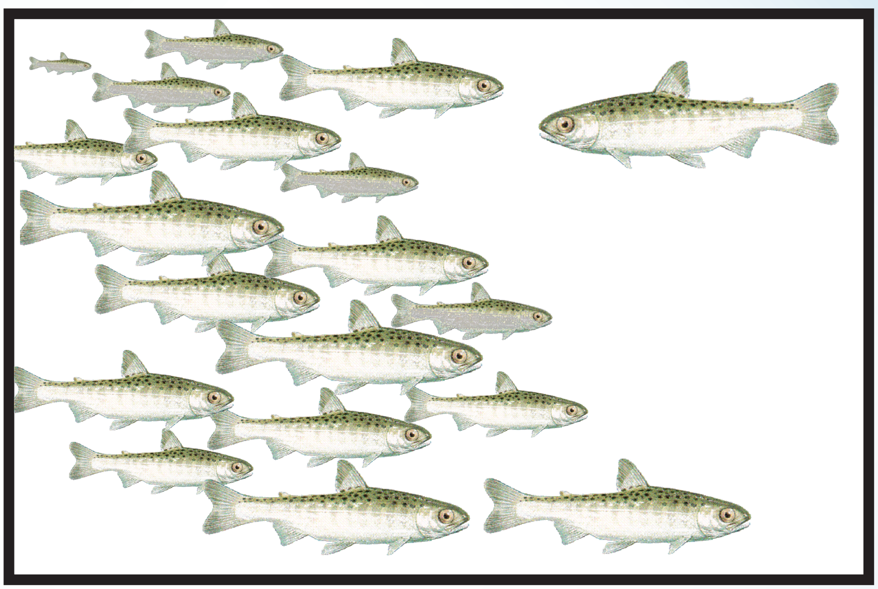
STATE OF WASHINGTON January 2019

Chehalis River Smolt Production 2018



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Washington Department of Fish and Wildlife
Fish Program Science

FPA 19-01

Chehalis River Smolt Production, 2018

Washington Department of Fish and Wildlife

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Executive Summary

This report provides the 2018 results from the juvenile salmonid monitoring study on the Chehalis River main stem near Rochester, WA. The primary objective of this study is 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) 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 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 19 to July 22, 2018.

Chinook outmigrants were subyearlings. Fork length of Chinook subyearlings increased steadily throughout the trapping period with an average of 45.8 mm (± 0.8 mm, standard deviation) and 101.4 mm (± 6.3 mm) in the first and last week of trapping, respectively. Roughly 73% of the total catch of wild Chinook subyearling outmigrants (≥45mm) occurred from May 21 to June 24. Abundance of wild Chinook subyearling outmigrants was estimated to be 295,708 ± 27,431 (standard deviation (SD)) with a coefficient of variation (CV) of 9.3%. This estimate did not include Chinook fry, which outmigrate immediately following emergence from the gravel and prior to the trapping period.

Coho outmigrants were both yearling and subyearlings. Scale age data indicated the subyearling component of the coho outmigration started sometime near the middle of May and that prior to this date all outmigrants were one year of age. Fork length of yearling outmigrants averaged 125.6 mm (±25.4 mm) whereas fork length of subyearling outmigrants averaged 95.4 mm (±5.8 mm). Roughly 79% of the total catch of wild coho outmigrants occurred from April 30 to May 20. Abundance of wild coho outmigrants was estimated to be 304,806 ± 43,998 (SD) with a CV of 14.4%.

Steelhead outmigrants were one, two, and three years of age. Fork length averaged 157.4 mm (± 11.6 mm) for one-year olds, 174.0 mm (± 23.1 mm) for two-year olds, and 194.8 mm (±23.1mm) for three-year olds. Roughly 81% of the total catch of wild steelhead outmigrants occurred from April 30 to May 20. Abundance of wild steelhead outmigrants was estimated to be 32,058 ± 15,864 (SD) with a CV of 49.5%.

Table 1. Abundance of Chinook, coho, and steelhead 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 (%)
Chinook	Wild	Parr, Transitional, Smolt	Subyearling	295,708 ± 27,431	9.3
Coho	Wild	Transitional, Smolt	Subyearling, Yearling	304,806 ± 43,998	14.4
Steelhead	Wild	Transitional, Smolt	Yearling	32,058 ± 15,864	49.5

Introduction

The Washington Department of Fish and Wildlife has monitored freshwater production of juvenile salmon in the Chehalis River since the early 1980s. Over this time, the work has focused on wild coho salmon 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 (Zimmerman 2018). Smolt abundance estimates from individual tributaries were generated in the 1980s and 1990s but have not been evaluated for nearly two decades. Further, there is currently no information on freshwater production of other salmonid species, including Chinook and chum salmon and steelhead 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 useful for evaluating variability and trends in freshwater production over time.

As a result, WDFW monitoring activities were recently expanded to develop a more comprehensive understanding of freshwater production among multiple species of salmonids in the Chehalis River 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. Operating a smolt trap in a large river while handling large numbers of fish comes with significant operational challenges associated with maintaining both fish health and staff safety under dynamic environmental conditions. A pilot study was conducted in 2017 that tested a new trap design and multi-species trapping protocols. The 2018 field season benefited from many refinements in the operational protocols that resulted from this pilot effort.

Objectives

The primary objective of this study is 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) 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 84 (river mile 52) of the main stem Chehalis River. This report includes results from the 2018 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 – 1350m) 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. 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 (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 outmigrate almost immediately after emergence. Fry are observed at the smolt trap immediately when installed 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.

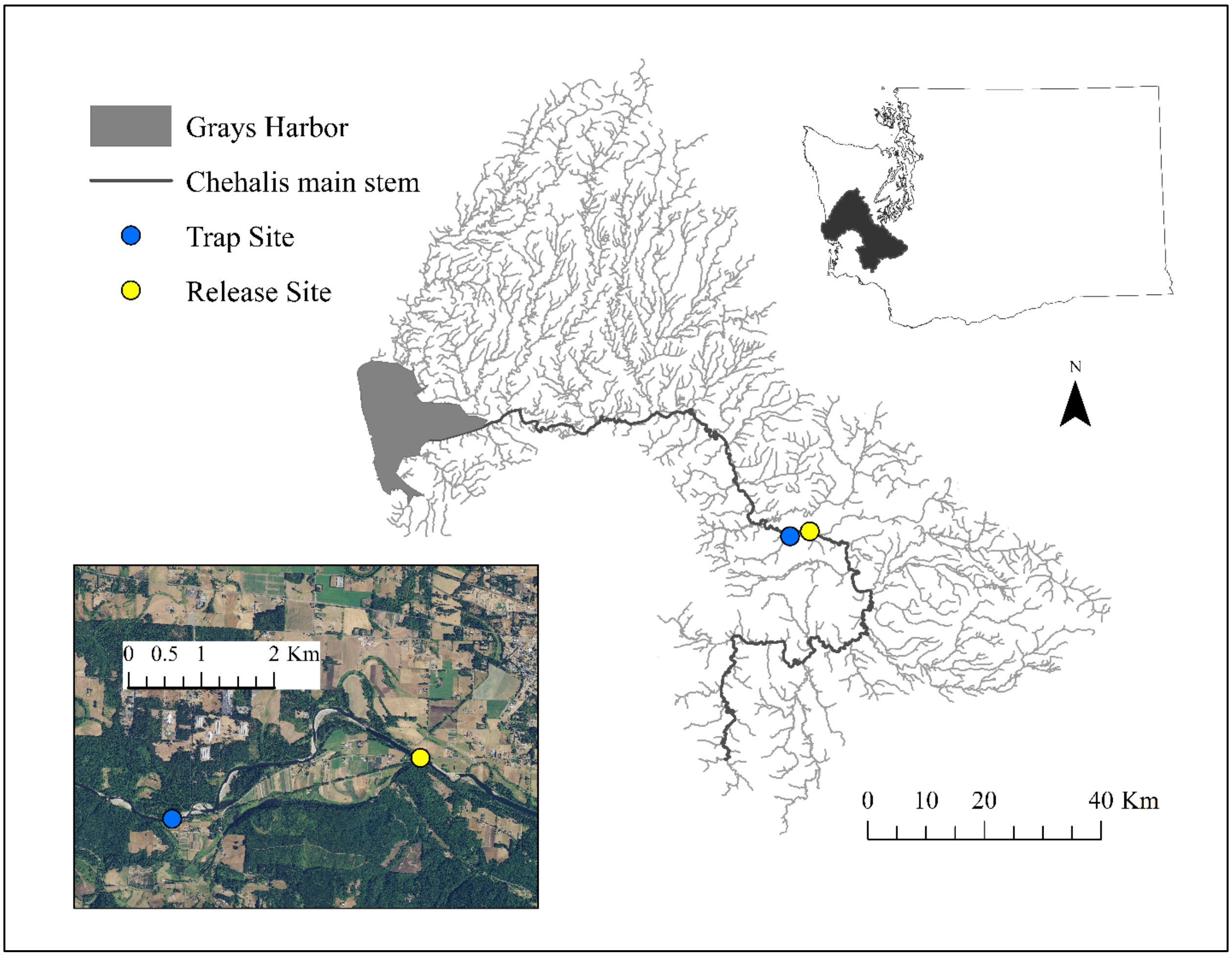

Figure 1. Location of screw trap (red dot) and release site for marked fish (yellow dot) in the Chehalis River, WA.

Trap Operation

A 2.4 m (8-foot) diameter rotary screw trap (RST) was operated near river kilometer 84 of the Chehalis River. This site was selected because it is the most downstream point in the basin with suitable characteristics to maximize RST efficiency throughout the trapping periods. Due to the location of this trap, our estimates represent a portion of the freshwater production in the Chehalis River as additional freshwater habitat occurs downstream (e.g., Black, Satsop, Wynoochee, Wishkah, and Hoquaim rivers). The trap was scheduled to operate continuously although unscheduled trap outages did occur due to high flow, debris, or trap malfunctions.

Environmental 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. Stream flow is monitored by the USGS discharge gage in Grand Mound, Washington (USGS 12027500).

Figure 2. Chehalis River screw trap.

Fish Collection

Fish were removed from the live box in the trap using a dip net twice per day (morning and evening) until water temperatures become unsuitable to sample fish in the evening. When fish were removed they were transferred to 5-gallon buckets, and moved to a trough with flowing river water for sampling and tagging. 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 class (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[a] →	
	Coho	1st 50 per week	1st 50 per week	1st 50 per week
	Steelhead	1st 50 per week[b]	1st 50 per week	All individuals
Scales	Chinook[c]	---	---	---
	Coho	---	---	1st 5 per week per size class (<100 mm, 100-149 mm, >150mm)
	Steelhead	---	---	1st 20 per week

[a]Measures of Chinook were not broken out by life stage group.
[b]Trout fry included both steelhead/rainbow trout and cutthroat.
[c]No scale samples were collected from Chinook.

Life stage categories followed WDFW protocols developed for the Lower Columbia ESU monitoring program (see Appendix A for life stage decision tree). The five life stage categories were 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 years in freshwater and was assigned in the field as either subyearling or yearling (≥ age 1). Field assignments into subyearling and yearling categories were based on a combination of length and date criteria and were specific to species (Tables 3 – 5). The current length-date criteria for these assignments are based on length distributions from previous trapping seasons and will be further refined with scale age data over time. 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. Therefore, the age composition of steelhead was further described using scale data.

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	---	March 1 – July 30	≤ 45 mm
Parr	Subyearling	March 1 – July 30	46 - 89 mm
Transitional, Smolt	Yearling	March 1 – July 30	≥ 90 mm

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

Life Stage	Age Class	Date Range	Length Range (mm FL)
Fry	---	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

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	---	March 1 – June 30	≤ 45
Parr, Transitional, Smolt	Subyearling	March 1 – June 30	46 - 100
Transitional, Smolt	Yearling (+)	March 1 – June 30	> 100
Parr, Transitional, Smolt	Subyearling	June 30 – July 31	45 - 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 Chinook, coho, and steelhead. All trap efficiency trials were conducted with wild (adipose fin intact) fish. For Chinook, trap efficiency trials were conducted with parr, 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 parr (P), 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
Chinook	Wild	P, T, S	SY	FL ≥ 45 mm
Coho	Wild	T, S	Y, SY	
Steelhead	Wild	T, S	Y	

Marked fish were released 4.5 kilometers upstream of the trap location at the Independence Road bridge on the right bank, roughly 20 meters upstream of the bridge (Figure 1, Table 7). In 2018, we explored an alternate release location for Chinook in order to reduce handling time and exposure to warmer temperatures that occurred during their outmigration period. Between May 21 and June 17, 2018, Chinook were released roughly 500 km upstream of the trap location on the left bank. Once transport issues were resolved, the release location for Chinook was returned to the Independent Road bridge location (4.5 km upstream of the trap location) between June 18 and July 22, 2018.

Mark types and rotation schedules allowed the data to be organized by week for the purpose of analysis. We used different mark types for each species (Table 7). All releases occurred within 1-3 hours of a trap check. For the early portion of the season (March 19 – June 3), two trap checks were performed daily (morning and evening) and subsequently, two upstream releases generally occurred. Warming stream temperatures after June 3 necessitated only one morning trap check through the end of the season. Coho and steelhead efficiency trials were conducted over the entirety of the trapping season. Chinook efficiency trials began period 9 (May 14). The later start date for Chinook was due to logistical challenges in the first year of attempting to run efficiency trials for Chinook.

Table 7. Trap efficiency marks and release locations for each abundance estimate group. Efficiency marks are coded wire tag (CWT), microject dye (MJ), 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)
Chinook	PCC	Weekly	2 week	Bridge	4.5
Coho	CWT, MJ	Weekly	5 week	Bridge	4.5
Steelhead	PIT	Individual	Individual	Bridge	4.5

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 allow for estimation during missed trapping days and for time strata with minimal efficiency data (Bonner and Schwarz et al 2011). Data input 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. Additionally, covariates were added to the model to accommodate variation in trapping conditions and improve estimates of trap efficiency. We included trap position as a covariate in the coho and steelhead models. Minor trap adjustments occurred throughout the season however one trap position move was substantial enough that we felt a trap position covariate should be included in the model. This trap position move was between a "high flow" position which was out of the thalweg because flows were too high to safely trap in the main flow. The second position was in the thalweg.

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 2018 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*), peamouth chub (*Mylocheilus caurinus*), northern pikeminnow (*Ptychocheilus oregonensis*), Pacific lamprey (*Entosphenus tridentatus*), and sculpin species. Non-native fish included American shad (*Alosa sapidissima*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), and other unidentified sunfish species.

Trap operation

We operated the trap from March 19, 2018 to July 22, 2018. We had 12 occurrences of trap outages (Appendix B). For all occasions, the outage time was known exactly because the trap stopped fishing when staff lifted the cone during periods of high flows and debris. Individual outages were less than 24 hours except for a high flow event on April 8th which resulted in a 3-day outage in trap operation.

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, minimized predation by checking the trap box multiple times per day, 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 97% (microject, 67 out of 69 marked) to 100% (CWT, 100 out of 100 marked) for coho and 96% for steelhead (PIT tags, 28 out of 29 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 96% (microject, 66 out of 69 marked) to 100% (CWT, 100 out of 100 marked) for coho and 100% for steelhead (PIT tags, 29 out of 29 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 coho ($D = 0.16$, $p = 0.28$) or steelhead ($D = 0.14$, $p = 0.1$).

To meet assumption 5, we released fish in an upstream location that was 4.5 km (2.8 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 coho were scanned for CWT and visually inspected for microject marks. All steelhead were scanned for PIT tags and visually inspected for PIT scars. All Chinook were visually inspected for caudal clips.

Chinook

The Chinook outmigrant estimate was derived for the ‘subyearling’ life history that included parr, transitionals, and smolts. Chinook outmigrants were observed in low numbers the first week of trapping (March 19th, trapping period 1), peaked in early June, and declined to low numbers again by the last week of trapping (July 17th, trapping period 18, Figure 3, Appendix C).

Scale age data were not collected from Chinook in 2018 with the exception of two opportunistic samples, both of which were determined to be subyearlings (Figure 4). Fork length of Chinook subyearlings increased steadily throughout the season with an average of 45.8 mm (± 0.8 mm, standard deviation) and 101.4 mm (± 6.3 mm) in the first and last week of trapping, respectively (**Error! Reference source not found.**).

We began efficiency trials for Chinook the week of May 14th (trapping period 9). Therefore, we applied a hierarchical estimate of trap efficiency (i.e., grand mean) generated by the BTSPAS algorithm to estimate trap efficiencies between March 19th and May 13th (trapping periods 1-8).

A total of 43,694 Chinook subyearling outmigrants were captured throughout the season (Appendix C; Periods 1 – 18). A total of 3,667 Chinook were marked and 678 were recaptured. Modeled weekly trap efficiencies ranged from 7.6 to 47.5%.

Abundance of wild Chinook subyearling outmigrants was estimated to be 295,708 ± 27,431 standard deviation (SD) with a CV of 9.3%.

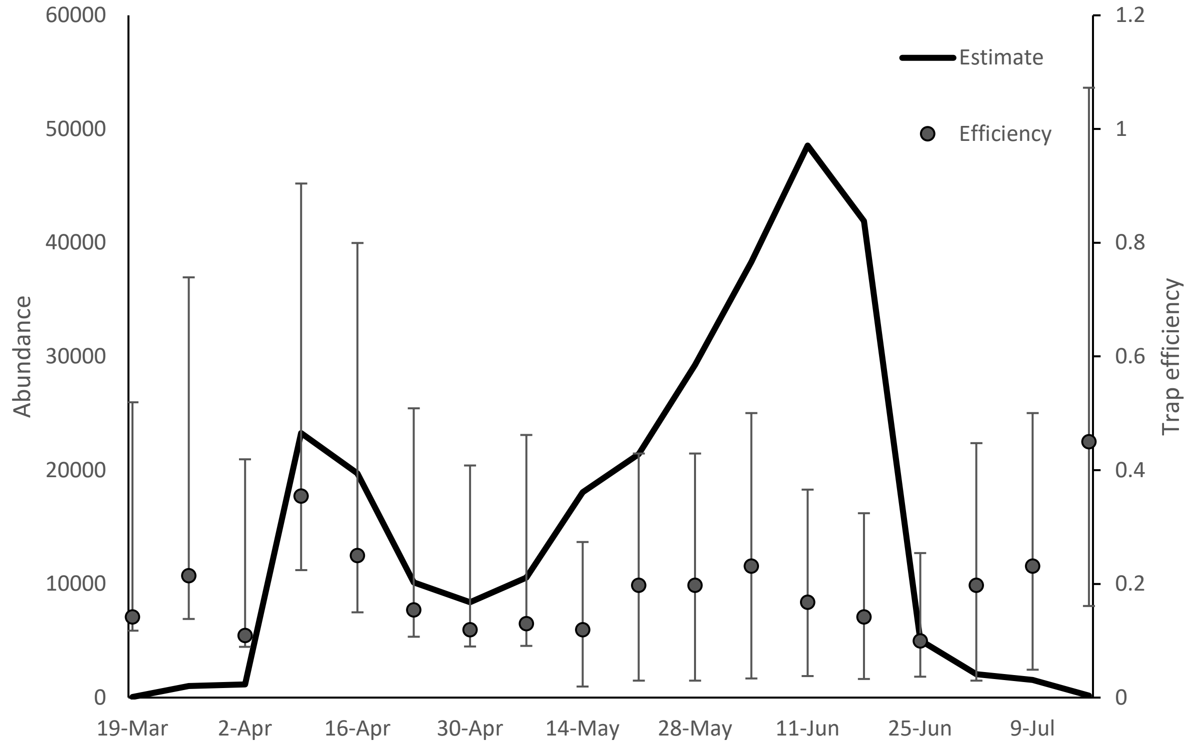

Figure 3. Migration timing of wild Chinook outmigrants (parr, transitionals, smolts) at the Chehalis River screw trap, 2018. Data are abundance and modeled trap efficiency with standard deviation by week. Data provided in Appendix C.

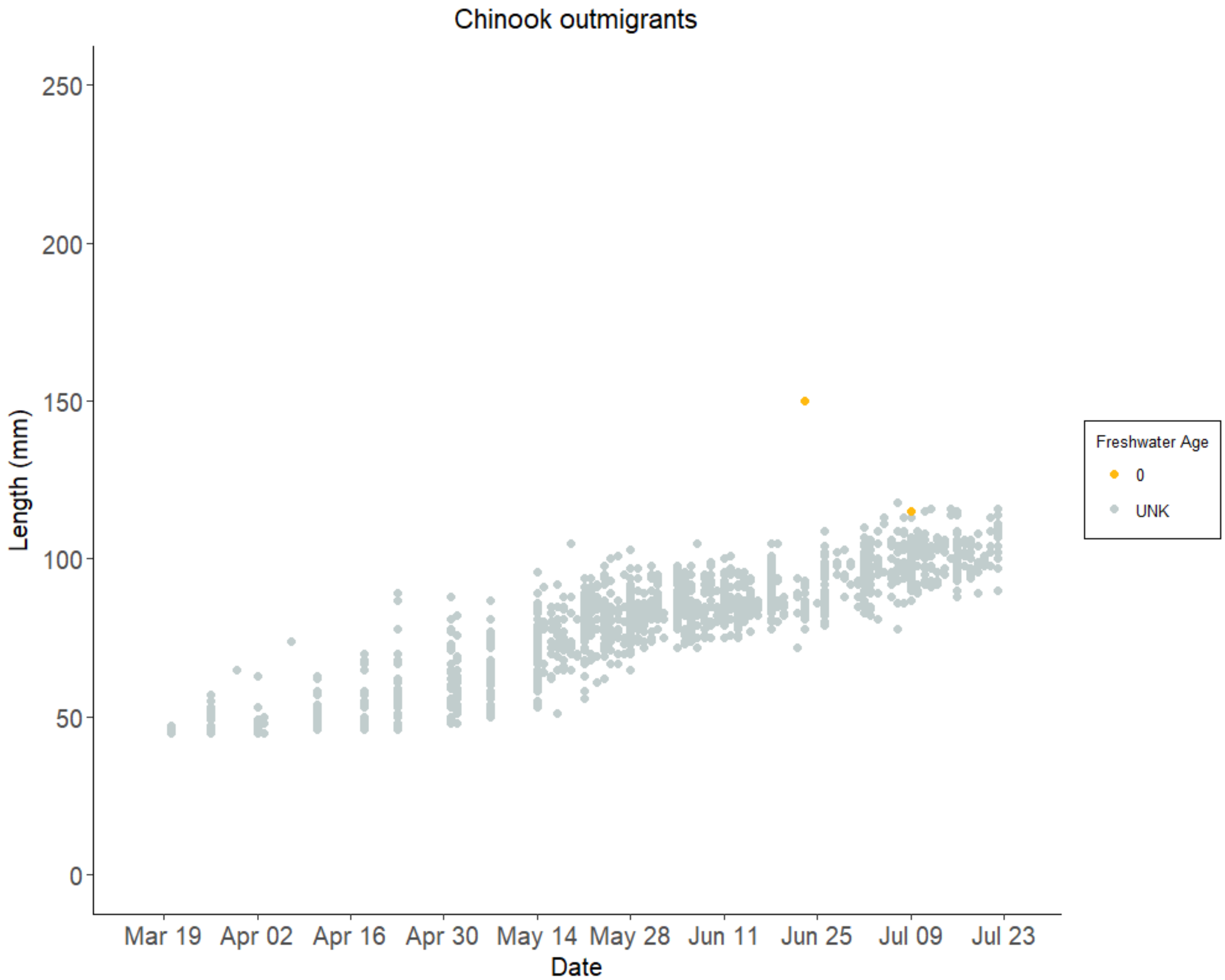

Figure 4. Fork lengths of wild Chinook outmigrants (parr, transitionals, smolts) at the Chehalis River screw trap, 2018. Scale data were opportunistically collected from two fish.

Coho

The coho outmigrant estimate included both subyearlings and yearlings in transitional and smolt life stages. Most of the outmigrants observed at the trap were yearlings that exhibited the 'smolt' phenotype. Coho outmigrants were observed in low numbers the first week of trapping (March 19th, trapping period 1), peaked in late April, and were last observed the week of July 7th (trapping period 16, Figure 5, Appendix D).

Scale age data indicated the subyearling component of the outmigration started sometime near the middle of May and that prior to this date all outmigrants were one year of age (Figure 6, Table 8). Fork length of yearling outmigrants averaged 125.6 mm ($\pm$25.4 mm) whereas fork length of subyearling outmigrants averaged 95.4 mm ($\pm$5.8 mm).

A total of 22,636 coho outmigrants were captured throughout the season (Appendix D). A total of 4,084 coho were marked and 551 were recaptured. Modeled weekly trap efficiencies ranged from 0.9 to 25%.

Abundance of wild coho outmigrants was estimated to be 304,806 ± 43,998 (SD) with a CV of 14.4%.

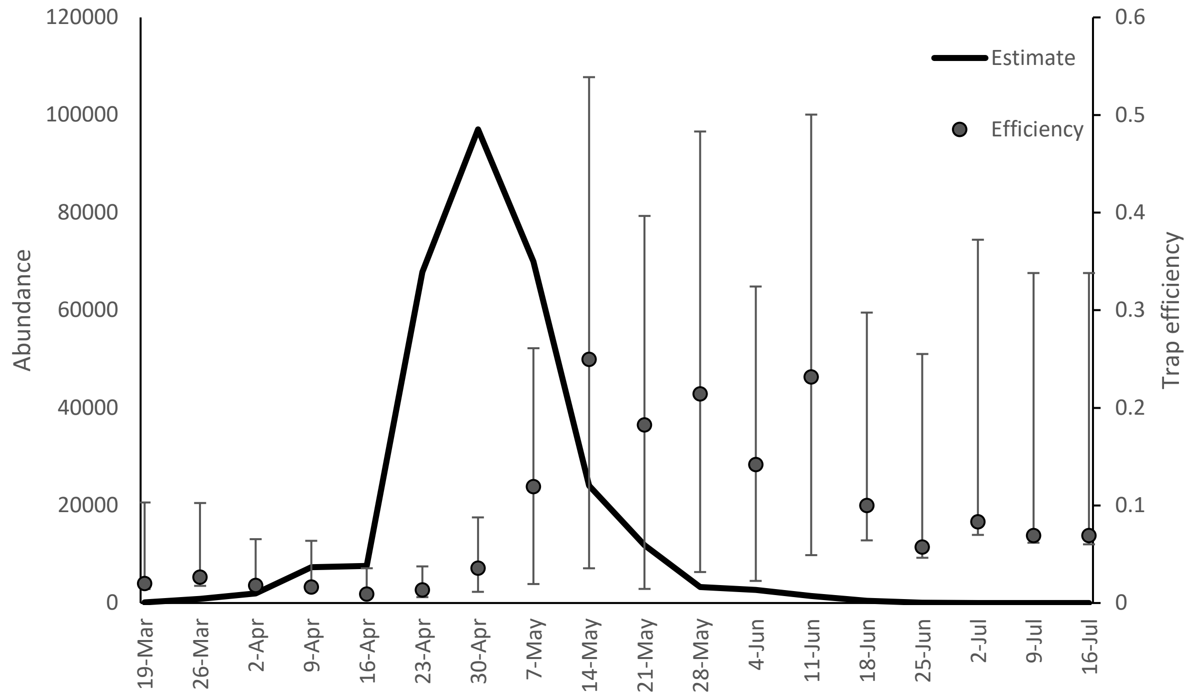

Figure 5. Migration timing of wild coho outmigrants (transitionals, smolts) at the lower Chehalis River screw trap, 2018. Data are abundance and trap efficiency with standard deviation by week. Data provided in Appendix D.

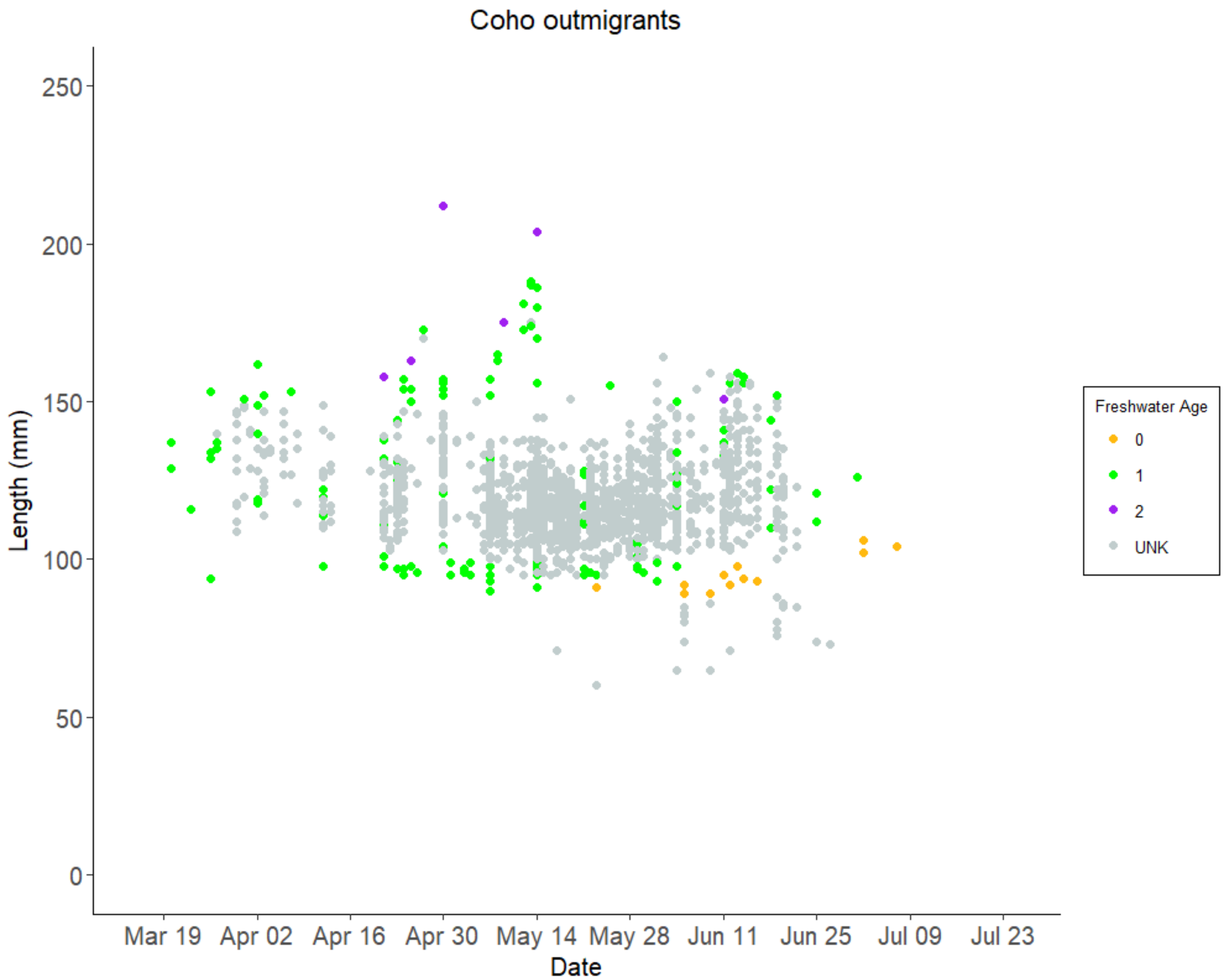

Figure 6. Plot of date-length-age data from wild coho outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2018.

Table 8. Freshwater ages of wild coho outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2018. Data are scale ages of sampled juveniles by week.

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

Steelhead

The steelhead outmigrant estimate included both transitional and smolt life stages. Steelhead outmigrants were first observed the week of March 26th (trapping period 2), peaked in late April, and were last observed the week of June 11th (trapping period 13, Figure 7, Appendix E).

Scale age data indicated that the sampled steelhead were one, two, and three years of age (Figure 8, Table 9). Fork length averaged 157.4 mm (± 11.6 mm) for one-year olds, 174.0 mm (± 23.1 mm) for two-year olds, and 194.8 mm (±23.1mm) for three-year olds.

A total of 1,114 steelhead outmigrants were captured throughout the season (Appendix E). A total of 991 steelhead were marked and 75 were recaptured. Modeled weekly trap efficiencies ranged from 0.5 to 21.4%.

Abundance of wild steelhead outmigrants was estimated to be 32,058 ± 15,864 (SD) with a CV of 49.5%.

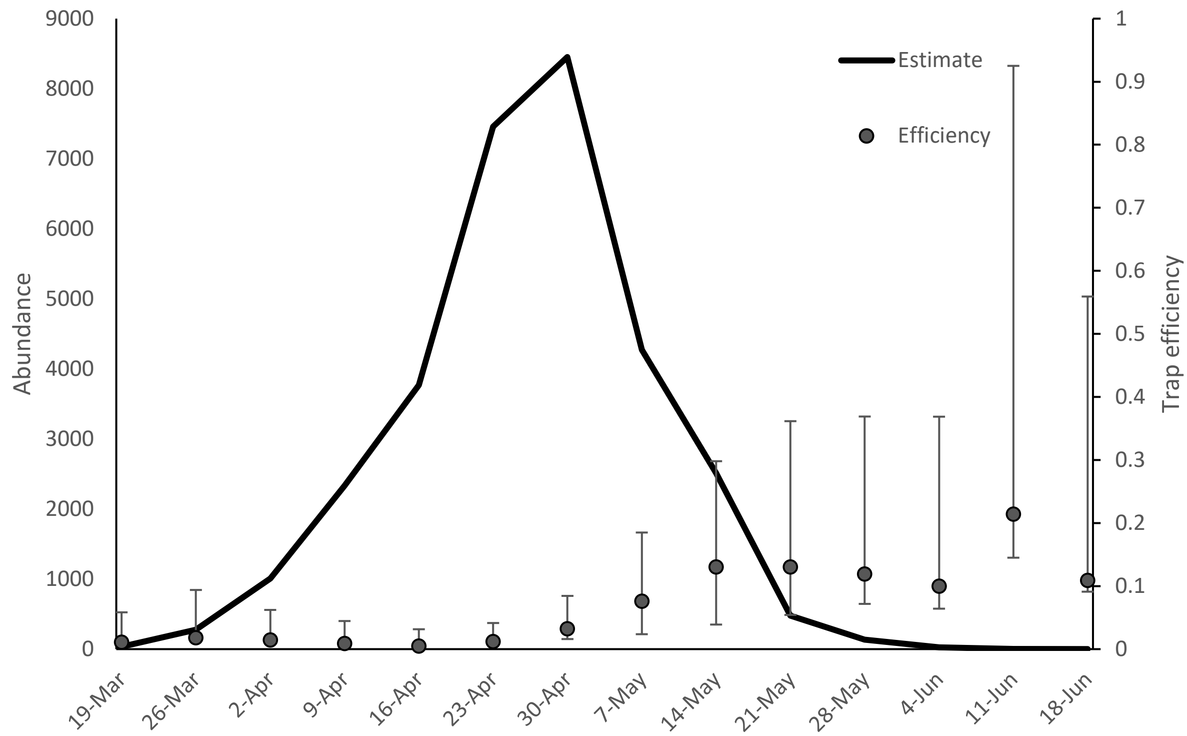

Figure 7. Migration of wild steelhead outmigrants (transitionals, smolts) at the lower Chehalis River screw trap, 2018. Data are abundance and trap efficiency with standard deviation by week. Data provided in Appendix E.

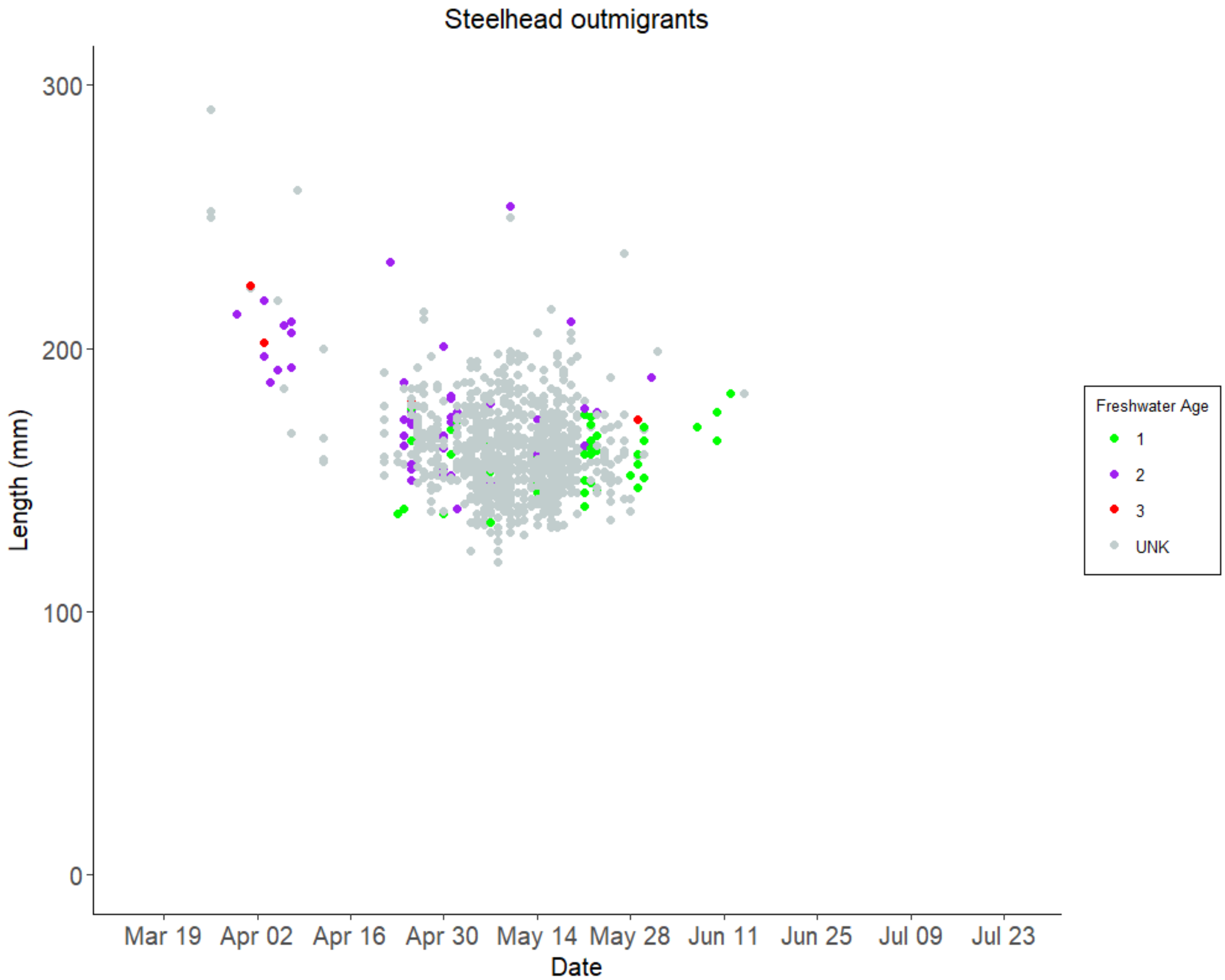

Figure 8. Plot of date-length-age data from wild steelhead outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2018.

Table 9. Freshwater ages of wild steelhead outmigrants (transitionals, smolts) at the Chehalis River screw trap, 2018. 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	3/19	3/25	0	0	0	0	0
2	3/26	4/1	6	0	1	1	4
3	4/2	4/8	13	0	8	1	4
4	4/9	4/15	4	0	0	0	4*
5	4/16	4/22	8	0	1	0	7*
6	4/23	4/29	22	4	13	1	4
7	4/30	5/6	20	4	16	0	0
8	5/7	5/13	20	8	9	0	3
9	5/14	5/20	21	11	8	0	2
10	5/21	5/27	20	14	3	0	3
11	5/28	6/3	12	8	1	1	2
12	6/4	6/10	0	0	0	0	0
13	6/11	6/17	0	0	0	0	0
14	6/18	6/24	0	0	0	0	0
15	6/25	7/1	0	0	0	0	0
16	7/2	7/8	0	0	0	0	0
17	7/9	7/15	0	0	0	0	0
18	7/16	7/22	0	0	0	0	0

*Scale card associated with periods 4 and 5 was lost and therefore ages were not determined

Discussion

Basin-wide Context

The abundance estimates provided in this report represent juvenile salmonids that completed their freshwater rearing in habitats upstream of the trap location, specifically the production from upstream of river kilometer 84. 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, juveniles that emerge from the gravel upstream of the trap location but redistribute to areas downstream of the trap location during their freshwater rearing period are also 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.

Annual freshwater production of wild coho smolts in the entirety of the Chehalis River has averaged 2 million (0.5 to 3.7 million) since WDFW began monitoring smolt production in the 1980s (Zimmerman 2018). Our estimate of approximately 300,000 coho outmigrants from habitat upstream of river kilometer 84 indicated 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 large proportion of wild coho appear to complete their freshwater rearing in the main stem and tributaries downstream of the trap location. 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 minor tributaries including Porter and Cloquallum Creek,. Our estimate of wild coho production above the trap site is consistent with WDFW monitoring results from the 1990s which also estimated 300-400K wild coho smolts produced upstream of the mainstem smolt trap (Seiler et al. 1997).

This report provides the first estimate of wild steelhead production from the Chehalis River basin. Our estimate of 32,058 steelhead outmigrants from the estimated 566 river km upstream of the trap (Statewide Integrated Fish Distribution, SWIFD, https://geo.nwifc.org/swifd/) corresponds to 57 wild steelhead smolts/km. 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) or the Wind River (average 240 smolts/km) (T. Buehrens, personal communication). The reasons for these differences are not yet apparent and may reflect the difference between available stream miles 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 are geomorphic characteristics typically associated with high quality steelhead spawning and rearing habitat in the Pacific Northwest (Gibbons et al. 1985). Of note, a recent study identified the Upper Chehalis sub-basin, which is one of multiple sub-basins located upstream of the smolt trap, as a particularly productive spawning area. Over five years of monitoring, surveyors estimated 600-1,000 redds (900-1,800 steelhead spawners) in this area of the basin (Ashcraft et al. 2017, Ronne et al. 2018). 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. 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). Finally, the steelhead outmigrant estimate from 2018 was imprecise. For example, the upper 95% confidence interval of our estimate was 63,000 outmigrants, or 112 smolts/km which is much closer to the smolt densities estimated from other rivers. Imprecision of the estimate was affected by a combination of low efficiencies and a major trap move when steelhead were being caught in higher numbers.

Our estimate of Chinook subyearling outmigrants represents a fraction of the total freshwater production of Chinook upstream of the trap location in 2018 and does not include the earlier timed fry migrants. However, the ‘subyearling’ estimate we have generated 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 make extensive use of estuary and nearshore growing environments prior to entering the ocean (Sandell et al. 2012, 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 have concluded that estimates of this life history reflect a freshwater rearing capacity (Anderson and Topping 2018, Zimmerman et al. 2015). Additional Chinook production beyond this capacity appears to migrate downstream as ‘fry’ in a density-dependent manner (Greene et al. 2005). Extending this density-dependent migration hypothesis to the Chehalis River will require additional years of juvenile monitoring coupled with adult Chinook spawner data above the trap location.

Next Steps

The main stem Chehalis River presents many challenges to smolt trap operation. In 2018, these challenges included high flows, warm stream temperatures, filamentous algae, and adult pikeminnow. Additional description of these issues and our approaches to address them are described below.

In 2018, high flow events during the coho and steelhead outmigrations necessitated trap outages that negatively impacted our estimates. This was particularly problematic for steelhead, which migrate slightly earlier than coho, and contributed to the low precision (reflected in large coefficient of variation) of the steelhead estimate in 2018. Challenges in trap operation begin when river flows at Grand Mound exceed 5,000 cubic feet per second. To extend the range of flows under which we were able to operate the trap in 2018, we identified a ‘high water’ fishing location that moved the trap out of the thalweg during higher flows. The trap efficiencies in the ‘high water’ position were lower than the ‘low water’ position because the ‘low water’ position was directly in the thalweg of the river. Lower trap efficiencies contribute to lower precision (higher coefficient of variation) in the final abundance estimates. In the future, we will aim to move the trap from the ‘high water’ to ‘low water’ positions as quickly as we deem safe following a high flow event.

Trapping conditions associated with the Chinook estimates were characterized by warm stream temperatures, large amounts of algae, and high catches of adult pikeminnow. The Chinook subyearling outmigration peaked in mid-June which presented challenges with fish handling under high stream temperatures. As catch of subyearling Chinook increased from May to June, mean monthly stream temperatures increased from 16.4 to 18.5°C, respectively (Table 10, Figure 9). During this time frame, we adjusted our fish sampling to early mornings when stream temperatures were lowest in order to reduce impacts of fish handling during the time of day with warm stream temperatures.

Chinook catches in the month of June also coincided with large amounts of filamentous algae and high catches of adult pikeminnow. The amount of filamentous algae collected by the trap was substantial enough to fill the live box within a 24-hour period on a several occasions (Figure 10). Algae fills space in the live box and can suffocate live fish. The daily occurrence of algae in the trap was unpredictable. However, once the algae began to collect in the live box, we increased the frequency of daily trap checks in an effort to reduce impacts of algae on fish. We also observed a sharp increase of adult pikeminnow catch in the month of June (Figure 11 and 12). Therefore, increased frequency of daily trap checks were also necessary for removing adult pikeminnow from the live box to reduce predation on other fish.

Table 10. Mean monthly stream temperatures°C (+ standard deviation) recorded at Chehalis River smolt trap near river km 84, 2018.

Month	Mean (+ SD)
March	9.4 (0.7)
April	10.2 (1.6)
May	16.4 (1.8)
June	18.5 (1.9)
July	21.7 (2.0)

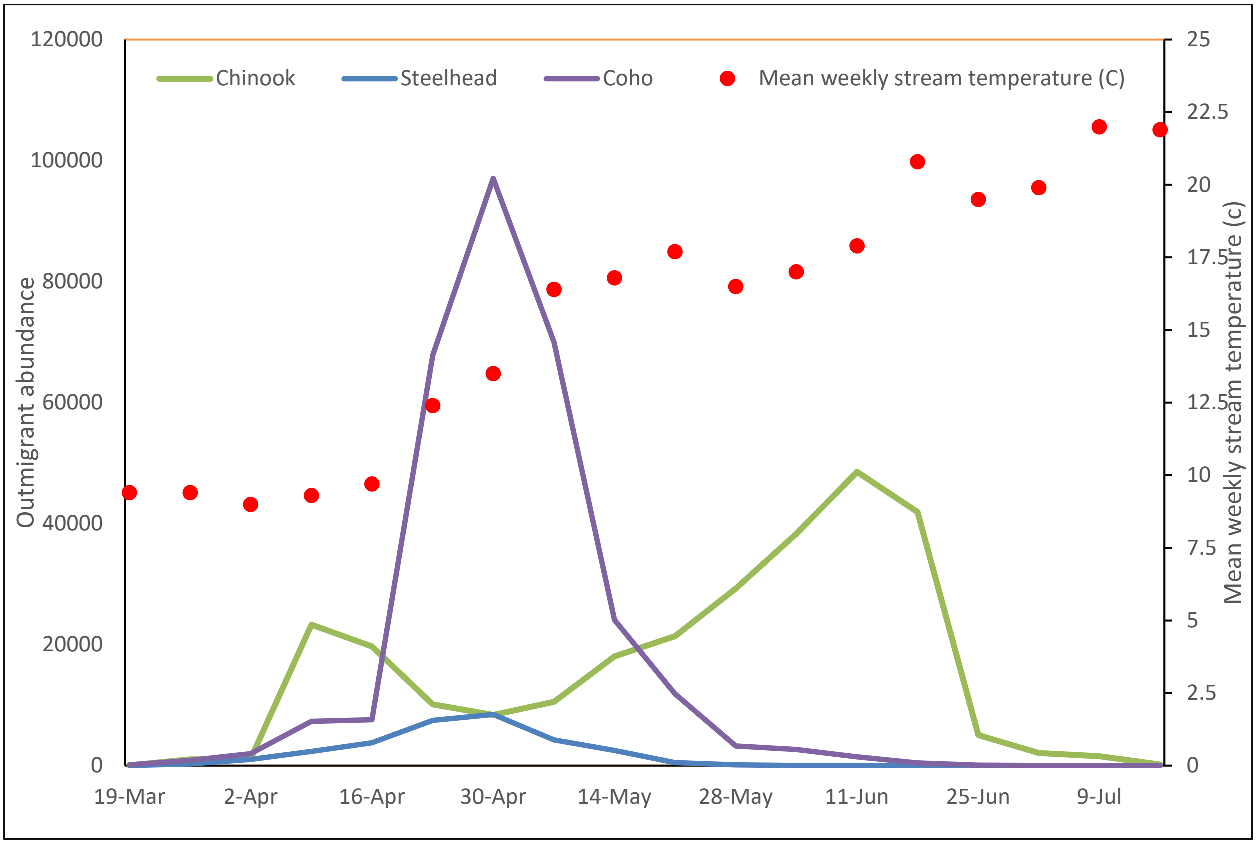

Figure 9. Chinook, steelhead, and coho outmigrant abundance and mean weekly stream temperature (°C) at the Chehalis River smolt trap, 2018.

Figure 10. Filamentous algae collected in a single day of operations at the Chehalis River screw trap, June 2018.

Figure 11. Pikeminnow catch on single day of trap operations of the Chehalis River screw trap, June 2018.

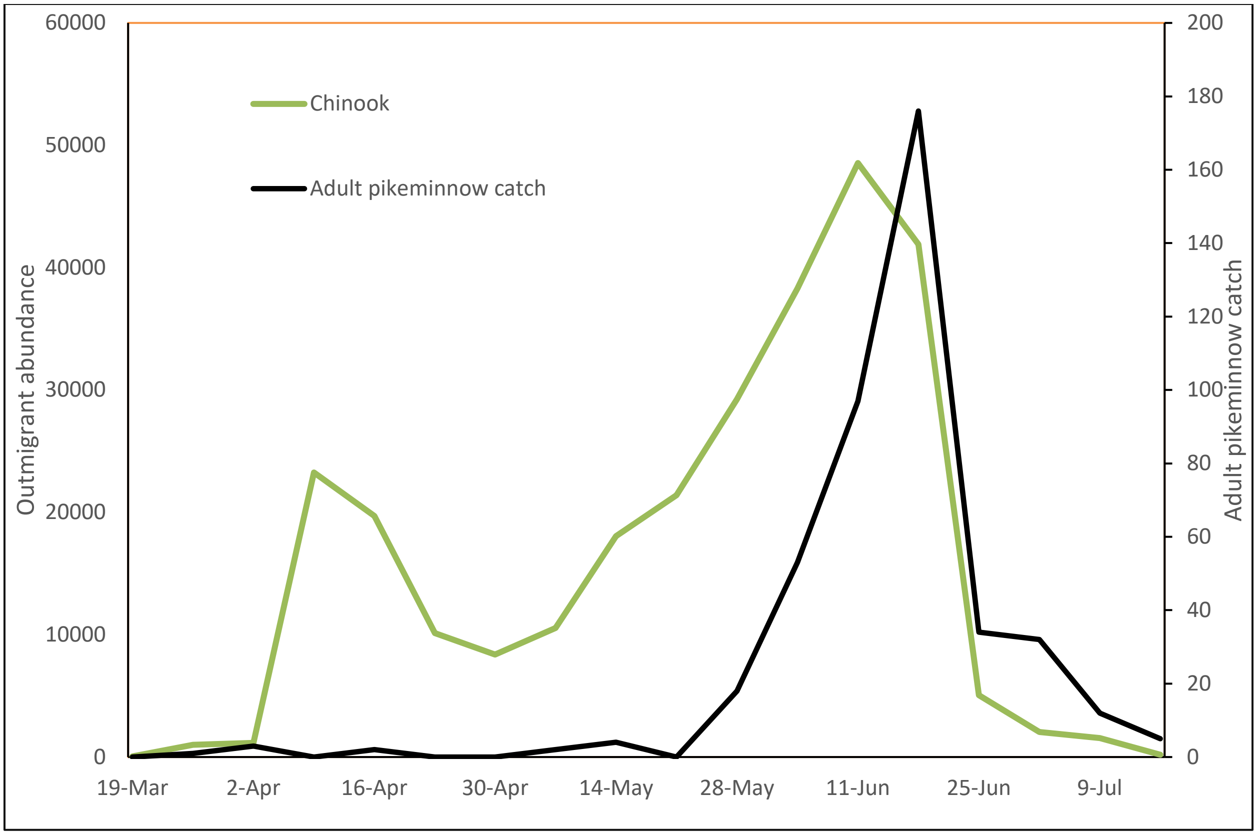

Figure 12. Chinook outmigrant abundance and adult Northern pikeminnow catch by week from the Chehalis River smolt trap, 2018.

In addition to environmental conditions, the quality (precision) of our estimates of Chinook subyearling outmigrants was influenced by the lack of trap efficiency trials at the beginning of the outmigration period. The absence of this information reflected prioritization of effort during the flow events and high coho numbers experienced in the early portion of the trapping season. To improve the estimation of Chinook outmigration, we plan to begin the Chinook efficiency trials at the start of the trapping season in future years. As was previously noted in this report, our estimate of the Chinook outmigration was partial and only included the portion of the population spawning above the trap site that reared in freshwater prior to outmigration. Based on observations in other western Washington monitoring programs (Anderson and Topping 2018, Zimmerman et al. 2015), the earlier timed fry are likely to comprise a substantial portion of the outmigration. Given the extreme flow conditions of the river in January and February, we do not currently have any plans to fish the trap during the early-timed fry migration.

In summary, the 2018 represents the first year for which wild Chinook and steelhead outmigrations have been described from the Chehalis River and the first time in two decades that wild coho outmigration has been specifically evaluated from the upper portion (upstream of the Black River) of the basin. In addition to abundance, we have 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 Chehalis River.

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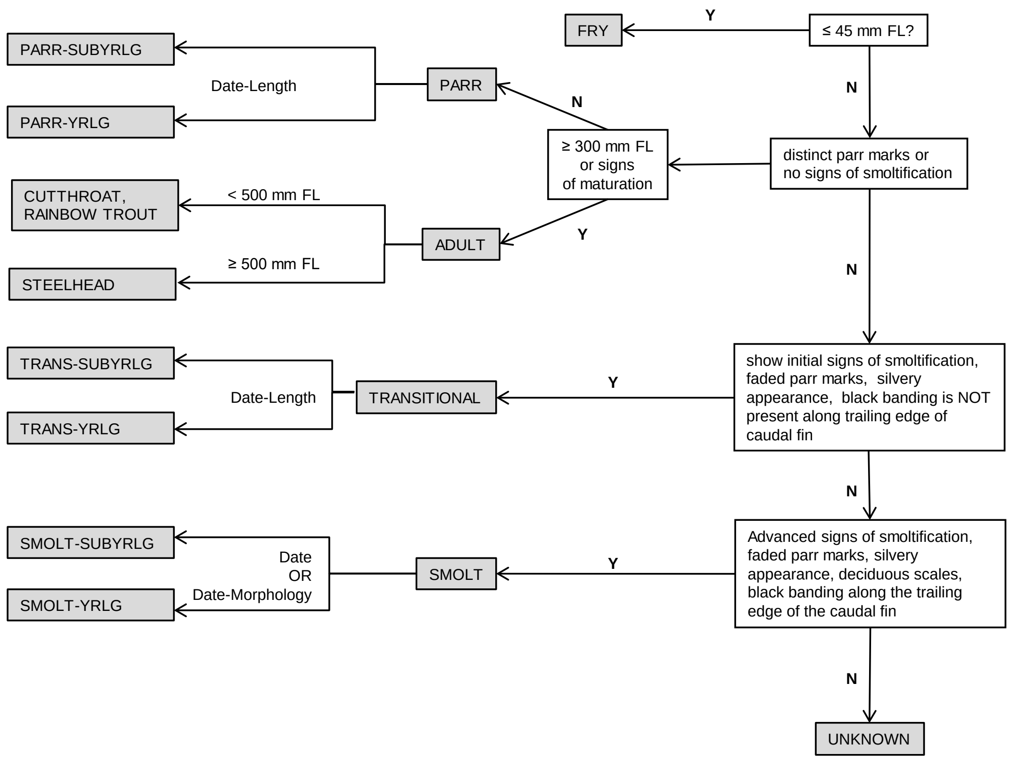
Appendices

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.



Updated 2.8.2016

Appendix B. Chehalis River missed trapping periods 2018. All missed trapping periods occurred by staff pulling the trap.

Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
4/8/2018, 10:28	Pulled trap	4/11/2018, 07:33	High flows and debris loads
4/11/2018, 18:30	Pulled trap	4/12/2018, 07:00	High flows and debris loads
4/12/2018, 18:54	Pulled trap	4/13/2018, 07:00	High flows and debris loads
4/13/2018, 18:02	Pulled trap	4/18/2018, 09:30	High flows and debris loads, Bingham trap crew needed backup
4/18/2018, 19:45	Pulled trap	4/19/2018, 06:00	High flows and debris loads
4/19/2018, 21:00	Pulled trap	4/20/2018, 06:00	High flows and debris loads
4/20/2018, 18:00	Pulled trap	4/21/2018, 06:00	High flows and debris loads
6/10/2018, 09:30	Pulled trap	6/10/2018, 13:30	High algae load plugging cone and live box
6/10/2018, 20:40	Pulled trap	6/11/2018, 05:00	High algae load plugging cone and live box
6/19/2018, 18:45	Pulled trap	6/20/2018, 08:00	High algae load plugging cone and live box
6/27/2018, 20:45	Pulled trap	6/28/2018, 05:00	High algae load plugging cone and live box

Appendix C. 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).

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop Fished
1	3/19	3/25	0	0	6	0.90
2	3/26	4/1	0	0	223	1
3	4/2	4/8	0	0	109	0.92
4	4/9	4/15	0	0	1652	0.20
5	4/16	4/22	0	0	2338	0.49
6	4/23	4/29	0	0	1562	1
7	4/30	5/6	0	0	974	1
8	5/7	5/13	0	0	1315	1
9	5/14	5/20	472	57	2211	1
10	5/21	5/27	598	116	4133	1
11	5/28	6/3	500	102	5966	1
12	6/4	6/10	499	117	8633	0.96
13	6/11	6/17	500	80	7640	0.97
14	6/18	6/24	300	41	5651	0.93
15	6/25	7/1	149	15	440	0.84
16	7/2	7/8	334	69	415	1
17	7/9	7/15	282	63	348	1
18	7/16	7/22	33	18	78	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 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	3/19	3/25	0	0	3	0.90
2	3/26	4/1	21	1	24	1
3	4/2	4/8	25	1	31	0.92
4	4/9	4/15	0	0	24	0.20
5	4/16	4/22	31	0	32	0.49
6	4/23	4/29	500	4	955	1
7	4/30	5/6	700	26	3556	1
8	5/7	5/13	700	80	8379	1
9	5/14	5/20	502	126	5916	1
10	5/21	5/27	599	115	2253	1
11	5/28	6/3	406	93	718	1
12	6/4	6/10	315	45	377	0.96
13	6/11	6/17	246	56	321	0.97
14	6/18	6/24	34	4	41	0.93
15	6/25	7/1	3	0	3	0.84
16	7/2	7/8	2	0	3	1
17	7/9	7/15	0	0	0	1
18	7/16	7/22	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.

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

Period	Start Date*	End Date*	Total Mark	Total Recap	Total Capture	Prop fished
1	3/19	3/25	0	0	0	0.90
2	3/26	4/1	6	0	6	1
3	4/2	4/8	0	0	14	0.92
4	4/9	4/15	0	0	4	0.20
5	4/16	4/22	0	0	8	0.49
6	4/23	4/29	95	0	95	1
7	4/30	5/6	252	8	271	1
8	5/7	5/13	294	21	315	1
9	5/14	5/20	277	33	319	1
10	5/21	5/27	50	10	62	1
11	5/28	6/3	13	2	15	1
12	6/4	6/10	3	0	3	0.96
13	6/11	6/17	1	1	2	0.97
14	6/18	6/24	0	0	0	0.93
15	6/25	7/1	0	0	0	0.84
16	7/2	7/8	0	0	0	1
17	7/9	7/15	0	0	0	1
18	7/16	7/22	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.

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