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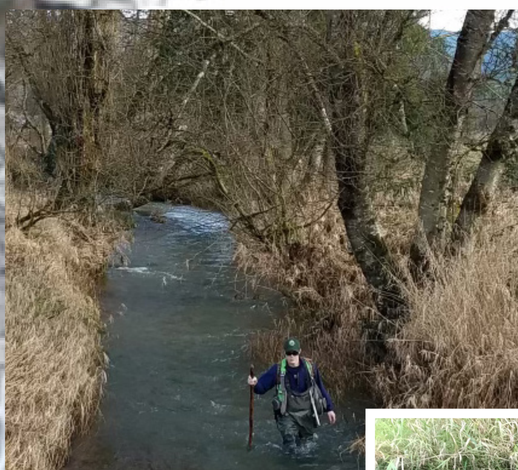
FEBRUARY 2022

Newaukum Adult Salmon and Steelhead Spawner Abundance, 2020-2021



by Lea Ronne,
Nick VanBuskirk,
Marisa Litz,
Mike Scharpf, and
Todd Seamons

Washington Department of
FISH AND WILDLIFE
Fish Program

FPT 22-01

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Lea Ronne[1], Nick VanBuskirk[1], Marisa Litz[2], Mike Scharpf[1] and Todd Seamons[2]

Author information:

[1]Washington Department of Fish and Wildlife Region 6 Fish Management, 48 Devonshire Road, Montesano, WA 98563

[2]Washington Department of Fish and Wildlife, Fish Science Division, 1111 Washington St SE, Olympia WA 98501

Acknowledgements

We would like to thank our surveyors for collecting data and samples during the 2020/2021 field season: Keith Brady, Justin Miller-Nelson, Brady Green, and Andrew Potter Maul. Thanks to Curt Holt for his extensive historical knowledge of the basin. Thanks to Kim Figlar-Barnes who helped with organization of data and biological samples. Scale ages were provided by WDFW Fish Ageing and Otolith Laboratory staff. We would also like to thank the small private landowners and Weyerhaeuser Corporation for allowing access to survey on their property. This work was funded by the Washington State Legislature and the Office of the Chehalis Basin.

Recommended citation: Ronne L., N. VanBuskirk, M. Litz., M. Scharpf. And T. Seamons. 2022. Newaukum Adult Salmon and Steelhead Spawner Abundance, 2020-2021, Washington Department of Fish and Wildlife, Olympia, Washington. FPT 22-01

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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 2020-2021 survey season of intensive adult spawner monitoring in the Newaukum basin for spring and fall Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and Steelhead Trout (*O. mykiss*).

A census redd (salmon nest) survey was conducted for all salmonids for the 2020-2021 season in the Newaukum basin (total escapement for Chinook and Coho Salmon in the 2020 run year and steelhead escapement in 2021 run year). However, due to the broad distribution of Coho Salmon in small creeks and tributaries with many private landowners, we were unable to completely survey all spawning habitat. The majority of spawning habitat was surveyed, and either a supplemental survey or a redd mile^{-1} estimate was used to expand redds for un-surveyed spawning habitat to generate a total estimate. The unsampled tributaries included in the total estimate represent areas that were historically expanded for stock assessment estimates (C. Holt, WDFW, personal communication). Major findings for the 2020-2021 season were:

- Spring Chinook adult abundance in 2020 was 4 times higher than 2019 at 700 adult spawners
- Fall Chinook abundance also increased from the previous year, although only by about 20% compared to 2019 levels at 1,063 adult spawners.
- Spring and fall Chinook spawning distribution overlapped spatially and temporally.
- Genetic analysis of run timing markers of opportunistically collected salmon carcasses showed hybridization between fall and spring run types; 75% of these heterozygotes were recovered in the main stem.
- Spring Chinook spawning occurred throughout the main stem Newaukum River, suggesting some fish may move into the lower Newaukum from the Chehalis River just before spawning. Additional effort to track spring Chinook holding patterns is needed to confirm this hypothesis.
- Fall Chinook spawned throughout the North and South Fork Newaukum River similar to 2019, but their distribution reached further upstream, most notably on the North Fork Newaukum and into some smaller tributaries like Mitchell and Lucas creeks.
- Coho Salmon increased in abundance by ~40% from 2019 and was the most abundant salmonid species in the Newaukum basin with 2,770 spawners.
- Spawn timing of Coho Salmon in the Middle Fork occurred three weeks earlier than in the North and South Fork Newaukum in 2020. Middle Fork, Kearney Creek, and Lost Creek had some of the highest spawning densities (>50 redd mile^{-1}) with little spawning in the main stem.
- Steelhead increased by ~100 fish in 2021 compared to 2020, however the majority appeared to be hatchery fish. Steelhead were mostly distributed in the upper North and South forks of the Newaukum River with few spawning in the main stem and Middle Fork. No redds were observed downstream of the smolt trap at river mile 5.8 on of the main stem.
- The number of steelhead repeat spawners increased by 17% in 2021 compared to 2020 with zero in 2019. A similar trend of increasing repeat spawners has been observed across coastal steelhead populations in western Washington.

On average (run years 2000 to 2020), the Newaukum River contributed between 18% and 45% of the Chehalis River spring Chinook population, yet both Newaukum River and Chehalis River basin populations have declined since 2000. In 2020, the Newaukum contributed 25% to the overall spring Chinook total spawner abundance, yet this was lower than the average (29%) for the time series indicating that Newaukum River spring Chinook contribution is still below the long-term average. Through long term monitoring of the Newaukum River, our program will generate a time series of species distribution, abundance, life history diversity, and other population-level metrics (e.g., productivity) that will be valuable as restoration projects are implemented throughout the upper Chehalis Basin.

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 and juvenile production occurring at the watershed scale (West et al. 2020; Olson et al. 2021) was determined to be the best way to evaluate salmon and steelhead response to changes in riverine habitat as a result of 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% (29% average from 2000-2019) of 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 study focuses on Spring and fall Chinook Salmon (*O. tshawytscha*), hereafter referred to as Chinook, Coho Salmon (*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 a value known as escapement (i.e., the number of salmon not caught by commercial or recreational fisheries that return to their natal habitat, Johnson et al. 2007). For this report, surveys were conducted from September 2020 to June 2021 throughout the known distribution of each species, with additional effort to document the upper limits of each species' spawning distribution. These surveys expanded upon the spatial coverage of long-term index reaches surveyed by the Washington Department of Fish and Wildlife (WDFW) for stock assessment purposes since at least 2000 (Appendix B).

Objectives

The overall goal of this study was to describe the abundance, spawn timing, spatial distribution, and life history diversity of adult spring and fall Chinook, Coho Salmon, and steelhead in the Newaukum River sub-basin during return years 2020/2021, and to determine the abundance of adult spawners above the juvenile smolt trap located at river mile 5.8 (Figure 1). In order to accomplish this goal, our objectives were to:

- Conduct weekly surveys by foot or boat (as conditions allowed) and collect information on redds, live fish, and carcasses;
- Conduct supplemental surveys during the peak of spawning to document activity on any potential spawning habitat not surveyed on a weekly basis;
- Increase steelhead biological sample size from carcass recovery efforts using catch-and-release hook and line sampling;
- Calculate the abundance of each species above and below the smolt trap; and
- Summarize results related to timing, spatial distribution, and life history diversity of spawners.

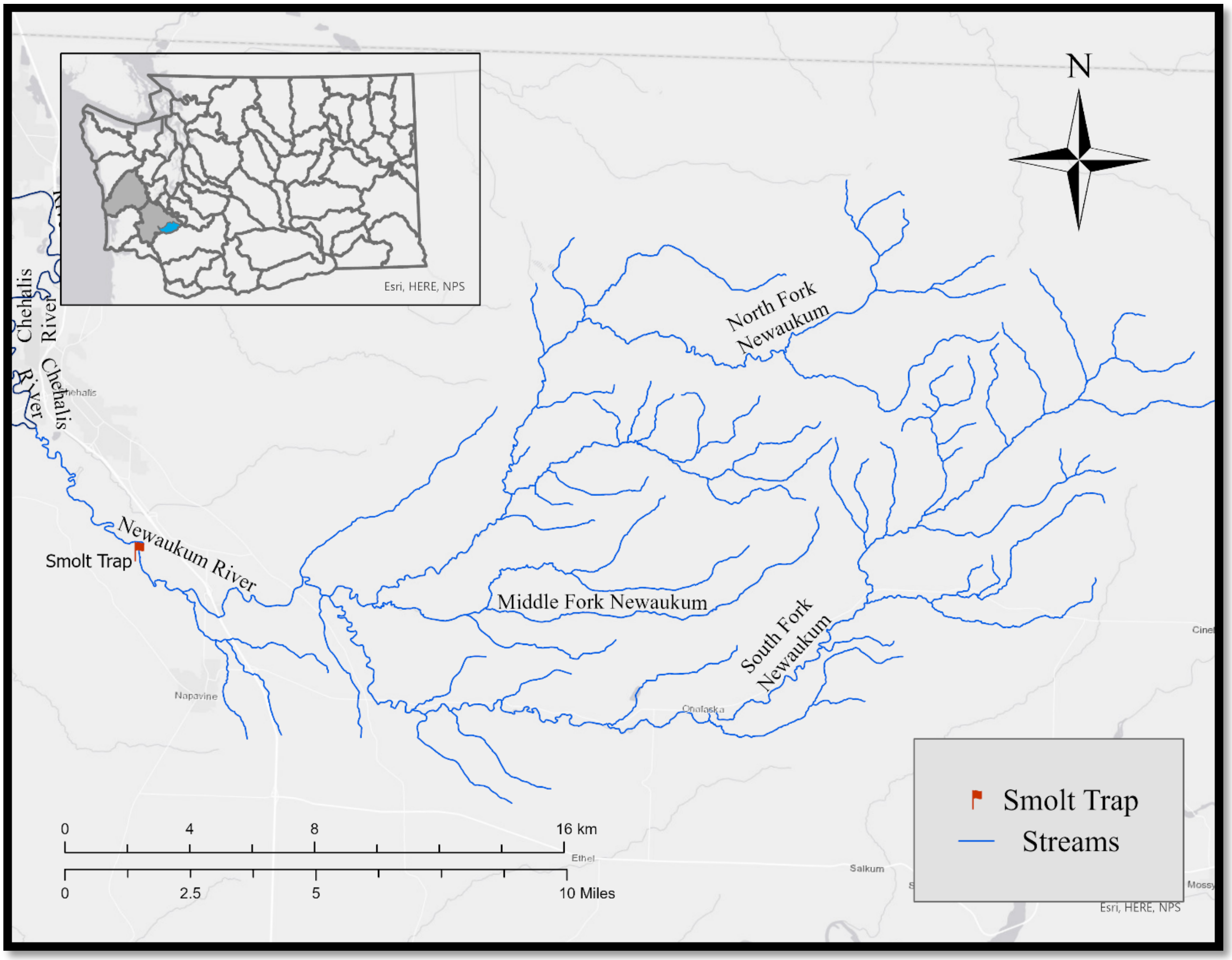

Figure 1. Overview map of the Newaukum River sub-basin of the greater Chehalis River basin, showing the juvenile smolt trap site.

Methods

Study 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. 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 two primary types of surveys used for this project: index and supplemental. Index surveys were designed to cover all or most of the available anadromous spawning areas and occurred approximately every seven days. These surveys were conducted throughout the spawn timing for all salmon and steelhead in the project area. Supplemental surveys occurred when spawning activity peaked for each species and covered as much potential spawning habitat as possible in areas that were not surveyed on a weekly basis. The ratio of redds visible in an index during peak 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.

Data Collection

Spawning ground surveys were conducted from September 2020 through June 2021, covering the spawn timing for each species. 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 identified to species, flagged, numbered, and georeferenced. Since spatial and temporal overlap in spawning activity occurs between fall Chinook and Coho Salmon, and between Coho Salmon 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 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 run type (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 C). 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.

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 each Chinook carcass and six or more scales from each steelhead for ageing. Fin clips were taken from both field-determined spring and fall Chinook carcasses for genetic run timing analysis. In addition, otoliths were taken for a separate study on spring Chinook otolith microchemistry, although results from that study were not available at the time of writing. Catch-and release via hook and line sampling of live steelhead was used to supplement biological samples from carcasses.

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 (redd mile^{-1}) expansion for unsurveyed habitat where spawning may have occurred using a species-specific expansion factor. 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 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 $\geq$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.

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 Salmon, 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 an assumed a 1:1 ratio of male to female steelhead. The redd based estimation methodology is based on multiple assumptions, including:

> **Assumption 1**: redds are correctly identified to species;
> **Assumption 2:** survey reaches represent spatial and temporal distribution of redds;
> **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 15th) were assumed to be of hatchery origin and late steelhead redds (after March 15th) were assumed to be of wild 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. However, winter steelhead hatchery production in the Chehalis River basin gets sourced from integrated broodstock programs that use natural origin (NOR) fish with spawn timing that more closely aligns with natural origin stocks. Therefore, we also collected information from live steelhead in the basin to generate a separate hatchery estimate based on visual mark status.

Recovered carcasses of adult Chinook, Coho Salmon, 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. Life history diversity was assessed based on age structure (years in freshwater and the ocean) and summarized for the sampled population. Age data were not collected from Coho Salmon in 2020, as all Coho Salmon were 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.

We covered the majority of spawning habitat for Coho Salmon by either index or supplemental surveys. A few areas that had previously been included in the stock assessments were unable to be accessed. For those areas, we expanded the redd count using the nearest applicable redds mile^{-1} density or used an average density value obtained from multiple similar streams.

Genetic Analysis

Tissue samples from opportunistically sampled spring and fall Chinook Salmon carcasses 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 salmon-specific single nucleotide polymorphisms (SNPs) were genotyped using a cost-effective method based on a custom amplicon sequencing called Genotyping in Thousands (GTseq) (Campbell et al. 2015). For each individual, pools were sequenced, de-multiplexed, and genotyped by generating a ratio of allele counts. The process had four segments: extraction, library preparation, sequencing, and genotyping. SNP markers used to infer adult run timing phenotype were those of Thompson et al. (2019). These markers were included in the GTseq SNP panel with a sex ID marker and 298 additional loci. To call run-type, the genotyping results from both SNP (homozygous spring-run, heterozygous, or homozygous fall-run) were required to agree.

Results

Abundance

During the 2020-2021 survey season, the estimated abundance of spring Chinook was 700 adults, fall Chinook was 1,063 adults, Coho Salmon was 2,770 adults, and steelhead was 1,214 adults (Table 1). For the 2020 run year, there was no evidence of hatchery origin (HOR) spring or fall Chinook found in the Newaukum River basin. By contrast, both 2020 Coho Salmon and 2021 steelhead had HOR spawners present, contributing 8% and 10% HOR rate, respectively. For steelhead, using the hatchery cutoff date of March 15th, which is standard throughout much of western Washington, HOR was estimated at 19% instead of 10% HOR determined by visual observations of carcasses and live counts. For Coho Salmon in Gheer Creek, a location where hatchery juveniles are released annually, HOR rate was calculated separately from the rest of the basin due to the high density (208 fish $mile^{-1}$) and percentage of HOR Coho Salmon (100%) on the spawning grounds. In all, there were 166 adult Coho Salmon estimated for 0.8 miles of Gheer Creek, and all were of hatchery origin.

Table 1. Abundance estimates for 2020 returns of spring Chinook Salmon, fall Chinook Salmon, Coho Salmon, and 2021 returns of steelhead trout above and below the smolt trap located on the Newaukum River. Two estimates were completed for steelhead trout, one using observational criteria based on biological data collected and the other using a standard March 15th hatchery cutoff date.

	HOR	NOR	**Total**	Below Smolt Trap	Above Smolt Trap
Spring Chinook Salmon	0	700	**700**	47	653
Fall Chinook Salmon	0	1,063	**1,063**	43	1,020
Coho Salmon	222	2,548	**2,770**	2	2,768
Steelhead*	150	1,064	**1,214**	0	1,214
Steelhead**	227	987	**1,214**	0	1,214

* HOR/NOR estimate based on biological data collected

** HOR/NOR estimate based on March 15th cutoff date historically used by WDFW

Run Timing

The first spring Chinook redds were observed in early September 2020, equivalent to statistical week (week of the year, SW) 37 (Figure 2, Appendix D). Peak spawning occurred in the beginning of October (SW 41). The first fall Chinook redd was observed in SW 41 during the peak spawn timing of spring Chinook. Fall Chinook spawning peaked mid-October (SW 42) but fall Chinook continued to spawn for four weeks past the peak week to mid-November (SW 46). The first Coho Salmon redds were observed during the peak of fall Chinook spawning at the end of October (SW 44). Coho Salmon had bimodal spawning peaks; the first occurred at the beginning of December (SW 50) and the second five weeks later at the end of December (SW 3). Middle Fork Newaukum Coho Salmon timing was three weeks earlier for the first spawning peak and did not show a second peak (Figure 3). During the second peak, spawning occurred primarily in the upper portions of South Fork Newaukum and its tributaries. Spawn timing for steelhead began at the beginning of February 2021 (SW 6) and peaked mid-April (SW 16). Steelhead continued to spawn for an additional eight weeks into June 2021 (SW 24).

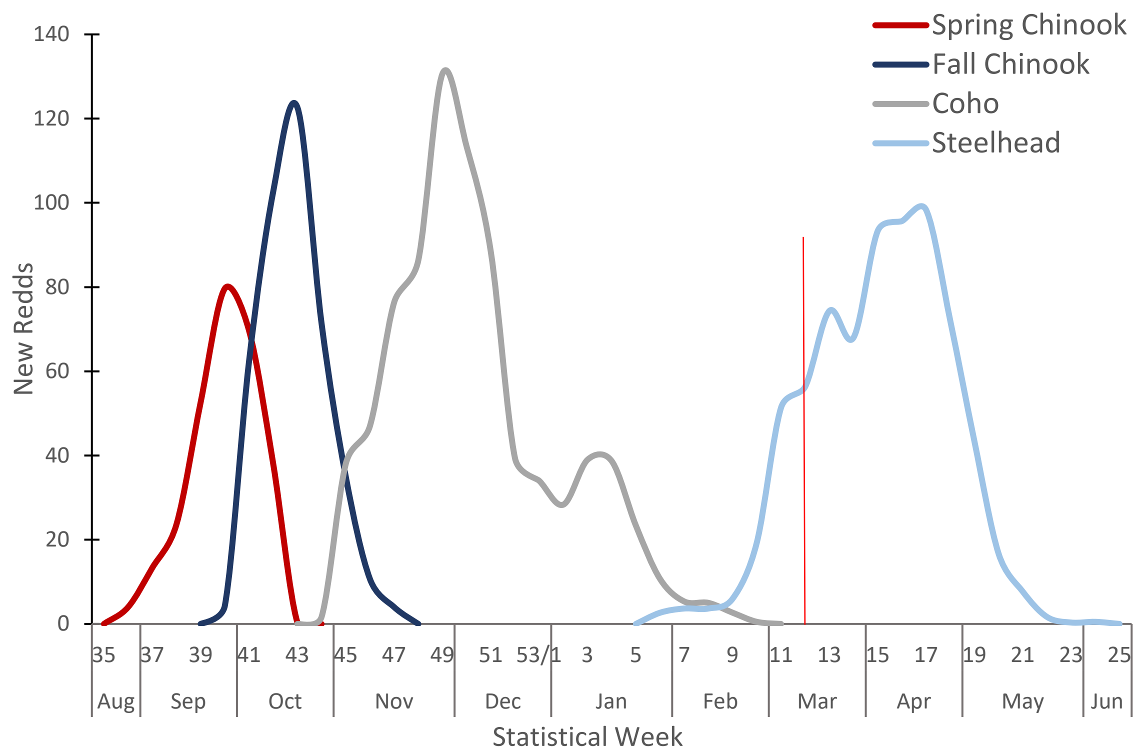

Figure 2. Run timing for 2020 Pacific Salmon and 2021 steelhead trout in the Newaukum River basin based on a three-week rolling average of new redds observed. Red line shows the standard March 15th cutoff date that the Washington Department of Fish and Wildlife uses for distinguishing hatchery origin from natural origin steelhead trout.

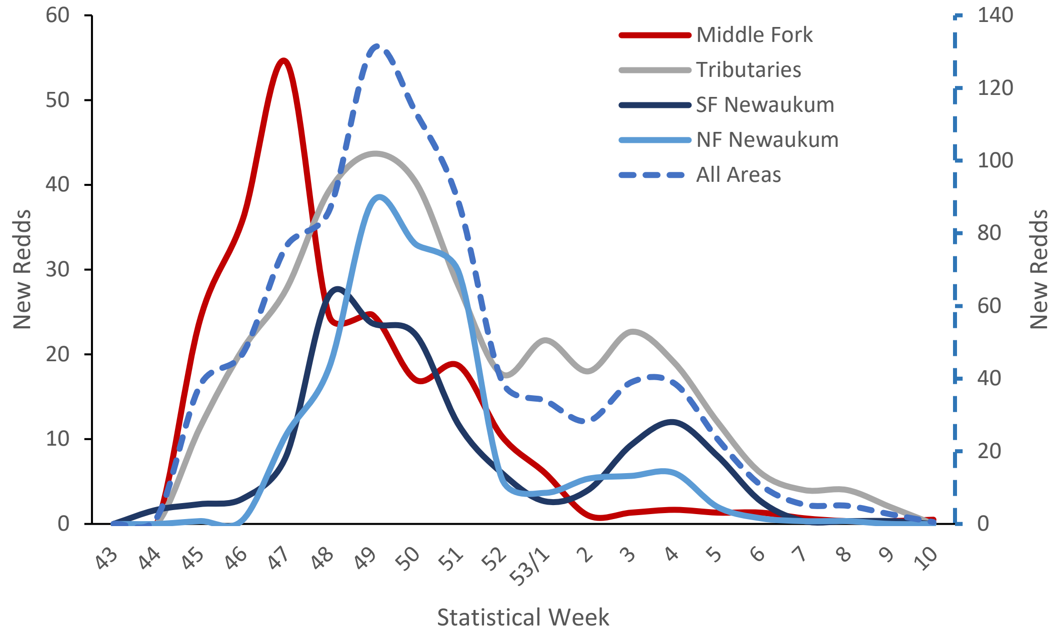

Figure 3. The 2020 Coho Salmon run timing by sub-area. Shows an earlier timing for Middle Fork Newaukum than other sub-areas. "All Areas" is plotted on the secondary axis.

Life History Diversity

Adult salmon and steelhead life history diversity metrics included age and sex composition, length data, and origin status (hatchery or natural). All spring and fall Chinook carcasses encountered, where clip status could be determined, had an adipose present (unmarked, UM). We collected biological data from 37 spring Chinook carcasses in 2020; of those, three came back as fall Chinook in genetic testing. Of the remaining 34 carcasses, 64% were male (n=21), 36% were female (n=12), and one of the carcasses was too degraded to determine sex. The majority of males came back as age 3 (n=13), whereas the majority of females came back as age 4 (n=9); one male came back as a jack (age 2, Figure 4). The average lengths (cm ± SD) of female, male, and jack fall Chinook recovered were 72.8 ± 5.6, 69.8 ± 9.6, and 45 cm, respectively.

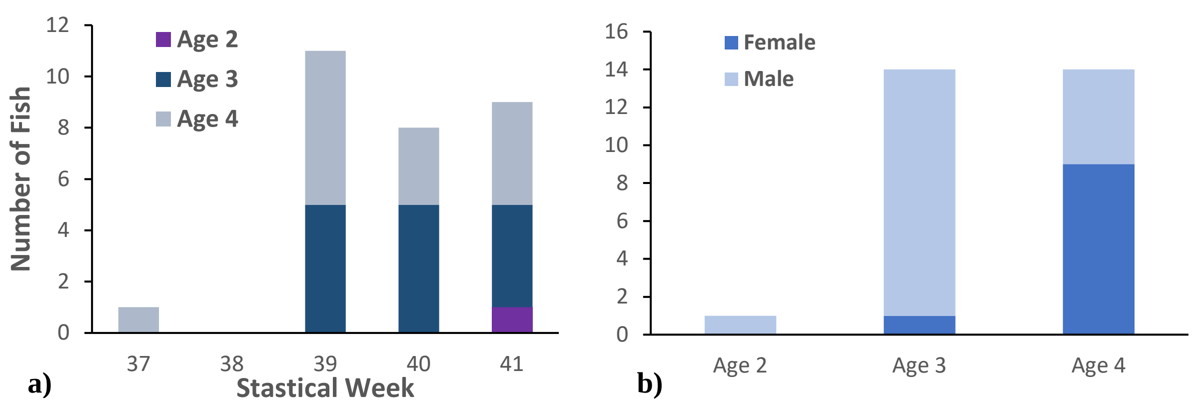

Figure 4. Total age from scale analysis for 2020 spring Chinook Salmon carcasses recovered in the Newaukum River basin a) by week of the year (Appendix D), b) by sex.

There were 57 fall Chinook carcasses recovered in 2020 and 62% were female (n=24), 38% were male (n=15), and no jacks were recovered. The average lengths (cm ± SD) of female and male fall Chinook recovered were 78.5 ± 4.5 and 74.5 ± 6.3, respectively. For fall Chinook carcasses sampled in 2020, 15% were scale age 3 (n=6), 75% were scale age 4 (n=30), and 10% were scale age 5 (n=4) (Figure 5). None of the fall Chinook carcasses recovered in 2020 were adipose clipped (AD), indicating they were all of natural origin.

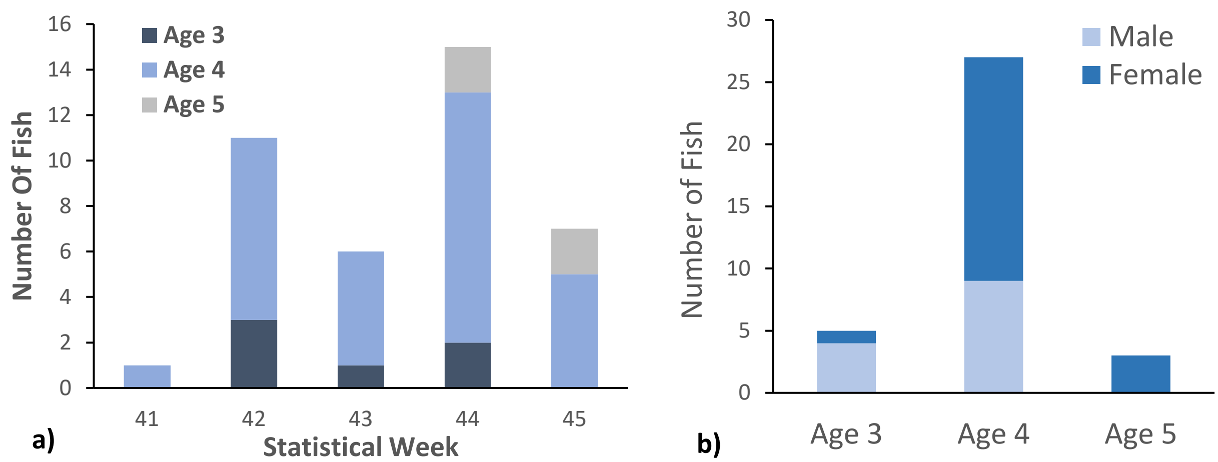

Figure 5. Total age from scale analysis for 2020 fall Chinook Salmon carcasses recovered in the Newaukum River basin a) by week of the year (Appendix D) b) by sex.

Throughout the basin, 57 Coho Salmon carcasses were recovered in the 2020-2021 season. No scales were taken for age analysis and all adult Coho Salmon were assumed to be ocean age 3. Overall, the sex ratio determined for UM Coho Salmon was 41% female and 59% male (Figure 6). The average lengths (cm ± SD) of recovered female and male Coho Salmon were 65.8 ± 3.3 and 66.3 ± 7.4, respectively. Hatchery Coho Salmon, and to a lesser extent steelhead, in the Newaukum basin are reared and released into Gheer Creek by aquaculture students attending the Onalaska High School. The only verified presence of hatchery origin (HOR) Coho Salmon outside of Gheer Creek was discovered in the South Fork Newaukum below the confluence with Gheer Creek and were likely strays from the Gheer Creek program. No hatchery presence was observed from sampled carcasses in the North Fork, Middle Fork Newaukum or other tributaries for the 2020 Coho Salmon run. The South Fork Newaukum River basin had 95.5% confirmed NOR (n=21) and 4.5% HOR (n=1) adult Coho Salmon in 2020. By contrast, Gheer Creek had 100% HOR (n=34) Coho Salmon carcasses recovered for the 2020 run. As a result, Coho Salmon escapement in Gheer Creek in 2020 was calculated separately from the rest of the basin to account for the disproportionate amount of hatchery fish in this stream relative to the rest of the Newaukum watershed. The Middle Fork and North Fork had zero HOR adult Coho Salmon represented in the fish sampled (n=20).

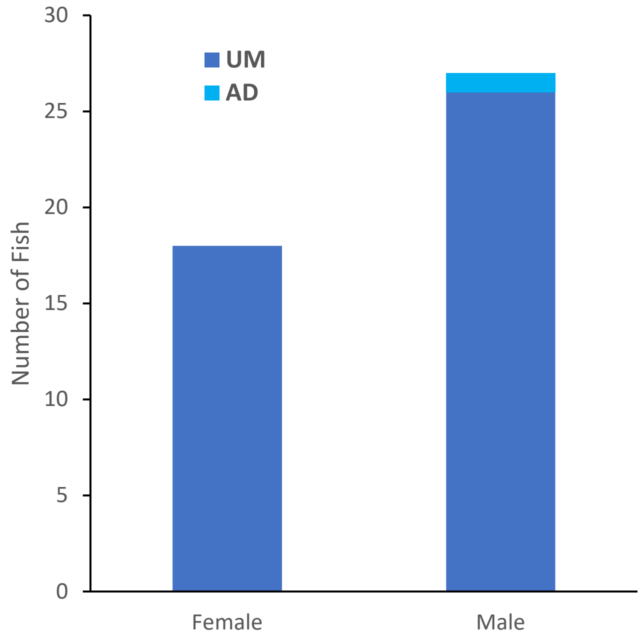

Figure 6. Relative contribution of hatchery/natural origin (HOR/NOR) by male and female 2020 Coho Salmon in the Newaukum River Basin outside of Gheer Creek. No jacks (< 47cm) were recovered.

In an effort to increase steelhead biological samples for sex, age, and origin, hook and line live sampling was implemented for the 2021 return year. Thirty-four samples were collected from live steelhead. Combined with six steelhead carcasses sampled this year, the total number of steelhead samples was 40, of which four were adipose clipped (10% HOR, 90% NOR). The most common age seen was age 2.1+, in both live and dead samples, for a total age of four at spawning (Appendix E, Figure 7). Compared to last year where none of the samples collected indicated repeat spawners, in 2021 five samples came back as repeat spawners. Of the NOR sampled steelhead, 37% were (n=11) female with an average fork length (cm ± SD) of 73.4 cm ± 7.2 and 63% male (n=19) with an average fork length of 73.5 cm ± 8.4.

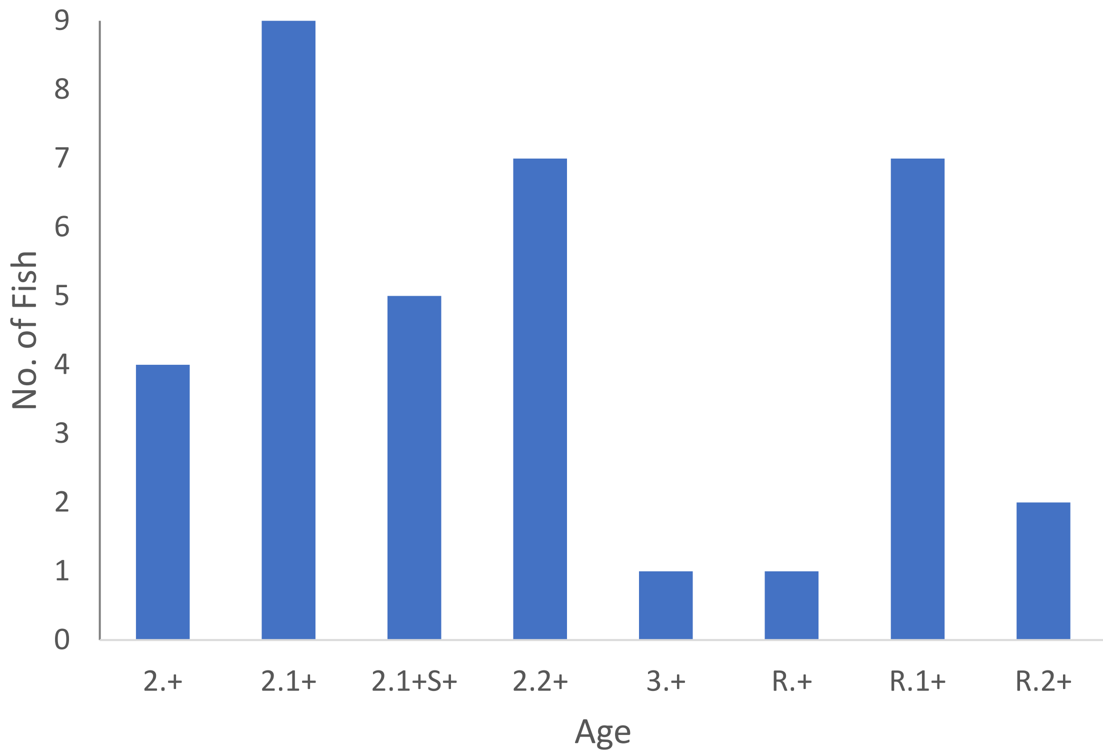

Figure 7. Age from scale analysis of 2021 steelhead trout with freshwater age on the left of the decimal and saltwater age to the right of decimal. 'R' indicates regenerated, so freshwater age is unknown, and 'S' indicates multiple spawns. Samples include both live hook and line and carcass sampling. Additional explanation of scale age notation in Appendix E.

Distribution

The spawning distribution of spring Chinook adults in 2020 was isolated to the forks and main stem Newaukum River (Figure 8), similar to 2019. Spring Chinook Salmon were sparsely distributed (< 10 redds mile^{-1}) throughout the North Fork, main stem Newaukum River, and much of the South Fork Newaukum. However, density on the South Fork Newaukum River increased (15.9 redds mile^{-1}) below Onalaska and had the highest density (16 redds mile^{-1}) just above Hwy 508. The highest density (6.2 redds mile^{-1}) in 2019 was above the Pigeon Springs area, which differed from 2020. Some streams like Middle Fork Newaukum, Kearney Creek and Lucas Creek, were not surveyed on a weekly basis during the spring Chinook spawning period as flows were too low for spring Chinook to access any potential spawning habitat. Fall Chinook had an average density in the Newaukum River basin of approximately 10 redds mile^{-1} but had higher densities (15-25 redds mile^{-1}) in the lower part of the South Fork Newaukum, below Onalaska (Figure 9). North Fork Newaukum River had higher densities in 2020 (15-25 redds mile^{-1}) than 2019 (11-15 redds mile^{-1}) but locations of high-density areas were similar to the previous year. However, in 2020, fall Chinook spawned further upstream on the North Fork Newaukum than observed in 2019. Fall Chinook also spawned in the Middle Fork Newaukum and larger tributaries of Kearney and Lucas creeks as flows increased in October 2020.

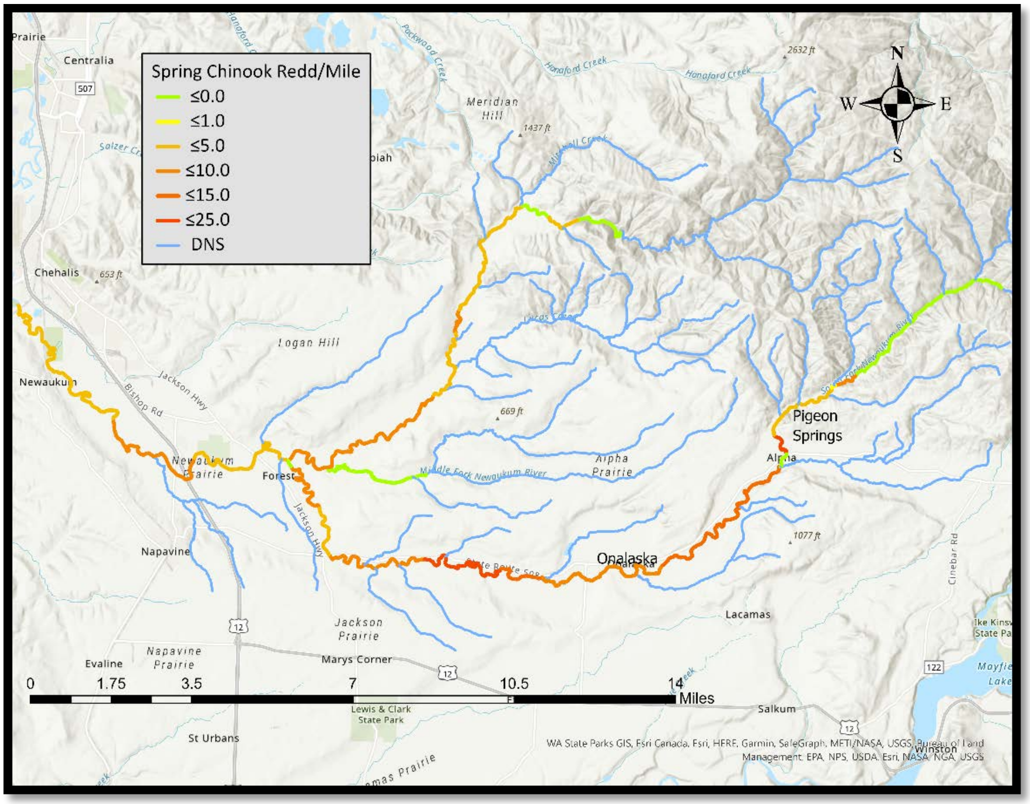

Figure 8. Distribution of 2020 spring Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin.

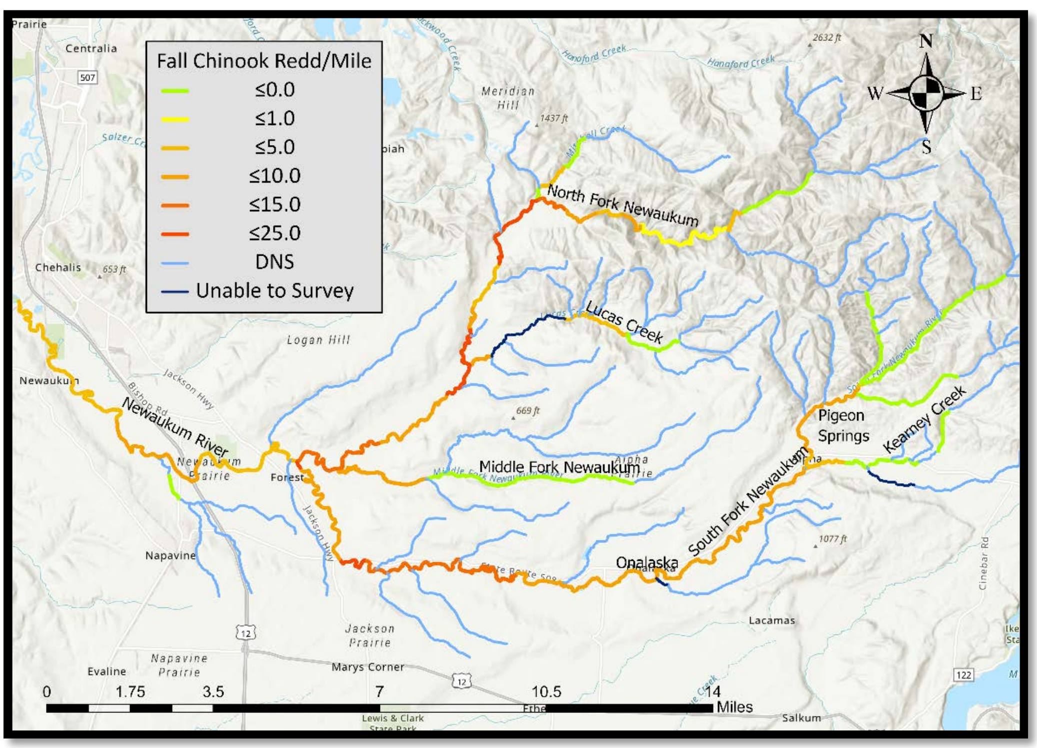

Figure 9. Distribution of 2020 fall Chinook Salmon, shown as redds mile^{-1}, for the Newaukum River basin. “Unable to Survey” sections indicate areas where presence was possible, but field staff were unable to access.

Coho Salmon primarily spawned in the forks and tributaries of the Newaukum basin in 2020 with minimal spawning in the main stem (Figure 10). Not unexpectedly, the highest spawning density (>100 redds mile^{-1}) occurred in Gheer Creek and was associated with 100% hatchery returns. Other high density areas (> 50 redds mile^{-1}) occurred in the Middle Fork, as well as Kearney Creek and Lost Creek. The South Fork Newaukum had the highest density (30 redds mile^{-1}) in the upper Pigeon Springs with Bernier and Beaver Creek in the same area also having high densities (15-25 redds mile^{-1}). The North Fork had Coho Salmon spawning primarily in the upper reaches, above Mitchell Creek, with the highest density (30 redds mile^{-1}) above the end of the North Fork Road. Two tributaries, Lost Creek and Door Creek were surveyed in 2020, but not 2019. Coho Salmon were expected in those areas, and densities were surprisingly high at 80 and 73 redds mile^{-1}, respectively. Other tributaries that may have potential for Coho Salmon spawning, but were unable to be accessed in 2020, include Jested Creek, upper Allen, upper Lost, and Door creeks.

Steelhead, like Coho Salmon, barely utilized the main stem Newaukum River for spawning habitat in 2021 (Figure 11). Instead, steelhead utilized the upper extents of both the North Fork and South Fork Newaukum River with high densities (30 redds mile^{-1}) in the North Fork Newaukum and >50 redds mile^{-1} in the Pigeon Springs area of the South Fork Newaukum. Although spawning occurred in the Middle Fork Newaukum, Mitchell, Kearney, Bernier, and Beaver creeks, it was at lower densities (<10 redds mile^{-1}). Lost and Door Creeks were sampled for the first time during the 2020-2021 run and showed similar densities (<10 redds mile^{-1}) compared to other tributaries surveyed. During the 2020-2021 survey season, we were unable to survey several locations on Lucas, Lost, and Door creeks in a consistent manner.

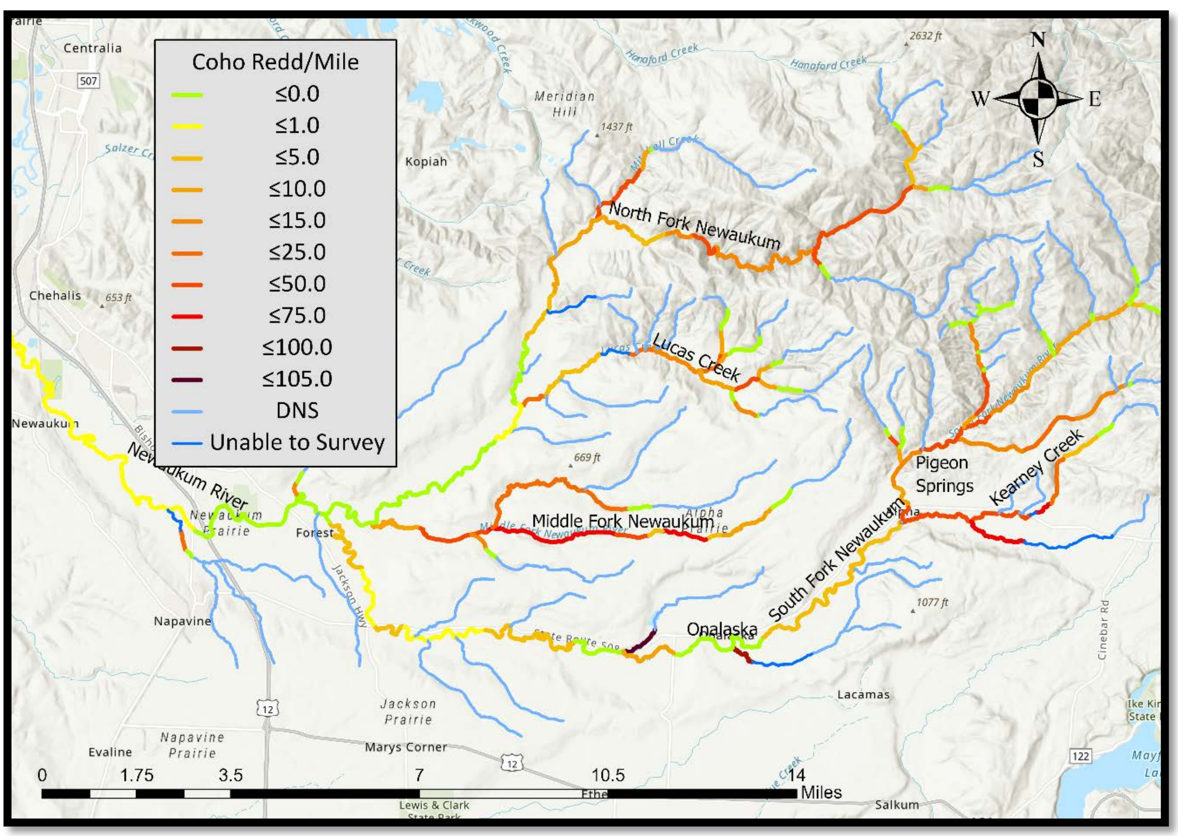

Figure 10. Distribution of 2020 Coho Salmon, shown as redds mile^{-1}, for the Newaukum River basin. “Unable to Survey” sections indicate areas where presence was possible, but field staff were unable to access.

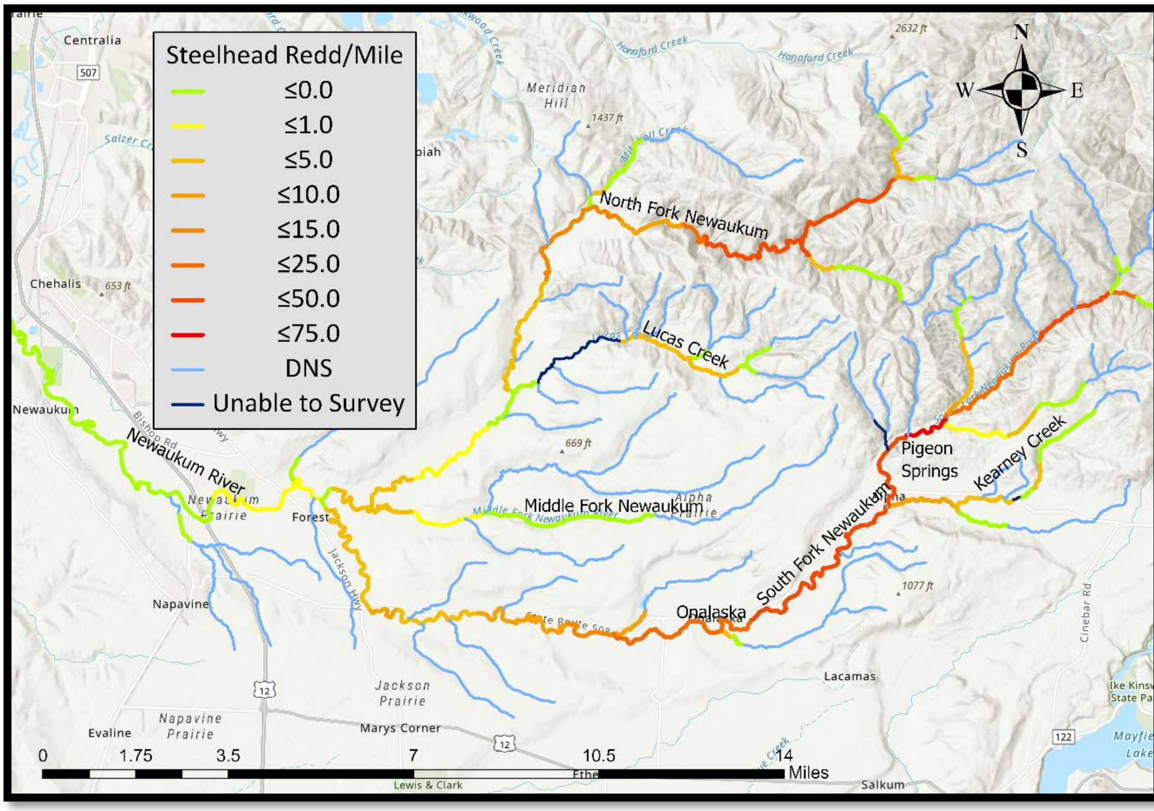

Figure 11. Distribution of 2021 steelhead, shown as redds mile^{-1}, for the Newaukum River basin. "Unable to Survey" sections indicate areas where presence was possible, but field staff were unable access.

Run Type Genetics

Tissue samples from Chinook Salmon carcasses were collected in 2019 and 2020 in an opportunistic manner during redd spawning ground surveys to determine genetic run timing and validate field calls. Of the 105 samples submitted for run timing determination, only 87 were successful genotyped for homozygous fall or spring run type on both markers. Heterozygosity (both spring and fall markers) showed up in 13% (n=11) of the samples. The heterozygote samples (n=10) were primarily collected around the October 15th date during SW 41 and 42 (Figure 12). There was only one heterozygote sample collected later during SW 45. The earliest genotyped fall Chinook carcass was collected five days before the spawning cut-off date of October 15th and the latest spring Chinook carcass was collected on the spawning cut-off date. Of those, only 6 samples (2019 n=3, 2020 n=3) came back different from the original field calls. All of these incongruent calls occurred within a 10-day period (SW 41-42) near the October 15th date used as a cut-off for the spring Chinook redd calls. Of the heterozygote genotypes, the field calls were primarily (91%) fall Chinook.

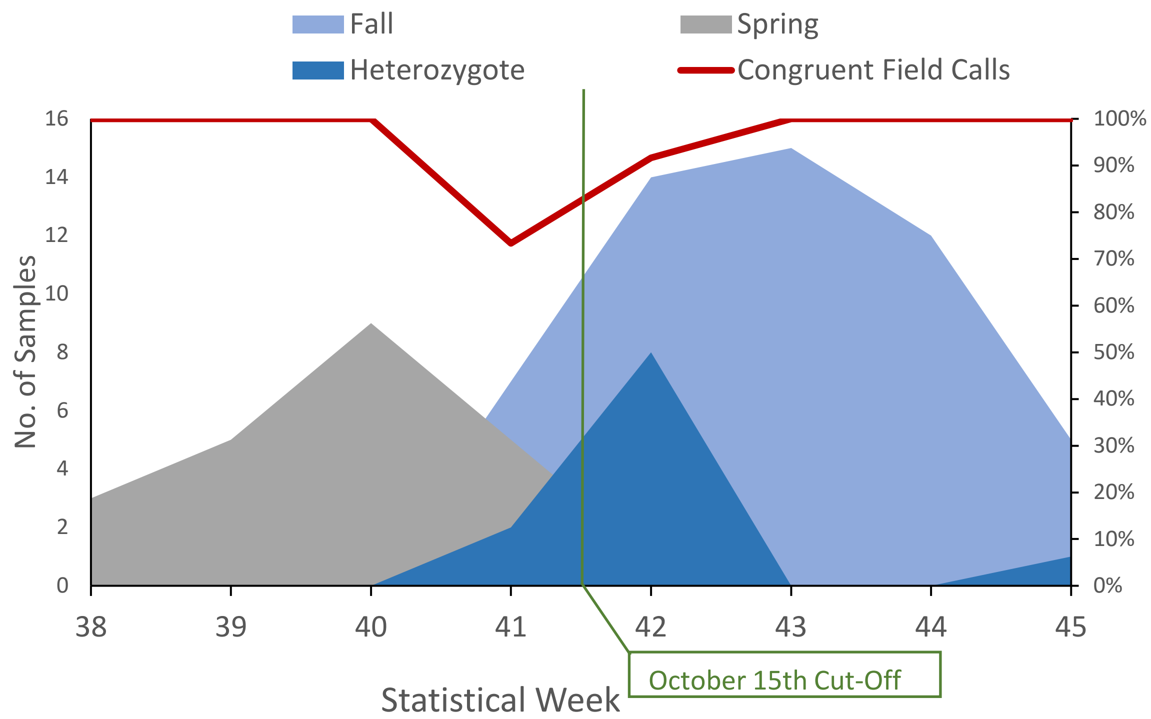

Figure 12. Genotyped run calls for 2019 and 2020 Chinook Salmon in the Newaukum sub-basin. Red line indicates the percentage of field calls that were congruent with the genotyped calls. The green vertical line shows the October 15th date used to determine spring.

The majority (76%) of genotyped spring Chinook were recovered in the upper South Fork Newaukum River, although there were a few recoveries in both the North Fork Newaukum River and the main stem Newaukum River (Figure 13). Seventy-five percent of the heterozygote genotype occurred in the main stem Newaukum River. No heterozygotes were found in either the North Fork or Middle Fork Newaukum but 25% occurred in the South Fork Newaukum. The samples genotyped as fall Chinook had the broadest distribution and occurred in all areas where Chinook redds were observed.

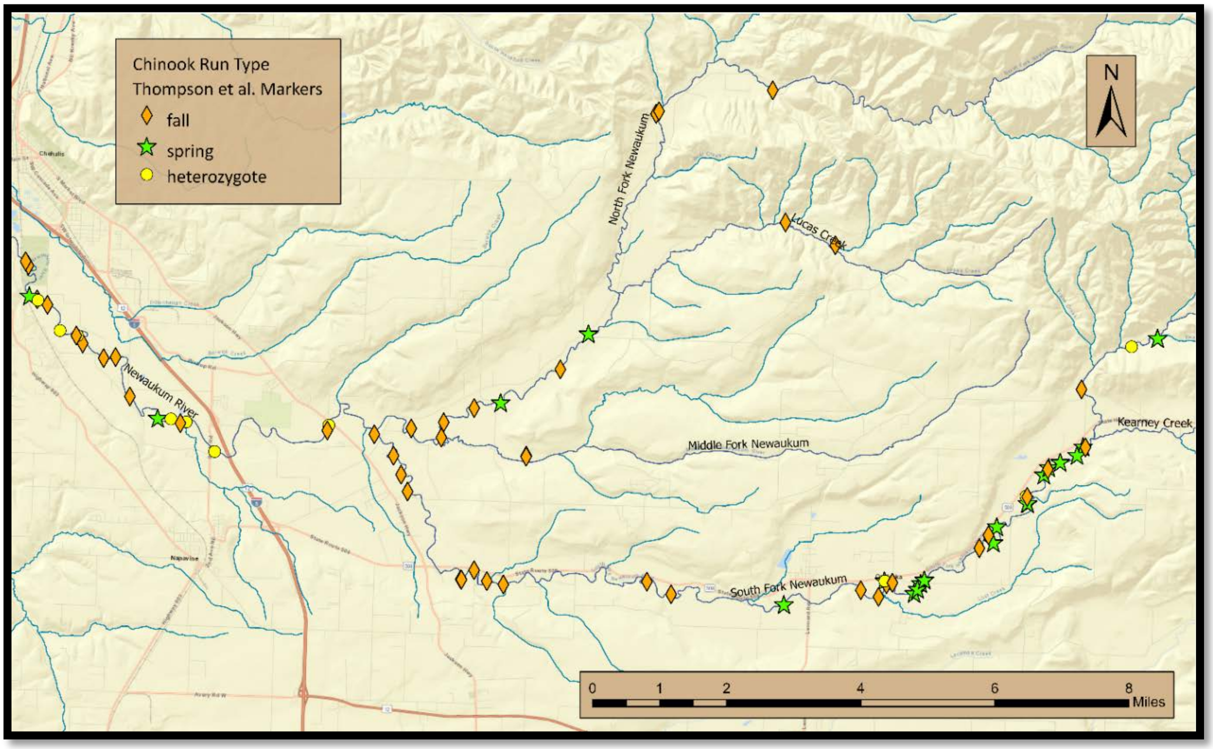

Figure 13. Location of opportunistic carcass recovery for genotyped Chinook samples collected in 2019 and 2020.

Discussion

Adult monitoring of salmon and steelhead in the Newaukum River basin, in conjunction with the juvenile monitoring program, is providing valuable information on population viability and the effects of habitat restoration on salmon and steelhead productivity. The Newaukum basin supports populations of spring and fall Chinook, Coho Salmon, and steelhead. On average (2000-2020) the Newaukum River contributed 29% of spring Chinook production to the Chehalis basin. However, this value has varied annually from 18% to 45% (Appendix A). The contribution of spring Chinook from the Newaukum River in 2020 (25%) was below the average contribution for the series but was 7% greater contribution than the previous year. There has been a decreasing trend in overall abundance of spring Chinook in the Newaukum River and throughout the Chehalis River basin over the last 20 years.

Historically (2000-2020), fall Chinook, Coho Salmon, and steelhead from the Newaukum River contributed an average of 8%, 12%, and 11%, respectively, to the total Chehalis River population. Overall, the percent contribution of Newaukum fall Chinook to the Chehalis River basin appears to be decreasing slightly over time with only 7% contribution in 2020. In contrast, the contribution of Newaukum Coho Salmon to the Chehalis basin appears to be increasing while the overall trend of abundance in the Chehalis River basin is decreasing (2000-2020). Over the last two decades, Newaukum River steelhead decreased slightly over time in both abundance and relative contribution to the Chehalis River total. However, 2021 steelhead trout in the Newaukum sub-basin had the highest contribution level of the time series (19%) and was nearly twice the average contribution. Nevertheless, the overall steelhead abundance trend in the Chehalis River populations has declined over this period. It should be noted that the new intensive monitoring methodology is different from the methodology employed in the rest of the Chehalis basin, and what was used in the Newaukum River prior to the 2019-2020 survey season. Trends and historical information will be useful in evaluating population-level responses to restoration projects and climate change.

Interestingly, the spring Chinook contribution to the Newaukum sub-basin from the North Fork Newaukum increased from only 7% in 2019 to 17% in 2020; however, the greatest contribution (66%) was from the South Fork Newaukum River, similar to the previous year. However, the highest density in 2020 on the South Fork Newaukum (16 redds $mile^{-1}$), shifted downstream from upper Pigeon Springs in 2019 to lower Pigeon Springs just above Hwy 508. There was also high density (15.9 redds $mile^{-1}$) from Gish Rd to Gheer Creek just below Onalaska. Fall Chinook had a similar distribution of densities to what was observed in 2019, with the highest densities (>20 redds $mile^{-1}$) in the lower South and North Forks of the Newaukum River. However, in 2020 there were also high densities (10-20 redds $mile^{-1}$) in the upper North Fork Newaukum River relative to 2019 (1-5 redd $mile^{-1}$). Whether these shifts in distribution for fall and spring Chinook are due to flow regimes, increased population pressure, natural fluctuation in spawning preference, or other factors remains unclear and is likely a combination of multiple factors.

Fall Chinook spawning overlapped both spatially and temporally with spring Chinook, suggesting hybridization is likely occurring in the Newaukum River. This was confirmed with genetic run-timing analysis of 2019 and 2020 carcasses that were collected during redd surveys. This opportunistic method of collecting data may be problematic for drawing conclusions based on location and date. However, there appears to be some indication that more hybridization is occurring in the mainstem Newaukum as opposed to either the South Fork or North Fork Newaukum. Of the 11 genotyped heterozygote samples, eight carcasses were recovered in the mainstem, where both spring and fall genotypes also occurred. The use of the entire main stem, including the lower section, by spring Chinook for spawning, may also indicate that some moved into the Newaukum from the main stem Chehalis River just prior to spawning. The confluence of the Newaukum and Chehalis rivers has previously been identified as an area of thermal refugia (Liedtke et al. 2017) Additional effort would be needed to determine holding patterns of spring Chinook to confirm this. More work, including directed efforts to collect carcass samples, is also needed to develop a more comprehensive and accurate picture of spring versus fall Chinook run-timing and the degree of hybridization of genetic run-types in the basin (Thompson et al. 2019).

Field calls of spring and fall Chinook salmon were mostly in agreement with the genetic results (homozygous spring and homozygous fall run-types). There were only six out of 87 carcasses with an incorrect run timing assignment based on field calls, three from each year of samples collected. All of the incongruent field calls were within a 10-day period around the October 15th cut-off date between spring and fall run timing, indicating a short window of uncertainty for run-type field calls. Even during this most uncertain time, field calls were in agreement with genetic results 71% of the time. It should be noted that the accuracy of the run-type field calls did not translate to the accuracy of the escapement estimates. Run-type field calls on carcasses recovered were not applied to the escapement estimates based on redds observed before or after October 15th. Redds were only called fall Chinook before that date if there was Chinook female on the redd that had characteristics of a fall, not spring migrant (see Appendix C). One of the limitations with opportunistic carcass sampling used for genotyping is that samples aren’t necessarily representative of population run-timing, run size, or distribution. Quantifying the relationship between genotype and phenotype at the population level will require a much more intensive study with higher levels of carcass recovery and consideration for heterozygous run-types (spring and fall hybrids).

Coho Salmon were the most abundant species spawning in the Newaukum River basin in 2020 and utilized many of the smaller tributaries including the Middle Fork Newaukum that had limited use by other species. Interestingly, peak spawn timing in the Middle Fork Newaukum was almost three weeks earlier than in other parts of the basin. A similar observation was documented in 2019. Also, Lost and Door Creeks were added to survey area in 2020, as landowner access was provided, but only peak surveys were conducted. An unexpectedly high number of redds were observed in these creeks in 2020, 14 and 29 respectively. When redds from these peak surveys were expanded for the rest of the Coho Salmon spawning season, those areas had a cumulative redd per mile of 80 redd-mile^{-1} and 91.3 redd-mile^{-1}, some of the highest redds per mile observed within the whole basin. In order to improve accuracy and precision of the estimate in the future, it is recommended that weekly surveys in those creeks be added to the survey area.

Coho redd densities were estimated in seven stream sections that were not surveyed in 2020. For these sections, either a nearest-neighbor fish density was applied, or we used average redd densities from streams with similar stream types. These seven stream or stream sections were not surveyed due to access issues. Assumptions were made that redd densities were similar in streams close in geographic location and comparable in hydro-morphology. In addition, it was determined that hatchery Coho Salmon in the Newaukum basin had the highest densities (> 100 redds mile^{-1}) in Gheer Creek where juveniles were released by the Onalaska High School hatchery program. However, it remains unclear how much hatchery strays contribute to natural origin juvenile production or how many of those juveniles return to spawn as adults.

In 2021, steelhead were the second most abundant adult salmonid in the Newaukum basin. The majority of spawning distribution for steelhead was surveyed on a weekly basis and unlike other species, most (81%) steelhead spawned in the upper North Fork above Mitchell Creek and upstream of Leonard Rd on the South Fork Newaukum. The hatchery component of steelhead was determined using two separate methods. The first method used the ratio of marked to unmarked steelhead encountered (carcasses and live hook and line samples), which estimated a 12% HOR rate. The second method used March 15th as a cutoff date for HOR spawners (a method employed by WDFW Chehalis stock assessment biologists), which estimated a 19% HOR rate based on early run timing for hatchery stocks. As noted in previous studies in the upper Chehalis River (Ashcraft et al. 2017; Ronne et al. 2018; 2020), the latter methodology may be problematic as the Chehalis River basin moved to integrated HOR steelhead programs, which makes use of NOR broodstock, thus creating hatchery origin steelhead with spawn timing similar to NOR steelhead. However, to remain consistent with the rest of the Chehalis River basin, HOR and NOR proportions and associated abundance were and will continue to be reported using both observational-based (live and dead sampling) and date-based methodologies.

Steelhead have complicated life histories with the potential for repeat spawning; these diverse life histories can improve resilience of a population (Schindler et al. 2010). Unlike the first year of data from the Newaukum that indicated limited life history diversity of spawning steelhead with no repeat spawners identified, in 2021 we documented five repeat spawners. This increase in repeat spawners was also documented in other coastal populations. This could have resulted from a few years of more favorable ocean conditions for marine survival (Nickelson 1986). Repeat spawning is important for population viability as older steelhead are generally larger and have increased fecundity compared to smaller/younger steelhead (Bowersox et al. 2019; Quinn et al. 2011). A closer examination quantifying interannual variation in repeat spawners would benefit from a broader dataset and comparison to other coastal steelhead populations. Future efforts will continue to focus on collecting samples to address this data gap in the Newaukum River basin.

As intensive adult monitoring continues in the Newaukum River basin, future work will continue to focus on generating unbiased estimates of spring and fall Chinook, Coho Salmon, and steelhead abundances and evaluate distribution, run timing, and life history diversity. A continued effort to cover the spawning habitat on a weekly basis for all species will help to produce accurate estimates. However, it may be necessary to consider new methodologies for Coho Salmon due to their broad distribution. As additional years of information with differing flow and abundance regimes get added to the time series, understanding of spatial distribution in the basin will be refined. Combining adult spawning estimates with juvenile smolt production estimates will also inform adult to smolt (freshwater) survival and smolt to adult (ocean) survival, providing valuable information on limiting stages throughout the life cycle. The first adult to smolt estimates for the Newaukum fish-in fish-out study showed 139.9 smolts-per-spawner for the 2019 Chinook brood year (Olson et al. 2021). Additional information provided by this work will improve the ability to detect changes in salmon and steelhead productivity and population viability as a result of restoration actions and climate change.

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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	2828	25%

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%

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%

*Preliminary

d) Steelhead Trout

For 2020 steelhead trout in the Newaukum, both the observational (includes both HOR and NOR) and the date derived (NOR only) methods are shown. Prior to 2020, only the date-based method was available and when comparing to the rest of the basin, therefore the date-based method is shown for consistency.

Newaukum Basin

Year	Observational Method	Date Method	**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	1,103	970	6,280	15%
2021	1,214	987	5,631**	18%

* No separate Newaukum estimate reported
** Preliminary data

Appendix B. Survey miles covered pre- and post-implementation of intensive monitoring in 2019-2020. Index indicates weekly surveys. Supplemental indicates surveys conducted once during peak spawning.

		2020-2021	**2019-2020**	**Pre-2019**
Spring Chinook	Index	44.2	47.8	5.5
	Supplemental	4.4	0.8	36.5
		48.6	**48.6**	**42.0**
Fall Chinook	Index	51.4	53.0	5.5
	Supplemental	19.9	18.3	42.1
		71.3	**71.3**	**47.6**
Coho Salmon	Index	73.2	72.9	4.0
	Supplemental	26.7	18.0	33.6
		99.9	**90.9**	**37.6**
Steelhead	Index	74.7	77.2	10.1
	Supplemental	11.6	10.3	28.3
		86.3	**87.5**	**38.4**

Appendix C. 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; 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	Presence of a fall Chinook female;
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 D. Dates by statistical week (week of year) for 2020-2021 survey season.

From Date	To Date	Statistical Week	From Date	To Date	Statistical Week
8/30/2020	9/5/2020	36	1/31/2021	2/6/2021	6
9/6/2020	9/12/2020	37	2/7/2021	2/13/2021	7
9/13/2020	9/19/2020	38	2/14/2021	2/20/2021	8
9/20/2020	9/26/2020	39	2/21/2021	2/27/2021	9
9/27/2020	10/3/2020	40	2/28/2021	3/6/2021	10
10/4/2020	10/10/2020	41	3/7/2021	3/13/2021	11
10/11/2020	10/17/2020	42	3/14/2021	3/20/2021	12
10/18/2020	10/24/2020	43	3/21/2021	3/27/2021	13
10/25/2020	10/31/2020	44	3/28/2021	4/3/2021	14
11/1/2020	11/7/2020	45	4/4/2021	4/10/2021	15
11/8/2020	11/14/2020	46	4/11/2021	4/17/2021	16
11/15/2020	11/21/2020	47	4/18/2021	4/24/2021	17
11/22/2020	11/28/2020	48	4/25/2021	5/1/2021	18
11/29/2020	12/5/2020	49	5/2/2021	5/8/2021	19
12/6/2020	12/12/2020	50	5/9/2021	5/15/2021	20
12/13/2020	12/19/2020	51	5/16/2021	5/22/2021	21
12/20/2020	12/26/2020	52	5/23/2021	5/29/2021	22
12/27/2020	1/2/2021	53/1	5/30/2021	6/5/2021	23
1/3/2021	1/9/2021	2	6/6/2021	6/12/2021	24
1/10/2021	1/16/2021	3	6/13/2021	6/19/2021	25
1/17/2021	1/23/2021	4	6/20/2021	6/26/2021	26
1/24/2021	1/30/2021	5	6/27/2021	7/3/2021	27

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".