Tulalip Tribes Natural Resources Department Report

SKYKOMISH RIVER JUVENILE SALMON OUT-MIGRATION STUDY PROGRESS REPORT

February – June 2022

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ACKNOWLEDGEMENTS

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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 manage salmon recovery.

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 mostly on Chinook and Coho Salmon because recovery efforts targeted at these species will also help other federally listed salmonid stocks in the watershed.

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.

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 from the ocean 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 level and approaches ~18.5 ft. at bank full depth. Summer low-flow at this location is ~3,030 cubic feet per second (CFS) and mean annual discharge is ~4,070 CFS. 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 is being purchased by the Tulalip Tribes for future stream restoration.

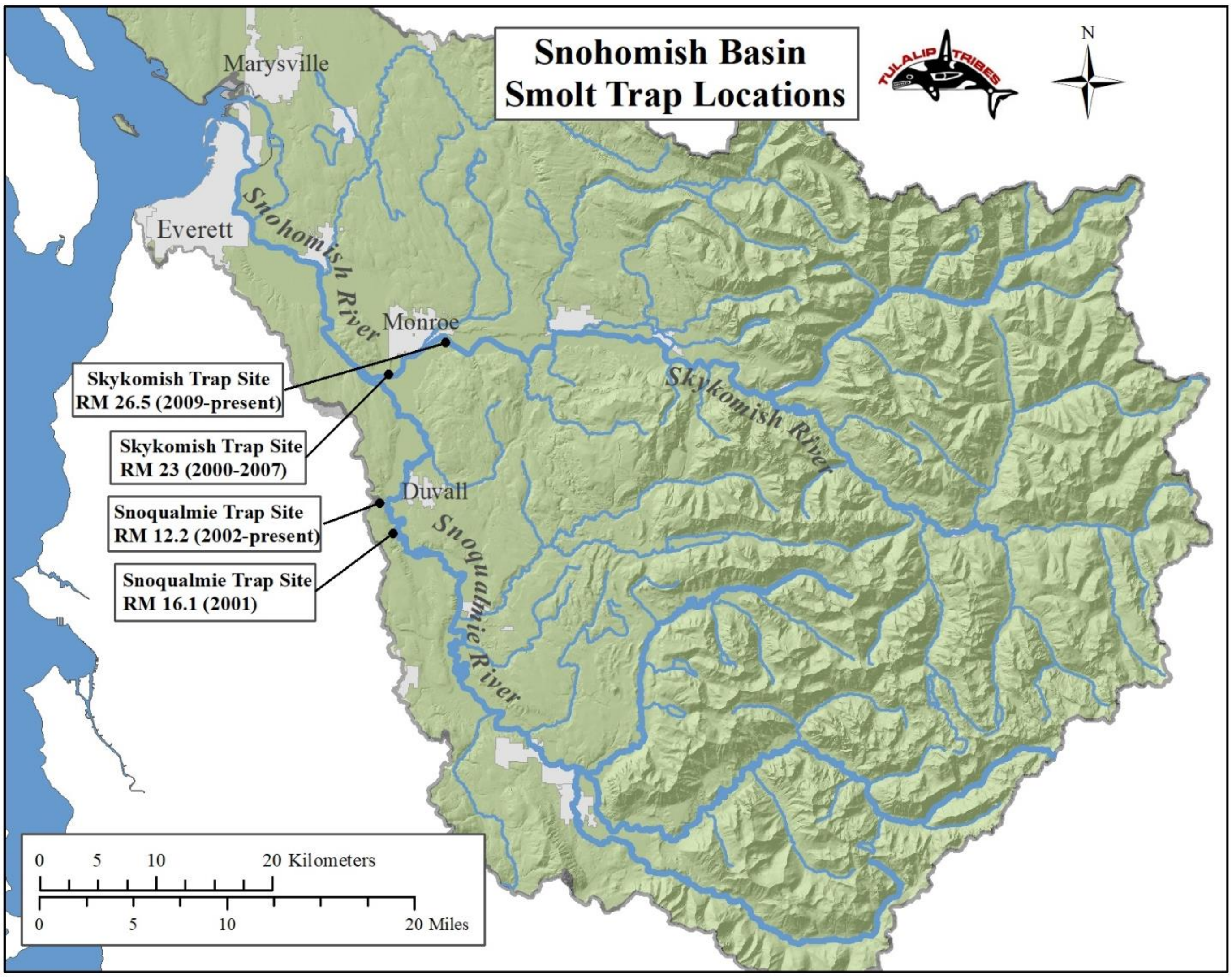

Figure 1: Map of the Snohomish watershed with the locations of the trap sites on the Skykomish and Snoqualmie Rivers.

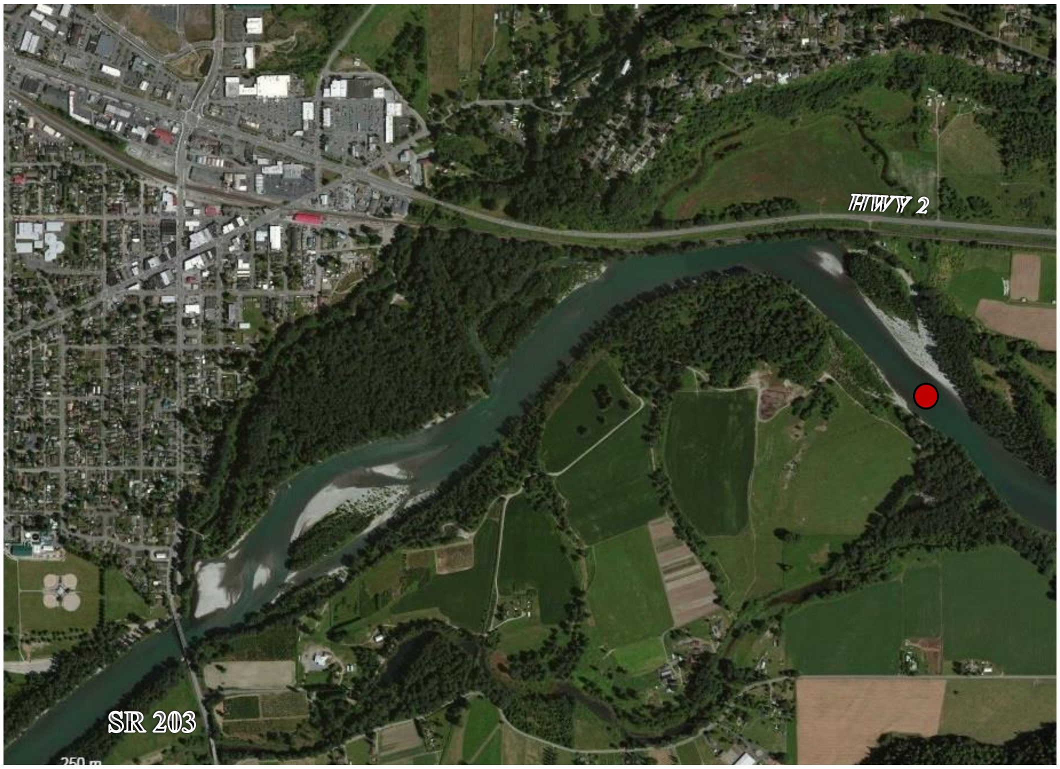

Figure 2: Aerial photograph of the trap site at river mile 26.5 on the Skykomish River. The red dot indicates the approximate trap fishing position.

Summary of Sampling Operations

The Skykomish River rotary screw trap is operated during the juvenile salmon outmigration from February through June. Sampling occurs on four to five weeknights and one or two weekdays per week. Sampling dates are stratified by Julian week (JW) in order to more accurately compare results from year to year. Table 1 shows the Julian weeks that were sampled in 2022 and the corresponding dates. In 2022, trapping was conducted from February 3rd to June 22nd (JW 5- JW 25). Normally, sampling occurs from JW 7 to JW 25 with some variability in timing. Sampling was started early in 2022 in order to improve Chinook Salmon production estimates. In 2022, the trap was operated for 925 hours, which is above the average effort of 823 hours (Table 2). Of those hours, 550 were fished at night, representing 68% of the total trapping effort. Sampling had to be cancelled on Julian weeks 10, 23 and 25 due to safety hazards caused by large flood events. These floods were large enough to necessitate the removal of the trap support lines, which would have hung dangerously close to the river.

Table 1. Julian weeks and corresponding dates for 2022 sampling season.

Julian Week	From	To
5	1/28	2/3
6	2/4	2/10
7	2/11	2/17
8	2/18	2/24
9	2/25	3/3
10	3/4	3/10
11	3/11	3/17
12	3/18	3/24
13	3/25	3/31
14	4/1	4/7
15	4/8	4/14
16	4/15	4/21
17	4/22	4/28
18	4/29	5/5
19	5/6	5/12
20	5/13	5/19
21	5/20	5/26
22	5/27	6/2
23	6/3	6/9
24	6/10	6/16
25	6/17	6/23

A detailed summary of catch numbers by month can be found in Appendix A. During the sampling season, a total of 216,777 salmonids were captured. Captured unmarked Chinook Salmon included 1652 sub-yearlings (0+) and 17 yearlings (1+). The number of 0+ Chinook Salmon caught at the Skykomish River trap in 2022 was slightly below the project average of 1,920 (Table 2). Captured unmarked Coho Salmon included 1,446 sub-yearlings and 2,879 yearlings. The number of unmarked 1+ Coho Salmon caught in 2022 (2,879) was only 86% of the project average of 3,360, but was well above the average catch since the trap was moved in 2009 (1,908). During the trapping and handling process a total of 49 salmonid mortalities were reported. The 49 mortalities included 33 unmarked Pink Salmon, two marked Chinook Salmon, two marked Coho Salmon, three Chum Salmon and nine unmarked Chinook Salmon. Seven of the nine unmarked Chinook Salmon mortalities were intentionally taken for a toxicology study. Mortality as a percentage of the total sub-yearling Chinook Salmon catch was 0.54% (Appendix A).

CATCH PER UNIT OF EFFORT (CPUE)

Catch data are converted to catch per unit effort (CPUE) for quick analyses dealing with run-timing and migration size. This allows for easier comparison of catch both within and between years. CPUE represents the number of fish caught per hour and can be averaged for a period by dividing the catch by the number of hours fished for that period. CPUE for 0+ Chinook Salmon demonstrated a likely peak in JW 12 (Figure 3). The peak CPUE for sub-yearling Chinook Salmon in 2022 was consistent with the usual emigration period between JW 11 and JW 17. The timing of the yearling Coho Salmon out-migration is more consistent from year to year, generally occurring from JW 17 to JW 21 and the peak CPUE in 2022 was exactly during this time frame (Kubo et al. 2013).

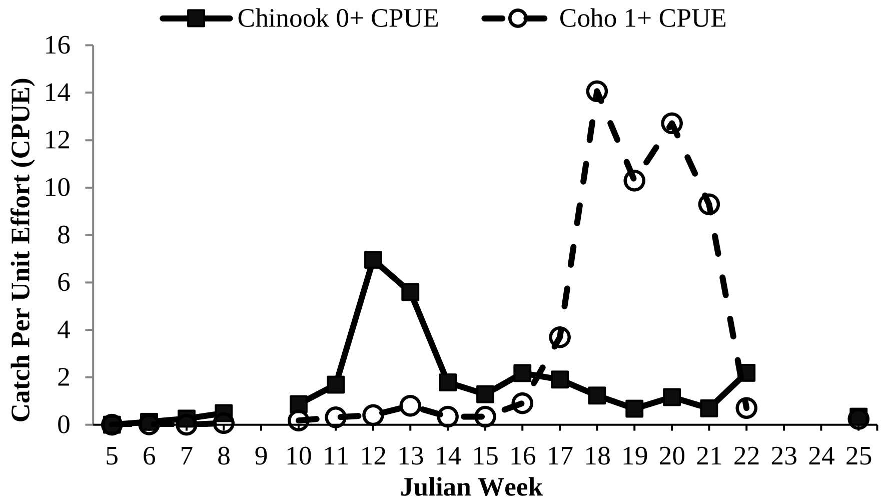

Figure 3. Natural-origin sub-yearling (0+) Chinook Salmon and yearling (1+) Coho Salmon CPUE by Julian week at the Skykomish River trap, 2022.

Average annual salmonid CPUE on the Skykomish trap has exhibited variability throughout the duration of the project due to fluctuating sampling conditions and the strength of a given year's out-migrant cohort. Average annual CPUE for sub-yearling Chinook Salmon in 2022 were below the project average (2001-2022), potentially indicating a smaller outmigration (Table 2, Figure 4 and 5). CPUE for yearling Coho Salmon in 2022 was also below average.

Table 2. Annual sampling effort and catch totals for unmarked sub-yearling Chinook and yearling Coho Salmon at the Skykomish River rotary screw trap 2000-2022.

Year	Effort (Hours)	0+ Chinook	1+ Coho	Chinook CPUE	Coho CPUE
2001	900	1786	5512	1.98	6.12
2002	671	1093	8851	1.63	13.18
2003	992	3394	8713	3.42	8.78
2004	1071	951	13949	0.89	13.02
2005	944	2411	3082	2.55	3.26
2006	1125	2928	6218	2.60	5.53
2007	446	1348	3882	3.02	8.69
2009	686	1650	1410	2.40	2.05
2010	1045	1989	1245	1.90	1.19
2011	666	765	1798	1.15	2.70
2012	1015	1323	3005	1.30	2.96
2013	1217	2446	4443	2.01	3.65
2014	888	1354	2625	1.52	2.96
2015	1078	1418	1596	1.31	1.48
2016	1031	490	2137	0.48	2.07
2017	843	3838	2154	4.55	2.55
2018	836	4407	1583	5.27	1.89
2019	985	3979	1699	4.04	1.72
2020	[a]				
2021	[b]				
2022	925	1652	2879	1.79	3.11
Average	914	2061	3567	2.31	3.90

[a] = Trapping shut down due to Covid-19

[b] = Sampling ended early due to a large tree that was lodged just upstream of the trap

Although CPUE can be used for trend detection, production estimates are better suited for this since they represent overall abundance by incorporating trap efficiency and include credible intervals. Nevertheless, it appears that Chinook Salmon CPUE was on a downward trend from 2001-2016 when it reached the project lows at approximately 0.48 fish per hour (Figure 4, Table 2). From 2017 to 2019 we saw a spike in CPUE, but 2022 had a CPUE of 0.2 fish per hour, which is near the project lows. 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 for both species following 2009 due to decreasing drainage area sampled. Woods Creek is known to have high Coho Salmon spawning activity and little Chinook Salmon spawning.

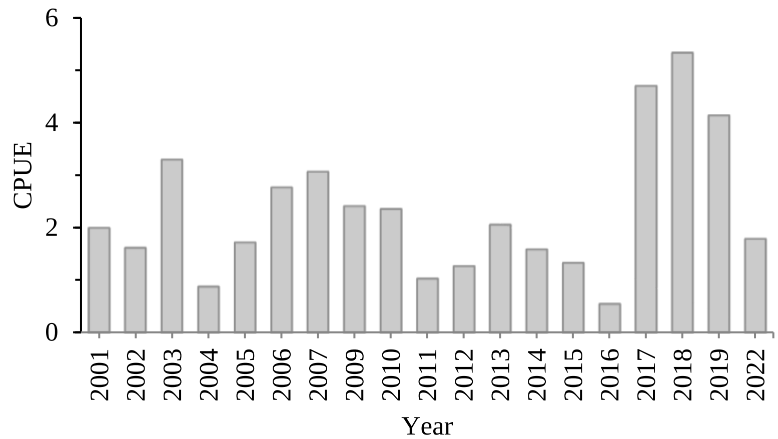

Figure 4. Natural-origin sub-yearling Chinook Salmon CPUE time series at the Skykomish trap by year; 2001-2022. The years 2008, 2020 and 2021 are not included due to missing or limited sampling seasons.

Yearling Coho Salmon catch rates were in a downtrend until 2010, when the lowest documented average CPUE of 1.19 occurred (Table 2, Figure 5). The overall decline in Coho Salmon catch rates is likely related to some degree to the relocation of the trap site to RM 26.5 in 2009 above the Woods Creek drainage, and 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. Overall, yearling Coho Salmon CPUE seems to show a general downtrend since sampling started. These fluctuations are likely influenced by interannual variance in sampling season, effort distribution, hydrologic conditions and the size of a given year's emigrating class.

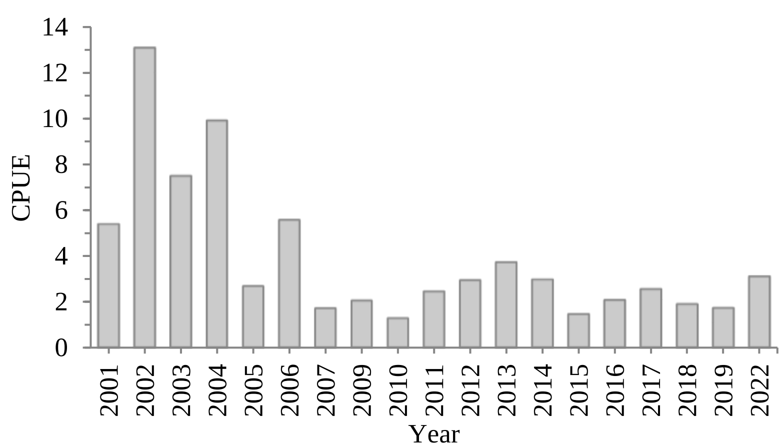

Figure 5. Natural-origin yearling Coho Salmon CPUE time series at the Skykomish trap by year; River mile 23: 2000-2007; River mile 26.5: 2009-2019. The years 2008, 2020 and 2021 are not included due to missing or limited sampling seasons.

PRODUCTION ESTIMATES

Production in this report refers to the abundance of out-migrating salmon at our trap sites. 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 fish 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 the number that are recaptured are tallied (see details in the efficiency section of this report).

This year, we transitioned to a new production estimate model in order to update our statistical methods. We cleaned the database and coded our data processing in order to recalculate all previous estimates. We now use 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 doesn't 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 don't sample continuously, we must expand the trap catch to estimate the total number of fish 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:

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

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 aren't 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 was 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 as well as those of other Puget Sound trapping efforts, we assume that the beginning and end of the sub-yearling Chinook Salmon emigration are Julian weeks 1 and 30, respectively (Conrad and MacKay 2000; Seiler et al. 2002; Lisi 2019; Topping and Anderson 2021b). Although we don't sample during the very beginning and end of the migration, the BT-SPAS package is able to impute production during these times with known certainty. In order to improve MCMC convergence and force our estimates to zero at the ends of the season, we enter catch values of one for Julian weeks one and 30 as well as for some of the adjacent un-sampled weeks (Carl Schwarz, personal communication).

In 2022, we estimate that approximately 289,279 natural-origin sub-yearling Chinook Salmon emigrated past our trap site on the Skykomish River. This production estimate is below the project average of 403,313 (Table 3).

Table 3. Natural-origin sub-yearling Chinook Salmon production estimates in the Skykomish River, 2001-2022.

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	399,128	265,730	654,917	0.24
2022	289,279	225,750	390,241	0.15
Average	*403,313*	*284,612*	*632,269*	*0.22*

[a] = Trap repairs/ moved trap site
[b] = Covid-19 shut down

There appears to be a downward trend in juvenile Chinook Salmon production since 2017, with 2017 being the largest estimated emigration on record. Before 2017, production estimates were on a slower downward trend, reaching the project low in 2016 (Figure 6, Table 3).

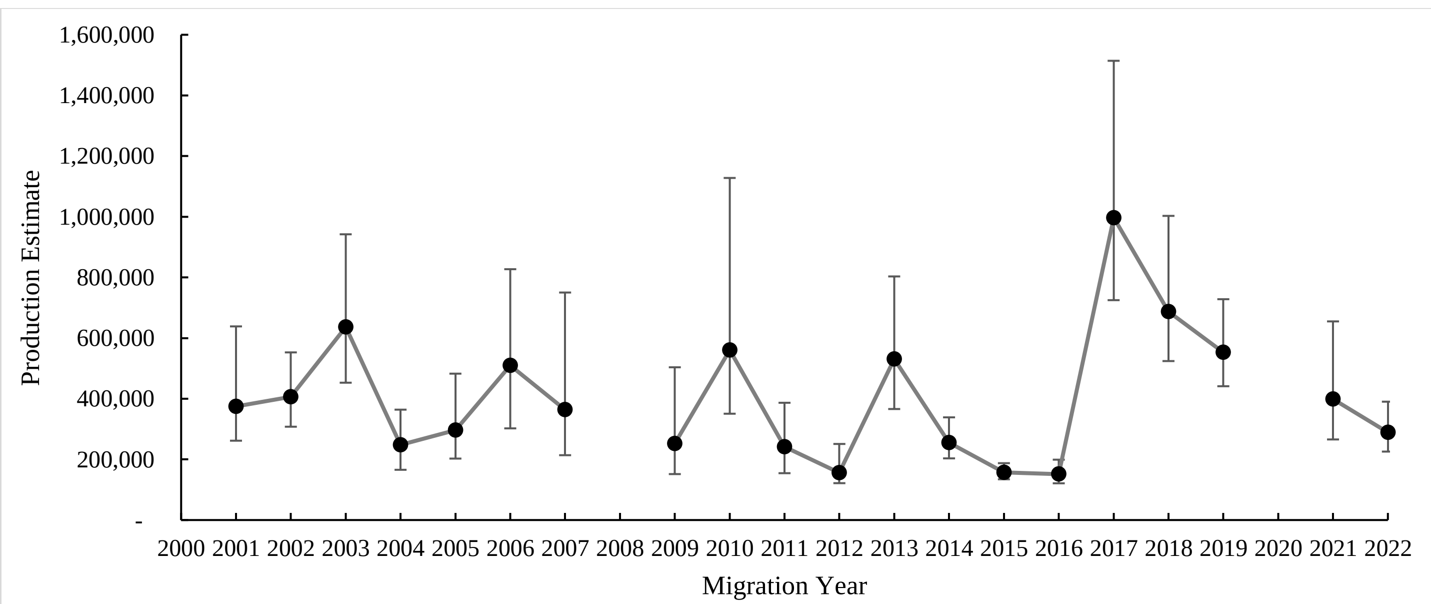

Figure 6. Natural-origin sub-yearling Chinook Salmon production estimates for the Skykomish River, 2001-2022. Error bars represent the 95% credible interval range.

In 2022, production appears to have peaked on JW 12, with most of the outmigration occurring between JWs 9 and 14 (Figure 7).

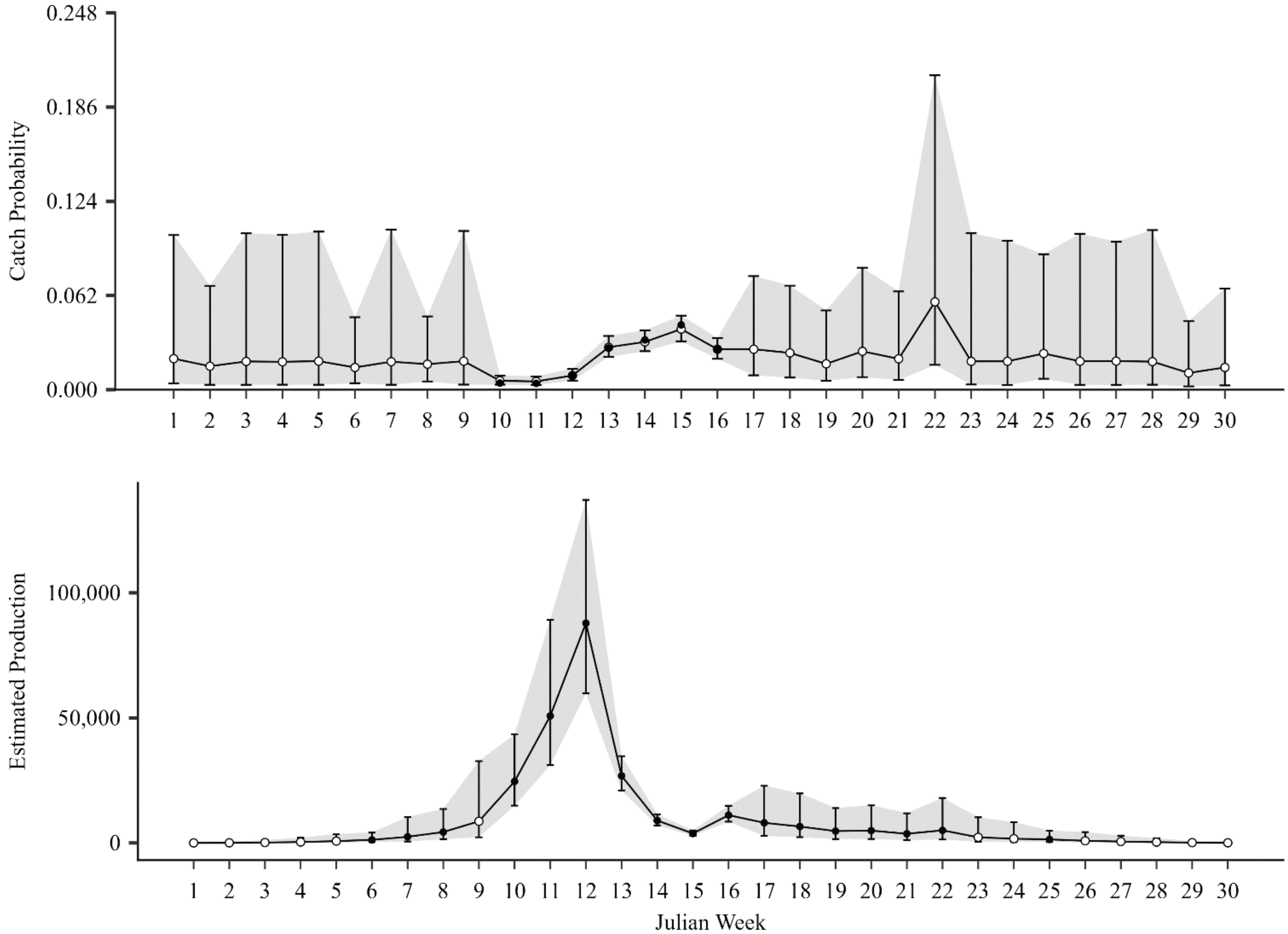

Figure 7. Natural-origin sub-yearling Chinook Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Skykomish River, 2022. Shaded areas represent the credible intervals. In the catch probability plot, closed circles represent actual efficiency tests values, while open circle values were modeled. In the production estimate plot, open circles represent unsampled weeks and closed circles represent sampled weeks.

Natural-Origin Yearling Coho Salmon

For yearling Coho Salmon, we assume that the emigration begins during JW seven and ends during JW 26. We consider Coho Salmon migration in JW six and 27 to be zero. In 2022, we estimate that approximately 819,926 natural-origin yearling Coho Salmon emigrated past our trap site on the Skykomish River. This production estimate is comparable to the project average of 847,132, but almost double the average since the trap was moved upstream in 2009 (565,873) (Table 4, figure 8).

Table 4. Natural-origin yearling Coho Salmon production estimates in the Skykomish River, 2001-2022.

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	772,624[b]			
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	564,303[b]			
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
Average (2009-2022)	565,873	411,220	842,111	0.19

[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

Although the trap was relocated upstream of Coho Salmon spawning and rearing habitat in Woods Creek in 2008, it is possible to see some population trends. In future reports, we will expand production estimates to include the entire watershed in order to better compare production across the entire temporal period. Taking those factors into account, it appears that yearling Coho production has been gradually declining over the course of the project with some variability from year to year (Figure 7).

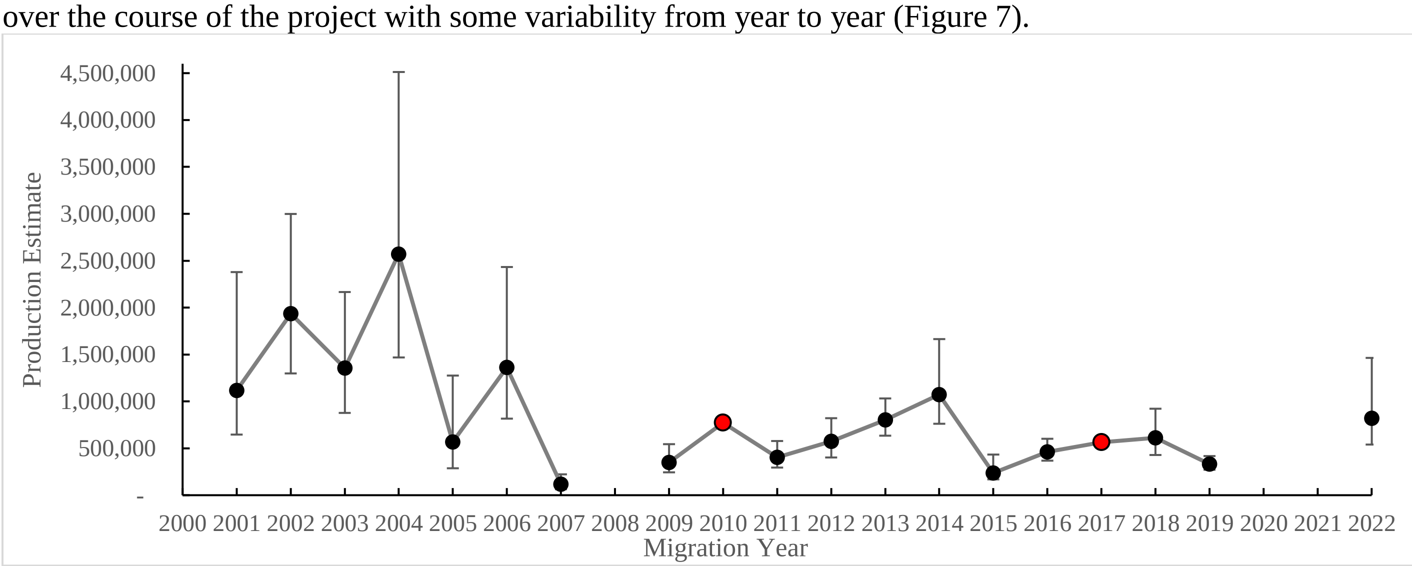

Figure 8. Natural-origin yearling Coho Salmon production estimates for the Skykomish River, 2001-2022. Red dots indicate years that used simple Petersen estimates with five-year means of efficiencies due to a lack of efficiency testing. Error bars represent the 95% credible interval range.

The 2022 credible interval range for yearling Coho Salmon was wider than recent years. This was likely due to uncertainty caused by only having three efficiency tests along with having three unsampled weeks. The natural-origin Coho Salmon outmigration happened mostly between JWs 17 and 21, which is consistent with all other years that have been monitored (figure 9).

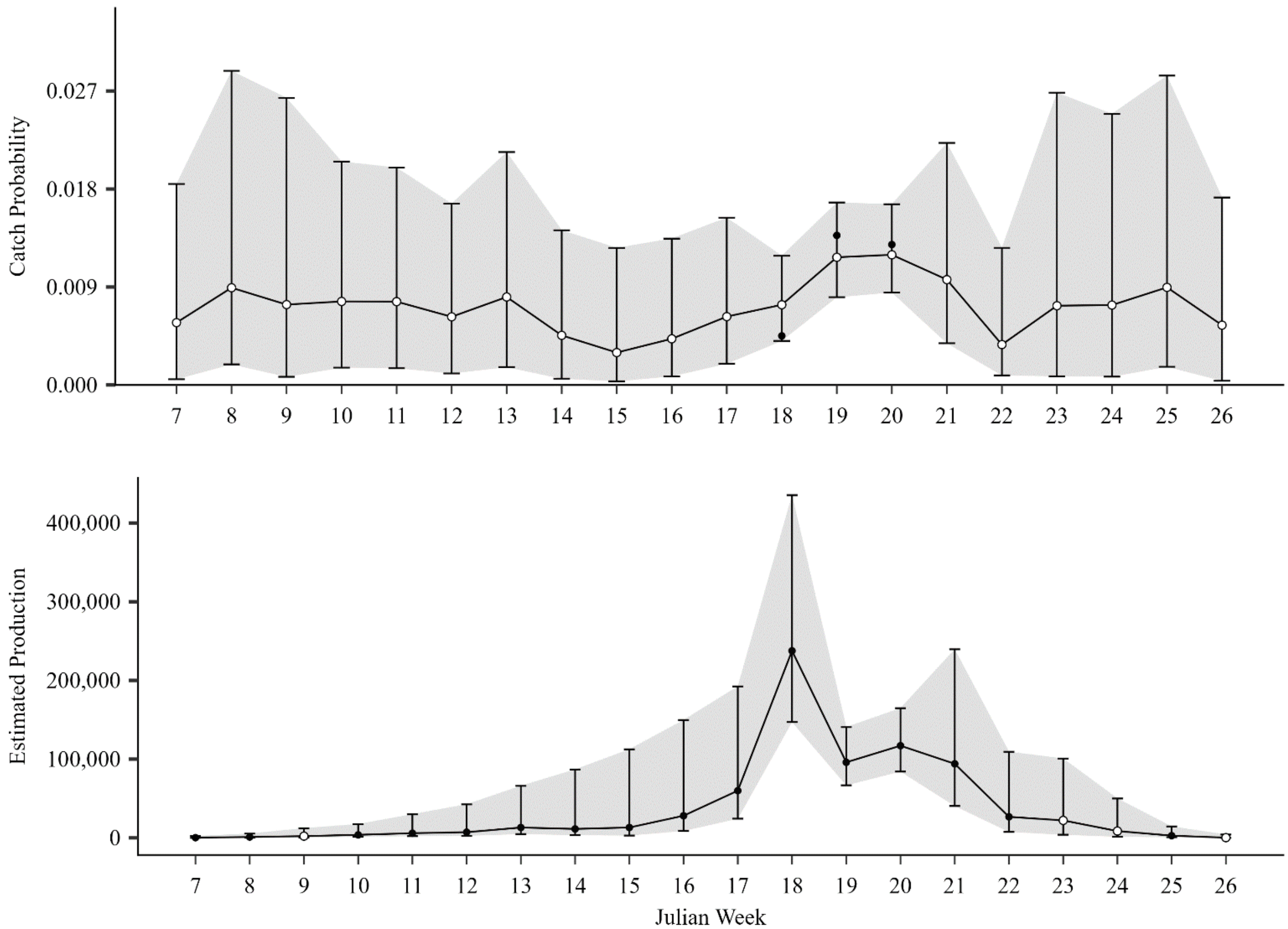

Figure 9. Natural-origin yearling Coho Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Skykomish River, 2022. Shaded areas represent the credible intervals. In the catch probability plot, closed circles represent actual efficiency tests values, while open circle values were modeled. In the production estimate plot, open circles represent unsampled weeks and closed circles represent sampled weeks.

Natural-Origin Yearling Chinook Salmon

In addition to the sub-yearling Chinook Salmon migrants (ocean-type) there are also Chinook Salmon that emigrate from the Skykomish River as yearlings (stream-type). Based on scale information collected from Snohomish River fall Chinook Salmon by the Washington Department of Fish and Wildlife (WDFW) and the Tulalip Tribes from 2005-2022, 13-15% of returning adults had stream-type rearing histories and migrated out as yearlings (Crewson and Alexandersdottir, 2022). Stream-type Chinook Salmon were caught in relatively low numbers compared to ocean-type Chinook Salmon at the Skykomish trap site from 2001-2022. Puget Sound Chinook Salmon stocks tend to be predominantly ocean-type, but a diversity of life history strategies can contribute to a species' resilience, so it is important to monitor and evaluate the survival of these stream-type

Chinook Salmon and the declining freshwater habitats that they rely on (Anderson and Topping 2017; Zimmerman et al. 2015).

Despite minimal catch numbers as well as a lack of efficiency tests for the yearling Chinook Salmon cohort, we decided to estimate yearling production in hopes of providing some insight into the relative contribution of yearling Chinook Salmon to overall production. In order to estimate yearling Chinook Salmon production, we use trap efficiency estimates from yearling Coho Salmon as a surrogate. We believe that yearling Coho Salmon may provide a useful surrogate since the average fork lengths of yearling Chinook and Coho Salmon captured at the traps are relatively similar in the Skykomish (96.0 mm & 96.2 mm, respectively), and because both species have been shown to have similar swimming speeds (Flagg et al. 1983; Nikl and Farrell 1993). While there may be differences in trap efficiency among species, we find that the aforementioned similarities support the use of yearling Coho Salmon efficiency as a surrogate for yearling Chinook Salmon. Additionally, we support using Coho Salmon efficiency because of operational feasibility and to minimize any further supplementation of hatchery Chinook Salmon (used in efficiency trials) in the Snoqualmie River system. Also, due to the low numbers of emigrating yearling Chinook Salmon, the production estimates tend to have a much wider credible interval range.

In 2022, we estimate that only 4,249 natural-origin yearling Chinook Salmon emigrated past our rotary screw trap on the Skykomish River. This number has declined from the peak production of 53,438 in 2009. Prior to 2009, stream type Chinook Salmon abundance was on an upward trend (Figure 10). It is possible that there were many more stream-type Chinook Salmon prior to our dataset.

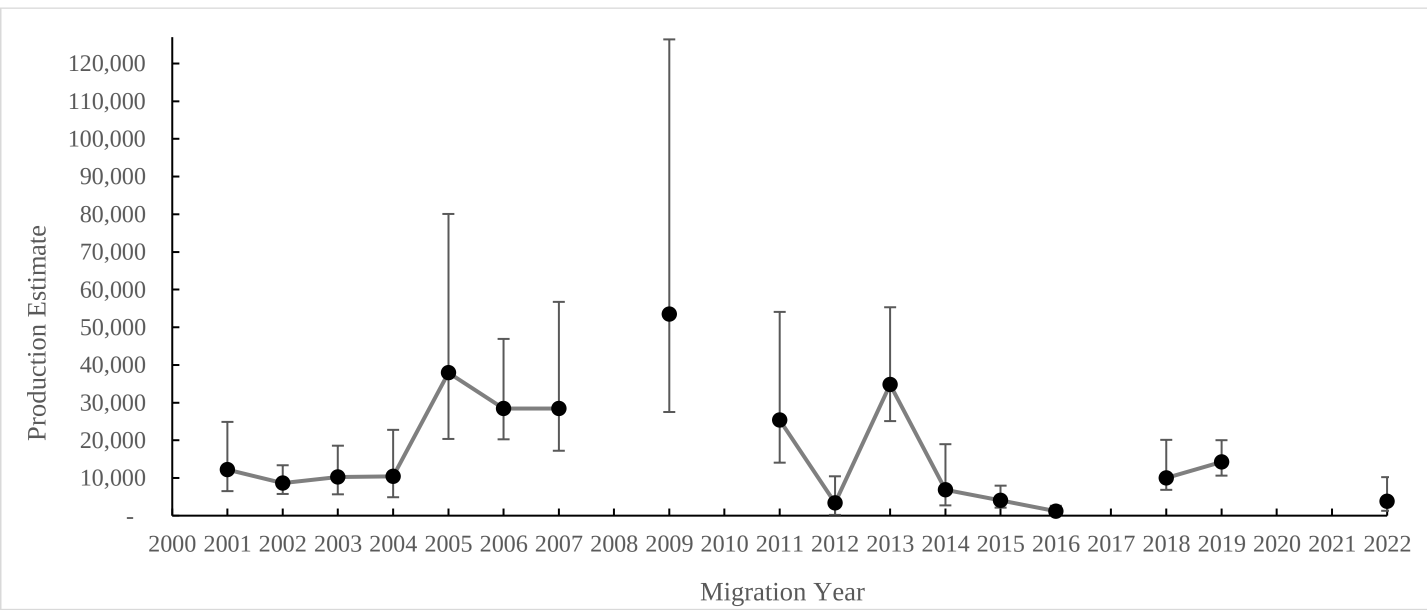

Figure 10. Natural-origin yearling Chinook Salmon production estimates for the Skykomish River, 2001-2022. Error bars represent the 95% credible interval range.

EFFICIENCY TESTING AND RESULTS

A total of 10 trap efficiency tests were conducted throughout the 2022 sampling season; seven for Chinook Salmon and only three for Coho Salmon (Table 4). 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. These releases were conducted weekly throughout the duration of the sampling season while hatchery Chinook and Coho Salmon were available. Following each release, the trap was operated continuously (except during debris removal) for a minimum of 32 hours. The trap was operating at an average efficiency rate of 2.11% for Chinook Salmon sub-yearlings and 1.04% for Coho Salmon yearlings during the 2022 sampling season (Table 4). During the 2022 season, trapping equipment was inspected and monitored frequently and the trap was found to be in fully operational condition with almost no escape paths detected and no major equipment malfunctions. On the last day of sampling, the debris removal door on the cone got knocked off, which may have provided a small escape path for a portion of one sampling event.

Table 4. Efficiency Release dates, species, and capture percentages for the Skykomish River smolt trap, 2022.

Species	Date	Released	Captured	Efficiency
Chinook	3/8/2022	2056	9	0.44%
Chinook	3/15/2022	2152	9	0.42%
Chinook	3/22/2022	2107	20	0.95%
Chinook	3/30/2022	2073	57	2.75%
Chinook	4/5/2022	2320	76	3.28%
Chinook	4/12/2022	2063	88	4.27%
Chinook	4/20/2022	2116	56	2.65%
Coho	5/3/2022	1996	9	0.45%
Coho	5/9/2022	2038	28	1.37%
Coho	5/18/2022	2403	31	1.29%
			2022 Average Chinook Efficiency	*2.11%*
			2022 Average Coho Efficiency	*1.04%*

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 spawners 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 925 hours was consistent with the project average of 914 (Table 2). Although we started early, we had to cancel trapping due to multiple large flooding events. Julian weeks 9, 23 and 24 were cancelled for safety issues caused by these high flows. Screw trap lines were removed both times to prevent the entanglement of boaters or floating trees. It is likely that cancelations due to flooding caused us to miss pulses of out-migrating fish, but our new production model provides more robust imputation for these unsampled periods. These cancellations and shortage of Coho Salmon efficiency tests contributed to somewhat higher uncertainty in our Coho Salmon production estimate.

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 throughout the duration of the 2022 season with no down-time associated directly with equipment failure.

Natural-origin sub-yearling Chinook Salmon production estimates were far lower than average this year. This was likely caused, in part by large flooding events that occurred during egg incubation. It has been shown that flood events of large magnitude or long duration can cause redd scouring, which can lead to lower egg survival (Zimmerman et al. 2015; Montgomery et al. 1996). This effect will be discussed more in our forthcoming 20-year report, along with egg-to-migrant survival estimates. Chinook Salmon natural production estimates have not shown a clear trend over the last twenty years, but escapement estimates still remain far below recovery goals (Snohomish County 2019).

We estimate that natural-origin yearling Coho Salmon production was about average in 2022 and much higher than the average since the trap was moved. There was a fairly high degree of uncertainty in this year's Coho Salmon estimate. Ensuring consistent efficiency testing in the future should make our credible intervals narrower. In order to improve trend detection for Coho Salmon natural production, it would be good to expand our production estimates to include the entire watershed since the trap location was moved upstream of Coho Salmon spawning and rearing habitat in Woods Creek in 2008. Although this move may have artificially lowered production estimates after 2008, 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). These escapement trends, along with juvenile abundance on the Skykomish and Snoqualmie Rivers, indicate that Coho Salmon populations are declining in the Snohomish River basin.

Natural-origin yearling Chinook Salmon out-migrations have been abnormally low in recent years. This is cause for concern since diminished life-history diversity can lower the resilience of Chinook Salmon stocks. The decline in stream-type Chinook Salmon may be an indicator that freshwater juvenile rearing habitat could be improved. 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 endangered salmon and steelhead populations in the Skykomish River.

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APPENDIX A: SUMMARY OF 2022 SKYKOMISH RIVER TRAP CATCH AND MORTALITIES

February

	Chinook Salmon				Coho Salmon			Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead		Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
	Unm 1+	Mark 1+	Unm 0+	Mark 0+	Unm 0+	Unm 1+	Mark 1+				Unm Smolts	Mark Smolts									
Day (63.5 hours of effort)																					
Catch	0	0	1	0	0	0	0	1	83	0	0	0	0	0	0	0	85	0	0	0	0
Morts.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Night (107.1 hours of effort)																					
Catch	2	0	45	0	7	5	1	151	1562	0	0	0	0	0	0	0	1773	3	1	10	0
Morts.	0	0	1	0	0	0	0	0	5	0	0	0	0	0	0	0	6	0	0	0	0
Monthly Totals (170.6 hours of effort)																					
Catch	2	0	46	0	7	5	1	152	1645	0	0	0	0	0	0	0	1858	3	1	10	0
Morts.	0	0	1	0	0	0	0	0	6	0	0	0	0	0	0	0	7	0	0	0	0

March

	Chinook Salmon				Coho Salmon			Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead		Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
	Unm 1+	Mark 1+	Unm 0+	Mark 0+	Unm 0+	Unm 1+	Mark 1+				Unm Smolts	Mark Smolts									
Day (95.3 hours of effort)																					
Catch	0	0	75	0	19	4	0	1344	5569	0	0	0	0	0	0	0	7011	0	3	1	1
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Night (148.3 hours of effort)																					
Catch	9	6	832	5	757	102	1	15791	45486	0	5	1	0	0	0	0	62995	14	15	18	0
Morts.	0	0	1	0	0	0	1	1	4	0	0	0	0	0	0	0	7	0	0	0	0
Monthly Totals (243.5 hours of effort)																					
Catch	9	6	907	5	776	106	1	17135	51055	0	5	1	0	0	0	0	70006	14	18	19	1
Morts.	0	0	1	0	0	0	1	1	4	0	0	0	0	0	0	0	7	0	0	0	0

APPENDIX A: SUMMARY OF 2022 SKYKOMISH RIVER TRAP CATCH AND MORTALITIES

April

	Chinook Salmon				Coho Salmon			Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead		Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
	Unm 1+	Mark 1+	Unm 0+	Mark 0+	Unm 0+	Unm 1+	Mark 1+				Unm Smolts	Mark Smolts									
Day (89.5 hours of effort)																					
Catch	1	36	51	5	44	4	3	970	10113	0	0	4	0	0	0	0	11231	1	4	1	0
Morts.	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Night (133.5 hours of effort)																					
Catch	3	1963	357	17	298	295	11	21013	81394	0	2	143	0	0	0	0	105496	5	58	14	1
Morts.	0	0	2	0	0	0	0	0	10	0	0	0	0	0	0	0	12	0	0	0	0
Monthly Totals (223.0 hours of effort)																					
Catch	4	1999	408	22	342	299	14	21983	91507	0	2	147	0	0	0	0	116727	6	62	15	1
Morts.	0	0	5	0	0	0	0	0	10	0	0	0	0	0	0	0	15	0	0	0	0

May

	Chinook Salmon				Coho Salmon			Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead		Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
	Unm 1+	Mark 1+	Unm 0+	Mark 0+	Unm 0+	Unm 1+	Mark 1+				Unm Smolts	Mark Smolts									
Day (100.3 hours of effort)																					
Catch	1	41	20	27	29	66	40	285	2965	0	0	3	0	0	0	0	3477	1	11	0	1
Morts.	0	0	1	0	0	0	1	2	13	0	0	0	0	0	0	0	17	0	0	0	0
Night (129.0 hours of effort)																					
Catch	1	4	237	3330	239	2372	2556	1748	9848	0	65	36	1	0	0	0	20437	3	59	13	1
Morts.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Monthly Totals (229.3 hours of effort)																					
Catch	2	45	257	3357	268	2438	2596	2033	12813	0	65	39	1	0	0	0	23914	4	70	13	2
Morts.	0	0	1	2	0	0	1	2	13	0	0	0	0	0	0	0	19	0	0	0	0

APPENDIX A: SUMMARY OF 2022 SKYKOMISH RIVER TRAP CATCH AND MORTALITIES

June

	Chinook Salmon Unm 1+	Chinook Salmon Mark 1+	Chinook Salmon Unm 0+	Chinook Salmon Mark 0+	Coho Salmon Unm 0+	Coho Salmon Unm 1+	Coho Salmon Mark 1+	Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead Unm Smolts	steelhead Mark Smolts	Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
Day (26.6 hours of effort)																					
Catch	0	0	4	332	8	4	0	0	5	1	0	0	0	0	0	0	354	0	1	0	0
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Night (32.2 hours of effort)																					
Catch	0	0	30	3809	45	27	0	0	2	0	4	1	0	0	0	0	3918	7	9	4	0
Morts.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Monthly Totals (58.8 hours of effort)																					
Catch	0	0	34	4141	53	31	0	0	7	1	4	1	0	0	0	0	4272	7	10	4	0
Morts.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Totals (925.1 total hours of effort)

	Chinook Salmon Unm 1+	Chinook Salmon Mark 1+	Chinook Salmon Unm 0+	Chinook Salmon Mark 0+	Coho Salmon Unm 0+	Coho Salmon Unm 1+	Coho Salmon Mark 1+	Chum Salmon	Pink Salmon	Sockeye Salmon	steelhead Unm Smolts	steelhead Mark Smolts	Cut. Trout	Rain. Trout	Trout Fry	Dolly/ Bull Trout	Total Salmonid Catch	Juv. Lamp.	Dace spp.	Sculpin spp.	Stickle-back
Catch	17	2050	1652	7525	1446	2879	2612	41303	157027	1	76	188	1	0	0	0	216777	34	161	61	4
Morts.	0	0	9	2	0	0	2	3	33	0	0	0	0	0	0	0	49	0	0	0	0
% Mort	0.00%	0.00%	0.54%	0%	0.00%	0.00%	0.1%	0.01%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%				
% of Total Catch	0.0%	0.9%	0.8%	3.5%	0.7%	1.3%	1.2%	19.0%	72.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	99.9%	0.0%	0.1%	0.0%	0.0%