Tulalip Tribes Natural Resources Department Report

SNOQUALMIE RIVER JUVENILE SALMON OUT-MIGRATION STUDY PROGRESS REPORT

February – June 2022

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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. The Snoqualmie sub-basin is managed by a partnership of local tribes and municipalities called the Snoqualmie Watershed Forum.

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).

SNOQUALMIE RIVER TRAPPING SITE

The current trap site is located on the Snoqualmie River 32 miles upriver from the ocean and 12 miles up from the confluence with the Skykomish River (Figure 1). It is on the Flooded Riveranch in Duvall, WA in a section of the channel that flows north (Figure 2). The river at this point has a wetted width of ~142 ft., a bankfull width of ~210 ft., a maximum bankfull depth of ~23.5 ft., and a summer low-flow depth of ~5 ft. The water surface velocity is ~3-4 ft./sec., the summer low flow discharge is ~847 cubic feet per second (CFS), and the mean annual discharge is ~3,800 CFS. The channel gradient is <1% and the substrate is principally sand and silt with some gravel and cobble on the western side of the channel. The land use adjacent to the trap is principally agriculture with riparian vegetation limited to the banks (e.g. <30 ft.). The riparian zone principally consists of grass, shrubs, and a few scattered trees. At the immediate trap site, the left bank is composed of a steep slope vegetated with mixed deciduous trees and an understory of blackberry and salmonberry (leading to West Snoqualmie Valley Rd NE). The right bank is steeply cut and leads to an active horse and cattle pasture. Riparian vegetation on the right bank is principally Japanese Knotweed, Himalayan Blackberry with an occasional Red Alder and Cottonwood. In 2003, a previous landowner had a fence built around the pasture on the right bank creating a buffer zone of ~50 ft. between the pasture and the river bank. This buffer was planted with an assortment of native riparian vegetation (Kubo et al. 2013).

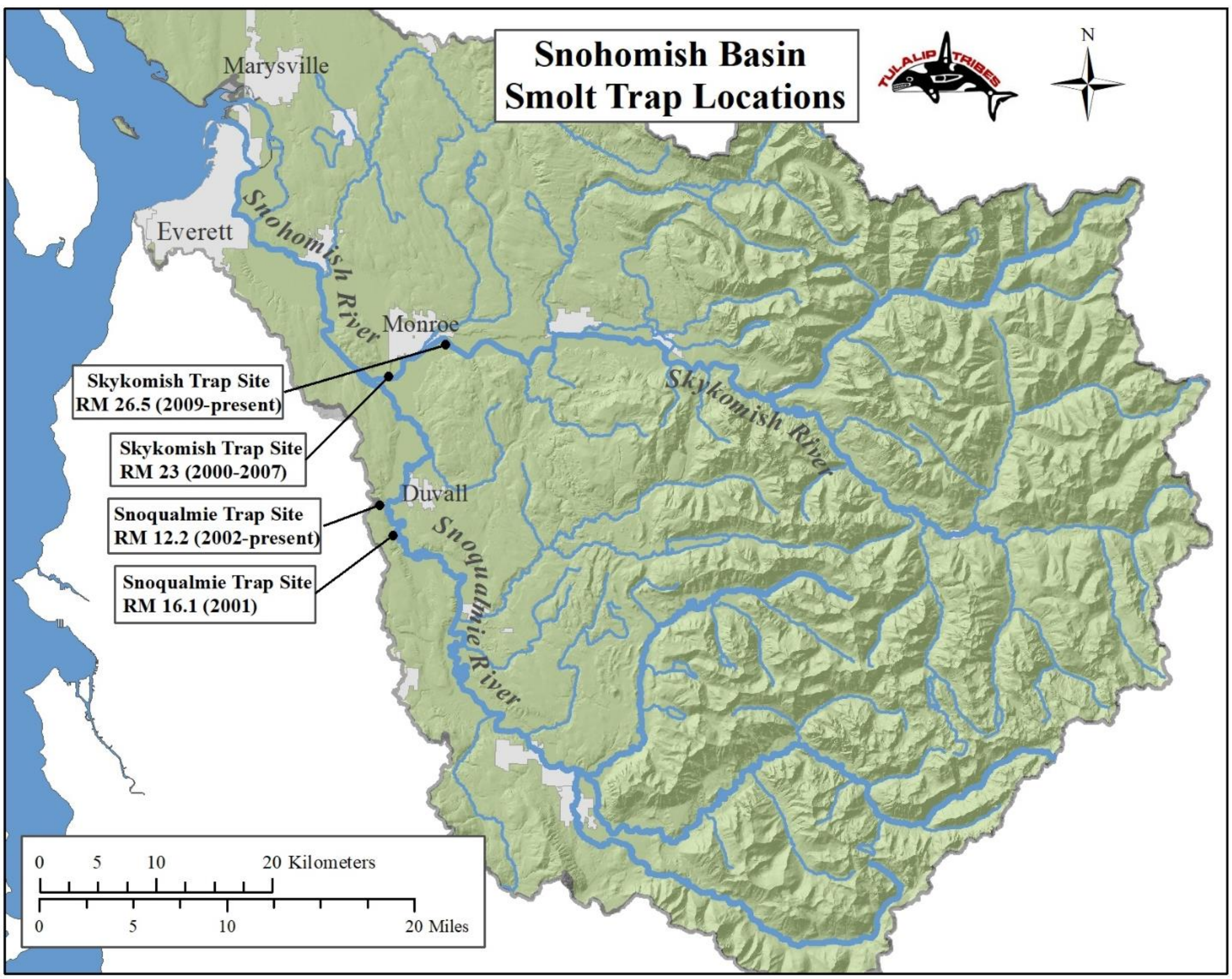

Figure 1: Map of the Snohomish watershed with the locations of the trap sites on the Skykomish and Snoqualmie Rivers.

Figure 2. Aerial photograph of the trap site at river mile 12.2 on the Snoqualmie River in Duvall, WA. The red dot indicates the approximate trap fishing position.

SUMMARY OF SAMPLING OPERATIONS

The Snoqualmie 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 compare results from year to year. Table 1 shows the Julian weeks that were sampled in 2022 and the corresponding dates. In 2022, sampling occurred from February 3rd to June 23rd (JW 5 -JW 25). Normally, sampling occurs from JW 7 to JW 25 with some variability in timing. The trap fished for approximately 913 hours, with 535 of those hours fished at night, representing 59% of the total trapping effort (Table 3). A total of 22 scheduled sampling events were cancelled due to unfavorable sampling conditions (i.e. high debris and discharge levels).

Table 1. Julian weeks and corresponding dates for the 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 13,474 salmonids were captured. Captured unmarked Chinook Salmon included 179 sub-yearlings (0+) and one yearling (1+). The number of unmarked sub-yearling Chinook Salmon caught at the Snoqualmie River trap in 2022 was well under the project average of 536 (Table 2). Captured unmarked Coho Salmon included 473 yearlings and 393 sub-yearlings. The number of unmarked 1+ Coho Salmon caught was roughly half the project average of 1,023. During the trapping and handling process a total of 22 salmonid mortalities were reported. The 22 mortalities included two unmarked Coho Salmon, three unmarked Chinook Salmon that died during trapping and handling and seven Chinook Salmon that were intentionally taken for toxicology screening. Mortality as a percentage of the total salmonid catch was approximately 0.16% (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 unmarked Chinook Salmon sub-yearlings showed three distinct peaks in 2022 at JW 8, JW 12 and JW 20 (Figure 3). The timing of the sub-yearling Chinook Salmon out-migration does not exhibit the observed consistency documented for yearling Coho Salmon. The yearling Coho Salmon out-migration showed one very clear peak during JWs 17-20, when approximately 1-3 fish per hour were encountered. This peak is temporally consistent with all other years of the trapping project, which generally occurs during JWs 17-21 (Kubo et al. 2013).

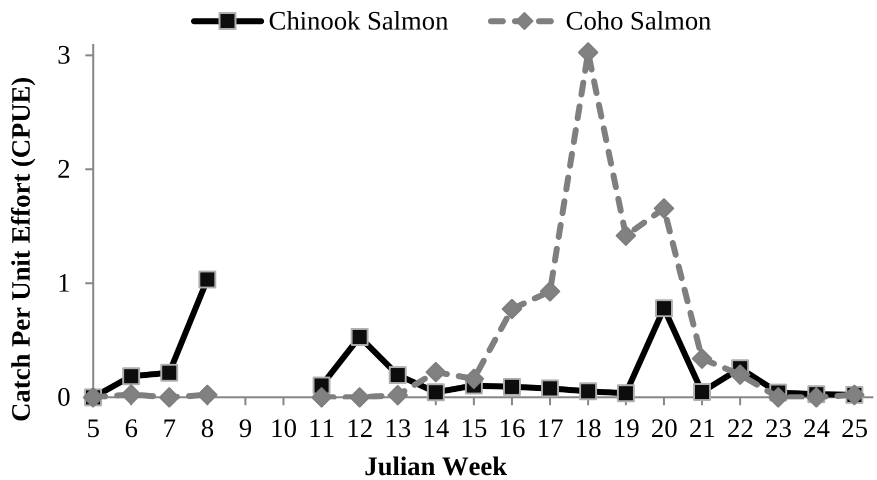

Figure 3. Sub-yearling (0+) Chinook Salmon and yearling (1+) Coho Salmon CPUE by Julian week at the Snoqualmie River trap, 2022.

Average annual salmonid CPUE on the Snoqualmie trap has exhibited variability throughout the duration of the project primarily due to fluctuating sampling conditions and the strength of a given year's out-migrant cohort. CPUE averages for sub-yearling Chinook and yearling Coho Salmon in 2022 were far below the interannual averages (2001-2022)(Table 2, Figure 4 and 5).

Table 2. Annual sampling effort and catch totals for sub-yearling Chinook and yearling Coho Salmon at the Snoqualmie River rotary screw trap 2001-2022.

Year	Effort (Hours)	0+ Chinook	1+ Coho	Chinook CPUE	Coho CPUE
2001	509	619	553	1.22	1.09
2002	712	584	1751	0.82	2.46
2003	946	887	1305	0.94	1.38
2004	1056	610	1127	0.58	1.07
2005	1006	672	1187	0.67	1.18
2006	1011	794	2031	0.79	2.01
2007	510	153	615	0.30	1.21
2008	318	275	587	0.87	1.85
2009	633	269	765	0.43	1.21
2010	1123	668	1149	0.60	1.02
2011	573	282	1662	0.49	2.90
2012	847	377	1384	0.44	1.63
2013	1218	623	1718	0.51	1.41
2014	805	293	1097	0.36	1.36
2015	1017	89	678	0.09	0.67
2016	1112	50	809	0.04	0.73
2017	1131	1517	925	1.34	0.82
2018	1117	1587	1517	1.42	1.36
2019	818	667	612	0.82	0.75
2020	[a]				
2021	764	582	563	0.76	0.74
2022	913	179	473	0.20	0.52
Average	864	561	1072	0.65	1.30

[a] = Trapping cancelled due to Covid-19

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 in 2015 and 2016 at approximately .09 and .04 fish per hour, respectively (Figure 4, Table 2). In 2017 and 2018, we saw a spike in CPUE, but over the last four years, it has been trending down again with 2022 having a CPUE of 0.2 fish per hour, which is near the project lows. This was likely due to lower egg-to-migrant survival rates caused by flooding during the egg incubation period (Zimmerman et al. 2015; Montgomery et al. 1996).

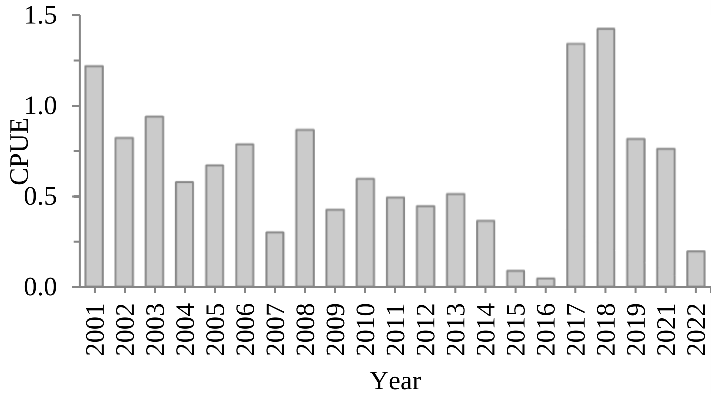

Figure 4. Natural-origin sub-yearling Chinook Salmon CPUE time series at the Snoqualmie trap by year; 2001-2022. Sampling was ended early in 2020 due to Covid-19.

Yearling Coho Salmon catch rates have remained fairly consistent throughout the project with some observed seasonal variability dependent on river conditions and the size of a given year's out-migrant cohort (Figure 5). In 2022, the average yearling Coho Salmon CPUE (.52) was much lower than the 2001-2022 average of 1.30. The total number of yearling Coho Salmon encountered was far below project averages to date at 473 individuals encountered (2001-2022t average: 1,072). Yearling Coho Salmon total annual catch and CPUE averages across all years show a slight decreasing trend at the Snoqualmie trap (Figure 5). Coho Salmon CPUE in 2022 was the lowest since we've been collecting data.

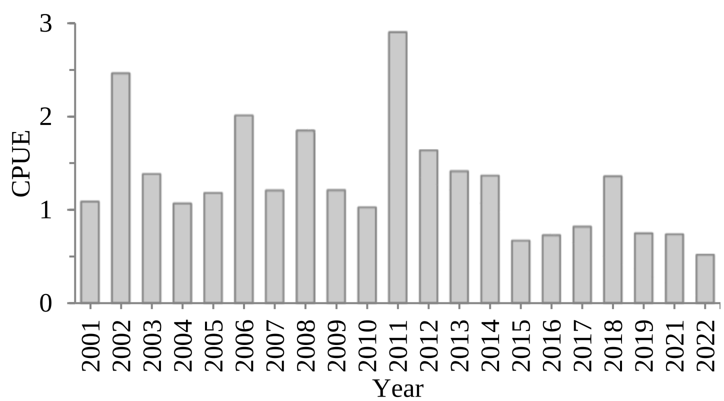

Figure 5. Natural-origin yearling Coho Salmon CPUE time series at the Snoqualmie trap by year; 2001-2022. Sampling was ended early in 2020 due to Covid-19.

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 Snoqualmie 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 Duvall, 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 BTSPAS 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 75,049 natural-origin sub-yearling Chinook Salmon emigrated past our trap site on the Snoqualmie River. This production estimate is below the project average of 130,491 (Table 3).

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

Migration Year	Production Estimate	2.5% Credible Interval	97.5% Credible Interval	Coefficient of Variation (CV)
2001	177,711[a]			
2002	127,298[a]			
2003	143,296[a]			
2004	90,991	39,058	209,056	0.47
2005	92,382	55,223	161,648	0.30
2006	131,345	73,788	224,840	0.29
2007	39,157	26,679	59,463	0.21
2008	[b]			
2009	45,090	24,717	99,747	0.43
2010	136,961	79,396	263,764	0.34
2011	75,453	44,265	134,453	0.29
2012	45,093	32,935	61,285	0.16
2013	185,552	129,271	263,720	0.18
2014	113,636	81,435	160,672	0.18
2015	18,322	14,798	23,081	0.12
2016	14,043	7,670	28,821	0.35
2017	515,311	400,949	684,023	0.14
2018	348,002	268,881	482,088	0.15
2019	156,010	113,813	233,437	0.23
2020	[c]			
2021	79,111	45,978	187,488	0.43
2022	75,049	41,333	161,474	0.40
Average	*130,491*	*87,070*	*202,298*	*0.27*

[a] = No efficiencies, used simple Petersen estimate with five-year mean of efficiencies

[b] = Trap repairs

[c] = 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).

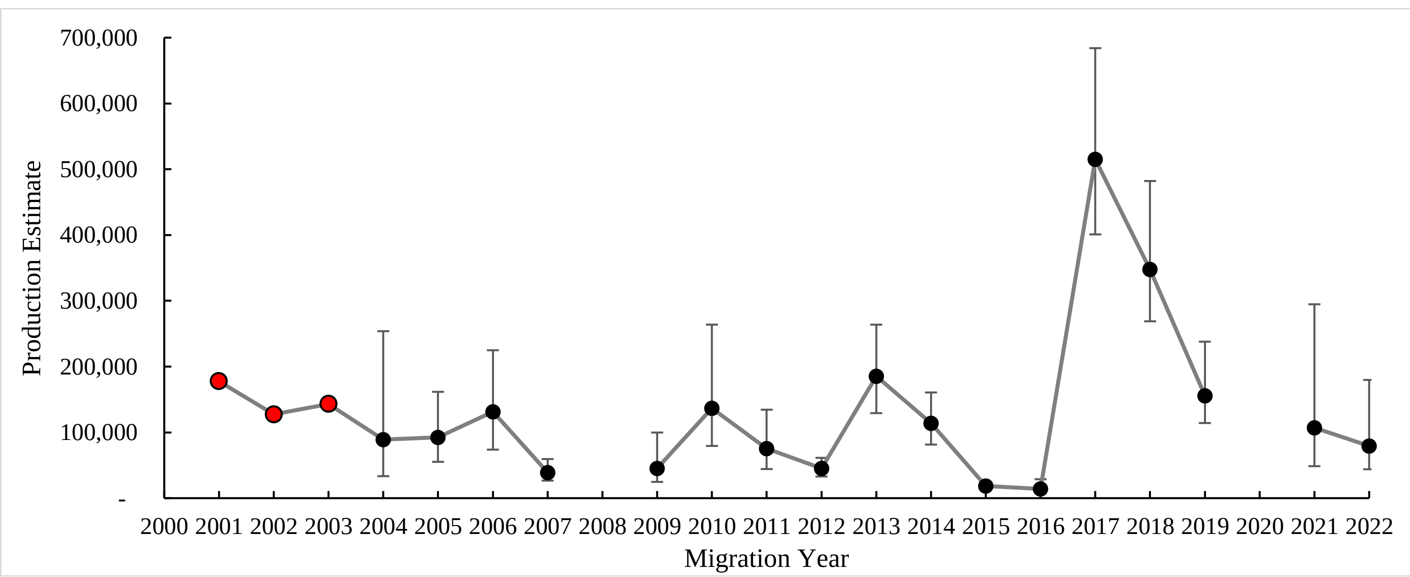

Figure 6. Natural-origin sub-yearling Chinook Salmon production estimates for the Snoqualmie River, 2001-2022. Red dots indicate years that used simple Petersen estimates with five-year means of efficiencies due to a lack of efficiency testing. Error bars represent the 95% credible interval range.

Production appears to have peaked in 2022 on JW 12, with most of the outmigration occurring between JWs 8 and 13 (Figure 7). Credible intervals were wide from JWs 8-12 due to a having consecutive unsampled weeks near the peak of the run and only having four efficiency tests.

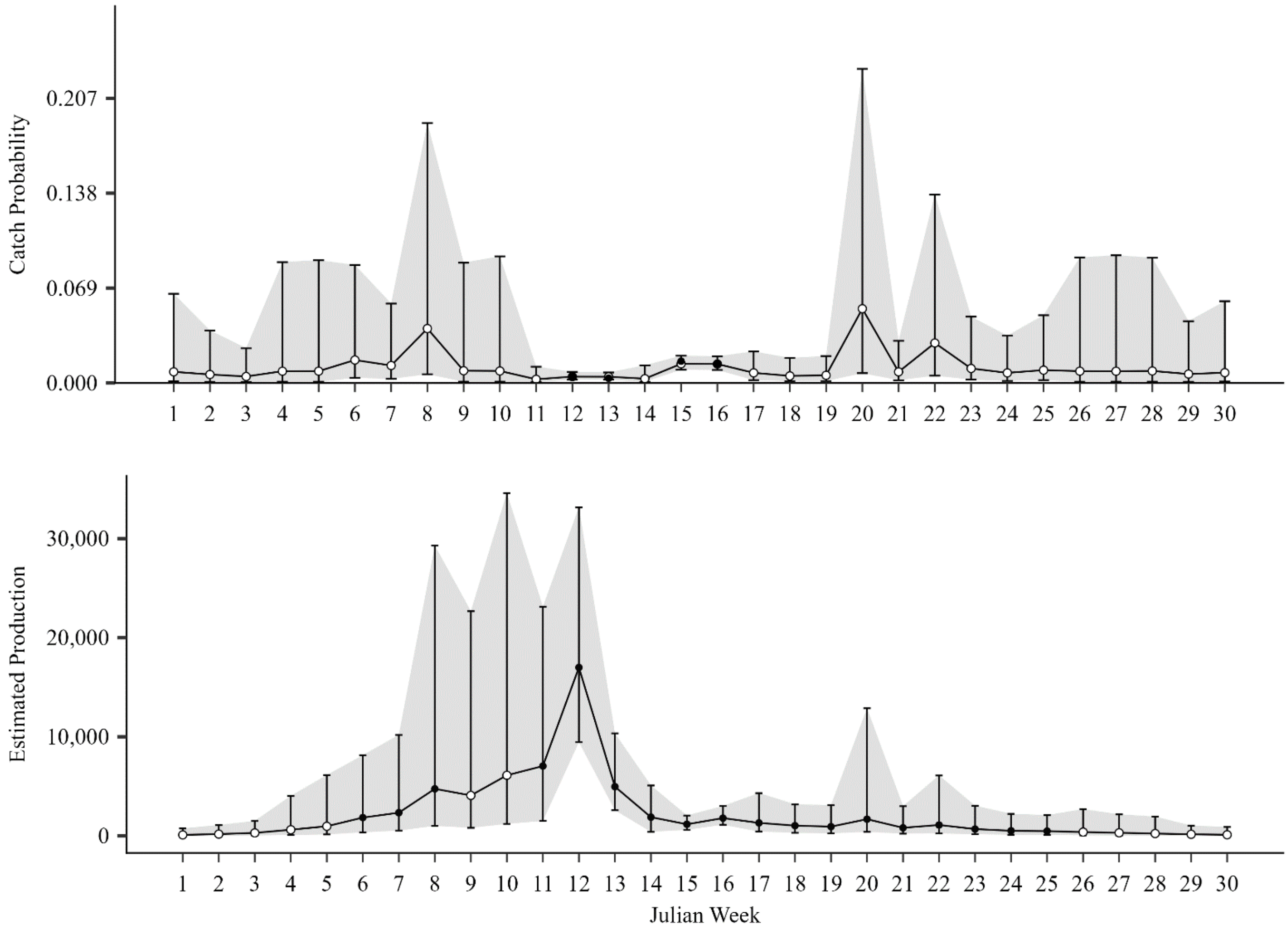

Figure 7. Natural-origin sub-yearling Chinook Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Snoqualmie River, 2022. Shaded areas represent the credible intervals. In the catch probability plot, closed circles represent actual efficiency 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, which is consistent with nearby river systems (Conrad and MacKay 2000; Seiler et al. 2002; Lisi 2019). We consider Coho Salmon migration in JWs 6 and 27 to be zero. In 2022, we estimate that approximately 359,582 natural-origin yearling Coho Salmon emigrated past our trap site on the Snoqualmie River. This production estimate is slightly below the project average of 376,104 (Table 4, figure 8).

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

Migration Year	Production Estimate	2.5% Credible Interval	97.5% Credible Interval	Coefficient of Variation (CV)
2001	142,125[a]			
2002	1,110,452	522,317	2,660,610	0.48
2003	404,132	266,255	634,378	0.24
2004	600,252	289,540	1,424,038	0.45
2005	171,946[a]			
2006	393,938	263,620	611,858	0.22
2007	62,329	46,197	89,366	0.18
2008	361,383[a]			
2009	274,187	170,606	521,329	0.47
2010	360,277	197,518	691,719	0.34
2011	734,889	494,744	1,135,904	0.22
2012	722,478	443,303	1,273,062	0.29
2013	511,735	385,433	735,163	0.17
2014	363,874	261,890	514,558	0.18
2015	180,367	139,988	239,550	0.14
2016	245,399	163,396	379,315	0.22
2017	238,528[a]			
2018	162,748	104,579	261,171	0.25
2019	245,866	158,173	416,729	0.26
2020	[b]			
2021	236,981	180,414	330,147	0.18
2022	359,582	236,660	601,188	0.25
Average	*376,104*	*254,390*	*736,476*	*0.27*

[a] = Insufficienct efficiencies, used simple Petersen with five-year mean of efficiencies

[b] = Covid-19 shut down

Although our credible intervals are wide on some years, it is possible to see some population trends. From 2002 to 2007, production trended downward, followed by an increase until 2011, when it dropped back down until 2015. Since then it has been trending sideways, although best fit indicates that yearling Coho Salmon production has been gradually declining over the course of the project (Figure 8).

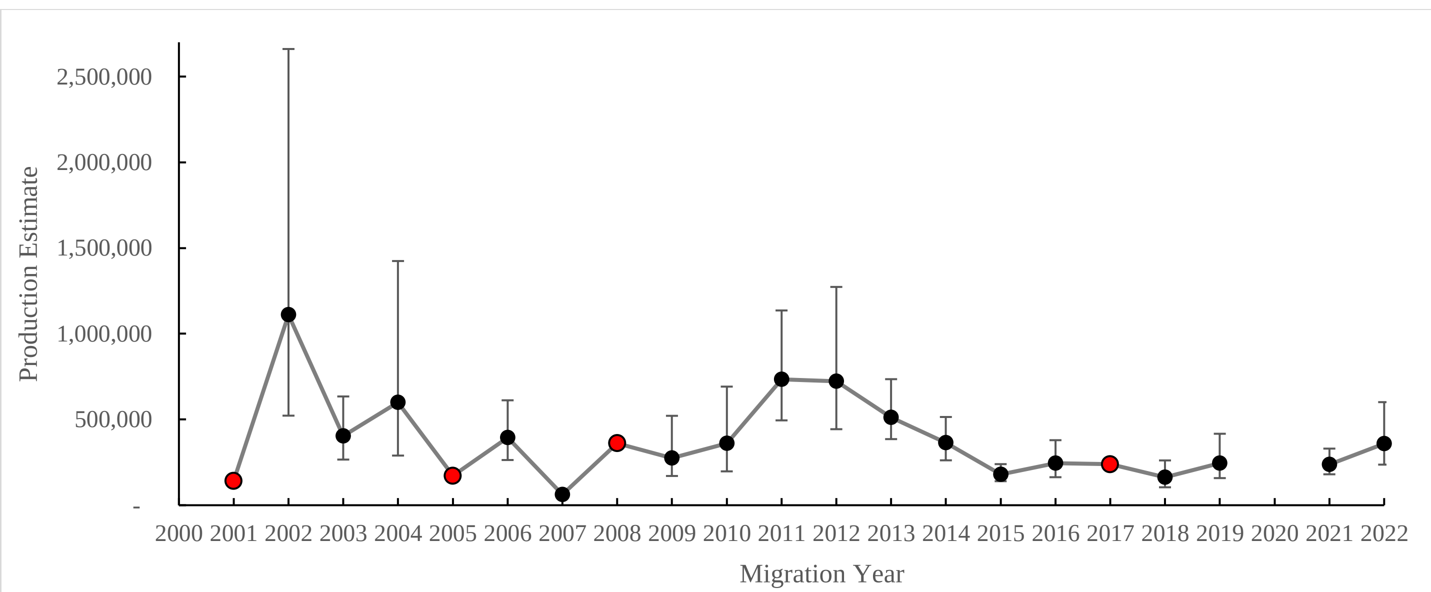

Figure 8. Natural-origin yearling Coho Salmon production estimates for the Snoqualmie River, 2001-2022. Red dots indicate years that used simple Petersen estimates with five-year means of efficiencies due to a lack of efficiency testing. Error bars represent the 95% credible interval range.

The 2022 credible interval range for yearling Coho Salmon was somewhat wider than recent years. This was due to uncertainty caused by only having four efficiency tests. The natural-origin Coho Salmon outmigration happened mostly between JWs 16 and 21 (Figure 9), which is consistent with other years.

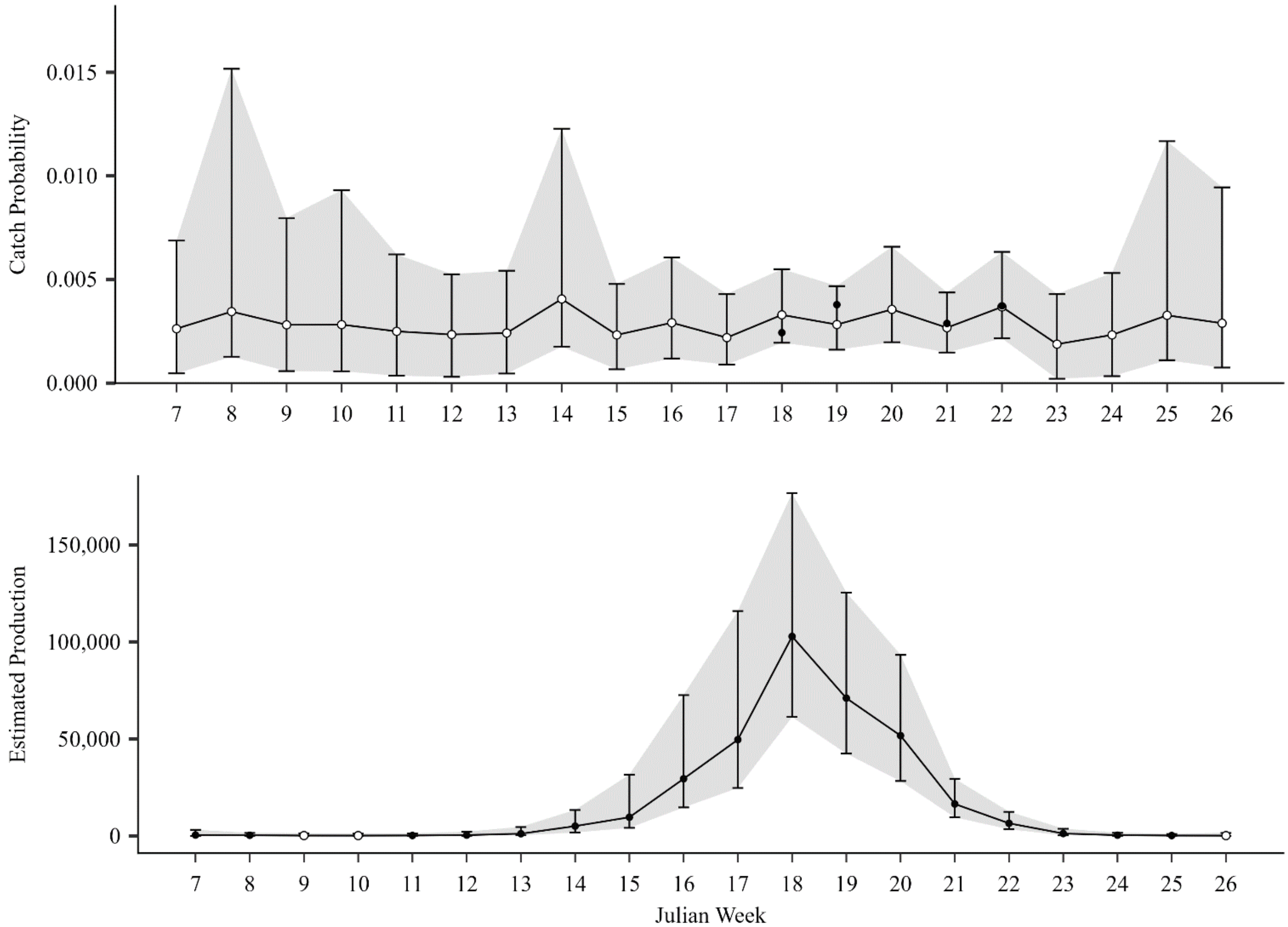

Figure 9. Natural-origin yearling Coho Salmon efficiency (i.e. catch probability, top panel) and production estimates (bottom panel) by Julian week in the Snoqualmie River, 2022. Shaded areas represent the credible intervals. In the catch probability plot, closed circles represent actual efficiency tests 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 Snoqualmie 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 Snoqualmie trap site from 2002-2022. 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 Snoqualmie River (89.7 mm & 97.8 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 578 natural-origin yearling Chinook Salmon emigrated past our rotary screw trap on the Snoqualmie River. This number is alarmingly low and has declined from the project peak in 2011, which was approximately 62,472 (Figure 10). It is possible that there were many more stream-type Chinook Salmon prior to our baseline dataset.

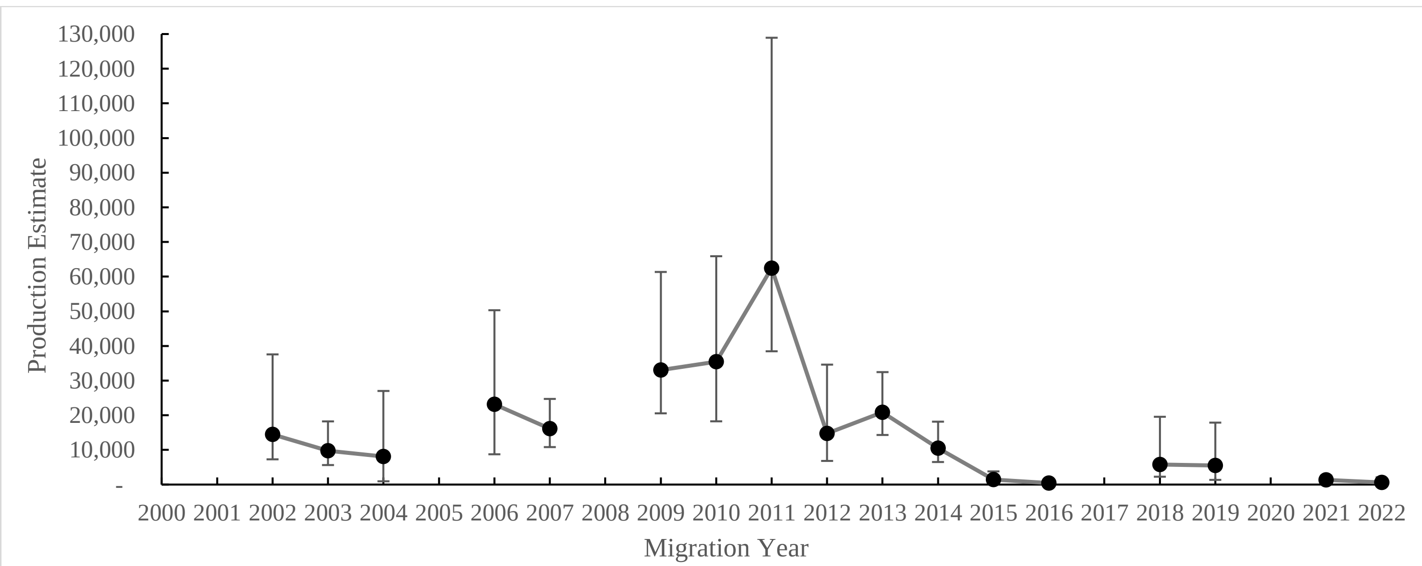

Figure 10. Natural-origin yearling Chinook Salmon production estimates for the Snoqualmie River, 2002-2022. Error bars represent the 95% credible interval range.

EFFICIENCY TESTING AND RESULTS

A total of eight trap efficiency tests conducted throughout the 2022 sampling season; four for Chinook Salmon and four for Coho Salmon (Table 2). During these tests, groups of hatchery-origin juvenile salmon were collected from Wallace River Hatchery, marked and released nearly a 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 .95% for Chinook Salmon sub-yearlings during the 2022 sampling season (Table 4). This efficiency estimate was lower than the average for this trapping location (2001-2022 average: 1.3%). Efficiency trials with yearling Coho Salmon indicate an efficiency of approximately 0.32%. This is also below the project efficiency average for yearling Coho Salmon at the Snoqualmie (2002-2022 average: 0.79%). During the 2022 season, trapping equipment was inspected and monitored frequently and the trap was found to be in fully operational condition with no escape paths detected and no major equipment malfunctions.

Table 4. Efficiency release dates and re-capture percentages at the Snoqualmie trap site; 2022.

Species	Date	Released	Captured	Efficiency
Chinook	3/23/2022	1999	9	0.45%
Chinook	3/29/2022	2301	8	0.35%
Chinook	4/13/2022	2016	32	1.59%
Chinook	4/19/2022	2078	29	1.40%
Coho	5/2/2022	2056	5	0.24%
Coho	5/10/2022	2114	8	0.38%
Coho	5/25/2022	2083	6	0.29%
Coho	5/31/2022	2145	8	0.37%
	2022 Average Chinook Efficiency			*0.95%*
	2022 Average Coho Efficiency			*0.32%*

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

The 2022 trapping season went generally well. Sampling was halted due to safety issues caused by high flows from JW 9-10 when the river reached 36,000 CFS and topped the bank, making the trap site inaccessible. Many sampling events were also cancelled from JW 23-25 due to high flows, but we were able to get some surveys in during this time period. 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.

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 just below average in 2022. Long-term monitoring of 1+ Coho Salmon out-migrations suggests that natural production is in decline. 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 and spawning habitat would greatly contribute to the recovery of threatened salmon and steelhead populations in the Snoqualmie River.

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

February

	Chinook Salmon		Coho Salmon		Chum Salmon	Pink Salmon	steelhead		Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
	0+	1+	0+	1+	0+	0+	Unm Smolts	Mark Smolts							
Day (43.8 hours of effort)															
Catch	17	0	0	0	0	74	0	0	0	0	91	1	0	0	0
Morts.	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Night (101.7 hours of effort)															
Catch	48	0	0	2	13	452	0	1	0	0	516	35	0	1	0
Morts.	3	0	0	0	0	1	0	0	0	0	4	0	0	0	0
Monthly Totals (145.4 hours of effort)															
Catch	65	0	0	2	13	526	0	1	0	0	607	36	0	1	0
Morts.	4	0	0	0	0	1	0	0	0	0	5	0	0	0	0

March

	Chinook Salmon		Coho Salmon		Chum Salmon	Pink Salmon	steelhead		Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
	0+	1+	0+	1+	0+	0+	Unm Smolts	Mark Smolts							
Day (49.3 hours of effort)															
Catch	8	0	4	0	17	1392	1	0	0	0	1422	0	0	0	0
Morts.	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Night (101.3 hours of effort)															
Catch	41	1	68	1	36	5024	2	0	0	0	5174	33	3	2	1
Morts.	2	0	2	0	0	0	0	0	0	0	4	0	0	0	0
Monthly Totals (150.6 hours of effort)															
Catch	49	1	72	1	53	6416	3	0	0	0	6596	33	3	2	1
Morts.	4	0	2	0	0	0	0	0	0	0	6	0	0	0	0

Appendix A: Summary of 2022 Snoqualmie River Trap Catch and Mortalities

April

	Chinook Salmon 0+	Chinook Salmon 1+	Coho Salmon 0+	Coho Salmon 1+	Chum Salmon 0+	Pink Salmon 0+	steelhead Unm Smolts	steelhead Mark Smolts	Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
Day (90.5 hours of effort)															
Catch	6	0	3	3	25	1340	0	0	0	0	1377	0	0	0	0
Morts.	2	0	0	0	0	4	0	0	0	0	6	0	0	0	0
Night (153.8 hours of effort)															
Catch	14	0	48	132	100	3809	2	10	0	0	4118	14	4	2	13
Morts.	0	0	0	0	0	5	0	0	0	0	5	0	0	0	0
Monthly Totals (244.3 hours of effort)															
Catch	20	0	51	135	125	5149	2	10	0	0	5495	14	4	2	13
Morts.	2	0	0	0	0	9	0	0	0	0	11	0	0	0	0

May

	Chinook Salmon 0+	Chinook Salmon 1+	Coho Salmon 0+	Coho Salmon 1+	Chum Salmon 0+	Pink Salmon 0+	steelhead Unm Smolts	steelhead Mark Smolts	Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
Day (98.9 hours of effort)															
Catch	3	0	22	26	7	39	0	1	0	0	99	0	0	0	4
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Night (121.3 hours of effort)															
Catch	33	0	224	302	11	49	3	8	0	0	636	35	11	0	3
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Totals (220.2 hours of effort)															
Catch	36	0	246	328	18	88	3	9	0	0	735	35	11	0	7
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

June

	Chinook Salmon 0+	Chinook Salmon 1+	Coho Salmon 0+	Coho Salmon 1+	Chum Salmon 0+	Pink Salmon 0+	steelhead Unm Smolts	steelhead Mark Smolts	Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
Day (95.0 hours of effort)															
Catch	4	0	3	1	0	0	0	0	0	0	8	5	3	0	0
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Night (57.4 hours of effort)															
Catch	5	0	21	6	0	0	0	1	0	0	33	24	8	1	3
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Totals (152.4 hours of effort)															
Catch	9	0	24	7	0	0	0	1	0	0	41	29	11	1	3
Morts.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Totals (912.8 total hours of effort)

	Chinook Salmon 0+	Chinook Salmon 1+	Coho Salmon 0+	Coho Salmon 1+	Chum Salmon 0+	Pink Salmon 0+	steelhead Unm Smolts	steelhead Mark Smolts	Resident Rainbow	Cut./Rain. Trout Fry/Parr	Total Salmonid Catch	Lamprey	Sunfish	Sculpin spp.	Stickle-back
Catch	179	1	393	473	209	12179	8	21	0	0	13474	147	29	6	24
Morts.	10	0	2	0	0	10	0	0	0	0	22	0	0	0	0
Mortality Rate	5.59%	0.00%	0.51%	0.00%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.16%				
% of Total Catch	1.3%	0.0%	2.9%	3.4%	1.5%	88.8%	0.1%	0.2%	0.0%	0.0%	98.2%	1.1%	0.2%	0.0%	0.2%