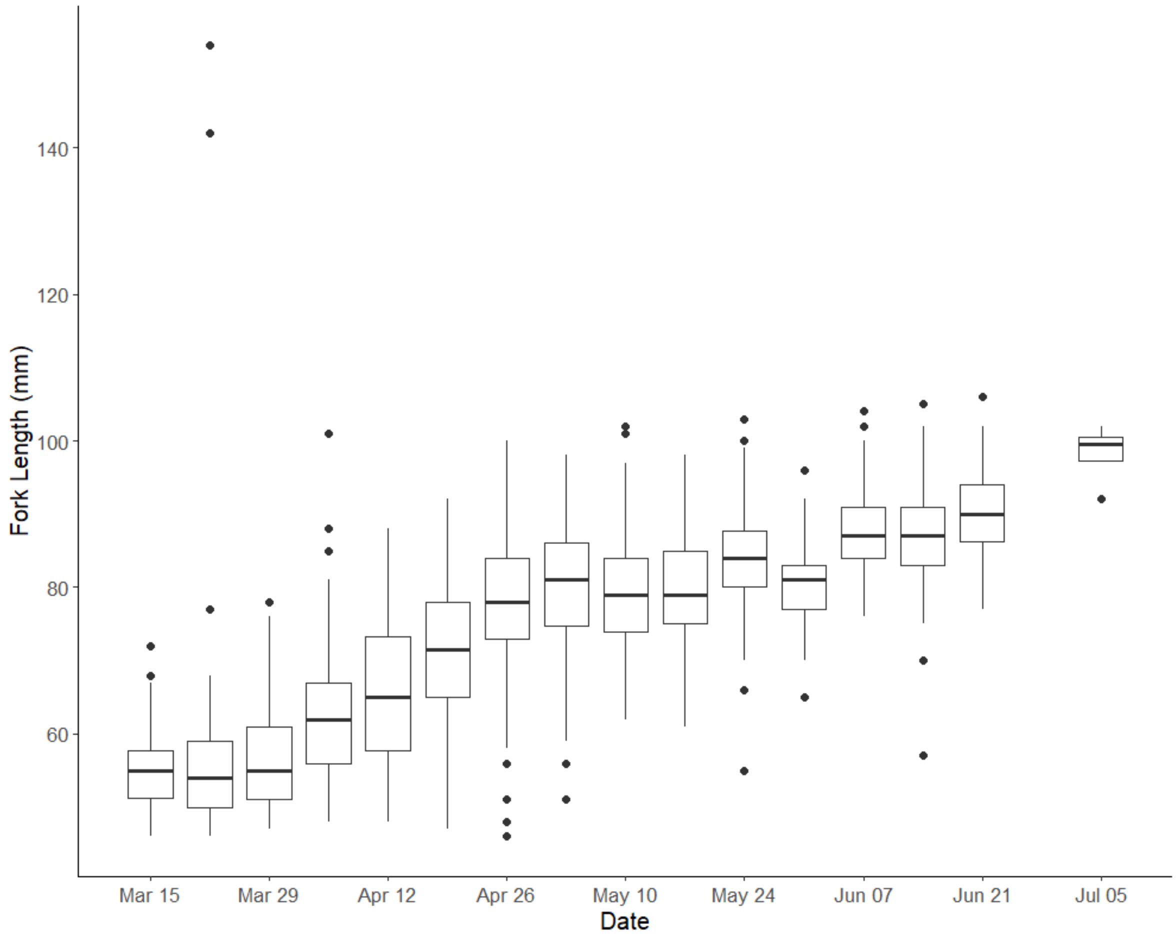
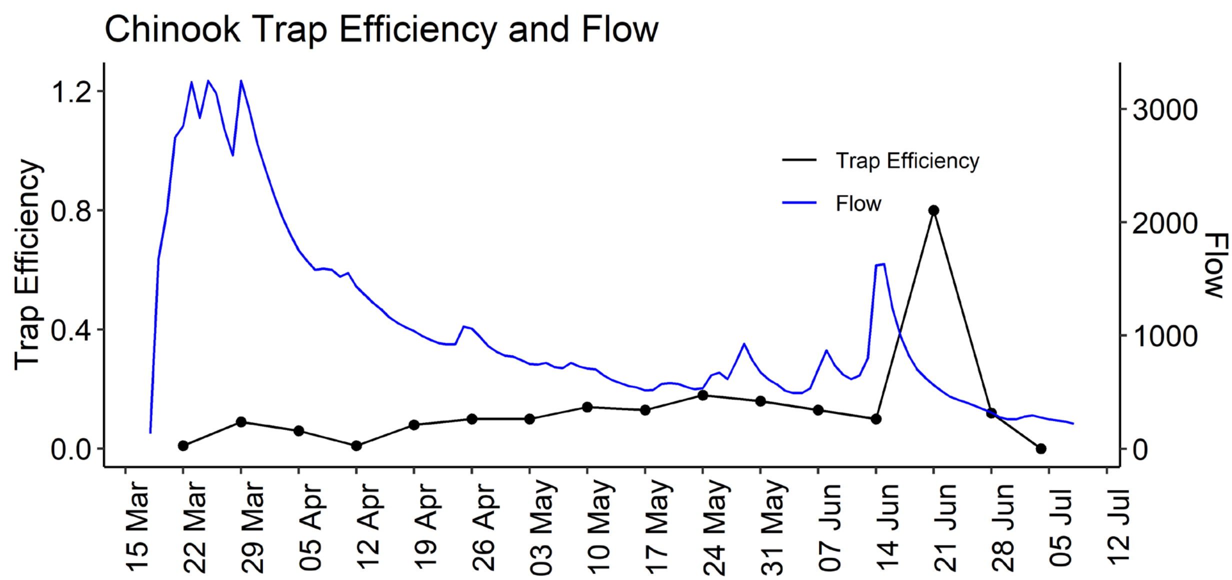


Figure 12 Box plots of fork lengths of wild Chinook outmigrants (transitionals, smolts) by week at the Chehalis River screw trap, 2021. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.



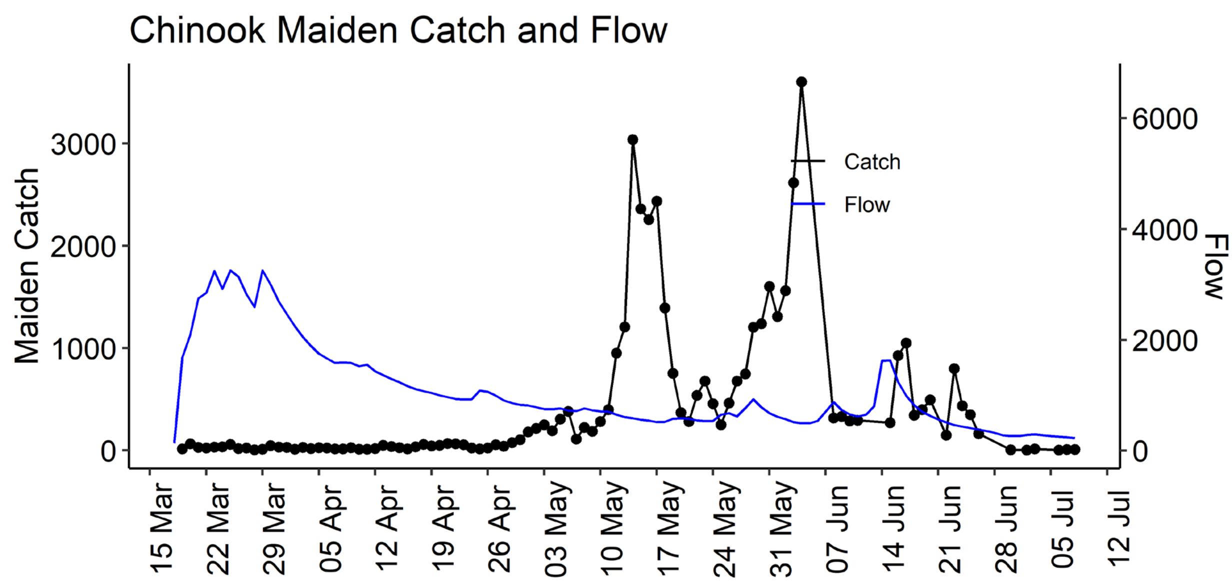


Figure 13 Chinook wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow CFS (top & bottom) as a function of period at the Chehalis smolt trap in 2021.

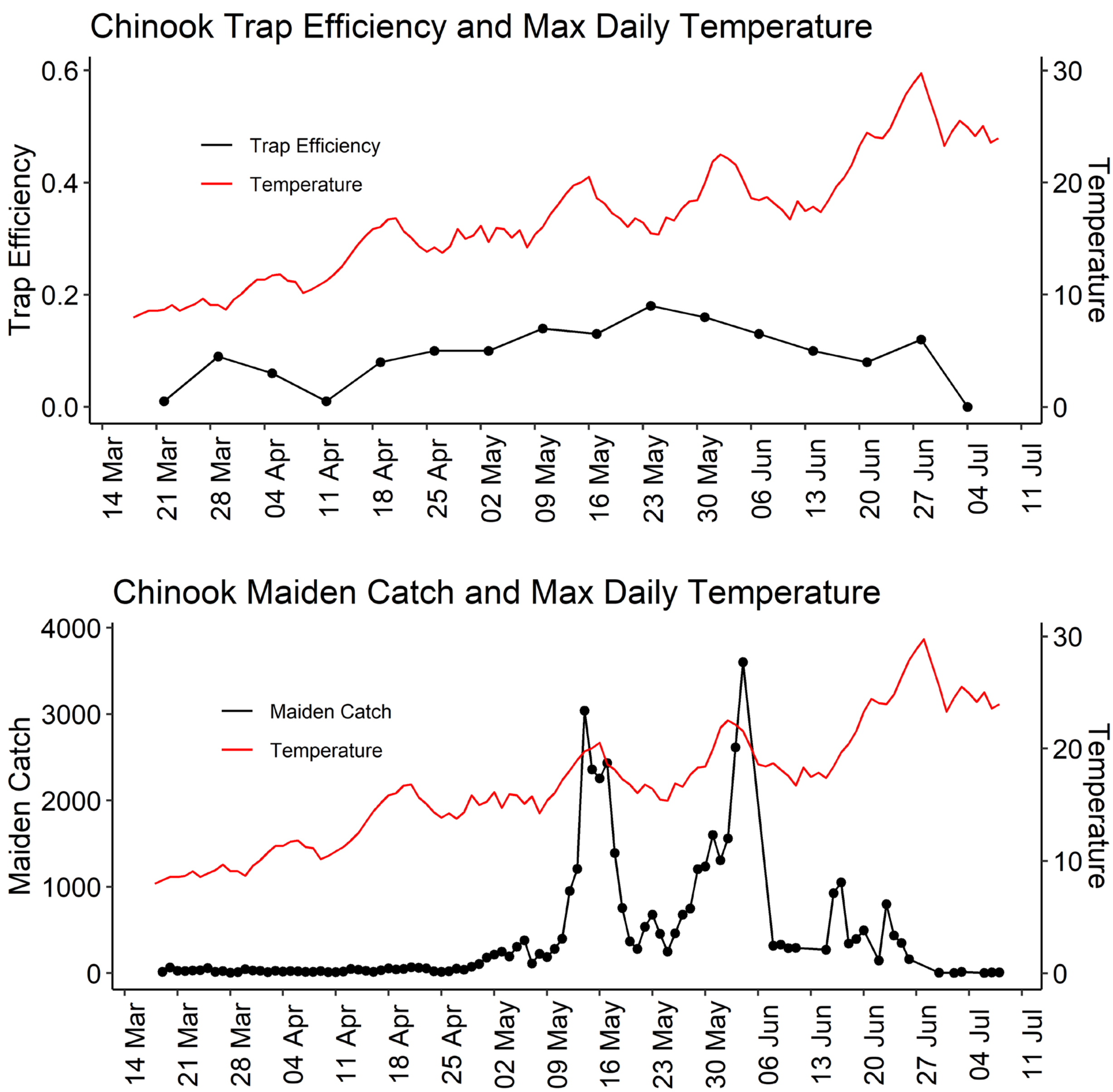


Figure 14 Wild Chinook transitional and smolt efficiency (top), maiden catch (bottom) and temperature (°C, top & bottom) as a function of period at the Chehalis smolt trap in 2021.

Table 10. Freshwater ages of wild Chinook outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2021. Data are opportunistic samples of large Chinook scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
1	3/8	3/14	0	0	0	0	0
2	3/15	3/21	2	0	2	0	0
3	3/22	3/28	0	0	0	0	0
4	3/29	4/4	0	0	0	0	0
5	4/5	4/11	0	0	0	0	0
6	4/12	4/18	0	0	0	0	0
7	4/19	4/25	0	0	0	0	0
8	4/26	5/2	0	0	0	0	0
9	5/3	5/9	0	0	0	0	0
10	5/10	5/16	0	0	0	0	0
11	5/17	5/23	0	0	0	0	0
12	5/24	5/30	0	0	0	0	0
13	5/31	6/6	0	0	0	0	0
14	6/7	6/13	0	0	0	0	0
15	6/14	6/20	0	0	0	0	0
16	6/21	6/27	0	0	0	0	0
17	6/28	7/4	0	0	0	0	0
18	7/5	7/11	0	0	0	0	0

Chinook subyearling abundance by run type

A total of 669 juvenile Chinook tissue samples were sent to the lab for processing. Of those, SNP genotypes were successfully obtained from 590 (88.2%). Chinook subyearlings had one of three genotypes associated with run-timing: homozygous spring (two copies of a spring allele), homozygous fall (two copies of a fall allele), and heterozygote (one spring allele and one fall allele, unknown run timing). Proportions of spring, fall, and heterozygote genotypes by week were apportioned according to the weekly abundance estimates with known precision based on results from the mark-recapture study (Table 11, Figure 15). We assumed that the error was distributed proportionally with genotype identity. No fish were sampled in the first or final week of trapping; however, the model predicted abundance during those periods, so proportions in these weeks were based on determinations from the next week or the week prior. If the correlation of the SNP genotype and adult run timing phenotype still holds, the Chinook subyearling outmigration abundance estimate consisted of an estimated 28,529 (6.6%) spring Chinook, 304,651 (70.3%) fall Chinook, and 100,007 (23.1%) of unknown run timing (i.e., heterozygotes).

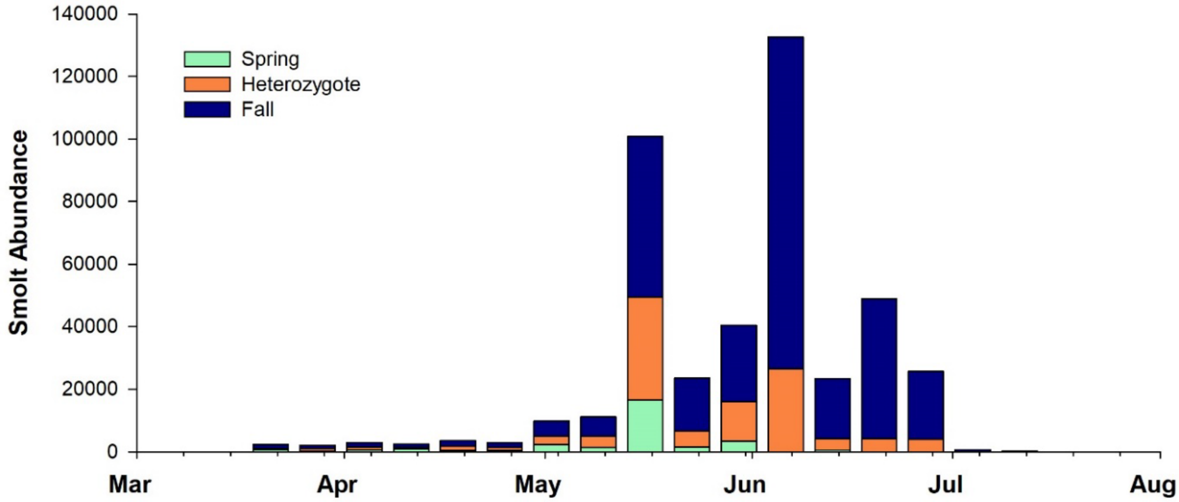


Figure 15. Chinook subyearling SNP genotype estimates from the mainstem Chehalis River trap by date. SNP genotypes are associated with adult run timing in Chehalis Chinook salmon (Thompson et al. 2019).

Table 11. Chinook subyearling genetic estimates by period and run type at the Chehalis River screw trap. Values were determined by multiplying weekly proportions of genetic run types with the modeled median abundance estimate.

Period	Start Date	End Date	Spring	Heterozygote	Fall	Total
1	8-Mar	14-Mar	4	3	8	15
2	15-Mar	21-Mar	679	407	1,222	2,309
3	22-Mar	28-Mar	188	863	976	2,027
4	29-Mar	4-Apr	547	875	1,532	2,954
5	5-Apr	11-Apr	795	506	1,085	2,386
6	12-Apr	18-Apr	377	1,414	1,697	3,489
7	19-Apr	25-Apr	436	872	1,620	2,928
8	26-Apr	2-May	2,332	2,545	4,877	9,754
9	3-May	9-May	1,342	3,578	6,261	11,180
10	10-May	16-May	16,462	32,924	51,444	100,829
11	17-May	23-May	1,413	5,182	16,958	23,553
12	24-May	30-May	3,368	12,631	24,420	40,419
13	31-May	6-Jun	0	26,507	106,029	132,536
14	7-Jun	13-Jun	585	3,508	19,291	23,383
15	14-Jun	20-Jun	0	4,141	44,725	48,866
16	21-Jun	27-Jun	0	4,050	21,601	25,651
17	28-Jun	4-Jul	0	0	643	643
18	5-Jul	11-Jul	0	0	260	260
19	12-Jul	18-Jul	0	0	2	2
Totals			**28,529 (6.6%)**	**100,007 (23.1%)**	**304,651 (70.3%)**	**433,186**

Discussion

Basin-wide Context

The abundance estimates provided in this report represent juvenile salmonids that completed their freshwater rearing in 2021 in habitats upstream of the trap location, specifically upstream of river kilometer 84 (river mile 52). The area upstream of the trap includes the upper Chehalis main stem, South Fork Chehalis River, Newaukum River, Skoookumchuck River, and other smaller tributaries. Large sub-basins of the Chehalis River watershed including the Black River and Satsop River flow into the Chehalis River downstream of the trapping location, so results do not reflect production estimates originating from these locations. In addition to freshwater production from the downstream sub-basins, 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 were not included in these estimates. This 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).

Estimates of annual freshwater production of wild coho smolts in the entirety of the Chehalis River Basin averaged 2.2 million (0.5 to 3.7 million) since WDFW began monitoring smolt production in the 1980s (Litz and Agha 2022). The proportion of coho habitat upstream of our trapping location represents approximately 30.6% of the rearing habitat relative to the entirety of the Chehalis Basin (Walther 2021). The proportion of freshwater production of coho salmon from upstream of our trapping location relative to basin-wide production has ranged from 9.3-24% in the years for which data are available (2017-2020). Based on these proportions, our estimates of coho outmigrants from habitat upstream of river kilometer 84 may suggest that a relatively small proportion of all wild coho in the Chehalis River watershed complete their freshwater rearing in the upper Chehalis, South Fork Chehalis, Newaukum, Skoookumchuck, and other small tributaries upstream of the trap site. However, 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 69.4% 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 estimates of juvenile coho production from 2017-2021 ranged from 220,194 to 463,566, with 2021 as the lowest observed estimate in the 5-year time series (Figure 16). Additionally, confidence intervals for the estimates have decreased compared to the first year of trapping, indicating that precision in our estimates is increasing (Figure 16). This has mainly been possible due to learning how our equipment operates best at this location and adapting field protocols and analytical methods to reduce bias and optimize precision. Finally, our estimates of wild coho production above the trap site from 2017-2021 are relatively consistent with WDFW monitoring results from the 1990s which also estimated 300,000-400,000 wild coho smolts produced upstream of the mainstem smolt trap (Seiler et al. 1997). 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).

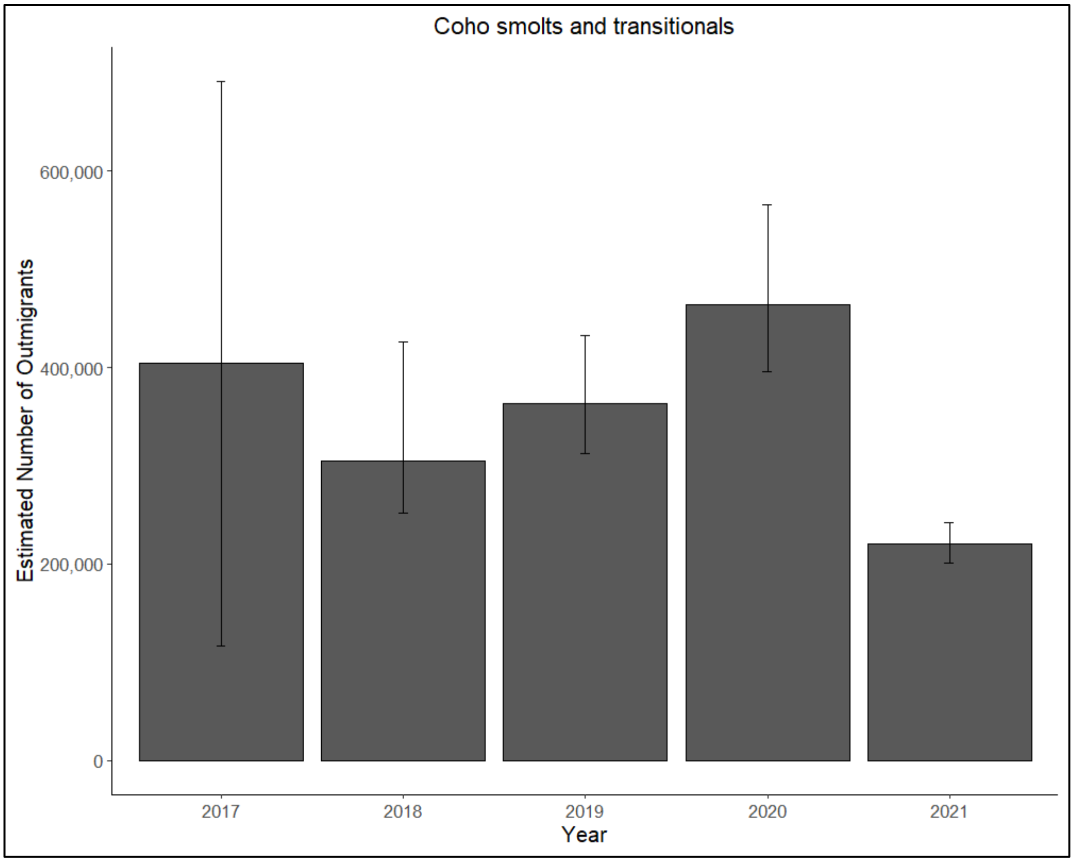


Figure 16. Annual time series of outmigrant abundance with 95% confidence intervals for wild coho smolts and transitionals produced above the Chehalis River smolt trap, 2017-2021.

This report provides the fourth reportable estimate of wild steelhead production from the Chehalis River basin upstream of river kilometer 84. Our estimate of 30,942 steelhead outmigrants from the roughly 566 river km upstream of the trap (Statewide Integrated Fish Distribution, SWIFD, https://geo.nwifc.org/swifd/) corresponds to 55 wild steelhead smolts km^{-1}, which is roughly average compared to our 2018 (32,058), 2019 (29,024), and 2020 (38,647) estimates of steelhead outmigrants (Figure 17). 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 Chehalis River trap. In contrast to the Coweeman and Wind rivers, much of the spawning and rearing habitats upstream of the trap on the Chehalis River are either low gradient main stem channel or small tributaries, neither of which have geomorphic characteristics typically associated with high quality steelhead spawning and rearing habitat in the Pacific Northwest (Gibbons et al. 1985). Of note, recent studies (Ashcraft et al. 2017, Ronne et al. 2018) identified the Upper Chehalis sub-basin, which is one of multiple sub-basins located upstream of the smolt trap, 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. Another possible explanation is that steelhead parr could rear 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). Additionally, current summer stream temperatures downstream of the trap are outside optimal rearing conditions for juvenile salmon and steelhead (Fogel et al. 2022).

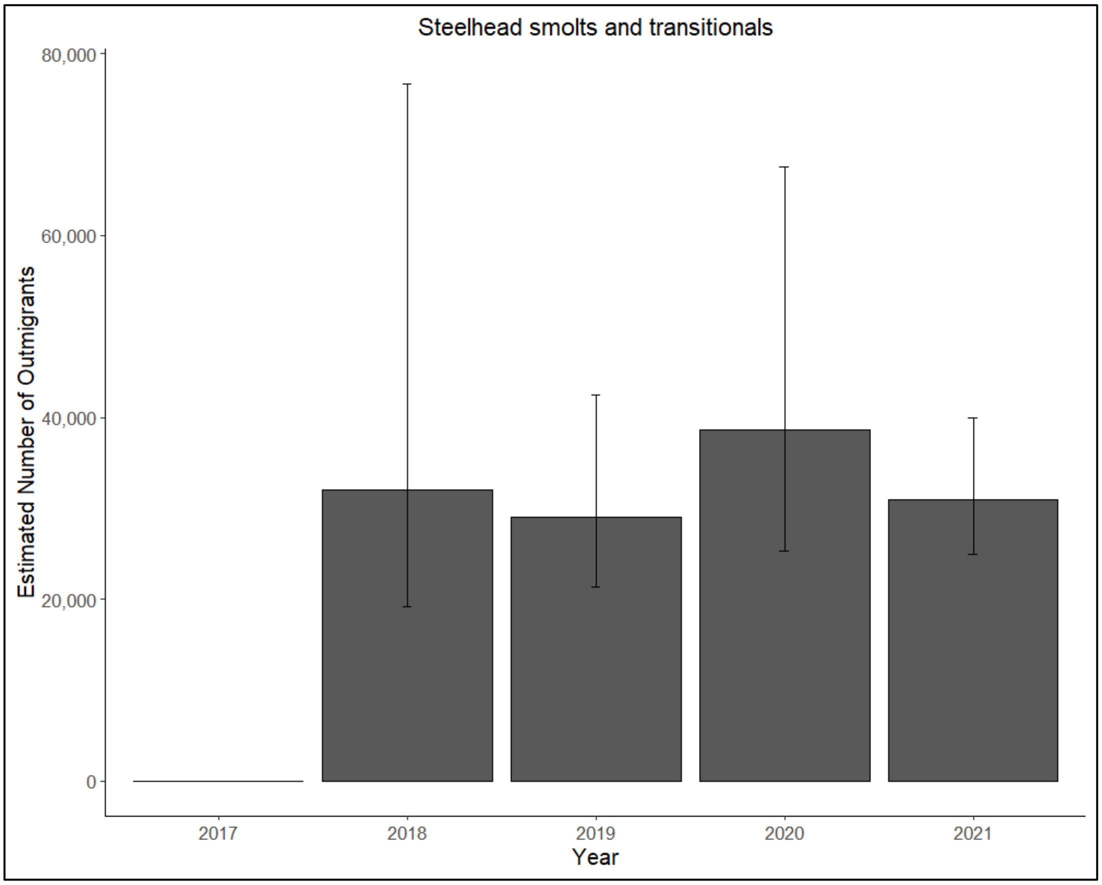


Figure 17. Annual time series of outmigrant abundance with error bars representing 95% confidence intervals for wild steelhead smolts and transitionals produced above the Chehalis River smolt trap, 2017-2021.

Our estimate of Chinook subyearling outmigrants represents a portion of the total freshwater production of Chinook upstream of the trap location in 2021 and does not include the earlier timed fry migrants. Our estimate of 438,032 Chinook subyearling outmigrants is our third reportable estimate above our Chehalis trapping location, which is considerably higher than our 2020 estimate of 320,358 outmigrants (Figure 18). The precision of our estimate in 2021 remains consistent with our 2018 and 2020 estimates (Figure 18). Generating a 'subyearling' estimate is relevant to habitat restoration planning because the 'subyearling' component of the outmigration represents the numbers of juveniles that are supported by freshwater habitats upstream of the trap site and previous work demonstrated that greater than 95% of adult Chinook returning to the upper Chehalis had a subyearling life history (Campbell et al. 2017). Fry migrants do not spend as much time rearing in freshwater habitats but rather make extensive use of estuary and nearshore growing environments prior to entering the ocean (Sandell et al. 2014, Beamer et al. 2005). 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 reflect a freshwater rearing capacity (Anderson and Topping 2018, Zimmerman et al. 2015). Additional Chinook production beyond this capacity appear to migrate downstream as 'fry' in a density-dependent manner (Greene et al. 2005). Extending this density-dependent migration hypothesis to the Chehalis River will require additional years of juvenile monitoring coupled with adult Chinook spawner data above the trap location.

Combining a genetic approach with our abundance estimates, we successfully estimated the abundance of outmigrating Chinook salmon having three genotypes associated with adult run timing with known precision. Our results suggest that the fall run genotype represents the largest component of the outmigration (304,651; 70.3%) followed by those of unknown run timing (i.e., heterozygotes; 100,007; 23.1%), followed by the spring run type (28,529; 6.6%) (Table 11). Because the traps being operated upstream of the Mainstem Chehalis trap also collected genetic samples, we were able to estimate how much each sub-basin being sampled (Newaukum River and Upper Chehalis River) contributed to the estimate from the Mainstem Chehalis trap. The Newaukum River outmigration was estimated to have produced 163,146 Chinook smolts, with fall run type accounting for 61.6% of the run, spring run type accounting for 20.5% of the run, and heterozygotes (accounting for 17.9% of the run (Olson et al. 2023). These proportions equate to 32.7%, 29.0%, and 116.0% of the Mainstem Chehalis River trap Chinook production estimates by run type. It is interesting to note that the Newaukum River was estimated to have produced more spring run type Chinook than the Mainstem Chehalis River (33,091 versus 28,529). Whether this is due to abiotic factors (e.g., loss due to environmental conditions), biotic factors (e.g., loss due to predation or density dependence), sampling error, or a combination of these, is not known. The Upper Chehalis was estimated to have produced 118,834 Chinook smolts, with the fall run type accounting for type 89.0% of the run, heterozygotes accounting for 10.1% of the run, and spring run types only accounting for 0.9% of the run (West et al. 2023). These proportions constituted 24.1%, 11.8%, and 3.8% respectively, of the Mainstem Chehalis River trap Chinook smolt production estimate by run type. Note that very few spring Chinook originated from the Upper Chehalis River compared to the Newaukum sub-basin.

Table 12. Number of genetics samples from Mainstem Chehalis River by period.

Period	Start Date	End Date	Spring	Heterozygote	Fall	Total
1	8-Mar	14-Mar	0	0	0	0
2	15-Mar	21-Mar	5	3	9	17
3	22-Mar	28-Mar	5	23	26	54
4	29-Mar	4-Apr	5	8	14	27
5	5-Apr	11-Apr	11	7	15	33
6	12-Apr	18-Apr	4	15	18	37
7	19-Apr	25-Apr	7	14	26	47
8	26-Apr	2-May	11	12	23	46
9	3-May	9-May	6	16	28	50
10	10-May	16-May	8	16	25	49
11	17-May	23-May	3	11	36	50
12	24-May	30-May	4	15	29	48
13	31-May	6-Jun	0	2	8	10
14	7-Jun	13-Jun	1	6	33	40
15	14-Jun	20-Jun	0	5	54	59
16	21-Jun	27-Jun	0	3	16	19
17	28-Jun	4-Jul	0	0	0	0
18	5-Jul	11-Jul	0	0	4	4
19	12-Jul	18-Jul	0	0	0	0
Totals			**70**	**156**	**364**	**590**

Assuming the association with adult run timing holds, this is consistent with abundance estimates of adult fall and spring Chinook in the Chehalis Basin, and our results are some of the first insights into the outmigration timing of juvenile spring, fall, and heterozygote run types, which indicated that spring run types outmigrated earlier than fall run types (Figure 15). The run timing of heterozygotes in the Chehalis Basin is unknown. Genotypes of adult voucher samples of known run timing were used to verify the association of our SNP markers. However, very few adult samples had the heterozygote run timing marker (Thompson et al. 2019). Heterozygotes are believed to show intermediate run timing (i.e., summer), and this observation seems to be supported by our data. Future efforts to measure juvenile run types could help better resolve outmigration timing of the different run types. Our analysis is valuable because it now allows us to track abundance trends in all run types and proportional trends among run types which is critical information when determining if habitat restoration, protection, or climate change are impacting run types disproportionately. Finally, this information is particularly important for the spring Chinook component considering populations are low and declining (Curt Holt, WDFW, personal communication).

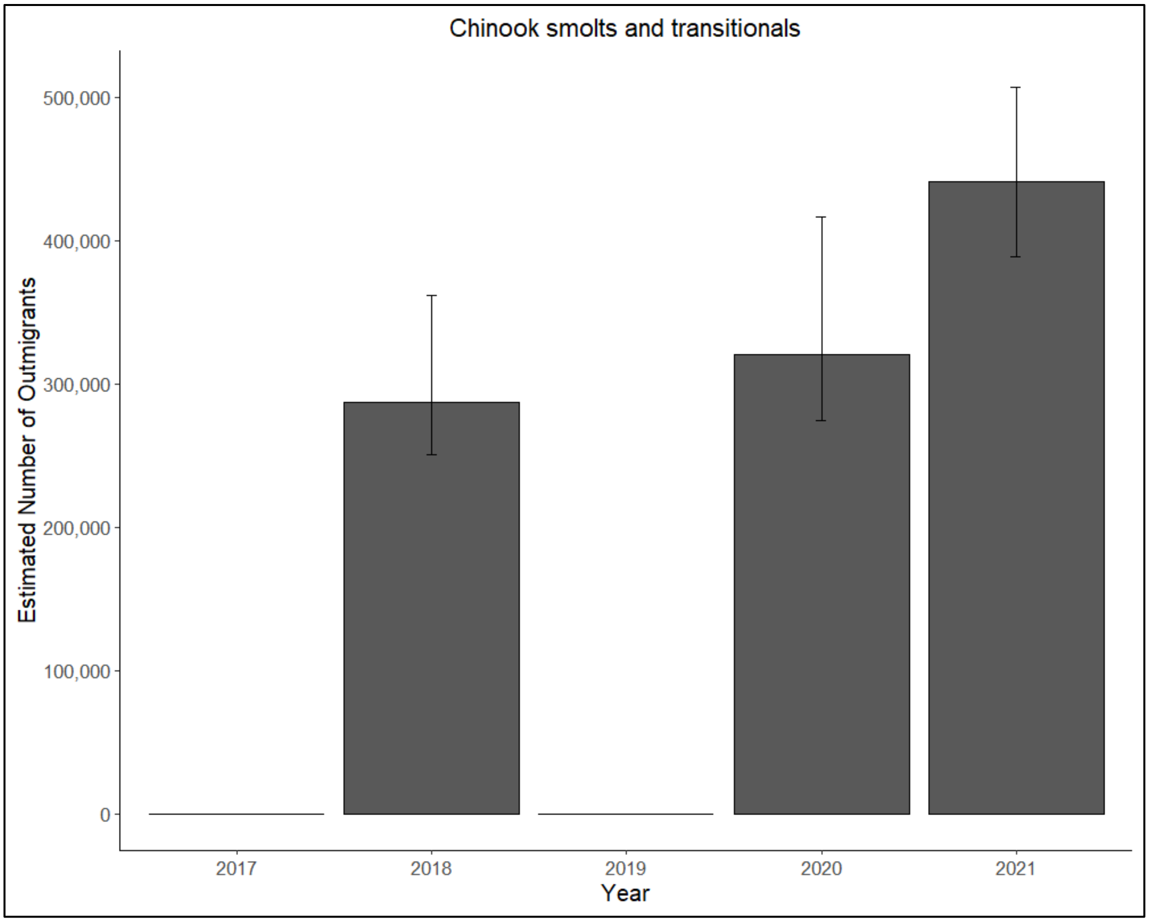


Figure 18. Annual time series of outmigrant abundance with error bars representing 95% confidence intervals for wild Chinook smolts and transitionals produced above the Chehalis River smolt trap, 2017-2021.

Next Steps

The main stem Chehalis River estimates presented here provide critical information for salmon and steelhead smolt production in the basin but trapping in this location presents many challenges. In 2021, these challenges included high flows, warm stream temperatures, and filamentous algae. Additional description of these issues and our approaches to address them are described below.

The 2021 season was our fourth year attempting a Chinook subyearling outmigration estimate (e.g., fishing into July), which is longer than the historical trapping seasons (e.g., historical trapping periods typically April-May from 1999-2015), and we experienced similar issues to those faced in 2019 and 2020. Temperature concerns were prevalent later in the season at this location in the Chehalis River. For example, maximum daily temperatures during June and July peaked at 29.8°C and 26.0°C, respectively (Table 13). Like 2019 and 2020, large algae aggregations were a serious issue, completely plugging the cone and live box. Algae issues were unpredictable and led to limiting fishing periods to when crew were present on the trap.

Adult northern pikeminnow and other piscivorous fish (e.g., smallmouth bass) had previously been observed to aggregate around the smolt trap and feed on fish released from the trap. We instructed the crews to monitor the live box for adult northern pikeminnow, however, we caught more adult pikeminnow in 2021 (141 adults) compared to 2020 (16 adults) and 2019 (59 adults), but fewer than 2018 (439 adults). This large difference in interannual adult pikeminnow catch may be attributed in part to differing trap positions between years. In 2018 our trapping position was impeded by low water late in our season. In 2018, we were unable to fish in the most efficient velocities and were forced to fish below the main thalweg. Our 2018 revolutions per minute of our screw trap often decreased to 4 later in the season. Lower velocity fishing locations may have contributed to our large northern pike minnow catches. In 2022, we plan to evaluate ways to mitigate the potential impact of northern pike minnow on salmonids in the trap live box.

In summary, 2021 represented the fourth year for which wild Chinook and steelhead outmigrations were described from the Chehalis River and the fifth time in two decades that wild coho outmigration were specifically evaluated from the upper portion (upstream of the Black River) of the basin. In addition to abundance, we described the life history characteristics and size of the outmigrants as these are characteristics that reflect how the existing habitat contributes to freshwater production of salmon and steelhead. Continuation of this monitoring will provide understanding of variability and trends in freshwater production over time. As part of a larger, integrated monitoring effort associated with the Chehalis Basin Strategy Aquatic Species Restoration Plan (http://chehalisbasinstrategy.com/), this status and trend information will inform future questions on the influence of habitat restoration projects or climate change impacts on freshwater production of salmon and steelhead in the Chehalis River.

Table 13. Mean and maximum of daily stream temperatures (°C) by month recorded at Chehalis River smolt trap near river km 84, 2018 - 2021

Year	2018	2019	2020	2021
Month	Maximum (°C)			
March	---	12.1	10.4	9.7
April	14.2	14.9	15.3	16.8
May	20.4	21.0	20.1	20.5
June	24.2	25.2	22.7	29.8
July	25.8	24.7	25.6	26.0

Year	2018	2019	2020	2021
Month	Mean (°C)			
March	---	7.3	8.0	7.9
April	10.2	11.3	11.8	12.2
May	16.4	16.6	15.6	15.8
June	18.5	16.8	17.3	20.2
July	21.7	20.1	19.9	22.3

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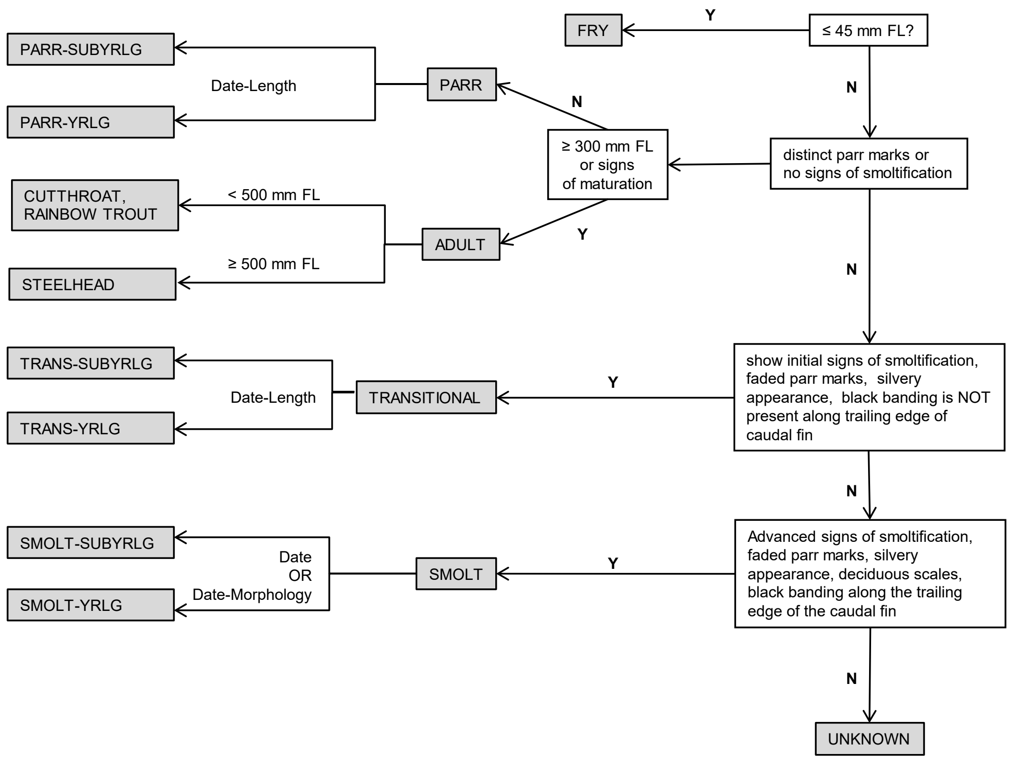
Appendices

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



Updated 2.8.2016

Appendix B. Chehalis River missed trapping periods 2021. All missed trapping periods occurred by staff pulling the trap.

Last Time Observed Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
3/21/21 2040	Visual	3/22/21 0830	Trap Stopper
3/23/21 2200	Visual	3/24/21 0900	Trap Stopper
3/24/21 2200	Visual	3/25/21 0830	Trap Stopper
4/3/21 1200	Visual	4/3/21 1445	Trap Stopper
6/4/21 1015	Scheduled	6/7/21 1220	Crew Days Off
6/11/21 0818	Scheduled	6/15/21 1200	Crew Days Off
6/20/21 1200	Scheduled	6/21/21 2200	Crew Days Off
6/26/21 0900	Scheduled	6/28/21 2124	Excessive Heat
7/3/21 1200	Scheduled	7/5/21 2130	Excessive Boater Traffic

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

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/8	3/14	N/A	N/A	N/A	N/A
2	3/15	3/21	0	0	0	1.00
3	3/22	3/28	11	0	13	1.00
4	3/29	4/4	32	0	37	1.00
5	4/5	4/11	71	3	82	1.00
6	4/12	4/18	330	19	464	1.00
7	4/19	4/25	500	52	2474	1.00
8	4/26	5/2	500	65	9129	1.00
9	5/3	5/9	500	103	7166	1.00
10	5/10	5/16	500	64	5972	1.00
11	5/17	5/23	500	85	1718	1.00
12	5/24	5/30	481	91	1207	0.99
13	5/31	6/6	114	15	528	0.63
14	6/7	6/13	30	6	70	0.55
15	6/14	6/20	51	5	373	0.86
16	6/21	6/27	29	4	55	0.64
17	6/28	7/4	0	0	1	0.66
18	7/5	7/11	0	0	0	0.94

*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 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	3/8	3/14	N/A	N/A	N/A	N/A
2	3/15	3/21	0	0	0	1.00
3	3/22	3/28	5	0	13	1.00
4	3/29	4/4	11	0	37	1.00
5	4/5	4/11	68	3	82	1.00
6	4/12	4/18	125	19	464	1.00
7	4/19	4/25	139	52	2474	1.00
8	4/26	5/2	315	65	9129	1.00
9	5/3	5/9	359	103	7166	1.00
10	5/10	5/16	353	64	5972	1.00
11	5/17	5/23	167	85	1718	1.00
12	5/24	5/30	42	91	1207	0.99
13	5/31	6/6	5	15	528	0.63
14	6/7	6/13	0	6	70	0.55
15	6/14	6/20	2	5	373	0.86
16	6/21	6/27	0	4	55	0.64
17	6/28	7/4	0	0	1	0.66
18	7/5	7/11	0	0	0	0.94

*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 Chinook outmigrants (parr, 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 violating the assumption of trapping over the entirety of the outmigration.

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/8	3/14	N/A	N/A	N/A	N/A
2	3/15	3/21	109	3	136	1.00
3	3/22	3/28	193	17	189	1.00
4	3/29	4/4	184	10	198	1.00
5	4/5	4/11	128	5	124	1.00
6	4/12	4/18	223	17	274	1.00
7	4/19	4/25	290	32	304	1.00
8	4/26	5/2	477	45	927	1.00
9	5/3	5/9	500	78	1689	1.00
10	5/10	5/16	500	61	12651	1.00
11	5/17	5/23	500	99	4473	1.00
12	5/24	5/30	500	77	6186	0.99
13	5/31	6/6	200	21	9091	0.63
14	6/7	6/13	210	21	1235	0.55
15	6/14	6/20	300	24	3487	0.86
16	6/21	6/27	200	23	1899	0.64
17	6/28	7/4	0	0	28	0.66
18	7/5	7/11	4	0	24	0.94

*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.