Tulalip Tribes Natural Resources Department Report

2000-2012 Skykomish and Snoqualmie Rivers Chinook and Coho Salmon Out-migration Study

2000-2012 Report

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<u>Raw data available upon request</u>

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INTRODUCTION

In May of 1999, the National Marine Fisheries Service (NMFS) listed the Puget Sound Chinook salmon as threatened under the federal Endangered Species Act (ESA). This listing included Chinook salmon from the Snohomish River Basin (Skykomish and Snoqualmie populations). Similarly, decreases in many runs of Puget Sound Coho salmon have resulted in a designation as a species of concern under ESA. The recovery of these species depends upon improving the effectiveness of habitat, harvest, and hatchery management across the basin. In order to achieve such improved effectiveness, additional information is necessary to fill important data gaps within the Snohomish system, including information on Chinook and Coho salmon abundance, productivity, spatial structure, and diversity (Snohomish Basin Salmonid Recovery Technical Committee, 2005). Information about the trends and inter-annual variability in these population parameters is critical to inform salmon recovery efforts, provides basic information on the productivity and capacity of the system, and can 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 recovery actions, habitat conditions, and potential ecological trajectories in the basin**.**

A key project helping to provide information on Snohomish salmon populations has been the operation of two rotary screw traps in the Skykomish and Snoqualmie rivers. Over the last 12 years, these projects involved trapping and enumerating juvenile Chinook and Coho salmon (as well as several un-targeted species) as they emigrate from the Snohomish River Basin to the Puget Sound. The goals of these trapping efforts were to estimate Chinook and Coho salmon natural production, migration patterns, and freshwater survival. These goals were accomplished through the direct quantification of juvenile salmon emigrations, evaluation of trap efficiency, and assessment of influential environmental attributes. This report summarizes the accomplishments made during the past 12 years of trapping operations. The objectives identified for this overall report were to:

1. Summarize and assess inter-annual variability in trapping efforts, catch, efficiency, fork lengths, as well as emigration timing and magnitude.

2. Assess potential factors influencing trap catch including turbidity, day/night migration, discharge, and trap efficiency.

3. Summarize estimates of production for naturally spawned Chinook and Coho salmon.

4. Summarize estimates of freshwater survival for naturally spawned Chinook and Coho salmon.

This project sampled an array of salmonid species and size classes; however, project goals aimed at estimating emigration and production of naturally spawned Chinook and Coho salmon. Production estimates focused on sub-yearling Chinook and yearling Coho because of life-history strategies and trapping limitations. Sub-yearling Coho tend to rear in riverine habitats and are not considered part of the emigrating cohort. Nomadic cohorts of sub-yearling Coho have been observed in streams from Oregon to Alaska (Salo and Bayliff 1958, Chapman 1962, Crone and Bond 1976, Hartman et al. 1982, Harke and Lucey 1999); however, since it can be difficult to determine if these emigrating Coho are redistributing in search of rearing habitats within the watershed or emigrating out to nearshore/marine habitats, they were not included in production estimates. Additionally, in the initial years of project operation, production estimates for yearling Chinook were not calculated because of minimal catch numbers and a lack of efficiency tests. This report aimed to provide some insight into yearling production over the sampled years; however, due to the aforementioned limitations, this report will primarily emphasize the sub-yearling cohort. Since we are interested in population patterns within the Skykomish and Snoqualmie rivers as well as across the Snohomish Basin, we will report results from each river separately and provide a basin-wide assessment in the discussion. Any additional data not included in this report is available upon request.

Throughout this report, weekly trapping data is discussed in terms of statistical week (SW). Each statistical week began at 00:00 (12:00 AM) on Sunday and ended at 23:59 (11:59 PM) on the following Saturday. This method allows for easier comparison of data from multiple years of this project. A table can be found in the appendix of this report showing the approximate month that each statistical week corresponded to (Appendix 1).

TRAPPING METHODS

Basin Description

Skykomish River

The Skykomish River basin originates along the western slope of the Cascade Mountain range drains approximately 844 square miles. The river has two principal forks: the North Fork and South Fork. The South Fork begins in the vicinity of Stevens Pass and flows generally west for 32 miles where it joins the North Fork near the town of Index (Figure 1). The North Fork begins north of Stevens Pass in the Henry M. Jackson Wilderness. It flows in generally a westerly to southwesterly direction until in joins the South Fork.

The Skykomish River supports anadromous populations of Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarkii*), Dolly Varden trout (*Salvelinus malma*), and Bull trout (*S. confluentus*). A very small population of river rearing sockeye salmon (*O. nerka*) can also be found in the Skykomish River; however, there is very little information known about this population. Resident salmonids using the Skykomish River system include cutthroat trout, rainbow trout, brook trout (*S. fontinalis*), Dolly Varden, and Bull trout. Other fish species found in the Skykomish include mountain whitefish (*Prosopium williamsoni*), sunfish spp., minnow spp., sculpin spp., lamprey spp., stickleback spp., sucker spp., and others. Hatchery raised Chinook salmon, Coho salmon, and steelhead trout are also released into the system. The hatchery fish are raised at the Washington Department of Fish and Wildlife's Wallace River Hatchery Complex and are released in the Wallace and Skykomish rivers.

Snoqualmie River

The Snoqualmie River basin originates along the western slope of the Cascade Mountain range and drains approximately 692 square miles. The river has three principal forks: the South Fork, Middle Fork, and North Fork. The South Fork begins in the vicinity of Snoqualmie Pass and flows generally west-northwest until it joins the other two forks near the town of Snoqualmie (Figure 1). The middle Fork originates in the Alpine Lakes Wilderness North of Snoqualmie Pass near the Dutch Miller Gap and flows in a generally westerly direction before its confluence with the North Fork and then the South Fork near the town of Snoqualmie. The headwaters of the North Fork lie further northwest in the Alpine Lakes Wilderness from which the fork flows in a southwesterly direction until reaching the other two forks. Anadromous salmon usage is limited to the mainstem of the Snoqualmie River downstream of Snoqualmie Falls, a 286 foot waterfall that is located at rive mile 40.3 near the town of Snoqualmie, downstream of the confluence of the three forks.

The Snoqualmie River supports anadromous populations of Chinook salmon, Coho salmon, chum salmon, pink salmon, steelhead trout, and cutthroat trout. Anadromous population of Dolly Varden trout, Bull trout, and sockeye salmon are found in the Skykomish River drainage of the Snohomish system and are presumed but not observed in the Snoqualmie. If these species are present in the Snoqualmie River their populations are likely small. Resident salmonids using the Snoqualmie River system include cutthroat trout, rainbow trout, and brook trout. Resident population of Dolly Varden and Bull trout may exist, based on their presence in the Skykomish River, but there is minimal information available for these populations. Other fish species in the Snoqualmie include whitefish, sunfish spp., minnow spp., sculpin spp., lamprey spp., stickleback spp., sucker spp., and others. Hatchery raised steelhead are released into the system by the Washington Department of Fish and Wildlife's Tokul Creek Hatchery Complex at various points in the Snoqualmie River and its tributaries.

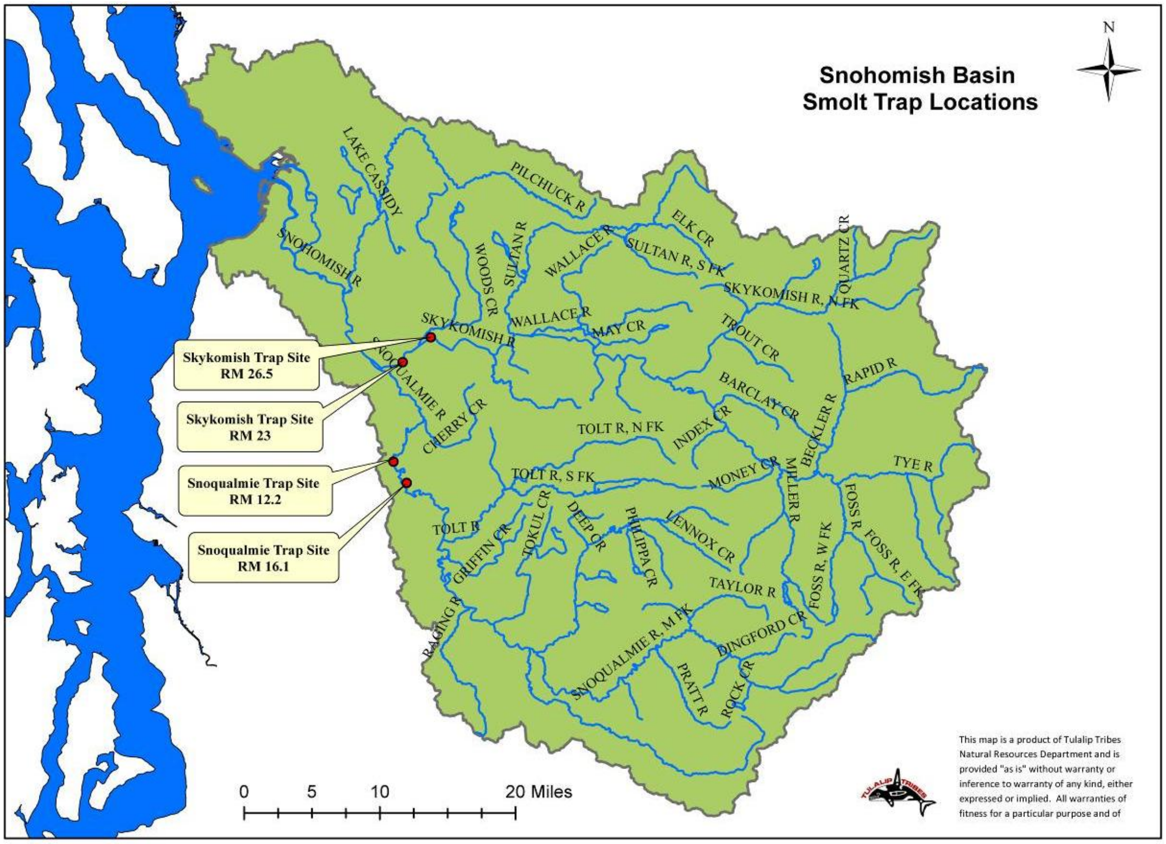


Figure 1: Map of the Snohomish watershed with the locations of the trap sites on the Skykomish and Snoqualmie Rivers.

<u>Site Selection</u>

The trapping sites on the Skykomish and Snoqualmie rivers were selected using aerial photos as well as foot and boat surveys. Site requirements include ample water velocities (i.e. greater than 3 ft./sec.), a constricted channel, adequate access, and a location low enough in the Skykomish and Snoqualmie systems to capture migrating juveniles from the major of drainages within the basin. Reliable anchor points on both sides of the river were also necessary to attach the cables that hold the traps in place.

Trap Description

The traps selected for use in these project were rotary screwtraps, based on a design by E.G. Solutions (Corvallis, Oregon) with modifications by the Lummi Natural Resources Department (Conrad and MacKay, 2000) (Figure 2). Rotary screwtraps were chosen because of low injury and mortality rates for sampled fish (Neuhauser personal communication, 2000). The rotary screwtraps are more versatile, can be used in a wider range of flow velocities, and are more easily deployed than inclined plane traps (MacKay personal communication, 2000). Figure 2 shows a trap in fishing and non-fishing positions. The opening of the cone of a screwtrap is 8 ft. in diameter and has an effective sampling depth of 4 ft. and an effective fishing area of 25.13 ft^2. When deployed into the fishing position, only half of the cone is submersed. Upon entering the mouth of the cone, internal vanes force the fish to the rear of the cone and into the live box. The cone and the live box are attached to a rectangular steel frame that can be raised and lowered using aircraft cable. The frame is suspended from an overhead aluminum support frame mounted on two pontoons that are 24 ft. long by 2.7 ft. wide. In entirety, the rotary screwtrap is 24 ft. long by 15 ft. wide.

The trap is secured into the river using 3/8" diameter low-stretch synthetic "Spectron 12" cables. Two cables, one on either side of the trap, are attached to hand winches mounted onto the pontoons. The winch lines run through snatch blocks mounted onto a stanchion, which is also part of the support frame used to suspend the steel frame and cone. A third cable spans the width of the river and functions as the bowline. The trap is attached to the bowline with a bridle fashioned out of steel cable. The bridle is attached to two anchor points on the bow of the trap and extends roughly 15 ft. in front of the trap structure where it is attached to the bowline using a 3" snatch block. When winching the trap into position the trap runs freely along the bowline, which allows for easier positioning and deployment. The hand winches are used to move the trap into the desired position in the channel. A 14-ft. aluminum skiff with a 6hp outboard is used to transport the crew between the deployed trap and the riverbank. When not operating, the screwtrap is positioned on the side of the channel, out of the main flow of the river.

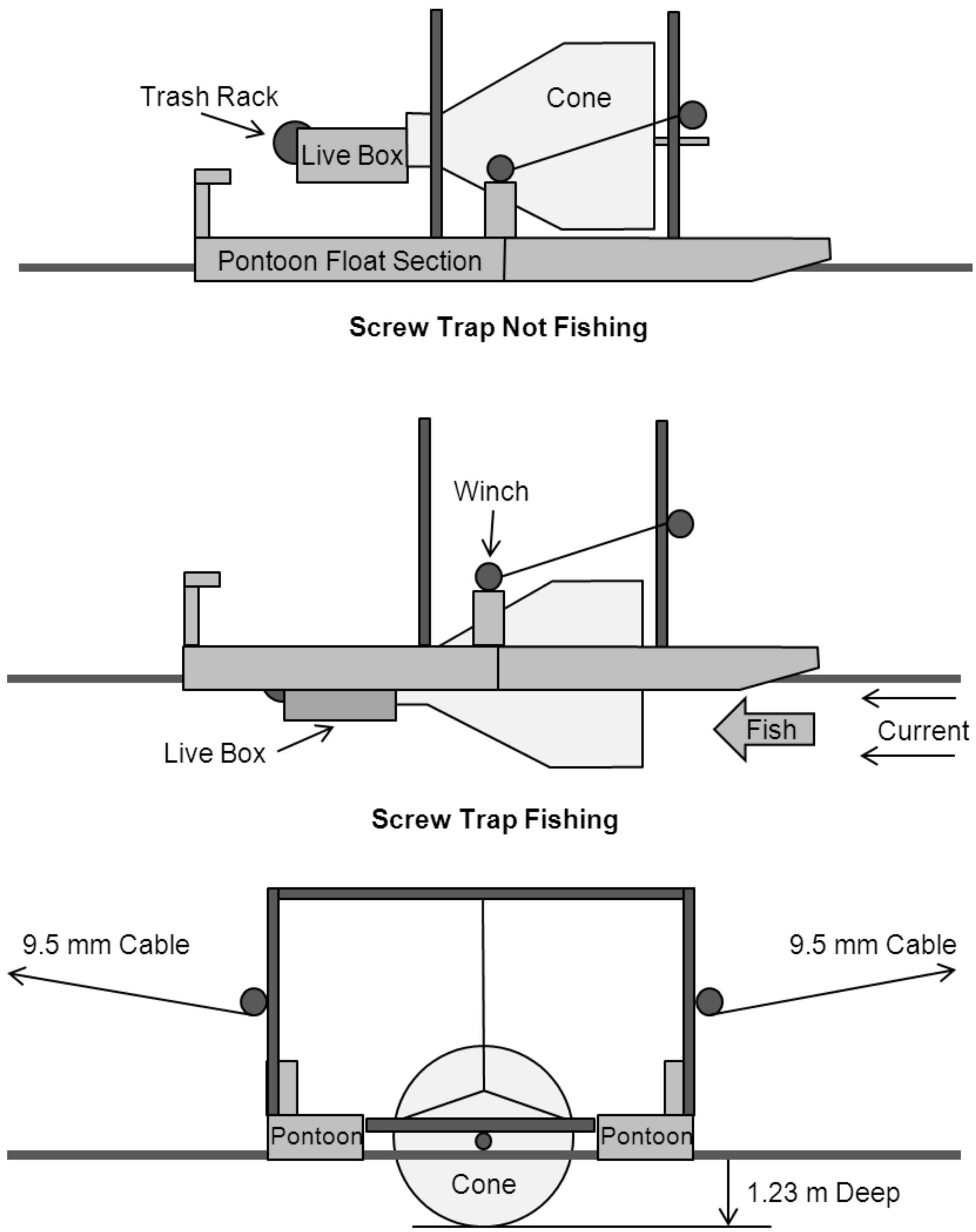


Figure 2: Schematic diagrams of the modified rotary screwtrap, designed by E.G. Solutions Inc., which was operated on the Skykomish River (Adapted from Conrad and MacKay, 2000).

Trap Sampling Effort

Trapping efforts over the initial years of the project indicated that catch rates tended to be considerably higher during nighttime sets than during daytime sets (Nelson and Rawson, 2001; Nelson and Kelder, 2002, 2003). Based upon these findings, the sampling regime was designed to maximize effort during nighttime hours while still conducting an adequate amount of sampling during the day to allow for comparison and quantification of daytime migration. Fishing shifts were roughly12 hours in length (i.e. 6:00 - 18:00 and 18:00 - 6:00). Due to changes in day length during the season, night shifts often began in the late afternoon and included a few hours of daytime effort. We were concerned that catch rates during the few hours of daylight before sunset were not representative of catch rates during all daylight hours. For this reason, we adjusted our sampling schedule to ensure that each sampling period would include a minimum of four hours of effort within the target stratum (i.e. day or night) to ensure a more representative sample of emigration during that stratum. Generally 3-5 night shifts and 1-4 day shifts were scheduled each week. When a fishing event spanned beyond sunrise or sunset, the live box was emptied and a new data sheet was started to allow separation of daytime and nighttime data.

A truly randomized schedule was not used largely because of scheduling and personnel difficulties. However, a schedule planned weeks in advance essentially samples a random cross section of environmental factors including discharge, turbidity, and weather. Trap operation was scheduled to begin in February and end in June. This timing is sufficient to cover most of the out-migration period for both ocean-type Chinook and Coho salmon (Seiler et al., 2000, 2002a, 2004a; Griffith et al., 2001; Dolphin, 2007a).

Rotary screw traps generally capture somewhere between 1% and 5% of the juvenile out-migration, depending upon the amount of trapping performed, conditions, and the objectives of the study (Conrad and MacKay, 2000; Seiler et al., 2000; Griffith et al., 2001). This type of trap is designed to capture juvenile fish that are migrating or moving within the water column. This project targets Chinook and Coho salmon but also capture juveniles of other salmon species as well as juveniles and adults of other fishes. While in operation, captured fish were counted and identified to species every three hours or more frequently depending on conditions.

Sampling Procedures

Captured individuals were netted from the live box and placed in 5 gallon buckets. From the buckets the fish were placed into a dishpan where they were anesthetized with a solution of clove oil and examined for marks (adipose clips and Bismark Brown dye). Species and fork length measurements were recorded for sampled salmonids in millimeters. Fork length is defined as the length from the most anterior part of the fish to the tip of the median caudal fin rays. When catch numbers were too high to allow measurement of every fish, a sub-sample (usually 50 of each species) was measured and the rest were identified to species, partitioned as sub-yearlings (age 0+) or yearlings (age 1+), and counted. After examination, the fish were placed into a bucket of fresh water and allowed to recover before they were released back into the river. All trapping and handling mortalities were recorded. Sunrise and sunset times (according to the U.S. Naval Observatory) for Monroe and Duvall, WA were used to separate daytime and nighttime sets for the Skykomish and Snoqualmie, respectively. Data recorded at the start and finish of each fishing event included time, rotational speed of the cone (rpm), water temperature (C˚), amount of debris, water clarity, weather conditions, river stage (e.g. rising or falling), and any comments regarding the equipment or conditions. We also recorded any periods of time when the cone was not fishing (i.e. raised) for debris removal or maintenance. Discharge, measured in cubic feet per second (cfs), for the Skykomish and Snoqualmie rivers were obtained from river gauges at Gold Bar (station number 12134500; river mile 43) and Carnation (station number 1214900; river mile 23), respectively. Data from these gauges are available in quarter-hour intervals.

PRODUCTION AND SURVIVAL ESTIMATION METHODS

Production

The number of emigrating wild sun-yearling Chinook and wild yearling Coho salmon can be estimated by expanding the capture rates observed during fishing events by the measured trap efficiencies, and then expanding these estimates for times when the trap was not fishing. Trap efficiency values for sub-yearling Chinook and yearling Coho used in these calculations are discussed in latter sections of this report.

In addition to the sub-yearling Chinook migrants (ocean-type) there are also wild Chinook that emigrate from the Skykomish River as yearlings (stream-type). Based on scale information collected on Snohomish River fall Chinook by the Washington Department of Fish and Wildlife (WDFW) and the Tulalip tribes, a percentage (typically 25%-30%) of returning adults have stream-type rearing histories (Snohomish Basin Salmonid Recovery Technical Committee, 1999). Stream-type Chinook salmon were caught in relatively low numbers compared to ocean-type Chinook at the Skykomish and Snoqualmie trap sites from 2000-2012. Despite minimal catch numbers as well as a lack of efficiency tests for the yearling Chinook cohort, we decided to estimate yearling production in hopes to provide some insight into the relative contribution of yearling Chinook to overall production. In order to estimate yearling Chinook production, we used trap efficiency estimates from yearling Coho as a surrogate. We felt that yearling Coho may provide a useful surrogate since the average fork lengths of yearling Chinook and yearling Coho captured at the traps were relatively similar in the Skykomish (98.17 mm & 97.3 mm, respectively) and Snoqualmie Rivers (91.8 mm & 97.4 mm, respectively), and because both species have been shown to have similar swimming speeds (Flagg et al. 1983, Nikl and Farrell 1993, Steven et al. 2004, Brown et al. 2006). While there may be differences in trap efficiency among species, we felt that these aforementioned similarities support the use of yearling Coho efficiency as a surrogate for yearling Chinook. Additionally, we support using Coho efficiency because of operational feasibility and to minimize any further supplementation of hatchery Chinook (used in efficiency trials) in the Snoqualmie River system.

We used statistical weeks (SW) as the temporal sampling unit. Statistical weeks began on Sunday of each week; see Appendix 1 for a table of statistical weeks and corresponding dates. Each statistical week was stratified into day and night periods, defined by sunrise and sunset times in Monroe and Duvall, WA. This diurnal stratification was done because catch rates suggested differences in migration behavior and/or trap efficiency for day and night periods. Diurnal differences in catch rate have also been documented on rotary screwtraps in other Puget Sound rivers (Seiler et al., 2000; Kinsel et al., 2008; Dolphin, 2011). Since sampling efforts differed between day and night periods it was necessary to consider production separately for each stratum to avoid bias in our estimate. For each week, data from all fishing events that were at least 4 hours long and had 100% of the effort falling within either the day or night stratum were used in this estimate.

The number of fish emigrating during each diel strata each week was estimated using the following formula (Rawson, 1984);

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

where:

$\hat{C}_{ix}$	=	Estimated production 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*
R	=	Number marked fish released
r	=	Number marked fish recovered
bc	=	Bias correction

The bias correction factor is necessary to correct for the inherent bias when multiplying by a ratio of two random variables. The bias correction factor for the estimated production is calculated using the formula (Rawson, 1984);

$$bc = 1 + (R - r) / (R * r) \qquad (2)$$

The variances for the estimates were calculated using the formula (Rawson, 1984);

$$Var[\hat{C}_{ix}] = n_{ix} * (n_{ix} + r) * R * (R - r) / ((r^3) * (f_{ix}^2)) \qquad (3)$$

where:

$Var[\hat{C}_{ix}]$ = Variance of production estimate for diel stratum *x* during week *i*

An estimate of total migration during all sampled strata was then calculated by summing the estimates for the individual strata;

$$\hat{C} = \Sigma\hat{C}_{ix} \qquad (4)$$

where:

$\hat{C}$ = Estimated production for both diel strata for all weeks sampled

The variance for both diel strata during all weeks sampled was calculated by summing the weekly values;

$$Var[\hat{C}] = \Sigma\, Var[\hat{C}_{ix}] \qquad (5)$$

where:

$Var\,[\hat{C}]$ = Variance of production estimate for all sampled strata

and the standard deviation, s, for the production estimate is;

$$s = \sqrt{Var\,[\hat{C}]} \qquad (6)$$

Because this sample is drawn from a normal distribution the 95% confidence interval for the production estimate is calculated with the formula;

$$95\%\ C.I.\ For\ \hat{C} = [\hat{C} - z_{\alpha}\,(s),\ \hat{C} + z_{\alpha}\,(s)] \qquad (7)$$

where:

$$z_{\alpha} = 1 - \alpha/2 \qquad (8)$$

Based on catch rates, we concluded that portions of the Chinook and Coho salmon emigrations occurred prior to sampling and extended beyond the sampling season. Therefore, we calculated the numbers of fish that would have emigrated during these un-sampled time periods and included them in our estimates of total production. For estimates of emigration that occurred before and after trapping we assumed which statistical weeks would have marked the beginning and end of the emigration periods for each species. Based on our data as well as those of other Puget Sound trapping efforts, we assumed that the beginning and end of the sub-yearling Chinook emigration were statistical weeks 1 and 30, respectively (Conrad and MacKay, 2000; Seiler et al., 2002a). For migration occurring before trapping began, we took the mean of the production estimates from the first two weeks of the season and considered migration in SW 52 to be zero. We then used linear interpolation to calculate production for the period before trapping started. To estimate migration after the trap was removed, we calculated the mean production for the last two statistical weeks sampled, assumed production during statistical week 31 to be zero, and estimated production from the end of trapping till SW 31 by linear interpolation. No confidence intervals were calculated for these estimates. For yearling Coho we assumed that the emigration began during SW 7 and ended during SW 26. We considered migration in SW 6 and 27 to be zero. To calculate production for SW 7 we took the mean production estimate from SW 8 and 9 and used linear interpolation in the same manner as we did for Chinook. To calculate production for SW 26 we interpolated with linear regression using the production estimate for SW 25 as our starting value. We did not use the mean production estimate for SW 24 and 25 to interpolate production for SW 26 because Coho emigration was in a steep decline at this point in the season and therefore we felt that including SW 24 in our calculation would artificially inflate our estimate for SW 26. Confidence intervals were not calculated around these estimates.

To estimate production for the statistical weeks that were not sampled during the trapping season, due to high discharge or other problems, we used the average of the statistical weeks before and after. In cases where the trap was not fished for multiple statistical weeks, we used linear interpolation to estimate production by using the average of the two weeks before and the two weeks after the un-sampled period as endpoints.

Freshwater Survival

By comparing our estimates of Chinook and Coho salmon production to the information that is available regarding annual spawning activity for these species we are able to calculate relative freshwater survival rates above the traps. The type of spawner information available in the Snohomish River Basin varies between the two species so it was necessary to employ different methods to produce our estimates. As a result of these differences, the estimates calculated for the two species differ in their precision and applicability in assessing survival. We are able to express Chinook freshwater survival as a percentage of eggs that survive to become migrants within the Skykomish and Snoqualmie Rivers. The location of the Skykomish trap changed from RM 23 (2000-2007) to 26.5 (2008-2012), which moved the site upstream of Woods Creek. Therefore, freshwater survival estimates in the prior time period included spawner information from Woods Creek while the latter time period did not include that portion of the Skykomish drainage that may be used by Chinook for Spawning.

In our assessment of survival rates for Coho we are able to calculate a survival index. The index we calculate cannot be used to quantify a level of survival or to compare survival rates between rivers, but it can be used to make relative comparisons of survival between multiple brood years across the Snohomish River Basin. Since Coho survival is calculated for the entire Snohomish Basin, rather than the Skykomish and Snoqualmie sub-watersheds (as organized in this report), we will display yearling Coho survival estimates following the Skykomish and Snoqualmie results in the *Snohomish Basin Coho Survival* section.

Chinook Egg-Migrant Survival

To estimate freshwater survival rates for wild Chinook in the Skykomish and Snoqualmie Rivers we simply divided our production estimates of sub-yearling and yearling Chinook by the estimated egg deposition above the trap sites for the respective brood years. The result of this calculation is an egg-migrant survival ratio expressed as a percentage. It should be noted that this approach does not incorporate differential survival rates between the two cohorts. Since yearling out-migrants are considerably more developed than their sub-yearling counterparts, when they emigrate from the river, they are likely to experience a considerably lower mortality rates. With our survival analysis, it is difficult to fully assess the differential egg-migrant survival rates between the cohorts because the relative contribution of each cohort to the emigrating population may not align with the relative percentage each cohort represents from the deposited eggs.

In order to arrive at an estimate of egg deposition we used information from WDFW spawner surveys as well as fecundity data collected at the Wallace River Hatchery. Redd counts are available for naturally spawning Chinook salmon in the Snohomish basin. These surveys are conducted by personnel from WDFW and other agencies and the data is compiled by WDFW. The spawning ground survey protocol for Chinook assumes that all of the potential spawning area in the basin is surveyed and all redds are counted. It is highly unlikely that all redds are counted in any given year but certainly the vast majority of them are identified and this is the best estimate of spawning activity available in the basin. Since the surveys are conducted in a consistent manner across years they provide a comparison of the relative amount of spawning that takes place in a given year. These data are broken down into sub-basins and river sections allowing us to include the areas upstream of the Skykomish and Snoqualmie trap site in our estimate of Chinook spawning. Because of the way the river sections are defined (e.g. Snohomish-Skykomish Mainstem), we are not able to completely tease out spawning that occurs upstream of the trap sites in these sections. We are able to exclude redd counts from the Pilchuck River and its tributaries as well as Woods creek in years 2008-2012 from our estimate of spawning above the traps. We are, however, unable to exclude spawning occurring in the mainstem Snohomish-Skykomish below RM 23 (2000-2007) and RM 26.5 (2008-2012) or the lower mainstem Snoqualmie below RM 12.2 from the redd counts. There is some spawning that occurs in these areas and therefore redd counts likely include a limited number of observations below the trap sites. As was stated above, it is also likely that there is some spawning upstream of the trap site that goes undocumented. For the purpose of our freshwater survival calculations we assume that the redd counts excluding the Pilchuck River, Woods Creek, and mainstems below the traps are a relatively accurate count of the number of Chinook redds upstream of the trap sites.

We derived redd counts from escapement estimates provided by WDFW (Pete Verhey, personal communication) assuming that 2.5 adult fish were associated with each redd. Fecundity data was gathered from hatchery Chinook returning to the Wallace River Hatchery (varying from 3,945-5,141 eggs per female). We used these values as our estimate of fecundity for naturally spawning Skykomish and Snoqualmie Chinook. Egg deposition for each brood year was estimated using the following formula;

$$D_b = CR_b * FE_b \tag{9}$$

where:

D_b = egg deposition upstream of the trap site during year *b*
CR_b = the number of Chinook redds that were surveyed upstream of the trap site during year *b*
FE_b = the fecundity of female Chinook during year *b*

We then calculated percent egg to migrant survival for wild Chinook using the formula:

$$S_b = (SP_{b+1} + SP_{b+2}) / D_b \tag{10}$$

where:

S_b = the percentage of eggs deposited in brood year *b* that survived to emigration
SP_{b+1} = wild sub-yearling Chinook production estimate for year *b+1*
SP_{b+2} = wild yearling Chinook production estimate for year *b+2*

Coho Survival Indices

The values we are able to calculate for Coho are different than those that we can calculate for Chinook in the Skykomish and Snoqualmie. The Coho spawner surveys conducted in the Snohomish River are designed around annual surveys of a number of predefined index reaches around the watershed. The observational data collected by the field crews are expressed as a numerical value called "fish days". The number of fish days recorded for all of the indices are added to a total count of the fish that are shuttled above sunset falls on the Skykomish River to yield a total number of fish days for the entire Snohomish Basin. The total number of fish days is then multiplied by a ratio calculated from a 1977 survey of the entire basin (Zillges, 1977) to arrive at an adjusted estimate of the total number of spawning adults in the Snohomish basin. In order to estimate egg-migrant survival for Coho we would need to be able to quantify the amount of spawning activity that occurred upstream of the trap site during a given brood year, which we are unable to do using the fish days index of Coho spawning. In lieu of producing an estimate of egg-migrant survival we have derived a method for making relative comparisons of survival rates in the Snohomish Basin between two or more brood years within this study.

Using the count of Coho above sunset falls and the estimated fish days in index reahces above the trap site, a relative index of the level of spawning that occurred each year in the Snohomish River Basin was calculated (Pete Verhey, personal communication). This is based on the assumption that fish counts within these index areas are proportional to the overall level of spawning activity that takes place above the trap site during any brood year; however, is likely quite conservative. By comparing this relative spawning activity to our production estimates we can calculate a number that we call the Snohomish Coho survival index (SnoCSI). This number cannot be related to any survival percentage, but it can be used to compare increases and decreases in survival between years of the study as well as what sort of freshwater conditions contribute to increases or decreases in survival. We did not include several index reaches below the trap sites in hopes to accurately represent escapement and production upstream of our sample sites. Additionally, we did not include Woods Creek in migration years after 2008 since the Skykomish trap was moved upstream of this tributary.

The SnoCSI can be calculated using the following formula:

$$\text{SnoCSI}_b = \text{P}_{b+2}/(\text{SF}_b + \text{IC}_b) \qquad (11)$$

where:

P_{b+2} = Coho production estimate for migration year *b+2* from both the Skykomish and Snoqualmie traps
SF_b = count of spawning adults in the Snohomish basin for brood year *b*
IC_b = adjusted estimate of total number of fish days for index reaches above the trap sites for brood year b

SKYKOMISH RIVER RESULTS

Trap Site Location and Characteristics

The Skykomish trap location was changed from river mile 23 (2000-2007) to 26.5 (2008-2012) due to the implementation of a log jam and channel formation restoration project as part of a mitigation bank. The trap site during prior years was located at the head of a lateral scour pool on the outside of a meander (Figure 3, Figure 4). The wetted width of the Skykomish River at this point was ~275 ft. during the spring out-migration period and the channel's bank full width was ~575 ft. The channel's maximum depth at the site was ~10 ft. at summer low-flow level and approaches ~19 ft. at bank full depth. Water surface velocity was ~5 ft./sec., summer low flow was ~3,360 cfs, and the mean annual discharge at this location was ~6,000 cfs. The channel gradient was < 1% and substrate was principally gravel and cobble. When fishing; the trap was positioned in the thalweg, near the left bank of the river (Figure 4). Land use adjacent to the prior project site was principally agriculture. Existing riparian vegetation (i.e. tree canopy) was primarily cottonwood and alder. At the immediate trapping site, the right-bank was composed of a gravel bar adjacent to an active farm. The left bank was hardened (i.e. riprapped) and had much of the natural riparian vegetation removed. The hardened bank protected agricultural lands on the south side of the river.

The trap site during latter years was located at the tail-out of a wide pool/run as it transitioned into a riffle, confined by two gravel point bars (Figure 3, Figure 4). The wetted width of the Skykomish River at this point was ~325 ft. during the spring out-migration period and the channel's bank full width was ~490 ft. The channel's maximum depth at the site was ~5 ft. at summer low-flow level and approaches ~18.5 ft. at bank full depth. Summer low-flow at this location was ~3,030 cfs and mean annual discharge was ~4,070 cfs. The channel gradient was < 1% and substrate was principally gravel and cobble. When fishing; the trap was positioned in the thalweg of river, near the center of the channel (Figure 4). Land use adjacent to the latter project site was principally agriculture; however, riparian vegetation was relatively intact (with some supplemental plantings). Existing riparian vegetation was primarily cottonwood and alder and planted riparian vegetation included cedar and spruce. At the immediate trapping site, the right-bank was composed of a gravel bar adjacent to a cottonwood stand. The left bank was just downstream of a hardened section (i.e. riprapped) with planted riparian vegetation integrated into a cottonwood stand. Adjacent to the stand was an active farm.

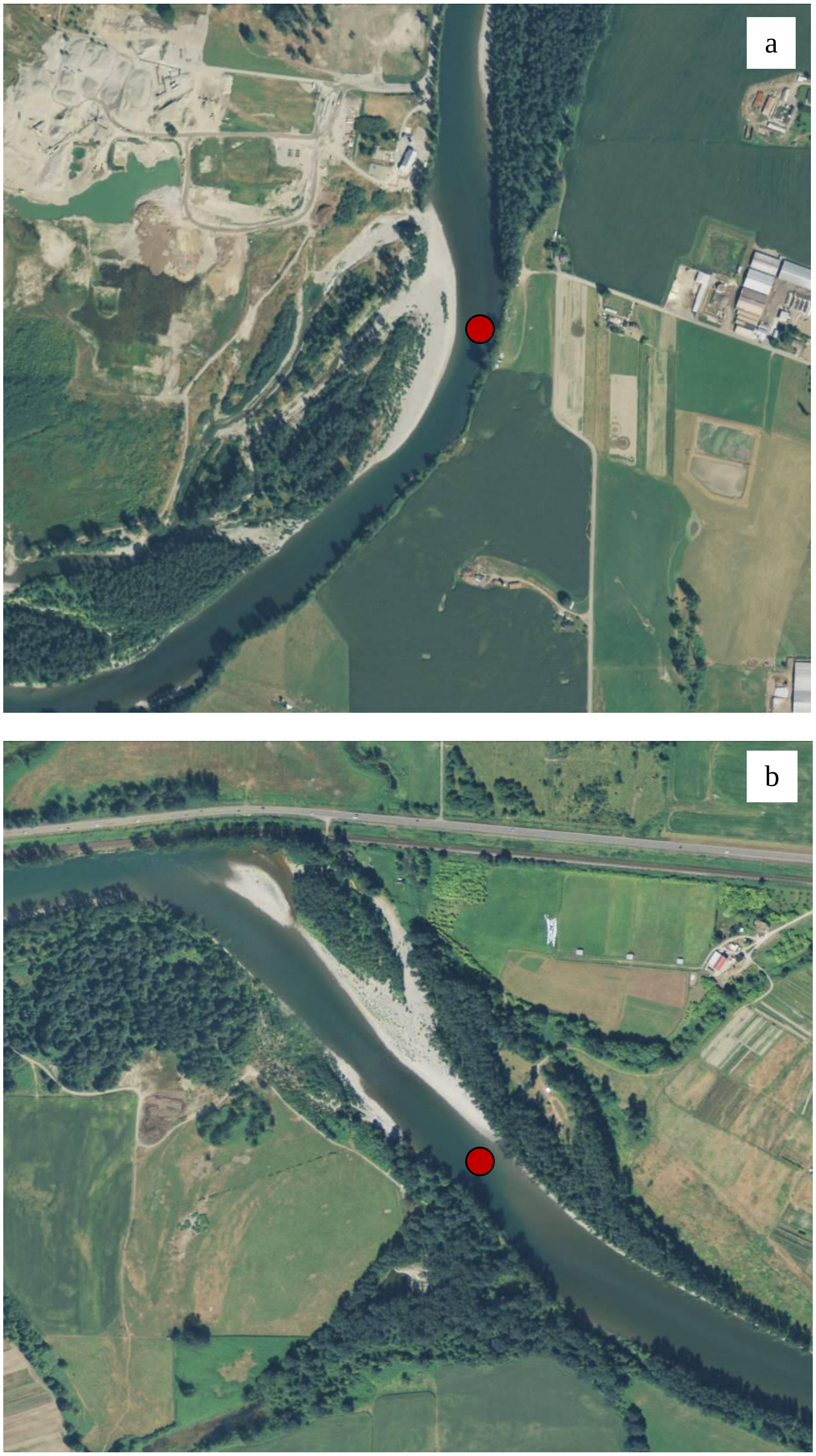
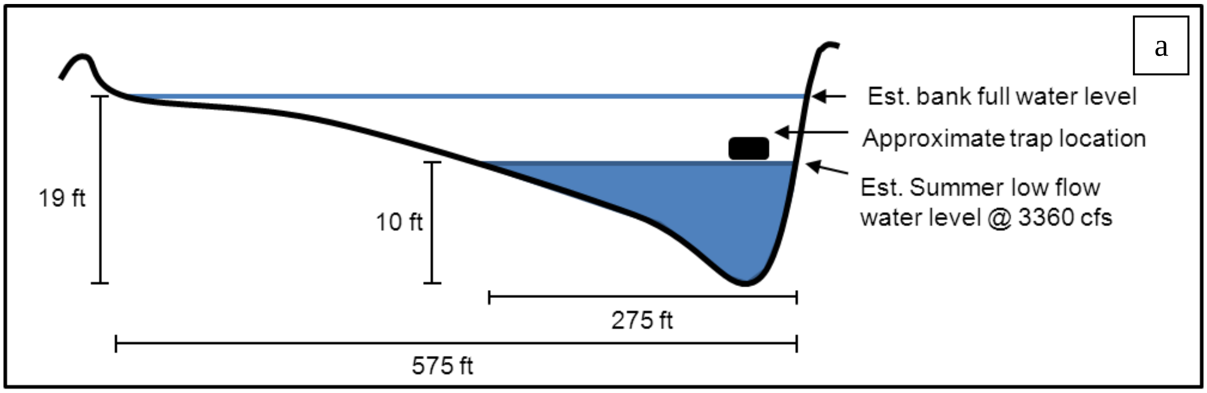


Figure 3: Aerial photograph of the trap site at river mile 23 (a) and 26.5 (b) on the Skykomish River with a point indicating the approximate trap fishing position. The river flows from the top to the bottom in photograph (a) and bottom to the top in photograph (b).



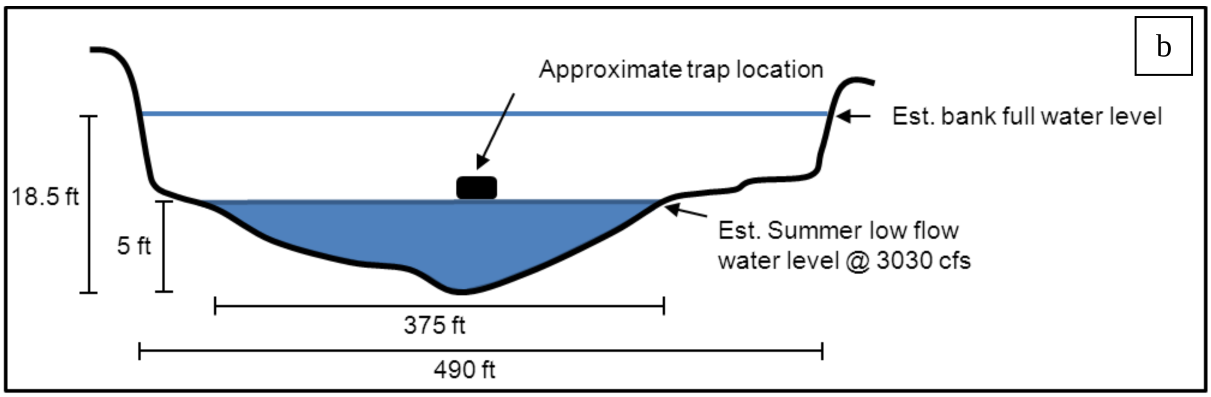


Figure 4: Cross section diagrams of the Skykomish River trap sites at river mile 23 (a) and 26.5 (b). Diagrams are not drawn to scale.

Trap Operation and Discharge

Rotary screw trap operation on the Skykomish River from 2000-2012 was generally conducted from February to June; however, yearly start week varied from SW 7-14 and end week varied from SW 23-28 (Table 1). 2000 was the pilot season for trapping efforts so start date, end date, and trapping hours were quite different from other years. Additionally, the Skykomish trap was not fished in 2008 because of repairs needed from damages sustained in 2007. Subsequently, 2008 was not included in overall analyses. The Skykomish trap has fished 9,887.6 hours over the last 12 years with yearly efforts ranging from 294.6 hours during the 2000 pilot year to 1125.2 hours during 2006. Across 2001-2012, average fishing time during the sample period was 872 hours. The trap was fished from 7-44% of the total daylight hours and 22-56% of the total night hours over the 12 sample periods. River flow or discharge has been suggested as a dominant factor affecting downstream migrant trapping (Seiler et al., 1998, 2000; Conrad and MacKay, 2000; Griffith et al., 2001). Discharge varied considerably at the Skykomish trap sites during the 12 sample seasons ranging from 11,500 cfs to 60,000 cfs at the initial site and 18,800 cfs to 51,800 cfs at the latter site. We were unable to operate the trap on several occasions during high discharge levels when water velocities and debris increased the likelihood of fish injury, trap damage, and potentially compromised the safety of crew members. During our experiences over the past 12 years we have found that fishing operations often become extremely difficult during drastically rising flow levels regardless of total discharge level. We did not attempt to sample at discharges in excess of ~12,000 cfs regardless of debris load.

Table 1: Summary of trap operations in the Skykomish River from 2000-2012.

		Hours fished			Total hours in sample period		Percent fished		Discharge (cfs)	
Year	Statistical weeks	Day	Night	Total fished	Day	Night	% Day	% Night	Min	Max
2000	14-28	100.7	193.9	294.6	1486.25	889.75	7%	22%	1,380	15,700
2001	7-14	190.4	696.5	886.9	1508.8	1237.75	13%	56%	1,100	11,500
2002	7-25	273.7	398	671.7	1437.25	1140.5	19%	35%	1,651	34,408
2003	8-25	467.6	524.5	992.1	1720.25	1303.75	27%	40%	1,749	34,467
2004	8-26	498.9	572.1	1071	1709.5	1370.5	29%	42%	1,048	19,278
2005	7-23	458.2	536.1	994.3	1595	1261	29%	43%	1,230	60,900
2006	8-25	544.8	580.4	1125.2	1228.5	1627.5	44%	36%	1,260	21,900
2007	10-23	221.2	225.6	446.8	1008	688.5	22%	33%	1,550	34,400
2009	10-24	374.8	312.9	687.7	1568.75	1119.25	24%	28%	1,250	51,800
2010	7-24	508.2	526.3	1034.5	1669.5	1354.5	30%	39%	1,330	13,600
2011	9-25	287.8	379.3	667.1	1265	998	23%	38%	1,610	31,300
2012	7-25	458.2	557.5	1015.7	1634	1325.25	28%	42%	1,900	18,800

Trap Catch

A total of 1,709,098 salmonids were captured in the Skykomish rotary screwtrap during 2000-2012 sampling efforts (Table 2). Over the 12 sample periods of trap operation a total of 22,667 wild juvenile Chinook (21,311 sub-yearling & 1,356 yearling) and 21,988 hatchery Chinook (13,555 sub-yearling & 8,433 yearling) salmon were captured. Yearling Chinook catch for 2007 was not included because of identification issues with sample screws. A total of 79,274 wild Coho (15,568 sub-yearling & 63,706 yearling) and 7,622 yearling hatchery Coho salmon were captured. Additionally, total catch of other salmonids included 360,242 Chum, 1,188,040 Pink, 4,109 wild steelhead, 25,484 hatchery steelhead, 337 Cutthroat & Rainbow trout, and 49 Dolly Varden & Bull trout. Releases from the Wallace River Hatchery ranged from 83,500-1,793,067 for sub-yearling Chinook, 55,400-290,000 for yearling Chinook, and 140,000-373,045 for yearling Coho (Table 3). Between 74.6-99.9% of sub-yearling Chinook (excluding 2000 since no sub-yearling Chinook were clipped), 85.1-100% of yearling Chinook, and 28.3-99.9% of yearling Coho and in those releases were externally marked with adipose fin clips. Taking these ranges into account, we estimate that approximately 0.04-34.9% of sub-yearling Chinook, 0.02-14.1% of yearling Chinook, and 0.01-25.9% of yearling Coho initially identified as wild were possibly of hatchery origin. Total Chinook mortalities from 2000-2012 ranged from 0.06-1.2 % of the total catch with average yearly mortality being 0.43%. Total Coho mortalities from 2000-2012 ranged from 0.04-0.8% of the total catch with average yearly mortality being 0.2%. Additional summary statistics for captured salmonids in the Skykomish from 2000-2012 are reporting in Table 2.

Table 2: Summary of trap catch in the Skykomish River from 2000-2012. Abbreviations are denoted as: mortalities at time of identification (morts), hatchery origin fish (Hat), cutthroat trout (Cutt), rainbow trout (Rain), Dolly Varden trout (Dolly), and Bull trout (Bull).

		Chinook				***Coho***					***Steelhead***		***Cutt/***	***Dolly/***	***Total***
		Wild 0+	***Wild 1+***	***Hat. 0+***	***Hat. 1+***	***0+***	***Wild 1+***	***Hat. 1+***	***Chum***	***Pink***	***Wild***	***Hat.***	***Rain***	***Bull***	***salmonids***
2000	Catch	1287	18	1	0	141	5972	360	6392	19441	376	246	30	5	34329
	Morts	16	0	0	0	2	15	1	187	235	0	0	0	0	456
	% Mort	1.2%	0.0%	0.0%	0.0%	1.4%	0.3%	0.3%	2.9%	1.2%	0.0%	0.0%	0.0%	0.0%	1.3%
2001	Catch	1786	117	60	1442	1819	5512	1556	54676	3018	487	2469	73	7	73102
	Morts	18	0	0	0	5	12	0	138	10	0	1	0	0	184
	% Mort	1.0%	0.0%	0.0%	0.0%	0.3%	0.2%	0.0%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.3%
2002	Catch	1093	32	31	4	1975	8851	200	14852	146196	584	2764	52	7	176657
	Morts	5	0	0	0	7	7	0	54	434	0	0	1	0	508
	% Mort	0.5%	0.0%	0.0%	0.0%	0.4%	0.1%	0.0%	0.4%	0.3%	0.0%	0.0%	1.9%	0.0%	0.3%
2003	Catch	3394	69	2655	279	2156	8713	505	79260	3969	407	1845	54	2	103312
	Morts	14	0	0	0	8	7	0	140	22	0	0	0	0	191
	% Mort	0.4%	0.0%	0.0%	0.0%	0.4%	0.1%	0.0%	0.2%	0.6%	0.0%	0.0%	0.0%	0.0%	0.2%
2004	Catch	951	56	1172	911	807	13949	1486	58081	162488	843	7129	22	3	247916
	Morts	9	0	0	3	1	5	0	116	323	0	0	0	0	459
	% Mort	1.0%	0.0%	0.0%	0.3%	0.1%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%
2005	Catch	2411	140	3278	1484	1725	3082	181	31515	2365	397	2272	9	2	47920
	Morts	15	0	25	0	7	7	0	31	1	4	25	0	0	115
	% Mort	0.6%	0.0%	0.0%	0.0%	0.4%	0.2%	0.0%	0.1%	0.0%	1.0%	1.1%	0.0%	0.0%	0.2%
2006	Catch	2928	292	4	14	744	6218	1634	35299	417729	366	4968	72	17	470322
	Morts	6	0	1	0	1	1	0	9	437	1	0	0	0	456
	% Mort	0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.3%	0.0%	0.0%	0.0%	0.1%
2007	Catch	1348	NA	0	69	815	3882	18	7489	36	425	996	2	0	15080
	Morts	12	NA	0	0	0	2	0	12	0	0	0	0	0	26
	% Mort	0.9%	NA	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%

Table 2: continued.

		Chinook				*Coho*					*Steelhead*		*Cutt/*	*Dolly/*	*Total*
		Wild 0+	*Wild 1+*	*Hat. 0+*	*Hat. 1+*	*0+*	*Wild 1+*	*Hat. 1+*	*Chum*	*Pink*	*Wild*	*Hat.*	*Rain*	*Bull*	*salmonids*
2009	Catch	1650	359	0	3791	142	1410	132	14577	3	41	574	2	0	22687
	Morts	9	0	0	0	10	3	0	74	0	0	0	0	0	96
	% Mort	0.6%	0.0%	0.0%	0.0%	7.0%	0.2%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
2010	Catch	2248	116	3874	61	2784	1245	126	26494	270984	80	329	9	2	308352
	Morts	3	0	1	0	4	0	0	22	171	0	0	0	0	201
	% Mort	0.14%	0.00%	0.03%	0.00%	0.14%	0.00%	0.00%	0.08%	0.06%	0.00%	0.00%	0.00%	0.00%	0.07%
2011	Catch	765	135	1	197	461	1798	1113	7911	2	37	392	6	1	12819
	Morts	1	0	1	0	0	9	0	18	0	0	0	0	0	29
	% Mort	0.1%	0.0%	100.0%	0.0%	0.0%	0.5%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
2012	Catch	1323	22	2451	178	1927	3005	310	22843	159972	61	1474	5	3	193578
	Morts	19	0	0	0	27	1	0	52	204	0	0	0	0	303
	% Mort	1.4%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%

Table 3: Summary of hatchery releases and adjusted trap catch for sub-yearling Chinook and yearling Coho on the Skykomish River from 2000-2012. Adjusted catch indicates the percentage of trap catch identified as wild but likely of hatchery origin. Wild fish could not be estimated for 2000 since no hatchery fish were clipped and an adjustment could not be made for 2004 since the adjustment included all wild fish that were sampled.

	Sub-yearling Chinook			Yearling Chinook			Yearling Coho		
Year	# release	% clipped	Adjusted trap catch	# release	% clipped	Adjusted trap catch	# release	% clipped	Adjusted trap catch
2000	83,500	0.0%	N/A	55,400	98.6%	0.0%	373,045	84.4%	1.1%
2001	1,223,194	80.3%	0.8%	500,000	100.0%	0.0%	155,345	70.8%	1.1%
2002	795,123	74.6%	1.0%	218,000	100.0%	0.0%	149,334	73.7%	11.7%
2003	1,026,559	80.2%	19.4%	250,000	99.7%	1.2%	142,765	27.8%	0.8%
2004	870,000	77.9%	34.9%	133,000	85.1%	N/A	154,500	30.1%	15.0%
2005	1,067,700	80.9%	32.0%	164,843	99.2%	8.3%	154,500	28.3%	24.9%
2006	876,505	76.0%	0.0%	246,183	99.6%	0.0%	167,000	81.7%	14.9%
2007	1,115,372	81.5%	0.0%	290,000	98.2%	0.4%	152,266	67.6%	5.9%
2009	1,168,281	99.4%	0.0%	261,507	98.7%	14.1%	152,005	99.2%	0.2%
2010	1,251,377	99.9%	0.1%	234,516	99.1%	0.1%	140,000	99.9%	0.1%
2011	1,010,000	98.9%	0.0%	249,740	98.3%	2.6%	141,000	99.8%	0.0%
2012	1,793,067	98.4%	0.3%	240,306	99.6%	3.6%	155,000	97.6%	0.2%

Fork Length Summary

Monthly length frequency histograms were used to estimate the threshold fork length values separating wild Chinook yearlings from sub-yearlings (Figure 5). Any fish with a fork length (FL) greater than or equal to the month's threshold value was considered to be a yearling. To account for growth during the season, histograms were constructed separately for each month to determine the shift in estimated threshold fork length value. Monthly fork length thresholds were confirmed from scale data collected during the 2012 sample season.

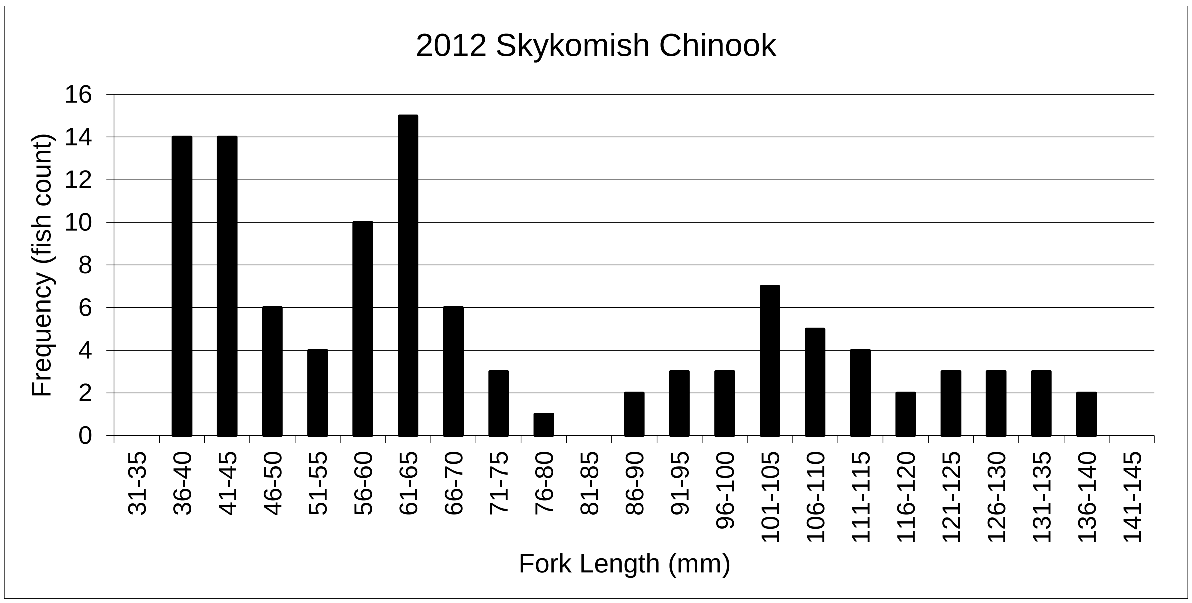


Figure 5: Example length frequency histogram from the Skykomish in April of 2012, used to determine the threshold value for separating wild sub-yearling from yearling Chinook. In this example month, 83 mm would have been used as the estimated fork length threshold value.

Wild sub-yearling Chinook fork lengths for the 12 sample seasons appeared to increase from ~40 mm in February to ~90 mm in late June (Figure 6). Additionally, we observed a wide spread and often bimodal distribution of wild sub-yearling Chinook fork lengths during May-June (Figure 7). Wild yearling Coho fork lengths for the 12 sample seasons did not exhibit a sustained period of increase but rather a slight increase in fork lengths from ~75 mm to ~100 mm during early April (Figure 8). Median fork length was fairly consistent from the start of sampling through early June (SW 26) with a relatively consistent spread in distribution across months (Figure 9).

As noted in the *Trap Catch* section, a certain percentage of sub-yearling Chinook, yearling Chinook, and yearling Coho were possibly of hatchery origin. These hatchery fish may have altered the percent frequency of fork lengths measured; however, in most years the percentage of adjusted catch was relatively low, which would likely result in a minimal influence on fork length trends.

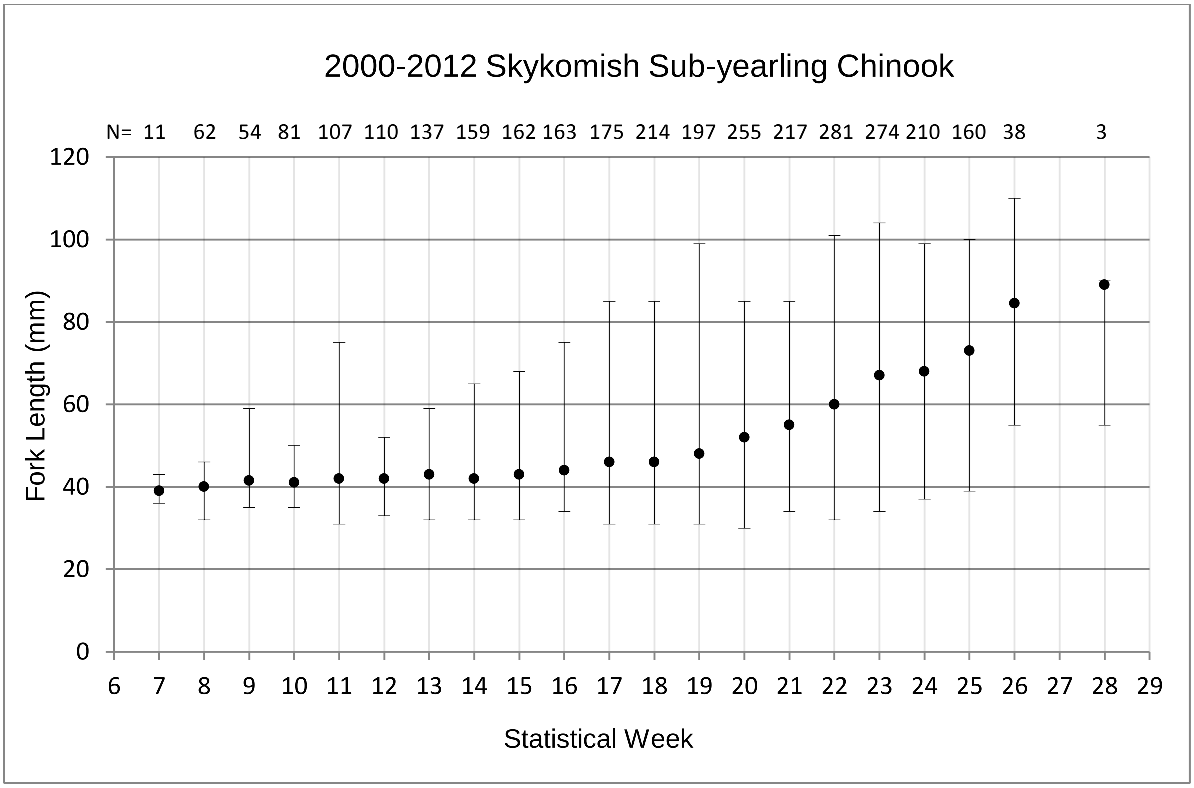


Figure 6: Observed wild sub-yearling Chinook fork lengths from 2000-2012 in the Skykomish River. Diamonds indicate median fork length with whiskers denoting maximum and minimum lengths.

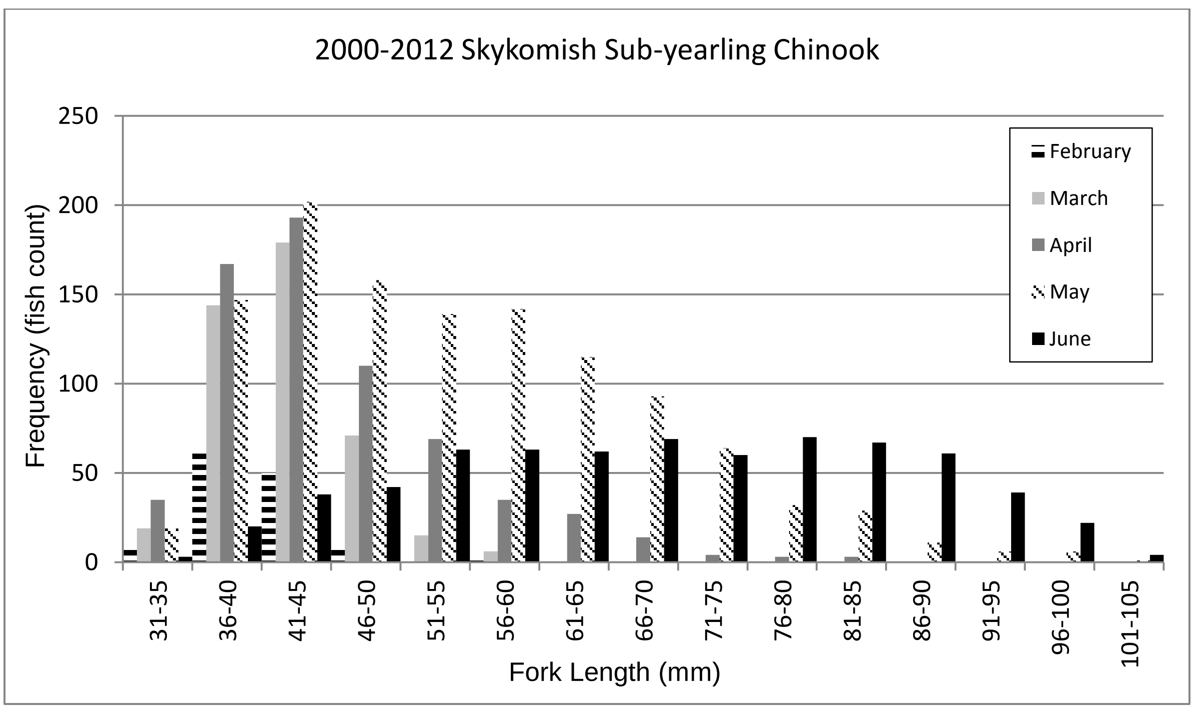


Figure 7: Fork length frequency distribution of wild sub-yearling Chinook measured at the Skykomish trap from 2000-2012.

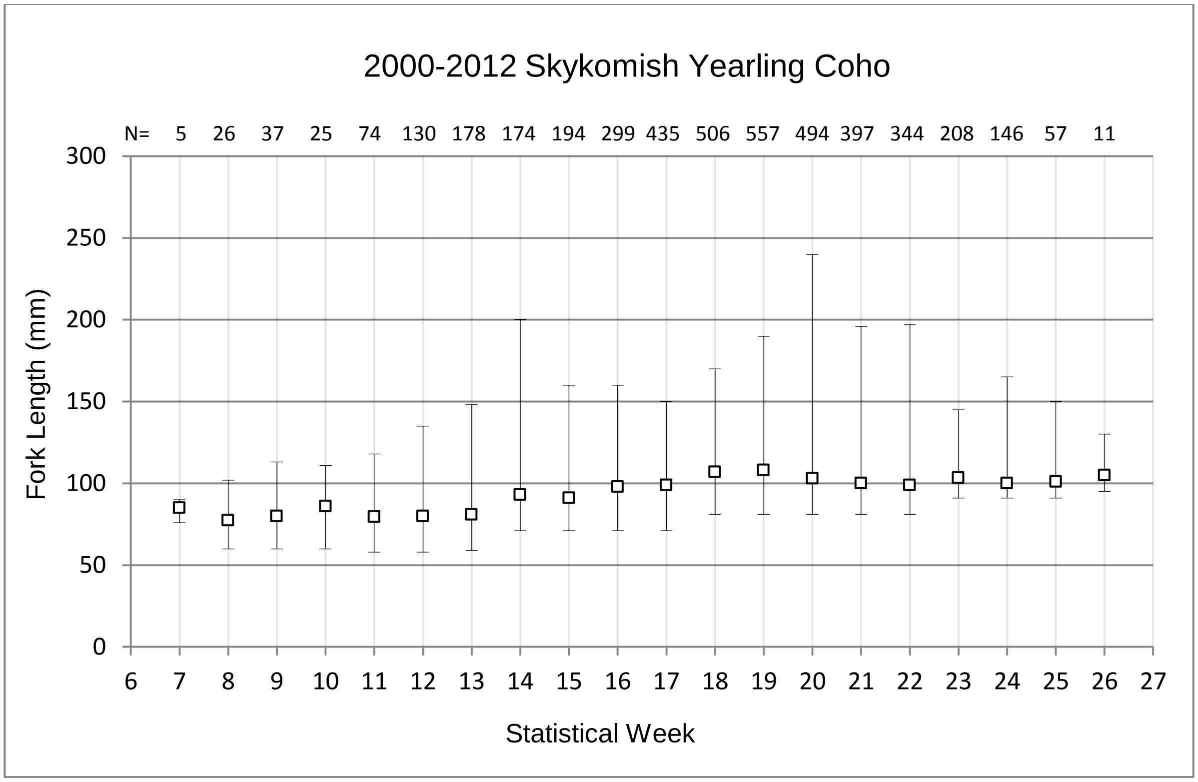


Figure 8: Observed wild yearling Coho fork lengths from 2000-2012 in the Skykomish River. Diamonds indicate median fork length with whiskers denoting maximum and minimum lengths.

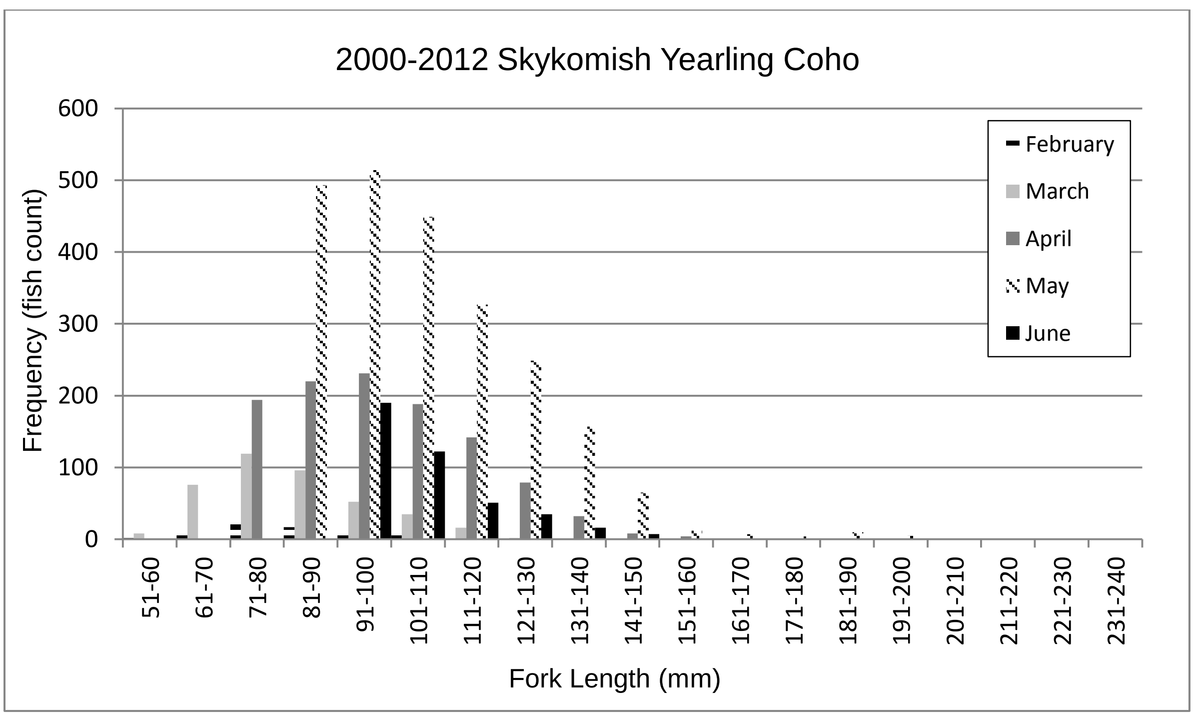


Figure 9: Fork length frequency distribution of wild yearling Coho measured at the Skykomish trap from 2000-2012.

Juvenile Salmonid Catch Rates

Catch data were converted to catch per unit effort (CPUE) for analyses dealing with migration size and timing. This allowed for easier comparison of catches both within and between years. Excluding the 2000 pilot year, average annual CPUE for sub-yearling Chinook and yearling Coho varied from 0.85-3.44 fish/hour and 1.34-12.74 fish/hour, respectively (Table 4). Average weekly CPUE varied from 0-17.79 fish/hour for wild sub-yearling Chinook and 0-62.85 fish/hour for wild yearling Coho. Generally, there was a bimodal distribution of wild sub-yearling Chinook catch with main peaks occurring during late March through April (~SW 12-17) and at the end of May through early June (~SW 21-23) (Figure 10). Roughly 50% of the sub-yearling Chinook catch occurred by mid-April (~SW 15) (Figure 11). The main peak in wild yearling Coho catch occurred during late April through early June (~SW 17-23) (Figure 12),with 50% of the yearling Coho catch occurring by mid-May (~SW 19) (Figure 13). Catch as well as the magnitude of peak migration was considerably higher for wild yearling Coho compared to wild sub-yearling Chinook. The peaks and timing of wild yearling Coho migration tended to be more consistent inter-annually whereas wild sub-yearling Chinook displayed very inconsistent migration timing and duration (Appendix 2). In 2003, 2005, 2006, and 2007, CPUE for wild sub-yearling Chinook was above 0 at the start of the sample period indicating that emigration had begun before the start of sampling; however, the initial catch rates during these years where quite low suggesting that only a small portion of sub-yearling Chinook emigration likely took place prior to sampling.

Table 4: Average annual CPUE (catch per unit effort) for sub-yearling Chinook and yearling Coho in the Skykomish River from 2001-2012.

	Average Annual CPUE	
Trapping Year	Sub-yearling Chinook	Yearling Coho
2001	1.85	6.11
2002	1.58	12.74
2003	3.44	6.34
2004	0.85	9.01
2005	2.55	3.01
2006	2.46	5.98
2007	3.17	1.40
2009	2.37	2.15
2010	2.19	1.35
2011	1.96	2.65
2012	1.22	2.83

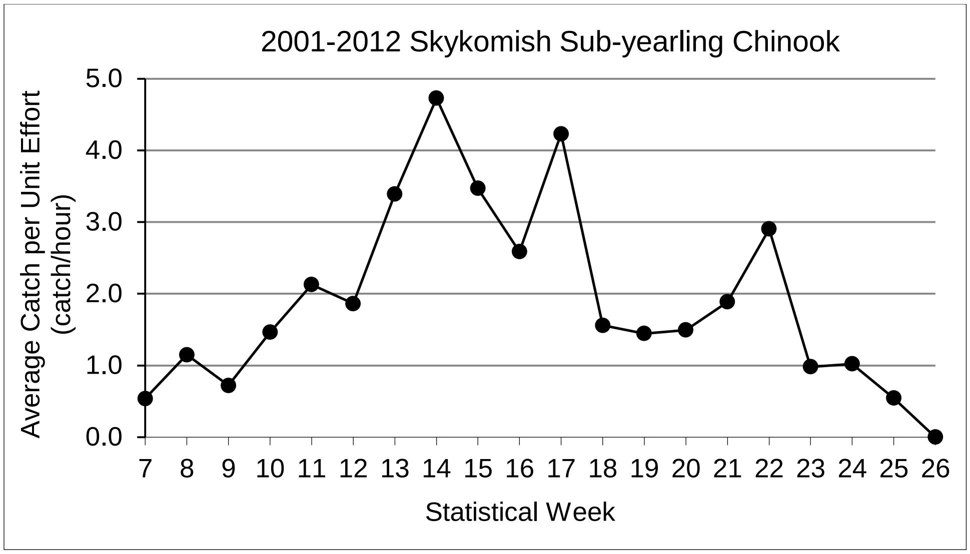


Figure 10: Average catch per unit effort (CPUE) for wild sub-yearling Chinook in the Skykomish River from 2001-2012.

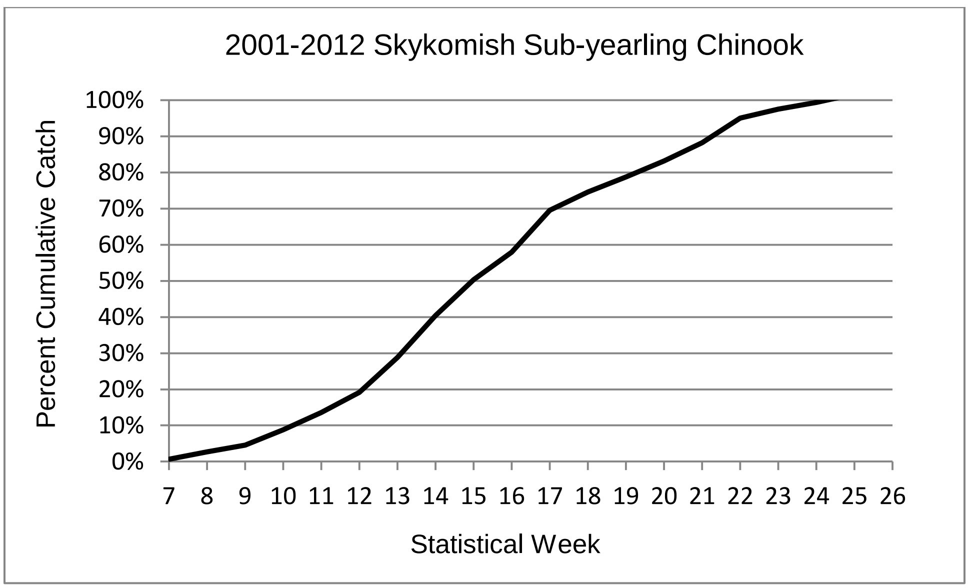


Figure 11: Percent of cumulative catch for wild sub-yearling Chinook in the Skykomish River from 2001-2012.

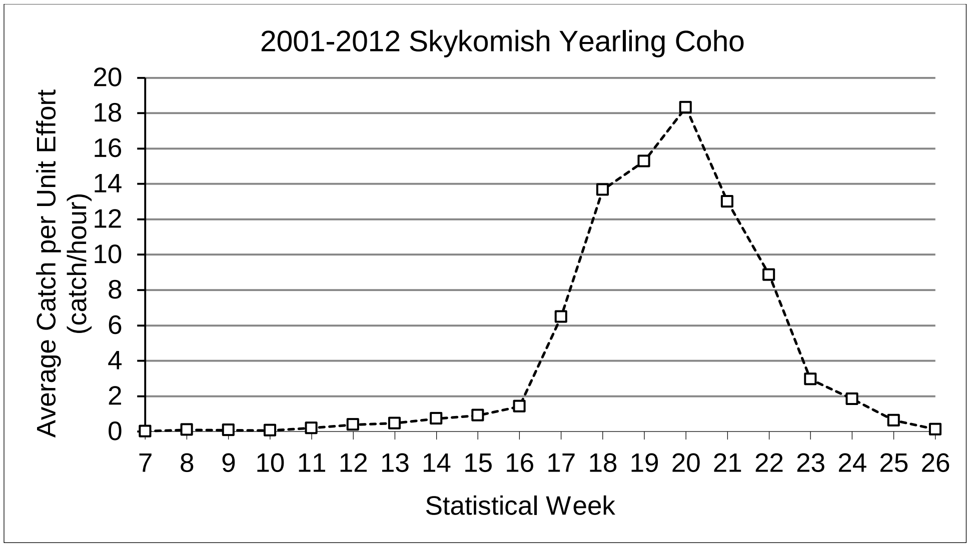


Figure 12: Average catch per unit effort (CPUE) for wild yearling Coho in the Skykomish River from 2001-2012.

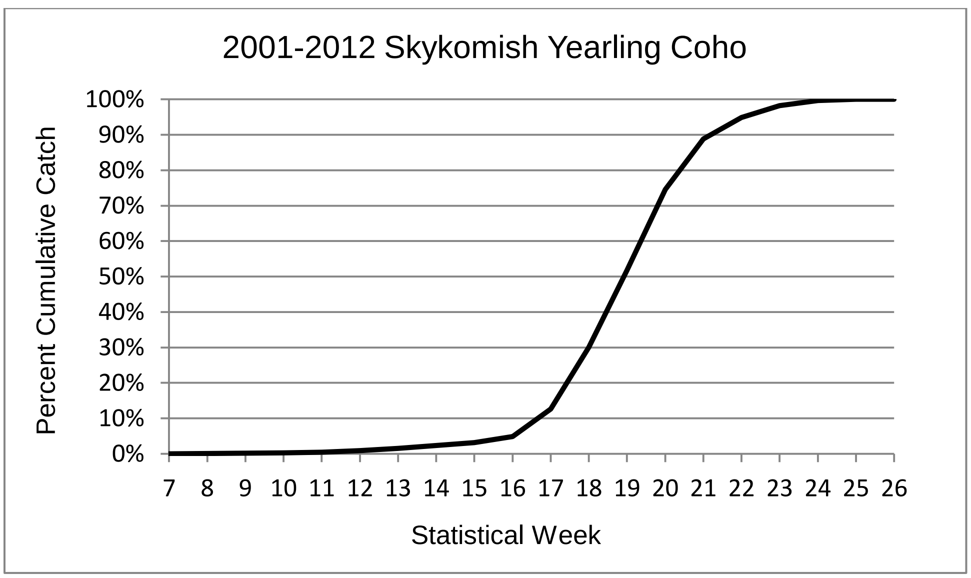


Figure 13: Percent of cumulative catch for wild yearling Coho in the Skykomish River from 2001-2012.

<u>Factors Affecting Catch Rates</u>

As we have seen in the previous section, CPUE varied a considerable amount within and among each sample period. Salmonid emigration is a dynamic phenomenon with a myriad of genetic, environmental, and behavioral factors potentially contributing to variability in migration size and timing. To confound this, CPUE varies as a function of both migration (i.e. the number of fish moving downstream past the trap during a given time period) and trap efficiency (i.e. the proportion of fish moving past the trap that are intercepted by the trap during the same time period). In this report, we assess the influence of variables likely to have a strong relationship with CPUE. Based on work conducted by others as well as our own observations we identified turbidity, diel period (i.e. day or night), and river discharge as three variables that likely influence CPUE (Conrad and MacKay, 2000; Seiler et al., 1998, 2000; Griffith et al., 2001). These variables were investigated with respect to naturally spawned populations of both sub-yearling Chinook and yearling Coho caught at the trap. In the *Trap Efficiency* section, we also assess the relationship of these variables to trap efficiency.

Turbidity

Analysis of turbidity and CPUE was conducted on data collected from 2002-2006 (turbidity measurements started in 2002). These analyses did not show a clear correlation between CPUE and turbidity for sub-yearling Chinook or yearling Coho at our chosen samples sites. These initial findings resulted in an exclusion of turbidity sampling in latter sample years (2007-2012). Subsequently, an overall assessment of turbidity and CPUE has not been included in this report.

Day/Night Catch Rates

Since fishing events were separated into day and night categories, we were able to compare catch rates between these strata. For this comparison, we only considered fishing events that occurred in the targeted stratum and had a minimum of 4 hours of effort. One way ANOVAs detected significant differences in CPUE between day and night fishing events from 2001-2012 for wild sub-yearling Chinook ($F_{1,20}$= 22.84, P<0.001) and wild yearling Coho ($F_{1,20}$= 10.23, P<0.05). In order to better isolate the effects of diel period to those of other variables such as seasonal timing and discharge we assessed paired day and night sampling events for each sample year. A similar approach has been used to analyze day and night catch rates on the Skagit River (Seiler et al., 2000). Chosen pairs contained consecutive sampling events (Day-Night or Night-Day) with a minimum of 4 hours of effort in each event. This allowed us to isolate the effects of day and night as precisely as possible within the sampling design. All pairs that met the aforementioned criteria were used in subsequent analyses. Data from individual sampling events were included in multiple pairs as long as the criteria were met. For each pair of sampling events the ratio of Day CPUE/Night CPUE (D:N ratio) was calculated for wild sub-yearling Chinook and wild yearling Coho. Ratios of less than 1 indicate higher catch rates during nighttime sets while ratios of greater than 1 indicate higher catch rates during daytime sets.

Annual D:N ratio from 2001-2012 for wild sub-yearling Chinook showed considerable variability ranging from 0.06 to 0.87 (Table 5). Similarly, D:N ratio from 2001-2012 for wild yearling Coho was quite variable ranging from 0 to 0.91 (Table 6). All 185 paired D:N ratios were <1, indicating that CPUE was generally higher at night. Although, D:N pairs in 2005 for wild sub-yearling Chinook and in 2007 for wild yearling Coho were close to 1, indicating that day and night CPUE were essentially equal during these seasons. The majority of D:N ratio results from the Skykomish trap illustrate a strong tendency for catch rates of wild sub-yearling Chinook and wild yearling Coho to be higher at night, which is supportive of the literature and other trapping efforts (McDonald, 1960; Groot and Margolis, 1991; Quinn, 2005; Kinsel et al., 2008; Dolphin, 2011).

Table 5: Summary of day and night catch for wild sub-yearling Chinook in the Skykomish River from 2001-2012.

		Effort (hours)		Catch		D:N Ratio
Year	# of pairs	Day	Night	Day	Night	for Season
2001	14	178.20	140.40	92	333	0.22
2002	14	144.50	130.30	39	236	0.15
2003	45	418.18	355.95	370	1958	0.16
2004	16	218.83	162.17	19	224	0.06
2005	16	219.58	159.92	338	283	0.87
2006	9	114.92	96.67	121	341	0.30
2007	8	111.67	72.00	149	212	0.45
2009	10	134.30	101.08	81	425	0.14
2010	22	298.93	218.23	401	597	0.49
2011	13	161.42	139.00	46	221	0.18
2012	18	232.00	177.42	47	354	0.10

Table 6: Summary of day and night catch for wild yearling Coho in the Skykomish River from 2001-2012.

		Effort (hours)		Catch		D:N Ratio
Year	# of pairs	Day	Night	Day	Night	for Season
2001	14	178.20	140.40	49	1433	0.03
2002	14	144.50	130.30	62	2272	0.02
2003	45	418.18	355.95	28	5920	0.00
2004	16	218.83	162.17	13	2597	0.00
2005	16	219.58	159.92	159	4	0.18
2006	9	114.92	96.67	30	435	0.06
2007	8	111.67	72.00	113	80	0.91
2009	10	134.30	101.08	193	376	0.39
2010	22	298.93	218.23	125	316	0.29
2011	13	161.42	139.00	195	362	0.46
2012	18	232.00	177.42	108	732	0.11

Discharge and Catch Rates

Based on the literature, as well as our own observations, we expected discharge to affect catch rates considerably (Groot and Margolis, 1991; Seiler et al., 1998, 2000; Conrad and MacKay, 2000; Griffith et al., 2001). In general, we would expect CPUE to rise with discharge either as a result of increased migration or increased trap efficiency to some peak level after which CPUE would eventually decline as the trap would fish an increasingly smaller proportion of the channel. Our field observations suggest that higher CPUE levels often are associated with periods of elevated and/or peak discharge. To assess these observations, we compared mean discharge levels during the sampling periods to CPUE for wild groups of sub-yearling Chinook and yearling Coho caught at the Skykomish screwtrap from 2001-2012.

Wild sub-yearling Chinook CPUE displayed positive relationships with daily mean discharge in 2001 (R^2=0.21) and 2004 (R^2=0.21). Wild yearling Coho CPUE exhibited positive relationship with discharge in 2001 (R^2=0.70), 2005 (R^2=0.37), 2006 (R^2=0.22), 2009 (R^2=0.38), 2010 (R^2=0.54), and 2012 (R^2=0.28). However, many of the sample periods for wild sub-yearling Chinook (8 of 12 years) and wild yearling Coho (6 of 12 years) did not show a trend between CPUE and discharge. We attempted to adjust our analyses to only include statistical weeks during peak catch rates, in order to filter out the influence of high flow events before or after juvenile migration (resulting in a misleading correlation of low CPUE with high discharge); however, this additional analysis did not provide any increases in correlation or statistical significance. Additionally, we thought that statistical weeks may not provide a fine enough temporal resolution to capture daily flow events. After preliminary analyses we discovered that high variability in daily CPUE with discharge resulted in insignificance regression correlations. It may have been possible that there is minimal correlation between CPUE and discharge at our sample sites, but it is likely that several significant factors influenced these results. For example, the trap was not operated often above ~12,000 cfs which may have under-represented catch rates at higher discharge levels. Additionally, as trap efficiency decreases with increasing discharge (due to a smaller proportion of sampled channel) the ability to accurately represent catch rates at higher discharge levels significantly decreases.

Trap Efficiency

In order to estimate the number of downstream migrants passing the trap it is necessary to understand what proportion of the fish moving past the trap are being captured. This proportion is referred to as trap efficiency in this report. Trap efficiency was estimated several times each year for sub-yearling Chinook and yearling Coho using mark and recapture techniques. In hopes to mirror natural timing patterns, marked sub-yearling Chinook were released around April to May and marked yearling Coho were released around May-June. For each efficiency test, a known number of juveniles were marked with Bismark Brown biological dye, released 1 river mile upstream of the trap, and the number of marked fish caught by the trap was recorded. The trap was deployed for at least 24-48 hours following the release to ensure that it sampled the majority of the time during which the marked fish were moving downstream past the trap site. The efficiency of the trap was estimated for each test by taking the ratio of the number of marked individuals recovered at the downstream trap (r) to the total number of marked individuals released (R). Confidence intervals were estimated for each test using standard methods (Fleiss, 1981). We expected to experience efficiencies somewhere between 1% and 5% based on our experience in the Skykomish River as well as information from previous studies conducted in the Nooksack, Skagit, and Stillaguamish rivers (Conrad and MacKay, 2000; Seiler et al., 2000; Griffith et al., 2001).

Efficiency tests of this kind operate under five basic assumptions: 1) there is an accurate count of the number of marked fish released, 2) 100% of recaptured fish are identified by the sampling crew, 3) individuals in the release group are captured at the same rate as wild individuals that pass the trap, 4) 100% survival of marked fish between release and migration past the trap, 5) 100% marked fish migrate past the trap while the trap is fishing and 6) that we capture at least one marked fish.

Efficiency Results

Chinook

A total of 56,859 marked sub-yearling Chinook were released in the Skykomish during trapping efficiency test conducted from 2001-2012. The majority of fish used in the mark groups were raised at the WDFW Wallace River Hatchery; however, from 2007-2009, the fish used in the mark group were raised at the Tulalip Bernie Kai-Kai Gobin Hatchery. We were confident that the numbers of marked fish in the releases as well as the number of recaptures were accurately quantified by the sampling crews. Mean fork lengths for the 44 release groups ranged from 44.8 mm to 86.36 mm. This discrepancy in mean fork length could be a source of error for our efficiency estimates if fish size has an effect on capture efficiency; due to variation in the ability of different size-classes to evade the trap.

It is unlikely that there is 100% survival of marked fish during any efficiency test; however, observed mortality rates among release groups did not appear high enough to significantly alter the results during any of these tests. Efficiency tests conducted over the years of this project suggest that the vast majority of marked fish migrate past the trap site within the first 24 to 36 hours after being released. If mortality of marked fish above the trap site or migration past the site while the trap was not deployed were sources of error in our efficiency estimates, they would act to bias trap efficiency low. For example, if 1000 marked fish were released and 10 were recaptured we would estimate trap efficiency at 1.00%. However, if 10% (100 individuals) of the fish in the release group either died before they passed the trap or migrated past the trap while it wasn't deployed and 10 fish were recaptured the actual efficiency would be 1.1% which is higher than our estimate.

Of the 56,859 marked sub-yearling Chinook that were released during the 44 tests, total yearly release numbers varied from 2,647-9,989 and recovered numbers varied from 30- 254 (Table 7). Yearly trap efficiency estimate varied from 1.0- 2.5% (average: 1.5%); which falls within the 1% to 5% range we had expected at the inception of the project. Other than 2007, it appears that trap efficiency for sub-yearling Chinook was higher at night. From 2001-2012, roughly 1000 marked sub-yearling Chinook were released during each efficiency test. In 2012, consultation with the WDFW and the Northwest Indian Fisheries Commission (NWIFC) indicated that roughly doubling release numbers would significantly increase our trap efficiency and decrease variation in our resulting production estimates. This was conducted for the 2012 trapping season and the percent recovered indeed increased roughly 1.5x from recovered percentages from 2001-2011. Subsequently, ~2000 sub-yearling Chinook will be used for efficiency tests in following years.

Table 7. Efficiency estimates from mark and recapture tests conducted using sub-yearling Chinook in the Skykomish River from 2001-2012.

2001-2012 Skykomish Sub-yearling Chinook								
		Number	Number				90% C.I.	
	Number of	Released	Recovered	Day	Night	% Total		
Year	Releases	[R]	[r]	Recovered	Recovered	Recovered	lower	upper
2001	3	7409	74	28	46	1.0%	0.8%	1.2%
2002	6	6265	57	24	30	0.9%	0.7%	1.1%
2003	5	5282	60	10	63	1.4%	0.9%	1.4%
2004	4	3,993	38	17	42	1.5%	0.7%	1.3%
2005	5	6514	126	24	102	1.9%	1.8%	2.2%
2006	3	3013	32	2	30	1.1%	0.8%	1.4%
2007	2	2647	30	22	8	1.1%	0.8%	1.6%
2009	3	2870	33	6	27	1.2%	0.9%	1.6%
2010	4	4302	70	10	61	1.7%	1.3%	2.0%
2011	4	4575	43	17	26	0.9%	0.7%	1.2%
2012	5	9,989	254	64	191	2.6%	2.3%	2.8%
Total	44	56,859	817	224	626	1.5%	1.4%	1.5%

Coho

A total of 24,233 marked yearling Coho were released during trapping efficiency test conducted from 2001-2012. As with the sub-yearling Chinook, the majority of fish used were raised at the Wallace River Hatchery other than years 2007-2009 where fish were raised at the Tulalip Bernie Kai-Kai Gobin Hatchery. We utilized the same procedures and assumptions for Coho efficiency tests as we did for Chinook. We are confident that the numbers of marked fish released as well as the numbers of recaptures for all 31 tests were accurately quantified by the sampling crews. Mean fork lengths for the 31 release groups ranged from 99 mm to 139 mm. As in the Chinook trials, we expected that any effect mortality or delayed migration might have had on these efficiency trials was negligible. If fish size, mortality, or delayed migration did have any effect on trap efficiency estimates we would expect that trap efficiency would be slightly underestimated.

Of the 24,233 marked yearling Coho that were released during the 31 tests, total yearly release numbers varied from 1,998-4,284 and recovered numbers varied from 15-52 (Table 8). Yearly trap efficiency estimate varied from 0.5-1.6% (average: 1.2%). In all of the sample years, it appears that trap efficiency for yearling Coho was higher at night. Similar to Chinook release numbers, consultation with the WDFW and the NWIFC resulted in a recommendation to increase efficiency releases from ~1000 fish to ~2000 per efficiency test, which will be instituted in the 2013 trapping season.

Table 8. Efficiency estimates from mark and recapture tests conducted using yearling Coho in the Skykomish River from 2001-2012.

2001-2012 Skykomish Yearling Coho								
		Number	Number				90% C.I.	
	Number of	Released	Recovered	Day	Night	% Total		
Year	Releases	[R]	[r]	Recovered	Recovered	Recovered	lower	upper
2001	2	2636	36	1	35	1.4%	1.0%	1.8%
2002	3	2522	36	4	32	1.4%	1.0%	1.9%
2003	4	4034	28	2	27	0.7%	0.5%	1.0%
2004	3	2,511	25	5	20	1.0%	0.7%	1.4%
2005	2	2695	30	6	24	1.1%	0.8%	1.5%
2006	3	3424	43	12	31	1.3%	1.0%	1.6%
2007	2	1998	44	21	23	2.2%	1.7%	2.8%
2009	3	3605	52	17	35	1.4%	1.1%	1.8%
2010	3	3233	15	8	7	0.5%	0.3%	0.7%
2011	3	3291	51	27	24	1.6%	1.2%	2.0%
2012	3	4,284	44	7	37	1.0%	0.8%	1.3%
Total	31	34,233	404	110	295	1.2%	1.1%	1.3%

Discharge and Efficiency

In the *Factors Affecting Catch Rates* section, we discuss the potential effects of environmental parameters including daylight and discharge on CPUE for wild sub-yearling Chinook and yearling Coho.

Results from efficiency tests suggested that trap efficiency was higher after dark for wild sub-yearling Chinook (224 day recovered; 626 night recovered) and yearling Coho (110 day recovered; 295 night recovered). Based on this apparent diurnal variation in trap efficiency, we should ideally generate separate efficiency estimates for daytime and nighttime periods. However, we have not been able to derive separate estimates for day and night trap efficiency since recaptures occurred over a time period spanning one or more days. In order to derive separate efficiency estimates for night and day, all marked fish would have to pass the trap before the end of the diel stratum in which they were released. Since the recapture period spans more than one day and one night period, efficiency estimates represent a composite of daytime and nighttime efficiency rates. By treating trap efficiency results as composite results for day and night, we are most likely weighting our efficiency estimates towards night time efficiency, as our releases generally occurred soon before nightfall and there is a good possibility that the majority of the marked fish passed the trap at night. This will bias trap efficiency high for daytime if nighttime efficiencies are greater than daytime.

To investigate the effect of discharge on trap efficiency, test results from 2001-2012 were compared to discharge. We expect that there is some optimal discharge level at which the trap is most efficient. We would expect the trap to be less efficient at low discharge levels due to marginal velocities for trap operation and we would also expect that efficiency would be decreased at higher discharge levels because the trap samples a smaller proportion of the river cross section under those conditions. We were unable to detect a relationship between trap efficiency and discharge for the 44 sub-yearling Chinook release events during the 2001-2012 trapping seasons. However, after using the average discharge across the efficiency tests as a separator (~3,850 cfs), there was a significantly ($\alpha = 0.05$) lower percent recovered in the higher discharge bin (3,925-8,155 cfs; n=18) compared to the lower bin (1,405-3,670 cfs; n=26). This may indicate that efficiency decreases with increasing discharge, but our collective data suggests that we were not able to observe a significant influence of discharge on efficiency estimates.

We were unable to detect a significant relationship between trap efficiency and discharge for the 31 yearling Coho release events during the 2001-2012 trapping seasons. Even after using the average discharge across the efficiency tests as a separator (~6,100 cfs), we were still unable to detect a significant difference in percent recovered between the higher discharge bin (6,225-9,700 cfs; n=18) and the lower bin (3,070-5,945 cfs; n=13).

We hypothesize that the variations in recapture rates observed among efficiency tests are a representative sample of the range of efficiencies that the trap operates at over the season. Since we had minimal support explaining the cause of the observed variability, we chose to use the composite results from efficiency tests, defined as the mean trap efficiency for each species across the trapping season. The composite values for the number of marked sub-yearling Chinook and yearling Coho released (R) and recovered (r) were used in production estimates. As we have stated, minor violations of the assumptions of these efficiency tests likely resulted in a slight underestimation of trap efficiency while the diel timing of the releases likely resulted in an opposite effect. Our observations suggest that these influences were quite small and we suspect that they effectively balance each other out over the course of sampling.

Skykomish River mile 23 (2000-2007) vs. 26.5 (2008-2012)

The Skykomish trap site was moved from RM 23 to RM 26.5 due to the implementation of a restoration project as part of a mitigation bank. The change in site location not only influenced where along the Skykomish sampling occurred, but also the type of channel and the suite of hydrologic attributes sampled. The latter location moved the Skykomish trap upstream of one primary tributary, Woods Creek. The differences in site characteristics were assessed through variation in juvenile salmonid CPUE and trap efficiency.

Catch per unit effort for sub-yearling Chinook was not significantly ($\alpha = 0.05$) different between the two trap site locations; however, we did observe a difference in yearling Coho CPUE (ANOVA: $F_{1,9}$= 4.83, $P=0.05$), with the prior site having higher CPUE (Table 9). Efficiency tests were not significantly different between the two trap site locations for both sub-yearling Chinook (ANOVA: $F_{1,9}$= 1.65, $P=0.23$) and yearling Coho (ANOVA: $F_{1,9}$= 0.33, $P=0.58$).

Table 9: Summary of catch per unit effort (CPUE) and trap efficiency between the Skykomish site at river mile 23 (2001-2007) and 26.5 (2009-2012)

River Mile 23				
	Average Catch per Unit Effort		Efficiency (% recovered)	
Sample Year	Sub-yearling Chinook	Yearling Coho	Sub-yearling Chinook	Yearling Coho
2001	1.98	5.41	1.0%	1.4%
2002	1.61	13.07	0.9%	1.4%
2003	3.29	7.49	1.1%	0.7%
2004	0.88	9.91	1.0%	1.0%
2005	2.42	3.1	1.9%	1.1%
2006	2.6	5.53	1.1%	1.3%
2007	3.02	1.74	1.1%	2.2%
Total Average	2.26	6.61	1.2%	1.3%
River Mile 26.5				
	Average Catch per Unit Effort		Efficiency (% recovered)	
Sample Year	Sub-yearling Chinook	Yearling Coho	Sub-yearling Chinook	Yearling Coho
2009	2.4	2.05	1.2%	1.4%
2010	2.19	1.2	1.6%	0.5%
2011	1.04	2.45	0.9%	1.6%
2012	1.3	2.96	2.5%	1.0%
Total Average	1.73	2.17	1.6%	1.1%

Out-migrant Production Estimates

Sub-yearling Chinook

According to our estimates, approximately 56-97% (average: 80%) of the emigration of wild sub-yearling Chinook occurred during the 2001-2012 sampled strata (Table 10). These portions of our estimates do not include Chinook that may have emigrated before or after the trapping season in addition to those which may have emigrated during un-sampled periods. We estimate that between 4,521-116,633 sub-yearling Chinook emigrated before trapping began and between 2,966-81,809 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods varied between 7,069-139,183 emigrating sub-yearling Chinook. We calculate that above RM 23, from 2001-2007, the Skykomish River produced between 246,358-857,124 wild sub-yearling Chinook and above RM 26.5, from 2009-2012, produced between 146,278-677,680 sub-yearling Chinook. Inter-annual production estimates from 2001-2012 are shown in Figure 14.

Table 10: Production estimates for wild sub-yearling Chinook in the Skykomish River from sample year 2001-2012.

2001	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7	SW 22	SW 25-30	Estimate
Day	83,340	60,865	105,815	3,408	8,761	0	95,509
Night	289,160	264,889	313,431	19,720	0	18,081	326,961
Total	372,500	339,421	405,579	23,128	8,761	18,081	**422,470**

2002	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6	SW 9-10,16,22	SW 26-30	Estimate
Day	58,210	46,061	70,359	2,528	13,046	5,505	79,289
Night	266,668	244,325	289,011	18,215	41,757	21,732	348,372
Total	324,878	299,446	350,310	20,743	54,803	27,237	**427,661**

2003	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	146,812	127,395	166,229	38,488		8,285	193,585
Night	523,708	479,976	567,440	37,650		12,054	573,412
Total	670,520	622,671	718,369	76,138		20,339	**766,997**

2004	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	74,100	57,250	90,950	0		520	74,620
Night	164,771	146,297	183,245	4,521		2,446	171,738
Total	238,871	213,867	263,875	4,521		2,966	**246,358**

2005	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6		SW 24-30	Estimate
Day	102,081	91,402	112,760	8,689		6,400	117,170
Night	155,234	143,026	167,442	48,045		5,161	208,440
Total	257,315	241,096	273,534	56,734		11,561	**325,610**

2006	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	205,053	157,766	252,340	4,253		16,688	225,995
Night	501,592	405,373	597,812	112,379		17,158	631,130
Total	706,646	563,139	850,152	116,633		33,846	**857,124**

Table 10 continued.

2007 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-9	SW 11, 12, 13,15, 22	SW 24-30	
Day	97,401	71,876	122,927	21,054	46,377	42,741	207,573
Night	278,574	221,997	335,151	86,162	92,806	3,761	461,303
Total	375,975	293,873	458,078	107,216	139,183	46,501	**668,876**
2009 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-9	SW 16	SW 25-30	
Day	86,610	63,513	109,707	9,460	7,069	14,320	88,815
Night	291,762	234,998	348,526	0	0	17,229	308,991
Total	378,372	298,511	458,233	9,460	7,069	31,549	**426,450**
2010 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-6		SW 25-30	
Day	243,843	201,284	286,403	0		74,411	318,255
Night	343,752	287,123	400,381	8,276		7,397	359,425
Total	587,595	488,407	686,784	8,276		81,809	**677,680**
2011 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-9	SW 14, 15 & 24	SW 26-30	
Day	50,386	34,126	66,647	3,930	10,557	9,103	73,977
Night	280,429	228,306	332,551	38,368	93,071	26,986	438,855
Total	330,815	262,432	399,198	42,298	103,628	36,089	**512,831**
2012 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-7	SW 17	SW 26-30	
Day	15,640	10,751	20,530	1,641	1,729	3,749	22,759
Night	91,554	80,038	103,071	8,160	17,221	6,582	123,517
Total	107,195	90,788	123,601	9,801	18,950	10,331	**146,278**

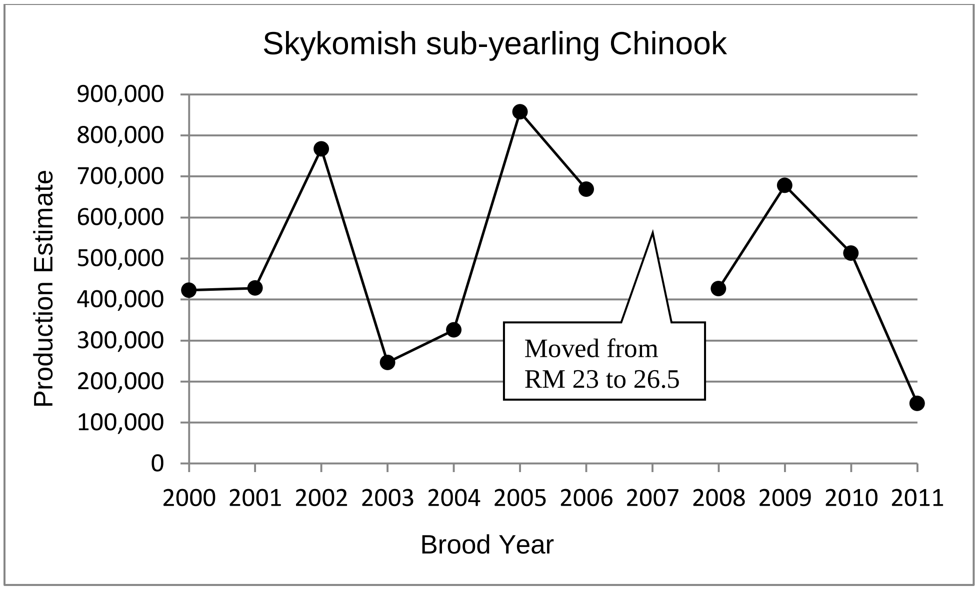


Figure 14: Trend in production estimates for wild sub-yearling Chinook in the Skykomish River for brood years 2000-2011.

Yearling Chinook

We estimate that approximately 51-100% (average: 90.6%) of wild yearling Chinook emigration in the Skykomish occurred during the sampled strata (Table 11Table 23). As mentioned previously, production estimates were not estimated for 2007 due to identification issues during that sample year. We estimate that in the Skykomish between 8-1,686 yearling Chinook emigrated before trapping began and another between 202-18,081 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods in the Skykomish varied between 622-6,823 emigrating yearling Chinook. We calculate that from 2001-2012 the Skykomish River produced between 6,973-101,023 wild yearling Chinook. Trends in inter-annual production estimates from brood year 2000-2010 are represented in Figure 15.

Table 11: Production estimates for wild yearling Chinook in the Skykomish River from sample year 2001-2012.

2001	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7	SW 22	SW 25-30	Estimate
Day	0	0	0	0	0	0	0
Night	18,788	14,966	22,610	23	0	18,081	36,891
Total	18,788	14,966	22,610	23	0	18,081	**36,891**

2002	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6	SW 9-10,16,22	SW 26-30	Estimate
Day	1,114	-145	2,373	0	424	0	1,538
Night	5,237	3,175	7,299	0	198	0	5,435
Total	6,351	3,935	8,767	0	622	0	**6,973**

2003	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	353	-334	1040	0		0	353
Night	11443	8514	14372	378		202	12023
Total	11796	8788	14804	378		202	**12376**

2004	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	2098	651	3545	0		0	2098
Night	6423	4120	8726	0		0	6423
Total	8521	5801	11241	0		0	**8521**

2005	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6		SW 24-30	Estimate
Day	10137	6765	13509	0		0	10137
Night	17930	14176	21684	0		276	18206
Total	28067	23021	33113	0		276	**28343**

2006	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 26-30	Estimate
Day	8,949	4,807	13,092	4		8	8,960
Night	47,147	39,235	55,058	5		13	47,164
Total	56,096	44,042	68,150	9		20	**56,124**

Table 11 Continued.

2007 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	Upper	SW 1-9	SW 11, 12, 13,15, 22	SW 24-30	
Day	15,932	8,986	22,877	833	4,445	2,399	23,609
Night	40,531	32,054	49,008	852	2,378	182	43,943
Total	56,462	41,040	71,885	1,686	6,823	2,581	**67,552**
2009 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	Upper	SW 1-9	SW 16	SW 25-30	
Day	6,190	3,086	9,293	0	710	0	6,190
Night	91,649	76,375	106,923	1,346	0	1,839	94,834
Total	97,838	79,461	116,216	1,346	710	1,839	**101,023**
2010 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	Upper	SW 1-6		SW 25-30	
Day	63,277	50,844	75,711	0		56,810	120,087
Night	87,685	73,885	101,485	0		6,350	94,035
Total	150,962	124,729	177,195	0		63,160	**214,122**
2011 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	Upper	SW 1-9	SW 14, 15 & 24	SW 26-30	
Day	7,440	4,695	10,185	0	0	0	7,440
Night	29,817	22,052	37,582	340	1,072	0	31,229
Total	37,257	26,747	47,766	340	1,072	0	**38,669**
2012 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	Upper	SW 1-7	SW 17	SW 26-30	
Day	1,235	221	2,250	0	0	0	1,235
Night	11,390	8,021	14,760	0	838	730	12,958
Total	12,626	8,241	17,010	0	838	730	**14,193**

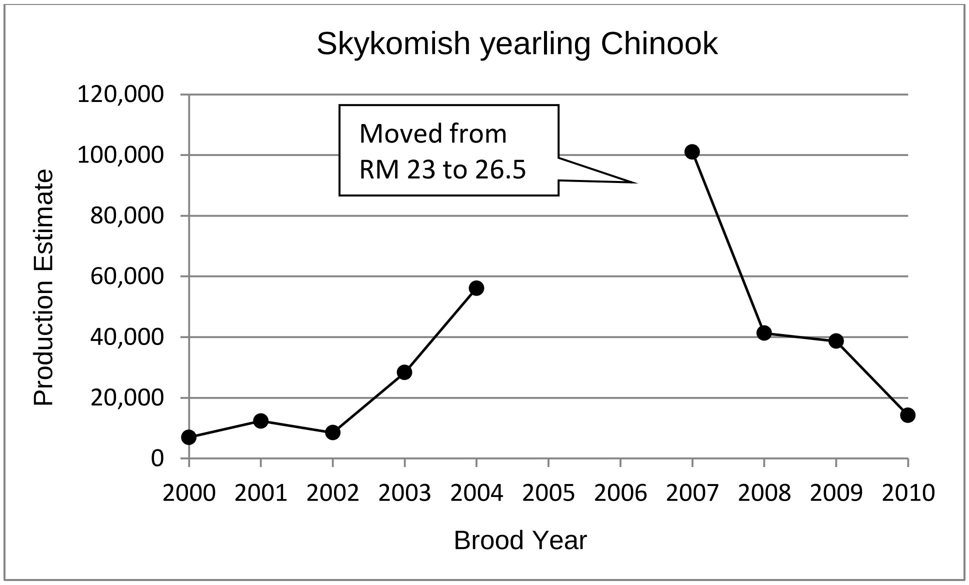


Figure 15: Trend in production estimates for wild yearling Chinook in the Skykomish River for brood years 2000-2010.

Coho

We estimate that approximately 88-100% (average: 95.2%) of the emigration of wild yearling Coho occurred during the 2001-2012 sampled strata (Table 12). These portions of our estimates do not include Coho that may have emigrated before or after the trapping season in addition to those which may have emigrated during un-sampled periods. We estimate that between 217-46,213 yearling Coho emigrated before trapping began and another between 1,859-13,791 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods varied between 210-72,938 emigrating yearling Coho. We calculate that above RM 23, from 2001-2007, the Skykomish River produced between 480,531-2,244,428 wild yearling Coho and above RM 26.5, from 2009-2012, produced between 338,628-626,006 yearling Coho. Inter-annual production estimates from 2001-2012 are shown in Figure 16.

Table 12: Production estimates for wild yearling Coho in the Skykomish River from migration year 2001-2012.

2001	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper		SW 22	SW 25-26	Estimate
Day	30,722	16,696	44,749		5,764	2,466	38,953
Night	730,027	633,759	826,296		0	11,325	741,352
Total	760,750	663,465	858,035		5,764	13,791	**780,305**
2002	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper		SW 9-10,16,22	SW 26	Estimate
Day	46,814	36,589	57,039		10,122	190	57,126
Night	1,605,887	1,382,262	1,829,512		62,816	2,942	1,671,645
Total	1,652,701	1,428,842	1,876,560		72,938	3,132	**1,728,771**
2003	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 7		SW 26	Estimate
Day	13,666	8,248	19,084	234		0	13,900
Night	1,957,601	1,694,860	2,220,342	1,939		1,859	1,961,399
Total	1,971,267	1,708,470	2,234,064	2,173		1,859	**1,975,299**
2004	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper				Estimate
Day	70,327	48,327	92,327				70,327
Night	2,174,101	1,803,222	2,544,980				2,174,101
Total	2,244,428	1,872,897	2,615,959				**2,244,428**
2005	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper			SW 24-26	Estimate
Day	76,203	60,991	91,415			14,916	91,119
Night	477,692	402,406	552,978			31,298	508,990
Total	553,895	477,087	630,703			46,213	**600,108**
2006	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 7		SW 26	Estimate
Day	137,638	108,876	166,399	497		2,944	141,079
Night	1,112,607	938,152	1,287,062	1,061		2,664	1,116,332
Total	1,250,245	1,047,028	1,453,461	1,558		5,608	**1,257,411**

Table12: continued.

2007 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 7-9	SW 11 -13,15 & 22	SW 24-26	Total Migration Estimate
Day	63,676	50,633	76,719	1,447	5,710	3,021	73,854
Night	361,012	316,812	405,212	3,858	34,584	7,223	406,677
Total	424,688	367,445	481,931	5,305	40,294	10,244	**480,531**

2009 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 7-9	SW 16	SW 25 & 26	Total Migration Estimate
Day	61,907	48,864	74,950	0	210	834	62,951
Night	263,963	219,763	308,163	497	0	11,217	275,677
Total	325,871	268,628	383,114	497	210	12,051	**338,628**

2010 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 7-9	SW 14,15 and 24	SW 26	Total Migration Estimate
Day	164,635	116,155	213,115	3,225	4,787	0	172,647
Night	575,160	427,157	723,163	644	0	19,984	595,788
Total	739,795	543,312	936,278	3,869	4,787	19,984	**768,435**

2011 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 7-10	SW 14 and 15	SW 24-26	Total Migration Estimate
Day	62,770	49,186	76,353	1,088	894	3,785	68,537
Night	307,221	258,662	355,779	1,186	3,992	17,814	330,213
Total	369,990	307,849	432,132	2,274	4,886	21,599	**398,750**

2012 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 7 and 8	SW 17	SW 26	Total Migration Estimate
Day	87,067	62,662	111,473	217	9605	201	97,090
Night	469,079	392,480	545,679	0	56,015	3,822	528,916
Total	556,147	455,141	657,152	217	65,620	4,023	**626,007**

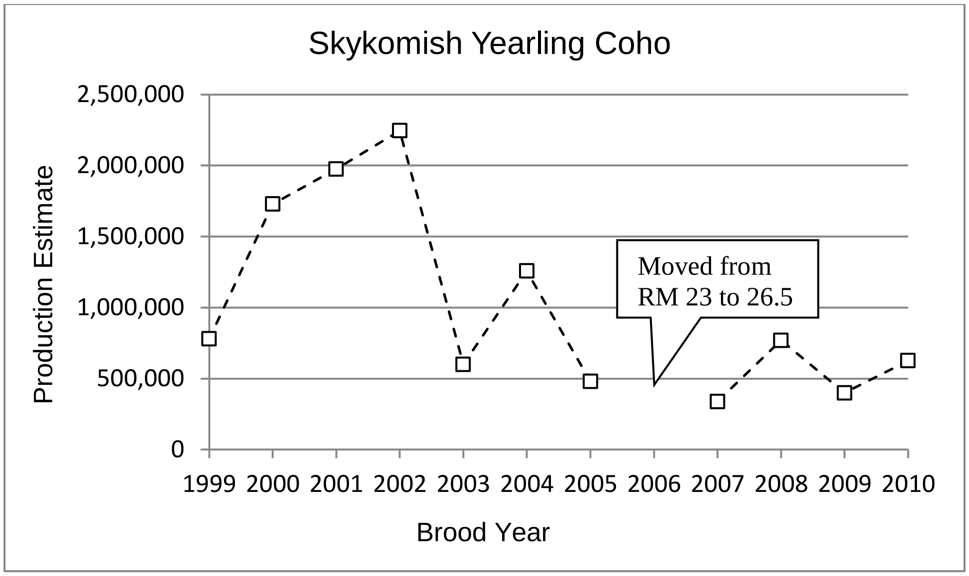


Figure 16: Trend in production estimates for wild yearling Coho in the Skykomish River for brood years 1999-2010.

Freshwater Survival

Chinook

We estimated egg to migrant survival of naturally spawned Chinook salmon for brood years 2000-2010 in the Skykomish River (Table 13). Egg-migrant survival in brood years 2005, 2006, and 2011 only include the sub-yearling cohort because of yearling identification issues in migration year 2007, a lack of yearling sampling in migration year 2008 (due to trap repair), and because yearling Chinook for migration year 2012 have yet to be sampled. Redd counts varied from 518 (2009) to 5,618 (2006) with total egg deposition ranging from 2,661,920 (2009) to 11,659,489 (2004). Approximate egg-migrant survival for sub-yearling Chinook from brood year 2000-2010 ranged from 2.8-25.5%. The highest egg-migrant survival was observed in brood years 2002, 2005, 2009, and 2010, while the lowest egg-migrant survival was observed in brood years 2000, 2001, 2003, 2004, and 2008.

Table 13. Estimates of egg-migrant survival for wild sub-yearling Chinook produced upstream of RM 23 (2000-2006) and RM 26.5 (2008-2011) in the Skykomish River for brood years 2000-2011.

Brood year (*b*)	WDFW escapement estimates	Redd count (CR_b)	Eggs per Female (FE_b)	Total egg deposition (D_b)	Sub-yearling Chinook production (SP_{b+1})	Yearling Chinook production (SP_{b+2})	Egg - Migrant survival (S_b)
2000	4582	1833	4510	8265674	422470	6972	5.2%
2001	4354	1741	4510	7853472	427661	12376	5.6%
2002	4222	1689	4451	7516049	766997	8521	10.3%
2003	3454	1382	4924	6802870	246358	28343	4.0%
2004	7389	2955	3945	11659489	325610	56124	3.3%
2005	3104	1241	4572	5675723	857124	NA	15.1%
2006	5618	2247	4693	10546262	668876	NA	6.3
2008	5298	2119	4130	8753651	426450	41300	5.3%
2009	1294	518	5141	2661920	677680	38669	26.9%
2010	2409	964	4780	4605573	512831	14193	11.4%
2011	1032	413	4273	1764045	146278	NA	8.3

SNOQUALMIE RIVER RESULTS

Trap Site Location and Characteristics

The Snoqualmie trap location was changed from river mile 16.5 (2001) to 12.2 (2002-2012) after the pilot season. The trap site during the pilot year was located adjacent to a row of pilings on the outside of a meander bend with the deepest portion of the river lying between the pilings and the east bank (Figure 17 & Figure 18). The inside of the meander bend formed a sand bar which became submersed at flow levels ~7000 cfs. The Snoqualmie River at this point had a wetted width ~140 ft., bank full width of ~220 ft., maximum bank full depth of ~28.5 ft., and a summer low-flow level of ~13 ft. Water surface velocity was ~3-4 ft./sec., summer low-flow discharge was ~655 cfs, and the mean annual discharge at this location was ~3,800 cfs. The channel gradient was < 1% and substrate was principally sand and silt. Land use adjacent to the prior project site was principally agriculture. The riparian vegetation in the vicinity was limited to the banks (e.g. <30 f) and principally consisted of grass, shrubs, and a few scattered willow and cottonwood trees. At the immediate trap site, the left bank was composed of a rather steep bank leading to an active cattle pasture. The right bank was also steeply cut and led to an active farm/pasture.

The trap site at the latter location was located in a straight section of the channel which flowed in a northerly direction (Figure 17 & Figure 18). The Snoqualmie River at this point had a wetted width of ~142 ft., bank full width of ~210 ft, maximum bank full depth of ~23.5 ft, and a summer low-flow level of ~5 ft. Water surface velocity was ~3-4 ft./sec., summer low flow discharge was ~847 cfs, and mean annual discharge was ~3,800 cfs. The channel gradient was <1% and the substrate was principally sand and silt with some gravel and cobble on the western side of the channel. The land use adjacent to the trap was principally agriculture with riparian vegetation limited to the banks (e.g. <30 ft.). The riparian zone principally consisted of grass, shrubs, and a few scattered willow and cottonwood trees. At the immediate trap site, the left bank was 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 was steeply cut and led to an active horse and cattle pasture. Riparian vegetation on the right bank was principally blackberry with an occasional alder and cottonwood. In 2003, the 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.

Figure 17: Aerial photograph of the trap site at river mile 16.1 (a) and 12.2 (b) on the Snoqualmie River with a point indicating the approximate trap fishing position. The river flows from the bottom to the top in both of these photographs.

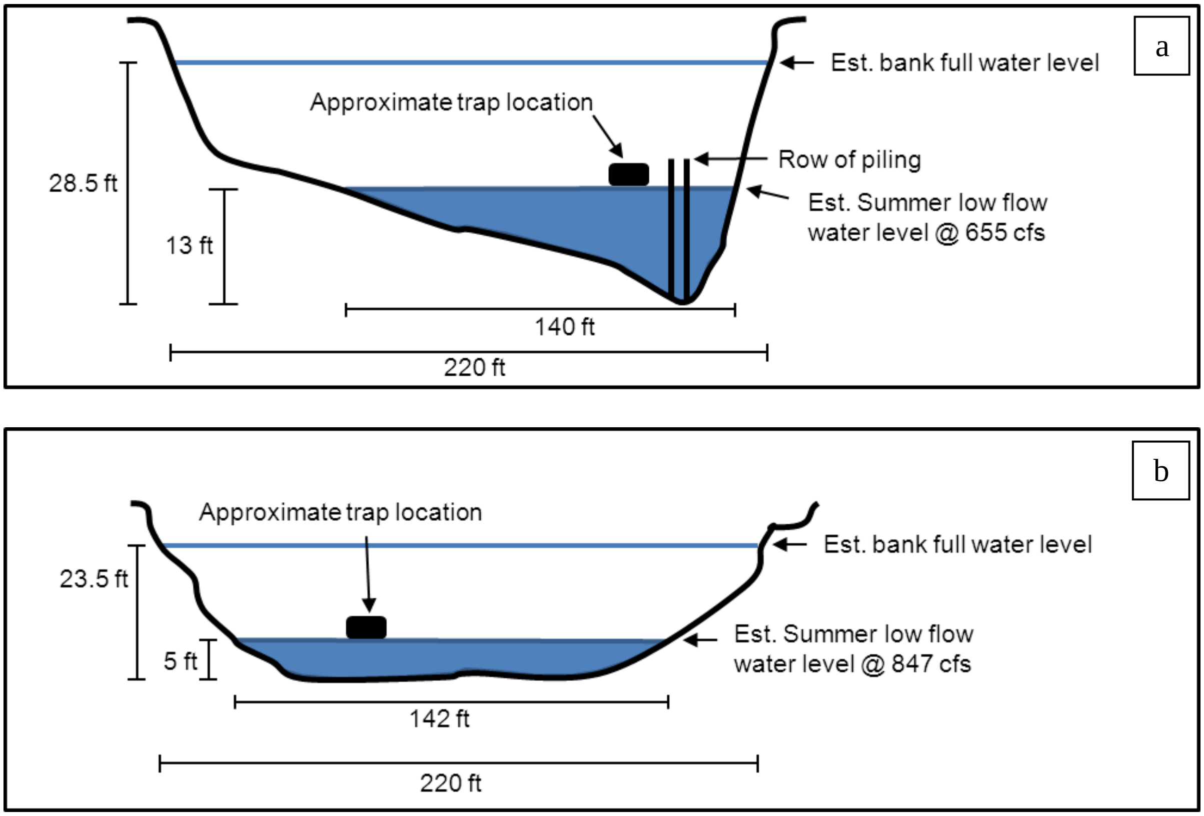


Figure 18: Cross section diagrams of the Snoqualmie River trap sites at river mile 16.1 (a) and 12.2 (b). Diagrams are not drawn to scale

Trap Operation and Discharge

Rotary screw trap operation on the Snoqualmie River from 2001-2012 was generally conducted from February to June; however, yearly start week varied from SW 7-17 and end week varied from SW 22-26 (Table 14). 2001 was the pilot season for trapping efforts and in 2008 the trap was only run for 6 weeks due to necessary rebuilding. Subsequently, 2008 was not included in overall analyses. The Snoqualmie trap has fished 9,194 hours over the last 11 years with yearly efforts ranging from 317.9 hours during 2008 to 1158.8 hours during 2012. Across 2001-2012, average fishing time during the sample period was 766.2 hours. The trap was fished from 2-16.2% of the total daylight hours and 14.6-80.5% of the total night hours over the 11 sample periods. Discharge varied considerably at the Snoqualmie trap sites during the 11 sample seasons ranging from 1,310 cfs to 9,420 cfs at the initial site and 1,250 cfs to 76,800 cfs at the latter site. We were unable to operate the trap on several occasions during high discharge levels when water velocities and debris increased the likelihood of fish injury, trap damage, and potentially compromised the safety of crew members. Similar to the Skykomish trap, we did not attempt to sample at discharges in excess of ~12,000 cfs regardless of debris load; however, trap operations at the Snoqualmie were usually more influenced by debris load rather than discharge.

Table 14: Summary of trap operations in the Snoqualmie River from 2001-2012.

		Hours fished			Total hours in sample period		Percent fished		Discharge (cfs)	
Year	Statistical weeks	Day	Night	Total fished	Day	Night	% Day	% Night	Min.	Max.
2001	15-25	108	401.1	509.10	1151.5	696.5	9%	58%	1,310	9,420
2002	8-26	263.5	448.3	711.80	1573.5	1351.8	17%	33%	2,355	21,806
2003	7-24	481.4	464.1	945.50	1679	1345	29%	35%	1,594	20,583
2004	8-26	490.2	565.8	1056.00	1821.5	1370.5	27%	41%	1,496	27,298
2005	7-24	472.8	533	1005.80	1706.5	1317.5	28%	40%	1,250	38,900
2006	8-24	496.5	503.2	999.70	1627.5	1228.5	31%	41%	1,620	22,500
2007	11-22	244.7	264.9	509.60	2013.75	1586.25	12%	17%	2,400	32,500
2009	10-25	304.2	328.4	632.60	1568.75	1119.25	19%	29%	1,310	76,800
2010	7-26	611.8	546.0	1157.80	1893.50	1466.50	32%	37%	1,450	11,700
2011	13-26	282.7	218.2	500.90	1141.8	787.8	25%	28%	2,020	33,100
2012	7-24	383.2	464.1	847.30	1522	1166	25%	40%	2,350	26,400

Trap Catch

A total of 201,919 salmonids were captured in the rotary screwtrap during 2001-2012 sampling effort (Table 15). Over the 11 sample periods of trap operation a total of 5,392 wild sub-yearling and 1,247 yearling juvenile Chinook salmon were captured. Yearling Chinook catch for 2007 was not included because of identification issues with sample screws. A total of 11,122 wild sub-yearling and 13,705 yearling Coho salmon were captured. Additionally, total catch of other salmonids included 13,030 Chum, 1,543,333 Pink, 933 wild steelhead, 1,544 hatchery steelhead, and 71 Cutthroat & Rainbow trout. Releases from the Tokul Creek Hatchery ranged from 152,000-198,171 for steelhead. Between 77-100% of the steelhead in those releases were externally marked with adipose fin clips. Taking these ranges into account, we estimate that approximately 2.3-20.1% of steelhead identified as wild were possibly of hatchery origin. Total Chinook mortalities from 2001-2012 ranged from 0.1-2.4 % of the total catch with average yearly mortality being 0.7%. Total Coho mortalities from 2001-2012 ranged from 0.0-1.7% of the total catch with average yearly mortality being 0.4%. Additional summary statistics for captured salmonids in the Snoqualmie from 2001-2012 are reporting in Table 15.

Table 15: Summary of trap catch in the Snoqualmie River from 2001-2012. Abbreviations are denoted as: mortalities at time of identification (morts), hatchery origin fish (Hat), cutthroat trout (Cutt), and rainbow trout (Rain).

		Chinook		*Coho*				*Steelhead*		*Cutt/*	*Total*
		0+	*1+*	*0+*	*1+*	*Chum*	*Pink*	*Wild*	*Hat.*	*Rain*	*salmonids*
2001	Catch	619	4	2045	553	856	1	49	91	5	4223
	Morts	4	0	6	2	1	0	1	2	0	16
	% Mort	0.7%	0.0%	0.3%	0.4%	0.1%	0.0%	2.0%	2.2%	0.0%	0.4%
2002	Catch	653	25	2131	1894	848	4126	111	213	14	10023
	Morts	5	0	14	0	7	41	0	4	0	71
	% Mort	0.8%	0.0%	0.7%	0.0%	0.8%	0.0%	0.0%	1.9%	0.0%	0.7%
2003	Catch	882	35	1052	1305	2689	5	39	106	10	6372
	Morts	1	0	3	1	14	0	0	0	0	19
	% Mort	0.1%	0.0%	0.3%	0.1%	0.5%	0.0%	0.0%	0.0%	0.0%	0.3%
2004	Catch	611	33	439	1127	1605	12794	125	62	1	16806
	Morts	12	0	1	0	2	20	0	0	0	35
	% Mort	2.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%
2005	Catch	677	91	2441	1187	1195	103	72	109	6	5910
	Morts	6	0	6	5	8	1	1	0	0	27
	% Mort	0.9%	0.0%	0.3%	0.4%	0.7%	0.0%	1.4%	0.0%	0.0%	0.5%
2006	Catch	761	90	478	2023	1009	49536	80	218	12	54210
	Morts	2	0	0	0	1	21	1	0	0	25
	% Mort	0.3%	0.0%	0.0%	0.0%	0.1%	0.0%	1.3%	0.0%	0.0%	0.1%
2007	Catch	120	NA	130	615	1337	5	41	206	10	2464
	Morts	2	NA	2	0	4	0	0	1	0	9
	% Mort	1.7%	NA	1.5%	0.0%	0.3%	0.0%	0.0%	0.5%	0.0%	0.3%
2009	Catch	259	132	163	765	403	0	103	301	8	2156
	Morts	0	3	0	1	3	0	0	0	0	7
	% Mort	0.0%	2.3%	0.0%	0.1%	0.7%	0.0%	0.0%	0.0%	0.0%	0.3%
2010	Catch	357	476	1135	1149	2722	68857	135	90	1	74951
	Morts	2	11	1	11	1	27	1	0	0	54
	% Mort	0.6%	2.3%	0.1%	1.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.1%
2011	Catch	284	147	106	1662	63	0	91	73	0	2444
	Morts	1	3	1	19	3	0	6	0	0	195
	% Mort	0.4%	2.0%	0.9%	1.1%	4.8%	0.0%	6.6%	0.0%	0.0%	8.0%
2012	Catch	377	21	953	1384	258	18626	77	68	4	21810
	Morts	7	0	15	2	1	170	0	0	0	195
	% Mort	1.9%	0.0%	1.6%	0.1%	0.4%	0.9%	0.0%	0.0%	0.0%	0.9%

Fork Length Summary

Similar to the Skykomish, monthly length frequency histograms were used to estimate the threshold fork length values separating Chinook yearlings from sub-yearlings (Figure 19). Monthly fork length thresholds were confirmed from scale data collected during the 2012 sample season.

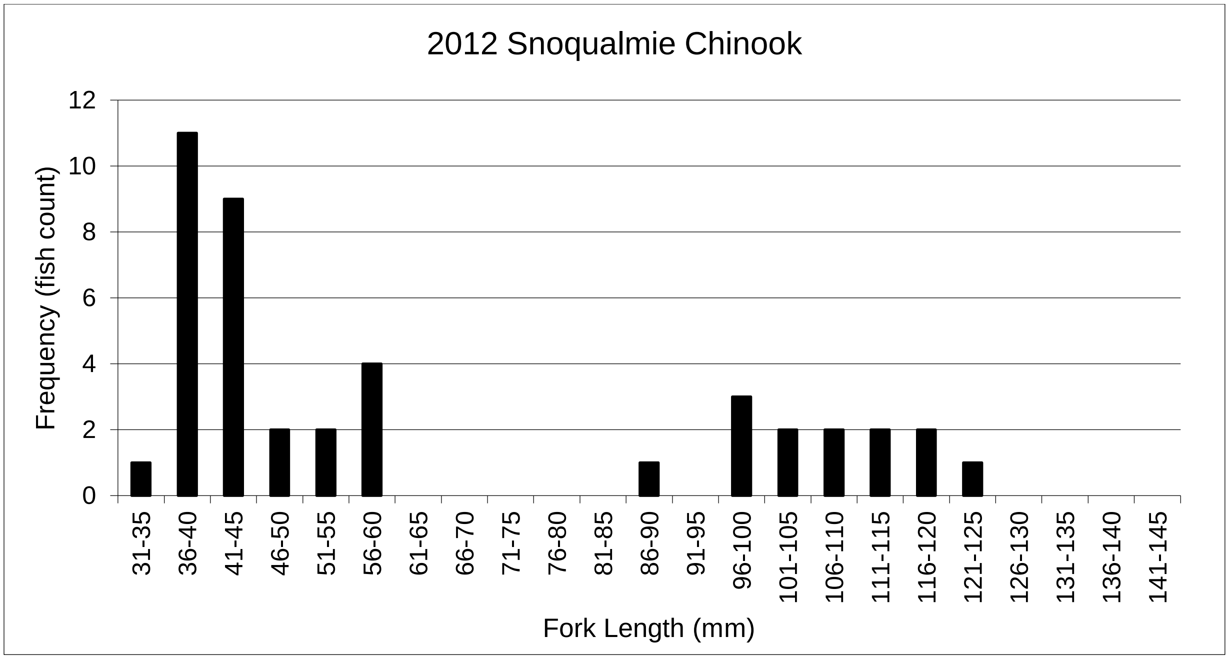


Figure 19: Example length frequency histogram from the Snoqualmie in April of 2012 used to determine the threshold value for separating wild sub-yearling from yearling Chinook. In this example month, 72 mm would have been used as the estimated fork length threshold value.

Wild sub-yearling Chinook fork lengths for the 11 sample seasons appeared to increase from ~40 mm in February to ~75 mm in late June (Figure 20). Additionally, we observed a wide spread and often bimodal distribution of wild sub-yearling Chinook fork lengths during May-June (Figure 21). Wild yearling Coho fork lengths for the 12 sample seasons did not exhibit a sustained period of increase but rather a slight increase in fork length from ~75 mm to ~100 mm during early April (Figure 22). Median fork length was fairly consistent from the start of sampling through early June (SW 26), with a relatively consistent spread in distribution across months (Figure 23).

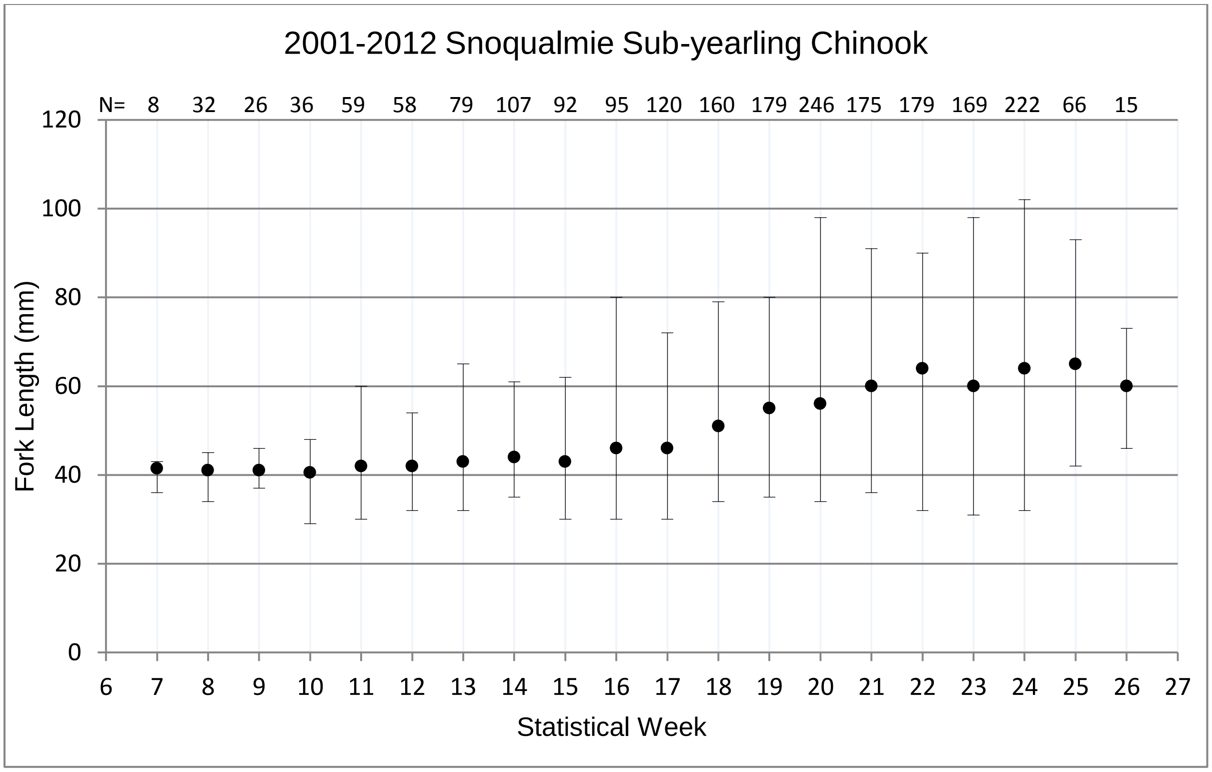


Figure 20: Observed wild sub-yearling Chinook fork lengths from 2001-2012 in the Snoqualmie River. Diamonds indicate median fork length with whiskers denoting maximum and minimum lengths.

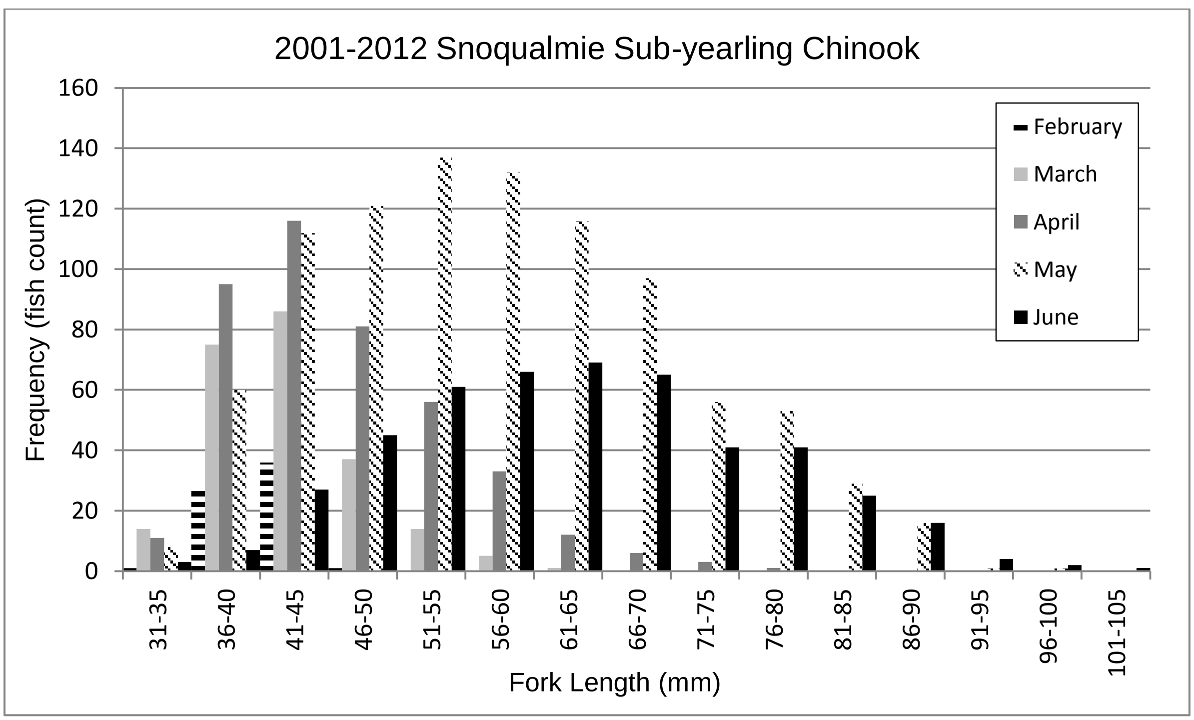


Figure 21: Fork length frequency distribution of wild sub-yearling Chinook measured at the Snoqualmie trap from 2000-2012.

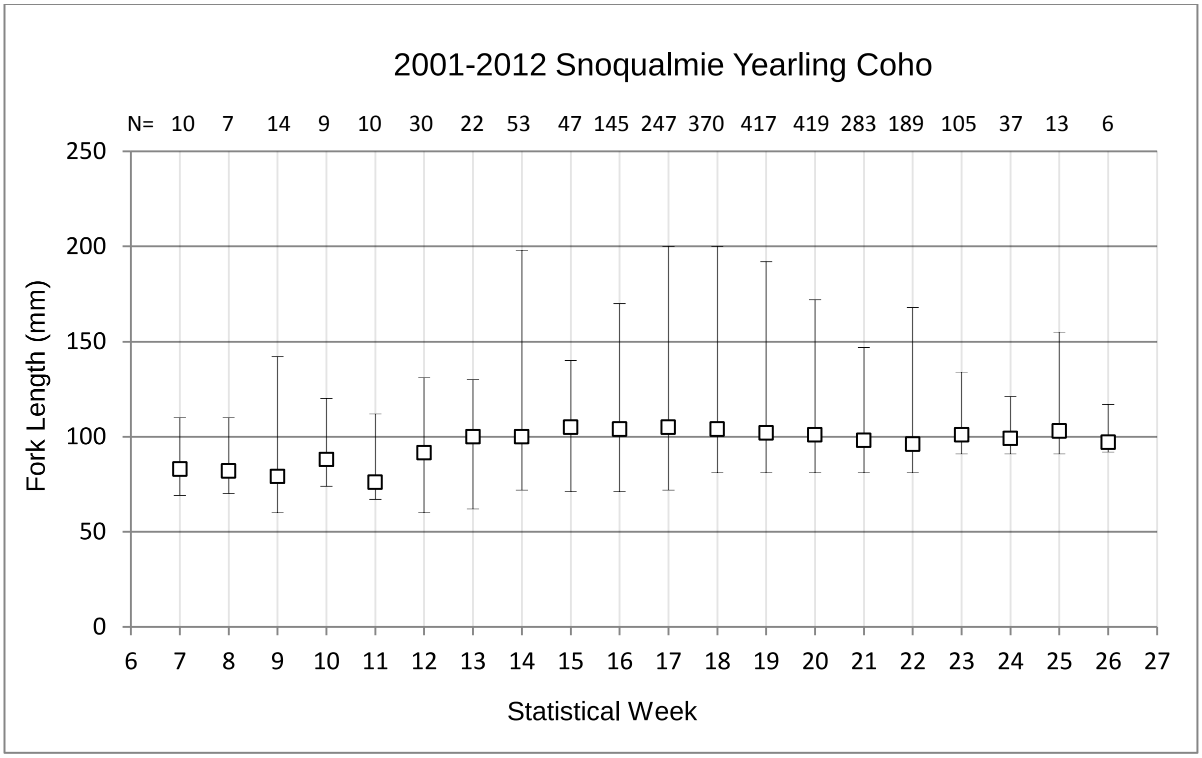


Figure 22: Observed wild yearling Coho fork lengths from 2001-2012 in the Snoqualmie River. Diamonds indicate median fork length with whiskers denoting maximum and minimum lengths.

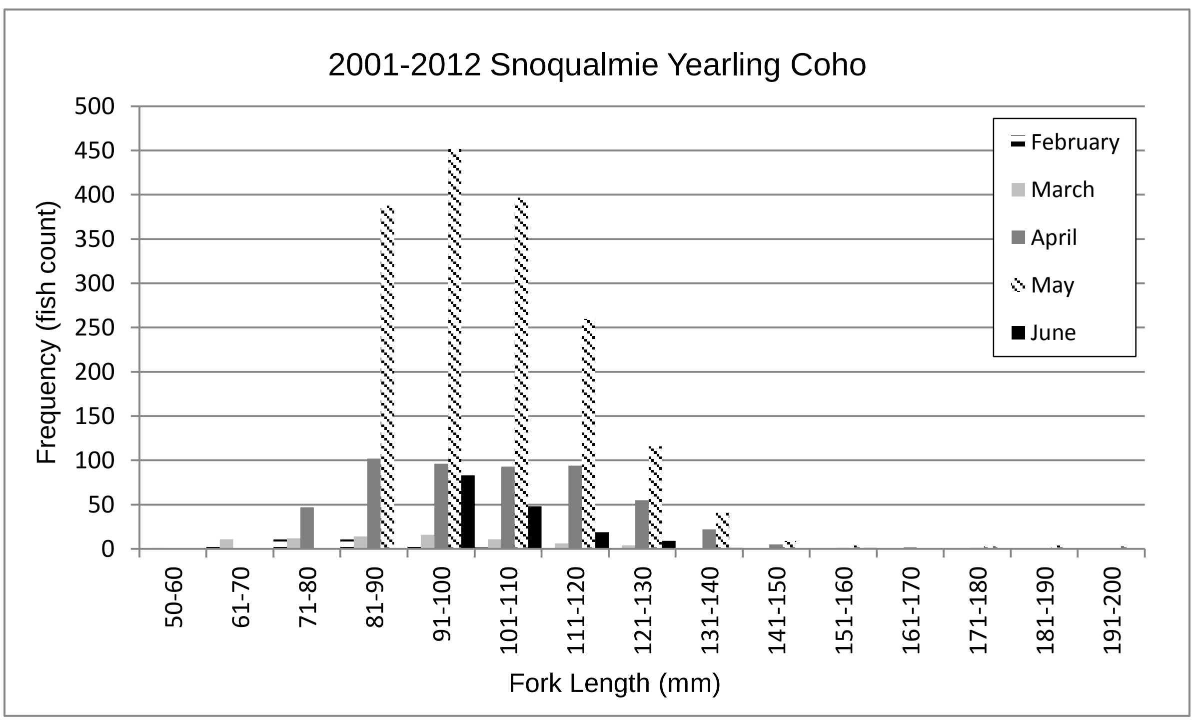


Figure 23: Fork length frequency distribution of wild yearling Coho measured at the Snoqualmie trap from 2001-2012.

Juvenile Salmonid Catch Rates

Similar to the Skykomish analyses, catch data were converted to catch per unit effort (CPUE). Average annual CPUE for sub-yearling Chinook and yearling Coho varied from 0.21-1.37 fish/hour and 0.98-3.19 fish/hour, respectively (Table 16). Average weekly CPUE varied from 0-17.79 fish/hour for wild sub-yearling Chinook and 0-62.85 fish/hour for wild yearling Coho. Generally, wild sub-yearling Chinook catch displayed a bimodal distribution with peaks occurring in earlier March (~SW 10-12) and in May through June (~SW19-24) (Figure 24). Roughly 50% of the sub-yearling Chinook catch occurring by mid-May (~SW 19) (Figure 25). The main peak in wild yearling Coho catch occurred during late April through early June (~SW 17-23) (Figure 26), with 50% of the yearling Coho catch occurring by mid-May (~SW 19) (Figure 27). Catch as well as the magnitude of peak migration was considerably higher for wild yearling Coho compared to wild sub-yearling Chinook. The peaks and timing of wild yearling Coho migration tended to be more consistent inter-annually whereas wild sub-yearling Chinook displayed very inconsistent migration timing and duration (Appendix 3). In 2001, 2002, 2004, 2005 and 2007, sub-yearling Chinook CPUE was above 0 at the start of the sample period indicating that emigration had begun before the start of sampling; however, the initial catch rates during these years where quite low suggesting that only a very small portion of the sub-yearling Chinook emigration likely took place prior to sampling.

Table 16: Average annual CPUE (catch per unit effort) for sub-yearling Chinook and yearling Coho in the Snoqualmie River from 2001-2012.

	Average Annual CPUE	
Trapping Year	Sub-yearling Chinook	Yearling Coho
2001	1.34	0.98
2002	0.79	1.86
2003	1.37	1.11
2004	0.82	1.03
2005	0.72	1.16
2006	0.83	2.07
2007	0.21	1.12
2009	0.37	1.18
2010	0.54	1.08
2011	0.40	3.19
2012	0.42	1.52

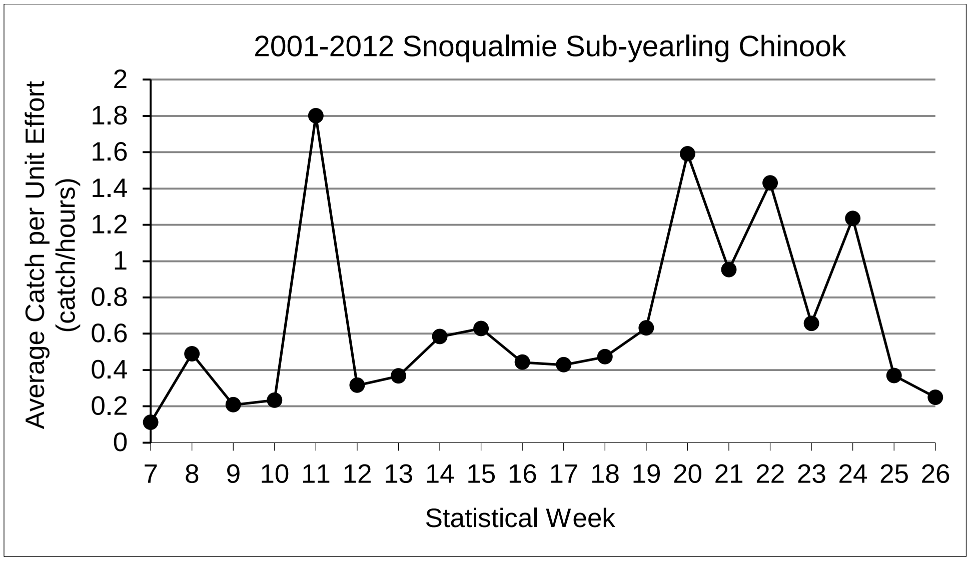


Figure 24: Average catch per unit effort (CPUE) for wild sub-yearling Chinook in the Skykomish from 2001-2012.

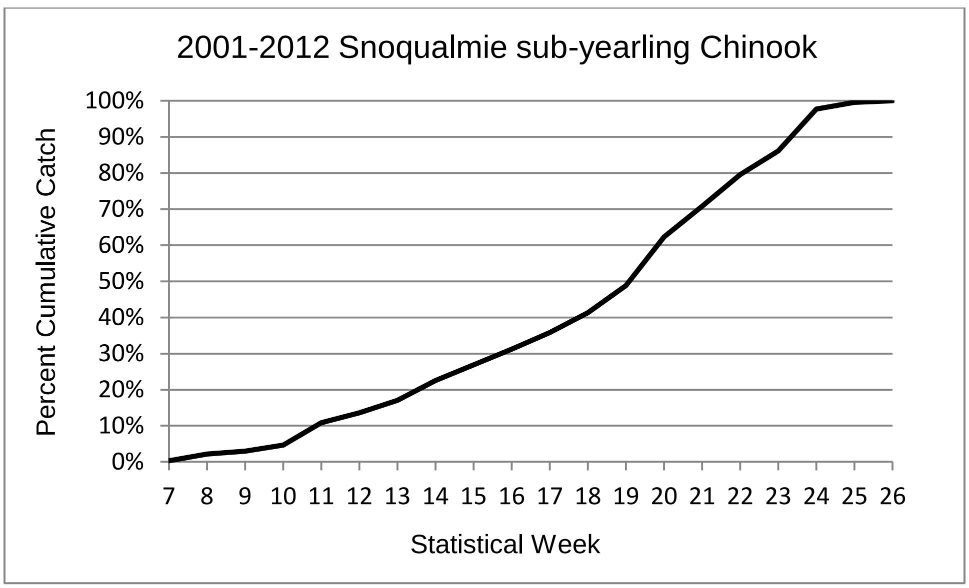


Figure 25: Percent of cumulative catch for wild sub-yearling Chinook in the Snoqualmie from 2001-2012.

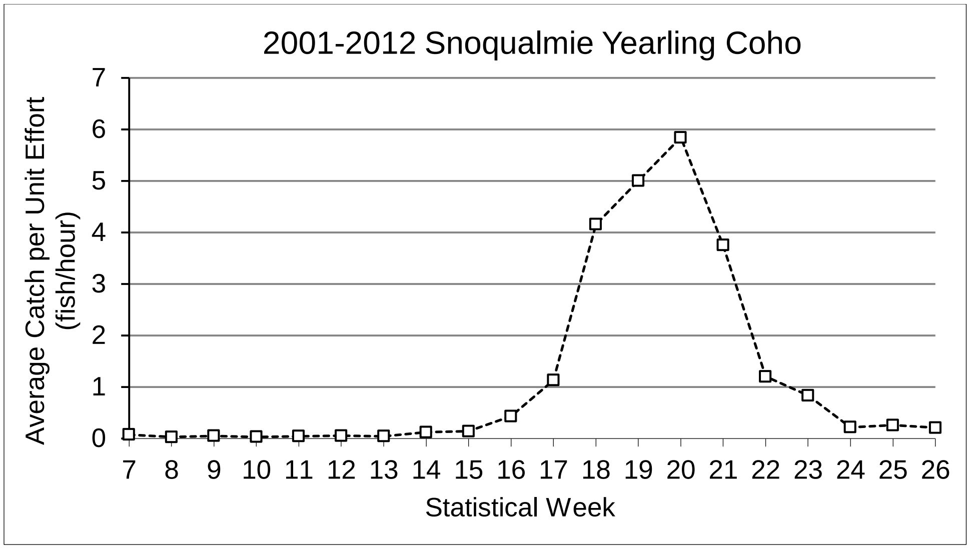


Figure 26: Average catch per unit effort (CPUE) for wild yearling Coho in the Snoqualmie River from 2001-2012.

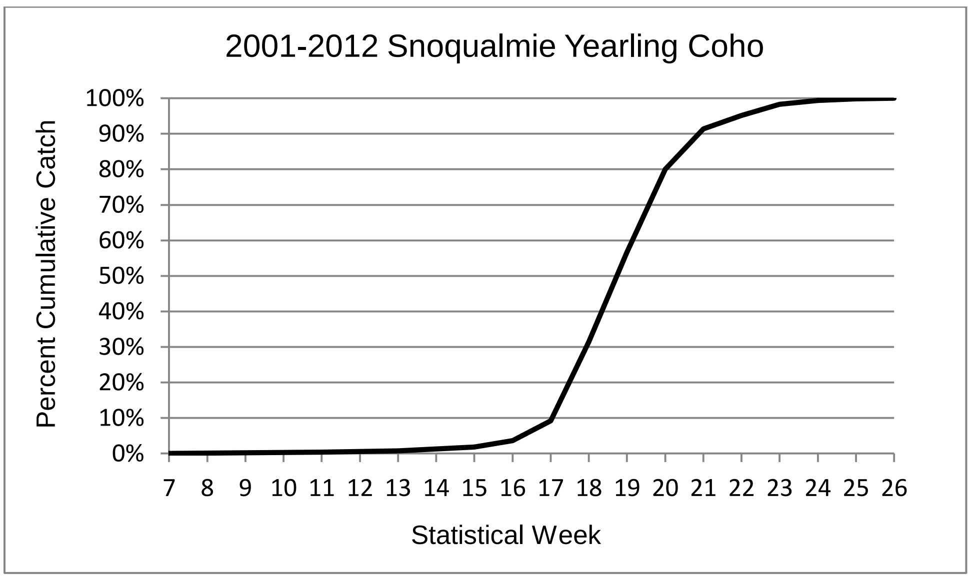


Figure 27: Percent of cumulative catch for wild yearling Coho in the Snoqualmie from 2001-2012.

Factors Affecting Catch Rates

Refer to Skykomish *Factors Affecting Catch Rates* section.

Turbidity

Similar to the Skykomish trap site, analyses of turbidity and CPUE did not show any clear correlations. Subsequently, turbidity was not collected in latter sample years and an overall assessment of turbidity and CPUE in the Snoqualmie will not be included in this report.

Day/Night Catch Rates

Since fishing events were separated into day and night categories, we were able to compare catch rates between these strata. For this comparison we only considered fishing events that occurred in the targeted stratum and had a minimum of 4 hours of effort. Since 2001 was the pilot year, it was not included in this analysis because of inconsistent day/night trapping, due to irregular scheduling. One way ANOVAs detected significant differences in CPUE between day and night fishing events from 2002-2012 for wild sub-yearling Chinook ($F_{1,20}$= 19.81, P<0.001) and wild yearling Coho ($F_{1,20}$= 17.88, P<0.001). In order to better isolate the effects of diel period to those of other variables such as seasonal timing and discharge, we assessed paired day and night sampling events for each sample year (refer to Skykomish *Day/Night Catch Rates* section for methodology). For each pair of sampling events the ratio of Day CPUE/Night CPUE (D:N ratio) was calculated for wild sub-yearling Chinook and wild yearling Coho. Ratios of less than 1 indicate higher catch rates during nighttime sets while ratios of greater than 1 indicate higher catch rates during daytime sets.

Annual Snoqualmie D:N ratio from 2002-2012 for wild sub-yearling Chinook showed considerable variability ranging from 0.15 to 0.84 (Table 17). Similarly, D:N ratio from 2002-2012 for wild yearling Coho (Table 18) was quite variable ranging from 0.08 to 0.54. All 202 paired D:N ratios were <1 indicating that night CPUE was generally higher at night. Although, D:N pairs in 2005 and 2009 for wild sub-yearling Chinook were close to 1, indicating that day and night CPUE were essentially equal during those seasons. The majority of D:N ratio results from the Snoqulamie trap illustrate a tendency for catch rates of wild sub-yearling Chinook and wild yearling Coho to be higher at night (although not as strong as in the Skykomish), which is supportive of the literature as well as other trapping efforts (McDonald, 1960; Groot and Margolis, 1991; Quinn, 2005; Kinsel et al., 2008; Dolphin, 2011).

Table 17: Summary of day and night catch for wild sub-yearling Chinook in the Snoqualmie River from 2002-2012.

		Effort (hours)		Catch		D:N Ratio
Year	# of pairs	Day	Night	Day	Night	for Season
2002	12	146.70	122.40	25	139	0.15
2003	30	246.75	244.28	89	212	0.42
2004	64	619.68	561.87	216	291	0.67
2005	16	206.75	164.92	105	100	0.84
2006	10	124.92	107.08	37	123	0.26
2007	7	90.80	66.25	15	25	0.44
2009	11	126.07	112.12	34	45	0.67
2010	21	269.27	104.00	36	104	0.29
2011	15	213.23	131.32	47	79	0.37
2012	16	220.58	172.50	32	67	0.16

Table 18: Summary of day and night catch for wild yearling Coho in the Snoqualmie River from 2002-2012.

		Effort (hours)		Catch		D:N Ratio
Year	# of pairs	Day	Night	Day	Night	for Season
2002	12	146.70	122.40	139	486	0.24
2003	30	246.75	244.28	74	621	0.12
2004	64	619.68	561.87	92	1126	0.07
2005	16	206.75	164.92	100	187	0.25
2006	10	124.92	107.08	15	166	0.08
2007	7	90.80	66.25	62	143	0.32
2009	11	126.07	112.12	104	170	0.54
2010	21	269.27	104.00	122	375	0.27
2011	15	213.23	131.32	136	758	0.11
2012	16	220.58	172.50	156	265	0.20

Discharge and Catch Rates

Wild sub-yearling Chinook CPUE displayed positive relationships with daily mean discharge in 2001 (R^2=0.56), 2003 (R^2=0.67), 2004 (R^2=0.37), 2005 (R^2=0.21), 2006 (R^2=0.45), 2009 (R^2=0.62), 2010 (R^2=0.51), 2011 (R^2=0.48), and 2012 (R^2=0.70). Wild yearling Coho CPUE exhibited a positive relationship with discharge in 2001 (R^2=0.50), 2006 (R^2=0.35), 2009 (R^2=0.56), and 2012 (R^2=0.30). The majority of the sample periods for wild sub-yearling Chinook (9 of 11 years) showed a positive correlation between CPUE and discharge; whereas, the majority of wild yearling Coho (7 of 11 years) did not show correlation between CPUE and discharge. Refer to Skykomish *Discharge and Catch Rates* section for additional discussion of additional CPUE-discharge correlations and analyses.

Trap Efficiency

Refer to Skykomish *Trap Efficiency* section for methodological details and efficiency test assumptions.

During the 2002-2003 trapping seasons, efficiency tests on the Snoqualmie aimed at using wild sub-yearling Chinook captured on the trap rather than hatchery raised Chinook out of concerns of straying (since the Snoqualmie watershed has no Chinook hatcheries). However, weekly catch of wild sub-yearling Chinook were not sufficient enough to conduct proper efficiency tests. Subsequently, wild Chum fry captured on the Skykomish trap were used as a surrogate for sub-yearling Chinook on the Snoqualmie (due to comparable sizes during migration). Initial analyses indicated that efficiency results were relatively similar between the species; however starting in 2004, we received approval to use hatchery raised sub-yearling Chinook for all subsequent years for consistency between traps and to ensure we had reliable release numbers for effective efficiency tests (rather than depending on variable weekly catch). To address the issue of straying, a risk analysis was performed to project how many of these released fish might survive to contribute to effective female spawners in the Snoqualmie (Mike Crewson, personal communication). This risk analysis indicated that the use of hatchery Chinook for efficiency tests might contribute 1 female spawner a year, which is approximately 0.1 % of the average natural spawning population. Subsequently, we decided that the low risk of using hatchery raised sub-yearling Chinook in the Snoqualmie was outweighed by the benefits of using the desired species and age class for efficiency tests. Due to the insufficient release numbers from 2002-2003, these years were not included in this overall report for clarity of analysis and comparability across traps.

Efficiency Results

Chinook

A total of 34,542 marked sub-yearling Chinook were released during trapping efficiency tests conducted from 2004-2012. The majority of fish used in the mark groups were raised at the Washington Department of Fish and Wildlife Wallace River Hatchery; however, from 2007-2009, the fish used in the mark group were raised at the Tulalip Bernie Kai-Kai Gobin Hatchery. Mean fork lengths for the 27 release groups ranged from 46.6 mm to 82.6 mm. This discrepancy in mean fork length could be a source of error for our efficiency estimates if fish size has an effect on capture efficiency; due to variation in the ability of different size-classes to evade the trap.

Of the 34,542 marked sub-yearling Chinook that were released during the 28 tests, total yearly release numbers varied from 2,347-7,987 and recovered numbers varied from 30-200 (Table 19). Yearly trap efficiency estimate varied from 1.3- 2.5% (average: 1.7%); which falls within the 1% to 5% range we had expected at the inception of the project. Other than 2009, it appears that trap efficiency for sub-yearling Chinook was higher at night. From 2004-2011 roughly 1100 marked sub-yearling Chinook were released during each efficiency test. Similar to the Skykomish, consultation with the WDFW and the NWIFC resulted in a recommendation to increase efficiency releases from ~1000 fish to ~2000 per efficiency test. This was conducted for the 2012 trapping season and the percent recovered indeed increased roughly 1.6x from recovered percentages from 2004-2011. Subsequently, ~2000 sub-yearling Chinook will be used for efficiency tests in following years.

Table 19: Efficiency estimates from mark and recapture tests conducted using sub-yearling Chinook in the Snoqualmie River from 2004-2012.

2004-2012 Sub-yearling Chinook								
		Number	Number				90% C.I.	
	Number of	Released	Recovered	Day	Night	% Total		
Year	Releases	[R]	[r]	Recovered	Recovered	Recovered	lower	upper
2004	4	5175	75	12	61	1.5%	1.2%	1.8%
2005	5	5900	99	12	88	1.7%	1.4%	2.0%
2006	3	3091	45	4	41	1.5%	1.1%	1.9%
2007	2	2579	33	2	31	1.3%	1.0%	1.7%
2009	3	3176	60	39	20	1.9%	1.5%	2.4%
2010	4	4287	60	8	52	1.4%	1.1%	1.7%
2011	2	2347	30	4	26	1.3%	0.9%	1.7%
2012	4	7987	200	18	182	2.5%	2.2%	2.8%
Total	27	34542	602	99	501	1.7%	1.6%	1.9%

Coho

A total of 29,010 marked yearling Coho were released during trapping efficiency test conducted from 2002-2012. As with the sub-yearling Chinook, the majority of fish used were raised at the Wallace River Hatchery other than years 2007-2009 where fish were raised at the Tulalip Bernie Kai-Kai Gobin Hatchery. Mean fork lengths for the 28 release groups ranged from 102 mm to 142 mm. As in the Chinook trials we expected that that any effect mortality or delayed migration might have had on these efficiency trials was negligible. If fish size, mortality or delayed migration did have any effect on trap efficiency estimates we would expect that trap efficiency would be slightly underestimated.

Of the 29,010 marked yearling Coho that were released during the 30 tests, total yearly release numbers varied from 1,810-3982 and recovered numbers varied from 10-62 (Table 20). Yearly trap efficiency estimate varied from 0.4-2.8% (average: 0.9%). Other than 2009, it appears that trap efficiency for yearling Coho was higher at night. Similar to the Skykomish, consultation with WDFW and the NWIFC resulted in increased Chinook efficiently release numbers in 2012 (from ~1000 to ~2000) as well as planned increases for Coho in 2013.

Table 20: Efficiency estimates from mark and recapture tests conducted using yearling Coho in the Snoqualmie River from 2002-2012.

2002-2012 Yearling Coho								
		Number	Number				90% C.I.	
	Number of	Released	Recovered	Day	Night	% Total		
Year	Releases	[R]	[r]	Recovered	Recovered	Recovered	lower	upper
2002	4	2262	10	2	8	0.4%	0.3%	0.8%
2003	4	4020	30	9	21	0.8%	0.5%	1.0%
2004	2	1810	10	1	9	0.6%	0.3%	1.0%
2005	2	2191	13	4	12	0.6%	0.4%	1.0%
2006	3	3984	35	6	28	0.9%	0.7%	1.2%
2007	2	2193	62	4	51	2.8%	2.3%	3.5%
2009	2	2294	23	18	5	1.0%	0.7%	1.4%
2010	3	2536	23	2	21	0.9%	0.6%	1.3%
2011	4	3738	29	10	19	0.8%	0.6%	1.1%
2012	3	3982	21	4	17	0.5%	0.4%	0.8%
Total	29	29010	256	60	191	0.9%	0.8%	1.0%

Discharge and Efficiency

Refer to Skykomish *Discharge and Efficiency* section for additional details and discussion.

We were able to detect a relationship between trap efficiency and discharge for the 28 sub-yearling Chinook release events during the 2004-2012 trapping seasons. After using the average discharge across the efficiency tests as a separator (~3,734 cfs), we were still unable to detect a significant difference in percent recovered between the higher discharge bin (3,735-6,995 cfs; n=12) and the lower bin (1,550-3,610 cfs; n=16).

We were unable to detect a significant relationship between trap efficiency and discharge for the 30 yearling Coho release events during the 2004-2012 trapping seasons. Similar to sub-yearling Chinook , even after using the average discharge across the efficiency tests as a separator (~4,918cfs), we were still unable to detect a significant difference in percent recovered between the higher (4,960-9,335 cfs; n= 12) and the lower bin (2,305-4,910 cfs; n=18).

We hypothesize that the variations in recapture rates observed among efficiency tests are a representative sample of the range of efficiencies that the trap operates at over the season. Since we had minimal support explaining the cause of the observed variability, we chose to use the composite results from efficiency tests, defined as the mean trap efficiency for each species across the trapping season. The composite values for the number of marked sub-yearling Chinook and yearling Coho released (R) and recovered (r) were used in production estimates. As we have stated, minor violations of the assumptions of these efficiency tests likely resulted in a slight underestimation of trap efficiency while the diel timing of the releases likely resulted in an opposite effect. Our observations suggest that these influences were quite small and we suspect that they effectively balance each other out over the course of sampling.

Out-migrant Production Estimates

Sub-yearling Chinook

According to our estimates, approximately 54-92% (average: 82%) of the emigration of wild sub-yearling Chinook occurred during the 2002-2012 sampled strata (Table 21). These portions of our estimates do not include Chinook that may have emigrated before or after the trapping season in addition to those which may have emigrated during un-sampled periods. We estimate that between 1,984-26,997 sub-yearling Chinook emigrated before trapping began and between 22,662-22,599 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods varied between 1,681-5,948 emigrating sub-yearling Chinook. We calculate that from 2002-2012 the Snoqualmie River produced between 40,633-257,262 wild sub-yearling Chinook. Trends in inter-annual production estimates from 2002-2012 are represented in Figure 28.

Table 21: Production estimates for wild sub-yearling Chinook in the Snoqualmie River from migration year 2002-2012.

2002	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7	SW 8, 11, 22	SW 27-30	Estimate
Day	36,596	28,306	44,886	740	2,349	3,511	43,196
Night	67,548	58,883	76,213	16,241	0	4,790	88,579
Total	104,144	92,152	116,136	16,981	2,349	8,301	**131,775**
2003	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6		SW 25-30	Estimate
Day	48,967	37,336	60,598	0		856	49,823
Night	176,190	153,660	198,720	26,997		4,252	207,439
Total	225,157	199,802	250,512	26,997		5,108	**257,262**
2004	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-7		SW 27-30	Estimate
Day	69,055	56,256	81,854	5,486		2,915	77,456
Night	52,952	46,022	59,882	1,048		1,349	55,349
Total	122,007	107,453	136,561	6,534		4,264	**132,805**
2005	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 1-6		SW 25-30	Estimate
Day	63,137	54,915	71,359	771		174	64,082
Night	54,387	47,926	60,848	11,604		7,473	73,464
Total	117,524	107,067	127,981	12,375		7,647	**137,546**

Table 20 continued:

2006 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-7		SW 25-30	Total Migration Estimate
Day	98,597	78,037	119,157	1,984		5,092	105,673
Night	45,776	32,277	59,275	0		5,469	51,245
Total	144,373	110,314	178,431	1,984		10,561	**156,918**

2007 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-10	SW 13	SW 23-30	Total Migration Estimate
Day	20,572	11,119	30,025	10,182	0	12,270	43,023
Night	24,902	15,571	34,234	6,095	1,681	8,648	41,326
Total	45,474	26,689	64,259	16,277	1,681	22,599	**84,350**

2009 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates	SW 15	SW 26-30	Total Migration Estimate
Day	20,280	12,977	27,583		1,545	660	22,485
Night	23,647	16,611	30,683		1,000	2,002	26,649
Total	43,927	29,588	58,266		2,545	2,662	**49,134**

2010 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-6		SW 27-30	Total Migration Estimate
Day	62,088	45,639	78,536	834		2,822	65,743
Night	111,118	85,240	136,995	2,886		7,761	121,765
Total	173,206	130,880	215,532	3,720		10,583	**187,508**

2011 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-13	SW 15 & 21	SW 27-30	Total Migration Estimate
Day	29,804	20,149	39,459	1,546	1,675	1,514	34,539
Night	32,457	22,055	42,858	2,254	4,273	6,446	45,430
Total	62,260	42,204	82,317	3,799	5,948	7,960	**79,968**

2012 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-8	SW 17	SW 25-30	Total Migration Estimate
Day	9,123	5,905	12,342	1,711	967	420	12,221
Night	19,924	14,822	25,025	2,576	1,749	4,163	28,412
Total	29,047	20,727	37,367	4,287	2,716	7,298	**40,633**

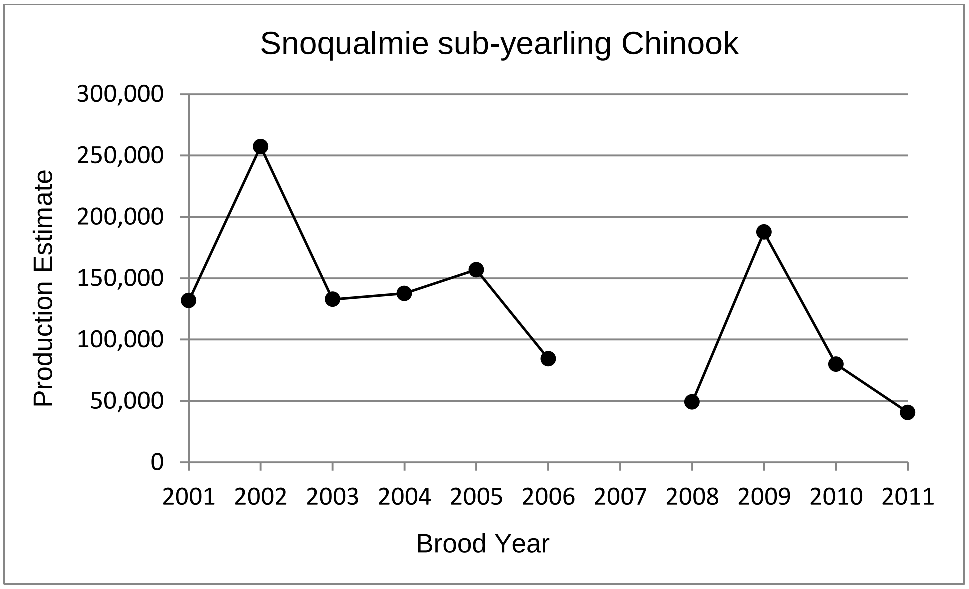


Figure 28: Trend in production estimates for wild sub-yearling Chinook in the Snoqualmie River for brood years 2001-2011.

Yearling Chinook

We estimate that approximately 67-100% (average: 92.5%) of wild yearling Chinook emigration in the Snoqualmie occurred during the sampled strata (Table 22Table 23). We estimate that in the Snoqualmie between 6-3,304 yearling Chinook emigrated before trapping began and another between 24-1,194 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods in the Snoqualmie varied between 2-15,204 emigrating yearling Chinook. We calculate that from 2002-2012 the Snoqualmie River produced between 5,167-64,852 wild yearling Chinook. Trends in inter-annual production estimates from brood year 2000-2010 are represented in Figure 29.

Table 22: Production estimates for wild yearling Chinook in the Snoqualmie River from sample year 2002-2012.

2002 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-7	SW 8, 11, 22	SW 27-30	Total Migration Estimate
Day	9,215	4,067	14,362	0	0	0	9,215
Night	3,116	1,123	5,108	0	0	0	3,116
Total	12,331	6,811	17,850	0	0	0	**12,331**

2003 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-6		SW 25-30	Total Migration Estimate
Day	3765	1413	6117	0		0	3765
Night	4027	1671	6383	0		857	4884
Total	7792	4463	11121	0		857	**8649**

2004 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-7		SW 27-30	Total Migration Estimate
Day	1458	35	2881	0		0	1458
Night	3709	1539	5879	0		0	3709
Total	5167	2572	7762	0		0	**5167**

2005 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-6		SW 25-30	Total Migration Estimate
Day	37842	29255	46429	0		0	37842
Night	1374	-91	2839	0		0	1374
Total	39216	30505	47927	0		0	**39216**

2006 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-7		SW 25-30	Total Migration Estimate
Day	6,552	3,470	9,634	0		23	6,574
Night	42,358	31,834	52,882	0		2	42,359
Total	48,910	35,303	62,516	0		24	**48,934**

2007 Diel Stratum	Sampled Strata Estimate	95% C.I. Lower	95% C.I. Upper	Un-Sampled Strata (Interpolated) Additional Estimates SW 1-10	SW 13	SW 23-30	Total Migration Estimate
Day	8,323	2,152	14,495	0	0	8	8,331
Night	51,144	41,442	60,845	6	2	22	51,173
Total	59,467	43,594	75,340	6	2	30	**59,504**

Table 22: Continued.

2009 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper		SW 15	SW 26-30	
Day	10,393	5,060	15,726		0	0	10,393
Night	29,797	22,749	36,844		0	1,111	30,908
Total	40,190	27,810	52,570		0	1,111	**41,301**
2010 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-6		SW 27-30	
Day	58,132	46,678	69,585	0		1,549	59,681
Night	89,381	71,713	107,049	0		7,530	96,911
Total	147,513	118,392	176,634	0		9,079	**156,592**
2011 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-13	SW 15 & 21	SW 27-30	
Day	13,101	7,625	18,578	1,719	3,874	0	18,694
Night	33,242	25,488	40,997	1,586	11,330	0	46,158
Total	46,344	33,113	59,575	3,304	15,204	0	**64,852**
2012 Diel Stratum	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total Migration Estimate
	Estimate	95% C.I. Lower	95% C.I. Upper	SW 1-8	SW 17	SW 25-30	
Day	1,066	258	1,873	0	135	1,194	2,394
Night	4,934	2,516	7,352	0	1,668	0	6,602
Total	5,999	2,774	9,225	0	1,803	1,194	**8,996**

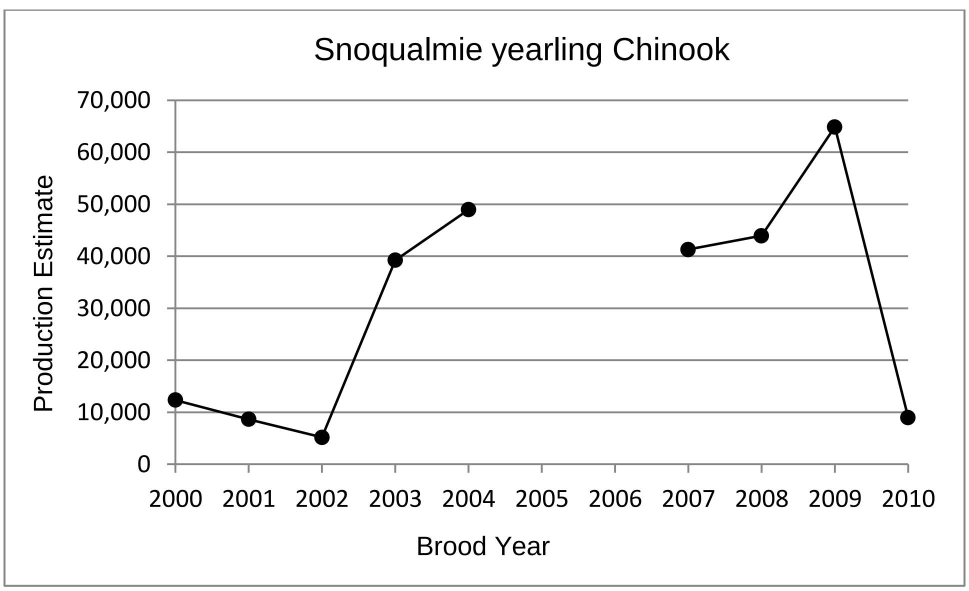


Figure 29: Trend in production estimates for wild yearling Chinook in the Snoqualmie River for brood years 2000-2010.

Coho

We estimate that approximately 78.6-100% (average: 95%) of the emigration of wild yearling Coho occurred during the 2002-2012 sampled strata (Table 23). These portions of our estimates do not include Coho that may have emigrated before or after the trapping season in addition to those which may have emigrated during un-sampled periods. We estimate that between 300-4,637 yearling Coho emigrated before trapping began and another between 128-8,948 emigrated after trapping was completed. Additionally, estimates from un-sampled strata during the sample periods varied between 50,555-146,017 emigrating yearling Coho. We calculate that from 2002-2012 the Snoqualmie River produced between 1,600,165-1,164,543 wild yearling Coho. Trends in inter-annual production estimates from 2002-2012 are represented in Figure 30.

Table 23: Production estimates for wild yearling Coho in the Snoqualmie River from sample year 2002-2012.

2002	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total
Diel		95% C.I.					Migration
Stratum	Estimate	Lower	Upper		SW 8, 11, 22		Estimate
Day	318,809	197,334	440,283		50,555		369,364
Night	795,179	593,152	997,207		0		795,179
Total	1,113,988	790,486	1,437,490		50,555		**1,164,543**

2003	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total
Diel		95% C.I.					Migration
Stratum	Estimate	Lower	Upper			SW 25-26	Estimate
Day	101,699	81,719	121,679			0	101,699
Night	371,777	319,447	424,107			4,049	375,826
Total	473,476	417,462	529,490			4,049	**477,525**

2004	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total
Diel		95% C.I.					Migration
Stratum	Estimate	Lower	Upper				Estimate
Day	46,990	33,159	60,821				46,990
Night	386,310	333,913	438,707				386,310
Total	433,300	379,108	487,492				**433,300**

2005	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total
Diel		95% C.I.					Migration
Stratum	Estimate	Lower	Upper			SW 25-26	Estimate
Day	88,963	71,106	106,820			0	88,963
Night	375,565	328,135	422,995			1,465	377,030
Total	464,528	413,848	515,208			1,465	**465,993**

2006	Sampled Strata			Un-Sampled Strata (Interpolated) Additional Estimates			Total
Diel		95% C.I.					Migration
Stratum	Estimate	Lower	Upper	SW 7		SW 25 and 26	Estimate
Day	494,195	404,768	583,621	1,055		300	495,550
Night	99,240	74,849	123,631	0		747	99,987
Total	593,434	479,617	707,252	1,055		1,047	**595,536**

Table 23: Continued.

2007	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 7-10		SW 23-26	Estimate
Day	7,061	5,000	9,122	124		1,989	9,174
Night	141,084	108,280	173,888	2,947		6,960	150,991
Total	148,145	113,280	183,010	3,071		8,949	**160,165**
2009	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper			SW 26	Estimate
Day	225,567	174,279	276,855			128	225,695
Night	99,363	75,984	122,742			0	99,363
Total	324,930	250,263	399,597			128	**325,058**
2010	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper				Estimate
Day	78,959	58,660	99,258				78,959
Night	298,829	233,825	363,833				298,829
Total	377,788	292,485	463,091				**377,788**
2011	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 7-15	SW 21		Estimate
Day	78,728	57,868	99,587	2,023	19,558		100,309
Night	472,839	381,343	564,335	2,614	126,459		601,912
Total	551,567	439,210	663,923	4,637	146,017		**702,221**
2012	Sampled Strata			Un-Sampled Strata (Interpolated)			Total
Diel		95% C.I.		Additional Estimates			Migration
Stratum	Estimate	Lower	Upper	SW 7-8	SW 17	SW 25-26	Estimate
Day	194,137	144,541	243,733	0	21430	690	216,257
Night	441,061	341,366	540,755	300	70,776	1,100	513,237
Total	635,197	485,907	784,488	300	92,206	1,790	**729,494**

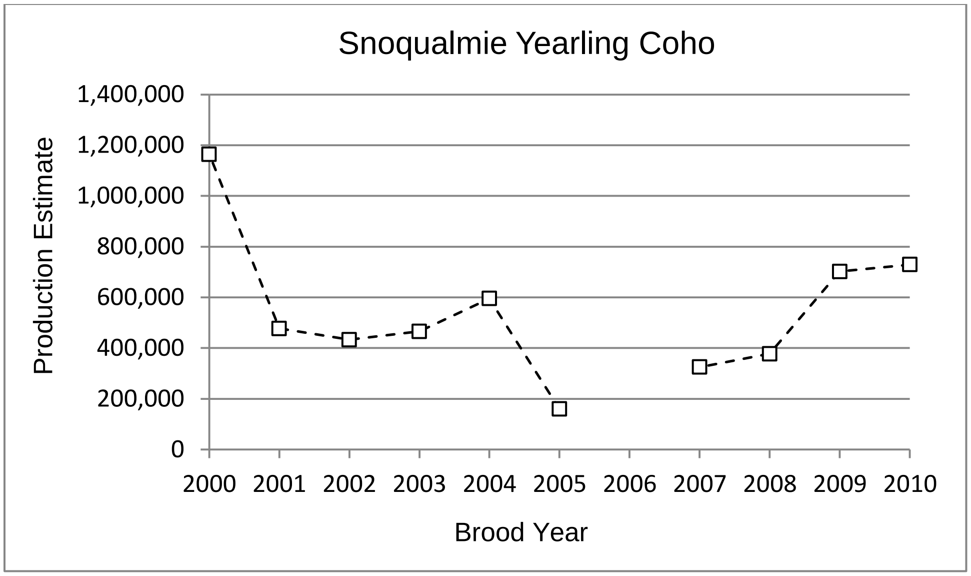


Figure 30: Trend in production estimates for wild yearling Coho in the Snoqualmie River for brood years 2000-2010.

Freshwater Survival

Chinook

We estimated egg to migrant survival of naturally spawned Chinook salmon for brood years 2001-2012 in the Snoqualmie River (Table 24). Egg-migrant survival in brood years 2005, 2006, and 2011 only include the sub-yearling cohort because of yearling identification issues in migration year 2007, a lack of yearling sampling in 2008 (due to trap repair), and because yearling Chinook for migration year 2012 have yet to be sampled. Redd counts varied from 358 (2009) to 3,588 (2001) with total egg deposition ranging from 1,196,542 (2011) to 6,522,865 (2001). Approximate egg-migrant survival for sub-yearling Chinook from brood year 2000-2011 ranged from 1.14-10.19%. The highest egg-migrant survival was observed in brood years 2002, 2005, 2009, and 2010 while the lowest egg-migrant survival was observed in brood years 2001, 2006, and 2008.

Table 24: Estimates of egg-migrant survival for wild sub-yearling Chinook produced in the Snoqualmie River for brood years 2001-2011.

Brood year (*b*)	WDFW escapement estimates	Redd count (CR_b)	Eggs per Female (FE_b)	Total egg deposition (D_b)	Sub-yearling Chinook production (SP_{b+1})	Yearling Chinook production (SP_{b+2})	Egg - Migrant survival (S_b)
2001	3588	1435	4546	6522865	131775	8649	2.2%
2002	2895	1158	4451	5153977	257262	5167	5.1%
2003	1975	790	4924	3889887	132805	39216	4.4%
2004	2988	1195	3945	4715557	137546	48934	4.0%
2005	1279	512	4693	4908964	156918	NA	6.7%
2006	2615	1046	4693	4908964	84350	NA	1.7%
2008	2560	1024	4130	4229575	48134	41301	2.1%
2009	895	358	5141	1840552	86939	43938	12.6%
2010	1788	715	4780	3417587	79968	64852	4.2%
2011	700	280	4273	1196542	40633	NA	3.4%

SNOHOMISH BASIN COHO SURVIVAL

Coho Survival

We calculated the Snohomish Coho survival index (SnoCSI) for brood years 2000-2010 (Table 25). Since the SnoCSI is only a relative index of survival, it is only useful for comparing survival rates from year to year at these specific trap sites. SnoCSI is not calibrated to any scale so we have no way of telling how much a difference of say ten index points represents in terms of survival percentage. What we can infer from this index is that lower SnoCSI values represent brood years that experienced lower survival rates or more specifically lower juvenile production per adult counted during spawner surveys. Based on these calculations it appears that brood years 2003, 2004, 2005, and 2007 had the lowest freshwater success rates of the 11years shown with SnoCSI values of 8, 11, 10, and 8, respectively. Brood years 2000, 2008, and 2010 displayed the highest survival rate with SnoCSI values of 46, 56, and 38, respectively.

Table 25: Estimated survival indices for wild yearling Coho in the Snohomish River Basin for brood years 2000-2010. Production estimates were pooled from both the Skykomish and Snoqualmie traps.

	Yearling Migrants		Escapement Indices		
Brood Year (*b*)	Migration Year (*b*+2)	Production Estimate (P_b+2)	Above Traps (IC_b)	Sunset Falls (SF_b)	Coho Survival Index ($SnoCSI_b$)
2000	2002	2894314	39,435	23843	46
2001	2003	2452824	118,808	50531	14
2002	2004	2677728	74,287	44278	23
2003	2005	1066101	99,782	31558	8
2004	2006	1852947	123,348	40867	11
2005	2007	640696	43,816	23322	10
2007	2009	663686	57,200	28720	8
2008	2010	1143223	11253	9078	56
2009	2011	1100971	43653	25092	16
2010	2012	1355500	26691	8600	38

DISCUSSION & CONCLUSIONS

Site Selection and Feasibility

A successful site for trapping juvenile salmonids depends on a number of conditions, such as access to the river, appropriate water velocities, available anchor points, suitable channel characteristics (e.g. constricted flow, some turbulence) and adequate capture efficiency. The sites selected for trapping the Skykomish and Snoqualmie River during this project were located at river mile 23 and 26.5, near Monroe, Washington and at river mile 12.2, near Duvall, Washington. The river channel at these locations provided the velocities and constricted flow necessary for trap operation. Additionally, these sites had easy access to the river with suitable trees on either bank to use as anchor.

Out-migration Patterns

Chinook

There was considerable variability in wild sub-yearling Chinook out-migration timing and CPUE among sample years and between the traps. We observed peaks in wild sub-yearling Chinook catch in the Skykomish around late March through April and late May to early June and in the Snoqualmie around March and May through June. These bimodal peaks in migration timing and CPUE were relatively similar to trapping observations on the Skagit (March-May & June) (Kinsel et al., 2008), Stillaguamish (March-April & May-June) (refer to Stillaguamish River references), Green (March-April & June) (refer to Green River references) and the Cedar Rivers (February-March & June) (refer to Cedar River references). Average CPUE of sub-yearling Chinook was considerably higher at the Skykomish trap site (2.11 fish/hour) compared to the Snoqualmie (0.71 fish/hour). However, the observed variation in CPUE for a given SW among years at the Skykomish and Snoqualmie was at times an order of magnitude different. For example, sub-yearling Chinook CPUE at the Skykomish during statistical week (SW) 14 was 17.79 fish/hour in 2011 and 1.55 fish/hour in 2012. This variation in CPUE can have significant impacts on production estimates, if peak migration periods are not adequately sampled due to high discharge events (e.g. 2002, 2007, 2011, and 2012). In addition to a relatively bimodal migration pattern, percent cumulative catch indicated that sub-yearling Chinook migration occurring over an extended period of time. The approximate date of 50% migration in the Skykomish (~mid–March) was relatively similar to the Skagit (~ late March) (Kinsel et al., 2008) and Cedar Rivers (~mid–March) (Kiyohara and Zimmerman, 2011b, 2012), whereas the 50% migration date in the Snoqualmie (~mid –May) was relatively similar to the Stillaguamish (~early May) (refer to Stillaguamish River references).

Chinook catch rates were considerably higher during periods of darkness, which is consistent with the literature (McDonald, 1960; Groot and Margolis, 1991; Quinn, 2005) as well as observations from other out-migrant trapping studies (Kinsel et al., 2008; Dolphin, 2011). The average day-night ratio was considerably lower in the Skykomish (0.28) than the Snoqualmie (0.42), which may indicate a less pronounced pattern of diel migration in the Snoqualmie. The Skykomish is relatively clearer (lower turbidity) than the Snoqualmie which may result in increased nocturnal migration due to anti-predator behavior. This pattern of nocturnal migration has also been shown in clearer systems such as the Skagit River (refer to Skagit River references); while turbid river systems like the Stillaguamish have shown less of a diel signal in Chinook migration (refer to Stillaguamish River references). Therefore, higher turbidity in the Snoqualmie, compared to the Skykomish, may have subsequently resulted in a dampened nocturnal migration signal.

As suggested in the literature, we expected discharge to influence Chinook migration (Groot and Margolis, 1991; Seiler et al., 1998, 2000; Conrad and MacKay, 2000; Griffith et al., 2001). Only 2 years on the Skykomish (2001 and 2004) appeared to show a correlation between sub-yearling Chinook migration and discharge; however, 9 years on the Snoqualmie (2001, 2003, 2004, 2005, 2006, 2009, 2010, 2011, and 2012) displayed a positive migration-discharge relationship. We hypothesize that the strength of these correlations may differ between the trap sites during moderate-high discharge events because of floodplain confinement, discharge dynamics, and channel morphologies. Compared to the channel morphology upstream of the Skykomish trap site (plane-bed & pool-riffle), the Snoqualmie River directly upstream of the trap site is characterized with more of a dune-ripple morphology with fewer soughs, braided segments, and gravel bars. At moderate-high discharge levels, these areas and channel features potentially act as refuge from displacement velocities. This may result in the Snoqualmie River displacing more juvenile salmon at moderate-high discharge levels relative to the Skykomish, resulting in a stronger discharge-migration relationship. During moderate-higher discharge events, it may be possible that the Skykomish provides floodplain and edge refuge habitat for juveniles resulting in a weaker migration-discharge correlation. However, we have minimal edge and floodplain habitat utilization information in both of these rivers to verify this hypothesis.

The river profile at the Snoqualmie trap site (other than the 2001 pilot season) is generally more incised in dimensions than the Skykomish, which is relatively wider with a sloped bed profile. Subsequently, the strength of the observed migration-discharge correlations in the Snoqualmie may be due to a minimal decrease in trap efficiency during high discharge events. If we assume that increased discharge (across moderate-high events) in the Skykomish results in greater horizontal vs. vertical channel fill, compared to Snoqualmie (likely characterized by greater vertical vs. horizontal channel fill), then we may infer that a trap on the Skykomish samples an increasingly smaller proportion of the thalweg at higher discharge events. Assuming that most juvenile displacement occurs in the thalweg, this conceptual understanding could explain why we observed a stronger discharge-migration relationship in the Snoqualmie (due to minimal change in trap efficiency) or could justify a weaker discharge-migration relationship in the Skykomish (due to decreased efficiency at moderate-high events).

Coho

The out-migration timing for wild yearling Coho was much more condensed than that of Chinook and displayed less variation in timing and magnitude. We observed a primary peak in yearling Coho CPUE around late April through May in both the Skykomish and Snoqualmie Rivers. Additionally, percent cumulative catch indicated that most of the migration occurred during a shorter period of time compared to sub-yearling Chinook. These patterns in yearling Coho migration timing and CPUE were relatively similar to trapping observations on the Skagit (April-May) (Kinsel et al., 2008), Nooksack (April-June) (Dolphin, 2011), Green (April-May) (refer to Green River references), and the Cedar Rivers (April-May) (refer to Cedar River references). Similar to Chinook, average CPUE of yearling Coho was considerably higher at the Skykomish trap site (5.03 fish/hour) compared to the Snoqualmie (1.46 fish/hour). As mentioned in previous sections, the Skykomish trap site was moved from RM 23 (2000-2007) to 26.5 (2008-2012), which placed it above the Woods Creek tributary. Woods Creek has been shown to support moderate usage by Coho and relatively minimal usage by Chinook (Snohomish Basin Salmonid Recovery Technical Committee, 2005). These generalizations are well supported by our trapping results which showed a negligible change in average sub-yearling Chinook CPUE but a 3x decrease in Coho CPUE from the prior (6.73 fish/hour) to latter (2.16 fish/hour) sample site. Efficiency test were not significantly different between the trap sites, which support the observed differences in catch rates as well as the relative contribution of Woods Creek.

Coho catch rates were considerably higher during periods of darkness at both trap sites, which is consistent with the literature (Groot and Margolis, 1991). However, unlike sub-yearling Chinook, the average day-night ratio was not considerably different between the Skykomish (0.22) than the Snoqualmie (0.23). This similarity in diel signal across both traps may suggest that differences in turbidity may have a negligible influence on juvenile Coho out-migration or that additional factors are potential driving our observations. For example, it may be possible that these Coho results are a function of age rather than turbidity. Since yearling Coho have spent a year in riverine systems, this Cohort has experienced predatory pressures longer than sub-yearling Chinook have. Our observations may be showing the filtered results of a year of selective predatory pressure on behavioral differences across diel strata. Our results support this hypothesis in that day-night ratios between rivers were not only similar in value but also relatively low (indicating a strong nocturnal signal). Another possible explanation may be that avian predation (primarily visually based) is highest on juvenile fish in this particular size class, which would increase nocturnal migration. Aside from exogenous factors, it may also be plausible that these patterns in diel migration are displaying differences in genetic and epigenetic signals between Chinook and Coho.

Similar to Chinook and likely all juvenile salmonid migrants, discharge has been shown to be a significant factor influencing Coho migration (Groot and Margolis, 1991). Six years on the Skykomish (2001, 2005, 2006, 2009, 2010, and 2012) and 4 years on the Snoqualmie (2001, 2006, 2009, and 2012) displayed a positive discharge-migration relationship for yearling Coho. While several years on both rivers showed a correlation between discharge and CPUE, the number of years showing a positive correlated is somewhat opposite of sub-yearling Chinook results. These patterns may be due to a multitude of reasons including minimal floodplain usage during yearling Coho migration or a relative higher percentage of thalweg migration compared to sub-yearling Chinook (producing tighter discharge-catch relationships). While the same discharge dynamics and channel morphologies that influence sub-yearling Chinook migration are concurrently influencing yearling Coho migration, it is possible that differences in behavior, size, and timing results in different correlation strengths. While we did observe a relative correlation between discharge and yearling Coho migration, our efficiency-discharge observations from both the Skykomish and Snoqualmie were not significantly correlated. Since we would expect to see a discharge-efficiency relationship, it is unclear why our observation showed no trend.

Fork Lengths

Chinook

The median fork length of sub-yearling Chinook increased at a fairly steady rate from early May though the end of June in both the Skykomish (~40 mm to ~90 mm) and Snoqualmie (~40 to ~70 mm) rivers. These results were relatively similar to observed sub-yearling Chinook fork length relationships in the Stillaguamish, Skagit, Nooksack, Green, and Cedar Rivers (refer to river references). We interpret such increasing trends in fork length as indications of growth during river residence. The observed monthly fork length frequency distributions across the Skykomish and Snoqualmie potentially indicate multiple sub-yearling Chinook life-history patterns including variation in timing of emergence, life history strategies, distance of natal redds, and sub-yearling residence times in stream edge habitats. The persistent presence of small Chinook (~40 mm) late into the sample seasons suggests that Chinook display an extended period of emergence. Additionally, during the latter parts of the sample seasons (May-June) there appeared to be a wide spread and often bimodal size distribution of sub-yearling Chinook, which we hypothesize, is indicative of the presence of different life history strategies. More precisely, these patterns likely represent a continuum of life history strategies for ocean-type Chinook. Our observations suggest that some Chinook migrate past the trap almost immediately after emerging from the gravel while other individuals spend some amount of time rearing in the river before leaving as larger sub-yearlings. It is not clear whether these differences in size are a result of the location of the natal redds in the watershed (i.e. larger fish coming from higher in the watershed have farther to travel and thus a longer time to grow before they reach the trap), if they are representative of different strategies being employed by fish hatching in the same area, or if a subset of sub-yearling Chinook are able to evade channel flows and utilize edge habitat increasing their rearing time, growth, and subsequent fork length at time of capture.

Coho

Median fork lengths for yearling Coho slightly increased during early April in both the Skykomish and Snoqualmie from ~75 mm to ~100 mm and remained fairly constant (~100 mm) through the end of sampling. These results were relatively similar to observed yearling Coho fork length relationships in the Green, Cedar, and Nooksack Rivers (refer to river references). The slight increase in fork length could potentially indicate growth accrued during migration from rearing locations to the trap (i.e. variation in rearing distance upstream). The minimal change in fork length across a given sample season may indicate a relative uniform cohort of out-migrating yearling Coho. It is possible that larger, more-fit individuals migrate earlier while the process is delayed in smaller fish as they attempt to gain body condition before making the transition to salt water. Additionally, spending a year in off-channel and edge habitats before migration may have resulted in relatively comparable selection pressures and growth conditions. The consistent fork lengths between the Skykomish and Snoqualmie may further support these suggestion as well as potentially similar genetic patterns.

Efficiency and Fork Length

We hypothesize that variation in trap efficiency is likely influenced by the size of the emigrating juveniles. It may be possible that efficiency increases with fish size (until a given threshold) if smaller fish are either more hesitant to migrate or if mortality is higher due to predation and/or handling. Additionally, efficiency may decrease after a given threshold with increasing fork length if larger fish are able to avoid the trap. Therefore, it is important to consider efficiency-size correlations when looking at a range of species size-classes that are trapped. As we collect more data in future years of this project, it will be important to continue evaluating trap efficiency with regard to discharge and fork lengths (e.g. consider differences in the size of fish caught compared to those released during efficiency tests). Until we are able to better explain the variables affecting instantaneous trap efficiency, this project will continue to use pooled efficiency estimates in our production calculations.

Out-Migration Production Estimates

As discussed in the Skykomish and Snoqualmie *Efficiency Results* sections, we used composite trap efficiency values for both sub-yearling Chinook and yearling Coho to calculate production because of high variation in our ability to describe specific relationships between variables such as discharge, fish size, diel strata, and instantaneous trap efficiency. As we strive to implement release groups closer to ~2000 fish in following years for both sub-yearling Chinook and yearling Coho, as suggested by the WDFW and the NWIFC, we hope to gain a better understanding of the trap efficiency with respect to these parameters. Subsequently, the production estimates calculated in this report may be adjusted in the future. As mentioned in *Production* methods section, our production estimates may slightly underestimate overall production, due to population contribution downstream of the traps.

Chinook

Sub-yearling Chinook production estimates from brood years 2000-2011 in the Skykomish were somewhat cyclic ranging from 146,278 to 857,124. Production estimates in the Snoqualmie generally displayed a declining trend from brood year 2002 (257,262) to 2011(40,633). Despite differences in magnitude and periodicity, cyclic patterns in sub-yearling Chinook production estimates have also been reported in the Stillaguamish, Nooksack, Skagit, and Green Rivers (refer to river references). Additionally, relative declining trends in production estimates were reported from the Stillaguamish and Green Rivers (refer to river references). Generally, production values were considerably higher in the Skykomish than the Snoqualmie which align with our observed CPUE values as well as escapement estimates from WDFW.

Yearling Chinook production estimates in the Skykomish displayed an increasing trend from brood year 2000-2004 and a declining trend from brood year 2007-2010. Yearling Chinook production estimates in the Snoqualmie were highly variable and displayed a general increasing trend until brood year 2010, where production was very low. In the Skykomish, the proportion of Chinook production attributed to the yearling cohort was consistency low (range: 2-19%; average: 7%) (Figure 31). However, compared to the Skykomish, the Snoqualmie appears to have a greater proportion of production attributed to the yearling cohort (range: 3-46%; average: 21%) (Figure 32). Specifically, in migration years 2009 and 2011 the yearling cohort contributed to more than 45% of production. These contributions not only emphasize the need to integrate the yearling cohort in Chinook production estimates, but suggest that the proportion of yearling contribution is more pronounced in the Snoqualmie River drainage.

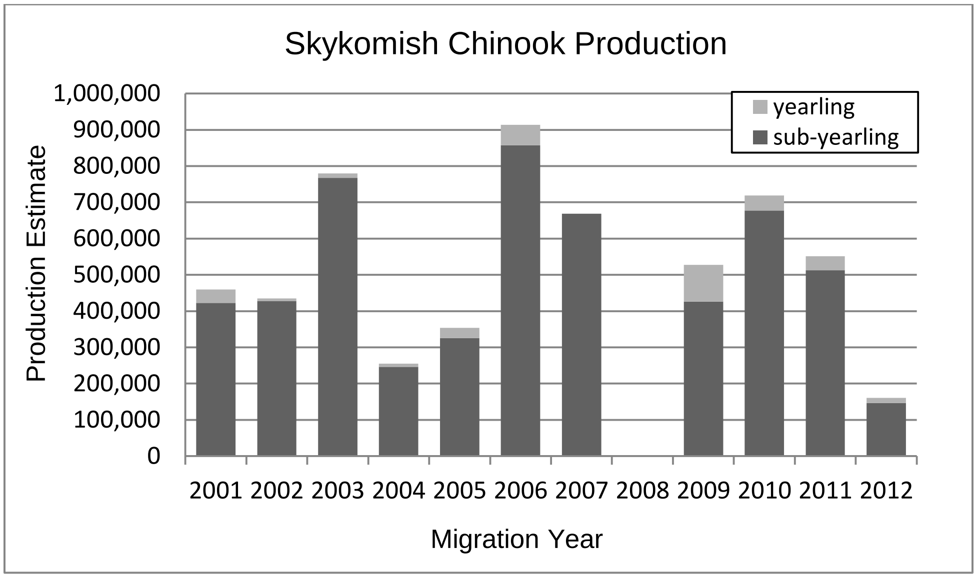


Figure 31: Skykomish sub-yearling and yearling Chinook production estimates for migration years 2001-2012. Yearling Chinook production was not included in 2007 due to identification issues.

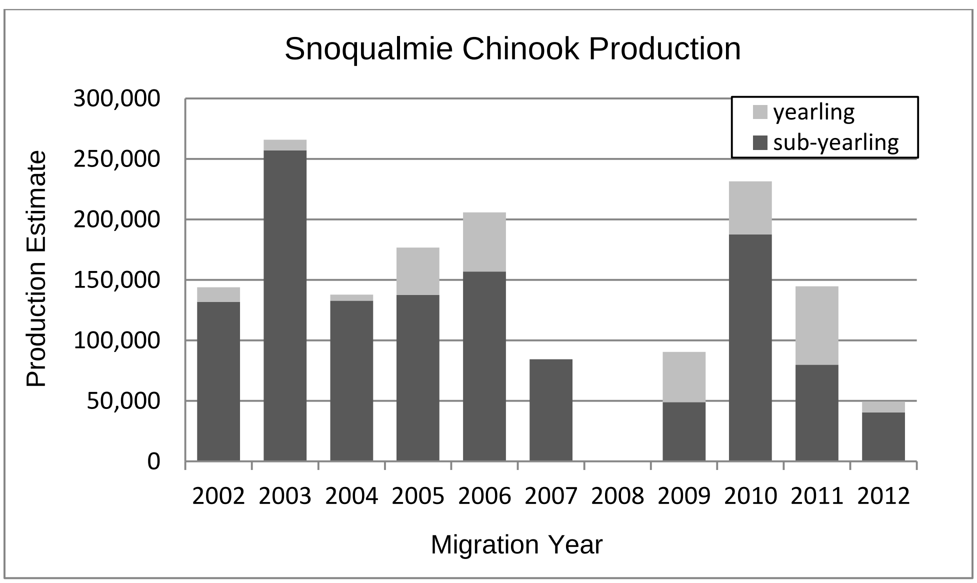


Figure 32: Ssnoqualmie sub-yearling and yearling Chinook production estimates for migration years 2001-2012. Yearling Chinook production was not included in 2007 due to identification issues.

Sub-yearling Chinook production estimates from brood year 2011 were the lowest across all sample years in both the Skykomish and Snoqualmie Rivers. These production estimates align with lower 2011 Chinook escapement; however, it is likely that several additional factors including trap efficiency and weekly CPUE influenced these results. As mentioned in the *Efficiency Results* sections, the number of sub-yearling Chinook released for efficiency tests was increased during the 2012 out-migrant season and resulted in a significant increase in trap efficiency compared to previous years. In our production estimate, as trap efficiency increases the amount of variation and bias correction decreases. Subsequently, with increased efficiency estimates, our overall production estimates significantly decrease. This relationship may have resulted in the relatively low 2011 sub-yearling Chinook production estimates. The number of sub-yearling Chinook released appeared to have a positive correlation with percent efficiency at the Skykomish and Snoqualmie trap sites (Figure 33 & Figure 34, respectively). Since trap efficiencies were considerably higher for both rivers in 2012, this may further suggest that efficiency does indeed increase with larger release numbers. Given this relationship and assuming that 2012 efficiency estimates provide the most accurate representation of trap efficiency, we can adjust past production estimates with 2012 efficiency values. Adjusting prior sample years resulted in a reduction in production estimates, and may have resulted in an overestimate of sub-yearling Chinook production between 4.1-63.7% in the Skykomish (Table 26) and 22.7- 79.2% in the Snoqualmie (Table 27). However, it may not be appropriate to assume that 2012 efficiency is representative across years. If we remove the 2012 sample season, the positive correlation between the number released and percent efficiency is no longer present (Skykomish : $R^2 = 0.02$, Snoqualmie: $R^2 = 0.12$). Assuming that 2012 efficiency may be an anomaly, we can adjust production estimates from brood year 2011 using the average efficiency from 2000-2011 trapping years. This adjustment results in an increase in production estimates in both the Skykomish (146,277 to 237,251) and Snoqualmie (40,633 to 60,486). These production values are still considerably lower than prior years, and only after subsequent years of release numbers similar to 2012 can we verify the correlation between efficiency and release number as well as determine if trap efficiency is closer to the 2012 estimate (~2.5%) or the 2000-2011 estimates (~1.3%).

It may also be possible that lower production estimates for brood year 2011 are attributed to CPUE in 2012 (Skykomish: 1.22, Snoqualmie: 0.42); which were considerably lower than average CPUE from 2000-2011 (Skykomish: 2.11, Snoqualmie: 0.72). In the 2012 season, the trap was not operated during statistical week 17 due to high discharge and debris conditions. This period appeared to fall right in the middle of peak sub-yearling Chinook migration (Appendix 2), which likely resulted in a significant underestimation of migration number and subsequent production estimate. Catch during this week was interpolated and included in the annual production estimation; however, it is possible that interpolation underestimated catch if there was a peak in migration during this period. To evaluate the potential influence of this event, we tried to estimate the CPUE during this period by using the average catch, hours fished, and possible weekly hours from all prior years during SW17. However, this should be interpreted with caution since it assumes consistent migration timing between years (which may not be the case). Adjusting these values for the 2012 sample season increased production estimates for brood year 2011 in both the Skykomish (146,277 to 173,088) and Snoqualmie (40,633 to 42,992), but these overall estimates are still considerably lower than prior years. In addition to these aforementioned factors, it is likely that egg-migrant survival and peak flow during incubation also influenced production estimates (discussed in the latter sections).

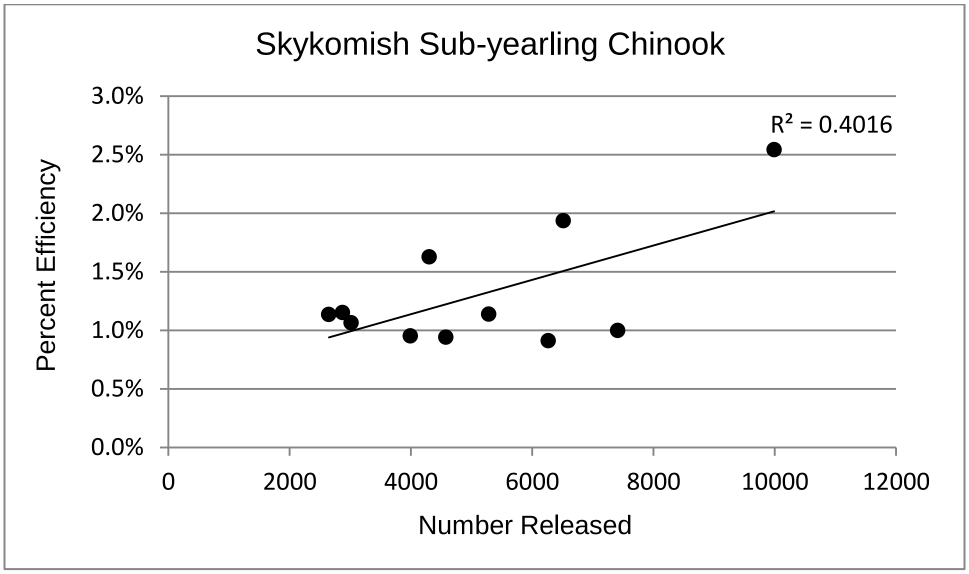


Figure 33: Percent trap efficiency plotted against the average release numbers of marked sub-yearling Chinook in the Skykomish for years 2001-2012.

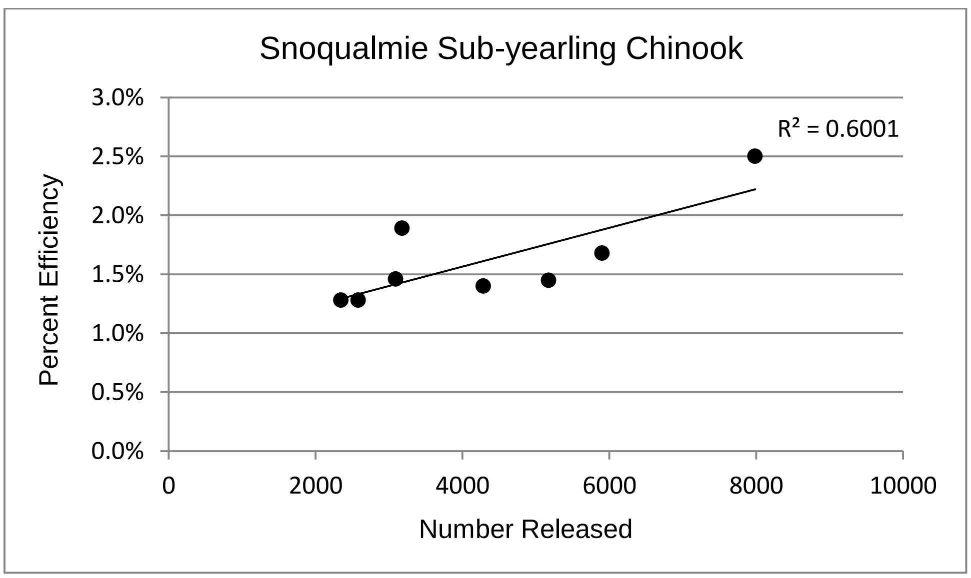


Figure 34: Percent trap efficiency plotted against the average release numbers of marked sub-yearling Chinook in the Snoqualmie for years 2004-2012.

Table 26: Adjusted production estimated for wild sub-yearling Chinook based on actual annual efficiency as well as 2012 efficiency in the Skykomish from migration years 2001-2012.

	Skykomish Production Estimates			
Year	Annual Efficiency	2012 Efficiency	% Overestimate	Average CPUE
2012	146278	146278		1.22
2011	512831	301999	41.1%	1.96
2010	677680	259027	61.8%	1.8
2009	426450	257051	39.7%	2.37
2007	668876	444547	33.5%	3.17
2006	857124	419369	51.1%	2.46
2005	325610	312419	4.1%	2.55
2004	246358	99279	59.7%	0.84
2003	766997	412897	46.2%	3.44
2002	427661	156828	63.3%	1.58
2001	422470	161279	61.8%	1.85

Table 27: Adjusted production estimated for wild sub-yearling Chinook based on actual annual efficiency as well as 2012 efficiency in the Snoqualmie from migration years 2002-2012.

	Snoqualmie Production Estimates			
Year	Annual Efficiency	2012 Efficiency	% Overestimate	Average CPUE
2012	40633	40633		0.42
2011	79968	48626	39.2%	0.40
2010	187508	39036	79.2%	0.31
2009	49134	37971	22.7%	0.37
2007	84350	53771	36.3%	0.21
2006	156918	96957	38.2%	0.83
2005	137546	89179	35.2%	0.72
2004	132805	83314	37.3%	0.82
2003	257262	165656	35.6%	1.37
2002	131775	97563	26.0%	0.79

Coho

Yearling Coho production estimates from brood years 1999-2010 in the Skykomish were relatively cyclic ranging from 338,628 to 2,244,428 displaying a declining trend over time. Production estimates in the Snoqualmie appeared to display a declining trend from brood year 2002 (1,164,543) to 2005(160,165) and an increasing trend from brood year 2007 (325,058) to 2010 (729,494). Generally, production values for yearling Coho were higher in the Skykomish than the Snoqualmie, which aligns with our observed CPUE values. Contrary to our observation, production estimates developed by WDFW (Zillges, 1977) suggest greater Coho production coming from the Snoqualmie compared to the Skykomish. It may be possible that our observations differ from the estimates developed by WDFW because of production occurring above sunset falls in the Skykomish drainage. The declining trend for yearling Coho production observed in the Skykomish is likely misleading due to the change in trap location. As previously mentioned, Coho production from Woods Creek was not captured after the trap was moved upstream, which likely resulted in underrepresentation compared to prior years. Adjusting these latter production estimates by the approximate differences in yearling Coho catch between the sites (average annual CPUE being ~3x greater downstream), results in a stable and possibly increasing trend in Coho production between brood years 2007-2010 (Figure 35).

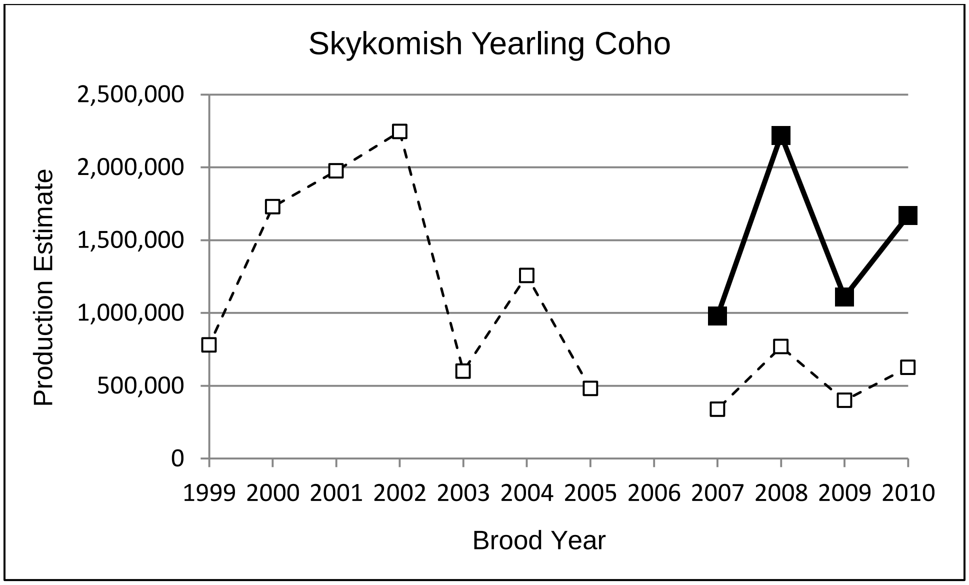


Figure 35: Adjusted production estimate trend for yearling Coho in the Skykomish River. Adjusted values are denoted by the solid line and filled symbols.

Freshwater Survival

Since the type of information on spawning activity above the trap sites varies between Chinook and Coho salmon, we had to employ quite different approaches to estimate riverine survival rates. Subsequently, we must consider the results for the two species in very different manners. There are several caveats built into our survival estimates including (but not limited to) potential false redds incorporated into the redd counts, missed redds in either the surveyed streams or un-surveyed streams, variation in fecundity across females, spawning occurring below the trap sites, and contribution of other size-year-classes to species survival. Additionally, our approach for estimating freshwater survival has the potential to bias significance with the number of spawners and redds, rather than the quality and availability of optimal spawning grounds, as discussed by Groot and Margolis (1999).

Chinook

For Chinook, we are able to calculate the percentage of eggs laid on spawning grounds that survive to emigration (egg to migrant survival). This metric is potentially useful because it allows for comparison of inter-annual freshwater survival rates within and among the Skykomish and Snoqualmie Rivers. Assessing survival rates may help to determine if and to what extent the freshwater life-history stage is limiting these Chinook populations. Additionally, these metrics allow for comparison to other Chinook bearing rivers in the Puget Sound region. We calculated Chinook egg-migrant survival rates for brood years 2000-2011 in the Skykomish and 2001-2011 in the Snoqualmie. Survival rates were considerably higher in the Skykomish (3.3-26.9%; average: 9.3%) compared to the Snoqualmie (1.8-12.6%; average: 4.6%), aside from 2003 and 2004, where survival rates were relatively similar between rivers. These estimated survival rates were comparable to the Skagit (3.9-13.5%), Stillaguamish (1.5-19.0%), and Cedar Rivers (5.2-19.2 %) (refer to footnote for river references). Brood years 2002, 2005, 2009, and 2010 on the Skykomish displayed considerably higher survival (10.3%, 15.1%, 26.9%, and 11.4%, respectively) compared to other brood years in Skykomish and all brood years in the Snoqualmie. Out of this subset of high survival years, only brood year 2002 had an escapement estimate above the average escapement from 2000-2011, and only fecundity in 2009 was above the standard deviation during these years. These results may indicate the influence of additional factors aside from escapement and fecundity.

Density-dependence in the Skykomish watershed may have potentially influenced survival due to limitations in the capacity of spawning and rearing habitats, both in quality and quantity (Snohomish Basin Salmonid Recovery Technical Committee, 2005). Egg to migrant survival in the Skykomish supports these potential habitat limitations showing a declining trend with increasing escapement (Figure 36). Even with relatively lower survival estimates, the Snoqualmie also showed a similar trend in decreasing survival with increasing escapement (Figure 37). Limitations in available spawning habitats may result in increased spawning in poor-quality sites as well as increased red superimposition, which are widely considered as major sources of density-dependent mortality (Quinn, 2005). Similarly, limitations in juvenile rearing habitat capacity may decrease egg to migrant survival by limiting conditioning prior to emigration as well as available refuge from flow and predation. These limitations in juvenile rearing habitat have been well documented in the Snohomish River Basin (Snohomish Basin Salmon Recovery Forum, 2005).

It is likely that the observed variation in survival is strongly influenced by exogenous factors including peak flows during incubation, large changes in discharge during spawning-incubation, predation, siltation, inadequate dissolved oxygen and aeration, temperature, and gravel quality. Peak flows have the potential to kill large numbers of deposited eggs either through suffocation from sediment deposition or by displacement from gravel scour (Healy 1991). It may be possible that low flows during spawning could magnify these effects by forcing Chinook to spawn deeper in the channel, increasing the vulnerability of eggs to high flows as well as density-dependent effects. These hypotheses are supported by results from the Skagit and Stillaguamish which have thoroughly documented a decrease in egg-migrant survival with increasing peak discharge during incubation (refer to river references). Similarly, results from the Skykomish and Snoqualmie support these correlations show a decreasing trend in survival with increasing peak discharge during incubation (Figure 38 & Figure 39). The strength of these discharge-survival correlations were greater in the Snoqualmie, compared to the Skykomish, which may indicate that peak discharge during incubation has a greater impact on Snoqualmie Chinook. Differences in the strength of these correlations in addition to varying ranges of egg to migrant survival and differences in density-dependent interactions, suggest that Chinook in the Skykomish may have different population dynamics than those in the Snoqualmie. The previously mentioned subset of Skykomish years which displayed considerably high survival also experienced relatively low peak discharge events during incubation. Additionally, brood year 2009 had the second lowest escapement estimate from 2000-2011 and yet the highest estimates egg-migrant survival. This high survival may be a result of low discharge during incubation as well as minimized density-dependent effects due to the low escapement. It should be noted that variability across sub-basins in the timing and magnitude of peak discharge during incubation may not be fully captured in these analyses due to differences in precipitation regimes and hydrologic responses between sub-basins.

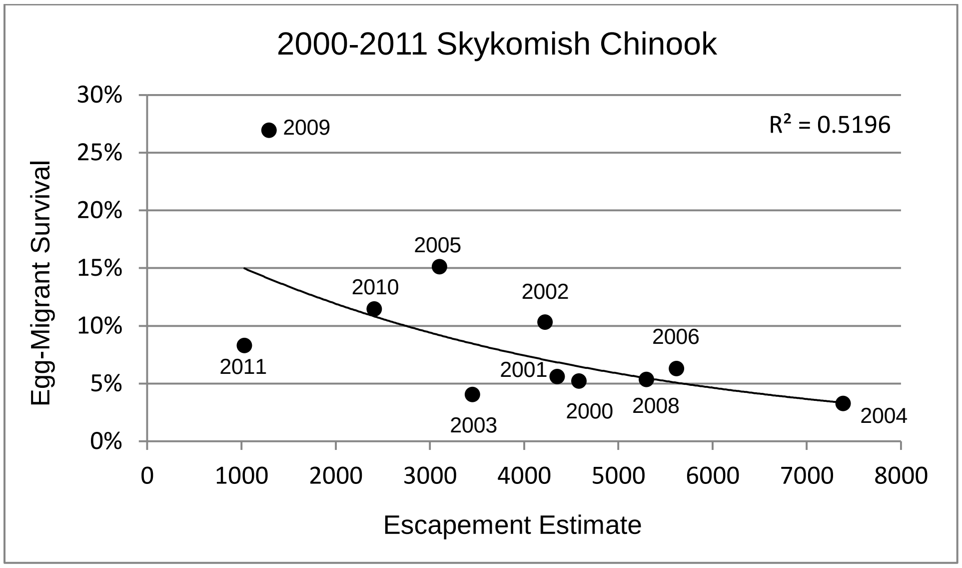


Figure 36: Egg-migrant survival for wild Chinook in the Skykomish River plotted against adult escapement estimates from brood year 2000-2011.

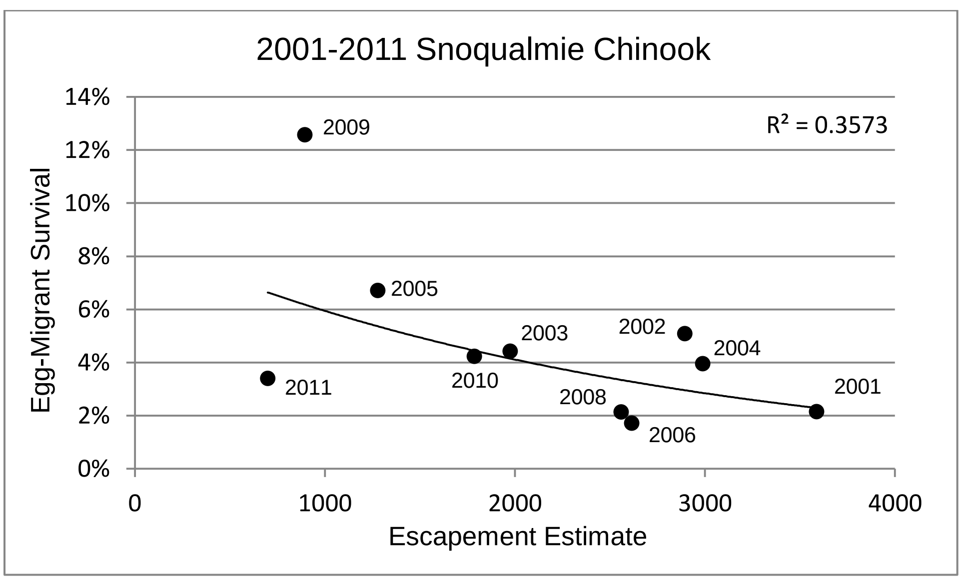


Figure 37: Egg-migrant survival for wild Chinook in the Snoqualmie River plotted against adult escapement estimates from brood year 2000-2011.

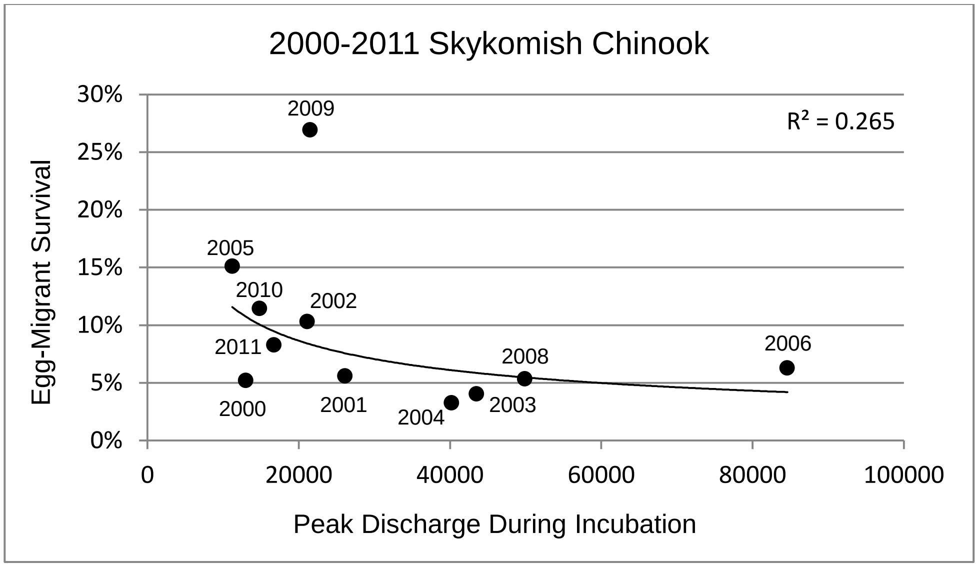


Figure 38: Egg-migrant survival plotted against peak discharge during incubation for sub-yearling Chinook in the Skykomish River from brood year 2000-2011. The incubation period was estimated using a 3-month period, which started 15 days before peak spawning (peak spawner/redd counts).

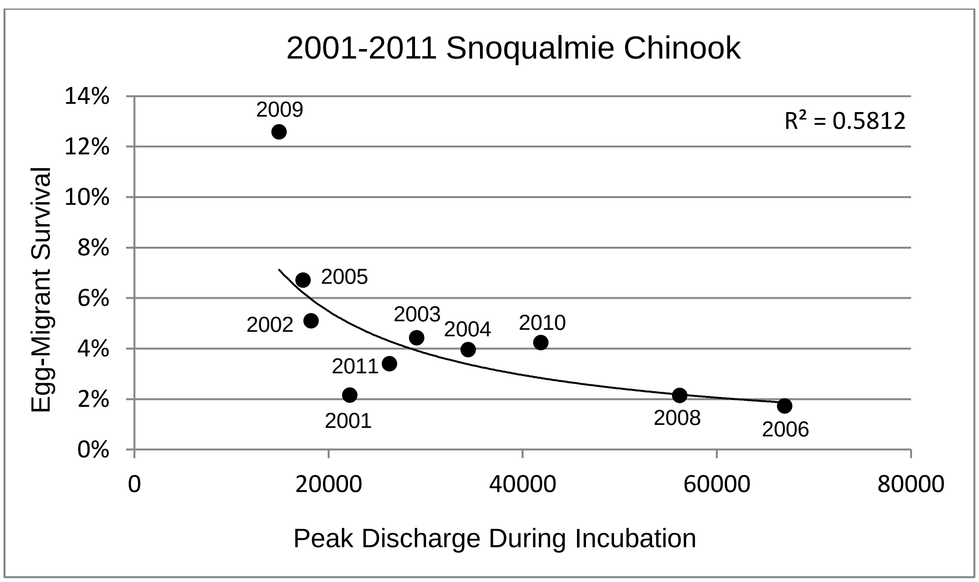


Figure 39: Egg-migrant survival plotted against peak discharge during incubation for sub-yearling Chinook in the Snoqualmie River from brood year 2001-2011. The incubation period was estimated using a 3-month period, which started 15 days before peak spawning (peak spawner/redd counts).

Coho

The spawner information available for Coho does not allow us to calculate individual survival for the Skykomish and Snoqualmie. Subsequently, we developed an index of survival across the Snohomish Basin allowing us to compare relative survival rates among brood years. This helped to identify which brood years were most successful and identify potential factors that contribute to increased or decreased survival for yearling Coho. All of the brood years which displayed high survival (2000, 2008, and 2010), were also characterized by escapement estimates well below the 2000-2010 average. Additionally, similar to trends observed for sub-yearling Chinook, yearling Coho survival appeared to decrease with higher estimated escapement indices (Figure 40). However, it should be noted that the slight increase in survival with larger escapement numbers may suggest that additional factors aside from escapement are influencing Coho survival. These results may indeed support potential density-dependent effects due to limited spawning and rearing habitats; however, the strength of these correlations should be interpreted with caution since escapement estimates only use index reaches and because Coho escapements are calculated with a basin-wide approach. It is likely that yearling Coho are influenced by similar exogenous factors that affect sub-yearling Chinook, but the relation, proportion, and significance of influential factors are likely different for each species due to variation in life-history strategies. For example, peak discharge during incubation seemed to be negatively correlated with survival for sub-yearling Chinook, but this discharge-survival relationship appears to be highly variable for yearling Coho (Figure 41). These species specific patterns may reflect different life-history strategies such as variation in the timing of adult spawning. If Chinook are spawning in the early fall, possibly before flows have significantly increased, they may be confined to limited spawning areas which may increase the risk of redds becoming disturbed by peak flows. On the other hand, if Coho are spawning more towards late fall and early winter, flows may have already increased enough to open additional spawning habitats and decrease the susceptibility of redds to high discharge events. Additionally, factors like predation and thermal stress prior to migration (e.g. summer rearing for Coho) are likely to influence each species uniquely due to differences in riverine residence time.

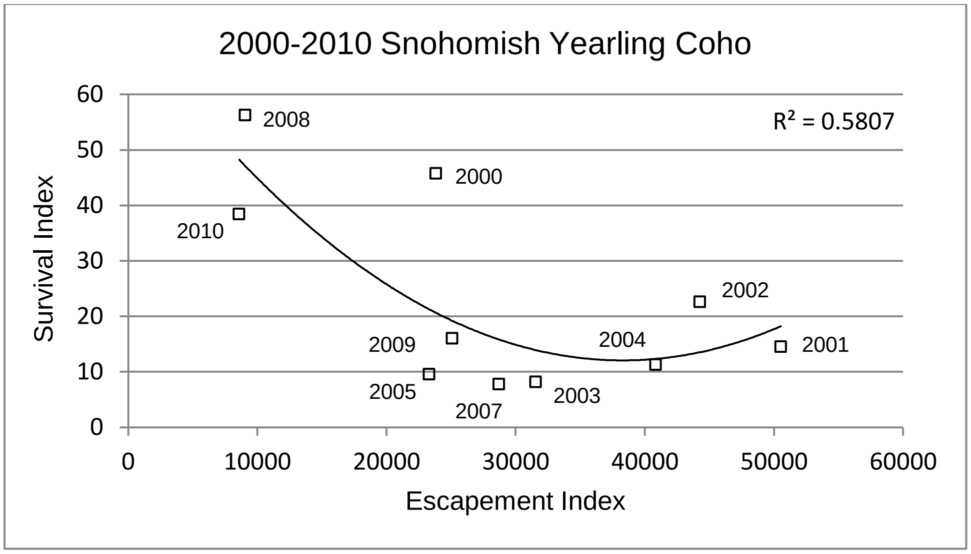


Figure 40: Survival indices for wild yearling Coho in the Snohomish River Basin plotted against adult escapement indices from brood year 2000-2010.

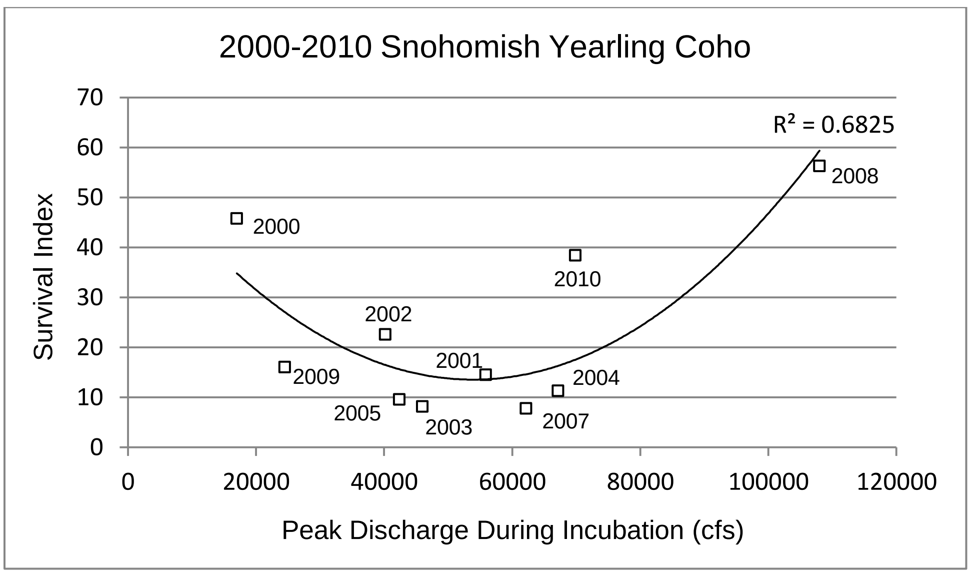


Figure 41: Estimated survival indices plotted against peak discharge during incubation for yearling Coho in the Snohomish Basin from brood year 2000-2010. The incubation period was estimated from December 1 to March 1 and flow was taken from the Snohomish River Station near Monroe, WA (gauge #12150800).

Chinook Production and Snohomish Basin Salmon Recovery

To help interpret our production estimates and assess production capacity in the Snohomish Basin, we decided to compare estimates from 2000-2011 with modeled estimates from the Ecosystem Diagnosis Treatment analysis (EDT). This comparison may help to determine the accuracy of modeling exercises such as EDT in estimating juvenile production capacities as well as evaluating the recovery implications of our results. In the Snohomish River

Basin, EDT was used to rate the quality, quantity, and diversity of habitats relative to Chinook salmon life-history needs (Snohomish Basin Salmonid Recovery Technical Committee, 2005). Additionally, this habitat life-history approach evaluated the potential performance of Chinook populations in current, properly functioning (as defined by NMFS), and historic habitat condition treatments. Included in this modeling exercise were estimations of juvenile migrant production and migrants per spawner for the Snohomish Basin. Subsequently, we compared our observed range of production estimates from the Skykomish (2000-2011) and Snoqualmie (2001-2011) to the migration estimates from each EDT habitat condition treatment. Since there is significant inter-annual variation in production estimates, we compared the EDT treatments with the average and relative range of our estimates.

Results from the juvenile migrant comparison indicated that our observed range of production estimates in the Skykomish and Snoqualmie were below those estimated across all EDT treatments (Figure 42). The upper boundary of the 2000-2011 juvenile migrant estimates in the Snoqualmie almost reached the estimate of EDT "current conditions"; however, the average was significantly lower. Results from the migrants per spawner comparison indicated that the Skykomish and Snoqualmie averages were below all EDT treatment estimates; however, the upper boundary of the 2000-2011 Skykomish estimates fell within the range of current, PFC, and PFC Plus EDT treatment conditions (Figure 43). Additionally, the upper bounds of the 2001-20011 Snoqualmie estimates fell within the range of the current EDT treatment condition (Figure 43). The results of these comparisons may indicate that our calculations of migrant production are underestimating current production in the Snohomish Basin, or that Chinook production during the last 12 years is actually lower than those estimated from EDT. Since a portion of juvenile migrant production occurred downstream of our traps and since we were not able to estimate yearling Chinook production, it is possible that our observed range of migrant production was underestimated compared to EDT (which assessed the entire Snohomish Basin). However, it is likely that these differences are minimal since we are able to monitor the majority of Chinook migration in the Snohomish Basin and since yearling Chinook catch was quite low. The results from the migrants per spawner comparison indicate that productivity is highly variable in the Skykomish, compared to the Snoqualmie, and that Chinook production capacity likely differs between the two river systems. These results, in addition to previously discussed differences in egg to migrant survival, survival-discharge correlations, and density-dependent interaction support differences between the Skykomish and Snoqualmie Chinook populations. If the ranges of our production estimates are indeed representative of Chinook production in the Skykomish and Snoqualmie, then some of the recovery needs in the Snohomish Basin (e.g. gains in rearing, floodplain, off-channel, and edge habitats) may actually be greater than predicted. As mentioned in the *Freshwater Survival* section, we observed a density-dependent effect which may be due to limitations in juvenile rearing habitats. These limitations are consistent with the Snohomish Basin Salmon Conservation Plan (Snohomish Basin Salmon Recovery Forum, 2005) and further emphasize the need to restore and protect rearing habitats. Additionally, if each river system is characterized with differential Chinook population dynamics (including survival rates and sensitivity to peak discharge), then it may be necessary to adjust recovery strategies within each river. These analyses emphasize the importance of considering variability in production and survival when assessing the status of Chinook populations, predicting how various habitat conditions will influence productivity, and evaluating salmon conservation and recovery strategies.

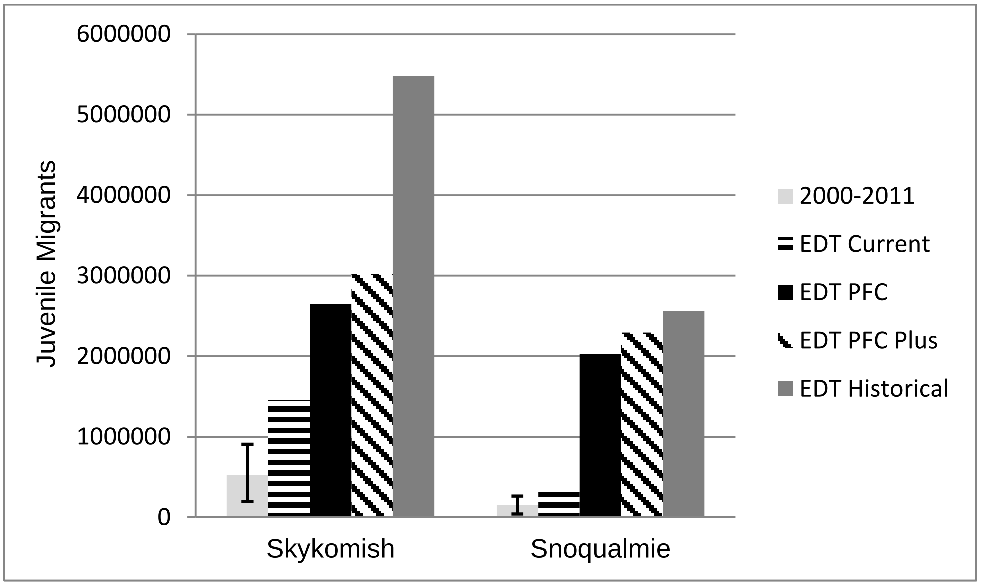


Figure 42: Estimated juvenile migrant production for wild Chinook in the Skykomish and Snoqualmie Rivers for 2000-2011 trapping and EDT treatment conditions (current, PFC, PFC Plus, and historical). Whiskers in the 2000-2011 estimates denote the maximum and minimum estimates. Properly function conditions (PFC) and PFC plus differed by their treatment of estuarine conditions. PFC assumed PFC conditions in freshwater and current conditions in the estuary whereas PFC plus used PFC conditions for freshwater and historic conditions for the estuary.

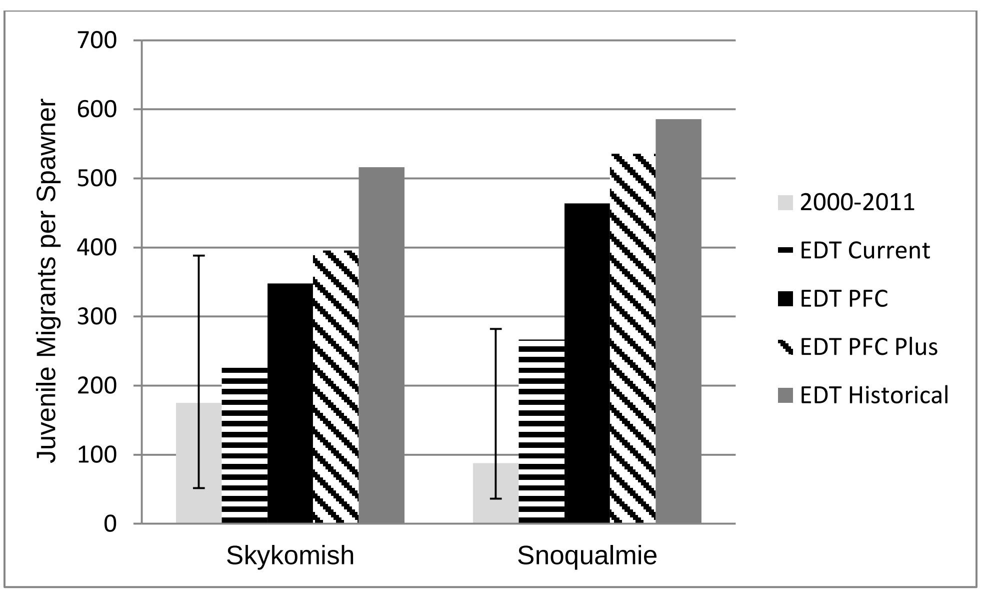


Figure 43: Estimated juvenile migrant per spawner for wild Chinook in the Skykomish and Snoqualmie Rivers for 2000-2011 trapping and EDT treatment conditions (current, PFC, PFC Plus, and historical). Whiskers in the 2000-2011 estimates denote the maximum and minimum estimates. Properly function conditions (PFC) and PFC plus differed by their treatment of estuarine conditions. PFC assumed PFC conditions in freshwater and current conditions in the estuary whereas PFC plus used PFC conditions for freshwater and historic conditions for the estuary.

RECOMMENDATIONS

This year was the 12th year of out-migrant trapping on the Skykomish River and 11th year on the Snoqualmie. Our experiences during these years prompt us to make the following recommendations for future sampling efforts.

1. Continue trapping the Skykomish and Snoqualmie River maintaining the same season duration and level of effort to better understand the inter-annual variation in migration size and timing.

2. Continue to investigate relationships between environmental variables such as discharge with juvenile Chinook and Coho salmon migration.

3. Continue to evaluate trap efficiency as it related to various environmental and biological variables.

4. Improve production estimates by accounting for variation in trap efficiency and migration due to certain environmental variables.

5. Improve Chinook production estimated by integrating the yearling cohort: either through the use of Coho efficiency as a surrogate or by running yearling Chinook efficiency test.

6. Begin evaluating production estimate for steelhead.

7. Begin to evaluate basin-wide production estimated through expansion and interpolation of unsampled drainages (e.g. production expansion based on available habitat or % spawners below traps).

8. Continue to evaluate freshwater survival estimates from multiple years and analyze variability with respect to environmental factors such as discharge during incubation.

9. Further develop the estimations of freshwater survival. Include a sensitivity analysis of freshwater indices.

10. Integrate out-migration patterns and survival estimates with monitoring efforts in the estuarine, nearshore, and marine ecosystems.

11. Provide an evaluation of data quality (QA/QC) to determine the range of error across data entry and analyses.

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Nooksack River: Conrad and Mackay, 2000; Dolphin, 2007a, 2007b, 2009, 2010, 2011.

Green River: Seiler et al., 2002b, 2004b, 2004c; Volkhardt et al., 2005a, 2005b, 2006c; Topping et al., 2008a, 2008b, 2009; Topping and Zimmerman, 2011, 2012.

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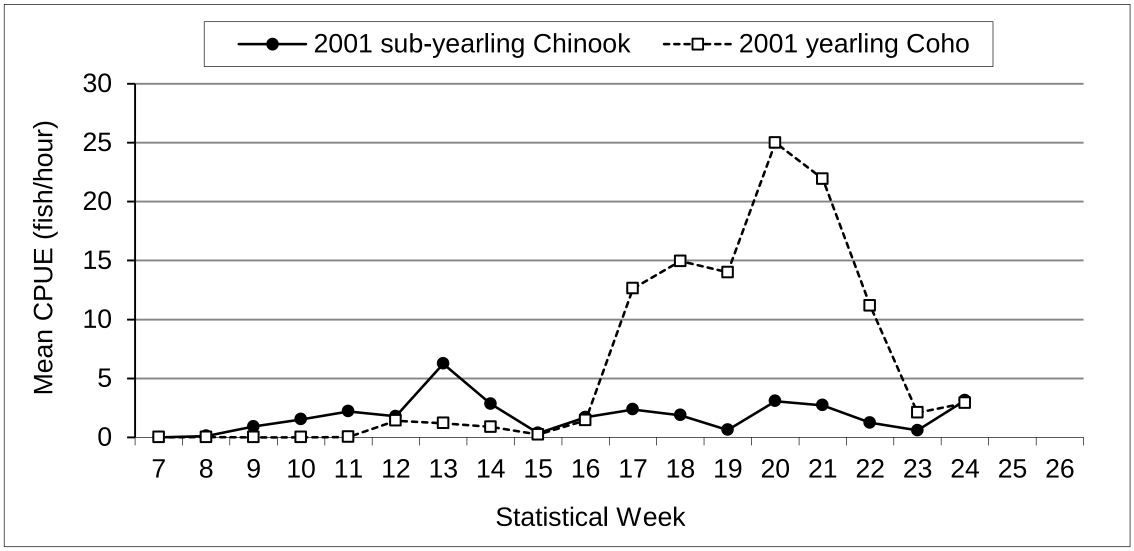
APPENDICES

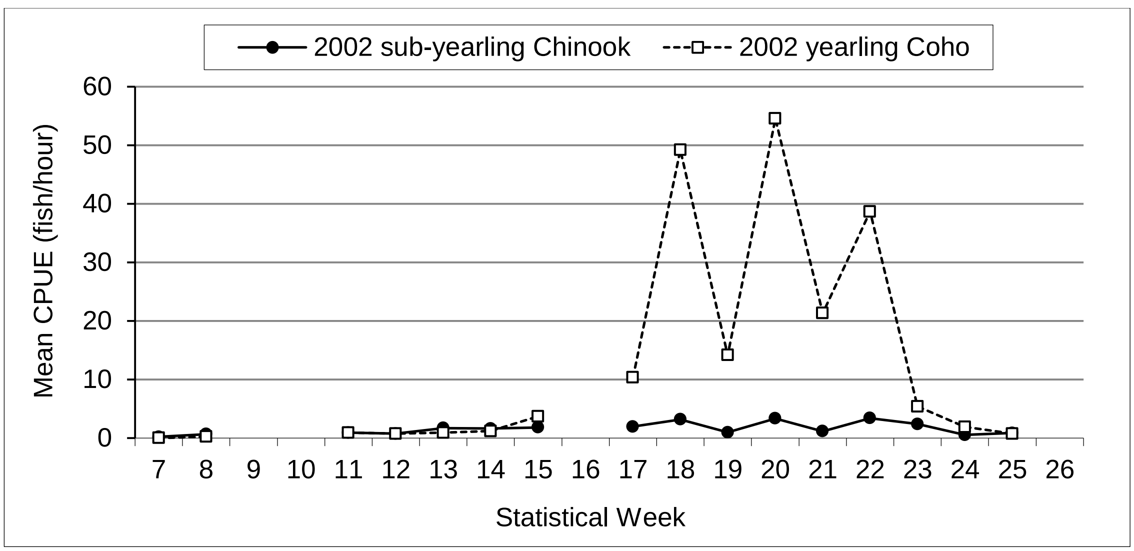
Raw data available upon request

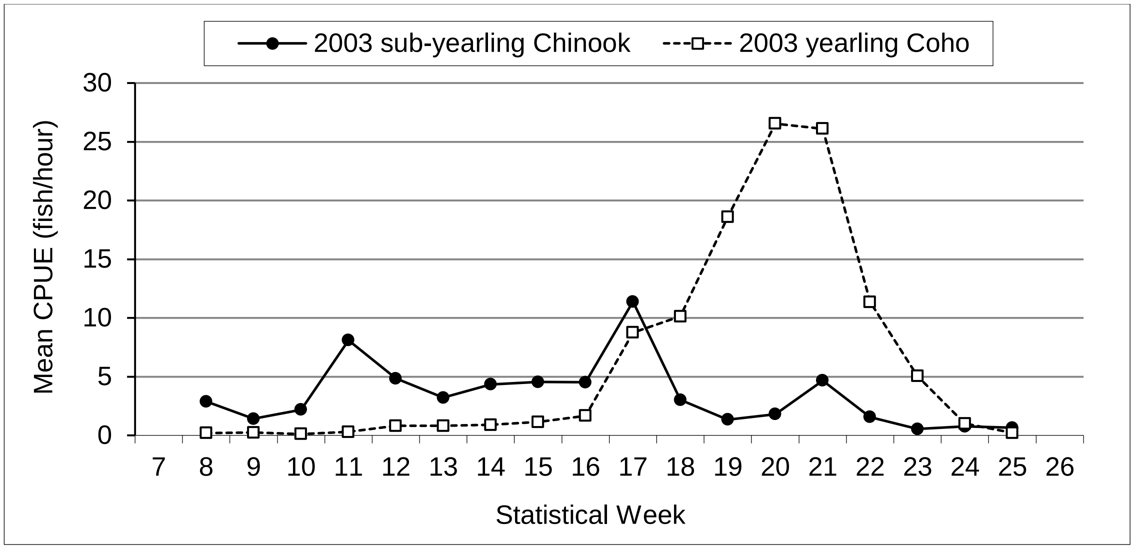
Appendix 1: Statistical weeks and approximate corresponding months.

Statistical Weeks	Corresponding Month
1 - 5	January
6 - 9	February
10 - 13	March
14 - 17	April
18 - 22	May
23 - 26	June
27 - 30	July

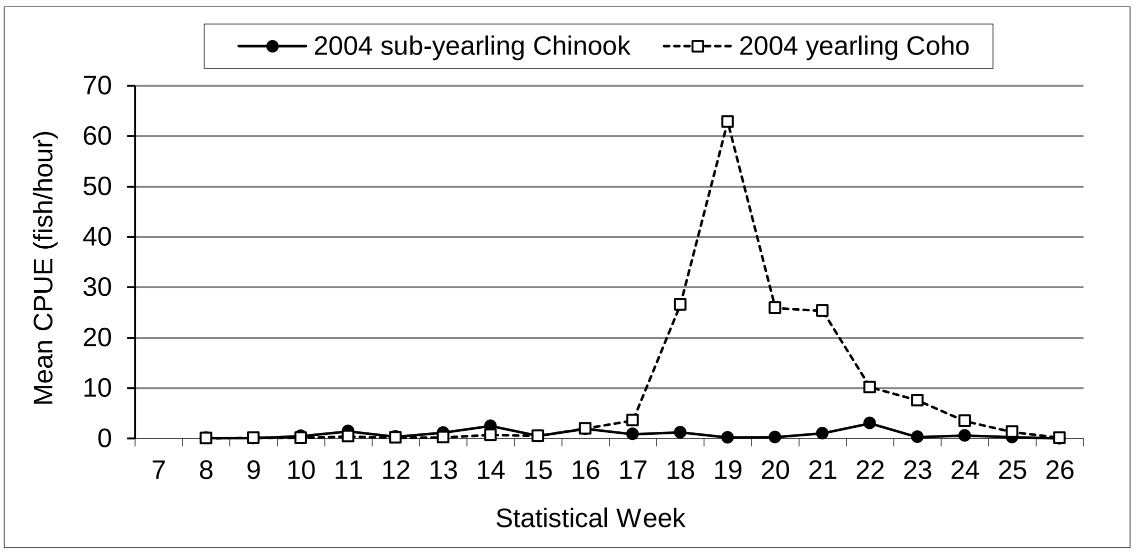
Appendix 2: Inter-annual catch per unit effort (CPUE) for wild sub-yearling Chinook and yearling Coho in the Skykomish River across 2001-2012 trapping seasons.



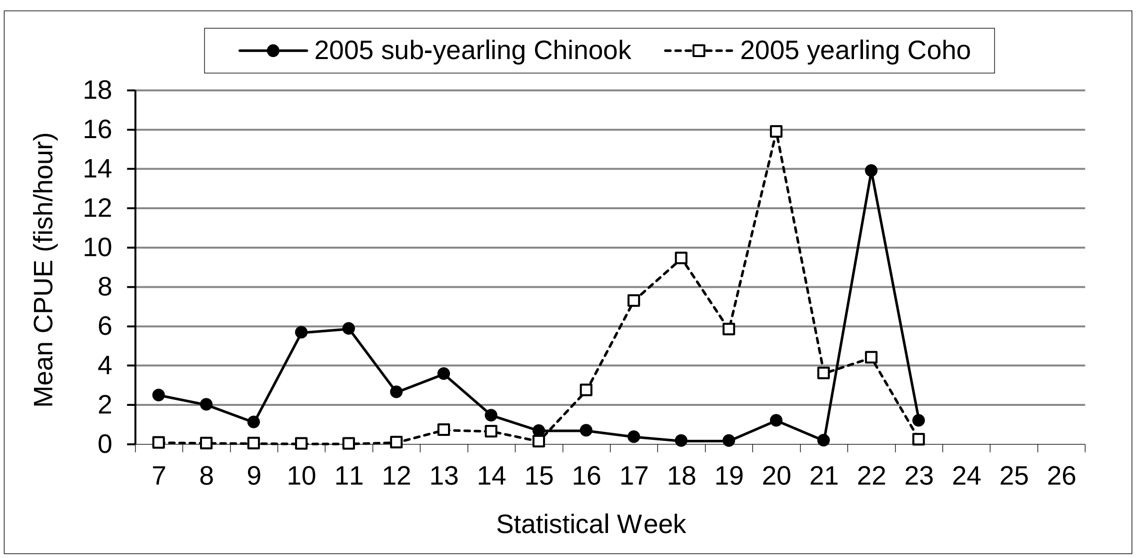




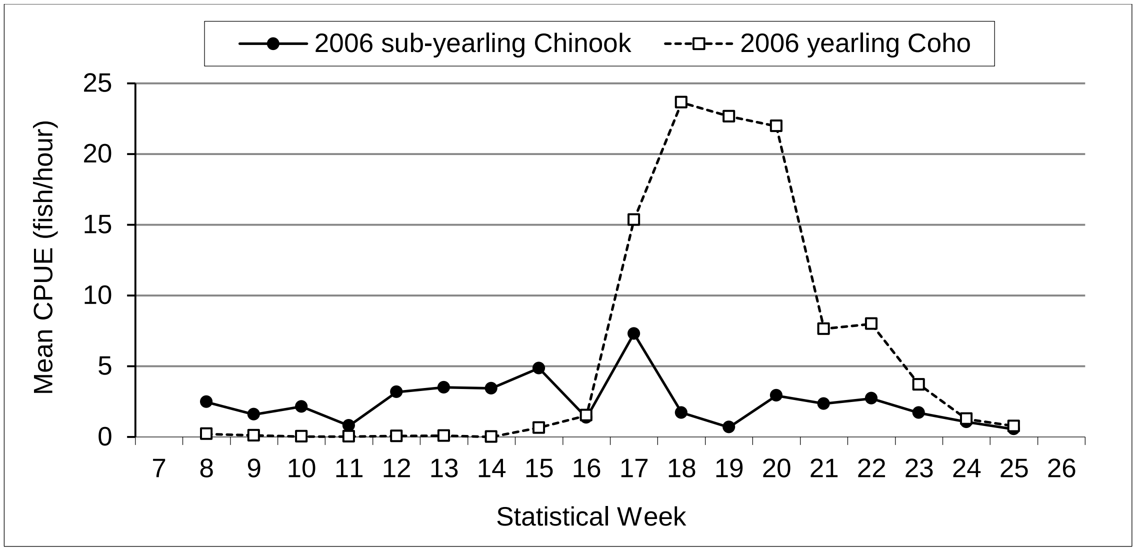
2003 sub-yearling Chinook
2003 yearling Coho
Mean CPUE (fish/hour)
30
25
20
15
10
5
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

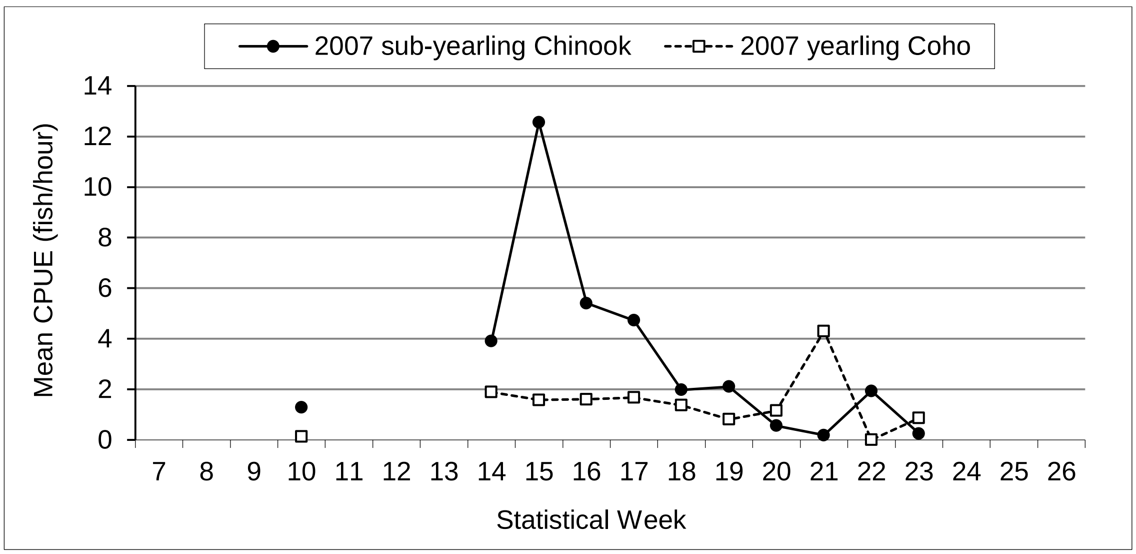


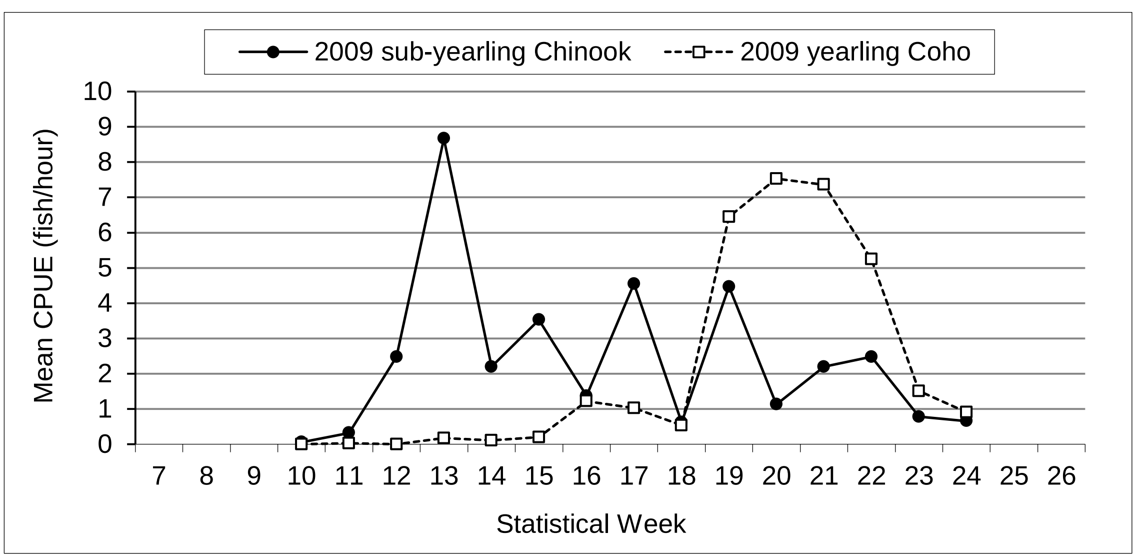
2004 sub-yearling Chinook
2004 yearling Coho
Mean CPUE (fish/hour)
70
60
50
40
30
20
10
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

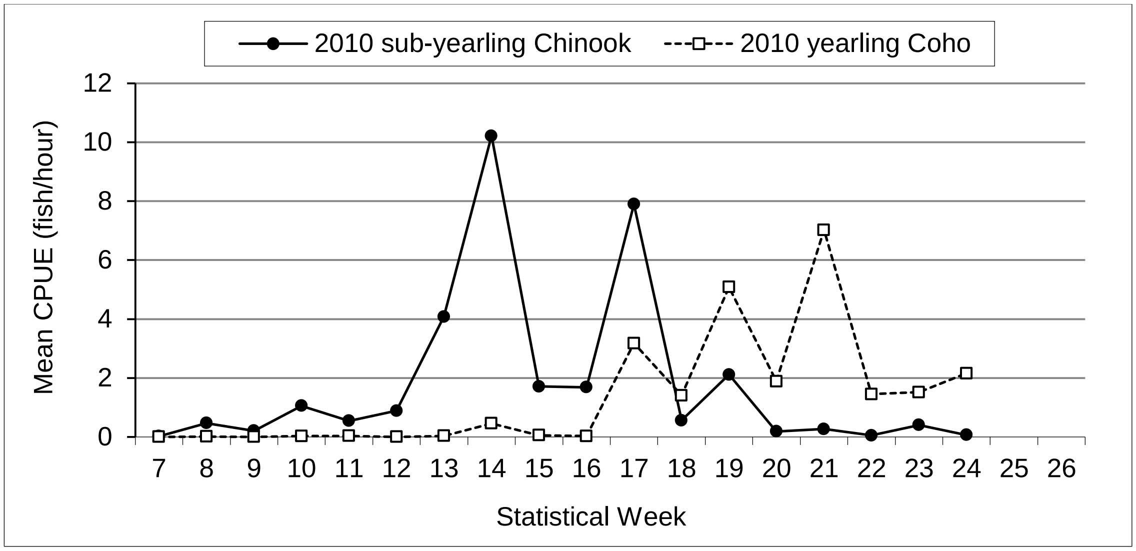


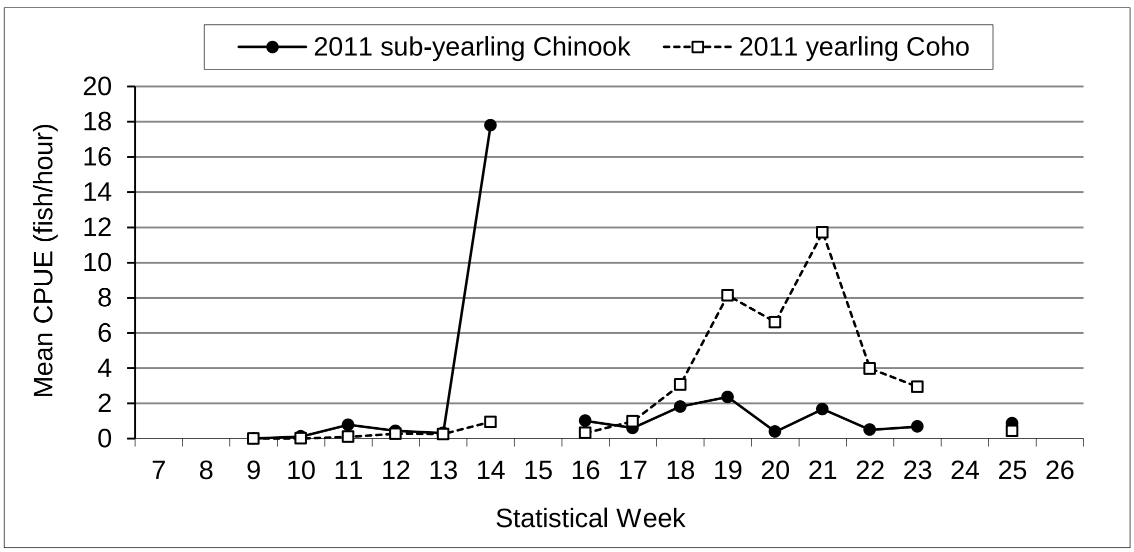
2005 sub-yearling Chinook
2005 yearling Coho
Mean CPUE (fish/hour)
18
16
14
12
10
8
6
4
2
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

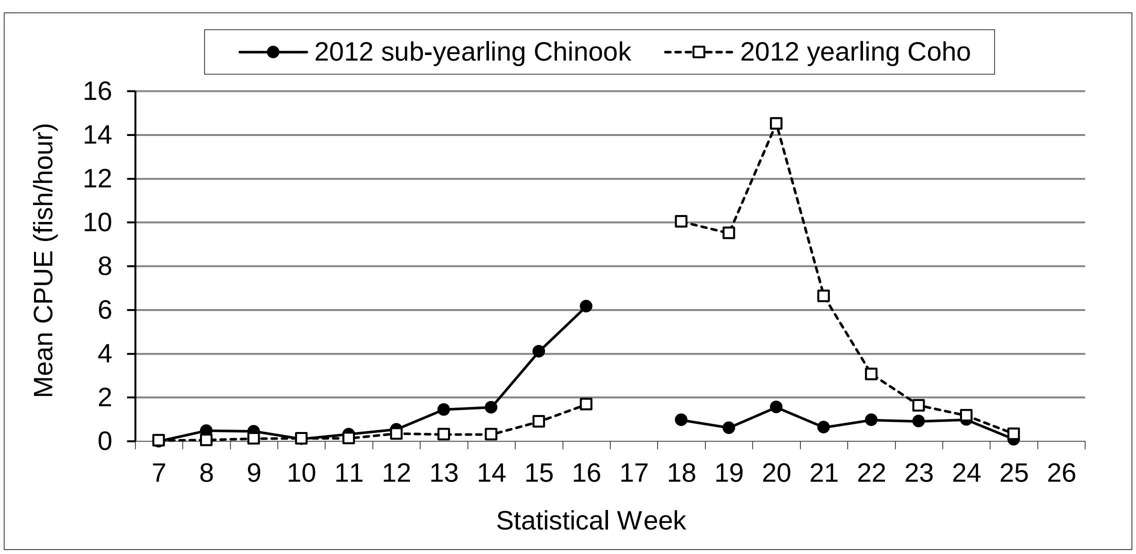

2006 sub-yearling Chinook
2006 yearling Coho
Mean CPUE (fish/hour)
0
5
10
15
20
25
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week


2007 sub-yearling Chinook
2007 yearling Coho
Mean CPUE (fish/hour)
0
2
4
6
8
10
12
14
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

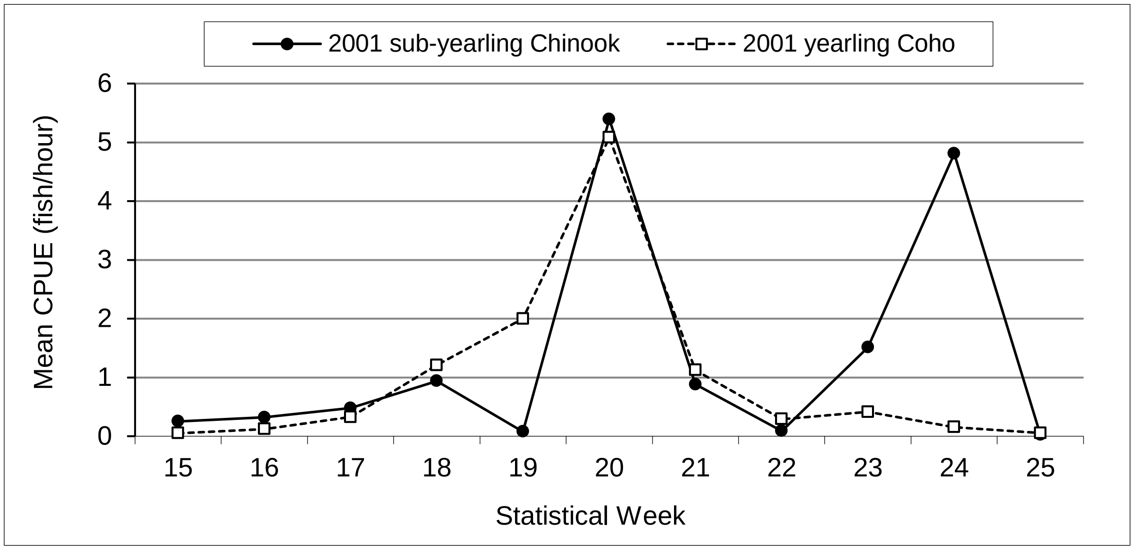

2009 sub-yearling Chinook
2009 yearling Coho
Mean CPUE (fish/hour)
0
1
2
3
4
5
6
7
8
9
10
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

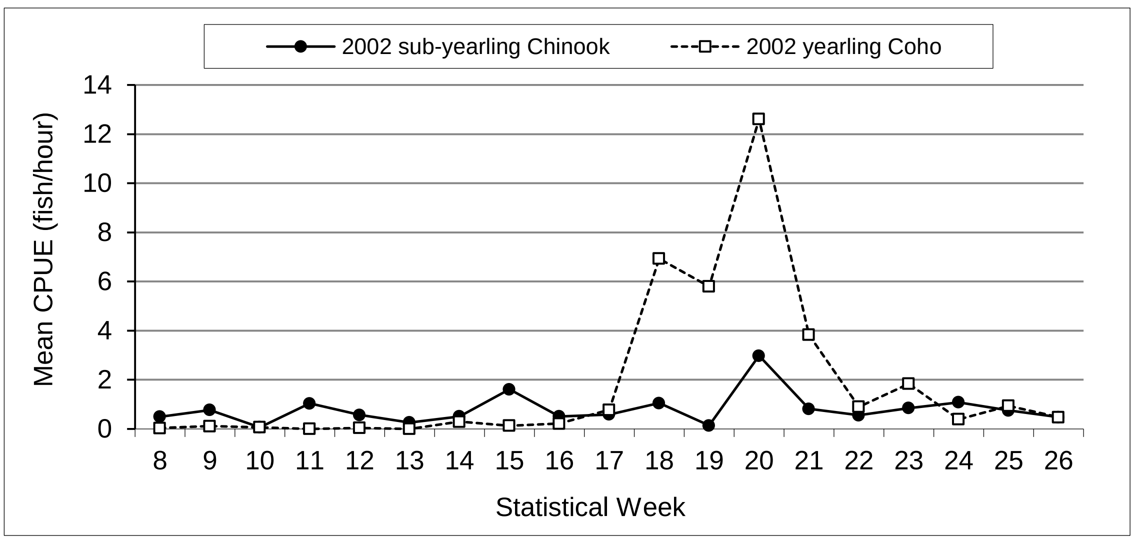

2010 sub-yearling Chinook
2010 yearling Coho
Mean CPUE (fish/hour)
0
2
4
6
8
10
12
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

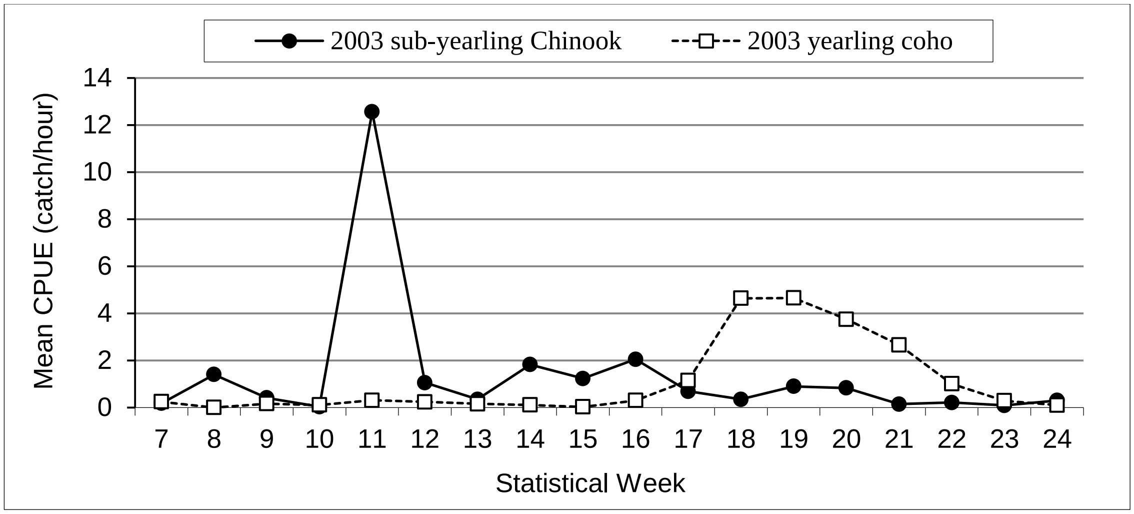

2011 sub-yearling Chinook
2011 yearling Coho
Mean CPUE (fish/hour)
0
2
4
6
8
10
12
14
16
18
20
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

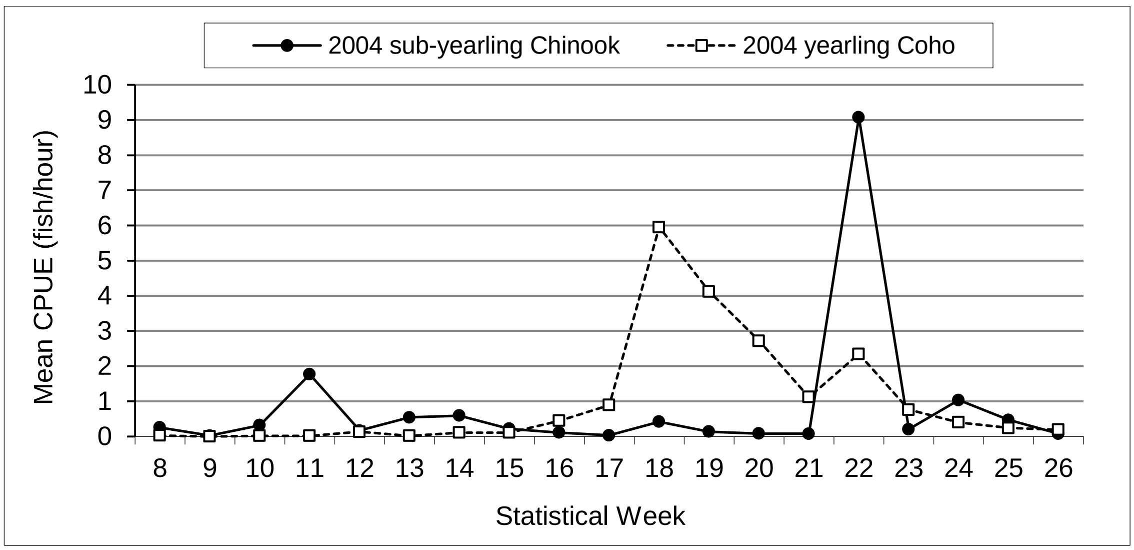

2012 sub-yearling Chinook
2012 yearling Coho
Mean CPUE (fish/hour)
0
2
4
6
8
10
12
14
16
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

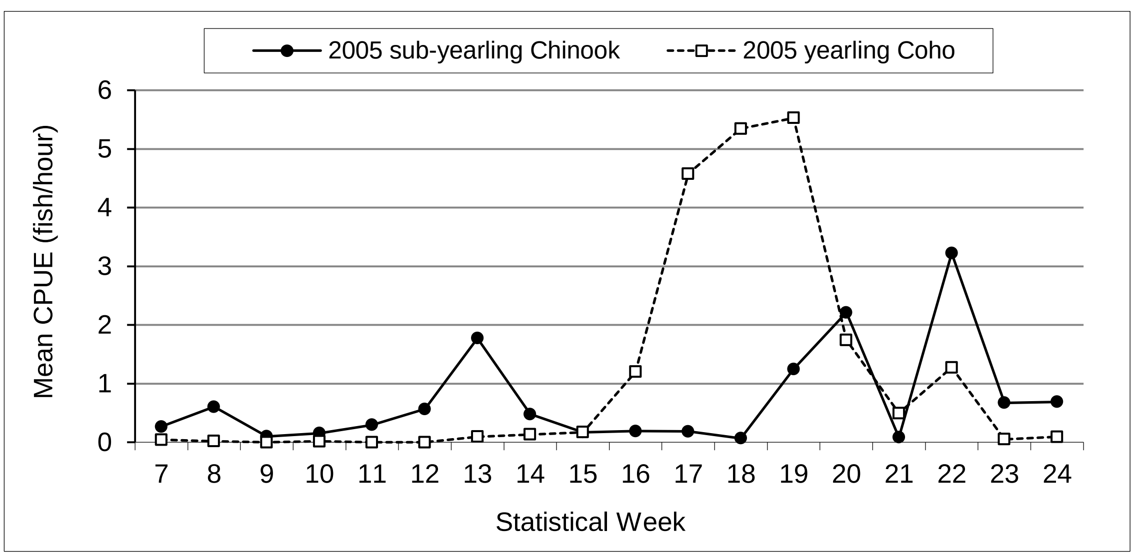
Appendix 3: Inter-annual CPUE Snoqualmie Inter-annual catch per unit effort (CPUE) for wild sub-yearling Chinook and yearling Coho in the Snoqualmie River across the 2001-2012 trapping seasons.

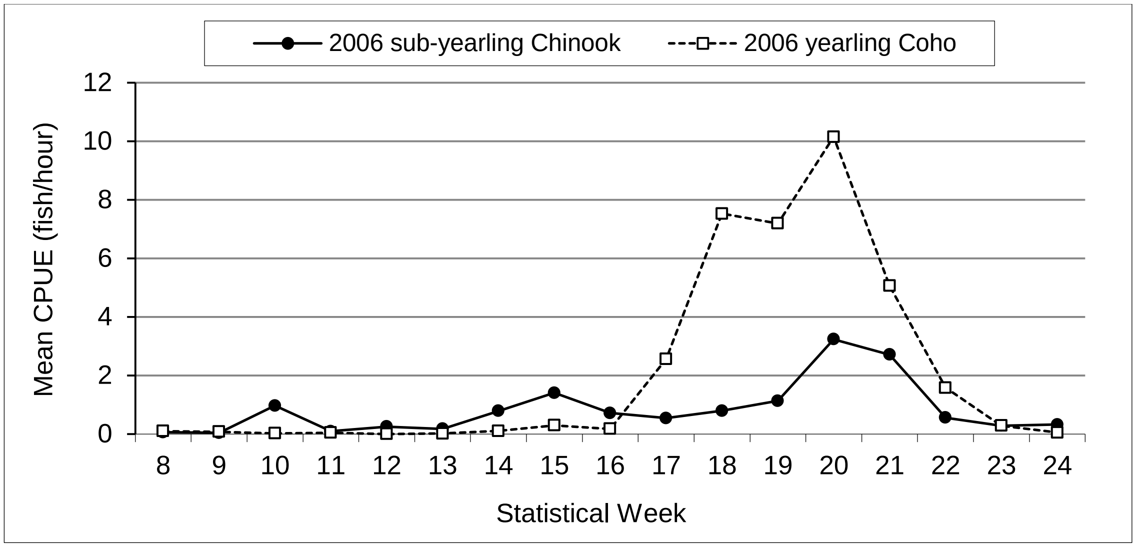


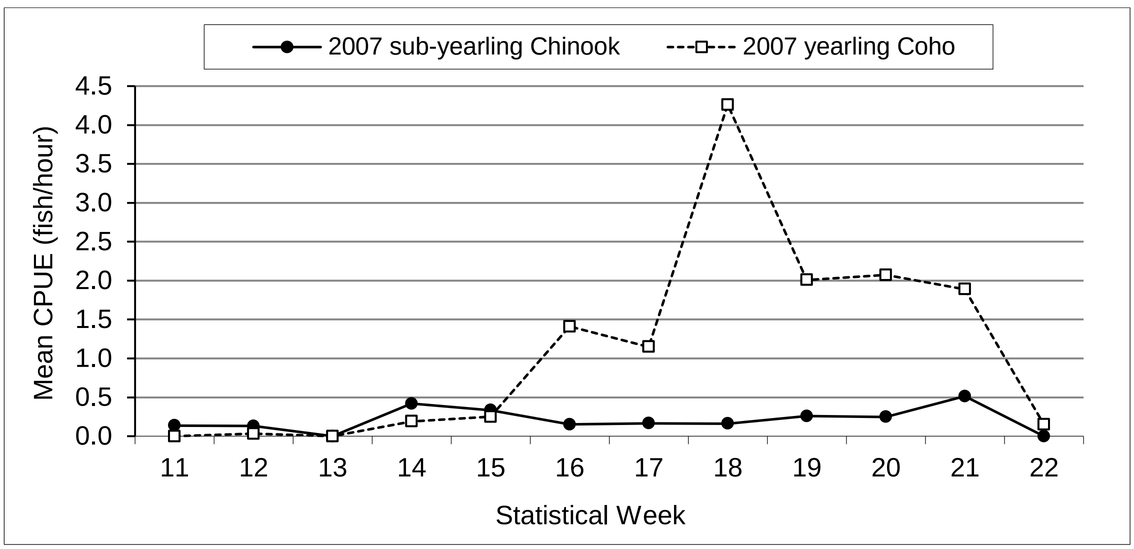


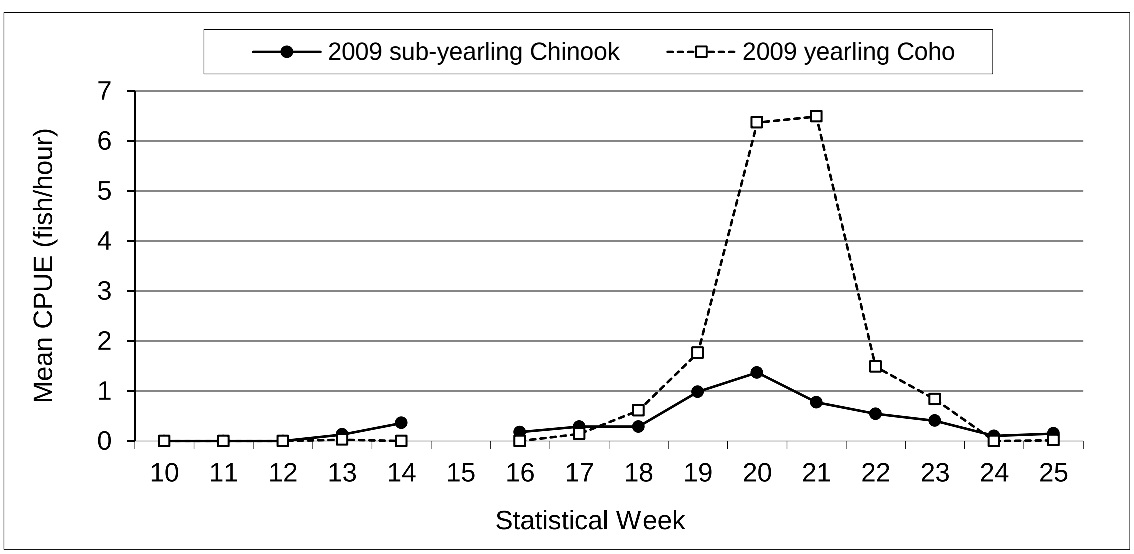

2003 sub-yearling Chinook
2003 yearling coho
Mean CPUE (catch/hour)
14
12
10
8
6
4
2
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Statistical Week

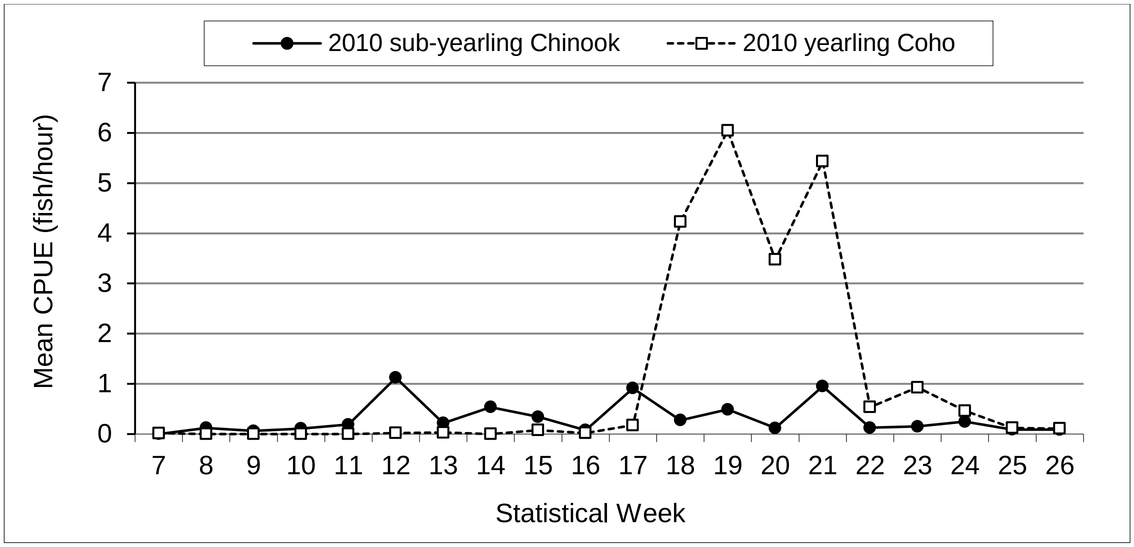

2004 sub-yearling Chinook
2004 yearling Coho
Mean CPUE (fish/hour)
10
9
8
7
6
5
4
3
2
1
0
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Statistical Week

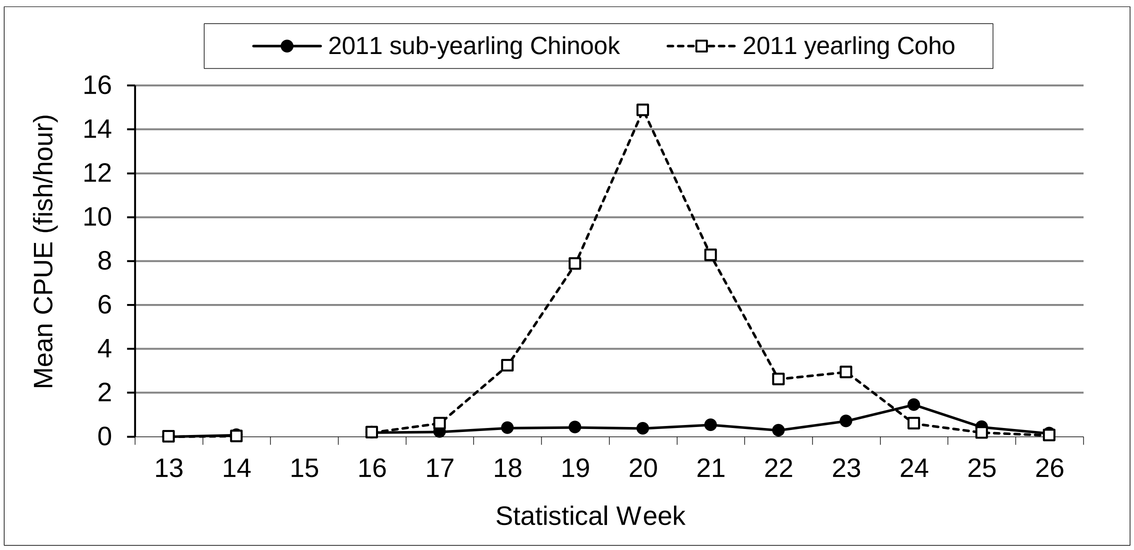

2005 sub-yearling Chinook
2005 yearling Coho
Mean CPUE (fish/hour)
6
5
4
3
2
1
0
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Statistical Week

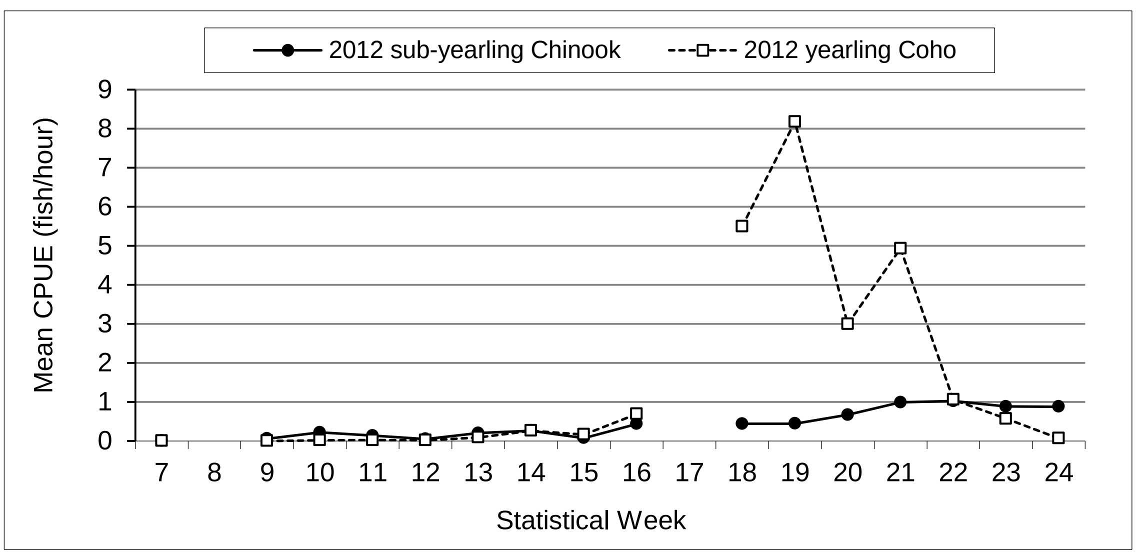

2006 sub-yearling Chinook
2006 yearling Coho
Mean CPUE (fish/hour)
0
2
4
6
8
10
12
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Statistical Week


2007 sub-yearling Chinook
2007 yearling Coho
Mean CPUE (fish/hour)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
11
12
13
14
15
16
17
18
19
20
21
22
Statistical Week


2009 sub-yearling Chinook
2009 yearling Coho
Mean CPUE (fish/hour)
0
1
2
3
4
5
6
7
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Statistical Week


2010 sub-yearling Chinook
2010 yearling Coho
Mean CPUE (fish/hour)
Statistical Week


2011 sub-yearling Chinook
2011 yearling Coho
Mean CPUE (fish/hour)
Statistical Week


2012 sub-yearling Chinook
2012 yearling Coho
Mean CPUE (fish/hour)
Statistical Week