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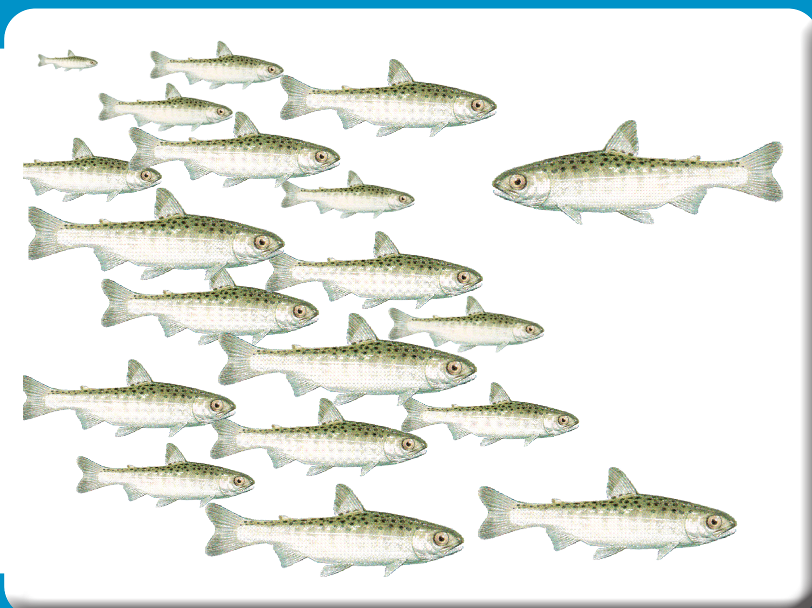
August 2021

Chehalis River Smolt Production, 2020



by Devin West, John Winkowski, Todd R. Seamons, and Marisa Litz

Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 21-06

Chehalis River Smolt Production, 2020

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Executive Summary

This report provides the 2020 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 (*O. mykiss*), 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 21, 2020.

Coho outmigrants were predominately of the yearling (or “1+”) age class (98.8%) with rare occurrences of subyearlings (or “0+”) and 2-year-old outmigrants (0.59% and 0.59%, respectively). Abundance of wild coho outmigrants was estimated to be 463,566 ± 42,944 standard deviation (SD) with a coefficient of variation (CV) of 9.2% (Table 1).

Steelhead outmigrants were one, two, and three years of age (45.4%, 50.3% and 4.3%, respectively), indicating three different juvenile life histories. Fork length averaged 162.4 mm (± 15.9 mm SD) for fish that were 1-year-old, 172.3 mm (± 17.2 mm SD) for 2-year old, and 187.3 mm (± 33.3 mm SD) for 3-year old. Abundance of wild steelhead outmigrants was estimated to be 38,647 ± 10,746 SD with a CV of 26.5% (Table 1).

Chinook outmigrants were subyearlings. Fork length of Chinook transitional and smolt subyearlings increased steadily throughout the trapping period with an average of 55.3 mm (± 5.9 SD) and 99.6 mm (± 7.0 SD) in the first and last full week of trapping, respectively. Abundance of wild Chinook subyearling outmigrants was estimated to be 320,358 ± 34,319 SD with a CV of 10.5% (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	463,566 ± 42,944	9.2
Steelhead	Wild	Transitional, Smolt	Yearling	38,647 ± 10,746	26.5
Chinook	Wild	Transitional, Smolt	Subyearling	320,358 ± 34,319	10.5

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 1,018 smolts mi^{-2} or 393 smolts km^{-2}) than any other western Washington watershed for which data currently exists (Litz 2021). Previously, smolt abundance estimates from individual tributaries throughout the Chehalis River Basin were generated in the 1980s and 1990s and prior to 2019, 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 (*O. tshawytscha*) and chum (*O. keta*) salmon 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 will become 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). 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 2020 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 fall, spring, and heterozygote run types; and 2) how do proportions of these run types vary across the outmigration? This report includes results from the 2020 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.

Similar to 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 are termed 'fry' (defined as juveniles ≤ 45 mm fork length, FL), which are individuals that out-migrate almost immediately after emergence. Fry are observed at the smolt trap 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.

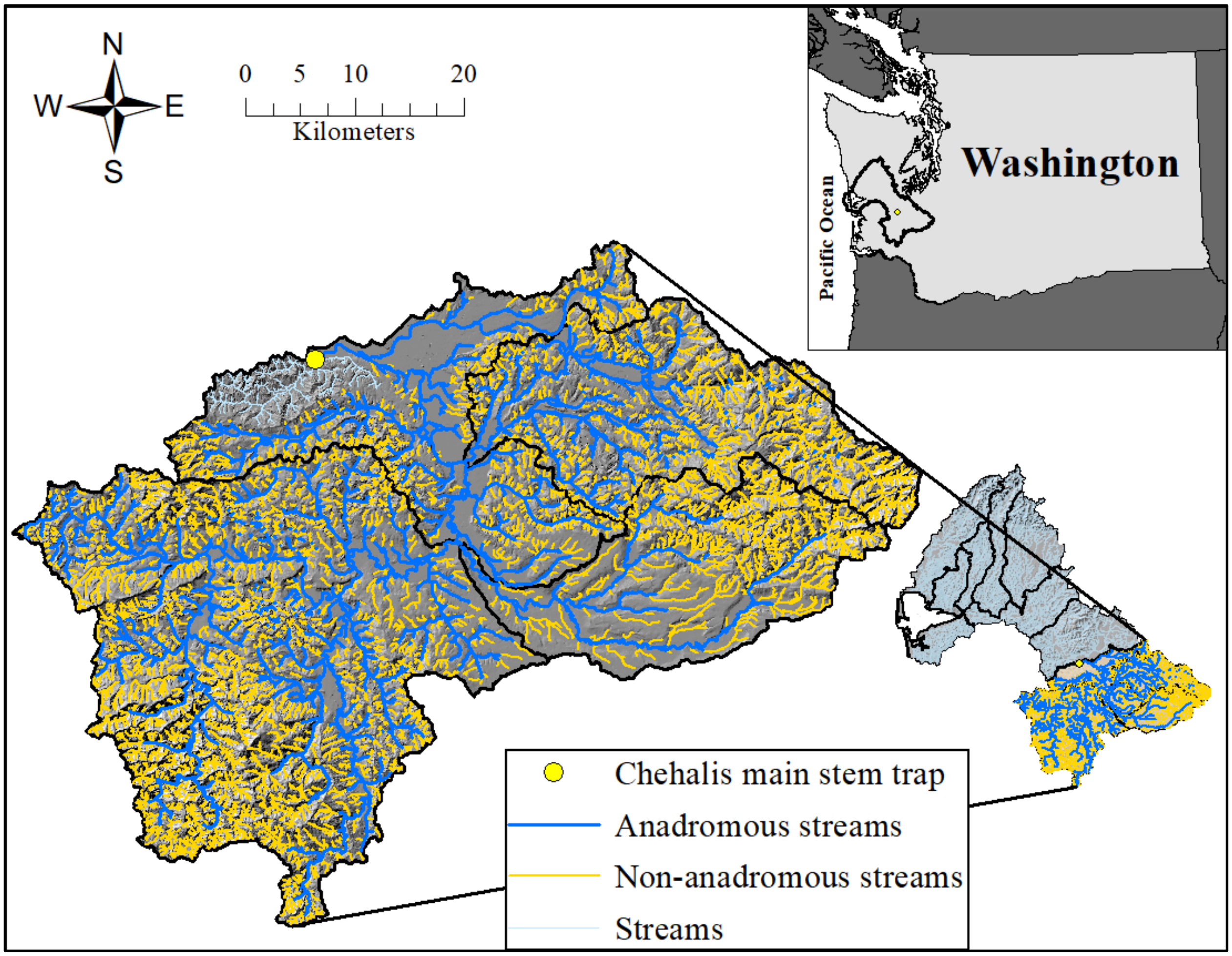


Figure 1. Main stem Chehalis River rotary screw trap. Anadromous streams represent stream habitat within the predicted coho salmon range of occurrence (1,390 km) using a 0.50 probability decision threshold (Walther 2021) upstream of the main stem Chehalis River rotary screw trap. Non-anadromous streams 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 (livebox) 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, debris, and trap outages related to the COVID-19 pandemic.

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, 2020 with the trap operating 24 hours per day 7 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 was diluted with water in a 500-ml container and roughly 15-25 ml of this diluted MS-222 solution was combined with roughly 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. 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 our secondary objective of 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	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 50 daily	1st 10 daily
Scales	Coho	---	---	1st 5 daily
	Steelhead	---	---	1st 5 daily
	Chinook[b]	---	---	---
DNA	Coho	---	---	---
	Steelhead	---	---	---
	Chinook	---	---	1st 10 daily up to 50 weekly

[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 are 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 35 years of trapping at the main stem Chehalis site, beginning in 1986, 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 get categorized as yearling in the field. These individuals are often opportunistically sampled for scales to verify age (Table 5).

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 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 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 (with minimal exceptions including missing approximately 2 weeks in early April due to the COVID-19 pandemic). 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 Wednesday and the trap was monitored for recaptures Thursday and Friday. 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 week	Bridge	4.5
Steelhead	PIT	Individual	Individual	Bridge	4.5
Chinook	PCC	Weekly	2 week	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 trials to reduce the probability of any assumption violations. These included mark/tag retention trials to ensure marks/tags were not lost, mark/tag detection trials to ensure that 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 6). 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.

We were unable to trap from March 25 to April 14, 2020 because of the COVID-19 pandemic. 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, we removed any marks for which the trap did not continuously fish for 48 hours after release because those marks were not available for recapture. For each species, we added two periods prior to our trapping season, with the first period set to 0 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. For coho estimates, we used the BTSPAS diagonal version 2014 model with model arguments as follows: number of chains = 4, iterations = 20,000, burn-in = 10,000, simulations = 1,000, and thin rate = 10. The Rhat convergence diagnostic value = 1.00, suggesting good model fit. For steelhead and Chinook estimates, we used the modified BTSPAS diagonal model (T. Buehrens, WDFW personal communication) with model arguments as follows: number of chains = 4, iterations = 20,000, burn-in = 10,000, simulations = 1,000, and thin rate = 10. The Rhat values for steelhead and Chinook = 1.00 and 1.02, respectively, suggesting good model fit. The BTSPAS analysis was executed in R v.3.4.1 (R Core Team, 2017) using the package BTSPAS (Bonner and Schwarz 2014).

Genetics

Genetic samples were collected from subyearling migrant Chinook from upstream of our trapping location (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 Ziploc 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 individual, 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. SNP markers used to infer adult run timing phenotype were those of Thompson et al. (2019). These markers were included in the GTseq SNP panel with a sex ID marker and 298 additional loci. To call run-type, the genotyping results from both SNP (homozygous spring-run, heterozygous, or homozygous fall-run) were required to be in agreement.

Results

Summary of Fish Species Encountered

We encountered a diverse assemblage of fish species throughout the 2020 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*), rock bass (*Ambloplites rupestris*), and other unidentified sunfish species (Centrarchidae).

Trap operation

We operated the trap from March 18 to July 21, 2020. There were 12 occurrences of trap outages of which only two were unintentional (e.g., debris stopping the trap) (Appendix B). For most occasions, the outage time was known exactly because the trap stopped fishing when staff intentionally lifted the cone during periods of high flows, warm water temperatures, heavy debris loads, or pandemic related outages. The largest outage was due to the COVID-19 pandemic, when trapping operations were stopped from March 25 through April 14, 2020. From April 14 through June 1, 2020, daily sampling resumed until the first trapping period in June, when our schedule was adjusted to 5 days per week through the remainder of the season.

Assumptions Testing Trials

In 2020, results from the mark retention trials indicated that mark/tag retention was high based on trials that lasted 24 hours. Estimated mark retention was 99.58% (coded wire tag = CWT, 238 out of 239 marked) for coho tested at our Bingham Creek research facility and 100% (passive integrated transponder = PIT tag, 17 out of 17 marked) for steelhead. We found that mark/tag related mortality was low. Estimated survival was 99.58% (CWT, 238 out of 239 marked) for coho and 100% for steelhead (PIT tag, 17 out of 17 tagged) over the 24-hour holding period. 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 periods 9-10 (D = 0.08, p = 0.88). However, a significant difference was found with the test during periods 9-10 for Chinook (D = 0.24, p = <0.01). For Chinook during these periods, maiden captures were smaller than recaptures. PIT tagging steelhead 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 2020 included yearlings in both transitional and smolt life stages. Of these life stages, over 99% 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 16, trapping period 3), peaked in late May, and declined through June (ending trapping period 16, Figure 3, Appendix C).

Scale age data indicated a small subyearling component of the coho outmigration that began sometime near the second week of June. Prior to this date, all scale sampled coho outmigrants were yearlings. A total of 353 scale samples were collected and 96.6% were aged successfully. Age 1 coho were the dominant age class (98.8%), and subyearling and age 2 were rare (0.59% and 0.59%, respectively) (Figure 4, Table 8).

A total of 19,429 coho outmigrants were captured throughout the season (Appendix C). A total of 4,420 coho were marked and 262 were recaptured. Modeled weekly trap efficiencies ranged from 2.5 to 11.7%.

Trap efficiency and maiden catches can both be affected by river flows. However, in 2020 river flows were relatively consistent over the duration of the coho outmigration (Figure 5).

Abundance of wild coho outmigrants was estimated to be 463,566 ± 42,944 (SD) with a CV of 9.2%.

In 2018, the total number of adult coho spawners in the Chehalis River upstream of the trap site was estimated to be 19,365 (1,006 hatchery origin = HOR and 18,359 natural origin = NOR), producing a smolt-per-spawner estimate of 23.9 for the 2018 brood year of naturally spawning coho. Estimating coho productivity through time is a goal of this study going forward.

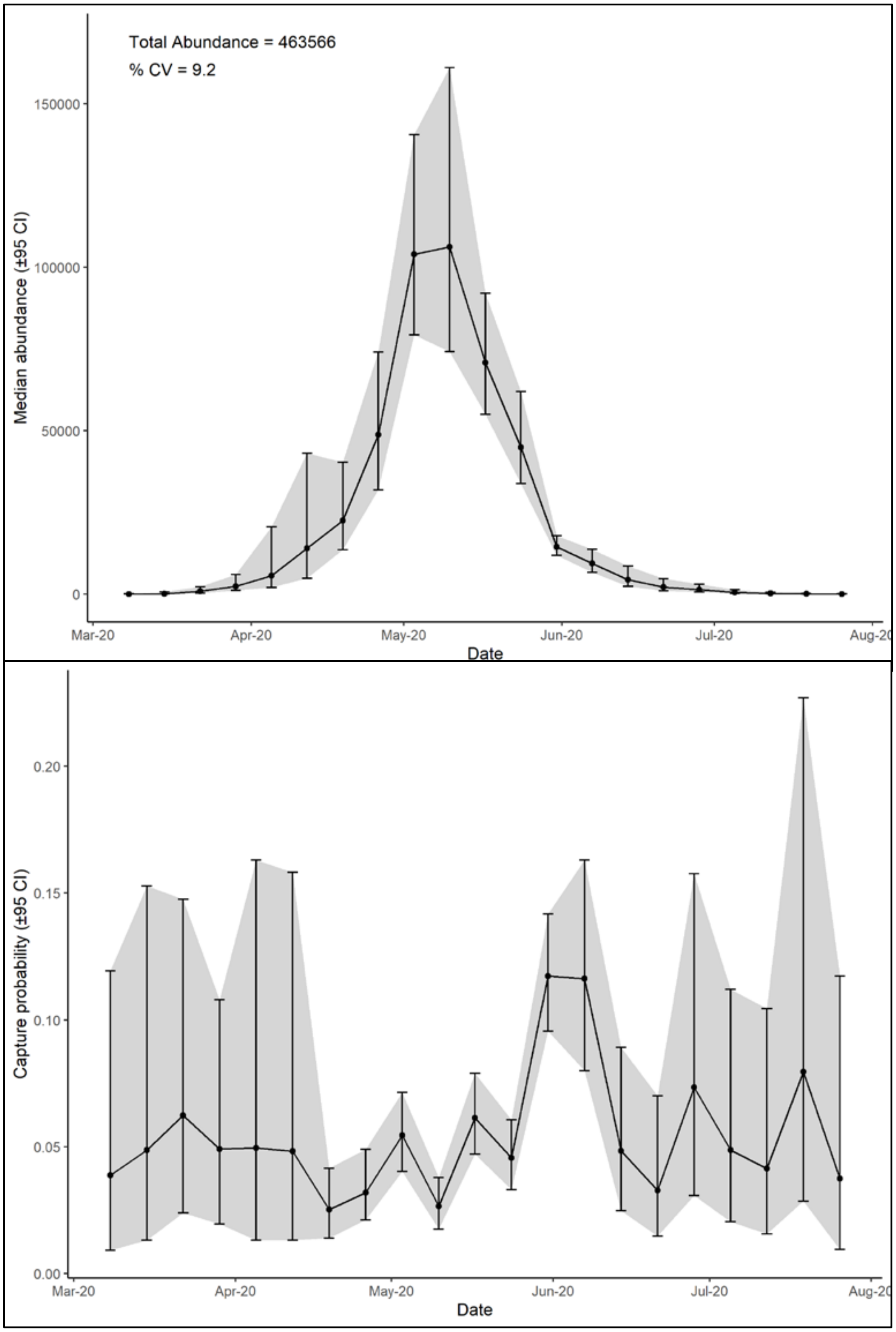


Figure 3. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild coho smolts and transitionals produced above the Chehalis River smolt trap in 2020**.** Error bars around trap efficiency estimates and shading around abundance estimates represent 95% confidence intervals. Data provided in Appendix C.

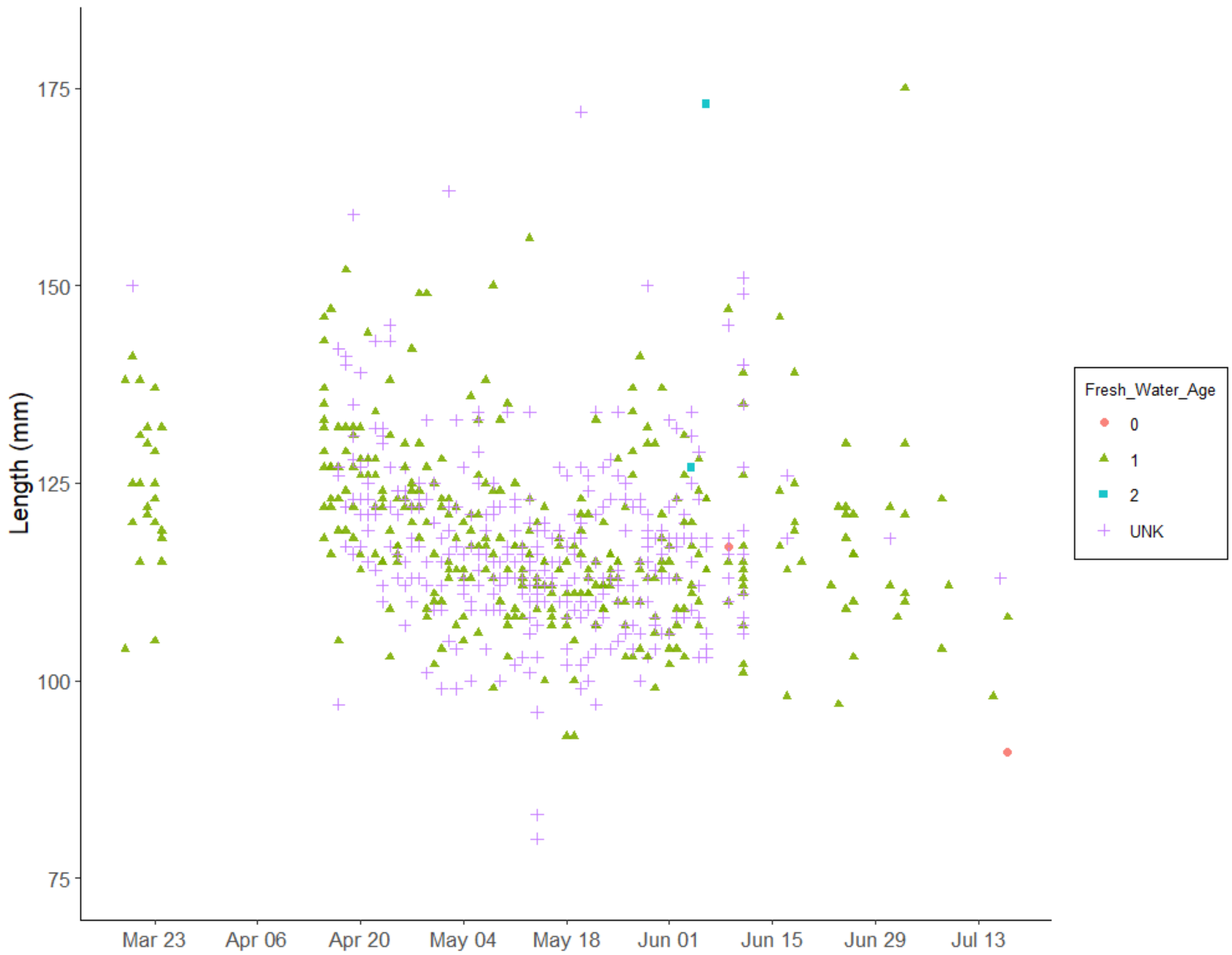


Figure 4. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2020.

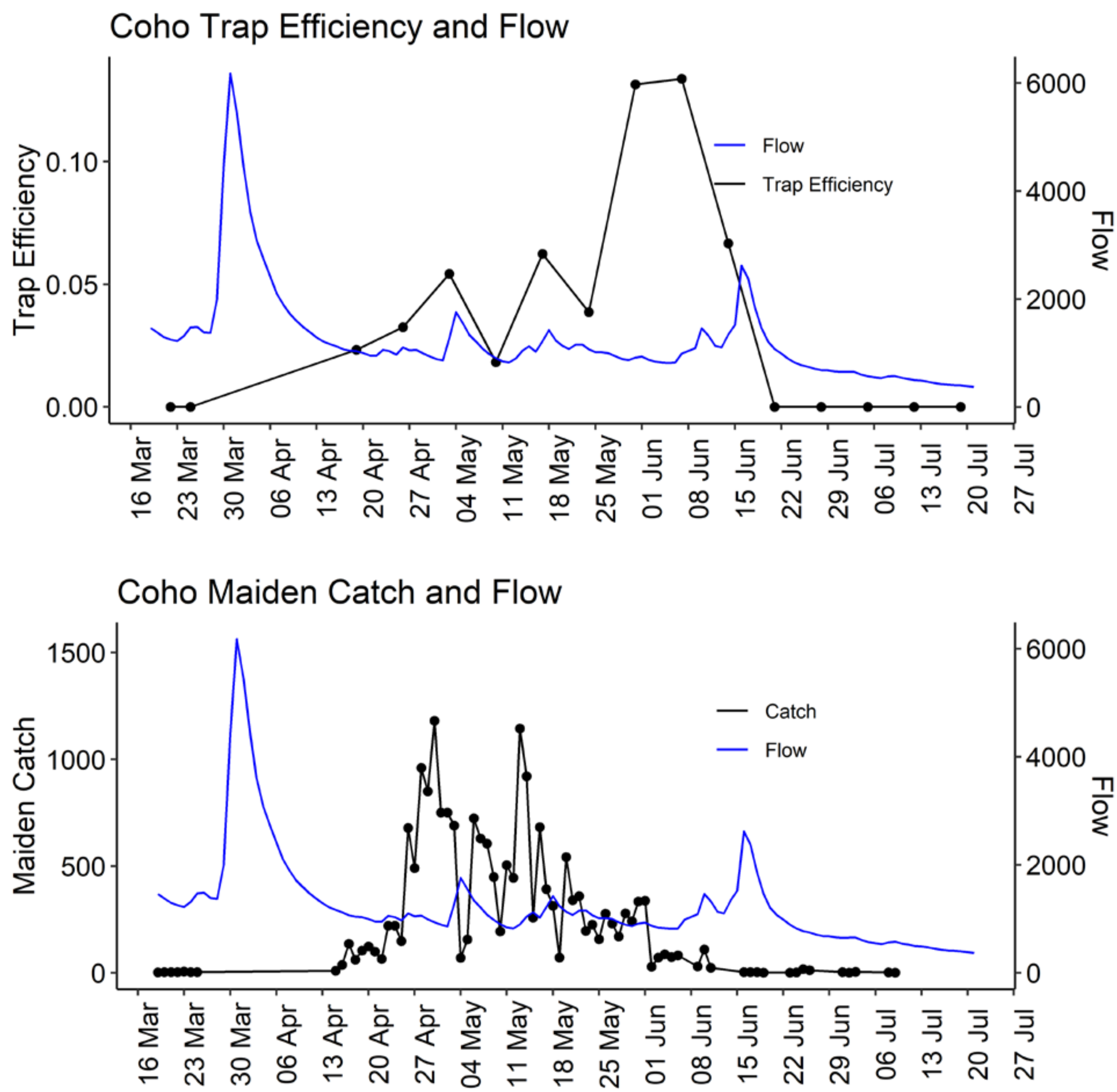


Figure 5. Coho wild transitional and smolt efficiency (top), maiden catch (bottom) and flow in cubic feet per second (cfs, top & bottom) as a function of period at the Chehalis smolt trap in 2020.

Table 8. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2020. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
3	3/16	3/22	14	0	13	0	1
4	3/23	3/29	10	0	10	0	0
5	3/30	4/05	NA	NA	NA	NA	NA
6	4/06	4/12	NA	NA	NA	NA	NA
7	4/13	4/19	31	0	31	0	0
8	4/20	4/26	35	0	32	0	3
9	4/27	5/03	35	0	35	0	0
10	5/04	5/10	35	0	34	0	1
11	5/11	5/17	35	0	35	0	0
12	5/18	5/24	35	0	35	0	0
13	5/25	5/31	35	0	33	0	2
14	6/01	6/07	30	0	28	2	0
15	6/08	6/14	17	1	15	0	1
16	6/15	6//21	12	0	10	0	2
17	6/22	6/28	13	0	13	0	0
18	6/29	7/05	9	0	8	0	1
19	7/06	7/12	3	0	3	0	0
20	7/13	7/19	4	1	2	0	1

Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Of these life stages, approximately 93% of outmigrants observed were classified as the smolt phenotype compared to transitional. Steelhead outmigrant numbers were low during the first week of trapping March 16 (trapping period 3), peaked around 3rd week in May, and were last observed the week of June 8 (trapping period 15) (Figure 6, Appendix D).

Scale age data indicated that steelhead were 1-, 2-, and 3- years-old (Figure 7, Table 9). A total of 221 scale samples were collected and 73.8% were aged successfully. Fork length averaged 162.4 mm (± 15.8 mm SD) for fish that were 1-year-old, 172.3 mm (± 17.2 mm SD) for 2-year old, and 187.2 mm (± 33.3 mm SD) for 3-year old. Age composition of successfully aged steelhead was 45.4% Age-1, 50.3% Age-2, and 4.3% Age-3.

A total of 890 steelhead outmigrants were captured throughout the season (Appendix D). A total of 738 steelhead were marked and 21 were recaptured. Modeled weekly trap efficiencies ranged from 0.1% to 4.8%.

Trap efficiency and maiden catches can both be affected by river flows. However, in 2020 river flows were relatively consistent over the duration of the steelhead outmigration (Figure 8).

Abundance of wild steelhead outmigrants was estimated to be 38,647 ± 10,746 (SD) with a CV of 26.5%

Adult steelhead spawners contributing to the 2020 smolt outmigration came from the 2016 through 2018 brood years. Spawner were estimated to be 2,670, 1,637 and 1,733 for these years, respectively. More monitoring is required to estimate steelhead productivity above the trap by brood year, but that is a project goal.

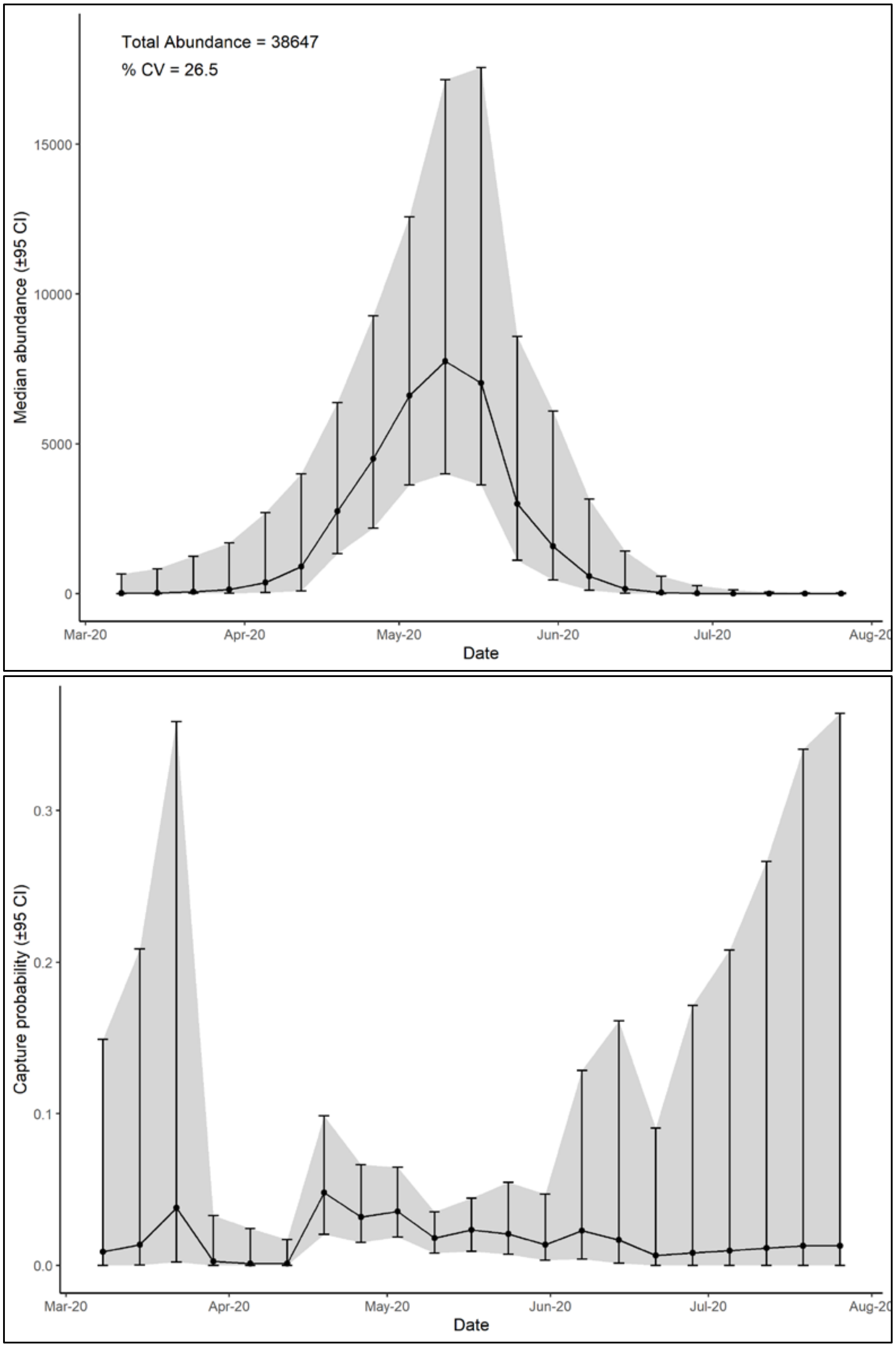


Figure 6. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild steelhead smolts and transitionals produced above the Chehalis River smolt trap in 2020**.** Error bars around trap efficiency estimates and shading around abundance estimates represent 95% confidence intervals. Data provided in Appendix D.

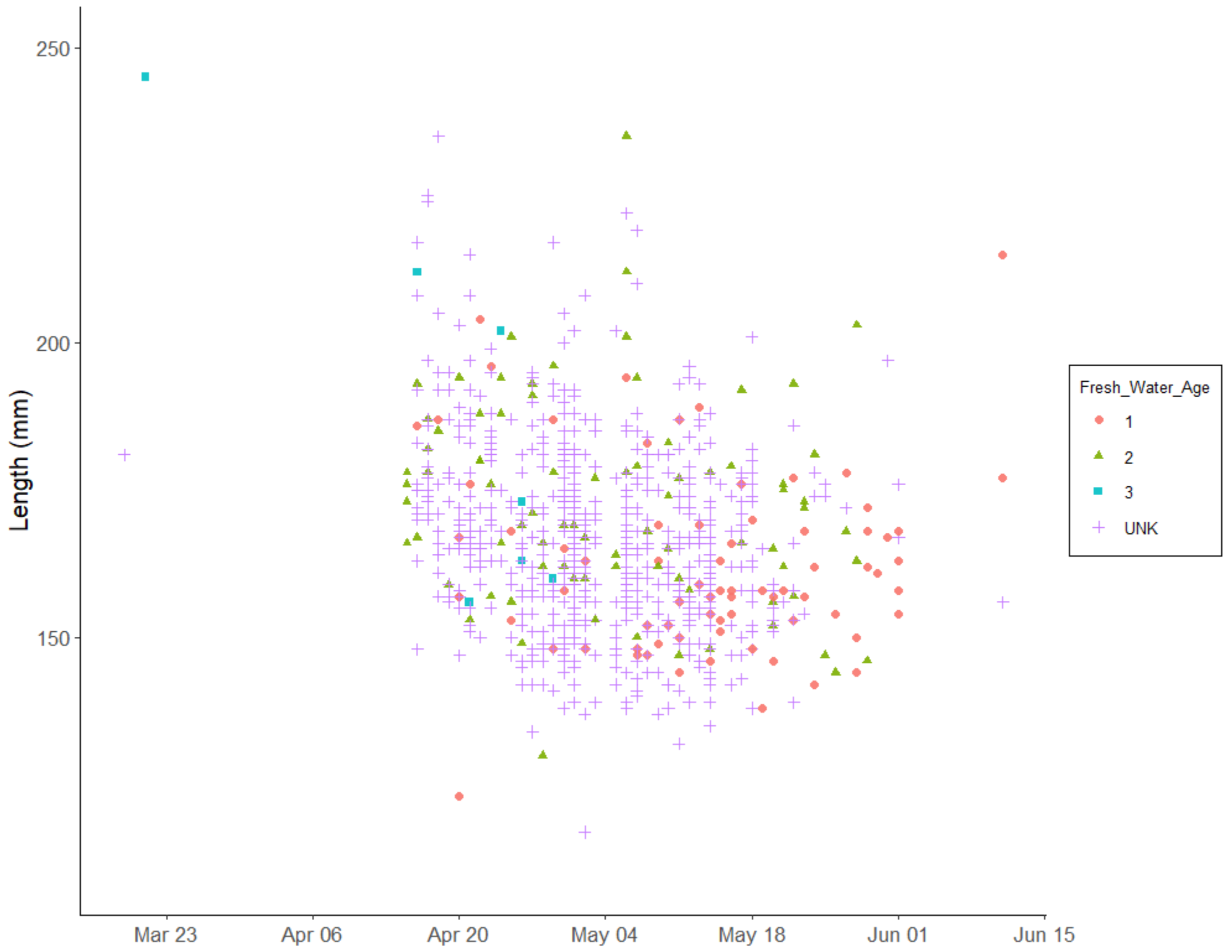
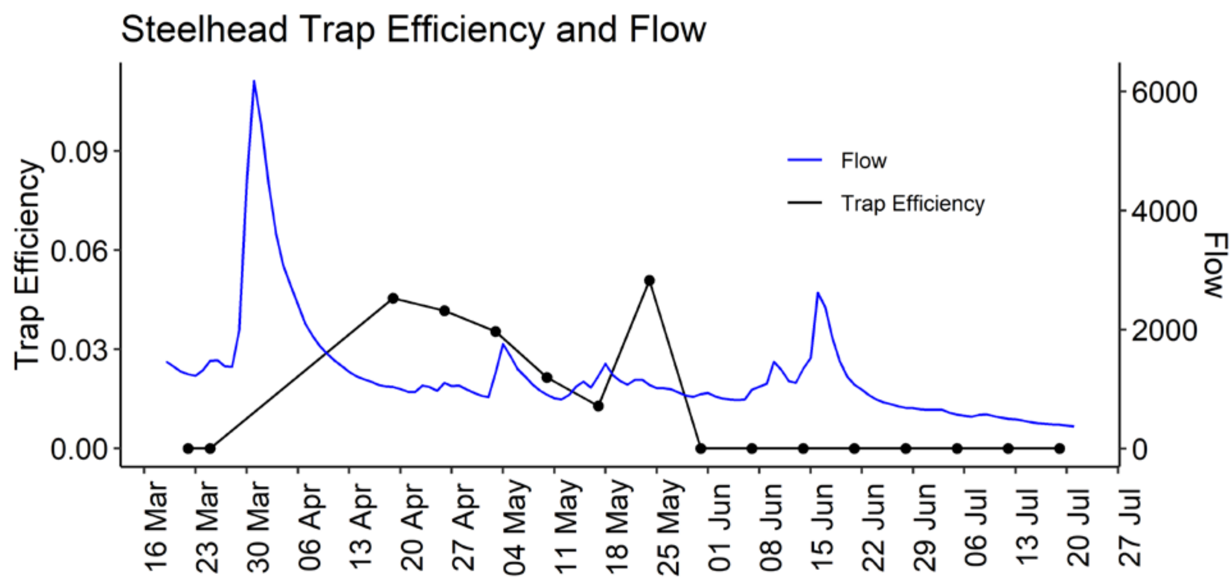


Figure 7. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2020.



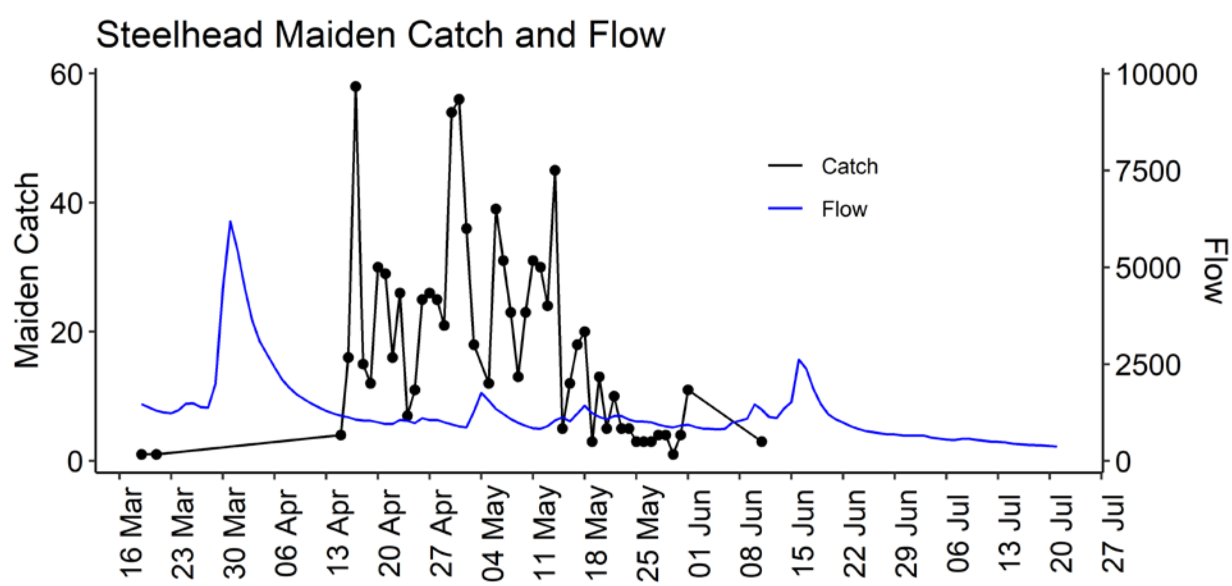


Figure 8. Steelhead wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow CFS (top & bottom) as a function of period at Chehalis smolt trap in 2020.

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

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 16 (trapping period 3), peaked around third week of June, and declined through the second week of July (Figure 9).

Generally, all Chinook outmigrants were assumed to be Age-0. Scale age data were opportunistically collected from five larger Chinook that ranged in fork length from 118-203 mm (Table 10). Two individuals were noted as yearlings and FL measured 177 and 203 mm. Subyearling Chinook ranged from 45-150 mm. Fork length of Chinook increased steadily throughout the season with an average of 55.4 mm (± 5.8, SD) and 99.3 mm (± 7.7 mm SD) in the first and last full week of trapping, respectively (Figure 10).

In 2020, a total of 16,345 Chinook subyearling outmigrants were captured (Appendix E; Periods 1 – 22). A total of 4,300 Chinook were marked, and 330 were recaptured Modeled weekly trap efficiencies ranged from 1.8% to 18%.

Trap efficiency and maiden catches can both be affected by river flows. However, in 2020 river flows were relatively consistent over the duration of the Chinook outmigration (Figure 11).

Abundance of wild Chinook subyearling outmigrants was estimated to be 320,358 ± 34,319 (SD) with a CV of 10.5%.

In 2019, the total number of adult spring Chinook that spawned in the Chehalis River above our trap site was estimated to be 950 (all NOR) and adult fall Chinook was estimated to be 5,389 (76 HOR and 5,313 NOR), producing an overall smolt-per-adult estimate of 50.5 for the 2019 brood year of naturally spawning Chinook. Estimating subyearling Chinook productivity through time is a goal of this study going forward.

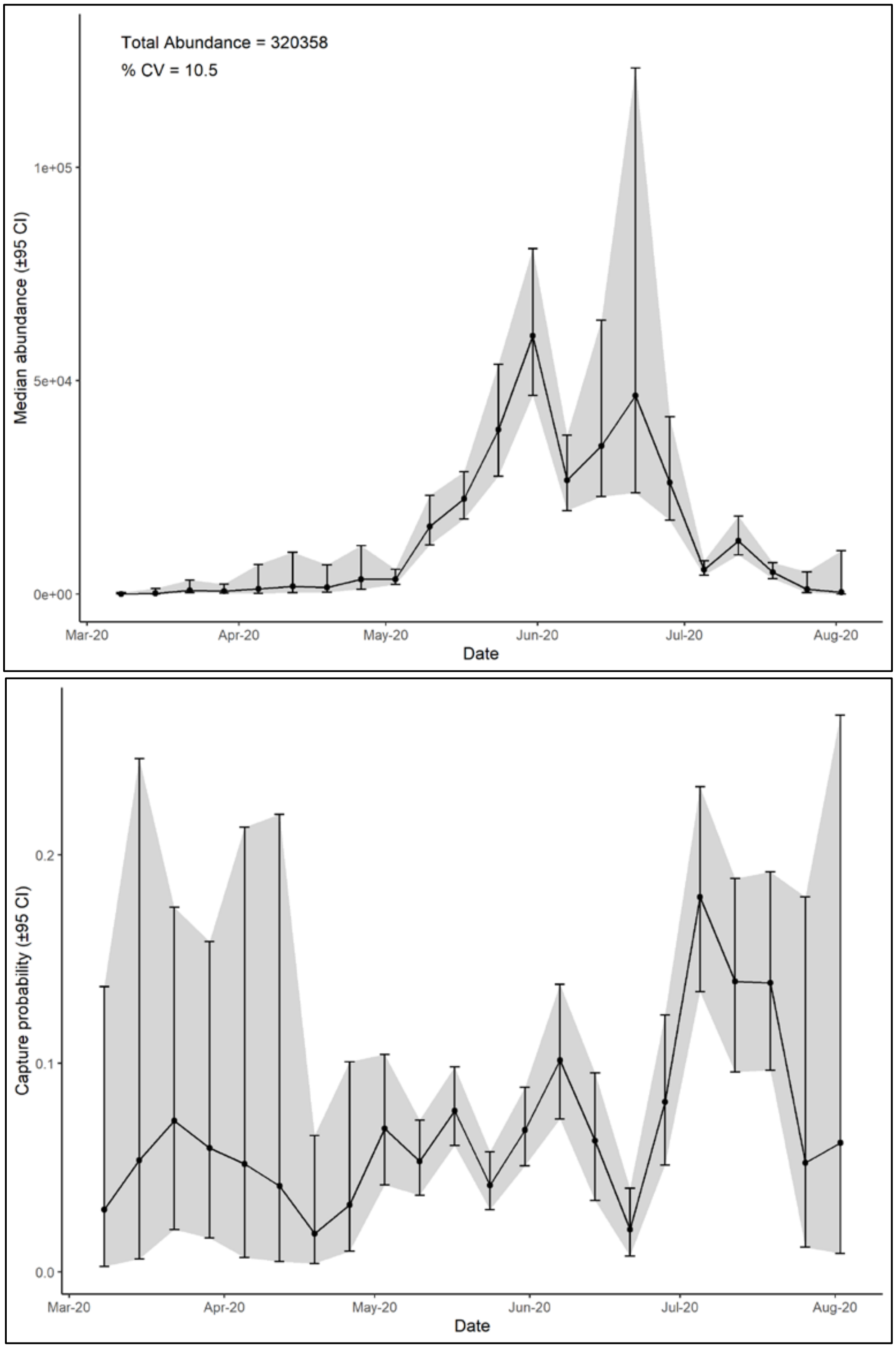


Figure 9. Number of outmigrants (top panel) and trap efficiency (bottom panel) by week for wild Chinook subyearlings produced above the Chehalis River smolt trap in 2020. Error bars and shading represent 95% confidence intervals.

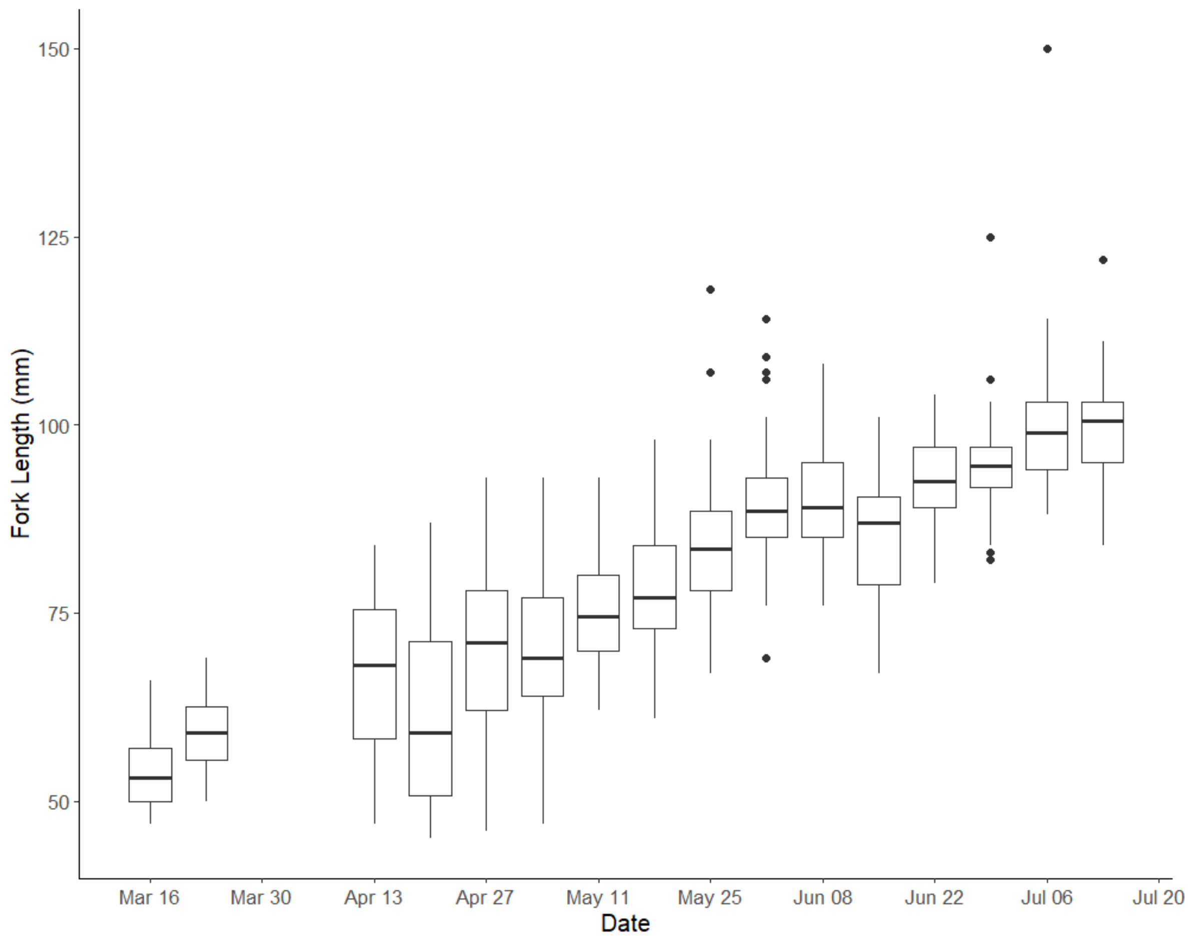


Figure 10. Box plots of fork lengths of wild Chinook outmigrants (transitionals, smolts) by week at the Chehalis River screw trap, 2020. Each box represents the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

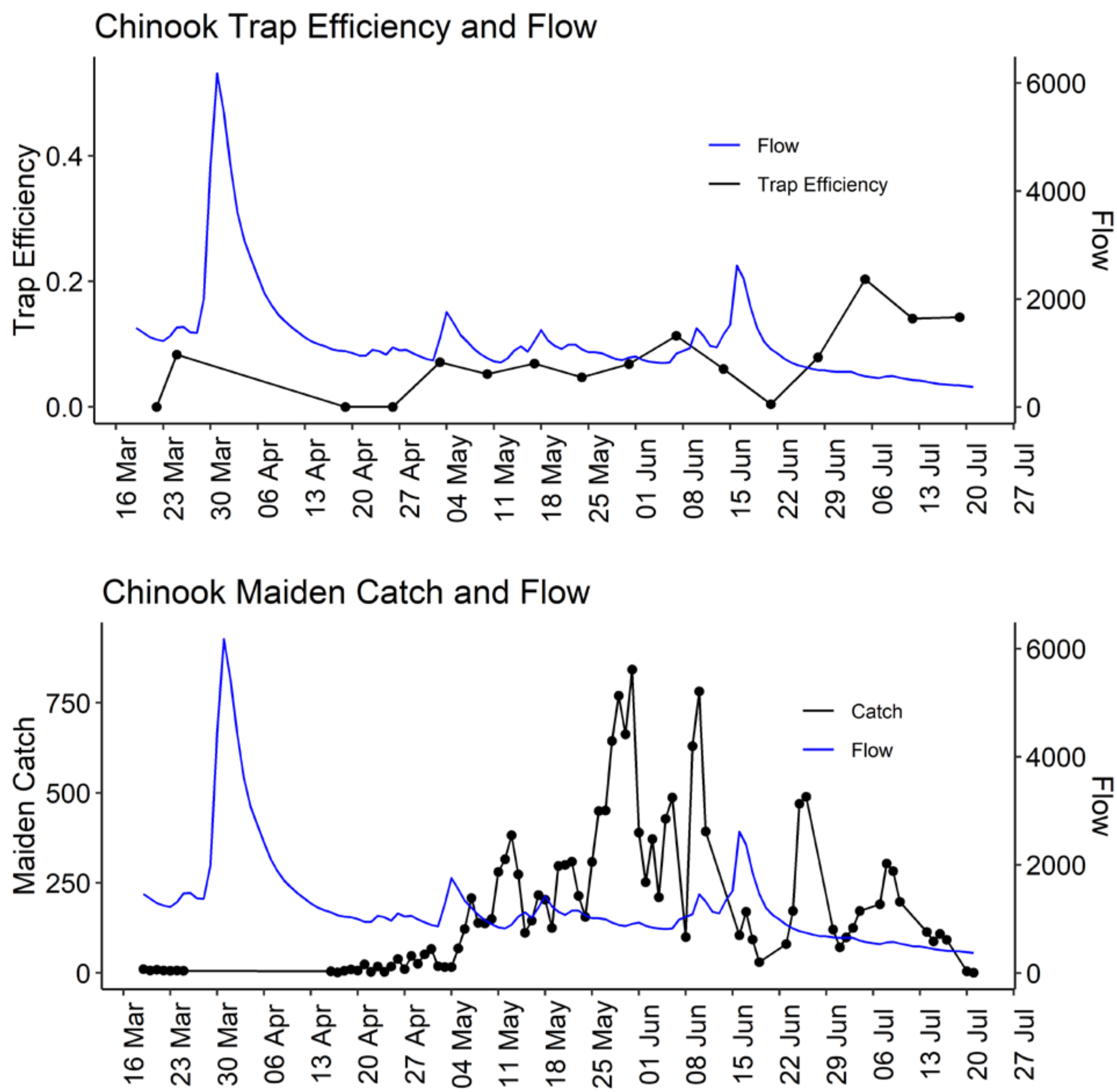


Figure 11. Chinook wild transitional and smolt trap efficiency (top), maiden catch (bottom) and flow CFS (top & bottom) as a function of period at the Chehalis smolt trap in 2020.

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

Chinook subyearling abundance by run type

A total of 693 juvenile Chinook tissue samples were sent to the lab for processing. Of those, SNP genotypes were successfully obtained from 614 (89%). 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 12). 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. Assuming that the correlation of the SNP genotype and adult run timing phenotype still holds, the Chinook subyearling outmigration abundance estimate consisted of an estimated 12,336 (4%) spring Chinook, 240,064 (78%) fall Chinook, and 56,990 (18%) of unknown run timing (i.e., heterozygotes).

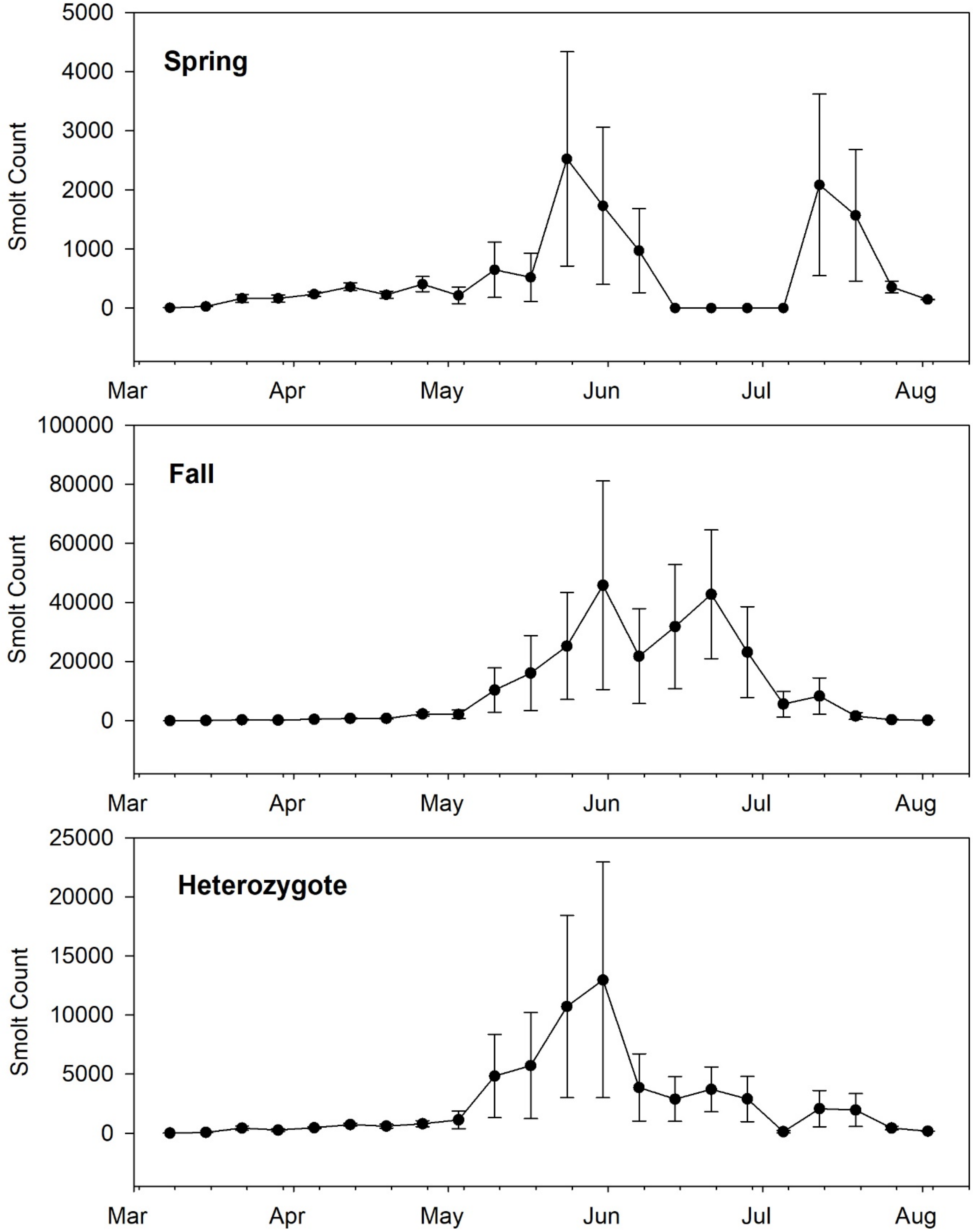


Figure 12. Chinook subyearling SNP genotype estimates by date. SNP genotypes are associated with adult run timing in Chehalis Chinook salmon (Thompson et al. 2019).

Table 11. Chinook subyearling genetic estimates by period and run type at the Chehalis River screw trap

Period	Start Date	End Date	Spring	Fall	Heterozygote	Total
1	2-Mar	8-Mar	5	9	13	27
2	9-Mar	15-Mar	27	50	72	149
3	16-Mar	22-Mar	164	301	438	903
4	23-Mar	29-Mar	162	216	270	649
5	30-Mar	5-Apr	235	484	477	1196
6	6-Apr	12-Apr	358	738	728	1824
7	13-Apr	19-Apr	226	752	602	1579
8	20-Apr	26-Apr	405	2,265	809	3,479
9	27-Apr	3-May	213	2,134	1,138	3,485
10	4-May	10-May	646	10,334	4,844	15,824
11	11-May	17-May	520	16,122	5,721	22,363
12	18-May	24-May	2,524	25,236	10,725	38,484
13	25-May	31-May	1,729	45,817	12,967	60,512
14	1-Jun	7-Jun	969	21,809	3,877	26,655
15	8-Jun	14-Jun	0	31,828	2,893	34,721
16	15-Jun	21-Jun	0	42,751	3,717	46,468
17	22-Jun	28-Jun	0	23,204	2,900	26,104
18	29-Jun	5-Jul	0	5,611	128	5,739
19	6-Jul	12-Jul	2,084	8,335	2,084	12,502
20	13-Jul	19-Jul	1,568	1,568	1960	5,097
21	20-Jul	26-Jul	355	355	444	1,154
22	27-Jul	2-Aug	145	145	182	472
Totals			**12,336 (4%)**	**240,064 (78%)**	**56,990 (18%)**	**309,389**

2020.

Discussion

Basin-wide Context

The abundance estimates provided in this report represent juvenile salmonids that completed their freshwater rearing in 2020 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. In addition to freshwater production from these sub-basins, some juveniles that emerge from the gravel upstream of the trap location and redistribute to areas downstream of the trap location during their freshwater rearing period are 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 2021). 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 of which data are available (2017-2019). 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. 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 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 2017-2020 ranged from 304,806-463,566, with 2020 as our highest observed estimate in the 4-year time series (Figure 13). Additionally, confidence intervals for our estimates have decreased compared to our first year of trapping, indicating that confidence in our estimates is increasing (Figure 13). 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 2017-2020 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).

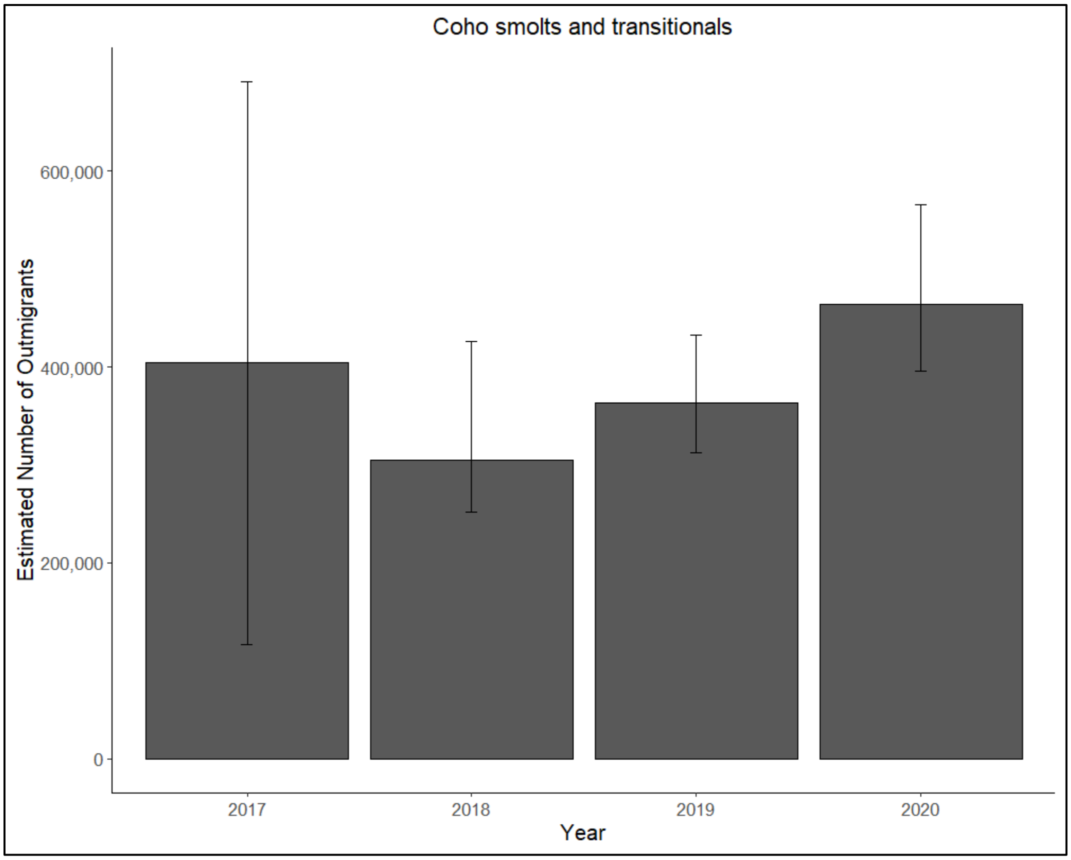


Figure 13. Annual time series of outmigrant abundance with 95% confidence intervals for wild coho smolts and transitionals produced above the Chehalis River smolt trap, 2017-2020.

This report provides the third reportable estimate of wild steelhead production from the Chehalis River basin upstream of river kilometer 84. Our estimate of 38,647 steelhead outmigrants from the roughly 566 river km upstream of the trap (Statewide Integrated Fish Distribution, SWIFD, https://geo.nwifc.org/swifd/) corresponds to 68 wild steelhead smolts km^{-1}, which is slightly higher compared to our 2018 (32,058) and 2019 (29,024) estimates of steelhead outmigrants (Figure 14). 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, 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. Although steelhead outmigrant estimates are not available from the Upper Chehalis sub-basin, this area has the high gradient, coarse substrate habitat typically associated with rearing of juvenile steelhead. In 2021, an additional smolt trap will be installed in the upper Chehalis sub basin, which will allow us to partition steelhead estimates at a finer spatial resolution. 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, summer stream temperatures downstream of the trap are outside optimal rearing conditions for juvenile salmon and steelhead (Winkowski unpublished data).

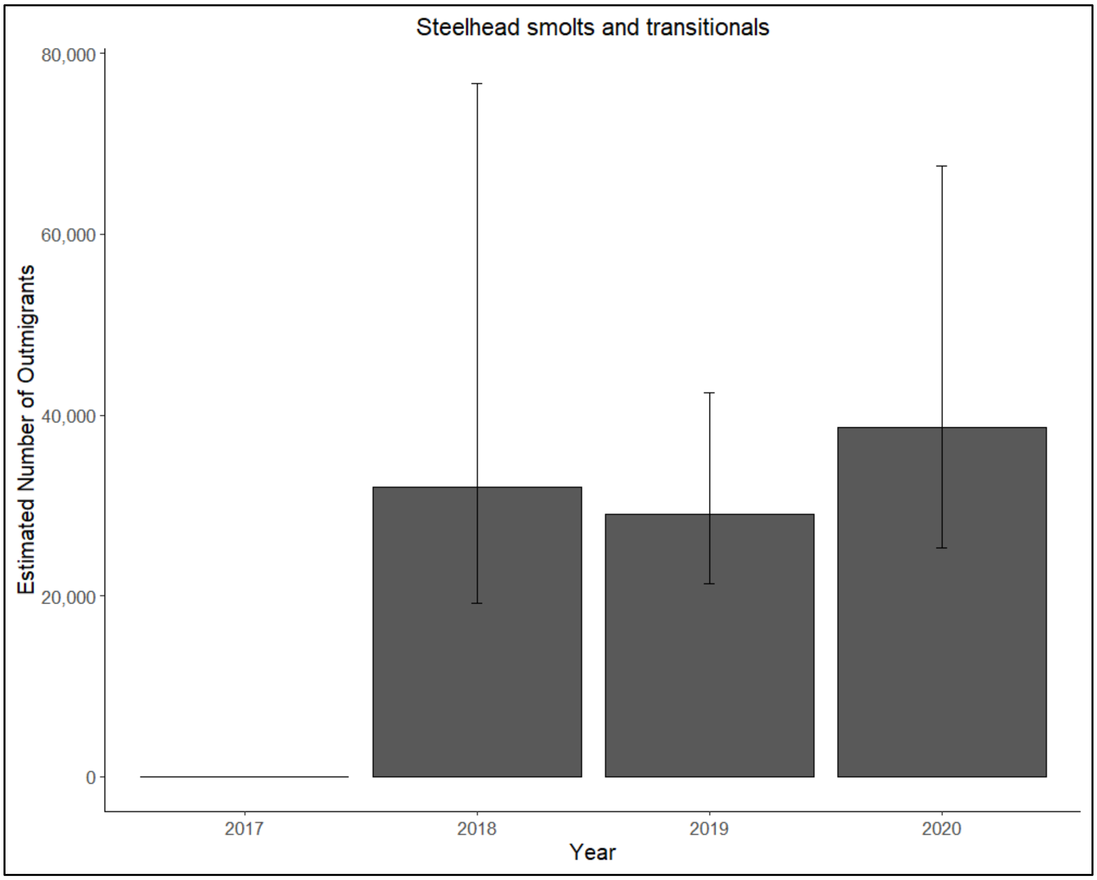


Figure 14. Annual time series of outmigrant abundance with error bars representing 95% confidence intervals for wild steelhead smolts and transitionals produced above the Chehalis River smolt trap, 2017-2020.

Our estimate of Chinook subyearling outmigrants represents a portion of the total freshwater production of Chinook upstream of the trap location in 2020 and does not include the earlier timed fry migrants. Our estimate of 320,358 Chinook subyearling outmigrants is our second reportable estimate above our Chehalis trapping location, which is slightly higher than our 2018 estimate of 295,708 outmigrants (Figure 15). The precision of our estimate in 2020 remains consistent with our 2018 estimate (Figure 15). 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 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 (78%) followed by those of unknown run timing (i.e., heterozygotes; 18%), and the spring run type (4%). Assuming that 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 relative proportion of the heterozygote component. The run timing of heterozygotes in the Chehalis Basin is unknown. Genotypes of well-phenotyped (i.e., known run timing) spring run and fall run adult samples used to verify the association of our SNP markers and adult run timing had almost no heterozygotes (Thompson et al. 2019). Heterozygotes are believed to show intermediate run timing (i.e., summer), but this is unverified in the Chehalis Basin. Future efforts could include work to verify the run timing of heterozygote adults. Our analysis is valuable because it now allows us to track abundance trends in all run types and proportional trends among run types which is critical information when determining if habitat restoration, protection, or climate change are impacting run types disproportionately. Finally, this information is particularly important for the spring Chinook component considering populations are low and declining (Curt Holt WDFW personal communication).

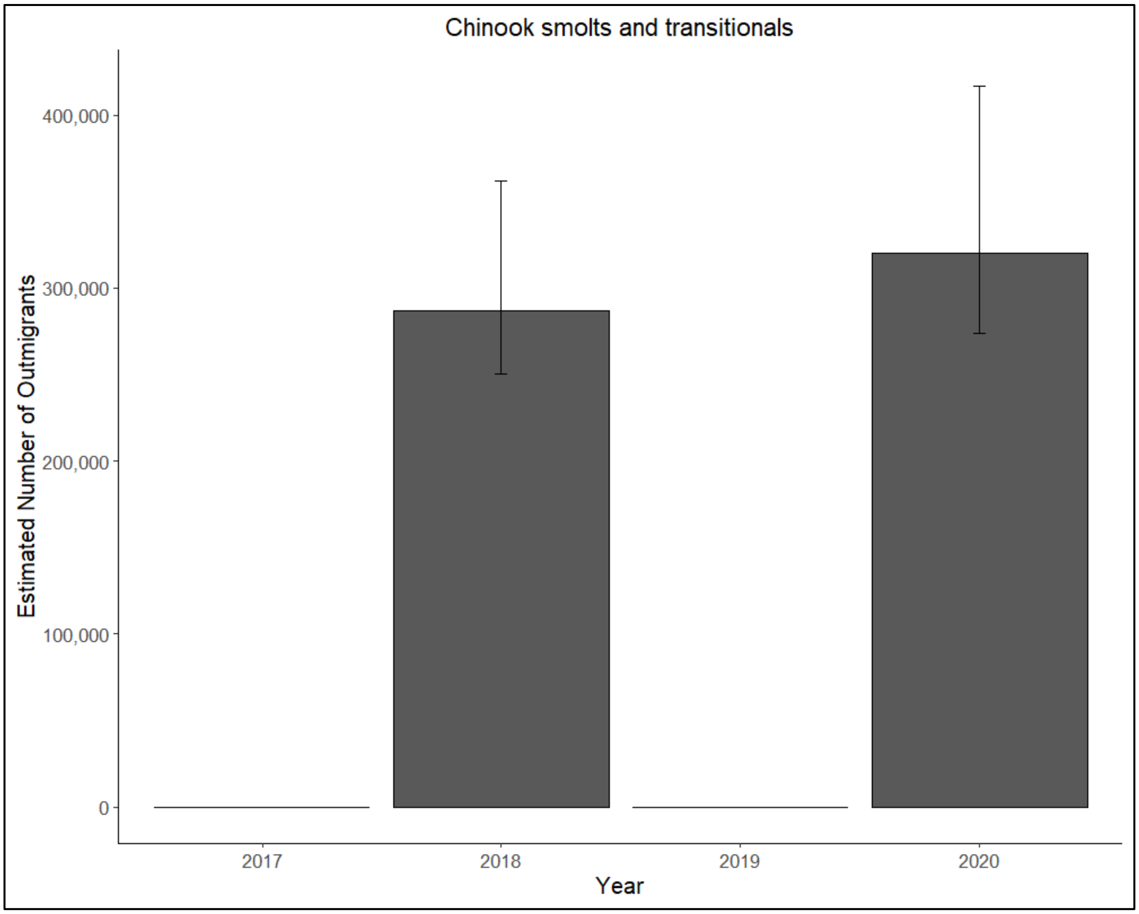


Figure 15. Annual time series of outmigrant abundance with error bars representing 95% confidence intervals for wild Chinook smolts and transitionals produced above the Chehalis River smolt trap, 2017-2020.

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 2020, these challenges included high flows, warm stream temperatures, filamentous algae, and adjusting to the COVID-19 pandemic. Additional description of these issues and our approaches to address them are described below. The 2020 season was our third year attempting a Chinook subyearling outmigration estimate (e.g., fishing through 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. Temperature concerns are prevalent later in the season at this location in the Chehalis River. For example, maximum daily temperatures during May and June peaked at 20.1℃ and 22.7℃, respectively, which was concurrent with increasing Chinook catch and a reduction of one crew member (Figure 16). Similar to 2019, large algae aggregations were a serious issue, completely plugging the cone and live box (Figure 17). Algae issues are 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 constructed and installed a volitional release chamber under the deck of our screw trap in an attempt to allow sampled fish time to acclimate to the river prior to release. We instructed the crews to monitor the live box for adult northern pikeminnow however, we caught fewer adult pikeminnow in 2020 (16 adults) compared to 2019 (59 adults) and 2018 (439 adults). This large difference in 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 weren't able 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.

During our 2020 season we faced a COVID-19 global pandemic. Within two weeks of beginning our trapping season, we were mandated to cease operations. Several weeks later we were allowed to continue our research with new safety protocols in place. Mask wearing, social distancing and new sanitization protocols were among the new standards we adapted to during our trapping season. Some of these protocols will continue to be implemented during our 2021 season.

In summary, 2020 represented the third year for which wild Chinook and steelhead outmigrations were described from the Chehalis River and the fourth 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 12. Mean and maximum of daily stream temperatures (℃) by month recorded at Chehalis River smolt trap near river km 84, 2020.

Month	Mean (℃)	Maximum (℃)
March	8.0	10.4
April	11.8	15.3
May	15.6	20.1
June	17.3	22.7
July	19.9	25.6

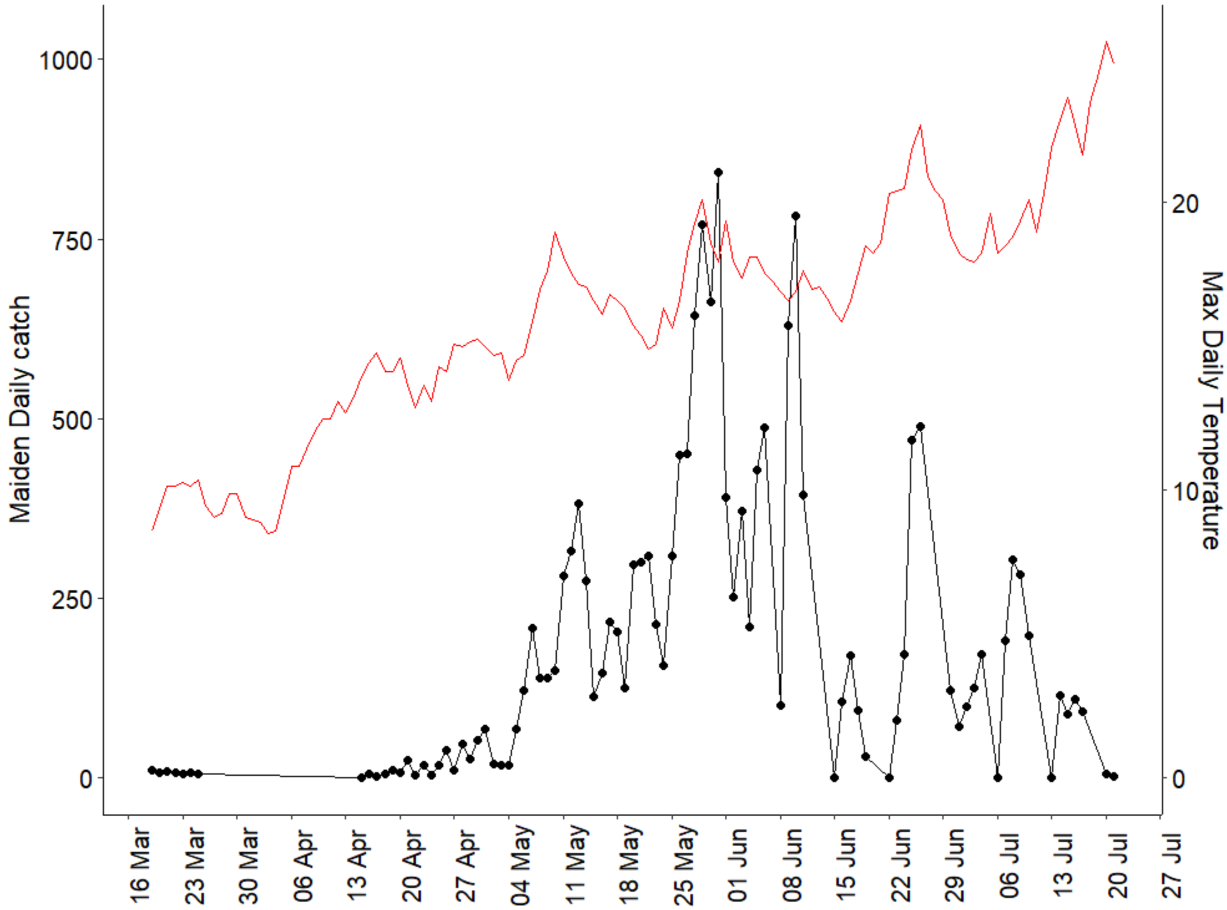


Figure 16. Chinook maiden catch (black line) and maximum daily stream temperature (°C) (red line) at the Chehalis River smolt trap, 2020.

Figure 17. Filamentous algae collected in a single day of operations at the Chehalis River screw trap, June 2020.

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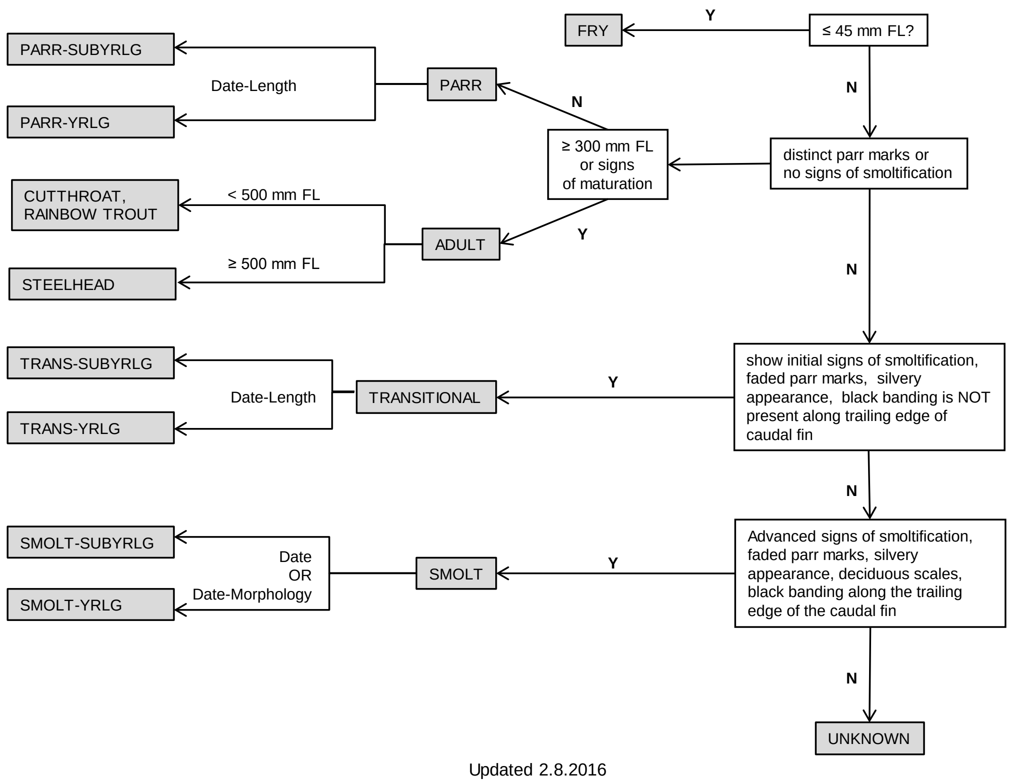
Appendices

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



Appendix B. Chehalis River missed trapping periods 2020. 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
3/25/20 19:00	Pulled trap	4/14/20 16:45	COVID-19 Lockdown
5/4/20	Visual	5/4/20 09:15	Cone Stopper
6/1/20 0:830	Pulled trap	6/1/20 10:00	Debris Drum Maintenance
6/6/20 12:28	Pulled trap	6/8/20 13:15	Crew Days Off
6/11/20 12:30	Pulled trap	6/15/20 12:00	Crew Days Off
6/19/20 11:04	Pulled trap	6/22/20 12:00	Crew Days Off
6/26/20 10:30	Pulled trap	6/30/20 02:40	Crew Days Off and Furlough
7/4/20 16:55	Pulled trap	7/6/20 12:15	Crew Days Off
7/10/20 10:00	Pulled trap	7/13/20 12:00	Crew Days Off
7/17/20 11:42	Pulled trap	7/20/20 13:00	Crew Days Off
7/20/20 18:00	Pulled trap	7/20/20 22:05	Swimmers Close to Trap
7/21/20	Visual	7/21/20 01:00	Cone Stopper

Appendix C. Final analysis 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	3/02	3/08	*NA	*NA	*NA	*NA
2	3/09	3/15	*NA	*NA	*NA	*NA
3	3/16	3/22	12	0	14	0.5
4	3/23	3/29	6	0	13	0.33
5	3/30	4/05	*NA	*NA	*NA	*NA
6	4/06	4/12	*NA	*NA	*NA	*NA
7	4/13	4/19	344	10	350	0.79
8	4/20	4/26	400	14	1556	1
9	4/27	5/03	700	36	5677	1
10	5/04	5/10	659	13	2829	1
11	5/11	5/17	705	43	4347	1
12	5/18	5/24	673	28	2048	1
13	5/25	5/31	700	89	1691	1
14	6/01	6/07	172	23	682	0.79
15	6/08	6/14	30	2	163	0.87
16	6/15	6/21	7	0	12	0.42
17	6/22	6/28	3	0	32	0.57
18	6/29	7/05	4	0	9	0.57
19	7/06	7/12	*NA	0	3	0.56
20	7/13	7/19	1	0	3	0.57
21	7/20	7/26	*NA	0	0	0.1

*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. Final analysis 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	3/02	3/08	*NA	*NA	*NA	*NA
2	3/09	3/15	*NA	*NA	*NA	*NA
3	3/16	3/22	1	0	2	0.5
4	3/23	3/29	0	0	0	0.33
5	3/30	4/05	*NA	*NA	*NA	*NA
6	4/06	4/12	*NA	*NA	*NA	*NA
7	4/13	4/19	66	3	105	0.79
8	4/20	4/26	72	3	144	1
9	4/27	5/03	174	7	236	1
10	5/04	5/10	140	2	141	1
11	5/11	5/17	156	2	165	1
12	5/18	5/24	59	3	61	1
13	5/25	5/31	18	0	22	1
14	6/01	6/07	0	0	11	0.79
15	6/08	6/14	0	0	3	0.87
16	6/15	6/21	0	0	0	0.42
17	6/22	6/28	0	0	0	0.57
18	6/29	7/05	0	0	0	0.57
19	7/06	7/12	0	0	0	0.56
20	7/13	7/19	0	0	0	0.57
21	7/20	7/26	0	0	0	0.1

*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. Final analysis 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	3/02	3/08	*NA	*NA	*NA	*NA
2	3/09	3/15	*NA	*NA	*NA	*NA
3	3/16	3/22	23	0	34	0.5
4	3/23	3/29	12	1	13	0.33
5	3/30	4/05	*NA	*NA	*NA	*NA
6	4/06	4/12	*NA	*NA	*NA	*NA
7	4/13	4/19	12	0	22	0.79
8	4/20	4/26	1	0	112	1
9	4/27	5/03	225	18	238	1
10	5/04	5/10	496	25	842	1
11	5/11	5/17	665	52	1726	1
12	5/18	5/24	702	28	1604	1
13	5/25	5/31	599	40	4128	1
14	6/01	6/07	309	34	2139	0.79
15	6/08	6/14	198	12	1905	0.87
16	6/15	6/21	236	1	398	0.42
17	6/22	6/28	177	15	1211	0.57
18	6/29	7/05	246	49	588	0.57
19	7/06	7/12	199	28	976	0.56
20	7/13	7/19	189	27	403	0.57
21	7/20	7/26	0	0	6	0.1
22	7/27	8/02	*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.