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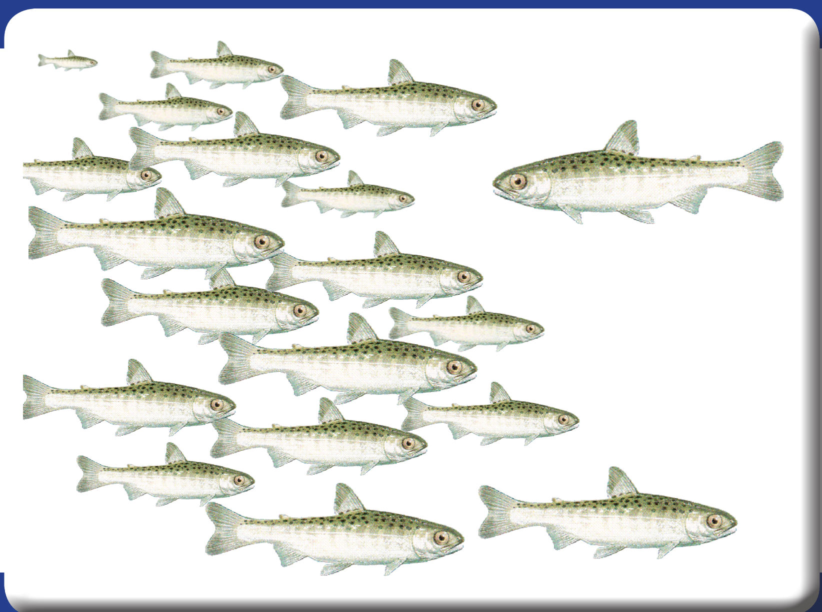
April 2020

Newaukum River Smolt Production, 2019



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Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 20-04

Newaukum River Smolt Production, 2019

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Executive Summary

This report provides the 2019 results from the juvenile salmonid monitoring study on the Newaukum River main stem near Centralia, WA. The primary objective of this study is to describe the freshwater production (e.g. smolt abundance) of Pacific salmon (*Oncorhynchus* spp.) and steelhead (*O. mykiss*) in the Newaukum River. Specifically, we describe the abundance, timing, and diversity (body size, age structure) of juvenile outmigrants for wild Chinook (*O. tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*). Based on the location and timing of our study, the results reflect juveniles that completed their freshwater rearing phase in habitats upstream of river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River.

To meet the study objectives, a 1.5 meter (5–foot) rotary screw trap was operated near river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River from March 13 to July 12, 2019.

Chinook outmigrants were subyearlings. 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, our goal was to estimate the subyearling (> 45mm fork length) component of the Chinook outmigration that generally occurs from March – July. Fork length of Chinook subyearlings increased steadily throughout the trapping period with an average of 55.0 mm (± 2.7 mm, standard deviation SD) and 78.4 mm (± 6.5 mm SD) in the first and last sampled week of trapping, respectively. Roughly 88% of the total catch of wild Chinook subyearling outmigrants were > 45mm. Abundance of wild Chinook subyearling outmigrants was estimated to be 277,109 ± 33,482 SD with a coefficient of variation (CV) of 11.8%.

Coho outmigrants were both yearling and subyearlings. Scale age data indicated the subyearling component of the coho outmigration started near the middle of May and that prior to this date outmigrants were primarily one year of age, or yearlings. Fork length of yearling outmigrants averaged 105.0 mm (± 12.9 mm SD) whereas fork length of subyearling outmigrants averaged 75.5 mm (± 7.9 mm SD). Abundance of wild coho outmigrants was estimated to be 51,228 ± 3,820 SD with a CV of 13.1%.

Steelhead outmigrants were one, two, and three years of age. Fork length averaged 140.0 mm (± 21.6 mm SD) for one-year olds, 162.9 mm (± 15.3 mm SD) for two-year olds, and 180.4 mm (± 19.4 mm SD) for three-year olds. We were not able to produce an accurate or precise estimate this season due to low recaptures and not trapping over the entirety of the steelhead outmigration.

Table 1. Abundance of Chinook, coho, and steelhead outmigrants that completed their freshwater rearing phase upstream of river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River. NA indicates no abundance estimate was produced.

Abundance Group	Origin	Life Stage	Age Class	Abundance ± Standard Deviation	Coefficient of Variation (%)
Chinook	Wild	Transitional, Smolt	Subyearling	277,109 ± 33,482	11.8
Coho	Wild	Transitional, Smolt	Subyearling, Yearling	51,228 ± 3,820	13.1
Steelhead	Wild	Transitional, Smolt	Yearling	NA	NA

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 wild coho salmon (*O. kisutch*) and generated estimates of wild coho 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 998 smolts mi^{-2}) than any other western Washington watershed for which data currently exists (Kendall et al. 2019). Smolt abundance estimates from individual tributaries were generated in the 1980s and 1990s but have not been evaluated for nearly two decades and were also focused on coho only. Therefore, there is currently limited information on freshwater production of other salmonid species, including Chinook (*O. tshawytscha*) and chum salmon (*O. keta*) and steelhead (*O. mykiss*) in the Chehalis River basin. Recent efforts under the Chehalis Basin Strategy (http://chehalisbasinstrategy.com/) to develop an Aquatic Species Restoration Plan have highlighted smolt (or juvenile outmigrant) data as an important information gap that will be critical for evaluating variability and trends in freshwater production over time and in response to restoration.

As a result, WDFW monitoring activities were recently expanded to develop a more comprehensive understanding of freshwater production among multiple species of salmonids and among multiple locations within the Chehalis Basin. In the future, we anticipate that this expanded effort will become part of an integrated monitoring program used to evaluate salmon and steelhead responses to changes in the riverine environment due to habitat restoration actions and climate change (http://chehalisbasinstrategy.com/). In 2019, the Newaukum River was selected to monitor smolt production to collect baseline information prior to restoration projects focused on enhancing salmon and steelhead rearing habitat in the basin. The Newaukum River supports runs of fall and spring run Chinook salmon, coho salmon, and steelhead trout. The Newaukum River is known to support a relatively large proportion (~25%) (WDFW unplublished data) of the spring Chinook population in the Chehalis River Basin. Additionally, in 2015 the Newaukum River was designated as a “pilot watershed” by Chehalis Lead Entity to guide restoration along all coast Lead Entity areas (http://www.chehalisleadentity.org/our-work/). Several restoration projects are currently being implemented and planned within the Newaukum River basin. For these reasons, accurate and precise estimates of salmon and steelhead smolt populations (e.g., freshwater production) in the Newaukum River are critical for monitoring status and trends of salmon and steelhead populations and responses to habitat restoration.

Objectives

The primary objective of this study was to describe the freshwater production of salmon and steelhead in the Newaukum River. Specifically, we describe the abundance, timing, and diversity (body size, age structure) of juvenile outmigrants for wild Chinook salmon, coho salmon, and steelhead. Based on the location and timing of our study, the results reflect juveniles that completed their freshwater rearing phase in habitats upstream of river kilometer 9.35 (river mile 5.8) of the main stem Newaukum River. In order to achieve this goal in the first year of this study, a trap site selection process within the Newaukum River was conducted months prior to operation. This report includes results from the 2019 field season.

Methods

Study Site

The Newaukum River is a major sub-basin of the Chehalis River, a large coastal drainage in Southwest Washington State. The Newaukum River is comprised of three forks (North, Middle, and South Fork) and a main stem that drains approximately 450 square kilometers from the foothills of the Cascade mountains. The main stem Newaukum enters the Chehalis River at approximately river mile 75.2, just south of the city of Centralia. The Newaukum River is relatively low elevation (~48 to 909 m) and low gradient with a rain dominant hydrology. Land use in the basin is predominately industrial timber production in the headwater locations and private residential and agricultural in lower elevation locations. Native anadromous salmonids in the Newaukum River include spring and fall Chinook salmon, coho salmon, winter steelhead, and cutthroat trout (*O. clarkii*). A hatchery program for coho and steelhead is operated by the Onalaska School District in the South Fork Newaukum, upstream of the smolt trap.

Similar to other rivers in western Washington, juvenile Chinook salmon in the Chehalis River have 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; Winkowski and Zimmerman 2018). The Chehalis main stem trap is downstream of the Newaukum trap, therefore juvenile Chinook salmon in the Newaukum presumably exhibit a similar life history behavior of outmigrating as sub yearlings. There are two predominant freshwater rearing strategies observed for juvenile Chinook salmon and these are observed at the Chehalis 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 that grow in freshwater for weeks to months after emergence and are observed at the smolt trap between the months of April and July. Subyearlings are the focus of our production estimates in the Newaukum River.

The trapping location on the Newaukum River (46°37'0.56 N, 122°56'12.51 W) 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., downstream most sites represent more of a complete basin smolt abundance estimate), and finally land owner permission for access if site is on private lands. After multiple float trips of the main stem Newaukum River a limited number of sites fit our criteria and our final site location represented the most downstream site where environmental conditions (e.g., flow, depth) were favorable and site access was granted for trapping operations. A small proportion of Chinook salmon spawn downstream of the trap site and therefore our Chinook abundance estimate represents a large portion, but not all, of the Chinook production in the Newaukum River. For coho salmon and steelhead in 2019, all spawning activity was estimated to occur upstream from our trapping site (C. Holt, WDFW personal communication).

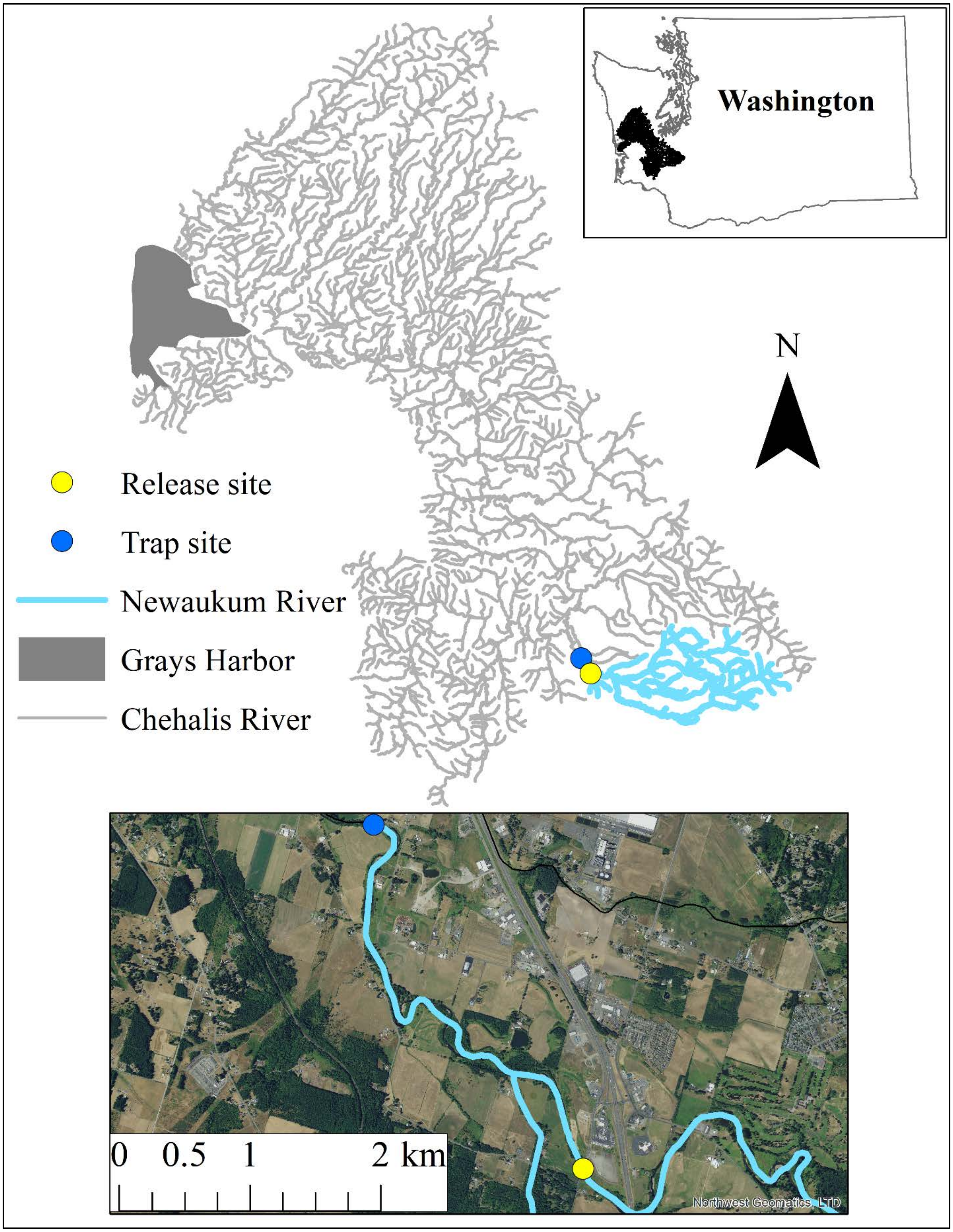


Figure 1. Location of trap site (blue dot) and upstream release site for marked fish (yellow dot) in the Newaukum River, sub basin to the Chehalis River, WA.

Trap Operation

A 1.5 m (5-foot) diameter rotary screw trap (RST) was operated near river kilometer 9.35 of the Newaukum River. In 2019, the trap was scheduled to operate continuously from March 13 through July 12, although unscheduled trap outages did occur due to high flow, warm (>18°C) water temperatures, debris, and trap malfunctions.

River temperature and trap status (e.g., fishing or not fishing, cone revolutions per minute) data were collected at each trap check. Instantaneous stream temperature was collected at the start of each sampling event and water temperatures in fish holding containers were monitored throughout sampling events. Stream temperature was also monitored with a temperature data logger (HOBO 64K Pendant) deployed adjacent to the trap and cabled to the bank that collected and logged temperature at 30-min intervals. Stream flow is monitored by the USGS discharge gage Newaukum River near Chehalis, Washington (USGS 12025000) which is located 2.7 km downstream of the trap site.

Figure 2. Newaukum River trap site.

Fish Collection

Fish sampling commenced in the morning on a daily basis 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 where water was refreshed frequently. 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 7-8 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. Chinook, coho, and steelhead were further categorized by life stage and age class, as described below. Marks associated with trap efficiency trials (see Trap Efficiency Trials section) and hatchery origin (clipped adipose fin) were examined on all Chinook, coho, and steelhead. Fork length and scales were collected from a subsample of wild (adipose fin intact) Chinook, coho, and steelhead (Table 2). We collected scale samples from coho in three distinct size classes (see Table 2) in order to inform the age class-length-date criteria used for categorizing subyearlings versus yearlings in the field.

Table 2. Sample rates for biological data collection from wild juvenile salmonids.

Sample Type	Species	Fry	Parr	Transitional/Smolt
Fork Length	Chinook	1st 50 per week	1st 50 per week	1st 50 per week
	Coho	1st 50 per week	1st 50 per week	1st 50 per week
	Steelhead	1st 50 per week[a]	1st 50 per week	All Efficiency marked individuals 100/Day
Scales	Chinook[b]	---	---	---
	Coho	---	---	1st 5 per week per size class (<100 mm, 100-149 mm, ≥150mm)
	Steelhead	---	---	1st 20 per week

[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 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 years in freshwater. The majority of outmigrating Chinook salmon in the Newaukum River are subyearling. Individuals above 150 mm would be well outside of the fork length range of subyearling outmigrants and would be labeled as yearling in the field (Table 3). For coho salmon all fry and parr were classified as subyearling and all smolts and transitionals were classified as yearling (Table 4). For steelhead, the field-assigned 'yearlings' were a mix of 1, 2, and 3-year-old fish that could not be distinguished by length in the field (Table 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	---	March 1 – June 30	≤ 45
Parr, Transitional, Smolt	Subyearling	March 1 – June 30	46 – 100
Transitional, Smolt	Yearling (+)	March 1 – June 30	> 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	---	March 1 – July 30	≤ 45
Parr	Subyearling	March 1 – July 30	46 – 89
Transitional, Smolt	Yearling	March 1 – July 30	≥ 90

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	---	March 1 – July 30	≤ 45
Parr	Subyearling	March 1 – July 30	46 – 75
Parr	Yearling (+)	March 1 – July 30	75 – 299
Transitional, Smolt	Yearling (+)	March 1 – July 30	90 – 299
Adult	Adult	March 1 – June 30	300 – 499
Adult	Adult	March 1 – June 30	> 500

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 Chinook, coho, and steelhead. All trap efficiency trials were conducted with wild (adipose fin intact) fish. Within the season, when wild fish numbers were low, we experimented with supplementing mark groups with hatchery origin fish. However, preliminary analyses suggested recapture rates differed when comparing wild and hatchery fish. Therefore, hatchery fish were ultimately not included in our calculation to estimate abundance of natural origin 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. Our trap did not operate for the full duration of the early-timed fry outmigration; therefore, no estimate was generated for Chinook fry and this life stage was not included in the trap efficiency trials. For coho and steelhead, trap efficiency trials were conducted with transitional and smolt life stages. Fry and parr life stages were not included in the trap efficiency trials for coho and steelhead because we assumed that these life stages were not actively 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 500 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 3.9 kilometers upstream of the trap location at the Rush Road bridge on the right bank, directly under the bridge (Figure 1, Table 7).

Mark types and rotation schedules allowed the data to be organized by week for the purpose of analysis. We used different mark types for salmon and steelhead (Table 7). All releases occurred within 1-3 hours of a trap check. Warming stream temperatures after June 28 necessitated major changes with our trapping operation including ceasing all our efficiency trails. Prior to June 28 Chinook, coho and steelhead efficiency trials had been conducted over the entirety of the trapping season with minimal exceptions.

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	4 week	Bridge	3.9
Coho	VIE	Weekly	4 week	Bridge	3.9
Steelhead	PIT	Individual	Individual	Bridge	3.9

Analysis

We used Bayesian Time-Stratified Population Analysis System (BTSPAS, Bonner and Schwarz 2014) to estimate abundance of Chinook, coho, and steelhead (Table 6). BTSPAS uses Bayesian P-splines and hierarchical modeling of trap efficiencies, 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 organized by week and included 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.

We used the diagonal version of the BTSPAS model that assumed all marks were recaptured during the time strata period (i.e., week) in which they were released. This assumption was met by the collected data. Prior to analysis, we removed any marks for which the trap did not continuously fish for 48 hours after release because these marks were not available for recapture. BTSPAS analysis was executed in R v.3.4.1 (R Core Team, 2017) using the package BTSPAS (Bonner and Schwarz 2014).

Results

Summary of Fish Species Encountered

We encountered a diverse assemblage of fish species throughout the 2019 trapping season. Native fish included juvenile Chinook and coho salmon, steelhead and cutthroat trout, mountain whitefish (*Prosopium williamsoni*), redside shiner (*Richardsonius balteatus*), dace species (*Rhinichthys* spp.), largescale sucker (*Catostomus macrocheilus*), three-spine stickleback (*Gasterosteus aculeatus*), northern pikeminnow (*Ptychocheilus oregonensis*), Pacific lamprey (*Entosphenus tridentatus*), brook lamprey (*Lampetra planeri*) and sculpin species (Cottidae). Non-native fish included bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), and other unidentified sunfish species (Centrarchidae).

Trap operation

We operated the trap from March 13, 2019 to July 12, 2019. We had three occurrences of trap outages (Appendix B). For two of the three outages, the outage time was known exactly because the trap stopped fishing when staff lifted the cone during periods of high flows and debris. One of these events started on April 11th and kept the trap out for three days. The last outage was a log stopping the cone before the crew had arrived onsite so exact time stopped is unknown. The latter two outages last for less than 24 hours.

Assumptions for Mark-Recapture Estimates

The six basic assumptions to be met for unbiased estimates in mark-recapture studies include: 1) the population is closed, 2) marks are not lost, 3) marking does not affect behavior, 4) initial capture probabilities are homogenous, 5) the second sample is random representative sample (i.e., marked and unmarked fish are completely mixed), and 6) mark status is reported correctly.

Assumption 1 is technically violated because all fish are emigrating. However, we adjust the approach to assume that the entirety of the population passed the trap during the period of trap operation. Therefore, to meet assumption 1, we trapped over the entire outmigration except for steelhead, and statistically adjusted for missed trapping days.

To meet assumption 2, we followed standardized marking and tagging protocols with known mortality and estimated mark retention by holding a subsample of fish for 24 hours after marking. Results indicated that mark retention was high. Estimated mark retention was 100% (VIE, 329 out of 329 marked) for chinook and 99% (VIE, 165 out of 166 marked) for coho and 100% for steelhead (PIT tags, 12 out of 12 tagged).

To meet assumption 3, we used standard procedures for marking, marked healthy fish only, and held a subsample of marked fish overnight to assess mark related mortality. Results indicated that mark-related mortality was low. Estimated survival was 98% (VIE, 324 out of 329 marked) for Chinook, 100% (VIE, 166 out of 166 marked) for coho, and 100% for steelhead (PIT tags, 12 out of 12 tagged) over the 24-hour holding period.

To meet assumption 4, we stratified data by week to minimize heterogeneity in initial capture probabilities over time. Temporal variability in capture probability was expected due to environmental conditions, such as flows or turbidity that changed substantially between the beginning of trap operation in March and the end of trap operation in July. We also tested for differences in initial capture probabilities due to body size using a Kolmogorov–Smirnov test. The fork length of maiden captures versus recaptures did not differ for Chinook, ($D = 0.198$, $p = 0.0759$) coho, ($D = 0.056$, $p = 0.682$) or steelhead ($D = 0.11$, $p = 0.721$).

To meet assumption 5, we released fish in an upstream location that was 3.9 km (2.4 miles) upstream from the trap location with multiple bends and complex habitat (e.g., wood, split channels) between the release location and the smolt trap where marked fish were recaptured.

To meet assumption 6, we attempted to minimize error through staff training and careful examination of every fish. Two samplers inspected every fish and agreed on mark status designations. All Chinook and coho were visually inspected for VIE marks. All steelhead were scanned for PIT tags and visually inspected for PIT scars.

Chinook

In 2019 the Chinook outmigrant estimate was derived for the 'subyearling' life history that included transitionals and smolts. Chinook outmigrants were observed in low numbers ($n < 100$) the first week of trapping (March 13th, trapping period 1), peaked in early June, and declined to low numbers again by the last week of trapping (July 12th, trapping period 18, Figure 4, Appendix C).

Scale age data were not collected from Chinook in 2019 as all juvenile fish were assumed to be age 0. Fork length of Chinook subyearlings increased steadily throughout the trapping period with an average of 55.0 mm (± 2.7 mm SD) and 78.4 mm (± 6.5 mm) in the first and last sampled week of trapping, respectively (Figure 3).

A total of 75,776 Chinook subyearling outmigrants were captured, 4,259 were marked, and 1,146 were recaptured (Appendix C; Periods 1 – 18). Modeled weekly trap efficiencies ranged from 2.9 to 52.4%.

Abundance of wild Chinook subyearling outmigrants was estimated to be 277,109 ± 33,482 SD with a coefficient of variation (CV) of 11.8%.

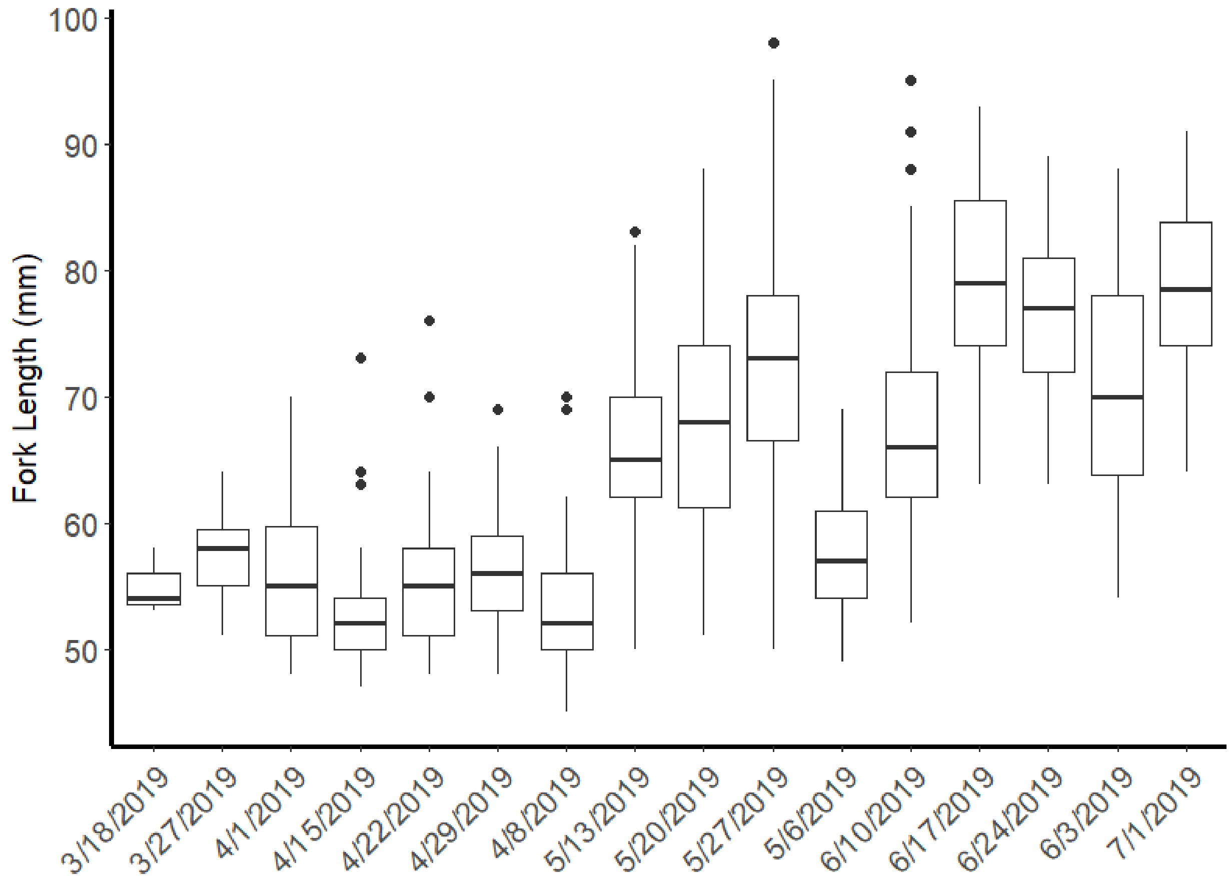


Figure 3. Box plots of fork lengths of wild Chinook subyearling outmigrants (transitionals, smolts) by week at the Newaukum River screw trap, 2019. Box's represent the median, first and third quartiles, whiskers represent the interquartile ranges, and dots represent outliers.

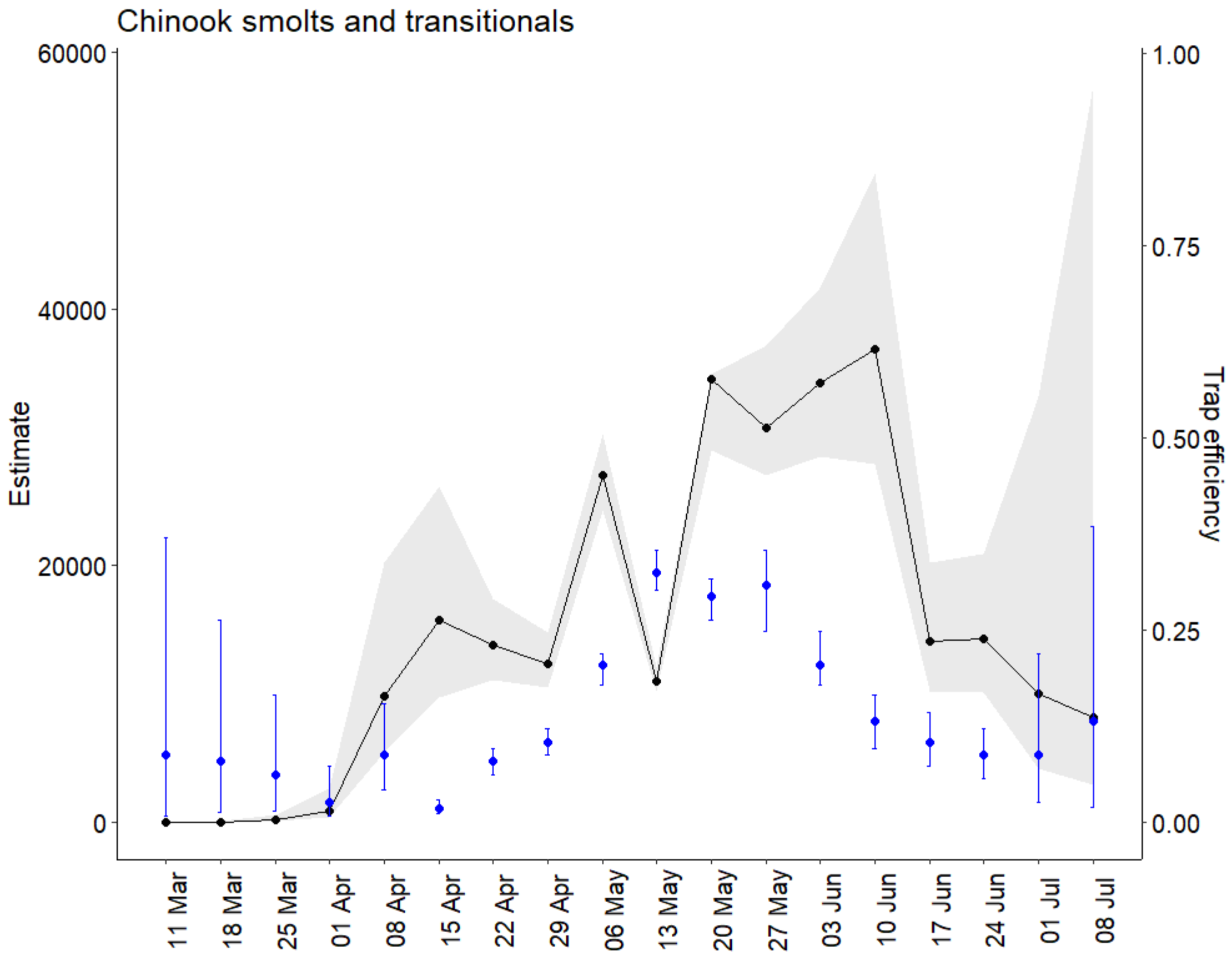


Figure 4. Migration timing of wild Chinook outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2019. Data are abundance (black line) and modeled trap efficiency (blue dots) with 95% confidence intervals (shading for abundance, bars for efficiency) by week. Data provided in Appendix C.

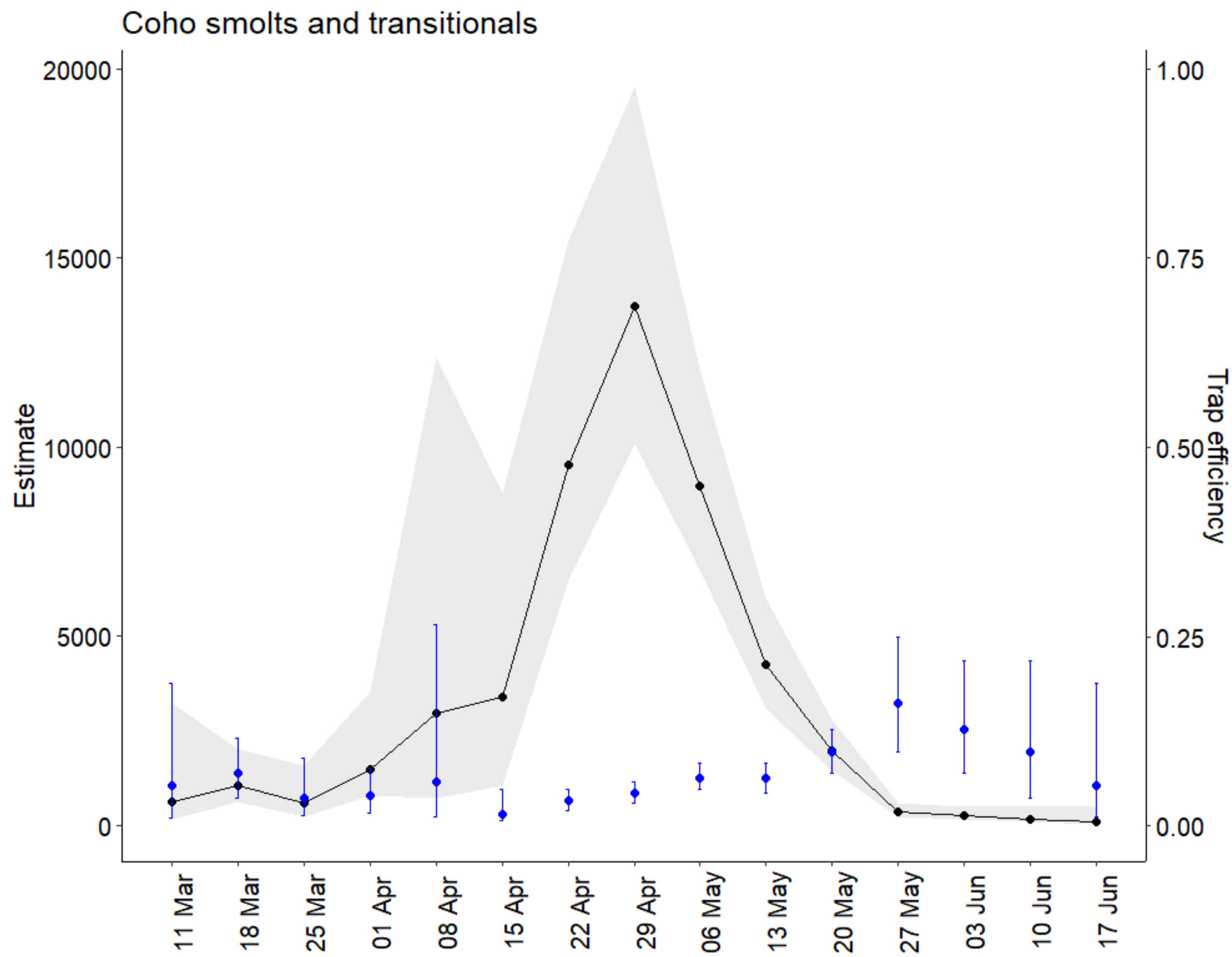
Coho

The coho outmigrant estimate included both subyearlings and yearlings in transitional and smolt life stages. Roughly 66% of the outmigrants observed at the trap were categorized as 'smolt' phenotype whereas 44% were categorized as 'transitional.' Coho outmigrants were observed in low numbers the first week of trapping (March 14th, trapping period 1), peaked in late April, and were last observed the week of June 28th (trapping period 16, Figure 5, Appendix D).

Scale age data indicated a subyearling component of the outmigration starting near the middle of May and prior to this date all sampled outmigrants were one year of age (Figure 6, Table 8, Table 9, Table 10). Fork length of yearling outmigrants averaged 105.0 mm (± 12.9 mm) whereas fork length of subyearling outmigrants averaged 75.5 mm (± 7.9 mm).

In 2019, a total of 3,379 coho outmigrants were captured, 2,448 coho were marked, and 196 were recaptured (Appendix D). Modeled weekly trap efficiencies ranged from 1.9 to 21.4%.

Abundance of 2019 wild coho outmigrants was estimated to be 51,228 ± 3,820 SD with a CV of 13.1%.



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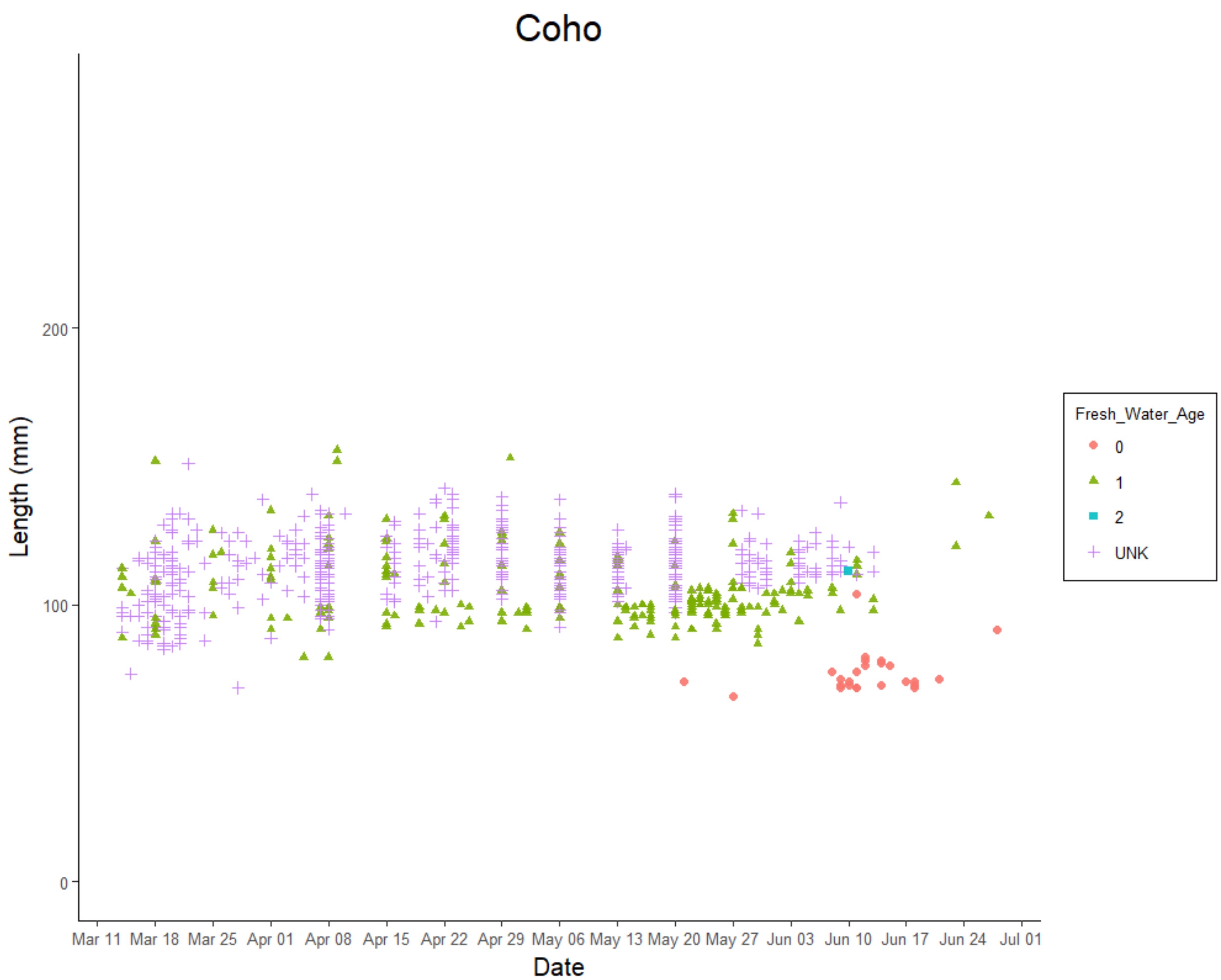

Figure 6. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2019.

Table 8. Freshwater ages of wild coho outmigrants < 100 mm FL (transitionals, smolts) at the Newaukum River screw trap, 2019. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
1	3/11	3/17	6	0	1	0	5
2	3/18	3/24	5	0	5	0	0
3	3/25	3/31	1	0	1	0	0
4	4/01	4/07	8	0	7	0	1
5	4/08	4/14	5	0	5	0	0
6	4/15	4/21	8	0	8	0	0
7	4/22	4/28	4	0	4	0	0
8	4/29	5/05	7	0	7	0	0
9	5/06	5/12	5	0	5	0	0
10	5/13	5/19	17	0	17	0	0
11	5/20	5/26	24	1	23	0	0
12	5/27	6/02	12	1	11	0	0
13	6/03	6/09	6	4	2	0	0
14	6/10	6/16	13	12	1	0	0
15	6/17	6/23	5	5	0	0	0
16	6/24	6/30	1	1	0	0	0
17	7/01	7/07	0	0	0	0	0
18	7/08	7/14	0	0	0	0	0

Table 9. Freshwater ages of wild coho outmigrants 100-149 mm FL (transitionals, smolts) at the Newaukum River screw trap, 2019. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
1	3/11	3/17	5	0	4	0	1
2	3/18	3/24	5	0	3	0	2
3	3/25	3/31	5	0	5	0	0
4	4/01	4/07	6	0	6	0	0
5	4/08	4/14	5	0	5	0	0
6	4/15	4/21	10	0	10	0	0
7	4/22	4/28	6	0	6	0	0
8	4/29	5/05	5	0	5	0	0
9	5/06	5/12	6	0	6	0	0
10	5/13	5/19	9	0	9	0	0
11	5/20	5/26	28	0	27	0	1
12	5/27	6/02	14	0	14	0	0
13	6/03	6/09	10	0	10	0	0
14	6/10	6/16	7	1	4	1	1
15	6/17	6/23	2	0	2	0	0
16	6/24	6/30	1	0	1	0	0
17	7/01	7/07	0	0	0	0	0
18	7/08	7/14	0	0	0	0	0

Table 10. Freshwater ages of wild coho outmigrants ≥ 150 mm FL (transitionals, smolts) at the Newaukum River screw trap, 2019. Data are scale ages of sampled juveniles by week.

Period	Start Date	End Date	No. Scales	Age-0	Age-1	Age-2	Not Determined
1	3/11	3/17	0	0	0	0	0
2	3/18	3/24	1	0	1	0	0
3	3/25	3/31	0	0	0	0	0
4	4/01	4/07	0	0	0	0	0
5	4/08	4/14	2	0	2	0	0
6	4/15	4/21	0	0	0	0	0
7	4/22	4/28	0	0	0	0	0
8	4/29	5/05	1	0	1	0	0
9	5/06	5/12	0	0	0	0	0
10	5/13	5/19	0	0	0	0	0
11	5/20	5/26	0	0	0	0	0
12	5/27	6/02	0	0	0	0	0
13	6/03	6/09	0	0	0	0	0
14	6/10	6/16	0	0	0	0	0
15	6/17	6/23	0	0	0	0	0
16	6/24	6/30	0	0	0	0	0
17	7/01	7/07	0	0	0	0	0
18	7/08	7/14	0	0	0	0	0

Steelhead

Our goal was to generate an unbiased abundance estimate of the steelhead smolt and transitional outmigration. However, due to environmental conditions and duration of our trapping, we violated Assumption 1 of trapping over the entirety of the outmigration. Therefore, our estimate of abundance for steelhead is unreportable in 2019. During trapping operations steelhead outmigrants were observed the first week of trapping March 11th (trapping period 1), peaked in early March, and were last observed the week of June 30th (trapping period 16, Appendix E).

Scale age data indicated that the sampled steelhead were one, two, and three years of age (Figure 7, Table 11). Fork length averaged 140 mm (± 21.6 mm) for one-year olds, 162.9 mm (± 15.3 mm) for two-year olds, and 180.4 mm (± 19.44) for three-year olds.

In 2019, a total of 484 steelhead outmigrants were captured, 358 steelhead were marked, and 31 were recaptured (Appendix E). Modeled weekly trap efficiencies ranged from 8.3 to 9.9% however, due to low capture rates, we were unable to generate a precise and unbiased estimate of abundance.

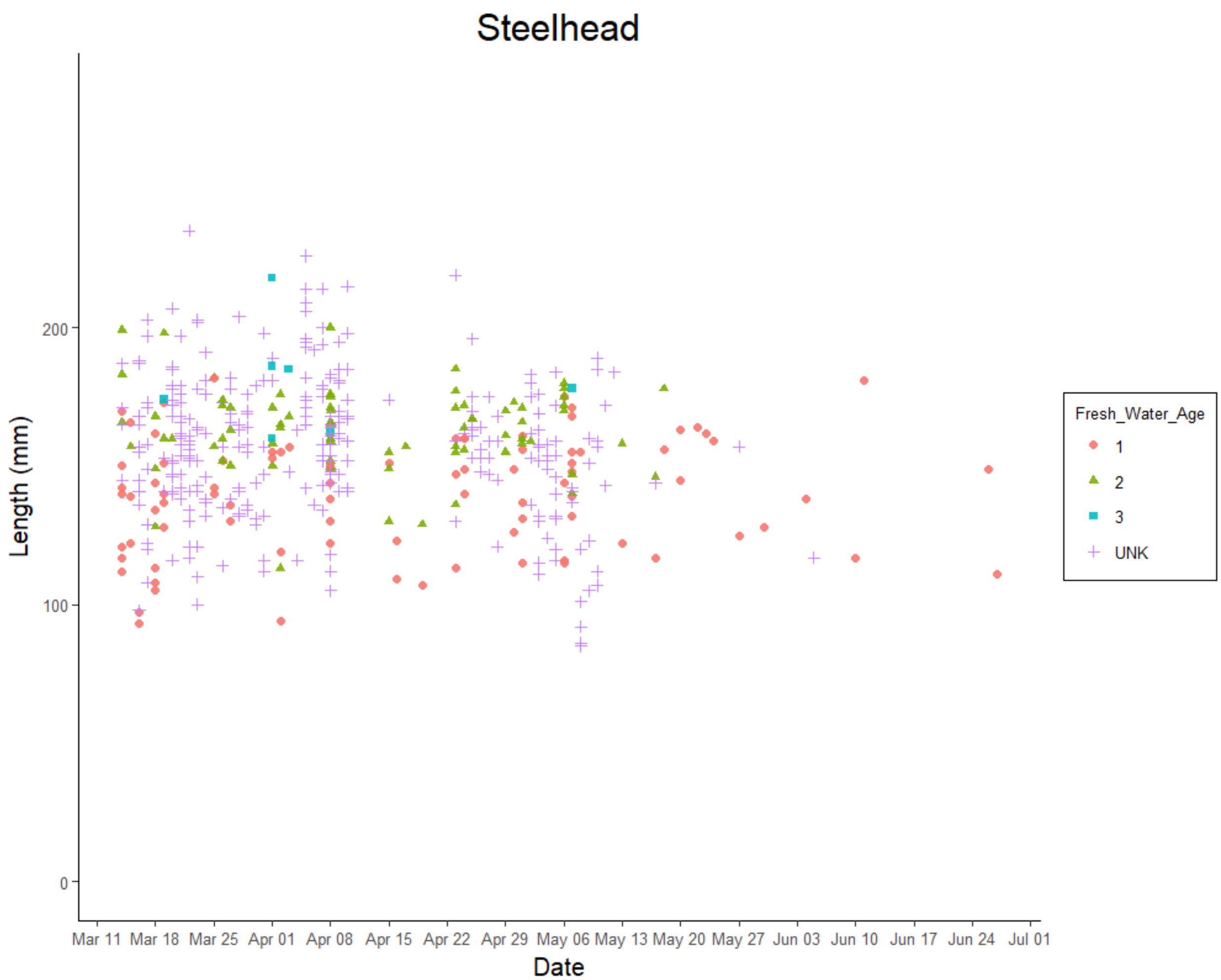

Figure 7. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2019.

Table 11. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Newaukum River screw trap, 2019. Data are scale ages of sampled juveniles by week.

Period	**Start Date**	**End Date**	**No. Scales**	**Age-1**	**Age-2**	**Age-3**	**Not Determined**
1	3/11	3/17	20	12	4	0	4
2	3/18	3/24	21	12	6	1	2
3	3/25	3/31	20	6	9	0	5
4	4/01	4/07	20	6	8	4	2
5	4/08	4/14	20	5	14	1	0
6	4/15	4/21	10	4	5	0	1
7	4/22	4/28	20	7	11	0	2
8	4/29	5/05	17	7	10	0	0
9	5/06	5/12	20	12	7	1	0
10	5/13	5/19	7	3	3	0	1
11	5/20	5/26	5	5	0	0	0
12	5/27	6/02	3	2	0	0	1
13	6/03	6/09	1	1	0	0	0
14	6/10	6/16	2	2	0	0	0
15	6/17	6/23	0	0	0	0	0
16	6/24	6/30	2	2	0	0	0
17	7/01	7/07	0	0	0	0	0
18	7/08	7/14	0	0	0	0	0

Discussion

Basin-wide Context

This report presents results from the 2019 salmon and steelhead smolt outmigration of the Newaukum River, the first year since 1988 of which any smolt monitoring has been conducted in 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 river kilometer 9.35. We acknowledge that some juveniles emerge from the gravel upstream of the trap location but redistribute to areas downstream of the trap location during their freshwater rearing period and are not included in the estimate. This caveat is especially true for coho salmon, known to redistribute in a downstream direction during the fall months in search of suitable overwintering habitat.

Our estimate of Chinook smolt and transitional subyearling outmigrants represents the subyearling portion of the Chinook outmigration upstream of the trap location and does not include the earlier timed fry migrants. However, the 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. Fry migrants do not spend much time rearing in freshwater habitats but rather move downstream shortly after emergence and 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, numbers of subyearling Chinook outmigrants remain relatively consistent from year to year and that abundance of this life history reflects a freshwater rearing capacity (Anderson and Topping 2018, Zimmerman et al. 2015). If rearing capacity is reached, additional juvenile Chinook may migrate downstream as fry in response to density-dependence (Greene et al. 2005). Extending this density-dependent migration hypothesis to the Newaukum River will require additional years of juvenile monitoring coupled with adult Chinook spawner data above the trap location.

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

By operating multiple smolt traps in the basin, we are able to partition smolt abundance estimates to specific locations, thereby providing a finer scale resolution of freshwater production in the basin. Annual freshwater production of wild coho smolts in Chehalis River Basin averaged 2 million (0.5 to 3.7 million) since WDFW began monitoring smolt production in the 1980s (Zimmerman 2018). From 2017-2019, coho smolt abundance bas been estimated in the Chehalis main stem at river mile 52 and has averaged around 350,000 coho smolts (Winkowski et al. 2018 and WDFW unpublished data). Therefore, the area above river mile 52 contributes to roughly 18%

of the coho smolt production in the basin. In 2019, specifically, coho smolt abundance at the Chehalis River smolt trap was estimated to be 363,214 (WDFW unpublished data). Therefore, in 2019, the Newaukum River coho abundance estimate (51,228) represents approximately 14% of the coho production above river mile 52 of the main stem Chehalis River. This information is critical for understanding status and trends of salmon smolt abundance in different locations in the basin and how they could be influenced by changes to the physical environment (e.g., restoration or climate change).

In 2019, we were unable to produce an estimate of wild juvenile steelhead outmigrants due to low capture and recapture rates and missing the early portion of the outmigration. In future seasons we may attempt to deploy the trap at an earlier date to capture the early outmigration period. Interestingly, in 2019 we were able to produce a steelhead abundance estimate for smolts encountered in the Chehalis main stem trap located approximately 31 miles downstream of the Newaukum site (29,024 ± 5,343 SD). The main stem trap became operational 14 days after the Newaukum trap, suggesting that the wild steelhead smolts were not rapidly moving downstream. Moreover, despite not generating an abundance estimate, we were able to observe 3 distinct age-classes of wild steelhead (ages 1-3), which improves understanding of life history diversity in the Newaukum sub-basin.

Next Steps

The Newaukum River presents many challenges to smolt trap operation. In 2019, these challenges included high flows and warm stream temperatures. High flow events early during the coho and steelhead outmigration period (April) necessitated trap outages that increased uncertainty of our estimates for those periods. This was particularly problematic for steelhead, which migrate slightly earlier and at a larger size than coho, and resulted in an unreportable estimate for steelhead in 2019. Challenges in trap operation began when river flows exceeded 800 cubic feet per second (USGS Stream Gage 1202500). To remedy this in 2020, we will explore trap positions suitable for fishing during higher flow events.

The Chinook subyearling outmigration in 2019 peaked in early June, which presented challenges for fish handling under high stream temperatures. As catch of subyearling Chinook increased from May to June, mean monthly stream temperatures increased from 15.4 to 18.3 ℃, respectively (Table 12, Figure 8). During this timeframe, we adjusted our fish sampling to early mornings when stream temperatures were lowest. We will follow a similar model in 2020. Also, as was previously noted in this report, our estimate of the Chinook outmigration represents the subyearling component of the outmigration and did not include fry outmigrants. Given the extreme flow conditions of the river in January and February when fry are outmigrating, we do not currently have plans to fish the trap during the early-timed fry migration.

Table 12. Mean monthly stream temperatures °C recorded at Newaukum River smolt trap near river km 9.35, 2019.

Month	Mean (°C)
March	6.5
April	10.2
May	15.4
June	18.3
July	20.3

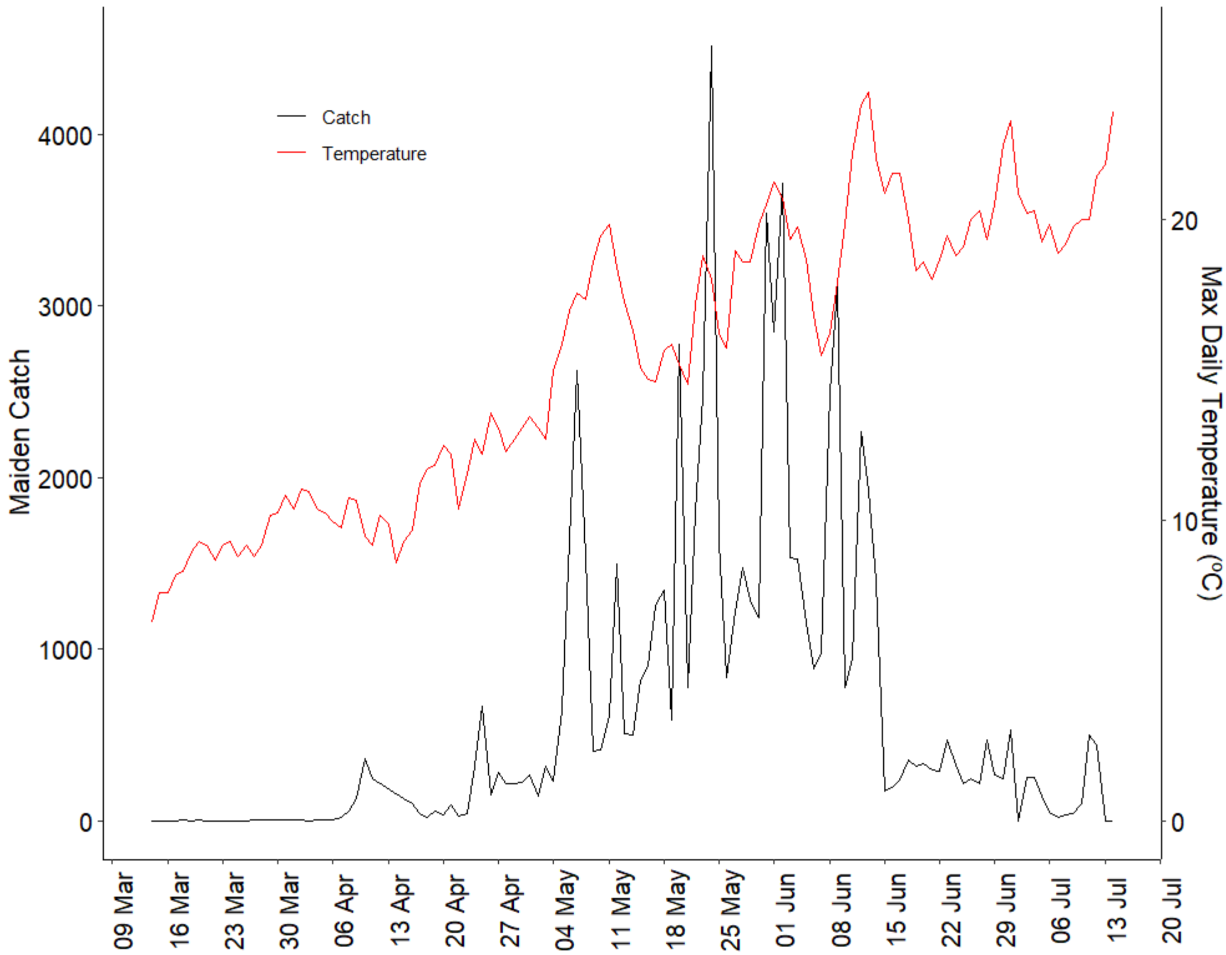

Figure 8. Chinook maiden catch and maximum daily stream temperature (°C) at the Newaukum River smolt trap, 2019.

In summary, 2019 represents the first year for which wild Chinook, coho and steelhead outmigrations have been described from any location in the Newuakum River in three decades. Our 2020 season will benefit from refinements resulting from this pilot year. For Chinook and coho, we generated unbiased and precise estimates of smolt abundance in 2019. For all three species, we described the timing, age structure, and size of the outmigrants as these are additional characteristics that reflect how the existing habitat contributes to freshwater production of salmon and steelhead. Continuation of this monitoring in future years will provide understanding of variability and trends in freshwater production over time. As part of a larger, integrated monitoring effort associated with the Aquatic Species Restoration Plan, this baseline information should also inform future questions on the influence of habitat restoration projects or climate change impacts on freshwater production of salmon and steelhead in the Newaukum River.

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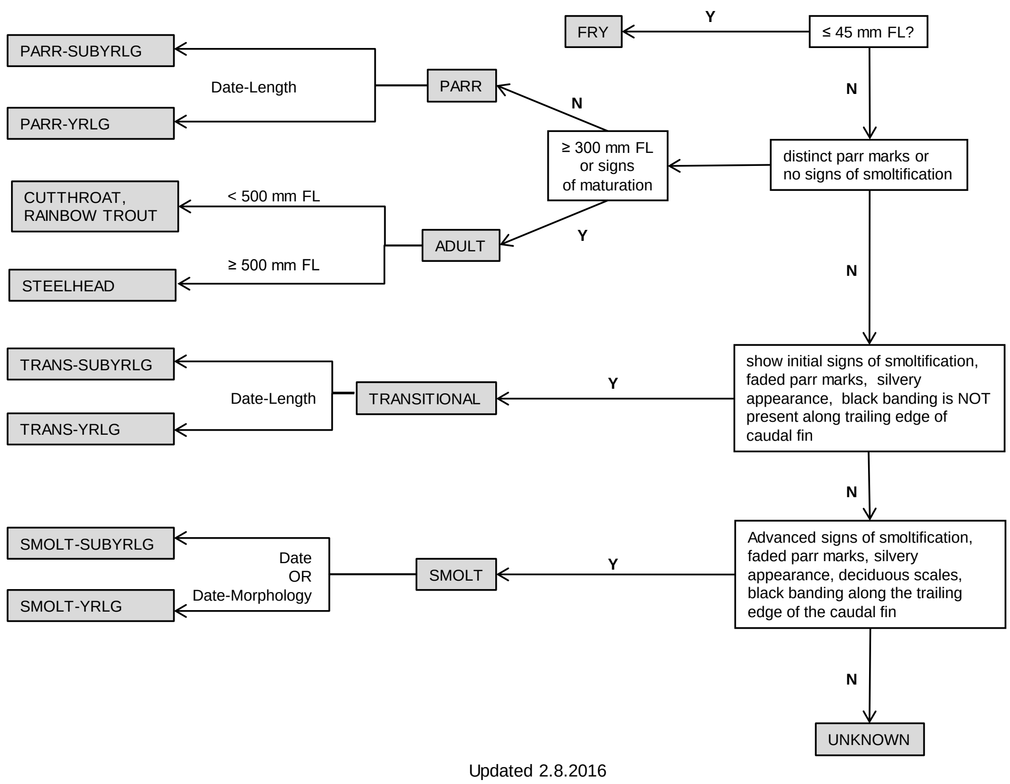
Appendices

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. Newaukum River missed trapping periods 2019. All missed trapping periods occurred by staff pulling the trap.

Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
NA	Visual	4/06/19 10:40 am	Trap stopper (unknown stop time)
4/11/19 10:40 am	Pulled trap	4/14/19 9:00 am	High flows and debris loads
7/01/19 8:50 am	Pulled trap	7/02/19 9:50 am	Plans were to pull trap and crane rescheduled so we kept fishing
7/12/19 7:30 am	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	3/11	3/17	0	0	0	0.66
2	3/18	3/24	3	0	3	1
3	3/25	3/31	7	1	15	1
4	4/01	4/07	34	2	39	1
5	4/08	4/14	38	2	787	0.58
6	4/15	4/21	455	10	469	1
7	4/22	4/28	529	65	1697	1
8	4/29	5/05	695	116	2036	1
9	5/06	5/12	717	230	8715	1
10	5/13	5/19	503	272	5909	1
11	5/20	5/26	499	235	14806	1
12	5/27	6/02	150	75	15292	1
13	6/03	6/09	179	61	11698	1
14	6/10	6/16	150	30	7673	1
15	6/17	6/23	150	26	2299	1
16	6/24	6/30	150	21	1989	1
17	7/01	7/07	0	0	1242	0.86
18	7/08	7/14	0	0	1107	0.62

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

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

Period	**Start Date***	**End Date***	**Total Mark**	**Total Recap**	**Total Capture**	**Prop fished**
1	3/11	3/17	0	0	29	0.66
2	3/18	3/24	93	7	95	1
3	3/25	3/31	27	3	27	1
4	4/01	4/07	71	3	75	1
5	4/08	4/14	100	10	389	0.58
6	4/15	4/21	66	1	67	1
7	4/22	4/28	391	15	416	1
8	4/29	5/05	518	26	765	1
9	5/06	5/12	468	40	763	1
10	5/13	5/19	340	28	347	1
11	5/20	5/26	249	32	254	1
12	5/27	6/02	69	20	77	1
13	6/03	6/09	41	9	45	1
14	6/10	6/16	13	2	23	1
15	6/17	6/23	2	0	7	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.

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

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/11	3/17	0	0	44	0.66
2	3/18	3/24	85	11	89	1
3	3/25	3/31	51	2	52	1
4	4/01	4/07	53	2	53	1
5	4/08	4/14	38	5	90	0.58
6	4/15	4/21	10	0	10	1
7	4/22	4/28	21	2	42	1
8	4/29	5/05	49	6	49	1
9	5/06	5/12	39	1	43	1
10	5/13	5/19	7	2	7	1
11	5/20	5/26	5	0	5	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.