Tulalip Tribes Natural Resources Department Report

SKYKOMISH RIVER JUVENILE SALMON OUT-MIGRATION STUDY PROGRESS REPORT

February – June 2024

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TABLE OF CONTENTS

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INTRODUCTION

Due to considerable declines in salmon populations, fisheries managers and stakeholders have been working collaboratively to restore salmon runs in the Snohomish watershed. In 1994, a partnership of 41 organizations formed the Snohomish Basin Salmon Recovery Forum (the Forum) in order to implement a watershed scale, scientifically-based, adaptive management strategy to better inform salmon recovery. The Snoqualmie sub-basin is managed by a partnership of local tribes and municipalities called the Snoqualmie Watershed Forum.

In 2005, the Forum adopted the *Snohomish River Basin Salmon Conservation Plan* in order to coordinate fisheries management on a watershed scale. To inform this planning with the best available science, it is necessary to gather and analyze data on Chinook and Coho Salmon abundance, productivity, survival, escapement, spatial structure, and life-history diversity within the Snohomish system (Snohomish Basin Salmonid Recovery Technical Committee, 2005). Information about the trends and inter-annual variability in these populations are critical to inform salmon recovery efforts, provide basic information on the productivity and capacity of the system, and lead to significant improvements in harvest management modeling and run forecasting. Additionally, the monitoring of production and survival along with other physical, chemical, and biological conditions provides a means to evaluate habitat restoration effectiveness, recovery actions, habitat conditions, and potential ecological trajectories in the basin**.**

In 1999, the National Marine Fisheries Service (NMFS) listed the Puget Sound Chinook Salmon *Oncorhynchus tshawytscha* as threatened under the federal Endangered Species Act (ESA). This listing included Chinook Salmon from the Snohomish River basin, which includes sub-populations from the Skykomish and Snoqualmie Rivers. Decreases in many runs of Puget Sound Coho Salmon *Oncorhynchus kisutch* have also resulted in their designation as a species of concern under the ESA. This report focuses on Chinook and Coho Salmon because recovery efforts targeted at these species will help other federally listed salmonid stocks, including Steelhead, in the watershed.

A key method for monitoring Snohomish River salmon populations has been the operation of rotary screw traps in the Skykomish and Snoqualmie rivers. Over the last 22 years, these projects have sampled juvenile Chinook and Coho Salmon as they emigrate to the Puget Sound. The goals of these trapping efforts are to estimate Chinook and Coho Salmon natural production, migration patterns, and freshwater survival. These goals are accomplished through the direct quantification of juvenile salmon emigrations, evaluation of trap efficiency, and assessment of influential environmental attributes. The Tulalip Tribes' trapping project has been classified as a project of high priority by the Forum because it is necessary for stock assessment, population monitoring and run forecasting (Snohomish Basin Salmonid Recovery Technical Committee, 2005).

SKYKOMISH RIVER TRAPPING SITE

The current trap site is located 26.5 miles upriver on the Skykomish River and six miles up from the confluence with the Snoqualmie River (Figure 1). It is in the tail-out of a wide pool/run as it transitions into a riffle, confined by two gravel point bars (Figure 2). The wetted width of the Skykomish River at this point is ~325 ft. during the spring out-migration period and the channel's bank full width is ~490 ft. The channel's maximum depth at the site is ~5 ft. at summer low-flow levels and approaches ~18.5 ft. at bank full depth. The channel gradient is < 1% and the substrate is mostly gravel and cobble. When fishing, the trap is positioned in the thalweg, near the center of the river (Figure 2). Land use adjacent to the current project site is principally agricultural with relatively intact riparian vegetation. Existing riparian vegetation is primarily cottonwood and alder with some planted cedar and spruce. At the immediate trapping site, the river right is composed of a gravel bar adjacent to a cottonwood stand. The left bank is just downstream of a rip-rapped bank with planted riparian vegetation integrated into a cottonwood stand and a larger cottonwood grove downstream on the inside bend. This land has been purchased by the Tulalip Tribes for stream restoration.

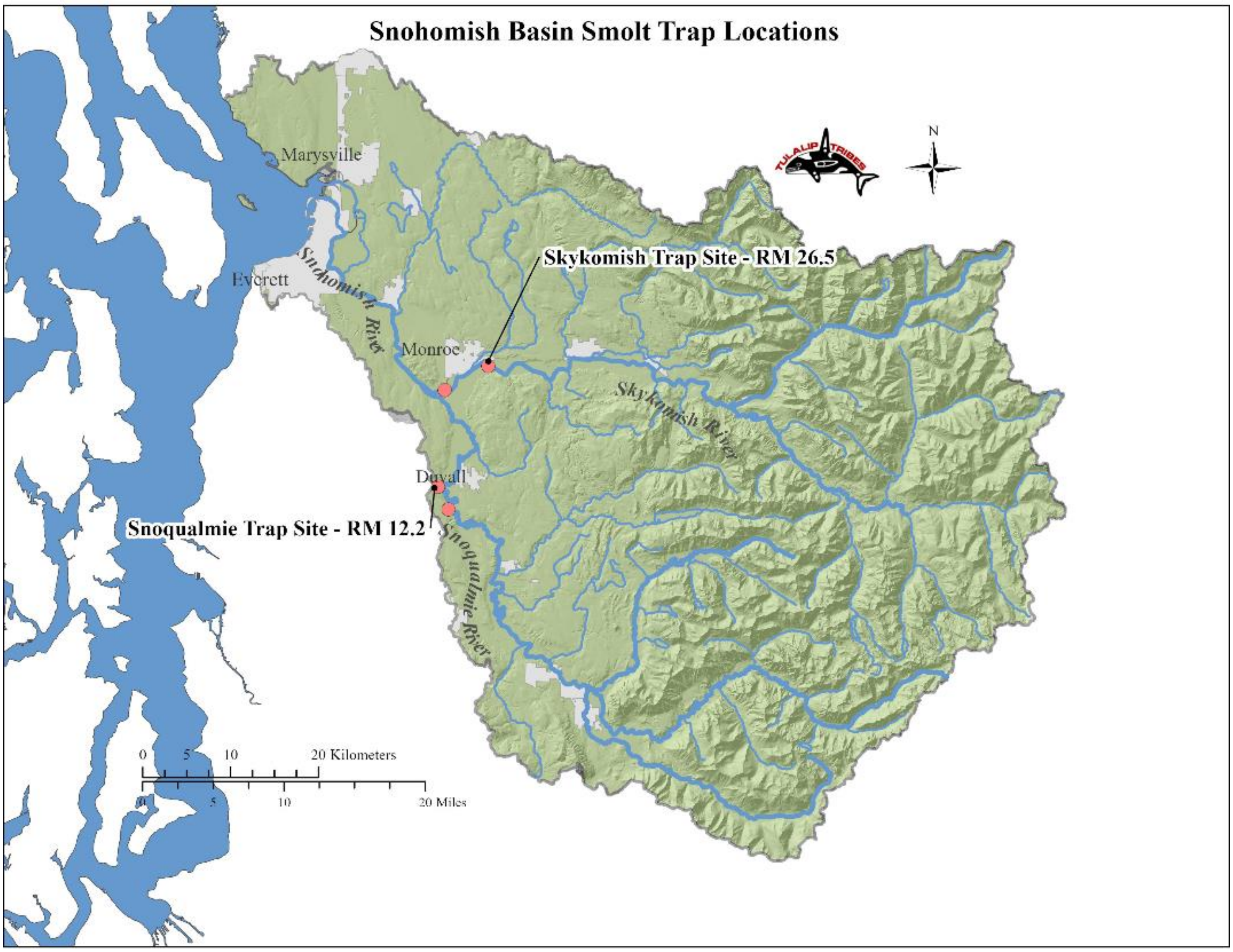

Figure 1: Map of the Snohomish watershed with the locations of the trap sites on the Skykomish and Snoqualmie Rivers.

Figure 2: Aerial photograph of the trap site at river mile 26.5 on the Skykomish River. The yellow X indicates the approximate trap fishing position.

SUMMARY OF SAMPLING OPERATIONS

The Skykomish River rotary screw trap operates during the juvenile salmon outmigration season, from February through June. Sampling is conducted on 4–5 weeknights and 1–2 weekdays each week, stratified by Julian week (JW) to allow more accurate year-to-year comparisons. In 2024, trapping occurred from February 13 to May 31 (JW 7–JW 22; Table 1). Sampling usually spans Julian week 7 to Julian week 25, though this timing can vary. High flows at the end of May prevented sampling into June, resulting in an earlier-than-usual end to the season. Overall, the trap operated for 826 hours—slightly below the average effort of 882 hours (Table 2). A total of 245 salmonid mortalities occurred during trapping and handling, including three unmarked sub-yearling Chinook Salmon, four unmarked sub-yearling Coho Salmon, eight Chum Salmon, and 230 Pink Salmon. Mortality for sub-yearling Chinook represented 0.38% of the total natural catch. A detailed summary of the season's catch is available in Appendix A.

Catch numbers for the 2024 season were well below average for all Chinook and Coho age classes. The number of sub-yearling Chinook Salmon caught was 39% of the project average, while unmarked yearling Coho Salmon reached only 58% of the project average (Table 2). Steelhead catch for unmarked individuals was lower than last season but is a reasonable value for the last 9 years. The catch for marked individuals was similar to previous year's numbers. Catch per unit effort calculations and production estimates confirm these low numbers, suggesting poor conditions for fish prior to and/or during outmigration.

Table 1. Julian weeks and corresponding dates for 2024 sampling season.

Start Week	End Week	Julian Week
1/2/2024	1/8/2024	1
1/9/2024	1/15/2024	2
1/16/2024	1/22/2024	3
1/23/2024	1/29/2024	4
1/30/2024	2/5/2024	5
2/6/2024	2/12/2024	6
2/13/2024	2/19/2024	7
2/20/2024	2/26/2024	8
2/27/2024	3/4/2024	9
3/5/2024	3/11/2024	10
3/12/2024	3/18/2024	11
3/19/2024	3/25/2024	12
3/26/2024	4/1/2024	13
4/2/2024	4/8/2024	14
4/9/2024	4/15/2024	15
4/16/2024	4/22/2024	16
4/23/2024	4/29/2024	17
4/30/2024	5/6/2024	18
5/7/2024	5/13/2024	19
5/14/2024	5/20/2024	20
5/21/2024	5/27/2024	21
5/28/2024	6/3/2024	22
6/4/2024	6/10/2024	23
6/11/2024	6/17/2024	24
6/18/2024	6/24/2024	25
6/25/2024	7/1/2024	26

CATCH PER UNIT OF EFFORT (CPUE)

Catch data are standardized into catch per unit effort (CPUE), which represents the number of fishes caught per hour of fishing effort. CPUE can be averaged over a given period by dividing the total catch by the total fishing hours, facilitating comparisons both within and across years. In 2024, CPUE data for unmarked Chinook Salmon sub-yearlings reveal a prominent peak at Julian weeks 21, with a smaller peak observed during Julian weeks 12–15 (Figure 3). Notably, the peak CPUE for sub-yearling Chinook Salmon in 2024 occurred later and was less pronounced compared to the typical out-migration period, which usually spans Julian weeks 11–17. The out-migration timing of yearling Coho Salmon is more consistent annually, typically spanning Julian weeks 17–21. The peak CPUE for yearling Coho Salmon in 2024 occurred within this expected timeframe (Kubo et al. 2013).

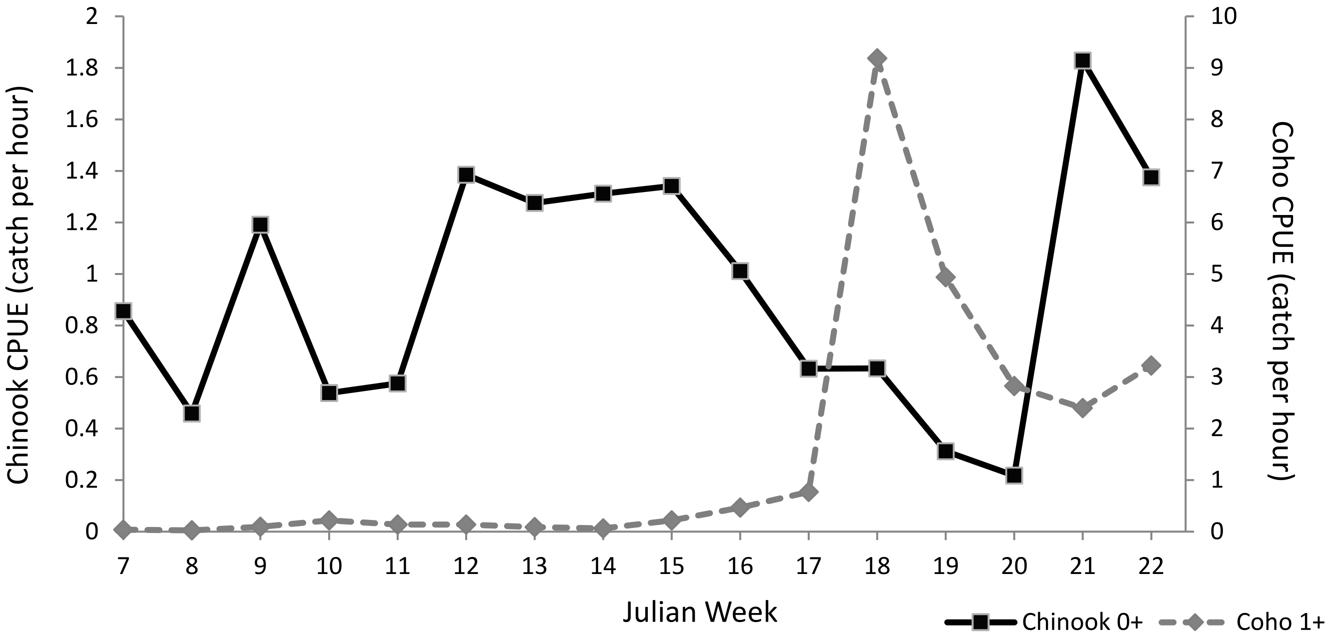

Figure 3. Natural-origin sub-yearling (0+) Chinook Salmon and yearling (1+) Coho Salmon CPUE by Julian week at the Skykomish River trap, 2024.

The average annual salmonid CPUE on the Skykomish trap has varied throughout the project due to changing sampling conditions and the strength of each year's out-migrant cohort. Last year, catch rates for both sub-yearling Chinook and yearling Coho were notably high, with CPUE well above the project average since the trap's relocation in 2009. This season, however, saw significantly lower catch rates, with CPUE well below the project average for both species. While the yearling Coho catch and CPUE reached about 66% of the project average, the Chinook catch was substantially lower, at just 40% of average, marking a considerable decline compared to recent years since 2017.

Table 2. Annual sampling effort, catch totals, and catch CPUE (fish per hour) for unmarked sub-yearling Chinook and yearling Coho Salmon at the Skykomish River rotary screw trap 2000-2024.

Year	Effort (Hours)	0+ Chinook	1+ Coho	Chinook CPUE	Coho CPUE
2000	309	1287	5972	4.17	19.36
2001	889	1770	4790	1.99	5.39
2002	672	1082	8779	1.61	13.07
2003	992	3267	7427	3.29	7.49
2004	1071	939	10608	0.88	9.90
2005	994	1704	2661	1.71	2.68
2006	1114	3075	6210	2.76	5.57
2007	447	1368	763	3.06	1.71
2008*					
2009	688	1654	1409	2.41	2.05
2010	974	2288	1245	2.35	1.28
2011	734	753	1796	1.03	2.45
2012	1016	1283	2992	1.26	2.95
2013	1194	2452	4443	2.05	3.72

2014	880	1392	2612	1.58	2.97
2015	1079	1433	1577	1.33	1.46
2016	1032	563	2137	0.55	2.07
2017	843	3961	2154	4.70	2.55
2018	836	4453	1583	5.33	1.89
2019	986	4076	1699	4.14	1.72
2020*	151	38	11		
2021*	287	1739	181		
2022	925	1652	2879	1.79	3.11
2023	901	3496	2924	3.88	3.25
2024	826	784	1279	0.95	1.55
Average	**882**	**2033**	**2195**	**2.38**	**2.36**

* = No values due to missing or limited trapping seasons.

Yearling Coho Salmon catch rates were in a downtrend until 2010, when the lowest documented average CPUE of 1.28 occurred (Table 2, Figure 4). In 2009, the trap was moved upstream from River mile (RM) 23 to its current location at RM 26.5. This relocation excluded the Woods Creek drainage from sampling, likely causing a catch decline, particularly for Coho following 2009 due to decreasing drainage area sampled. Woods Creek is known to have high Coho Salmon spawning activity but little Chinook Salmon spawning. The overall decline in Coho Salmon catch rates is also related to a decline in the Coho Salmon escapement in the latter half of the 2000s (Pacific Fishery Management Council 2019). Following relocation in 2009, catch rates have remained fairly consistent both in total catch and CPUE. While catch rates for this season are not dramatically lower than the project average, they are about 1.63 fish per hour lower than the two previous years.

The catch-per-unit-effort (CPUE) for sub-yearling Chinook showed a declining trend from 2001 until 2016, reaching a project low of approximately 0.55 fish per hour (Figure 4, Table 2). From 2017 to 2019, CPUE rose significantly above prior years before dipping just below average in 2022. In 2023, CPUE increased sharply to 3.88 fish per hour, reaching 163% of the project average. Unfortunately, this season's catch rates and CPUE have shown a marked decline, falling well below average (Figure 4). While fluctuations in habitat conditions and out-migration success are common, this steep decline in a previously upward-trending population is concerning and warrants further investigation. The significant flooding in December 2023 along the Skykomish River and low escapement may have contributed to this sudden drop.

Although CPUE is valuable for identifying trends, production estimates are generally more reliable for assessing overall abundance, as they account for trap efficiency and incorporate credible intervals.

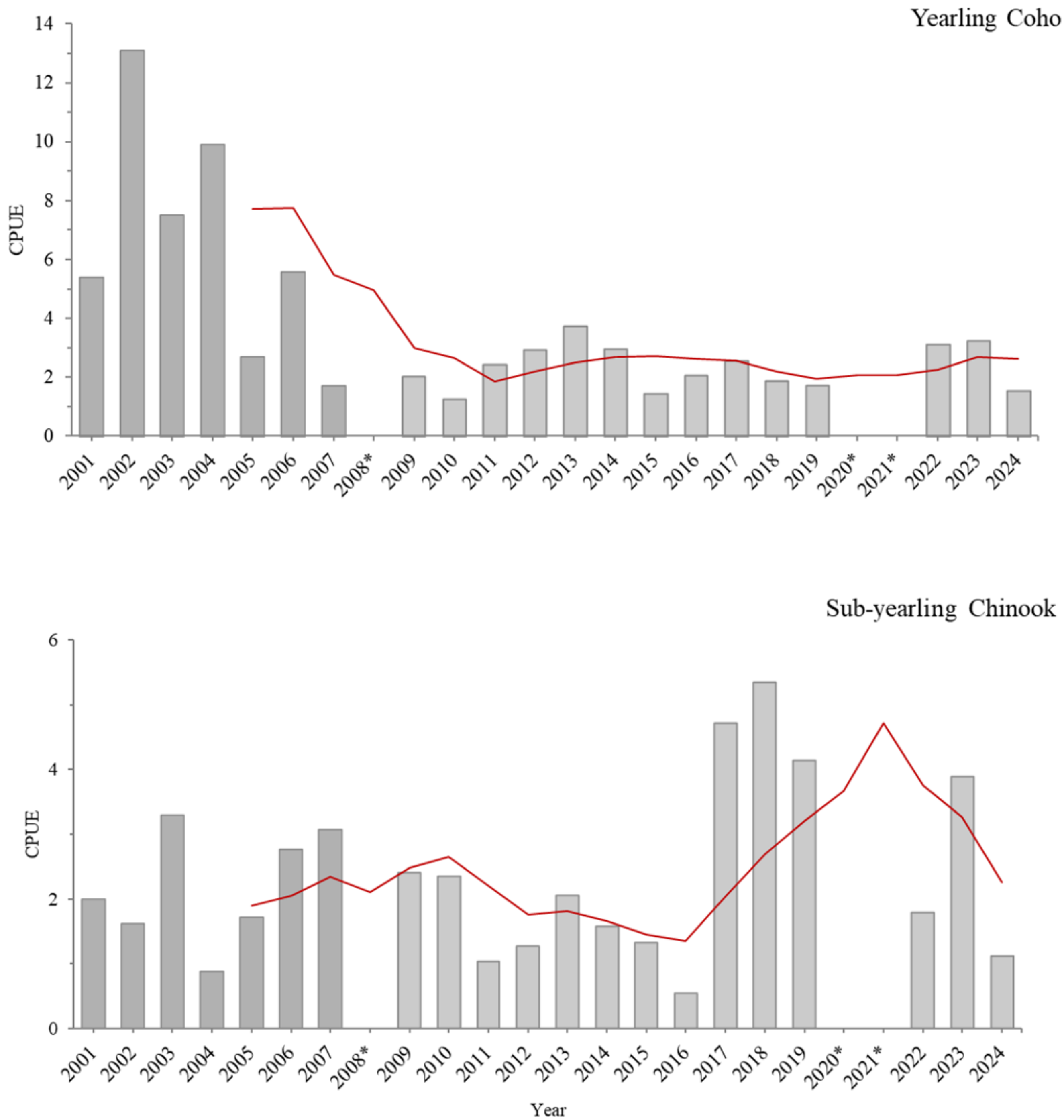

Figure 4. Natural-origin sub-yearling Chinook Salmon and yearling Coho Salmon CPUE time series at the Skykomish trap by year: 2000-2007 (River mile 23); 2009-2024 (River mile 26.5). The years 2008, 2020 and 2021 are not included due to missing or limited sampling seasons. The red line shows the 5-year moving average for CPUE.

PRODUCTION ESTIMATES

Production in this report refers to the abundance of out-migrating salmon at the trap site. Our traps catch around one to three percent of the emigrating salmon and this proportion is known as trap efficiency. In order to estimate the total number of fishes passing the trap, we use the efficiency to expand the catch. Trap efficiency is estimated using mark-recapture efficiency trials where marked fish are released upstream of the trap weekly and those recaptured are tallied (see details in the efficiency section of this report).

Our database was cleaned and this season's data has been uploaded into SQL. Over the coming year, we will clean and upload previous years' data. We transitioned to a new production estimate model, a Bayesian time-stratified Petersen estimator that relies on a hierarchical, semi-parametric model with penalized spline (P-spline) smoothing to estimate production during sampled and un-sampled strata. Posterior distributions are modelled in Just Another Gibbs Sampler (JAGS) software using Markov chain Monte Carlo (MCMC) simulations. Studies have shown Bayesian inference models to be the best fit when trap efficiencies are too variable to pool, when there are strata with minimal efficiency data, and when there are trap outages (Schwarz et al. 2009, Bonner and Schwarz 2011, Oldemeyer et al. 2018). This model also provides statistically robust imputations of production and efficiency during un-sampled periods.

Our trap efficiency values tend to exhibit too much heterogeneity to apply a pooled Petersen estimator. Pooling efficiencies would introduce bias given the variability in efficiency test values. Time-stratified Petersen estimators assume homogeneity within each stratum, so efficiency testing must be conducted consistently to avoid bias. Simple Petersen estimators can be a decent option when efficiency testing is done regularly throughout the season, but due to constraints around river size and hatchery releases, this would be highly challenging on the Skykomish River. Simple Petersen estimates do not account for variance in efficiency testing, so it is likely that these models are underestimating uncertainty. Comparisons of mark-recapture estimators have shown that Bayesian inference models provide a higher level of precision compared to pooled or stratified Petersen estimates and also give more accurate estimates of uncertainty (Bonner and Schwarz 2011, Oldemeyer et al. 2018).

Production estimates are modeled using the Bayesian Time-Stratified Population Analysis System (BT-SPAS) R package, version 2021.11.02 (available at www.github.com/cschwarz-stat-sfu-ca/BTSPAS). We use the diagonal model with three chains, iterations are set at 200,000, burn in period is 100,000 and 6,000 iterations are saved, which makes the thin rate 50. Bayesian inference allows us to use credible intervals, so we report a 95% credible interval, which means that actual production has a 95% probability of being within the interval. This provides an easily understandable measure of uncertainty. For our point estimates, we use the median values of the posterior distribution since the distributions are log-normal with asymmetric tails. Our 95% credible interval is bounded by the 2.5th and 97.5th percentiles. Model convergence and mixing is checked using trace plots and by checking the autocorrelation. Brooks-Rubin-Gelman statistic values are calculated and kept under 1.1. If the model does not converge sufficiently, we increase the iterations and burn-in period. Goodness of fit is checked using deviance information criterion as well as Freeman-Tukey and deviance statistic plots. Splines are split using the "jump after" function whenever catch numbers jump up or down rapidly and if it improves the fit.

Each Julian week is stratified into day and night periods, defined by sunrise and sunset times in Monroe, WA. This diurnal stratification is used because catch rates suggest differences in migration behavior and/or trap efficiency between day and night periods. Since we do not sample continuously, we must expand the trap catch to estimate the total number of fishes that would have been caught for each Julian week and diel stratum. Daytime catch is expanded into unsampled daytime strata and nighttime catch is expanded into unsampled nighttime strata. This expansion is done by dividing the catch by the proportion of the week sampled with the following formula:

$$\hat{C}_{ix} = n_{ix} / f_{ix} \qquad (1)$$

where

$\hat{C}_{ix}$ = estimated catch for diel stratum x during week i
n_{ix} = catch for diel stratum x during week i
f_{ix} = proportion of diel stratum fished during week i.

This expansion assumes that catch rates are similar during sampled and unsampled periods. In order to avoid violating this assumption, we reject some sampling events that are less than four hours if they occur during a time that could bias catch rates. For example, if a sampling event was only three hours long and occurred immediately before sunset, we would reject it because the catch rate is likely higher around sunset than the rest of the day. Occasionally, we don’t reject these short effort events when recent surveys balance out the times sampled. Also, weeks with low effort are rejected since it is less likely that catch rates remained the same throughout the entire week. It is important to separate day and night strata before making this expansion, but once the expansion is done, catch during the two diel strata are summed so that a total catch for each week can be input into the production model. With our previous model, we were able to calculate the variance in this expansion, but we currently are not able to incorporate it into our credible interval estimate. We think that with our dataset, it is more important to account for the variance in efficiency testing than the variance in this expansion since the efficiency testing is a much larger source of variance.

The coefficient of variation (CV) is calculated by dividing the posterior standard deviation by the mean. Since the posterior standard deviation is drawn from a probability density, CV in BT-SPAS is a direct measure of uncertainty in the parameter value, rather the more commonly used classical inference CV, which is a measure of the variance in estimate values if the experiment were repeated many times. This Bayesian version of CV provides a more intuitive metric for interpreting uncertainty.

Natural-Origin Sub-Yearling Chinook Salmon

Based on our data and findings from other Puget Sound trapping studies, we assume that the sub-yearling Chinook Salmon emigration begins in Julian week 1 and concludes by week 30 (Conrad and MacKay 2000; Seiler et al. 2002; Lisi 2019; Topping and Anderson 2021b). Although we do not sample during the very start and end of the migration period, the BT-SPAS package is capable of inferring production for these unsampled weeks. To improve MCMC convergence and ensure our estimates taper to zero at the season’s boundaries, we input catch values of one for Julian weeks 1 and 30, as well as for some adjacent unsampled weeks (Carl Schwarz, personal communication).

In 2024, we estimate that approximately 152,464 natural-origin sub-yearling Chinook Salmon emigrated past our trap site on the Skykomish River. This estimate is significantly below the project average of 393,221, representing roughly 39% of the long-term average. While slightly lower than the decreases in catch and CPUE (45% and 47%, respectively), this estimate is considered reasonable (Table 3). The discrepancy is likely due to the production model's use of weekly efficiencies throughout the season rather than assuming a constant CPUE. The CV (a measure of uncertainty, where lower values indicate greater reliability) for the 2024 estimate is 0.15, which is below the project average and reflects high confidence in the model's estimates.

Table 3. Natural-origin sub-yearling Chinook Salmon production estimates in the Skykomish River, 2001-2024.

Migration Year	Production Estimate	2.5% Credible Interval	97.5% Credible Interval	Coefficient of Variation (CV)
2001	375,060	261,643	638,483	0.26
2002	405,924	307,717	552,788	0.15
2003	636,143	452,850	942,176	0.19
2004	248,020	165,738	363,986	0.20
2005	296,236	202,722	482,705	0.24
2006	510,128	302,321	827,053	0.25
2007	364,439	213,834	750,146	0.44
2008[a]				
2009	252,074	151,590	503,704	0.37
2010	560,966	350,573	1,127,872	0.39
2011	241,483	154,529	386,676	0.25
2012	155,966	121,638	250,867	0.21
2013	530,655	366,065	803,224	0.21
2014	255,309	203,401	338,638	0.13
2015	157,208	134,528	187,572	0.08
2016	151,339	121,230	199,080	0.14
2017	996,899	724,979	1,514,165	0.20
2018	686,634	524,215	1,002,894	0.18
2019	553,375	441,194	728,195	0.13
2020[b]				
2021[c]	399,128	265,730	654,917	0.24
2022	289,279	225,750	390,241	0.15
2023	432,124	356,859	565,876	0.12
2024	133,570	98,139	183,521	0.16
Average	**393,221**	**280,188**	**609,954**	**0.21**

a = Trap repairs/ moved trap site
b = Covid-19 shut down
c = Low confidence due to low effort

Before 2017, production estimates showed a gradual long-term decline, reaching a project low in 2016 (Figure 5, Table 3). This was followed by a record peak in 2017, the highest estimated emigration on record, and then a gentle downward trend from 2017 to 2022, with average estimates and no major fluctuations. Last year's production estimates were above-average values that aligned with previous years. This season, however, we observed a sharp decline, resulting in our second-lowest recorded out-migration since 2001 (only lower in 2016; Table 3, Figure 5). In 2024, production peaked in julian weeks 12-13, with the majority of out-migration occurring between Julian weeks 11 and 16 (Figure 6).

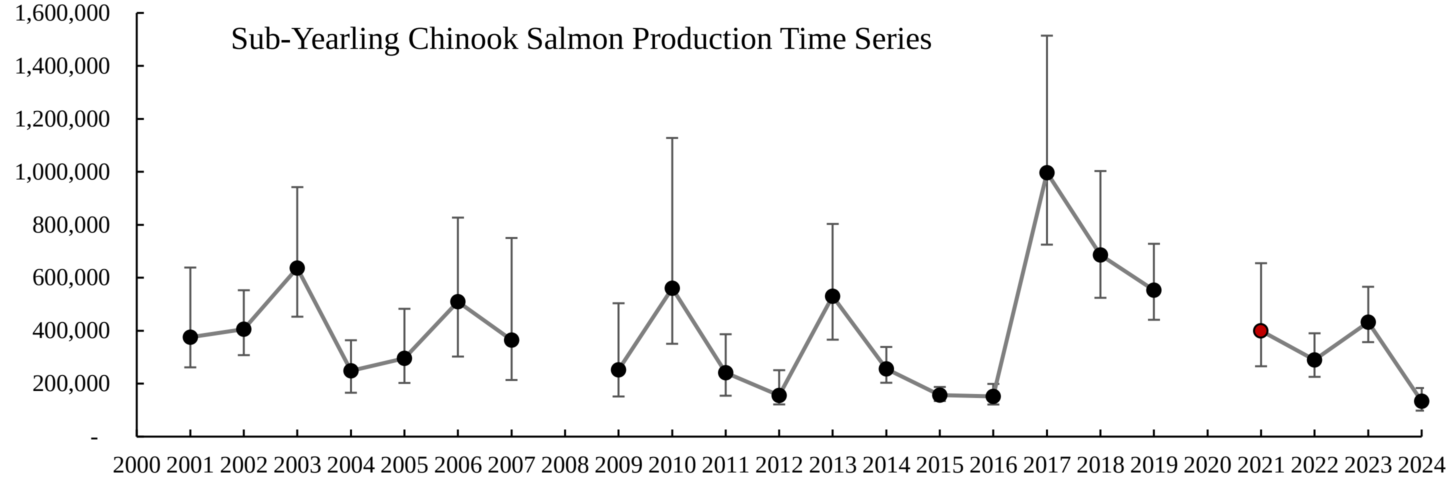

Figure 5. Natural-origin sub-yearling Chinook Salmon production estimates for the Skykomish River, 2001-2024. Error bars represent the 95% credible interval range. Red dot indicates that the production estimate has low confidence due to low effort for that year. Data is missing for 2020 due to Covid-19.

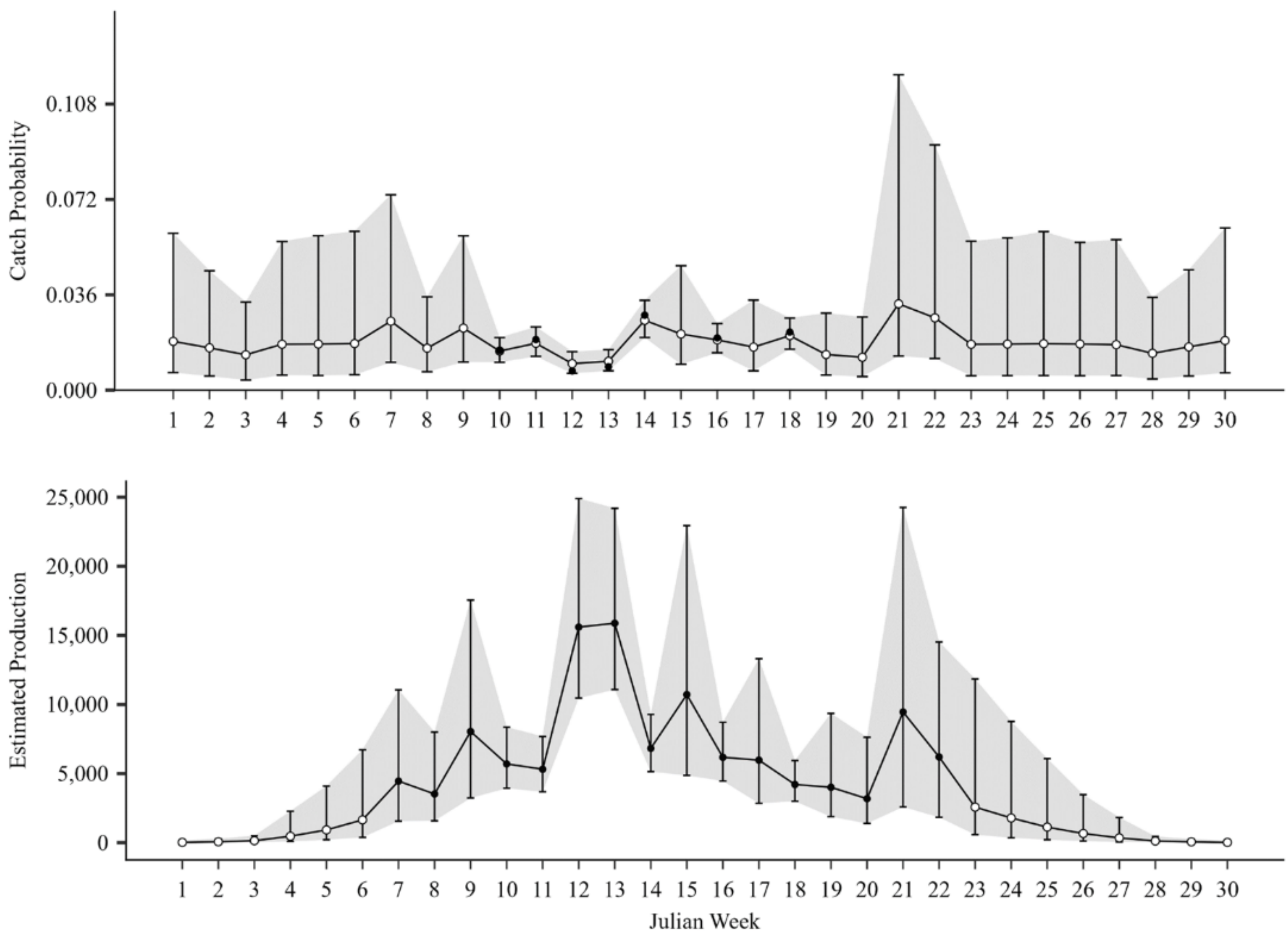

Figure 6. Natural-origin sub-yearling Chinook Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Skykomish River, 2024. Shaded areas represent the credible intervals. In the catch

probability plot, closed circles represent actual efficiency tests values, while open circle values represent modeled ones. In the production estimate plot, open circles represent unsampled weeks and closed circles represent sampled weeks.

Natural-Origin Yearling Coho Salmon

For yearling Coho Salmon, we assume emigration begins in Julian week 7 and ends by Julian week 26, with no migration expected in Julian week 6 or Julian week 27. In 2024, we estimate that approximately 522,860 natural-origin yearling Coho Salmon emigrated past our trap site on the Skykomish River. This production estimate is below the average of 599,647 and represents about 87% of the project's overall average since the trap was relocated upstream in 2009 (Table 4, Figure 7). Yearling Coho production has remained relatively stable throughout the project, with some year-to-year variability (Figure 7). The CV—a measure of uncertainty, where lower is preferable—for the 2024 estimate is slightly above the project's average but still an improvement over last season. The elevated CV likely resulted from uncertainty caused by having only one efficiency test, conducted in Julian week 22; this test was also applied to Julian week 21 to meet the BT-SPAS model's requirement for at least two efficiency measurements. The low number of efficiency tests puts a large caveat on these production estimates and indicates that the credible interval is likely larger than estimated. A simple Petersen estimate was also run with an efficiency of 0.66% (efficiency from julian week 20) and a production estimate of 579,063 was determined. This estimate is higher than what was predicted from the BT-SPAS model but within the credible interval.

The peak of natural-origin Coho Salmon out-migration occurred between Julian weeks 17 and 22, aligning with trends observed in previous years (Figure 8).

Table 4. Natural-origin yearling Coho Salmon production estimates in the Skykomish River, 2001-2024.

Migration Year	Production Estimate	2.5% Credible Interval	97.5% Credible Interval	Coefficient of Variation (CV)
2001	1,115,611	646,091	2,378,896	0.44
2002	1,935,526	1,298,266	2,998,647	0.22
2003	1,354,132	877,320	2,166,201	0.23
2004	2,571,352	1,468,705	4,511,959	0.29
2005	568,995	287,081	1,275,233	0.44
2006	1,361,263	816,160	2,432,828	0.31
2007	118,470	63,669	222,453	0.33
2008[a]				
2009	349,263	243,846	544,168	0.22
2010[b]	772,624			
2011	405,037	294,504	577,755	0.18
2012	573,537	402,180	821,050	0.18
2013	801,396	634,454	1,031,667	0.13
2014	1,072,216	761,702	1,664,305	0.21
2015	232,056	167,879	377,597	0.23
2016	461,968	368,178	601,446	0.13
2017[b]	564,303			
2018	611,173	428,699	921,904	0.20
2019	332,160	271,065	417,316	0.11
2020[c]				
2021[d]				
2022	819,926	539,698	1,463,905	0.29

2023	876,537	446,146	1,696,272	0.45
2024	522,860	308,850	892,606	0.28
Average (2009-2023)	**599,647**	**405,600**	**917,499**	**0.22**

a = Trap repairs/ moved to new site

b = Insufficient efficiencies, used simple Petersen with five-year mean of efficiencies

c = Covid-19 shut down

d = Sampling stopped due to LWD jam above trap

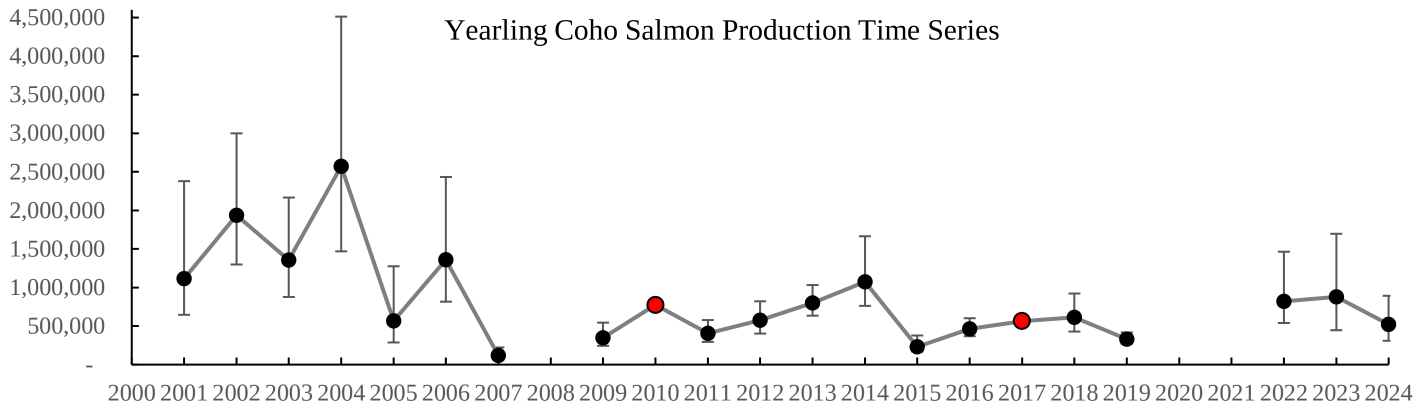

Figure 7. Natural-origin yearling Coho Salmon production estimates for the Skykomish River, 2001-2024. Red dots indicate years that used simple Petersen estimates with five-year means of efficiencies due to a lack of efficiency testing. Error bars

represent the 95% credible interval range.

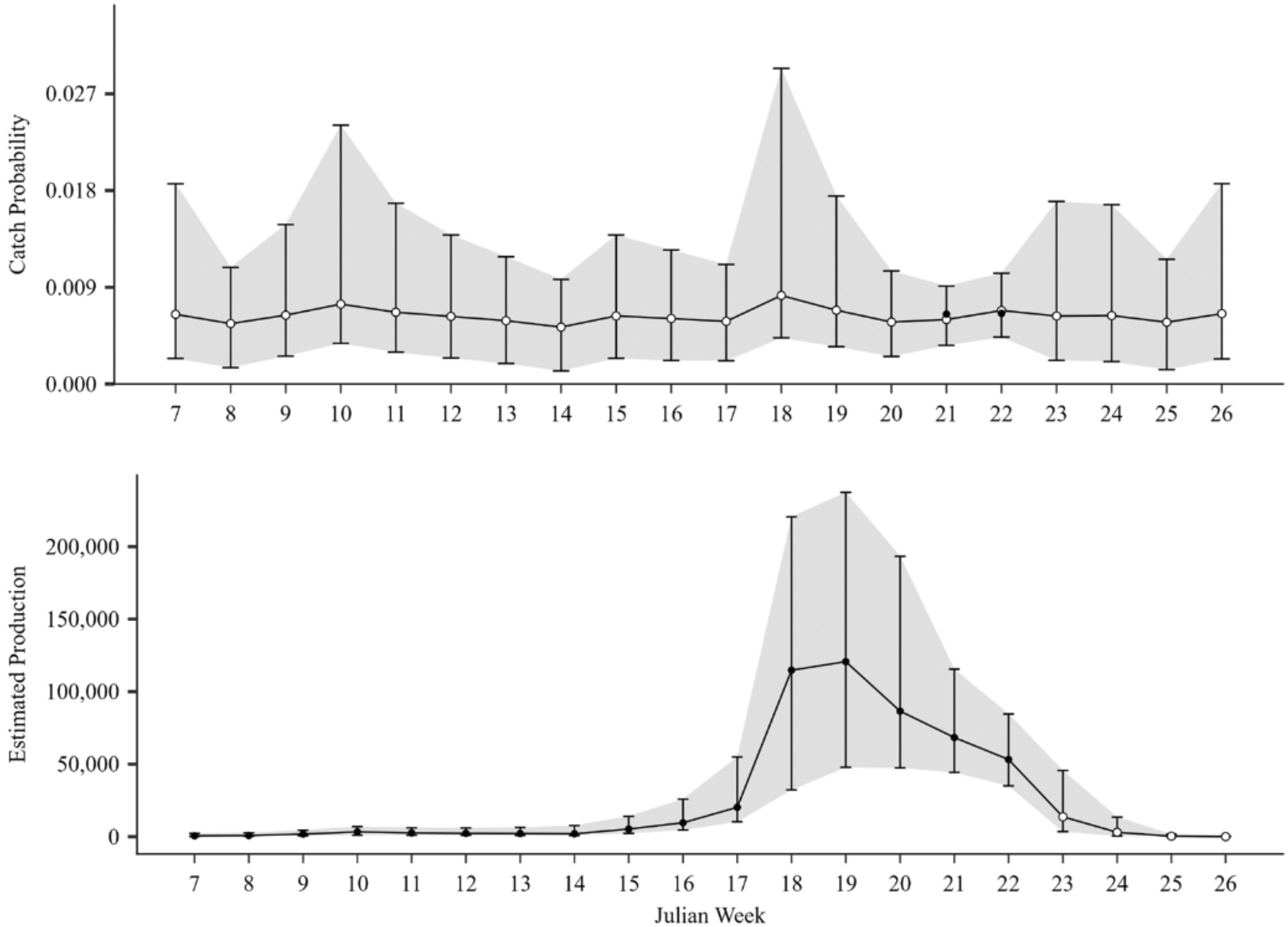

Figure 8. Natural-origin yearling Coho Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Skykomish River, 2024. Shaded areas represent the credible intervals. In the catch probability plot, closed circles represent actual efficiency tests values, while open circle values were modeled. In the production estimate plot, open circles represent unsampled weeks and closed circles represent sampled weeks.

EFFICIENCY TESTING AND RESULTS

During the 2024 season, trapping equipment was inspected and monitored frequently and the trap was found to be in full operational condition with almost no escape paths detected. Occasional bearing malfunctions slowed the screw trap rotations to 2-3 rpm (6 rpm is desired) in April which likely caused reduced efficiency during these instances. Efficiency releases were conducted weekly throughout the duration of the sampling season while hatchery Chinook and Coho Salmon were available. In May, high river flows caused efficiency releases to be canceled until May 28th. During these tests, groups of hatchery-origin juvenile salmon were collected from Wallace River Hatchery, marked and released approximately one mile upstream of the trap site.

The trap was operating at an average efficiency rate of 1.72% for Chinook Salmon sub-yearlings. The single test for Coho yearlings had an efficiency of 0.66% during the 2024 sampling season (Table 5). Efficiency tests were rejected if the efficiency was less than 0.3% for Coho Salmon or less than 0.4% for Chinook Salmon. Tests that fall below this threshold are deemed not representative of the actual trap efficiency; no tests fell below the threshold this season. Yearling Coho typically have less efficiency than sub-yearling Chinook due to their larger size and ability to avoid the screw trap.

Table 5. Efficiency Release dates, species, and capture percentages for the Skykomish River smolt trap, 2024.

Species	Date	Released	Captured	Efficiency
0+ Chinook	3/5/2024	2070	31	1.50%
0+ Chinook	3/13/2024	1830	35	1.91%
0+ Chinook	3/19/2024	1778	13	0.73%
0+ Chinook	3/27/2024	2147	19	0.88%
0+ Chinook	4/2/2024	1871	53	2.83%
0+ Chinook	4/16/2024	1924	38	1.98%
0+ Chinook	4/30/2024	2005	44	2.19%
1+ Coho	5/28/2024	2131	14	0.66%
	2024 Average Chinook Efficiency			**1.72%**
	2024 Average Coho Efficiency			**0.66%**

red = Efficiency too low (Coho <0.3; Chinook <0.4) for production modelling.

GENETIC MONITORING

Along with estimating natural production, the rotary screw trap provides an efficient way to gather genetic samples from juvenile salmonids and monitor the run timing of hatchery-origin fish. We take small fin clips from natural-origin Chinook Salmon and steelhead (*Oncorhynchus mykiss*). The steelhead samples are used to monitor the proportion of effective hatchery contribution (PEHC) in natural-origin steelhead. This research is conducted by Bethany Craig, Joseph Anderson, Ken Warheit and Todd Seamons from the Washington Department of Fish and Wildlife.

The Chinook Salmon genetic samples are used for genetic monitoring by the Tulalip Tribes' stock assessment program. These samples are genotyped to estimate relative productivity and gene flow between hatchery and natural-origin fish and to compare genetic estimates to demographic-based estimates of the proportion of hatchery-origin fish spawning naturally ($pHOS_{G,D}$) and proportion of natural influence ($PNI_{G,D}$) estimates. Additionally, Chinook from 19 spawning cohorts across the basin are genotyped to assess population structure, run timing markers, effective population size and the effective number of breeders by origin, time, and location.

DISCUSSION

This year's fishing effort of 826 hours was below the project average of 882 (Table 2) because the final few weeks of the sampling season were cancelled due to safety issues caused by high flows. It is likely that cancelations due to flooding caused us to miss the final pulse of out-migrating fish, but our new production model provides more robust imputation for these unsampled periods. The shortage of Coho Salmon efficiency tests contributed to somewhat higher uncertainty in our Coho Salmon production estimate. In previous years, Coho efficiency releases had large variability in catch rate and ranged from 2% to 0%. Our efficiency for this year is likely slightly lower than previous years but within a reasonable range. Aside from the aforementioned scheduling difficulties, all trapping equipment including the trap itself, the boat, and all associated supplies were in full working order and operated as expected for the 2024 trapping season.

Chinook Salmon natural production estimates have not shown a clear trend over the last twenty years, and escapement estimates still remain far below recovery goals (Snohomish County 2019). This year showed a near record low in Chinook out-migration and a sharp decline in abundance compared to previous years. Variability in abundance and cohort strength is common among fish during their early life stages, as high mortality rates are typical. However, it is crucial to investigate whether these declines are further intensified by human activities or natural events. While this decline could be caused by a multitude of factors, high flows in early winter could have contributed to significant red scour and egg mortality.

In December 2023, the Skykomish River experienced a major flood event, reaching a flow rate of over 50,000 CFS, which likely impacted the number of fishes captured in the screw trap. Embryo mortality from stream bed scour is dependent on timing of floods, location of spawning, and egg burial depths (Goode et al. 2013). Winter floods are especially harmful to fall spawners as their eggs are incubating in the streambed during this time. In snowmelt basins, fall spawners could also be at high risk as climate warming increases the quantity of rainfall and the frequency and magnitude of winter floods (Goode et al. 2013). While high-flow events like the one in December are unavoidable, enhancing habitat within the river could be a critical step in mitigating their effects. Recent research has shown that floodplain reconnection, barrier removal, bank armor removal, wood augmentation, estuary restoration and shade restoration could greatly improve salmonid productivity in the Snohomish Basin (Beechie et al. 2023). Improvements in juvenile salmon rearing habitat would greatly contribute to the recovery of threatened salmon and steelhead populations in the Skykomish River.

It is important to note that we caught much fewer hatchery-origin Chinook in the screw trap this season. It is possible that the unusually low numbers for Chinook are caused by poor catch efficiency due to several high flow events that coincided with hatchery releases. At the end of the season, trapping efforts ended early due to high flows right before the largest Chinook release from the Wallace River Hatchery. This release is usually when the majority of hatchery fish are caught in the season and likely an explanation for why the hatchery numbers are so low compared to previous years.

We estimate that natural-origin yearling Coho Salmon production was slightly below average in 2024 but we did not observe the sharp decline in abundance that sub-yearling Chinook experienced. Sampling years 2022 and 2023 had a much higher production estimate but when we look across the project period (2001-2024) this year's production remains within normal variation. Conducting more yearling Coho efficiency testing in the future should make our credible intervals narrower but will require new strategies for transporting and releasing fish of that size. Overall, our reported estimates appear to align well with Coho Salmon escapement estimates in the Snohomish basin, when adjusted for brood year (Pacific Fishery Management Council 2019; Snohomish County 2019).

For the 2024 season, our primary goal was to enhance consistency in release sites and increase the number of fishes released to reduce variability in the efficiency rates. While we succeeded in improving consistency for efficiency releases, further improvements in our Coho release methods are needed. It is important to highlight that the Skykomish River experienced unusually high flows toward the end of the season, which led to the cancellation of several Coho releases. Additionally, high mortality during yearling Coho releases remains a significant concern, directly affecting our efficiency rates. Looking ahead, our objective for the upcoming year is to maintain consistent sub-yearling Chinook releases while increasing the number of Coho releases to reduce uncertainty in yearling Coho production.

REFERENCES

Anderson, J. H., P. C. Topping. 2017. Juvenile life history diversity and freshwater Productivity of Chinook Salmon in the Green River, Washington. North American Journal of Fisheries Management 38:180-193.

Beechie, T. J., A. Goodman, O. Stefankiv, B. Timpane-Padgham and M. Lowe. 2023. Habitat Assessment and Restoration Planning (HARP) Model for the Snohomish and Stillaguamish River Basins. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC_CR_2023_02.

Bonner, S. J. 2008. Heterogeneity in capture-recapture Bayesian methods to balance realism and model complexity. PhD thesis. Simon Frasier University, Burnaby, British Columbia.

Bonner, S. J., Schwarz, C. J. 2011. Smoothing population size estimates for time-stratified mark-recapture experiments using Bayesian p-splines. Biometrics 67, 1498-1507.

Conrad, R. H. and M. T. MacKay, 2000. Use of a rotary screw trap to monitor the out-migration of Chinook salmon yearlings from the Nooksack River: 1994-1998. Northwest Fishery Resource Bulletin, Project Report Series No. 10., Olympia WA.

Crewson, M. and M. Alexandersdottir. 2022. Recent productivity of Skykomish and Snoqualmie natural origin Chinook Salmon (*Oncorhynchus tshawytscha*). The Tulalip Tribes Natural Resources Department, Tulalip, WA.

Flagg, T. A., E. F. Prentice, and L.S. Smith. 1983. Swimming stamina and survival following direct seawater entry during parr-smolt transformation of coho salmon (*Oncorhynchus Kisutch*). Aquaculture. 32:383-39.

Goode, J.R., Buffington, J.M., Tonina, D., Isaak, D.J., Thurow, R.F., Wenger, S., Nagel, D., Luce, C., Tetzlaff, D., Soulsby, C., 2013. Potential effects of climate change on streambed scour and risks to salmonid survival in snow-dominated mountain basins. Hydrological Processes 27, 750–765. https://doi.org/10.1002/hyp.9728

Kinsel, C., M. Zimmerman and G. Vokhardt, L. Kishimoto, and P. Topping. 2007-2008. Years 2006-2007. Two annual reports. Skagit River Wild Salmon Production Evaluation Annual Report. Washington Department of Fish and Wildlife, Olympia, WA.

Kubo, J., Finley, K., Nelson K. 2013. 2000-2012 Skykomish and Snoqualmie Rivers Chinook and Coho Salmon Out-Migration Study. Tulalip Tribes Natural Resource Division, Tulalip WA.

Lisi, P. 2019. Evaluation juvenile salmon production in 2018 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife, Olympia, WA.

Lisi, P., J. Anderson, T. Zackey, M. Pouley, E. Seay, J. Keith, K. Nelson, J. Griffith, K. Konoski, C. Scofield, A. Voloshin, A. Berger, M. McHenry, M. Elofson, M. Liermann, G. Pess, P. Topping, C. Kinsel, M. Klungle, A. Lindquist, and J. Weinheimer. 2022. Synchrony of freshwater and marine survival among Chinook salmon populations in Puget Sound. Report submitted to Puget Sound Partnership, under the Puget Sound Ecosystem Monitoring Program.

Montgomery, D. R., J. M. Buffington, N. P. Peterson, D. Schuett-Hames, and T. P. Quinn. 1996. Stream-bed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences, 53:5, 1061-1070

Nikl, D. l. and A. P. Farrell. 1993. Reduced swimming performance and gill structural changes in juvenile salmonids exposed to 2 (thiocyanomethylthio) benzothiazole. Aquatic Toxicology. 27:245-264.

Oldemeyer, B. N., T. Copeland, and B. P. Kennedy. 2018. A multiyear hierarchical Bayesian mark-recapture model incorporating data on recurring salmonid behavior to account for sparse or missing data. National Marine Fisheries Service. Fisheries Bulletin 116:254-265.

Pacific Fishery Management Council. 2019. Salmon Rebuilding Plan for Snohomish River Natural Coho. 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Schwarz, C.J., D. Pickard, K. Marine and S.J. Bonner. 2009. Juvenile Salmonid Outmigrant Monitoring Evaluation, Phase II. December 2009. Final Technical Memorandum for the Trinity River Restoration Program, Weaverville, CA.

Seiler, D., L. Kishimoto, and S. Neuhauser. 1998-2004. Years 1997-2003. Six annual reports. Skagit River wild 0+ Chinook production evaluation, annual report. Washington Department of Fish and Wildlife, Olympia, WA.

Snohomish Basin Salmon Recovery Forum. 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division. Everett, WA.

Snohomish County. 2019. Snohomish River Basin – Salmon Conservation Plan Status and Trends. Snohomish County Department of Public Works, Surface Water Management Division. Everett, WA.

Topping, P. and J. Anderson. 2021, 2021b. Years 2019-2020. Two annual reports. Green River juvenile salmonid production evaluation. Washington Department of Fish and Wildlife, Olympia, WA.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 in D. H. Johnson, and coeditors, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Voloshin, A., C. Scofield and J. Griffith. 2022. Mainstem Stillaguamish River smolt trapping project 2021 annual report. Stillaguamish Tribe of Indians, Arlington, WA.

Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor and D. E. Pflug. 2015. Abundance, Survival, and Life History Strategies of Juvenile Chinook Salmon in the Skagit River, Washington. Transactions of the American Fisheries Society, 144:3, 627-641

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APPENDIX A: SUMMARY OF 2024 SKYKOMISH RIVER TRAP CATCH AND MORTALITIES

	Chinook				Coho				Chum	Pink	Steelhead		Cutthroat Trout	Total Salmonid Catch	Lamprey	Dace spp.	Sculpin spp.	Sunfish spp.	Stickleback	Mountain Whitefish	Peamouth	Bass
	Unmarked		Marked		Unmarked		Marked				Unmarked	Marked										
	0+	1+	0+	1+	0+	1+	0+	1+	0+	0+	Smolts	Smolts										
February																						
Catch	104	2	0	0	4	6	0	0	220	3815	0	0	0	4151	1	4	17	0	0	0	0	0
Mortalities	0	0	0	0	0	0	0	0	2	26	0	0	0	28	0	0	0	0	0	0	0	0
March																						
Catch	246	0	0	0	87	36	0	0	13643	49555	3	1	0	63571	3	36	24	0	0	1	0	0
Mortalities	0	0	0	0	0	0	0	0	4	65	0	0	0	69	0	0	0	0	0	0	0	0
April																						
Catch	244	12	7	283	143	282	3	0	2080	61207	6	178	0	64445	3	42	9	0	1	0	0	0
Mortalities	0	0	0	0	0	0	0	0	1	137	0	0	0	138	0	0	0	0	0	0	0	0
May																						
Catch	187	1	0	0	221	955	0	1048	25	1773	12	25	1	4248	7	42	7	1	0	1	1	1
Mortalities	3	0	0	0	4	0	0	0	1	2	0	0	0	10	0	0	0	0	0	0	0	0
Total																						
Catch	781	15	7	283	455	1279	3	1048	15968	116350	21	204	1	136415	14	124	57	1	1	2	1	1
Mortalities	3	0	0	0	4	0	0	0	8	230	0	0	0	245	0	0	0	0	0	0	0	0
% Mortalities	0.38	0	0	0	0.88	0	0	0	0.05	0.20	0	0	0	0.18	0	0	0	0	0	0	0	0