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Newaukum Adult Salmon and Steelhead Spawner Abundance, 2022-2023

by Lea Ronne, Marisa Litz, Mike Scharpf, Todd Seamons, and Andrew Claiborne

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Table of Contents

Acknowledgements ... iii
List of Tables ... v
List of Figures ... vi
Executive Summary ... 1
Introduction ... 3
Objectives ... 3
Methods ... 4
Study Design and Area ... 4
Data Collection ... 5
Analysis ... 7
Carcass Mark Recapture ... 8
Genetic Analysis ... 8
Scale Analysis ... 9
Results ... 9
Run Timing All Species ... 9
Chinook Salmon ... 11
Run Type Genetics ... 11
Abundance ... 13
Distribution ... 14
Life History Diversity ... 16
Coho Salmon ... 18
Abundance ... 18
Distribution ... 17
Life History Diversity ... 18
Steelhead Trout ... 18
Abundance ... 18
Distribution ... 19
Life History Diversity ... 20
Discussion ... 21
References ... 25
Appendices ... 28

List of Tables

Table 1. *Successfully genotyped Chinook samples from the Newaukum River basin showing sample size and percent composition using both the Thompson et al. markers and using additional informative markers that have been identified to determine run type.* 11

Table 2. *Abundance estimates for 2022 returns from census redd surveys using the current method (October 15th cutoff date and live calls on redds) to determine run type and run type proportioned based on the genotyped carcasses.* 14

Table 3. *Escapement estimates for 2022 spring and fall Chinook from the South Fork Newaukum River using the current method generated from redd counts in index areas and supplemental surveys, redd counts across the entire Newaukum spawning distribution (full census), and carcass-mark recapture (CMR). Run based on in field calls.* 14

Table 4. *Spawning distribution of 2022 Chinook in relation to the juvenile traps collecting the outmigrant smolt and fry. Run differentiation based on redd calls and cutoff date.* 15

Table 5. *The average length (cm) with standard deviation of sampled Chinook carcasses calculated for female and male, field call run type, and genetic run type.* 18

Table 7. *Newaukum River basin steelhead trout spawner abundance estimates from 2023 of natural origin (NOR) and hatchery origin (HOR) spawners. Estimates based on March 15th cut-off date to determine hatchery and natural origin. All steelhead trout spawned upstream of the smolt trap in 2023.* 19

Table 8. *Abundance estimates for 2022 Chinook based on a co-study (in review) using trans-generational mark recapture (tGMR). Proportion of run was determined from both the genetics of the initial adult carcasses as well as the genetic proportions of outmigrating juveniles.* 22

List of Figures

Figure 1. *Overview map of the Newaukum River, sub-basin of the greater Chehalis River basin, showing the juvenile trap sites.* 4

Figure 2. *Coho survey frame for 2022 using a combination of Generalized Random Tessellation Stratified (GRTS) and index core surveys.* 5

Figure 3. *Chinook Salmon carcass sampling flowchart.* 6

Figure 4. *Run timing for 2022 Pacific Salmon and 2023 steelhead trout in the Newaukum River basin based on a three-week rolling average of new redds observed. The red vertical lines show the standard October 15th and March 15th cutoff date that the Washington Department of Fish and Wildlife uses for distinguishing spring Chinook from fall Chinook and hatchery origin from natural origin steelhead trout for abundance estimates and management purposes.* 10

Figure 5. *Genotyped run calls for 2022 Chinook Salmon in the Newaukum sub-basin. The horizontal line indicates the percentage of field assignments that were congruent with the genotype. The redd vertical line shows the October 15th date used to differentiate spring from fall Chinook.* 12

Figure 6. *Location of opportunistic carcass recovery for genotyped Chinook samples collected in 2022 to show temporal and geographic separation of samples collected before and after the October 15th date used as a cut-off for spring Chinook spawning.* 13

Figure 7. *Distribution of 2022 spring Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin.* 15

Figure 8. *Distribution of 2022 fall Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin.* 16

Figure 9. *The sex composition of 2022 Chinook Salmon carcasses using field calls and genetic analysis calls to determine run type. Note: not all samples used in the field run calls (n = 55) were able to be genetically tested (n = 41) for run type.* 17

Figure 10. *Age composition from scale analysis of 2022 Chinook Salmon carcasses using field calls and genetic analysis calls to determine run type. Note: not all samples used in the field run calls (n = 58) were genetically assigned (n = 42) to run type.* 17

Figure 11. *Newaukum River basin Coho Salmon project time series of spawner abundance estimates from 2019 to 2022 of natural origin (NOR) and hatchery origin (HOR) spawners.* 18

Figure 12. *Percentage of hatchery origin spawners (pHOS) by sub-area of 2022 Coho Salmon in the Newaukum River Basin determined by carcass recovery. The white star is the release location for hatchery Coho Salmon.* 17

Figure 13. *Distribution of 2022 Coho Salmon, shown as redds mile^{-1}, for the Newaukum River basin. The areas expanded for using the GRTS method were given the redd mile^{-1} estimate generated for those areas.* 18

Figure 14. *Newaukum River basin steelhead trout project time series of spawner abundance estimates from 2020 to 2023 of natural origin (NOR) and hatchery origin (HOR) spawners.* 19

Figure 15. *Distribution of 2023 steelhead, shown as redds mile^{-1}, for the Newaukum River basin.* 20

Figure 16. *Age from scale analysis of 2023 run of steelhead trout with freshwater age on the left of the decimal and saltwater age to the right of decimal. 'R' indicates regenerated, so freshwater age is unknown, and 'S' indicates multiple spawns. Samples include both live hook and line and carcass sampling. Additional explanation of steelhead scale age notation in Appendix E.* 21

Executive Summary

The Newaukum River basin was selected as a "pilot watershed" in 2015 by Chehalis Lead Entity to help guide and monitor salmon recovery projects in the Chehalis River basin with the goal of assessing limiting factors, data gaps, and restoration targets (http://www.chehalisleadentity.org/our-work/). Since then, both an adult and juvenile monitoring program have been implemented in the basin, allowing for adult and juvenile in-stream production estimates. This report covers the 2022-2023 survey season of intensive adult spawner monitoring in the Newaukum basin for Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and steelhead trout (*O. mykiss*).

Redd based estimates were conducted similar to previous years with a few exceptions. Additional methods for monitoring were implemented for Chinook Salmon with the help of funding from Pacific Salmon Commission to look at the possibility of refining and improving monitoring techniques. In addition to the redd based estimates we conducted carcass mark recapture, and a trans-generation mark recapture method. The additional carcass work needed for these methods also allowed us to increase our sample size for genetic run testing. A Generalized Random-Tessellation Stratification (GRTS) method was used in combination with core index redd surveys for monitoring Coho Salmon. The redd based method using index and supplemental surveys was the same as previous years for steelhead trout. Major findings for the 2022-2023 season were:

- Spring Chinook adult abundance of **291** spawners is less than the previous two years but more than the first year of the intensive study (2019). Fall Chinook adult abundance of **383** spawners is the lowest abundance reported in over 20 years.
- Chinook run type based on genetics indicates that run timing based on the date and presence of lives on redds does not give a complete or accurate picture of Chinook run types in the Chehalis River basin. Of the samples tested, 25% were determined to be heterozygotes (i.e., spring-fall hybrids). Additional genetic testing throughout the Chehalis Basin where spring Chinook occur should be a priority.
- Distribution of Chinook shifted lower in the basin; most notably fall Chinook spawning in the lower main stem Newaukum River. Spring Chinook also showed a slight shift downstream but primarily during the later part of the run. The earliest spawning spring Chinook were still detected in the South Fork Newaukum upstream of Onalaska.
- Natural origin (NOR) Coho Salmon adult abundance was **3,860** spawners, approximately 1,000 less than the previous year but still higher than the long-term average of 2,674. However, hatchery origin (HOR) Coho Salmon adult abundance was 4,430, and for the first time the HOR component was larger than the NOR component.
- An increase in HOR spawning in previously low pHOS areas like upper NF Newaukum and Mitchell and Lucas creeks went from under 2% to over 30% in 2022, with Lucas Creek showing the greatest increase to 50% pHOS.
- Total spawner abundance of steelhead trout was 1,100 adults in 2023. Using the date method of March 15th to distinguish NOR and HOR determined **915** and **185** steelhead, respectively. However, the March 15th date is known to be an imperfect method for distinguishing hatchery- from natural-origin steelhead stock in the Grays Harbor basin. Utilizing the total spawners on the spawning ground and indicating an unknown proportion is of hatchery origin would be a more accurate way of reporting abundance.

The runs in 2022 revealed diminished counts for both spring and fall Chinook salmon, underscoring the importance of prioritizing restoration initiatives within the Newaukum River basin that benefit all Chinook stocks. However, ongoing challenges related to climate change and habitat degradation must be addressed to ensure the long-term sustainability of salmon and steelhead populations. Continued investment in habitat restoration, hatchery management, and collaborative conservation efforts will be vital for future success.

Introduction

In 2007 and 2009, large-scale flooding in the Chehalis River basin occurred, resulting in closures of parts of I-5, property damage, economic losses, and public health and safety risks. As a result, the Chehalis Basin Strategy was developed as a process to identify means to protect communities and fish from flooding and restore habitat to support aquatic species (http://chehalisbasinstrategy.com/). The Newaukum sub-basin was selected in 2015 by the Lead Chehalis Entity as a "pilot watershed" for early projects to help guide restoration throughout the Chehalis River basin (http://www.chehalisleadentity.org/our-work/). An integrated program to monitor adult salmon returning to their freshwater spawning habitat (Ronne et al. 2021) and juvenile production occurring at the watershed scale (West et al. 2020) was determined to be the best way to evaluate salmon and steelhead response to changes in riverine habitat resulting from restoration actions and environmental change. The Newaukum sub-basin was selected, in part, because it supports a spawning population of spring Chinook Salmon (*Oncorhynchus tshawytscha*) that has contributed anywhere from 18% to 45% (22% average from 2000-2022) to the total Chehalis River basin spring Chinook Salmon abundance (Appendix A). There is growing concern about the status of this population in the Chehalis River basin, so restoration and other activities are being developed to help support the population, whose numbers have shown a downward trend over the last two decades.

This monitoring effort focuses on spring and fall Chinook Salmon, hereafter referred to as Chinook, Coho (*O. kisutch*), and winter-run steelhead trout (*O. mykiss*), hereafter referred to as steelhead. The framework for this study, which includes intensive monitoring of abundance, distribution, and run timing of adult salmonids, began in the Newaukum sub-basin in September 2019. Prior to this, limited monitoring occurred to produce abundance estimates used by fish managers. Throughout time, surveys based on redd (i.e., salmon nest) counts and live counts have been used to generate an estimate of an escapement (i.e., the number of salmon not caught by commercial or recreational fisheries that return to their natal habitat, Johnson et al. 2007).

In 2022, leveraging the existing intensive monitoring infrastructure, we initiated a project funded by the Pacific Salmon Commission (PSC) to compare different Chinook monitoring methods: the limited monitoring by WDFW prior to 2019, the current intensive monitoring, carcass mark-recapture (CMR), and transgenerational genetic mark-recapture (tGMR). This co-study aims to refine and improve monitoring techniques for application throughout the Chehalis River basin. Additionally, we implemented a pilot study using a Generalized Random-Tessellation Stratification (GRTS) method for monitoring Coho to determine if GRTS was a more efficient method to survey a species with such a broad distribution.

Objectives

The overall goal of this monitoring project was to describe the abundance, spawn timing, spatial distribution, and life history diversity of adult spring and fall Chinook, Coho, and steelhead in the Newaukum River sub-basin during return years 2022/2023, and to determine the abundance of adult spawners above the juvenile fry and smolt traps (Figure 1) as part of the fish in / fish out monitoring program supported by the Chehalis Basin Strategy.

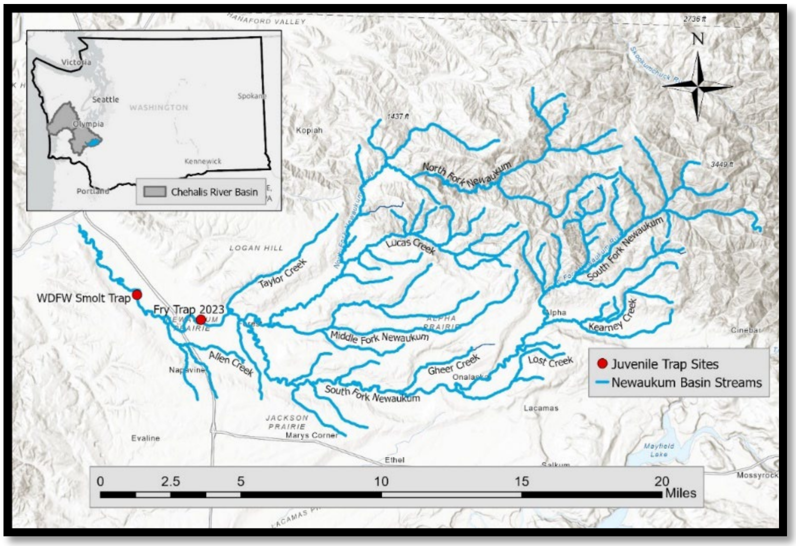

Figure 1. *Overview map of the Newaukum River, sub-basin of the greater Chehalis River basin, showing the juvenile trap sites.*

Methods

Study Design and Area

The study area focused on the Newaukum River, a sub-basin of the Chehalis River. Prior to 2019, index reaches surveyed for salmon and steelhead were designed as part of a Chehalis River basin-wide stock assessment effort with limited spatial coverage within the Newaukum River sub-basin. Starting in 2019, the spatial and temporal coverage within the basin was expanded to cover as much of the spawning habitat as possible for each species. There were three primary study designs used for this project: census index for Chinook, index and supplemental for steelhead trout, and a pilot study using index and Generalized Random-Tessellation Stratification (GRTS, Figure 2) for Coho. All study designs used redd counts to generate estimates based on a fish per redd expansion. Census index surveys were designed to cover all the available anadromous spawning areas and occurred approximately every seven days throughout both spring and fall Chinook spawning. Index and supplemental surveys occurred for steelhead. Steelhead index surveys were done on the majority of spawning habitat on a 7–14-day rotation but additional supplemental surveys were done once during peak spawn timing targeting potential spawning habitat that was not surveyed on a weekly basis. The ratio of redds visible in an index during peak spawning to how many were observed in that index throughout the entire season was applied to expand supplemental survey observations to account for the entire spawning season. A combination of core index surveys and GRTS surveys were conducted during Coho season. The core index surveys were completed in areas with the highest density of spawning on a weekly basis. For the rest of the potential spawning habitat within the basin, we employed the GRTS design (Stevens and Olsen2004) for spawning ground surveys to generate unbiased estimates of spawner populations within our study area. This approach utilized a Geographic Information System (GIS) line layer as a sampling frame to ensure spatially balanced site selection across the river systems. Sites were chosen systematically, with an oversampling strategy to account for potential access issues, ensuring a comprehensive spatial representation. The *spsurvey* package in R was utilized for data aggregation and analysis, providing robust estimators for totals and variances while accounting for the spatial structure of the data (Kincaid et al. 2016).

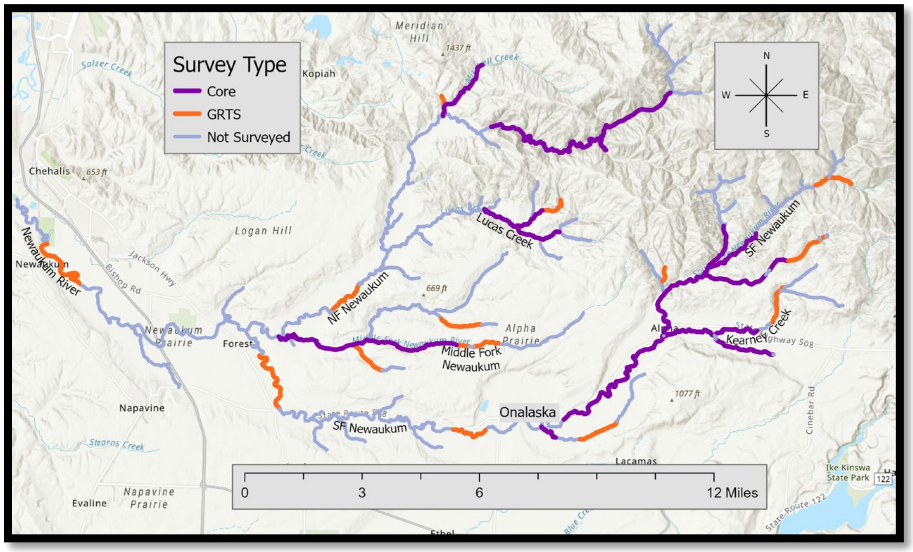

Figure 2. *Coho survey frame for 2022 using a combination of Generalized Random Tessellation Stratified (GRTS) and index core surveys.*

Data Collection

Spawning ground surveys were conducted from September 2022 through June 2023, covering the spawn timing for each species of salmon and steelhead. Surveys comprised of locating and monitoring redds, counting live and dead fish, and sampling carcasses for adipose mark status (marked/unmarked), coded-wire tag (CWT) status, and biological material (e.g., scales for ageing and tissue for genetics). Each redd was flagged, numbered, and georeferenced. Since spatial and temporal overlap in spawning activity occurs between fall Chinook and Coho, and between Coho and steelhead, surveyors were trained to recognize subtle redd differences between each species based on habitat use and redd structures (Burner 1951, Gallagher et al. 2007) in order to assign a species to each redd. In addition, surveyors continually explored potential spawning areas through supplemental and exploratory surveys above and below known spawning habitat.

We followed the WDFW Region 6 District 17 protocol to assign field run timing determinations (spring or fall) to Chinook redds based on timing, redd condition, and phenotypic characteristics, behavior, and condition of any associated live fish observed within close proximity of the redd. These assignments also used information on fall Chinook behavior and activity, flow levels, and other spawning activity within the basin. Redds constructed after October 15th were all assumed to be fall Chinook, but redds constructed on or prior to October 15th were assigned either spring or fall Chinook based on weight of evidence criteria (Appendix B). If a surveyor was unable to make an informed decision on run type of a redd constructed on or prior to October 15th, the redd was designated spring Chinook.

For Coho and steelhead, carcasses were opportunistically recovered during redd surveys and sampled for species, sex, adipose mark status, CWT presence, and biological data. Mark status and CWTs were used to determine if adult spawners were of hatchery origin (HOR). Sex and fork length were collected to assist with life history diversity metrics. Three or more scales were collected from unmarked Coho carcass and six or more scales from each steelhead for ageing.

Surveys for Chinook carcasses were more intensive with surveys happening twice a week. In the South Fork Newaukum, a CMR study was implemented using an open population mark-recapture study design. This design has several assumptions (Seber 1982):

1. ***Equal Catchability***: Each carcass that is present during a sampling event, tagged or untagged, has the same probability of being sampled.
2. ***Equal Persistence***: Each carcass, tagged or untagged, has the same probability of survival (i.e., persisting in the study areas to following sampling period).
3. ***Tag Loss and Recovery***: Tagged carcasses do not lose their marks and all marks are recognized and recorded properly on recovery.
4. ***Instantaneous Sampling***: The samples are instantaneous, (i.e., the time it takes to sample and release the sample is negligible).

Sampling methods were designed to minimize, as much as possible, any violations to these assumptions. Each dead fish was examined for tags placed the previous week and if no tags were present, fish condition was assessed to see if the fish was suitable for tagging (Figure 3).

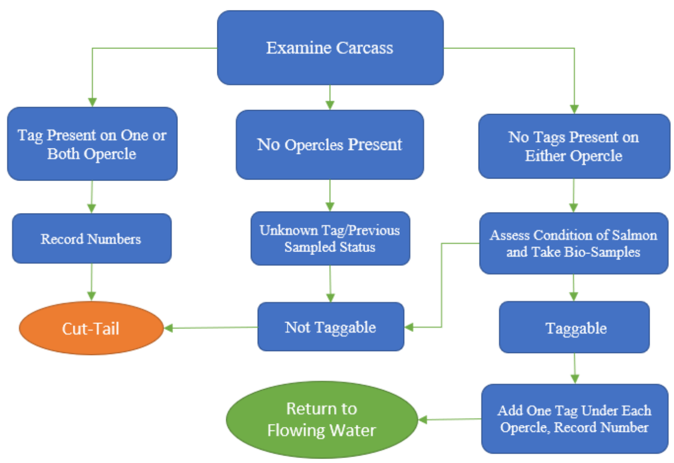

Figure 3. *Chinook Salmon carcass sampling flowchart.*

It was important to examine both opercles for tags and note if a) tags were present, b) no tag was present but opercle was present, or c) if the opercle was missing. If a fish was recovered with one tag present on one opercle but no tag present on the other opercle, it was considered a tag loss on recapture. If the opercle was missing it was not considered a loss on recapture. If the fish was not tagged it was assessed to determine if the carcass was likely to survive until the next survey event.

Carcass condition was rated as follows and only conditions 1-3 were considered taggable:

1. Fresh, clear eyes, red gills, firm flesh, both opercles intact
2. Clear eyes, mostly firm flesh but may have some softening, white gills, both opercles intact

3. Cloudy eyes, flesh softer but intact, both opercles intact
4. Cloudy eyes, flesh very soft
5. Falling apart, skeleton

Carcasses considered taggable had one tag stapled under each opercle and the tagged carcasses were returned to a moving body of water so that they could mix with the remaining populations. Biodata was collected from all Chinook on the first encounter only, including scales for aging and fin clips for genetic run timing analysis and tGMR.

Analysis

Estimates of abundance were based on 1) enumerated redds in index reaches, 2) enumerated and expanded redds in supplemental reaches, and 3) redd density, expressed in redds per mile (redds $mile^{-1}$), expanded for unsurveyed habitat and/or GRTS within the survey frame. Redds observed in supplemental reaches were expanded by the ratio of visible-to-cumulative redds observed in the nearest applicable index reach. The visible-to-cumulative ratio refers to the number of redds visible in an index reach on the day of, or within one day of, the supplemental survey, divided by the cumulative redds observed in that index reach for the entire spawning season. The timing of supplemental surveys was selected to coincide with when the highest proportion of total redds for the season were visible. The visible-to-cumulative expansion factor was applied if the visible-to-cumulative ratio was ≥0.20 at the time the supplemental survey occurred. If the visible-to-cumulative ratio was <0.20, the number of observed redds in the supplemental reach was included in the abundance estimate, but no expansion was applied. The result of this calculation was the estimate of the total number of redds in the supplemental survey reach for the season.

For Coho surveys, the GRTS sampling was used to estimate redds-per-mile in a select subset of streams that were a random, spatially balanced representation of all unsurveyed areas of the basin. Data analysis followed the GRTS methodology, where the total number of redds was estimated based on the observed counts and the inclusion probability of each site. The core surveys counts were added to the GRTS expansion to get a total redd estimate.

Species-specific expansion for Chinook assumed 1.0 female adult per redd and 1.5 males per female (Orelle 1976), which is the standard expansion used by WDFW for stock assessment in western Washington. For Coho, the expansion from redd estimate to adult spawners assumed 1.0 female per redd and 1.0 male per female, which is also the standard expansion used by WDFW for stock assessment in western Washington. For steelhead, the expansion from redd estimate to adult spawners assumed 0.81 females per redd and 1.0 male per female and was based on previous trap studies conducted in Snow Creek, Washington (USFWS and WDG 1980, Freymond 1982). The steelhead expansion factor reflected a combination of multiple redds built by a single female steelhead and assumed a 1:1 ratio of male to female steelhead. The redd based estimation methodology is based on multiple assumptions, including:

Assumption 1: species assignments for redds are correct;
Assumption 2: survey reaches are representative of spatial and temporal spawning distribution;
Assumption 3: true redds are accurately distinguished from natural scour and test digs;
Assumption 4: the ratio of fish per redd is constant among years and is accurately represented by the species-specific expansion factor; and

Assumption 5: there is no difference in spawn timing distribution between supplemental reaches and index reaches used in the visual-to-cumulative ratio expansions (proportional visibility of redds between related index reaches and supplemental reaches).

The steelhead redd counts were partitioned as either early or late to align with WDFW methodology, whereby early steelhead redds (on or before March 15^{th}) were assumed to be of hatchery origin and late steelhead redds (after March 15^{th}) were assumed to be of natural origin. Early redds were assumed to be of hatchery origin as many hatchery steelhead programs in western Washington produce fish with early run and spawn timing.

Recovered carcasses of adult Chinook, Coho, and both live and dead (carcasses) steelhead were used to determine the ratio of hatchery- to natural-origin fish (HOR:NOR) based on the adipose fin and CWT status or scale morphology. Steelhead origin was further validated by scale growth patterns as determined by the WDFW Otolith and Ageing Lab (Appendix E). Life history diversity was assessed based on age structure (years in freshwater and the ocean) and summarized for the sampled population. Age data was collected from Coho in 2022 as part of a life history study for another project even though typically all Coho are assumed to be age 3 (Weitkamp et al. 1995, Seamons et al. 2020).

Spatial distribution of all spawning fish was visualized using ArcGIS Pro by plotting redds and redds $mile^{-1}$ for each species. Spawning locations were documented in map form by overlaying the areas surveyed as index and supplemental reaches. Spatial distribution of spawning activity was also summarized for each species and represented as the proportion of redds in main stem versus tributary habitat. These calculations were based on the total number of redds and included redds estimated from visible-to-cumulative expansions in supplemental reaches.

Carcass Mark Recapture

Carcass tagging data were used to estimate spawner abundance in CMR index reaches. The carcass tagging data were analyzed with a Jolly-Seber (JS) estimator. The formula for the JS estimator is:

$$\widehat{N} = \frac{(M+1)(C+1)}{\mathrm{R+1}} - 1$$

The JS estimator of spawner abundance estimate for each reach was based on the "super population" model (Schwarz et al. 1993) and parameterized in a Bayesian framework. A comprehensive description of this JS model, including summary statistics, fundamental parameters, derived parameters, and likelihoods can be found in Rawding et al. (2014) and Bentley et al. (2018). For this model, spawner escapement is the sum of gross births (i.e., arrival of new carcasses) that enter the system over the study period and includes the estimated number of carcasses present during each sampling period and the carcasses estimated to have entered the system after one sampling period and removed from the system prior to the next sampling period.

Genetic Analysis

Tissue samples from opportunistically sampled spring and fall Chinook carcasses in 2022 (n=76) were tested for genetic run timing using methods outlined in Thompson et al. (2019).

Briefly, genomic DNA was isolated from fish tissue with Machery-Nagle silica based column extraction kits following the manufacturers protocol for animal tissues. Chinook-specific single nucleotide polymorphisms (SNPs) were genotyped using a cost-effective method based on a custom amplicon sequencing called Genotyping in Thousands (GTseq) (Campbell et al. 2015). For each individual, pools were sequenced, de-multiplexed, and genotyped by generating a ratio of allele counts. The process had four segments: extraction, library preparation, sequencing, and genotyping. WDFW's Chinook salmon Gtseq SNP panel has one sex ID marker, 298 nuclear SNP markers, and 33 markers known to be correlated with run timing. The Thompson et al. (2019) SNP markers used in previous analyses are two of the 33 markers. The genotypes of thirteen of the additional markers are 100% correlated with those of the Thompson et al. (2019) markers in Chehalis Chinook salmon. The genotypes of the additional informative markers were used to infer run-timing of individuals who had missing data at both Thompson et al. (2019) markers. To call run-type using the Thompson et al. (2019) markers, the genotyping results from both SNPs (homozygous spring-run, heterozygous, or homozygous fall-run) were required to agree. Using the additional informative markers, genotypes for at least two of the markers had to be present and had to agree in run-type call.

Scale Analysis

Scale analysis was used to determine age and iteroparity. The scale analysis was completed by the WDFW Fish Ageing Lab each spawn year for run reconstruction and co-management purposes. Scales were mounted on gummed scale cards in the field. Acetate impressions were made of each card using a heated hydraulic press and viewed using a digital microscope camera (e.g., Leica S9i ©). Alternating zones of tightly and widely spaced circuli, termed annuli, were identified and indicated the number of winters or years a fish has lived. For steelhead trout, iteroparity was also identified based on scars present when a scale resorbs during a previous spawning migration then regrows leaving a scar that is discernable. For steelhead, age was designated using the European age notation described in Koo (1962) and adapted for winter steelhead (WDFW 1978, Scott and Gill 2008). Numbers to the left of the decimal point represent years spent in freshwater and "." indicates the initial seaward migration. Numbers to the right of the decimal point indicate years at sea and the "+" is used to represent the annulus that occur(s) as the fish migrate back to freshwater. A "S" denotes a spawn scar. For Chinook and Coho, age was recorded using Gilbert/Rich notation (Gilbert and Rich 1927, Groot and Margolis 1991). Gilbert/Rich notation consists of two numbers where the second number is a subscript (e.g., 5_2). The first number describes the total years of life between when a fish was deposited in gravel as an egg and capture. The subscript describes the year of life the fish migrated to sea. The first number in the Gilbert/Rich notation is equal to total age.

Results

Run Timing All Species

The first spring Chinook redds were observed in early September 2022, equivalent to statistical week (week of the year, SW) 37 (Figure 4, Appendix C). Peak spawning occurred in the beginning of October (SW 41). The first fall Chinook redd was observed in SW 42 overlapping with the later spring Chinook spawning. Fall Chinook spawning peaked mid-October (SW 44) and continued to spawn two weeks past the peak week to mid-November (SW 46). The peak spawning of fall chinook was two weeks later than previous years but ended about the same time.

The first Coho redds were observed at the end of October (SW 43) overlapping with the last three weeks of fall Chinook spawning. Coho in the Newaukum typically have a bimodal spawning with two waves of the run called A and B runs. The A run typically occurs at the beginning of December (SW 49) and the B run later in January (SW 4). This was clearly shown in the 2021 and 2020 runs but not as clearly in the 2019 run. The bimodal peak for the 2022 run was unable to be clearly distinguished. Similar to previous years, there was a clear separation in timing for the early coho peak spawning in the Middle Fork Newaukum River from the rest of the basin being about two week earlier than the rest of the spawning. Spawn timing for steelhead began at the beginning of January 2023 (SW 2), about a month earlier than previous years, and peaked mid-March (SW 12) one week after the state used date to determine hatchery origin (HOR) Steelhead from natural origin (NOR) steelhead. Steelhead continued to spawn for an additional eight weeks into May 2023 (SW 20) ending almost a month earlier than the previous year.

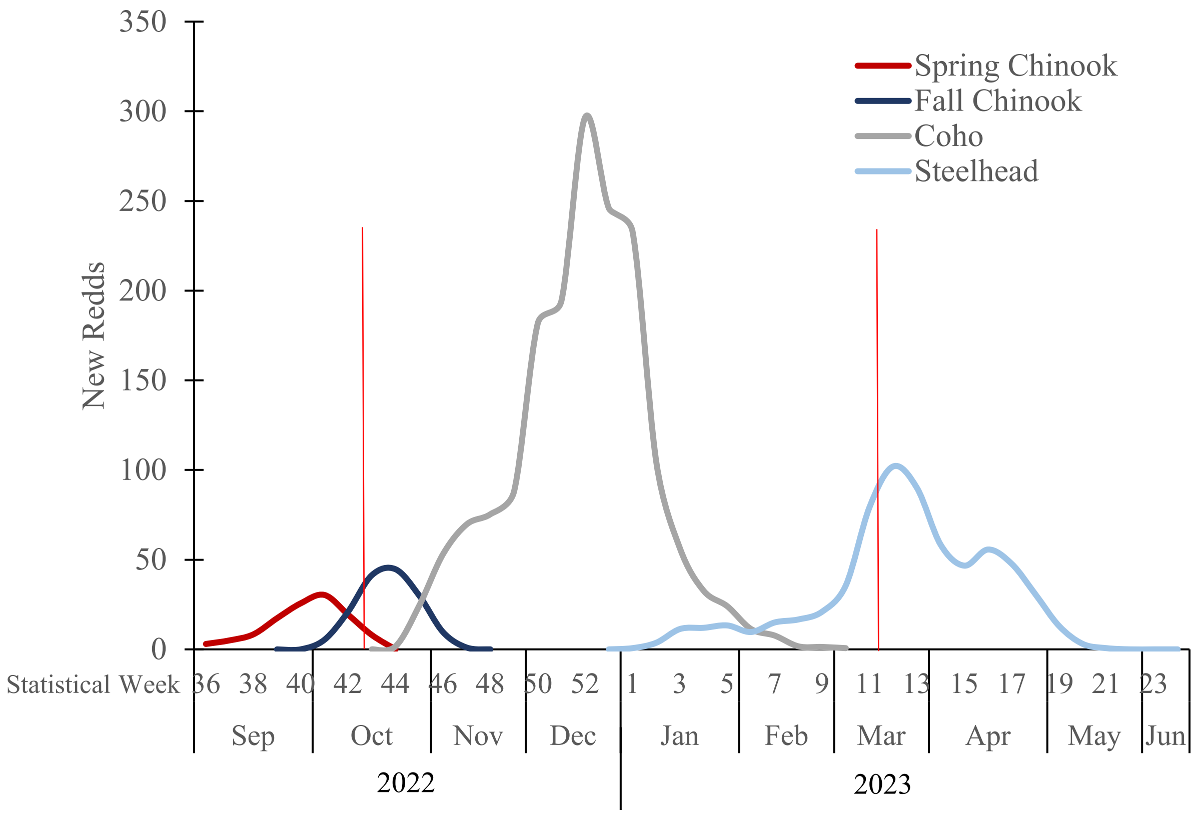

Figure 4. *Run timing for 2022 Pacific Salmon and 2023 steelhead trout in the Newaukum River basin based on a three-week rolling average of new redds observed. The red vertical lines show the standard October 15th and March 15th cutoff date that the Washington Department of Fish and Wildlife uses for distinguishing spring Chinook from fall Chinook and hatchery origin from natural origin steelhead trout for abundance estimates and management purposes.*

Chinook Salmon

Run Type Genetics

Tissue samples from Chinook carcasses were collected in 2022 during spawning ground surveys to determine genetic run timing and compare to field calls. Carcass surveys were done twice a week to increase the number of samples. Of the 76 samples submitted for run timing determination, 45 were successfully genotyped using the Thompson et al. (2019) markers (Table 1). Utilizing additional informative markers, we were able to determine run type on 60 total samples; 15 more than using just the Thompson et al. (2019) markers. However, only the Thompson et al. (2019) markers were used in proportioning the abundance later in the report to remain consistent with previous years information.

Table 1. *Successfully genotyped Chinook samples from the Newaukum River basin showing sample size and percent composition using both the Thompson et al. markers and using additional informative markers that have been identified to determine run type.*

	Thompson Markers		Additional Informative Markers	
	n	**% Comp.**	**n**	**% Comp.**
Fall	25	56%	32	53%
Heterozygote	11	24%	15	25%
Spring	9	20%	13	22%
Total	**45**		**60**	

Homozygous spring Chinook showed up in 22% (n=13) of the samples and were recovered between September 8th and October 18th (Figure 5). Heterozygous run timing (both spring and fall markers) showed up in 25% (n=15) of the samples. The heterozygous samples were collected between October 5th and November 3rd. Homozygous falls were the most abundant and present in 53% (n=32) of the samples. The earliest genotyped fall Chinook carcass that had fully spawned was collected on October 5th, ten days before October 15th, the cut-off date for spring Chinook redd calls. The latest spring Chinook carcass was collected on October 18th.

Of the fall and spring genotyped sampled carcasses, eleven came back different from the original run type field calls. Four genotyped spring Chinook were assigned fall Chinook in the field and seven genotyped fall Chinook were assigned as spring Chinook in the field. All the incongruent calls occurred between October 5th – October 18th, the period with the highest overlap between spring and fall runs according to field surveys. Of the 15 heterozygous genotypes, field calls were 73% (n=11) fall Chinook and 27% (n=4) spring Chinook.

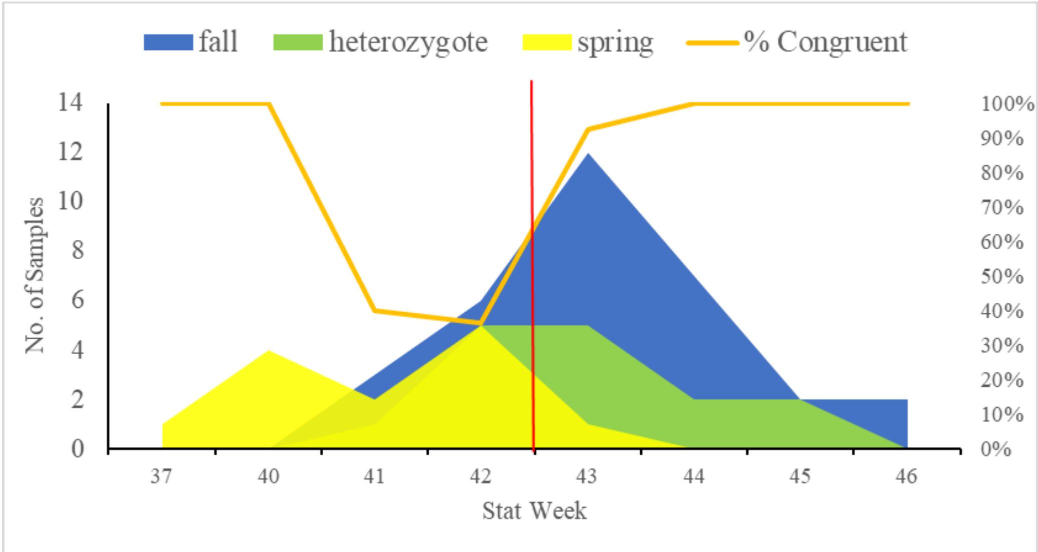

Figure 5. *Genotyped run calls for 2022 Chinook Salmon in the Newaukum sub-basin. The horizontal line indicates the percentage of field assignments that were congruent with the genotype. The redd vertical line shows the October 15th date used to differentiate spring from fall Chinook.*

Of 13 genotyped spring Chinook, 69% were recovered in the South Fork Newaukum River (n=9) and 38% (n=4) were recovered upstream of Onalaska (Figure 6). There were also 31% (n=4) of genotyped spring Chinook recovered in the main stem Newaukum River. Of 32 genotyped fall Chinook samples, 34% (n=11) were recovered in the South Fork Newaukum, all downstream of Onalaska. The remainder (n=21) were recovered in the main stem Newaukum. The majority (87%, n=13) of heterozygote genotypes were recovered from the main stem Newaukum River and only 13% (n=2) were recovered in the South Fork Newaukum, all downstream of Onalaska.

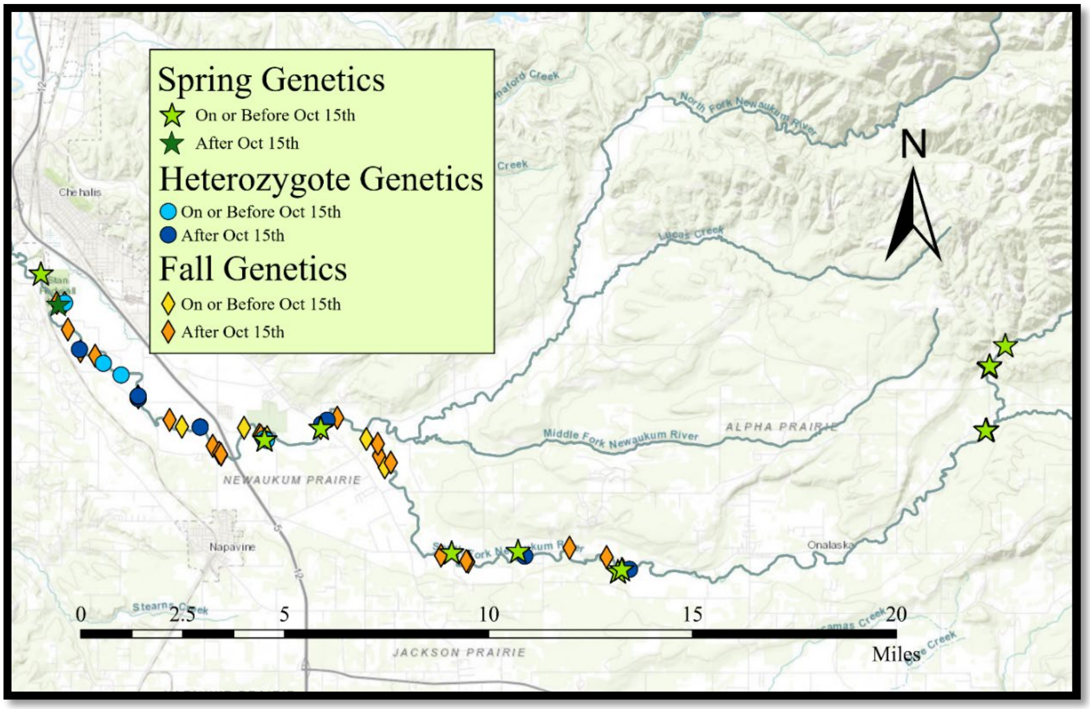

Figure 6. *Location of opportunistic carcass recovery for genotyped Chinook samples collected in 2022 to show temporal and geographic separation of samples collected before and after the October 15th date used as a cut-off for spring Chinook spawning.*

Abundance

In 2022, multiple methods were used to estimate adult spawner abundance to verify or recalibrate escapements of Chinook in the Newaukum River basin. These methods included redd-based estimates (pre-2019 and current methodologies), carcass-mark-recapture (CMR) method, and tGMR method. Abundance estimates for tGMR are not fully reported in this paper as it covers a broader scope than just adults. In addition, we explored genetic testing as a way to proportion run types in the redd based estimates as a possible alternative to the current date method.

Redd Based Estimates

The current method of census redd surveys estimated 291 spring Chinook adults and 383 fall Chinook using the October 15th cut-off date between spring and fall Chinook redd construction (Table 2). Total Chinook estimates were about 30% less than the 2021 (n=968) and 60% less than the 2020 (n=1,763), the lowest total Chinook estimates in the basin since the intensive study began in 2019. Using the genetic proportions of carcasses to separate the redd based Chinook estimates into run types, we observed a much smaller homozygous spring Chinook run of only 146 adults (compared to 291), a slightly smaller homozygous fall Chinook component of 359 adult spawners (compared to 383), and 169 heterozygote adult spawners, which were not identified using the redd based methodologies.

Table 2. *Abundance estimates for 2022 returns from census redd surveys using the current method (October 15th cutoff date and live calls on redds) to determine run type and run type proportioned based on the genotyped carcasses.*

Run Type	Current Method	Genotype
Spring Chinook	291	146
Fall Chinook	383	359
Heterozygote	-	169
Total Chinook	674	674

Carcass Mark Recapture Estimates

Carcass tagging in 2022 was only conducted on the South Fork Newaukum as previous surveys showed that the SF had the highest density of spawning Chinook. However, in 2022 we were only able to tag 18 carcasses and only recovered 3 fish that were tagged. This generated an estimate of 128 (95% C.I. = 53-314) adult Chinook, with 61 spring Chinook (95% C.I. = 15-206) and 67 fall Chinook (95% C.I. = 16-165) based on the carcass field calls (Table 3). The large confidence interval was attributed to the small sample size of tagged carcasses. The CMR method estimated 63.3% fewer spring Chinook than the current survey-based method, 40.7% fewer fall Chinook, and 54.1% fewer Chinook overall. However, this method did produce an estimate with known precision, and the 95% C.I. did encompass the survey-based result.

Table 3. *Escapement estimates for 2022 spring and fall Chinook from the South Fork Newaukum River using the current method generated from redd counts in index areas and supplemental surveys, redd counts across the entire Newaukum spawning distribution (full census), and carcass-mark recapture (CMR). Run based on in field calls.*

South Fork Escapements		
	Redd Census	**CMR (95% CI)**
Spring Chinook	178	61 (15-206)
Fall Chinook	113	67 (16-165)
Total	291	128 (53-314)

Distribution

Distribution was based on location data of redds and portrayed as redds-per-mile where run types were based on in-field redd calls. The spawning distribution of Chinook was limited to the forks and main stem Newaukum River, similar to previous years. However, in 2022 there was a shift in distribution. Most obviously, the average percent of the fall Chinook that spawned upstream of the smolt trap in the previous three years was 91%. In 2022, only 58% of the fall Chinook run spawned upstream of the smolt trap (Table 4). Less obvious was spring Chinook, which, although the majority spawned upstream of the smolt trap (87%), appeared to shift spawning density lower in the basin (Figure 7). In previous years, the highest densities of spring Chinook spawned in the South Fork Newaukum, but in 2022 the highest densities (8-9 redds mile^{-1}) were in the main stem Newaukum just above the smolt trap. It should be noted that the earliest spawning spring Chinook did so in the upper South Fork in similar areas to previous years, but at a lower density than in previous years.

Table 4. *Spawning distribution of 2022 Chinook in relation to the juvenile traps collecting the outmigrant smolt and fry. Run differentiation based on redd calls and cutoff date.*

	WDFW Smolt Trap			2023 Fry Trap		
	% Above	Upstream	Below	**% Above**	Upstream	Below
Spring Chinook	**87%**	253	38	**73%**	213	78
Fall Chinook	**58%**	223	160	**41%**	158	225

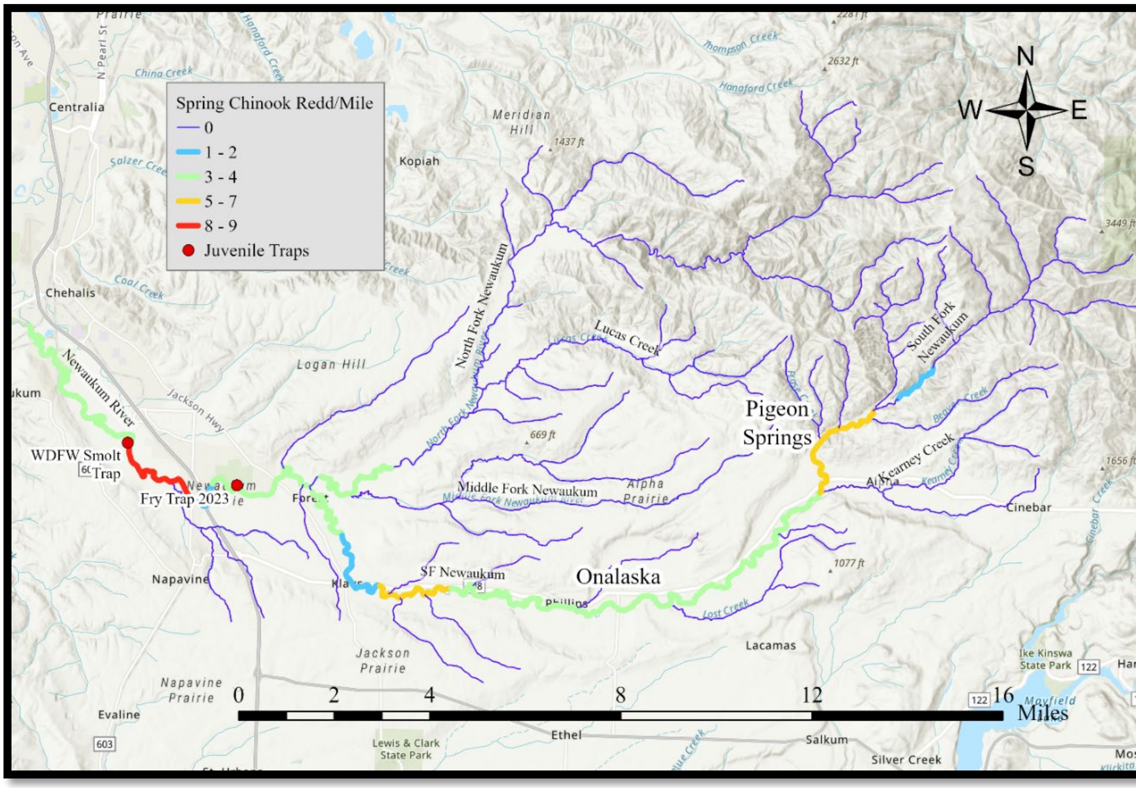

Figure 7. *Distribution of 2022 spring Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin.*

Fall Chinook had the highest density (14.5 redds mile^{-1}) on the main stem Newaukum, between I-5 and the smolt trap (Figure 8). In previous years, there were higher concentrations of spawning Chinook in the lower SF and mid North Fork Newaukum (average ~10 redds mile^{-1}) but little to no spawning in those same areas in 2022.

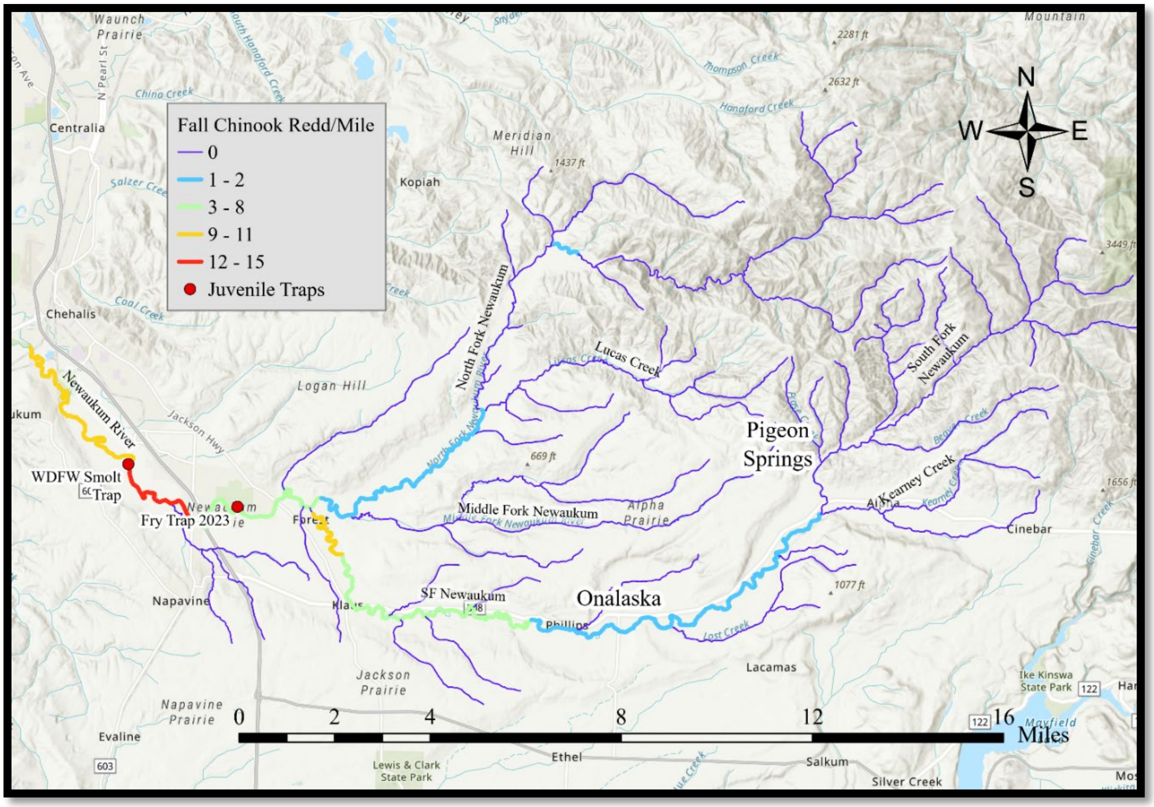

Figure 8. *Distribution of 2022 fall Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin.*

Life History Diversity

All the Chinook carcasses encountered in 2022, where clip status was determined, had an adipose fin present (unmarked, UM), and were considered of natural origin. Of the Chinook carcasses collected that were determined to be spring run type based on the field run call and where sex was determined, 53% were female (n=10) and 47% were male (n=9, Figure 9). When the sex ratio was based on the genetic run type of spring run, the sex ratio increased to 60% female (n=6) and 40% male (n=4). The genetic run type call for fall Chinook had a sex ratio of 41% female (n=9) and 56% male (n=13) and the heterozygous run call had a ratio of 44% female (n=4) and 56% male (n=5).

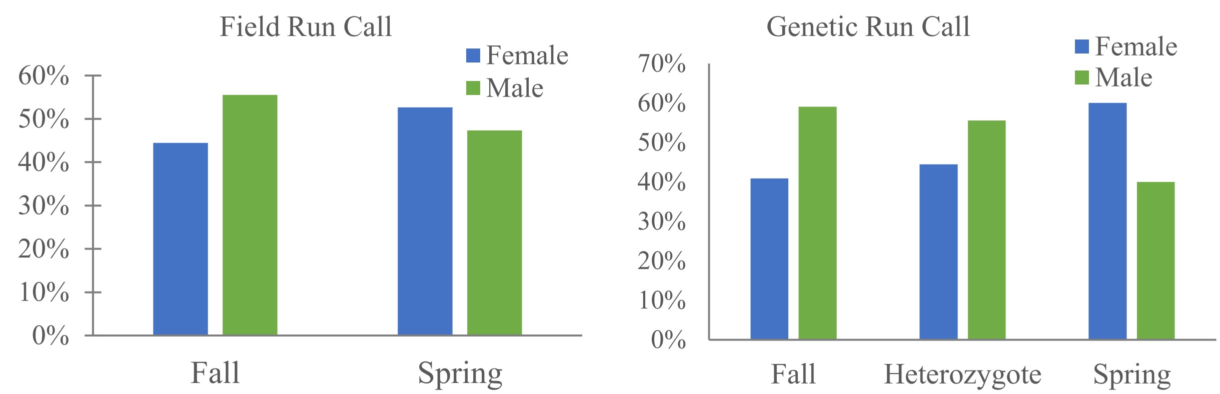

Figure 9. *The sex composition of 2022 Chinook Salmon carcasses using field calls and genetic analysis calls to determine run type. Note: not all samples used in the field run calls (n = 55) were able to be genetically tested (n = 41) for run type.*

Age was determined from scales collected from Chinook carcasses and based on the field run type call. Spring Chinook came back with 5% scale Age-2 (n=1), 24% scale Age-3 (n=5), 52% scale Age-4 (n=11), and 19% scale Age-5 (n=4, Figure 10). Fall Chinook age based on the field run call came back as 27% scale Age-3 (n=10), 68% scale Age-4 (n=25) and 5% scale Age-5 (n=2). When the genetic run type call was used to examine scale ages, spring Chinook was composed of 30% scale Age-3 (n=3), 60% scale Age-4 (n=6), and 10% scale Age-5 (n=1). Heterozygotes were composed of 44% scale Age-3 (n=4) and 56% scale Age-4 (n=5). Fall Chinook based on the genetic run type call had 26% scale Age-3 (n=6), 61% scale Age-4 (n=14), and 13% scale Age-5 (n=3).

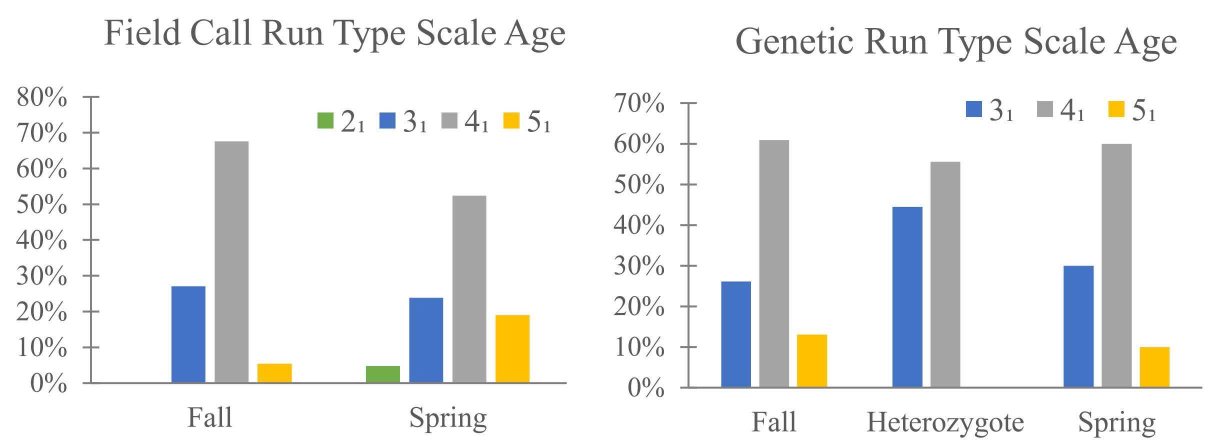

Figure 10. *Age composition from scale analysis of 2022 Chinook Salmon carcasses using field calls and genetic analysis calls to determine run type. Note: not all samples used in the field run calls (n = 58) were genetically assigned (n = 42) to run type.*

The average lengths in Chinook were determined for spring and fall run types using both the field calls and genetic calls (Table 5).

Table 5. *The average length (cm) with standard deviation of sampled Chinook carcasses calculated for female and male, field call run type, and genetic run type.*

Field Call Run Average Length	**Female**	**Male**
Spring	76.4 (± 3.3)	73.3 (± 16.1)
Fall	75.9 (± 4.0)	76.5 (± 14.1)

Genetic Run Average Length	**Female**	**Male**
Spring	74.8 (± 3.7)	71.3 (± 5.9)
Heterozygote	75.8 (± 3.8)	73.8 (± 9.3)
Fall	76.4 (± 4.0)	76.2 (± 16.5)

Coho Salmon

Abundance

In the 2022 survey season, we estimated a natural origin (NOR) abundance of 3,860 Coho adult spawners (Table 6). This is an increase of 18% from the previous 20-year average. The hatchery origin (HOR) Coho spawner population experienced a substantial increase to 4,430 adults which represented 53% of the total spawning population in the Newaukum River basin. This increase is 14 times that of the average HOR from the last 5 years. Supplemental information on Coho estimates can be found in Appendix D.

Table 6. *Newaukum River basin Coho Salmon spawner abundance estimates from 2022 of natural origin (NOR) and hatchery origin (HOR) spawners. All Coho spawned upstream of the smolt trap in 2022.*

2022 Coho Salmon	**Adult Spawners**	**Upstream of Smolt Trap**
NOR	3,860	3,860
HOR	4,430	4,430
Total	8,290	8,290

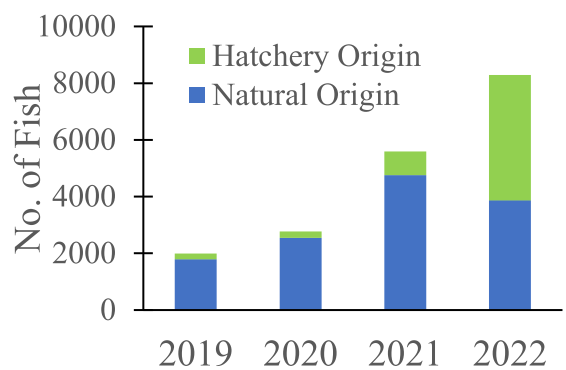

Figure 11. *Newaukum River basin Coho Salmon project time series of spawner abundance estimates from 2019 to 2022 of natural origin (NOR) and hatchery origin (HOR) spawners.*

In 2022, the proportion of hatchery-origin spawners (pHOS) from the Newaukum River basin's subbasins revealed an increase of hatchery influence compared to 2021, with some subbasins experiencing significant shifts. The upper North Fork Newaukum and Mitchell Creek areas, previously exhibiting a minimal hatchery presence at 1.7% pHOS, observed a substantial increase to 30% pHOS, indicating a notable rise in hatchery origin spawners (Figure 12). Similarly, the Middle Fork Newaukum also saw a sharp increase in hatchery spawners, ascending from 11.6% to 51%, and in Lucas Creek, PHOS increased from 1.7% to 50% between 2021 and 2022. The lower South Fork and main stem Newaukum maintained similar pHOS values to the previous year, but the upper South Fork Newaukum and tributaries also had a marked increase.

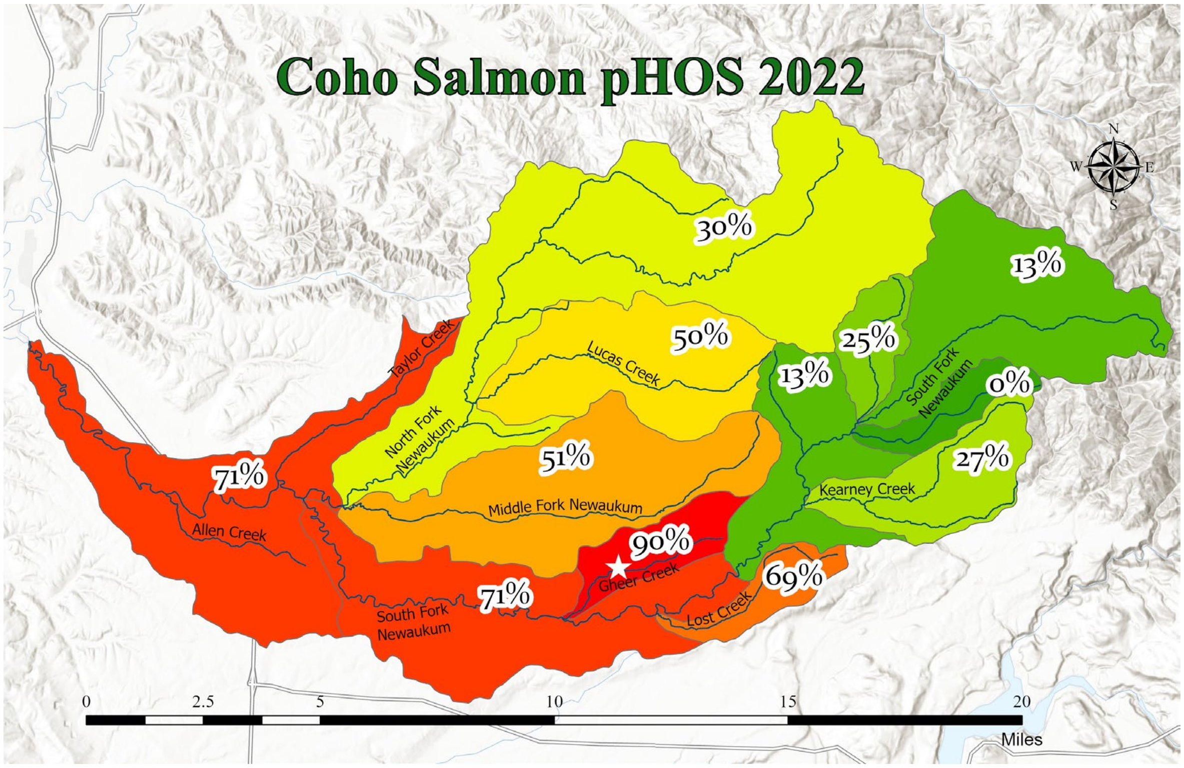

Figure 12. *Percentage of hatchery origin spawners (pHOS) by sub-area of 2022 Coho Salmon in the Newaukum River Basin determined by carcass recovery. The white star is the release location for hatchery Coho Salmon.*

Distribution

In 2022, there was no obvious shift in the distribution of Coho spawning from previous years with high densities in the Middle Fork and the upper areas of the forks (Figure 13). Kearney, Mitchell and Lucas Creeks also had high abundances during the 2022 spawning season. Gheer Creek and Lost Creek had some of the highest densities of Coho, but they were primarily composed of hatchery origin spawners. The GRTS method used in 2022 made it harder to determine shifts in distribution. Outside of the core indexes, GRTS indexes were randomly chosen one-mile sections which made it difficult to detect interannual distribution shifts. All areas that were estimated using the GRTS method had a density of 18.4 redds mile^{-1}.

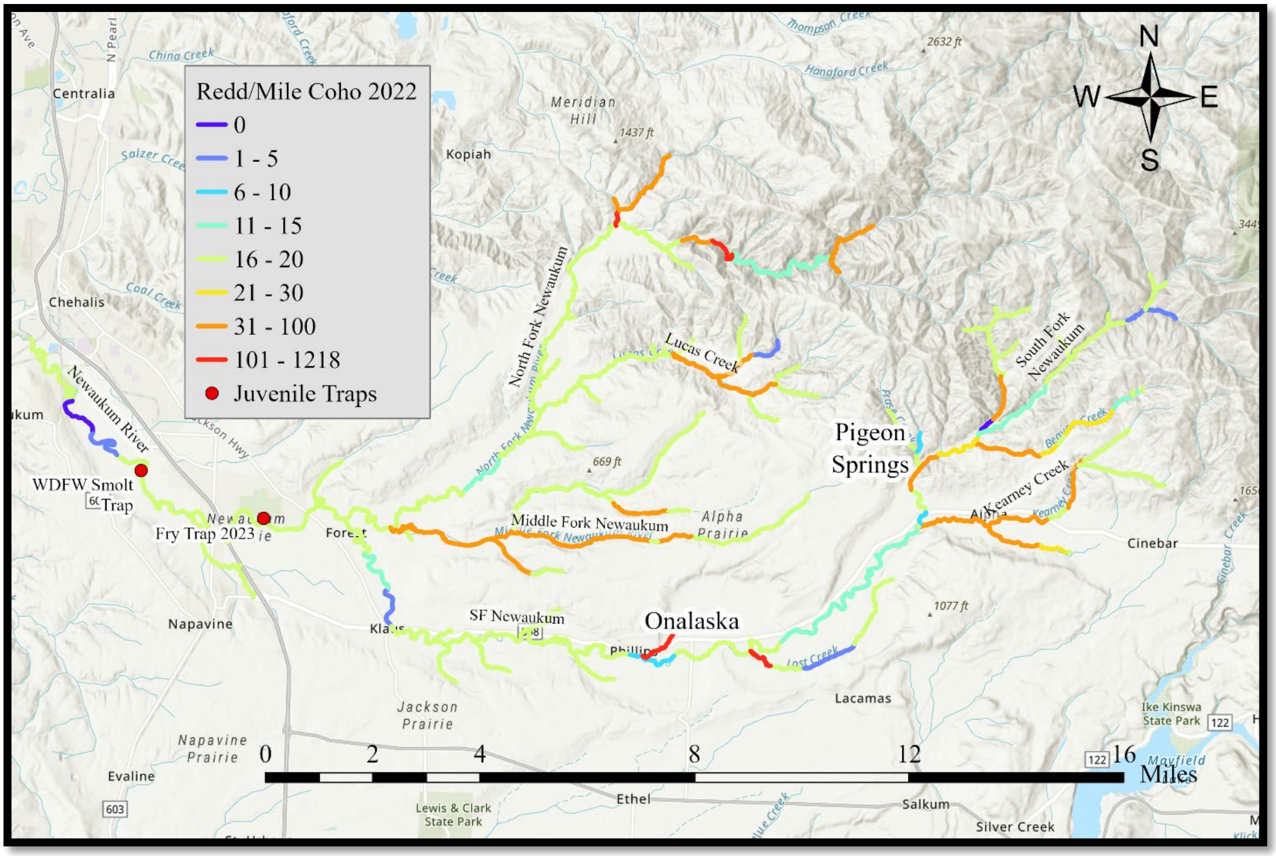

Figure 13. *Distribution of 2022 Coho Salmon, shown as redds mile^{-1}, for the Newaukum River basin. The areas expanded for using the GRTS method were given the redd mile^{-1} estimate generated for those areas.*

Life History Diversity

Throughout the basin, 72 adipose clipped (AD) and 87 unmarked (UM) Coho carcasses were recovered in the 2022-2023 season in the basin outside of Gheer Creek. In Gheer Creek, 52 AD and 6 UM carcasses were recovered. From the recovered unmarked carcasses, 51% were male with an average fork length of 70.3 cm ± 8.3 and 49% female with an average fork length of 65.4 cm ± 3.6. Of the UM Coho carcasses, 42 scale ages were determined, and of those, three were assigned Age-4 whereas the rest were assigned Age-3 which is the typical age Coho return. The scales were also used to determine that five of the 42 UM samples were likely hatchery fish.

Steelhead Trout

Abundance

Total steelhead trout for 2023 run year was estimated at 1,100 adult spawners. The hatchery portion of steelhead was determined by a cut-off date; any redd created on or before March 15th was considered HOR and any redd created after that date was considered NOR. This method generated an estimate of 185 HOR and 915 NOR steelhead trout (Table 7). However, unmarked, or NOR steelhead, were seen spawning prior to this date and adipose clipped, or HOR steelhead, were seen spawning after this date. The 2023 estimate is higher than the previous year's estimate but is similar to first two years of the study (Figure 14).

Table 6. *Newaukum River basin steelhead trout spawner abundance estimates from 2023 of natural origin (NOR) and hatchery origin (HOR) spawners. Estimates based on March 15th cut-off date to determine hatchery and natural origin. All steelhead trout spawned upstream of the smolt trap in 2023.*

2023 Steelhead Trout

	Adult Spawners	**Upstream of Smolt Trap**
Natural Origin	915	915
Hatchery Origin	185	185
Total	**1,100**	**1,100**

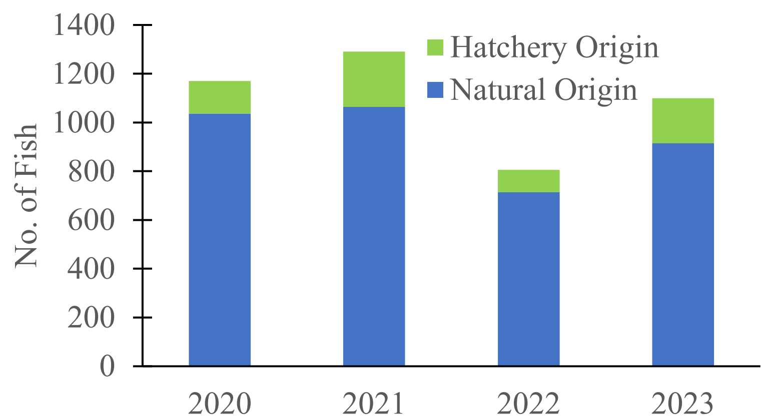

Figure 14. *Newaukum River basin steelhead trout project time series of spawner abundance estimates from 2020 to 2023 of natural origin (NOR) and hatchery origin (HOR) spawners.*

Distribution

Steelhead, like Coho, rarely utilize the lower Newaukum River basin for spawning habitat in 2023 run year (Figure 15). Instead, steelhead utilized the upper portions of both the North Fork and South Fork Newaukum River. The highest densities (46 redds mile^{-1}) occurred in the lower Pigeon Springs area just above Highway 508. High densities (35 redd mile^{-1}) also occurred in the South Fork Newaukum between Onalaska and Kearney Creek. In previous years, the highest densities occurred further up in the basin. The Middle Fork Newaukum, Lucas, and Beaver creeks had low activity in the 2023 steelhead spawning season.

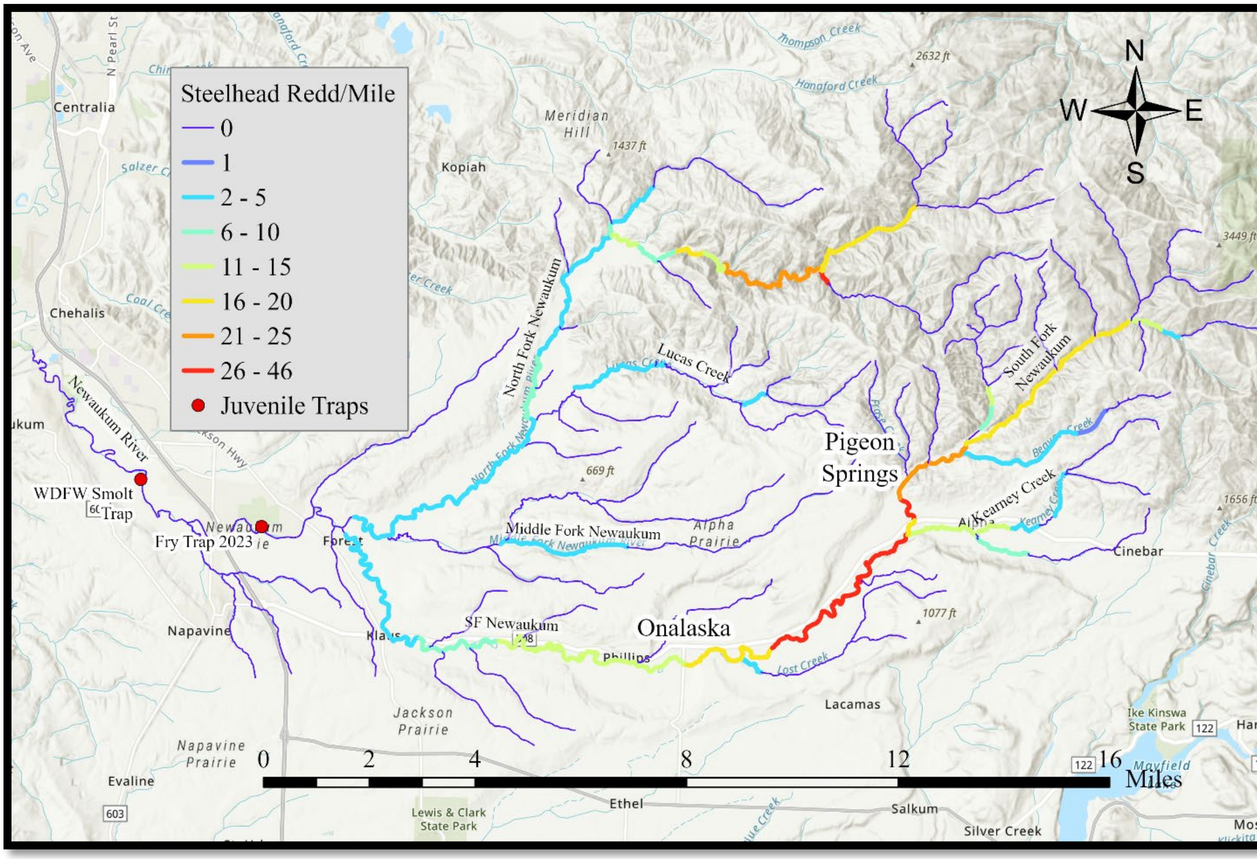

Figure 15. *Distribution of 2023 steelhead, shown as redds mile^{-1}, for the Newaukum River basin.*

Life History Diversity

The biological sample size of steelhead in 2023 was small with only eighteen samples collected. Hook and line sampling accounted for six of those samples, the rest were carcasses. Of those samples, twelve had their adipose fins present (UM) and three had their adipose fins removed (AD). However, it was determined that one of the unmarked samples was a hatchery raised steelhead based on scale analysis. All hatchery steelhead were collected in the South Fork Newaukum River. One was collected just downstream of Gheer Creek, where hatchery steelhead are released annually, and four were collected upstream from there, with one being collected close to the upper extent of steelhead spawning activity.

Of the UM, or NOR samples, there was an even split among Age 2.1+, 2.2+, and 3.1+ steelhead for a total age of four or five at spawning, with this being their first spawning event (Figure 16, Appendix E). Interestingly, in 2023 run year, we recovered a sample that showed a steelhead on its fourth spawning event. Due to regenerated scales in freshwater, the total age could not be determined, but it was at least six-years-old and likely older in total age. Of the fish sampled where sex could be determined, only one, the repeat spawner, was determined to be female.

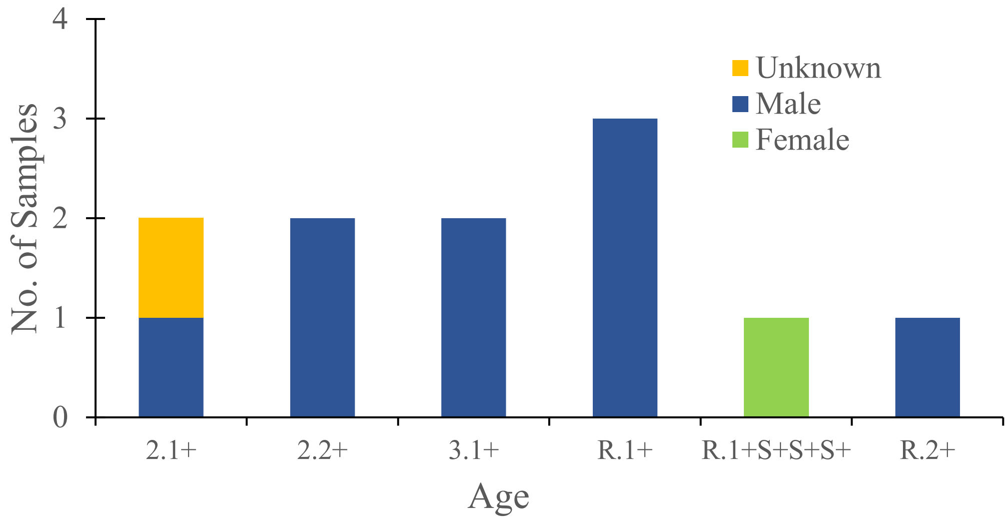

Figure 16. *Age from scale analysis of 2023 run of steelhead trout with freshwater age on the left of the decimal and saltwater age to the right of decimal. 'R' indicates regenerated, so freshwater age is unknown, and 'S' indicates multiple spawns. Samples include both live hook and line and carcass sampling. Additional explanation of steelhead scale age notation in Appendix E.*

Discussion

The Newaukum basin supports populations of spring and fall Chinook, Coho, and steelhead trout. The rigorous adult and juvenile monitoring programs for salmon and steelhead in the Newaukum River basin are crucial for understanding fish response to restoration actions. This comprehensive monitoring provides information that guides the setting of restoration priorities and evaluation of outcomes. By facilitating a systematic science-policy feedback loop, these monitoring activities ensure that restoration strategies are continuously refined and adapted based on empirical evidence, thereby enhancing their effectiveness and sustainability.

The spatial distribution in the Newaukum River basin of spawning spring and fall Chinook salmon in 2022 was notably different in relation to the smolt and fry trapping locations. Spring Chinook, totaling 291 adults, predominantly spawned upstream, with about 87% above the smolt trap and 73% above the fry trap. In contrast, the 383 fall Chinook displayed a shift, with only 58% spawning above the WDFW smolt trap and 41% above the fry trap operated by West Fork Environmental. This distribution shift was likely influenced by low water flows during the spawning period which limited upstream movement. This concentration of spawning in the lower basin areas can increase the risk of redd damage, especially in the mainstem, due to scouring during high flows later in the winter (Johnson et al. 2007, Pess et al. 2002). Spawning lower in the basin also results in concentrated spawning in a reduced area which can lead to competition for adult spawning space (i.e., redd superimposition), as well as juvenile competition for resources upon emergence, reducing overall survival.

Fish Management uses abundance estimates derived from redd counts, with a cutoff date of October 15th, to distinguish spring and fall Chinook redds. However, this method is complicated by the presence of hybrid Chinook, which show genetic markers for both spring and fall runs, with intermediate spawn timing compared to pure spring and fall Chinook, and interannual variation in spawning location. Of the 76 carcasses recovered, only 45 were able to be assigned a run type using the Thompson et al. (2019) markers with 20% as spring run type, 56% as fall run type, and 24% as heterozygotes. Applying these proportions to the total estimated population resulted in estimates of 146 spring Chinook, 359 fall Chinook, and 169 heterozygotes. However, these numbers may not reflect proportions in abundance accurately due to potential variations in carcass recovery rates throughout the season. Out-migrating juvenile genetic testing do show similar proportions (Olson et al. 2023). Also, a co-study (in review) using tGMR in the basin, generated an estimate of spawner abundance based on the recapture of the 2022 adult genetics in 2023 outmigrating juveniles. This analysis produced an estimate of 658 total adult Chinook in the Newaukum Basin, with 132 spring Chinook, 366 fall Chinook, and 161 heterozygotes when using the adult genotype proportions (Table 8). The proportion of juveniles showed a similar spring Chinook component but there appeared to be a greater proportion of heterozygotes and a lower proportion of fall Chinook when looking at the outmigrating juvenile offspring. This estimate also generated a 95% confidence interval of 520-797 adult Chinook for the 2022 escapement. Additional comparison of genetic run types from spawning adults and outmigrating juvenile could be helpful in looking at survival choke points. One hypothesis could be that the increased crowding and spawning by later entering Chinook lower in the basin, led to reduced survival due to superimposition or scouring.

Table 7. *Abundance estimates for 2022 Chinook based on a co-study (in review) using trans-generational mark recapture (tGMR). Proportion of run was determined from both the genetics of the initial adult carcasses as well as the genetic proportions of outmigrating juveniles.*

	tGMR (95% CI)	
	Adult Proportions	**Juvenile Proportions**
Spring Chinook	132 (104-159)	134 (106-163)
Fall Chinook	366 (289-443)	309 (244-375)
Heterozygote Chinook	161 (127-195)	215 (170-260)
	658 (520-797)	

Carcass recovery data from the week prior to October 15th, which included 13 Chinook, suggest that the use of the October 15th date cutoff may lead to overestimations of spring Chinook and possibly underestimations of fall Chinook. Of the 13 carcasses recovered, genetic testing revealed three spring Chinook, five heterozygotes, and five fall Chinook had all partially or fully spawned prior to October 15th. This indicates that the classification of redds based on the October 15th cutoff may not accurately reflect true spawn timing, impacting the validity of abundance estimates using current methods. We attempted to mitigate this by reclassifying redds before the 15th as fall Chinook redds if live spawners present on redds had fall characteristics (see Appendix C). In the week prior to the cutoff date in 2022, 40% of the redds in the lower main stem Newaukum River were classified as fall Chinook redds. This helps reduce inaccuracies in using a date cutoff, however, it does not address the hybrid, or heterozygote, run types. A remaining data gap is related to how run-timing genotype affects phenotypic expression. It is assumed that hybrids spawn later than spring Chinook but earlier than fall Chinook, however this assumption has not been tested in the Newaukum. With respect to alternative spawner escapement methodologies, further exploration is needed to determine if alternative methods used in the Chehalis River Basin can produce improved accuracy in escapement estimates for different run-timing of Chinook. However, it is clear that with increased extreme weather events and flow regimes, the stringent date and location cutoffs will become less reliable. It is also important to note that with the increased focus and concern for spring Chinook, we do not neglect fall Chinook. Fall Chinook had the lowest abundance in the Newaukum in 2022 we have seen in over 20 years. This low abundance is extremely concerning, and any efforts directed towards improving spring Chinook stock should be extended to fall Chinook.

Coho continue to utilize a greater proportion of small tributaries in the basin relative to other species and the GRTS method allowed us to account for more of these in the estimate than we have been able to in the past. In 2022, the Newaukum River basin observed a natural-origin (NOR) Coho abundance almost 20% higher than the 20-year average at 3,860 spawners. Hatchery-origin (HOR) Coho also returned at a higher-than-average rate with 4,430 spawners and exceeded NOR spawners for the first time since intensive monitoring began in 2019. This increase in HOR was 432% more than the previous year's (833 in 2021) hatchery return.

Due to the increased hatchery return the influence of pHOS in some subbasins experienced a large increase. The upper North Fork and Mitchell areas, previously with minimal hatchery presence at 1.7% pHOS, saw a substantial increase to 30% pHOS. The Middle Fork Newaukum and Lucas Creek also experienced notable increases. This shift in the abundance dynamic between NOR and HOR Coho in 2022 marks a critical point for consideration in the management and conservation strategies within the basin, as the proliferation of hatchery-origin fish could have implications for the genetic diversity and ecological interactions within the salmonid community.

Spatial distribution patterns for Coho in 2022 showed no major shifts from previous years, with high densities in the Middle Fork and tributaries in the Newaukum basin. Gheer Creek and Lost Creek had high densities, primarily composed of HOR spawners. The normal bimodal run pattern, with a separation between early and late runs, was not observed in the 2022 spawning season, possibly due to the high hatchery abundances. Age analysis indicated that most Coho were Age-3, typical for returning Coho, with a few Age-4 individuals. Interestingly, five of the 42 unmarked (UM) scale samples were identified as hatchery fish, raising concerns about the source of these unmarked hatchery Coho since the normal miss-clip, or poor clip, rate is less than 1%. This may indicate that the hatchery component of the run was greater than estimated.

Steelhead spawning commenced noticeably earlier in the 2023 run, beginning in January, a departure from previous years by approximately one month. The peak occurred in mid-March, closely following the state's cut-off date used for differentiating HOR from NOR steelhead, which could suggest adjustments in hatchery release strategies or ecological responses to environmental conditions. Abundance in 2023 run was 915 NOR adult spawners which is just slightly lower than the average of approximately 940 from the first three years of intensive monitoring. During the 2023 run, we were unable to supplement carcass recoveries with sufficient hook and line sampling to produce a HOR estimate based on biological data to supplement the March 15th cutoff date.

Steelhead have complex life histories with the potential for repeat spawning; these diverse life histories can improve resilience of a population (Schindler et al. 2010). On average, between 10 – 15% of coastal Chehalis Basin steelhead are repeat spawners each year. Of the 15 samples we collected from the 2023 run, only one was identified as a repeat spawner.

Interestingly, this one repeat spawner returned to spawn during the three previous years and was back for a fourth year. Only one year (2021) of the last four years of surveys have we observed >10% repeat spawners. Repeat spawning is important for population viability as older steelhead are generally larger and have increased fecundity compared to smaller and younger steelhead (Bowersox et al. 2019; Quinn et al. 2011). A comprehensive analysis of the variability in repeat spawners would be enhanced by a larger dataset and by comparison with other coastal steelhead populations to determine if repeat spawners are becoming less prevalent across western Washington.

Effective restoration in the Newaukum River Basin will significantly benefit salmon and steelhead populations by enhancing their spawning and rearing habitats, mitigating the impacts of low flows, and maintaining genetic diversity. Through targeted restoration efforts and adaptive management informed by rigorous monitoring, we can ensure the resilience and sustainability of these critical fish populations amidst changing environmental conditions.

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Appendices

Appendix A. Escapement estimates for available data with contribution of Newaukum populations to the Chehalis River basin. Total escapement does not include Humptulips.

a) Spring Chinook Salmon

Escapement Year	Newaukum River	Total Escapement	% of Total
2000	566	3135	18%
2001	1,218	2,860	43%
2002	815	2,598	31%
2003	396	1,904	21%
2004	1,041	5,034	21%
2005	595	2,130	28%
2006	850	2,481	34%
2007	293	652	45%
2008	298	996	30%
2009	303	1,123	27%
2010	760	3,495	22%
2011	743	2,563	29%
2012	283	878	32%
2013	1,021	2,459	42%
2014	315	1,583	20%
2015	465	1,824	25%
2016	277	926	30%
2017	525	1,405	38%
2018	125	495	25%
2019	175	983	18%
2020	700	2,828	25%
2021	545	2,578	21%
2022	291	1,350	22%

b) Fall Chinook Salmon

Year	Newaukum River	Total Escapement	% of Total
2000	684	7,892	9%
2001	571	7,902	7%
2002	893	9,691	9%
2003	2,287	16,111	14%
2004	1,697	26,320	6%
2005	1,608	13,367	12%
2006	951	12,545	8%
2007	924	10,750	9%
2008	1,222	12,079	10%
2009	580	6,857	8%
2010	538	11,158	5%
2011	836	16,292	5%
2012	901	9,778	9%
2013	811	10,158	8%
2014	592	8,590	7%
2015	612	13,226	5%
2016	1,007	7,117	14%
2017	862	9,594	9%
2018	1,399	14,801	9%
2019	858	11,129	8%
2020	1063	15,934	7%
2021	423	8,175*	4%
2022	383	9,337	4%

*Updated since 2021-2022 report

c) Coho Salmon

Estimates shown are total spawners, includes hatchery origin (HOR) and natural origin (NOR).

Year	Newaukum Basin	Total Escapement	% of Total
2000	4,186	32,679	13%
2001	4,459	61,916	7%
2002	6,346	87,776	7%
2003	7,162	75,309	10%
2004	2,813	45,482	6%
2005	1,893	30,857	6%
2006	2,161	15,922	14%
2007	2,097	22,698	9%
2008	2,654	31,643	8%
2009	5,545	65,517	8%
2010	7,444	87,959	8%
2011	4,977	58,093	9%
2012	5,442	63,523	9%
2013	4,466	52,133	9%
2014	7,916	92,402	9%
2015	1,661	19,386	9%
2016	3,821	31,730	12%
2017	2,876	22,691	13%
2018	5,186	45,649	11%
2019	1,988	26,969	7%
2020	2,770	20,675	13%
2021	5,594	58,059	10%
2022	8,290	52,828*	16%

*Preliminary

d) Steelhead Trout

Escapement of NOR based on March 15th cut-off date.

Year	Newaukum	Total Escapement	% of Total
2000	1,644	11,679	14%
2001	1,124	9,802	11%
2002	734	10,440	7%
2003	930	8,424	11%
2004	1,712	15,825	11%
2005	1,062	9,059	12%
2006	1,348	10,418	13%
2007	988	7,602	13%
2008	632	6,493	10%
2009	*	6,956	
2010	673	6,765	10%
2011	364	6,090	6%
2012	415	7,592	5%
2013	1,225	9,776	13%
2014	772	6,944	11%
2015	1,570	10,568	15%
2016	833	8,824	9%
2017	325	4,618	7%
2018	464	6,840	7%
2019	492	6,130	8%
2020	970	6,280	15%
2021	987	5,631	18%
2022	674	5,341	13%
2023	915	6,257	15%

* No separate Newaukum estimate reported

Appendix B. Description of spring-run Chinook vs. fall-run Chinook characteristics used to distinguish run-types during their overlapping spawning period around October 15th.

		Spring Chinook	Fall Chinook
Overlap			
	Fish[a]	Grey, olive, or black/dark in color;	Red, green, or purple in color;
		Dull and/or dusky appearance, not bright and shiny colors;	Bright, shiny colors, vivid
		Low energy level, lethargic, exhibiting an unwillingness to be spooked off of redds (for females) or into quick currents; [b]	High energy level, spooking easily and powering through riffles and low water areas, exhibiting a frantic behavior when spooked or scared
		Fungus present on fish and edges of snout, and fins showing wear;	No or minimal amounts of fungus and/or wear
		Have a soft caudal peduncle	Have a firm caudal peduncle
	Redds	Presence of a spring Chinook female;	Presence of a fall Chinook female;
		If no female presence: Before/on October 15th the redd was recorded as spring-run type unless other fish presence indicates fall Chinook After October 15th the condition of the redd determines run type If redd was built on/prior to Oct. 15th it was recorded as spring-run type If redd was built after Oct. 15th it was recorded as fall-run type	
Post-overlap		After Oct. 15th live fish and redds are fall-run type unless the observation is different from the rest of the observations in the survey	

[a]: For live fish – justify decision with 3 of the 4 characteristics; for carcasses – justify decision with 2 of the 3 characteristics

[b]: Energy level and behavior of fish on a redd was used to clarify run type on live fish and associated redds only

Appendix C. Dates by statistical week (week of year) for 2022 - 2023 survey season.

2022

JANUARY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
1	26	27	28				
2	2	3	4				
3	9	10	11	1			
4	16	17	18	1			
5	23	24	25	26	27	28	29
6	30	31	1	2	3	4	5

Calendar Month is in this cell. Calendar for this month is automatically updated in cells B4 through H10 and contains dates from previous, current, and next month

FEBRUARY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
6	30	31	1	2	3	4	5
7	6	7	8	9	10	11	12
8	13	14	15	16	17	18	19
9	20	21	22	23	24	25	26
10	27	28	1	2	3	4	5
11	6	7	8	9	10	11	12

MARCH

Week #	Su	Mo	Tu	We	Th	Fr	Sa
10	27	28	1	2	3	4	5
11	6	7	8	9	10	11	12
12	13	14	15	16	17	18	19
13	20	21	22	23	24	25	26
14	27	28	29	30	31	1	2
15	3	4	5	6	7	8	9

APRIL

Week #	Su	Mo	Tu	We	Th	Fr	Sa
14	27	28	29	30	31	1	2
15	3	4	5	6	7	8	9
16	10	11	12	13	14	15	16
17	17	18	19	20	21	22	23
18	24	25	26	27	28	29	30
19	1	2	3	4	5	6	7

MAY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
19	1	2	3	4	5	6	7
20	8	9	10	11	12	13	14
21	15	16	17	18	19	20	21
22	22	23	24	25	26	27	28
23	29	30	31	1	2	3	4
24	5	6	7	8	9	10	11

JUNE

Week #	Su	Mo	Tu	We	Th	Fr	Sa
23	29	30	31	1	2	3	4
24	5	6	7	8	9	10	11
25	12	13	14	15	16	17	18
26	19	20	21	22	23	24	25
27	26	27	28	29	30	1	2
28	3	4	5	6	7	8	9

JULY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
27	26	27	28	29	30	1	2
28	3	4	5	6	7	8	9
29	10	11	12	13	14	15	16
30	17	18	19	20	21	22	23
31	24	25	26	27	28	29	30
32	31	1	2	3	4	5	6

AUGUST

Week #	Su	Mo	Tu	We	Th	Fr	Sa
32	31	1	2	3	4	5	6
33	7	8	9	10	11	12	13
34	14	15	16	17	18	19	20
35	21	22	23	24	25	26	27
36	28	29	30	31	1	2	3
37	4	5	6	7	8	9	10

SEPTEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
36	28	29	30	31	1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	1
41	2	3	4	5	6	7	8

OCTOBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
40	25	26	27	28	29	30	1
41	2	3	4	5	6	7	8
42	9	10	11	12	13	14	15
43	16	17	18	19	20	21	22
44	23	24	25	26	27	28	29
45	30	31	1	2	3	4	5

NOVEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
45	30	31	1	2	3	4	5
46	6	7	8	9	10	11	12
47	13	14	15	16	17	18	19
48	20	21	22	23	24	25	26
49	27	28	29	30	1	2	3
50	4	5	6	7	8	9	10

DECEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
49	27	28	29	30	1	2	3
50	4	5	6	7	8	9	10
51	11	12	13	14	15	16	17
52	18	19	20	21	22	23	24
53	25	26	27	28	29	30	31
1	1	2	3	4	5	6	7

2023

JANUARY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
1	1	2	3	4	5	6	7
2	8	9	10	11	12	13	14
3	15	16	17	18	19	20	21
4	22	23	24	25	26	27	28
5	29	30	31	1	2	3	4
6	5	6	7	8	9	10	11

FEBRUARY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
5	29	30	31	1	2	3	4
6	5	6	7	8	9	10	11
7	12	13	14	15	16	17	18
8	19	20	21	22	23	24	25
9	26	27	28	1	2	3	4
10	5	6	7	8	9	10	11

MARCH

Week #	Su	Mo	Tu	We	Th	Fr	Sa
9	26	27	28	1	2	3	4
10	5	6	7	8	9	10	11
11	12	13	14	15	16	17	18
12	19	20	21	22	23	24	25
13	26	27	28	29	30	31	1
14	2	3	4	5	6	7	8

APRIL

Week #	Su	Mo	Tu	We	Th	Fr	Sa
13	26	27	28	29	30	31	1
14	2	3	4	5	6	7	8
15	9	10	11	12	13	14	15
16	16	17	18	19	20	21	22
17	23	24	25	26	27	28	29
18	30	1	2	3	4	5	6

MAY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
18	30	1	2	3	4	5	6
19	7	8	9	10	11	12	13
20	14	15	16	17	18	19	20
21	21	22	23	24	25	26	27
22	28	29	30	31	1	2	3
23	4	5	6	7	8	9	10

JUNE

Week #	Su	Mo	Tu	We	Th	Fr	Sa
22	28	29	30	31	1	2	3
23	4	5	6	7	8	9	10
24	11	12	13	14	15	16	17
25	18	19	20	21	22	23	24
26	25	26	27	28	29	30	1
27	2	3	4	5	6	7	8

JULY

Week #	Su	Mo	Tu	We	Th	Fr	Sa
26	25	26	27	28	29	30	1
27	2	3	4	5	6	7	8
28	9	10	11	12	13	14	15
29	16	17	18	19	20	21	22
30	23	24	25	26	27	28	29
31	30	31	1	2	3	4	5

AUGUST

Week #	Su	Mo	Tu	We	Th	Fr	Sa
31	30	31	1	2	3	4	5
32	6	7	8	9	10	11	12
33	13	14	15	16	17	18	19
34	20	21	22	23	24	25	26
35	27	28	29	30	31	1	2
36	3	4	5	6	7	8	9

SEPTEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
35	27	28	29	30	31	1	2
36	3	4	5	6	7	8	9
37	10	11	12	13	14	15	16
38	17	18	19	20	21	22	23
39	24	25	26	27	28	29	30
40	1	2	3	4	5	6	7

OCTOBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
40	1	2	3	4	5	6	7
41	8	9	10	11	12	13	14
42	15	16	17	18	19	20	21
43	22	23	24	25	26	27	28
44	29	30	31	1	2	3	4
45	5	6	7	8	9	10	11

NOVEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
44	29	30	31	1	2	3	4
45	5	6	7	8	9	10	11
46	12	13	14	15	16	17	18
47	19	20	21	22	23	24	25
48	26	27	28	29	30	1	2
49	3	4	5	6	7	8	9

DECEMBER

Week #	Su	Mo	Tu	We	Th	Fr	Sa
48	26	27	28	29	30	1	2
49	3	4	5	6	7	8	9
50	10	11	12	13	14	15	16
51	17	18	19	20	21	22	23
52	24	25	26	27	28	29	30
1	31	1	2	3	4	5	6

Appendix D. Coho Estimate Additional Information. a) Methods used to generate an estimate for Coho Salmon in the Newaukum River basin. b) Hatchery origin (HOR) and natural origin (NOR) estimate was based on carcass recoveries.

a) Estimate by method

	Adult Spawners	**Lower (95% CI)**	**Upper (95% CI)**
GRTS	3458	2011	4904
Census	2884		
Gheer Creek	1948		
Total	**8290**	**6843**	**9736**

b) HOR and NOR breakout	Carcasses			Total		Adult Spawners	
	AD	**UM**	**pHOS**	**Redds**	**Adults**	**Hatchery**	**Natural Origin**
Core SF Above 508 + Tribs	1	10	9%	245	490	45	445
Core SF Below 508 + Tribs	36	35	51%	376	752	381	371
Core MF, Lucas Tribs	24	20	55%	470	940	513	427
Core NF Upper + Tribs	2	10	17%	351	702	117	585
GRTS Only	8	9	47%	1728.8	3457.6	1627	1830
Gheer Creek	52	6	90%	974	1948	1747	202
Total						**4,430**	**3,860**

c) GRTS Analysis Output

Method	**StrmLength**	**Estimate**	**StdError**	**MarginofError**	**LCB95Pct**	**UCB95Pct**
GRTS	477242.7	1728.8	369	723.3	1005.5	2452.1
Census	181425.4	1442	0	0	0	0
Total	658668.1	3170.8	369	723.3	2447.5	3894.1

Appendix E. Winter steelhead age notation key provided by Andrew Claiborne, WDFW scale lab.

Age (European)	Freshwater Winters	Saltwater Winters	Total Age at Spawning	Spawning Count	Notation Notes
1.1+	1	1	3	0	
1.1+S+	1	1	4	1	
1.1+S+S+	1	1	5	2	
1.2+	1	2	4	0	
2.+	2	0	3	0	
2.+S+	2	0	4	1	
2.1+	2	1	4	0	
2.1+S+	2	1	5	1	
2.1+S+S+	2	1	6	2	
2.2+	2	2	5	0	
2.2+S+	2	2	6	1	
2.3+	2	3	6	0	
3.+	3	0	4	0	
3.1+	3	1	5	0	
3.1+S+	3	1	6	1	
3.1+S+S+	3	1	7	2	
3.2+	3	2	6	0	
3.2+S+	3	2	7	1	
3.3+	3	3	7	0	
4.+	4	0	5	0	
4.1+	4	1	6	0	
R					Regenerated Scale
R.1+		1		0	Regenerated in FW
R.1+S+		1		1	Regenerated in FW
R.1+S+S+		1		2	Regenerated in FW
R.2+		2		0	Regenerated in FW
R.2+S+		2		1	Regenerated in FW
R.3+		3		0	Regenerated in FW
W1.+	1	0	2	0	
W1.1+	1	1	3	0	
W1.1+S+	1	1	4	1	
W1.2+	1	2	4	0	
W1.2+S+	1	2	5	1	
W1.3+	1	3	5	0	

In the European age notation, the number of freshwater annuli (winters) precedes the decimal.

In the European age notation, the number of saltwater annuli (winters) follows the decimal.

"W" before freshwater age-1 indicates wild pattern.

Fish designated freshwater age 1 with no "W" are hatchery fish

"+" denotes winter from summer run.

To determine brood year for Winter SH using European Notation, subtract the total age at spawning from the spawn year.

Total age at spawning = add numbers left and right of decimal, any spawn checks (a single "S"= 1 year), and one additional year.

Note that total age at spawning cannot be determined when scale is regenerated "R".