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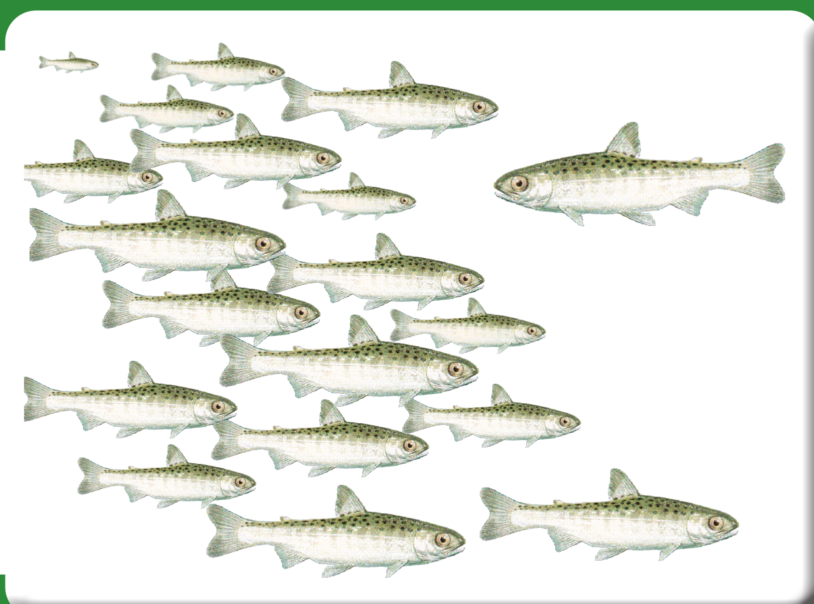
Upper Chehalis River Smolt Production, 2021



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Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 23-07

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Executive Summary

This report provides the first year of results from a juvenile salmonid monitoring study on the Upper Chehalis River main stem near Pe Ell, Washington in 2021. 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 24 to July 2, 2021.

The Chinook salmon outmigrants quantified were subyearlings, not fry. The majority of Chinook fry (≤ 45 mm fork length) outmigrate 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 50.3 mm (± 3.2 mm, standard deviation SD) and 92.1 mm (± 7.6 mm SD) in the first and last sampled week of trapping, respectively. During this time roughly 98% of the total catch of wild Chinook outmigrants were (> 45 mm). Abundance of wild Chinook subyearling outmigrants was estimated to be 118,834 ± 7,513 SD with a coefficient of variation (CV) of 6.3%.

The coho outmigrants quantified were yearlings. Scale age data indicated the presence of two age classes, one- and two-year-olds. The average fork length of age one yearling outmigrants was 115.1 mm (± 11.5 mm SD) and age two yearling outmigrants averaged 131.3 mm (± 17.8 mm SD). Abundance of wild coho outmigrants was estimated to be 12,932 ± 1,656 SD with a CV of 12.6%.

Steelhead outmigrants were one, two, and three years of age. Fork length averaged 149 mm (± 15.7 mm SD) for one-year olds, 162 mm (± 15.3 mm SD) for two-year olds, and 210.5 mm (± 55.4 mm SD) for three-year olds. Abundance of wild steelhead outmigrants was estimated to be 9,736 ± 2,857 SD with a CV of 27.6%.

Table 1. Abundance of Chinook, coho, and steelhead outmigrants that completed their freshwater rearing phase upstream of river kilometer 151.7 (river mile 94.3) of the Upper Chehalis River.

Abundance Group	Origin	Life Stage	Age Class	Abundance ± Standard Deviation	Coefficient of Variation (%)
Chinook	Wild	Transitional, Smolt	Subyearling	118,834 ± 7,513	6.3
Coho	Wild	Transitional, Smolt	Subyearling, Yearling	12,932 ± 1,656	12.6
Steelhead	Wild	Transitional, Smolt	Yearling	9,736 ± 2,857	27.6

Introduction

The Washington Department of Fish and Wildlife 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 1,011 smolts mi^{-2} or 390 smolts km^{-2}) than any other western Washington watershed for which data currently exists (Litz 2023). 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.

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 the integrated status and trends monitoring program used to evaluate salmon and steelhead responses to changes in the riverine environment as a result of habitat restoration and protection actions and climate change (M&AMT 2021). 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 rkm 174 (river mile 108.2) has brought about a 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, our 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. An additional objective in 2021 was to quantify the life history of subyearling Chinook salmon throughout their outmigration. Our research questions were: 1) can subyearling Chinook population estimates be partitioned by fall, spring, and heterozygote run types; and 2) how do proportions of these run types vary across the outmigration? To achieve these objectives, juvenile trapping at a new site in the Upper Chehalis River was conducted in spring and summer 2021. This report includes results from that first field season in 2021.

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 drains numerous small tributaries including Elk, Crim, Big, Rock, Jones, and Browns 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 admarked coho and 25,000 to 30,000 admarked 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. The Quinault tribe also recently began conducting juvenile research downstream of the trap site with multiple fry traps primarily assessing run types and abundance of juvenile Chinook outmigranting fry.

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; West et al. 2021). 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 are termed ‘fry’ (defined as juveniles ≤ 45 mm fork length, FL), which are individuals that outmigrate almost immediately after emergence. Fry are observed at the smolt trap beginning in mid-March but have been presumably out-migrating since January, based on other smolt traps in the Puget Sound and other areas (Anderson and Topping 2018; Zimmerman et al. 2015; Kiyohara and Zimmerman 2012; Groot and Margolis 1991). The second pulse of Chinook outmigrants are termed ‘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 and represented an area of high interest within the basin where conditions (e.g., flow, depth) were favorable and site access was granted for trapping operations.

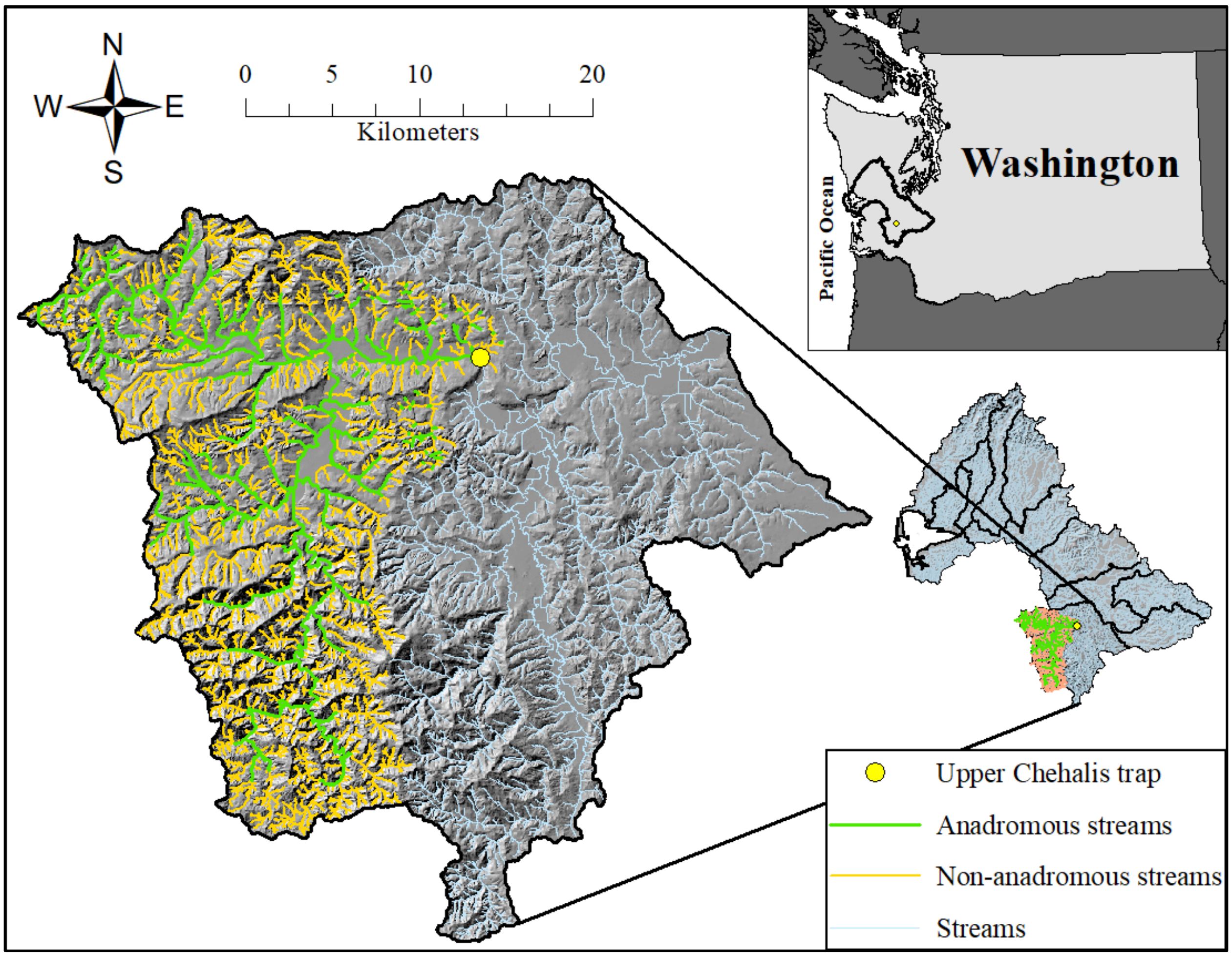


Figure 1. Upper Chehalis main stem rotary screw trap (46.634747, -123.167972). Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (299.8 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the upper Chehalis River rotary screw trap. 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 2021, the trap was scheduled to operate continuously from March 24 through July 2, although unscheduled trap outages did occur due to high flows, warm (> 18°C) water temperatures (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 13.41 km upstream of the trap (USGS 12020000).

Figure 2. Upper Chehalis River trap site.

Fish Collection

Fish sampling commenced daily in the morning 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, transferred to 5-gallon buckets, and moved to small dish tubs for sampling. Fish were anaesthetized with tricaine methanesulfonate (MS-222) prior to enumeration and biological sampling. An anaesthetizing solution was created by diluting 10 – 25 ml of a MS-222 solution (5g of MS-222 dissolved in 500 ml of water in a 500 ml container) into 2 – 3 L of water. This solution was replaced as necessary. Samplers continually evaluated fish response to the solution and targeted the lowest dosages needed to complete biological sampling.

During sampling, all fish were identified to species and enumerated. Chinook, coho, and steelhead were further categorized by life stage and age class. 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. We expected to capture hatchery origin coho and steelhead, released upstream of the trap site at WDFW acclimation ponds located on Eight Creek, a tributary to Elk Creek. Fork length (FL) and scales were collected from a subsample of wild (adipose fin intact) coho and steelhead (Table 2). Only fork lengths were collected from Chinook (no scales). Genetic samples were also collected from Chinook subyearlings to achieve a secondary objective for this study of quantifying the life history 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	Chinook	1st 10 daily	1st 10 daily	1st 10 daily
	Coho	1st 10 daily	1st 10 daily	All efficiency marked individuals (100 daily)
	Steelhead	1st 10 daily[a]	1st 10 daily	All Efficiency marked individuals (100 daily)
Scales	Chinook[b]	---	---	---
	Coho	---	---	1st 5 daily
	Steelhead	---	---	1st 5 daily
DNA	Chinook	---	---	1st 10 daily up to 50 weekly
	Coho	---	---	---
	Steelhead	---	---	---

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

Life stage categories followed WDFW protocols developed for the Lower Columbia ESU monitoring program (see Appendix A for life stage decision tree). The five life stage categories include fry, parr, transitional, smolt, and adult. Fry and adults were assigned based on length criteria (fry ≤ 45 mm FL and adults > 300 mm FL [cutthroat], 301 – 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. 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 age (Table 3). For these reasons 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 4). 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 5). Therefore, the age composition of steelhead was further described using scale data.

Table 3. 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

Table 4. 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 5. 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	> 45
Adult (Resident RBT)	NA	Start – end	300 - 499
Adult (STLH kelt)	NA	Start – end	> 500

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 using selected species, origin, and life stages to estimate outmigrant abundance (Table 6). Species included in the trap efficiency trials were Chinook, coho, and steelhead. All trap efficiency trials were conducted with wild (adipose fin intact) fish. For Chinook, trap efficiency trials were conducted with transitional and smolt life stages because these were the life stages for which we intended to generate an abundance estimate. Efficiency trials were not conducted on Chinook fry outmigrants as the trap was not operated 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. The goal was to mark a maximum of 100 fish per species per day and 700 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 estimates were subyearling (SY) and yearling (Y). FL = Fork length.

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

Marked fish were released 1.43 kilometers upstream of the trap location at the intersection of River Rd and State Route 6 (Table 7).

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 7). Releases generally occurred within 1-3 hours of the start of a trap check.

Table 7. Trap efficiency marks and release locations for each abundance estimate group. Efficiency marks are visible implant elastomer tag (VIE) and passive integrated transponder tag (PIT).

	Trap Efficiency Marks			Release location	
Abundance Group	Mark Types	Rotation Schedule	Mark Rotation	Description	Distance upstream of trap (rkm)
Chinook	VIE	Weekly	5 week	Intersection	1.43
Coho	PIT	Individual	Individual	Intersection	1.43
Steelhead	PIT	Individual	Individual	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. 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

The Bayesian Time-Stratified Population Analysis System (BTSPAS, Bonner and Schwarz 2014) was used to estimate abundance of Chinook, coho, and steelhead (Table 6). This method uses Bayesian P-splines and hierarchical modeling of trap efficiencies to determine abundance with known precision through time, which allows for estimation during missed trapping days and for time strata with minimal efficiency data (Bonner and Schwarz et al 2011). Data for the analysis were stratified by week and included the total catch of unmarked fish (i.e., maiden captures), marks released, marks recaptured, and proportion of time sampled. The proportion of time sampled each week was included to adjust for missed catch during trap outages.

No trapping occurred from June 26 to June 28, 2021, due to river temperatures > 18°C. However, for the missed trapping period, 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 Chinook and steelhead, two periods were added prior, and one period post the trapping season. For coho, two periods were added prior to the trapping season. 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 coho and Chinook estimates, a BTSPAS non-diagonal model was used, and for steelhead the diagonal model was used. In each case, the model arguments were as follows: number of chains = 4, iterations = 10,000, burn-in = 5,000, sims = 2,500 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 1.1 for all parameters (Gelman et al. 2004). The BTSPAS analysis was executed in R v.3.4.1 (R Core Team, 2017) using R version 2021.1.1 (R Core Team 2021) and the BTSPAS package (Bonner and Schwarz 2014).

Genetics

Genetic samples were collected from subyearling migrant Chinook originating from upstream of our trapping location on the upper Chehalis River (rkm 151.7) 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 comprised 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

A diverse assemblage of fish species were encountered throughout the 2021 trapping season. Native fish included juvenile Chinook and coho salmon, steelhead and cutthroat trout, redside shiner (*Richardsonius balteatus*), dace species (*Rhinichthys spp.*), speckled dace (*R. osculus*), longnose dace (*R. cataractae*), sucker species (*Catostomus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), Pacific lamprey (*Entosphenus tridentatus*), brook lamprey (*Lampetra planeri*), and sculpin (Cottidae). Non-native fish included rock bass (*Ambloplites rupestris*).

Trap operation

The trap was operated from March 24, 2021 to July 2, 2021. There were four occurrences of trap outages (Appendix B). For all four events, the outage time was known exactly because the trap stopped fishing either when staff lifted the cone during periods of high flows, temperatures > 18°C, debris and maintenance, or there was a trap alarm. The first of these events began on June 26, 2021, and lasted for two days due to high river temperatures. The next three outages lasted for less than 4 hours.

Assumption Testing Trials

In 2021, 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, 29 tagged) for Chinook and 100% (passive integrated transponder = PIT tag, 10 tagged) for coho and 100% (PIT tag, 18 tagged) for steelhead. A double tag/mark experiment with steelhead also indicated that mark retention was high at 93.7% (16 total recaps, 15 with PIT tag and scar present at time of recapture). For all trials, mark/tag related mortality was low. Estimated survival was 89.7% (VIE, 26 out of 29 tagged) for Chinook and 100% for coho (PIT tag, 10 out of 10 tagged) and 100% for steelhead (PIT tag, 18 out of 18 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 versus recaptures did differ significantly for Chinook during period 13 ($D = 0.33$, $p < 0.01$). For Chinook during this period, maiden captures were larger than recaptures. PIT tagging coho and steelhead allowed for logistic regression analysis of probability of recapture by fork length. The relationship for coho between probability of recapture and fork length was not significant ($p = 0.94$) and the relationship for steelhead was significant ($p = 0.02$), indicating that tagged steelhead may be more susceptible to recapture than non-tagged fish.

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 22th, trapping period 3), peaked around the third week of June, and declined to low numbers again by the last week of trapping (July 2th, trapping period 17, Figure 3, Appendix C).

Generally, all Chinook outmigrants were assumed to be Age-0. Chinook ranged from 45 to 105 mm. Fork length of Chinook increased steadily throughout the season with an average of 50.3 mm (± 3.2 mm SD) and 92.4 mm (± 5.9 mm SD) in the first and last weeks of trapping, respectively (Figure 4).

A total of 15,168 Chinook subyearling outmigrants were captured of these, 4,593 were marked, and 634 were recaptured (Appendix C; Periods 1 – 18). Modeled weekly trap efficiencies ranged from 4.2 to 18.1%. Trap efficiency and maiden catches may be affected by river flows. In 2021, average daily river flows increased to > 100 cubic feet per second (CFS) on June 13th and 14th (Figure 5). Abundance of wild Chinook subyearling outmigrants was estimated to be 118,834 ± 7,513 SD with a coefficient of variation (CV) of 6.3%.

In 2020, the total number of adult spring Chinook that spawned in the Chehalis River above our trap site was estimated to be 128 (all NOR) and adult fall Chinook was estimated to be 996 (all NOR), producing an overall smolt-per-adult estimate of 105.7 for the 2020 brood year of naturally spawning Chinook (C. Holt, WDFW, personal communication). Estimating subyearling Chinook productivity through time is a goal of this study going forward.

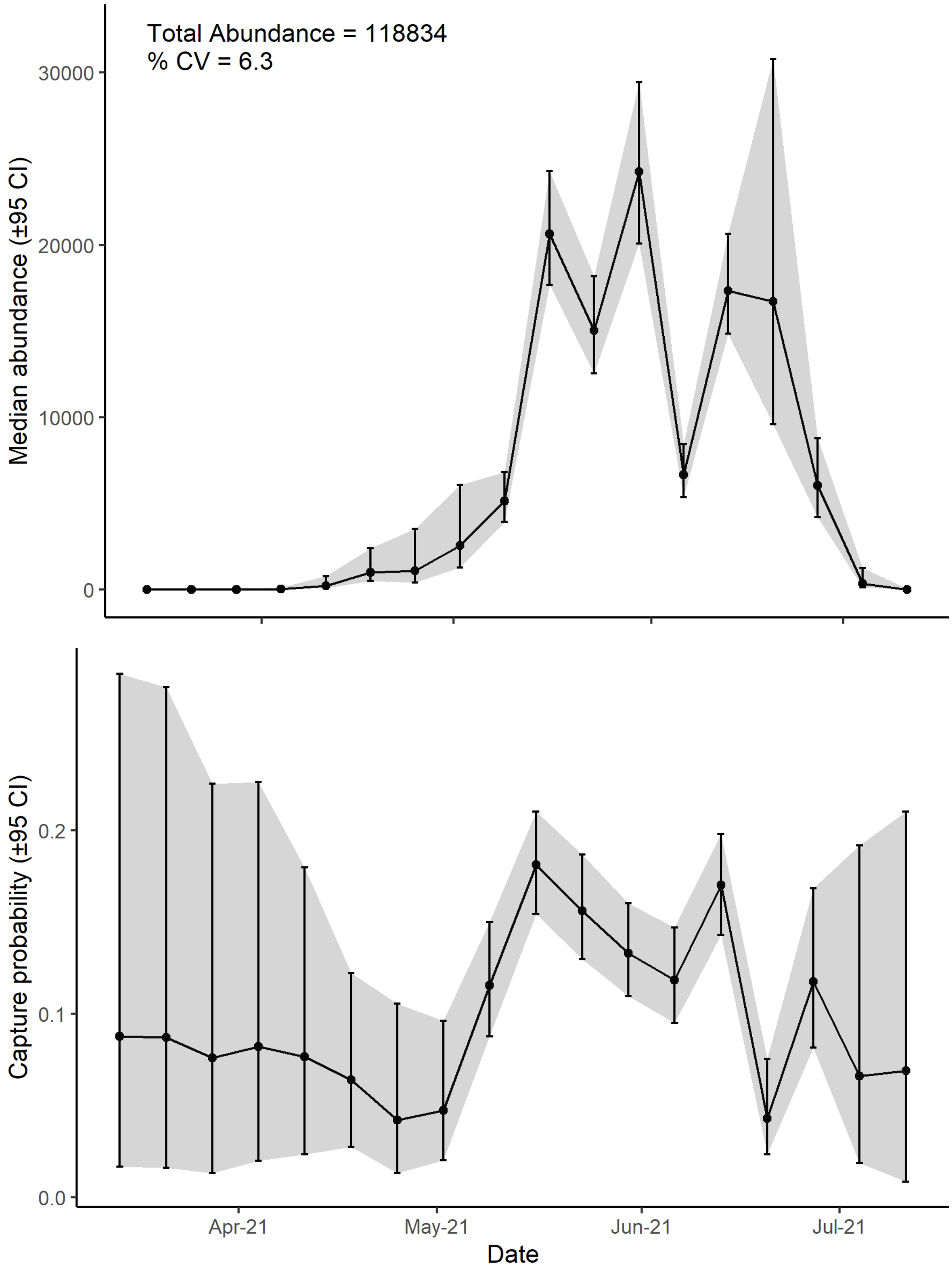


Figure 3. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Upper Chehalis River smolt trap in 2021. The total estimate is 118,834 with a CV of 6.3%. Error bars and shading around point estimates represent 95% confidence intervals.

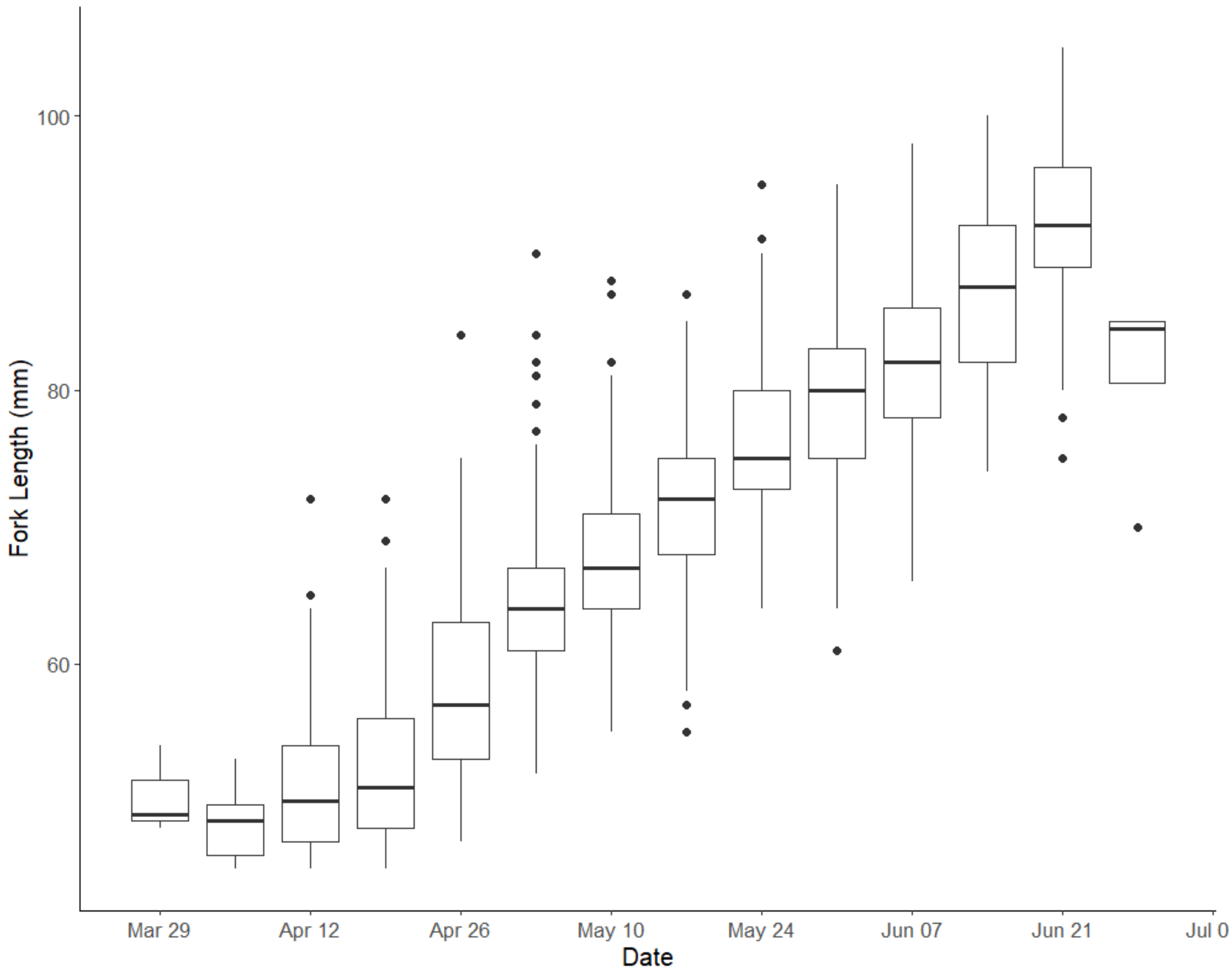
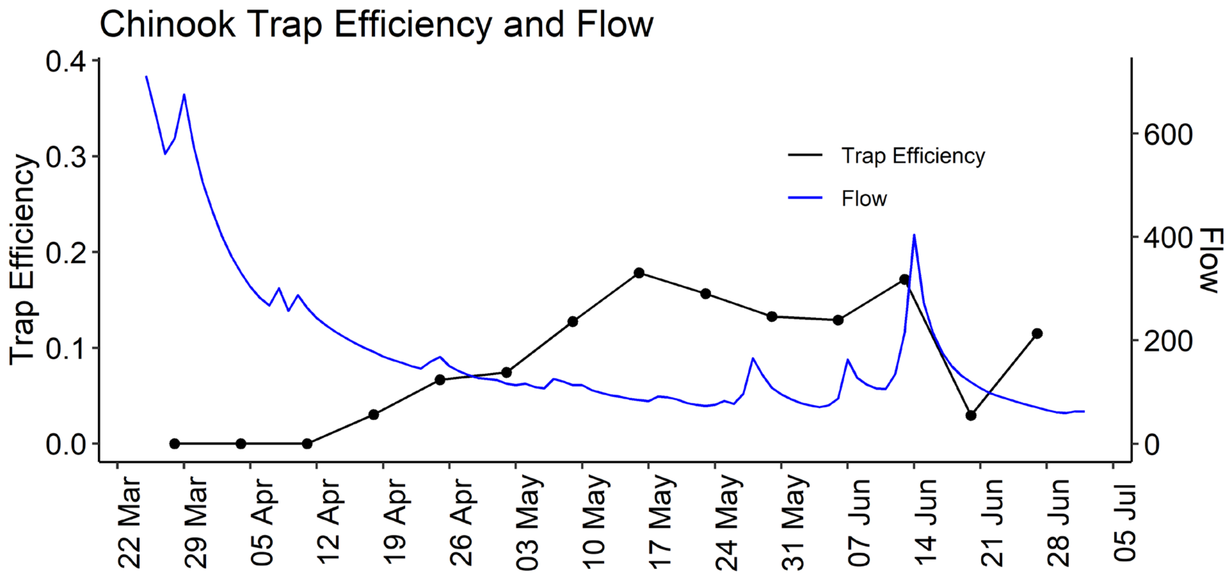


Figure 4. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Upper Chehalis River screw trap, 2021. Boxes represent the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.



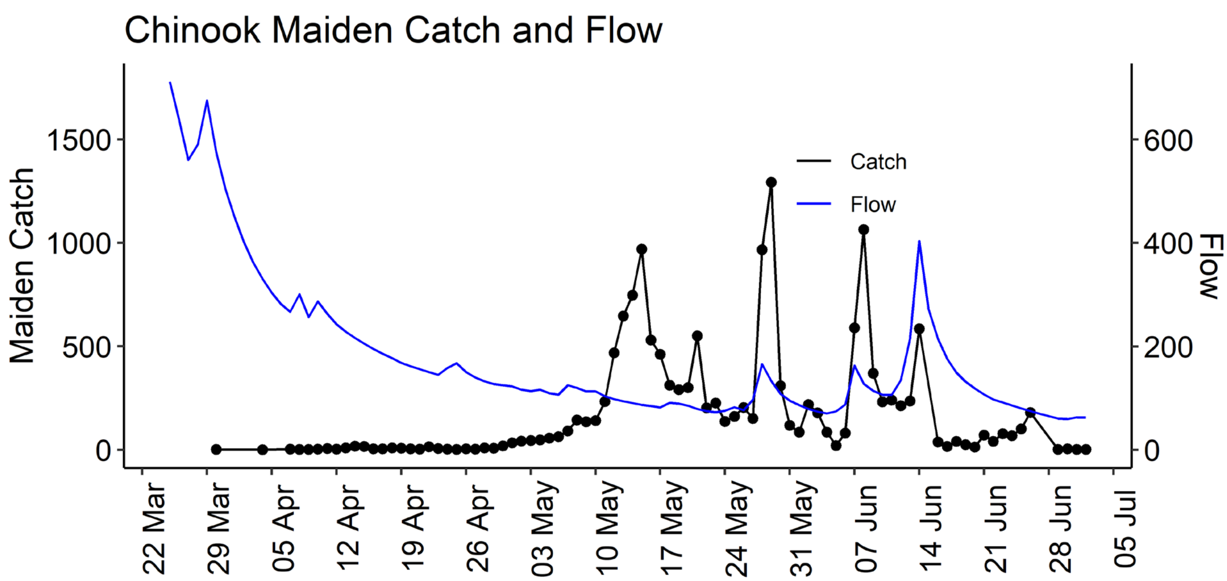


Figure 5. Chinook wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow in cubic feet per second (CFS top & bottom) as a function of period at the Upper Chehalis smolt trap in 2021.

Chinook subyearling abundance by run type

A total of 563 juvenile Chinook tissue samples from the upper Chehalis River smolt trap were sent to the lab for processing in 2021. Of those, SNP genotypes were successfully obtained from 440 samples (78%). Chinook subyearlings had one of three genotypes associated with run-timing: homozygous spring (two copies of a spring allele), homozygous fall (two copies of a fall allele), and heterozygote (one spring allele and one fall allele, unknown run timing). Proportions of spring, fall, and heterozygote genotypes by week were apportioned according to the weekly median abundance estimates with known precision based on results from the mark-recapture study (Table 8, Figure 6). No fish were sampled in the first three or final two weeks 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 1,073 (0.9%) spring Chinook, 104,294 (89.0%) fall Chinook, and 11,819 (10.1%) of unknown run timing (i.e., heterozygotes).

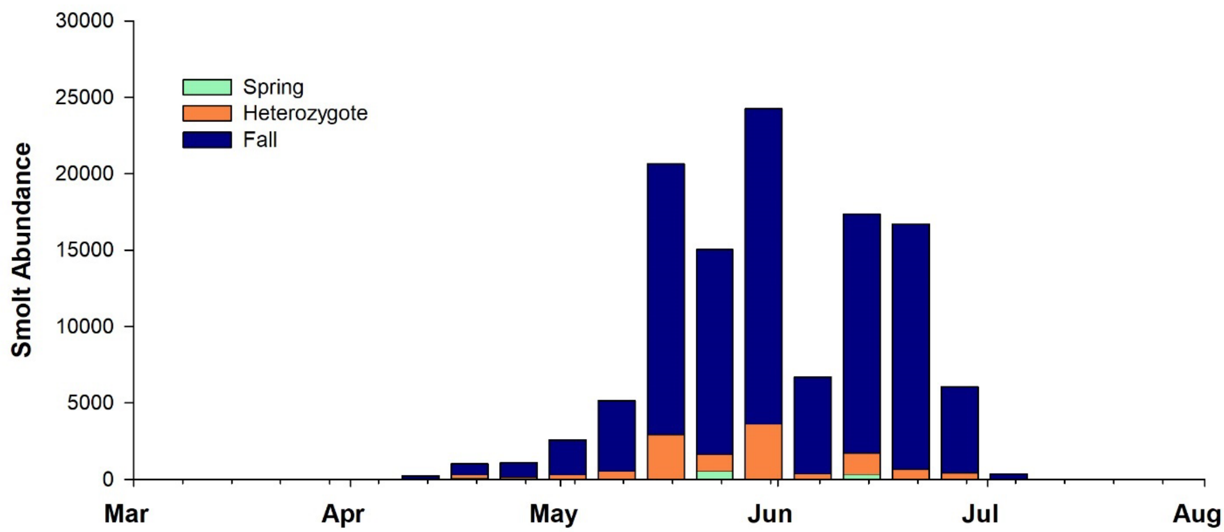


Figure 6. Chinook subyearling SNP genotype weekly median estimates from the upper Chehalis River trap by date. SNP genotypes are associated with adult run timing in Chehalis Chinook salmon (Thompson et al. 2019).

Table 8. Chinook subyearling genetic weekly median estimates by period and run type at the upper Chehalis River screw trap.

Period	Start Date	End Date	Spring	Heterozygote	Fall	Total
1	8-Mar	14-Mar	0	0	0	0
2	15-Mar	21-Mar	0	0	0	0
3	22-Mar	28-Mar	0	0	3	3
4	29-Mar	4-Apr	0	0	33	33
5	5-Apr	11-Apr	0	67	166	233
6	12-Apr	18-Apr	113	198	708	1,019
7	19-Apr	25-Apr	56	112	925	1,093
8	26-Apr	2-May	0	303	2,270	2,572
9	3-May	9-May	0	555	4,595	5,150
10	10-May	16-May	0	2,948	17,688	20,635
11	17-May	23-May	557	1,114	13,367	15,037
12	24-May	30-May	0	3,637	20,610	24,246
13	31-May	6-Jun	0	371	6,311	6,682
14	7-Jun	13-Jun	347	1,388	15,615	17,350
15	14-Jun	20-Jun	0	668	16,034	16,702
16	21-Jun	27-Jun	0	433	5,625	6,058
17	28-Jun	4-Jul	0	26	338	364
18	5-Jul	11-Jul	0	0	6	6
Totals			**1,073 (0.9%)**	**11,819 (10.1%)**	**104,294 (89.0%)**	**117,186**

Coho

The coho outmigrant estimate included yearlings in transitional and smolt life stages. Approximately 73% of the outmigrants observed at the trap were categorized as the ‘smolt’ phenotype whereas 27% were categorized as ‘transitional’. Coho outmigrants were observed in low numbers the first week of trapping (March 22th, trapping period 3), peaked in late May, and were last observed the week of June 21st (trapping period 16, Figure 7, Appendix D).

Scale age data indicated no subyearling component of the coho juvenile outmigration. A total of 317 scale samples were collected and 91.2% were successfully aged. Age 1 coho were the dominant age class (93.4%) and age 2 were much less prevalent (6.6%) (Figure 8, Table 8). Fork length of yearling outmigrants averaged 115.1 mm (± 11.5 mm) whereas fork length of two-year-old outmigrants averaged 131.3 mm (± 17.8 mm).

In 2021, a total of 903 coho outmigrants were captured, 887 coho were marked, and 64 were recaptured (Appendix D). Modeled weekly trap efficiencies ranged from 6.7 to 7.5%. Trap efficiency and maiden catches may both be affected by river flows. In 2021 average daily river flows increased to > 100 cubic feet per second (CFS) on June 13th and 14th (Figure 9). The abundance of 2021 wild coho outmigrants was estimated to be 12,932 ± 1,656 (SD) with a CV of 12.6%.

In 2019, the total number of adult coho spawners in the Chehalis River upstream of the trap site was estimated to be 1,395 (all NOR), producing a smolt-per-spawner estimate of 9.3 for the 2019 brood year of naturally spawning coho (C. Holt, WDFW, personal communication). Estimating coho productivity through time is a goal of this study going forward.

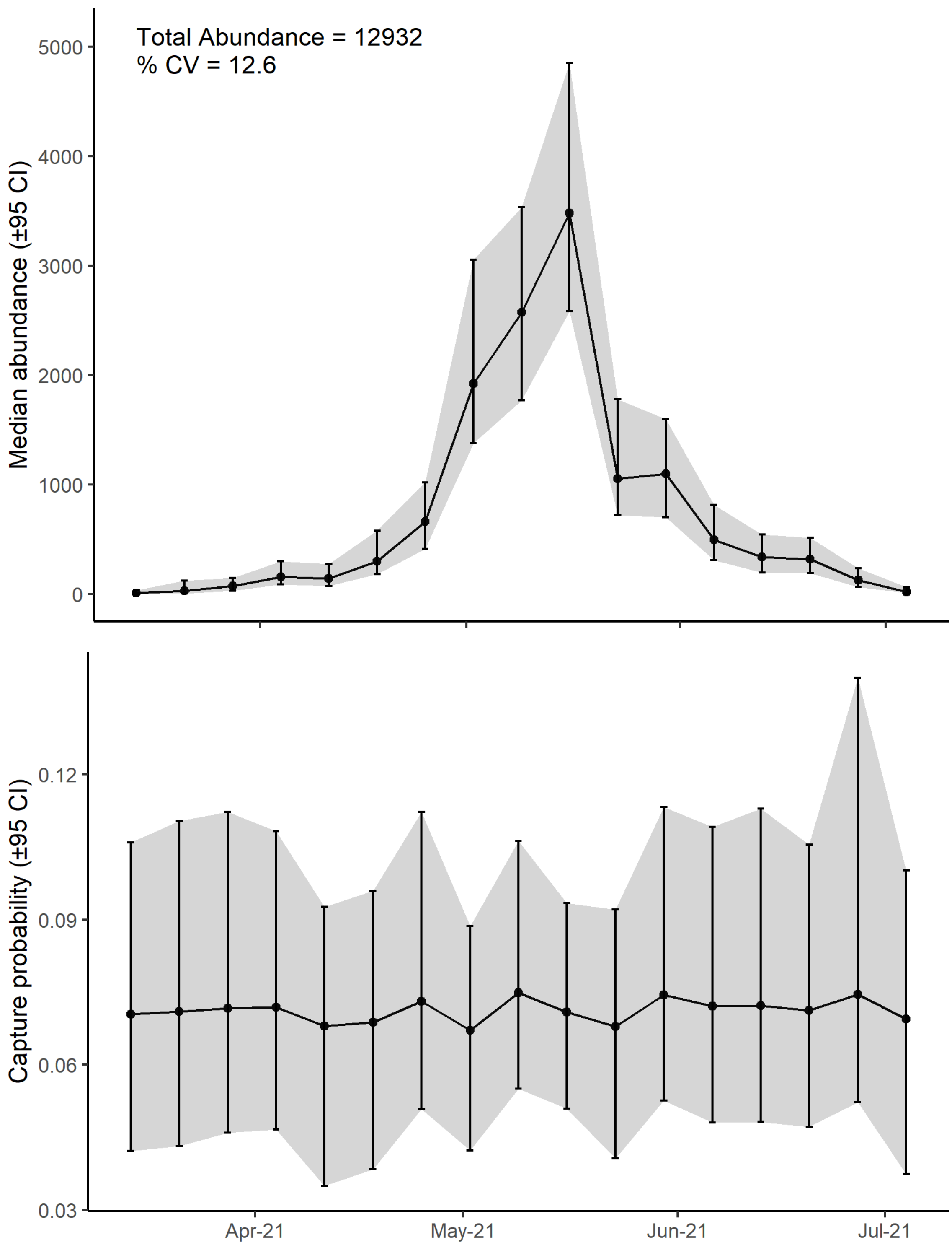


Figure 7. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho smolts and transitionals produced above the Upper Chehalis River smolt trap in 2021**.** The total estimate is 12,932 with a CV of 12.6%. Error bars and shading around point estimates represent 95% confidence intervals.

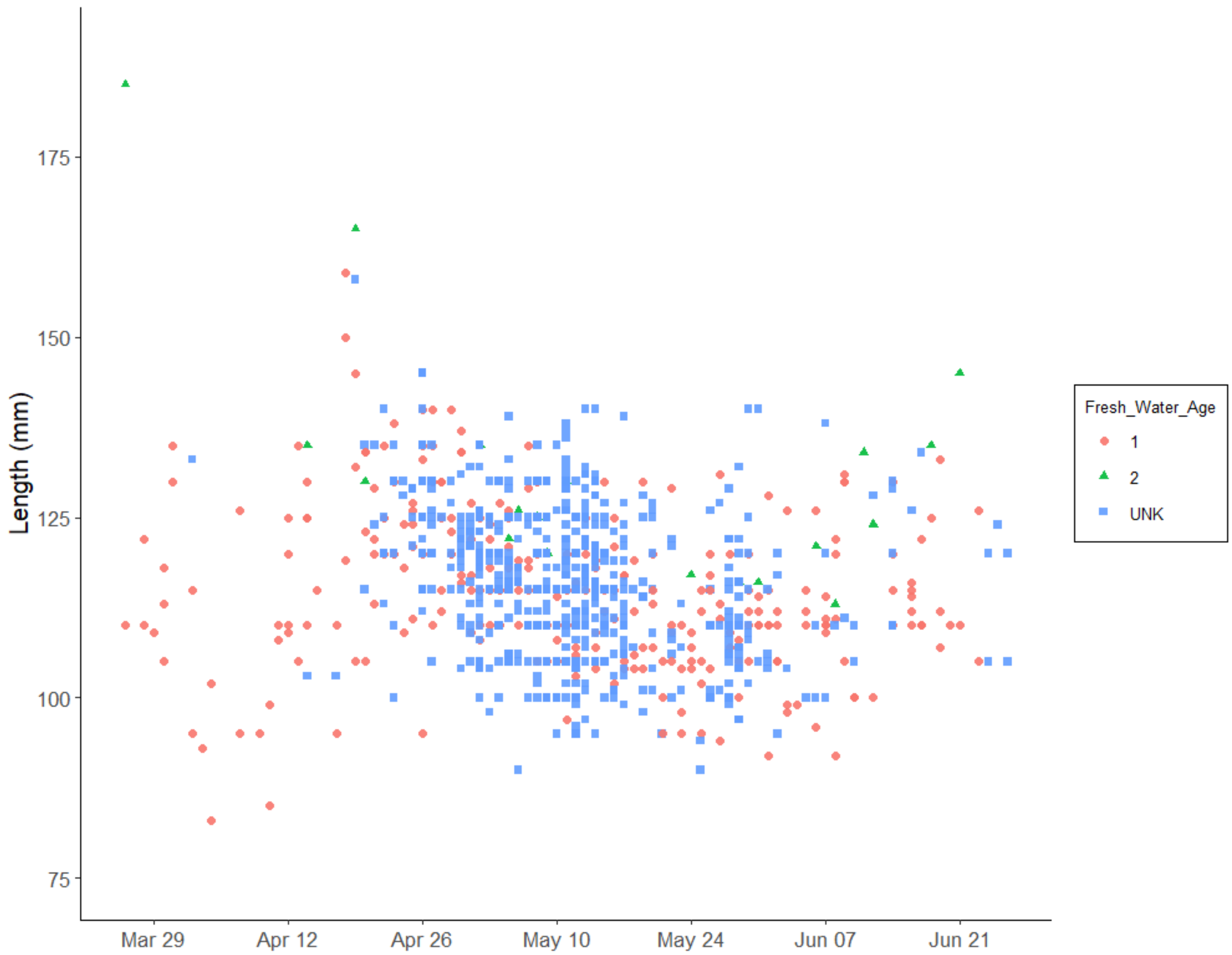


Figure 8. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2021.

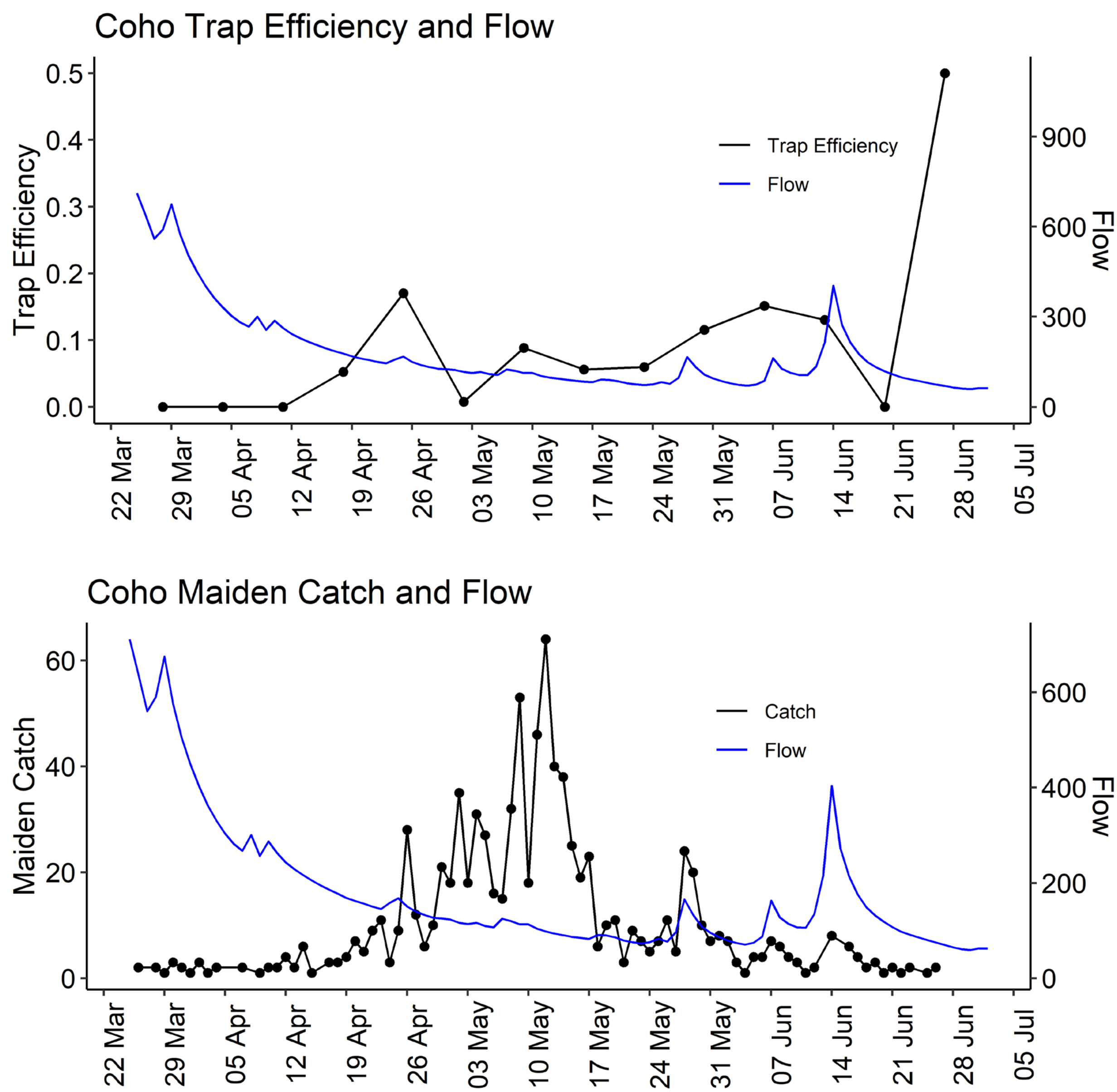


Figure 9. Coho wild transitional and smolt trap raw efficiency (top), maiden catch (bottom) and flow in CFS (top & bottom) as a function of period at the Upper Chehalis smolt trap in 2021.

Table 9. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Upper 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
3	3/22	3/28	4	0	3	1	0
4	3/29	4/04	12	0	11	0	1
5	4/05	4/11	7	0	7	0	0
6	4/12	4/18	18	0	16	1	1
7	4/19	4/25	32	0	28	2	2
8	4/26	5/02	35	0	33	1	1
9	5/03	5/09	35	0	28	4	3
10	5/10	5/16	35	0	31	1	3
11	5/17	5/23	33	0	27	0	6
12	5/24	5/30	35	0	28	2	5
13	5/31	6/06	27	0	22	2	3
14	6/07	6/13	20	0	16	3	1
15	6/14	6/20	20	0	17	1	2
16	6/21	6/27	4	0	3	1	0
17	6/28	7/04	0	0	0	0	0

Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Of these life stages, approximately 59% of outmigrants observed were classified as the smolt phenotype compared to 41% transitional. Steelhead outmigrant numbers were low during the first week of trapping March 22 (trapping period 1), peaked mid-May, and were last observed the week of June 28 (trapping period 17) (Figure 10, Appendix E).

Scale age data indicated that the sampled steelhead were one, two, and three years of age (Figure 11, Table 11). Fork length averaged 149 mm (± 15.7 mm) for one-year olds, 162 mm (± 15.3 mm) for two-year olds, and 211 mm (± 64 mm) for three-year olds. Age composition of successfully aged steelhead was 71.4% Age-1, 26.5% Age-2, and 2.1% Age-3.

A total of 376 steelhead outmigrants were captured throughout the season (Appendix E). A total of 373 steelhead were marked and 16 were recaptured. Modeled weekly trap efficiencies ranged from 3.5% to 4.4%. Trap efficiency and maiden catches may both be affected by river flows. In 2021 average daily river flows increased to > 100 cubic feet per second (CFS) on June 13th and 14th (Figure 12). Abundance of wild steelhead outmigrants was estimated to be 9,736 ± 2,857 (SD) with a CV of 27.6%.

Adult steelhead spawners contributing to the 2021 smolt outmigration came from the 2017 through 2019 brood years. Spawners were estimated to be 1,143, 963, and 1,078 for these years, respectively (C. Holt, WDFW, personal communication). More monitoring is required to estimate steelhead productivity above the trap by brood year, but that is a project goal.

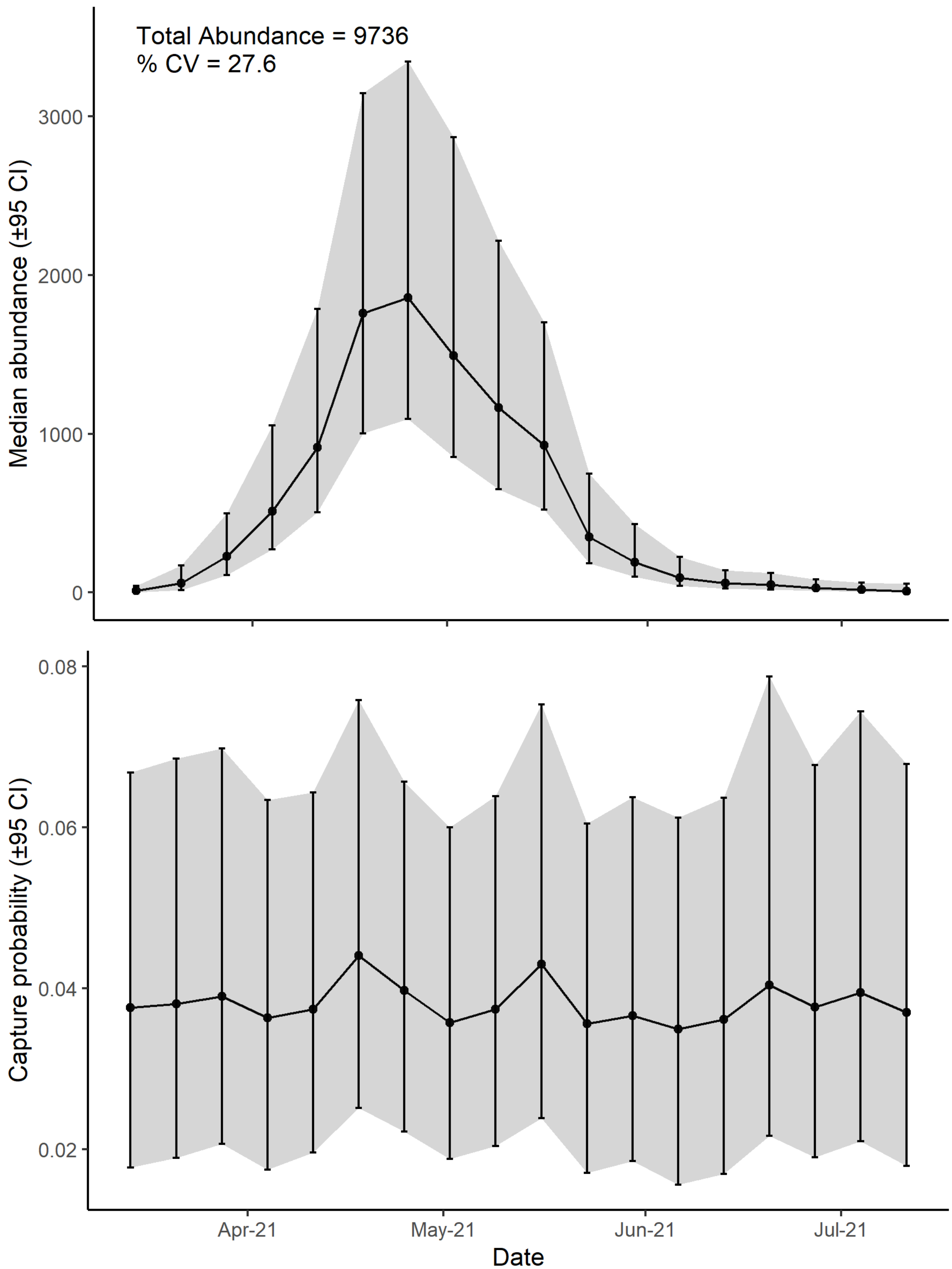


Figure 10. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild steelhead smolts and transitionals produced above the Upper Chehalis River smolt trap in 2021**.** The total estimate is 9,736 with a CV of 27.6%. Error bars and shading around point estimates represent 95% confidence intervals.

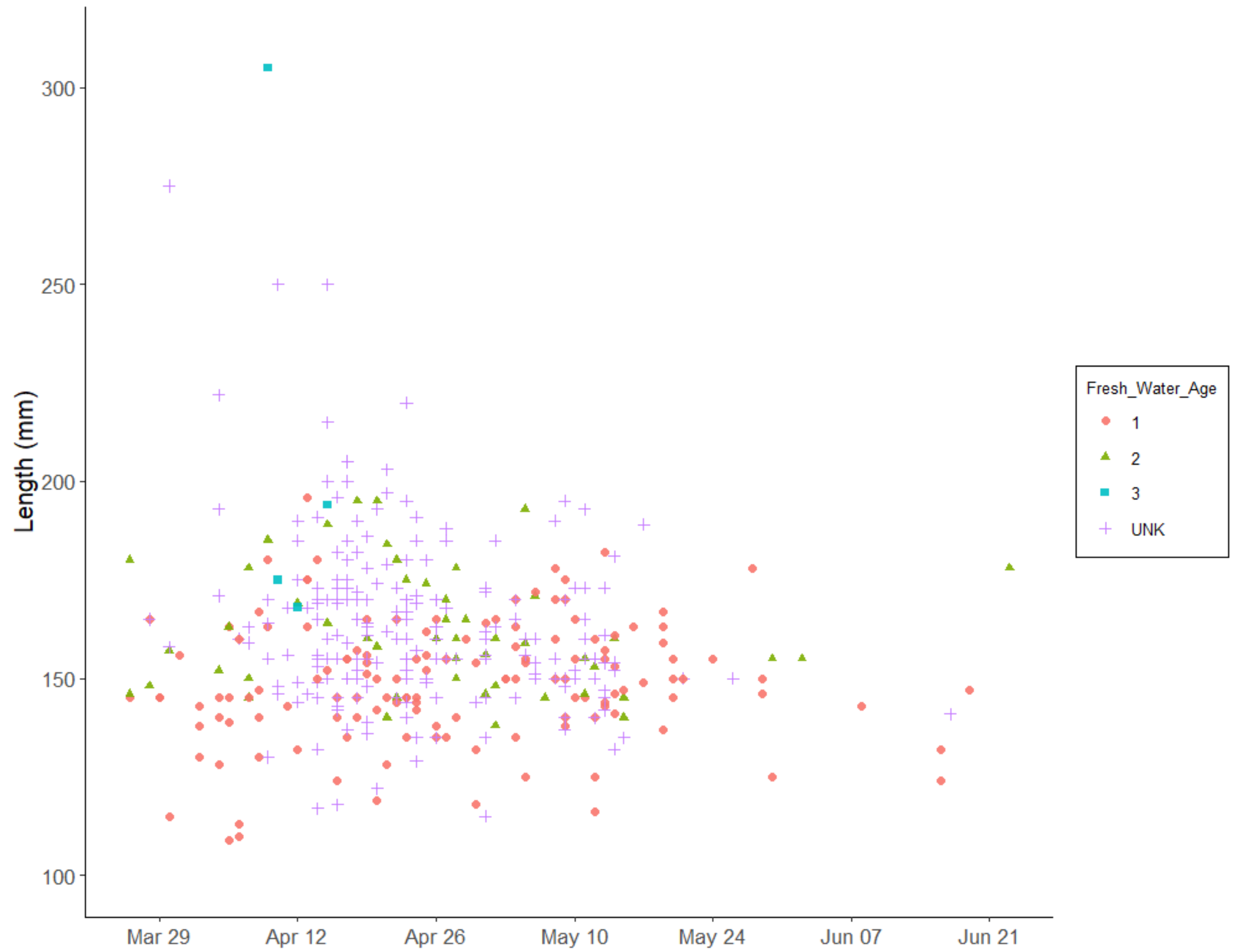
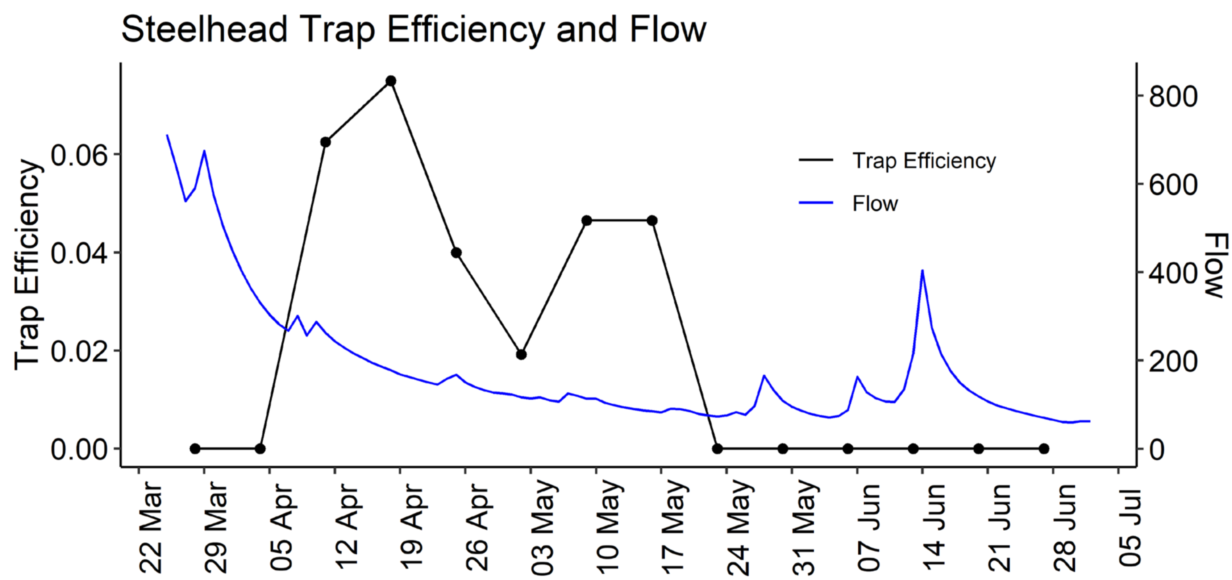


Figure 11. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Upper Chehalis River screw trap, 2021.



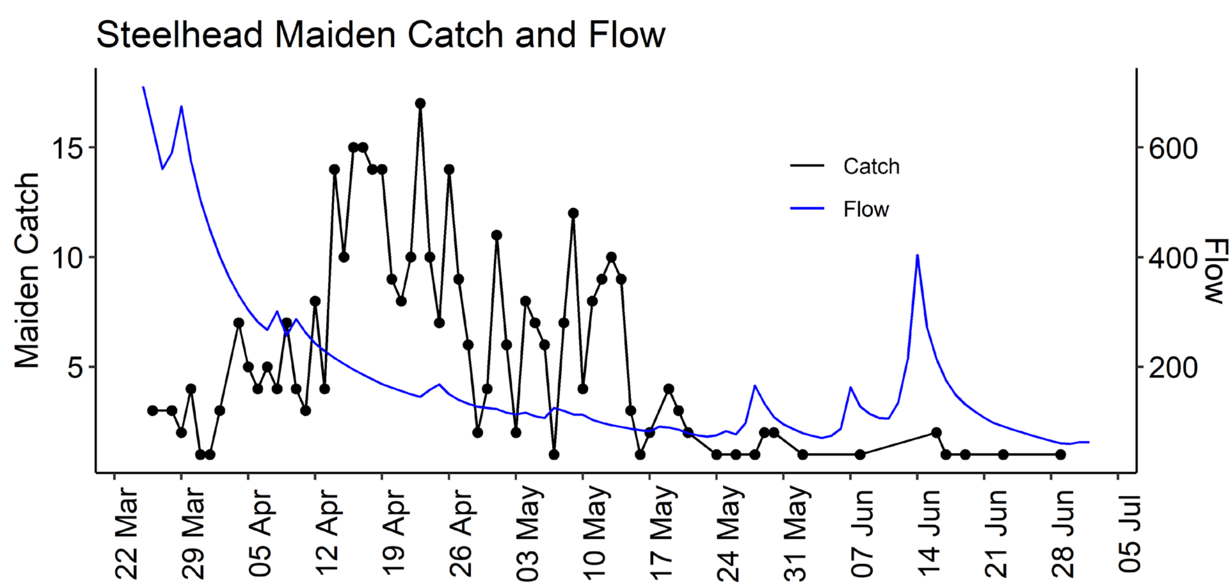


Figure 12. Steelhead wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow CFS (top & bottom) as a function of period at Upper Chehalis smolt trap in 2021.

Table 10. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Upper 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
3	3/22	3/28	6	2	3	0	1
4	3/29	4/04	15	10	2	0	3
5	4/05	4/11	31	15	5	2	9
6	4/12	4/18	34	17	4	2	11
7	4/19	4/25	35	22	9	0	4
8	4/26	5/02	31	12	14	0	5
9	5/03	5/09	28	20	4	0	4
10	5/10	5/16	28	19	6	0	3
11	5/17	5/23	11	9	0	0	2
12	5/24	5/30	7	5	1	0	1
13	5/31	6/06	1	0	1	0	0
14	6/07	6/13	1	1	0	0	0
15	6/14	6/20	4	3	0	0	1
16	6/21	6/27	1	0	1	0	0

Discussion

Basin-wide Context

This report presents results from the 2021 salmon and steelhead smolt outmigration of the Upper Chehalis River and includes the first 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 a 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 the percent spawner contribution above the FRE facility relative to the entire Chehalis basin for spring Chinook, fall Chinook, coho, and steelhead was 1.24%, 3.37%, 2.72% and 15.43%, 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 only

4% of the basin's spawning habitat for steelhead occurring in this area (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 to steelhead production in the Chehalis Basin and provide much-needed 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.

The estimate of Chinook subyearling outmigrants represents a portion of the total freshwater production of Chinook upstream of the trap location in 2021 since it does not include the earlier timed fry migrants. The subyearling estimate of 118,834 Chinook is the first reportable estimate ever produced for this portion of the Chehalis basin. This estimate represents 27.1% of the total subyearling production above the Lower Chehalis mainstem trap (rkm 84) in 2021 (Olson et al. in press). 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 > 95% of adult Chinook returning to the upper Chehalis had a subyearling life history (Campbell et al. 2017). Fry migrants do not spend much time rearing in freshwater habitats but rather make extensive use of downstream, 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 concluded that abundance of this life history reflects a freshwater rearing capacity (Anderson and Topping 2018, Zimmerman et al. 2015). Additional Chinook production beyond this capacity appears 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.

By combining a genetic approach with our abundance estimates, we successfully estimated the abundance of outmigrating Chinook salmon with three genotypes associated with adult run timing. Our results suggest that the fall run genotype represents the largest component of the subyearling outmigration (89.0%) followed by those of unknown run timing (i.e., heterozygotes; 10.1%), and the homozygous spring run type (0.9%). The number of spring Chinook spawners upstream of the trap in 2020 was 128 (11.4% of the total) and the number of fall Chinook spawners was 996 (88.6% of the total). Spawning ground surveys do not account for heterozygous run types, but the genetic results indicate that many of the spring Chinook spawner field calls upstream may be misclassified and are the heterozygous run type. More work to determine the relative abundance of adult spring, fall, and heterozygous run types in the upper basin is required to fill this current data gap.

The run timing of heterozygotes in the Chehalis Basin is unknown. Genotypes of adults with known run timing were used to verify the association of our SNP markers, however, these samples contained few heterozygotes (Thompson et al. 2019). Heterozygotes are believed to show intermediate run timing (i.e., summer), but this is unverified in the Chehalis Basin. Future efforts to disentangle run timing of spring, fall, and heterozygotes could include work to verify the run timing of heterozygote adults. Our analysis is valuable because it now allows us to track subyearling abundance trends across all run types and determine their production trends which is critical information for determining if habitat restoration, protection, or climate change are impacting run types disproportionately. However, more work to characterize the relative proportion and production of fry by run type is needed.

Estimates of annual freshwater production of wild coho smolts in the Chehalis River Basin averaged 2.1 million (0.5 to 3.7 million) since WDFW began monitoring smolt production in the 1980s (Litz 2023). 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 freshwater production of coho salmon from upstream of our trapping location relative to basin-wide production was estimated to be quite low at 0.6% in 2021. 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 for 2021 was 12,932. This number represents 5.9% of the estimate for coho production above our Lower Chehalis mainstem trapsite in 2021. 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).

This report provides the first reportable estimate of wild steelhead smolt production from the Upper Chehalis River basin upstream of river kilometer 151.7. This estimate represents 31.5% of the estimate for steelhead production above the Lower Chehalis mainstem trapsite in 2021. The estimate of 9,736 steelhead outmigrants from the roughly 299.8 anadromous rkm upstream of the trap (Walther 2021) corresponds to 32.5 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 the high gradient, 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). Scale results indicated a higher proportion of age 1 steelhead as compared to our other trapping operation within the Chehalis basin.

Successfully aged steelhead ages 1-3 proportions were: 71.4%, 26.4% and 2.1%, respectively. This high proportion of age 1 migrants shows an early migration age and possible rearing below the trapsite. 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.

Next Steps

The Upper 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. 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℃ and 30.6℃, 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 12). When river temperature exceeds 18°C sampling protocols were minimized to reduce fish stress. Another challenge faced during the 2021 trapping season was the difference in river flows throughout the trapping season. At the start of the season Chehalis River flows near Doty were nearly 900 cfs and when the season concluded flows had dropped to 55 cfs. Given the extreme flow conditions of the river in January and February when Chinook fry are out-migrating, there are no plans to fish the trap during the early-timed fry migration as changes in flow make it difficult to maintain minimal trapping positions throughout the outmigration.

Table 11. Mean monthly stream temperatures °C recorded at Upper Chehalis River smolt trap near river km 151.7, 2021.

Month	Mean (℃)
April	12.7
May	14.5
June	18.8
July	22.1

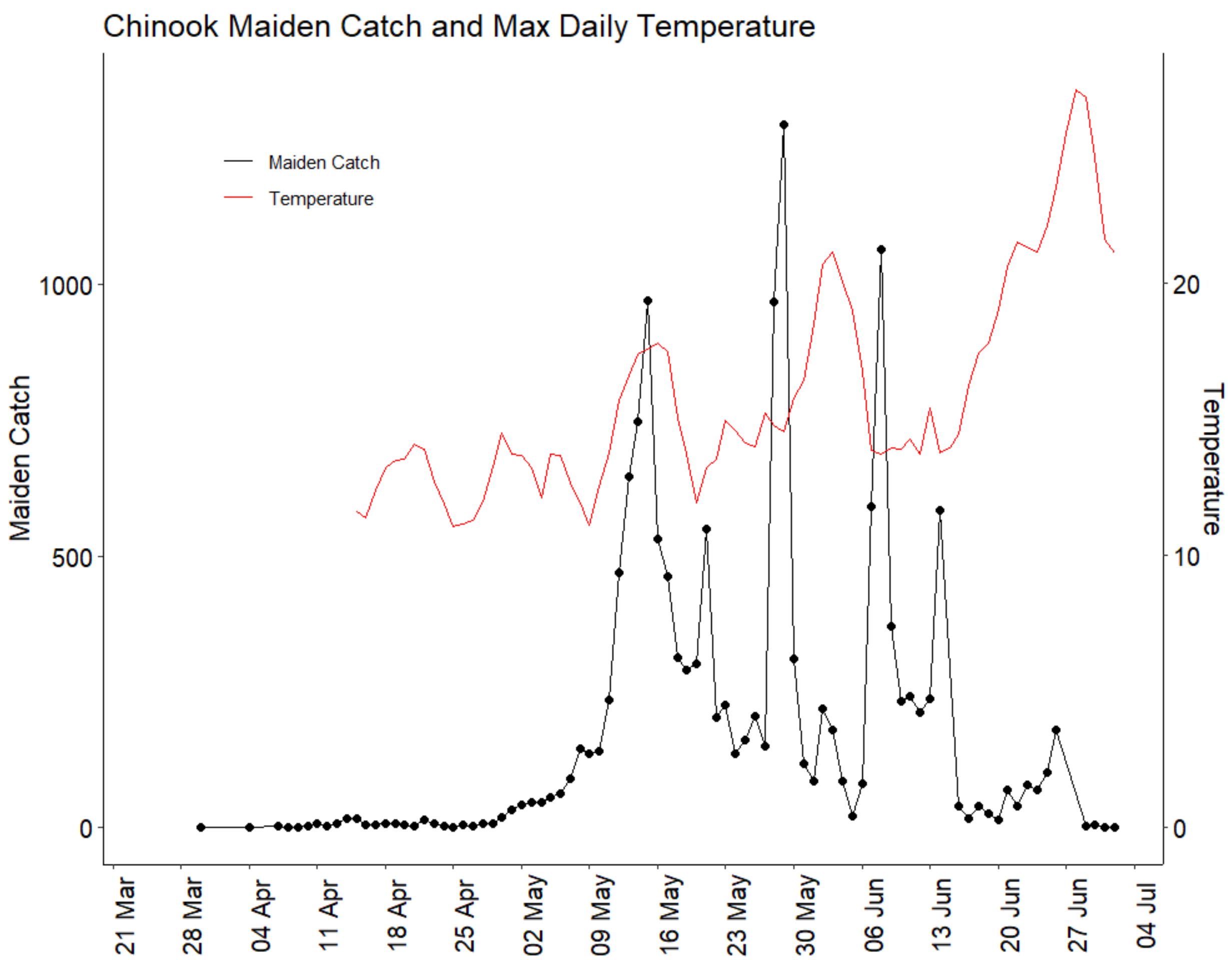


Figure 13. Chinook maiden catch and average daily stream temperature (°C) at the Upper Chehalis River smolt trap, 2021.

In summary, 2021 represents the first 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. 2023. 2023 wild coho forecasts for Puget Sound, Washington Coast, and Lower Columbia, Washington Department of Fish and Wildlife, Olympia, Washington FPA 23-01.

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 (in press)

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL 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.

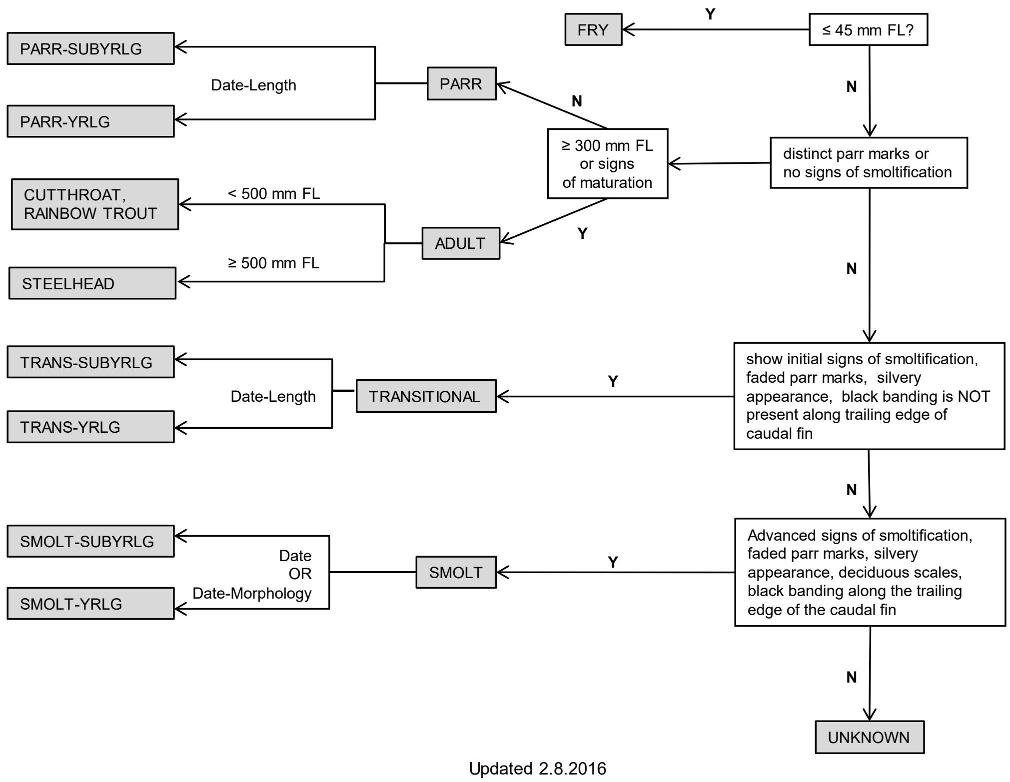
West, D., J. Winkowski, T. Seamons, and M. Litz. 2021. Chehalis River Smolt Production, 2020, FPA 21-06. Washington Department of Fish and Wildlife, Olympia, Washington.

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.



Appendix B. Upper Chehalis River missed trapping periods 2021.

Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
3/29/2021 0300	Trap Alarm	3/29/2021 0345	Trap stopper
4/07/2021 0933	Pulled trap	4/07/2021 1300	Trap position moved
5/03/2021 0930	Pulled trap	5/03/2021 1030	Trap position moved
6/26/2021 0730	Pulled trap	6/28/2021 2030	High River Temperature
7/02/2021 0718	Pulled trap		Trap completed for season

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

Period	**Start Date***	**End Date***	**Total Mark**	**Total Recap**	**Total Capture**	**Prop fished**
1	3/08	3/14	*NA	*NA	*NA	*NA
2	3/15	3/21	*NA	*NA	*NA	*NA
3	3/22	3/28	0	0	0	.62
4	3/29	4/04	3	0	3	.996
5	4/05	4/11	17	0	19	.98
6	4/12	4/18	66	2	67	1
7	4/19	4/25	45	3	45	1
8	4/26	5/02	121	9	122	1
9	5/03	5/09	502	64	587	.99
10	5/10	5/16	717	128	3739	1
11	5/17	5/23	695	109	2347	1
12	5/24	5/30	700	93	3225	1
13	5/31	6/06	573	74	790	1
14	6/07	6/13	700	120	2947	1
15	6/14	6/20	237	7	722	1
16	6/21	6/27	217	25	543	.76
17	6/28	7/04	0	0	12	.49
18	7/05	7/11	*NA	*NA	*NA	*NA

*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.
*NA's indicate estimated missing data modeled in final analysis.

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

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/08	3/14	*NA	*NA	*NA	*NA
2	3/15	3/21	*NA	*NA	*NA	*NA
3	3/22	3/28	4	0	4	.62
4	3/29	4/04	12	0	13	.996
5	4/05	4/11	7	0	7	.98
6	4/12	4/18	19	1	19	1
7	4/19	4/25	47	8	48	1
8	4/26	5/02	128	1	130	1
9	5/03	5/09	192	17	192	.99
10	5/10	5/16	249	14	250	1
11	5/17	5/23	67	4	69	1
12	5/24	5/30	78	9	82	1
13	5/31	6/06	33	5	34	1
14	6/07	6/13	23	3	23	1
15	6/14	6/20	24	0	24	1
16	6/21	6/27	4	2	8	.76
17	6/28	7/04	0	0	0	.49

*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.
*NA's indicate estimated missing data modeled in final analysis.

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

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/08	3/14	*NA	*NA	*NA	*NA
2	3/15	3/21	*NA	*NA	*NA	*NA
3	3/22	3/28	6	0	6	.62
4	3/29	4/04	17	0	18	.996
5	4/05	4/11	32	2	32	.98
6	4/12	4/18	80	6	80	1
7	4/19	4/25	75	3	75	1
8	4/26	5/02	52	1	52	1
9	5/03	5/09	43	2	43	.99
10	5/10	5/16	43	2	44	1
11	5/17	5/23	11	0	11	1
12	5/24	5/30	7	0	7	1
13	5/31	6/06	1	0	1	1
14	6/07	6/13	1	0	1	1
15	6/14	6/20	4	0	4	1
16	6/21	6/27	1	0	1	.76
17	6/28	7/04	0	0	1	.49
18	7/05	7/11	*NA	*NA	*NA	*NA

*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.
*NA's indicate estimated missing data modeled in final analysis.